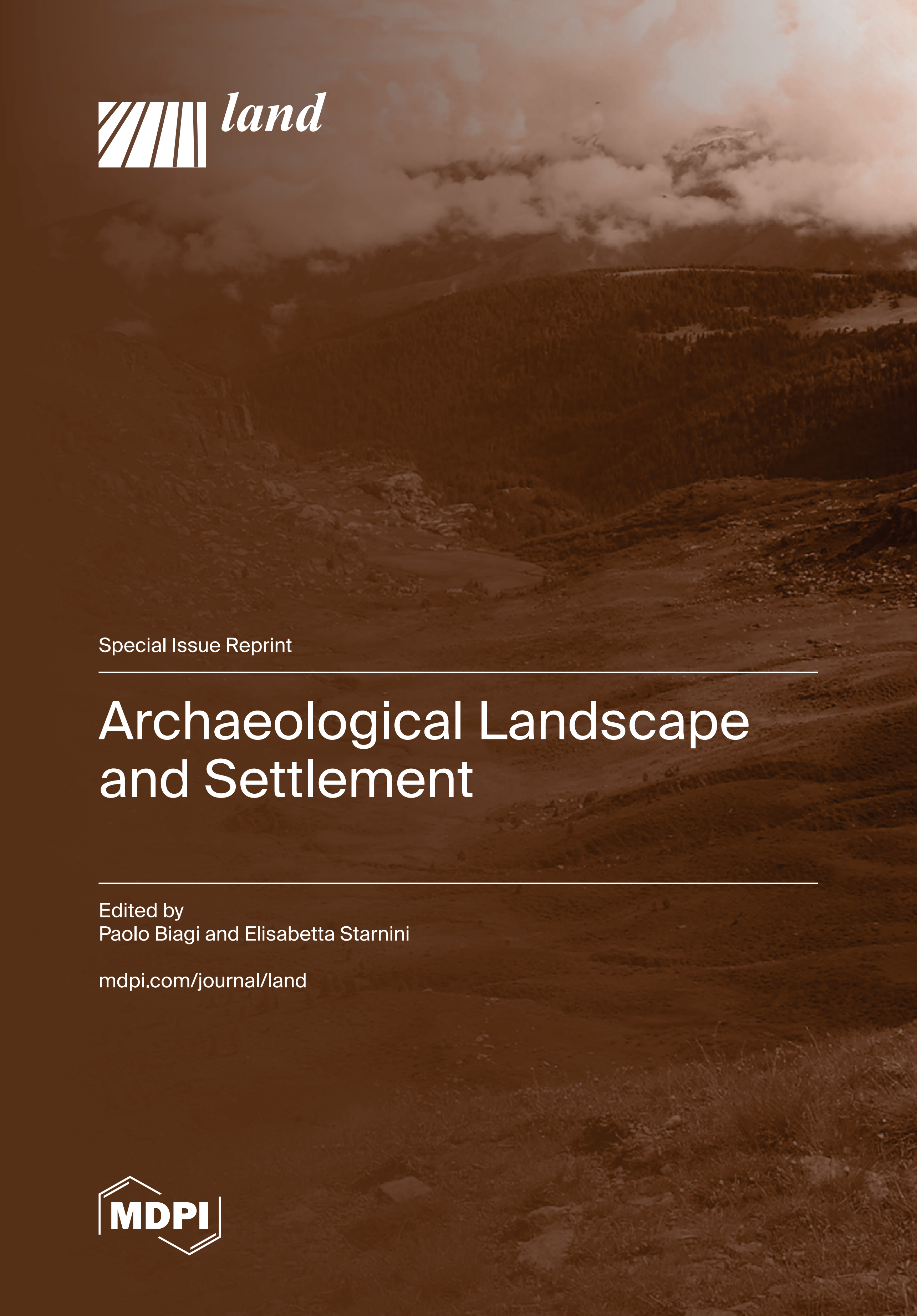

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Archaeological Landscape and Settlement

Edited by
Paolo Biagi and Elisabetta Starnini

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About the Editors

Paolo Biagi

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Preface

The scope of this volume is to provide new data on aspects of landscape archaeology and show how and why methods, paradigms, and perspectives have changed during the last fifty years regarding conceiving, approaching, and studying the archaeology of the human past. The methods we employ now to interpret archaeological landscapes and the effect of human impact and climatic variations on various territories are just some that have greatly improved from the end of the Seventies onward; this is due to different reasons. Among them are ethnoarchaeological and archaeometric approaches, the systematic and accurate use of radiocarbon dating of different types of organic material, and the help of many scientific disciplines that have been developed to interpret the most hidden aspects of the way humans exploited plains, mountains, river banks and coastal strips. These events led to dramatic, sometimes irreversible changes. They took place through the ages, mainly due to subsistence economic reasons and the exploitation of raw material sources, including rocks, metal ores, and clays for pottery production.

The present volume consists of fifteen papers. They show a great variety of approaches used by archaeologists and other scholars from several parts of the world to improve some aspects of landscape archaeology and to interpret the processes that took place in different prehistoric and historical periods, transforming the territory and leading to the present situation.

The guest editors are deeply indebted to all the authors who were kind enough to provide papers for publishing a new volume of the Landscape series and to present new and original data from their research, many of which are currently underway.

Paolo Biagi and Elisabetta Starnini
Editors

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Article

Landscape and Settlement over 4 Millennia on the South Side of Lake Issyk Kul, Kyrgyzstan: Preliminary Results of Survey Research in 2019–2021

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Abstract: This paper discusses the preliminary results of archaeological surveys conducted in the Juuku Region of north-central Kyrgyzstan on the south side of Lake Issyk-Kul. Our goal was to document ancient and contemporary agropastoral systems over a four-millennia period. During the surveys, about 350 loci were identified as settlements, burial mounds, graves, single artifact finds, and artifact scatters (ceramic). The areas of Juuku Valley surveyed included two discrete polygons: Polygon 1, Lower Juuku at 1750 to 1950 m asl in elevation and Polygon 2, Chak Juuku or Upper Eastern Branch Juuku Valley at 2060 to 2100 m asl in elevation. Three radiometric dates and preliminary archaeobotanical studies were conducted at three exposed profile cuts. The methods included here are: (1) pedestrian surveys; (2) use of digital maps (Google Earth, Nakarte); (3) placing archaeological loci within known chronological time periods; (4) AMS dating of charcoal samples collected from profile deposits; and (5) preliminary identification of plant remains found from archaeobotanical samples. The results of our research represent the first step toward inventorying and interpreting archaeological data in the Juuku Valley derived from field studies.

Keywords: archaeological survey; Inner Tian Shan Mountain region; iron age; medieval period; agropastoralism

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1. Introduction

We investigate the impact of ancient farming and herding systems upon the natural landscape of a river valley and alluvial fan of the Inner Tian Shan Mountain region over a four-millennia time period. The Inner Tian Shan region is an important part of the historically known trade and migration routes described as the proto-silk routes and by others as the Inner Asian Mountain Corridor [1] linking the desert-oases of Central Asia, the Eurasian steppe, and the territories of the Chinese Dynasties from the Bronze Age (ca. 2500 BCE to 900 BCE) through contemporary times. This article reports on the preliminary results of pedestrian surveys conducted in 2019 and 2021 in the Juuku Valley on the south side of Lake Issyk-Kul (Figure 1). This landscape ranges from high alpine meadows surrounded by conifer forests to semi-arid grass-covered steppe lands. Our working hypothesis is that ancient farming and herding practices along with human settlement over a landscape were shaped by the local climate and environment, while in turn such human activities altered those natural landscapes. To test this hypothesis, we chose two sample polygons in the Juuku Valley for field survey, one in the upper valley and the other in the lower reaches. Our objective is to examine the long-term effects of land clearing for farming and herding as well as the alteration of land surfaces through the construction of architectural features. The results of our field seasons include an inventory of approximately 350 activity loci. We collected radiocarbon samples and sediment samples from three site profiles. The soil samples have been analyzed by archaeobotanists who identified the remains of ancient seeds. These preliminary results contribute to the larger discussion of Late Holocene human impact upon the mountainous regions of Central Asia. As such, this is the first step toward creating site inventories that can be used as future planning tools for land development, cultural heritage, and the preservation of natural landscapes in the Issyk-Kul basin.

Figure 1. Locator map of Kyrgyzstan. Kizil Suu is the study region.

New forms of evidence for explaining the trade, communication, and migration networks of the intermontane regions of Central Asia and their importance to the Eurasian steppe have included detailed archaeobotanical research tracing the pathways of domesticated plants [2–6]. Ancient DNA studies have traced human population movements [7–9], while isotope analyses of ancient human and animal bone materials have documented mobility and dietary practices [10,11]. These laboratory studies on ancient plant, animal, and human remains augment a rich inventory of material culture from archaeological settlements. Our research turns to a more mundane but important strategy for examining ancient mobility patterns in a single valley area. Since the 1990s, archaeologists have used basic survey methods for finding and inventorying archaeological sites in the Tian Shan mountains and surrounding region for the Iron and Bronze Age materials in the neighboring Republic of Kazakhstan [12–17]. In Western Tian Shan, ethnoarchaeological observations on the seasonal movements of pastoral transhumance have noted the use of winter and spring/autumn camps, thus suggesting that the Bronze Age agropastoral site of Adunoqiaolu was also occupied during winter months [18,19]. Survey research at Juuku Valley serves as an excellent contrast to previous archaeological survey research on the alluvial fans of the northern Tian Shan range [12,14,15].

In 2018 and 2019, archaeological surveys in the Kochkor Valley of the Inner Tian Shan have been conducted [20,21]. Lynne Rouse and her colleagues [20,21] have undertaken UAV surveys and GIS mapping in the Kochkor Valley, also situated on the south side of Lake Issyk-Kul. The objectives of their surveys have been to record upland archaeological features dating from the Bronze Age through Medieval periods in conjunction with archaeological excavations conducted at the upland site of Chap at 2000 m asl. that have deposits dating from 1065 BCE to 825 BCE. Rouse and her colleagues intend to document the Inner Asian Mountain corridors along this important passageway of the Inner Tian Shan range [20]. During the Late Bronze occupational phase, archaobotanists discovered ancient seeds of *Hordeum vulgare* (hulled and unhulled barley), *Triticum* (free-threshing and possible glume wheats), *Panicum miliaceum* (broomcorn millet), *Setaria italica* (foxtail millet), and *Pisum sativum* (pea) [22–24]. Indeed, current research on plant and animal remains and material culture throughout Central Eurasia have demonstrated the importance of agropastoralism from the Bronze through Medieval periods [25].

The goal of our preliminary studies of the Juuku Valley is to develop a set of hypotheses and methods using archaeological survey for examining the long-term evolution of agropastoral systems. From the Bronze Age through the historic period, over four millennia during the late Holocene, people have practiced agriculture and pastoralism in regions of Central Asia [14,23,25]. The purpose of these preliminary surveys are to discover when and where certain groups of people (Andronovo, Saka, Wusun, Turkic, Medieval Qarakhanid, and Ethnographic Kirghiz) were inhabiting this valley. In nearby regions, the changes from the mixed herding and farming systems of the Bronze and Iron Ages to irrigated farming systems in combination with pastoralism during the Medieval and historic periods have had a significant impact. Our goal is to outline how this evolutionary process may have taken place in a single valley of Central Asia.

2. Materials and Methods

Study Area

The environmental setting and physical landscape features of the Juuku Valley (see Locator Map, Figure 2) are also important for documenting both anthropogenic and nature-induced changes in the Juuku Valley during the late Holocene. The Juuku Valley is a small intermontane valley formed by the mountain streams flowing southward to Lake IsskyKul. The lake itself is fed by 102 streams and rivers and fluctuates 20 cm in water level due to glacial melt [26]. The main glacier peak of this valley is It Tash (elevation 4808 m) and the entire valley extends 50 km north towards the southern littoral of Lake Issyk-Kul. The geology of Juuku Valley is similar to that of Dzhety-Ogyuz valley to the east [27]. The Paleozoic granites and metamorphic rocks are the foundation for the Dzhety-Ogyuz valley and neighboring valleys. Overlaying these granites are Jurassic quartzites. The Eocene and Pliocene deposits consist of a series of red sandstone formations. The surface alluval deposits of indeterminate age include gravels, pebbles, sand, and loam. The valleys and gorges on the south side of the Issyk-Kul basin have been subject to frequent earthquake disturbances, many impacting Medieval settlements [28,29].

Figure 2. Locator Map of Juuku Valley. The lower cluster of points is Upper Juuku, and the upper cluster of points is Lower Juuku.

The vertical zonation below the glaciers consists of rocky terrain with some traces of desert-like vegetation. From 3400 to 3000 m there are grassy meadows and a sub-alpine climate and at elevations of 3000 m to 2000 m, Tian Shan spruce trees surround meadows of perennial grasses and shrubs. This is the upland zone (2000 to 3000 m) currently used by Kyrgyz herders for grazing sheep, goats, cattle, and horses and for cultivating small fields of barley and fodder crops. In our study area, this upland zone is demarcated as the Upper Juuku Valley. From here, the gorge opens into the Lower Juuku, an alluvial valley consisting of terraces and benches above the streams and rivers (an area of about 10.5 sq km). Below this alluvial valley is a large alluvial fan (44 sq km) where the Juuku River empties into Lake Issyk-Kul. The Lower Juuku area today has large, irrigated fields of wheat, barley, oats, alfalfa and hay; flocks and herds of animals graze along the edges of the fields and in stubble areas. Along the far reaches of the alluvial fan near the shoreline of Lake Issyk-Kul (ca. 1600 m) there are marshlands and rich pasture areas.

Two sample polygons in the Juuku Valley were chosen for intensive survey because they appeared to have a high density of burial mounds constructed of stone and/or earth (kurgans) and architectural features (Figure 2). We chose these two polygons because they represent two different vertical zones. Polygon 1 in the Lower Juuku Valley, an area of 6.4 sq km, is situated in the productive zone of wheat, barley, oats, fodder plants, and winter grazing in 1750 to 1900 m asl. The 6.4 sq km area is approximately half of the total alluvial valley of the Lower Juuku Valley. Below this alluvial valley is a large fan that reaches the southern shoreline. Polygon 2 in the Upper Juuku Valley, with an area of 0.5 sq km, consists of a series of terraces and a narrow floodplain with steep colluvial deposits along the eastern branch of the Juuku River. Polygon 2 is situated in the zone of summer pasture area, tourist camping, fishing spots, and forest service reserves at elevations from 2000 m to 2100 m asl. The pedestrian surveys conducted by a team of three field archaeologists were aided by inspection of imagery from Google Earth, Soviet maps, and other digital maps (Nakarte). The loci were recorded using Garmin GPS units. Each locus was recorded by coordinates, described, and photographed in the field. From detailed notes, Excel spreadsheets were created for all site and artifact loci. During 15 field days in 2019 and 30 field days in 2021, we amassed an inventory of over a total of 1000 loci from the Kizil Suu, Saruu, and Juuku Valleys.

In addition to surface survey, we also recorded archaeological features such as pits, house structures, storage pits, and fire pits found in exposed stratigraphic profiles. Many of the exposed stratigraphic profiles were erosional or river cuts or the result of road construction and farming activities. Three stratigraphic profiles found at settlement sites were selected for more detailed analyses. Radiocarbon samples and soil samples for archaeobotanical analyses were taken from these three exposed profiles, one in the Lower Juuku polygon and two in the Upper Juuku polygon. In Polygon 1 (Lower Juuku), at Loci 387, large burnt wood samples for radiometric dating and an archaeological soil sample of 17 L were collected from a house pit. In Polygon 2, two stratigraphic profiles from two different erosional cuts were identified as archaeological house pit fills containing mudbrick remains, plastered floors, and midden deposits. At the Settlement 1 profile, 14.5 L of soil was collected for archaeobotanical analyses, and a small charcoal sample was removed for radiometric dating. Then, at the Settlement 2 profile, 11.5 L of soil was collected for archaeobotanical analyses, and a charcoal sample was removed for radiometric dating.

The wood charcoal samples (species unknown) were collected from the three profiles by the field archaeologists. Radiometric analyses were conducted at the Beta Analytic Laboratory (Coral Gables, FL, USA) using AMS methods. The samples taken from the three profiles were wood charcoal pieces. The reporting on these results includes conventional radiocarbon dating and the d13C ratio that can be used by other researchers in the future according to conventional standards [30]. Wood charcoal was dated because the field researchers did not recognize the seed material in the initial sample collection. The authors are aware of old wood effects and in future publications will date carbonized seeds as well as wood charcoal.

The soil samples were processed in the Republic of Kyrgyzstan using a SMAP flotation machine with mechanized agitation to wash sediments. The agitation process washes the archaeological sediments so that organic materials are caught in the overflow spout in geological sieves of 0.344 mm mesh. These organic materials are referred to as the light fraction, and then sieved with mesh sizes of 2.00, 1.40, 1.00, and 0.50 mm. When sorted, this fraction contains carbonized seeds, pips, leaves, and other remains. The heavy fraction was collected and sieved from 1.4 mm to 1.0 mm mesh. Both heavy and light fractions were sorted using atlases for seed identification [31,32] by two archaeobotanists at the Max Planck Institute for Human History, Archaeobotany Laboratory [33]. Preliminary archaeobotanical and radiometric analyses of these three stratigraphic columns represent very preliminary data that shall be used for refining a regional chronology for settlements and for designing a more comprehensive research study of human land use along a vertical gradient.

3. Results

During the 2019 and 2021 surveys, we registered about 350 loci (single artifact finds, sherd scatters, graves, burial mounds (kurgans), house foundations, and house depressions in the Lower Juuku and Upper Juuku). These loci were also placed in chronological sequences based on local typologies for burial monuments, settlements, and artifacts (ceramics). Our initial observations suggest that the large Medieval settlements (fortresses, citadels, caravanserais, and proto-urban towns) found in Juuku and the neighboring valleys of Sutti Bulak, Chichi Khan cover over and obscure earlier Bronze and Iron Age settlements. When both Medieval and Iron Age ceramic sherds are found on the same land surfaces and loci this indicates that later Medieval deposits cover over and obscure earlier Iron Age settlement features. The prominent appearance of above-ground mortuary features Iron Age burial mounds (kurgans), often 5 to 50 m in diameter and 0.1 to 3 m or more in height [20,21]. These burial mounds are often located near Medieval walls, farmsteads, and dwellings, therefore, marking clear boundaries between Medieval settlements and Iron Age mortuary complexes. Logically, this also means that the places where Iron Age burial mounds exist today are landscapes that were not used by later Medieval populations for house or settlement construction. These landscape palimpsests are essential to developing a deeper and more nuanced approach to site and non-site archaeology in regional contexts [34–36].

3.1. Chronology

During the survey, we established a local historical chronology based on archaeological and historical sources from the Tian Shan Mountain and surrounding regions. These phase designations are based on archaeological research conducted in Kyrgyzstan over the past one-hundred years on settlements, burial mounds, graves, and artifact collections throughout north-central Kyrgyzstan and the Semirech'ye region of southeastern Kazakhstan [36–38]. More recent kurgan imagery from UAVs from the Kok Sai area of the Kochkor Valley have been documented [21] (p. 12). Gino Caspari [39,40] has used Google Earth, Worldview2, and Ikonos imagery to record the looting and destruction of Iron Age burial mounds in Xinjiang. During the Soviet period, Vinnik identified about 17 Medieval period settlements along the SW coast of Lake Issyk-Kul [41]. Medieval sites are most easily identified by standing mudbrick walls, large enclosure walls, and standard measurements for tortuls or caravanserais [42]. Literature searches assisted us in placing our survey findings into these chronological and phase designations [38,41], see Table 1.

In this section we discuss the survey results and include some preliminary descriptions and results of three stratigraphic profiles. Each survey polygon is a self-contained unit of analysis so as not to confuse the reader. We chose each polygon on the basis of its location on the vertical gradient.

3.2. Polygon 1

Polygon 1 is a survey area (ca. 6.4 sq km) located on the Lower Juuku alluvial valley where the terraces rise about 30 m above the entrenched stream bed and is situated about 6 km south from the shores of Lake Issyk-Kul (Figure 3). Today, the upper alluvial valley is farmed by tractor and heavy equipment where large, irrigated fields are cultivated in crops of wheat, barley, oats, and fodder crops. The 323 loci documented in the 2019 and 2021 surveys are found between 1750 m asl and 1950 m asl. There is a density of 50 loci per sq km.

Table 1. Time Periods, Phase Designations, and Dates used for the Juuku Valley Survey.

Time Period	Phase Designation	Dates
Late Bronze Age		2000 BCE–900 BCE
	Final Bronze	1100 BCE–800 BCE
Iron Age		800 BCE–550 CE
	Saka	800 BCE–260 BCE
	Wusun	140 BCE–437 CE
	Kenkol (only in TianShan)	200 CE–550 CE
Medieval Period		500 CE–1500 CE
	Turkic Period	552 CE–900 CE
	Qarakhanid	942 CE–1228 CE
Early Kirghiz		1500 CE–1700 CE
Kirghiz Ethnographic Period		1700 CE–Present
Soviet Period		1917–1991
Post-Soviet, Kyrgyz Nation		**1991–**

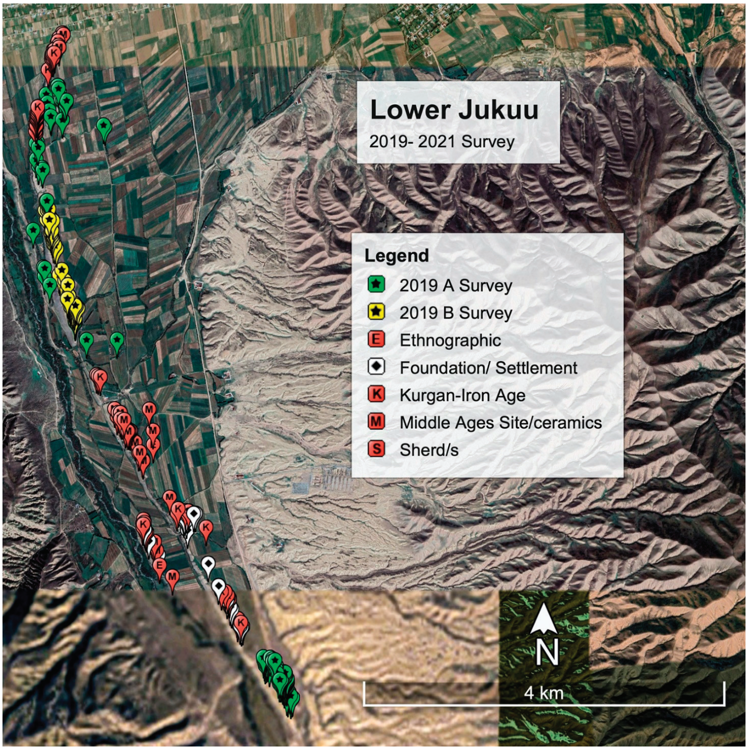

Figure 3. Lower Juuku, Google Earth Image. Survey Data.

3.2.1. Site Types Found in Lower Juuku

Most loci found from survey were mortuary remains: 192 mortuary remains (burial mounds, graves, and 1 mausoleum) were found, a total of 31 settlement and architectural features (17 settlement sites), and 21 artifact finds (Figure 3).

3.2.2. Settlements in Polygon 1

A total of 17 settlements have been identified in Lower Juuku (Figure 4). The settlements assigned to specific time periods according to ceramic and artifact finds in addition to architectural features such as the citadel (shakristan), the surrounding residential areas (rabat), stone foundations, and room or house depressions.

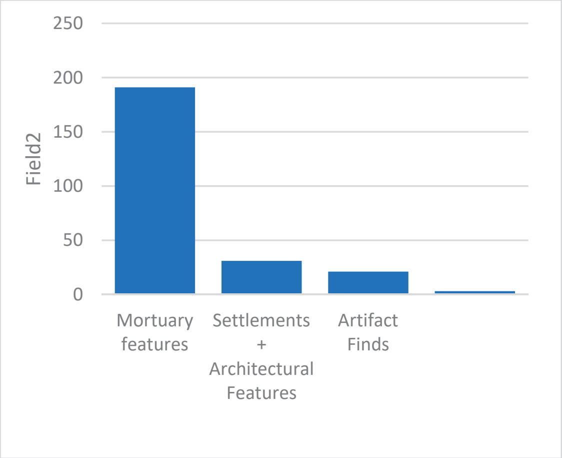

Figure 4. Histogram of site types in Lower Juuku: mortuary features, settlements and architectural features, and artifact finds. The *x*-axis represents types of loci, and the *y*-axis or Field 2 is the number of loci.

3.2.3. Locus 387: Historic or Ethnographic Kirghiz House

One site (Locus. 387, Table 2) is a large settlement located on the eastern bank above the lower Juuku stream at an elevation of 1892 m asl. The settlement is located above the road cut. On the surface, there is one visible single room foundation that is probably part of a much larger settlement. The single row of rocks is rectangular in form, about 4.5 m east–west by 5.5 m north–south. Inside the stone wall foundations is a depression. The profile section, located along the south bend of a road cut, is 4.5 m in length and 1.4 m in depth from the present ground surface (Figure 5). In the profile is the house fill of a structure built of mudbrick that was destroyed by a bulldozer cut when building the dirt road. The humic layer covers a thick layer of mudbrick (about 20 cm thick). Underneath the humic and upper mudbrick layer is a thick midden deposit about 40 to 60 cm thick. This midden layer consists of a thick lens of cultural material including animal bones (cattle) and chunks of charcoal, some as large as 1 cm in diameter. No artifacts were found in the profile, although coarseware ceramic sherds were found on the ground surface near the road cut. The flotation samples were taken from this thick cultural level about 60 cm from the present ground surface along with over 10 g of burnt wood (charcoal) for radiometric dating. At 60 cm to 1 m below the present ground surface was a thick layer of mud brick foundations, yellow buff in color. This mudbrick layer may have been the original floor level because below the mudbrick were large river cobbles probably used as foundation stones. Upon initial inspection, we identified the site as a Medieval settlement. The reason we believed the site to be from the Medieval period was because of the redware sherds found near the road cut. However, the radiometric dating places it within the ethnographic

Kirghiz period = (*floruit* 1682–1932 cal CE). In the opinion of the researchers, it is doubtful that the wood charcoal samples were contaminated by either natural or cultural forces due to the intact stratigraphy found in this road cut. In stratigraphic profiles where there are not actual index fossils (diagnostic sherds and metal artifacts) it is easy to misjudge the dating of a house pit, especially when ethnographic houses are also constructed of stone foundations and mudbrick walls, the same materials used to construct Medieval houses.

Table 2. Results from Radiocarbon Sample of Locus 387, Lower Juuku, Settlement 1.

Lab. ID #	Sample ID #	Material/ Pretreatment	d13C o/oo (IRMS)	Conventional 14C Age	Calendar Calibration of Radiocarbon AGE to Calendar Years
Beta-6093781	Locus 387	(charred material): acid/alkali/acid	−26.5	110 +/− 30 BP	95.4% probability: (68.6%) 1800–1938 cal AD (150-12 cal BP) (25.7%) 1682–1738 cal AD (268–212 cal BP) (1.2%) 1754–1762 cal AD (196–186 cal BP)

Figure 5. Photograph showing the Profile of the Kirghiz Ethnographic Period Settlement.

These are AMS (accelerated mass spectrometry) dates. The accuracy is at 95.4%, and each portion or percentage represents the range (or ranges) with an associated probability of an identifiable timescale [30]. IRMS is the method of measurement used at the Beta

Analytic Laboratory. The results were calibrated using INTCAL20 [43]. This measurement found in Column 4 (d13C o/oo) can be used by future investigators to recalibrate these results should new calibrations be established.

3.2.4. Preliminary Archaeobotanical Results from Locus 387

A caveat is in order here. Most archaeobotanical studies conducted at sites such as the Chap site, a Late Bronze Age site and Paykend, or a Qarakhanid Medieval site depend on the collection of large samples of archaeological sediments, sometimes entire house fills or pit fills [22,44]. Our soil samples are very small and can only be considered as preliminary in nature. Thus. the results from the flotation of these samples must be interpreted as preliminary results and shall be reported upon in greater depth in another publication. From the 17 L sample, the archaeobotany team discovered a total of 41 seeds, the majority being wild plants. The field crops included barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), and peas (*Pisum sativum*), along with the major component of carbonized chenopods and weed seeds of wild *Fabaceae* and grasses (*Poacae*) [33].

3.3. Polygon 2

Polygon 2 or Upper Juuku (Chak Juuku) is 20 km from the edge of the lake and is a narrow valley that consists of dissected terraces on either side of the eastern branch of the Juuku Gorge, a section where red sandstone formations form the steep gorge (Figure 6). This area was chosen for intensive survey due to its location on a terrace above the eastern branch of the Juuku Stream at an elevation about 300 m higher than the Lower Juuku survey polygon. This survey area consists of the two banks (east and west) of the Eastern Juuku stream and is about 0.5 sq km in area. Approximately 37 loci were identified per 0.5 sq km. The loci range from 2060 m asl to 2100 m asl. The natural vegetation includes semi-arid shrubs and grasslands with pockets of spruce in the higher elevations and willows and aspens and other riparian species along the stream banks.

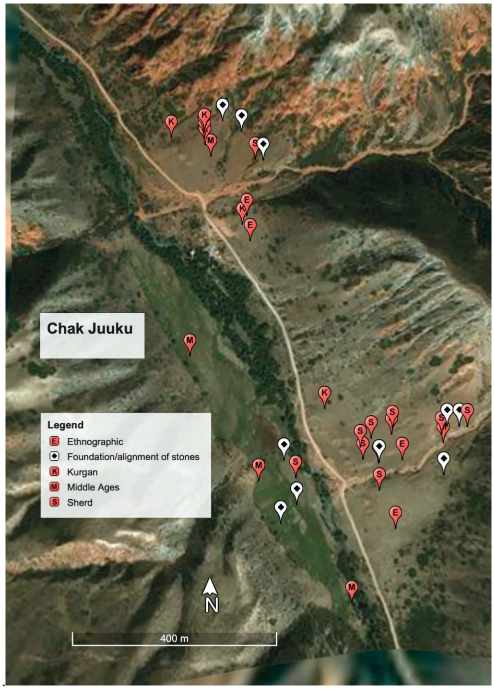

Figure 6. Upper Juuku (Chak Juuku), Google Image, Survey.

In Table 3 we describe the settlements, burial mounds, graves, and artifact finds in the Chak Juuku area. In addition, there are two other settlements of unknown age (Loci 184 and Loci 185) found in the vicinity of the Settlement 1, the Wusun period site. It is possible that these stone foundations could be associated with Settlement 1, although no temporal indications such as ceramic sherds were found at these settlements.

Table 3. Sites and Finds from Upper Juuku by time period.

Chronological Period	Settlements	Mortuary Remains	Artifacts
Ethnographic Kirghiz Period (1700 CE to Present)	Stone corral with possible room blocks	Group 1 * (10+ stone graves Locus 144) Group 2 * (6+ stone graves Locus 181) Group 3 * (2 stone graves Locus 174) Single Stone Grave (Locus 160) Single Stone Grave (Locus 502)	
Medieval Period (500 to 1500 CE)	Settlement 2 (17.5 m × 12 m), 3–5 rooms, double stone wall construction, Qarakhanid Period, Redware sherd, Grinding Stone fragment (Locus 170/493) Settlement 4: Large mudbrick and stone complex on w. bank of Chak Juuku stream, 51 m × 20 m (Locus 498) Settlement 5 or Mill: Double stone wall construction, on west bank of Chak Juuku stream, 8 m × 6 m (Locus 500) Settlement 6: Mudbrick room block (2 rooms), 5 m × 10 m, on west bank of Chak Juuku stream, (Locus 501)		3 Qarakhanid glazed ceramics, 5+ redware sherds found at modern corral (Locus 191)
Iron Age (Saka and Wusun period, ca. 800 BCE to 437 CE)	Settlement 1: Double stone alignments, consisting of four rooms with deep depressions, 15 m × 10 m, 1 redware rim, (Loci 182-83)	Saka kurgan Group * 1: 5 stone kurgans, (Loci. 186-88 and possibly Locus 190) 3 separate Saka kurgan, (Loci 177, 180, 192)	1 redware sherd with yellow slip, (Locus192)
Late Bronze Age (2000–900 BCE		Rectangular stone enclosure, possibly 1–4 graves (Locus 154)	

* Groups are defined as linear clusters of graves or kurgans.

3.3.1. Settlement 1

Settlement 1, situated at 2057 m in elevation on an upper terrace above a ravine: It is a Wusun Period site dating from 22–206 cal AD (see Table 4). The settlement is located on both sides of the erosional gully. On the north side there are no indication of house foundations, only shallow depressions of house pits. The south side of the gully consists of the outline of three or four room blocks. Room 1 is about 5 m (north–south) × 3 m (east–west), and its west wall outlines Room 2, which is 5 m (north–south) by 4 m (east–west). The outline of Room 3 is further east, where there are only traces of a south wall (3 m in length) and a trace of a north wall (1 m in length). On the south side of this room block is a thick stone wall two courses wide. These stone walls are constructed of irregular boulders. The erosional cut of the exposed profile is about 2.5 m in depth from the surface and runs in an east–west direction from the reaches of a small sandstone canyon that dissect this terrace. The stratigraphic profile is located on a south-facing erosional cut found on a steep terrace bank at 2044 m asl. The exposed profile is 3 m in length and has a depth from the present ground surface 2 m in depth (Figure 7). There are roughly about six different archaeological layers within the house pit fill. Each layer is around 20 to 30 cm thick of midden deposit consisting of chestnut and red-clay soils intermixed with charcoal and disintegrating mudbrick. There were many animal bones fragments and one cattle vertebrate found at 80 cm below the present ground surface. A redware Iron Age ceramic with white slip discovered at 90 cm below the surface. There were at least three discernible layers of thin plaster floors. At about 1.5 m below present ground surface there were small angular stones and small pebble and sand deposits that appear to be subsoil (non-cultural soil). From an exposed profile of charcoal room fill, three archaeobotanical soil samples (14.5 l) were taken in layers 4 and 5, near where the Iron Age ceramic sherd was found. The small charcoal sample was also taken in the same vicinity.

Table 4. Results from Radiocarbon Samples from Upper Juuku at Settlement 1 (Locus 183) and Settlement 2 (Locus 165).

Lab. ID #	Sample ID #	Material/Pretreat	d13C o/oo (IRMS)	Conventional 14C Age	Calendar Calibration of Radiocarbon Age to Calendar Years
Beta-603779	Locus 183	(charred material): acid/alkali/acid	−22.7	1930 +/− 30 BP	95.4% probability (95.4%) 22–206 cal AD (1928–1744 cal BP)
Beta-603780	Locus 170	(charred material): acid/alkali/acid	−25.3	1020 +/− 30 BP	95.4% probability (81.7%) 978–1048 cal AD (972–902 cal BP) (11.4%) 1082–1130 cal AD (868–820 cal BP) (2.3%) 1127–1151 cal AD (813–799 cal BP)

Preliminary archaeobotanical remains found at Settlement 1: There were a small number of carbonized seeds identified from four domesticated crops including barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), broomcorn millet (*Panicum millaceum*), and foxtail millet (*Setaria italica*). More than half the assemblage included wild plants such as chenopods, wild legumes, and cleavers [33].

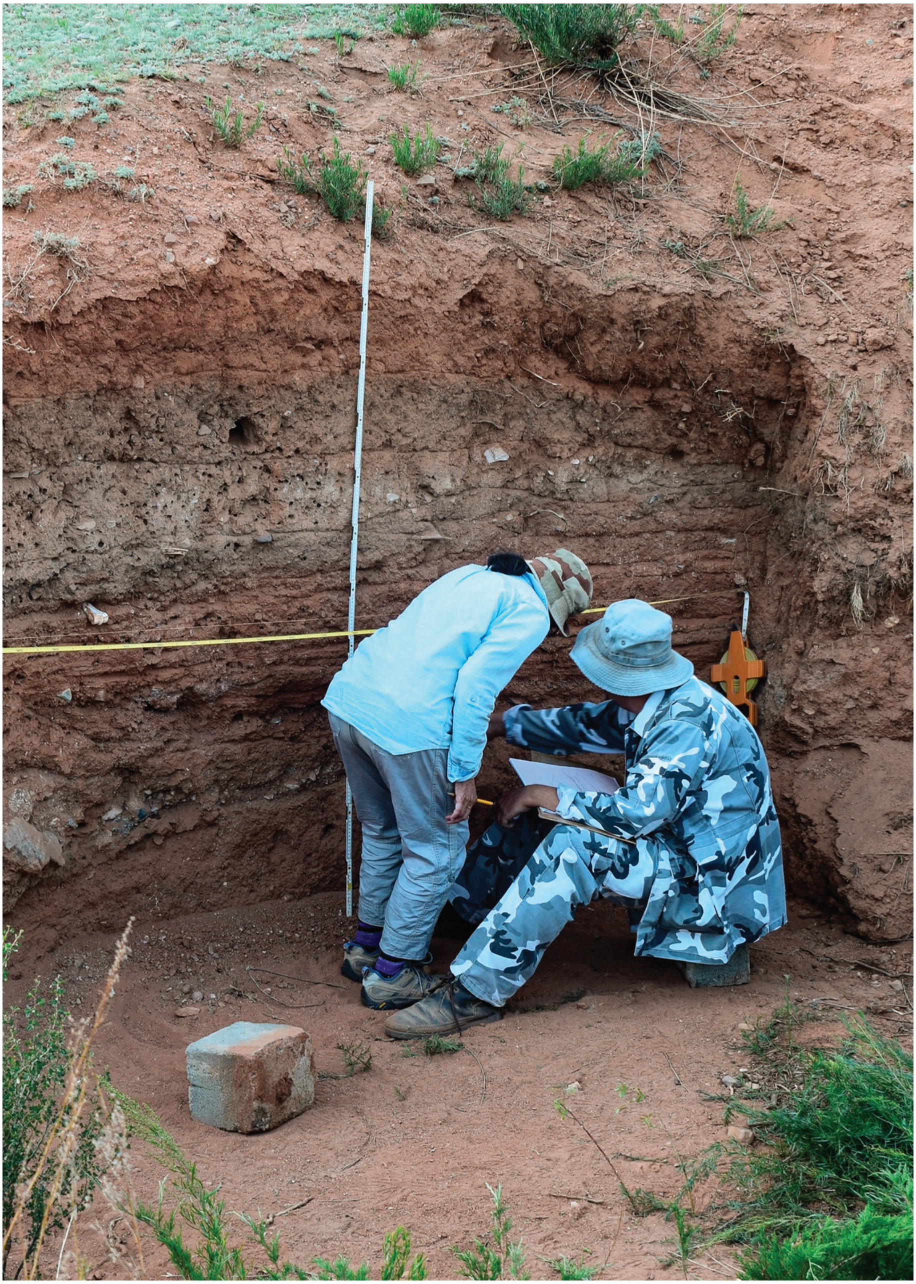

Figure 7. Profile of the Iron Age Site at Upper Juuku, two archaeologists working at the profile.

3.3.2. Settlement 2

Settlement 2, situated at an upper terrace at an elevation of 2090 m asl: It is a series of double-walled stone alignments of at least four large room blocks and measures about 17.5 m × 12 m. The stratigraphic profile examined is a west-facing cut found at a deep erosional gully that dissects this upper terrace (Figure 8). When this cut was first discovered, a sheep scapula was found at about 1.3 m in depth from the present ground surface. The cultural levels at this profile are complex since the house fill represents at least three or four different occupation levels. The burnt wood (charcoal) sample and two flotation samples were taken approximately between 50 to 80 cm below the present ground surface in the second to third fill or midden sequence. At about 1.7 to 2.0 m below the surface are a series of thin buff-colored plastered floors or laminations that may represent the different layers of an ancient *sufa* or *kang* (sleeping bench). We did not take charcoal wood samples for dating or the flotation samples from the *sufa* or floor levels because there was no visible carbonized ash, soil, or charcoal at those levels. The site is dated to the Medieval Qarakhanid period and has an approximate radiometric dating of 990–1050 cal AD (see Table 4). This is also confirmed by the Medieval redware ceramics and a granite grinding stone found on the surface of this settlement. The archaeobotanical remains showed a paucity of seeds from the 11.5 L of collected sample, only one barley seed (*Hordeum vulgare*) was identified, the rest were wild seeds [33].

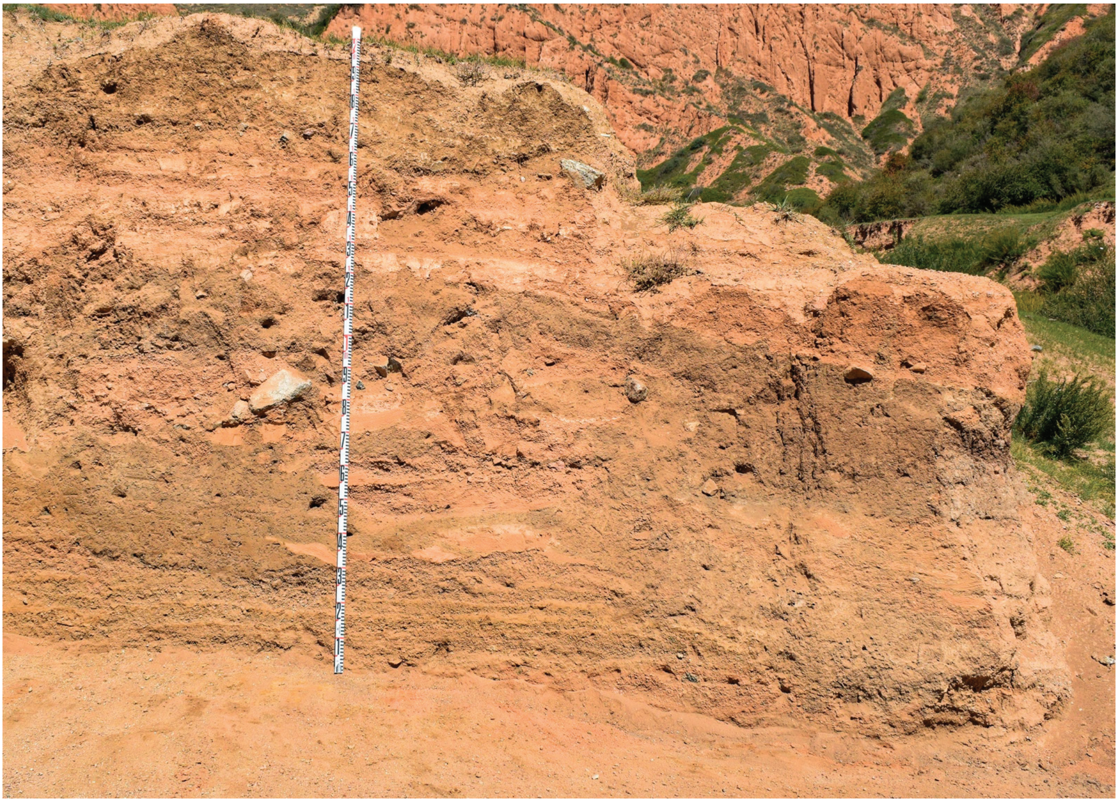

Figure 8. Photograph at Profile of Medieval Settlement at Upper Juuku.

3.3.3. Radiometric Dating

At Settlement 1 (Iron Age site) and Settlement 2 (Qarakhanid Phase) Medieval Period charcoal samples were taken from the profiles. AMS dating was obtained from both settlements. The following dates are reported in Table 4.

These are AMS (accelerated mass spectrometry) dates. The accuracy is at 95.4%, and each portion or percentage represents the range (or ranges) with an associated probability of an identifiable timescale [30]. IRMS is the method of measurement used at the Beta Analytic Laboratory. The results have been calibrated using INTCAL20 [43]. This IRMS measurement found in Column 4 (d13C o/oo) can be used by future investigators to recalibrate these results should new calibrations be established.

3.4. Mortuary Complexes

There were many lines of Iron Age burial mounds found in both Upper and Lower Juuku. The largest number of burial sites were earthen or stone mounds known as *kurgans*. Most kurgans are from the Saka period, represented by linear clusters of stone or earthen kurgans. The clusters range from 3 mounds to 16 mounds in alignment. In some cases, the stone Saka kurgans (ranging in diameter from 2.8 m to 11 m in diameter and from flat to 1.5 m in height) are interspersed or found in proximity to the earthen Saka kurgans (ranging in diameter from 5.5 m to 97 m in diameter and from 0.4 to 2.5 m in height). In Lower Juuku, the largest kurgan cluster (16 kurgans) covers a distance of 220 m and is aligned 4.6 degrees east of North. The three largest earthen kurgans cover a linear distance of 400 m and are aligned at 10 degrees west of north. A third group consists of six kurgans covering a distance of 270 km and follow a direction of 13 degrees west of north. In Figure 9 there are two large Saka period earthen mounds found in the Lower Juuku. These earthen kurgans are identified as Saka period elite kurgans based on their size, earthen construction, and the *krepida* (rock apron) found on the north side of the kurgan [45].

Figure 9. Photograph of large earthen Saka kurgans found in the Lower Juuku Valley.

In addition to the Saka kurgans are Wusun kurgans that have an outer rectangular or square stone outline with an inner circular stone ring. The Wusun kurgans range in size from 2.5 m × 2.5 m to 9 m × 9 m and are flat to 1.2 m in height; the average is 0.4 m in height. Of particular interest is the close proximity of the Saka stone and earthen kurgans to the Wusun stone kurgans. There appear to be clear spatial boundaries between the Saka and Wusun graves, something that requires further investigation.

3.5. Stone Corral

In the Upper Juuku Valley, a stone corral was located. Currently, the chronological period for this stone corral is unknown. The corral is built of boulders and medium-sized stones, in places one to three courses in width. The outline of the corral is almost rectangular with rounded corners. It measures 20 m (north–south) × 13 m (east–west). To the north of the corral is a small rectangular stone structure that measures 8 m × 6 m. This could be a storage room or a dwelling used by herders. This corral is an important feature of agropastoralism in the Upper Juuku Valley (Figure 10).

Figure 10. Photograph showing a stone corral in Upper Juuku.

3.6. Artifacts

Many artifacts were either found as isolated finds or as parts of scatters. The grinding stones were usually made of granite with a concave surface. Figure 11 is a granite grinding stone found as an isolated surface find. The grinding stone measures 30 cm (length) × 18 cm (width) × 5 cm (thickness).

Figure 11. A granite grinding stone found on the surface.

Over 100 ceramic sherds were found from Upper and Lower Juuku surveys. The majority of the ceramics were redware coarse wares with sand or crushed rock temper. During the survey we made rough distinctions between the Iron Age handmade ceramics (coil or slab) and the Medieval wheel-thrown ceramics. In addition, we found handle, rim, and base fragments, spindle whorls, and a very few pieces of glazed Qarakhanid ceramics. More detailed analyses of these ceramics will be conducted by a ceramics specialist in the future. Figure 12 shows the interior of redware ceramic sherds, some with fabric impressions and red slip. These ceramic pieces date to the Iron Age and represent hand-made or slow wheel ceramics. A detailed description of fabric-impressed ceramics and actual fabric fragments from Bronze and Iron Age contexts at the site of Begash in the Dzhungari Alatau Mountains of southeastern Kazakhstan was conducted by Paula Doumani Dupuy and her colleagues [46]. Similar redware sherds, sometimes with light slip, have been found at Iron Age sites in the Talgar region of southeastern Kazakhstan [14,47].

Figure 12. Redware ceramic sherds; interiors showing fabric impressions and red slip, probably Iron Age period ceramics.

4. Discussion

Although an old-fashioned, tried and true method, we prefer to walk the ground. Pacing the diameter of a burial mound by foot or measuring how high it rises above the ground by standing at its base and eyeballing its relative height gives us a three-dimensional perspective. We also follow a line of mounds along a ridge, just as one experiences a row of graves in a modern cemetery. Since this land was used to memorialize the dead, where did the people farm crops or herd sheep? New technologies such as UAVs (drones) or visual inspection of digital map images of burial mounds, graves, or houses are the initial way to locate sites from your desktop. Afterwards, the field archaeologist checks these loci on the ground. A digital image usually does not show small objects (ceramic sherds and stone tools) on the surface. By walking across a settlement, we often find ceramic sherds or grinding stones inside enclosures. Diagnostic ceramic sherds may indicate when a site was occupied. We begin to intuit why ancient people selected these terraces, ridges, and valleys. Ancient walls and room depressions take form as habitations. Our field sketches as notes create a memory bank of what we have seen and found. If we find a piece of broken pottery on a freshly ploughed field, it triggers our recollections. Why was this pot dropped here and did the plough move the broken sherds to this spot? Often the sherds are most visible in farmers' furrows. So, beneath our feet may lie storage pits or trash middens. The field surveys help us discover ancient settlements. In the future, we or others can undertake full coverage survey by traversing complete landscapes.

The site density at these two polygons in the Juuku Valley appears to be much higher than site densities on the Talgar alluvial fan on the edge of the northern Tian Shan mountains. Moreover, the Juuku Valley appears to have a larger representation of sites from the Bronze Age through historic periods. Thus, the Juuku Valley is an excellent micro-region for more in-depth investigations of agro-pastoral systems over a long period of time and in different cultural phases. In 2021, we conducted further reconnaissance of Iron Age settlements, often noting that it was more difficult to find and locate early period settlements from the Bronze and Iron Ages than we initially expected. Most likely, earlier Bronze and Iron Age settlements have been buried by more recent Medieval and historic sites or have been destroyed by modern agricultural practices such as ploughing and irrigation. In the Lower Juuku, where the majority of large-scale tractor and irrigation agriculture occurs, surveys may yield better results if conducted in the early spring or early fall before intensive cropping and after harvesting.

Today the Lower Juuku Valley is well-suited for the cultivation of wheat, barley, oats, and fodder crops during the summer months when large tracts of land can be irrigated and cultivated using large machinery. Sheep, goats, cattle, and horses are often pastured on the agricultural stubble after harvest. The Upper Juuku is more suitable for summer pasturelands for cattle, sheep, goats, and horses. Its rich forest and riparian areas attract a variety of wild animals and fish, deeming this area desirable for upland herding, fishing, and foraging. In the past there may have been pockets of arable land in the Upper Juuku for the cultivation of short season crops such as barley and millets.

5. Conclusions

Archaeological surveys are necessary in this region of north-central Kyrgyzstan for two main reasons: (1) the upland areas far from the perimeter of Lake Issyk-Kul are poorly known by Kirghiz archaeologists; (2) the south side of Lake Issyk-Kul is an under-developed tourist area. As this area continues to develop as a tourist area and as an agricultural region for the cultivation of wheat, barley, and fodder, more archaeological sites will be destroyed. Settlement archaeology, especially for the prehistoric periods, is little known in the Republic of Kyrgyzstan. Recently, research on Epipaleolithic through Neolithic layers at Obishir have been conducted by international teams of archaeologists [48–50]. As archaeologists begin to explore the early beginnings of foraging, pastoral, and agricultural economies in Kyrgyzstan, surveys such as the Juuku Valley and the Kochkor surveys will become more essential for the next generation of archaeologists [20,21,51]. Our work represents a modest first step in establishing systematic archaeological survey methods to reconstruct settlement–subsistence systems in this region of Central Asia. The results of the surveys will also be used to select areas for test excavations and large-scale block excavations of both mortuary and settlement complexes. Future test excavations shall yield archeozoological and archaeobotanical materials along with ceramics, stone and bone tools, and metal indicative of ancient herding and farming adaptations. Finally, it is our hope that these physical, archaeological, and cultural landscapes will be preserved through local and national efforts [52]. An inventory of archaeological loci then becomes the initial path toward preserving such fragile landscapes.

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Institutional Review Board Statement: This project did not require an IRB statement since no human or animal subjects were used in this scientific study.

Data Availability Statement: The results of the archaeological surveys are currently archived by C.Chang (USA) and S.S.Ivanov (Kyrgyz National University). These include GPS data points, digital mapping, fieldnotes, and preliminary reports. The radiometric data is archived by Beta Analytic Laboratory in Coral Gables, Fl (USA). Artifact collections (ceramics, metal, and stone) are archived at the Kyrgyz National University in the Faculty of Far Eastern Studies. The archaeobotanical material is archived at the Max Planck Institute of Human History, Archaeology Department under the supervision of Robert N. Spengler, III, Laboratory Director of the Archaeobotany Laboratory.

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References

1. Frachetti, M.D. Multiregional emergence of mobile pastoralism and nonuniform institutional complexity across Eurasia. *Curr. Anthropol.* **2012**, *53*, 2–38. [CrossRef]
2. Spengler, R., III. *Fruit from the Sand: The Silk Route Origins of the Foods We Eat*; University of California Press: Berkeley, CA, USA, 2019.
3. Fuller, D.Q.; Lucas, L. Adapting crops, landscapes, and food choices: Patterns in the dispersal of domesticated plants across Eurasia. In *Human Dispersal and Species Movement*; Boivin, N., Petraglia, M., Cressard, R., Eds.; Cambridge University Press: Cambridge, UK, 2017; pp. 304–331.
4. Hermes, T.; Frachetti, M.D.; Doumani Dupuy, P.; Mar'yashev, A.; Nebel, A.; Makarewicz, C.A. Early integration of pastoralism and millet cultivation in Bronze Age Eurasia. *Proc. R. Soc. B Biol. Sci.* **2019**, *286*, 20191273. [CrossRef]
5. Motuzaite-Matuzeviciute, G. The earliest appearance of domesticated plant species and their origins on the western fringes of the Eurasian Steppe. *Doc. Praehist.* **2012**, *39*, 1–21. [CrossRef]
6. Lister, D.L.; Jones, H.; Oliveira, H.R.; Petrie, C.A.; Liu, X.; Cockram, J.; Kneale, C.J.; Kovaleva, O.; Jones, M.K. Barley heads east: Genetic analyses reveal routes of spread through diverse Eurasian landscapes. *PLoS ONE* **2018**, *13*, e0196652. [CrossRef]
7. Scorrano, G.; Yediay, F.E.; Pinotti, T.; Feizabadifarahani, M.; Kristiansen, K. The genetic and cultural impact of the Steppe migration into Europe. *Ann. Hum. Biol.* **2021**, *48*, 223–233. [CrossRef]
8. Jeong, C.; Balanovsky, O.; Lukaniova, E.; Kahbatkyzy, N.; Flegontov, P.; Zaporozhchenko, V.; Immel, A.; Wang, C.C.; Ixan, O.; Khussainova, E.; et al. The genetic history of admixture across inner Eurasia. *Nat. Ecol. Evol.* **2019**, *3*, 944–976. [CrossRef]
9. Gokcumen, O.; Frachetti, M. The Impact of Ancient Genome Studies in Archaeology. *Annu. Rev. Anthropol.* **2020**, *41*, 277–298. [CrossRef]
10. Ventresca Miller, A.R.; Makarewicz, C.A. Isotopic approaches to pastoralism in prehistory: Diet, mobility, and isotopic reference sets. In *Isotopic Investigations of Pastoralism in Prehistory*; Routledge Press: Abingdon, UK, 2017; pp. 1–14.
11. Ventresca Miller, A.R.; Haruda, A.; Varfolomeev, V.; Goryachev, A.; Makarewicz, C.A. Close management of sheep in ancient Central Asia: Evidence for foddering, transhumance, and extended lambing seasons during the Bronze and Iron Ages. *Sci. Technol. Archaeol. Res.* **2020**, *6*, 41–60. [CrossRef]
12. Chang, C.; Tourtellotte, P.A. The Kazakh-American Talgar Project Archaeological Field Surveys in the Talgar and Turgen-Asi Areas of Southeastern Kazakhstan: 1997–1999 by Claudia Chang and Perry A. Tourtellotte. In *Kurgans, Ritual Sites, and Settlements Eurasian Bronze and Iron Age*; Davis-Kimball, J., Murphy, E.M., Koryakova, L., Yablonsky, L.T., Eds.; International Series 890; BAR Publishing: Oxford, UK, 2000; pp. 83–88.
13. Chang, C.; Tourtellotte, P.; Baipakov, K.M.; Grigoriev, F.P. *The Evolution of Steppe Communities from the Bronze Age to Medieval Periods in Southern Kazakhstan (Zhetysu)*; Almaty, KZ.: Sweet Briar, VA, USA, 2002.
14. Chang, C. *Rethinking Prehistoric Central Asia: Shepherds, Farmers, and Nomads*; Routledge: Abingdon, UK, 2017.
15. Ullah, I.I.T.; Chang, C.; Tourtellotte, P. Water, dust, and agro-pastoralism: Modeling socio-ecological co-evolution of landscapes, farming, and human society in southeast Kazakhstan during the mid to late Holocene. *J. Anthropol. Archaeol.* **2019**, *48*, 101067. [CrossRef]
16. Frachetti, M.D. *Pastoralist Landscapes and Social Interaction in Bronze Age Eurasia*; University of California Press: Berkeley, CA, USA, 2009.

17. Beardmore, R.; Bonora, G.L.; Kurmankulov, Z. Preliminary Report on the 2007–2008 IAEK Campaigns in the Syrdarya Delta. *East West* **2008**, *58*, 385–390.
18. Caspari, G.; Betts, A.; Jia, P. The Bronze Age in the Western Tianshan, China: A new model for determining seasonal use of sites. *J. Archaeol. Sci. Rep.* **2017**, *14*, 12–20. [CrossRef]
19. Tian, D.; Festa, M.; Cong, D.; Zhao, Z.; Jia, P.W.; Betts, A. New evidence for supplementary crop production, foddering and fuel use by Bronze Age transhumant pastoralists in the Tianshan Mountains. *Sci. Rep.* **2021**, *11*, 13718. [CrossRef]
20. Rouse, L.M.; Krumnow, J. On the fly: Strategies for UAV-based archaeological survey in mountainous areas of Central Asia and their implications for landscape research. *J. Archaeol. Sci. Rep.* **2020**, *30*, 102275. [CrossRef]
21. Rouse, L.M.; Tabaldiev, K.; Motuzaite Matuzeviciute, G. Exploring Landscape Archaeology and UAV-Based Survey in the Kochkor Valley, Kyrgyzstan. *J. Field Archaeol.* **2021**, *47*, 32–58. [CrossRef]
22. Matuzeviciute, G.M.; Mir-Makhamad, B.; Tabaldiev, K. The first comprehensive archaeobotanical analysis of prehistoric agriculture in Kyrgyzstan. *Veg. Hist. Archaeobotany* **2021**, *30*, 743–758. [CrossRef]
23. Motuzaite Matuzeviciute, G.; Tabaldiev, K.; Hermes, T.; Ananyevskaya, E.; Grikpedis, M.; Luneau, E.; Merkyte, I.; Rouse, L.M. High-altitude agro-pastoralism in the Kyrgyz Tien Shan: New excavations of the Chap farmstead (1065–825 cal BC). *J. Field Archaeol.* **2020**, *45*, 29–45. [CrossRef]
24. Motuzaite Matuzeviciute, G.; Hermes, T.R.; Mir-Makhamad, B.; Tabaldiev, K. Southwest Asian cereal crops facilitated high-elevation agriculture in the central Tien Shan during the mid-third millennium BCE. *PLoS ONE* **2020**, *15*, e0229372. [CrossRef]
25. Spengler, R.N., III; Miller, A.V.; Schmaus, T.; Matuzevičiūtė, G.M.; Miller, B.K.; Wilkin, S.; Taylor, W.T.T.; Li, Y.; Roberts, P.; Boivin, N. An Imagined Past? Nomadic Narratives in Central Asian Archaeology. *Curr. Anthropol.* **2021**, *62*, 251–286. [CrossRef]
26. Giralt, S.; Julia, R.; Klerkx, J.; Riera, S.; Leroy, S.; Buchaca, T.; Catalan, J.; De Batist, M.; Beck, C.; Bobrov, V.; et al. 1000-Year Environmental History of Lake Issyk-Kul. In *Dying and Dead Seas Climatic Versus Anthropic Causes*; Nihoul, J.C.J., Zavialov, P.O., Micklin, P.P., Eds.; NATO Science Series: IV: Earth and Environmental Sciences; Springer: Dordrecht, The Netherlands, 2004; Volume 36, pp. 253–285. [CrossRef]
27. Abdrakhmetov, K.; Korjenkov, A.M. *Climate Evolution in Central Asia during the Past Few Million Years: A Case Study from Issyk-Kul, ICDP Workshop Bishkek, Kyrgyzstan, June 12th to 17th, 2011. Field Excursions Guidebook*; GFZ Helmskotz-Zentrum: Potsdam, Germany, 2011.
28. Korjenkov, A.M. (Ed.) *Strong Earthquakes, Historical and Ancient Earthquakes of Issyk kul and Their Position in the Formation of the Northern Tian Shan Range*; IFZ: Moscow, Russia, 2018; pp. 1–173.
29. Strelnikov, A.A.; Korzhenkov, A.M. Destruction of medieval archaeological monuments by strong earthquakes in the Southwestern Issyk-Kul Basin, Tien Shan. *Seism. Instrum.* **2021**, *57*, 55–74. [CrossRef]
30. Millard, A.R. Conventions for Reporting Radiocarbon Determinations. *Radiocarbon* **2014**, *56*, 555–559. [CrossRef]
31. Cappers, R.T.; Bekker, R.M. *A Manual for the Identification of Plant Seeds and Fruits*; Barkhuis: Eelde, The Netherlands, 2022; Volume 23.
32. Neef, R.; Cappers, R.T.; Bekker, R.M. *Digital Atlas of Economic Plants in Archaeology*; Barkhuis: Eelde, The Netherlands, 2012; Volume 17.
33. Mir-Makhamad, B.; (Max Planck Institute for the Science of Human History, Department of Archaeology, Jena, Germany); Spengler, R.N., III; (Archaeobotanical Laboratory, Max Planck Institute for the Science of Human History, Department of Archaeology, Jena, Germany). Preliminary Archaeobotanical Report on the Juuku Valley. 2021; *Unpublished work*.
34. Dunnell, R.C.; Dancey, W.S. The siteless survey: A regional scale data collection strategy. In *Advances in Archaeological Method and Theory*; Schiffer, M.B., Ed.; Academic Press: New York, NY, USA, 1983; Volume 6, pp. 267–287.
35. Cherry, J.F.; Davis, J.L.; Mantzourani, E. Landscape history and archaeology. In *Northern Keos in the Cycladic Islands*; Cherry, J.F., Davis, J.L., Mantzourani, E., Eds.; Institute of Archaeology, University of California: Los Angeles, CA, USA, 1991; pp. 57–68.
36. Akishev, K.A.; Kozhomberdiev, I. *Archaeological Monuments in the Vicinity of Issyk Kul*; Izdatel’sko Ilim: Bonn, Germany, 1975.
37. Ivanov, S.S. On the problem of the cultural gap at the turn of the Saka and Wusun periods in the area surrounding the Tian Shan mountains. *Strat. Plus Archaeol. Cult. Anthropol. J.* **2016**, *3*, 67–86.
38. Biran, M. The Qarakhanids’ Eastern Exchange: Preliminary Notes on the Silk Roads in the Eleventh and Twelfth Centuries. In *Complexity of Interaction along the Eurasian Steppe Zone in the First Millennium CE*; Bemman, J., Schamuder, M., Eds.; Bonn Contributions to Asian Archaeology; Vor-und Frubgeschitchtliche Archaologie Rheinische Friedvich-Wilhelms-Universitat: Bonn, Germany, 2015; Volume 7, pp. 575–595.
39. Caspari, G. Assessing Looting from Space: The Destruction of Early Iron Age Burials in Northern Xinjiang. *Heritage* **2018**, *1*, 320–327. [CrossRef]
40. Caspari, G. Quantifying Ritual Funerary Activity of the Late Prehistoric Southern Kansas Region (Xinjiang, China). *Asian Perspect.* **2020**, *59*, 421–452. Available online: https://www.muse.jhu.edu/article/774820 (accessed on 8 March 2022). [CrossRef]
41. Vinnik, D.F.K. The historical topography of medieval Issyk kul basin. In *Ancient Medieval Cultures of Kyrgyzstan*; USSR: Frunze, Kirghizstan, 1967.
42. Amanbaeva, B.E.; Kol’chenkov, B.A.; Sulaimanova, A.T. *Archaeological Monuments of the Kyrgyzstan Portion of the Great Silk Road*; Institute of History and Culture: Bishkek, Kyrgyzstan, 2015.

43. Reimer, P.T.; Austin, W.E.N.; Bard, E.; Bayliss, A.; Blackwell, P.G.; Ramsey, C.B.; Butzin, M.; Cheng, H.; Edwards, R.L.; Friedrich, M.; et al. The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0–55 cal kBP). *Radiocarbon* **2020**, *62*, 725–757. [CrossRef]
44. Mir-Makhamad, B.; Mirzaakhmedov, S.; Rahmonov, H.; Stark, S.; Omel'chenko, A.; Spengler, R.N. Qarakhanids on the Edge of the Bukhara Oasis: Archaeobotany of Medieval Paykend. *Econ. Bot.* **2021**, *75*, 195–214. [CrossRef]
45. Parzinger, H. Burial mounds of Scythian elites in the Eurasian steppe: New discoveries. *J. Br. Acad.* **2017**, *5*, 331–335. [CrossRef]
46. Doumani Dupuy, P.N.; Spengler, R.N.; Frachetti, M.D. Eurasian textiles: Case studies in exchange during the incipient and later Silk Road periods. *Quat. Int.* **2018**, *468*, 228–239. [CrossRef]
47. Heinsch, M.; Vandiver, P.B.; Lyublyanovics, K.; Choyke, A.M.; Reedy, C.; Tourtellotte, P.; Chang, C. Ceramics at the Emergence of the Silk Road: A Case of Village Potters from Southeastern Kazakhstan during the Late Iron Age. *MRS Proc.* **2015**, *1656*, 251–281. [CrossRef]
48. Shnaider, S.V.; Krajcarz, M.T.; Viola, T.B.; Abdykanova, A.; Kolobova, K.A.; Fedorchenko, A.Y.; Alisher-Kyzy, S.; Krivoshapkin, A.I. New investigations of the Epipalaeolithic in western Central Asia: Obishir-5. *Antiquity* **2017**, *91*, e3. [CrossRef]
49. Osipova, E.; Danukalova, G.; Brancaleoni, G.; Krajcarz, M.T.; Abdykanova, A.; Shnaider, S. Palaeoenvironmental conditions of the Palaeolithic–Neolithic transition in the Fergana Valley (Central Asia)—New data inferred from fossil molluscs in Obishir-V rockshelter (Kyrgyzstan). *Quat. Int.* **2021**, *605*, 287–299. [CrossRef]
50. Taylor, W.T.; Pruvost, M.; Posth, C.; Rendu, W.; Krajcarz, M.T.; Abdykanova, A.; Brancaleoni, G.; Spengler, R.; Hermes, T.; Schiavinato, S.; et al. Evidence for early dispersal of domestic sheep into Central Asia. *Nat. Hum. Behav.* **2021**, *5*, 1169–1179. [CrossRef] [PubMed]
51. Tabaldiev, K.S. *Ancient Monuments of the Tian Shan*; Centralnoaziatskogo Universiteta: Bishkek, Kyrgyzstan, 2011; 318p.
52. Chang, C. Archaeological sites, cultural heritage, and sustainable development in the Republic of Kazakhstan. In *Education, Human Rights and Peace in Sustainable Development*; Nugmanova, M., Mikkola, H., Rozanov, A., Komleva, V., Eds.; Intechopen: London, UK, 2019; Volume 87, pp. 1–8. [CrossRef]

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The Transformation of Indigenous Landscape in the First Colonized Region of the Caribbean

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Abstract: This paper presents an archaeological reconstruction of indigenous landscape transformations in the first colonized region of the Caribbean. The arrival of Columbus in 1492 in the northern region of the island of *Haytí* (the current Dominican Republic and Haiti) signified a profound change in the lives of the island's communities, transforming their everyday actions and their perceptions of landscape. To address this complex topic, this research tackled a key problem in landscape archaeology: while the "landscape" concept has been extensively debated, there is a growing tendency to use the concept without clear definitions and to obscure important methodological aspects of how scholars bridge the divide between their conceptual definitions and the archaeological record. This paper approaches this problem by applying the concepts of 'sites as tendencies' and 'contested taskscapes'. This theoretical and methodological framework allows for the reconstruction of the indigenous landscape and, more importantly, highlights how the colonization process impacted the everyday tasks and perceptions of Hayti's indigenous people through the profound transformation of their landscape.

Keywords: landscape; taskscape; indigenous communities; Spanish colonialism; Caribbean

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1. Introduction

The idea of landscape as used in archaeology today is a complex product of decades of archaeological, anthropological and geographical debates [1–9]. In particular, the ambiguous use of the concept today [10] reflects the challenges faced by both processual and post-processual archaeologists in making sense of past realities within their specific theoretical frameworks [11–14]. This dichotomy between processual and postprocessual trends is still palpable, yet clear discussions on the methodological implications of these two very different approaches are less common. One group of scholars continues to use the concept of landscape in the processual sense, i.e., they understand landscape as the passive environmental context for human behavior. By contrast, other researchers use the term to refer to the resulting cultural meanings that humans create in the process of interacting with their surroundings. The issue does not arise from the use of either of these perspectives on landscape per se, but rather the lack of explicit discussion of their methodological and theoretical implications, particularly when scholars seek to draw on a combination of both perspectives.

This problem becomes salient when, for instance, one tries to combine the advantages of regional survey, geographical information systems, and spatial statistics with a conceptual framework that studies transformations in landscape perception as a result of cultural conflict. For this, an articulation of processual and postprocessual methods and theories is imperative. The proposal presented in this paper is based on Tim Ingold's idea of the Dwelling perspective. Over 30 years ago, Ingold suggested a way to overcome the dual and supposedly contradictory ideas of landscape from the processual and post-processual perspectives in archaeology. Ingold aimed "to move beyond the sterile opposition between the naturalistic view of the landscape as a neutral, external backdrop to human activities, and the culturalistic view that every landscape is a particular cognitive or symbolic ordering of space." [15]. The key to achieving this, lay in the realization that the full power of the landscape concept extends beyond the visual and includes "a world in which we can expect to find formations of the land such as hills and valleys, mountains and plains, interspersed with settlements such as villages and towns and threaded by paths, roads and waterways." [16]. For Ingold, there was no fundamental difference between 'landscape' and 'environment', as both are the result of the intertwining combinations of natural and cultural elements over time. The result of the histories of interactions between people, things and nature are that "landscape is not land looked at but land shaped . . . In this medieval sense, landscape already couples the land with tasks of shaping: landscape is taskscape because to shape the land is to work it" [17].

Ingold used the concept of taskscape to articulate the complexities of the intertwinement between people, things, tasks and the environment [4]. The concept of taskscape is a bridge between two realms: for archaeology, it can be a heuristic tool that connects the shape and content of the archaeological record with the idea of landscape. There are several recent examples of the use of taskscape in archaeology, for example see: [18–21]. In the Haytí case study, working through the taskscape perspective allowed for the integration of material evidence (e.g., archaeological sites and artefact distributions at the regional scale) with theoretical notions about human movement, action, and landscape knowledge at different spatial scales. This integration, in turn, proved key to understanding both the ways that indigenous tasks shaped the island's landscape and how these were collectively transformed after 1492.

Yet, for two important reasons, the taskscape concept by itself was not sufficient to properly achieve the desired goal of this research. First, in order to avoid ambiguities in the use of 'landscape' and 'taskscape', clearly defined spatial categories had to be developed. Following an extensive review of the concept of the archaeological site, the notion of 'sites as tendencies' was elaborated as a means of defining of taskscapes in the archaeological record. Second, as the case study focused on contexts of colonial war, enslavement and displacement, the concept of taskscape was reconsidered in terms of how it might relate to the contexts of conflict that the indigenous people suffered. To overcome this second challenge, current debates over landscape, colonization and conflict in archaeology were drawn on to create the idea of 'contested taskscapes'.

A complete review of the arguments for the definition of these two concepts is beyond the scope of this paper [22]. In general terms, the idea of 'sites as tendencies' is based on the understanding that human actions in the world leave traces of their particular intentions and activities, which, in addition to their spatial recurrence, also tend to be recurrent in time. Each particular site contains evidence of one or more tasks that were carried out by human actors in particular environmental contexts and places. The analysis of materials and sites from this perspective allows for a clear definition of taskscapes that articulates directly with the archaeological record. The idea of 'contested taskscapes' came as a second stage in the analytical process and emerged through the combination of Ingold's taskscape [4] and Bender's work on contested landscapes [23–25]. Briefly stated, the contested taskscape concept permitted the identification and classification of the material evidence and patterns left on the terrain by cultural conflicts in the past. By grouping and categorizing these conflicts on the ground, it was possible to identify contested taskscapes and define the resulting landscape transformations.

2. Material and Methods

The study area where these two concepts were explored was the coast of Montecristi, a province located in the northwestern Dominican Republic (Figure 1). After several field seasons in the region, a total of 102 previously unregistered archaeological sites were recorded and grouped by size, location, ceramic affiliation and function [26].

Figure 1. The province of Montecristi (Dominican Republic) in the context of the contemporary Caribbean.

The regional archaeological pattern (Figure 2) in the Montecristi coastal area consists of four groups of archaeological sites. The first of these groups include the large habitation sites (>3 ha, *n* = 8), which are always located higher than 150 masl. All of these sites contained ceramics with Meillacoid (800–1550 AD) attributes as the main component, in association with ceramics from the Chicoid series (900–1700 AD) and a mixed ceramic component that includes stylistic attributes from the Meillacoid and Chicoid series (1000–1700 AD). These sites have a high diversity of lithic artefacts (axes, scrappers, flints, cores, hammerstones, and grinding stones) and a limited variety of shell objects (axes and scrapers). Most sites also showed a great assortment of mollusk shells, with a total of 17 species identified across the region, with 5 to 8 of these species recorded at each of the large habitation sites. The most common species at all sites were *Codakia orbicularis* sp., *Lobatus costatus* sp., and *Lobatus gigas* sp. (Figure 3). These sites are usually located over 1 km from water sources, while fewer are located at a distance less than 500 m.

The second class of sites includes medium-sized habitation sites (between 1 to 3 ha, *n* = 17), which are mostly located below 80 masl and with only a few between 100 to 200 masl. Most of these sites contain exclusively Meillacoid ceramics and only very limited numbers of lithic artefacts, mostly axes and/or hammer stones (usually 1 to 2 per site). The mollusk specimens are not diverse, with most sites containing 3 to 5 species. Unlike the previous category, these sites are usually located close to water sources (<500 m).

The third class of sites–the small habitation sites (<1 ha, *n* = 49)–do not show a specific pattern of elevation. At half of these sites, it was not possible to identify a specific ceramic affiliation as materials tend to be very fragmented and scarce. In the other half, mostly Meillacoid ceramics were registered, and in a few cases, together with Chicoid and mixed Meillacoid-Chicoid components. Stone artefacts were limited at these sites, with only one lithic artefact often recorded (usually an axe or a hammerstone). The same pattern generally held for shell artefacts, with only one artefact observed, in most cases, this was either a hammer or a *gubia* (a shell artefact used in woodworking and agriculture). In most of these sites, 1 to 3 species of mollusks were recorded.

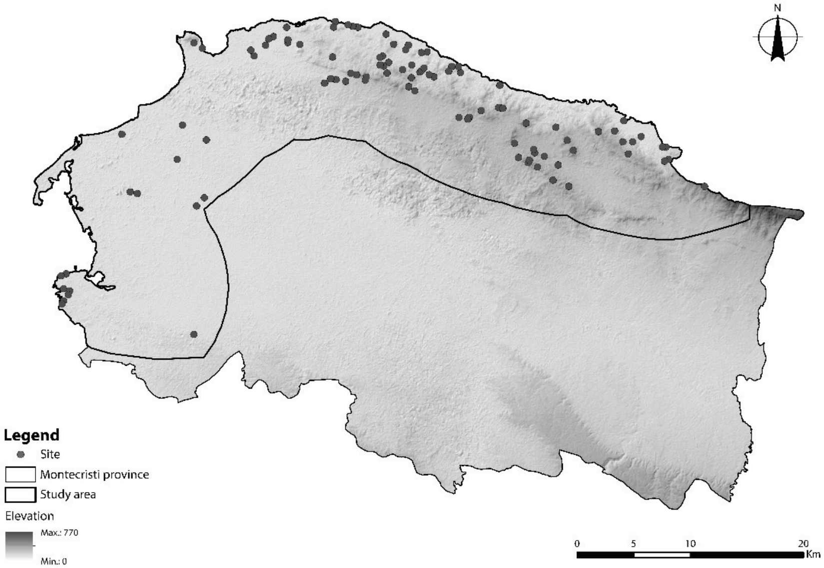


Figure 2. Registered archaeological sites in the coast of Montecristi, Dominican Republic.

Figure 3. Most common mollusk shells registered on the research area.

The final category included is the resource exploitation sites (<3 ha). These sites are characterized by the absence of ceramics or other lithic and shell artefacts. They are exclusively located along the coastline and are usually very close to each other. This pattern suggested that, rather than defining them as sites, they should be perceived as "exploitation zones". The material culture associated with these sites was very limited, comprising only a few ceramic sherds (either unidentified or Meillacoid) and lithic artefacts (either scrapers or flakes). The few shell artefacts recorded were perforators, gubias or hammers.

The preliminary interpretation of these results suggests that the large sites were permanent living places that formed a focus for daily activities. Based on the diversity of material culture present, such sites may have also served as locations where exchange networks were maintained at the local and possibly regional level. Second, the medium-sized sites seem to have been related to temporary or permanent housing activities and, given that both the material evidence and its diversity is less, they may have had fewer inhabitants or existed for shorter periods of time. As in neighboring areas, these medium sites also could have been related to specific activities such as agriculture or could have served as *rancherías* (small hamlets) for hunting parties or fishermen going to the coast [27]. Third, the small sites might have been related to specific tasks, possibly daily activities which recurred over time but that did not need to be done in exactly the same place (e.g., a location where marine products were processed once or multiple times before being transported to hamlets or the main settlement). The patterning of these sites highlights the dynamics and mobility of people in their landscape and the decisions related to this movement.

3. Discussion: Indigenous and Spanish Taskscapes

The taskscape concept is used here as a bridge to connect the materiality of the archaeological record with the abstract idea of landscape. In conceptual terms, this is rendered by using the taskscape as a layer within the complexity of the landscape [28]. A recent example of this was provided by Ingold [17] by using one of Brueghel's paintings. This painting shows a sixteenth-century European settlement, with representations of people's day-to-day activities being carried out in specific places within the town. From an archaeological perspective, this painting highlights three main aspects: the spatial relationships, the idea of spatial scale, and how they are used to define a place. Drawing on Ingold's reading of this painting, it is clear that 'place' can refer to both the location where a specific task is being carried out as well as the entire town. For Ingold, a place is defined by the overlapping lines left by people's movements through the world, in a process he defined as the meshwork of entangling lines [29]. If each location in the painting is the result of a person or a group of persons' movement in the town and the world, each location (including the town) constitutes a place. Since Ingold's definition would fits multiple scales, the idea of taskscape can be deemed multiscalar. Scale may not be an issue when working the idea of landscape in art or ethnography, since the observer in these disciplines has access to the whole "image". In archaeology, however, the spatial scale is a challenge as considering different spatial scales for analysis will potentially result in different reconstructions and interpretations of past humans patterns within the landscape.

To minimize potential misinterpretation and biased classification, and following the idea that the taskscape forms a key level in the process of archaeological analysis, three spatial scales of taskscape were defined for the case study presented here, each of which relates to the tasks and movement of indigenous people in the past.

3.1. Small-Scale Taskscapes

The first scale where a set of tasks was identified was that of the site. Based on all of the previously-described size and functional categories, the primary activities at this scale are related to general domestic activities and the exploitation of land and sea resources, which include tasks of craft production, as well as agricultural, hunting, and fishing activities. This first level of the indigenous taskscape relates directly to daily activities, that is, with the decisions and actions at the level of local communities and their dwelling in the world.

The general pattern reconstructed from this evidence is that there tends to be a large place (large-size sites) that can be associated with permanent areas of habitation and the common tasks of a settlement. These main settlements were "surrounded" by other places (medium and small-size sites and exploitation of sea resource sites) that were associated with highly specialized activities such as marine resource processing, lithic workshops and/or agricultural production. This whole combination of tasks constitutes the first layer of taskscape, and refers to the internal taskscape of each settlement or areas close to the main settlement.

3.2. Medium-Scale Taskscapes

A second scale of the indigenous taskscape occurs at the level of the study area. At this scale, it was possible to identify tasks that interconnect most of the archaeological sites. For example, the presence of specific materials at particular sites, such as mollusk shells and lithic artefacts, indicate tasks related to specialized exploitation of marine resources. The presence of these same mollusks, however, at some of the larger settlements indicates their exchange and/or trade throughout the research area. This taskscape also suggests daily interactions between different communities from distant settlements (possibly between culturally different populations). Figure 4 shows a representation of the connections between particular sea resource sites where a specific mollusk shell-type was identified (in this case *Cittarium pica*, sp.) and the habitation settlements where that same type of shell was recorded. As can be inferred from the image, there seems to be a pattern of distribution and redistribution of the marine resources across larger zones of the study area.

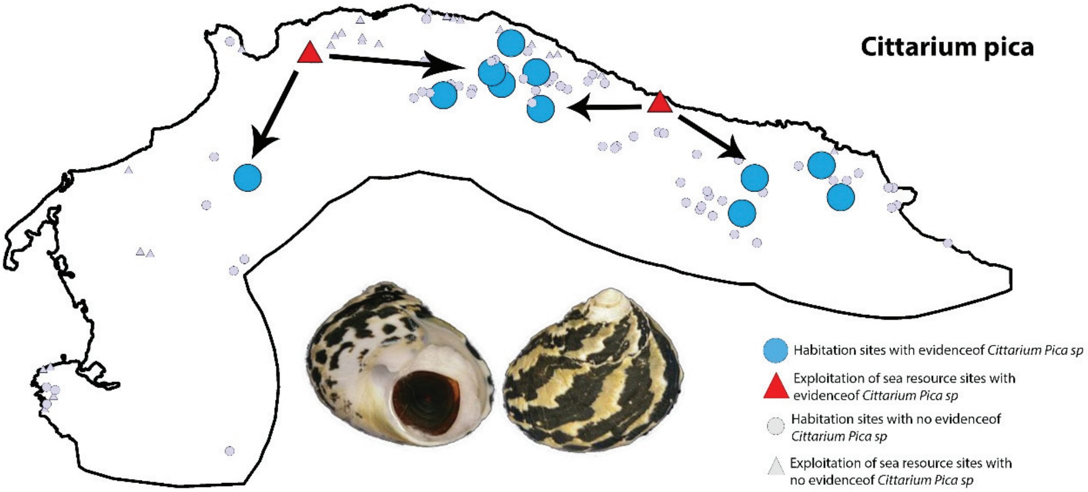


Figure 4. Ideal representation of medium-scale taskscapes.

3.3. Large-Scale Taskscapes

The third scale of the indigenous taskscape was defined when evaluating the regional distributions of the ceramic series present in the region. In the northern sector of the island, two ceramic series dating to the Late Ceramic Age (1100–1500 AD) and the early colonial period (1500–1600 AD) have been classified: Meillacoid and Chicoid [30–33]. The particular distribution pattern of the sites related to the Meillacoid ceramics between the coastal areas of the Montecristi province and the eastern province of Puerto Plata, as well as the characteristic distribution patterns of the Chicoid sites in the region, seem to highlight a political taskscape (Figure 5). This taskscape could have been based on the relationships and interactions between different communities and the rights to access certain areas. Socio-political and cultural reasons could be the main causes for the absence of sites with Chicoid ceramics in the area of the coast of Montecristi. The coastal area of Montecristi also has important topographic (its location at the end of the Cordillera Septentrional) and ecological features (endemic areas of the only mammals on the island, the hutia and solenodon, and easy access to the mangroves), which may have played a role in the interest of Meillacoid-using communities in maintaining control over this area and its resources. Alternatively, conflicts among indigenous groups could also have contributed to this particular pattern.

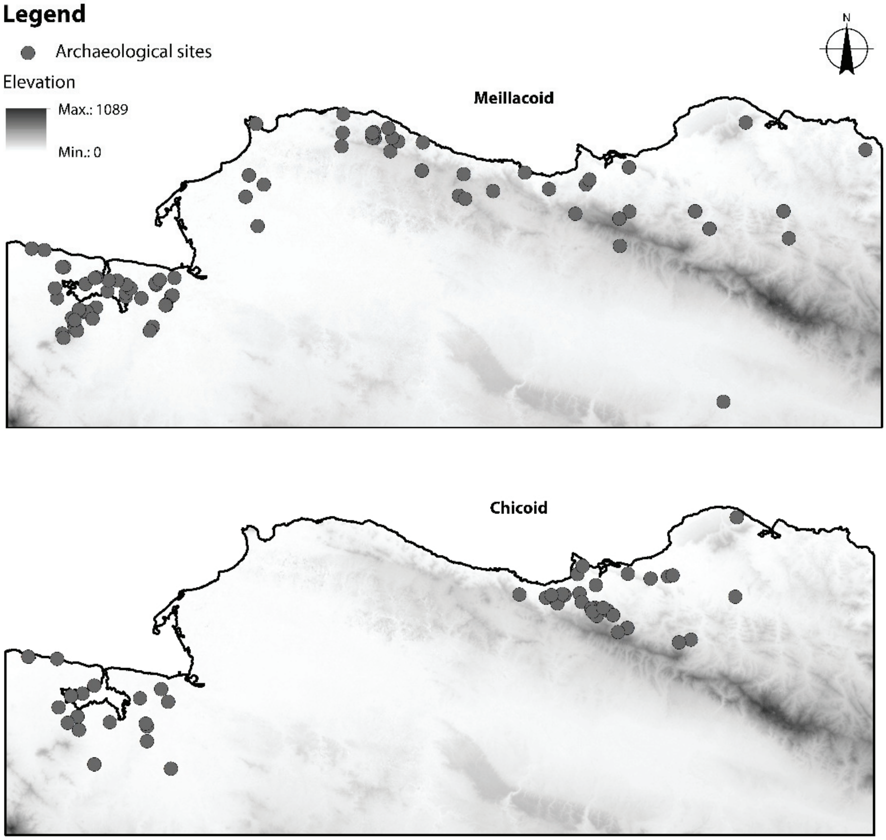


Figure 5. Large-scale taskscapes. Ceramic series distribution pattern: (above) Meillacoid, (below) Chicoid. The data for this image comes from [27,34–36].

3.4. Indigenous Landscape

The indigenous landscape, that the early Spanish observed, can be reconstructed is composed of a variety of places and artefacts that indicate the diversity of activities carried out by past communities. The patterned distribution of places revealed the past inhabitants' recurrent interests of interacting, exploiting and selecting activity places based on topography. The pattern is defined by "central" places related to habitation, trade and perhaps political centrality, followed by a series of medium to small places related to other non-domestic activities such as the exploitation/processing of marine resources, agriculture and, possibly, other activities such as logging and/or production of lithic artefacts. In addition, the non-domestic sites tend to afford the best visibility of the surroundings and marine environment, as has already been proposed for neighboring areas in the region [35,37,38]. These patterns are also observed in other neighboring research areas, such as the coastal region of the Puerto Plata province and northeastern Haiti, with some local particularities possibly related to the topography and culture of the different indigenous communities. The indigenous landscape before 1492 was dynamic and diverse, where communities seem to have shared similar cultural features that are evident across multiple scales. However, at the largest analytical scale, there are indications of cultural heterogeneity that might have resulted from ethnic differences, cultural territories and/or conflict relations.

3.5. Spanish Taskscapes

A good example of the Spanish movements during the early phase of colonization and that formed part of their strategies to reach the inland gold area and control of indigenous population is the so-called *Ruta de Colón* [39,40]. Figure 6 shows a reconstruction of this route as well as some hypothetic lines of the Spanish movements, based on the early chronicles reports. The figure also shows the location of the Spanish towns and forts, from the earliest town of La Isabela (1493) to the fort at Jánico (1494) where the gold mines were located. Following Ingold's [16,29] definition of place, each fort and town formed a 'node' resulting from the repeated passage and selection of certain places as a consequence of the move from the coast to the mainland. In addition, the selection by the Spanish of those specific places for settlement responded to the several indigenous settlements that already existed along this route, as reported by the early chronicles [41–44]. The 'lines' created by the Spanish movement is evidence of their intentions to successfully exploit and transfer gold to the coast, as well as the need to dominate the territory and its people. The forts were built near resistant or important settlements of the indigenous groups. For example, the fort of La Magdalena was built in the Cibao valley, close to Los Hidalgos pass through the northern mountain range, within the area known by the indigenous people as the province of Macorís, and to the north of the supposed area of residence of Cacique Caonabo. Cacique is a word the indigenous people used to refer to their leaders. The early Spanish compare this term to that of king. This fort was destroyed by the indigenous people of the area and, shortly after, the Spanish replaced it with the fort of La Esperanza [43]. On the other hand, some Spanish towns were built near key natural resources (gold veins, rivers, coast) as well as near important indigenous settlements. For example, the town of Concepción de la Vega was founded near the settlement of Cacique Guarionex, with whom the Spanish initially had formed an alliance and later fought several fierce battles.

The initial colonial landscape was shaped by the exploitation of the island's mineral and human resources through the *factoría* system [45]. This was a colonialist system originally developed in Portugal and applied to the Spanish in the conquest of the Canary Islands [46]. The Spanish landscape was made up of two taskscapes. One is based on the exploitation of resources and the other on the military control of the territory. These taskscapes allow an understanding of part of the Spanish logic in conquering the indigenous world, and represent elements of the transformation of the indigenous landscape into the Spanish colonial one during the first years of colonization. The Spanish landscape during these the first years on the island of Haytí was characterized by, in the first place, closely spaced settlements to aid the movement of troops and suppress the constant indigenous uprisings, such as the one that destroyed the fort of La Magdalena or the uprising of the caciques Guarionex and Mayobanex [41]. Second, these settlements, whether villages or forts, served as forms of control and domination of the local population and protected of the movement of resources between the inland and the coast.

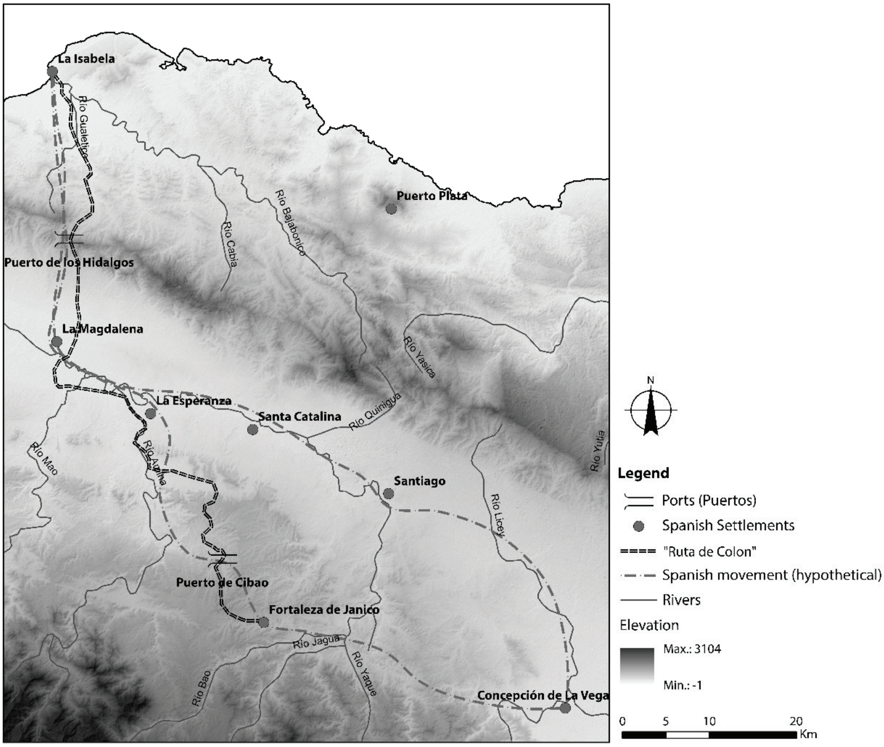


Figure 6. Spanish settlements and movements in the north of Haytí during the first years of colonization (approximate locations based on Sauer [47]).

4. Conclusion: The Transformation of the Indigenous Landscape

To fully understand the transformation of indigenous landscapes on northern Haytí, the regional archaeological patterns formed by indigenous taskscapes were compared to the regional patterns of movement and settlement of the early Spanish colonizers in the same study region. This comparison led to the idea that the transformation of the indigenous landscape can be explained on two analytical levels. These levels have been conceptualized as *Day-to-day* and *Imaginary*. The first explains the changes that occurred within the indigenous communities in terms of the tasks, practices and movements that characterized the quotidian indigenous taskscape before the arrival of the Spanish. The second level has to do with the representations developed by the first Spanish invaders of the indigenous world and how these representations themselves contributed to the transformation of the indigenous landscape.

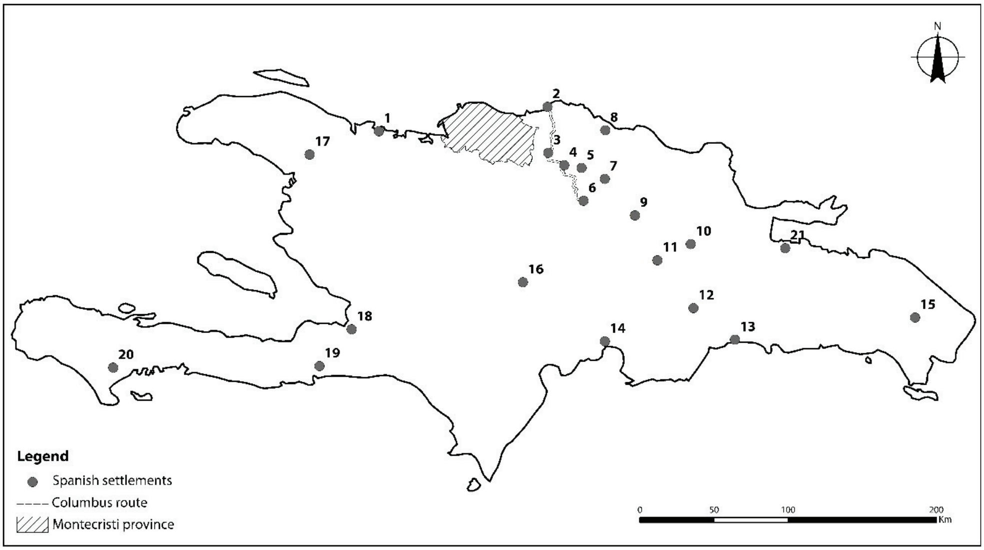
4.1. Day-To-Day Level: Contested Taskscapes

One way to conceptualize the conquest of the indigenous world and its initial transformation is through the idea of contested taskscapes [22]. From the earliest years of colonization, the Spanish invaders depended on the local population to obtain basic products and resources. For example, beginning during the second voyage, Columbus imposed a tribute in gold and food on the indigenous people [41]. In the case of gold, indigenous populations were forced to carry out the task of mineral extraction at known gold veins and rivers, where, in general, the activity followed pre-invasion patterns. However, the intensity of this task radically changed, as did the reasons for the work, with indigenous people preferring to commit suicide and induce abortions to avoid the horrors of enslaved labor in the gold mines for themselves and their descendants [41,48]. In this sense, although the task remained the same and it was carried out in the same places, the taskscape, the constitutive acts of dwelling, changed radically and consequently a conflict was created.

In the case of food production, something similar happened. Even though the indigenous communities continued to produce food according to their traditional knowledge and practices in the usual places, there was a change in the motivation behind the execution of these same tasks. The Spanish demanded a quota greater than the one they were used to producing, leading to the occurrence of a conflict in the daily tasks that constituted the indigenous agricultural taskscape. An example of this was recorded in the early chronicles, when the cacique Guarionex tried to increased cassava production to pay the Spanish more ever a larger quota and lessen the aggression of the *conquistadores*. However, shortly after these negotiations, Guarionex would go to war with the Columbus brothers since his people had not been able to produce as much food as expected [41,42]. In addition, Guarionex and his people were affected by the Spanish presence near their towns and traditional areas as well as by the fear and rage instilled in them by witnessing what the Spanish were doing to other indigenous groups.

A third contested taskscape can be identified in the Spanish settlements along the island (Figure 7). When Nicolás de Ovando became governor of La Española (1502–1509), other mechanisms to deal with local populations and resources were implemented. By that time, the Spanish had moved to displacing entire communities to Spanish towns to continue fulfilling the tasks of food production and gold exploitation, as well as general servitude. As the people were “inserted” in the Spanish villages, in a process known as *encomiendas y repartimientos* [49], the new places where these tasks were to occur were far from where they traditionally took place. An archaeological example that supports the existence of these contested taskscapes comes from the province of Montecristi [26]. During the survey in this area, there was only one place where material culture related to the second half of the 16th-century was recorded, namely in the area where the original foundations of the villa of Montecristi (*circa* 1535) were located [50]. In the rest of the area, no evidence of early 16th-century European material culture was found. In fact, all Spanish or European materials postdate the 17th-century. This could be evidence that during the beginning of the conquest and colonization process (*circa* 1493 to 1502), the Spanish villages did not have rural areas, since their focus was on territorial access and control. After Columbus’s second voyage, the Spanish started their attempts to introduce European animals and vegetables to the island environment [51]. As a result of the food crisis in Spain and Portugal and the efforts of Nicolás de Ovando to improve the quality of the colony since 1502, Spanish efforts in cultivation had not fully started [51]. During the first decade of the colonization, the indigenous communities and their towns were the equivalent of the “countryside” for food production. As mentioned, the indigenous agricultural taskscapes were maintained in their traditional places, serving as rural areas for the Spanish, until the populations were displaced to the Spanish villages. This created a key space of contestation, and after several decades, helped to promote the creation of new creole rural communities.

Following this discussion, the idea of the contested taskscape can be connected with two levels of human experience. First, the physical level, which refers to the conflicts that occurred through the materiality of placemaking. For example, the establishment of Spanish forts and settlements close to important indigenous settlements. Second, the cognitive level, which refers to the perceptions of individuals and communities that live in and move between those places where physical conflict was manifest. For example, individuals and communities suffered a strong psychological impact when they become enslaved and had to continue exploiting resources that were known and familiar to them, in places that possibly carried deep cultural meanings. Bender has explained that studies of conflicts and diasporas generally focus on broad social and political scales “without too much consideration of what this might involve in terms of intimate and personal engagement” [23]. In this sense, when day-to-day tasks (the basis of the cultural skills and knowledge of an individual or of a community) were carried out under conditions of force and enslavery, this affected both the people's perception of those tasks in themselves and their perception of the landscape where those tasks were carried out. This, in turn, would have generated both a personal conflict with the task in question and with the "constitutive acts of dwelling" [17], i.e., with the taskscape. With the development of the colonial state, the stress on indigenous people increased as they were continuously pressured to increase production, to accept new ideologies and religion, and finally to be integrated into the Spanish system as new subjects of a sovereign they did not choose. As Bender [24] has rightly expressed, "the mutual incomprehension engendered by totally different social, political and economic practices extends to include the inability to recognize or at least tolerate a completely different understanding of place and landscape." The indigenous and Spanish taskscapes, at their different spatial scales, naturally came into direct conflict since their basic notions of nature, territory and ownership were radically different.



Settlement's names: 1. La Navidad / Puerto Real, 2. La Isabela, 3. La Magdalena, 4. La Esperanza, 5. Santa Catalina, 6. Fortaleza de Jánico, 7. Santiago de los Caballeros, 8. Puerto Plata, 9. Concepción de La Vega, 10. Cotuí, 11. Bonao, 12. Buenaventura, 13. Santo Domingo, 14. Azua, 15. Salvaleón de Higuey, 16. San Juan de la Maguana, 17. Lares de Guahaba, 18. Verapaz, 19. Villanueva de Yaquimo, 20. Salvatierra de la Sabana, 21. Santa Cruz

Figure 7. Distributions of early Spanish settlements.

4.2. Level of the Imaginary: Historical Homogeneities and Archaeological Diversities

The second level concerns how the first Spanish invaders represented the indigenous people. The image created during the first decades of colonization not only transfigured the landscape and the indigenous world in the past but also did so for the future Caribbean populations that came into being with a distorted idea of the island of Haytí before 1492. This issue can be explored from two perspectives. The first concerns the invisibilization of indigenous communities and their presence in the landscape. The early chroniclers, whether due to the difficulty in understanding indigenous cultures or a lack of interest in deep descriptions, presented a vague image of the indigenous people. Based on their understanding of the world, the first Spanish tried to identify in the indigenous communities hierarchical and spatial patterns similar to those that existed in Europe at that time. In spatial terms, this led to the definition of indigenous "territories" [52] that, based on the available archaeological evidence from the northern region of the island [26,27,34,35,53,54], do not seem to reflect the cultural diversity or the political organization before 1492.

An example of this comes from the 1516 map of Andrés de Morales (Figure 8), which divided the island into five regions. While a subsequent report by Peter Martyr d'Anghiera [48] based on Morales' report and map described these as natural regions, the

20th-century economist Bernardo Vega [52] interpreted these regions as political territories related to the indigenous cacicazgos (chiefdoms). However, the map of Morales does not depict borders between these territories and Martyr d'Anghiera simply states that: "The pilot Morales, brings me a new description that from time immemorial the indigenous people used." [48]. The evidence from both the map and the documentary record does not suggest that this description included the delimitation of chiefdoms, as later proposed by Vega [52]. Indeed, the claim that these natural geographical regions which probably were imbued with cultural and historical meanings represented chiefly territories effaced, rather than explained, indigenous diversity. Nevertheless, the wider idea of indigenous territories connected to hierarchical political structures was present in several colonial chronicles and was finally depicted in Charlevoix's map in 1731 (Figure 9).

Figure 8. Map of Haytí during the early colonial period by Andres de Morales in 1516 (taken from Frati [55]).

Without doubting the existence of hierarchical societies on the island, it is important to recognize that the representation of homogeneous indigenous territories (i.e., one *cacique* (king) controlling one large territory (nation)) facilitated the explanation of indigenous cultural complexity for initial colonial observers. By contrast, the archaeological data, in combination with the different indigenous taskscapes defined here, reveal a diverse indigenous landscape shaped by multiple spatial scales of community interaction. This patterning is suggestive of the presence of multi-ethnic and politically centralized groups at small scales, rather than large cacicazgos occupying large and homogeneous territories. The first transformation of the indigenous landscapes of Haytí, therefore, happened at this level of Spanish colonial representation. The resulting image of homogeneous territories controlled by highly centralized political polities obscured the island's multiple scales of interaction, the reality of which has been recovered only recently by archaeological research.

A second transformation of the indigenous landscape occurred with the eradication of the diversity of communities by creating homogeneous ethnicities. This point is detailed here through the example of the ethnonym "Taíno". Several authors have highlighted that the early Spanish merged together a wide range of ethnic groups in the island of Haytí since they were unable to recognize internal cultural differences [56]. The Taíno are the classic example of this since they have been identified as the major indigenous group in the Greater Antilles [57,58]. However, Caribbean researchers have realized that, in order to do justice to the complexity of these ethnic groups without obscuring their cultural dynamics, terms such as "Tainoness" [56,59,60] or symbolic reservoir [61] are more appropriate to characterize the indigenous culture of these communities.

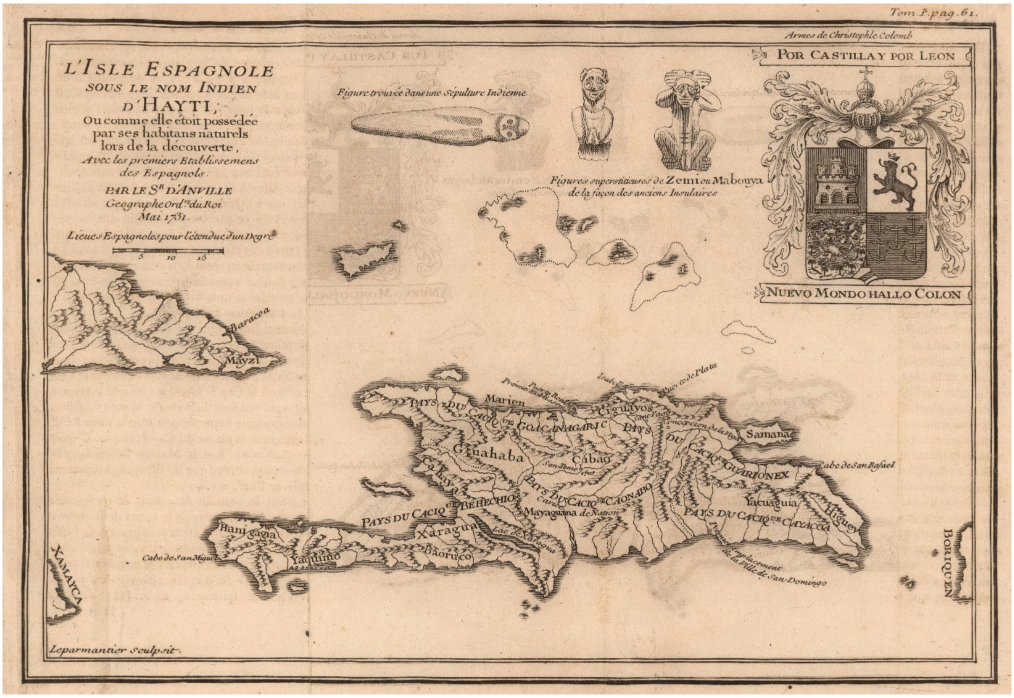


Figure 9. Map of Haytí showing the supposed indigenous territories by Pierre-Francois-Xavier de Charlevoix in 1731 (courtesy of the digital collection of John Carter Brown Library at Brown University).

The first reference to the term Taíno was made on Columbus's second voyage when upon arriving on the beach of an island he was greeted by people shouting "Taíno, Taíno". The meaning of this word has been identified as "good" or "noble" [60–62]. In the 19th-century, the term Taíno began to be applied to define a particular ethnic group and to their language. The first reference to Taíno as the equivalent of an ethnic group that inhabited the Greater Antilles has been attributed to Rafinesque in 1836 [60], although the term was also used a few years later by Martinus in 1867 [61]. In 1871, Brinton used the term Taíno to describe the linguistic classification of the Arawak language spoken in those islands [62]. The popularization of the term Taíno was a consequence of the historical reconstructions that took place throughout the 19th-century, which condensed the previous generalizations and homogenizations of the ethnic and linguistic diversities of the indigenous groups of the northern Caribbean. For example, in his report about his coexistence with the indigenous people from the northern region of Haytí, Fray Ramón Pané mentioned that he was first sent by Columbus to live in the province of Macorís, where the fort of La Magdalena fort was located, and then to move and live with the cacique Guarionex, because this cacique and his people spoke a language that was understood throughout the island [43]. Still, Pané did not indicate whether Macorís was an ethnic group or that Guarionex and his language were Taíno. The idea that Guarionex was a Taíno cacique first appeared in the 19th-century historical reconstructions and was further consolidated in archaeological and historical scholarship in the 20th-century. The meaning of Macorís, as a language or ethnic unit, is still strongly debated among specialists.

The criticism raised by recent scholars in their quest to clarify the indigenous patterns before the arrival of Europeans parallels the foregoing critique of colonial cartographic depictions. The representations of indigenous communities made by the early colonizers and missionaries were deeply marked by a European understanding and classification of the world. This “environmental orientalism” [63] was a perspective that originated in the Middle Ages, and shaped how indigenous people were seen. The radically different ways of classifying and understanding the world by indigenous and Spanish groups is perhaps best exemplified in the simplicity with which the Spanish represented the indigenous world and its landscapes. In summary, through their process of interpreting it, the Spanish and other European colonists would transform the diverse, multi-ethnic and pluri-linguistic indigenous landscape into a homogenous “indigenous” landscape characterized by a limited set of homogenous ethnic groups and their territories. This early distorted vision which helped transform the indigenous landscape in the early colonial period, would be reaffirmed by 18th- and 19th-century naturalists, and more recently, further reinforced by archaeological models in the 20th century.

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References

1. Binford, L.R. Willow Smoke and Dogs’ Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *Am. Antiq.* **1980**, *45*, 4–20. [CrossRef]
2. Tilley, C. *A Phenomenology of Landscape. Places, Paths and Monuments*; Berg: Oxford, UK, 1994.
3. Olwig, K.R. Recovering the Substantive Nature of Landscape. *Ann. Assoc. Am. Geogr.* **1996**, *86*, 630–653. [CrossRef]
4. Ingold, T. *The Perception of the Environment: Essays on Livelihood, Dwelling and Skill*; Routledge: London, UK, 2000.
5. Anschuetz, K.F.; Wilshusen, R.H.; Scheick, C.L. An Archaeology of Landscapes: Perspectives and Directions. *J. Arch. Res.* **2001**, *9*, 157–211. [CrossRef]
6. Hicks, D.; McAtackney, L. Introduction: Landscapes as Standpoints. In *Envisioning Landscape: Situations and Standpoints in Archaeology and Heritage*; Hicks, D., McAtackney, L., Fairclough, G., Eds.; Left Coast Press, Inc.: Walnut Creek, CA, USA, 2007; pp. 13–29.
7. Cosgrove, D. *Geography and Vision. Seeing, Imagining and Representing the World*; I. B. Tauris & Co Ltd.: London, UK, 2008.
8. Descola, P. *Beyond Nature and Culture*; The University of Chicago Press: Chicago, IL, USA, 2013.
9. Gosden, C.; Green, C.; Cooper, A.; Creswell, M.; Donnelly, V.; Franconi, T.; Glyde, R.; Kamash, Z.; Mallet, S.; Morley, L.; et al. *English Landscapes and Identities: Investigating Landscape Change from 1500 BC to AD 1086*; Oxford University Press: Oxford, UK, 2021.
10. Gosden, C.; Head, L. Landscape–A Usefully Ambiguous Concept. *Archaeol. Ocean.* **1994**, *29*, 113–116. [CrossRef]

11. Binford, L.R. The Archaeology of Place. *J. Anthropol. Archaeol.* **1982**, *1*, 5–31. [CrossRef]
12. Thomas, J. The politics of vision and the archaeologies of landscape. In *Landscape. Politics and Perspectives*; Bender, B., Ed.; Berg: Providence, RI, USA, 1993; pp. 19–48.
13. Bender, B. *Stonehenge: Making Space*; Berg, Bloomsbury Academic: Oxford, UK, 1998.
14. Barrett, J.C.; Ko, I. A phenomenology of landscape: A crisis in British landscape archaeology? *J. Soc. Archaeol.* **2009**, *9*, 275–294. [CrossRef]
15. Ingold, T. The temporality of the landscape. *World Archaeol.* **1993**, *25*, 152–174. [CrossRef]
16. Ingold, T. *Being Alive. Essays on Movement, Knowledge and Description*; Routledge: London, UK, 2011.
17. Ingold, T. Taking taskscape to task. In *Forms of Dwelling. 20 Years of Taskscapes in Archaeology*; Rajada, U., Mills, P., Eds.; Oxbow: Oxford, UK, 2017; pp. 16–27.
18. Herrera Malatesta, E. On contested taskscapes. In *The creation of Landscapes: Borders, Movement and Conflicts*; Herrera Malatesta, E., Borck, L., Eds.; unpublished book.
19. Bender, B. Landscapes on-the-move. *J. Soc. Archaeol.* **2001**, *1*, 75–89. [CrossRef]
20. Bender, B. Place and Landscape. In *Handbook of Material Culture*; Tilley, C., Keane, W., Küchler, S., Rowlands, M., Spyer, P., Eds.; Sage: London, UK, 2006; pp. 303–314.
21. Bender, B.; Winer, M. (Eds.) *Contested Landscapes: Movement, Exile and Place*; Berg: Oxford, UK, 2001.
22. Herrera Malatesta, E. *Una Isla, Dos Mundos. Estudio Arqueológico Sobre el Paisaje Indígena de Haytí y su Transformación al Paisaje Colonial de La Española (1200–1550)*; Sidestone Press: Leiden, The Netherlands, 2018.
23. Logan, A.L.; Dores Cruz, M. Gendered Taskscapes: Food, Farming, and Craft Production in Banda, Ghana in the Eighteenth to Twenty-first Centuries. *Afr. Archaeol. Rev.* **2014**, *31*, 203–231. [CrossRef]
24. Antczak, A.; Antczak, K.A.; Antczak, M.M. Risky business: Historical archaeology of the Dutch salt enterprise on La Tortuga Island, Venezuela (1624-38). *Post-Mediev. Archaeol.* **2015**, *49*, 189–219. [CrossRef]
25. Michelaki, K.G.; Braun, V.; Hancock, R.G.V. Local Clay Sources as Histories of Human–Landscape Interactions: A Ceramic Taskscape Perspective. *J. Archaeol. Method Theory* **2015**, *22*, 783–827. [CrossRef]
26. Rajada, U.; Mills, P. *Forms of Dwelling. 20 Years of Taskscapes in Archaeology*; Oxbow: Oxford, UK, 2017.
27. Ulloa Hung, J.; Herrera Malatesta, E. Investigaciones Arqueológicas en el Norte de la Española, entre viejos esquemas y nuevos datos. *Boletín Mus. Hombre Dominic.* **2015**, *46*, 75–107.
28. Thomas, J. Concluding Remarks: Landscape, taskscape, life. In *Forms of Dwelling. 20 Years of Taskscapes in Archaeology*; Rajada, U., Mills, P., Eds.; Oxbow: Oxford, UK, 2017; pp. 268–279.
29. Ingold, T. *Lines. A Brief History*; Routledge: London, UK, 2007.
30. Rouse, I. *Prehistory in Haiti: A Study in Method*; Yale University Press: New Haven, CT, USA, 1939.
31. Rouse, I. *Migrations in Prehistory. Inferring Population Movement from Cultural Remains*; Yale University Press: New Haven, CT, USA, 1986.
32. Veloz Maggiolo, M.; Ortega, E.; Fuentes, A.C. *Los Modos de Vida Mellacoides y sus Posibles Orígenes. Un Estudio Interpretativo*; Museo del Hombre Dominicano: Santo Domingo, República Dominicana, 1981.
33. Ortega, E.J. *Compendio General Arqueológico de Santo Domingo*; Academia de Ciencias de la República Dominicana: Santo Domingo, República Dominicana, 2005; Volume I.
34. Moore, C.; Tremmel, N. *Settlement patterns in Pre-Columbian Haiti: An Inventory of Archaeological Sites*. 1997, p. 156. Available online: http://ciat.bach.anaphore.org/archives/show/HTIGOUVCIAT_ETU_Amenagement_de-209 (accessed on 22 September 2021).
35. Ulloa Hung, J. *Arqueología en la Línea Noroeste de La Española. Paisajes, Cerámicas e Interacciones*; Instituto Tecnológico de Santo Domingo: Santo Domingo, República Dominicana, 2014.
36. Herrera Malatesta, E.; Hofman, C.L. Indigenous Landscape Transformation on Northern Haytí: An Archaeological and Environmental Database of the Montecristi Coast. *J. Open Archaeol. Data* **2019**, *7*, 1–5. [CrossRef]
37. De Ruiter, S. Mapping History: An analysis of site locations in the northwestern Dominican Republic. Master' Thesis, Leiden University, Leiden, The Netherlands, 2012.
38. Ransijn, S. The (Re)construction of Ancient Indigenous Landscapes through Visibility Analyses. Analysing visibility patterns from multiple viewsheds during the Late Ceramic Age (AD 800–1500) in the coastal zone of the Montecristi Province, Dominican Republic. Undergraduate Thesis, Leiden University, Leiden, The Netherlands, 2017.
39. Morrison, S.E. *Admiral of the Ocean Sea. A life of Christopher Columbus*; Little, Brown and Company: Boston, MA, USA, 1942; Volume II.
40. Ortega, E.J. *La Isabela y la Arqueología en la Ruta de Colón*; Ediciones de la Universidad Central del Este: Santo Domingo, República Dominicana, 1988.
41. De Las Casas, B. *Breve Relación de la Destrucción de las Indias Occidentales*; Juan, F., Ed.; Hurtel: Filadelfia, PA, USA, 1821.
42. De Las Casas, B. *Historia de las Indias*; Imprenta de Miguel Ginesta: Madrid, Spain, 1875.
43. Pané, F.R. Relación acerca de las antigüedades de los indios. In *Fray Ramón Pané: Relación Acerca de las Antigüedades de los Indios*; Arrom, J.J., Ed.; Siglo XXI Ediciones: Ciudad de México, Mexico, 2001; pp. 1–49.
44. De Oviedo y Valdés, G.F. *Historia General y Natural de las Indias, Islas y Tierra-Firme del Mar Océano*; Imprenta de la Real Academia de la Historia: Madrid, Spain, 1851.

45. Moya Pons, F. *The Dominican Republic. A National History*; Markus Wiener Publishers: Princeton, NJ, USA, 2010.
46. Cassá, R. *Indios de las Antillas*; Ediciones Abya-Yala: Quito, Ecuador, 1995.
47. Sauer, C.O. *The Early Spanish Main*; University of California Press: Berkeley, CA, USA, 1966.
48. Martyr d'Anghiera, P. *Décadas del Nuevo Mundo, por Pedro Mártir de Anglería, Primer Cronista de Indias*; Jose Porrua e Hijos Sucs.: Ciudad de México, Mexico, 1964.
49. Mira Caballos, E. *El Indio Antillano. Repartimiento, Encomienda y Esclavitud (1492–1542)*; Muñoz Moya Editor: Sevilla, Spain, 1997.
50. Ortega, E.J. *Ensayo Histórico y Arquitectónico de la Ciudad de Montecristi*; Museo del Hombre Dominicano, Fundación Ortega Alvarez, Inc.: Santo Domingo, República Dominicana, 1987.
51. Del Río Moreno, J. *Los Inicios de la Agricultura Europea en el Nuevo Mundo*; Academia Dominicana de la Historia: Santo Domingo, República Dominicana, 2012.
52. Vega, B. *Los Cacicazgos de la Hispaniola*; Fundación Cultural Dominicana: Santo Domingo, República Dominicana, 1990.
53. Koski-Karell, D.A. Prehistoric Northern Haiti: Settlement in Diachronic Ecological Context. Ph.D. Thesis, The Catholic University of America, Washington, DC, USA, 2002.
54. Jean, J.S. *La Biographie d'un Paysage. Etude sur les Transformations de Longue Durée du Paysage Culturel de la Région de Fort-Liberté, Haïti*; Sidestone Press: Leiden, The Netherlands, 2019.
55. Frati, C. *El Mapa Más Antiguo de la Isla de Santo Domingo (1516) y Pedro Mártir de Anglería*; Leo S. Olschki Editore: Firenze, Italy, 1929.
56. Rodríguez Ramos, R. *Rethinking Puerto Rican Precolonial History*; The University of Alabama Press: Tuscaloosa, AL, USA, 2010.
57. Granberry, J.; Vescelius, G.S. *Languages of the Pre-Columbian Antilles*; The University of Alabama Press: Tuscaloosa, AL, USA, 2004.
58. Wilson, S.M. *The Archaeology of the Caribbean*; Cambridge University Press: Cambridge, UK, 2007.
59. Rodríguez Ramos, R. Puerto Rican precolonial history etched in stone. Ph.D. Thesis, University of Florida, Gainesville, FL, USA, 2007.
60. Oliver, J.R. *Caciques and Cemí Idols: The Web Spun by Taíno Rulers between Hispaniola and Puerto Rico*; University of Alabama Press: Tuscaloosa, AL, USA, 2009.
61. Curet, L.A. The Taíno: Phenomena, Concepts, and Terms. *Ethnohistory* **2014**, *61*, 467–495. [CrossRef]
62. Keegan, W.F.; Hofman, C.L. *The Caribbean before Columbus*; Oxford University Press: New York, NY, USA, 2017.
63. Pálsson, G. Human-Environmental Relations: Orientalism, Paternalism and Communalism. In *Nature and Society: Anthropological Perspectives*; Descola, P., Pálsson, G., Eds.; Routledge: New York, NY, USA, 1996; pp. 63–81.

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Ancient Agricultural and Pastoral Landscapes on the South Side of Lake Issyk-Kul: Long-Term Diachronic Analysis of Changing Patterns of Land Use, Climate Change, and Ritual Use in the Juuku and Kizil Suu Valleys

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Abstract: The main goal of this paper is to present results of preliminary archaeological research on the south side of Lake Issyk-Kul in Kyrgyzstan. We test the hypothesis that agropastoral land use changed over four millennia from the Bronze Age through the Kirghiz period due to economic, socio-political, and religious shifts in the prehistoric and historic societies of this region. Our research objectives are to: (1) describe and analyze survey results from the Lower Kizil Suu Valley; (2) discuss the results of radiometric and archaeobotanical samples taken from three stratigraphic profiles at three settlements from the Juuku Valley, including the chronological periods of the Wusun (140 to 437 CE), the Qarakhanid (942 to 1228 CE), and the historic Kirghiz (1700 to present CE); and (3) conduct preliminary GIS spatial analyses on the Iron Age mortuary remains (Saka and Wusun periods). This research emerges out of the first archaeological surveys conducted in 2019–2021 and includes the Lower Kizil Suu alluvial fan; it is an initial step toward developing a model for agropastoral land use for upland valleys of the Inner Tian Shan Mountains.

Keywords: archaeological landscapes; Iron Age; Medieval Period; agriculture; pastoralism; vertical zonation; Issyk-Kul Lake; archaeobotany; GIS mapping

1. Introduction

During the summer field seasons of 2019 and 2021 archaeological reconnaissance and survey was conducted on the south side of Lake Issyk-Kul in the Juuku and Lower Kizil Suu Valleys in the Republic of Kyrgyzstan (see locator map, Figure 1). Archaeological sites spanning the Bronze Age through ethnographic Kirghiz periods have been identified [1] that cover a four millennia period. In this paper we specifically provide the detailed stratigraphic profiles for two settlements in the Upper Juuku Valley. We add additional radiometric dates recovered from ancient seeds discovered during the archaeobotanical analyses. These archaeobotanical and radiometric sequences provide a baseline for examining the development of settlement patterns over the last three or four millennia of human occupation on the south side of Lake Issyk-Kul. The paper also puts forth preliminary GIS spatial analyses of site loci found in the Lower Kizil Suu, an alluvial fan covering about 19.7 sq km in total area. These survey data can be used to reconstruct ancient land-use patterns of agriculture and pastoralism over the last four millennia. The Central Tian-Shan region was important as a segment of a larger trade, migration, and communication route, tying Central Asia to both the east and west branches of the proto-Silk Road routes. In the Juuku and Kizil Suu Valleys, the ecoclines spanning 1600 to 2100 m asl provide ideal conditions for cultivation of wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), the two East Asian millets (*Panicum miliaceum* and *Setaria italica*) and the herding of sheep, goat, cattle, and horses. In addition, humans likely foraged for wild plants and hunted wild animals, such as deer, ibex, hare, rodents, waterfowl, and other birds. Not only did the natural landscape provide a range of potential subsistence niches for ancient populations, but these populations also altered local environments through their settlement activities. By the Medieval period and possibly as far back as the Iron Age (ca. 800 BCE to 550 CE) ancient people also built check dams and simple irrigation systems. The burial *kurgans* (earthen or stone mounds), often ranging from 2 to 90 m in diameter and from flat to 9 m in height, were mortuary monuments that altered the natural land surfaces. The high density of burial mounds, settlements, and features on the alluvial fans and valleys Saka (800 BCE to 260 BCE to Wusun periods 140 BCE to CE 438) may also be used as rough demographic indicators of the populations occupying these valleys.

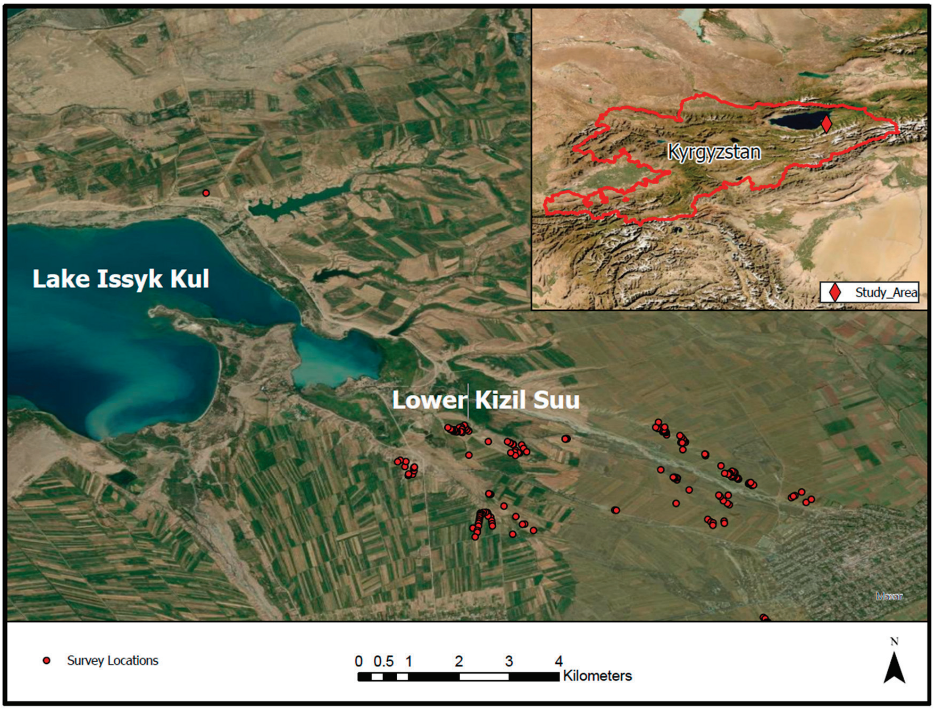

Figure 1. Locator Map of Study Area of Kizil Suu region.

By tracing changing settlement and land-use patterns over a four millennia period of the Late Holocene by means of survey research, we lay out a long-term strategy for testing our ideas about the social development of upland societies in this region. We have also conducted some preliminary studies in: (1) radiometric dating of stratigraphic deposits at three settlements using both charcoal and carbonized seed samples [1]; (2) archaeobotanical analyses of soil samples taken from cultural deposits at these three settlements; and (3) preliminary spatial analyses of the kurgan locations from the Lower Kizil Suu alluvial fan. The three profiles located at an Iron Age settlement, a Medieval (Qarakhanid) settlement, and a 19th century Kirghiz settlement, were selected for radiometric dating of seeds and charcoal, and initial archaeobotanical analyses of carbonized plant materials from ancient contexts. These initial chronological sequences at Juuku Valley allow for speculative hypotheses about changing land use patterns from the latter part of the Iron Age through the present Kirghiz period of occupation. The recent research done by palynologists working in the Karakol area of Issyk-Kul provides invaluable proxies for documenting climate change over four millennia of occupation. The spatial analyses of burial mound loci, known as kurgans, for two sets of Iron Age cultural phases, the Saka period (ca. 800 BCE to 260 BCE) and the Wusun period (ca. 140 BCE to 437 CE) are significant indicators of ritual landscapes and their boundaries along the ridges above stream beds on the large alluvial fan of Kizil Suu. GIS (Geographic Information Systems) analyses provide statistically relevant data about spatial relations between the mortuary landscapes of two different Iron Age cultural groups. The spatial boundaries between Saka and Wusun culture groups, may also represent a kind of “filling in” strategy whereby the later Wusun groups situated themselves in territories proximate to earlier Saka burial grounds, yet maintained clear spatial and ritual boundaries.

Our intentions are to elucidate changing patterns of subsistence over time; also we eventually hope to contribute to a more fine-grained understanding of pastoral mobility, agricultural sedentism, and short and long-distance exchange routes along one segment of the Inner Asian Mountain Corridor. Frachetti [2] defined the Inner Asian Mountain Corridor as a series of short-distance pastoral pathways, which served as geographic pulses for large-scale long-distance mobility across the geographic regions of Central Asia, the Eurasian steppe, and northeastern China. Although contemporary archaeologists have the laboratory tools to trace population movements and shifts through aDNA on human skeletal material [3,4] and isotopic analyses of human and animal bone remains from archaeological sites [5,6], there is still the need for detailed archaeological field research. Surveys and excavations at ancient sites not only provide important material, such as ancient seeds, animal bones, and other ecofacts, but they also document the artifacts, features, and architecture of ancient monuments and settlements. These rich contextual data then allow field archaeologists to re-evaluate, revise, and reconstruct former patterns of social, political, and religious organization of societies, especially those with little textual data. In order to design comprehensive research programs field archaeologists often have to conduct pedestrian surveys such as ours in the Juuku and Lower Kizil Suu valleys, searching for artifacts scatters, architectural features, such as house structures, pits, and fireplaces, and burial mounds. These data will inform us as to how we may conduct long term research that includes test sondages, block excavations, and laboratory studies.

How did ancient and historic populations use both agrarian and pastoral strategies to adapt to upland valleys and in turn transform these physical landscapes over the past four millennia? In recent papers [7–13] archaeologists and other specialists working in Central Eurasia have tended to define the articulation of agriculture with pastoralism using the umbrella term “agro-pastoralism”. In this paper we specifically refer to these separate economic strategies of land use as pastoralism and agriculture. This then allows us to examine how both economic strategies and land use systems sometimes articulated with one another, and at other times were practiced in opposition and even in conflicting ways. In the vast literature on Eurasian nomadic pastoralism, social anthropologists, and archaeologists such as Khazanov [14] and Kradin [15] have already argued that there were almost no cases of “pure pastoralism” since most Eurasian pastoral groups also practiced foraging, fishing, and farming. The northern Mongolian reindeer herders were one of the few pastoral groups who almost exclusively engaged in pastoral pursuits. One way of bypassing the tendency to pigeon-hole and, therefore, typologize pastoral strategies from “pure nomadic pastoralism” to settled agro-pastoralism is to examine the nature of variation within all ancient and modern pastoral societies and their complicated relationships with the “outside world”. Those relations, between the historic populations of Kirghiz and Kazakhs who practiced animal husbandry and their settled neighbors were often quite varied and, in many cases, demonstrated the necessity for mutual dependence and symbiosis, as well as competition over water and land [14,16]. Over 50 years ago, Dyson-Hudson [17] reprimanded social anthropologists and geographers for typologizing pastoral societies on the basis of their mobility practices, thus ignoring so many other variables that exist in nomadic pastoral life such as the species herded by humans, the fact that herders and their animals represent "co-incident populations of animals and humans," and the social and political advantages gained by regular seasonal or cyclical movement in search of pasture and water. In the recent literature on Central Eurasia archaeologists have argued about the nature of agropastoralism versus pastoral nomadism during the Bronze Age through the Medieval periods [7]. Nomadic mobility and its role for the spread of Indo-European language, the new technologies of metalworking (specifically bronze production), and the importance of horse transport (both riding and as traction animals) [2,18] have dominated our understandings of agricultural and pastoral interactions over the last four millennia of Eurasian steppe and mountain adaptations. Contributing to these discussions have been the exciting new developments of complete radiometric sequences of both Bronze and Iron Age settlement and cemetery contexts, DNA studies on human skeletal remains, archaeobotanical findings of early crops of domesticated millets, wheat, and barley, and the use of isotopic studies on both human and faunal materials [5,6,19–22]. No doubt it has been an exciting time for the fine-grained laboratory analyses of seeds, animal bones, and human remains.

At the same time field archaeologists continue to survey and excavate settlements and burial grounds along the Inner Asian Mountain Corridor, often testing the Corridor hypothesis [23–27]. Archaeological studies of pastoral mobility have been successful in delineating both short and long-distance mobility during the Bronze Age in particular [2,6,28,29]. More recent studies of mobility patterns in the Iron Age and Medieval Periods in Central Asia have begun to tease out patterns of mobility as well as symbiosis and competition between agriculturalists and mobile pastoralists [6,10,20,30–33]. Settlement pattern studies have been initiated in the nearby Kochkor Valley by Rouse and her team [25,26]. Recently Motuzaite-Mateviciute and her team [22] have examined 78 human and 84 animal samples from 17 archaeological sites in Kyrgyzstan, primarily along the Naryn corridor and the south side of Lake Issyk-Kul for carbon and nitrogen isotopes indicating the consumption of millets at Bronze Age through Medieval period occupations. The initial conclusions show that millet consumption and fodder use did not occur before the Bronze Age, and in two cases, the very early use of millet may have come from immigrants from outside this region [22].

We suggest that our survey results show the influx of new groups into these valleys. Here we present a chronology for the South side of Lake Issyk Kul. This chronology can then be used to define how each cultural group in a given time period most likely practiced different economic strategies and ritual land use (see Table 1).

Table 1. Time Periods, Phase Designations, and Dates used for the Juuku and Lower Kizil Suu Surveys.

Time Period	Phase Designation	Dates
Late Bronze Age		2000 BCE–900 BCE
	Final Bronze	1100 BCE–800 BCE
Iron Age		800 BCE–550 CE
	Saka	800 BCE–260 BCE
	Wusun	140 BCE–437 CE
	Kenkol (only in TianShan)	200 CE–550 CE
Medieval Period		500 CE–1500 CE
	Turkic Period	552 CE–900 CE
	Qarakhanid	942 CE–1228 CE
Early Kirghiz		1500 CE–1700 CE
Kirghiz Period		1700 CE–Present
Soviet Period		1917–1991
Post-Soviet, Kyrgyz Nation		**1991–**

For example, the Andronovo Bronze Age farmers and herders of the second millennium BCE were replaced by Iron Age nomadic confederacies. Some groups within the Iron Age nomadic confederacies continued to cultivate barley, wheat, and the two millets, as well as herd sheep, goats, cattle, and horses [31]. During the latter part of the Iron Age, outside groups like the Wusun, may have incorporated indigenous Saka groups into their quasi-states or confederacies. In the Turkic and Medieval periods, (ca. 600 to 1500 CE) the rise of urbanism is apparent from the variety of site types including rural homesteads and outlying corrals and encampments, caravanserais, military outposts, early towns, and cities [34,35]. The demographic increases during the Turkic and Medieval periods undoubtedly placed more pressure on local resources, including land. When did the local people begin to use irrigation and who owned the herds of domesticated animals? During the later periods when early states became increasingly hierarchical, questions such as who worked the land, and who owned land as property become essential elements in our models of land-use. Also, it is important to consider how the Medieval and historic Kirghiz periods were also those times of maximum pressure on land, water, and other natural resources, especially in these small, circumscribed upland valleys? Greater impact on the natural landscapes must also have affected local communities, not only economically, but socially and politically and may have aided in the transformation of sacred landscapes. Our answer to such broad questions begins with documenting the results of our archaeological surveys and the ancillary studies conducted because of the 2019 and 2021 field seasons. Each aspect of this project, such as the survey results, the radiometric dating at three settlements, preliminary archaeobotanical analysis, and GIS spatial analysis of Lower Kizil Suu mortuary landscapes all contribute to the diachronic study of landscape change in the Late Holocene.

2. Materials and Methods

2.1. Study Area

In this paper we discuss the research results of three settlement profiles from the Juuku Valley and the survey results of the Lower Kizil Suu Valley (Figure 2). Both upland valleys are found on the south side of Lake Issyk-Kul, a large saline lake located between the Northern and Inner Tian Shan Mountain ranges. Lake Issyk-Kul is fed by 102 streams and lakes; the lake levels fluctuate according to seasonal glacial melt. Juuku Valley is a small intermontane valley with the high peak of It-Tash (elevation of 4808 m) to the south and extends about 50 km to the north where it empties into the Lake Issyk-Kul. The two survey polygons of the Juuku Valley, Polygon 1 in the Lower Juuku alluvial valley, is about 6.4 sq km and ranges from 1750 to 1950 m asl and Polygon 2 in the Upper East River Branch of the Juuku Valley is about 0.5 sq km in area and ranges from 2060 to 2100 m asl (see Figure 2). The survey results found on both polygons of the Juuku Valley have already been reported by Chang, Ivanov, and Tourtellotte [1]. The geology of these upland valleys is similar to that of the Dzhety-Ogyuz Valley described by Abdrakhmetov and Korjenkov [36]. Paleozoic granites and metamorphic rocks form the foundation of the Juuku and Kizil Suu valleys. The Lower Kizil Suu is a broad alluvial fan of 19.7 sq km; the Kizil Suu streams empty into Lake Issyk-Kul. The elevation of the alluvial fan ranges from 1610 to 1740 m asl (see Figure 2, map of Lower Kizil Suu). Jurassic quartzites cover the earlier granites and metamorphic rock. The distinctive red sandstone formations found in these intermontane regions are a result of Eocene and Pliocene deposits. The terraces, alluvial valleys, and alluvial fans consist of fluvial deposits of boulders, river cobbles, pebbles, and sand often covered with deposits of topsoils consisting of sand, clays, silt, loess, and humic layers. There is substantial seismic activity apparent on the south side of Lake Issyk-Kul [37,38].

Climatic conditions in the environs of Karakol on the South side of Lake Issyk-Kul can be reconstructed from pollen cores taken in 1998 [39]. These archives show the occurrence of a wetter period from 2450 to 750 BCE based on the decline of *Ephedra*, a species associated with the dry conditions of the Artemisia steppe.

According to the Karakol pollen core samples, there appears to be a spruce (*Picea* sp.) die back, or cooling period from 1450 BCE to 950 BCE, usually the Late Bronze Age/Final Bronze Age period [39] (Table 2). Again, the documented Dark Ages of cold and wet, occurred between CE 300 to 600, at the Wusun and Early Turkic periods [39]. Then a relatively dry phase occurred during the Medieval period, ca. 1000 to CE 1350, during the Qarakhanid occupation of this region. The "Little Ice Age" took place between ca. 1500 to CE 1850, within the historic Kirghiz occupation. The climate became colder, and at an Issyk-Kul core (IK98i-28) as well as Core C087 there appears to be an increase in *Picea* (spruce) as well as an increase in Poaceae (grasses), which may be attributed to human impact due to farming [39]. During the Little Ice Age, the Tian Shan glaciers were most extensive. These pollen records suggest the following climatic trends: (1) wetter and colder conditions at the end of the Bronze Age that continued into the Iron Age; (2) the peak of the wet and cold conditions came towards the end of the Iron Age (CE 300 to 600), also known as the Dark Ages elsewhere; (3) during the height of Medieval occupation in this region, the Qarakhanid period (10th to 12th centuries CE), was marked by a relatively dry and warm period; and finally after the 15th century and into the 19th century, the Little Ice Age marked a cooling and moist period. If climate proxies from pollen cores can be collected from the Kizil Suu area it may be possible to correlate local climatic trends with changing land use patterns.

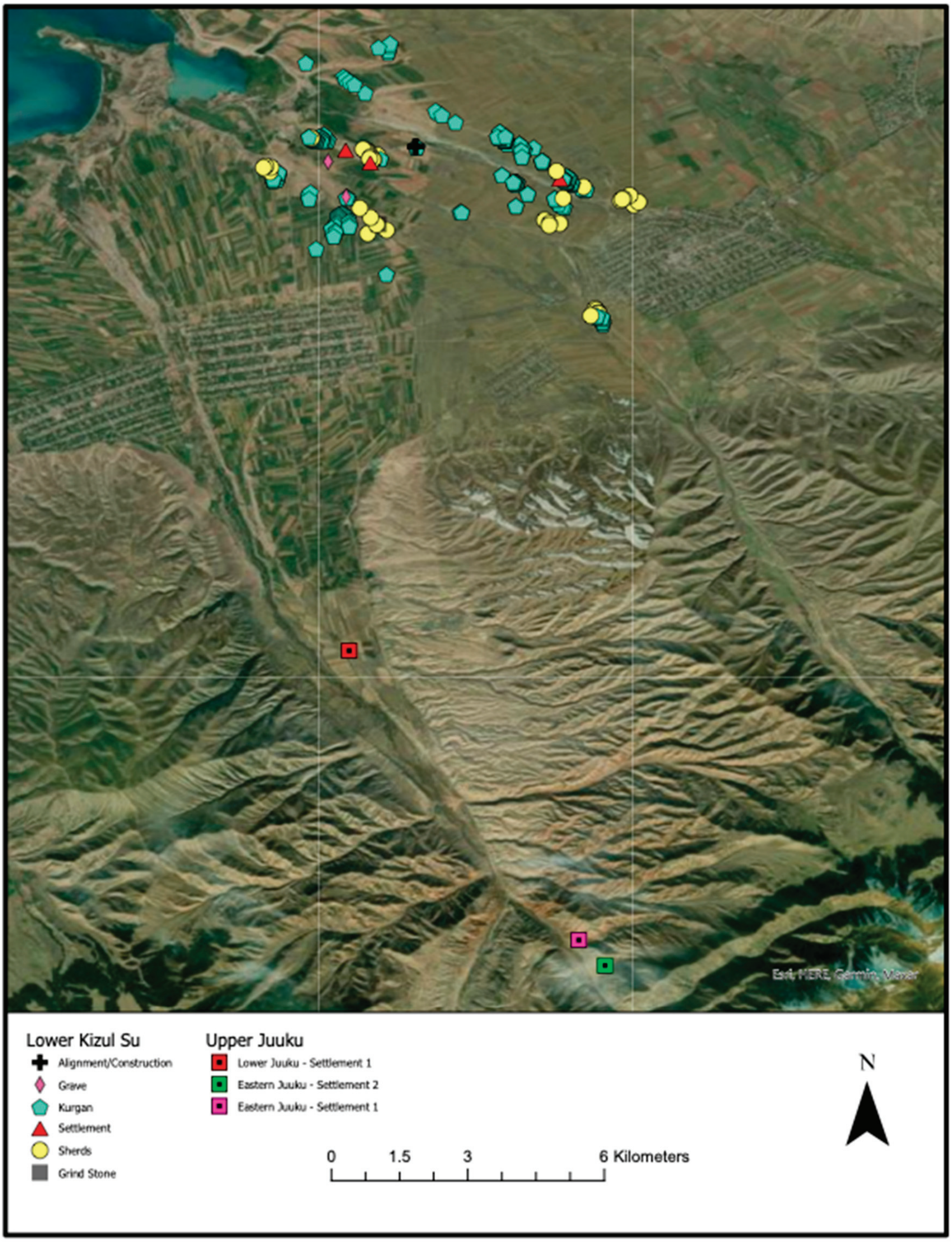

Figure 2. Map of Lower Kizil Suu Survey also shows the location of Eastern Juuku, Settlement 1 (1st to 5th century CE), Eastern Juuku, Settlement 2 (10th to 11th centuries CE), and Lower Juuku, Settlement 1 (17th to 19th centuries CE).

Table 2. Dates, Time Periods, Climatic Trends on the South side of Lake Issyk Kul according to Pollen Cores from the Karakol area [39].

Dates	Approximate Time Period	Climatic Trend
1450 BCE to 950 BCE	Late Bronze Age/Final Bronze Age	Cooling period, spruce die-back
300 to 600 CE	Wusun Period/Early Turkic Period	Cool and wet phase
1000 to 1350 CE	Medieval Period/Qarakhanid Period	Dry phase
1500 to 1850 CE	Historic Period of Kirghiz occupation	Little Ice Age (cool and wet)

2.2. Description of Survey Methods

Chang, Ivanov, and Tourtellotte [1] conducted pedestrian archaeological surveys within the two polygons of the Juuku Valley. This article reports specifically on the survey results from the Lower Kizil Suu alluvial fan. A detailed study of digital maps from Nakarte and Google Earth allowed the team to locate areas where potential archaeological loci such as settlements, corrals, and burial mounds were visible from aerial views. Pedestrian surveys were conducted on the lower Kizil Suu alluvial fan during 2021. We covered a small sample area (0.53 sq km) of the total area of the alluvial fan (19.7 sq km), at elevations from 1610 to 1740 m asl. (The sample survey area is about 0.02 percent of the total alluvial fan area). Since so many of the lower terraces in Kizil Suu were planted in grain crops during the field season of 2021, we restricted our survey to the higher, stony terraces. These terraces and ridges were often the areas of Iron Age kurgans. A second phase of our sample survey was to field walk in agricultural fields that had been plowed, cut, or recently planted during the months of August and September. About 11 fields were intensively surveyed, an area of approximately 48 hectares (see Table 3). The overall survey methodology was opportunistic, often dependent on our own pre-survey predictions for promising areas for site locations. For example, the Saka kurgans were often visible on Google Earth or Nakarte digital imagery and therefore provided us with estimates of where clusters or concentrations of site loci might be found in Lower Kizil Suu. All materials found on survey, from isolated artifact finds to more house outlines were identified as loci. If it was apparent that a group of house foundations were part of a settlement, a series of points (loci) were recorded, but they were considered a single site. The survey team recorded artifact finds (ceramic sherds, grinding stones, etc.), artifact scatters (more than 5 artifacts per 10 m radius), house or pit depressions, stone foundations of houses and enclosures, paths marked by stone walls, and architectural features such as house foundations, walls, fences, and corrals, and graves, burial mounds, and other mortuary features associated with cemeteries. Figure 3 shows two field archaeologists recording a stone kurgan in Lower Kizil Suu. When the archaeological artifacts or features could be dated chronologically, they were placed in time periods. Excel data sheets were constructed for each archaeological loci recording GPS (Global Positioning Systems) coordinates and relevant site characteristics.

Table 3. Lower Kizil Suu Survey of Agricultural Fields.

Field Number	Field Area in Hectares	Finds
1	14.3	12 sherds
2	14.5	3 kurgans, 3 sherds
3	2.8	5 sherds, 1 hearth
4	1.49	5 sherds
5	1.65	5 sherds
6	1.94	2 sherds
7	3.9	11 sherds (between 50–100)
8	1.88	8 sherds 1 foundation
9	0.29	2 sherds
10	4.14	1 Kirghiz ethnographic grave, 1 Saka kurgan 7 sherds 1 grinding stone
11	1.13	8 sherds
TOTALS	**48.02**	

Figure 3. Recording stone kurgans in the Lower Kizil Suu. Large earthen Saka kurgans in the background.

2.3. Stratigraphic Profiles at Juuku Valley Settlements

Two stratigraphic profile cuts, Settlement 1 and 2 in the Upper Juuku Valley were drawn by the field team. The Lower Juuku settlement was photographed and recorded, but not drawn. The stratigraphic profiles illustrate cultural and natural soil layers. Several liters of archaeobotanical soil samples were taken from the Settlement 1 (EJS1) and Settlement 2 (EJS2) in Upper Juuku Valley and from Settlement 1 (LJS1) in Lower Juuku Valley. Additional radiometric dating of two charred seeds was taken from archaeobotanical findings at Settlement 1 (EJS1) in the Upper Juuku, a Wusun (Iron Age) settlement.

2.4. Radiometric Dating

Two samples of carbonized barley (*Hordeum vulgare*) and free-threshing wheat (*Triticum aestivum*) grains were selected for dating from the Eastern Juuku-Settlement-1. Dates were measured at Woods Hole Oceanographic Institute's Radiocarbon Laboratory and SUERC Radiocarbon Dating Laboratory. The results were calibrated using OxCal v4.4.2 software [40,41] and the IntCal 20 curve [42].

2.5. Archaeobotanical Methods

We conducted water flotation on seven sediment samples taken in 2019 from three archaeological sites in the Juuku Valley, using an overflow tank system, in September of 2021. Three of these samples were collected from site-EJS1 (Eastern Juuku-Settlement-1). Another two samples were collected from site-EJS2 (Eastern Juuku-Settlement-2) and two samples from site-LJS1(Lower Juuku-Settlement-2). In this report, we use the site nomenclature, as laid out in Table 4.

Table 4. Radiocarbon results from carbonized material found at three Settlements recovered from the Juuku Valley.

#	Lab ID	Material/Pretreat	d13C o/oo IRMS	Conventional Dates (BP)	Calibrated Dates at 95.4% (AD)	Settlement	
1	OS-165284	Wheat grain	—	1850 +/− 15	130–237	Site-EJS1	Eastern Juuku Settlement 1
2	OS-165285	Barley grain	—	1680 +/− 15	376–532	Site-EJS1	
3	Beta-603779	(charred material) acid/alkali/acid	−22.7	1930 +/− 30	22–206	Site-EJS1	
4	Beta-603780	(charred material) acid/alkali/acid	−25.3	1020 +/− 30	978–1151	Site-EJS2	Eastern Juuku Settlement 2
5	Beta-603781	(charred material) acid/alkali/acid	−26.5	110 +/− 30	1682–1932	Site-LJS1	Lower Juuku Settlement 1

Heavy fractions of each sample were collected down to 1.0 mm and light fractions down to 0.355 mm. The heavy fractions were sorted in Kyrgyzstan; while all light fraction samples were dried and transported to the Palaeoethnobotany Laboratory at the Max Planck Institute for the Science of Human History in Jena, Germany. Sediment samples ranged from 4.0 to 9.0 L in volume; in total, 43 L of sediment were floated and analyzed. In the laboratory, light fraction samples were sieved with mesh sizes of 2.00, 1.40, 1.00-, and 0.50- mm. Material smaller than 0.5 mm was not analyzed. After sieving, all samples were systematically sorted and specimens were analyzed under a low magnification microscope, a Leica M205C. Charred wood fragments larger than 2.00 mm were weighed and sorted, but they were not analyzed into a taxonomy. Length, width, and thickness measurements were made digitally with a Keyence VHX 6000 microscope for all whole wheat and barley grains. Highly fragmentary pieces of grains and legumes were placed into the categories:

Cerealia and Legume. Cerealia, Legume, crop by-products (like rachises and culm nodes), mineralized seeds, and unidentifiable seed fragments were not counted in the totals.

2.6. ArcGIS Methods for Spatial Analysis

The site locations from Lower Kizil Suu were imported into ArcGIS Pro 2.8 using the latitude and longitude coordinates for each locus. In the ArcGIS database an additional feature class was created for only the Iron Age mortuary remains of Saka and Wusun burial mounds (Figure 2). In an earlier article we put forth a chronology for Saka occupation (800 to 260 BCE) while the later Wusun occupation occurred between 140 BCE to 437 CE [1]. To understand the spatial distribution of the Saka and Wusun burial mounds, we conducted a co-location analysis to measure the spatial association between the Saka and Wusun loci. This statistic tests whether there is a spatial association between Saka and Wusun kurgans and measures the local patterns of spatial association between the Saka and Wusun kurgans using a co-location quotient statistic. The co-location quotient is calculated by analyzing each feature associated with the Wusun sites individually to determine if they are co-located with the Saka sites (e.g., fall within the same neighborhood of the Saka sites). In other words, we test the hypothesis that the later Wusun population either chose their site locations proximate to the earlier Saka burial mounds, or alternatively chose locations not proximate to the earlier Saka burial mounds, yet still in the same geographic region. The results of the co-location analysis will then show a distribution of co-location quotient values that determine the probability that the observed value might occur because of random distribution. If the resulting p-value is less than 0.05, the co-location quotient for the feature is statistically significant. Co-location quotient values greater than 1 indicates a statistically co-located group of sites. A co-location quotient less than 1 indicates a statistically isolated group of sites. We extend the co-location analysis by calculation the median centers of the Saka and Wusun kurgans, as well as calculating the directional ellipses of those kurgans.

3. Results

3.1. Survey Results

Elsewhere the survey results in the Juuku Valley have been reported [1]. A total of 277 loci were found from pedestrian survey on the Lower Kizil Suu alluvial fan: 168 loci were identified as stone or earthen kurgans; 14 loci were identified as settlements (stone alignments, house constructions, and fire pits); and 86 loci were either single sherds or sherd scatters; 9 were Bronze Age through Kirghiz graves. We also surveyed agricultural fields spacing transects 20 m. apart. Table 2 shows the results of 11 Agricultural Field Surveys, a total of 48.02 ha.

3.2. Stratigraphic Profiles

Two profiles are presented here from Settlements 1 and 2 found in the Eastern Upper Juuku branch. Both profiles were found on the eastern terraces below red sandstone foundations. These are erosional cuts from intermittent stream channels or run-off flowing toward the Eastern Branch of the Juuku River.

3.2.1. Profile at Site-EJS1 (Wusun Period Settlement)

The surface of this profile is situated at an elevation of 2044 m asl on a dissected terrace above the eastern branch of the Juuku River. The drawn profile (Figure 4) is about 3 m in length and about 1.5 m in depth. The cut shows a house pit with several periods of occupation and some thin ash layers. The lowest layers: brown sandy loam, red sandy or loam levels with coarse sand, and pebble and rock layer are probably the natural, parent soil of the ravine. The brown clay layers are prepared floors, and the ash layers are fire pits and areas with ash deposits. These ashy deposits are where the wood charcoal and archaeobotanical samples (EJS1) were collected. The dark grey layer with melted mudbrick and large stones represents a later re-building phase of this house pit. The cultural levels begin at the very surface of the profile cut (dark brown with humus or topsoil).

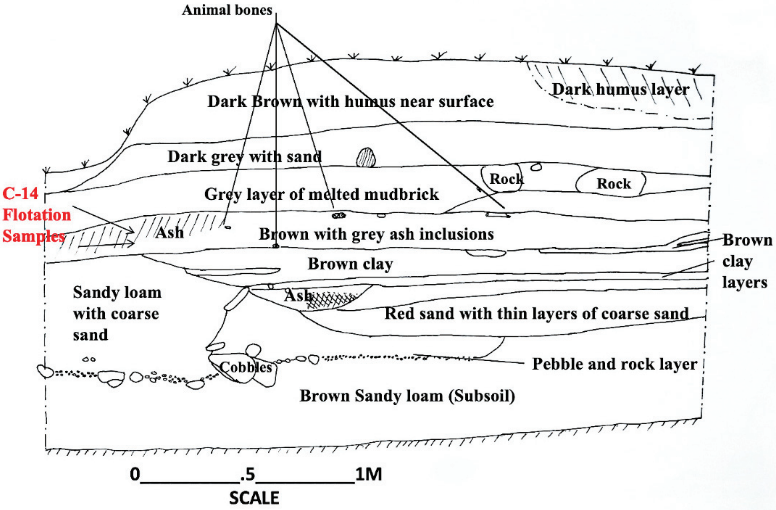

Figure 4. Archaeological Stratigraphy at Settlement 1 (EJS1): A section of a house pit. South facing profile.

3.2.2. Profile at Site-EJS2 (Qarakhanid Period Settlement)

The surface of this profile is situated at an elevation of 2090 m asl on an erosional gully that dissects an upper terrace above the Eastern branch of the Juuku River. The drawn profile is west facing, showing a series of occupational levels of a Medieval room. The profile measures 2.5 m in length and is 1.9 m in maximum depth. The bottom layer of sandy loam is the parent or natural subsoil below the cultural deposits (Figure 5). The series of light or thin clay levels found at the center of the profile drawing are a *sufa* or *kang* (plastered or clay sleeping platform/bed often found in Medieval dwellings). Above the clay levels is grey fill with ashes, representing midden or trash fill thrown into the dwelling over the earlier *sufa*. Later, a pit was dug into this midden layer which is lined with stones on the left-hand side and has sand and rubble on the bottom. This pit measures about 80 cm in length and 40 cm in depth. There are several middens or occupation levels above the center pit and a shallow ash pit to the left of the center pit. This upper ash pit measures about 70 cm in length and is about 15–20 cm thick. Above both pit features is a grey layer with burnt soil and ash, most likely a midden. The thick mud brick wall consists of individual unfired bricks and is 1.6 m in length and about 65 cm in height. Towards the top of the profile are destroyed or eroded mudbricks covered with dark humus. This later mudbrick wall covered over the earlier midden and deposits of the two ash pits and the earlier *sufa* which rested on a prepared occupation floor. Charcoal wood samples were taken from this profile (Beta 603780) from the ash pit to the left of center. Archaeobotanical samples were taken from the ash pits and the grey ashy midden levels.

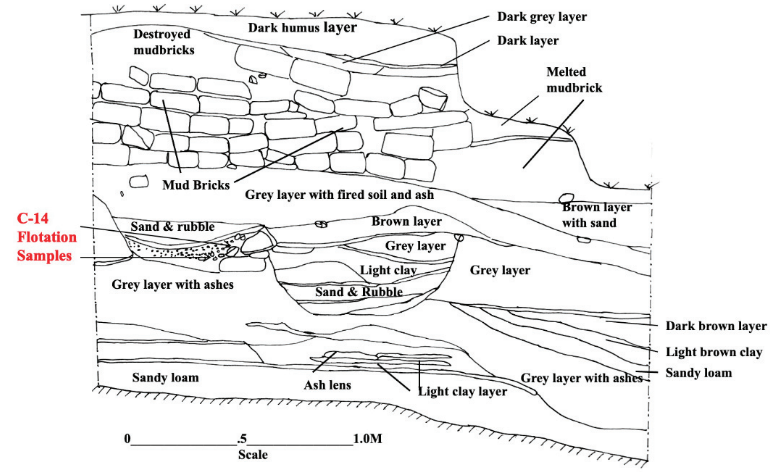

Figure 5. Archaeological Stratigraphy at Settlement 2 (EJS2). A section of a dwelling. West facing profile.

3.3. Results of Radiometric Dating

The results of two new radiocarbon dates are shown in Table 4 (#1 and #2), the occupation at Site-EJS1, the eastern Juuku-Settlement-1 spans from 130 to 532 cal. CE. Earlier presented radiocarbon dates from three sites at the Juuku Valley (Table 1, #3, 4, and 5) [1]: the occupation of Site-EJS1 (Eastern Juuku-Settlement-1) was dated to the Wusun Period (22–206 cal. CE), Site-EJS2 (Eastern Juuku-Settlement-2) dated to the end of the Qarakhanid period (978–1130 cal. CE), and Site-3 (Lower Juuku-Settlement-2) dated to the Kyrgyz ethnographic Period (1800–1932 cal. CE) [1]. New results from the one carbonized seed of barley (OS-165285) and one carbonized seed of wheat (OS-165284) corroborate the time sequence for the Eastern Juuku Settlement 1, established from charcoal wood samples (Beta-603779). The second sample at EJS1 expands the occupation period at the Wusun settlement to the beginning of sixth century CE.

3.4. Results of Archaeobotanical Analyses

A total of 43 L of floated sediment yielded 773 carbonized seeds and grains, which included domesticated crops and wild herbaceous plants. In addition to seeds, we recovered wheat (*Tiritcum aestivum*, *n* = 2) and barley (*Hordeum vulgare*, *n* = 7) rachises, grass culm nodes (*n* = 25), Cerealia (*n* = 7), Legumes (*n* = 1), and unidentifiable seed fragments (*n* = 22) that were too damaged to differentiate to properly identify. In total, 44.5 g of charred wood fragments (>2.0 mm) were recovered, predominantly coming from samples from site-2 (Figures 6 and 7).

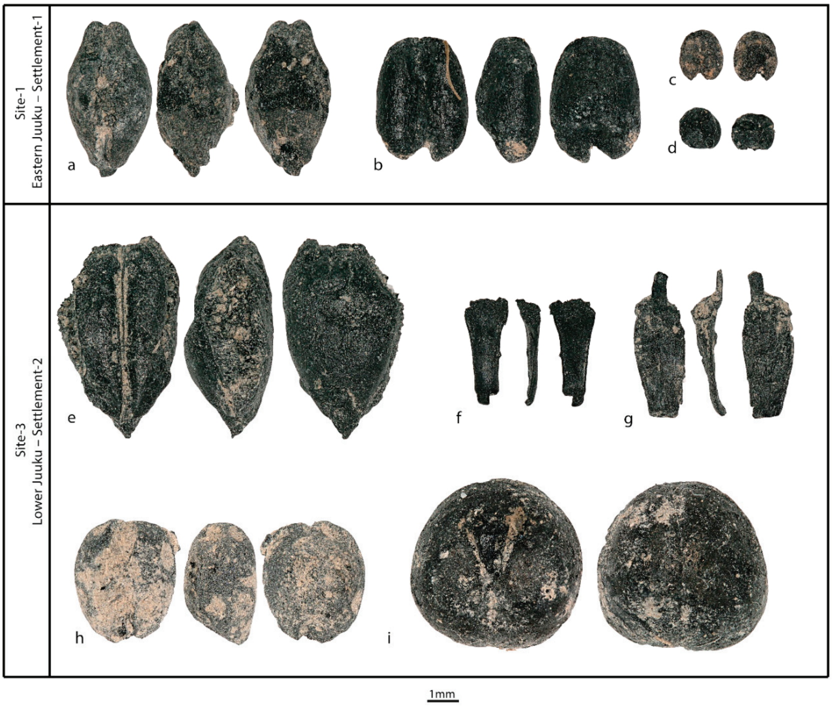

Figure 6. Site-EJS1: (**a**)—*Hordeum vulgare*, (**b**)—*Triticum aestivum*, (**c**)—*Setaria italica*, (**d**)—*Panicum millaceum*; Site-LJS1: (**e**)—*Hordeum vulgare*, (**f**)—Rachis of *Hordeum vulgare*, (**g**)—Rachis of *Triticum aestivum*, (**h**)—*Triticum aestivum*, and (**i**)—*Pisum sativum*.

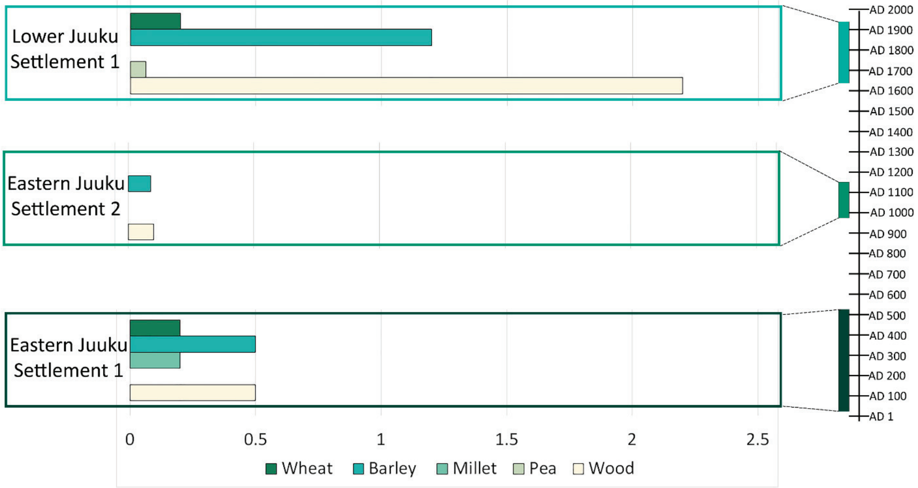

Figure 7. Cultivated crop and wood density from three sites at the Juuku Valley.

3.4.1. Eastern Juuku-Settlement 1, 1st–5th Centuries CE

Three samples (14.5 L) were taken from different profiles of site-1 (EJS1), from which we recovered 39 carbonized seeds. The total density (seed/liter of sediment) was 2.7 seeds per one liter, where 0.9 were domesticated and 1.8 were from wild herbaceous plants.

Four grain crops were identified at Site-1: barley ($n = 8$), wheat ($n = 3$), broomcorn millet (*Panicum millaceum*, $n = 1$), and foxtail millet (*Setaria italica*, $n = 2$). The average length of 3 wheat grains was 3.34 mm and the average width was 2.54 mm. There were 8 barley grains recovered, only 3 of them were measurable. The average length of these grains was 4.74 mm and the average width was 2.69 mm.

Wild plants represent a large part of the site-1 assemblage (Table 5). The dominant wild plants belong to the amaranth family (Amaranthaceae), notably chenopods (*Chenopodium* sp.), which are some of the most commonly recovered wild seeds in archaeological assemblages across Eurasia. In addition to plants of the amaranth family, seeds of the small wild legume family (Fabaceae) and cleavers (*Galium* sp.) were identified.

Table 5. Archaeobotanical counts from each Juuku Valley site.

Juuku 2021		**Eastern Juuku, Settlement-1 (1st–5th Centuries AD)**			**Eastern Juuku, Settlement-2 (10th–11th Centuries AD)**		**Lower Juuku, Settlement-1 (17th–19th Centuries AD)**		**Total**
	Sample #	FSJ6	FSJ6	FSJ3	FSJ6	FSJ7	FSJ4	FSJ5	
	Volume (L)	5.5	5.5	5	5.5	6	8	9	**43**
	Wood (Fragments > 2.00 mm) (g)	0.3	0.3	2.6	0.3	0.9	17.9	18.6	**44.5**
Grain Parts *Not in Totals	Wheat Rachis (Hexaploid)						1	1	**2**
	Barley Rachis						5	2	**7**
	Cerealia			3					**7**
	Legume								**1**
	Culm Node						11	14	**25**
Domesticated Grains and Legumes	*Hordeum vulgare* var. *vulgare*			5	1		11	11	**31**
	Triticum aestivum			1			3	2	**8**
	Panicum miliaceum								**1**
	Setaria italica			1					**2**
	Pisum sativum						1		**1**
Amaranthaceae	Amaranthaceaa	10	10	5	10	4	6	32	**62**
	Perisperm (Amaranthaceae)								**2**
	Chenopodium sp.	3	3	7	3	8	219	203	**440**
	Salsola type						4		**4**
Asteraceae	Asteraceae							1	**1**
Apiaceae	Apiaceae							2	**2**
Brassicaceae	small Brassicaceae							1	**1**
	Thlapsi Type							1	**1**
Fabaceae	Fabaceae						4		**4**
	small Fabaceae	1	1		1	1		13	**15**
	Medicago/Melilotus			1			7	10	**18**
	Trigonella sp.						2	1	**3**
Poaceae	Poaceae						1	4	**5**
	Small Poaceae					1		6	**10**
	Pooid						2	2	**4**
	Avena sp.						19	27	**49**
	Setaria (Wild)							1	**1**
	Bromus type						4	5	**9**
	Stipa type						6	3	**9**
	Panicoid						1		**1**
Polygonaceae	Polygonaceae						2	5	**7**
	Polygonum spp.						7	4	**11**
	Rumex spp.							3	**3**
Plantaginaceae	*Plantago* sp.	2	2		2		2	7	**11**
Rosaceae	*Potentilla* sp.						18	24	**42**
Rubiaceae	*Galium* sp.					2		4	**8**
Solanaceae	Solanaceae							3	**3**
Thymelaeaceae	*Thymelae* sp.							1	**1**
	Unidentified Seeds							6	**6**
	Unidentifiable Seed Fragments (not in total)			4		5		6	**22**
Total		**16**	**16**	**20**	**16**	**17**	**319**	**382**	**773**

3.4.2. Eastern Juuku-Settlement 2, 10th to 11th Centuries CE

A total of 33 carbonized seeds were recovered from two samples (11.5 L) coming from site-2 (EJS2). The total seed density was 2.9 seeds per liter. The seed assemblage is composed of mainly wild plants, only one barley grain was collected from the two samples. Many uncarbonized seeds likely represent high contamination with modern seeds, notably, again, chenopods; an abundance of uncarbonized insects (assumed to be modern intrusions) further attests to bioturbation at the site. Compared with the other two settlements discussed above, only 1.2 g of charcoal fragments larger than 2.00 mm was recovered from the samples.

3.4.3. Lower Juuku-Settlement 1, 17th to 19th Centuries CE

Two samples (17 L) were taken from site-3 (LJS1), located 6 km to the northwest of EJS1 and EJS2. Seed density is relatively higher than from the other two sites, 701 seeds were recorded with a density of 41.2 seeds per one litter of sediment, where 1.6 are domesticated crops and 39.6 are from wild plants. Compared with site 1, slightly more domesticated crops were recovered from those two samples. Collectively, there were three clearly domesticated field crops, including barley, wheat, and peas (*Pisum sativum*). In addition to grains, barley and wheat rachises were identified. All the wheat rachises have the characteristic morphology of hexaploid free-threshing wheat. There were only 5 wheat grains recovered, two of them were measured, where the average length was 4.5 mm and the average width was 3.6 mm. The most dominant crop in these two samples was barley ($n = 22$). While only 11 barley grains were measurable, their average length was 5.0 mm and the average width was 2.7 mm. Legumes are represented only by one pea.

Wild herbaceous seeds are the most abundant plant type in the samples. Many of the seeds could not be identified to the species level, but, again, the most numerous types were the chenopods. In addition to carbonized chenopods, there were many uncarbonized seeds that did not count, as they were presumed to be modern intrusions. The next most numerous types of weed seeds were the wild Fabaceae and grasses (Poaceae). Among the wild grasses, 46 wild oats (*Avena* sp.) were identified, and are presumed to represent weeds in local agricultural fields. Wild oats are prominent weeds in wheat and barley fields in the region today. In total, seeds of at least 27 different plant groups were attested. The overall abundance of wild seeds in LJS1 is much higher than at the other settlements analyzed in this preliminary study. In addition, to the high seed density recorded in these samples, 36.5 g of wood were recovered.

Archaeobotanical studies of first millennium BCE sites in the mountain foothills of Inner Asia, including Tuzusai, Tseganka 8, Taldy-Bulak, Begash, Chap, and Kyzyltepa [9,30,43–46], have demonstrated that agriculture was intensified during the beginning of the first millennium BC. Recent data illustrate that at least some portion of the overall population at this time remained stationary year-round to tend agricultural fields in the mountain foothills and to monitor grape vineyards. Our results in Table 4 bring new insights to the period just a few centuries after the increased focus on mixed farming systems, and these new data attest to the use of domesticated plants at the Juuku settlement during the first centuries CE (Figure 7). Compared with settlements across the Talgar alluvial fan in southeastern Kazakhstan, it appears that a similar assemblage of crops and a comparable mixed system of farming and pastoralism continued.

Often crop processing by-products are used to determine whether crops were grown locally or potentially imported [46,47], and yet, no rachises or culm nodes have been recovered from site-EJS1, dated to the first half of first millennium AD. Crop chaff was recovered together with grains at site-LJS1, providing loose evidence for local cultivation in the Kyrgyz Ethnographic Period.

3.5. Results of the ArcGIS Spatial Analyses

Results of the co-location analysis indicate that the Wusun sites, while clustered amongst themselves, are statistically isolated from the Saka sites in Figure 8 (co-location mean = 0.27, $p = 0.0087$). This isolation runs counter to a visual interpretation suggesting Wusun kurgans occur within the same spatial locations as the Saka kurgans. Table 6 shows the minimum and maximum colocation quotients. This spatial isolation suggests that Wusun kurgans were placed in a manner that facilitated "filling in" of space between the Saka kurgans, while maintaining a spatially distinct separation from the Saka kurgans. In addition, there may have been an historical reason for this, such as a political strategy by the Wusun to dominate or at least incorporate the indigenous Saka people. One way for the Wusun to assert themselves over the indigenous Saka was by occupying the similar mortuary areas that are also spatially distinct from the Saka mortuary areas. The Wusun could do so by utilizing available space in-between the existing Saka mortuary ground (Figure 9). Figure 10 shows area of actual co-location of Saka and Wusun Kurgans on the east side of Chong Kizil Suu River.

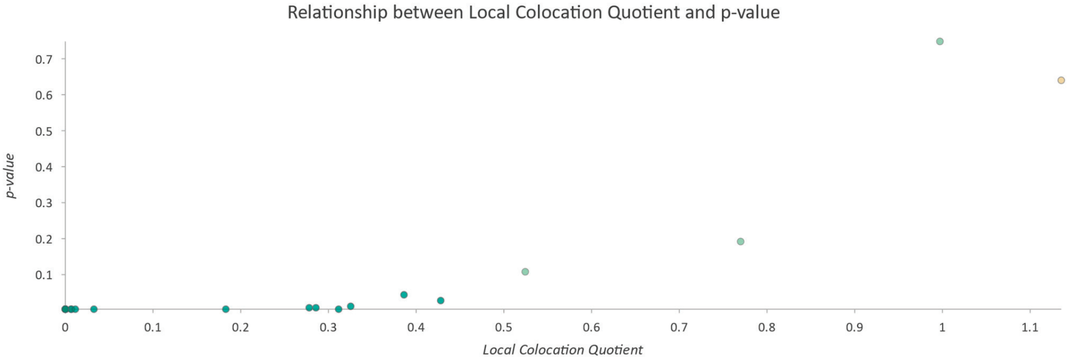

Figure 8. This graph shows the relationship between the Local Colocation Quotient and the *p*-value. With few exceptions, the Local Colocation Quotients indicate that the Wusun Kurgans are spatially isolated from the Saka Kurgans. There are two sites that are considered spatially isolated, yet not statistically significant. All other Wusun kurgans are significantly spatially isolated The colors in this figure correspond to the colors in Figure 10.

Table 6. Minimum and Maximum Local Co-locations and their counts. We find that the majority of the Wusun Kurgans have local colocation quotients that indicate statistically significant spatial isolation (<1).

Minimum of Local Colocation Quotient	Maximum of Local Colocation Quotient	Label	Count
0	0.1	0–0.1	10
0.1	0.3	0.1–0.3	2
0.3	0.4	0.3–0.4	4
0.4	0.6	0.4–0.6	2
0.6	0.7	0.6–0.7	0
0.7	0.9	0.7–0.9	1
0.9	1	0.9–1	0
1	1.1	1–1.1	2

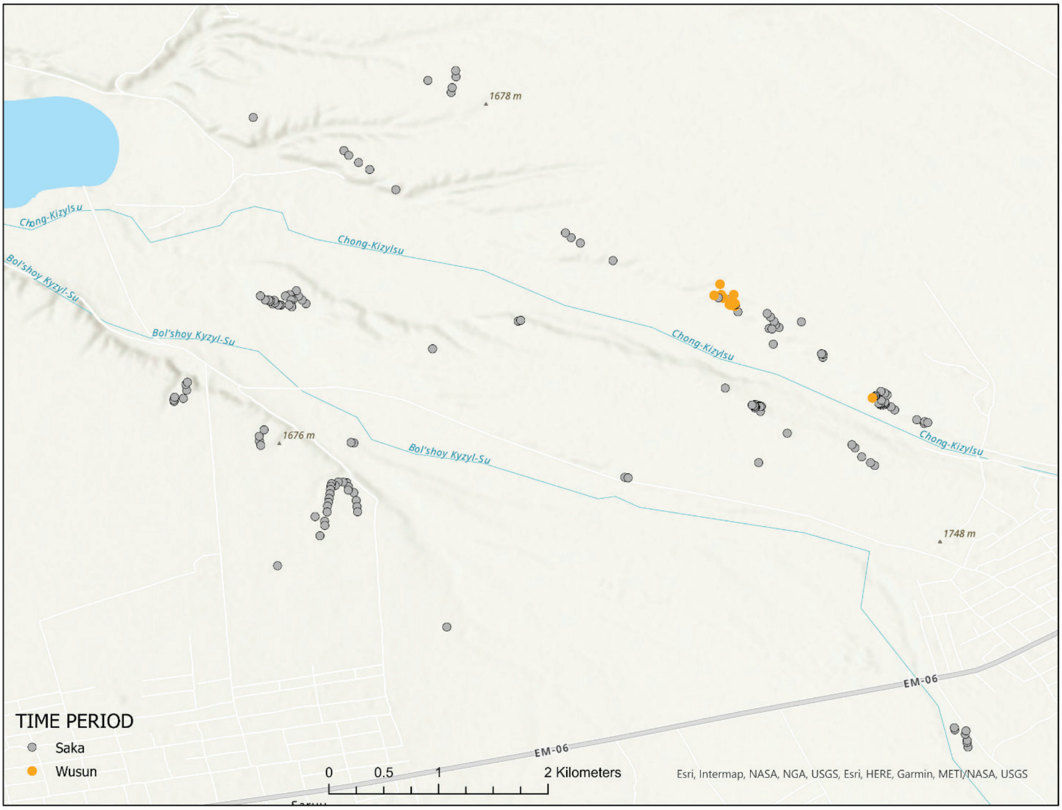

Figure 9. This map shows the spatial distribution of Saka and Wusun kurgans in Lower Kizil Suu.

Further analysis of the co-location outputs suggests the clustered nature of the Wusun sites, are in part, driving the statistical isolation (Table 6). Whereas the Saka locations exhibit a dispersed spatial arrangement (Figure 10). We find that the median centers of the distribution are quite separate, while the directional ellipses indicate a southeast-northwest trend which follows the linear ridgelines of the area.

Further analysis of the co-location outputs suggests the clustered nature of the Wusun sites, are in part, driving the statistical isolation (Table 6), whereas the Saka locations exhibit a dispersed spatial arrangement (Figure 11).

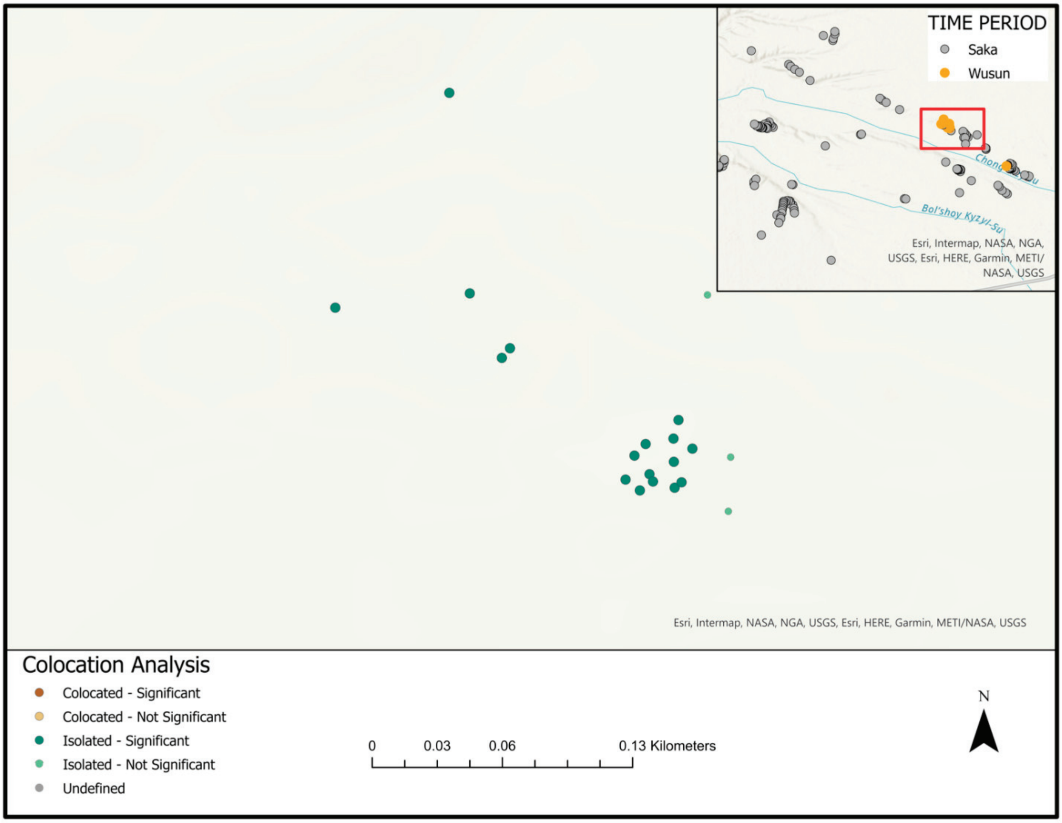

Figure 10. The results of the co-location analysis are indicated in the key and correspond to the main map (area in the red box in the inset map). In this particular cluster, all but two Wusun Kurgans are statistically spatially isolated from the Saka Kurgans. The two lighter green locations are still considered isolated, yet do not make statistical significance.

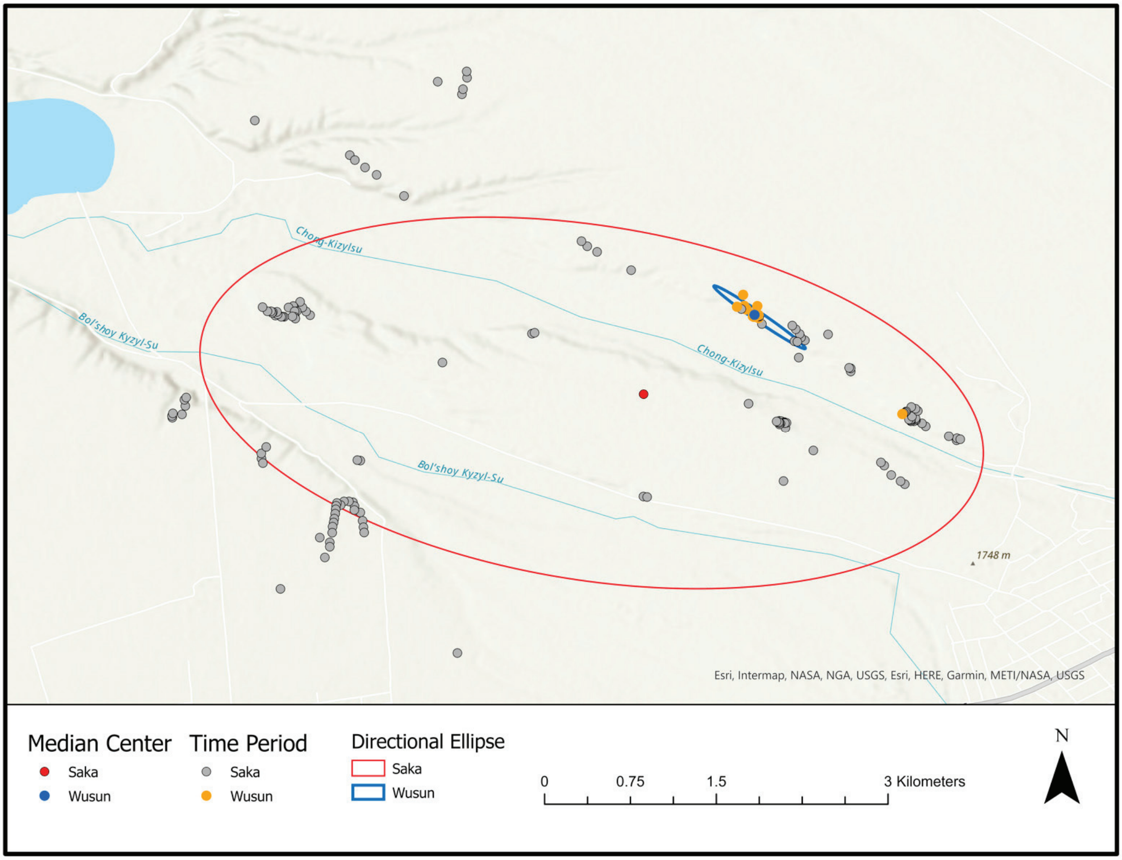

Figure 11. In this map, Wusun kurgans are noted by the orange symbology, while the Saka Kurgans are noted by the grey symbology. Both exhibit a similar directional ellipse, that falls in line with the topography of the area (e.g., following ridgelines), however the red (Saka) and blue (Wusun) exhibit two distinct median centers of spatial distribution.

4. Discussion

The results of the 2019 and 2021 survey in the Juuku and Kizil Suu valleys are quite promising for examining site locations along a vertical gradient. These well-watered alluvial valleys and fans, and upland areas represent at least three different vertical zones: (1) the alluvial fan of Lower Kizil Suu (elevation 1610–1740 m asl); (2) the alluvial valley of Lower Juuku (elevation 1750–1950 m asl); and (3) the upland eastern Juuku Valley (elevation 2060–2100 m asl). Lociof kurgans, settlements, and artifact scatters occur in both valleys along the terraces and valleys of the Juuku and Kizil Suu streams. Of particular interest are the detailed stratigraphic profiles found in the Upper Juuku Valley; EJS1-is an Iron Age settlement (the Wusun period) that shows multiple levels of occupation within a house pit and EJS2 is a Medieval settlement (the Qarakhanid period) that has multiple floor levels and characteristic architectural features such as a sufa, clay floors, ash pits, and well-formed mudbrick walls.

At the Wusun period settlement in Upper Juuku, remains from four domesticated species are found (wheat, barley, and the two millets) along with a considerable component of wild seeds. During the period of occupation, between 130–527 CE, this also might correspond with the pollen records of cold and wet conditions, also seemed to be amenable to upland agriculture as well as animal herding (sheep bones and other animal fauna were found at this site). In contrast, the Medieval Qarakhanid site in Upper Juuku had only one barley grain and considerable evidence of bioturbation and disturbance. The meager seed remains at the Qarakhanid site may be due to either: (1) small sample size or (2) taphonomic disturbances. While speculative, we seek to further test the possibility that during the Qarakhanid period, upland sites were primarily used as camps or way stations for mobile pastoral groups or traders. According to pollen data, the Qarakhanid period falls within a period of dry and warm conditions, thus perhaps upland agriculture was less important since most crops could be grown at lower elevations. In contrast, the ethnographic Kirghiz settlement found in Lower Kizil Suu has the richest archaeobotanical remains that include barley, wheat, the two millets, and peas. This settlement is dated towards the end of the Little Ice Age (15th to 19th centuries) when the climate could have been undergoing warmer and drier conditions. Also, at lower elevations it is apparent that the Kirghiz could grow a wide range of domesticated crops.

The spatial analysis of Iron Age burial mounds is of considerable significance for interpreting Iron Age settlement patterns, beyond what can be visually observed.

Although Table 3 shows great potential for finding artifact scatters and settlement features in plowed agricultural fields; to date the most of sites have been identified as Iron Age kurgans. Settlement sites are much harder to identify because they can be buried below the surface. When artifact scatters such as ceramic sherds are found in plowed fields, it is not possible to know whether these scatters or single artifact finds are indicators of buried settlements without excavating test trenches below the surface. Not only are stone and earthen kurgans readily visible on the landscape, but they also marked the territories of different population groups. The Saka kurgans predominate the landscape. Their locations often overlook prime agricultural lands. The Wusun kurgans are much smaller in size, usually distinguished by an inner stone circle enclosed by two to four rectangular stone structures.

In the co-location analysis, it is apparent that most Saka and Wusun kurgans have their own independent mortuary fields, except for the one area on the east bank of Chichi Kizil Suu where both Saka and Wusun kurgans co-locate. Like the contemporary practice in which ethnographic Kirghiz graves are often placed on Saka earthen burial mounds, the Wusun groups sometimes chose locations near already established Saka burial grounds. Earlier we put forth the hypothesis that the Wusun were in-filling a mortuary territory used by earlier Saka groups as a kind of political or social strategy to also claim the same ritual landscapes. We hope to explore these ideas of why the Iron Age kurgans are located on terraces and ridge lines above the bottom lands near stream and riverbeds. In other publications [31,48,49] we have documented lines of kurgans on the Talgar alluvial fan in southeastern Kazakhstan at the foot of the northern Tian Shan range. These lines of kurgans represent territorial markers of important agricultural or pasture territories claimed by kin or clan groups. Similar linear groupings of Saka kurgans in the Juuku and Lower Kizil Suu valleys also could be indicators of a mortuary burial ground used to mark individual territories or boundaries. In any case the intrusion of Wusun populations into the Kizil Suu Valley sometime after the first century CE, also can be seen in their selection of burial ground territories.

5. Conclusions

The data, analyses, and interpretations in this article are part of a long-term research project: the main objective of this archaeological field project is to test hypotheses of land use practices during the Late Holocene period along the intermontane valleys of the Inner Tian Shan range. These preliminary studies indicate that agricultural and pastoral systems developed over time according to changing climatic conditions and along a vertical gradient of the valley. We might speculate that the cultivation of early grains (barley, wheat, and the two millets) occurred as far back as the Bronze Age and possibly earlier, as apparent from archaeobotanical findings of barley and wheat at the Chap Site in the Kochkor Valley [9,22,45]. By the Iron Age, these domesticated crops were probably well-established even during the cooler and wetter periods from 1450 to 750 BCE and another cool and wet period from 300 to 600 CE, and again from 1500 to 1900 CE [39]. If indeed the pollen cores from near Karakol are also indicative of climatic pulses for the last three millennia in the Juuku and Kizil Suu valleys, then perhaps the local population also fluctuated their economic strategies between agriculture and pastoralism accordingly. Our archaeobotanical samples are small and perhaps too scanty to make bold claims about how land use changed over time. The archaeobotanical analysis of additional collections from other settlements along with zooarchaeological analysis of animal bone remains shall provide more proxies for reconstructing changing land use. It also seems possible establishing a definite correlation between climatic research based upon pollen proxies could be successfully integrated with traditional archaeological materials (seeds, plant remains, animal remains, and artifacts). Nevertheless, these are the kinds of directions we hope to move our research project. Studying long-term diachronic changes over four millennia through multi-disciplinary approaches: archaeo-botany, zooarchaeology, geoarchaeology, and spatial analysis allow us to understand the complex dynamics between human populations, their herd animals, crops, and the natural landscapes of Central Asia. Finally, there is much to be said about ritual burial landscapes that also can provide many clues about the underlying economic and socio-political systems of ancient pastoral and agricultural groups. Do the Wusun newcomers seek to occupy Saka territories, or was there a different kind of ideological boundary system? All these are questions that future spatial analyses can begin to answer. Finally, there is one direction we hope to pursue more rigorously—that of the identification of the Bronze Age through Medieval period settlements in the intermontane valleys. Field data appears to indicate that the large Medieval sites might cover up or bury earlier Iron Age or Bronze Age settlements; yet those Medieval settlements seldom disturb the burial grounds of either Saka or Wusun kurgans. Why is this so? And what may it tell us about the different palimpsests of archaeological land use that exist in these circumscribed valleys during the Late Holocene.

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References

1. Chang, C.; Ivanov, S.S.; Tourtellotte, P.A. Landscape and Settlement over 4 Millennia on the South Side of Lake Issyk Kul, Kyrgyzstan: Preliminary Results of Survey Research in 2019–2021. *Land* **2022**, *11*, 456. [CrossRef]
2. Frachetti, M.D. Multiregional Emergence of Mobile Pastoralism and Nonuniform Institutional Complexity across Eurasia. *Curr. Anthr.* **2012**, *53*, 2–38. [CrossRef]
3. Gokcumen, O.; Frachetti, M. The Impact of Ancient Genome Studies in Archaeology. *Annu. Rev. Anthr.* **2020**, *49*, 277–298. [CrossRef]
4. Unterländer, M.; Palstra, F.; Lazaridis, I.; Pilipenko, A.; Hofmanová, Z.; Groß, M.; Sell, C.; Blöcher, J.; Kirsanow, K.; Rohland, N.; et al. Ancestry and demography and descendants of Iron Age nomads of the Eurasian Steppe. *Nat. Commun.* **2017**, *8*, 14615. [CrossRef]
5. Ventresca Miller, A.R.; Makarewicz, C.A. Isotopic approaches to pastoralism in prehistory: Diet, mobility, and isotopic reference sets. In *Isotopic Investigations of Pastoralism in Prehistory*; Routledge Press: Abingdon, UK, 2017; pp. 1–14.
6. Hermes, T.R.; Frachetti, M.D.; Doumani Dupuy, P.N.D.; Mar'Yashev, A.; Nebel, A.; Makarewicz, C.A. Early integration of pastoralism and millet cultivation in Bronze Age Eurasia. *Proc. R. Soc. B* **2019**, *286*, 20191273. [CrossRef]
7. Spengler, R.N., III; Miller, A.V.; Schmaus, T.; Matuzevičiūtė, G.M.; Miller, B.K.; Wilkin, S.; Taylor, W.T.T.; Li, Y.; Roberts, P.; Boivin, N. An Imagined Past? Nomadic Narratives in Central Asian Archaeology. *Curr. Anthropol.* **2021**, *62*, 251–286. [CrossRef]
8. Ventresca Miller, A.R.V.; Haruda, A.; Varfolomeev, V.; Goryachev, A.; Makarewicz, C.A. Close management of sheep in ancient Central Asia: Evidence for foddering, transhumance, and extended lambing seasons during the Bronze and Iron Ages. *STAR Sci. Technol. Archaeol. Res.* **2020**, *6*, 41–60. [CrossRef]
9. Matuzeviciute, G.M.; Mir-Makhamad, B.; Tabaldiev, K. The first comprehensive archaeobotanical analysis of prehistoric agriculture in Kyrgyzstan. *Veg. Hist. Archaeobot.* **2021**, *30*, 743–758. [CrossRef]
10. Ullah, I.I.; Chang, C.; Tourtellotte, P. Water, dust, and agro-pastoralism: Modeling socio-ecological co-evolution of landscapes, farming, and human society in southeast Kazakhstan during the mid to late Holocene. *J. Anthr. Archaeol.* **2019**, *55*, 101067. [CrossRef]
11. Betts, A.; Jia, P.; Abuduresule, I. A new hypothesis for early Bronze Age cultural diversity in Xinjiang, China. *Archaeol. Res. Asia* **2019**, *17*, 204–213. [CrossRef]
12. Li, Y.; Storozum, M.; Tian, D.; Frachetti, M.; Su, K.; Wang, X. Farming strategies of 1st millennium CE agro-pastoralists on the southern foothills of the Tianshan Mountains: A geoarchaeological and macrobotanical investigation of the Mohuchahangoukou (MGK) site, Xinjiang, China. *PLoS ONE* **2019**, *14*, e0217171. [CrossRef] [PubMed]
13. Spate, M.; Yatoo, M.A.; Penny, D.; Shah, M.A.; Betts, A. Palaeoenvironmental proxies indicate long-term development of agro-pastoralist landscapes in Inner Asian mountains. *Sci. Rep.* **2022**, *12*, 54. [CrossRef] [PubMed]
14. Khazanov, A.M. *Nomads and the Outside World*, 2nd ed.; The University of Wisconsin Press: Madison, WI, USA, 1994; pp. 232–262.
15. Kradin, N. Nomadic empires in inner Asia. In *Complexity of Interaction along the Eurasian Steppe Zone in the First Millennium CE*; Vfgarchpress: Bonn, Germany, 2015; pp. 11–48.
16. Masanov, N.E. *Kochevaya Tsivilizatsiya Kazkakhov: Osnov'i Zhisznedelatmel'nosti Nomadnogo Obshestsva (Nomadic Kazakh Civilization: The Foundation of Nomadic Society*; Sostinvest: Almaty, Kazakhstan; Moscowand, Russia, 1995. (In Russian)
17. Dyson-Hudson, N. The Study of Nomads. In *Perspectives on Nomadism*; Irons, W., Dyson-Hudson, N., Eds.; E.J. Brill: Leiden, The Netherlands, 1972; pp. 2–29.
18. Anthony, D.W. *The Horse, the Wheel and Language; How Bronze-Age Riders from the Eurasian Steppes Shaped the Modern World*; Princeton University Press: Princeton, NJ, USA; Oxford, UK, 2007.
19. Beisenov, A.Z.; Svyatko, S.V.; Duysenbay, D.B.; Akhiyarov, I.K.; Reimer, P.J.; Arkheologiya, P. New Isotopic Data on the Diet of the Saka Period Population from Central Kazakhstan. *Povolzhskaya Arkheologiya (Volga River Reg. Archaeol.)* **2020**, *3*, 208–218. [CrossRef]
20. Spengler, R.; Miller, N.; Neef, R.; Tourtellotte, P.A.; Chang, C. Linking agriculture and exchange to social developments of the Central Asian Iron Age. *J. Anthr. Archaeol.* **2017**, *48*, 295–308. [CrossRef]
21. Miller, A.R.V.; Spengler, R.; Haruda, A.; Miller, B.; Wilkin, S.; Robinson, S.; Roberts, P.; Boivin, N. Ecosystem Engineering Among Ancient Pastoralists in Northern Central Asia. *Front. Earth Sci.* **2020**, *8*, 168. [CrossRef]
22. Matuzeviciute, G.M.; Ananyevskaya, E.; Sakalauskaite, J.; Soltobaev, O.; Tabaldiev, K. The integration of millet into the diet of Central Asian populations in the third millennium BC. *Antiquity* **2022**, *96*, 560–574. [CrossRef]
23. Caspari, G.; Betts, A.; Jia, P. The Bronze Age in the Western Tianshan, China: A new model for determining seasonal use of sites. *J. Archaeol. Sci. Rep.* **2017**, *14*, 12–20. [CrossRef]
24. Tian, D.; Festa, M.; Cong, D.; Zhao, Z.; Jia, P.W.; Betts, A. New evidence for supplementary crop production, foddering and fuel use by Bronze Age transhumant pastoralists in the Tianshan Mountains. *Sci. Rep.* **2021**, *11*, 13718. [CrossRef]
25. Rouse, L.M.; Krumnow, J. On the fly: Strategies for UAV-based archaeological survey in mountainous areas of Central Asia and their implications for landscape research. *J. Archaeol. Sci. Rep.* **2020**, *30*, 102275. [CrossRef]

26. Rouse, L.M.; Tabaldiev, K.; Matuzeviciute, G.M. Exploring Landscape Archaeology and UAV-Based Survey in the Kochkor Valley, Kyrgyzstan. *J. Field Archaeol.* **2021**, *47*, 32–53. [CrossRef]
27. Frachetti, M.D.; Smith, C.E.; Traub, C.; Williams, T. Nomadic ecology shaped the highland geography of Asia's Silk Roads. *Nature* **2017**, *543*, 193–198. [CrossRef] [PubMed]
28. Dupuy, P.N.D.; Zhuniskhanov, A.S.; Bullion, E.A.; Kiyasbek, G.K.; Tashmanbetova, Z.K.; Rakhmankulov, E.Z.; Isin, A.I. The newly discovered bronze age site of Koken: Merging micro-regions with major study zones in the high steppes of Kazakhstan. *Archaeol. Res. Asia* **2021**, *27*, 100292. [CrossRef]
29. Rouse, L.M.; Cerasetti, B. Ojakly: A Late Bronze Age mobile pastoralist site in the Murghab Region, Turkmenistan. *J. Field Archaeol.* **2014**, *39*, 32–50. [CrossRef]
30. Spengler, R.; Frachetti, M.; Doumani, P.; Rouse, L.; Cerasetti, B.; Bullion, E.; Mar'Yashev, A. Early agriculture and crop transmission among Bronze Age mobile pastoralists of Central Eurasia. *Proc. R. Soc. B Boil. Sci.* **2014**, *281*, 20133382. [CrossRef]
31. Chang, C. *Rethinking Prehistoric Central Asia: Shepherds, Farmers, and Nomads*; Routledge: Abingdon, UK, 2017.
32. Frachetti, M.D.; Maksudov, F. The landscape of ancient mobile pastoralism in the highlands of southeastern Uzbekistan, 2000b.c.–a.d.1400. *J. Field Archaeol.* **2014**, *39*, 195–212. [CrossRef]
33. Mir-Makhamad, B.; Mirzaakhmedov, S.; Rahmonov, H.; Stark, S.; Omel'Chenko, A.; Spengler, R.N. Qarakhanids on the Edge of the Bukhara Oasis: Archaeobotany of Medieval Paykend. *Econ. Bot.* **2021**, *75*, 195–214. [CrossRef]
34. Tabaldiev, K.S. *Ancient Monuments of the Tian Shan*; Centralnoaziatskogo Universiteta: Bishkek, Kyrgyzstan, 2011; p. 318.
35. Amanbaeva, B.E.; Kol'chenkov, B.A.; Sulaimanova, A.T. *Archaeological Monuments of the Kyrgyzstan Portion of the Great Silk Road*; Institute of History and Culture: Bishkek, Kyrgyzstan, 2015.
36. Abdrakhmetov, K.; Korjenkov, A.M. *Climate Evolution in Central Asia during the Past Few Million Years: A Case Study from Issyk-Kul, ICDP Workshop Bishkek, Kyrgyzstan, June 12th to 17th, 2011. Field Excursions Guidebook*; GFZ Helmskotz-Zentrum: Potsdam, Germany, 2011.
37. Korjenkov, A.M. (Ed.) *Strong Earthquakes, Historical and Ancient Earthquakes of Issyk Kul and Their Position in the Formation of the Northern Tian Shan Range*; IFZ: Moscow, Russia, 2018; pp. 1–173.
38. Strelnikov, A.A.; Korzhenkov, A.M. Destruction of Medieval Archaeological Monuments by Strong Earthquakes in the Southwestern Issyk-Kul Basin, Tien Shan. *Seism. Instrum.* **2021**, *57*, 55–74. [CrossRef]
39. Leroy, S.A.; Giralt, S.R. Humid and cold periods in the last 5600 years in Arid Central Asia revealed by palynology of Picea schrenkiana from Issyk-Kul. *Holocene* **2020**, *31*, 380–391. [CrossRef]
40. Bronk Ramsey, C. Bayesian Analysis of Radiocarbon Dates. *Radiocarbon* **2009**, *51*, 337–360. [CrossRef]
41. Bronk Ramsey, C. OxCal 4.4. 2020. Available online: https://c14.arch.ox.ac.uk/oxcal/OxCal.html (accessed on 28 February 2022).
42. Reimer, P.J.; Austin, W.E.N.; Bard, E.; Bayliss, A.; Blackwell, P.G.; Ramsey, C.B.; Butzin, M.; Cheng, H.; Edwards, R.L.; Friedrich, M.; et al. The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0–55 cal kBP). *Radiocarbon* **2020**, *62*, 725–757. [CrossRef]
43. Spengler, R.; Chang, C.; Tourtellotte, P.A. Agricultural production in the Central Asian mountains: Tuzusai, Kazakhstan (410–150b.c.). *J. Field Archaeol.* **2013**, *38*, 68–85. [CrossRef]
44. Wu, X.; Miller, N.F.; Crabtree, P. Agro-Pastoral Strategies and Food Production on the Achaemenid Frontier in Central Asia: A Case Study of Kyzyltepa in Southern Uzbekistan. *Iran* **2015**, *53*, 93–117. [CrossRef]
45. Matuzeviciute, G.M.; Tabaldiev, K.; Hermes, T.; Ananyevskaya, E.; Grikpedis, M.; Luneau, E.; Merkyte, I.; Rouse, L.M. High-Altitude Agro-Pastoralism in the Kyrgyz Tien Shan: New Excavations of the Chap Farmstead (1065–825 cal b.c.). *J. Field Archaeol.* **2020**, *45*, 29–45. [CrossRef]
46. Herrmann, G.; Kurbansakhatov, K. The International Merv Project Preliminary Report on the Second Season (1993). *Iran* **1994**, *32*, 53–75. [CrossRef]
47. Spengler, R.N.; Frachetti, M.D.; Doumani, P.N. Late Bronze Age agriculture at Tasbas in the Dzhungar Mountains of eastern Kazakhstan. *Quat. Int.* **2014**, *348*, 147–157. [CrossRef]
48. Chang, C.; Tourtellotte, P.A. The Kazakh-American Talgar Project Archaeological Field Surveys in the Talgar and Turgen-Asi Areas of Southeastern Kazakhstan: 1997–1999 by Claudia Chang and Perry A. Tourtellotte. In *Kurgans, Ritual Sites, and Settlements Eurasian Bronze and Iron Age*; Davis-Kimball, J., Murphy, E.M., Koryakova, L., Yablonsky, L.T., Eds.; International Series 890; British Archaeological Reports: Oxford, UK, 2000; pp. 83–88.
49. Chang, C. Lines of Power: Equality or hierarchy among the Iron Age agropastoralists of southeastern Kazakhstan. In *Revolutions and Regimes: The Archaeology of Power and Politics in Eurasia*; Hartley, C., Yazicioglu, C.B., Smith, A.T., Eds.; Cambridge University Press: Cambridge, UK, 2012; pp. 122–142.

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The Spatiotemporal Patterns of Human Settlement during the Longshan and Erlitou Periods in Relation to Extreme Floods and Subsistence Strategy in the Upper and Middle Qin River Reaches, Central China

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Abstract: Human settlement numbers have significantly changed before and after ~4000 cal. y BP in the upper and middle Qin River reaches, but the external and internal factors driving this change remain unclear. In this study, we examine changing spatial and temporal patterns of the Longshan and Erlitou settlements in relation to extreme flooding at ~4000 cal. y BP and a variety of subsistence strategies during the Longshan and Erlitou periods. The results indicate that settlement number, settlement distribution, and subsistence strategies exhibited obvious shifts between the Longshan and Erlitou periods, and the episode at ~4000 cal. y BP was an extreme-flood-rich interval within and around the Qin River Basin. During the Longshan and Erlitou periods, millet-based agriculture dominated local subsistence strategy, and ancient people would prefer to reside in the areas suitable for farming, causing the valley plains in the upper and middle Qin River reaches to contain most Longshan and Erlitou settlements. However, the frequent occurrence of extreme floods at ~4000 cal. y BP, in conjunction with intergroup conflicts due to a large amount of population immigration during the late Longshan period, is likely to have jointly decreased the settlement number and shrunk the spatial range of human settlement distribution. Subsequently, with the end of the extreme-flood-rich episode and the increasing proportion of higher-water-requirement foxtail millet in cropping structures of human subsistence strategy, more Erlitou settlements were distributed in the wetter valley plains of the middle Qin River reaches.

Keywords: human settlement; spatiotemporal pattern; Longshan period; Erlitou period; extreme floods; subsistence strategy; Qin River Basin

1. Introduction

The characteristics of past human activities are closely related to the environment around them. Relationships between past human activities and environmental variations are important issues and have been studied worldwide over the past three decades [1–10]. Abrupt climatic change events and associated dramatic environmental changes have been suggested as important factors behind the rise and fall of prehistoric and historic cultures [11–17]. The Holocene has witnessed several major abrupt climatic change events. The change that occurred at approximately 4000 cal. y BP (within a broad range from ~4200 to ~3800 cal. y BP) has been identified as a dramatic worldwide cooling and drying event (i.e., the 4.2 or 4.0 ka event) in a variety of natural archives [18–22]. The collapse of several agriculture-based ancient civilizations across the globe, such as ancient

Egypt [23,24], ancient India [25,26], and Mesopotamia [27,28], has been attributed to severe droughts induced by this event. However, human–environment interactions are much more complex [5,9,29,30]. Subsistence strategy and its variability have likely also affected the evolution of ancient cultures [14,31–33].

The archaeological culture of China also experienced remarkable changes at ~4000 cal. y BP; the contemporaneous abrupt climatic event was proposed to have played an important role in the demise of Neolithic cultures in China [34,35]. Specifically, the drying and cooling induced by the event occurring at ~4000 cal. y BP was widely accepted as the trigger of cultural collapses on the monsoon fringe of northern China [36–38], while this drying and cooling change in climate might be insufficient to collapse the cultures in the presently humid and warm parts of China [34,39]. The dramatic environmental variations (i.e., abnormal or extreme floods) associated with this event have been widely found in the middle and lower reaches of the Yangtze River and Yellow River, and their relations with local cultural transformation have been intensively discussed [40–49]. It is noteworthy that when other contemporaneous Neolithic cultures declined across China at ~4000 cal. y BP, only the archaeological culture in the Central Plains witnessed the most marked sociopolitical transformation and successfully evolved into the more advanced state-level culture, the Erlitou culture [50,51]. Consequently, possible impacts of the abrupt climatic event occurring at ~4000 cal. y BP, especially associated environmental changes (i.e., extreme floods) on the crucial cultural evolution in the Central Plains, have attracted wide academic attention [40,45–49,52–54].

The Qin River Basin is located in the north part of the Central Plains (Figure 1a), and local archaeological cultures during the Longshan (from ~4400 to ~4000 cal. y BP) and Erlitou (from ~3900 to ~3500 cal. y BP) periods had been obviously influenced by those in the southern Shanxi and northern Henan regions [55–57]. In comparison with the previous Longshan period, the number of local human settlements had clearly decreased during the Erlitou period [58–60]. Moreover, extreme floods associated with the abrupt climatic change event occurring at ~4000 cal. y BP were also widely found within and around the Qin River Basin (Figure 1a). However, the spatiotemporal pattern of the cultural evolution before and after ~4000 cal. y BP and its relationship to extreme flood and subsistence strategy variety has been rarely studied in the Qin River Basin.

In this study, we first selected the upper and middle Qin River reaches to analyze the changes in human settlement distribution patterns during the Longshan and Erlitou periods. Then, we reviewed the geological evidence of extreme floods occurring at ~4000 cal. y BP within and around the Qin River Basin, and collected archaeobotanical data with floatation results in the surrounding areas. Finally, the spatiotemporal variation in human settlements between the Longshan and Erlitou periods and its relationship to extreme flood and variety of subsistence strategies was examined.

2. Study Area

The Qin River Basin, situated in the eastern part of the Loess Plateau (Figure 1a), is a major tributary of the Yellow River, with a drainage area of ~1.35×10^4 km^2 and length of ~485 km [61]. Topographically, the Qin River Basin inclines from north to south, with elevation dropping from ~2500 m above sea level (asl) to ~100 m asl (Figure 1c). Climatologically, the Qin River Basin is strongly affected by the East Asian Monsoon system, with more than 70% of the total precipitation occurring during summer. The mean annual precipitation ranges from 550 mm to 750 mm and presents a decreasing trend from south to north; the mean annual temperature ranges from 9 °C to 14 °C [61]. The river is divided into upper, middle, and lower sections at Zhangfeng and Wulongkou (Figure 1c). Moreover, there are four landscape types in the Qin River Basin; from north to south, they are as follows: stony mountain region, earth–rock hilly region, valley region, and alluvial plain region, with stony mountain region and earth–rock region mainly distributing in the upper reaches, valley region in the middle reaches, and alluvial plain region in the lower reaches (Figure 1c).

Table 1. Records of extreme floods occurring at ~4000 cal. y BP within and around the Qin River Basin (see Figure 1 for their locations).

Region	No.	Site	Proxies [1]	Dating Method	Sample No.	Dating Materials	Dating Data (y BP)	Dating Data (cal. y BP)	Time (cal. y BP)	References
Qin River Basin	1	Q02010-1	FS	14C	Q02010-1	Bulk	3846 ± 120	4253 ± 162	4250	[62]
	2	Q02017-1	FS	14C	Q02017-1	Bulk	3910 ± 150	4335 ± 195	4340	[62]
	3	Q02020-1	FS	14C	Q02020-1	Bulk	3587 ± 210	3886 ± 268	3890	[62]
	4	Q02026	FS	14C	Q02026	Bulk	3686 ± 130	4000 ± 160	4000	[62]
Adjacent area of the Qin River Basin	5	PJCK	SWD	OSL	PJCK-1	-	-	4370 ± 530	4400–4300	[63]
					PJCK-2	-	-	4300 ± 660		
	6	FHXC	SWD	OSL	OSL-3	-	-	3910 ± 580	4200–3900	[64]
					OSL-2	-	-	4020 ± 450		
					OSL-1	-	-	4190 ± 580		
	7	CHZ	SWD	OSL	CHZ-2	-	-	4290 ± 175	4200–4000	[65]
					CHZ-3	-	-	4170 ± 130		
	8	YGZ	SWD	OSL	YGZ-3	-	-	4010 ± 240	4200–4000	[66]
					YGZ-4	-	-	4030 ± 260		
					YGZ-5	-	-	4190 ± 100		
	9	Zhoujiazhuang	FS	AMS ^{14}C	H78	Charcoal	3570 ± 35	3949 ± 46	4400–4000	[45]
					H93	Charcoal	3615 ± 35	3930 ± 43		
					H79	Charcoal	3630 ± 35	4395 ± 117		
					H87	Charcoal	3960 ± 80	4409 ± 116		
	10	Xijincheng	FS	Archaeological culture	-	-	-	late Longshan period	4200–4000	[45]
	11	Mengzhuang	FS	Archaeological culture	-	-	-	late Longshan period	4200–4000	[67]
	12	Erlitou	FS	OSL	L2	-	-	3805 ± 248	4000–3800	[45]
					L3	-	-	4044 ± 338		
	13	TXC	SWD	OSL	TXC-2	-	-	4030 ± 400	4000–3800	[49]
					TXC-3	-	-	4080 ± 450		

[1] FS—flood sediments; SWD—slackwater deposits.

Table 2. The counted results of plant remains from selected archaeological sites around the study area (see Figure 1 for their locations).

No.	Name	Period	Foxtail Millet	Broomcorn Millet	Rice	Wheat	Soybean	References
1	Xijing	Longshan	100	18	0	0	0	[68]
2	Zhoujiazhuang1	Longshan	61	9	0	0	0	[68]
	Zhoujiazhuang2	Longshan	9135	772	142	0	0	[69]
3	Jiajiabao	Longshan	66	11	0	0	0	[68]
4	Shangyukou	Longshan	44	5	2	0	0	[68]
5	Hucun	Longshan	166	20	2	1	0	[68]
6	Zhangjiazhuang	Longshan	337	13	0	0	0	[68]
7	Chengjiazhuang	Longshan	99	22	1	0	0	[68]
8	Nanbaishi	Longshan	105	10	0	0	0	[68]
9	Shuinan	Longshan	131	50	0	4	0	[68]
10	Taosi	Longshan	9160	606	30	13	0	[70]
11	Xijincheng	Longshan	740	5	82	1	8	[71]
12	Shangcun	Longshan	243	83	0	0	0	[72]
13	Dalaidian	Longshan	3341	216	1	2	44	[73]
14	Gouxi I	Erlitou	148	3	0	0	0	[68]
15	Beiyang	Erlitou	3408	178	0	0	0	[68]
16	Jiajiabao	Erlitou	522	32	7	0	3	[68]
17	Xinzhuang	Erlitou	783	47	0	0	0	[68]
18	Daze II	Erlitou	517	21	0	0	0	[68]
19	Guojiazhuang	Erlitou	639	42	0	0	0	[68]
20	Yueyabao I	Erlitou	26	2	0	0	0	[68]
21	Zhangdeng	Erlitou	2342	154	0	10	1	[74]

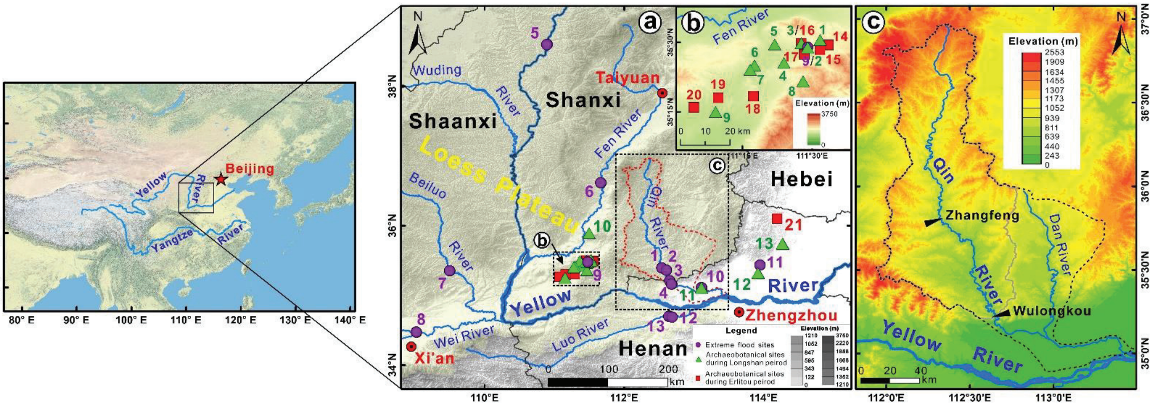

Figure 1. Study area. The labeled sites are extreme flood records that occurred at ~4000 cal. y BP within and around the Qin River Basin (purple circles, no. 1–13), and selected archaeobotanical records during Longshan (green triangles, no. 1–13) and Erlitou (red boxes, no. 14–21) periods around the Qin River Basin. Detailed information on the records of the extreme floods and archaeobotanical results are given in Tables 1 and 2, respectively. (**a**) A large-scale geographic context of the Qin River Basin. (**b**) Map showing the locations of serval selected archaeobotanical records. (**c**) Topographical background of the Qin River Basin, and the locations of Zhangfeng and Wulongkou, which divide the Qin River into upper, middle, and lower sections.

Due to its proximity to the core area of the Central Plains, archaeological discoveries in the Qin River Basin have suggested that local archaeological cultures had been dramatically affected by the archaeological cultures from the southern Shanxi and northern Henan regions during the Longshan and Erlitou periods [55–57]. Although no record of subsistence strategy was collected from the Qin River Basin (Table 2), the close similarities of ceramic assemblages clearly indicate that much communication has existed among these archaeological cultural regions [55–58]. It thus can be inferred that the subsistence strategies in the Qin River Basin would have been very similar to the southern Shanxi and northern Henan regions.

Owing to easy channel migration in low reaches of the river [61], the lower reaches of the Qin River are not included in this study in order to eliminate uncertainty on the impact analysis of extreme floods occurring at ~4000 cal. y BP. In addition, it should be mentioned that although the Dan River is the biggest tributary of the Qin River, due to its location joining the Qin River at the lower floodplain (Figure 1c), this tributary is also not included in this study. Finally, only the upper and middle reaches of the Qin River are included in the present study (Figure 1c).

3. Materials and Methods

The primary archaeological data in this paper are from the fascicle of the Chinese Cultural Relics Atlas in Shanxi Province [58]. Moreover, some data are also taken from relevant archaeological survey or excavation reports [55,75]. The data from the Chinese Cultural Relics Atlas in Shanxi Province were compiled based on the administrative unit of county in a unified format and map projection, and we digitized the data using ArcGIS software and positioned the locations (i.e., longitudes and latitudes) of the digitized sites. For the archaeological data from relevant archaeological survey or excavation reports, the locations were determined on Google Earth based on their textual description (including location and attributes). Then, all human settlements were plotted on the relief map obtained from the Shuttle Radar Topography Mission (SRTM4.1) digital elevation model (DEM) (http://www.gscloud.cn/, accessed on 20 May 2022) with a spatial resolution of 30 × 30 m. First, the spatial analysis tools of ArcGIS were used to map the temporal and spatial distribution between the Longshan and Erlitou periods, and calculate the statistical results of human settlements at different elevations and slopes. Furthermore, buffer analysis was also used to discuss the distance between human settlements and the rivers.

Second, to explore the relationship of human settlement distribution pattern changes between the Longshan and Erlitou periods to extreme floods and the variety of subsistence strategies, the records of extreme flood occurring at ~4000 cal. y BP (Figure 1a; Table 1) and archaeobotanical data (Figure 1a,b; Table 2) during the Longshan and Erlitou periods within and around the Qin River Basin were collected. Here, it should be mentioned that our selections of the extreme floods were based on the following criteria: the strata unit representing the extreme floods must be well-dated by absolute dating methods or well-constrained by archaeological cultures (Table 1). Finally, human settlement distribution pattern changes and their relation to extreme floods and subsistence strategy variety were examined.

4. Results

4.1. Spatial Distribution Characteristics of Human Settlement

4.1.1. Spatial Distribution Variation in Human Settlement

Figure 2 illustrates the spatial distribution of human settlements in the upper and middle Qin River reaches between the Longshan and Erlitou periods. Regarding the number of human settlements, it is clear that there were many more Longshan settlements than Erlitou settlements, exhibiting significant change in the number of human settlements before and after ~4000 cal. y BP. During the Longshan period, human settlements were relatively ubiquitously spread across the study area, but the number of human settlements was smaller in the middle reaches than in the upper reaches of the Qin River (Figure 2a), while during the Erlitou period, although the total number of human settlements was relatively small, the number was seemingly larger in the middle reaches than in the upper reaches (Figure 2b).

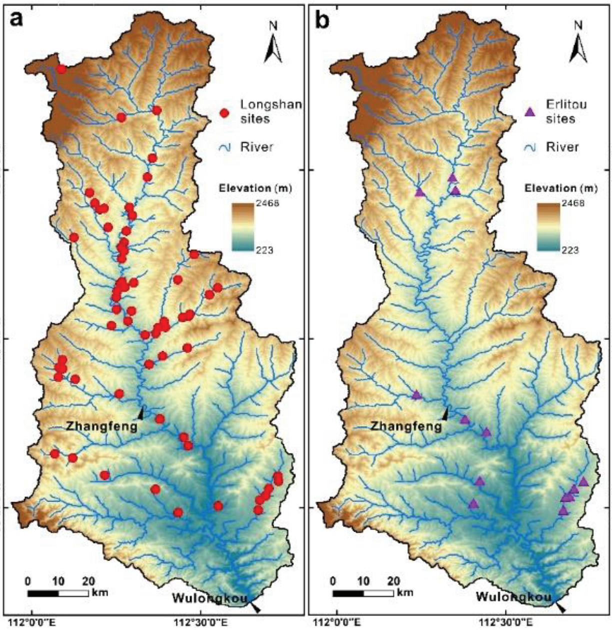

Figure 2. Human settlement distributions of the Longshan period (**a**) and the Erlitou period (**b**) in the upper and middle Qin River reaches.

4.1.2. Elevation, Slope, and the Distance from the Closest Rivers of Human Settlement

To further explore the spatial distribution characteristics of human settlements during the Longshan and Erlitou periods, the associated factors of elevation, slope, and the distance from the closest river of these settlements were analyzed. Figure 2 and Table 3 show that most human settlements (77.78%) were distributed at elevations between 800–1200 m asl during the Longshan period, with relatively smaller proportion distributing at elevations lower than 800 m asl and higher than 1200 m asl. During the Erlitou period, there was a higher proportion (84.62%) of human settlements distributing at elevations between 600–1000 m asl, especially in the elevation range of 600–800 m asl, accounting for 61.54%, likely suggesting that, in comparison with the previous Longshan period, the distribution elevation of human settlement had decreased during the Erlitou period (Figure 2).

Table 3. The elevation distribution of human settlements in the upper and middle Qin River reaches between the Longshan and Erlitou periods.

Elevation (m asl)	Longshan Period		Erlitou Period	
	Number	Proportion	Number	Proportion
<600	3	4.76%	0	0.00%
600–800	6	9.52%	8	61.54%
800–1000	25	39.68%	3	23.08%
1000–1200	24	38.10%	2	15.38%
1200–1400	4	6.35%	0	0.00%
>1400	1	1.59%	0	0.00%

Because slope gradient directly influences human choice of where to live and the suitability of the area around each human settlement for agricultural development, the slope data were extracted using ArcGIS 10.0 software from the DEM of the Qin River Basin (Figure 1c). The results of human settlement slope in this study were first classified into five levels based on slope gradient (Figure 3; Table 4), and then the slope was divided into three grades: an excellent grade (0–6°), a good grade (6–15°), and a poor grade (>15°). The results show that the Longshan and Erlitou sites were found to be concentrated within the 2–6° and 6–15° ranges, with 39 and 11 sites, respectively, accounting for 61.90% and 84.61% of the total number of human settlements (Table 4). However, compared to the Longshan period, the proportion of the human settlements on the excellent and good grades significantly increased during the Erlitou period from a previous 73.02% to 92.31% (Table 4).

Table 4. Statistical results of human settlements on different slopes in the upper and middle Qin River reaches between the Longshan and Erlitou periods.

Slope (°)	Longshan Period		Erlitou Period	
	Number	Proportion	Number	Proportion
0–2	7	11.11%	1	7.69%
2–6	14	22.22%	6	46.15%
6–15	25	39.68%	5	38.46%
15–25	13	20.63%	1	7.69%
>25	4	6.35%	0	0.00%

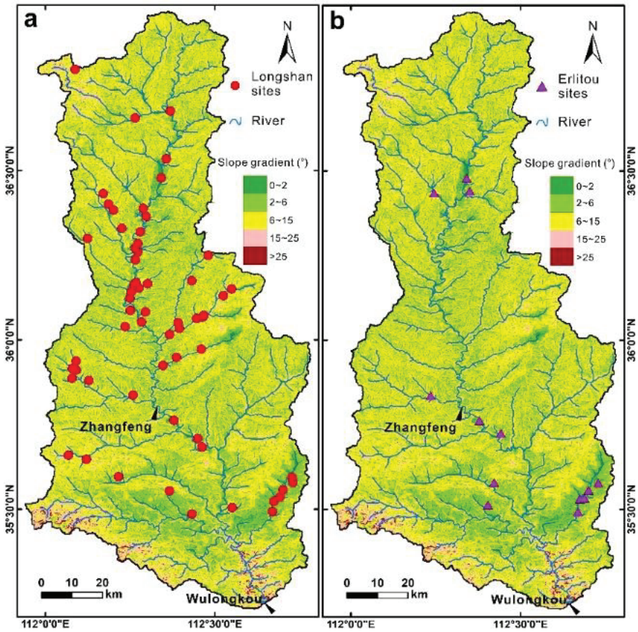

Figure 3. The slope distribution of human settlements during the Longshan period (**a**) and the Erlitou period (**b**).

Generally, people lived close to rivers for the convenience of fetching water. However, people might not choose to live in areas too close to rivers because they are prone to flooding. Because the upper and middle reaches of the Qin River are mountainous and hilly regions with large valley slope, the river courses have had few changes since the Holocene epoch [61]. Thus, the buffer zone of rivers was analyzed using ArcGIS 10.0 software within a 1.5 km range at intervals of 500 m. The results show a close relationship between the human settlement distribution and the distance to the river during the Longshan and Erlitou periods (Figure 4; Table 5). Both Longshan and Erlitou sites were mainly distributed in a range of 1000 m beyond water courses, accounting for 92.06% and 84.62%, respectively.

Table 5. Statistical results of the distance between human settlements and rivers during the Longshan and Erlitou periods.

Distance from River (m)	Longshan Period		Erlitou Period	
	Number	Proportion	Number	Proportion
0–500	41	65.08%	9	69.23%
500–1000	17	26.98%	2	15.38%
1000–1500	4	6.35%	1	7.69%
>1500	1	1.59%	1	7.69%

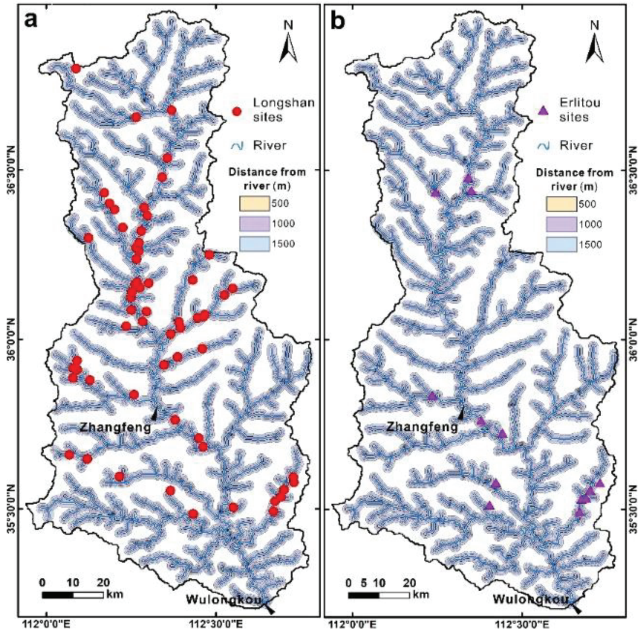

Figure 4. Distances between human settlement and river course in the upper and middle Qin River reaches during the Longshan period (**a**) and the Erlitou period (**b**).

4.2. Extreme Floods Occurring at ~4000 cal. y BP within and around the Qin River Basin

Many studies have reported extreme flood occurrences at ~4000 cal. y BP within and around the Qin River Basin [45,49,62–67]. However, several reported extreme-flood-indicating strata were not well constrained in their chronologies [76]. To explore the relationship between human settlement distribution and extreme floods, reliable chronologies of extreme flood occurring at ~4000 cal. y BP should be examined. As aforementioned, we purposely targeted the reported extreme floods that must be well dated by absolute dating methods or well constrained by archaeological cultures within and around the Qin River Basin, and thirteen records that contain evidence of extreme floods dated at ~4000 cal. y BP were selected (Table 1).

Table 1 and Figure 1a obviously show that the episode at ~4000 cal. y BP (with a relatively broad range from 4300 to 3800 cal. y BP) was an episode of frequent extreme flooding within and around the Qin River Basin. Except for five selected sites located in the low-lying floodplain area (no. 4, 8, 10, 12, and 13 in Figure 1a), the remaining eight selected sites are situated in highlands or in the transitional zone between highlands and lowlands (Figure 1a). In particular, four sites (no. 1–4 in Figure 1a) were distributed in the middle and lower Qin River reaches. Consequently, the episode at ~4000 cal. y BP was indeed an extremely flood-rich episode in the Qin River Basin.

4.3. Subsistence Strategy and Its Varieties around the Qin River Basin

To uncover the subsistence strategies in the upper and middle Qin River reaches, the archaeobotanical data from the southern Shanxi and northern Henan regions were used in this study (Figure 1a) due to these regions exhibiting much communication on archaeological cultures during the Longshan and Erlitou periods [55–58]. The selected archaeobotanical data include 13 records during the Longshan period and 8 records during the Erlitou period (Table 2), and the percentages of their counts are summarized in Figure 5. During the Longshan and Erlitou periods, although there were five main types of crops around the Qin River Basin, namely, foxtail millet (*Setaria italica*), broomcorn millet (*Panicum miliaceum*), rice

(*Oryza sativa*), wheat (*Triticum aestivum*), and soybean (*Glycine max*), foxtail and broomcorn millets were the two mainly cultivated crops (Table 2, Figure 5). Isotopic data from human bone remains in southern Shanxi and northern Henan regions also suggest that humans primarily relied on millet-based agriculture during the Longshan and Erlitou periods [77–80]. However, obvious differences in cropping structures existed between the Longshan and Erlitou periods. Specifically, during the Longshan period, the average proportions of foxtail millet and broomcorn millet were 86.52% and 11.87%, respectively. The average proportion of foxtail (broomcorn) millet had increased (decreased) to 94.52% (5.21%) during the Erlitou period, clearly suggesting the further improvement of the dominant role of foxtail millet in cropping structures of human subsistence strategy (Figure 5).

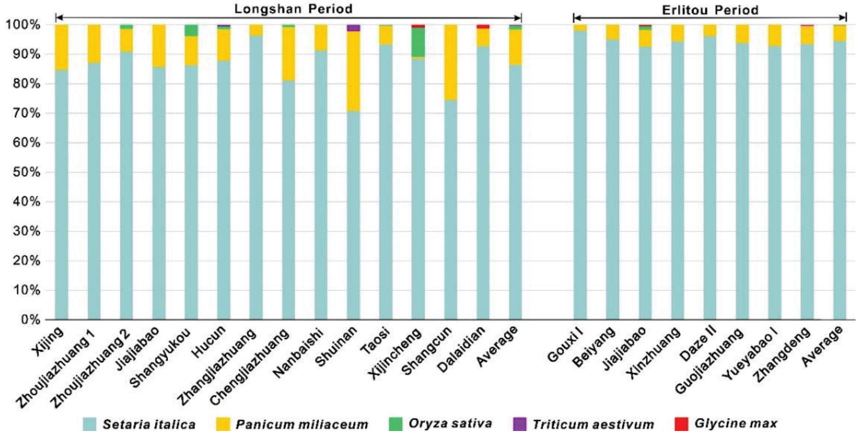

Figure 5. Abundance ratio of corps from the flotation results around the Qin River Basin during the Longshan and Erlitou periods.

5. Discussion

5.1. Relationship between Human Settlement Distribution and Subsistence Strategy

Archaeobotanical studies over the past two decades have revealed that sedentary agriculture dominated the subsistence strategy between ~6000 and ~5000 cal. y BP in the Central Plains and the surrounding areas, and agriculture occupied a more prominent position in local human subsistence strategy during the following Longshan and Erlitou periods [81,82]. This is consistent with the selected archaeobotanical results around the Qin River Basin (Figure 5). Consequently, during the Longshan and Erlitou periods, local ancient people would have preferred to reside in the areas suitable for farming. As aforementioned, the terrain in the study area inclines from north to south, with elevation dropping from ~2500 m asl to ~200 m asl (Figure 2), and only the valleys of the Qin River are relatively wide, flat, and conducive to the growth of crops [61]. As a result, most human settlements of the Longshan and Erlitou periods in the study area were located close to rivers (Figure 3), with settlement slopes concentrating within the 0–15° range (Table 4). In other words, these human settlements were concentrated in the valley plains. However, it should be noted that, in comparison with the Longshan period, the average proportion of foxtail (broomcorn) millet increased (decreased) from a previous 86.52% (11.87%) to 94.52% (5.21%) during the Erlitou period (Figure 5). Related studies found that foxtail millet requires higher soil fertility and water requirements, as well as a longer growing period than broomcorn millet [83,84]. As a result, the proportion of broomcorn millet in contemporaneous cropping structures was higher in areas north of the study area [85,86]. In the study area, mean annual precipitation presents a decreasing trend from south to north [61], and the middle Qin River reaches are mainly composed of valley plains with a lower slope gradient (Figure 3). Thus, the middle reaches of the Qin River are more suitable for foxtail millet cultivation than the upper reaches, likely causing more human settlements to be distributed in the middle reaches during the Erlitou period (Figure 2).

5.2. Relationship between Human Settlement Distribution and Extreme Floods at ~4000 cal. y BP

The collected geological evidence in this study unquestionably indicates that the episode at ~4000 cal. y BP was indeed an extreme-flood-rich episode within and around the Qin River Basin (Figure 1a; Table 1). This flood-rich episode at ~4000 cal. y BP in the study area is relatively well corroborated by the statistically summed flood occurrence frequency with a bin of 400 years in the Yellow River Basin [76]. Although the cause of frequent extreme flooding occurrence at ~4000 cal. y BP in the Yellow River Basin remains unclear, most studies thought it was associated with the abrupt climatic change event occurring at ~4000 cal. y BP [40–49,65–67]. As stated earlier, the distances of most human settlements and river courses were less than 1000 m during both the Longshan and Erlitou periods (Table 5), suggesting that human settlements in the upper and middle Qin River reaches were extremely vulnerable to floods. Thus, frequent extreme flooding occurrences at ~4000 cal. y BP would inevitably influence the people dwelling near the river. As a result, between the Longshan and Erlitou periods, both the number and spatial distribution patterns of human settlements presented significant changes (Figure 2). Obvious changes in spatial distribution patterns of human settlements between the Longshan and Erlitou periods most likely were local human responses to the extreme-flood-rich episode at ~4000 cal. y BP.

5.3. Possible Impact of Human Cultural Factors on Human Settlement Pattern Variation

Archaeological surveys and excavations of past decades have demonstrated that remarkable sociopolitical variations existed during the transitional stage (i.e., at ~4000 cal. y BP) from the Longshan period to the following Erlitou period in China [50,51,87,88]. In this context, a large population likely migrated from the area north of the study area and triggered intergroup conflict during the late Longshan period [89–93]. Through the contrast of unearthed ceramic assemblages, archaeologists in China have speculated that a large population had migrated from the northern Shanxi and Shaanxi regions to southern Shanxi and northern Henan regions and then likely caused conflict with local groups [90,91]. This speculation is supported by the evidence of violence observed at the Taosi site (no. 10 in Figure 1a, green triangle) [92] and sudden increase in the number of weapons and walled sites around the study area during the late Longshan period [51,91–94]. Consequently, extensive human immigration and subsequent intergroup conflict could possibly also cause settlement number decreases and the obvious spatial pattern variation in human settlements between the Longshan and Erlitou periods in the upper and middle Qin reaches.

6. Conclusions

By comparing the spatiotemporal changes in human settlement, a variety of subsistence strategies during the Longshan and Erlitou periods, and extreme floods at ~4000 cal. y BP in the upper and middle Qin River reaches, the following conclusions can be drawn.

(1) Human settlement distribution patterns between the Longshan (from ~4400 to ~4000 cal. y BP) and Erlitou (from ~3800 to ~3500 cal. y BP) periods were significantly different. The Longshan settlements were ubiquitously spread across the study area, while the Erlitou settlements were concentrated in the valley plains of the middle Qin River reaches, and the number of human settlements decreased significantly during the Erlitou period.

(2) The collected geological evidence containing well-age-constrained extreme flooding unquestionably indicates that the episode at ~4000 cal. y BP was an extreme-flood-rich episode within and around the Qin River Basin.

(3) Foxtail and broomcorn millets were the two mainly cultivated crops during the Longshan and Erlitou periods in the study area. However, there were distinct differences in the cropping structures of human subsistence strategy, presenting a higher (lower)

proportion of foxtail (broomcorn) millet during the Erlitou period than during the Longshan period.

(4) Both extreme floods at ~4000 cal. y BP and the variety of subsistence strategies influenced human settlement distribution patterns in the upper and middle Qin River reaches. Millet-based agriculture dominated local subsistence strategy during the Longshan and Erlitou periods; thus, the valley plains suitable for agricultural cultivation hosted most Longshan and Erlitou settlements. However, frequent extreme floods and intergroup conflicts due to a large amount of human immigration at ~4000 cal. y BP that occurred within and around the Qin River Basin are likely to have jointly caused significant settlement number reduction and spatial range shrinking of settlement distribution. After ~4000 cal. y BP, owing to increasing proportion of higher-water-requirement foxtail millet in cropping structures of human subsistence strategy, more Erlitou settlements were distributed in the wetter middle Qin River reaches.

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References

1. Ortloff, C.R.; Kolata, A.L. Climate and collapse: Agro-ecological perspectives on the decline of the Tiwanaku State. *J. Archaeol. Sci.* **1993**, *20*, 195–221. [CrossRef]
2. Binford, M.W.; Kolata, A.L.; Brenner, M.; Janusek, J.W.; Abbott, M.; Curtis, J.H. Climate variation and the rise and fall of an Andean civilization. *Quat. Res.* **1997**, *47*, 235–248. [CrossRef]
3. DeMenocal, P.B. Cultural responses to climate change during the late Holocene. *Science* **2001**, *292*, 667–673. [CrossRef] [PubMed]
4. Li, K.F.; Gao, W.H.; Wu, L.; Hu, H.N.; Gong, P.P.; Li, S.Y.; Jin, R.; Si, Y. Spatial expansion of Human settlement during the Longshan period (~4.5–~3.9 ka BP) and its hydroclimatic contexts in the lower Yellow River floodplain, Eastern China. *Land* **2021**, *10*, 712. [CrossRef]
5. Butzer, K.W. Collapse, environment, and society. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 3632–3639. [CrossRef]
6. Wu, L.; Lu, S.G.; Zhu, C.; Ma, C.M.; Sun, X.L.; Li, X.X.; Li, C.C.; Guo, Q.C. Holocene environmental archaeology of the Yangtze River Valley in China: A review. *Land* **2021**, *10*, 302. [CrossRef]
7. Büntgen, U.; Myglan, V.S.; Ljungqvist, F.C.; McCormick, M.; Cosmo, N.D.; Sigl, M.; Jungclaus, J.; Wagner, S.; Krusic, P.J.; Esper, J.; et al. Cooling and societal change during the Late Antique Little Ice Age from 536 to around 660 AD. *Nat. Geosci.* **2016**, *9*, 231–236. [CrossRef]
8. Li, K.F.; Zhu, C.; Jiang, F.Q.; Li, B.; Wang, X.H.; Cao, B.; Zhao, X.F. Archaeological sites distribution and its physical environmental settings between ca 260–2.2 ka BP in Guizhou Province, Southwest China. *J. Geogr. Sci.* **2014**, *24*, 526–538. [CrossRef]
9. Dong, G.H.; Li, R.; Lu, M.X.; Zhang, D.J.; James, N. Evolution of human-environmental interactions in China from the Late Paleolithic to the Bronze Age. *Prog. Phys. Geogr.* **2020**, *44*, 233–250. [CrossRef]
10. Li, K.F.; Gao, W.H. Holocene climate change in Henan area: A synthesis of proxy records. *Quat. Int.* **2019**, *521*, 185–193. [CrossRef]
11. Weninger, B.; Alram-Stern, E.; Bauer, E.; Clare, L.; Danzeglocker, U.; Joris, O.; Claudia, K.E.; Gary, R.F.; Todorova, H.; Andel, T. Climate forcing due to the 8200 cal yr BP event observed at Early Neolithic sites in the eastern Mediterranean. *Quat. Int.* **2006**, *66*, 401–430. [CrossRef]
12. Anderson, D.G.; Maasch, K.A.; Sandweiss, D.H. *Climate Change and Cultural Dynamics: A Global Perspective on Mid-Holocene Transitions*; Academic Press: London, UK, 2007.

13. Boyd, W.E. Social change in late Holocene mainland SE Asia: A response to gradual climate change or a critical climatic event? *Quat. Int.* **2008**, *184*, 11–23. [CrossRef]
14. Dong, G.H.; Wang, L.; Cui, Y.F.; Elston, R.; Chen, F.H. The spatiotemporal pattern of the Majiayao cultural evolution and its relation to climate change and variety of subsistence strategy during late Neolithic period in Gansu and Qinghai Provinces, northwest China. *Quat. Int.* **2013**, *316*, 155–161. [CrossRef]
15. Lespez, L.; Glais, A.; Lopez-Saez, J.; Drezen, Y.L.; Tsirtsoni, Z.; Davidson, R.; Biree, L.; Malamidou, D. Middle Holocene rapid environmental changes and human adaptation in Greece. *Quat. Res.* **2016**, *85*, 227–244. [CrossRef]
16. Liu, L.; Chen, X.C.; Wright, H.; Xu, H.; Li, Y.; Chen, G.; Zhao, H.; Kim, H.; Lee, G. Rise and fall of complex societies in the Yiluo region, North China: The spatial and temporal changes. *Quat. Int.* **2019**, *521*, 4–15. [CrossRef]
17. Park, J.; Park, J.; Yi, S.; Kim, J.C.; Lee, E.; Choi, J. Abrupt Holocene climate shifts in coastal East Asia, including the 8.2 ka, 4.2 ka, and 2.8 ka BP events, and societal responses on the Korean peninsula. *Sci. Rep.* **2019**, *9*, 10806. [CrossRef] [PubMed]
18. Mayewski, P.A.; Rohling, E.E.; Stager, J.C.; Karlén, W.; Maasch, K.A.; Meeker, L.D.; Meyerson, E.A.; Gasse, F.; van Kreveld, S.; Holmgren, K.; et al. Holocene climate variability. *Quat. Res.* **2004**, *62*, 243–255. [CrossRef]
19. Railsback, L.B.; Liang, F.Y.; Brook, G.A.; Voarintsoa, N.R.G.; Sletten, H.R.; Marais, E.; Hardt, B.; Cheng, H.; Edwards, R.L. The timing, two-pulsed nature, and variable climatic expression of the 4.2 ka event: A review and new high-resolution stalagmite data from Namibia. *Quat. Sci. Rev.* **2018**, *186*, 78–90. [CrossRef]
20. Zhang, H.W.; Cheng, H.; Cai, Y.J.; Spötl, C.; Kathayat, G.; Sinha, A.; Edwards, R.L.; Tan, L.C. Hydroclimatic variations in southeastern China during the 4.2 ka event reflected by stalagmite records. *Clim. Past* **2018**, *14*, 1805–1817. [CrossRef]
21. Wiener, M.H. The interaction of climate change and agency in the collapse of civilizations ca. 2300–2000 BC. *Radiocarbon* **2014**, *56*, 1–16. [CrossRef]
22. Ran, M.; Chen, L. The 4.2 ka BP climatic event and its cultural responses. *Quat. Int.* **2019**, *521*, 158–167. [CrossRef]
23. Stanley, J.D.; Krom, M.D.; Cliff, R.A.; Woodward, J.C. Nile flow failure at the end of the Old Kingdom, Egypt: Strontium isotopic and petrologic evidence. *Geoarchaeology* **2003**, *18*, 395–402. [CrossRef]
24. Marshall, M.H.; Lamb, H.F.; Huws, D.; Davies, S.J.; Bates, R.; Bloemendal, J.; Boyle, J.; Leng, M.J.; Umer, M.; Bryant, C. Late Pleistocene and Holocene drought events at Lake Tana, the source of the Blue Nile. *Glob. Planet. Chang.* **2011**, *78*, 147–161. [CrossRef]
25. Staubwasser, M.; Sirocko, F.; Grootes, P.M.; Segl, M. Climate change at the 4.2 ka BP termination of the Indus valley civilization and Holocene south Asian monsoon variability. *Geophys. Res. Lett.* **2003**, *30*, 1425. [CrossRef]
26. Dixit, Y.; Hodell, D.A.; Petrie, C.A. Abrupt weakening of the summer monsoon in northwest India ~4100 yr ago. *Geology* **2014**, *42*, 339–342. [CrossRef]
27. Weiss, H.; Courty, M.A.; Wetterstrom, W.; Guichard, F.; Senior, L.; Meadow, R.; Crunow, A. The genesis and collapse of third millennium north Mesopotamian civilization. *Science* **1993**, *261*, 995–1004. [CrossRef]
28. Carolin, S.A.; Walker, R.T.; Day, C.C.; Ersek, V.; Sloan, R.A.; Dee, M.W.; Talebian, M.; Henderson, G.M. Precise timing of abrupt increase in dust activity in the Middle East coincident with 4.2 ka social change. *Proc. Natl. Acad. Sci. USA* **2019**, *116*, 67–72. [CrossRef]
29. Nicoll, K.; Zerboni, A. Is the past key to the present? Observations of cultural continuity and resilience reconstructed from geoarchaeological records. *Quat. Int.* **2020**, *545*, 119–127. [CrossRef]
30. Degroot, D.; Anchukaitis, K.; Bauch, M.; Burnham, J.; Carnegy, F.; Cui, J.; Luna, K.; Guzowski, P.; Hambrecht, G.; Huhtamaa, H.; et al. Towards a rigorous understanding of societal response to climate change. *Nature* **2021**, *591*, 539–550. [CrossRef]
31. Jia, X.; Dong, G.H.; Li, H.; Brunson, K.; Chen, F.H.; Ma, M.M.; Wang, H.; An, C.B.; Zhang, K.R. The development of agriculture and its impact on cultural expansion during the late Neolithic in the Western Loess Plateau, China. *Holocene* **2013**, *23*, 85–92. [CrossRef]
32. Pokharia, A.K.; Agnihotri, R.; Sharma, S.; Bajpai, S.; Nath, J.; Kumaran, R.N.; Negi, B.C. Altered cropping pattern and cultural continuation with declined prosperity following abrupt and extreme arid event at similar to 4200 yrs BP: Evidence from an Indus archaeological site Khirsara, Gujarat, western India. *PLoS ONE* **2017**, *12*, e0185684. [CrossRef]
33. Li, K.F.; Gong, P.P.; Hu, H.N.; Jia, W.Y.; Liu, X.L.; Gao, W.H. Spatial variability of human subsistence strategies during the Longshan period (~4.6–~3.9 ka BP) and its possible physical environmental contexts in the Yellow-Huai River area, East China. *Sci. Cult.* **2021**, *7*, 105–116.
34. Liu, F.G.; Feng, Z.D. A dramatic climatic transition at ~4000 cal. yr BP and its cultural responses in Chinese cultural domains. *Holocene* **2012**, *22*, 1181–1197. [CrossRef]
35. Sun, Q.L.; Liu, Y.; Wünnemann, B.; Peng, Y.J.; Jiang, X.Z.; Deng, L.J.; Chen, J.; Li, M.T.; Chen, Z.Y. Climate as a factor for Neolithic cultural collapses approximately 4000 years BP in China. *Earth-Sci. Rev.* **2019**, *197*, 102915. [CrossRef]
36. An, C.B.; Tang, L.Y.; Barton, L.; Chen, F.H. Climate change and cultural response around 4000 cal yr B.P. in the western part of Chinese Loess Plateau. *Quat. Res.* **2005**, *63*, 347–352. [CrossRef]
37. Cui, J.X.; Sun, Z.Y.; Burr, G.S.; Shao, J.; Chang, H. The great cultural divergence and environmental background of Northern Shaanxi and its adjacent regions during the late Neolithic. *Archaeol. Res. Asia* **2019**, *20*, 100164. [CrossRef]
38. Xiao, J.L.; Zhang, S.R.; Fan, J.W.; Wen, R.L.; Xu, Q.H.; Yoshio, I.; Toshio, N. The 4.2 ka event and its resulting cultural interruption in the Daihai Lake basin at the East Asian summer monsoon margin. *Quat. Int.* **2019**, *527*, 87–93. [CrossRef]

39. Wu, W.X.; Liu, T.S. Possible role of the “Holocene event 3” on the collapse of Neolithic cultures around the central plain of China. *Quat. Int.* **2004**, *117*, 153–166.
40. Wang, W. Discussion on the large-scale cultural changes at ~2000 BC in China. *Archaeology* **2004**, *1*, 67–77. (In Chinese)
41. Yu, S.Y.; Hou, Z.F.; Chen, X.X.; Wang, Y.X.; Song, Y.G.; Gao, M.K.; Pan, J.R.; Sun, M.; Fang, H.; Han, J.Y.; et al. Extreme flooding of the lower Yellow River near the Northgrippian-Meghalayan boundary: Evidence from the Shilipu archaeological site in southwestern Shandong Province, China. *Geomorphology* **2020**, *350*, 106878. [CrossRef]
42. Zhang, H.W.; Cheng, H.; Sinha, A.; Spötl, C.; Cai, Y.J.; Liu, B.; Kathayat, G.; Li, H.Y.; Tian, Y.; Li, Y.W.; et al. Collapse of the Liangzhu and other Neolithic cultures in the lower Yangtze region in response to climate change. *Sci. Adv.* **2021**, *7*, eabi9275. [CrossRef]
43. Wu, Q.L.; Zhao, Z.J.; Liu, L.; Granger, D.E.; Wang, H.; Cohen, D.J.; Wu, X.H.; Ye, M.L.; Bar-Yosef, O.; Lu, B.; et al. Outburst flood at 1920 BCE supports historicity of China’s Great Flood and the Xia dynasty. *Science* **2016**, *353*, 579–582. [CrossRef]
44. Wu, L.; Zhu, C.; Ma, C.M.; Li, F.; Meng, H.P.; Liu, H.; Li, L.Y.; Wang, X.C.; Sun, W.; Song, Y.G. Mid-Holocene palaeoflood events recorded at the Zhongqiao Neolithic cultural site in the Jianghan Plain, middle Yangtze River Valley, China. *Quat. Sci. Rev.* **2017**, *173*, 145–160. [CrossRef]
45. Zhang, J.N.; Xia, Z.K. Deposition evidences of the 4 ka BP flood events in central China plains. *Acta Geogr. Sin.* **2011**, *66*, 685–697, (In Chinese with English Abstract).
46. Tan, L.C.; Shen, C.C.; Cai, Y.J.; Cheng, H.; Edwards, R.L. Great flood in the middle-lower Yellow River reaches at 4000 a BP inferred from accurately-dated stalagmite records. *Sci. Bull.* **2018**, *63*, 206–208. [CrossRef]
47. Huang, C.C.; Pang, J.L.; Zha, X.C.; Su, H.X.; Jia, Y.F. Extraordinary floods related to the climatic event at 4200 a BP on the Qishuihe River, middle reaches of the Yellow River, China. *Quat. Sci. Rev.* **2011**, *30*, 460–468. [CrossRef]
48. Huang, C.C.; Pang, J.L.; Zha, X.C.; Zhou, Y.L.; Su, H.X.; Li, Y.Q. Extraordinary floods of 4100–4000 a BP recorded at the late Neolithic ruins in the Jinghe River Gorges, middle reach of the Yellow River, China. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2010**, *289*, 1–9. [CrossRef]
49. Zhang, Y.Z.; Huang, C.C.; Tan, Z.H.; Chen, Y.L.; Qin, H.J.; Huang, C.; Li, Y.Q.; Zhang, Y.X.; Li, X.G.; Shulmeister, J.; et al. Prehistoric and historic overbank floods in the Luoyang Basin along the Luohe River, middle Yellow River basin, China. *Quat. Int.* **2019**, *521*, 118–128. [CrossRef]
50. Liu, L.; Chen, X.C. *The archaeology of China: From the Late Paleolithic to the Early Bronze Age*; Cambridge University Press: Cambridge, UK, 2012.
51. Liu, L. *The Chinese Neolithic: Trajectories to Early States*; Cambridge University Press: Cambridge, UK, 2004.
52. Rosen, A.M. The impact of environmental change and human land use on alluvial valleys in the Loess Plateau of China during the Middle Holocene. *Geomorphology* **2008**, *101*, 298–307. [CrossRef]
53. Lu, P.; Lü, J.Q.; Zhuang, Y.J.; Chen, P.P.; Wang, H.; Tian, Y.; Mo, D.W.; Xu, J.J.; Gu, W.F.; Hu, Y.Y.; et al. Evolution of Holocene alluvial landscapes in the northeastern Songshan region, Central China: Chronology, models and socio-economic impact. *Catena* **2021**, *197*, 104956. [CrossRef]
54. Li, K.F.; Gao, W.H. Human settlement distribution patterns during the Longshan and Xinzhai-Erlitou periods and their hydrogeomorphic contexts in the Central Plains, China. *Catena* **2021**, *204*, 105433. [CrossRef]
55. Liu, Y.; Zhang, G.H.; Cheng, Y.; An, J.F. Excavation report of Hecun Site in Zezhou County, Shanxi Province. *J. Natl. Mus. China* **2014**, *4*, 44–58. (In Chinese)
56. National Museum of China; Shanxi Provincial Institute of Archaeology; Changzhi Municipal Bureau of Cultural Relics and Tourism. *Survey Report of Early Archaeological Cultures in the Upper Reaches of the Zhuozhang River*; Science Press: Beijing, China, 2015. (In Chinese)
57. Shanxi Provincial Institute of Archaeology. Investigation report of Xilimen Site in Gaoping County, Shanxi Province. *Huaxia Archaeol.* **2021**, *5*, 3–9. (In Chinese)
58. Bureau of National Cultural Relics. *Atlas of Chinese Cultural Relics—Shanxi Volume*; SinoMaps Press: Beijing, China, 2006. (In Chinese)
59. Hosner, D.; Wagner, M.; Tarasov, P.E.; Chen, X.; Leipe, C. Spatiotemporal distribution patterns of archaeological sites in China during the Neolithic and Bronze Age: An overview. *Holocene* **2016**, *26*, 1576–1593. [CrossRef]
60. Li, J.C.; Han, L.Y.; Zhang, G.M.; Su, Z.Z.; Zhao, Y.F. Temporal-spatial variations of human settlements in relation to environment change during the Longshan culture and Xia-Shang periods in Shanxi Province, China. *Quat. Int.* **2017**, *436*, 129–137. [CrossRef]
61. Yellow River Jiaozuo Bureau. *Annals of Qin River*; The Yellow River Water Conservancy Press: Zhengzhou, China, 2009. (In Chinese)
62. Fu, P. Design Flood Calculation of the Qin River Based on Paleoflood Method. Master’s Thesis, Hohai University, Nanjing, China, 2005. (In Chinese with English Abstract).
63. Guo, Y.Q. Study on the Rare Paleofloods Discharge Restoration at Ten-Millennium Scale from Several Rivers in Monsoonal Areas of China. Doctor’s Thesis, Shaanxi Normal University, Xi’an, China, 2017. (In Chinese with English Abstract).
64. Li, Y.Q.; Huang, C.C.; Ngo, H.H.; Yin, S.Y.; Dong, Z.B.; Zhang, Y.Z.; Chen, Y.L.; Lu, Y.J.; Guo, W.S. Analysis of event stratigraphy and hydrological reconstruction of low-frequency flooding: A case study on the Fenhe River, China. *J. Hydrol.* **2021**, *603*, 127083. [CrossRef]

65. Zhang, Y.Z.; Huang, C.C.; Pang, J.L.; Zha, X.C.; Zhou, Y.L.; Wang, X.Q. Holocene palaeoflood events recorded by slackwater deposits along the middle Beiluohe River valley, middle Yellow River basin, China. *Boreas* **2015**, *44*, 127–138. [CrossRef]
66. Huang, C.C.; Pang, J.L.; Zha, X.C.; Zhou, Y.L.; Su, H.X.; Zhang, Y.Z.; Wang, H.S.; Gu, H.L. Holocene palaeoflood events recorded by slackwater deposits along the lower Jinghe River valley, middle Yellow River basin, China. *J. Quat. Sci.* **2012**, *27*, 485–493. [CrossRef]
67. Yuan, G.K. The reason for the ruin of the Longshan city-site at Mengzhuang. *Archaeology* **2000**, *3*, 39–44. (In Chinese)
68. Song, J.X.; Wang, L.Z.; Fuller, D.Q. A regional case in the development of agriculture and crop processing in northern China from the Neolithic to Bronze Age: Archaeobotanical evidence from the Sushui River survey, Shanxi province. *Archaeol. Anthropol. Sci.* **2019**, *11*, 667–682. [CrossRef]
69. Jiang, Y.C.; Dai, X.M.; Wang, L.Z.; Wang, X.Y.; Qin, L. Plant macro-remains reveals the agricultural pattern and regional variation of Shanxi Plateau during Longshan Period. *Quat. Sci.* **2019**, *39*, 123–131, (In Chinese with English Abstract).
70. Zhao, Z.J.; He, N. Flotation results and analysis at Taosi site in 2002. *Archaeology* **2006**, *5*, 77–86. (In Chinese)
71. Chen, X.X.; Wang, L.Z.; Wang, Q. Analysis of floatation results from the 2006–2007 excavation of Xijincheng site in Bo'ai County, Henan Province. *Huaxia Archaeol.* **2010**, *3*, 67–76. (In Chinese)
72. Liu, Z.; Li, H.M.; Zhang, Z.Q.; Guo, Q.; Li, H.; Jia, X. Utilization of plant resources in Longshan Period in the Central China: Take Shangcun site in Xinxiang City Henan Province as an example. *Agric. Hist. China* **2021**, *1*, 13–21, (In Chinese with English Abstract).
73. Wu, X.; Guo, M.J.; Wang, R.; Guo, R.Z.; Jin, G.Y. Analysis of plant remains of Longshan period at Dalaidian site in Hebi City, Henan Province. *East Asia Archaeol.* **2017**, *14*, 184–201. (In Chinese)
74. Liu, H.; Song, G.D.; Li, S.T. Analysis of carbonized macroremains from the Zhangdeng site, Henan. *Acta Anthropol. Sin.* **2021**, *40*, 1063–1071, (In Chinese with English Abstract).
75. Shanxi Cultural Relics Bureau. *Selected Important New Discoveries in the Third Cultural Relics Census in Shanxi Province*; Science Press: Beijing, China, 2010. (In Chinese)
76. Wang, H.Y.; Jia, Y.N.; Zhang, Y.Z.; Wang, N.L.; Luo, P.P.; Qiu, H.J.; Ayidina, S.; Xiao, Q.L.; Chen, D. Research progress of paleoflood events in the Yellow River Basin since the last deglaciation. *Prog. Geogr.* **2021**, *40*, 1220–1234, (In Chinese with English Abstract). [CrossRef]
77. Zhang, X.L.; Qiu, S.H.; Bo, G.C.; Wang, J.X.; Zhong, J. Stable carbon and nitrogen analysis of human bones from the Erlitou and Taosi sites. In *Science for Archaeology (Volume 2)*; Archaeological Science and Technology Center, Institute of Archaeology, Chinese Academy of Social Sciences, Eds.; Science Press: Beijing, China, 2007; pp. 41–48. (In Chinese)
78. Ling, X.; Chen, L.; Xue, X.M.; Zhao, C.C. Stable isotopic analysis of human bones from the Qingliang temple graveyard, Ruicheng County, Shanxi Province. *Quat. Sci.* **2010**, *30*, 415–421, (In Chinese with English Abstract).
79. Hou, L.L.; Hu, Y.W.; Zhao, X.P.; Li, S.T.; Wei, D.; Hou, Y.F.; Hu, B.H.; Lv, P.; Li, T.; Song, G.D.; et al. Human subsistence strategy at Liuzhuang site, Henan, China during the proto-Shang culture (~2000–1600 BC) by stable isotopic analysis. *J. Archaeol. Sci.* **2013**, *40*, 2344–2351. [CrossRef]
80. Yang, F.; Wang, Q.; Wang, F. Stable carbon and nitrogen isotope evidence of human and animal diets at the Xijincheng site, Bo'ai County of Henan Province. *Quat. Sci.* **2020**, *40*, 418–427, (In Chinese with English Abstract).
81. Zhao, Z.J. The process of origin of agriculture in China: Archaeological evidence from flotation results. *Quat. Sci.* **2014**, *34*, 73–84, (In Chinese with English Abstract).
82. Yuan, J. *Research on Subsistence from the Neolithic to the Bronze Age in China*; Fudan University Press: Shanghai, China, 2021. (In Chinese)
83. Chai, Y. *Common Millet*; China Agricultural Press: Beijing, China, 1999; pp. 56–101. (In Chinese)
84. Guedes, J.D.; Butler, E.E. Modeling constraints on the spread of agriculture to Southwest China with thermal niche models. *Quat. Int.* **2014**, *349*, 29–41. [CrossRef]
85. Sheng, P.F.; Shang, X.; Zhou, X.Y.; Storozum, M.; Yang, L.P.; Guo, X.N.; Zhang, P.C.; Sun, Z.W.; Hu, S.M.; Sun, Z.Y.; et al. Feeding Shimao: Archaeobotanical and isotopic investigation into early urbanism (4200–3000 BP) on the northern Loess Plateau, China. *Environ. Archaeol.* **2021**, 1–15. [CrossRef]
86. Li, H.M.; Cui, Y.F.; James, N.; Ritchey, M.; Liu, F.W.; Zhang, J.N.; Ma, M.M.; Dong, G.H. Spatiotemporal variation of agricultural patterns in different geomorphologic and climatic environments in the eastern Loess Plateau, north-central China during the late Neolithic and Bronze Ages. *Sci. China Earth Sci.* **2022**, *65*, 934–948. [CrossRef]
87. The Institute of Archaeology in Chinese Academy of Social Sciences. *Chinese Archaeology: Neolithic*; China Social Science Press: Beijing, China, 2010. (In Chinese)
88. Zhang, C.; Pollard, A.M.; Rawson, J.; Huan, L.M.; Liu, R.L.; Tang, X.J. China's major Late Neolithic centres and the rise of Erlitou. *Antiquity* **2019**, *93*, 588–603. [CrossRef]
89. Liu, X. *Selected Essays on the Archaeology of Xia, Shang and Zhou*; Science Press: Beijing, China, 2014; pp. 3–41. (In Chinese)
90. Han, J.Y. The expansion and influence of the Laohushan Culture. *Cult. Relics Cent. China* **2007**, *1*, 20–26. (In Chinese)
91. Han, J.Y. Violent cultural changes in Longshan period and tribal warfare in Chinese legendary Era. *J. Soc. Sci.* **2020**, *1*, 152–163, (In Chinese with English Abstract).

92. Shanxi Archaeological Team of The Institute of Archaeology in Chinese Academy of Social Sciences; Shanxi Provincial Institute of Archaeology; Linfen Municipal Bureau of Culture. Excavation on the city-site at Taosi, Xiangfen, Shanxi, in 2002. *Acta Archaeol. Sin.* **2005**, *3*, 307–346, (In Chinese with English Abstract).
93. Sun, Z.Y.; Shao, J.; Di, N. A synthesis of the archaeological discovery and research on the Shimao site. *Cult. Relics Cent. China* **2020**, *1*, 39–62. (In Chinese)
94. Wei, X.T. Discussion on the age of the Longshan city sites in the Central Plains and the reasons for their rise and fall. *Huaxia Archaeol.* **2010**, *1*, 49–60. (In Chinese)

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Article

Between Plain and Plateau: Micro-Transitions in Zooarchaeological Landscapes in the Guanzhong Region of Northwest China

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Abstract: Transitions in animal exploitation patterns are caused by topographical and climatic variations on both macro and micro scales. This paper presents temporally and spatially contextualized faunal profiles from 27 sites in the Guanzhong (关中) region of Shaanxi province (陕西省), PRC which date from the Early Neolithic to the Bronze Age (ca. 6000–1000 BCE). Climatic and environmental data was cross-referenced with archaeological, archaeobotanical and (where appropriate) historical sources to examine the reasons for the clear micro-transitions observed. Faunal profiles from sites in the Wei River plain (渭河盆地), loess plateau, and the transitional zone between them were analyzed. Animal utilization was found to vary substantially between different zones during the period under analysis. The transition in praxis between the Wei River valley and the loess plateau was not gradual. The hilly transition zone was found to have its own distinct animal exploitation pattern. These spatio-temporal differences in animal exploitation were caused by changes in both the local microclimates and the topography of the landscape in which the communities were living. Some regions apparently reverted to 'earlier' animal exploitation patterns in response to climatic changes. These environmental factors were also augmented by internal social developments and interactions with neighboring communities.

Keywords: Guanzhong; loess plateau; zooarchaeology; landscape; Neolithic; Bronze Age

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1. Introduction

The analysis of faunal remains within archaeological contexts usually focuses on the reconstruction of subsistence strategies, ancient economies, and past diets [1], but they can also provide useful insights into past environments and landscape use. In China, zooarchaeology has been applied on a site-by-site basis, with its main objectives being to understand: (1) faunal temporal and spatial distribution; (2) human-animal relationships; (3) past environments [2]. An increasing number of studies have enhanced our understanding of domestication [3,4], regional trajectories [5,6], secondary products [7–9], and craftsmanship [10–12]. Another application has been to reconstruct the impact of humans on past environments. Research in this direction has often focused on animal extinctions [13,14]. Paleoenvironmental reconstruction through the study of mollusks, small mammals, and parasites has also proved effective [15,16].

Most of the zooarchaeological and archaeobotanical research conducted to date is based in and around the Songshan (宋山) region of Henan Province (河南省) [12,17–22]. This is demonstrative of the tendency of research in China to coalesce around large and famous sites, which having been located according to historical texts, are considered to hold the greatest importance, for instance, Shimao (石峁) in North Shaanxi or Yangshao (仰韶) in Henan [23].

The Guanzhong plain and surrounding areas in Central Shaanxi are significantly less studied. The majority of the studies of ancient human occupation in this region from the Neolithic to the dynastic period to date have focused on archaeological evidence drawn from artifacts and ancient written sources [24]. Although there is some research that engages with the ancient climate through the use of zooarchaeology and archaeobotany, many of these studies are based on assumptions of a causal relationship between the environment and human actions, which remove human agency from the equation. The tendency for studies of human mobility and landscape exploitation to resort to environmental determinism and Euclidian approaches to the landscape has also previously been highlighted, but bears repeating [25].

This study takes 27 sites from the Guanzhong region which date from the Neolithic through to the Bronze Age (Figure 1, Table 1) to explore the exploitation of the landscape in different ecological regions through frequencies of the different taxa.

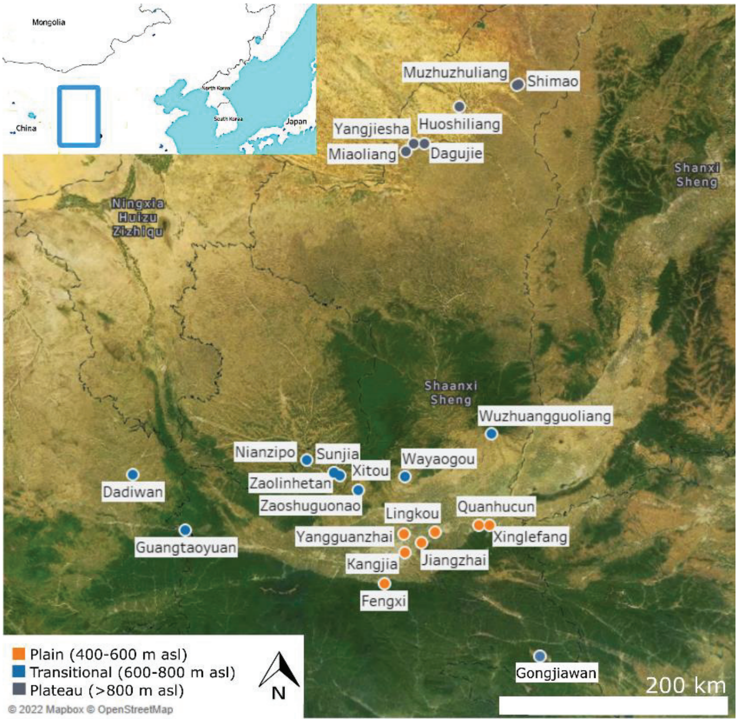

Figure 1. Map showing sites referenced in this paper.

For the purpose of this study, these sites have been divided into three topographically determined regions: plain, transitional, and plateau. The plain occupies the primary and secondary river terraces of large river valleys. These rivers are loess heavy and have a strong tendency to flood. The transitional zone consists of deep gullies carved into the soils of the loess plateau. These regions are formed of pockets of dense vegetation interspersed with scrubby bush. Small areas of flat land in the river valleys provide small areas of flat land for cultivation. The plateau sites are set in the broad plains of the loess plateau (黄土高原), which are relatively dry and can only be cultivated with irrigation.

Since many of the excavations from which our faunal profiles are taken were undertaken in the mid to late 20th century, zooarchaeological protocols were not followed to a modern standard. In particular, collection tended to be manual, with methods such as sieving and screening being the exception rather than the rule. This naturally has a significant impact on the resulting zooarchaeological profiles, which are often biased against small animals and small elements [26]. Additionally, these profiles are taken from the excavation of settlements and can therefore be taken to represent the diet of the occupants, and to a certain extent the local ecology [27].

Table 1. Chronology of Northern China and coordinates of the sites included in this study. Chronologies for Chinese archaeological cultures are determined on the basis of a large number of calibrated radiocarbon dates obtained from archaeological sites, which are published in [35].

Period	Dates	Zone	Site	Latitude	Longitude
Early Neolithic (Laoguantai 老官台)	6000–5000 BCE	Transitional	Dadiwan I 大地湾 I	35.02024	105.92629
			Guangtaoyuan 光桃园	34.49701	106.53101
Mid-Neolithic (Yangshao 仰韶)	5000–3000 BCE	Plain	Jiangzhai 姜寨	34.38374	109.21308
			Lingkou 零口	34.4785	109.36208
			Quanhucun 泉护村	34.54805	109.86111
			Xinglefang 兴乐坊	35.0376556	108.216578
			Yangguanzhai 梓官寨	34.46559	109.0113
		Transitional	Dadiwan II, III, IV 大地湾 II, III, IV [1]	34.49701	106.53101
			Gongjiawan 巩家湾 [1]	33.72038	11022784
			Wayaogou 瓦窑沟	35.00073	109.02031
			Wuzhuangguoluo 五庄果裸	35.39524	110.00372
		Plateau	Dagujie 大古界	38.03320	109.24746
			Yangjiesha 杨界沙	38.03961	109.12052
Late Neolithic (Longshan 龙山)	3000–1900 BCE	Plain	Kangjia 康家	34.29272	109.02815
		Transitional	Gongjiawan 巩家湾 [1]	33.72038	11022784
		Plateau	Huoshiliang 火石梁	38.36503	109.64894
			Miaoliang 庙梁	37.96861	109.0353
			Muzhuzhuliang 木柱柱了梁	38.55466	110.29661
			Shimao 石峁	38.56727	110.31886
Bronze Age (Pre-Shang 先商 * /Shang 商 /Proto-Zhou 先周)	1900–1600 BCE	Plain	Fengxi 沣西	33.99684	108.78804
		Transitional	Nianzipo 碾子破	35.14965	107.90275
			Sunjia 孙家	35.037656	108.216578
			Xitou 西头	35.037656	108.216578
			Zaolinhetan 枣林河滩	35.00568	108.27936
			Zaoshuguonao 枣树沟脑	34.872778	108.495833

* The regional transitional period between the Late Neolithic and the Bronze Age is culturally unclear, with a possible Erlitou (二里头)cultural phase between 1900–1600 BCE. Relevant archaeological (and zooarchaeological) evidence is, however, too little to make definitive claims. Therefore, this time period is referred to as "Pre-Shang" in this paper. [1] This site occurs across multiple phases and is therefore included in each.

The earliest sites included in this study show faunal profiles which are dominated by wild species, especially deer and other large or medium-sized mammals. Domestic species, such as pigs and bovids are notably scarce or absent. With the advent of animal domestication, humans have considerably extended the natural range of domesticated species through artificial feeding, landscape modification, and selective breeding [28–30]. The post-domestication assemblages are dominated by domestic species, this means that the potential for faunal data which might provide information on past ecologies is reduced.

Nevertheless, the distribution of domesticates is still limited to a certain degree by their basic physiology and dietary adaptations and has the potential to give indications, albeit generalized, of past environments and ancient landscape exploitation. For example, the mobility of the populations and their livestock within and across the landscape provides insights into the use of and impact on the landscape by humans and their animals. Certain animal types require a more sedentary existence (e.g., pigs and fowl), whilst others require and can tolerate greater mobility (e.g., bovids and equines). This leads to different faunal profiles:

(1) Profiles dominated by pigs supplemented by bovids are indicative of communities that relied mostly on agriculture and moved domestic herds of herbivores across short distances within a localized landscape, as part of a mixed agropastoral economy [31]. The presence of fowl is also presumed in such assemblages, however, their bones are often either not present or not recorded. This may be due to taphonomic processes or recovery bias against small elements.

(2) Profiles dominated by herd animals (caprines and cattle in this study) are usually indicative of seminomadic or specialized pastoralism [32]. Such seminomadic pastoralism can include transhumant communities in which the herds are moved seasonally between pastures (for example, summer pastures in the uplands and winter in the lowlands or vice versa) and can be evidenced by complementary sets of mortality profiles from upland and lowland sites [33]. Specialized pastoralism relies heavily on one (sometimes two) species of herd animals, which are extensively moved in the landscape. This degree of mobility precludes pig and fowl husbandry, the presence of such animals within the faunal profiles can be put down to trading or raiding [34].

As the distribution of species is to some degree limited by their physiology and foraging behavior, the result is that some animals are associated with certain environments [36,37]. In mapping the sites in terms of their topographic locations it is possible to trace the variations in animal exploitation on a much smaller scale. Faunal data from 27 sites in Guanzhong have been collected and mapped onto a satellite image with contour lines and considered alongside chronological and environmental data. This was done with the aim of understanding micro-transitions in animal exploitation patterns and, thus, exploring past human strategies of landscape exploitation. This study found that even within this limited region (<10,000 km^2) the animal utilization varied substantially between different zones during the period under analysis, each showing distinctive exploitation patterns, and with some regions apparently reverting to 'earlier' animal exploitation patterns in response to climatic influences.

Study Area

The study area includes three zones: the Wei River plain, transitional zone, and loess plateau. Twenty-one of the sites selected for this study are located in the Guanzhong plain and its surrounding transitional zones with six of the sites located 200 km to the north on the loess plateau. These sites have been included since they represent the only available zooarchaeological profiles for the loess plateau against which to contrast the animal exploitation present in the Guanzhong plain and its surrounding transitional zones.

The Guanzhong plain runs west to east across central northern China and occupies an area of 12,000 km. It is surrounded by the loess plateau to the north and the Qinling mountains (秦岭山脉) to the south. The Wei River flows through the region from west to east, from Baoji (宝鸡) where it enters the plain between the Liupan (六盘山) and Qinling mountains at an elevation of 600 m asl and continues 300 km to the confluence of the Wei and Yellow Rivers to the east of Huayin (华阴市) at 300 m asl [38]. Many small rivers feed into the Wei River from the Qinling Mountains, but its largest tributaries, the Jing 泾 and Luo 洛 Rivers, flow from the north. The Wei, Jing, and Luo all drain from the loess plateau and, therefore, have a high silt content and large seasonal variations in flow [39]. This high silt content means that the soil of the Guanzhong plain is mostly composed of loess which has been eroded and redeposited by water, before being modified by millennia of farming. The rivers running from the Qinling run clear and have a more regular flow than those which run from the north due to the monsoon winds which deposit precipitation on the mountains [40,41].

The Guanzhong region has seen continual human occupation from the Neolithic period through to the modern day. The Neolithic period is generally divided into three phases: Laoguantai, Yangshao, and Longshan. The regional transitional period between the Late Neolithic and the Bronze Age is unclear, with a possible occupation of the Erlitou Culture between 1900 and 1600 BCE. This is then followed by the historical period which is divided according to dynasties. In this paper, sites dating from the Early Neolithic through to the Bronze Age are analyzed with the terms Early, Mid, and Late Neolithic being used to improve the accessibility of the paper to scholars outside of China (Table 1).

The distribution of sites in the region shifts significantly during the course of this time period [42,43]. In the Neolithic, the majority of sites are found in the Hanjiang Plain (汉江盆地) of the Qinling Mountains and eastern Gansu Province (甘肃省) in the region close to Tianshui (天水市). It has been suggested that deforestation in the Qinling during the Early and Mid Neolithic caused erosion, which raised the level of the river beds, meaning that the seasonal floods became a greater threat to the settlements on the secondary terraces within the mountain valleys and increased the potential for catastrophic landslides [44]. There is a sharp increase in sites in the Guanzhong plain region during the Mid Neolithic. It has previously been suggested that this increase in sites was made possible by the advent of irrigation which allowed for the cultivation of the fast-draining soils of the Guanzhong plain [45]. However, the fact that settlement in this area would have also been subject to even greater flooding risks than those of the mountain valleys makes these interpretations problematic.

It should be noted that many sites are attributed to different time periods on the basis of the different forms of pottery found therein. This, therefore, means that all sites at which Laoguantai style are found are dated to a single time period with only a few sites being dated using other methods. If the persons occupying the sites in the Hanjiang valley continued to use Yangshao-style pots after the adoption of Longshan potteries in the Guanzhong plain and loess regions, it is possible that these sites might have been misattributed. This could explain the relative absence of sites in this region recorded as belonging to the Longshan periods. This sort of residuality has been observed in European and West Asian contexts [46] but is rarely considered in terms of Chinese archaeology.

2. Materials and Methods

2.1. Zooarchaeological Approach

This study is based on zooarchaeological data from 27 Neolithic and Bronze Age sites (25 already published and 2 in publication) in the Guanzhong region dated to between 6000 and 1000 BCE, including 2 sites (Gongjiawan and Dadiwan) at which the zooarchaeological data spans more than one phase. These sites were re-examined individually. The locations of these sites are shown in Figure 1. The main faunal data analyzed in this paper is the NISP (Number of Identified Specimens) for each site. NISP is a straightforward system used to compare species representation across multiple contexts and datasets [47–49]. MNI (Minimum Number of Individuals) accepted standard practice zooarchaeology [2,50]. Where possible MNI data have been excluded from these analyses due to the inherent subjectivity of the analysis when it comes to combining bones, the variety of data aggregation methods, and the MNI positive correlation with NISP [47,50,51]. In some cases, it was necessary to use MNI data for comparison with other regions.

With the exception of two assemblages (Lingkou and Gongjiawan), the NISP exceeded 100, providing a reasonably sized data set for comparisons. The NISP was not reported for the faunal remains from Wuzhangguoluo, but only the percentage proportion of the taxonomic representation. However, this was a minor issue because the percentage of NISP of different fauna was calculated for each site, and then, the average value in different areas and periods were used. This prevented bias related to the potential differences in the NISP from different sites. The %NISP distribution per site is included in Appendix A. In order to assure transparency, the standard deviation of each set of percentages was also calculated. Although it should be noted that in some cases the standard deviations were notably high this is to be expected with such a small dataset. The analysis herein presented focuses on those percentages which have relatively low standard deviations.

The total NISP analyzed was 48,545, 1106 from 2 Early Neolithic sites (Laoguantai Culture), 21,565 from 13 sites dated between 5000 and 3000 BCE (Yangshao Culture), 6071 from 6 sites dated to between 3000–1900 BCE (Longshan Culture), and 19,803 from 6 sites dated to between 1900–1050 BCE (Pre Shang/Shang/Proto Zhou Period). The distribution of data is biased by local researchers' tendency to focus on the intricacies of the Yangshao economy and the early phases of the domestication of pigs [52,53]. Chi-square test suggests that the difference in the distribution is statistically significant at $p < 0.05$ ($X^2 = 15{,}466.1$, df = 12, $p < 0.00001$).

This study divides the faunal remains into four main groups: one wild taxa, deer, and three main domesticates, cattle, pig, and caprine. Owing to the morphological similarity of sheep and goat and considering the uncertainties surrounding the standards to distinguish the two [54–57], these two animals ertr were combined into a single "caprine" category, which is used to refer to "sheep/goat". These taxa were selected because they were sufficiently evenly represented in the study area to be used for comparison across time and space. In addition, they are fairly common, and their bones have been well studied, making them relatively easy to identify in (and therefore more likely to have been reported for) each of the sites; these animals (and their bones) are also large enough to reduce the chance of recovery bias. They, however, may have been subjected to unavoidable fragmentation bias for the same reasons (i.e., larger bones produce more fragments) [49]. All the other taxa were included in the category "Others", and specific species are mentioned where relevant.

2.2. Mapping the Data

The faunal assemblages were mapped onto satellite and contoured maps using Tableau; this then permitted a clear understanding of the elevation and physical geography of the sites. The proximity to the nearest river, flat land within the vicinity of the site, elevation, and, where possible, the modern vegetation at the site were recorded. These factors were then combined to group the sites by type of site location according to overall topography: plain, transitional, and plateau.

The overall distribution sites in the region during each time period were plotted according to the data published in the *Zhongguo wenwu ditu ji: Shaanxi ce* [58]. As the result of the third round of the archaeological survey, these 'cultural heritage maps' are the most complete data available for the location of archaeological sites, despite being over twenty years old at this point.

3. Results

When the data from *Zhongguo wenwu ditu ji: Shaanxi ce* were mapped according to their time period, as expected, the resulting distribution was uneven, with the majority of the sites being dated to the Mid and Late Neolithic (Figure 2). This has been attributed to both recovery bias and apparent historical migrations of populations [42,59,60] (Figure 3).

It was, nevertheless, possible to identify clear temporal and spatial variations in the occurrence and abundance of animal species in the overall study area (Table 2). High standard deviation values were expected, given the small sample size and, in some cases, lack of reports of certain taxa (see Appendix A), while we acknowledge that it is problematic, we are constrained by the quality of the data available. There is also a significant reduction in the variety of taxa, which appears to be, at least partially, due to habitat loss [61,62], however, the impact of recording bias in favor of domesticated and well-known species is also a factor [2,52].

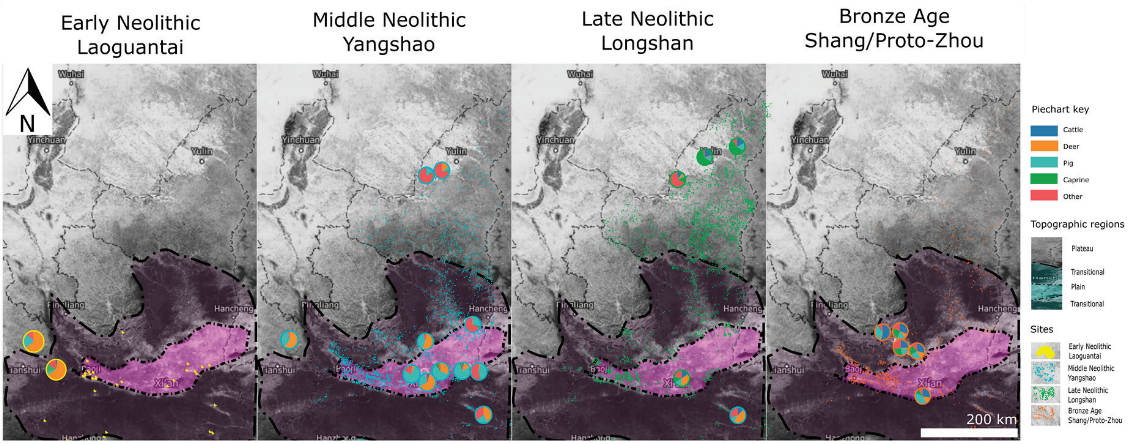

Figure 2. Maps showing the distribution of sites within the study region divided by time period with the three regions highlighted. The pie charts correspond to sites with zooarchaeological assemblages included in this study, while all other sites from each of the time periods are shown as small dots. (N.B. The dots for the Early Neolithic are by necessity larger than those of the periods due to the paucity of sites during this period). (Tableau, F. Monteith).

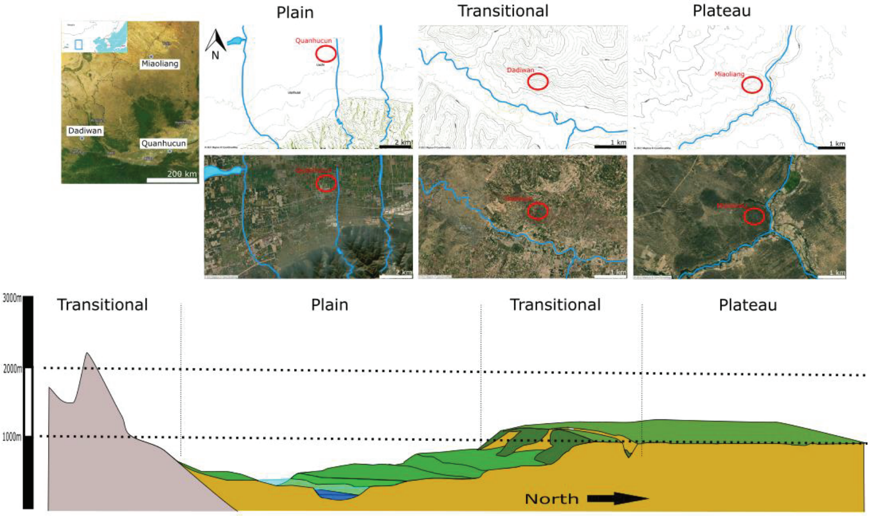

Figure 3. Landscape definitions, with the sites of Quanhucun, Dadiwan, and Miaoliang as examples. (Tableau and Inscape, F. Monteith).

The faunal profiles for the Early Neolithic sites in this study are dominated by wild fauna, with deer taxa making up to the 64% NISP on average. The Mid Neolithic shows a sharp increase in the prevalence of pigs (40% NISP on average), although the presence of deer remained significant (31% NISP on average). The assemblages from the following periods (Late Neolithic and dynastic periods) show a marked increase in the number of bovids, especially caprines (31% NISP on average in the Late Neolithic) and cattle (33% NISP in the Bronze Age).

Table 2. Average taxonomic abundance for Deer, Pig, Caprine, Cattle, and Others by NISP per time period. Data are presented in raw numbers (N) and percentages (%). Data sources are available in Appendix A. Differences between sites are highlighted using Standard Deviation (SD).

Period	**Deer**			**Pig**			**Caprine**			**Cattle**			**Other**			**Tot**		
	N	**%**	**SD**	**N**	**%**	**SD**	**N**	**%**	**SD**	**N**	**%**	**SD**	**N**	**%**	**SD**	**N**	**%**	**No. of Sites**
Early Neolithic	707	63.9	0.6	148	13.4	12.7	66	6.0	8.6	20	1.8	2.1	165	14.9	2.62	1106.0	100.0	2
Mid Neolithic	6706	31.1	26.5	8497	39.4	22	259	1.2	2	237	1.1	1.3	5866	27.2	31.79	21,565	100.0	13
Late Neolithic	941	15.5	22	899	14.8	9.2	1900	31.3	26.5	977	16.1	4.7	1354	22.3	24.3	6071	100.0	6
Bronze Age	1644	8.3	5.2	5069	25.6	10.5	3505	17.7	10.9	6515	32.9	10.9	3070	15.5	7.9	19,803	100.0	6

Further resolution is achieved when micro-variations in the physical geography of the region are considered. Three broad categories have been identified, plain, transitional zone, and the plateau (Figure 3).

In this study 'plain' is used to describe sites located on the Wei River plain. This region is at a relatively low elevation (c. 400–600 m asl). The land here is formed of almost flat terraces, which rise in steps from the river channel. The Wei River has a large seasonal variation in flow, historically it tended to flood and change course. This means that settlement on the plain usually occurred in areas of relatively increased elevation, with no sites being recovered from the primary terraces of the rivers. Set in the rain shadow of the Qinling Mountains, it is relatively dry with the majority of its water being supplied by the rivers. This means that prior to the advent of irrigation systems the potential for cultivation would have been restricted to the primary river terraces [38].

The transitional zone is formed by deep gullies which have eroded from the loess plateau. Aridification over the course of the 20th and 21st centuries has led to increased erosion in this region making an accurate reconstruction of the original form of the landscape here problematic. This region is characterized by small pockets of scrubby vegetation within the gullies. Although the hillsides are now terraced, this is a relatively recent innovation. Historically, this region would have only had limited land for cultivation. Although the Gongjiawan site is located in the Qinling mountains rather than the loess transitional zone, it is included in the latter category since the topography of the site is similar to that of the transitional zone.

The plateau is characterized by expanses of flat land cut across by rivers. These rivers run in relatively deep and narrow valleys, which only gradually change their courses. The climate here is presently semi-arid with sand dunes being evident on the satellite imagery. During the period of study, this region would have been less arid than it is in the modern day [63,64]. Although it would have been ideal to compare the sites in the plain and transitional zones with sites on the plateau closer to the Wei River Basin, those included in this study were the closest sites at which zooarchaeological studies had been undertaken for which the data had been published in a publicly accessible format. The concentration of sites in this region is likely due to its proximity to the Shimao site, which is a focal site for the Longshan Culture.

When these zooarchaeological profiles are divided into three broad categories in terms of the physical geography in their vicinity—plain, transitional, and plateau—the micro-regional differences in the taxonomic abundance and faunal exploitation in different time periods are highlighted (Table 3, Figures 2 and 4). Again, the presence of high standard deviation values while unfortunate was expected and may be attributed to the small sample size and the aforementioned research biases.

Table 3. Average taxonomic abundance for Deer, Pig, Caprine, Cattle, and Others by %NISP per time period and per zone. Those instances for which there are no data available are marked with the notation NR. Differences between sites are highlighted using Standard Deviation (SD). Given the small sample size, high standard deviation values are expected. Data sources are listed in Table Appendix A.

Zone	Age	N. Sites	Deer		Pig		Caprine		Cattle		Others		Total
Plain	Early Neolithic	0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
	Mid Neolithic	5	23.2	25.5	57.06	20.6	2.12	2.9	1.76	1.8	15.86	21.6	100
	Late Neolithic	1	35.6	NA	15	NA	11.9	NA	15.9	NA	21.6	NA	100
	Bronze Age	1	14.6	NA	41.2	NA	8.1	NA	27.5	NA	8.6	NA	100
Transitional	Early Neolithic	2	63.9	0.6	13.35	12.7	6.05	8.6	1.75	2.1	14.95	2.6	100
	Mid Neolithic	6	45.4	24.8	34.03	12.3	0.22	0.4	0.92	0.9	19.43	27.5	100
	Late Neolithic	1	48.1	NA	11.1	NA	0	NA	11.1	NA	29.7	NA	100
	Bronze Age	5	7	4.8	22.56	8	19.68	11	33.92	11.76	16.84	8	100
Plateau	Early Neolithic	0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
	Mid Neolithic	2	7.95	11.2	11.15	5.44	1.65	1.8	0	0	79.25	7.6	100
	Late Neolithic	4	3.1	3.5	15.6	11.7	43.8	22.5	17.4	5	20.1	31	100
	Bronze Age	0	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

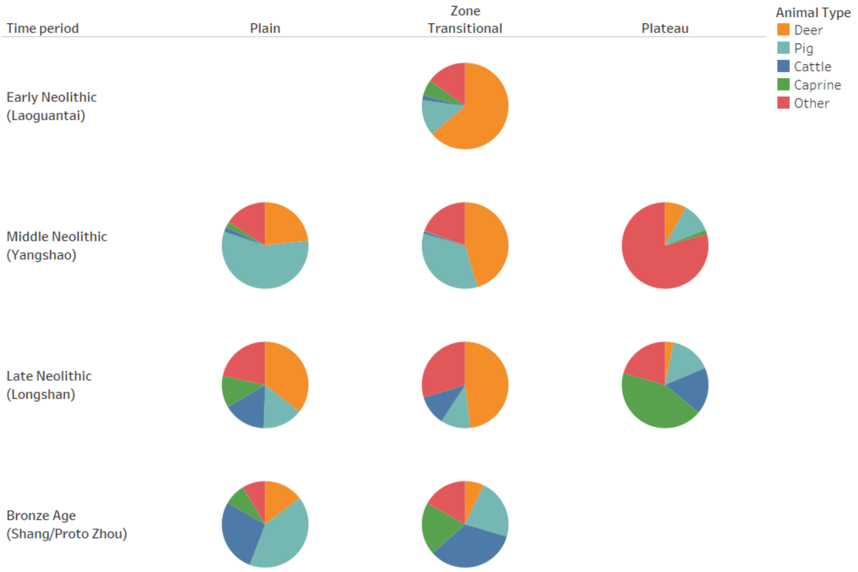

Figure 4. Pie charts showing the % NISP on average in each of the zones divided according to time period. (Drawn using tableau by F. Monteith).

3.1. Early Neolithic (Laoguantai Culture)

There are only 2 sites with faunal profiles in the transitional zone during this period. The faunal assemblages are dominated by wild species, among which cervids are the most common (64% NISP on average). Evidence of rhinoceroses (*Didermoceros sumatrensis*) and wild horses (*Equus caballus przewalskii*) have also been recorded along with golden snub-nosed monkeys (*Rhinopithecus roxellana*).

The proportion of pigs was relatively high (13% NISP on average). Given the fairly early domestication of pigs in the region at around 7000–7500 BP [65,66], some of these specimens may be domesticated, however, this is difficult to ascertain, since the process of pig domestication appears to have gradually arisen from commensal interactions. Additionally, there are methodological problems in the identification of domesticated versus wild suines during these early phases [66,67]. Bovids recovered in these assemblages are presumed to have been wild, on the basis of the identification of wild water buffalo (*Babulus* sp.) in the Guantaoyuan site and the relatively late introduction of domestic bovines and caprines into Central China [2].

3.2. Mid-Neolithic (Yangshao Culture)

There are faunal profiles for all three micro-regions during the Yangshao period with 5 sites on the plain, 6 sites in the transitional zone, and 2 sites on the plateau. The average site data for the faunal assemblages recovered in each of these three regions during this period is markedly different. These results show that during the Yangshao period, pigs were dominant in the plain (57% NISP on average) and that they were also an important taxon in the transitional zone (34% NISP on average). However, they only represent a minor percentage of the faunal assemblages in the plateau sites (11% NISP on average). During this period the majority of specimens are established as being domestic, with only a few individuals exhibiting the taxonomic characteristics associated with wild pigs [68].

The transitional zone was characterized by the highest proportion of deer remains (45% NISP on average), in contrast to the plain and plateau (23% NISP on average and 8% NISP on average, respectively).

The faunal profiles of the sites in the plateau are dominated by small mammals (79% NISP on average), especially hares (*lepus capensis*) (67% NISP on average), during this phase. This is in contrast to the plain and transitional zones, wherein the "Others" category only represents a relatively small proportion of the data (16% NISP on average and 19% NISP on average, respectively), but shows more taxonomic variety.

3.3. Late Neolithic (Longshan Culture)

There are faunal profiles available for all three regions during the Longshan Period with 1 site on the plain, 1 site in the transitional zone, and 4 sites on the plateau. There is a notable increase in domestic bovines in all three areas (plain 16% NISP up from 1% NISP on average in the Yangshao period, transitional zone 11% NISP on average up from 1% NISP on average, and plateau 18% NISP on average up from 0% NISP on average) during this period. In the plateau, a sharp increase in caprine (43.8% NISP on average up from 1.65% NISP on average in the Mid Neolithic) is recorded. The proportion of pigs is reduced compared to the Mid Neolithic, nevertheless, this taxon remains well represented in all the assemblages (plain 15% of NISP on average, transitional 11% of NISP on average, and plateau 16% NISP on average). The percentage of deer remains relatively high, particularly in the transitional zone (48% NISP) and the plain (36% NISP), while it is much lower in the plateau (3% NISP on average).

In one site on the plain, Kangjia, antler fragments make up 27% of the deer NISP [69], boosting the overall deer NISP. There has been much debate about whether to include antlers in the quantification of deer, since a single deer may shed multiple antlers during the course of its lifespan. Best practice does not include antlers that are not still attached to the cranium since they may have been collected individually from elsewhere and brought to the site [70]. If such practice is to be followed, the % NISP for deer would be around one-third lower in the plain.

The faunal assemblage for the Kangjia site shows a significantly greater variety of species within the category herein described as 'Others'. This includes small quantities of canids, both domestic (*Canis sp.*) and wild (*Vulpes sp.*), as well birds (*Phasianus* sp. and *Gallus* sp.), small mammals (*Lepus* sp.), and aquatic species including mollusk shells and fish bones. The "Others" forms an important category in the Gongjiawan site which is located in the transitional zone, however, the taxonomic variety is reduced when compared to the Yangshao-phase faunal assemblage [71]. In Miaoliang which is located in the plateau region, a large number of wild horses have been found.

3.4. Bronze Age (Shang, Proto-Zhou)

There are only faunal profiles for the plain (1 site) and the transitional zone (5 sites) during the Bronze Age. In both regions the domestic assemblage was prevalent, the deer category only representing 15% NISP in the plain, and 7% NISP on average in the transitional zone. The domestic assemblage was fairly homogenous with only a few taxa represented.

In the Fengxi site which is located on the plain, pigs are prevalent (41% NISP), in contrast to the transitional zone, where they are less represented (23% NISP on average). In both cases, there is a further sharp increase in cattle (27% NISP in Fengxi up from 16% NISP on average, and 34% NISP on average in the transitional zone up from 11% NISP). These bovines have been identified as domesticated species. There is a slight decrease in caprines on the plain (8% NISP), but a sharp increase in the transitional zone (20% NISP on average up from 0% NISP on average). Other domestic species, such as dogs (*Canis familiaris*) and horses (*Equus caballus*), were also found in the plain and the transitional zone.

4. Discussion

From the Early Neolithic to the Bronze Age, the Guanzhong region underwent a shift in animal exploitation, from wild species to pigs between the Early to Mid Neolithic, to an increasing number of bovids from the Mid Neolithic through to the Bronze Age. Looking at the data from the perspective of subsistence strategies, they are in line with current research on the topic, which shows that hunting and fishing were practiced in the region in the Early Neolithic, but that their importance declined during the Mid and Late Neolithic (Yangshao and Longshan periods), possibly due to population growth and increased demand for meat for both consumption and ritual purposes. Husbandry, by contrast, developed along with agriculture [72–76].

The original environment of the Guanzhong region has been almost completely erased. Fossil pollen, which is often used to track changing vegetation over time, does not preserve well in the loess soil of the Guanzhong region, and those wetlands, which might have existed, and which would have preserved the pollen record, have been almost completely eliminated by anthropogenic activities [77]. A growing corpus of studies of paleoclimatic indicators, which are discussed more in detail in the following sections, have argued that prehistoric regional vegetation was highly spatially variable with different ecosystems characterizing the three locations, plain, transitional, and plateau, across time. Zooarchaeological finds have also shown important regional differences that are addressed below.

4.1. Early Neolithic (Laoguantai Culture)

Our Early Neolithic assemblages come from the transitional zone. While the fragmentary distribution of the published material (especially old reports) may have led to some data being overlooked, the paucity of information reflects the low number of Early Neolithic sites discovered in the Guanzhong region. There are only 20 or so small settlements, which have not all been reported archaeologically and zooarchaeologically [58,78]. This region may have originally been scarcely populated, or the continual migration of the river channels might have erased the presence of such settlements from the archaeological record [77]. However, it is also possible that future research will recover further sites.

The faunal assemblages mostly include wild species, of which deer are the most prevalent. Palaeoecological studies undertaken in the region suggest that gullies and valleys were covered by forests and small grassland patches, therefore, the abundance of cervids is unsurprising [79–81]. The same habitat could have been shared by other wild hoofed animals, such as wild horses and Sumatran Rhinos, and carnivores, like bears and wild canids, which are also present in our Early Neolithic faunal assemblages. The discovery of golden snub-nosed monkeys in Guantaoyuan also suggests that the area was still forested during this period [82–84].

The pigs in these Early Neolithic sites would have been predominantly wild, with perhaps a few domestic or semi-domestic specimens. Although pigs seem to have been domesticated at around 7000 BP in Central Shaanxi [65,66], distinguishing wild and domestic specimens in these early stages of domestication has proven to be problematic. One problem is that the domestication of pigs probably progressed through a "commensal" pathway in three phases, "dependence", "initial exploitation" and "exploitation", with a high degree of interbreeding between domestic and wild individuals [66,67]. This makes a clear-cut taxonomic identification problematic. Methodologically, dental size and morphology have been the dominant technique to distinguish between wild and domestic pigs [85]. Reference, however, has usually been taken from larger western specimens of Eurasian boar [86], which, as noted by [87], may not be appropriate for comparison with inherently smaller Chinese pigs. C and N isotopes analysis increasingly used to assess domestication by examining the nutrition of individual specimens, has produced controversial results for pre-Yangshao pigs in Dadiwan [88–90].

Those few bovines and caprine specimens found in the Early Neolithic faunal assemblages were wild specimens. For bovines, more detailed information has been provided in the reports, where they were identified as wild water buffalos. Although many aspects of cattle domestication are still poorly understood, the sharp increase in specimens in the Late Neolithic would indicate that it occurred in this period or slightly earlier, thus supporting the wild status of our specimens [91–93]. The reports give little data on the caprines recovered. It is believed that domestic sheep and goats were introduced into China from Western Asia through the Hexi corridor ca. 3000–2500 BCE [2,6,94]. Early Neolithic caprines from our sites were, therefore, presumably wild. However, the recent discovery of domestic sheep's remains dating to 6000 BCE in Southern Kyrgyzstan [95], leaves room for further research on the timing and modes of introduction of this taxon into China.

The profile for our sites suggests the existence of hunters in the transitional zone, who mainly preyed on deer. Cervids mostly require woodlands and grasslands. Palaeoecological research indicates that, indeed, the gullies and valleys north of the plain were covered by forests in the Early Neolithic period [79–81]. Therefore, it is reasonable to argue that Early Neolithic communities likely exploited their immediate environs to some extent. This included wetlands, which were likely relatively extensive [96]. The exploitation of freshwater resources—mollusks and fish for food, and shells for making tools and ornaments—has been attested by recent studies on aquatic finds in Guantaoyuan [16,97].

There has only been limited research to date on the agriculture in this region during the Early Neolithic [98], however, the contribution of farming to local subsistence strategies was presumably small. There is significant data to affirm the presence of agricultural practice in the contemporaneous Peilingang (裴李岗) and Cishan (慈山) cultures, in present-day Henan Province [19,99]. Domestic pigs and dogs have been found to be relatively abundant [66,100]. Fowl were also recovered and they are usually presumed to be chickens or pheasants, although the early date of bird domestication in Central China is somewhat controversial [101,102].

In contrast to the faunal assemblages found in Henan, the faunal assemblages in the Guanzhong region are more consistent with low-investment or incipient farming profiles than cultavist or pastoralist profiles. There is also very limited evidence for anthropogenic deforestation for agricultural or husbandry purposes during the Early Neolithic, with even deforestation through fire apparently being absent [103]. There is some evidence of incipient farming at the Dadiwan site. Isotope analysis of pig and human bones at this site provides some convincing (though not definitive) evidence for pig domestication [88]. Similarly, the retrieval of some broomcorn millet (*Panicum miliaceum*) at the site represents the earliest potential evidence to date of regional millet cultivation [98].

4.2. Mid-Neolithic (Yangshao Culture)

Our dataset for the Mid Neolithic is richer than that of the Early Neolithic, with data being available for all three zones, plain, transitional, and plateau. When compared to the Early Neolithic, the number of sites discovered in Guanzhong is two orders of magnitude larger (ca. N = 1500 compared to ca. N = 20 in the Early Neolithic) [78]. It is difficult to ascertain whether the area came to be more extensively occupied during the Mid Neolithic, if the sites are better preserved during this period due to changes in site selection criteria or environmental factors, or if research is biased by selective archaeological excavations. It is likely to be a mix of all three factors, Chinese archaeologists have to date shown greater interest in the large Neolithic sedentary centers, which formed the foundations of the Chinese Civilization [2,52,53]. Yangshao cultural sites have been well studied in terms of agricultural development and diversification, as well as the rise of intensive animal husbandry [88,104]. It is these factors, prompted by favorable climatic conditions of the Holocene Climatic Optimum, which appear to have been the prevailing forces behind the demographic growth and more extensive land occupation present in this region during this period [105–107].

In the plain, the faunal assemblages are dominated by domestic species including a large number of pigs, alongside fewer fowl and dogs. The domestication status of these animals has been assessed by zooarchaeological methods [85,108–112], isotopic, and DNA research [113–115]. Deer were exploited, as well as local freshwater sources, fish, turtles, and mollusks, for subsistence, tool making, and decorations [16,116]. This zooarchaeological profile is consistent with a relatively sedentary lifestyle, in which cultivation and pig husbandry were the main means of subsistence and were supplemented by hunting and fishing.

Early Yangshao sites in the plain, such as Banpo (半坡) or Jiangzhai, were small and likely occupied discontinuously (but repetitively) [117,118]. The presence of fences in these sites suggests, however, that livestock husbandry was already an established practice [119,120]. In time settlements became progressively larger, suggesting an increase in population, and were occupied more consistently for more prolonged periods of time [116]. Water management constructions, such as ditches for drainage may have been intended to mitigate the frequent flooding of the loess-heavy Luo, Jing, and Wei rivers [121,122]. Such water management constructions could also have assisted cultivation. Evidence of localized fires related to anthropogenic activities, such as vegetation clearance for land reclamation, further supports the presence of intensive agriculture during the Mid Neolithic [103]. Most importantly, archaeobotanical and isotopic research has indicated that substantial cultivation of dominantly dry crops—broomcorn millet (*Panicum miliaceum*) and foxtail millet (*Setaria italica*)—was established in the plain, in order to feed both humans and livestock [74,123,124]. As the yield of foxtail millet is higher than that of broomcorn millet, its introduction in the Wei River plain could be one of the factors behind the increase in population and the intensification of husbandry during the Mid-Neolithic [88]. It also suggests that the climate may have been more humid, as foxtail millet is less draught-tolerant than its broomcorn counterpart. Phytolith evidence for rice (*Oryza sativa*) recovered in at least two of our sites, Quanhucun and Yangguanzhai, indicates greater access to water at these sites [104].

The discovery of foxtail millet and rice in Guanzhong raises also the question of possible interactions between the Central Plain of Henan with the communities in the Guanzhong region during the Mid Neolithic. Foxtail millet is common in the eastern regions of China throughout the Neolithic, however, it has not been frequently found in sites in Guanzhong until the Mid-Neolithic period [125]. Early evidence of mixed rice–millet farming has been discovered in Peiligang cultural sites in eastern and central China [53,126]. The westward spread of crops seems to have occurred along with certain types of pottery, by the gradual migration of small communities of farmers [126].

Faunal assemblages recovered from the transitional zone show some degree of continuity in animal exploitation with the Early Neolithic, with a high proportion of deer and a fairly high proportion of small mammals, and a lower, yet significant, presence of pigs. Deer are the most prevalent species, which indicates that intensive hunting on the hills and gullies remained a factor in the local subsistence. However, domestic pigs raised on fodder [88,127–129] would have provided a stable meat supply, making intensive hunting—which is high risk and does not provide a secure form of sustenance—unnecessary [130]. It is possible that deer were hunted for more than just their meat. Hunting was possibly a resource collection activity in the transitional zone [98] especially since deer bones, in particular metapodials and antlers, are good for tool making, since they are straight, dense, and easy to shape. At Wayaogou 4% NISP of deer elements were reported as being worked, and they make up 95% of the whole assemblage of worked bones at the site [131]. The acquirement of skin and leather could also have been other reasons for hunting aside from meat.

The presence of deer, and the great majority of sika and roe deer, suggests that the surrounding area, although not necessarily directly adjacent to the site, was formed of scrubby forest interspersed with meadowland. This habitat would also have been ideal for hares, which were similarly well represented in the assemblages. Hare bones were tested isotopically, revealing that their C3-based diet was different from the C4-based one of the humans, pigs, and dogs. This indicates that they were hunted at some distance from the site, possibly even in plateaus, where hares have been abundantly found in relation to settlements (see below). By contrast, isotopic results for rat bones indicated that they shared a similar diet with humans and domestic animals, suggesting that they live in, or very close to human settlements [127]. Insufficient bovine and caprine skeletal elements (0.92% and 0.22% NISP on average respectively) are present for the domestication status of these taxa to be established with any degree of certainty.

The plateau is characterized by a high proportion of small mammals, along with a significant presence of pigs. This suggests that, while the economy may have been dependent upon pig husbandry for meat, small game rodents were also exploited as a source of meat/marrow and fur. It is usually difficult to evaluate the presence of small mammals in sites, as they may have been deposited through accidental intrusion, by non-human predators, or as by-products of human habitat niches, which created favorable contexts for these taxa. However, given the relatively high quantity and concentration of specific *lepus* sp. in these settlements, it can be suggested that their deposition was probably related to subsistence, and may be taken as evidence of some hunting activity. Bone and stone hunting tools discovered in the sites support this conclusion [132]. Hunting may have occurred near, around, or in the site: results of isotope analysis on hare bones from Yangjiesha have revealed that these animals shared a C4-based diet similar to humans and pigs, suggesting some form of commensal relationship with humans [133].

Deer did not play a significant role in the regional economy. This can be understood in the context of different ecological conditions. Early studies, largely based upon written sources, claimed that the plateau was heavily forested in the mid-Holocene [40]. However, more recent research into climatic indicators has revealed that this was never the case: the plateau appears to have always been dominated by grasslands with no large areas of stable forest vegetation [80,81,134]. This is a niche environment, which would only have supported certain herbivores, including a few deer species, and small mammals, such as hares. Increasing human disturbance in the landscape by burning for land reclamation [103] would also have further reduced the habitat for deer. At the same time, the loess friability and porosity would have made the area appropriate for plowing, draining, and growing roots for millet. There is evidence of millet consumption at the Yangjiesha site, where fairly abundant grains of broomcorn and foxtail taxa were recovered [135].

4.3. Late Neolithic (Longshan)

The dataset for the Longshan period is smaller than the one for Yangshao, and most of the data comes from the plateau, with only one site with a faunal profile available for the plain and the transitional zone, respectively. While the above-mentioned research bias likely affected the sites' distribution to some extent, this scenario may also reflect the decrease in density of human occupation in the Wei basin, and a relative increase in Northern Shaanxi during the Late Neolithic. This has largely been attributed to northward human migrations from the plain, and southward migration of communities from Inner Mongolia, which are believed to have occurred as a response to climatic deterioration [42,59,60].

Our evidence shows that the Late Neolithic was characterized by a general increase in caprines and bovines, at the expense of pigs, across the whole Guanzhong area. Diversified use of animal resources might have augmented human adaptability to the progressively cold and dry climate, which followed the Holocene Climatic Optimum [136–138]. Climatic deterioration had a significant impact on agriculture. Foxtail millet became the most important crop, although broomcorn millet and rice were also cultivated in some areas [126,139]. The reorganization of agricultural production may have led to an adjustment of subsistence strategies in different regions in response to various degrees of climatic deterioration [140,141].

There is only one faunal profile for the plain during this period, from the Kangjia site. The three main domestic taxa (pig, cattle, and caprine) are all fairly well represented as well as wild species. This profile suggests that pig husbandry was still central in the local economy, although it was increasingly supplemented by herding and hunting.

Deer are prevalent. Although the % NISP may have been boosted by antler fragments (which make up 22% of the deer NISP), this points to hunting as being a significant activity for the community. As discussed above, the presence of domestic species at the site would reduce the need to hunt for meat and suggests that deer were exploited for other purposes. In Kangjia, deer bones and antlers were important materials for producing utilitarian tools and oracle bones. Oracle bones were crucial tools for divination and their processing has been associated with the emergence of social complexity, with a gradual emergence of craft and ritual specialists taking control over ritual practices from the Late Neolithic onwards [142]. The relationship between hunting and social stratification has been suggested by ancient written sources and archaeological evidence, according to which hunting was a significant social activity carried out by the elites in the pre-Shang and early Shang periods [143]. It is apparent that Longshan cultural communities had already undertaken the process of social stratification [144]. It is therefore possible that in addition to complementing the community's diet, hunting deer was a symbol of emerging social power.

Domestic species, including pigs, cattle, and caprines are all well-represented. The presence of domestic cattle and caprine specimens at these sites aligns with previous research, which indicates that these species had been introduced into China by the Late Neolithic [2,6,93,145,146]. Although pigs would still have represented a significant source of meat, it appears that cattle and caprines would have also been raised for their meat and their secondary products. It is possible that cattle were also employed for draught or transportation, however, paleopathological data for the bones in this assemblage are insufficient for firm conclusions to be drawn.

Climatic deterioration, alongside the frequent floods, would have affected agriculture on the plain, reducing the viable arable land area, especially for millet, which requires dry cultivation. However, this land could still have been suitable for growing rice [59,104,116]. In order to cope with changing conditions, the local economy, previously based on dry agriculture and pig husbandry, may have been integrated with some form of bovid herding. This implies a wider and seasonal use of the surrounding environment, possibly transhumance into the valleys of the transitional zone [147].

The faunal profile of the transitional zone shows a prevalent presence of deer and a significant proportion of pigs and cattle. The report of the faunal remains from Gongjiawan suggests that deer were semi-domestic. While there is no sufficient zooarchaeological data to confirm this hypothesis, and no relevant research has been conducted on deer domestication, it is plausible that these animals would have orbited around the settlements for food and interacted with humans to some degree. Further zooarchaeological research and isotopic analysis would provide some clarification for this question.

The presence of fairly numerous domestic species, suggests that deer was exploited for purposes, other than meat acquirement. Deer skeletal elements were used for tool-making. Moreover, there is clear evidence for hunting being a significant activity in the transitional zone, rooted in the early communities of hunters-gatherers that inhabited the region in the Early Neolithic, and even prior to that [98], and it may have evolved in a symbolic social practice [143].

The dominant presence of sika deer in Gongjiawan suggests the existence of fairly extensive temperate, broad-leaf deciduous forests and woodlands, which would have been necessary for this species to proliferate [71]. Persisting relatively humid conditions are evidenced by discoveries of local freshwater mollusk shells, although their quantity and variety significantly reduced compared to the Mid Neolithic [16,71].

Dry agriculture, which had become increasingly difficult in the plain, may still have been practiced to some degree in the transitional zone [59,148,149], however, insufficient analyses have been undertaken to date in this section of the Guanzhong region. This lacuna could also be symptomatic of a relative decline of agriculture in the region in favor of other activities. Deterioration in climatic conditions would have led to cultivation being less productive [64], however, there is no notable change in demography [149]. In order to support the community, subsistence strategies would have shifted toward (or have been heavily supplemented by) herding of caprines and cattle. If agriculture was not fully productive, it would have provided a limited surplus to feed livestock. In this regard, bovid husbandry would be more efficient than raising pigs, since bovids do not compete with humans for food. They would also be used for secondary products such as milk, hides, and wool [7].

The climatic deterioration during the Longshan period affected the three zones outlined in this study to varying degrees, with the transition in climate being most intense in the plateau [64]. This is reflected in the faunal assemblages from the four relevant sites, which display the use of a diversified set of taxa, with a prevalence of caprines, and a fair proportion of other domestic and wild species. The profile is consistent with an incipient mixed agro-pastorist economy.

Wild fauna still played a significant role in the regional economy, but the deer was little represented. A large majority of deer were sika. According to C13 isotopic research for Shimao and Gaojiawan, they survived on a relatively rich C4 diet, suggesting that they interacted with humans, perhaps by living close to the sites [150]. This, in turn, may indicate that the ecological deterioration, brought about by the increasingly dry and cold climate (and farming-related anthropogenic activities), may have led deer to establish some form of commensal relationship with humans for survival. The high proportion of wild horses (*Equus ovodovi*) in Miaoliang (70% NISP) suggests that hunting was still a significant practice, either to acquire meat, material for making tools, or social status, as discussed above.

Agriculture was practiced [140,151] along with pig husbandry, which was still an important activity for meat provision. It was, however, supplemented with bovid herding, which appears to have become the staple form of subsistence. Research on paleoclimate by [64,152] has shown that climatic deterioration towards aridity in the Loess Plateau caused many agricultural economies to shift toward agro-pastoralism and mobile pastoralism from the beginning of the second millennium BCE. The diversified use of faunal resources in the plateau during the Late Neolithic can represent the early stages of this process. While bovids are fairly tolerant of arid conditions, pigs require a plentiful and dependable source of water [153]. The increase in caprines, in particular, may also be related to the southern migration of pastoralist communities from Inner Mongolia, which has been mentioned in written sources [60] and supported archaeologically [113].

The diversification of the regional economy should also be considered from the perspective of an incipient regional social complexity during the Longshan period [144]. In Shimao, a large walled center, which survived intensive millet agriculture [140], the proportion of pigs is larger compared to other sites. By contrast, in Muzhuzhuliang, a great deal of the local economy was based on herding, with sheep being exploited for their secondary products—milk, skin, and wool—in addition to their meat [154]. Analyses in Miaoliang suggest that foxtail millet farming production was likely not sufficient to feed the community, which in turn would have to rely on sheep and cattle herding and horse hunting [151]. Notably, the horse species hunted by the resident of the Miaoliang site, *Equus ovodovi*, had long been believed to be extinct in the Pleistocene. Only recent genetic evidence on various groups of remains, including those from Mioaliang, has indicated that it survived until ~3500 BP [155].

4.4. Bronze Age (Shang, Proto Zhou)

Evidence for the Bronze Age period comes from the plain (1 site) and the transitional zone (5 sites). Coincidentally, these two zones cover what is historically known as the Bin region, which is presumed to be the ancestral land of the Zhou [156,157]. It has recently been intensively investigated by Northwest University and the Shaanxi Institute of Cultural Relics and Archaeology in the context of the project "The Archaeological Investigation of the Ancient Bin Area", with the main goal of understanding the dynamics of the rise of the Zhou dynasty, culminating in the defeat of the Shang. This can explain to a certain extent, the abundance of sites in the plain and the transitional zones, in comparison with the relative paucity of known sites in the plateau zone. Other than Fengxi, zooarchaeological reports used in this study were conducted under the umbrella of this project.

The Bronze Age in Central Shaanxi is characterized by further climatic deterioration, which promoted a further increase in bovid herding. This came to increasingly supplement pig husbandry, although to varying degrees in different zones.

The faunal assemblage from the site of Fengxi, located in the plain of the Wei River Valley, includes a relatively large proportion of pigs [76]. This, along with the discovery of significant quantities of millet [158], suggests that millet-based agriculture and pig husbandry remained the main subsistence pattern on the plain. A significant proportion of cattle and a small number of caprines indicate the existence of supplementary herding activity. Mortality profiles for these taxa suggest that sheep were killed in their early life, thus likely used for meat, while cattle usually survived into adulthood, which would have allowed for their exploitation for milk and, possibly, strength for agricultural purposes.

The faunal assemblages from the transitional zone are dominated by domestic species, wild animals being significantly scarcer. This suggests an economy based on animal husbandry, with a small contribution from other activities. Although the Bronze Age witnessed a general decline in hunting, this may have been practiced to different degrees: while in Zaoshuguonao deer finds were more numerous and hunting tools relatively common, paucity of bones and antlers and the dearth of arrowheads from Xitou and Sunjia indicates that hunting did not form a significant part of the local subsistence [75,159,160]. Ref. [161] argued that, from the Late Neolithic to the Bronze Age, the Guanzhong region underwent a shift from a meat-oriented toward an antler-oriented hunting practice. MNE (Minimum Number of Elements) analysis results for the assemblages in Zaoshuguonao, Sunjia, and Xitou support this conclusion and more specifically indicate that deer antlers and bones were largely exploited for tool-making [160,161]. Archaeological and textual evidence both indicate that during the Bronze Age, the importance of hunting became increasingly social rather than necessary for survival [74,143].

The exploitation of aquatic resources was also nominal. In spite of the increasing regional aridity, the paucity of mollusks and fish in these sites is unexpected, given the large local water system. While this lack in our assemblages is likely due to poor sieving and taphonomic agents, it can also reflect a decline in fishing practices [16,74].

Bovids were prevalent in the transitional zone during this period. The growing importance of bovines and caprines in the region, as discussed above, could be due to the climate becoming colder and dryer during this period [64,152]. Under such climatic conditions, agricultural productivity would have declined, prompting a wider and more diversified use of the landscape, including expansion into marginal lands, in order to permit bovid herding. Research in Central Asia and Northern China has demonstrated that in the Bronze Age and in the Iron Age a flexible agro-pastoralist system was successfully established in arid and semi-arid regions to cope with this harsher environment [162–164].

Increasing caprine and cattle herding may have occurred under the influence of neighboring pastoral communities in the north, which had started their southward migration during the Late Neolithic. At the end of the second millennium BCE, small and large-scale movements of mobile and semi-mobile pastoralists dramatically increased and created a solid network of interaction across Central Asia, Northwest China, and Mongolia [162,165]. Interactions between residents of Central Shaanxi and northern agro-pastoralists and pastoralist societies are documented by archaeological evidence of steppe-type of artifacts in the former region [157,166] and are further suggested by written sources [156].

Mortality profiles available for four of the sites indicate that the three main domestic species (pigs, cattle, and caprines) were exploited for meat and secondary products to different extents at different sites [75,160,167]. This can be explained in terms of various degrees of reliance on agriculture and discussed from the perspective of emerging social complexity. Few archaeobotanical studies have been undertaken in the transitional zone [168], however different caprines/cattle-pigs ratios can be indicative of more intensive agricultural practices in some sites than in others [31,75]. Zooarchaeological research conducted in Zaoshuguonao and Zoalinhetan has revealed profiles consistent with the former being a larger agricultural center and the second being a smaller settlement [75,169]. Also, our zooarchaeological analysis of Xitou and Sunjia faunal assemblages has revealed a clear size difference in pigs and, especially, in cattle between the two sites. This may reflect diversity in economic structures, with a larger agricultural center requiring sizable animals (i.e., Xitou), and a smaller settlement (i.e., Sunjia), where smaller less-demanding specimens, would be preferred for their secondary products and light work [160].

Evidence of finished and unfished worked bones from all sites indicates that some taxa were exploited for the local production of tools and ritual objects. Not only deer, but also cattle bones, were used to make artifacts. In particular, by the Bronze Age, cattle had become the most important taxa for oracle bone production [142]. Indeed, cattle scapulae were fairly commonly recovered in all our sites, although at Nianzipo, specimens made of horse and other animals' scapulae were also found [167]. This further suggests a certain degree of regional variability in animal exploitation for ritual purposes, which can be related to a greater development of social complexity in the local Bronze Age [75,160,161].

5. Conclusions

This study has found that the Guanzhong region underwent a shift in animal exploitation, from wild species in the Early Neolithic to pig husbandry in the Mid Neolithic, when the area was experiencing the Climatic Optimum and a consequent substantial agricultural development. Climate deterioration from the Late Neolithic meant that localized communities had to adapt to new, less favorable conditions for cultivation. Generally, this appears to have been achieved through the resumption of hunting practices and, especially, the adoption of bovine and caprine herding.

Considering regional ecological variability, we found that even within the limited Guanzhong region (<10,000 km^2) animal utilization varied considerably between three different zones, the Wei River plain, the transitional region, and the Loess Plateau, during the period under analysis. Against expectations, it was found that there was not a gradual transition in praxis between the Wei River valley and the loess plateau with the hilly transition zone having its own distinct animal exploitation pattern.

In the Mid Neolithic, the economy of the plain was dominated by dry agriculture and pig husbandry. Agriculture and husbandry remained central economic activities even during the climatic deterioration from the Late Neolithic onward: the former, however, would have switched into mixed dry and rice farming, and the latter was integrated with some bovid husbandry and deer hunting. Herded animals were used for their secondary products and aid in agriculture, in addition to their meat. Deer hunting would have provided supplementary meat and important material for tool-making. It also increasingly became a significant social activity, related to emergent social complexity in the Longshan Culture. In the Bronze Age, millet-based agriculture and pig husbandry were still the main subsistence strategies on the plain.

The exploitation of wild species underpinned the socio-economic foundation of the communities of the transitional zone until the Bronze Age. Throughout all the periods under study, deer hunting was particularly important, either for food, tool-making, or practiced for socio-ritual purposes. Pigs appear in significant numbers in the transitional zone, only in the Mid Neolithic, when an intensive agricultural system was developing in the whole Guanzhong region. Climatic deterioration following the Climatic Optimum prompted the need to diversify animal exploitation. In addition to hunted deer, herded bovids became increasingly important, for meat and their secondary products, including as draught animals. Diversification in animals' exploitation could also be favored by incipient social complexity and contacts with mobile and semi-mobile pastoralists from present-day North Shaanxi and Inner Mongolia.

The plateau presented a more complex scenario, partially because of the scarcity of zooarchaeological data, compared to other zones. Pig husbandry and dry-agriculture were practiced in the Mid Neolithic, supplemented by small game rodents, which were either orbiting around the site or were kept captives by the communities. The Late Neolithic witnessed an increase in caprines herding, which was integrated into the local subsistence strategies, perhaps as a consequence of the interactions with pastoral communities in the North. We did not have data for the Bronze Age, however, information collected by isotopic studies suggests that dry-agriculture and pig husbandry was practiced in the plateau during this period [170].

While this research is based on a limited number of sites, in their regional context, the results show the existence of micro-transitions in animal exploitation patterns and a variety of human landscape exploitation strategies on a smaller scale. Spatio-temporal differences in animal exploitation were caused by changes in both the local microclimates and the form of landscape in which the communities were living. In each case, the animals represent efficient exploitation of the immediate environment. These environmental factors were also augmented by internal social developments and interactions with neighboring communities. Further, more extensive and interdisciplinary research in North China would allow for a better understanding of different local zooarchaeological landscapes and, thus, effectively inform research on long-term, large-scale phenomena, such as pastoralism and ecological and climate change.

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Appendix A. Taxonomic Abundance by %NISP for Each of the Sites Considered in This Study

ID	Age	Site	Zone	NISP	% Deer	% Pig	% Sheep/Goat	% Cattle	% Others	Source
1	Early Neolithic	Guantaoyuan	Transitional	405	63.5	4.4	12.1	3.2	16.8	[84,97,171]
2	Early Neolithic	Dadiwan I	Transitional	701	64.3	22.3	0	0.3	13.1	[65]
3	Mid Neolithic	Dadiwan II	Transitional	3505	69.1	25.7	0	1.2	4	[65]
4	Mid Neolithic	Jiangzhai	Plain	1778	63.9	29.3	0	4	2.8	[120]
5	Mid Neolithic	Wayaogou	Transitional	6022	57.1	38.8	0.3	0.5	3.8	[131]
6	Mid Neolithic	Lingkou	Plain	81	30.9	58	6.2	0	4.9	[110]
7	Mid Neolithic	Dadiwan III	Transitional	2533	62.4	34	0	1.9	1.7	[65]
8	Mid Neolithic	Yangguanzhai	Plain	375	3.9	77.3	0	1.7	17.1	[109]
9	Mid Neolithic	Xinglefang	Plain	318	2.2	44.7	0.3	0	52.8 [1]	[108]
10	Mid Neolithic	Quanhucun	Plain	2646	15.1	76	4.1	3.1	1.7	[112]
11	Mid Neolithic	Gongjiawan	Transitional	51	43.1	19.6	0	0	37.3	[148]
12	Mid Neolithic	Dagujie	Plateau	138	15.9	7.3	2.9	0	73.9 [2]	[172]
13	Mid Neolithic	Yangjiesha	Plateau	493	0	15	0.4	0	84.6 [3]	[173]
14	Mid Neolithic	Wuzhuangguoluo	Transitional	NR	0	31	1	0	68	[174]
15	Mid Neolithic	Dadiwan IV	Transitional	3625	41.2	55.1	0	1.9	1.8	[65]
16	Late Neolithic	Kangjia	Plain	320	35.6	15	11.9	15.9	21.6	[69]
17	Late Neolithic	Miaoliang	Plateau	231	6.9	2.6	12.6	10.8	67.1 [4]	[175]
18	Late Neolithic	Gongjiawan	Transitional	27	48.1	11.1	0	11.1	29.7	[71]
19	Late Neolithic	Huoshiliang	Plateau	1111	2.5	12	63	19.5	3	[176]
20	Late Neolithic	Shimao	Plateau	1572	0.1	30.5	42.6	22.7	4.1	[145]
21	Late Neolithic	Muzhuzhuliang	Plateau	2810	NR	17.3	57.1	16.9	8.7	[154]
22	Bronze Age	Sunjia	Transitional	398	10	15.3	29.5	26.6	18.6	[160]
23	Bronze Age	Xitou	Transitional	247	5.2	18.2	20.3	36.8	19.5	[160]
24	Bronze Age	Zaoshuguonao	Transitional	8555	13.8	24.1	22.7	28.7	10.7	[75]
25	Bronze Age	Zaolinhetan	Transitional	1318	3.4	19.5	25	24.3	27.8	[75]
26	Bronze Age	Nianzipo	Transitional	9086	2.6	35.7	0.9	53.2	7.6	[167]
27	Bronze Age	Fengxi	Plain	199	14.6	41.2	8.1	27.5	8.6	[76]

[1] 49% shellfish, [2] 55.7% hare, [3] 67% hare, [4] 67% wild horse.

References

1. Charles, M.; Halstead, P. Biological resources exploitation: Problems of theory and method. In *Handbook of Archaeological Science*; Brothwell, D.R., Pollard, A.M., Eds.; Wiley: Chichester, UK, 2000; pp. 365–378.
2. Yuan, J. *Zhongguo Dongwu Kaoguxue* 中国动物考古学 *(Chinese Zooarchaeology)*; Wenwu Chubanshe: Beijing, China, 2015.
3. Huang, Y. Dongwu guge shuliang fenxi he jiachu xunhua fazhan chu shen 动物骨骼数量分析和家畜驯化发展初深 (Quantitative analysis of animal bones and the initial development of livestock domestication). In *Dongwu Kaogu (Di 1 ji)* 动物考古(第1辑); Henan Sheng Wenwu Kaogu Yanjiusuo 河南省文物考古研究所, Ed.; Wenwu Chubanshe: Beijing, China, 2010; pp. 2–32.
4. Yuan, J. Lun Zhongguo xin shiqi shidai jumin huoqu roushi ziyuan de fangshi 论中国新石器时代居民获取肉食资源的方式 (Discussing the ways Chinese Neolithic people acquired meat). *Kaogu Xuebao* **1999**, *1*, 1–22.
5. Flad, R.; Yuan, J.; Li, S. Zooarchaeological evidence for animal domestication in Northwest China. In *Late Quaternary Climate Change and Human Adaptation in Arid China*; Madsen, D.B., Chen, F., Gao, X., Eds.; Elsevier: Amsterdam, The Netherlands, 2007; pp. 167–203. [CrossRef]

6. Yuan, J.; Huang, Y.; Yang, M.; Lu, P.; Tao, Y.; Yang, S. Gongyuan qian 2500 nian-gangyuan qian 1500 nian Zhongyuán diqu dongwu kaoguxue yanjiu 公元前2500年/公元前1500年中原地区动物考古学研究 (Zooarchaeological research in the Central Plain from 2500 BCE to 1500 BCE). In *Keji Kaogu (Di 2 ji)* 科技考古 (第2辑); Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo Kaogu Keji Zhongxin 中国社会科学院考古研究所考古科技中心, Ed.; Kexue Chubanshe: Beijing, China, 2007; pp. 12–34.
7. Brunson, K.; He, N.; Dai, X. Sheep, cattle, and specialization: New zooarchaeological perspectives on the Taosi Longshan. *Int. J. Osteoarchaeol.* **2016**, *26*, 460–475. [CrossRef]
8. Li, Z.; Brunson, K.; Dai, L. Zhongyuan diqu xin shiqi shidai dao qingtongqi shidai zaoqi yangmao kaifa de dongwu kaoguxue yanjiu 中原地区新石器时代到青铜器时代早期羊毛开发的动物考古学研究 (Zooarchaeological Research on Wool Explotation Development from the Neolithic to the Early Bronze Age in the Central Plain). *Di Siji Yanjiu* **2014**, *1*, 149–157.
9. Li, Z.; Campbell, R.; Brunson, K.; Yang, J.; Tao, Y. The exploitation of domestic animal products from the Late Neolithic Age to the Early Bronze Age in the heartland of Ancient China. In *Animal Secondary Products: Domestic Animal Exploitation in Prehistoric Europe, the Near East and the Far East*; Greenfield, H.J., Ed.; Oxbow Books: Oxford, UK, 2014; pp. 56–79.
10. Campbell, R.; Zhipeng, L.; Yuling, H.; Yuan, J. Consumption, exchange and production at the Great Settlement Shang: Bone-working at Tiesanlu, Anyang. *Antiquity* **2011**, *85*, 1279–1297. [CrossRef]
11. Hou, Y.; Campbell, R.; Li, Z.; Zhang, Y.; Li, S.; He, Y. The Guandimiao bone assemblage (and what it says about the Shang economy). *Asian Perspect.* **2018**, *57*, 281–310. [CrossRef]
12. Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo Anyang Gongzuo Dui 中国社会科学院考古研究所安阳工作队. Henan Anyang shi Tiesanlu Yinxu wenhua shiqi zhi gu zuofang yizhi 河南安阳市铁三路殷墟文化时期制骨作坊遗址 (Bone-working workshop of the Yinxu cultural period, in Tiesanlu, Anyang, Henan). *Kaogu* **2015**, *8*, 37–62.
13. Elvin, M. *The Retreat of the Elephants: An Environmental History of China*; Yale University Press: New Haven, CT, USA, 2004.
14. Tong, H. Occurrences of warm-adapted mammals in north China over the Quaternary Period and their paleo- environmental significance. *Sci. China Ser. D Earth Sci.* **2007**, *50*, 1327–1340. [CrossRef]
15. Lan, W.; Zhang, J.; Weng, Y.; Fan, W. Fu tu jisheng chong kaoguxue fangfa de tansuo yu shijian 腹土寄生虫考古学方法的探索与实践 (Exploration and practice of archaeolological methods to study parasites in soils). *Kaogu* **2011**, *11*, 87–93.
16. Li, F.; Wu, N.; Lu, H.; Zhang, J.; Wang, W.; Ma, M.; Zhang, X.; Yang, X. Mid-Neolithic exploitation of mollusks in the Guanzhong Basin of Northwestern China: Preliminary results. *PLoS ONE* **2013**, *8*, e58999. [CrossRef]
17. You, Y.; Chen, W. The uses of domesticated animals at the Early Bronze Age City of Wangjinglou, China. *Int. J. Osteoarchaeol.* **2021**, *31*, 789–800. [CrossRef]
18. Wang, C.; Lu, H.; Gu, W.; Zuo, X.; Zhang, J.; Liu, Y.; Hu, Y. Temporal changes of mixed millet and rice agriculture in Neolithic-Bronze Age Central Plain, China: Archaeobotanical evidence from the Zhuzhai site. *Holocene* **2017**, *28*, 738–754. [CrossRef]
19. Zhang, J.; Lu, H.; Gu, W.; Wu, N.; Zhou, K.; Hu, Y.; Xi, Y.; Wang, C. Early Mixed Farming of Millet and Rice 7800 Years Ago in the Middle Yellow River Region, China. *PLoS ONE* **2012**, *7*, e52146. [CrossRef] [PubMed]
20. Li, K.; Gao, W.; Wu, L.; Hu, H.; Gong, P.; Li, S.; Jin, R.; Si, Y. Spatial expansion of human settlement during the Longshan Period (~4.5–~3.9 ka BP) and its hydroclimatic contexts in the Lower Yellow River floodplain, Eastern China. *Land* **2021**, *10*, 712. [CrossRef]
21. Ma, X. Henan Lingbao Xipo yizhi dongwu qun ji xiangguan wenti 河南灵宝西坡遗址动物群及相关问题 (Fauna at Xipo site in Lingbao, Henan, and relevant issues). *Caoyuan Wenwu* **2007**, *4*, 48–61.
22. Zhang, Q.; Hou, Y.; Li, X.; Styring, A.; Lee-Thorp, J. Stable isotopes reveal intensive pig husbandry practices in the middle Yellow River region by the Yangshao period (7000–5000 BP). *PLoS ONE* **2021**, *16*, e0257524. [CrossRef]
23. von Falkenhausen, L. On the historiographical orientation of Chinese archaeology. *Antiquity* **1993**, *67*, 839–849. [CrossRef]
24. Liao, Y.; Lu, P.; Mo, D.; Wang, H.; Storozum, M.J.; Chen, P.; Xu, J. Landforms influence the development of ancient agriculture in the Songshan area, central China. *Quat. Int.* **2019**, *521*, 85–89. [CrossRef]
25. Jia, X.; Li, H.; Lee, H.F.; Liu, Z.; Lu, Y.; Hu, Z.; Sun, X.; Zhao, Z. Agricultural adaptations to the topography and climate changes in Central China during the mid- to late-Holocene. *Holocene* **2021**, *31*, 1705–1715. [CrossRef]
26. Lam, Y.H.; Brunson, K.; Meadow, R.; Jing, Y. Integrating taphonomy into the practice of zooarchaeology in China. *Quat. Int.* **2010**, *211*, 86–90. [CrossRef]
27. Mainland, I. The uses of archaeological faunal remains in Landscape Archaeology. In *Handbook of Landscape Archaeology*; David, B., Thomas, J., Eds.; Routledge: London, UK; New York, NY, USA, 2008; pp. 544–550.
28. Zohary, E.T.; Tchernov, E.; Horwitz, L.K. The role of unconscious selection in the domestication of sheep and goats. *J. Zool.* **1998**, *245*, 129–135. [CrossRef]
29. Crabtree, T.J. Zooarchaeology in Oceania. *Archaeol. Ocean.* **2016**, *51*, 1–6. [CrossRef]
30. Sabatini, S.; Bergerbrant, S.; Brandt, L.Ø.; Margaryan, A.; Allentoft, M.E. Approaching sheep herds origins and the emergence of the wool economy in continental Europe during the Bronze Age. *Archaeol. Anthropol. Sci.* **2019**, *11*, 4909–4925. [CrossRef]
31. Miller, N. Farming and herding along the Euphrates: Environmental constraint and cultural choice (fourth to second millennia B.C.). *MASCA Res. Pap. Sci. Archaeol.* **1997**, *14*, 123–132.
32. Marshall, F.; Capriles, J.M. Animal Domestication and Pastoralism: Socio-Environmental Contexts. In *Encyclopedia of Global Archaeology*; Smith, C., Ed.; Springer: New York, NY, USA; Heidelberg, Germany; Dordrecht, The Netherlands; London, UK, 2014; pp. 249–257.

33. Arnold, E.R.; Greenfield, H. An archaeological perspective on the origin of vertical transhumant pastoralism and the colonization of marginal habitats in temperate south-eastern Europe. In *Colonization, Migration and Marginal Areas: A Zooarchaeological Approach*; Mondini, M., Munoz, S., Winkler, S., Eds.; Oxbow Books: Oxford, UK, 2004; pp. 296–317.
34. Robinson, J. Ecological niche define the limits of pig agroecology: A comparative review of evidence from early centres of sedentary agriculture. *Agroecol. Sustain. Food Syst.* **2019**, *43*, 704–717. [CrossRef]
35. Zhongguo Shehui Xueyuan Kaogu Yanjiusuo 中国社会科学院考古研究所. *Zhongguo Kaoguxue Zhong Tan Shisi Niandai Shujuji* 中国考古学中碳十四年代数据及 *(C14 Data in Chinese Archaeology)*; Wenwu Chubanshe: Beijing, China, 1991.
36. Stuart, A.J. *Pleistocene Vertebrates in the British Isles*; Longman: London, UK, 1982.
37. Yalden, D.W. *The History of British Mammals (Poyser Natural History S.)*; T. and A. D. Poyser Ltd.: London, UK, 1999.
38. Lander, B. Birds and beasts were many: The ecology and climate of the Guanzhong Basin in the Pre-Imperial Period. *Early China* **2020**, *43*, 207–245. [CrossRef]
39. Li, X. *Shui Jing Zhu Xiao Jian Tu Shi. Weishui Liuyu Zhu Pian* 水经注校笺图释●渭水流域诸篇 *(Notes on the Jing River System: Various Articles Abouth the Wei River Basin)*; Fudan Daxue Chubanshe: Shanghai, China, 2017.
40. Shi, N. *Zhongguo Lishi Dili Gangyao* 中国历史地理纲要 *(An Outline of Chinese Historical Geography)*; Shanxi Renmin Chubanshe: Taiyuan, China, 1991.
41. Nylan, M. Supplying the Capital with water and food. In *Chang'an 26 BCE: An Augustan Age in China*; Nylan, M., Vankeerberghen, G., Eds.; University of Washington Press: Seattle, WA, USA, 2015; pp. 99–130.
42. Wang, L.; Cui, Y. The Spatiotemporal pattern of cultural evolution response to agricultural development and climate change from Yangshao Culture to Bronze Age in the Yellow River Basin and surrounding regions, North China. *Front. Earth Sci.* **2021**, *9*, 657179. [CrossRef]
43. Lander, B. Environmental Change and the Rise of the Qin Empire: A Political Ecology of Ancient North China. Ph.D. Thesis, Columbia University, New York, NY, USA, 2015.
44. Sang, G.; Chen, X. Ba he zhongxiayou hedao lishi bianqian jiqi huanjing yingxiang 灞河中下游河道历史变迁及其环境影响 (Historical changes in the course of the Ba River, at its middle and lower reaches, and its environmental impact). *Zhongguo Lishi Dili Luncong* **2007**, *2*, 24–29.
45. Wang, Z.; Tang, Z. *Atlas of Woody Plants in China: Distribution and Climate*; Springer: Heidelberg, Germany, 2011.
46. Van de Weghe, N.; Docter, R.; De Maeyer, P.; Bechtold, B.; Ryckbosch, K. The triangular model as an instrument for visualising and analysing residuality. *J. Archaeol. Sci.* **2007**, *34*, 649–655. [CrossRef]
47. Grayson, D.K. On the quantification of vertebrate archaeofaunas. In *Advances in Archaeological Method and Theory*; Schiffer, M.B., Ed.; Academic Press: New York, NY, USA, 1979; pp. 199–237.
48. Gilbert, A.S.; Singer, B.; Perkins, D. Quantification experiments in computer simulated faunal collections. *Ossa* **1982**, *8*, 79–94.
49. O'Connor, T.C. *The Archaeology of Animal Bones*; Sutton Publishing: Stroud, UK, 2000.
50. Lyman, R.L. *Vertebrate Taphonomy*; Cambridge University Press: Cambridge, UK, 1994.
51. Watson, J.P.N. The estimation of the relative frequencies of mammalian species: Khirokitia 1972. *J. Archaeol. Sci.* **1979**, *6*, 127–137. [CrossRef]
52. Lin, M. A statistical view for Chinese zooarchaeology: From the Neolithic to Pre-Han periods. *Archaeol. Anthropol. Sci.* **2016**, *8*, 89–95. [CrossRef]
53. Underhill, A.P. Current Issues in Chinese Neolithic Archaeology. *J. World Prehistory* **1997**, *11*, 103–160. [CrossRef]
54. Buitenhuis, H. A quantitative approach to species determination in Ovicapridae. In *Archaeology of the Near East II*; Buitenhuis, H., Uerpmann, H., Eds.; Backhuys: Leiden, The Netherlands, 1995; pp. 140–155.
55. Salvagno, L.; Albarella, U. A morphometric system to distinguish sheep and goat postcranial bones. *PLoS ONE* **2017**, *12*, e0178543. [CrossRef] [PubMed]
56. Zeder, M.A.; Lapham, H. Assessing the reliability of criteria used to identify postcranial bones in sheep, *Ovis*, and goats, Capra. *J. Archaeol. Sci.* **2010**, *37*, 2887–2905. [CrossRef]
57. Zeder, M.A.; Pilaar, S. Assessing the reliability of criteria used to identify mandibles and mandibular teeth in sheep, *Ovis*, and goats, Capra. *J. Archaeol. Sci.* **2010**, *37*, 225–242. [CrossRef]
58. Guojia Wenwu Ju 国家文物局. *Zhongguo Wenwu Dituji: Shaanxi Fence* 中国文物地图集:陕西分册 *(Atlas of Chinese Cultural Relics: Shaanxi Volume)*; Wenwu Chubanshe: Beijing, China, 1999.
59. Cui, J.; Sun, Z.; Burr, G.S.; Shao, J.; Chang, H. The great cultural divergence and environmental background of Northern Shaanxi and its adjacent regions during the late Neolithic. *Archaeol. Res. Asia* **2019**, *20*, 100164. [CrossRef]
60. Huang, C.; Zhao, S.; Pang, J.; Zhou, Q.; Qian, S.; Li, P.; Mao, L.; Ding, M. Climatic aridity and the relocations of the Zhou Culture in the Southern Loess Plateau of China. *Clim. Change* **2003**, *61*, 361–378. [CrossRef]
61. Li, B.; Pan, R.; Oxnard, C.E. Extinction of snub-nosed monkeys in China during the past 400 years. *Int. J. Primatol.* **2002**, *23*, 1227–1244. [CrossRef]
62. Lander, B.; Brunson, K. Wild mammals of ancient north China. *J. Chin. Hist.* **2018**, *2*, 291–312. [CrossRef]
63. Huang, C.; Zhou, J.; Pang, J.; Han, Y.; Hou, C. A regional aridity phase and its possible cultural impact during the Holocene Megathermal in the Guanzhong Basin, China. *Holocene* **2000**, *10*, 135–143. [CrossRef]
64. Huang, C.; Pang, J.; Zhou, Q.; Chen, S. Holocene pedogenic change and the emergence and decline of rain-fed cereal agriculture on the Chinese Loess Plateau. *Quat. Sci. Rev.* **2004**, *23*, 2525–2535. [CrossRef]

65. Qi, G.; Lin, Z.; An, J. Dadiwan Yizhi Dongwu Yicun Jianding Baogao 大地湾遗址动物遗存鉴定报告. In *Qin'an Dadiwan: Xinshiqi Shidai Yizh Fajue Baogao 秦安大地湾：新石器时代遗址发掘报告 (Qin'an Dadiwan: A Neolithic Site Excavation Report)*; Gansu Sheng Wenwu Kaogu Yanjiusuo, Ed.; Wenwu Chubanshe: Beijing, China, 2006; pp. 861–910.
66. Yuan, J.; Flad, R. Pig domestication in ancient China. *Antiquity* **2002**, *76*, 224–232.
67. Zeder, M.A. Pathways to animal domestication. In *Biodiversity in Agriculture: Domestication, Evolution, and Sustainability*; Gepts, P., Famula, T.R., Bettinger, R., Eds.; Cambridge University Press: Cambridge, MA, USA, 2012; pp. 227–259.
68. Rowley-Conwy, P.; Albarella, U.; Dobney, K. Wild. Distinguishing wild boar from domestic pigs in prehistory: A review of approaches and recent results. *J. World Prehistory* **2012**, *25*, 1–44. [CrossRef]
69. Liu, L.; Yan, Y.; Qin, X. Shaanxi Linyu Kangjia Longshan wenhua yizhi 1990 nian fajue dongwu yicun 陕西临渔康家龙山文化遗址 1990 年发掘动物遗存 (Animal remains excavated in 1990 at the Longshan cultural site of Kangjia, in Linyu, Shaanxi). *Huaxia Kaogu* **2001**, *1*, 3–24. [CrossRef]
70. Knight, B.; Milner, N.; O'Connor, T.; Elliott, B.; Robson, H.K.; Buckley, M.; Witkowski, P.; Charlton, S.; Craig, O.; Collins, M. Faunal remains: Results by species. In *Star Carr Volume 2: Studies in Technology, Subsistence and Environment*; Milner, N., Conneller, C., Taylor, B., Eds.; White Rose University Press: York, UK, 2018; pp. 195–254.
71. Hu, S. Shaanxi Danfeng Gongjiawan xin shiqi shidai dongwu guge fenxi 陕西丹凤巩家湾新石器时代动物骨骼分析 (Analysis of Neolithic animal bones in Gongjiawan, Danfeng, Shaanxi). *Kaogu Yu Wenwu* **2001**, *6*, 53–57.
72. Fu, Y. Shaanxi fufeng anban yizhi dongwu yicun de yanjiu 陕西扶风案板遗址动物遗存的研究. In *Fufeng Anban Yizhi* 扶风案板遗址 *(Remains at Anban, in Fufeng)*; Xibei Daxue Wenbo Xueyuan Kaogu Zhuanye 西北大学文博学院考古专业, Ed.; Kexue Chubanshe: Beijing, China, 2000; pp. 290–294.
73. Zhang, Y. Xunyi xiaweiluo yizhi dongwu yicun jianding baogao 旬邑下魏洛遗址动物遗存鉴定报告. (Report on the identification of animal remains at xiaweiluo site in xunyi). In *Xunyi Xiaweiluo Yizhi* 旬邑下魏洛遗址; Xibei Daxue Yichan Wenhua Xueyuan Shaanxi Kaogu Yanjiusuo 西北大学遗产文化学院 陕西考古研究所, Ed.; Kexue Chubanshe: Beijing, China, 2006; pp. 546–548.
74. Cheng, P.; Zhou, W.; Gong, W.; Zhu, Z.; Yang, Y.; Burr, G.S.; Du, H. Paleodietary analysis of humans in Guanzhong Basin, Shaanxi Province, since 8000 BP. *Radiocarbon* **2017**, *59*, 1435–1446. [CrossRef]
75. Li, Y.; Zhang, C.; Wang, Z.; Dou, H.; Liu, H.; Hou, F.; Ma, M.; Qian, Y.; Chen, H. Animal use in the late second millennium BCE in Northern China: Evidence from Zaoshugounao and Zaolinhetan in the Jing River valley. *Int. J. Osteoarchaeol.* **2020**, *30*, 318–329. [CrossRef]
76. Yuan, J. Fengxi chutu dongwu guge yanjiu baogao 沣西出土动物骨骼研究报告 (Report on the research on animal skeletal elements unearthed in Fengxi). *Kaogu Xuebao* **2000**, *2*, 246–256.
77. Zhang, W.; Lu, H.; Li, C.; Dodson, J.; Meng, X. Pollen preservation and its potential influence on paleoenvironmental reconstruction in Chinese loess deposits. *Rev. Paleobotany Palynol.* **2017**, *240*, 1–10. [CrossRef]
78. Liu, L. *The Chinese Neolithic: Trajectories to Early States*; Cambridge University Press: New York, NY, USA, 2004.
79. Liu, T.; Guo, Z.; Wu, N.; Lu, H. Prehistoric vegetation on the Loess Plateau: Steppe or forest? *J. Southeast Asian Earth Sci.* **1996**, *13*, 341–346.
80. Lu, H.; Liu, D.; Guo, Z. Natural vegetation of geological and historical periods in Loess Plateau. *Chin. Sci. Bull.* **2003**, *48*, 411–416. [CrossRef]
81. Shen, H.; Li, X.; Spengler, R.; Zhou, X.; Zhao, K. Forest cover and composition on the Loess Plateau during the Middle to Late-Holocene: Integrating wood charcoal analyses. *Holocene* **2021**, *31*, 38–49. [CrossRef]
82. Li, B.; Jia, Z.; Pan, R.; Ren, B. Changes in distribution of the snub-nosed monkey in China. In *Primates in Fragments*; Marsh, L.K., Ed.; Kluwer Academic/Plenum: New York, NY, USA; Boston, MA, USA; Dordrecht, The Netherlands; London, UK; Moscow, Russia, 2003; pp. 29–51.
83. Li, Y.; Huang, K.; Tang, S.; Feng, L.; Yang, J.; Li, Z.; Li, B. Genetic structure and evolutionary history of *Rhinopithecus roxellana* in Qinling Mountains, Central China. *Front. Genet.* **2021**, *11*, 611914. [CrossRef] [PubMed]
84. Hu, S. Shaanxi Baoji Guantaoyuan xin shiqi yizhi zhong shouci yu woguo beifang faxian jinsihou deng zhongyao dongwu yicun 陕西宝鸡关桃园新石器遗址中首次于我国北方发现金丝猴等重要动物遗存 (Important animal remains discovered for the first time in northern China, at the Guantaoyuan Neolithic site in Baoji, Shaanxi: The golden snub-nosed monkeys and other fauna). *Shoulei Xuebao* **2006**, *4*, 39–40.
85. Wang, H.; Wang, W.; Hu, S.; Lu, Y.; Ma, D. Weishui liuyu xin shiqi shidai jiazhu de xunhua yu siyang celüe 渭水流域新石器时代家猪的驯化与饲养策略 (Domestication and breeding strategies of domestic pigs in the Neolithic Age in the Wei River Basin). *Kaogu* **2013**, *9*, 87–98.
86. Mayer, J.J.; Novak, J.M.; Brisbin, I.L. Evaluation of molar size as a basis for distinguishing wild boar from domestic swine: Employing the present to decipher the past. In *Ancestors for the Pigs: Pigs in Prehistory*; Nelson, S.M., Ed.; MASCA: Philadelphia, PA, USA, 1998; pp. 39–53.
87. Yuan, J. Zhongguo xin shiqi shidai jiachu qiyuan de wenti 中国新石器时代家畜起源的问题 (The question of the origin of animal domestication in Neolithic China). *Kaogu* **2001**, *5*, 51–58.
88. Barton, L.; Newsome, S.D.; Chen, F.; Wang, H.; Guilderson, T.P.; Bettinger, R.L. Agricultural origins and the isotopic identity of domestication in Northern China. *Proc. Natl. Acad. Sci. USA* **2009**, *106*, 5523–5528. [CrossRef]
89. Wang, X.; Fuller, B.T.; Zhang, P.; Hu, S.; Hu, Y.; Shang, X. Millet manuring as a driving force for the Late Neolithic agricultural expansion of North China. *Sci. Rep.* **2018**, *8*, 5552. [CrossRef]

90. Price, M.; Hongo, H. The archaeology of pig domestication in Eurasia. *J. Archaeol. Res.* **2020**, *28*, 557–615. [CrossRef]
91. Zhang, H.; Paijmans, J.; Chang, F.; Wu, X.; Chen, G.; Lei, C.; Yang, X.; Wei, Z.; Bradley, D.G.; Orlando, L.; et al. Morphological and genetic evidence for early Holocene cattle management in Northeastern China. *Nat. Commun.* **2013**, *4*, 2755. [CrossRef]
92. Cai, D.; Sun, Y.; Tang, Z.; Hu, S.; Li, W.; Zhao, X.; Xiang, H.; Zhou, H. The origins of Chinese domestic cattle as revealed by Ancient DNA analysis. *J. Archaeol. Sci.* **2014**, *41*, 423–434. [CrossRef]
93. Chong, Y. *The Origin of Cattle in China from the Neolithic to the Early Bronze Age*; Bar International Series S2959: Oxford, UK, 2020.
94. Qi, G. Donghuishan mudi shougu jianding baogao 东灰山墓地兽骨坚定报告 (Report on animal bones found at the cemetery of Donghuishan). In *Minyue Donghuishan Kaogu- Siba Wenhua Mudi de Jieshi yu Yanjiu* 民乐东灰山考古- 四坝文化墓地的揭示与研究; Gansu Sheng Wenwu Kaogu Yanjiusuo 甘肃省文物考古研究所, Jilin Daxue Beifang Kaogu Yanjiushi 吉林大学北方考古研究室, Eds.; Kexue Chubanshe: Beijing, China, 1998; pp. 184–185.
95. Taylor, W.T.T.; Pruvost, M.; Posth, C.; Rendu, W.; Krajcarz, M.T.; Abdykanova, A.; Brancaleoni, G.; Spengler, R.; Hermes, T.; Schiavinato, S.; et al. Evidence for early dispersal of domestic sheep into Central Asia. *Nat. Hum. Behav.* **2021**, *5*, 1169–1179. [CrossRef]
96. Feng, Z.; An, C.; Tang, L.; Jull, T.A. Stratigraphic evidence of a Megahumid climate between 10,000 and 4000 years B.P. in the Western Part of the Chinese Loess Plateau. *Glob. Planet. Change* **2004**, *43*, 145–155. [CrossRef]
97. Hu, S.; Zhang, Y.; Zhang, T. Baoji Guantaoyuan yizhi dongwu yicun gu huanjing yiyi 宝鸡关桃园遗址动物遗存古环境意义 (The significance of the animal remains found at Guantaoyuan site in Baoji for palaeoevironmental studies). *Xibei Daxue Xuebao* **2007**, *37*, 115–118.
98. Bettinger, R.L.; Barton, L.; Richerson, P.J.; Boyd, R.; Hui, W.; Won, C. The Transition to agriculture in northwestern China. *Dev. Quat. Sci.* **2007**, *9*, 83–111. [CrossRef]
99. Lu, T. *The Transition from Foraging to Farming and the Origin of Agriculture in China*; John and Erica Hedges: Oxford, UK, 1999.
100. Xiang, H.; Gao, J.; Cai, D.; Luo, Y.; Yu, B.; Liu, L.; Liu, R.; Zhou, H.; Chen, X.; Dun, W.; et al. Origin and dispersal of early domestic pigs in northern China. *Sci. Rep.* **2017**, *7*, 5602. [CrossRef]
101. Xiang, H.; Gao, J.; Yu, B.; Zhou, H.; Cai, D.; Zhang, Y.; Chen, X.; Wang, X.; Hofreiter, M.; Zhao, X. Early Holocene chicken domestication in Northern China. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 17564–17569. [CrossRef]
102. Peters, J.; Lebrasseur, O.; Best, J.; Miller, H.; Fothergill, T.; Dobney, K.; Thomas, R.M.; Maltby, M.; Sykes, N.; Hanotte, O.; et al. Questioning new answers regarding Holocene chicken domestication in China. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, e2415. [CrossRef]
103. Huang, C.; Pang, J.; Chen, S.; Su, H.; Han, J.; Cao, Y.; Zhao, W.; Tan, Z. Charcoal records of fire history in the Holocene loess–soil sequences over the southern Loess Plateau of China. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2006**, *239*, 28–44. [CrossRef]
104. Zhang, J.; Lu, H.; Wu, N.; Li, F.; Yang, X.; Wang, W.; Ma, M.; Zhang, X. Phytolith evidence for rice cultivation and spread in Mid-Late Neolithic archaeological sites in central North China. *Boreas* **2010**, *39*, 592–602. [CrossRef]
105. Qiao, Y. Development of complex societies in the Yiluo region: A GIS based population and agricultural area analysis. *Indo-Pac. Prehistory Assoc. Bull.* **2007**, *27*, 61–75. [CrossRef]
106. Ma, X. *Emergent Social Complexity in the Yangshao Culture: Analyses of Settlement Patterns and Faunal Remains from Lingbao, Western Henan, China (c. 4900–3000 BC)*; Archeopress: Oxford, UK, 2005.
107. Liu, L.; Chen, X. *The Archaeology of China: From the Late Paleolithic to the Early Bronze Age*; Cambridge University Press: Cambridge, UK, 2012.
108. Hu, S.; Yang, Q.; Yang, M. Shaanxi Huayin Xinglefang yizhi dongwu yicun fenxi 陕西华阴兴乐坊遗址动物遗存分 (Animal remains at Xinglefang, in Huayin, Shaanxi). *Kaogu Yu Wenwu* **2011**, *6*, 117–125.
109. Hu, S.; Wang, W.; Guo, X.; Zhang, W.; Yang, M. Shaanxi Gaoling Yangguanzhai Huanhao Ximan zhi dongwu yicun fenxi 陕西高陵杨官寨环壕西门址动物遗存分析 (Analysis of faunal remains found at the west gate of Huanhao in Yangguanzhai, Gaoling, Shaanxi.). *Kaogu Yu Wenwu* **2011**, *6*, 97–107.
110. Zhang, Y.; Zhou, Q.; Yan, Y.; Yin, S. Shaanxi Lintong Lingkou cun wenhua yizhi jichui dongwu yihai 陕西临潼零口村文化遗址脊椎动物遗骸 (Vertebrate remains at the Lingkou cultural site in Lintong, Shaanxi Province.). In *Lintong Lingkou Cun* 临潼零口村; Sanqin Chubanshe: Xi'an, China, 2004; pp. 523–525.
111. Pechenkina, E.A.; Benfer, R.A., Jr.; Wang, Z. Diet and health changes at the end of the Chinese Neolithic: The Yangshao/Longshan transition in Shaanxi Province. *Am. J. Phys. Anthropol.* **2002**, *117*, 15–36. [CrossRef] [PubMed]
112. Hu, S. Hua xian Quanhucun yizhi chutu dongwu guge yicun yanjiu 华县泉护村遗址出土动物骨骼遗存研究 (Research on animal skeletal remains unearthed from the site in the Quanhu Village in Huaxian County). In *Hua Xian Quanhucun 1997 Nian Kaogu Fajue Baogao* 华县泉护村*1997*年考古发掘报告; Shaanxi Sheng Kaogu Yanjiuyuan 陕西省考古研究院, Ed.; Wenwu Chubanshe: Beijing, China, 2007.
113. Chen, L.; Xiong, J.; Jing, S.; Sun, Z. Shaanxi Shenmu Shimao chengzhi jisi keng chutu tougu yanjiu 陕西神木石峁城址祭祀坑出土头骨研究 (Research on the skulls unearthed from the sacrificial pit at Shimao City Site in Shenmu, Shaanxi Province). *Kaogu Yu Wenwu* **2016**, *4*, 134–142.
114. Wang, R. Fishing, Farming, and Animal Husbandry in the Early and Middle Neolithic of the Middle Yellow River Valley, China. Ph.D. Thesis, University of Illinois at Urbana-Champaign, Champaign, IL, USA, 2004.
115. Barton, L.; Bingham, B.; Sankaranarayanan, K.; Monroe, C.; Thomas, A.; Kemp, B.M. The earliest farmers of Northwest China exploited grain-fed pheasants not chickens. *Sci. Rep.* **2020**, *10*, 2556. [CrossRef]

116. Wa, Y.; Hein, A. A buried past: Five thousand years of (pre)history on the Jing-Wei floodplain. *Asian Archaeol.* **2020**, *4*, 1–15. [CrossRef]
117. Chang, K. *The Archaeology of Ancient China*, 4th ed.; Yale University Press: New Haven, CT, USA; London, UK, 1987.
118. Peterson, C.E.; Shelach, G. Jiangzhai: Social and economic organization of a Middle Neolithic Chinese village. *J. Anthropol. Archaeol.* **2012**, *31*, 265–301. [CrossRef]
119. Zhongguo Kexueyuan Kaogu Yanjiusuo 中国科学院考古研究所. *Xi'an Banpo* 西安半坡 *(Banpo in Xi'an)*; Wenwu Chubanshe: Beijing, China, 1963.
120. Xi'an Banpo Bowuguan 西安半坡博物; Shaanxi Sheng Kaogu Yanjiusuo 西省考古研究所; Lintong Xian Bowuguan 临潼县博物馆. *Jiangzhai: Xin Shiqi Shidai Yizhi Fajue Baogao* 姜寨:新石器时代遗址发掘报告 *(Jiangzhai: A Neolithic Site Excavation Report)*; Wenwu Chubanshe: Beijing, China, 1988.
121. Gu, H.; Huang, C.; Zhou, Y.; Pang, J.; Zha, X.; Zhang, Y. Guanzhong pendi Yangguanzhai yizhi Yanggaunzhai yizhi gu hongshui shijian shi guang ce nian 关中盆地杨官寨遗址古洪水事件释光测年 (OSL dating study on the palaeoflood events recorded in the Yangguanzhai Neolithic ruins in the Guanzhong Basin). *Dili Yanjiu* **2012**, *31*, 1837–1848.
122. Huang, C.; Pang, J.; Zha, X.; Zhou, Y.; Su, H.; Wan, H.; Ge, B. Sedimentary records of extraordinary floods at the ending of the mid-Holocene climatic optimum along the upper Weihe River, China. *Holocene* **2011**, *22*, 675–686. [CrossRef]
123. Shaanxi Sheng Kaogu Yanjiuyuan 陕西省考古研究院; Xibei Daxue Wenhua Yichan Xueyuan 西北大学文化遗产学院. Shaanxi Gaoling Yangguanzhai yizhi H85 fajue baogao 陕西高陵杨官寨遗址 H85发掘报告 (Excavation report of H85 at Yangguanzhai in Gaoling, Shaanxi). *Kaogu Yu Wenwu* **2018**, *6*, 3–19.
124. Tang, L.; Yang, L.; Ye, W.; Yin, Y.; Liu, X.; Zhao, Z.; Wang, W. Gudai zhiwu de yiyao gongneng chutan: Yi Shaanxi Gaoling Yangguanzhai yizhi H85 chutu zhiwu yicun wei li 古代植物的医药功能初探: 以陕西高陵杨官寨遗址H85出土植物遗存为例 (A preliminary study on the medical function of ancient plants: A case study of the remains of plants unearthed from Yangguanzhai site in Gaoling, Shaanxi Province, H85). *Di Siji Yanjiu* **2020**, *40*, 486–498.
125. Lee, G.; Crawford, G.; Liu, L. Plants and people from the early Neolithic to Shang periods in North China. *Proc. Natl. Acad. Sci. USA* **2007**, *104*, 1087–1092. [CrossRef] [PubMed]
126. He, K.; Lu, H.; Zhang, J.; Wang, C.; Huan, X. Prehistoric evolution of the dualistic structure mixed rice and millet farming in China. *Holocene* **2017**, *27*, 1885–1898. [CrossRef]
127. Guan, L.; Hu, Y.; Hu, S.; Sun, Z.; Qin, Y.; Wang, C. Shan bei Jingbian Wuzhuangguoluo dongwu gu de C he N wending tongweisu fenxi 陕北靖边五庄果裸动物骨的 C 和 N 稳定同位素分析 (C and N stable isotope analysis of animal bones from Wuzhuangguoluo, Jingbian, Northern Shaanxi). *Di Siji Yanjiu* **2008**, *28*, 1160–1165.
128. Chen, X.; Hu, S.; Hu, Y.; Wang, W.; Ma, Y.; Lu, P.; Wang, C. Raising practices of Neolithic livestock evidenced by stable isotope analysis in the Wei River Valley, North China. *Int. J. Osteoarchaeol.* **2014**, *26*, 42–52. [CrossRef]
129. Luo, Y. Guanzhong diqu shiqian dongwu kaoguxue yanjiu de ji ge wenti 关中地区史前动物考古学研究的几个问题 (Problems in prehistoric zooarchaeological research in the Guanzhong Area). *Kaogu Yu Wenwu* **2009**, *5*, 89–94.
130. Kent, S. Cross-cultural perceptions of farmers as hunters and the value of meat. In *Farmers as Hunters: The Implications of Sedentism*; Kent, S., Ed.; Cambridge University Press: Cambridge, UK, 1989; pp. 1–17.
131. Wang, H. Animal Subsistence of the Yangshao Period in the Wei River Valley: A Case-Study from the Site of Wayaogou in Shaanxi Province, China. Ph.D. Thesis, University College London, London, UK, 2011.
132. Shaanxi Sheng Kaogu Yanjiuyuan 陕西省考古研究院; Yulin Shi Wenwu Kaogu Kantan Gongzuodui 榆林市文物考古勘探工作队. Shaanxi Hengshan Yangjiesha yizhi fajue jianbao 陕西横山杨界沙遗址发掘简报 (Brief report on the excavation of Yangjiesha site in Hengshan, Shaanxi). *Kaogu Yu Wenwu* **2011**, *6*, 64–72.
133. Sheng, P.; Hu, Y.; Sun, Z.; Yang, L.; Hu, S.; Fuller, B.T.; Shang, X. Early commensal interaction between humans and hares in Neolithic northern China. *Antiquity* **2020**, *94*, 1–15. [CrossRef]
134. Xie, S.; Wang, Z.; Wang, H.; Chen, F.; An, C. Moci jian bingqi yilai huangtu gaoyuan de caoyuan zhibei jingguan laizi fenzi huashi de zhengju 末次间冰期以来黄土高原的草原植被景观来自分子化石的证据 (Molecule fossil evidence for paleovegetation changes in the Loess Plateau grassland since the last interglacial period). *Zhongguo Kexue D Ji Diqiu Kexue* **2002**, *32*, 28–35.
135. Sheng, P.; Shang, X.; Yang, L.; Zhang, P.; Hao, J.; Wang, W.; Wang, C. Shaanxi Hengshan Yangjiesha yizhi zhiwu yicun de chubu yanjiu 陕西横山杨界沙遗址植物遗存的初步研究 (Preliminary study on plant remains from Yangjiesha, in Hengshan, Shaanxi Province). *Kaogu Yu Wenwu* **2017**, *3*, 123–128.
136. Cai, Y.; Tan, L.; Cheng, H.; An, Z.; Edwards, R.L.; Kelly, M.J.; Kong, X.; Wang, X. The Variation of summer monsoon precipitation in Central China since the Last Deglaciation. *Earth Planet. Sci. Lett.* **2010**, *291*, 21–31. [CrossRef]
137. Zhou, A.; Sun, H.; Chen, F.; Zhao, Y.; An, C.; Dong, G.; Wang, Z.; Chen, J. High-resolution climate change in Mid-late Holocene on Tianchi lake, Liupan Mountain in the Loess Plateau in Central China and its significance. *Chin. Sci. Bull.* **2010**, *55*, 2118–2121. [CrossRef]
138. Marcott, S.A.; Shakun, J.D.; Clark, P.U.; Mix, A.C. A Reconstruction of regional and global temperature for the past 11,300 Years. *Science* **2013**, *339*, 1198–1201. [CrossRef]
139. Pechenkina, E.A.; Ambrose, S.H.; Ma, X.; Benfer, R.A., Jr. Reconstructing northern Chinese Neolithic subsistence practices by isotopic analysis. *J. Archaeol. Sci.* **2005**, *32*, 1176–1189. [CrossRef]

140. Sheng, P.; Shang, X.; Zhou, X.; Storozum, M.; Yang, L.; Guo, X.; Zhang, P.; Sun, Z.; Hu, S.; Sun, Z.; et al. Feeding Shimao: Archaeobotanical and Isotopic Investigation into Early Urbanism (4200–3000 BP) on the Northern Loess Plateau, China. *Environ. Archaeol.* **2021**, 1–15. [CrossRef]
141. Qu, Y.; Hu, K.; Yang, M.; Cui, J. Xin shiqi shidai Guanzhong diqu renlei shengye moshi yanbian de shengwu kaoguxue zhangju 新石器时代关中地区人类生业模式演变的生物考古学证据 (Bioarchaeological evidence for the evolution of human occupational patterns in Guanzhong during the Neolithic period). *Renleixue Xuebao* **2018**, *37*, 96–109. [CrossRef]
142. Flad, R.K. Divination and power: A multiregional view of the development of oracle bone divination in early China. *Curr. Anthropol.* **2008**, *49*, 403–437. [CrossRef]
143. Fiskesjö, M. Rising from blood-stained fields: Royal hunting and state formation in Shang China. *Bull. Mus. Far East. Antiq.* **2001**, *73*, 49–191.
144. Liu, L. Mortuary ritual and social hierarchy in the Longshan Culture. *Early China* **1996**, *21*, 1–46. [CrossRef]
145. Hu, S.; Yang, M.; Sun, Z.; Shao, J. 2012–2013 niandu Shaanxi Shenmu Shimao yizhi chutu dongwu yicun yanjiu 2012–2013 年度陕西神木石峁遗址出土动物遗存研究 (Research on animal remains unearthed in 2012-2013 from Shimao, in Shenmu, Shaanxi). *Kaogu Yu Wenwu* **2016**, *4*, 109–121.
146. Dongwu Kaogu Keti Zu 动物考古课题组. Zhonghua wenming xingcheng shiqi de dongwu kaoguxue yanjiu 中华文明形成时期的动物考古学研 (Zooarchaeological research during the formation of the Chinese civilization). In *Keji Kaogu Di San Ji* 科技考古第三季; Zhongguo Shehui Kexueyuan Kaogu Yanjiusuo 中国社会科学院考古研究所, Ed.; Kexue Chubanshe: Beijing, China, 2011; pp. 80–99.
147. Dai, L.; Balasse, M.; Yuan, J.; Zhao, C.; Hu, Y.; Vigne, J.D. Cattle and sheep raising and millet growing in the Longshan age in central China: Stable isotope investigation at the Xinzhai site. *Quat. Int.* **2016**, *426*, 145–157. [CrossRef]
148. Lu, H.; Zhang, J. Guanzhong diqu de xin shiqi gu wenhua fazhan yu gu huanjing bianhua de guanxi 关中地区的新石器古文化发展与古环境变化的关系 (Relationship between the development of ancient Neolithic cultures and changes in the ancient environment in Guanzhong). *Di Siji Yanjiu* **2008**, *28*, 1050–1060.
149. Li, X.; Shang, X.; Dodson, J.; Zhou, X. Holocene agriculture in the Guanzhong Basin, NW China indicated by pollen and charcol evidence. *Holocene* **2009**, *19*, 1213–1220. [CrossRef]
150. Sun, N.; Hu, S.; Sun, Z. Shan bei diqu dongwu guge de zhifangsuan dan ti tan tongweisu fenxi 陕北地区动物骨骼的脂肪酸单体碳同位素分析 (Compound specific carbon isotope analysis of individual fatty acids from animal bones in northern Shaanxi, China). *Di Siji Yanjiu* **2022**, *42*, 69–79.
151. Fu, W.; Din, A.; Shao, J. Shan bei jingbian Miaoliang yizhi fu xuan jieguo yu fenxi 陕北靖边庙梁遗址浮选结果与分析 (Flotation analysis and results at Miaoliang, in Jingbian, northern Shaanxi). *Di Siji Yanjiu* **2022**, *42*, 119–128.
152. An, C.; Tang, L.; Barton, L.; Chen, C. Climate change and cultural response around 4000Cal yr B.P. in the western part of Chinese Loess Plateau. *Quat. Res.* **2005**, *63*, 347–352. [CrossRef]
153. Burrin, D.G. Nutrient requirements and metabolism. In *Biology of the Domestic Pig*; Pond, W.G., Mersmann, H.L., Eds.; Cornell University Press: Ithaca, NY, USA, 2001; pp. 309–389.
154. Yang, M.; Hu, S.; Guo, X.; Wang, W. Shaanxi sheng Shenmu xian Muzhuzhuliang yizhi yang gu yanjiu 陕西省神木县木柱柱梁遗址羊骨研究 (Study on sheep bones from Muzhuzhuliang, in Shenmu County, Shaanxi Province). *Nongye Kaogu* **2017**, *3*, 13–18.
155. Cai, D.; Zhu, S.; Gong, M.; Zhang, N.; Wen, J.; Liang, Q.; Sun, W.; Shao, X.; Guo, Y.; Cai, Y.; et al. Radiocarbon and genomic evidence for the survival of *Equus Sussemionus* until the late Holocene. *eLife* **2022**, *11*, e73346. [CrossRef]
156. Khayutina, M. Western Zhou cultural and historic setting. In *The Oxford Handbook of Early China*; Childs-Johnson, E., Ed.; Oxford University Press: Oxford, UK, 2020; pp. 365–400.
157. Zhang, T. *Guanzhong Shang dai Wenhua Yanjiu 关中商代文化研究 (Research on the Shang Culture in Guanzhong)*; Wenwu Chubanshe: Beijing, China, 2004.
158. Xu, L. 1997 nian Fengxi fajue baogao 1997年沣西发掘报告 (Report on the excavations at Fenxi in 1997). *Kaogu Xuebao* **2000**, *2*, 199–256.
159. Xibei Daxue Wenhua Yichan Xueyuan 西北大学文化遗产学院; Shaanxi Sheng Kaogu Yanjiuyuan 陕西省考古研究院; Xunyi Xian Wenwu Luyou Ju 旬邑县文物旅游局. Shaanxi sheng Xunyi xian Xitou yizhi diaocha jianbao 陕西省旬邑县西头遗址调查简报 (Brief report on the investigations at Xitou, in Xunyi County, Shaanxi Province). *Caoyuan Wenwu* **2020**, *1*, 16–27.
160. Festa, M.; Monteith, F.; Dou, H.; Orton, D.; Wang, Q.; Zong, T.; Zhang, C.; Liu, B.; Li, Y. Forthcoming. Faunal exploitation during the Shang-Zhou transition: Evidence from the Jing River Valley in Central Shaanxi. *Int. J. Osteoarchaeol* **2022**, *in press*.
161. Li, Y.; Zhang, C.; Chen, H.; Wang, Z.; Qian, Y. Sika deer in Bronze Age Guanzhong: Sustainable wildlife exploitation in ancient China? *Antiquity* **2021**, *95*, 940–954. [CrossRef]
162. Frachetti, M.D.; Smith, C.E.; Traub, C.M.; Williams, T. Nomadic ecology shaped the highland geography of Asia's Silk Roads. *Nature* **2017**, *543*, 193–198. [CrossRef] [PubMed]
163. Ullah, I.; Chang, C.; Tourtellotte, P. Water, dust, and agro-pastoralism: Modeling socio-ecological co-evolution of landscapes, farming, and human society in southeast Kazakhstan during the mid to late-Holocene. *J. Anthropol. Archaeol.* **2019**, *55*, 101067. [CrossRef]
164. Wang, L.; Wang, Y.; Li, W.; Spate, M.; Reheman, K.; Sun, Q.; Wang, B.; Xu, H.; Zhang, Z.; Zhang, G.; et al. Inner Asian agro-pastoralism as optimal adaptation strategy of Wupu inhabitants (3000–2400 cal BP) in Xinjiang, China. *Holocene* **2021**, *31*, 203–216. [CrossRef]

165. Høisæter, T.L. Polities and nomads: The emergence of the Silk Road exchange in the Tarim Basin region during late prehistory (2000–400 BCE). *Bull. SOAS* **2017**, *80*, 339–363. [CrossRef]
166. Wang, Z.; Chen, H. Shaanxi Chunhua Zaoshugounao yizhi 2008 niandu fajue de zhuyao shouhuo 陕西淳化枣树沟脑遗址2008年度发觉的主要收获 (Main achievements of the 2008 excavations at Zaoshugounao in Chunhua, Shaanxi). *Xibei Daxue Xuebao* **2010**, *40*, 32–36. [CrossRef]
167. Zhongguo Shehui Kexue Xueyuan Kaogu Yanjiusuo 中国社会科学学院考古研究所. *Nanlinzhou Nianzipo* 南邻州•碾子破 *(South of Lingzhou, Nianzipo);* Shijie Tushuguan Chubanshe: Beijing, China, 2007.
168. Chen, S.; Fu, W.; Liu, J.; Tang, L.; Zhai, L.; Zhao, Z.; Wen, R. Shaanxi Xunyi Zaolinhetan Yizhi Tanhua Zhiwu Yicun Yanjiu 陕西旬邑枣林河滩遗址炭化植物遗存研究 (Study on the remains of carbonized plants at Zaolinhetan, in Xunyi, Shaanxi). *Nanfang Wenwu* **2019**, *1*, 103–112.
169. Lan, D. Shaanxi Chunhua Zaoshugounao Yizhi Chutu Ren he Dongwu Guge de Wending Tongweisu Fenxi 陕西淳化枣树沟脑遗址出土人和动物骨骼的同位素分析 (Isotopic Analysis of Human and Animal Skeletal Elements Unearthed at Zaoshugounao, in Chunhua, Shaanxi Province). Master's Thesis, Northwest University, Xi'an, China, 2017.
170. Li, X.; Zhang, S.; Lu, M.; Qiu, M.; Wen, S.; Ma, M. Dietary shift and social hierarchy from the Proto-Shang to Zhou Dynasty in the Central Plains of China. *Environ. Res. Lett.* **2020**, *15*, 035002. [CrossRef]
171. Hu, S.; Li, B. Zhongguo Baoji Guantaoyuan xin shiqi yizhi zhong faxian de jinsihou tougu ji qi yiyi 中国宝鸡关桃园新石器遗址中发现的金丝猴头骨及其意义 (Discovery and significance of the golden snub-nosed monkey skulls from the Neolithic site of Guantaoyuan, Baoji, China). *Shoulei Xuebao* **2006**, *26*, 417–420.
172. Hu, S.; Yang, L.; Kang, N.; Yang, M.; Li, X. Shaanxi Hengshan xian Dagujie yizhi dongwu yicun fenxi 陕西横山县大古界遗址动物遗存分析 (Analysis of the faunal remains from Dagujie, in Hengshan County, Shaanxi Province). *Kaogu Yu Wenwu* **2012**, *4*, 106–112.
173. Hu, S.; Sun, Z.; Yang, L.; Kang, N.; Yang, M.; Li, X. Shan bei Hengshan Yangjiesha yizhi dongwu yicun yanjiu 陕北横山杨界沙遗址动物遗存研究 (Faunal remains from Yangjiesha, in Hengshan, Northern Shaanxi). *Renleixue Xuebao* **2013**, *32*, 77–92. [CrossRef]
174. Hu, S.; Sun, Z. Shan bei Jingbian Wuzhuangguoluo dongwu yicun ji gu huanjing fanxi (Analysis of faunal remains and paleoenvironment at Wuzhuangguoluo, in Jingbian, northern Shaanxi. 陕北靖边五庄果裸动物遗存及古环境分析. *Kaogu Yu Wenwu* **2005**, *6*, 72–84.
175. Hu, S.; Yang, T.; Yang, M.; Shao, J.; Di, N. Shan bei jing bian Miaoliang yizhi dongwu yicun yanjiu jian lun Zhongguo mu ye de xingcheng 陕北靖边庙梁遗址动物遗存研究兼论中国牧业的形成 (Research on faunal remains from Miaoliang, in Jingbian, northern Shaanxi, and the formation of animal husbandry in China). *Di Siji Yanjiu* **2022**, *42*, 17–31.
176. Hu, S.; Zhang, P.; Yuan, M. Yulin Huoshiliang yizhi dongwu yicun yanjiu 榆林火石梁遗址动物遗存研究 (Research on animal remains at Huoshiliang). *Renleixue Xuebao* **2008**, *27*, 232–248.

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Article

Kiukainen Culture Site Locations—Reflections from the Coastal Lifestyle at the End of the Stone Age

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Abstract: The Kiukainen culture constitutes a poorly known phase at the end of the Stone Age in Finland, approximately 2500–1800 cal. BC. It is best known for its pottery, and most of the finds are from the coastal area of the Baltic Sea between Helsinki and Ostrobothnia. Previous research on the culture was done several decades ago, so this study aims to define the geographical distribution of the sites known thus far and discuss the landscape around the settlement sites. Creating an overall view of the culture and lifestyle of the people is also an important part of the study. First, it focuses on different collections of Kiukainen pottery and then maps the location of all the sites where pottery has been found. For the landscape visualizations, three different areas were chosen for closer evaluation. Elevation models were, then, used to visualize the Stone Age coastal landscape. Altogether, we identified 99 settlement sites with a confirmed connection to Kiukainen culture. One common feature of the locations is a connection to the sea. The sites are located in various types of environments, but they all have easy access to seafaring and good landing possibilities from the sea.

Keywords: Stone Age; Kiukainen culture; pottery; settlement site; Baltic Sea; shoreline modelling; landscape archaeology; coastal changes

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1. Introduction

The Kiukainen culture was a coastal Neolithic culture that existed on the southern and western coasts of Finland during approximately 2500–1800 cal. BC, starting at the beginning of the Final Neolithic and continuing until the Bronze Age. Its central distribution area extends from southern Ostrobothnia to the Gulf of Finland near the Helsinki region (Figure 1), but only a few inland settlements have been discovered to date. Outside the actual core area, Kiukainen ceramics have been found in some known Neolithic settlement sites. The Kiukainen culture was a uniform cultural group in terms of pottery and stone artefacts, as well as in terms of living in a maritime environment, along the coastline of the Baltic Sea. It was first identified as a unique cultural form by the Finnish archaeologist Julius Ailio in 1909 [1], and since then, the Kiukainen culture has, periodically, been the subject of more focused research. The last in-depth study dealing with the culture is Carl Fredrik Meinander's 1954 book *Die Kiukaiskultur* [2].

The Kiukainen culture was preceded by the pan-European Corded Ware Culture, 2900–2200 cal. BC, which spread to Finland from the southern Baltic region by two local cultural groups. They included the Pyheensilta group [3], which lived on the southern and western coasts of Finland during approximately 3200–2400 cal. BC, and the Pöljä group, which mainly inhabited the inland and the coast of Ostrobothnia during 3200–2500 cal. BC [4]. Scholars believe that the Kiukainen culture arose as a result of the diffusion of these different populations and cultural forms, but the populations also had significant connections with contemporary Scandinavia at the time [2,5]. The diffusion can be seen in material culture. It has recently been suggested that the Kiukainen culture ended with a period of desolation and cultural interruption before the Bronze Age began on the coasts of Finland [6]. However, the continued presence of people in the Bronze Age in many settlement sites and distribution areas used by the Kiukainen culture speaks against this theory. The beginning of the Bronze Age eventually occurred gradually due to strong Scandinavian connections and cultural influence, but from an archaeological standpoint, the change of eras is a time of few discoveries.

Figure 1. Southwestern Finland, highlighted in yellow. The central distribution area of Kiukainen culture extends from southern Ostrobothnia to the Gulf of Finland near the Helsinki region.

Kiukainen culture settlements have typically been discovered on sandy beaches by the sea, with the largest concentrations being in the inner archipelago and in the estuaries of rivers that flow into the sea, such as in today's Turku city region, at the mouth of the Kokemäenjoki River in Harjavalta and Lappfjärd in Kristiinankaupunki. In many places, the settlements have been several hectares in size, and inhabitation continued in such places for hundreds of years. However, it is difficult to determine, without available datings, whether the use of the site was continuous or whether nearby settlement sites were used at different times. In addition, the use of the sites continued in many places into the Bronze Age, which has often made it difficult to date discoveries. Inhabitation along the coasts only became permanent, at latest, during the time of the Kiukainen culture, and scholars have suggested that the late settlements were no longer located on the sandy beaches next to the sea but on the other side of meadows, suitable, perhaps, for grazing, located between such former sites and the sea [7,8]. Settlement sites have also been discovered far out in the archipelago. These were possibly seasonal sites focused on marine fishing and hunting [9].

The connection between archaeological site locations and shoreline displacement has been a point of research interest in many studies in Finnish archaeology, e.g., [10–13]. Some more recent studies with more precise GIS materials and methods have been done in the last 15 years, as more open-access materials have become available [14]. Recent studies in geology have also begun to focus on land uplift and shoreline displacement since more precise GIS data is now available [15,16]. In 2001, researchers conducted an interesting study that modelled dwelling sites and sources of livelihood in the Espoo area near Helsinki [17]. The study concluded that Kiukainen sites in the Espoo area had a strong connection to marine resources, with sites being located on the seashore and islands. According to the study findings, change in the location of the settlements reflected major cultural changes during the formation of Kiukainen culture. However, it only included five Kiukainen sites, and the area of the study was quite limited, so statistical methods could not be used in the study. In Finland, more modern GIS analyses or methods have not yet been fully adapted to archaeology, but some basic studies have been done using, for example, interpolation methods [18] and cost surface analysis [19]. In Norway, a very interesting and relevant study was conducted in 2021 [20]. The research established that the peopling of the coastline in prehistory involved a series of active choices, and the main factors informing these decisions were good landing conditions and monitoring locations, followed by sufficient shelter from prevailing winds.

The first aim of this study is to define the geographical distribution of Kiukainen pottery and Kiukainen culture. Though some basic studies on Kiukainen culture were done decades ago, the results of those studies are outdated. The overall view of Kiukainen culture is indistinct, and more information is needed about the essence of Kiukainen culture. The geographical distribution of the culture has not been fully studied before, since the research focus, to date, has been more on individual sites or certain areas, as one study from the year 2001 points out [17]. The second aim of the study is to determine the types of landscapes or environments in which the settlement sites of Kiukainen sites were located. The choice of residence and local environment around the sites can give hints about the subsistence strategy of the culture. The third aim is to discuss the lifestyle of Kiukainen culture settlements based on research knowledge collected thus far. By lifestyle, we mean more than just subsistence strategy or nutrition. The term also includes, for instance, cultural contacts, traveling, social networks, and artefacts, which together constitute the mode of living of an individual or group. A broad perspective is important, and thus, this article highlights and especially discusses such an aspect.

The existing studies of individual archaeological sites and interpretations, based on only one site, are comparable to a study of finds without any context. Without a broader overall cultural picture in the background, the interpretations of individual sites remain weak and thin. From the fieldwork perspective, an overall picture is needed to provide more of a specific research focus during field studies. Knowledge about the geographical distribution of Kiukainen culture can also support future field studies because, most likely, many sites are still unidentified or undiscovered. Similar to artefacts, archaeological sites or monuments also have their own context, which is an idea that has inspired us in this research project.

2. Materials and Methods

Kiukainen ware forms its own uniform group that differs from preceding or contemporary pottery styles in the Northern Baltic Sea region. The vessels are thick-edged and rough-made, always flat-bottomed, and are usually straight-edged designs. Mild profiling also occurs sometimes. The vessels vary in size from small beakers to large storage vessels, but most are a few litres in size. Clay material was often mixed with crushed stone or sand, but organic temper or limestone was often used as well, causing the ceramics to be porous. Only the upper part of the surviving vessels is decorated. However, the lower undecorated parts often contain a textile imprint. The decoration consists of horizontal rows of pits, dots, lines, comb or ring stamps, and sometimes, spiral cord prints (Figure 2). Horizontal or vertical zig-zag lines are also typical. Though other decorations have also been found on vessels, the vessel is usually decorated only with pits and one other decorative element; for more, see [1,2,5].

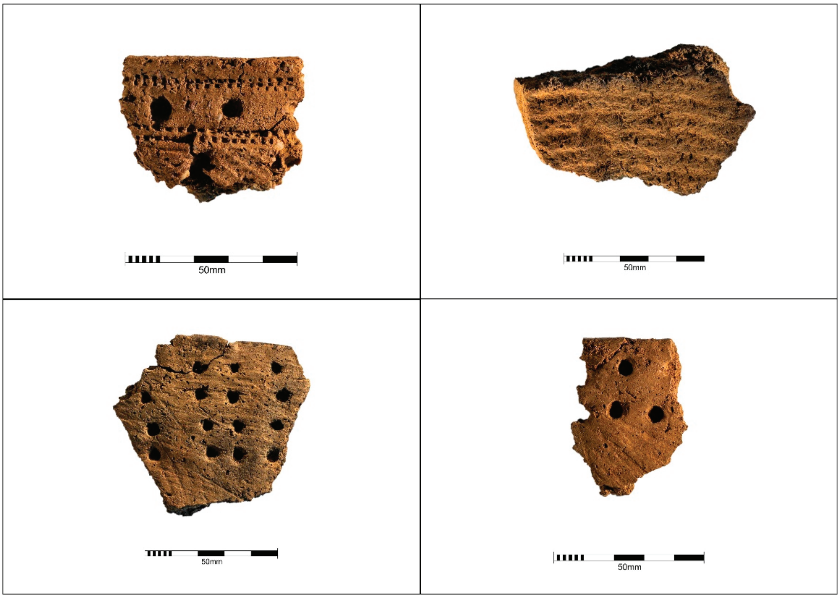


Figure 2. Kiukainen pottery, photo by Marjo Karppanen. Upper right bottom of a vessel with textile imprints; the rest are rim sherds.

The preliminary search for settlement sites representative of Kiukainen culture has been based on information provided in the Register of Ancient Monuments, previously published studies, and excavation reports. Based on this information, we have viewed all the finds from settlement sites that seem promising and have confirmed that they belong to the Kiukainen culture as a result of Kiukainen-type ware found at the sites. Most of the work has been done in the collections of the Finnish Heritage Agency, the Museum of Åland, and the Museum of Satakunta.

One challenge in defining the settlement sites is that little research has been done on them, and none of them have been fully excavated. Many of them have been found as part of archaeological surveys, meaning that, typically, only a small amount of material has been found, and it can be difficult to identify ceramics with certainty. The easily corroding and largely undecorated ceramics have also presented difficulties of their own because only decorated or otherwise clearly diagnostic pieces of pottery can be identified as Kiukainen with any degree of certainty.

After analysing and recognizing Kiukainen pottery, the coordinates of site locations confirming a connection to the culture were collected from the Register of Ancient Monuments. The Finnish Heritage Agency maintains and updates the register. The register includes information about site type, location, possible dating, descriptions, and possible links to research reports. Sites also have a name and individual number code, which are used to list the sites. Every archaeological site in the register has coordinates in point format, and most of the sites have protected area definitions in polygon format. All information about archaeological sites in Finland is open-access form. The register can be found at the Finnish Heritage Agency's website, at its Cultural Environment service window (Kulttuuriympäristön palveluikkuna), but only in Finnish [21]. It is also possible to download the register for GIS use or else use it in GIS programs via open geographic information interfaces (VMS and VFS forms). After downloading the site register, it was possible to identify and list all sites where Kiukainen pottery has been found with the QGIS program. However, some sites excavated decades ago are not in the register, so some of those site locations are uncertain. Additionally, a few sites located outside the present borders of Finland (the Karelia area of Russia) were left out because the locations of those sites are uncertain. Sites located in the Åland Islands were identified using the Kulturarv website [22], updated by the Åland provincial government.

The mapping of the sites where Kiukainen ware has been found revealed some interesting site clusters. After examining the distribution results, three areas were chosen for closer evaluation and comparison. One factor in the choice was previous research history and knowledge of the sites in the area. For instance, some excavations of possible importance were done decades ago with poor documentation levels, while at other sites, the available research is quite limited and was only done at a small scale. Not all sites have confirmed dating since radiocarbon dating was never done on the finds. Those sites where the amount of Kiukainen pottery that was found was very small and other pottery types were dominant were considered too uncertain to compare. Comparison areas were chosen far from each other, where the landscape and topography are different. Many interesting sites are located near the city of Turku. The Turku city area was not studied as part of this research project, though, due to heavy land use and buildings.

Three areas that were chosen are the municipalities of Kemiönsaari, Harjavalta, and Kristiinankaupunki. Two nearby sites from the municipality of Nakkila were included in the Harjavalta study area because of the close geographical connection between them. To visualize the Stone Age shoreline, digital elevation models (elevation model 2 m) were downloaded from the open-data file service of the National Land Survey of Finland [23]. The elevation models are raster datasets that are based on laser scanning data, the point density of which is at least 0.5 points per square meter [24]. With the QGIS program, basic data visualization tools (unique values) were used to colourize the water blue to illustrate the shoreline. Information about changing sea levels during the Stone Age was collected from many different available sources, such as excavation reports and shoreline displacement chronologies. The Geological Survey of Finland provides open access to GIS data about the different soil types [25] in Finland. Unfortunately, the Geological Survey of Finland's most accurate soil type datasets do not cover the full Kemiönsaari area or Kristiinankaupunki area. As a replacement, the datasets from the Finnish Forest Centre were used to identify rocky areas. The Finnish Forest Centre datasets can be downloaded from its website [26] or used via open geographic information interfaces (VMS and VFS forms). The datasets include information about soil type in the forestry areas of Finland and the datatype area polygons. For background information and knowledge about the site (found on the Finnish Heritage Agency's webpages, specifically its cultural environment research reports), previous fieldwork history, such as excavation reports or survey reports, were also used.

3. Results

Altogether, we identified 99 sites with confirmed connections to the Kiukainen culture (Figure 3). The list of the sites can be found in Appendix A (Table A1). Uncertain cases, where the pottery could not be clearly identified, and those sites that have an inaccurate location were left out of the results. The distribution of Kiukainen culture sites is strongly connected to the Stone Age shoreline of the Baltic Sea. The core area, where the number of sites and pottery finds is highest, is the shoreline between Espoo and Kristiinankaupunki. The results include only six inland sites where Kiukainen pottery could be identified. Three of those sites could be reached from the sea via the Kokemäenjoki River. The distribution map also revealed an approximately 80 km gap in shoreline colonialization between Pori and Kristiinankaupunki. The reason for the gap remains unclear, but it can also reflect a gap in field research history. The distribution map of Kiukainen culture can be considered, to some extent at least, to also reflect the general state of research on the Stone Age in Finland, as archaeological surveys have primarily focused on areas of changing land use around modern growth centres. Almost all archaeological surveys in Finland are done by commercial archaeology companies for different types of zoning and construction projects. Surveys are rarely done in areas that do not have active land use. It should also be strongly highlighted that the Kiukainen pottery findings are from sites that have been excavated. Those sites that have not been excavated but that are listed in the register after an archaeological survey are difficult to identify because only a very limited number of finds are collected during the survey. The total number of Kiukainen sites is most likely much higher, and the distribution map only reflects the current research situation.

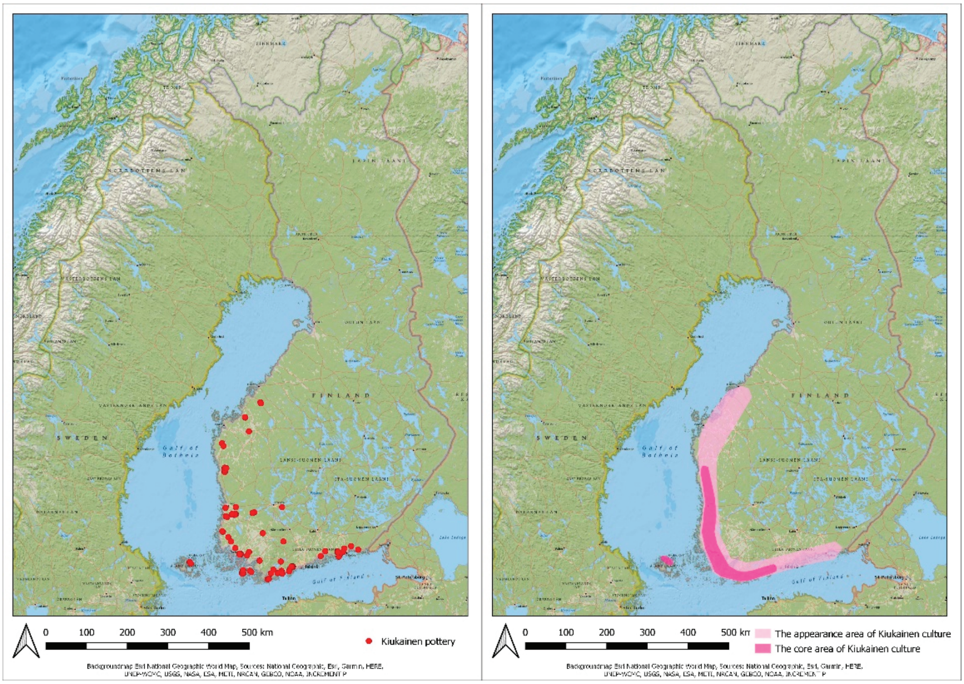


Figure 3. The distribution map of Kiukainen culture (**right**) where individual sites are marked with red dots. The heatmap of the Kiukainen culture (**left**). The heatmap was constructed by evaluating site density and also the number of pottery finds.

The three areas chosen for closer review, Kemiönsaari, Harjavalta, and Kristiinankaupunki, are located about 100 km apart from each other (Figure 4). Kemiönsaari, in the Southwest Finland region, is the southernmost of the sites, and it is also currently part of the archipelago. The Harjavalta area is in the middle of the Satakunta region, formerly part of the Western Finland Province. The northernmost review area is Kristiinankaupunki, in the Ostrobothnia region.

Background map ESRI National Geographic World Map, Sources: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, INCREMENT P

Figure 4. The Kiukainen culture areas that were selected for closer review.

The Kiukainen sites in Kemiönsaari are located on large rocky islands in the archipelago area (Figure 5). Only the northernmost site of Näset was located on the shore of a smaller island. The sites are oriented towards the east because it afforded the best shelter from the western winds and better landing possibilities while navigating at sea (Figure 6). Since the sites are on islands, it is obvious that seafaring was quite familiar to the people of the Kiukainen culture. Landing on sandy beaches must have been easier than landing on a rocky shoreline, which could be one explanatory factor for site locations in the area.

Figure 5. The locations of Kiukainen sites in the Kemiönsaari area. Grey areas in the background of the map are rocky areas, while the yellow areas are cultivated fields, and the light green or empty white areas in between are forests.

Archaeological excavations have been carried out at four of the settlement sites in the area. Jordbro and Knipängsbacken were partially excavated by C. F. Meinander in 1947, while small excavation was done in Hammarsboda by the University of Turku in 1991, and excavations were done at the Ölmosviken site in 2017–2021 [2,27,28]. Based on the research and C14 dating, the settlement sites may have been used at different points in time, but Ölmosviken shows signs of habitation for hundreds of years between 2300 and 1800 cal. BC. Jordbro is possibly younger than the other settlements, as five Bronze Age burial cairns have been discovered there, demonstrating a continuity of settlement to the Bronze Age.

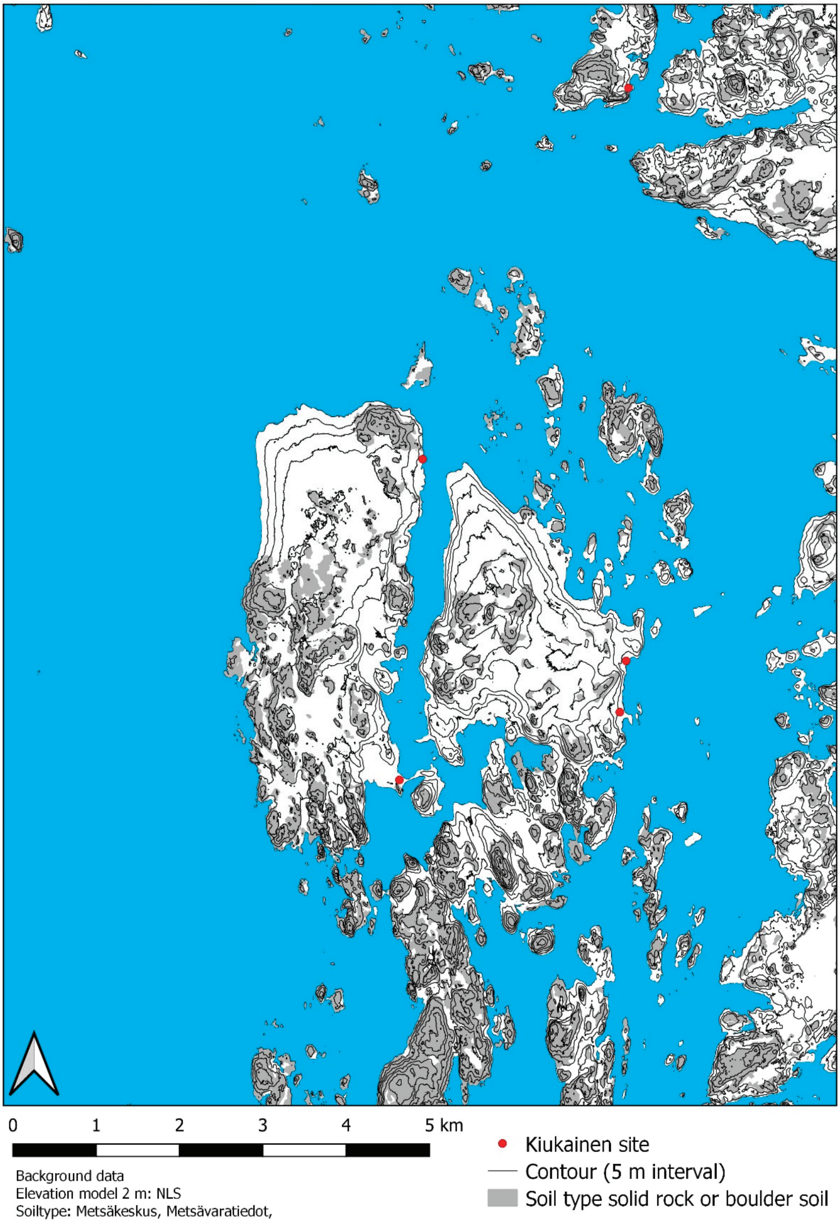


Figure 6. The locations of Kiukainen sites in the Kemiönsaari area and sea are visualized at 19 MASL. Areas with the soil type solid rock or boulder soil are visualized as grey.

The soil near the sites is mainly sand and gravel and, therefore, not particularly fertile, but on the other hand, larger barren-rock areas are located a little further away. Pollen analysis has been done at the nearby Söderbyträsket Lake, revealing that Pinus, Betula, and Alnus were the dominant types of trees during the period of Kiukainen culture. Additionally, Quercus, Populus, Tilia, Fraxinus, Ulmus, and Corylus grew nearby, which, together, accounted for about 20% of the vegetation [29]. Thus, except for the most barren areas, the area consisted mainly of deciduous forest, and the vegetation was lusher than today. The first signs of cultivation are from the Bronze Age, 1210–1010 cal BC. [29], but the surroundings close to the residences would have been suitable, at least, for keeping goats and sheep already at the end of the Stone Age. So far, however, research has revealed no signs of such livestock practices, but the burned bone material is dominated by seal bones, at least at Ölmosviken [30]. A considerable number of the bones come from young individuals, which suggests that the catch took place in the spring and early summer.

The archipelago area was particularly favourable for seal hunting and fishing in the Stone Age, which, together with seabird hunting, were the most likely reasons for people moving to the area and for the establishment of settlements. The west and south sides of the island group would have given way to a wide and open sea, but the surroundings of the settlements consisted of sheltered archipelagos. This type of environment provided an abundance of fish, birds, and seals and, thus, plenty of food for people throughout the year. While information is unclear as to whether the sites were inhabited year-round, Ölmosviken contains traces of the dwelling pits. The pits probably originated from buildings partially dug into the ground, which would have been warm enough for people to live in during the cold seasons. On the mainland, the nearest large settlements would have been in the Turku region, about 45 km away and close to the sea, so the settlement of the area can also be connected to the marine fishing practiced by the communities that lived there.

The landscape in Harjavalta is quite different than in the Kemiönsaari area. In Harjavalta, the topography is a plane, and sites are located in small, forested areas near cultivated fields (Figure 7). The Kiukainen culture was discovered and named after the settlement site of Uotinmäki in the area at the beginning of the 20th century. In addition to Uotinmäki, archaeological excavations were carried out at Kaunismäki and Saamanmäki, the results of which have been presented in the book *Die Kiukaiskultur* [2]. Later, excavations were also done at the Lyytikänharju site, which nonetheless dates mainly to the time of the Pyheensilta group [31,32]. In recent years, residences named Kraakanmäki 1–3 have been investigated, with newer research results and C14 dates available from two of the excavations [33,34].

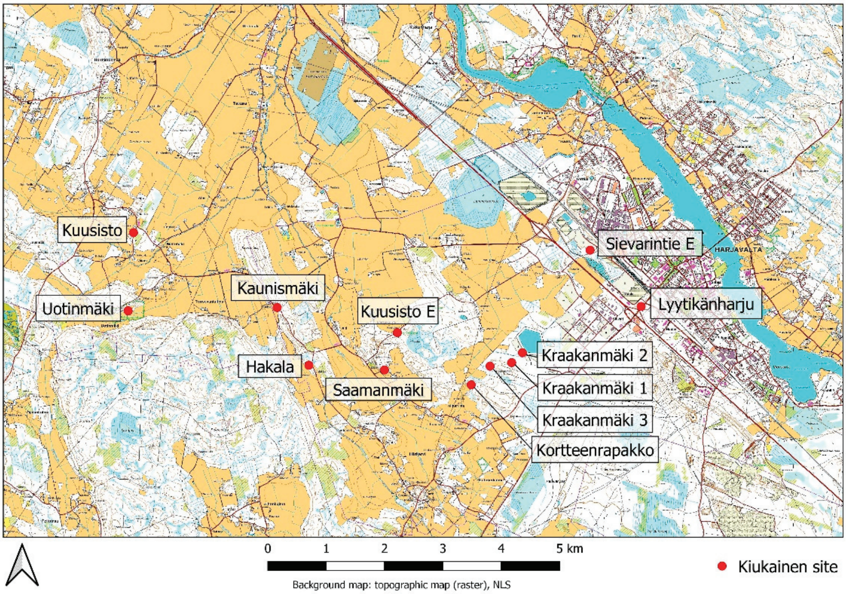


Figure 7. The locations of Kiukainen sites in the Harjavalta area. Grey areas in the background of the map are rocky areas, while the yellow areas are cultivated fields, and the light green or empty white areas in between are forests.

The settlements are located on the shores of a large and sheltered sea bay. The Kokemäenjoki River flowed into the bay, forming an estuary there (Figure 8). Due to the large flow of the river and the shallowness of the bay, the water in the bay has been brackish with very little salt. Many of the shorelines were probably lined with thick reeds. The area has been attractive, especially, in terms of fishing, as Kokemäenjoki River was well known for its salmon during historical times. The shallow reed banks have also attracted other fish and waterfowl to the area.

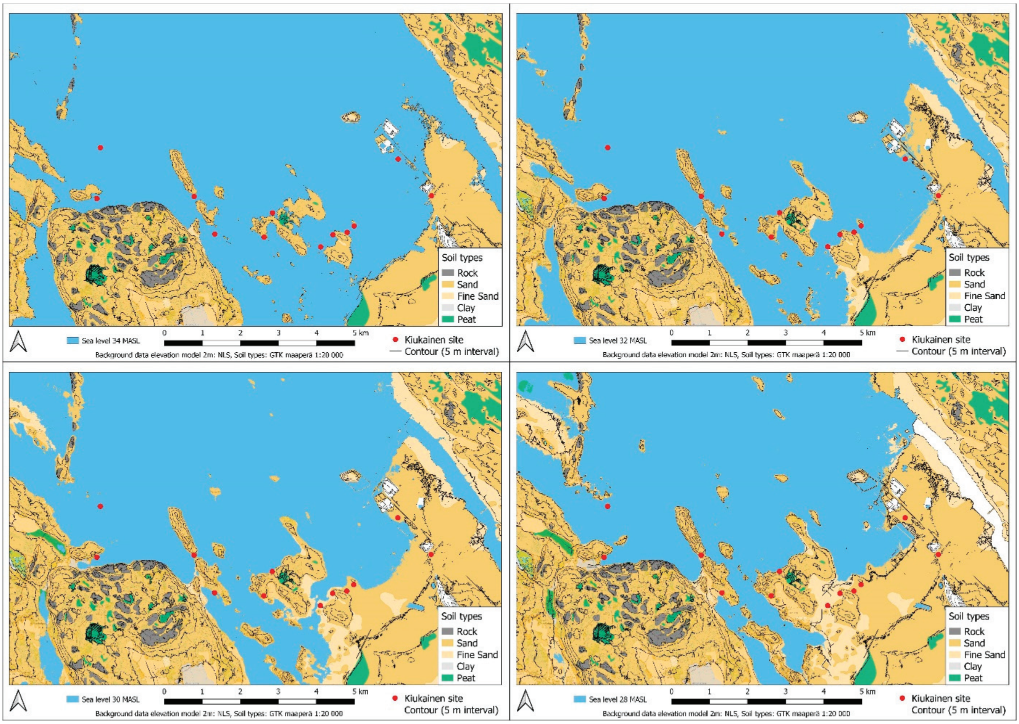
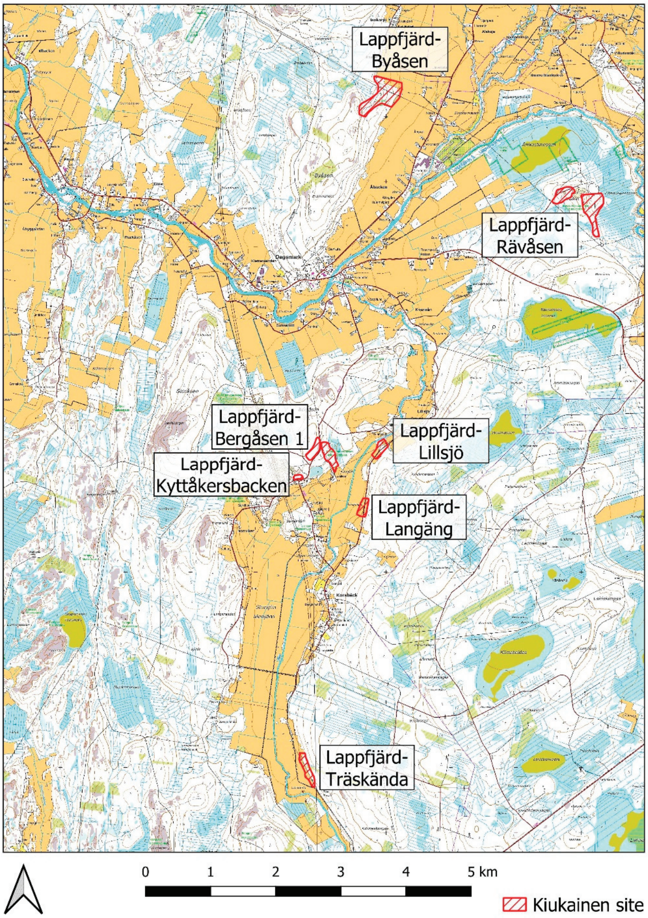


Figure 8. The locations of Kiukainen sites in the Harjavalta area with different landscape visualizations. The Sea is visualized at 34 MASL (**upper left**), 32 MASL (**upper right**), 30 MASL (**lower left**), and 28 MASL (**lower right**). Soil types are visualized with different colours.

The maps clearly show how the environment changes quickly as the land rises from the sea (Figure 8). It seems likely that, due to such changes, many residences would have soon been located far from the beach and, thus, probably subject only to short-term use. On the other hand, due to the steeper topography, Uotinmäki, Kaunismäki, and Saamanmäki remained constantly close to the seashore, making them habitable from one century to the next. Kuusisto's site remained underwater throughout the Stone Age and only emerged from the water during the Bronze Age. However, Kiukainen pottery has been found at the site, so either the information about the height of the place is inaccurate or Kiukainen-type pottery was, perhaps, used relatively late in the Bronze Age.

The settlements were located in the areas protected from the wind because the ancient sea bay was wide and open. Based on their location, the immediate proximity to the sea was important, and settlement continued for a long time only in places that have remained close to the shoreline. Inhabitation also continued in such places during the Bronze Age, but Lyytikänharju and Kraakanmäki 1–3, were only used while they remained close to the sea. The surroundings of the residences inhabited for a much longer time at Uotinmäki, Kaunismäki, and Saamanmäki were suitable for early farming already at the time of the Kiukainen culture, for they were situated on lush slopes.

The settlements in the Kristiinankaupunki area have only been excavated at Langängen in 1950 and in Rävåsen in 1994–1999 [2,35]. The area is known for containing a large number of residences belonging to the Kiukainen culture, but due to the research situation, ceramics have only been found in a few (Figure 9). Most of the settlements seem to have been located by the sea, with the water level having been about 40 m higher than today (Figure 10). The same also applies to places where ceramics have not been found. At that time, they were located on the shores of a sheltered bay formed by the mainland and an island on its western side. The Gulf of Bothnia opened to the western side of the area, and the rivers Kärjenjoki and Lapväärtinjoki ran down to the southwestern end of the area. The waters near the residences would have been sheltered and well suited for fishing and catching waterfowl.



Background map: topographic map (raster), NLS

Figure 9. The locations of Kiukainen sites in the Kristiinankaupunki area. Grey areas in the background of the map are rocky areas, while the yellow areas are cultivated fields, and the light green or empty white areas in between are forests.

Land uplift in the area occurred quickly at the end of the Stone Age, having been more than a meter per century at the time. The landscape was, therefore, constantly changing, and the sheltered sea area narrowed into two lakes, which were later drained. Their height would have been about 35 m, but many settlements would have already been far from the shore at this point. In terms of time, the separation of the lakes from the sea dates back to the Bronze Age, approximately 1500 cal. BC. The finds at the settlement called Langäng, which was located on the shore of a smaller lake called Lillsjön, continued to a height of about 35.5 m, and C. F. Meinander, who excavated the site, considers it possible that the settlement continued to be inhabited during the lake phase as well [2]. At other sites, settlement may have continued into the Bronze Age, as several Bronze Age cairns have been found in the area and at the settlement sites. However, the sea connection had already been lost by then, and the settlement's subsistence was probably based on something other than just marine resources.

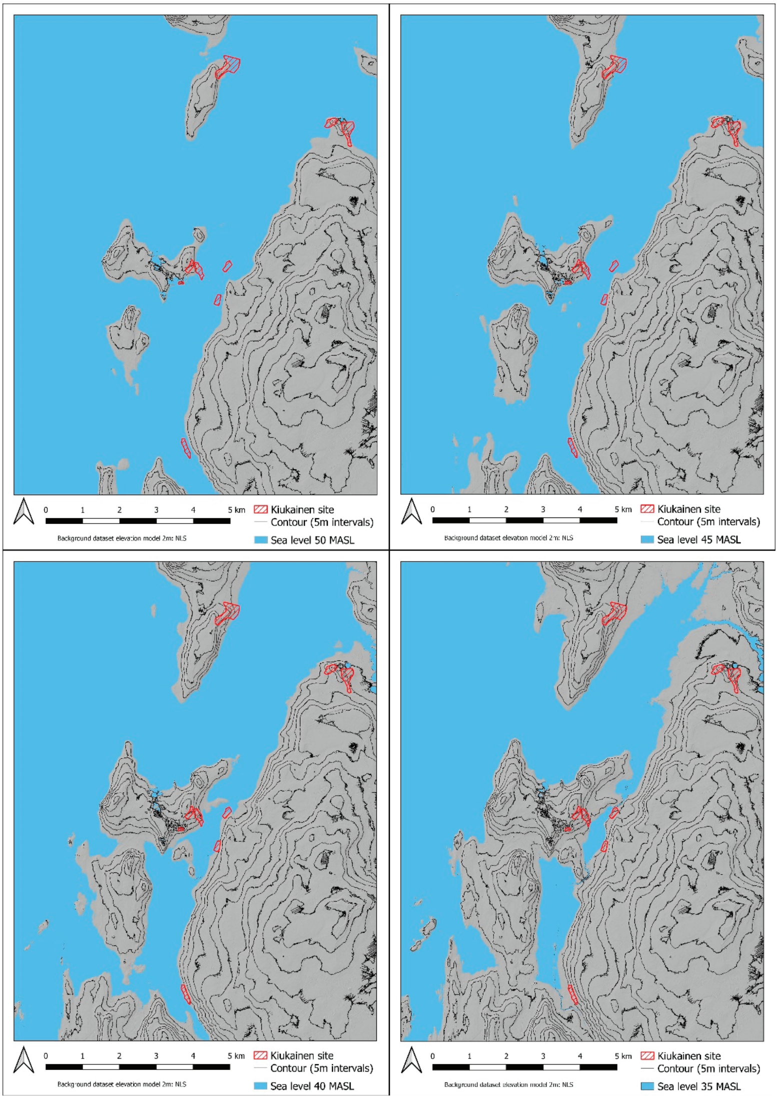
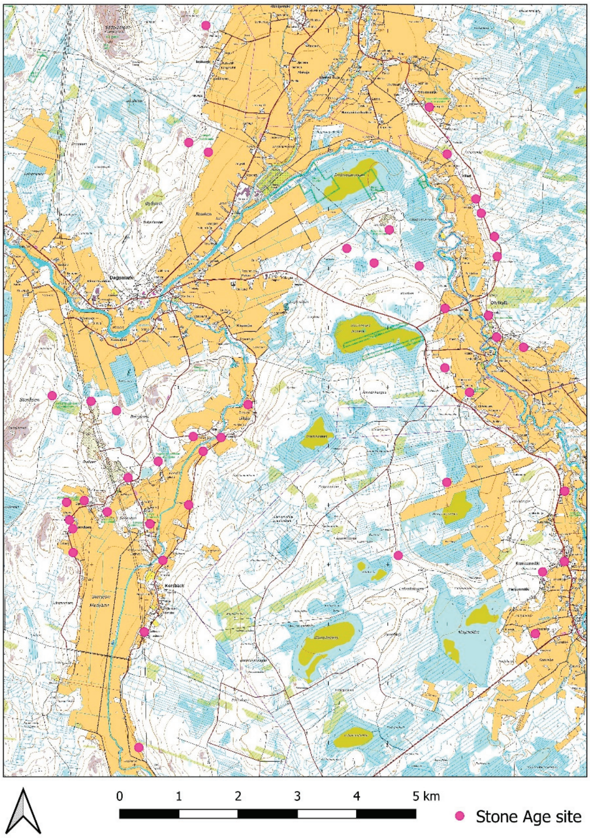


Figure 10. The locations of Kiukainen sites in the Kristiinankaupunki area with different landscape visualizations. The Sea is visualized at 50 MASL (**upper left**), 45 MASL (**upper right**), 40 MASL (**lower left**), and 35 MASL (**lower right**).

Råvåsen is a clear exception to the other settlement sites along the shorelines of the sea, having been inhabited for a long time before the Kiukainen culture. However, some Kiukainen ceramics have been found there at a height of approximately 50 m above the sea level today [36]. At the end of the Stone Age, the settlement was located at least four hundred meters from the sea and the mouth of the river Lapväärtinjoki. The area between it and the sea consisted of low reeds and possibly meadows. The site may, therefore, have been used during the time of the Kiukainen culture more for the purposes of tending livestock and engaging in small-scale farming than for taking advantage of marine resources. The surroundings of other sites in the area could also have been suitable for small-scale farming in addition to fishing, as low, seaside meadows and fertile soil would have existed in the vicinity, especially at the very end of the Kiukainen culture.

It must be noted that many more sites in the area around Kristiinankaupunki have been defined as Stone Age settlement sites in the register (Figure 11). More Kiukainen culture sites may exist in the area, but the lack of field studies, and especially excavations, make it difficult to interpret just which of the sites may have been inhabited simultaneously or by the same culture. As seen from the previous map (Figure 8), the seven known Kiukainen sites are located at different heights, and some are multi-period sites. Landscaping and building activities have also damaged some of the sites, so the original site location and zone may have been different than how it appears in the register today.



Background map topographic map (raster), NLS

Figure 11. The locations of sites that have been defined as Stone Age in the Kristiinankaupunki area. Grey areas in the background of the map are rocky areas, while the yellow areas are cultivated fields, and the light green or empty white areas in between are forests.

As seen from the comparison, the Kiukainen culture sites have been located in variable landscapes and topographies. Easy connection to the sea and landing possibilities have been one key demand for such sites. In the area around the rocky island of Kemiönsaari, the best places have been located on the eastern shores of the island, which would have given the best shelter from the open sea to the west or southwest. In the Harjavalta area, changes in the landscape and location of the seashore occurred rapidly, so some of the sites have been used only for a short period. In the Kristiinankaupunki area, sites are also oriented towards the east or, then, located in a sheltered bay, as the sea opens to the west. With respect to future research and, especially, GIS analysing methods, such great variation in landscapes makes it difficult to use f.x. predictive modelling. The results from the site environment confirm previous knowledge about Kiukainen culture having been a marine culture with certain local adaptations, such as possible small-scale cultivation at some sites.

4. Discussion

The adoption of farming and pastoralism in Finnish Neolithic cultures has been a topic of discussion for a long time. According to the latest research, communities in southern Finland engaged in farming and pastoralism even before the Kiukainen culture. Based on pollen studies and the location of the settlements, it has been suggested that small-scale farming may have been important, already, at the time of typical Comb Ceramic culture (4100–3550 cal. BC) [37]. At the latest, these subsistence strategies arrived from elsewhere in the Baltic region together with the Corded Ware culture, from 2900 BC onwards. So far, archaeologists have only found evidence of nomadism practiced in Finland at the time, but traces of dairy fats have been found in pottery [38]. In addition, goat hair has also been found in a grave dated to the time of the Corded Ware culture [39]. However, no evidence of cultivation has been discovered, though it would have been entirely possible based on the location of the settlement sites in fertile environments. The Pyheensilta group has been poorly studied, but based on the location of the settlement sites, marine fishing and hunting were of great importance to such communities. The Pyheensilta group, however, had active connections with groups belonging to the East Swedish Pitted Ware culture in the Åland Islands, where carbonized grains have been found [40].

The subsistence patterns of Kiukainen culture were based, mainly, on marine resources, but evidence of small-scale farming has also been found in recent years. In the excavations done at the Riihivainio settlement site in Turku, archaeologists found evidence of contemporaneous field cultivation in connection with the Kiukainen culture [41]. Most of the excavated settlements have been interpreted as places mainly related to hunting, but archaeologists have discovered grinding stones, especially in the settlements located at the mouth of Kokemäenjoki River, with the stones probably having been used to grind grains [42]. However, all the grinding stones have been found in settlements that continued to be used in the Bronze Age. Farming possibly also included the use of arrow-bladed stone axes, most likely used as hoes [42]. In the distribution area of the Kiukainen culture, signs of cultivation have also been found in the sediments of lakes and moors dating to the end of the Stone Age [29,43,44].

The Kiukainen culture exhibited inhabitation practices in the Åland Islands after the disappearance of the Pitted Ware culture from the same settlement sites. The radiocarbon dates suggests that domesticated animals, such as cattle, sheep, and pig, were kept in the Åland islands during the Late Neolithic by the Pitted Ware culture [45]. However, the cultural and populational continuity between the Pitted Ware culture and the Kiukainen culture is still unclear, but the Kiukainen population may well have also maintained small-scale cultivation and husbandry in the Åland Islands. In addition, the oldest sheep bone found in Finland (2200–1950 cal. BC) comes from one of the northernmost Kiukainen culture sites in Kvarnabba Pedersöre [46]. On the other hand, it has been suggested that Kiukainen culture returned to the hunter-gather-fisher lifestyle [38,47], but based on this evidence, the small-scale husbandry was likely one part of the subsistence on the coastal life.

The settlements belonging to the Kiukainen culture are all concentrated on the shores of the Baltic Sea. Pottery spread inland to only a few places, and they are all in the area of the Kokemäenjoki River watershed. The strong connection of the entire cultural phase to the coasts and archipelagos tells not only of the importance of the sea as a source of food but also about its importance in connecting people between different regions. Without the sea and the archipelago, the Kiukainen culture, with its maritime lifestyle, would never have flourished. The contacts between the settlement sites occurred via water, and such contact must have occurred frequently because the material culture of the various settlements has been quite similar throughout the Kiukainen culture area. Ceramics produced by other contemporaneous cultures have not been found in the sites belonging to the Kiukainen culture area except in the Åland islands, and in this sense, the contact between the inland areas and places along the long coastline seems to have been limited. On the other hand, the material culture shows clear Scandinavian influences, so connections existed across the sea. In the future, it would be important to study those cross-sea contacts in the direction of Scandinavia and the Baltics. The length of the coastline where Kiukainen sites have been found is approximately 720 km, and the length of the core area is approximately 400 km. The distance from the Åland Islands to the nearest coastal sites in Turku or Kemiönsaari is approximately 120 km. In the future, different GIS methods, such as least-cost past analysis, could give interesting results about routes, travel times, and so forth.

However, from the perspective of current research and GIS analysis, the Register of Ancient Monuments has many problems. The level of information and site descriptions vary. In some cases, it may mention pottery type or, for example, dating, but some sites only receive brief descriptions without any important accompanying details. Information about the sites has been collected for decades, and some descriptions or locations can be based on very old surveys or small-scale excavations. The user must evaluate data reliability for each individual site, and thus, forming a reliable overall picture is difficult. A lack of proper classifications or keywords makes the register difficult to use with GIS programs. The points or polygons have age classes, such as dating = “stone age” and type = “settlement site,” but they fail to provide any additional search options or keywords; hence, the few existing options do not yield a good result when trying to find more specific information on a site other than just dating or type. Additionally, sites can have similar names, so the only reliable identifier is the individual site number. However, if a user wants to list multiple sites, as in this study, searching each site on a case-by-case basis, using only the site number, is a slow process.

Today, archaeological fieldwork in Finland includes detailed archaeological fieldwork guidelines and instruction [48], updated by the Finnish Heritage Agency. However, the information collected fifty or a hundred years ago is a different story. Conducting GIS analyses with unreliable GIS data is problematic. In the future, better tools to evaluate the data quality will be needed. Adding more tools and search options or keywords could support researchers and authorities, too. Updating the register and collecting new information by doing fieldwork is an ongoing and slow process, and at the same time, storing the data requires new solutions [49].

5. Conclusions

The lifestyle of the Kiukainen culture settlements seemingly included a combination of marine resources, seafaring, and small-scale farming, if possible, while being integrated with the local environment and landscape. The use of multiple resources afforded the coastal communities more stable lifestyles in that period of changing climate and environment. However, much more research is still needed, and we would like to open a discussion about how the Kiukainen culture fit into the Stone Age lifestyle and landscape archaeology more generally.

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Data Availability Statement: Data available in a publicly accessible repository that does not issue DOIs Publicly available datasets were analyzed in this study. This data can be found at: https://www.museovirasto.fi/fi/palvelut-ja-ohjeet/tietojarjestelmat/kulttuuriympariston-tietojarjestelmat/kulttuuriympaeristoen-paikkatietoaineistot (accessed on 20 August 2022) and https://aland.maps.arcgis.com/apps/webappviewer/index.html?id=9d7cc07ab4004f0ca620038c4fd416ca (accessed on 20 August 2022).

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. The list of archaeological sites where Kiukainen pottery has been found and discussed in this study.

Municipality	Site Number	Site Name
Espoo	49010002	Finns
Espoo	49010040	Mynt
Espoo	49010004	Backisåker 1
Espoo	49010001	Grankulla
Espoo	49010021	Lillgus storåker
Eurajoki	51010029	Irjanteen hautausmaa
Eurajoki	51010009	Etukämppä
Hamina	917010013	Hietojanvuori
Harjavalta	79010009	Kuusisto E
Harjavalta	79010001	Kaunismäki A ja B
Harjavalta	79010006	Saamanmäki
Harjavalta	79010025	Lyytikänharju
Harjavalta	79010023	Sievarintie E
Harjavalta	1000038606	Kraakanmäki 3
Harjavalta	1000038607	Kortteenrapakko
Harjavalta	1000006682	Hakala
Harjavalta	1000022768	Kraakanmäki 2
Harjavalta	1000022767	Kraakanmäki 1
Humppila	103010001	Järvensuo 1
Inkoo	1000000046	Malmskyan
Inkoo	149010060	Vahrs
Inkoo	149010056	Malmgård
Inkoo	149010068	Staffans
Inkoo	149010069	Nysvenskas
Inkoo	1000006090	Kasabergen
Kaarina	202010026	Ravattula Ristimäki

Table A1. *Cont.*

Municipality	Site Number	Site Name
Kaarina	202010020	Muikunvuori
Kangasala	211010006	Sepänjärvi 1
Kemiönsaari	243010042	Nedergård
Kemiönsaari	243010045	Eländet
Kemiönsaari	1000019364	Ölmosviken
Kemiönsaari	40010014	Knipnäsbacken
Kemiönsaari	40010036	Hammarsboda 4
Kemiönsaari	40010015	Jordbro
Kemiönsaari	1000031089	Näset (Skinnarviksvägen)
Kirkkonummi	257010027	Pappila
Kirkkonummi	257010053	Framhoparn
Kirkkonummi	257010081	Kolsarby
Kotka	285010017	Niskasuo
Kristiinankaupunki	409010030	Lappfjärd-Bergåsen 1
Kristiinankaupunki	409010049	Lappfjärd-Träskända
Kristiinankaupunki	409010047	Lappfjärd-Lillsjö
Kristiinankaupunki	409010028	Lappfjärd-Langäng
Kristiinankaupunki	409010040	Lappfjärd-Kyttåkersbacken
Kristiinankaupunki	409010041	Lappfjärd-Byåsen
Kristiinankaupunki	409010044	Rävåsen
Laitila	1000000142	Ahtkorvenmäki
Laitila	1000000092	Hangassuo
Laitila	1000004424	Miilunpohjansuo
Lohja	444010047	Kittiskoski E
Loppi	433010014	Kuitikas
Loviisa	701010023	Koirankallio
Loviisa	585010015	Strömbo
Mynämäki	503010040	Pyheensilta, Laajoen luoteispuoli
Nakkila	1000001335	Uotinmäki ja Uotinmäki W
Nakkila	531010005	Kuusisto
Nousiainen	538010037	Kylävuori
Närpiö	605010001	Pörtom-Raineåsen
Närpiö	605010020	Pörtom-Langbacken
Paimio	577010030	Kehioja
Paimio	577010038	Halkilahti
Pedersöre	990010035	Esse-Jättegobacken/Smedasforsen A + B
Pedersöre	990010004	Esse-Kvarnnabba
Pori	609010084	Kirkkokangas IV
Porvoo	613010040	Böle

Table A1. *Cont.*

Municipality	Site Number	Site Name
Pyhtää	624010017	Brunamossen 2
Pyhtää	624010029	Trollberget
Pyhtää	624010037	Eetinniitty 1
Pyhtää	624010036	Kaarlinsaari 1
Pyhtää	624010038	Eetinniitty 2
Pyhtää	1000007139	Nygård 2
Pyhtää	1000007141	Längkärrsskogen 2
Pyhtää	1000007159	Nygård 1
Pyhtää	1000007149	Eetinniitty 4
Pyhtää	1000016854	Eetinniitty 5
Raasepori	220010082	Grågälan-Träskhusåkern
Raasepori	220010036	Dragongatan
Raasepori	1000039580	Sannäsmalmen
Raasepori	1000032776	Gloviken
Salo	734010002	Alhonpelto
Sastamala	912010046	Liekolankatu
Sastamala	912010022	Haapakallio
Sastamala	912010017	Hiukkasaari
Seinäjoki	975010014	Viinapränninlaakso
Turku	853010022	Kotirinne
Turku	202010037	Pähkinämäki 2
Turku	853010008	Riihivainio
Turku	853010048	Niuskala
Turku	853010019	Maaria Kärsämäki
Turku	853010029	Kanttorinmäki
Ulvila	293010007	Eskola
Ulvila	293010006	Hämäläinen I
Virolahti	935010004	Kattelus 1
Vöyri	559010022	Torplindorna S
Vöyri	559010018	Fårmossen 1–2
Vöyri	559010025	Torplindorna N
Åland-Saltvik	Sa 20.8	Myrsbacka I
Åland-Saltvik	Sa 21.1	Krokars
Åland-Saltvik	Sa 20.8	Svinvallen

References

1. Ailio, J. *Die Steinzeitlichen Wohnplatzfunde in Finland*; Kommission bei der Akademischen Buchhandlung: Helsinki, Finland, 1909; pp. 93–94.
2. Meinander, C.F. Die Kiukaiskultur. In *Suomen Muinaismuistoyhdistyksen Aikakirja 53*; Puromiehen kirjapaino Oy, K.F., Ed.; Finska Fornminnesforeningen: Helsinki, Finland, 1954; pp. 7–30, 30–32, 43, 60–66, 134–148.
3. Vikkula, A. Pyheensilta Keramiikka. Ph.D. Thesis, University of Helsinki, Helsinki, Finland, 1987.
4. Nordqvist, K.; Mökkönen, T. Pöljä Ware: Properties, Dating and Regional Variation. *Fennosc. Archaeol.* **2021**, *38*, 29–58.

5. Äyräpää, A. Fornfynd från Kyrkslätt och Esbo socknar. In *Suomen Muinaismuistoyhdistyksen Aikakirja 32*; Puromiehen kirjapaino Oy, K.F., Ed.; K.F. Puromie: Helsinki, Finland, 1922; pp. 147–148.
6. Lang, V. Homo Fennicus. In *Itämerensuomalaisten Etnohistoria*; Suomalaisen Kirjallisuuden Seura: Helsinki, Finland, 2020; p. 249.
7. Edgren, T. *Kivikausi. Suomen Historia I*; Weilin&Göös: Espoo, Finland, 1984; p. 91.
8. Huurre, M. *Satakunnan Historia I*; Satakunnan Maakuntaliitto: Pori, Finland, 1991; p. 233.
9. Lehtonen, K. Eurajoen Etukämppä-hylkeenpyytäjien ja kalastajien tukikohta. In *Kentältä Poimittua 6—Kirjoitelmia Arkeologian Alalta*; Museoviraston Arkeologian Osaston Julkaisuja N:o 11; Helsinki, Finland, 2005; pp. 5–18. Available online: https://www.finna.fi/Record/arto.014342939 (accessed on 27 July 2022).
10. Siiriäinen, A. Archaeological shore displacement chronology in Northern Ostrobothnia, Finland. *Iskos* **1979**, *2*, 5–23.
11. Siiriäinen, A. On archaeology and land uplift in Finland. *Spec. Pap.-Geol. Surv. Finl.* **1987**, *2*, 43–45.
12. Nunes, M. A model for the early settlement of Finland. *Fennosc. Archaeol.* **1987**, *4*, 3–18.
13. Kylli, J. Maa kohoaa, mutta miten? *Muinaistutkija* **2001**, *4*, 22–32.
14. Hakonen, A. Shoreline Displacement of the Finnish Bothnian Bay Coast and the Spatial Patterns of the Coastal Archaeological Record of 4000 BCE–500 CE. *Fennosc. Archaeol.* **2017**, *34*, 5–25.
15. Aukia, L.-M. Rannansiirtyminen ja Ihmisen Toimintaympäristön Muutos Mätäjokilaakson Alueella Esihistoriallisella Ajalla. Master's Thesis, University of Helsinki, Helsinki, Finland, 2010.
16. Räsänen, A. Rannansiirtyminen Oulun Seudulla Alkaen 6000 BP GIS-Mallinnuksella Kuvattuna. Master's Thesis, University of Oulu, Oulu, Finland, 2015.
17. Kylli, J. Asutussysteemi ja toimeentulo muinaisessa Espoossa ja lähiympäristössä. *Muinaistutkija* **2001**, *1*, 2–13.
18. Koskinen, J. Suon Peittämän Esihistoriallisen Maaston Mallinnus: Paikkatietomenetelmän Arviointi Savitaipaleen Rajalamminsuon Kenttämittausten Avulla. Master's Thesis, University of Helsinki, Helsinki, Finland, 2018.
19. Debenjak-Ijäs, A. Asutusta Etsimässä: Menetelmiä Myöhäisrautakautisen Asutuksen Paikallistamiseksi. Master's Thesis, University of Helsinki, Helsinki, Finland, 2018.
20. Damm, C.B.; Skandfer, M.; Jordan, P.D. Peopling Prehistoric Coastlines: Identifying Mid-Holocene Forager Settlement Strategies in Northern Norway. *J. Marit. Archaeol.* **2022**, *17*, 131–160. [CrossRef]
21. Kulttuuriympäristön Palveluikkuna—Webpage. Available online: https://www.kyppi.fi/palveluikkuna/portti/read/asp/default.aspx (accessed on 27 July 2022).
22. Kulturarv—Webpage. Available online: https://aland.maps.arcgis.com/apps/webappviewer/index.html?id=9d7cc07ab4004f0ca620038c4fd416ca (accessed on 27 July 2022).
23. Avoimien Aineistojen Tiedostopalvelu—Webpage. Available online: https://tiedostopalvelu.maanmittauslaitos.fi/tp/kartta?lang=fi (accessed on 27 July 2022).
24. Maanmittauslaitos–Korkeusmalli 2 m. Available online: https://www.maanmittauslaitos.fi/kartat-ja-paikkatieto/asiantuntevalle-kayttajalle/tuotekuvaukset/korkeusmalli-2-m (accessed on 27 July 2022).
25. GTK–Hakku. Available online: https://hakku.gtk.fi/ (accessed on 2 August 2022).
26. Metsäkeskus, Paikkatietoaineistot. Available online: https://www.metsakeskus.fi/fi/avoin-metsa-ja-luontotieto/aineistot-paikkatieto-ohjelmille/paikkatietoaineistot (accessed on 27 July 2022).
27. Tuovinen, T. 1991. Available online: https://www.kyppi.fi/palveluikkuna/raportti/read/asp/hae_liite.aspx?id=101806&ttyyppi=pdf&kansio_id=322 (accessed on 15 August 2022).
28. Fast, J.; Soisalo, J. 2017–2021. Available online: https://www.kyppi.fi/palveluikkuna/mjreki/read/asp/r_kohde_det.aspx?KOHDE_ID=40010015 (accessed on 15 August 2022).
29. Alenius, T. The Paleoecological Study of Three Mires on the Island Kemiönsaari, SW Finland. Appendix 2 in H. Asplund. Kimittae. Sites, Centrality and Long-Term Settlement Change in the Kemiönsaari Region in SW Finland. Doctoral Dissertation, University of Turku, Turku, Finland, 2008; pp. 565–584.
30. Nurminen, K. Kemiönsaari Ölmosviken 2021, KM 43254. Osteologinen Analyysi Kivikautisen Asuinpaikan Kaivauksen Luista. Unpublished Excavation Report. 2022. Available online: https://www.kyppi.fi (accessed on 3 July 2022).
31. Meinander, C. Harjavalta Lyytikänharju. 1955. Available online: https://www.kyppi.fi/palveluikkuna/raportti/read/asp/r_raportti_det.aspx?RAPORTTI_ID=128607 (accessed on 3 July 2022).
32. Taskinen, H. Harjavalta Lyytikänharju. 1983. Available online: https://www.kyppi.fi/palveluikkuna/raportti/read/asp/r_raportti_det.aspx?RAPORTTI_ID=128598 (accessed on 3 July 2022).
33. Pesonen, P. Harjavalta Kraakanmäki 1, Tutkimusraportti. 2014. Available online: https://www.kyppi.fi/palveluikkuna/mjhanke/read/asp/r_hanke_det.aspx?HANKE_ID=10726 (accessed on 3 July 2022).
34. Pesonen, P. Harjavalta Kraakanmäki 2, Tutkimusraportti. 2014. Available online: https://www.kyppi.fi/palveluikkuna/mjhanke/read/asp/r_hanke_det.aspx?HANKE_ID=10724 (accessed on 3 July 2022).
35. Edgrén, H. (Ed.) Rävåsen. In *Finskt Museum 2002*; 109 Årgången; Finska Fornminnesföreningen: Helsingfors, Finland, 2005.
36. Ruonavaara, L. Fyndmaterialet Rävåsen. In *Finskt Museum 2002*; 109 Årgången; Edgrén, H., Ed.; Finska Fornminnesföreningen: Helsingfors, Finland, 2005; p. 35.
37. Mökkönen, T. Kivikautinen maanviljely Suomessa. *Suom. Mus.* **2009**, *116*, 5–35.
38. Cramp, L.J.; Evershed, R.P.; Lavento, M.; Halinen, P.; Mannermaa, K.; Oinonen, M.; Kettunen, J.; Perola, M.; Onkamo, P.; Heyd, V. Neolithic dairy farming at the extreme of agriculture in northern Europe. *Proc. R. Soc.* **2014**, *281*, 20140819. [CrossRef] [PubMed]

39. Ahola, M.; Kirkinen, T.; Vajanto, K.; Ruokolainen, J. On the scent of an animal skin: New evidence on Corded Ware mortuary practices in Northern Europe. *Antiquity* **2018**, *361*, 118–131. [CrossRef]
40. Vanhanen, S.; Gustafsson, S.; Ranheden, H.; Björck, N.; Kemell, M.; Heyd, V. Maritime Hunter-Gatherers Adopt Cultivation at the Farming Extreme of Northern Europe 5000 Years Ago. *Sci. Rep.* **2019**, *9*, 4756. [CrossRef] [PubMed]
41. Pukkila, J. Turku Räntämäki Riihivainio-muinaispeltoa tutkimassa. In *Pitkin Poikin Aurajokea-Arkeologisia Tutkimuksia*; Turun Museokeskus Raportteja 23; Turun Museokeskus: Turku, Finland, 2019; pp. 7–24.
42. Salo, U. *Sastamalan Historia 1,1. Esihistoria*; Karisto oy: Hämeenlinna, Finland, 2004; pp. 123, 124, 128.
43. Tolonen, M. Vegetational history in coastal SW Finland studied on a lake and peatbog by pollen and charcoal analyses. *Ann. Bot. Fenn.* **1987**, *24*, 353–370.
44. Aalto, M.; Siiriäinen, A.; Vuorela, I. Humppila Järvensuo—A preinvestigation for an archaeological and paleobotanical project in SW Finland. *Iskos* **1985**, *5*, 165–177.
45. Storå, J. Sealing and animal husbandry in the Ålandic Middle and Late Neotithic. *Fennosc. Archaeol.* **2021**, *17*, 57–81.
46. Bläuer, A.; Kantanen, J. Transition from hunting to animal husbandry in Southern, Western and Eastern Finland: New dated osteological evidence. *J. Archaeol. Sci.* **2013**, *40*, 1646–1666. [CrossRef]
47. Pääkkönen, M.; Holmqvist, E.; Bläuer, A.; Evershed, R.P.; Asplund, H. Diverse Economic Patterns in the North Baltic Sea Region in the Late Neolithic and Early Metal Periods. *Eur. J. Archaeol.* **2019**, *23*, 4–21. [CrossRef]
48. Museovirasto–Arkeologisten Kenttätöiden Laatuohjeet. Available online: https://www.museovirasto.fi/fi/kulttuuriymparisto/arkeologinen-kulttuuriperinto/arkeologisen-kulttuuriperinnon-tutkimus/arkeologisten-kenttatoiden-laatuohjeet (accessed on 31 July 2022).
49. Roiha, J. *Digitaaliset Aineistot Arkeologisissa Kenttätutkimuksissa-Nykytila ja Kehittämistarpeet*; Museovirasto (Finnish Heritage Agency): Helsinki, Finland, 2020.

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Article

Using Interdisciplinary Techniques for Digital Reconstruction of Anti-Turkish Fortification Watchtower

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Abstract: Modern heritage protection goes beyond the mere protection of individual buildings and objects. Modern technologies and techniques of field data capture and visual (3D) presentations are increasingly penetrating this field and are becoming more and more essential and necessary for archives, cadastres, and users and visitors of museums, exhibitions, collections, and archaeological parks. In the area between Kotlje and Ravne na Koroškem, Slovenia, in 1476–1477, 9 to 10 anti-Turkish fortifications, called Turške Šance, reportedly were erected. The remains were left to decay slowly. This paper highlights the possibility of applying interdisciplinary data capture and 3D visualization techniques that are used in the fields of civil engineering and architecture for digital reconstruction of the anti-Turkish fortification as a case study in order to present them in the most contemporary way and emphasize them on a local, regional, national, and international level. Unfortunately, similar remains elsewhere in Europe are primarily ignored (with some notable exceptions). The digital reconstruction of anti-Turkish watchtowers therefore represented an extended reconstruction to revive that part of the historical heritage of Slovenia using the proposed techniques.

Keywords: anti-Turkish fortification; 3D visualization; watchtower; tschartake; moat; trench; mound; čardak; Çardak; digital archaeology

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1. Introduction

Archaeological studies include the documentation and investigation of archaeological vestiges and the development of virtual recreations and reconstructions [1].

In this paper, the focus is on the type of virtual reconstruction in which computer graphics are used to reconstruct nonexistent historic objects to provide a better understanding of and generate hypotheses and interpretations of various evidence. Further, we propose an applicable framework with steps for the virtual archaeological reconstruction process of small-scale historic monuments with an interdisciplinary scenario in which accessible architectural and civil engineering tools are used for surveying and 3D modeling.

Virtual reconstruction is an archaeological and architectural field that has transitioned to the digital realm in recent decades [2]. Virtual, which means "potential" and conveys the likelihood of an object having existed in the past, comes from the Latin word "virtus". Such reconstruction predates the invention of the computer and is not just a digital issue. The Envois de Rome of the French Academy of Sciences provides strong support for the theory of reconstruction in archaeology and building [3].

According to El-Hakim et al. [4], there are numerous reasons for the 3D reconstruction of heritage sites, the most important of which are: reconstructing historic monuments that no longer or only partially exist; visualizing scenes from perspectives that are impossible to achieve in the real world; interacting with objects without risk of damage; and providing virtual tourism and exhibits. Therefore, both experts and the general public are already aware of 3D reconstructions of historic structures, even entire towns. A significant body of literature has also been written on the advantages and disadvantages of this method [5].

The first commercial 3D software package, Wavefront Technologies, was introduced in 1984 to meet the expanding demands of motion pictures, after which three-dimensional computer graphics techniques grew in popularity in the television and film industries. The earliest recorded work was that of the bath building at Caerleon Roman Fort in South Wales [6]. A year later, the Old Minster of Winchester's animated virtual tour became the first of its kind [7].

A wide range of cultural organizations, including museums, are now able to apply interactive techniques and information technologies due to the advancement of their software and hardware as well as a reduction in their prices. A lack of exhibition space, high exhibition costs, and the fragility of some artifacts that museum administrators desire to safeguard against potential damage were all addressed by these new technologies. To visualize the cultural background of museum exhibitions, curators have acknowledged and successfully utilized the significance of the new methodologies and instruments [8,9]. Furthermore, museum curators use these new technologies to digitize information on exhibition artifacts and to display and spread cultural information to the public in an appealing and effective manner [8].

According to Demetrescu [2], the reconstruction pipeline shown in Figure 1 begins with the gathering of all the facts about a monument on the field (survey or excavation). All accessible sources are gathered in addition to the work being done on the field, including old sketches, pictures, and data from situations that are extremely similar. The so-called dossier comparatif [10] is a convenient place to store and organize all of these details. The next step is to use the dossier comparatif to produce the eidotipi, sketches, or technical drawings using digital tools [11], during which the researcher can make any necessary corrections to their initial hypothesis before beginning to model in 3D. In this scheme, the 3D model appears to be the final stage and the result of the entire procedure. If there is an "incongruity", as a result, the 3D reconstruction hypothesis must be changed. The simulation serves as a test of the accuracy of the reconstruction; the researcher must make changes to the dossier comparatif or eidotipi or simply conduct more research or find other sources of study.

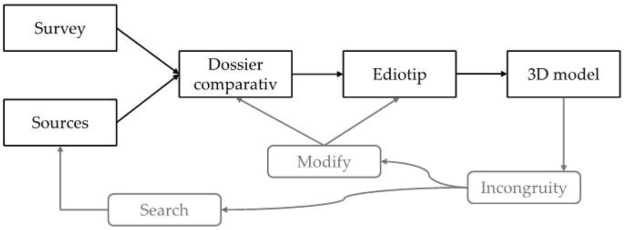

Figure 1. Archaeological theory in virtual reconstruction according to Demetrescu [2].

Both reality-based modeling, which is the digital acquisition through a 3D survey of existing archaeological contexts [2], and source-based modeling, which is the virtual restoration of nonexisting archaeological contexts [12], can be used to create 3D content for cultural heritage. In the first instance, the model's "accuracy" is quantitative, whereas in the second instance, the accuracy is qualitative because it is derived from sources with different degrees of reliability.

The goal of this research was to propose the steps involved in heritage visualization, including the sources that were chosen and how they were used in the virtual reconstruction, rather than to suggest solutions for the visualization of the 3D model's degree of reliability.

According to Demetrescu [13], virtual reconstruction is occasionally confused with mesh reconstruction or postprocessing of a digital capture. It consists of a number of phases that include documenting, interpreting, and visualizing missing archaeological contexts. Although the scientific world has acknowledged the promise of this application [13–18], there are not many case studies on reconstruction in the literature, and its contributions to the incorporation of 3D modeling in archaeological research methods are not very common either. Only 20% of studies on the application of 3D technology in archaeology, according to Münster and Koehler [19], concentrated on the 3D reconstruction of lost contexts. Additionally, most of the initiatives covered in 452 journal papers and conference proceedings included constructing models for already-existing structures and collecting data. Only 16% were concerned with architecture that is no longer in existence, which is intriguing for research on the connections between conventional humanities and digital technologies [19]. Additionally, most authors were connected to institutes that deal with computing (70%) whereas only 14% and 9% respectively come from the engineering and architectural professions. Due to this, virtual reconstruction of lost heritage is still a relatively undefined discipline in the field of archaeological research and its methodology is still highly dispersed in terms of data transparency and acceptance.

However, technical workflows are well established and comparable to other 3D modeling chores such as engineering and design for a VR or CAD modeling of nonexistent objects. Dealing with historical sources or transdisciplinary workflows are more often the specific challenges for these interpretative reconstructions [19].

Therefore, the goal of this paper was to propose an applicable interdisciplinary framework with steps for the virtual archaeological reconstruction process of small-scale historic monuments that no longer or only partially exist.

1.1. Digital Archaeology and Interdisciplinary Methods

Today, the practice of making digital replicas of artworks and restoring and recontextualizing them within artificial simulations is widespread in the virtual heritage domain [20]. The modern audience increasingly relies on audio–visual aids to absorb complex ideas or stories quickly [21]. Visual reconstructions of archaeological sites and materials have been around since before the formal construction of archaeology as a discipline itself. However, there has been an expansion of the methods of reconstructing and representing the past in recent decades due to the use of digital technology [22]. The 3D modeling of archaeological sites and artifacts can generate aesthetically pleasing visualizations; nevertheless, considerations of scientific accuracy, ethics, and educational value are needed. From a scientific point of view, it is also important to show the process, appropriate documentation, and used source materials [23].

The use of visual aids and digital media in archaeology is critical not only for public dissemination, but also within the academic community. As a result, museums, cultural institutions, and government agencies should revise their public-interest strategies for history, archaeology, and the environment. Archaeologists are borrowing tools, techniques, and theories from other disciplines to improve the way they collect, analyze, and disseminate archaeological data. Digital media and technology provide a variety of novel and creative methods for capturing public attention and increasing overall competency and appreciation for the past [24,25]. Modern 3D software tools can help with heritage visualization production. They can significantly improve visuals and aesthetics for the presentation of a holistic image of the past, even if they are mostly employed for animation, gaming, and architecture [26].

Therefore, this study highlighted the possibility of applying interdisciplinary data capture and 3D visualization techniques being used in the fields of civil engineering and architecture for digital reconstruction of an anti-Turkish watchtower as a case study, as well as an overview of the practical process of performing such science-based archaeological 3D reconstructions and visualizations, so that they are constructed and presented in the most scientifically sound, informative, and entertaining manner possible in order to ultimately inform and engage the wider public. According to Lopez-Menchero and Grande [27], as long as computer-based visualizations are utilized to enhance archaeological heritage rather than to draw attention away from the actual site or an item in a museum, it is beneficial. Furthermore, if the artifact or location is appropriately introduced and contextualized with the significance of the legacy to a larger historical discourse, there may be a higher appreciation for the object or location [25].

1.2. Case Study—Turške Šance in Slovenia

The system of anti-Turkish trenches (mounds) and fortifications (towers), which is said to have been mentioned already at the end of the 15th century, was used as a case study. The chronicler Jakob Unrest wrote in his *Austrian Chronicle*, which covers the period from 1452–1499, that in 1476 the lords of the land collected a tax which they used to build walls and military outposts to defend against Turkish incursions, starting with a long barrier with outposts near Ravne in Carinthia [28]. Unrest is later quoted by many authors as constantly repeating the following phrase: "Ein lange Lanndt Wer zw Guettenstaynn mit Posteyn" [29], which they translated to mean that at Ravne, there were long barriers with guardhouses [30] that were built by locals after the Turkish invasion in 1476, according to Unrest.

The construction was thought to have taken place at the end of 1476 and the beginning of 1477 [31–33]. There were said to be 9 to 10 fortifications in all. They were placed along the old road from the Ravne manor to the church of St. Mohor and Fortunat in Podgora. The church, which had already been damaged before, was secured with a moat. The Grinfels manor was included in the new anti-Turkish valley barrier [34], which started on the left bank of the Meža river and continued to the foot of the mountain Uršlja gora to the Dvornik farm in a total distance of just over 4 km. In July 1478, the Turk forces returned from Carinthia with loot and many captives, passing Slovenj Gradec [35]. What happened to the Turkish trenches after 1478 is not known.

The first preserved map of the Turkish trenches dates from the second half of the 16th century [36] (see upper right corner in Figure 2a—due to cartographic reduction, only five are depicted); they are also drawn on the Franciscan-Josephine cadastre (third military measurements (1769–1787)) on the Franciscan map, but from 1825, they are not marked. Some similar watchtowers on the Kolpa River between todays Slovenia/Croatia state border can also be seen in Figure 2b by Martin Stier from 1664.

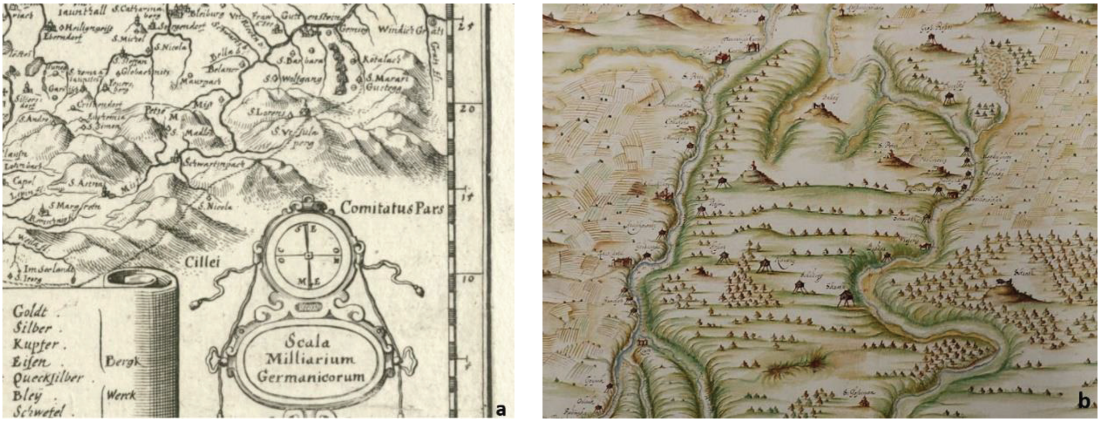

Figure 2. (**a**) A Carinthia map in the second half of the 16th century (I. Holzwurm (1575–1617)) [36]; (**b**): watchtowers on the Kolpa river, Slovenia/Croatia state border [37].

Most trenches today have a diameter between 30 and 40 m; the size of the central space, where the watchtowers were supposed to stand, varies between 5 × 5 to 6 × 6 m. The exception is double trench number 6 (TŠ 6), which is larger and where a military crew could be accommodated in the wooden watchtower in the middle plateau. The shape of the wooden watchtower or "Čardak", as we know it from many Croatian sites and the later Vojna Krajina [11–39], seems to be the most likely. It is interesting to see that the same word

"Chardak" is today also used for a balcony with the windows closed [40]. The word derives from a Persian chahartaq (having four arches) (in German, tschartake; in Turkish, Çardak), meaning a watchtower and an important element of the fortification systems in the time of the Ottoman Empire. The term was also known in the mid-east area [41].

In Posavje, the Čardaks stood only on the left, Habsburg side of the bank of the Sava River, while on the right side of the Ottoman Empire stood the so-called caravels [38]. In addition to Croatia, Čardaks were built on the territory of Carniola, Styria, Carinthia, and Hungary [38]. The oldest type of Čardak was square [38] and was first mentioned in Croatia in 1521 and Styria in 1522 [39].

Research on Croatian sites and reconstructions of Čardaks along the Austro-Hungarian border (e.g., Hohenbrugg in the valley of the Raba River and Burgauberg-Neudauberg (Austrian part of Gradiščanski)) would indicate the most probable appearance of Slovenian watchtowers if they were reconstructed. Except for the double larger mound, the area of the central plateau on all the other moats, where watchtowers could have been built, was approximately 4 × 4 to 5 × 5 m in size (surface area, therefore between 20 and 25 m^2). The watchtowers stood on four corner pillars with a diameter between 20 and 25 cm and a height of approximately 3 m [12,39]. A wooden house was built on top of these pillars. The house had a wooden floor with a central opening for lowering and raising a ladder, through which the guards could climb into the upper part. The opening could be closed with a wooden flap if necessary. The floor and walls of the house were built from horizontal planks. On the wooden floor of the guardhouse, four supporting pillars for the roof structure and a protective wooden fence were placed (parapet).

The walls were closed only up to about two-thirds; the rest was open on all four sides with larger rectangular openings for observation of the surroundings. The wall was additionally protected from the inside with narrower vertical boards. The roof was covered with oak shingles [39] (in our area, more likely larch). Oakwood was mainly used for the construction of the Čardak and roof. Boards, posts, and shingles were attached with variously shaped forged iron nails. The lower part of the Čardak was secured with a fence with sharpened stakes attached to the pillars. Part of the fence had to be moved to access the porch. There was room for 6 to 10 guards in such a Čardak. In the house itself, we could expect a wooden bench, modest beds (bags of hay), a wooden chest for storing weapons/earthenware/lamps, a movable ladder and perhaps an even smaller earthen stove for cooking/heating, remains of lead grains for guns, metal parts, military boots, etc. [39].

Horses were tied up near the Čardak, and there had to be a place to light a bonfire with prepared brambles and branches. Signaling could also take place by shooting or ringing bells in churches [39]. Among weapons, Matijaško [39] lists personal cold armaments (e.g., knives), mortars, rifles (matches), and long spears.

The guardhouse was therefore protected first by a high embankment, then by a ditch with stagnant water, further by the steep bank of the central elevation, and then by the elevation of the guardhouse from the ground. In addition, as the terrain's configuration shows, the guardhouse with other trenches in more exposed places was most likely protected in areas with a wooden palisade.

The form of Čardaks was preserved until the 18th century. Most of them were built after the peace agreement signed in Srijemski Karlovci (Serbia) in 1699 between representatives of the Holy League and the Ottoman Empire [39]. Croatia's only reconstructed Čardak (younger, from the 18th century) is in the Lonjsko field Nature Park in the Krapje Dol ornithological reserve.

2. Archaeological Context—Similar Watchtowers in Europe

At least 33 similar constructions or remains were found across Europe (Table 1). Most of them in are in Croatia (15), Serbia (7), Germany (5), Austria (3), and BIH (2); 1 is unknown. Most of them, according to gathered data, were built in the 16th or 17th century.

Their positions are also visible in Figure 3. Some location data and construction years were unavailable.

Table 1. Čardaks across Europe.

No.	Place	Country	E	N	Year or Century
1	Lütjenburg [42]	Germany	10°34′18.4″	54°18′05.1″	/
2	Dragići [43]	Croatia	17°18′44.9″	45°12′24.1″	/
3	Senj [44]	Croatia	14°54′32.5″	44°59′23.0″	16th cent.
4	Otočac [44]	Croatia	15°13′47.4″	44°52′07.8″	16th cent.
5	Slunj [44]	Croatia	15°34′55.0″	45°06′57.3″	16th cent.
6	Glina [44]	Croatia	16°05′32.8″	45°20′25.3″	16th cent.
7	Hrastovica [44]	Croatia	15°08′47.8″	45°58′08.8″	16th cent.
8	Sisak [44]	Croatia	16°22′58.2″	45°28′34.0″	16th cent.
9	Ivanić [44]	Croatia	16°23′36.9″	45°42′32.4″	16th cent.
10	Koprivnica [44]	Croatia	16°49′25.4″	46°10′03.7″	16th cent.
11	Križevci [44]	Croatia	16°32′18.5″	46°01′58.2″	16th cent.
12	Đurđevac [44]	Croatia	17°03′48.5″	46°02′27.6″	16th cent.
13	Drnje [44]	Croatia	16°55′55.2″	46°12′48.7″	16th cent.
14	Stupanj [45]	BIH	19°05′25.7″	44°48′20.2″	/
15	Subotište [45]	Serbia	19°57′24.5″	44°50′53.0″	/
16	Ada [45]	Serbia	20°06′47.9″	45°48′57.7″	/
17	Lisačka [45]	Serbia	/	/	/
18	Majur [45]	Serbia	19°38′56.8″	44°46′07.6″	/
19	Bosut [45]	Serbia	19°21′47.0″	44°56′37.2″	/
20	Protina Bašta [45]	/	/	/	/
21	Beli Breg [45]	Serbia	21°49′09.1″	43°28′30.1″	/
22	Petrova gora to	Croatia to	16°01′36.6″	46°09′53.9″	1669
23	Novi Grad [46]	BIH	16°23′28.8″	45°02′14.3″	1669
24	Stara Gradiška to	Croatia to	17°14′37.9″	45°08′55.9″	/
25	Zemun [46]	Serbia	20°17′28.7″	44°52′52.6″	/
26	Pforzheim [47]	Germany	8°46′55.9″	48°54′16.0″	1695–1697
27	Ötisheim [48]	Germany	8°49′53.7″	48°58′07.4″	1695–1697
28	Sulzfeld [48]	Germany	8°52′03.6″	49°05′05.0″	1695–1697
29	Eppingen [47]	Germany	8°56′25.5″	49°06′40.0″	1695–1697
30	Lafnitz [49]	Austria	16°01′26.3″	47°22′27.3″	1700
31	Burgau [50]	Austria	16°04′53.8″	47°08′30.4″	/
32	Fehring [51]	Austria	16°00′49.8″	46°56′12.3″	1706
33	Vikići [52]	Croatia	/	/	/

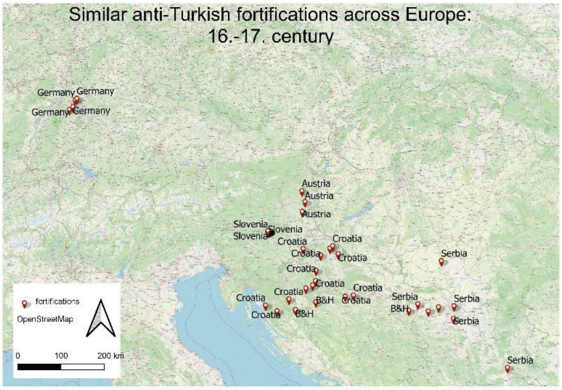

Figure 3. Similar watchtowers across Europe.

Some reconstructions have been made. Figure 4 shows examples from several places in Germany, Austria, Serbia, and Croatia. According to the literature, the Croatian rebuilding is the most similar to the fortifications that could be erected in Slovenia previously. The watchtowers were recreated using materials that were most likely used at the time of their creation (larch or oak). However, reconstructions of buildings that have been demolished are rarely carried out. In such cases, cheaper methods such as 3D modeling can be used. A good example is the creation of a 3D model of the altars and interiors of the Çatalhöyük houses in Turkey [53], the church of San Nicolò, Italy [54], or the recreation of the lararium of the Roman domus of Torreparedones [55].

Figure 4. Some 1:1 reconstructions: (**a**) Niefern-Oschelbron, Germany; (**b**) Burgau/Lafnitz, Austria; (**c**) Šumadija, Serbia; (**d**) Dragalić, Croatia.

3. Civil Engineering Context

3.1. Fieldwork Methods

3.1.1. Aero-Photogrammetry Modeling

With the help of the point cloud obtained using a DJI Mavic Pro drone (Shenzhen DJI Sciences and Technologies Ltd., Shenzhen, PRC), we created 3D models of the terrain using different programs (Pix4D (S.A., Prilly, Switzerland), Autodesk Recap EDU ver. 6.2, and Recap Photo EDU ver. 20.3.1.47 (Autodesk Inc., San Francisco, CA, USA)). This photogrammetry software uses images to generate point clouds, digital surface and terrain models, orthomosaics, textured models, and more. A digital elevation model, which is a model that contains all elevations such as trees, roofs of buildings, etc., was also created.

With the help of the drone photos, a 3D model of the moat was created in Recap Photo. Official free Lidar recordings were also available to us. With the use of the Recap program, a 3D model of the surroundings also was created (Figure 5).

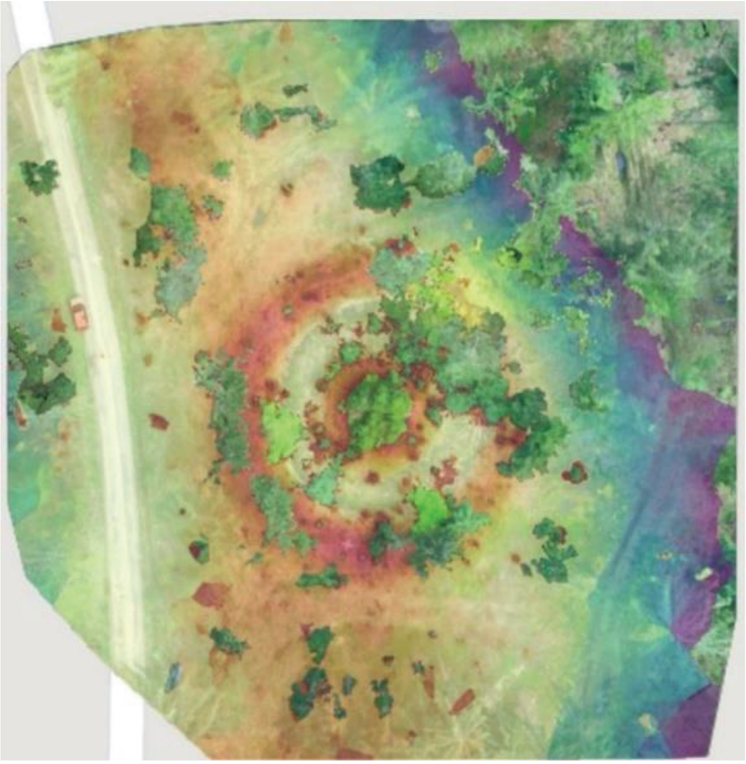

Figure 5. 3D model of TŠ3 trench.

3.1.2. Archaeological Excavations

The excavation was carried out at the location of the third moat (TŠ3) in 2020. The archaeological research aimed to determine what materials the watchtower was made of, how it was built, and the age of the objects found. Two probes were opened (see the geodetic plan in Figure 6). The work in Probe 1, which ran over the outer embankment, was carried out mechanically. On the central plateau, excavations in Probe 2 (Figure 7) were carried out exclusively by hand due to the steep bank of the trench and standing water in the ditch. The depth of standing water in the ditch was between 0.3 and 0.5 m at that time. Probe 2 was placed along the entire length of the plateau (it occupied more than 38% of the surface) in the least forested part (see Figures 6 and 7). The double ditch (TŠ6), given its position at the top of the ridge and the double ditch that surrounded it, was at least intended for a permanent or occasionally inhabited military crew that had to stay in the watchtower. Unfortunately, TŠ6 could not be explored further at the time because it was not fully accessible. In Probe 1, no traces of fortifications or the remains of some stakes that would additionally protect the tower were found. The oldest and only discovery during the research was a late medieval clay roof tile from Probe 1. The absence of archaeological records (traces) may indicate that a guardhouse was not built on this trench (TŠ3) but may also mean that the watchtower was not fully built.

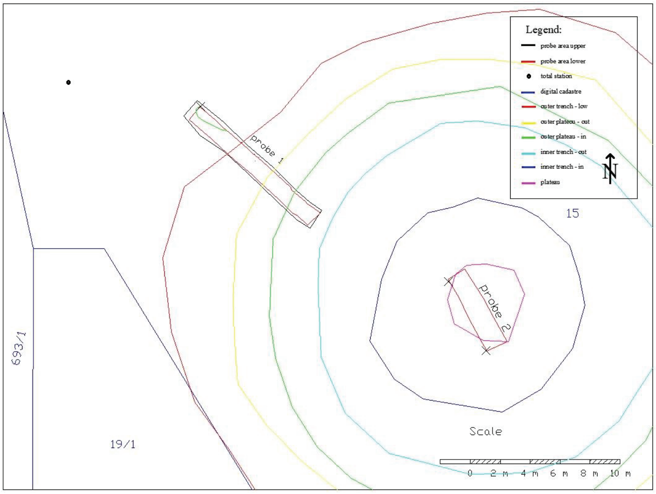

Figure 6. Geodetic plan of excavations.

Figure 7. Probe 2 (view to the north).

3.1.3. Metal Detector Investigation

The entire area of TŠ3 was also investigated using a metal detector. Seventeen points of potential interest were identified. All were located on the embankment; the sensor did not detect any metal remains on the central plateau. After surveying all the points, the objects were excavated. Most were scraps of various aluminum foil, cans, and bottle caps. A post-war copper hunting cartridge (RWS 7 × 64), a Yugoslavian five para coin (item T216), and an iron nut from a tractor (item T215) were found. All finds were between 2 and 10 cm deep in the humus layer of Probe 1.

3.2. Static, Material, and Cost Calculations

In the territory of the central and southern Balkans, there has been a square tower form of architecture built of stone (kula or tower house) since the 13th century. They served both civilian (residential buildings) and military purposes. The phenomenon of the extended family typical of Southeastern Europe, in which the home was often protected, gave rise to the kula or tower house [56].

Čardak, as already explained in the introduction, is the Turkish word for a wooden building on four pillars. At the time of the Ottoman invasions, they were the most widespread form of wooden guardhouses in the wider territory of Serbia, Croatia, Austria, and Germany. They were intended for reconnaissance, so their shape was most probably based on the kula or tower house. They were used to monitor the movements of Turkish troops and alert the local population.

Wooden construction was typical for this period in our area, both in the countryside and in cities (the exception was the castles or mansions of the upper classes) [57]. Building with wood was cheaper and the consumption of wood for a Čardak was small. Wood began to run out in our country in the 17th century (due to glassworks and ironworks). Wood was also more accessible (it could be cut and processed in the immediate vicinity), there was almost no transport, and the technological process was simple.

The structural safety assessment of heritage objects is a common process in assessing the condition of the structure and is needed in the cases of reconstruction, renovation, and/or rebuilding. The cases such as Torre de la Vela in la Alhambra, Granada, Spain [58]; Qutb Minar, India, as one of the tallest stone masonry towers [59]; the medieval masonry bell tower in the Cathedral of Fiesole, Italy [60]; and churches after the earthquake [61] are good examples of including static analysis in the heritage building research.

Regarding the history of construction, the characterization of the construction materials, seismic assessment, and static and dynamic monitoring, many studies have been carried out in the Mallorca Cathedral. They included historical investigations of the building's development, examination of the soil beneath it and its structural components, structural assessments using both straightforward and sophisticated methods, and monitoring [62]. Furthermore, a study by Gençer [63] aimed to identify factors influencing structural resistance and failure mechanisms of ashlar Cilician dry masonry watchtowers under lateral stress. Then, by using the quasistatic tilting approach, virtual towers were created based on the characteristics found in the case study.

Another study by Elyamani in 2018 [64] aimed to provide a proposal for the reuse of the Baron Empain Palace in Cairo. To support this reuse proposal, a 3D numerical model of the palace was created and the new expected loads were applied on it. It was discovered that the palace's walls and foundations could withstand the new loads. The slabs were discovered to be unable to sustain the new loads in some places; further investigation and analysis are required to determine their actual capacity.

For this study, the static calculation of the digitally designed watchtower was carried out according to Eurocode regulations and the analysis was carried out using the SCIA Engineer program. The model can be seen in Figure 8. All possible loadings were considered: constant load, payload, wind load, snow load, and earthquake load. The roofing, pillars, rod arms between the platform and the column, and the platform were also dimensioned. A material utilization review was also conducted.

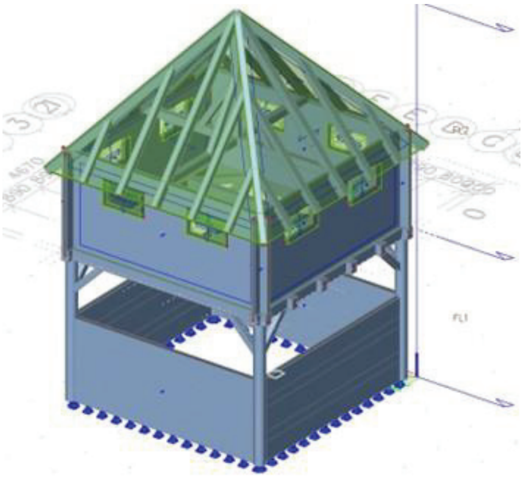

Figure 8. Static calculations for a watchtower.

Each element that made up the watchtower was listed as a segment of the wooden structure along with its dimensions and the number of individual pieces; only a part was given in m^2 for a more straightforward interpretation and cost estimation (Table 2).

Table 2. Elements of the watchtower.

Element	**Dimensions (cm)** **Width**	**Height**	**Length**	**Number (Pieces)**
		Lower part		
Support column	Ø = 26 cm	-	300	4
Supporting diagonal	12	12	80	8
Cross board (bottom)	3	20	427	8
Pillar fence	Ø = 8 cm	-	170	97
A stake with a point	8	8	210	101
Pointed pillar (door)	Ø = 16 cm	-	230	2
Diagonal (door)	10	1.5	110	2
		Upper part		
Board—wall	8	15	490	52
Board—floor	20	5	434	22
Crossbars (platform)	16	22	450	8
Stick hands	12	12	132	4
		Roof (inclination 45°)		
Rafter	12	16	333	8
Beams	12	16	450	6
Stick hands	12	12	132	4
Roofing (shingles)	area:		64.45 m^2	
Substructure for shingles	4	5	305	*
		Ladder		
Pillar	6	15	410	2
Walking crossbars	10	6	75	8
		Shutters		
Horizontal slats (frame)	15	4	100	16
Vertical slats (frame)	10	3	42	16
Cross slats	9.5	3	80	32
Diagonal	10	1.5	41	8
		Bridge		
Boards	20	5	200	92
Boards (construction)	8	16	500	6
Transverse beams	8	16	200	8
Pillars	Ø = 25 cm	-	550	5
Pillars	Ø = 25 cm	-	190	4
Slats (fence)	10	15	478	6
Slats (diagonal)	10	10	85	24
Substructure for walking boards	8	16	500	5
Gravel fill		0.59 m^3		
		Foundation		
Point foundations	80	80	80	4

* The number of slats (dimensions 4 × 5 × 305 cm) that served as a substructure for the selected roofing depended on the roof construction itself and the selected shingle dimensions.

The watchtower was thus divided into three segments: the lower part, the upper part, and the roof, which covered the entire tower. A ladder used for vertical communication in the watchtower and shutters were also included on the list. A special section was also dedicated to the bridge and the foundations, where only the approximate values of the individual point foundations were listed.

Sustainable tourism should embrace concerns for environmental protection; social equity; the quality of life; cultural diversity; and a dynamic, viable economy delivering jobs and prosperity for all [65]. Nowadays, when referring to cultural heritage objects, one of the first aspects implies not only the object itself, but also creating 3D models using different technologies [66]. Nowadays, many researchers explore different methods for documentation, management, and sustainability of cultural heritage, which has become an interdisciplinary approach to the development of culture [67]. A 3D model of cultural heritage is one of the possibilities for sustainable tourism and cultural heritage. In the Strategic Baselines of the Development Cohesion Region of Eastern Slovenia [68] and the strategy of the Regional Development Program for the Carinthia Development Region 2021–2027 [69], one of the main goals in the field of sustainable tourism is the goal of developing and upgrading the basic tourist infrastructure, including the revitalization of cultural heritage buildings. By researching the Turške Šance watchtowers, including their appearance and a detailed analysis of the construction costs, some potential investors should be encouraged to engage in a physical reconstruction.

Table 3 shows the inventory of the needed material necessary for constructing the entire wooden structure, consisting of the previously listed materials.

Table 3. Prices for needed materials.

Purchase Goods	Purchase Price (EUR per Piece)	Quantity	Price (EUR)
Oak support round column Ø = 26 cm, 300 cm	25	4	100
Oak round column Ø = 25 cm, 550 cm	43.85	5	219.25
Oak round column Ø = 25 cm, 200 cm	15.95	4	63.8
Beam (larch) 12 × 12 × 400 cm	17.6	6	105.6
Oak board 3 × 20 × 430 cm	15	8	120
Larch round pillar Ø = 16, 250 cm	12.75	2	25.5
Wood pointed pillar round Ø = 8, 200 cm	7.47	100	747
Rectangular stake (larch) 8 × 8 × 400 cm	8.49	101	857.49
Oak board 8 × 15 × 490 cm	33	52	1716.00
Solid flat larch slats 10 × 1,5 × 200 cm	6.5	4	26
Wood—Siberian larch 5 × 20 × 450 cm	41	22	902
Wood—Siberian larch 16 × 22 × 450 cm	48.4	8	387.2
Beam (larch) 12 × 16 × 400 cm	23.47	8	187.76
Beam (larch) 12 × 16 × 450 cm	26.4	6	158.4
Beam (larch) 6 × 15 × 410 cm	14.27	2	28.54
Beam (larch) 10 × 6 × 100 cm	5.63	8	45.04
A flat board made of Siberian larch 15 × 4 × 400 cm	14.25	4	57
Wood—Siberian larch 3 × 10 400 cm	12.21	2	24.42
Wood—Siberian larch 3 × 9.5 × 400 cm	11.96	7	83.72
Wood—Siberian larch 5 × 20 × 400 cm	36.7	46	1688.2
Siberian larch tree 8 × 16 × 500 cm	19.55	11	215.05
Siberian larch tree 8 × 16 × 400 cm	15.65	4	62.6
Beam (larch) 10 × 15 × 500 cm	23.79	6	142.74
Beam (larch) 10 × 10 × 400 cm	12.07	6	72.42
Roof **	EUR 72.00/m^2	64.45 m^2	4640.59
Natural gravel 0/63 mm	EUR 8.92/m^3	0.59	5.26
SUM			12,681.58

** The production of the entire roof structure using the materials found in the list of works and the price per m^2 for the entire roof was considered under the assumption that the roof consisted of rafters and horizontal layers and was laid in two layers with nailed shingles. The shingles, as well as the entire roof, were made of Siberian larch wood.

The prices of individual pieces were valid for the period of spring 2020 in the Slovenian territory. They were obtained from technical stores with building materials and other intermediaries of wood products or semifinished products. The prices of semifinished wood products may vary depending on the price changes in the market for forest wood assortments. They also differed in the cases of volume discounts from the technical wood broker or other contractual factors when purchasing semifinished products.

Since there not all the dry wooden semifinished products in the exact dimensions needed for the project are available, the processing of the purchased materials will result in some wasted (unnecessary) parts, which should be managed in an appropriately (ecologically indisputable) way.

In addition to each product's value, the purchase price per piece included the trade margin and the tax, which was 22% according to the Slovenian VAT legislation at the general rate.

4. Architectural Context—Results

After collecting the data, a 3D digital reconstruction was prepared. When architects design projects, they must produce a representation for the client that translates their concepts and the structure's requirements. Therefore, the process of creating a visualization is done in terms of tools and materials modified from digital 3D modeling approaches used in architecture. According to Schoueri and Ferreira [22], realistic foundations should underlie the building and its surroundings. The archaeological structures are frequently complex and made up of both old and new constructions in varying stages of development. Therefore, it is important to take care and consider how the visualizations are created and presented.

The modeling process was started using Graphisoft Archicad 23 software (Educational version, Budapest, Hungary). The modeling began with simple blocks that delineated the structure's dimensions as well as known wall heights and the roofing situation. The wall thicknesses and door and window openings were estimated for the structure and were included at this stage.

To create the best possible reconstruction, contemporary analogies to the most common trend for the region and time period were researched. The towers on the Turkish moats were the same as Čardaks in terms of the construction method and the use of materials, and thus served as an example.

The watchtower (Figure 9) was placed on four round pillars made of oak wood on which stood a simple wooden guard room with a square floor plan of 4.5 m × 4.5 m intended for about eight guards. Support columns with a diameter of about 25 cm were buried in the ground. The strengthening foundations for the columns were represented by larger stones, which filled the holes and served for drainage purposes and prevented the rotting of the buried wood. The height of the walls of the guard room corresponded to the average size of a standing man (about 1.9 m). It was made of wooden oak layers, which were used for walls and floors. They were connected in the corner with a carpenter's bond and fastened with forged nails.

Figure 9. The 3D visualization of the watchtower [70].

The upper part of the guard room was built of horizontal wooden beams up to approx. two-thirds. To be able to guard and observe the surroundings, square openings were cut above them in the upper part, which could be closed with simple wooden covers in case of bad weather. On the inside of the house, narrower vertical boards were nailed to these two-thirds. The roof of the guard room rested on four vertical pillars and was covered with oak shingles.

A wooden bridge made of the same materials as the watchtower itself led to the watchtower (Figure 10). Two intermediate supports were added for static stability and a fence for safety.

Figure 10. Bridge leading to the watchtower over the trench [70].

The interior of the guard room was complemented by the most necessary furniture, namely a wooden bench, a bunk bed, a wooden chest, and a small clay oven for cooking food and pottery (Figures 11 and 12). The selected archaeological objects represented typical pieces of interior design, tools, and weapons from this period [39].

Figure 11. Interior of the guard room [70].

Figure 12. Interior of the guard room [70].

5. Discussion

As presented in the Introduction, some interdisciplinary reconstructions have been documented in the past decades [19,71] and also in recent years; however, most of them were of existing objects [4,13,64,72,73] The virtual reconstructions that were carried out for objects that no longer or only partly existed [5,74] used complicated frameworks and tools such as the specialized design software Rhinocerous 3D, visual blueprint programming, Agisoft Metashape, or the Stencil Kaarta instrument, or expensive equipment such as a terrestrial laser scanner. Therefore, this study presented a possible interdisciplinary scenario in which the accessible architectural software Archicad ver 23 was used for modeling and Lumion software ver. 10.5 (Leiden, The Netherlands) for architecture was used for visualization along with the use of most common modeling techniques in architectural practice. Furthermore, for the photogrammetry analysis of the land, a DJI drone and official free Lidar data were used for the 3D analysis of the location. Furthermore, manual on-site archaeological excavation and soil analysis with a metal detector were carried out.

Moreover, the reconstruction pipeline [2] was extended with applicable tools for each of the phases, adding to the archaeological theory in the virtual reconstruction (Figure 13). In addition, this paper also focused on the application of tools that are economically very feasible. Such application can be achieved with the tools of any midsized design company.

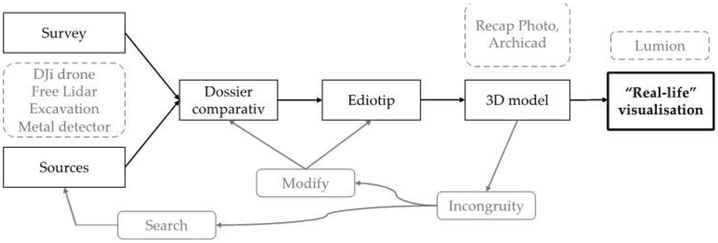

Figure 13. Extended pipeline with applicable tools.

6. Conclusions

A unique system of anti-Turkish fortifications—defensive ditches that were prepared for the construction of watchtowers, or Čardaks—that has been preserved in Preški Vrh was used as a case study. It was built in the last quarter of the 15th century by the Carinthian provincial estates as a valley barrier against Turkish invasions. The moats were of various shapes and sizes; 10 are mentioned in the literature and 9 are recognized in the field today. Among them, only five have been preserved to their original extent. For the defense of Carinthia, valley barriers were also built in Železna Kapla, in Vrata in Gortina, in Fala in the Drava Valley, on the Jezersko Pass, and on the Ljubelj Pass.

The Turkish moats represent an exceptional cultural and natural heritage (wetlands in ditches). The forest is increasingly overgrowing them and a lot of damage has been done by frost; the moats are being destroyed by cutting down the forest and removing stumps (forest hauling).

Research into the Turkish trenches contributed to a greater understanding of the period in which the Slovenian territory experienced one of its greatest devastations. At the same time, due to the unresponsiveness of the authorities at the time, the farmers had to organize themselves and build a defense system of trenches and watchtowers to protect their property and their lives.

The research revealed that several similar watchtowers were built in Serbia, Bosnia and Hercegovina, Croatia, Austria, and Germany. Some of them were physically reconstructed.

For our virtual reconstruction, an extended reconstruction pipeline was used. A 3D model of one of the remains was made using a DJI Mavic Pro drone and Pix4D, Autodesk Recap, and Recap Phot software.

Archaeologic excavations were also conducted in two probes in the TŠ3 trench. Unfortunately, no physical evidence was found concerning watchtowers or military equipment that would indicate the presence of an army from this period. No particular discoveries were made with the metal detector either.

In addition, a 3D model of a watchtower was created. All needed static calculations were made in the case of the physical reconstruction. All required materials were listed with the exact dimensions and number of pieces. A list of costs was also created. Finally, a 3D digital reconstruction/rendering was created for the watchtower and its interior.

One of the main goals in the field of sustainable tourism is the revitalization of cultural heritage buildings. By researching the watchtowers and their appearances, and by conducting a detailed analysis of the construction costs, some potential investors should be encouraged to engage in a physical reconstruction.

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Data Availability Statement: Data supporting the reported results can be found at: https://www.srips-rs.si/storage/app/media/RAZVOJ%20KADROV/SIPK/2020%20-%20PROJEKTI/MB/gpa-projekt-1-1.pdf (accessed on 18 July 2022).

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References

1. Galeazzi, F. 3-D virtual replicas and simulations of the past: 'Real' or 'Fake' representations? *Curr. Anthropol.* **2018**, *59*, 268–286. [CrossRef]
2. Demetrescu, E. Virtual reconstruction as a scientific tool: The extended matrix and source-based modelling approach. *Commun. Comput. Inf. Sci.* **2018**, *817*, 102–116.
3. Piccoli, C. Visualizing antiquity before the digital age: Early and late modern reconstructions of Greek and Roman cityscapes. *Analecta Praehist. Leiden.* **2017**, *47*, 225–257.
4. El-Hakim, S.F.; Beraldin, J.A.; Picard, M.; Godin, G. Detailed 3D reconstruction of large-scale heritage sites with integrated techniques. *IEEE Comput. Graph. Appl.* **2004**, *24*, 21–29. [CrossRef]
5. Liverani, P. 3D Reconstructions: A Critical Reflection Starting from the Roman Forum. In *Archaeology and Economy in the Ancient World, Proceedings of the 19th International Congress of Classical Archaeology, Cologne/Bonn Germany, 22–26 May 2018*; Propylaeum: Heidelber, Germany, 2021.
6. Smith, I. Sid and Dora's bath show pulls in the crowd. *Computing* **1985**, 7–8.
7. Reilly, P.; Todd, S.; Walter, A. Rediscovering and modernising the digital Old Minster of Winchester. *Digit. Appl. Archaeol. Cult. Herit.* **2016**, *3*, 33–41. [CrossRef]
8. Sylaiou, S.; Liarokapis, F.; Sechidis, L.; Patias, P.; Georgoula, O. Virtual Museums: First Results of a Survey on Methods and Tools. *Virtual Real.* **2005**, 1–6.
9. Scali, G.; Segbert, M.; Morganti, B. Multimedia applications for innovation in cultural heritage: 25 European trial projects and their accompanying measure TRIS. In Proceedings of the 68th IFLA General Conference and Council, Glasgow, UK, 18–24 August 2002.
10. Gros, P. Hercule à Glanum. Sanctuaires de transhumance et développement urbain. *Gallia* **1995**, *52*, 311–331. [CrossRef]
11. Medri, M. *Manuale di Rilievo Archeologico*; Laterza: Bari, Italy, 2003.
12. Remondino, F.; Rizzi, A. Reality-based 3D documentation of natural and cultural heritage sites-techniques, problems, and examples. *Appl. Geomat.* **2010**, *2*, 85–100. [CrossRef]
13. Demetrescu, E. Archaeological stratigraphy as a formal language for virtual reconstruction. Theory and practice. *J. Archaeol. Sci.* **2015**, *57*, 42–55. [CrossRef]
14. Ryan, N. Documenting and validating virtual archaeology 1. *Archeol. Calc.* **2001**, *12*, 245–273.

15. Frischer, B.; Niccolucci, F.; Ryan, N.; Barceló, J. From CVR to CVRO: The Past, Present, and Future of Cultural Virtual Reality. In Proceedings of the VAST Conference for Virtual Reality, Archaeology and Cultural Heritage, Arezzo, Italy, 1–12 November 2000.
16. Hermon, S.; Niccolucci, F.; D'Andrea, A. Some Evaluations on the potential Impact of Virtual Reality on the Archaeological Scientific Research. In Proceedings of the 11th International Conference on Virtual Systems and Multimedia, Ghent, Belgium, 3–5 October 2005; pp. 105–114.
17. Hermon, S.; Nikodem, J. 3D Modelling as a Scientific Research Tool in Archaeology. In Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA), Berlin, Germany, 2–6 April 2007; pp. 1–6.
18. Niccolucci, F. Setting standards for 3D visualization of cultural heritage in europe and beyond. In *Paradata and Transparency in Virtual Heritage*; Routledge: London, UK, 2016; pp. 23–36.
19. Münster, S.; Koehler, T. 3D Reconstruction of Cultural Heritage Artifacts: A Literature Based Survey of Recent Projects and Workflows. In *Virtual Palaces, Part II. Lost Palaces and their Afterlife. Virtual Reconstruction between Science and Media*; Palatium: Heidelberg, Germany, 2016; pp. 87–102.
20. Pietroni, E.; Ferdani, D. Virtual restoration and virtual reconstruction in cultural heritage: Terminology, methodologies, visual representation techniques and cognitive models. *Information* **2021**, *12*, 167. [CrossRef]
21. Manovich, L. What Is Digital Cinema? *Digit. Dialectic* **2018**, 1–27.
22. Schoueri, K.M.G.; Ferreira, L.M. A Very Short Introduction To Digital Archaeology. *Notandum* **2020**, *54*, 143–156. [CrossRef]
23. Pfarr-Harfst, M. *Typical Workflows, Documentation Approaches and Principles of 3D Digital Reconstruction of Cultural Heritage*; Lecture Notes in Computer Science; Springer: Cham, Switzerland, 2016; p. 10025.
24. Lambert, J. *Digital Storytelling*; Amsterdam University Press: Amsterdam, The Netherlands, 2007; Volume 41.
25. Gabellone, F. Digital technologies and communication: Prospects and expectations. *Open Archaeol.* **2015**, *1*, 102–118. [CrossRef]
26. Bentkowska-Kafel, A.; Denard, H.; Baker, D. *Paradata and Transparency in Virtual Heritage*; Routledge: London, UK, 2016.
27. Lopez-Menchero, V.M.; Grande, A. The Principles of the Seville Charter. In Proceedings of the XXIIIrd International CIPA Symposium, Prague, Czech Republic, 12–16 September 2011.
28. Lesjak, K. Sistem Utrdb Med Kotljami in Ravnami na Koroškem. Ph.D. Thesis, University of Ljubljana, Ljubljana, Slovenia, 2018, Abstract.
29. Reiner, J. Wallschanzen bei Guttenstein in Kärnten. *Carinthia I* **1881**, *71*, 50–57.
30. Baš, F. Turške šance pri Kotljah. *Koroški Fužinar* **1954**, *7/12*, 17–18.
31. Grobelnik, I. Vojaški dogodki v Mislinjski dolini do leta 1920. *Slov. Gradec Mislinjska Dol. II* **1999**, 137–254.
32. Simoniti, V. *Turki so v Deželi Že. Turški Vpadi na Slovensko Ozemlje v 15. in 16. Stoletju*; Mohorjeva Družba: Celje, Slovenia, 1990.
33. Unrest, J. Monument Germaniae Historica. Scriptores rerum Germanicarum. Nova series. Tomus XI. In *Oesterreichische Chronik*; Böhlau: Weimar, Germany, 1957.
34. Sapač, I. Dvorec Grinfels. In *Katalog Občasne Razstave*; Koroški pokrajinski Muzej: Slovenj Gradec, Slovenia, 2016; pp. 15–53.
35. Štih, P.; Simoniti, V. Na stičišču svetov. In *Slovenska Zgodovina od Prazgodovinskih Kultur do Konca 18. Stoletja*; Modrijan: Ljubljana, Slovenia, 2009.
36. Holtzwurm, I. Archidvcatvs Carinthiae Fertilissimi Carantania Olim Et Carnia, Dicti, Ex Diligenti Omnivm locorum Perlustratione et Dimensione, Noua, Vera, et Exactissima Geographia. Available online: https://mapy.mzk.cz/en/mzk03/001/040/106/2619266720/ (accessed on 18 July 2022).
37. Krmpotić, L. *Izvještaji o Utvrđivanju Granica Hrvatskog Kraljevstva od 16. do 18. Stoljeća*; Hrvatski zapisnik: Hannover, Germany, 1997.
38. Kljajić, J. Vojnokrajiški čardaci u Slavonsko-srijemskom Posavlju u 18. i 19. stoljeću. *Povij. Pril.* **2002**, *21*, 130–158.
39. Matijaško, M. Arheološki tragovi i moguća rekonstrukcija protuturskog čardaka. Gornji Hum, Općina Breznički Hum, Arheološki lokalitet Humščak (elaborat). 2018.
40. Tomovska, R.; Radivojević, A. Tracing sustainable design strategies in the example of the traditional Ohrid house. *J. Clean. Prod.* **2017**, *147*, 10–24. [CrossRef]
41. Djamali, M.; Chaverdi, A.A.; Balatti, S.; Guibal, F.; Santelli, C. On the chronology and use of timber in the palaces and palace-like structures of the Sasanian Empire in 'Persis' (SW Iran). *J. Archaeol. Sci. Rep.* **2017**, *12*, 134–141. [CrossRef]
42. Turmhügelburg Lütjenburg. Available online: https://www.turmhuegelburg.de/ (accessed on 18 July 2022).
43. Brod Portal, Čardak iz Doba Osmanlija na Pašnjaku Iva. 2018. Available online: http://www.brodportal.hr/clanak/cardak-iz-doba-osmanlija-na-pasnjaku-iva-20991 (accessed on 18 July 2022).
44. Wikipedia. Vojna Krajina. *Natur Park Stromberg Heuchelberg*. Available online: https://hr.wikipedia.org/wiki/Vojna_krajina (accessed on 18 July 2022).
45. Šeguljev, N. Moja Trđava, Poslednji Čardak na Savi. 2019. Available online: https://tvrdjavadotblog.wordpress.com/2019/11/17/poslednji-cardak-na-savi/ (accessed on 18 July 2022).
46. Wikipedia. Čardak. Available online: https://en.wikipedia.org/wiki/%C4%8Cardak (accessed on 10 July 2022).
47. Wikipedia. Eppingen Lines. Available online: https://en.wikipedia.org/wiki/Eppingen_lines (accessed on 18 July 2022).
48. Naturpark Stromberg-Heuchelberg. Eppingen-Linien_Weg. Available online: https://www.naturpark-stromberg-heuchelberg.de/erleben/wandern/eppinger-linien-weg/ (accessed on 18 July 2022).

49. Wikipedia. Chartaque. Available online: https://en.wikipedia.org/wiki/Chartaque#/media/File:Barockschanze_Gersbach.jpg (accessed on 18 July 2022).
50. Archeo-Serwis. Roof Covering on a Chartaque (Marktgemeinde Burgau, Austria). Available online: https://www.archeo-serwis.eu/portfolio-rekonstrukcje,0,21/roof_covering_on_a_chartaque__marktgemeinde_burgau__austria___2014.html (accessed on 18 July 2022).
51. Fehring, S. Tschartake—Grenzwachturm. Available online: http://www.fehring.at/_betriebe/288/Tschartake_--_Grenzwachturm/?category=51ee77440ff584.96096149 (accessed on 18 July 2022).
52. Hrvatska Enciklopedija Mrežno Izdanje, Čardak. Leksikografski Zavod Miroslav Krleža. 2021. Available online: https://www.enciklopedija.hr/natuknica.aspx?id=13180 (accessed on 18 July 2022).
53. Lercari, N. 3D visualization and reflexive archaeology: A virtual reconstruction of Çatalhöyük history houses. *Digit. Appl. Archaeol. Cult. Herit.* **2017**, *6*, 10–17. [CrossRef]
54. Banfi, F. HBIM, 3D drawing and virtual reality for archaeological sites and ancient ruins. *Virtual Archaeol. Rev.* **2020**, *11*, 16–33. [CrossRef]
55. Cáceres-Criado, I.; Triviño-Tarradas, P.; Valderrama-Zafra, J.M.; García-Molina, D.F. Digital preservation and virtual 3D reconstruction of 'The Baker's house' in the archaeological site of Torreparedones (Baena, Cordoba-Spain). *Digit. Appl. Archaeol. Cult. Herit.* **2022**, *24*, e00218. [CrossRef]
56. Jaeger-Klein, C. The Traditional Tower Houses of Kosovo and Albania—Origin, Development and Influences. In Proceedings of the UBT International Conference, Priština, Kosovo, 27 October 2018.
57. Kušar, D. Timber buildings and the fires in the medieval towns. *Les* **2002**, *53*, 196–201.
58. Vuoto, A.; Ortega, J.; Lourenço, P.B.; Javier Suárez, F.; Claudia Núñez, A. Safety assessment of the Torre de la Vela in la Alhambra, Granada, Spain: The role of on site works. *Eng. Struct.* **2022**, *264*, 114443. [CrossRef]
59. Peña, F.; Lourenço, P.B.; Mendes, N.; Oliveira, D.V. Numerical models for the seismic assessment of an old masonry tower. *Eng. Struct.* **2010**, *32*, 1466–1478. [CrossRef]
60. Bru, D.; Ivorra, S.; Betti, M.; Adam, J.M.; Bartoli, G. Parametric dynamic interaction assessment between bells and supporting slender masonry tower. *Mech. Syst. Signal Process.* **2019**, *129*, 235–249. [CrossRef]
61. Briceño, C.; Noel, M.F.; Chácara, C.; Aguilar, R. Integration of non-destructive testing, numerical simulations, and simplified analytical tools for assessing the structural performance of historical adobe buildings. *Constr. Build. Mater.* **2021**, *290*, 123224. [CrossRef]
62. Elyamani, A.; Roca, P. One Century of Studies for the Preservation of One of the Largest Cathedrals Worldwide: A Review. *Sci. Cult.* **2018**, *4*, 1–24.
63. Gençer, F. Structural characteristics of ashlar roman watchtowers in cilicia region, anatolia. *Mediterr. Archaeol. Archaeom.* **2019**, *19*, 63–78.
64. Elyamani, A. Re-Use Proposals and Structural Analysis of Historical Palaces in Egypt: The Case of Baron Empain Palace in Cairo. *Sci. Cult.* **2018**, *4*, 53–73.
65. Zeng, L.; Li, R.Y.M.; Nuttapong, J.; Sun, J.; Mao, Y. Economic Development and Mountain Tourism Research from 2010 to 2020: Bibliometric Analysis and Science Mapping Approach. *Sustainability* **2022**, *14*, 562. [CrossRef]
66. Vilceanu, B.; Herban, S.; Grecea, O. 3D models for a sustainable development of cultural heritage. *Eng. Sust. DevIntl UAB–B* **2015**, *2*, 157–160.
67. Tobiasz, A.; Markiewicz, J.; Lapinski, S.; Nikel, J.; Kot, P.; Muradov, M. Review of Methods for Documentation, Management, and Sustainability of Cultural Heritage. Case Study: Museum of King Jan III's Palace at Wilanów. *Sustainability* **2019**, *11*, 7046. [CrossRef]
68. European Structural and Investment Funds; Republic of Slovenia; Development Council of the Cohesion Region of Eastern Slovenia. Strateška Izhodišča Razvoja Kohezijske Regije Vzhodna Slovenija. 2019, p. 77. Available online: https://vzhodna-slovenija.si/wp-content/uploads/2020/08/200204_Publikacija.pdf (accessed on 10 July 2022).
69. Regional Development Agency Koroška. *Regionalni Razvojni Program za Koroško Razvojno Regijo 2021–2027*; Regional Development Agency Koroška: Dravograd, Slovenia, 2019; p. 54. Available online: https://rra-koroska.si/download/regionalni-razvojni-program-za-korosko-razvojno-regijo-2021-2027/?wpdmdl=3694&refresh=633aa59a8a1371664787866 (accessed on 9 September 2022).
70. Kamnik, P.M.; Jaušovec, R.; Nekrep Perc, M.; Djura Jelenko, M.; Čepin, S.; Gonza, D.; Korpič, N.; Lah, A.; Popič, A.; Šoster, Z.; et al. *Arheološki Park Turške Šance, Šance za Zanamce*; University of Maribor: Maribor, Slovenia, 2020.
71. Hoppe, S.; Breitling, S. Virtual Palaces, Part II Lost Palaces and their Afterlife. In *Virtual Reconstruction Between Science and Media*; Palatium: Munchen, Germany, 2016.
72. Galasso, F.; Parrinello, S.; Picchio, F. From excavation to drawing and from drawing to the model. The digital reconstruction of twenty-year-long excavations in the archaeological site of Bedriacum. *J. Archaeol. Sci. Rep.* **2021**, *35*, 102734. [CrossRef]
73. Bajena, I.; Hochschule, B. Knowledge Representations of Digital Reconstruction in 3D Models. 2022, pp. 2–4. Available online: https://wp.unil.ch/llist/files/2022/06/COMHUM_2022_paper_11.pdf (accessed on 15 September 2022).
74. Demetrescu, E.; Ferdani, D. From field archaeology to virtual reconstruction: A five steps method using the extended matrix. *Appl. Sci.* **2021**, *11*, 5206. [CrossRef]

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Historical Landscape Elements of Abandoned Foothill Villages—A Case Study of the Historical Territory of Moravia and Silesia

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Abstract: During the second half of the 20th century, a number of settlements disappeared for various reasons, especially in the hilly landscapes of northern Moravia and in the Czech part of Silesia. Currently, in the relevant localities, it is possible to identify preserved original landscape structures (scattered greenery, water elements, original woody plants, terraces, etc.) and other historical landscape elements with heritage potential. The typical elements of the above-mentioned localities of abandoned settlements are agrarian stone walls that document previous agricultural land use. These structures are generally located outside the original building plots on the edges of previously farmed land. Another important historical element is the unused access roads to arable land, which are still visible in lidar pictures. Numerous elements of the extinct settlements also include the remains of building materials and local quarries of building stone. This paper presents and classifies the historical landscape elements and their typology and proposes a methodology for identification and documentation.

Keywords: landscape dynamics; historical landscape structure; abandoned settlement; cultural heritage

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1. Introduction

During the 20th century, hundreds of settlements disappeared in the Czech Republic, with the most affected area being the border region (outside the Czech-Slovak part) and the decisive impulse being the displacement of the original German population in the post-World War II period.

These peripheral locations are made up of mountain units with less favourable climatic conditions, yet these sites have been used extensively for agriculture. These areas were mostly settled in the 13th century as part of the so-called Great Colonisation (German Eastern Colonisation) by the original Slavic and incoming German populations [1]. It was mainly German colonists who inhabited the upland and mountainous parts of the territory. The forestry, cattle breeding, mining, glassmaking, and weaving developed in these areas impacted landscape changes [2]. The settlements were conditioned by quite common factors [3]. The primary reasons for establishing settlements in these particular locations were the mineral resources (most often iron ore) and access to timber in wooded areas, namely, the higher spruce stands. Due to the widely dispersed nature of the distribution of settlements in the area, these were mostly self-contained enclaves with no significant relationships with surrounding communities (except for parish and official affiliations).

The disappearance of settlements has occurred for various reasons throughout the history of human settlement. In Central European, settlement development was completed in the Middle Ages (with very few exceptions). Since then, the number of permanent settlements has steadily decreased. The main reason for this is the progress in land management technologies and transport. This means that land can be farmed from further afield, making it unnecessary to maintain small settlements in remote locations that are difficult to access and inefficient for modern infrastructure. This is why in some countries, villages are being depopulated as part of rural-to-urban migration [4]. However, it is possible that the situation is changing somewhat with the transition to a post-productive society, part of which may seek more remote locations with the idea of a higher quality of life [5].

Within this general trend, there are, of course, usually specific reasons for the disappearance of settlements. These causes may have been natural disasters (in the Central European environment, mainly floods; elsewhere, earthquakes, volcanic eruptions, avalanches, mudflows, etc.) or unhealthy environments [6]. Wars and violent actions, usually accompanied by economic decline, and also epidemics of infectious diseases have had a significant impact. At other times, people left for economic reasons when a territory was losing competitiveness or the local resource base was depleted.

Another reason for the disappearance of settlements is the construction of large technical works to which the settlements in their path must give way. These may be mining activities, waterworks, military facilities, or other activities. In such cases, the settlements are dismantled in a controlled manner, usually including the salvage of suitable artefacts. The affected inhabitants often protested vigorously against such action. An extreme case is the Three Gorges Dam on the Yangtze River, which resulted in the imminent displacement of at least 1.3 million people [7].

Sometimes settlements also disappear as a result of population movements due to ethnic, religious or environmental migrations. This category includes the disappearance of settlements from the territory of the present-day Czech Republic, Poland and several other countries [8,9]. Similar experiences can also be found in Poland [10,11] and Slovenia [12].

In the former Soviet Union, the disappearance of villages in the last century was associated with forced collectivisation [13]. However, the depopulation of villages in remote areas is still taking place today [14]. A study reported that about 800 villages have disappeared in Ukraine over the last 30 years [15]. However, it is not clear in how many cases the extinction is physical and when it is administrative. In Israel, villages abandoned by Arab citizens after the Arab–Israeli wars (1947) were demolished in the 1960s [16]. Research on the potential of vanished structures in Ukraine for economic restoration is also interesting [17–19].

Bański et al. [20] addressed the broader spatial and socio-economic context. Especially in the southern parts of Europe, this problem is still relevant in the context of rural and land abandonment [21]. In Bulgaria, this tendency is highlighted by the overall mass emigration of people from their country [22]. The reuse of abandoned buildings is widely discussed, e.g., [23], especially in relation to an eventual tourism function [24], for social agriculture purposes [25] or for the creation of ecovillages [26].

The study of landscapes can document the development of society and social constructs [27]. A number of studies confirm the need to interpret the links between ecosystem feedback and societal development [28]. Key changes can be seen as the transition from a pre-productive to a productive society in the past, resulting in industrialisation and urbanisation, among other things, and the transition from a productive [29] to a post-productive society in the present [30]. At present, this means that the rural landscape is changing from a space for primary production (agricultural and forestry production and mining) to a space for consumption in the context of tourism and living in a more environmentally friendly way.

For the purpose of our paper, landscape memory is one of the key concepts [31]. The mapping of landscape features for understanding landscape memory and identity is emphasised, for example, by Šťastná et al. [32]. Building on landscape history and the legacy of the past is emphasised by Biddau et al. [33]. While settlements that have disappeared in the distant past are of interest to archaeologists [34] and have become part of the historical heritage, settlements that have disappeared in the recent past touch upon identity and the present time—at least as long as there are memorials.

Crucially, as settlements disappear, so does local knowledge and socio-cultural capital [35], i.e. local culture. Sometimes some of this culture manages to be transferred to new places; other times, it disappears almost irreversibly. It is the loss of local culture that can be seen as the main negative effect of settlement loss. Sometimes the original landscape is preserved in works of art [36]. Landscape is one of the key components of human identity and quality of life [37]. This presupposes public participation, which is in line with the spirit of the European Landscape Convention of 2000 [38]. This is the main motive of our research.

Even after several decades, a number of features can be found in the contemporary landscape that attests to the previous permanent presence of humans. These places—which can be considered traditional landscapes in terms of typology [39]—provide a good opportunity to observe the evolution of the landscape in the context of demographic change and reduced anthropic pressure on the landscape. The local landscape records a complex history of a place or region (including political decisions) that can still be read in its structure. This landscape also forms an integral part of our European cultural heritage.

Today, we are faced with the task of identifying and evaluating the changes implemented in the landscape of vanished settlements. The knowledge gained about the area can be used in landscape planning (e.g., [40,41]) and strengthening regional identity (e.g., [42]). The aim of this paper is to elaborate on a compendium and typology of landscape elements in abandoned settlements and to propose a methodology for their identification and documentation in order to provide a basis for landscape planning.

2. Materials and Methods

Historical landscape features were mapped on the sites of settlements that physically disappeared in the period immediately after the Second World War in the eastern part of the Czech–Polish border area (see Figure 1). The exclusive cause of the physical disappearance of settlements was the controlled demolition of buildings abandoned after the forced departure of the original German population. These sites were identified on the basis of historical demographic data and a comparison of aerial photographs from the pre- and post-World War II periods. All identified localities were involved in the study on historical landscape features.

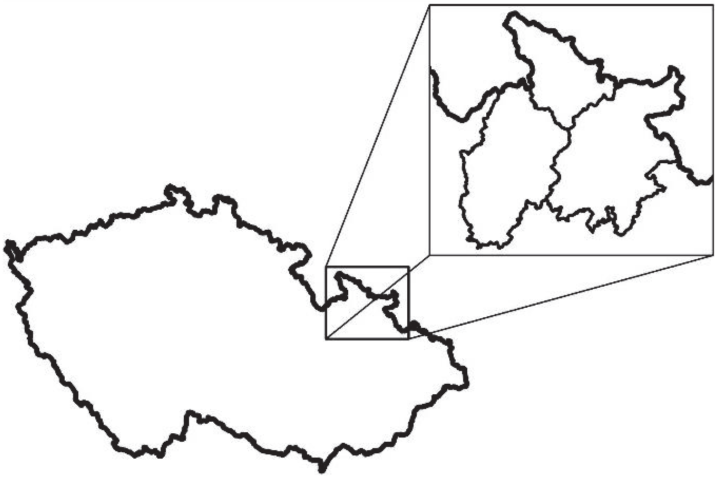


Figure 1. Delimitation of the addressed territory within the Czech Republic.

2.1. Model Area

This paper presents a narrowed area defined by the Moravian–Silesian border with Poland. The solved territory consists mainly of mountains and hilly areas (the landscape of rugged hills and the highlands of Hercinica and the landscape of distinct slopes and rocky mountain ridges, with a very rare combination of landscapes of plains and flat hills). In terms of soil quality, less fertile soils prevail. A large part of the territory is located in a cold climate zone, characterised by a short summer. Forests and pastures predominate. Figure 2 shows a more detailed overview of the territory and location of abandoned settlements.

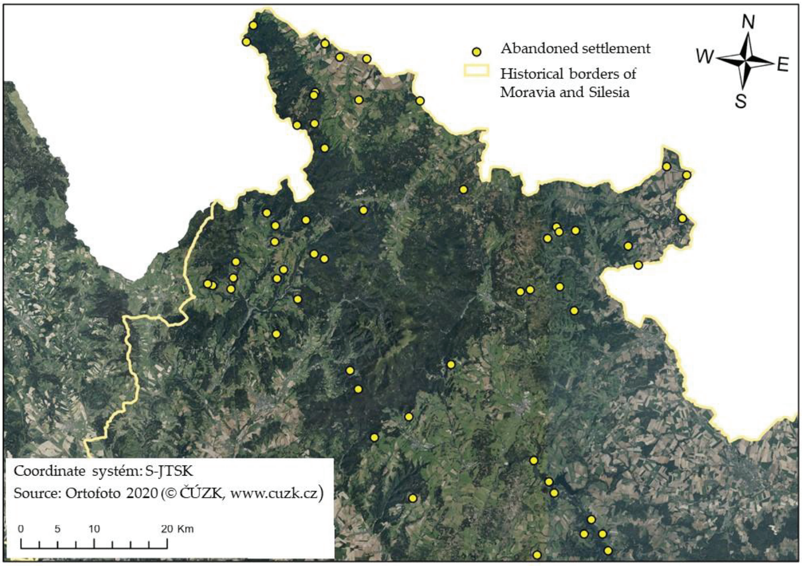


Figure 2. Delimitation of the addressed territory in a detailed view.

2.2. Data Collection

Landscape features were identified at these sites based on an analysis of current and historical aerial survey imagery (see Figure 3), a digital relief model (DRM, based on lidar scanning of the earth's surface), drone imagery and field survey. Aerial survey images and the DRM were studied within the website https://ags.cuzk.cz/archiv/ (accessed on 15 August 2021). These websites (free of charge) are provided by the Czech Office for Surveying, Mapping and Cadastre. The S-JTSK/Krovak East North coordinate system (EPSG 5514) was used. The DRM works with an absolute mean height error of 0.18 m in open landscapes and 0.3 m in forested terrains. The accuracy of DMR 5G is defined on comparative bases (152 clearly defined horizontal areas with an area of at least 50 × 50 m). Elevation point clouds are georeferenced in the UTM (Universal Transversal Mercator) coordinate reference system on the GRS 80 ellipsoid (ETRS89) and in the ellipsoidal elevation reference system relative to the GRS 80 ellipsoid. The data were collected in 2013. Surviving small (dotted), spatial and linear structures evidencing previous permanent human presence were the subject of interest, with a view to their recording, possible future conservation and use in presentation and education. The character of the landscape features and the extent of their preservation were evaluated in relation to elevation, original location in the village (intra-villan/extra-villan) and current long-term land use.

The current long-term use of the area and the extent of change from the pre-extinction landscape structure were analysed based on aerial photographs from the period immediately before (1930s–1940s) and just after the war (1950s–1960s), with the time series extended to the present. Field verification was also undertaken. The change in landscape texture was also taken into account. The structure of the landscape can be understood as the spatial distribution of landscape elements (fields, forests, settlements, etc.) connected by mutual relations. Texture is a spatial representation of the landscape structure, taking into account the size of individual homogeneous areas (the background is made up of highlighted visible lines and polygons based on aerial survey images).

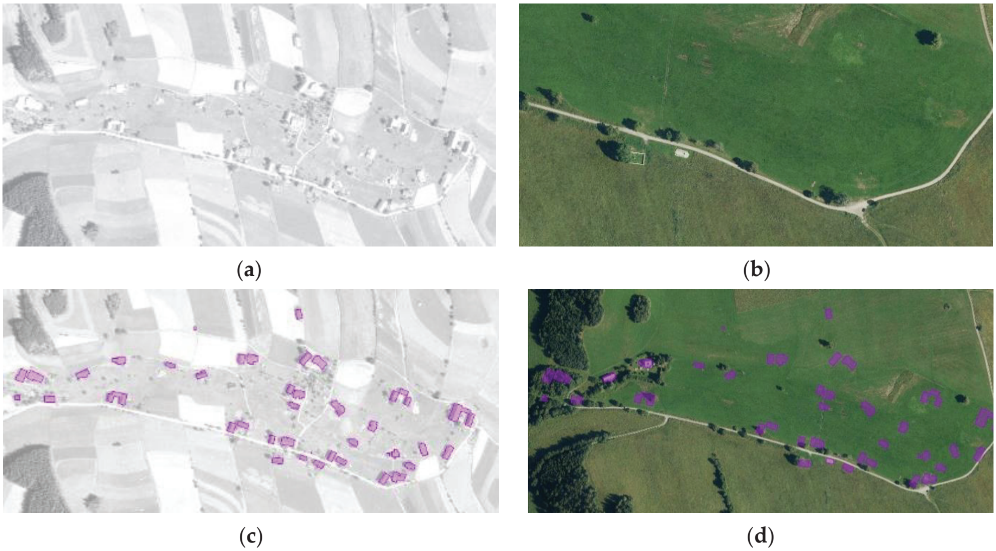


Figure 3. Identification of abandoned settlements based on the aerial survey images comparison: (**a**) aerial survey image (1946); (**b**) aerial survey image (2020); (**c**,**d**) marking the demolished buildings' locations. Source: Ortofoto 2020 (© ČÚZK, www.cuzk.cz (accessed on 15 January 2020)), image 1946—VGHMÚř Dobruška, © Ministry of Defense of the CR.

The first step was the analysis of small (dotted), spatial and linear structures on historical aerial surveying images and their comparison with current orthophotomaps, lidar scanning images and drone images. This was followed by a targeted field survey combined with a broader survey of the entire cadastre territory of the abandoned settlement, aimed at determining the more minor features that could not be read from the aforementioned documents. The broader survey took place mainly in the vicinity of the extinct buildings, along the extinct roads and formerly cultivated and (currently) abandoned agricultural land. The visibility of the features identified by the wider field survey on the above-mentioned materials (orthophoto, drone survey, lidar scan) was subsequently checked retrospectively. See Figure 4 below for more details. Individual treasure trove sources of information on extant historic features were evaluated for accessibility, interpretive reliability and added informational value. Based on this evaluation, a recommended procedure for the identification of historic landscape features in areas of radical land use change was compiled.

The specification of the scale category of elements:

- Small structure: several dm^2—max. 5 m^2;
- Linear structure: the decisive factor is the elongated shape of the element, which is surrounded on both sides by a different environment; min. length of the line is 1 m, but each structure has to be assessed individually;
- Spatial structure: min. 5 m^2 (each structure has to be assessed individually).

A detailed diagram of the methodological procedure is presented in Figure 5.

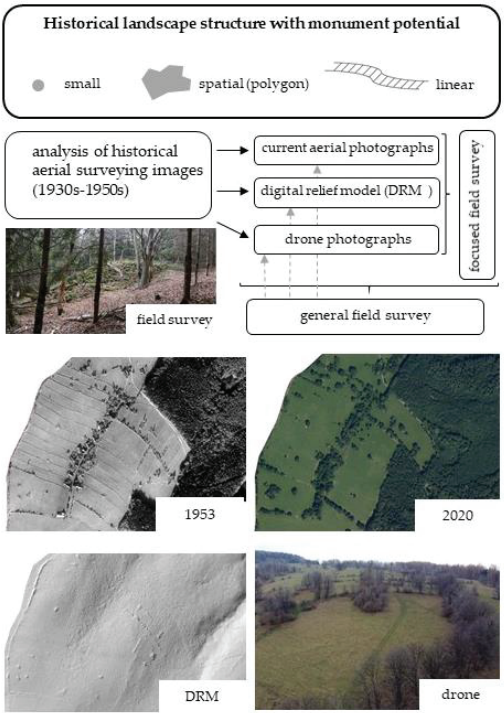


Figure 4. Scheme of methodical procedure.

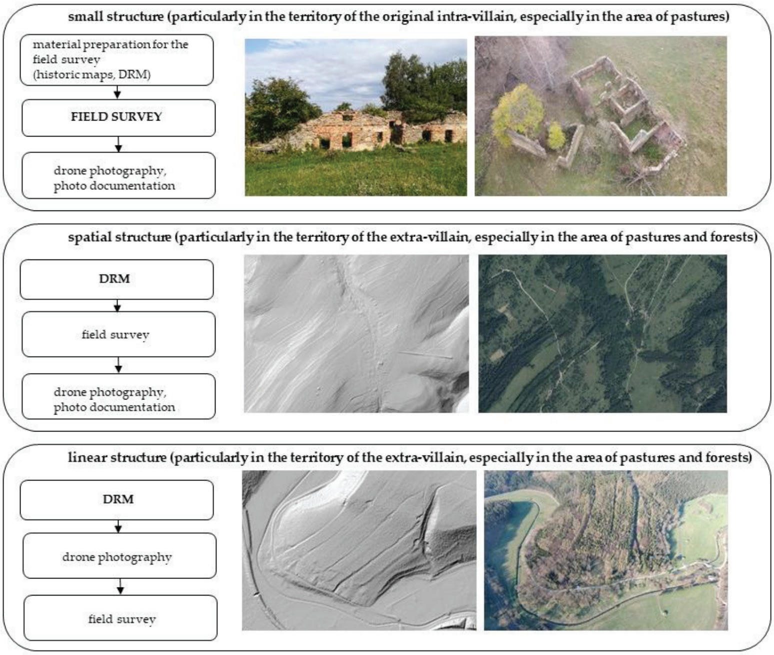


Figure 5. Diagram of the methodical framework for the study of the historic landscape structure in localities of abandoned settlements.

3. Results

3.1. Basic Context—Overview of Identified Historical Landscape Features

A total of 51 sites located in close proximity to the state border was evaluated. The altitude of the sites ranged from lowland areas of 250 m to foothill areas at an altitude of about 700 m above sea level. In terms of typology, the features listed in Table 1 can be identified at the sites in question on the basis of the overall methodology (a combination of all the above steps).

Table 1. Typology of features identified on the territory of the extinct settlements.

Type	Specification	Character
small (dotted)	surface localisation	agrarian heaps, heaps of building stones, ruins of buildings, bridges, small stone walls; old fruit trees, deciduous solitary trees
	subsurface localisation	cellars, wells
linear	elements linked to the road network	historical paths (e.g., original stone paving, many bollards), alleys
	elements related to management	agrarian bunds, terrace farming; linear greenery (excluding avenues)
spatial	interconnected network of elements	preserved landscape texture, preserved structure of the plain (previous farmhand), road network
	integral territory	building stone quarries, building plans, cemeteries

3.2. Trends of Landscape Structure and Texture Changes

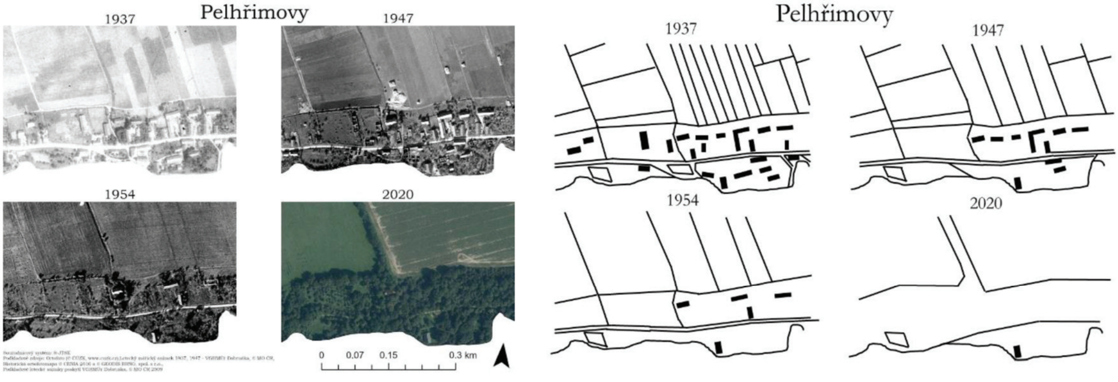
Changes in the landscape structure and the long-term land use on the sites of the disappeared settlements in Moravia and Silesia after the Second World War correspond to the Czech trend of afforestation at higher elevations and increasing the area of soil blocks. Due to the peripheral location of all the monitored sites, it is possible to observe a long-term stabilised landscape structure, and, at the same time, it is possible to determine these trends of landscape structure changes:

- Afforestation of open visual sites;
- Radical transformation of the structure of agricultural land stock without historic landscape structures;
- Transformation of the structure of agricultural land stock with a significantly preserved historic landscape texture.

Within the field survey, the analysis of drone images and the digital relief model, it was possible to distinguish the intra-villan from the extra-villan of the village on the basis of the partially preserved road network (denser network in the central part of the original village), the newly created clusters of scattered greenery in the places of the original buildings, or, on the contrary, the non-forestation of the original areas of the intra-villan with the simultaneous afforestation/spontaneous expansion of woody vegetation in the surroundings.

Almost all sites were economically exploited. The type of exploitation depended on the altitude in the following gradient, from the lowest to the highest positions: intensive crop production, extensive pastures, and monoculture forestry.

The change in landscape texture is very pronounced in the monitored sites. Almost all sites experienced a partial loss of historical landscape texture (see below for details), but very often, the basic skeleton of the original landscape structures was preserved. The reason for this change is the consolidation of agricultural land and intensive forestry. A visual comparison of landscape changes in the example of the extinct village of Pelhřimovy is shown in Figure 6.



(a) (b)

Figure 6. Graphic materials for a comparative presentation of the dynamics of (**a**) landscape structure; (**b**) landscape texture. Source: Ortofoto 2020 (© ČÚZK, www.cuzk.cz), image 1946—VGHMÚř Dobruška, © Ministry of Defense of the CR.

3.3. Spatial Characteristics of the Identified Landscape Features

It was possible to identify at least one original settlement relict on the territory of each abandoned settlement. The best observable element is the ruins of buildings, which, however, only appear in about a third of the locations. Changes in the relief indicating the original intra-village can be commonly observed in the DRM (up to 90% of the monitored locations). The least widespread element is relicts in the form of underground buildings and historically paved roads. Native trees (fruit trees or other deciduous trees) can be identified quite often.

In the intra-villan of the village, there is only a minimal number of original elements proving the original settlement. As a rule, these are the ruins of buildings or the piles of building stone at the sites of the original building plots. These remnants of building material are typical for almost all extinct settlements. The material shows variability in terms of material used and original purpose. Most commonly found here are phyllite, gneiss and slate due to the regional geology. In most cases—due to the massive removal of original material for use in new buildings in other locations—these are smaller structures in the footprints of former building plots or near roads. In addition to the stones that once formed the outer walls of the original buildings, the sites often contain the remains of roofing materials in the form of slate sheets with typical holes for anchoring them onto the roof structure.

The ruins of the original buildings are of unique value, providing very valuable evidence of the past settlement of these remote localities as well as the materials used, construction techniques and settlement in often very difficult climatic conditions. The sites assessed can be divided into settlements in terms of the preservation of original buildings:

- With few preserved original buildings, usually outside the central part of the original village or settlement;
- With ruins illustrating the specific genius loci of the area (Figure 7);
- Without remains of the previous settlement.

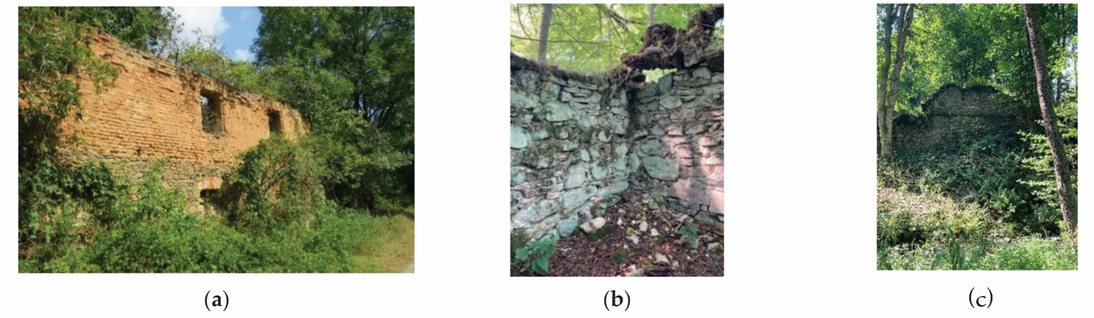

(**a**) (**b**) (c)

Figure 7. Ruins of buildings: (**a**) Pelhřimovy 50.1784936 N, 17.6598617 E; (**b**) Hraničky 50.3106700 N, 16.9746497 E; (**c**) Libavá 49.7012961 N, 17.5890353 E.

In the selected sites, sacral buildings were also preserved (nine sites); in this context, no significant dependence on the current use and altitude could be traced. The spatial differentiation and the precision of the demolition work, which depends on the local administration, is more evident here (also refers to the demolition of ordinary buildings), with the largest number of such buildings in the eastern part of Bohemian Silesia.

Less frequently, non-forest vegetation, especially original solitary deciduous trees (most often lime and ash), is preserved in the original intra-villages. The location of these elements is typically in the immediate vicinity of the disappeared buildings (also confirmed by Majewska [43]). Historic tree plantations and avenues without current direct connection to the road network can be identified in the territory of abandoned settlements. On historical maps, it is possible to trace the roads to which these elements belonged in the past. However, the occurrence of these features is rather rare in the study area.

Old fruit trees are another visible sign of past permanent settlement on the sites of vanished settlements. These elements are evidence of the orchard and fruit-growing tradition in the region and create the potential for their renewal. Fruit trees used to be a common feature of fields, gardens, meadows and pastures in the Czech–Polish border region, but today they sporadically complement the coarse-grained landscape mosaic, mostly with mono-functional use. Solitary old fruit trees can be found both in open landscapes as part of meadows and pastures and as part of today's woodlands. Old fruit trees make an important contribution to the specific historical and landscape footprint of the cultural landscape.

The elements identified in the village intra-villan can best be identified by a combination of detailed field surveys and drone imagery, especially because the exclusive preservation of point microstructures and area and linear elements could not be regenerated due to continuous relatively intensive farming. Surface point features are traceable in historical mapping. These are mainly solitary trees in the vicinity of the original buildings. This step can, therefore, only be considered complementary in order to confirm the location of the tree at the original building and to confirm its historical origin. The other point features that are abundant in the area are more likely to be subsurface structures that can only be identified by field surveys (wells, cellars, but also bridges and other structures). The same applies to small-scale surface structures (bordering on point structures)—these are mainly preserved ground plans of original buildings (clear levelling of the terrain, including any surrounding slope modifications that correspond to the original location of the building). Visible building footprints are preserved exclusively in the current woodland.

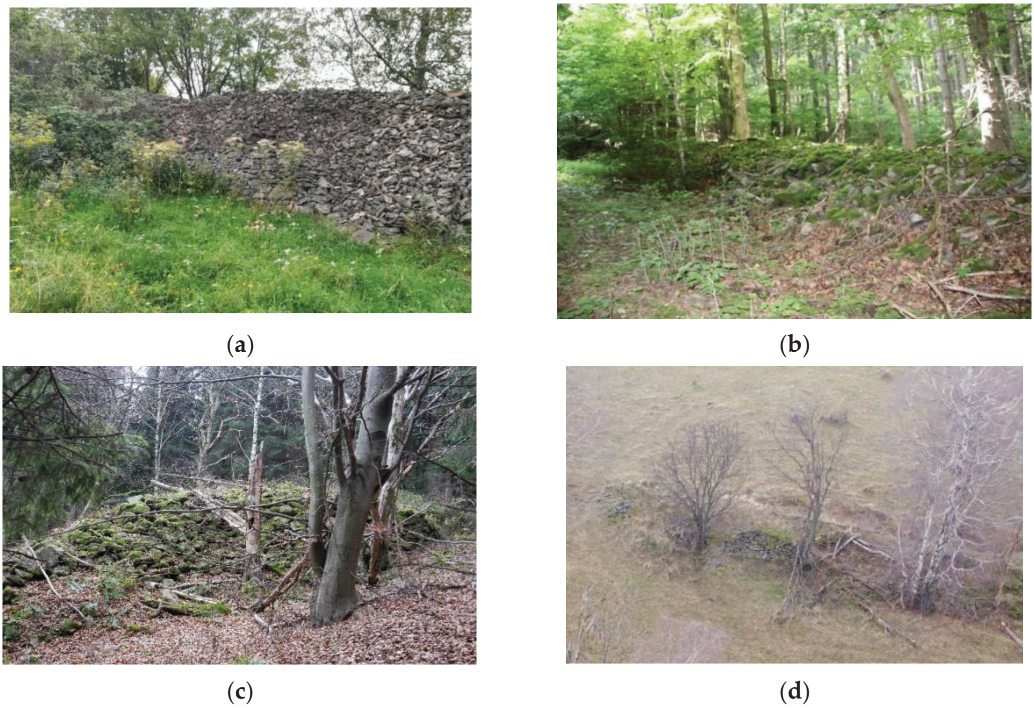
The territory of the vast majority of the original village intra-villan remained open in space (it is not forested; only scattered greenery is present). The predominant use of these areas is extensive grazing (intensive agriculture is typical only for the rare lowland areas). In the other areas (5 sites in total), there has been targeted afforestation of the site, including the original intramural area. It can be concluded that the current land use does not have a significant impact on the preservation of historical landscape elements in the original areas of intra-villans.

The open landscape adjacent to the formerly built-up part of the settlement is characterised by spatial and linear structures, which are preserved to a greater extent in the higher locations. However, point structures can also be found—typically in the form of agrarian mounds (a dome-shaped anthropogenic landform made up of stones loosely stacked on top of each other; these are smaller formations of a non-linear nature associated with agricultural farming—see below). These structures are best identified in the DRM (digital relief model). This is due to their location in the current forest cover (the former use of these areas was demonstrably agricultural—in the form of arable land). A combination with field surveys is ideal to confirm the type and physical form of the structure. In the field, these features often blend in with the surrounding vegetation and residual wood piles (Figure 8). Supplemental drone imagery may be used; it is recommended in areas with no vegetation cover.

Figure 8. Stone pile—demonstration in the field and in the DRM, elements can be observed in the red frame; ZABAGED®Height chart DMR G5 (ags.cuzk.cz); adjusted.

A related typical linear element of the higher locations of the extinct settlements is agrarian mounds (stone walls). These features provide evidence of previous agricultural use of the landscape and are often the only reminder of the former daily presence of people in these remote locations. These structures are typically located outside the original building plots on the edges of previously farmed land (ploughland). These features are typical of sloping land with shallow stony soil. In order to increase fertility and improve soil cultivation, stones were collected and loosely deposited on the edge of the land, where they formed a natural boundary and had an anti-erosion function.

Individual sites are highly variable in terms of the shapes of stone structures. The most frequent are long stone walls (mounds) in open landscapes; exceptionally, they may contain niches (findings of such stone walls on the Polish side are confirmed by Latocha) [44]. Sites with stone walls are currently most often used as pastures. However, stone walls (Figure 9) can also be found within forest stands. The woodland is generally typical of the highest elevations and very steep slopes, where agricultural management would be unthinkable today.



(**a**) (**b**) (**c**) (**d**)

Figure 9. Stone walls: (**a**) Hřibová 50.3468017 N, 17.0068733 E; (**b**) Kamenné 50.2874683 N, 17.0471761 E; (**c**) Hřibová 50.3465264 N, 17.0137519 E; (**d**) Hřibová 50.3478356 N, 17.0129886 E.

Stone structures add to the character of the contemporary landscape and support the specific genius loci of abandoned sites. Apart from their aesthetic dimension, they contribute significantly to the biodiversity and stability of the current landscape system (e.g., [45–47]). The question of formalising their protection in Czech law is very topical.

The location of these features is possible on the basis of current orthophotos, provided that the feature is located in view-open locations and without vegetation line cover. This combination is not very common. However, the linear foliage that often accompanies stone bunds in the form of network structures can be considered an indicator of the occurrence of these anthropogenic landforms. Once identified, a combination of field surveys and drone imagery is necessary. The DRM is the most suitable basis, as it captures structures regardless of the current land use, and it is possible to identify even small linear microstructures in the terrain hidden by dense forest cover. However, a field survey is also required here.

Another relatively common (though partially) preserved element is road networks. With the disappearance of man from the landscape, many of the roads have disappeared, but they are still visible in the present relief—whether they are smaller footpaths or massive bridleways cut into the terrain. In this context, it is necessary to distinguish the actively used road network today, which is preserved only in axial roads. Residual, currently unused historic roads are often not visible in the terrain. However, they can be very well observed in the DRM, where lines corresponding to the historical state of the road network can be identified even in the field. These structures are most often located in forest stands. In Figure 10, we can see a set of historic droveways that were used to manage the fallow (strip) land belonging to individual farmsteads located in the lower parts of the property. Today, this area is covered by woodland.

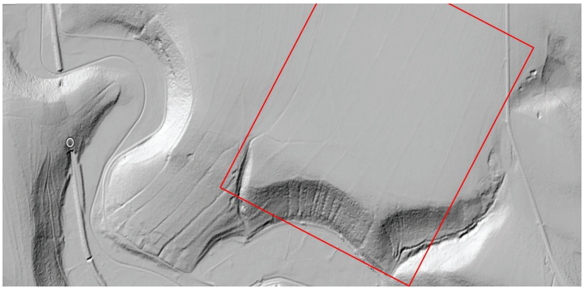
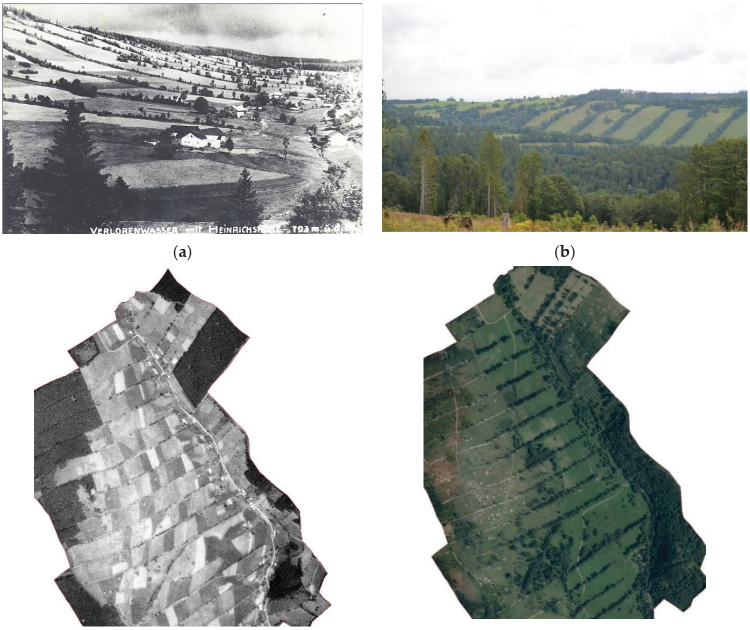


Figure 10. System of historic tracks in the DRM, ZABAGED®Height chart DMR G5 (ags.cuzk.cz, (accessed on 8 May 2012)., accessed on 20 July 2022); adjusted.

A related surviving historical landscape element of a flat character is the preserved ploughland (a set of former fields with a different current use, roads, agrarian mounds or terraces); see Figure 11. This flat structure is preserved in most of the higher locations, regardless of the type of farming (grazing, forestry). This structure is most visible in the DRM. A combination with field surveys is possible, which has a verification but not identification character (in the field, these structures are often not visible at all in a contextual view but rather as separate microstructures). The other sources of information are only applicable in the case of plastic structures (stone bunds and terrace farming); however, the image of the original pluvium is only partially visible compared to the images in the DRM. This output provides a very valuable record of the structure of agricultural land in the past.



(**a**) (**b**)

(**c**) (**d**)

Figure 11. Preserved landscape texture (Ztracená Voda, 50.2030528 N, 17.4801681 E): (**a**) photo from the beginning of the 20th century; (**b**) actual photo (2020); (**c**) aerial survey image (1937); (**d**) aerial survey image (2020). Source: Ortofoto 2020 (© ČÚZK, www.cuzk.cz, accessed on 20 March 2020), image 1946—VGHMÚř Dobruška, © Ministry of Defense of the CR.

Local sources of building material in the form of small-scale quarries can also be found in the vicinity of the extinct settlements as part of the wider hinterland of individual estates. According to witnesses, these quarries served as a repository of material for repairing roads, houses, walls, etc. However, these structures are poorly observable in all types of evidence, including field surveys, and have mostly been incorporated as part of demolitions and controlled landscaping or have blended into the surrounding area through natural succession.

Sporadic surviving features are also represented in the sites by the torsos of cemeteries, cobbled paths and stone bollards along defunct roads. In the Czech–Polish border area, these elements are very rare. The first reason is the more precise demolitions in localities near the state border and the long-term isolation of this area; the second reason is the total change of management in the landscape (mono-functional agriculture or forestry combined with land consolidation)

3.4. Methods of Identification

Spatial and linear historic structures are better preserved (more frequently and to a greater extent) in areas that have been reforested compared to areas that are used for extensive grazing and particularly for crop production.

Most point line elements are located in the places of the original intra-village, whose territory is currently used as pasture. A field survey is necessary for identification; other documents can be used to prepare a targeted survey and local drone photography.

The other structures—linear and space (spatial)—are best observed in the extra-village, with simultaneous use for forestry and grazing. The primary basis for the detention of these structures is the DRM.

For a general overview, see Table 2.

Table 2. Overview of the occurrence of landscape structure types according to current land use.

Localisation/Type	Intra-Villan Arable Land	Extra-Villan Arable Land	Intra-Villan Pasture	Extra-Villan Pasture	Intra-Villan Forest	Extra-Villan Forest	Source
small	▒	░	▒	▒	▒	░	survey
spatial	░	▒	░	█	░	█	DRM
linear							DRM
preservation of landscape structures					░ rare	▒ partly	█ significant

All spatial and linear features identified in the DRM were verified, but a combination with a targeted field survey was required. However, this survey could not reveal the overall composition (e.g., network, connected pelements) but only separate sub-parts. On the other hand, no false negative results were detected—all plastic linear and spatial elements could be observed to the same extent in the DRM as well as within the field survey.

4. Discussion and Conclusions

The tendency to abandon landscapes and settlements is nothing new. What is new is the optics of looking at this phenomenon. Previously, the abandonment of landscapes was viewed negatively or as a 'banalization of the landscape' [48]. Today, the optics are directed towards nature conservation combined with extensive small-scale agriculture. This shift is also confirmed by D'Angelo [49]: the current trend can be described as a return to the appreciation of traditional agricultural landscapes—mostly for biodiversity conservation reasons, but also for cultural and historical motives. Human activity is not in conflict with biodiversity. Strengthening the links between biodiversity conservation and grassland maintenance/restoration (including rural built heritage) is not only an opportunity but probably the only way to preserve these unique places in the long term [50]. Failure to respect native landscape structures, including the driving forces that enable their creation or protection, hinders the enhancement of landscape and biocultural diversity and the positive integration of socio-cultural and environmental diversity in general [51].

From the point of view of historical landscape structures, the linear and surface structures that are located outside the original intra-villan of the municipality are significant for the border localities of extinct settlements. The preservation of these structures can be expected to a greater extent in areas with formal landscape protection, a trend confirmed by Sklenička [52]. However, the assessed areas are usually located almost entirely outside the territorial nature protection guaranteed by law. Thus, the preservation of structures can be attributed mainly to higher elevations and extensive agriculture or to the preservation of these structures in forest cover (this is especially the case for historic ploughland). Subsidies also play a role, particularly in relation to grazing at higher altitudes. Research by Aimar [53] confirms the need for the active conservation and management of historic landscape structures as indicators of landscape integrity and quality, a prerequisite for their use in place-based landscape management. This is related to the change in the current paradigm of the issue addressed, which is shifting from the simple conservation of values to their creative use in local development [54]. The need to introduce new practices based on the compatibility between conceptual human action and biodiversity enhancement (with emphasis on peripheral areas of mountain and foothill landscapes), which will result in a stabilised landscape with socio-cultural potential for local populations, is also highlighted by García-Ruiz et al. [55].

All identified elements contribute significantly to the diversity of the cultural landscape, especially in terms of recording the historical land use of the territory and the long-term time required for their creation. Moreover, these elements were preserved without special protection. This testifies to the permanence of the human footprint on landscapes. This applies in particular to relief traces—e.g., visible floor plans of buildings, ploughs, driveways, etc. These elements also usually create habitats for other species of plants and animals. Hence, we can talk about strengthening biodiversity on several levels with a mutual effect (e.g., [56,57]). Scherreiks et al. [58] came to the conclusion that species richness cannot be unequivocally explained only by the current conditions of the landscape and that the historical structure of the landscape is relevant for the high species richness observed today. This thesis is also the reason for the registration and protection of historical landscape elements [59].

The typology of historical landscapes for Czechia was prepared by Erlich et al. [60]. They divided historical landscapes into composed, organic and associative landscapes. In this systematization, the landscape of extinct settlements would mostly fall under organically developed relict landscapes, where evolution has already ended, but significant characteristics persist. The research importance of these historical landscapes (composed not conceptually but on the basis of joint use and cultivation of land) is confirmed by Kučera et al. [61].

The paper proposes a methodology for the analysis of landscape elements in the area of extinct settlements and their possible typology (and their specific forms) on the example of abandoned settlements in the eastern part of the Czech–Polish border area. This methodology is also applicable to other Central European territories after possible modification according to local conditions. Its purpose is its potential use for landscape planning and other decision-making processes affecting the landscape. The methodology uses a combination of old maps and historical information with modern remote sensing methods, including the deployment of drones. It can be assumed that the possibilities of these methods will be further developed. However, it should be stressed that despite the expected advances in modern methods, field surveys and work with historical sources remain an integral part of the methodology.

Climate change poses a certain challenge to the landscape of abandoned settlements. Given the location of these settlements in mountain and foothill areas, the threat of drought is not as urgent here, which could lead to some revitalisation of agricultural production. In this context, the low risk of drought can be understood as an advantage compared to lower locations. Current developments also show the limits of globalisation. The idea of unlimited travel and global cooperation is taking hold. This could lead to a new perspective on the use of domestic land.

Significantly, there is virtually no fallow land in the study sites [62]. The disappearance of settlements did not mean the abandonment of the landscape, which continues to be exploited. Traditional agricultural and forestry uses have been joined in the post-reproductive era by tourism uses.

In this way, the landscapes of vanished settlements in the post-productive period acquire another function—that of tourism. It is possible to use the qualities of the formerly urbanised landscape, returned to a greater or lesser extent to the open landscape, which in mountain and foothill positions acquires the aesthetically positive qualities of a mosaic of forests, meadows, fields, water areas and streams, scattered greenery and remnants of settlements. Educational trails are being built to remind people of the development of the landscape and its causes. Part of this may be nostalgic tourism [63], where former residents or their descendants return to places linked to the history of their lives; this is expressed through emotions referred to as heimweh [64]. If the disappearance of a settlement is linked to violent events or disasters, it could also be dark tourism [65]. Latocha [66] suggested a possible return to agricultural use, the renovation of old houses, the partial restoration of the sacral landscape, and tourist infrastructure and educational initiatives (educational trails, eco-museums, information boards) for the Polish Kłodzko afforestation.

Although the landscapes of the extinct settlements are in relatively good condition, greater tourism development has been hampered by inadequate infrastructure [67]. The area is also specific in that the original settlers were displaced to Germany and very limited access was only allowed after the political liberation. Rather, in the post-war period, the state sought to sever ties with the indigenous population and build new relationships. However, this was clearly not successful in the case of the disappeared settlements. There are hardly any original survivors left. Therefore, the development of the landscape and its use for tourism is actually in its infancy. The dissemination of knowledge and information is a crucial issue in this respect.

The question of cross-border cooperation remains. Given that the Polish side has also undergone processes of post-war population exchange based on ethnicity with similar consequences, such cooperation would be directly offered. On the other hand, there are also differences in relation to the landscape, as there has not been such consistent collectivisation in Poland.

Further physical disappearances of rural settlements in large numbers are not expected. However, the abandonment or disappearance of industrial or infrastructural sites and buildings may have similar consequences for the landscape. Therefore, further monitoring, analysis and assessment of the landscape of abandoned settlements is expected.

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References

1. Kouřil, P. Středověká kolonizace na severovýchodní Moravě a ve Slezsku a její odraz v archeologických pramenech. *Archae-logia Hist.* **1993**, *18*, 141–150.
2. Kozáková, R.; Pokorný, P.; Mařík, J.; Čulíková, V.; Boháčová, I.; Pokorná, A. Early to high medieval colonization and alluvial landscape transformation of the Labe valley (Czech Republic): Evaluation of archaeological, pollen and macrofossil evidence. *Veg. Hist. Archaeobotany* **2014**, *23*, 701–718. [CrossRef]
3. Chisholm, M. *Rural Settlement and Land Use*; Routledge: London, UK, 2017.
4. Jaszczak, A.; Kristianova, K.; Vaznonienė, G.; Žukovskis, J. Phenomenon of abandoned villages and its impact on transfor-mation of rural landscapes. *Manag. Theory Stud. Rural. Bus. Infrastruct. Dev.* **2018**, *40*, 467–480. [CrossRef]
5. Prados-Velasco, M.J. *Naturbanization: New Identities and Processes for Rural-Natural Areas*; CRC Press: London, UK, 2008. [CrossRef]
6. McLeman, R.A. Settlement abandonment in the context of global environmental change. *Glob. Environ. Chang.* **2011**, *21*, S108–S120. [CrossRef]
7. Gleick, P.H. Three Gorges Dam Project, Yangtse River, China. In *The World's Water*; Gleick, P.H., Ed.; Island Press: Washington, DC, USA, 2009; pp. 139–150.
8. Kučera, Z.; Kučerová, S. Historical geography of Persistence, Destruction and Creation: The case of rural landscape transformations in Czechia´s resettled borderland. *Hist. Geogr.* **2012**, *38*, 165–184.
9. Vaishar, A.; Dvořák, P.; Nosková, H.; Zapletalová, J. Present consequences of the post-war migration in the Czech borderland for regional development. *Quaest. Geogr.* **2017**, *36*, 5–15. [CrossRef]
10. Wolsk, J. The landscape of abandoned villages in the Western Bieszczady: The problem of definition and classification. *Geogr. Pol.* **2016**, *89*, 371–387. [CrossRef]
11. Heffner, K.; Latocha, A. Desolated Villages as Examples of Spatial, Economic and Social Marginalization in the Polish-Czech Borderland and Their Current Transformations. In *Responses to Geographical Marginality and Marginalization. Perspectives on Geographical Marginality*; Nel, E., Pelc, S., Eds.; Springer: Cham, Switzerland, 2020; Volume 5, pp. 123–142. [CrossRef]
12. Mares, P.; Rasin, R.; Pipan, P. Abandoned Landscapes of Former German Settlement in the Czech Republic and in Slovenia. In *Cultural Severance and the Environment. Environmental History*; Rotherham, I.D., Ed.; Springer: Dordrecht, The Netherlands, 2013; pp. 289–309. [CrossRef]
13. Kalugina, Z.; Fedeeva, O. "Hard luck story" of abandoned villages (sociological study). *J. Reg. Econ. Sociol.* **2006**, *3*, 79–96.
14. Rumyantsev, I.N.; Smirnova, A.A.; Tkachenko, A.A. Rural settlements "without population" as a geographical and statistical phenomenon. Вестник Московского Университета. *Серия 5. География* **2019**, *1*, 29–37.
15. Lozynskyy, R.; Zubyk, A. Transformation of the Rural Settlement Network in the Carpathian Region of Ukraine (1989–2020). *Eur. Ctry.* **2022**, *14*, 281–301. [CrossRef]
16. Shai, A. The Fate of Abandoned Arab Villages in Israel, 1965–1969. *Hist. Mem.* **2006**, *18*, 86–106. [CrossRef]
17. Smaliychuk, A.; Müller, D.; Prishchepov, A.V.; Levers, C.; Kruhlov, I.; Kuemmerle, T. Recultivation of abandoned agricultural lands in Ukraine: Patterns and drivers. *Glob. Environ. Chang.* **2016**, *38*, 70–81. [CrossRef]
18. Ruskule, A.; Nikodemus, O.; Kasparinskis, R.; Bell, S.; Urtane, I. The perception of abandoned farmland by local people and experts: Landscape value and perspectives on future land use. *Landsc. Urban Plan.* **2013**, *115*, 49–61. [CrossRef]
19. Fayet, C.M.; Reilly, K.H.; Van Ham, C.; Verburg, P.H. The potential of European abandoned agricultural lands to contribute to the Green Deal objectives: Policy perspectives. *Environ. Sci. Policy* **2022**, *133*, 44–53. [CrossRef]
20. Bański, J.; Wesołowska, M. Disappearing Villages in Poland—Selected Socioeconomic Processes and Spatial Phenomena. *Eur. Ctry.* **2020**, *12*, 221–241. [CrossRef]
21. Milosevic, M.; Milivojevic, M.; Calic, J. Spontaneously abandoned settlements in Serbia, Part 1. *J. Geogr. Inst. Jovan Cvijic SASA* **2010**, *60*, 39–57. [CrossRef]
22. Zapletalová, J.; Stefanova, A.; Vaishar, A.; Stefanov, P.; Dvořák, P.; Tcherkezova, E. Social development of ecologically sen-sitive rural areas: Case studies of the Moravian karts (Czech Republic) and the Devetashko plato (Bulgaria). П*роблеми на* Г*еографията* **2016**, *3–4*, 56–68.
23. García, A.I.; Ayuga, F. Reuse of Abandoned Buildings and the Rural Landscape: The Situation in Spain. *Trans. ASABE* **2007**, *50*, 1383–1394. [CrossRef]
24. Silva dos Santos, P.C.S.; Lucas, S.M.M.F.A. Sustainable rehabilitation of abandoned villages through tourism. *Propos. Village Colmeal* **2017**, *9*, 88–106.
25. Cardaci, A.; Versaci, A. Adaptive reuse for social agriculture: A sustainable approach for the recovery of abandoned villages in Sicily. In *REHAB 2017: Proceedings of the 3rd International Conference on Preservation, Maintenance and Rehabilitation of Historical Buildings and Structures*; Amoêdo, R., Lisa, S., Pinheiro, C., Eds.; Green Lines Institute for Sustainable Development: Braga, Portugal, 2017; pp. 169–179.
26. Güler, K.; Kahya, Y. Developing an approach for conservation of abandoned rural settlements in Turkey. *A/Z ITU J. Fac. Arch.* **2019**, *16*, 97–115. [CrossRef]
27. Ashmore, W. Social archaeologies of landscape. In *A Companion to Social Archaeology*; Meskell, L., Preucel, R.W., Eds.; Blackwell: Oxford, UK, 2004; pp. 255–271.
28. Kempf, M. Modeling multivariate landscape affordances and functional ecosystem connectivity in landscape archeology. *Archaeol. Anthr. Sci.* **2020**, *12*, 159. [CrossRef]

29. Janssen, J.; Knippenberg, L.W.J. The Heritage of the Productive Landscape: Landscape Design for Rural Areas in the Netherlands, 1954–1985. *Landsc. Res.* **2008**, *33*, 1–28. [CrossRef]
30. Tilzey, M.; Potter, C. Productivism versus Post-Productivism? Modes of Agri-Environmental Governance in Post-Fordist Agricultural Transitions. In *Sustainable Rural Systems (Unpaged)*; Robinson, G., Ed.; Routledge: London, UK, 2008. [CrossRef]
31. Jones, O.; Garde-Hansen, J. (Eds.) *Geography and Memory: Explorations in Identity, Place and Becoming*; Palgrave Macmillan: Basingstoke, UK, 2012.
32. Šťastná, M.; Vaishar, A.; Vavrouchová, H.; Mašíček, T.; Peřinková, V. Values of a suburban landscape: Case study of Podolí u Brna (Moravia), The Czech Republic. *Sustain. Cities Soc.* **2018**, *40*, 383–393. [CrossRef]
33. Biddau, G.M.; Marotta, A.; Sanna, G. Abandoned landscape project design. *City Territ. Arch.* **2020**, *7*, 10. [CrossRef]
34. Masini, N.; Gizzi, F.T.; Biscione, M.; Fundone, V.; Sedile, M.; Sileo, M.; Pecci, A.; Lacovara, B.; Lasaponara, R. Medieval Archaeology Under the Canopy with LiDAR. The (Re)Discovery of a Medieval Fortified Settlement in Southern Italy. *Remote Sens.* **2018**, *10*, 1598. [CrossRef]
35. Franco-Moraes, J.; Clement, C.R.; de Oliveira, J.C.; de Oliveira, A.A. A framework for identifying and integrating sociocultural and environmental elements of indigenous peoples' and local communities' landscape transformations. *Perspect. Ecol. Conserv.* **2021**, *19*, 143–152. [CrossRef]
36. Borcz, Z. *Real Landscape and Its Painterly Representation*; Wroclaw University of Life Sciences: Wrocław, Poland, 2009.
37. Těšitel, J.; Korbmüller, B.; Stöglehner, G. *Vital Landscapes*; NEBE: České Budějovice, Czech Republic, 2014.
38. Jones, M. The European Landscape Convention and the question of public participation. In *Justice, Power and Political Landscape (Unpaged)*; Olwig, K., Mitchell, D., Eds.; Routledge: London, UK, 2009. [CrossRef]
39. Antrop, M. Why landscapes of the past are important for the future. *Landsc. Urban Plan.* **2005**, *70*, 21–34. [CrossRef]
40. Marcucci, D.J. Landscape history as a planning tool. *Landsc. Urban Plan.* **2000**, *49*, 67–81. [CrossRef]
41. Sánchez, M.L.; Cabrera, A.T.; Del Pulgar, M.L.G. Guidelines from the heritage field for the integration of landscape and heritage planning: A systematic literature review. *Landsc. Urban Plan.* **2020**, *204*, 103931. [CrossRef]
42. Rędzińska, K.; Szulczewska, B.; Wolski, P. The landscape thresholds analysis as an integrated approach to landscape interpretation for planning purposes. *Land Use Policy* **2022**, *119*, 106141. [CrossRef]
43. Majewska, A. Depopulated localities of former east Prussia as isolated components of the landscape structure in the form of clusters of high vegetation. *J. Geogr. Politi. Soc.* **2019**, *9*, 42–50. [CrossRef]
44. Latocha, A.; Reczyńska, K.; Gradowski, T.; Świerkosz, K. Landscape memory in abandoned areas—Physical and ecological perspectives (Central European mountains case study). *Landsc. Res.* **2018**, *44*, 600–613. [CrossRef]
45. Corlett, R.T. The Role of Rewilding in Landscape Design for Conservation. *Curr. Landsc. Ecol. Rep.* **2016**, *1*, 127–133. [CrossRef]
46. Plieninger, T.; Hui, C.; Gaertner, M.; Huntsinger, L. The Impact of Land Abandonment on Species Richness and Abundance in the Mediterranean Basin: A Meta-Analysis. *PLoS ONE* **2014**, *9*, e98355. [CrossRef]
47. Burnet, J.E.; Ribeiro, D.; Liu, W. Transition and Transformation of a Rural Landscape: Abandonment and Rewilding. *Sustainability* **2021**, *13*, 5130. [CrossRef]
48. Vicente-Serrano, S.M.; Lasanta, T.; Cuadrat, J.M. Transformaciones en el paisaje del Pirineo como consecuencia del abandono de las actividades económicas tradicionales. *Pirineos* **2000**, *155*, 111–133. [CrossRef]
49. D'Angelo, P. Agriculture and landscape. From cultivated fields to the wilderness, and back. *J-READING* **2016**, *1*, 47–56.
50. Haller, A.; Bender, O. Among rewilding mountains: Grassland conservation and abandoned settlements in the Northern Apennines. *Landsc. Res.* **2018**, *43*, 1068–1084. [CrossRef]
51. Agnoletti, M. Rural landscape, nature conservation and culture: Some notes on research trends and management approaches from a (southern) European perspective. *Landsc. Urban Plan.* **2014**, *126*, 66–73. [CrossRef]
52. Sklenicka, P.; Kottová, B.; Šálek, M. Success in preserving historic rural landscapes under various policy measures: Incentives, restrictions or planning? *Environ. Sci. Policy* **2017**, *75*, 1–9. [CrossRef]
53. Aimar, F.; Gullino, P.; Devecchi, M. Towards reconstructing rural landscapes: A case study of Italian Mongardino. *J. Rural Stud.* **2021**, *88*, 446–461. [CrossRef]
54. Di Fazio, S.; Modica, G. Historic Rural Landscapes: Sustainable Planning Strategies and Action Criteria. The Italian Experience in the Global and European Context. *Sustainability* **2018**, *10*, 3834. [CrossRef]
55. García-Ruiz, J.; Lasanta, T.; Nadal-Romero, E.; Lana-Renault, N.; Álvarez-Farizo, B. Rewilding and restoring cultural landscapes in Mediterranean mountains: Opportunities and challenges. *Land Use Policy* **2020**, *99*, 104850. [CrossRef]
56. Nowińska, R.; Czarna, A.; Kozłowska, M. Cemetery types and the biodiversity of vascular plants—A case study from south-eastern Poland. *Urban For. Urban Green.* **2020**, *49*, 126599. [CrossRef]
57. Slámová, M.; Jančura, P.; Daniš, D. Methods of Historical Landscape Structures Identification and Implementation into Landscape Studies. *Ekologia* **2013**, *32*, 267–276. [CrossRef]
58. Scherreiks, P.; Gossner, M.M.; Ambarlı, D.; Ayasse, M.; Blüthgen, N.; Fischer, M.; Klaus, V.H.; Kleinebecker, T.; Neff, F.; Prati, D.; et al. Present and historical landscape structure shapes current species richness in Central European grasslands. *Landsc. Ecol.* **2022**, *37*, 745–762. [CrossRef]
59. Grunenberg, S.; Hilpert, M. Elements of the Historical Cultural Landscape: Mapping Methods and Results in the District of Augsburg. *KN J. Cartogr. Geogr. Inf.* **2021**, *71*, 121–127. [CrossRef]

60. Ehlich, M.; Kuča, K.; Kučová, V.; Pacáková, B.; Pavlátová, M.; Salašová, A.; Šantrůčková, M.; Vorel, I.; Weber, M. *Typologie Historické Kulturní Krajiny České Republiky [Certified Methodology]*; National Monument Institute: České Budějovice, Czech Republic, 2020.
61. Kučera, P.; Novák, J.; Löw, J.; Dohnal, T. Historical Landscape Structures and Their Importance for Landscape Character. *Acta Univ. Agric. Silvic. Mendel. Brun.* **2015**, *63*, 49–57. [CrossRef]
62. Kozak, M.; Pudełko, R. Impact Assessment of the Long-Term Fallowed Land on Agricultural Soils and the Possibility of Their Return to Agriculture. *Agriculture* **2021**, *11*, 148. [CrossRef]
63. Ceisel, C.M. *Globalized Nostalgia: Tourism, Heritage, and the Politics of Place*; Routledge: London, UK, 2018. [CrossRef]
64. Christou, P.A. Tourism experiences as the remedy to nostalgia: Conceptualizing the nostalgia and tourism nexus. *Curr. Issues Tour.* **2018**, *23*, 612–625. [CrossRef]
65. Martini, A.; Buda, D.M. Dark tourism and affect: Framing places of death and disaster. *Curr. Issues Tour.* **2018**, *23*, 679–692. [CrossRef]
66. Latocha, A. Modern transformation of deserted settlements in the Sudetes Mountains, SW Poland. *GeoScape* **2020**, *14*, 80–95. [CrossRef]
67. Vaishar, A.; Dvořák, P.; Hubačíková, V.; Zapletalová, J. Contemporary development of peripheral parts of the Czech-Polish borderland: Case study of the Javorník area. *Geogr. Pol.* **2013**, *86*, 237–253. [CrossRef]

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Archaeomagnetic Dating of Three Furnaces inside the Middle Age Settlement of San Genesio (San Miniato, Pisa, Italy)

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Abstract: Archaeomagnetic dating using full geomagnetic vector was performed on three furnaces cropping out at San Genesio archaeological zone, an ancient settlement located in the Arno River plain, near San Miniato (Pisa). The first evidence of human presence in this area dates back to the period between the VI century BCE and 1248 CE, when the village of San Genesio was destroyed by the inhabitants of the nearby castle of San Miniato. Three burned structures were located at different stratigraphic levels. The SGEN01 represents a kiln to produce pottery. The SGEN02 is probably a furnace for domestic use, while the SGEN03 is interpreted as a metallurgic kiln due to the presence of some hematite fragments possibly coming from Elba Island. Both mean paleodirections and absolute intensity were compared with the global geomagnetic model SCHA.DIF4K (Pavón-Carrasco et al., 2021) for Europe. The obtained age intervals at the 65% probability are 846-911 CE for SGEN01, 696-799 CE for SGEN02, and 623-644 CE for SGEN03. These new absolute dates agree well with their archaeological/stratigraphic position and with the history of the archaeological place.

Keywords: Vicus Wallari; San Genesio; San Miniato; archaeomagnetism; furnaces

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1. Introduction and Historical-Archaeological Setting of the San Genesio Area

The San Genesio archaeological site (43°41′30.59″ N, 10°52′58.3″ E) is located in the Arno River alluvial plain (*Basso Valdarno*, which is Italian for Lower Arno Valley, Figure 1), at the foot of San Miniato hills, halfway between the cities of Pisa and Florence. This area was the place of an important settlement during medieval times and has been intensively studied by archaeologists since 2001. The following synthesis of the history of this very important and complex archaeological place is mainly based on the exhaustive work of [1].

The geological framework of the San Genesio area [2] had a strong influence on the positioning and the existence itself of this settlement. San Genesio lies near the confluence of the Elsa River with the Arno River, at the southern margin of the Arno River valley. Its altitude (29 m a.s.l.) still today preserves this area from the flooding of these two important waterways. The San Miniato hills to the south of the village were probably rich in woods, while this portion of the Elsa Valley is characterized by the presence of clayey sediments of the Pleistocene age deposited in an ancient marshy environment. These sediments are often more than 75% clay-rich (units *p* and *p2* in the geological map of Figure 1). As is known, water, wood, and clay are the three elements necessary for the production of ceramics. In addition, the presence of the Arno and Elsa Rivers is a further element that has certainly favored the passage and the marketing of goods from San Genesio over time, including the products of the furnaces which are the subject of the present work.

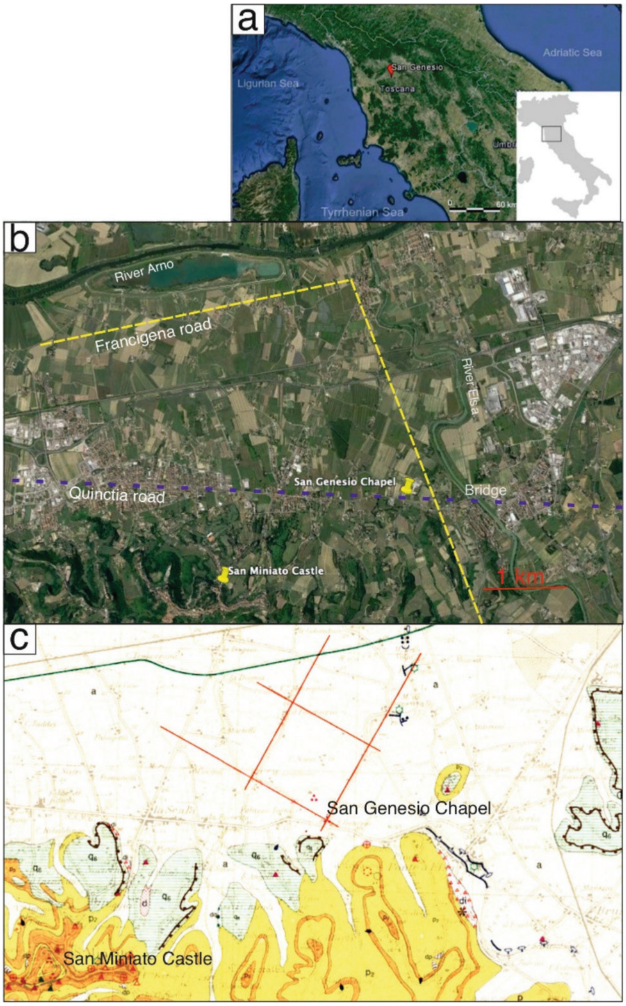


Figure 1. San Genesio location in Tuscany (**a**) and positioning of the archaeological area on Google Maps, at the crossing of the ancient roads *Francigena* and *Quinctia* (**b**) (modified from [3]). The area of San Genesio inside the geological map of [2] (**c**). The red crossed lines in (**c**) correspond to the Roman centuriation traced in 183 BCE [1], of which the archaeological area is located in the southernmost corner.

San Genesio has always had an enviable and strategic position, both militarily and commercially, as it is located (i) more or less at the same distance from the cities of Florence, Lucca, and Pisa; (ii) at the intersection of the Francigena road with the ancient *Quinctia* Roman road, which was built around 123 BCE, perhaps by the consuls *Titus Flaminius* and *Titus Quintus*, to connect the ancient city of Florence (*Florentiae*) with the ancient city of Pisa (*Pisae*) (Figure 1); (iii) not far from the confluence of the rivers Elsa and Arno; and (iv) close to easy crossings of both these waterways, such as the bridge over the Arno whose presence is remembered at least 600 m from today's archaeological site in the 11th century CE (Figure 1). For these reasons, the area in which the San Genesio settlement is located has always been a peculiar site, rich in resources and more or less always inhabited and exploited from both an agricultural and commercial point of view. It was certainly so (i) in the first Etruscan age, since the middle of the 6th century BCE; (ii) in the Roman period, from the end of the fourth beginning of the 3rd century BCE; and (iii) during the Late Antiquity crisis and the Lombard age, when it was situated at the extreme offshoots of the diocesan territory of Lucca. Throughout the Early and High Middle Ages, San Genesio was one of the most important and well-known parish churches (*Pieve*) of the Lower Arno Valley, which was of great importance in the political strategies of the Lucca episcopate. Later on, the Collegiate Church of San Genesio was visited by the most important personalities of the complex historical period between the eleventh and the thirteenth centuries, which was marked by the growth of the Communes and conflict between the Church and the Empire.

The ancient Roman communication routes, albeit decayed and in large sections compromised, and the wide river valleys guided the penetration of the Germanic populations during the period of the Gothic War, which lasted almost two decades (from 535 to 554 CE) and materialized with the Lombard occupation of this territory following the expedition of Agilulf in central Italy between 593 and 595 CE. This portion of the Arno Valley thus became the border of the Lombard dominion in Tuscany (which is actually the old *Tuscia*, which included more jurisdictions than the present-day Tuscany, especially southward in the current Latium region) and, along this stretch of the river, numerous clashes took place between the Lombards and the Byzantines who lived in the upper portion of the Arno Valley (*Valdarno superiore* and *Mugello* areas). Along this border, a series of military villages ("*vici militares*") were born, the memory of which is still present today in the toponymy of clearly Lombard origin of some places. From the Lombard domination also derives the belonging for a long time of this portion of Lower Arno Valley to the diocese of Lucca, as Lucca was the capital of Lombard Tuscany. The area of interest experienced a period of total or partial abandonment between the 5th and the early 6th century CE, when only the presence of Roman–Byzantine populations is testified and the area was mainly used as a cemetery [4]. Then, the area of interest was repopulated under the Lombard rule at the end of the 6th century CE. This territory was controlled by a Lombard character named Wallar, perhaps an official of the Lucca court, from whose name also comes the ancient toponym of this settlement "*Vicus Wallari*".

During the first half of the 7th century CE, the site of San Genesio seems to have been the subject of another, at least partial, abandonment. However, the first written evidence of the existence of a church and a village of some importance in this place dates back to 714 CE, from which the site will henceforth take the name of San Genesio, which is still preserved today: "*Sancti Ginesii, in vico qui dicitur Walari*" (San Genesio in the village that people name Wallari) [5]. This first church, datable at least to the end of the 7th century CE, was later (presumably during the mid-8th century CE) replaced by a new three-nave structure that was found during archaeological excavations under the remains of a later and more complex ecclesiastical building, datable to the first half of the 11th century.

Until the middle of the eighth century CE, the parish church of San Genesio remained directly under the bishopric of Lucca. Starting from the 770s–780s of the 8th century CE, following the conquest of these territories by the Franks, the bishop introduced concessions in "benefit" to private individuals in some way related to him. Even the parish church of San Genesio with the territory controlled by it suffered this fate. In fact, even the name of San Genesio appears in the "*Breve de Feora*" (dated between 890 and 900 CE), which lists these benefits. In the 10th century CE, the parish church of San Genesio, around which a small urban agglomeration was born at the beginning of this century, is counted among the main "*ecclesiae baptismales*" of that part of the diocese of Lucca which was located south of the Arno River.

In the 10th century CE, the castle of San Miniato, located on top of the hill overlooking San Genesio, grew in importance. The castle of San Miniato became the permanent residence of a vicar of the German emperor, and, on several occasions, the emperors (e.g., Henry III) stopped in San Miniato on their way to Rome. San Miniato thus became a direct dependence of the empire, and, as testified by written sources, at least from the first half of the 11th century, the inhabitants of San Genesio and the whole territory belonging to its parish paid taxes to the owners of the San Miniato castle, even when the parish remained under the control of the bishop of Lucca.

The transformation of the church of San Genesio into a larger and more complex building with a crypt and frescoes dates back to the same period, i.e., the first half of the 11th century. At the same time, the Lucca curia promoted the creation of a rectory with a rectangular cloister next to the new church, thus transforming the original parish church into a monastic complex ("Collegiata") around which the medieval village developed. These expansion works prelude to a long period of domination of San Genesio, both on the religious structures of San Miniato and on just under 40 chapels and rectories distributed in this area. This period of splendor lasted until the end of the 12th century, as sanctioned by a privileged act of Pope Celestino III dated 24 April 1194. During the various political vicissitudes that followed one another in this period, on the one hand, the importance of San Miniato as a center of imperial power grew, on the other hand, all the important meetings between the various protagonists of medieval life, including popes and emperors, took place in San Genesio for its strategic position at the crossroads of the most important communication routes. Towards the end of the twelfth century, hatred between San Genesio and San Miniato was born and fueled, due to the political conflicts between the Papacy and the Empire and between the various Tuscan Communes that side with one or the other. The decline of San Genesio began in conjunction with the events that led to the signing of the Guelph League between the Tuscan Communes against the Emperor in 1197. However, it was Emperor Frederick II who marked the fate of San Genesio, first transforming the castle of San Miniato into one of the key strongholds of the defensive system of Florence and then establishing, with an act issued in 1216, the submission of San Genesio to San Miniato. Although in 1240 San Miniato lost the dominion of San Genesio and the favor of the emperor, in 1248, the inhabitants of San Miniato razed San Genesio to the ground. From that moment, the dominion of Lucca over this part of the lower Arno Valley ended. The ancient village of San Genesio was never rebuilt, and only the written memory remains of the past splendor, while the memory of this place fades. At the time of the systematic archaeological excavation, the San Genesio area was occupied only by crops and a small chapel built in the nineteenth century.

Three furnaces were excavated during the archaeological surveys. They are positioned at different geometric and stratigraphic levels within the excavated area and were ascribed to different types of use. From top to bottom, the SGEN01 furnace, positioned inside the stratigraphic unit US-29172, was labeled as activity structure n. 102, and interpreted as a ceramic kiln. The SGEN02 furnace, situated in the stratigraphic unit US-37129, was called activity structure n. 399, while the SGEN03 furnace (US-38119; activity structure n. 662) was interpreted as a metallurgic structure due to the presence of some hematite fragments, possibly coming from Elba Island, inside it. The aim of the present work was to position these three structures within the local chronostratigraphy summarized above. This aim was achieved through the archaeomagnetic analysis method and was made possible by the recent and impressive improvement of the reference paleomagnetic curves for the medieval period [6–9].

2. Archaeomagnetic Sampling

Oriented hand samples (Figure 2) were obtained using the Modified *Thellier* Sampling Technique already described in [10]. The main modification to the classical Thellier's method [11] consists in a preliminary surrounding of the samples with plastered bandages. This technique allows one to collect a greater quantity of materials with a low risk of movement of fine particles. For example, the blocks of baked clays sampled during this work have an average dimension of 8 cm × 8 cm × 4 cm. Then a plaster cap with a perfectly horizontal plane was superposed on the sample using a precision level (Figure 2). A total of 47 (Tables 1–3) independently oriented samples were collected (16 from SGEN01, 16 from

SGEN02, and 15 from SGEN03), using both a magnetic compass and a sun compass, and marked with reference directions on the large (6–8 cm in diameter) plaster caps.

Figure 2. Sampled structures. (**a**–**c**): The plane of ca. 80 × 30 cm of SGEN01 ceramic furnace. (**d**,**e**): Sampling the plane (ca. 70 × 50 cm) of the SGEN02 furnace, probably a domestic structure. (**f**): Building a perfectly horizontal plane for the accurate orientation with a solar compass on top of the plane (ca. 30 × 25 cm) of the SGEN03 metallurgic furnace.

Table 1. Sampling and Directional data: Analytical results SGEN01.

Subset	**Sample**	**Dec (°)**	**Inc (°)**	**VRM %**	**Dec (°)**	**Inc (°)**
01	04	5.2	65.0	9.5	7.8	65.3
01	05	9.4	62.8	5.3	12.0	62.9
01	07	11.6	64.1	8.7	9.3	64.3
01	08	6.4	65.3	7.3		
01	09	9.4	66.3	8.3	8.9	66.6
01	10	15.4	65.7	10.1	8.7	66.1
01	11	11.8	66.6	7.9	12.3	66.8
01	12	8.9	69.0	7.7	12.4	69.2
01	13	17.0	66.4	7.8	14.0	67.6
01	14	15.4	67.6	7.6	12.6	68.1
01	15	18.4	67.2	4.7	19.8	67.8
01	16	18.4	67.0	4.1	20.3	66.7

Mean directions

Subset	Lat. (°N)	Long. (°E)	n/N	Dec (°)	Inc (°)	k	α^{95}	VRM %
SGEN01	**43.69**	**10.88**	**12/16**	**11.9**	**66.4**	**107**	**1.2**	**7**

Table 2. Sampling and Directional data: Analytical results SGEN02.

Subset	**Sample**	**Dec (°)**	**Inc (°)**	**VRM %**	**Dec (°)**	**Inc (°)**		
02	01	−0.9	67.6	14.0				
02	02	0.0	66.6	5.7				
02	03	14.4	66.3	4.9	15.0	66.8		
02	04	−7.2	68.1	6.2				
02	05	0.9	72.0	9.5				
02	06	4.9	65.5	8.0				
02	07	0.1	68.4	7.9				
02	08	3.2	68.4	7.3				
02	09	−2.4	71.8	15.3				
02	11	−0.9	68.0	8.6				
02	12	1.9	64.9	6.4	0.4	63.7		
02	13	5.3	63.5	12.7				
02	14	0.6	65.4	5.1				
02	15	−4.2	68.8	13.3				
Mean directions								
Subset	Lat. (°N)	Long. (°E)	n/N	Dec (°)	Inc (°)	k	α^{95}	VRM %
SGEN02	**43.69**	**10.88**	**14/16**	**1.2**	**67.5**	**639**	**1.5**	**8.9**

Table 3. Sampling and Directional data: Analytical results SGEN03.

Subset	**Sample**	**Dec (°)**	**Inc (°)**	**VRM %**	**Dec (°)**	**Inc (°)**		
03	01	−7.7	63.6	2.9	−8.6	63.2		
03	02	1.8	64.6	2.8	−1.5	64.7		
03	04	−0.1	66.2	2.9	−1.1	67.3		
03	05	−3.3	65.0	2.9	−4.0	65.3		
03	06	3.1	64.6	2.9	1.1	65.7		
03	09	−6.5	64.3	2.3	−8.2	63.1		
03	10	1.5	62.1	4.0	−2.5	62.9		
03	11	−1.8	63.6	2.6	−3.5	62.8		
03	12	−4.5	63.2	2.6	−4.5	63.2		
03	13	−1.0	63.6	3.1	−1.4	63.8		
03	14	−4.5	64.9	3.9	−4.4	64.9		
03	4BIS	−1.5	65.2	2.9	−3.5	64.6		
03	7BIS	−12.6	64.3	5.9	−6.9	63.6		
Mean directions								
Subset	Lat. (°N)	Long. (°E)	n/N	Dec (°)	Inc (°)	k	α^{95}	VRM %
SGEN03	**43.69**	**10.88**	**13/15**	**−3.5**	**64.3**	**2090**	**0.8**	**3.2**

3. Laboratory Proceedings

Directional measurements (Tables 1–3) were performed on all 47 sampled clay fragments by means of the large cell induction magnetometer of the Saint Maur des Fossés Laboratory (Institute de Physique du Globe de Paris) in Paris [12]. Perfect plaster cubes (12 cm × 12 cm × 12 cm) were introduced into the magnetometer while the pre-analytical database was prepared in the Archaeomagnetic Laboratory of IGG-CNR at Villa Borbone, Viareggio (Italy). The archaeointensity measurements and magnetic mineralogy experiments were carried out at the facilities of the Servicio Arqueomagnetico Nacional of UNAM in Morelia (Mexico).

4. Directional Analyses

A preliminary viscous remanent magnetization cleaning was performed [13]. The procedure consists of storing the samples for about 20 days in a free magnetic shield before magnetic measurements. After that, the same procedure was repeated after reversing the samples by 180°. In this way, the index of the acquired viscous remnant magnetization

(VRM) could be estimated and subtracted to the full TRM (thermoremanence magnetization) vector. In the case of the San Genesio analyses, the VRM index resulted in quite high mean values of 7.4% (SGEN01), 8.9% (SGEN02), and 3.2% (SGEN03). Samples yielding a magnetic viscosity index >15%, as defined by the VRM/TRM ratio, were rejected from further procedures.

In order to retrieve the primary characteristic of the remanent magnetization, samples were demagnetized by employing alternating fields (AF), up to a maximum AF peak of 40 mT. The remanent magnetizations were measured after each demagnetization step (Figures 3 and 4). Representative demagnetization diagrams for SGEN01-14 and SGEN03-04 samples are reported in Figure 3. Samples from the SGEN02 structure are characterized by a relatively weak remanent magnetization. For this reason, the AF demagnetization procedure was fully applied only to the sample SGEN02-12, which shows a linear demagnetization segment (Figure 4b).

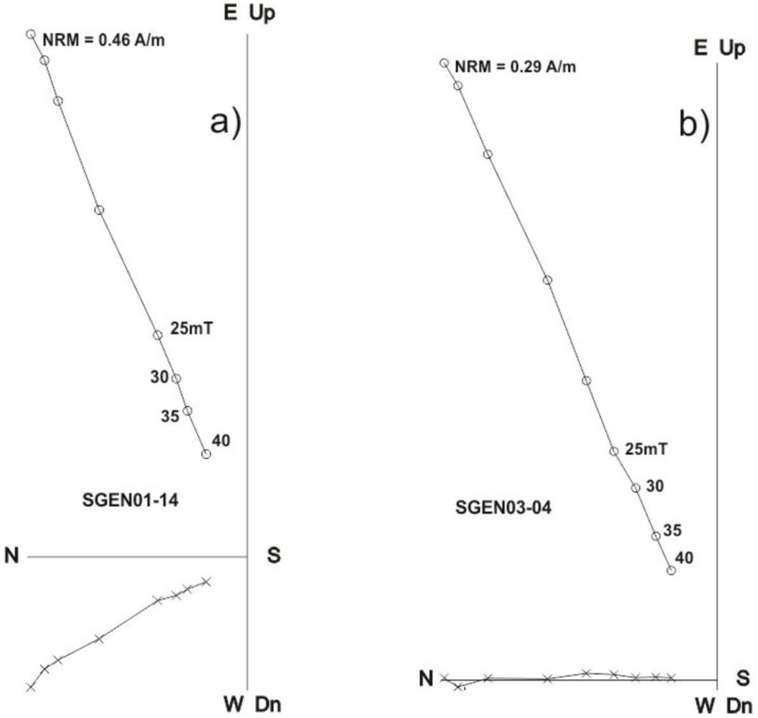


Figure 3. AF demagnetization curves for selected samples. See text for the explanations.

The demagnetization trends of most samples from the SGEN01 site show a lowering of the declination values with increasing demagnetization peaks (Figure 4a). This fact implies that few samples had to be discarded, as they moved outside the McFadden confidence circle [14]. This behavior can be interpreted as due to either unstable magnetic mineralogy or to a displacement of the kiln during past times. As anticipated, the baked clays from the plain of the SGEN02 furnace show a very low magnetization. This fact is particularly evident in the samples characterized by the presence of less-colored clay, as, for instance, samples SGEN02-1,9,10,15,16 (Figure 2). In these samples, the lack of red color for a portion of the sampled clays probably correspond to a lower heating degree and, consequently, the absence or deficiency of iron oxidation, which is the process responsible for the red color. In the majority of the samples from the SGEN03 furnace, an unstable secondary component between NRM and 5–10 mT is quite evident, while the characteristic remanent magnetization (CHRM) was successfully isolated from 10 mT upward, where a linear segment trending toward the origin of the orthogonal projection was defined (Figure 3).

As a general statement, a reliable archaeomagnetic age depends on two main factors. They are (i) good statistics, resulting in low values of the α_{95} parameter (the semi-angle of confidence of the conic surface that collects all the directional measurements) and high values of the k-precision parameter [15] and (ii) the use of a valid reference curve (PSVC) or a portion of it [6–9,16,17]. The accurate sampling methodology and the high number of independent, big-size, solar-oriented samples (N = 15–16) resulted in good analytical statistics for the San Genesio furnaces, with α_{95}/k values of 1.23/1077 (SGEN01), 1.48/639 (SGEN02), and 0.85/2090 (SGEN03) (Tables 1–3). The relatively low α_{95} value of the SGEN02 furnace is particularly valuable when considering the low magnetization of the baked clays of this structure.

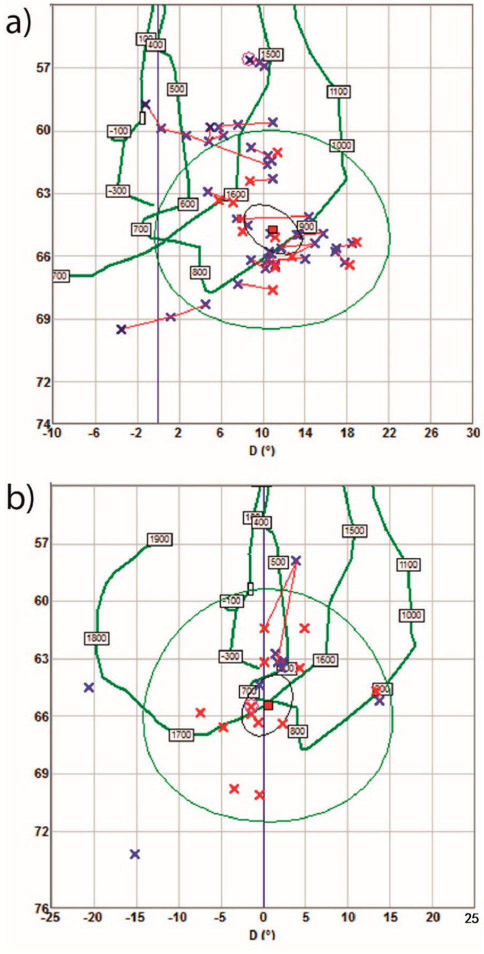


Figure 4. *Cont.*

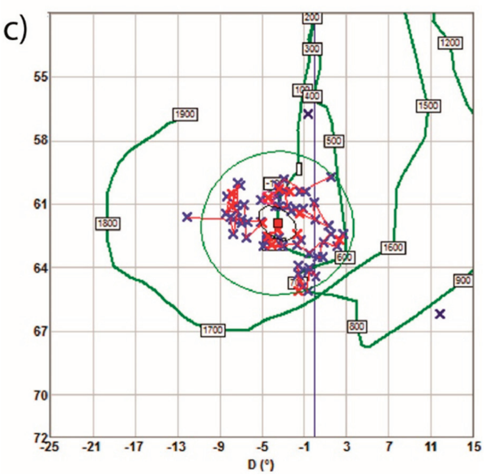


Figure 4. Graphic outputs of the Saint Maur des Fossés large cell inductometer for (**a**) SGEN01; (**b**) SGEN-02; (**c**) SGEN03. The AF demagnetization patterns of each specimen are shown. The green [14] circles of confidence are also shown. Degrees of inclination of the TRM vector are reported on the vertical axis. Declination degrees are on the horizontal axis. The geomagnetic secular variation curve reported, for graphical preliminary age indication, is that of [18].

5. Archaeointensity Determinations

Three virgin fragments of the sampled clays have been used for intensity measurements. They are one fragment of the SGEN01 (13 samples) and two fragments of the SGEN03 (14 samples).

Samples were prepared in three different ways, according to the process to be applied. A small specimen (~1 cm × 1 cm) from each studied fragment was cut, placed, and fixed inside a 1″ plastic cubic sample holder to facilitate its alternating field demagnetization treatment. Chips from each of the available fragments were crushed and pulverized with an agate mortar and pestle to obtain approximately 250 mg for use with the advanced variable field translation balance (AVFTB). For the archaeointensity measurements, fragments were broken into at least 6 specimens and pressed into salt pellets to facilitate their treatment as standard paleomagnetic cores. Specimens (belonging to the same fragment) were positioned into the pellets in six different directions (+X, −X, +Y, −Y, +Z, −Z), relative to the a priori chosen direction of the shard to minimize or mitigate the thermoremanent magnetization anisotropy effects. All remanences were measured with a JR6a spinner magnetometer, while isothermal remanent magnetization (IRM), hysteresis loops, backfield, and high-temperature thermomagnetic curves were obtained using an advanced variable field translation balance (also known as the Curie Balance). In some cases, susceptibility vs. temperature continuous curves were recorded using an AGICO Kappa-bridge magnetic susceptibility meter equipped with a furnace.

The Thellier–Coe method [13,19,20] was used for the ancient field determinations procedure. This is a very standardized procedure but is reported here below for completeness. Samples were heated and cooled in air using an ASC Scientific TD48-SC furnace. Fifteen temperature steps were distributed from room temperature to 585 °C. During the in-field steps of the protocol, a laboratory DC magnetic field of (50.0 ± 0.05) μT was applied during heating and cooling along the *z*-axis of the cylindrical samples. Every third temperature step, a pTRM check (control heating) was performed to detect possible changes in the pTRM's acquisition capacity. The cooling rate dependence of TRM was investigated following a modified procedure to that described by [21]. At the end of the AI experiments, all specimens were heated two more times at 560 °C under the same laboratory field. The last measurement (in-field step) of the AI experiment was designated as TRM1. Then, a second TRM (TRM2) was given to all the samples but this time using a longer cooling time (~6 to 7 h). Finally, a third TRM (TRM3) was created using the same cooling time as that used during the TRM1 creation (~40 to 45 min). The cooling rate factor f_{CR} was calculated as the ratio between the intensity acquired during a long and a short cooling time: f_{CR} = TRM2/TRM1. Changes in TRM acquisition capacity were estimated through the percentage variation between the intensity acquired during the same cooling time (f_{AC} = TRM3/TRM1). The cooling rate correction was only applied when the corresponding change in TRM acquisition capacity was close to 1 and $f_{CR} > 1$ [22].

In total, 19 samples (Table 4) yielded technically acceptable paleointensity determinations. For these samples, the NRM fraction f ranges between 0.86 and 0.61, while the quality factor q varies from 6.8 to 14.4. The individual archaeointensity values obtained in this study range from 35.7 to 71.2 μT, with medium values of 38.7 μT for SGEN01/13 and 66.1 μT and 67.8 μT for the two fragments of SGEN03/14.

Table 4. Summary of archaeointensity determination with Coe et al., 1978, including quality parameters together with interval of temperatures involved.

SAMPLE	LAB REF	N	T1-T2	f	g	q	H(anc)	σH
SGEN01/13	51	12	200-585	0.62	0.82	9.6	37.6	1.2
	52	13	150-585	0.61	0.83	9.2	40.7	2.1
	53	13	150-585	0.56	0.86	7.6	43.6	2.2
	54	13	150-585	0.72	0.84	10.3	38.6	2.5
	55	12	200-585	0.73	0.81	11.2	38.4	2.2
	56	12	200-585	0.69	0.82	8.3	36.5	2.1
	57	13	150-585	0.74	0.84	12.6	35.7	1.9
							38.7	**2.7**
SGEN03/14A	60	13	150-585	0.81	0.87	14.4	63.1	3.1
	61	11	250-585	0.80	0.85	9.3	64.4	3.2
	62	11	250-585	0.74	0.81	6.8	66.1	3.4
	63	12	200-585	0.82	0.83	14.1	67.2	3.9
	64	11	250-585	0.79	0.82	11.2	69.6	4.1
	65	12	200-585	0.86	0.86	14.8	68.1	4.2
							66.1	**2.9**
SGEN03/14B	66	11	250-585	0.83	0.88	14.3	71.2	4.3
	67	11	200-575	0.79	0.83	11.1	68.2	4.2
	68	11	250-585	0.85	0.84	15.8	67.4	4.3
	69	11	250-585	0.82	0.84	12.6	68.8	4.1
	70	11	250-585	0.78	0.80	8.9	66.7	3.9
	71	12	150-575	0.79	0.52	8.2	65.6	4.5
							67.8	**1.9**

The main concern during any absolute-intensity study is related to the uncertainty of whether the technically determined values have geomagnetic significance and thus confirm the primary thermoremanent origin of the magnetization created in these samples during the cooling from high temperatures. Most representative Arai–Nagata plots are presented in Figures 5 and 6. In both cases, the determinations seem to be of high technical quality. Associated saturation magnetization vs. temperature curves yielded reasonably reversible heating and cooling segments pointing to Ti-poor titanomagnetite (almost pure magnetite) as the principal magnetic carrier. The continuous susceptibility plot, however, shows marked irreversibility for sample SGEN01 (Figure 7) with evidence for two ferromagnetic phases during the heating, while the cooling curve only indicates the presence of magnetite. This behavior may be due to the inversion of unstable titanomaghemites into magnetite, and, thus, the remanent magnetization may be suspected to have chemical or thermochemical remanent magnetization [23]. Due to this fact, the intensity value of sample SGEN01 was not used for the archaeomagnetic-dating exercise, and probable age intervals were estimated based only on magnetic inclination and declination. The susceptibility vs. temperature curve for sample SGEN03 shows reversible behavior during the heating–cooling cycle and indicates evidence of a single ferromagnetic phase (magnetite) on both segments. In this case, the archaeomagnetic dating was achieved using the full geomagnetic vector (direction and intensity). As already proved by [24], continuous susceptibility curves appear more sensitive to magnetic mineralogy than directional ones, which agrees with theoretical considerations. Magnetic susceptibility thermal variation combines the thermal variation of the two magnetic parameters (spontaneous magnetization, Ms, and coercive force, Hc) when induced magnetization (i.e., when saturation is reached) describes the thermal evolution of spontaneous magnetization only.

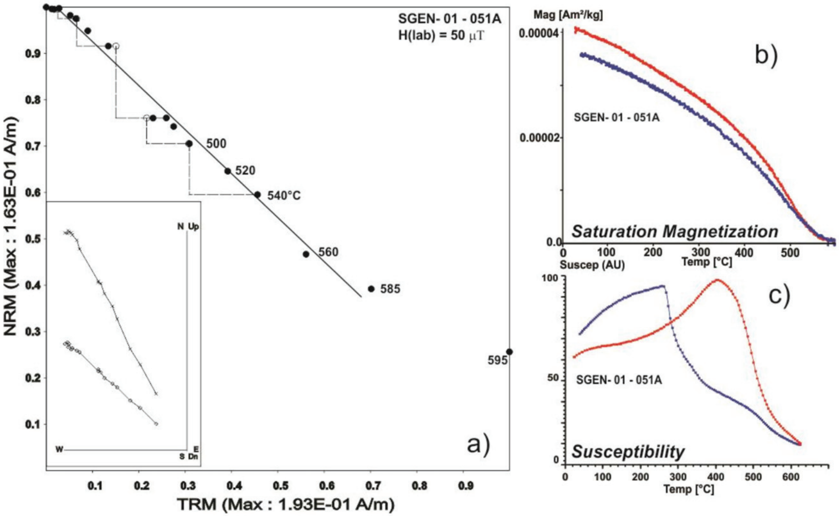


Figure 5. Thellier–Coe paleointensity determination for sample SGEN01 together with associated NRM endpoint (**a**) orthogonal vector plot. Also shown are saturate magnetization (**b**) and susceptibility (**c**) vs. temperature continuous thermomagnetic curves.

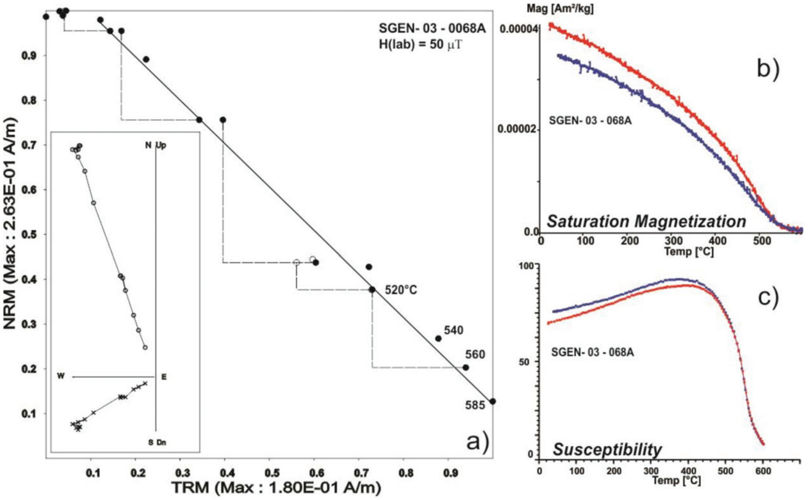


Figure 6. Thellier–Coe paleointensity determination for sample SGEN03 together with associated NRM endpoint (**a**) orthogonal vector plot. Also shown are saturate magnetization (**b**) and susceptibility (**c**) vs. temperature continuous thermomagnetic curves.

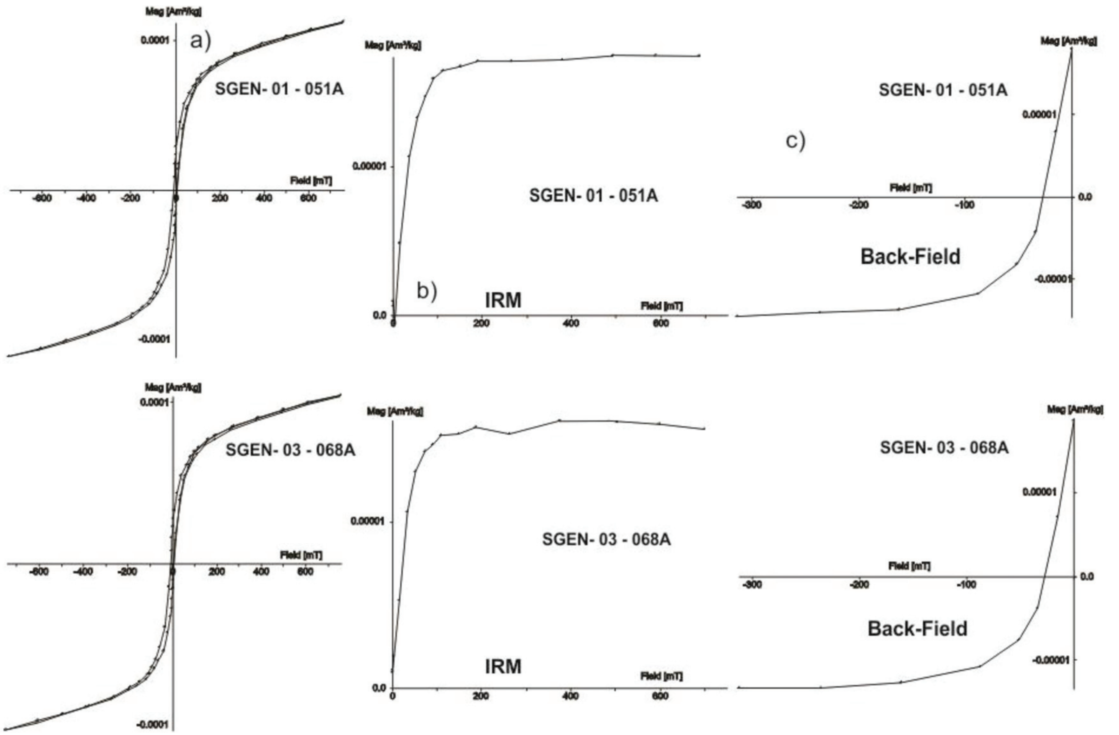


Figure 7. A summary of rock-magnetic experiments carried out on San Genesio samples: (**a**) hysteresis plot obtained with variable field translation balance, (**b**) associated isothermal-remanent acquisition curve, and (**c**) back-field experiments to retrieve the coactivity of remanence.

6. Archaeomagnetic Ages

The directional and intensity measurements on the three San Genesio furnaces were processed using the SCHA.DIF.4k model proposed by [6], which is the most complete PSVC currently available for Europe. The resulting ages for the analyzed structure are SGEN01: 855–987 CE at the 95% probability level and **846–911 CE** at the 65% probability level; SGEN02: 651–848 (95%), **696–799 CE** (65%). The SGEN01 ceramic furnace results indicate a younger and larger age interval compared to the one obtained by the 6.0 version of the PSVC curve [8] (Table 5). This fact is due to the flat top (Figure 8) of the updated reference geomagnetic curve SCHA.DIF.4k, which is used in the 8.0 version of the MATLAB tool for archaeomagnetic dating produced by [7]. The same effect (Table 5 and Figure 9) takes place for the age range of SGEN02, which is widened compared to the age previously obtained with the second version of the curve [9].

Table 5. Directional ages calculated from different versions of the PSVC. (1) SHA.DIF.14k model [7]. (2) SCHA.DIF.4k model [9].

	(1)	(2)
SGEN01	759–849 CE	**846–911 CE**
SGEN02	680–721 CE	**696–799 CE**
SGEN03	624–631 CE	**623–644 CE**

The obtained directional age for the SGEN03 furnace is 611–676 CE (at the 95% probability level) and **623–644 CE** at the 65% probability level (Table 5). By adding the mean of intensity data obtained from the analysis of two fragments of the same furnace, a value of

621–650 CE is obtained with a 95% probability level using both directional and intensity curves of [7,8], and a value of 624–631 results at the 65% probability level (Table 5 and Figure 10a). We processed SGEN03 data also with the reference curve of [9], but the still imprecise intensity curve available for this time interval [8] in the version 8.0 of the dating tool resulted in a loss of precision of this datum. For this reason, we accept here the only directional and slightly less precise age obtained by the 8.0 version of the dating tool (Figure 10b). This choice is reasonable also considering that the high precision of the data obtained for this furnace (α_{95} 0.8) requires an equally precise reference curve to obtain a reliable age.

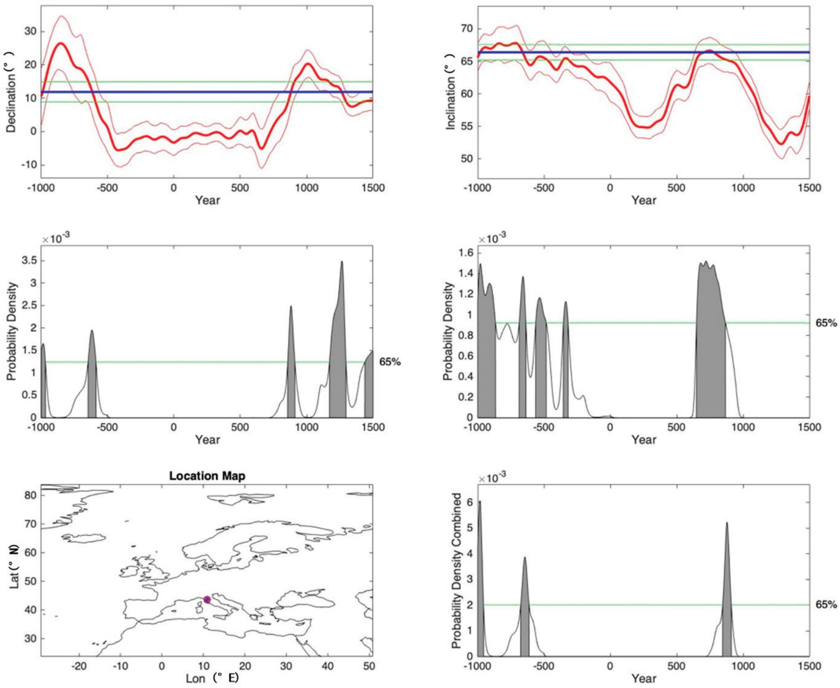


Figure 8. Archaeomagnetic dating of the SGEN01 furnace. Inclination and declination curves are shown with their probability density. The SCHA.DIF.4k model proposed by [9] has been used. Calibrated date intervals are given at a 65% level.

As we have seen (Table 5), the obtained ages based on the new version of the dating tool [9] differ slightly from the directional ages previously obtained by the use of older, less complete reference curves [7]. In fact, absolute ages depend on the adopted reference curve, and these two pieces of information should always be considered together. Furthermore, the perfect curve for describing changes in directional and intensity geomagnetic values can only be drawn for the period after 1640, when direct measurements of the earth's magnetic field began [25]. Of course, also for this curve, the uncertainties decrease with the increase in the number and precision of the measurements made over time by scholars of magnetism. For the previous periods, it is necessary to rely totally on reference curves built on data obtained from measurements made on objects of known age, obtained in another way. For this reason, the geomagnetic reference curves have varied a lot over time and, consequently, also the age determinations that were based on these varying reference curves.

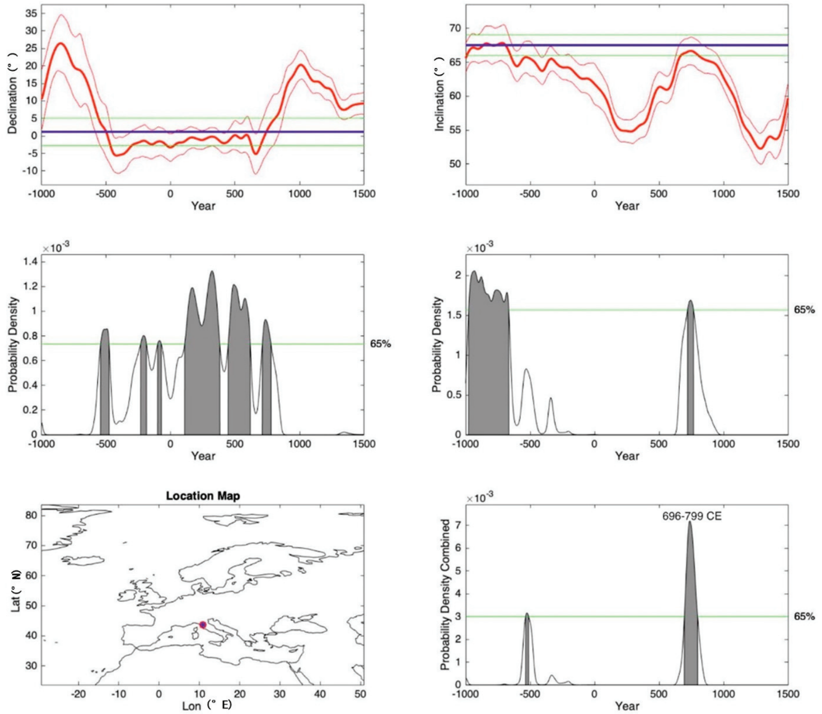
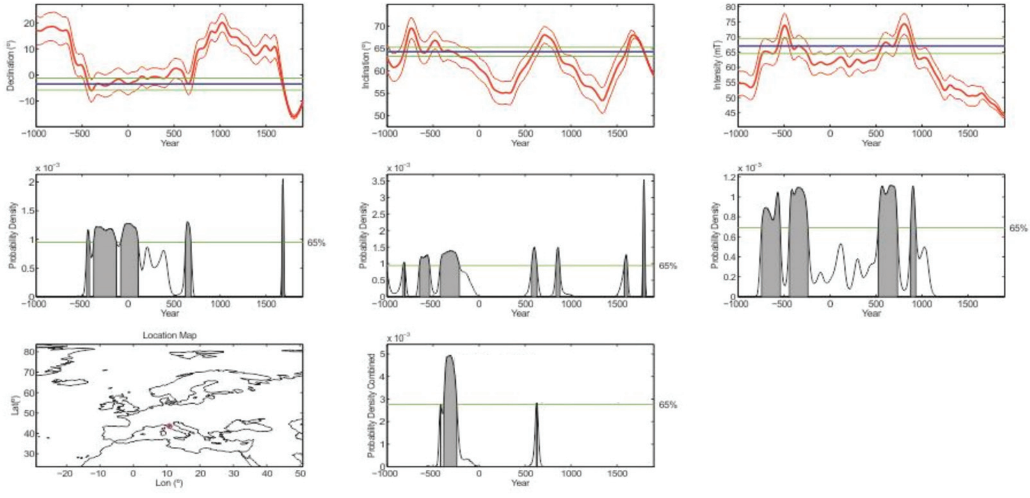


Figure 9. Archaeomagnetic dating of the SGEN02 furnace. Inclination and Declination curves are shown with their probability density. The SCHA.DIF.4k model proposed by [9] has been used. Calibrated date intervals are given at a 65% level.



(**a**)

Figure 10. *Cont.*

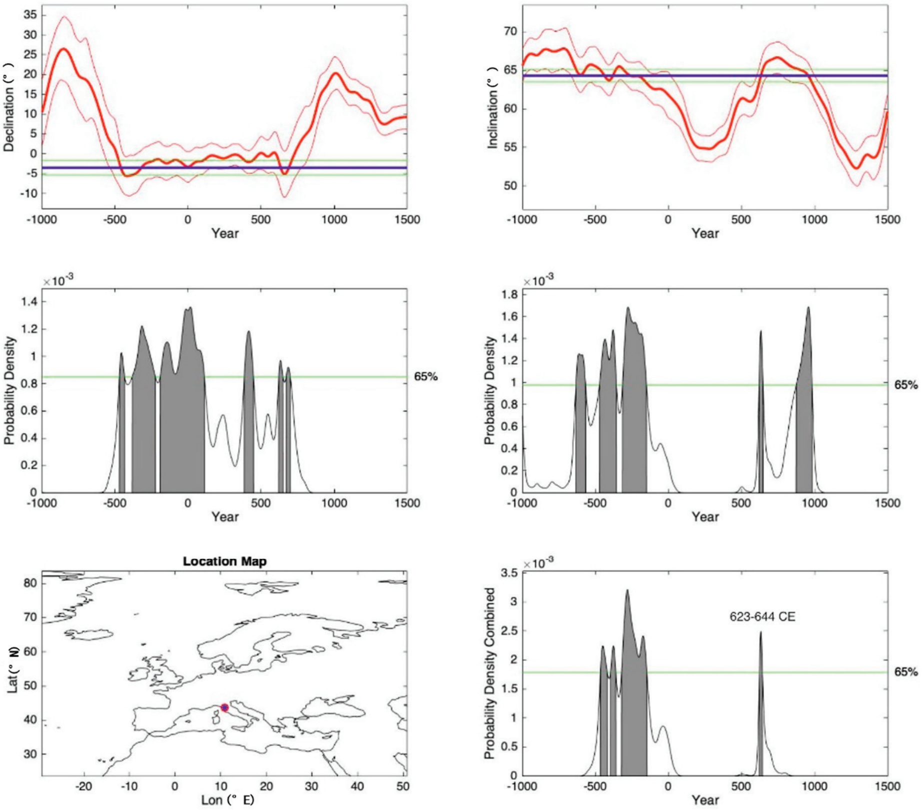


Figure 10. (**a**)—Archaeomagnetic dating of the SGEN03 furnace. Full vector curves are shown with their probability density. SHA.DIF.14k model proposed by [7] has been used. Calibrated date intervals are given at a 65% level. (**b**)—Archaeomagnetic dating of the SGEN03 furnace. Inclination and declination curves are shown with their probability density. The SCHA.DIF.4k model proposed by [9] has been used. Calibrated date intervals are given at a 65% level.

7. Data Discussion and Conclusions

At the transition between the 9th and 10th centuries CE, the settlement built around the San Genesio parish church was a place of passage and rest for numerous travelers due to its location at the intersection between the Via *Francigena* and the *Quintia* [1]. Thus, the presence of a ceramic kiln used for the production of pottery is expected in this time period, consistent with the age interval of furnace SGEN01, from 846 to 911 CE with a probability of 65%. The SGEN02 furnace shows the largest age interval, from 696 to 799 CE with a probability of 65%, among the three analyzed structures. This result could be due to the higher analytical uncertainty, with α_{95} of 1.5, compared to the other two furnaces SGEN01 and SGEN03, with α_{95} of 1.2 and 0.8, respectively. In turn, these higher analytical uncertainties can be related to the feeble magnetization of the clay used for building this furnace, as suggested by the obtained results and the partial lack of red color. The 8th century CE corresponds to the more probable period for the first reconstruction and enlargement of the parish church of San Genesio (which will be cited from this moment on as "ecclesia Sancti Genesii" in the latin written sources) when perhaps it was decided to promote it as a baptismal church ("*ecclesiae baptismales*"), a title that was found in documents starting from 763 [1]. It is very probable that this period also corresponds to a growth of the inhabited area and consequently of service structures, such as shared domestic ovens, as the structure of SGEN02 could be tentatively interpreted.

In the San Genesio area, four major funerary phases have been recognized [26,27]. The first one (Late Antique) has been dated to the 6th century CE and is the oldest cemetery phase recorded at this site. The second one (Early Medieval I) dates to the 7th–9th century CE, while the third phase (Early Medieval II) dates to the 10th century CE [4]. The fourth and last phase (Late Medieval) spans from the 11th to the 13th centuries. In this framework, the SGEN03 furnace is of interest for the presence of graves curved inside the furnace itself (Figure 2). The archaeomagnetic directional age estimated for the SGEN03 structure (from 623 to 644 CE with a probability of 65%) is the most precise of the obtained ages in the studied area. The obtained age range for this furnace positions this structure before the presence of the first ecclesiastical structure at San Genesio (the second half of the 7th century AD) and at the beginning of the second of the known funerary phases. Furthermore, the age and the metallurgic use of this furnace are consistent with the archaeological investigation that has attested the presence of craft activities during this period [1,4].

In conclusion, this archaeomagnetic study allowed us to give an age to three furnaces belonging to three distinct phases of frequentation and use of the site of San Genesio, which agreed with their stratigraphic order and the very complex overlap of structures and memories that characterized this important archaeological place during times.

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References

1. Cantini, F.; Salvestrini, F. *Vico Wallari—San Genesio, Ricerca e Indagini Archeologiche su una Comunità del Medio Valdarno Inferiore Fra Alto e Pieno Medioevo*; Atti della giornata di studio, San Miniato, Italy, 1 December 2007; Firenze University Press: Florence, Italy, 2010; p. 184. Available online: https://books.fupress.com/catalogue/vico-wallari--san-genesio-ricerca-storica-e-indagini-archeologiche-su-una-comunit-del-medio-valdarno/1936 (accessed on 28 October 2022).
2. Dominici, S.; Mazzanti, R.; Nencini, C. Geologia dei dintorni di San Miniato tra l'Arno, l'Elsa e l'Era. *Quad. Mus. St. Nat. Livorno* **1995**, *14*, 1–27.
3. Mendera, M.; Cantini, F.; Mercante, F.; Silvestri, A.; Gallo, F.; Molin, G.; Pescarin Volpato, M. Where does the medieval glass from San Genesio (Pisa, Italy) come from? In Proceedings of the AIHV Annales du 20me Congrès, Fribourg/Romont, Switzerland, 7–11 September 2015; Verlag Marie Leidorf GmbH, Geschäftsführer: Rahden, Germany; pp. 360–365, ISBN 978-3-86757-024-4.
4. Viva, S.; Cantini, F.; Fabbri, P.F. Post mortem fetal extrusion: Analysis of a coffin birth case from an Early Medieval cemetery along the Via Francigena in Tuscany (Italy). *J. Archaeol. Sci. Rep.* **2020**, *32*, 102419. [CrossRef]
5. Cantini, F.; Viva, S.; Marani, F. La necropoli di seconda metà VI secolo di San Genesio (San Miniato-Pisa): Elementi endogeni ed esogeni. In *Dalle steppe al Mediterraneo, Popoli, Culture, Integrazione, Proceedings of the Atti del Convegno Internazionale di Studi, Fondazioni e Rituali Funerari Delle Aristocrazie Germaniche nel Contesto Mediterraneo, Cimitile-Santa Maria Capua Vetere*; Naples, Italy, 18–19 June 2015; Ebanista, C., Rotili, M., Eds.; Guida Editor: Naples, Italy, 2017; pp. 251–268. ISBN 978-88-6866-357-5.
6. Pavón-Carrasco, F.J.; Rodriguez-Gonzalez, J.; Osete, M.L.; Torta, J.M. A Matlab tool for archaeomagnetic dating. *J. Archaeol. Sci.* **2011**, *38*, 408–419. [CrossRef]
7. Pavón-Carrasco, J.F.; Osete, M.L.; Torta, M.J. A geomagnetic field model for the Holocene based on archaeomagnetic and lava flow data. *Earth Planet. Sci. Lett.* **2014**, *388*, 98–109. [CrossRef]
8. Pavón-Carrasco, J.F.; Gómez-Paccard, M.; Hervé, G.; Osete, M.L.; Chauvin, A. Intensity of the geomagnetic field in Europe for the last 3 ka: Influence of data quality on geomagnetic field modeling. *Geochem. Geophys. Geosyst.* **2014**, *15*, 2515–2530. [CrossRef]

9. Pavón-Carrasco, F.J.; Campuzano, S.A.; Rivero-Montero, M.; Molina-Cardín, A.; Gómez-Paccard, M.; Osete, M.L. SCHA.DIF.4k: 4000 Years of Paleomagnetic Reconstruction for Europe and Its Application for Dating. *J. Geophys. Res. Solid Earth* **2021**, *126*, e2020JB021237. [CrossRef]
10. Schnepp, E.; Worm, K.; Scholger, R. Improved sampling techniques for baked clay and soft sediments. *Phys. Chem. Earth* **2008**, *33*, 407–413. [CrossRef]
11. Thellier, E. Sur la direction du champ magnétique terrestre en France durant les deux dernières millénaires. *Phys. Earth Planet. Int.* **1981**, *24*, 89–132. [CrossRef]
12. Le Goff, M. *Inductomètre à Rotation Continue Pour la Mesure des Faibles Aimantations Rémanentes et Enduites en Magnétisme des Roches, Mém. Diplôme d'Ingénieur*; CNAM: Paris, France, 1975.
13. Thellier, E.; Thellier, O. Sur l'intensité du champ magnétique terrestre dans le passé historique et géologique. *Ann. Geophys.* **1959**, *15*, 285–376.
14. McFadden, P.L. Rejection of palaeomagnetic observations. *Earth Planet. Sci. Lett.* **1982**, *61*, 392–395. [CrossRef]
15. Ficher, R.A. Dispersion on a sphere. *Proc. R. Soc. London (A)* **1953**, *217*, 295–305.
16. Mcintosh, G.; Catanzariti, G. An introduction to archaeomagnetic dating. *Geochronometria* **2006**, *25*, 11–18.
17. Malfatti, J.; Principe, C.; Gattiglia, G. Archaeomagnetic investigation of a metallurgic furnace in Pisa (Italy). *J. Cult. Herit.* **2011**, *12*, 1–10. [CrossRef]
18. Bucur, I. The direction of the terrestrial magnetic field in France during the last 21 centuries. *Phys. Earth Planet. Inter.* **1994**, *87*, 95–109. [CrossRef]
19. Coe, R.S. Paleo-intensities of the earth's magnetic field determined from tertiary and quaternary rocks. *J. Geophys. Res.* **1967**, *72*, 3247–3262. [CrossRef]
20. Coe, R.S.; Grommé, S.; Mankinen, E.A. Geomagnetic paleointensities from radiocarbon-dated lava flows on Hawaii and the question of the Pacific nondipole low. *J. Geophys. Res.* **1978**, *83*, 1740–1756. [CrossRef]
21. Chauvin, A.; Garcia, Y.; Lanos, P.; Laubenheimer, F. Paleointensity of the geomagnetic field recovered on archaeomagnetic sites from France. *Phys. Earth Planet. Inter.* **2000**, *120*, 111–136. [CrossRef]
22. Morales, J.; Goguitchaichvili, A.; Acosta, G.; González-Morán, T.; Alva-Valdivia, L.; Robles Camacho, J.; Hernández-Bernal, M.S. Magnetic properties and archeointensity determination on Pre-Columbian pottery from Chiapas, Mesoamerica. *Earth Planets Space* **2009**, *61*, 83–91. [CrossRef]
23. Dunlop, D.J.; Özdemir, Ö. *Rock Magnetism. Fundamentals and Frontiers*; Cambridge Studies in Magnetism Series; Cambridge University Press: Cambridge, UK, 1997; pp. 1–573.
24. Goguitchaichvili, A.; Morales, J.; Urrutia-Fucugauchi, J. On the use of continuous thermomagnetic curves in paleomagnetism. *C. R. Acad. Sci. Earth and Planet. Sci.* **2001**, *11*, 699–704.
25. Principe, C.; Malfatti, J. Giuseppe Folgheraither: The Italian pioneer of archaeomagnetism. *Earth Sci. Hist.* **2020**, *39*, 305–335. [CrossRef]
26. Riccomi, G.; Minozzi, S.; Zech, J.; Cantini, F.; Giuffra, V. Stable isotopic reconstruction of dietary changes across Late Antiquity and the Middle Ages in Tuscany. *J. Archaeol. Sci. Rep.* **2020**, *3*, 102546. [CrossRef]
27. Viva, S.; Lubritto, C.; Cantini, F.; Fabbri, P.F. Evidence of Barbarian migrations and interpersonal violence during the Gothic War in sixth-century Tuscany: The case of the Goth horseman from San Genesio (Pisa). *Archaeol. Anthropol. Sci.* **2022**, *14*, 39. [CrossRef]

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Depopulation of the Northern Border of Mesoamerica during the Early Postclassic: Evidence from the Reappraisal of Archaeomagnetic Data

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Abstract: The Mesoamerican Postclassic and Epiclassic were periods of drastic change and transformation related to social, political and economic aspects as well as settlement patterns. Mexico's northern boundary expansion, rise, and subsequent demise is a matter of debate which remains essentially unsolved. Possible causes include climatic changes, landscape degradation or prolonged bellicose relations with nomadic groups. Still, no consensus exists on why such apparent instability and decline occurred at major archaeological settlements on the northern Mesoamerican border, also known as the septentrional frontier. The scarcity of absolute chronological constraints is definitively a handicap that impedes the assessment of northern Mesoamerica's development from its apogee to its decline. The archaeomagnetic method has been used during the last decades to analyze burned archaeological artifacts belonging to Mesoamerica's north and central-west frontiers, including different Mexican states. Namely, high-resolution studies were carried out at Aguascalientes (El Ocote), Guanajuato (El Cóporo, Lo de Juárez and Plazuelas), Jalisco (Cerro de Los Agaves, La Palma and El Palacio de Ocomo) and Zacatecas (La Quemada). It was successfully proved that archaeomagnetic dating might greatly contribute to refining the chronology and development of major pre-Hispanic settlements. These studies were based on available geomagnetic curves at the time of publication. However, global geomagnetic models have experienced substantial improvement with the development of local/regional reference archaeomagnetic curves during the last few years. Hence, the need arises for a critical reassessment of reported age intervals and corresponding chronological contexts. Updated archaeomagnetic ages are recalculated considering the geomagnetic models SHA.DIF.14K and SHAWQ.2K as well as the two regional paleosecular variation curves for Mesoamerica. A bootstrap resampling method is used to obtain an optimal age range for each studied structure. These new absolute chronologies indicate that the last fire exposure of the vast majority of the analyzed artifacts unequivocally corresponds to the Mesoamerican early Postclassic related to the depopulation stage apparently caused by environmental changes.

Keywords: Mesoamerica; northern frontier; paleoclimate; archaeomagnetism; chronology; abandonment; depopulation

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1. Introduction

The northern border of Mesoamerica, also known as Marginal Mesoamerica, was a matter of debate due to the presence of a series of important pre-Hispanic settlements occupied by groups of Mesoamerican farmers between approximately 200 and 900 AD. In the

1940s, Paul Kirchoff proposed the territorial extension and cultural features of Mesoamerica, whose northern border reached the Sinaloa River, Santiago, Lerma, Moctezuma and Panuco [1]. The region north of these tributaries was occupied by nomadic groups during the 16th century, creating the cultural areas of *Aridoamérica* and *Oasisamérica* [2,3] . . . Although ethnohistoric data addressed the conditions of the northern border in the 16th century [4,5], there was little archaeological information at this time with which to understand pre-Hispanic occupation [6]. The first archaeological surveys began in the 1960s, reorienting the extension of the northern frontier of Mesoamerica, which was called Marginal Mesoamerica because it was located on the margins of the Mesoamerican cultural area [7]. Within this framework, many archaeological surveys were carried out in the states of Durango, Zacatecas, San Luis Potosí, Jalisco and Guanajuato, recovering essential information on ceramic and lithic types and settlements. Moreover, it was possible to propose new hypotheses around temporalities and population migrations [8].

By the early 1960s, Pedro Armillas presented his environmental hypothesis about the expansion of the Mesoamerican border towards the North of Mexico by agricultural groups. Such expansion was associated with favorable climatic conditions for cultivation during the first millennium; however, when this environment disappeared, the region was abandoned between 900 and 1000 AD [9–12]. Different researchers widely accepted this idea to explain the cultural developments in this Mesoamerican territory [13–20]. In the 1980s, new advances were made to assess the regional resources, population mobility, relations with the Valley of Mexico, chronology and nature of the borders of this region. This strengthened the idea of an occupation by Mesoamerican agricultural groups during the first millennium of the Christian Era that ended in approximately 900/1000 [21]. Regarding the abandonment of this region, the following three hypotheses have been proposed. Hypothesis 1 considered environmental conditions [9,11]. Hypothesis 2 suggested the rupture of Mesoamerican trade networks due to a drastic transformation of the region [14,21]. Hypothesis 3 put forward a possibility of the intensification of the struggle between the different groups for the control of land for agriculture, affecting the economy [22,23].

It is imperative to point out that conflictive events and fires caused by the inhabitants themselves occurred in some settlements during their final stage, as has been indicated for Plazuelas [24–28], Cóporo [29,30] and La Quemada [31]. In Cerro Barajas (state of Guanajuato), the population was reduced, ritual areas were closed and abandonment offerings were deposited [32]. In situ, burned structures are excellent candidates for magnetic studies, and thus archaeomagnetism may decisively contribute to increasing the quantity and quality of absolute chronology data. Archaeomagnetism investigates the history of the Earth’s magnetic field in terms of variations in direction (inclination and declination) and intensity. Archaeomagnetism uses archaeological materials that have undergone heating processes at relatively high temperatures (beyond the Curie temperature of magnetite and/or hematite). The principle of archaeomagnetism [33,34] is based on the peculiarities of the geomagnetic field and magnetic properties of iron oxides commonly found in most archaeological artifacts. The artifacts acquire a remanent magnetization in a specific time. As the Earth’s magnetic field changes in direction and intensity with time (paleosecular variations), the moment of the acquisition of the remanent magnetization can be determined by comparing these parameters with known records of the geomagnetic field in the past in a specific locality. When the past variations of the Earth’s magnetic field have been well established, archaeomagnetic dating can be as precise as the more expensive methods of absolute dating. Moreover, the great advantage of the archaeomagnetic method is that it directly dates the object, while radiocarbon age is commonly associated with different archaeological contexts. In areas where radiocarbon ages are sparse and of dissimilar qualities, archaeomagnetism emerges as a unique alternative.

Archaeomagnetic studies on the northern border of Mesoamerica have increased considerably in recent years (Figures 1 and 2 and Table 1) since several of the archaeological settlements in the region have in situ burned structures, such as floors, hearths, ovens and cavities. These studies have not only provided absolute chronological data lacking in each study site, but have also allowed the delineation of regional, cultural and social dynamics. In the present manuscript, we review available archaeomagnetic surveys in light of new global geomagnetic models and local paleosecular variation curves to determine the timing of the last fire exposure of studied artifacts. Moreover, a bootstrap resampling methodology was applied to estimate the most representative time intervals for each structure, periodizing local reference curves against global geomagnetic models. The objectives of our study are:

(1) Creating a reliable regional archaeomagnetic database upon the reappraisal of existing data considering recently available global geomagnetic models and local paleosecular variation curves for Mesoamerica.

(2) Estimating the archaeomagnetic age intervals of demise and abandonment at the Mesoamerican septentrional frontier by studying burned archaeological features.

(3) Defining the relationship (if any) between the age intervals of abandonment and paleoclimate changes through the analysis of the existing environmental record.

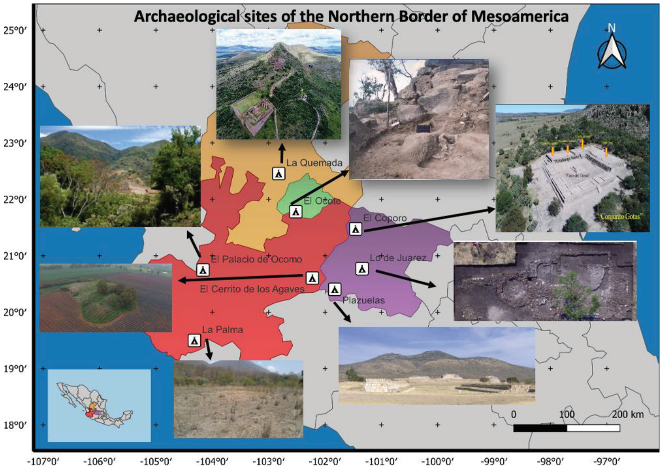

Figure 1. Location of the archaeological sites mentioned in the text.

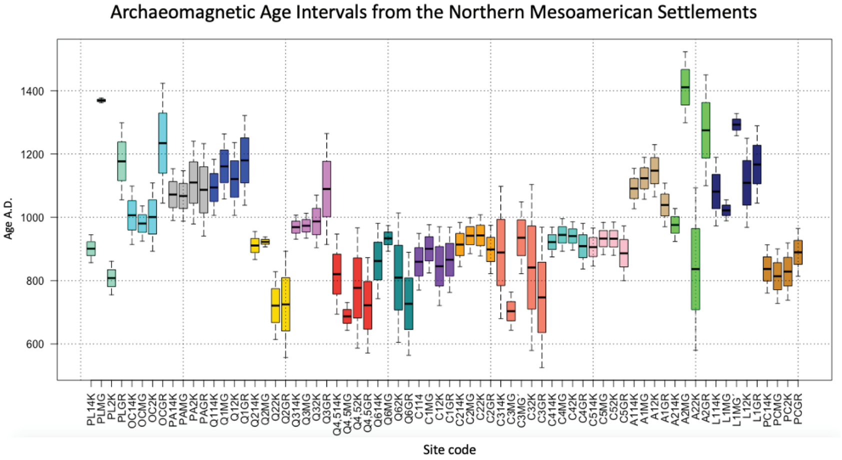

Figure 2. Possible archaeomagnetic age intervals computed using global geomagnetic models and regional reference paleosecular variation curves (see text for more details).

Table 1. Available archaeomagnetic data for the archaeological sites belonging to the northern frontier of Mesoamerica indicating their location, possible age intervals and the geomagnetic model used.

Author	Archaeological Site	Location	Inclination (°)	Declination (°)	Intensity	α_{95}	Dating Interval Obtained (A.D.)
Morales et al., 2015 [28]	Plazuelas	Guanajuato	20.3	351.5	46.6 ± 1.32 μT	2.8°	907–997
Cejudo et al., 2019 [35]	El Ocote	Aguascalientes	34.8	351.9		4.3°	**916–1088** 1205–1335
Pomedio et al., 2022 [36]	La Palma	Jalisco	32.7	344.4		3.8°	986–1150
López et al., 2019 [31]	La Quemada	Zacatecas	40.59	345.55	56.5 ± 3.9 μT	3.4°	1018–1163
			33.67	356.16	40.6 ± 2.6 μT	2.1°	722–820 **854–968**
Torreblanca et al., 2020 [30]	La Quemada	Zacatecas	34.7	351.3		2.6°	931–1006
García-Pimentel et al., 2020 [30]	El Cóporo	Guanajuato	33.4	358.9		2.7°	**693–947** 1463–1526 1571–1623
			33.1	354.7		3.2°	757–980
			25.7	353.8		4.2°	769–946
			27.4	351.4		3.9°	840–977
			30.5	353.2		8.7°	**685–1069** 1231–1332 1403–1538 1565–1645
			24.3	349.3		3.7°	863–967
			26.4	352.4		2.8°	827–963
Esparza et al., 2022 [37]	El Cerrito de Los Agaves	Jalisco	36.15	338.23		3.8°	1025–1155
			34.18	354.35		3.8°	**914–1028** 1213–1501 1617–1655
López et al., 2021 [38]	Lo de Juárez	Guanajuato	35.05	348.66		1.8	973–1204
Morales et al., 2020 [39]	El Palacio de Ocomo	Jalisco	21.6	357		3.1°	759–915

2. Archaeomagnetic Studies along the Northern Frontier of Mesoamerica

2.1. Plazuelas, Guanajuato

The Plazuelas archaeological zone is located in the community of San Juan El Alto Plazuelas to the west of the City of Pénjamo (state of Guanajuato). The main structure of the site is a buildup of quarry buildings, which is material acquired from the same ravine in which the pre-Hispanic settlement is located. Existing archaeological evidence indicates the site's occupation in the Late Classic or Epiclassic period between 600 AD and 900 AD. However, the age of the foundation of the site is the subject of debate. It could originate from the culture known as the Bajío Tradition brought by people who first populated this pre-Hispanic city. The site was occupied for 300 years and then was destroyed, burned and abandoned [24–28].

An archaeomagnetic investigation of an oriented burned floor was carried out on the extreme east of the archaeological site. It was possible to determine the direction (declination and inclination) and intensity of the remanent magnetization of the burned floor: Dec = 351.5°, Inc = 20.3° with $\alpha_{95} = 2.8°$ and intensity I = 46.6 ± 1.32 μT. The MATLAB tool developed by [40,41] was implemented using the CALS3k global geomagnetic model of the last three millennia. The combined probability of these three parameters gave the interval from 907 to 997 AD as the most probable age at the time of the last exposure to fire of the analyzed floor, with a confidence of 95% [28].

2.2. El Ocote, Aguascalientes

The El Ocote archaeological site is located 40 km southwest of the city of Aguascalientes near the community of Ocote and is distributed on the top and around the Los Tecuanes hill. Since 2000, reconnaissance studies have been continuously carried out on the site, and it is believed that the site's development occurred mainly between 650 and 850 AD during the Epiclassic period [35,42]. Consequent systematic excavations revealed a burned floor within the archaeological quadrant I on a surface of approximately 60 m^2 at an average depth of 0.60 m with respect to the present-day surface. Six in situ fragments were magnetically oriented to carry out the archaeomagnetic study [35]. The mean directions were obtained for the specimens exhibiting stable, single-component behavior. Subsequently, the dating tool implemented in Matlab [41] was used, considering the SHA.DIF.14K global model of the last fourteen thousand years [35]. The mean direction values obtained were Dec = 351.9°, Inc = 34.8° with α_{95} = 4.3°. We obtained the age interval 986 to 1088 AD by comparing the mean direction with the reference paleosecular variation curves. The dates obtained by radiometric methods correspond to the early development of the settlement [35]; the archaeomagnetic age corresponds to the late occupation of the site.

2.3. La Palma, Sierra Manantlán, Jalisco

The first archaeological explorations were carried out at the La Palma site within the Archaeology of the Sierra de Manantlán project. The surveys included a large area located to the northeast of the community of Cuzalapa within the valley of the same name on the southern slope (south of the state of Jalisco). The site comprises an area of 2.5 km^2 extending from north to south along the Las Tablas stream and is divided into five sectors [36]. In one of the reconnaissance studies, a burnt floor fragment was identified on the southeast corner of structure 1. The floor was characterized by a reddish brown to grayish color with a thickness of 13 cm and reached an approximate area of 60 by 64 cm. Within this stratigraphic unit, a medium-density occupation was inferred judging from the simple ceramic and lithic artifacts without the presence of decorated or diagnostic elements [36]. The mean direction was determined using the Fisher statistics analysis, obtaining an inclination Inc = 32.7°, declination Dec = 344.4° with parameters k = 181 and α_{95} = 3.8°. This mean direction was compared with the geomagnetic model SHA.DIF.14k (Pavón-Carrasco et al., 2014) [37] obtaining the age interval 986–1150 AD as the most probable age of the last fire exposure of the floor [36].

2.4. La Quemada, Zacatecas

The archaeological site of La Quemada is located in the center of the state of Zacatecas, Mexico, in the municipality of Villanueva south of the city of Zacatecas (the valley of Malpaso). La Quemada is one of the largest settlements within the northern border of Mesoamerica (Jimenez Betts, 2005). The archaeological zone is characterized by traces of strong fires, making it an excellent target for archaeomagnetic studies. Burnt floor samples were collected in the sacrificial plaza and in the Hall of Columns to determine the age ranges of the fall and abandonment of the site that apparently occurred as a religious closure ritual [31].

Two samples, LQ3 and LQ4, corresponded to the north sector of the Hall of Columns; the first corresponds to a burnt, hardened clay floor, and the second sample corresponds to a wall fragment. *The Plaza de los Sacrificios*, located on the third level of the settlement on the top of the hill, consists of a large plaza with an altar in the center and rooms to the east, south and west and a pyramidal base to the north. Samples LQ1 and LQ2 were taken from this area, corresponding to burned floors [31].

The mean directions for the *Plaza de los Sacrificios* were obtained using all the specimens corresponding to LQ1 and LQ2 that yielded Inc = 33.67° and Dec = 356.16° with precision parameters k = 323 and α_{95} = 2.1°. The mean directions for the *Hall of Columns* were calculated taking into account the eight specimens corresponding to sample LQ3, which yielded Inc = 40.59° and Dec = 345.55°, k = 266 and α_{95} = 3.4°. Specimens belonging to sample LQ1 corresponding to the *Plaza de los Sacrificios* provided an average paleointensity of 40.6 ± 2.6 μT, while the specimens belonging to the LQ3 sample corresponding to the Hall of Columns yielded an average paleointensity of 56.5 ± 3.9 μT [31]. We used the SHA.DIF.14K model [40,41] and obtained the age 854–968 AD as the most probable age of the fire of the floors of the *Plaza de los Sacrificios* (LQ1 and LQ2). We obtained the second probable age interval 722–820 AD, which should not be completely ruled out. For the

Hall of Columns (LQ3), the obtained age interval 1018–1163 AD does not coincide with the available radiocarbon age estimates [31].

A second archaeomagnetic study was carried out at La Quemada to place the main *Ballgame Court* within an absolute chronological framework. On this occasion, two hearths located in rooms associated with the court and a burned cavity on one of the walls were sampled. The *Ballgame Court* is located on the first level of the settlement at the foot of the hill's southern slope and consists of a structure 80 m long by 15 m wide with a north–south orientation. Archaeological excavations revealed the presence of three rooms associated with the *Ballgame Court* divided by masonry walls and associated with three phases of occupation based on overlapping architectural elements [30].

The first areas selected for the archaeomagnetic sampling corresponded to the two hearths that were found within the remnants from the last phase of occupation. Hearth 1 consisted of a rectangular hole on the ground 25 cm long by 15 cm wide and 10 cm deep. The second hearth had a circular shape of 50 cm in diameter and was covered with clay slabs. The third area selected for sampling was located in the outer zone of the *Ballgame Court*, in which a folded (sunken) wall and secondary deposits of bone remains were found. In the northwest corner carved into the bedrock a hole approximately 30 cm in diameter by 9 cm deep was discovered, which was covered with ash [30].

The mean direction obtained for Hearth 1 was obtained from 13 out of 16 specimens yielding Inc = 34.7°, Dec = 351.3° with α_{95} = 2.6°. For Hearth 2, the mean direction was obtained from 8 out of 12 specimens yielding Inc = 33.4°, Dec = 358.9° with α_{95} = 2.7 °. Finally, the mean direction for the burned cavity was obtained from 6 of 11 specimens that yielded Inc = 33.1°, Dec = 354.7° with α_{95} = 3.2°. Although the average directions of the three structures were very similar, Torreblanca et al. (2020) [30] performed archaeomagnetic dating on each of the structures separately. For Hearth 1, the interval 931–1006 AD was obtained as the most probable age of last heating or use. Hearth 2 sample analyses provided two age intervals: 693–947 AD and 1463–1623 AD. We obtained the age interval 757–980 AD as the most probable age of the last use or heating of the burned cavity [30]. Three of these intervals correspond to the La Quemada occupation phase and its transition to the Ciudadela phase, which represents the last period of activity in the area before the ballcourt was abandoned. However, the interval 1463–1623 AD corresponding to Hearth 2 shows a possible late occupation, which could be interpreted as a reoccupation of the site during the Postclassic period by Zacatecan groups [30].

2.5. El Cóporo, Guanajuato

El Cóporo is an archaeological zone located in the municipality of Ocampo in the northwest of the state of Guanajuato (Sierra de Santa Bárbara) next to the community of San José del Torreón. El Cóporo was created on the hill of the same name whose flat top was used to build the ceremonial area. Both on the slopes and flat parts, there is evidence of multiple ancient constructions. These spaces were made up of architectural ensembles called Llano, Gotas, Montes, Puerto del Aire, Cóporo, Caracol and Pilar [29]. Six sites were located where clear evidence of burned floors could be observed; 15 archaeomagnetic samples were collected there [30]. Since the average directions obtained for each site showed similar values, the probable age intervals of the last burning of the floors were also similar. The obtained age intervals were between the years 820 and 950 AD; for some samples, however, a wide interval from 685 to 1069 AD was obtained [30].

The ceramics and archaeological artifacts correspond to the last stage of occupation, corresponding to the Epiclassic period (600 to 900 AD). During the fall of Teotihuacán in approximately 550 AD, a decline of commercial networks occurred, and a new territorial conformation emerged that led to new regional government centers. During this stage, the Tunal Grande reached its maximum territorial extension, and El Cóporo became the Ocampo Valley's capital [30]. The abandonment of the Cóporo is the subject of debate; archaeological evidence indicates its decline around the year 900 AD, while recent studies [29] mention a period of reoccupation by the Toltecs around 950 AD. Later, in 1000 AD, Tunal Grande became completely uninhabited by Mesoamerican agricultural groups. The main result of this investigation is the fact that, regardless of the sampling site along the Cóporo, the absolute archaeomagnetic dating intervals are similar, indicating that a large, generalized and widespread fire occurred in a single episode. The presence of burned floors and collapsed buildings supports this hypothesis. However, the possibility of a closing ritual should be considered, since there is no evidence of violent or warlike actions [30].

2.6. Cerrito de Los Agaves, Jalisco

El Cerrito de Los Agaves is located 800 m north of the La Luz community, municipality of Jesús María, Jalisco, in the southeast portion of the region called Los Altos de Jalisco. The central area is made up of a large closed patio (Main Plaza), which has a central altar [43]. The first archaeological excavations at the site were carried out in 2017; the ceramic materials collected in the test pits were not enough to establish a chronological series. However, it was possible to place them in the Epiclassic period when comparing them with materials found at other sites in Los Altos (the central region of Jalisco and the adjacent Bajío region). In 2018, a second archaeological season was carried out in which the central altar and the main mound were studied. A 4 m deep hole was traced and excavated for each structure, which allowed the observation of the tamping of the patio that joins both constructions, partially freeing an access stairway that corresponds to the last construction stage [43].

The mean paleodirections for burned floors were calculated following Fisher's statistics, obtaining the following results: for the interior floor, an inclination Inc = 36.15° and a declination Dec = 338.23° with parameters k = 257 and α_{95} = 3.8°; for the floor exterior, an inclination Inc = 34.18° and a declination Dec = 354.35° with parameters k = 210 and α_{95} = 3.8°. Two archaeomagnetic intervals were obtained: one from 1025 to 1155 AD and one between 914 and 1028 AD [43]. New absolute archaeomagnetic ages show that the main period of occupation of El Cerrito de Los Agaves occurred between the years 600 and 1000 AD. Seven absolute radiocarbon dates were carried out in nearby sites in the region of Los Altos de Jalisco, with ages corresponding to the Bajío Tradition and Tunal Grande Tradition. The available radiocarbon results found are similar to the archaeomagnetic age intervals [43].

2.7. Lo de Juarez, Guanajuato

The Lo de Juárez site is located 6 km north of the city of Irapuato next to the Loma de Juárez community in the state of Guanajuato, Mexico. Structure 1 (a housing unit) and Structure 2 (a living space) were identified during the archaeological excavation. Inside Structure 1, a circular structure with a diameter of 50 cm was excavated, which includes a central hearth made up of basaltic rocks. Ceramic materials and a dozen human burials were also recovered. The work carried out in Structure 2 included the excavation of a cove on the western section at a depth of 1.30 m. A circular alignment was identified with quarried basaltic rocks arranged on a limestone stratum Ten standard paleomagnetic cores were drilled for the hearth and then oriented using both magnetic and solar compasses [38].

The mean directions together with the absolute intensities (for the furnace) were compared to the SHA.DIF.14K geomagnetic model [41] and the interval of 973–1204 AD was obtained as the probable age of the last use of the hearth corresponding to Structure 1.

The age obtained for the hearth of Structure 1 (973–1204 AD) indicates human activity in the area during the period of the depopulation of the northern border (900–1300 AD) in the early Postclassic. On the other hand, the result obtained for the oven of Structure 2 (36 BC–40 AD) represents the oldest absolute dating available in the region of the Guanajuato River basin and therefore suggests that the Lo de Juárez site may correspond to the Interphase (100 BC–1 BC) and Mixtlán (1 AD–250 AD) phases [38].

3. Data Analysis and Main Outcomes

A detailed review of archaeomagnetic studies along the northern border of Mesoamerica was carried out. This review allowed the elaboration of a valuable database (Figure 2 and Table 2) that contains the directional data of all the archaeological artifacts and the absolute intensity values. The archaeomagnetic age intervals obtained in our study are listed in Table 1. The global geomagnetic model SHA.DIF.14K [41] was used in eight of the nine studies. In a single case, CALS.3K was employed for the Plazuelas site by Morales et al. (2015) [28]. The SHAWQ2k global geomagnetic model was published recently and is based on a strict selection of available global archaeomagnetic and volcanic data. This new model presents a better description of the geomagnetic field during the last two millennia [44]. In addition, the local paleosecular variation curve (CVPS) by Mahgoub et al. (2019) [45] is based on data from historical lavas and archaeological artifacts exposed to fire in Mesoamerica during the last 46,000 years. The paleosecular variation directional curve for the last three millennia was published by García-Ruíz et al. (2022) [46]; it is based on 82 strictly selected archaeodirections of burned archaeological artifacts and recent volcanic eruptions. Archaeomagnetic dating was carried out for all the sites discussed in this manuscript using the global geomagnetic models SHA.DIF.14K and SHAWQ.2K, as well as the local paleosecular variation curves of Mahgoub et al. (2019) [45] and García-Ruíz et al. (2022) [46] (Table 2).

To obtain the most representative age interval at the statistical level, we applied the bootstrap resampling method first described by Efron (1979) [47]. We created a matrix of 200 theoretical observations for each archaeological artifact and four age intervals obtained using two global geomagnetic models and two local secular variation curves considering the minimum and maximum values. A uniform probability distribution of 40 values was calculated for the intervals derived from the global models and 60 values for the local reference variation curves giving greater weighting to local curves. The uniform distribution is considered the simplest probability model and is characterized by the fact that the cumulative distribution function, taken as a random variable, follows the uniform distribution over the interval (0,1). The uniform distribution is applied to determine powerful functions on randomness tests [48]. The outliners are equally considered between the maximum and minimum values [49]. The bootstrap resampling method does not require prior knowledge of the distribution function of an event and is based on random sampling. The method consists of creating samples of size n that allow the obtainment of a distribution function of the mean values for all generated data. Once the frequency function of the bootstrap mean values has been generated, the standard deviation of the bootstrap mean (Figure 3 and Table 3) and a confidence interval are calculated [50]. In this work, the bootstrap mean value of the age of each dated artifact was calculated along with its standard deviation and α_{95} confidence interval. Starting from the 200 theoretical observations generated for each artifact, resampling with a replacement of size n = 10,000 was performed. This generated 10,000 samples of 200 random values taken from the original sample, creating a matrix of 200 rows and 10,000 columns. Each column represents a subsample obtained from the original sample of the 200 initial theoretical observations. Subsequently, the mean of each of these subsamples, its standard error and 95% confidence interval were obtained.

Detailed archaeomagnetic surveys of the in situ burned archaeological structures indicate ages that correspond to the end of the Epiclassic and the beginning of the early Postclassic. Tables 1 and 2 summarize the results of the archaeomagnetic studies carried out in archaeological sites located on the northern border of Mesoamerica (Figure 1). Table 2 presents the results of the new dating approach used in this study. The four archaeomagnetic ages obtained for each archaeological artifact correspond to the two global geomagnetic models and the two local paleosecular variation curves, respectively. Figure 2 shows our study age intervals; each color corresponds to the same artifact. Abbreviated codes 14K, MG, 2K and GR refer to the model or curve used; SHA.DIF.14K and SHAWQ.2K respectively.

Assuming that the archaeomagnetic studies provide the age of the last use or exposure to fire, it is interesting to observe the contemporaneity of most of the ages for the different archaeological zones. All of the dates overlap the interval from 800 to 1100 AD linked to the apparent depopulation of the northern border of Mesoamerica during the early Postclassic.

Table 2. Reappraisal of archaeomagnetic age intervals using global geomagnetic models and local reference curves (see text for more details).

Archaeological Site	Site Code	Location	Dated Material	SHA.DIF.14k (14K) (A.D.)	Mahgoub et al., 2019 [45]. (MG) (A.D.)	SHAWQ.2K (2K) (A.D.)	García-Ruíz et al., 2022 [46]. (GR). (A.D.)
Plazuelas	PL	Guanajuato	Burned floor	857–945	1362–1377	755–861	1055–1299
El Ocote	OC	Aguascalientes	Burned floor	**914–1099** 1193–1337	**925–1036** 1279–1463	893–1109	1045–1424
La Palma	PA	Jalisco	Burned floor	990–1154	988–1147	979–1241	941–1233
La Quemada	Q1	Zacatecas	Burned floor	1006–1183	1058–1264	1006–1236	1038–1322
	Q2		Burned floor	704–825 **867–955**	**907–938** 1388–1506	614–828	557–893
La Quemada	Q3	Zacatecas	Fire pit	931–1007	**934–1013** 1307–1411	904–1070	914–1265
	Q4, Q5		Fire pit	**694–947** 1464–1524 1572–1624	**643–731** 1430–1541	**587–967** 1572–1692	571–873
	Q6		Burned cavity	743–981	**893–974** 1350–1497	605–1014	**564–890** 1178–1295
El Cóporo	C1	Guanajuato	Burned floor	770–949	824–977	721–970	763–969
	C2		Burned floor	844–984	885–999	878–1008	822–975
	C3		Burned floor	**680–1098** 1201–1348 1389–1546 1559–1651	**643–764** **822–1049** 1276–1542	579–1104	**525–969** 1016–1434
	C4		Burned floor	875–969	893–996	730–846 **896–986**	837–981
	C5		Burned floor	846–966	882–984	880–985	800–973
El Cerrito de Los Agaves	A1	Jalisco	Interior burned floor	1027–1155	1057–1190	1065–1230	970–1108
	A2		Exterior burned floor	**924–1028** 1214–1492 1623–1655	**1299–1523**	**580–1093** 1189–1487	427–738 **1100–1450**
Lo de Juárez	L1	Guanajuato	Fire pit	973–1190	**989–1055** 1258–1328	968–1250	1045–1289
El Palacio de Ocomo	PC	Jalisco	Burned floor	761–913	728–900	738–919	814–965

Judging from the data shown in Figure 2, it is evident that the four data obtained for our study age intervals are very similar. However, there are sites where these age intervals are considerably distant, such as the burned floor of Plazuelas. Although both the global geomagnetic models and the local curves yield probable age intervals with a confidence interval of 95%, in this study, we consider giving greater weight to the age intervals provided by the regional reference paleosecular variation curves. The bootstrap resampling method allowed us to unify the four age intervals obtained from the geomagnetic models and the local curve in a single interval generating 10,000 mean bootstrap values. The frequency histogram for the average age of each archaeological artifact indicates the limits of the confidence interval and its mean. The results of this exercise are reported in Table 3. The histograms were plotted for each archaeological artifact to illustrate the distribution of the bootstrap resampling data (Figure 3).

The most probable optimized age intervals obtained from the different archaeological artifacts (burned floors, ovens, hearths and a burned cavity) from the archaeological sites of the northern border of Mesoamerica provided an age range between 750 and 1100 AD. This matches archaeomagnetic ages obtained in our study and corresponds to the stage of apparent depopulation during the early Postclassic (Figure 4).

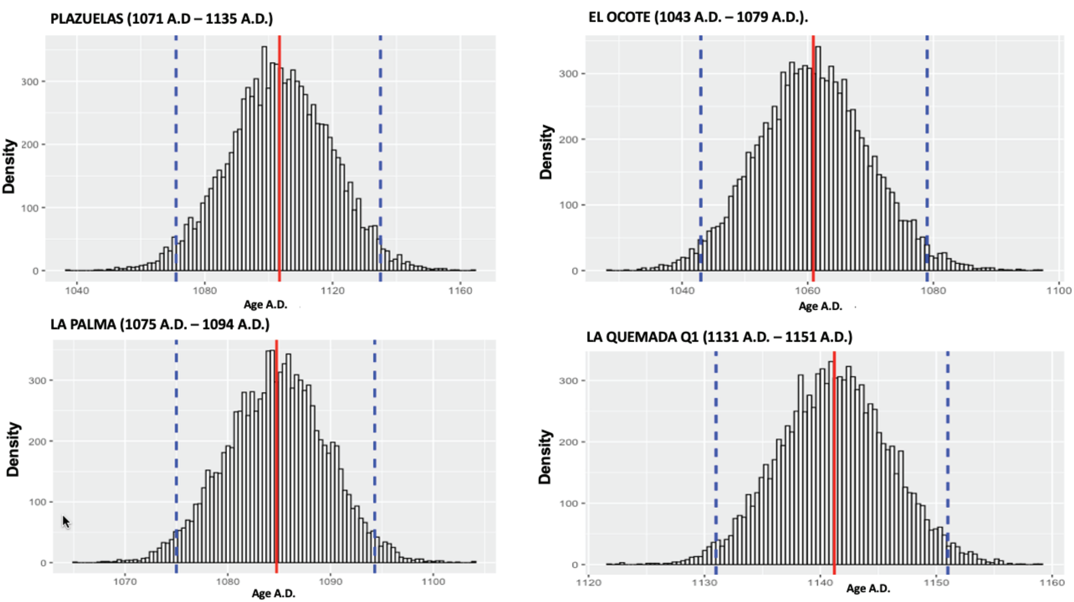

Figure 3. Histograms of the age intervals obtained for the burned floors of Plazuelas, El Ocote, La Palma and La Quemada by bootstrap resampling method; the red line indicates the mean age of the dated archaeological artifact, while the blue lines delimit the 95% confidence interval.

Table 3. Age intervals retrieved applying bootstrap method (please see text for more details).

Archaeological Site	Site Code	Location	Mean (A.D.)	Standard Deviation (Years)	95% Age Confidence Interval (A.D.)
Plazuelas	PL	Guanajuato	1103	32	1071–1135
El Ocote	OC	Aguascalientes	1061	18	1043–1079
La Palma	PA	Jalisco	1085	9.6	1075–1094
La Quemada	Q1	Zacatecas	1141	10	1131–1151
	Q2		821	16	805–837
La Quemada	Q3	Zacatecas	1017	12	1005–1029
	Q4,Q5		744	12	732–756
	Q6		843	16	827–859
El Cóporo	C1	Guanajuato	874	8	866–882
	C2		923	6	917–929
	C3		823	19	804–842
	C4		931	5.2	926–936
	C5		917	6	911–923
El Cerrito de Los Agaves	A1	Jalisco	1092	8	1084–1100
	A2		1159	34	1125–1193
Lo de Juárez	L1	Guanajuato	1136	14	1122–1150
El Palacio de Ocomo	PC	Jalisco	843	8	835–851

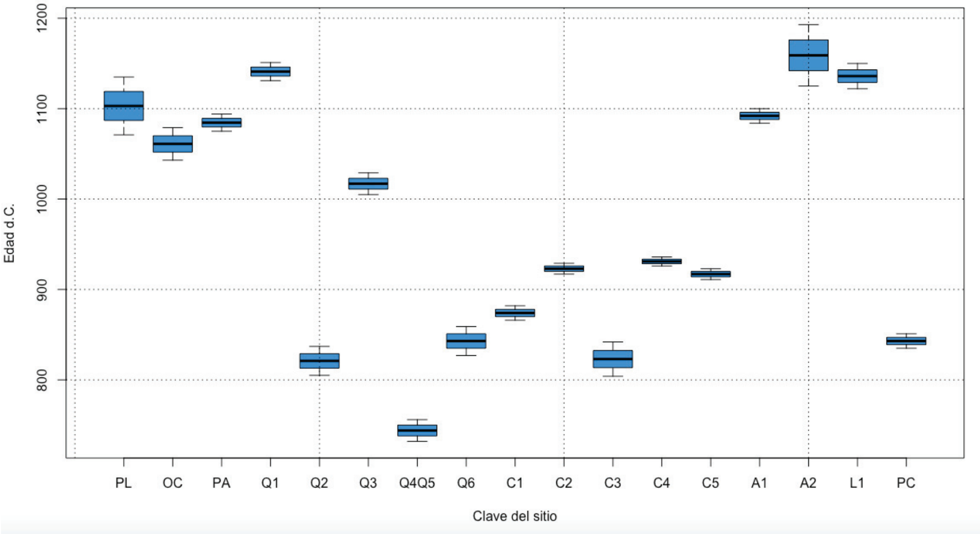

Figure 4. Age intervals for archaeological artifacts from sites located on the northern border of Mesoamerica calculated using the bootstrap method.

4. Discussion

We archaeomagnetically dated several burnt pre-Hispanic floors that correspond to roofed spaces, whether that be rooms or a porch. Other samples were from indoor stoves and ovens. The floors were studied at the sites of La Quemada, Cóporo and Plazuelas. The fires in these sites are likely associated with deliberated incendiary events and ritual abandonment. The definition of the archaeological contexts of abandonment has been extensively discussed in Lopez (2003) [51]: "In strictly archaeological terms, a locality can be considered abandoned when a stratigraphic event covers the interfaces where the social actors work, since otherwise it can continue to be frequented, either by members of the same community or by individuals from other communities".

The data obtained from the hearths and ovens are on structures created for combustion. Archaeomagnetism allows us to determine the age of the last moment when these areas were exposed to high temperatures. In the case of La Quemada, all three hearths were different; two were built inside the rooms, and a third was a cavity in a rock. The two interior hearths had different shapes and composting materials that could indicate different functions. One of them was composed of four slabs of rhyolite placed vertically and covered with mud, while the other hearth was semi-spherical in shape and made of clay. Different temporalities for the hearths of La Quemada were obtained in our study. The oldest age (hearths Q4 and Q5) is around 744 AD; the youngest (hearth Q3) is around 1017 AD, while the age of the burned cavity (hearth Q6) is around 843 AD.

We also note that La Quemada and Cóporo presented remains of charred beams and scattered roof fragments on the burned floors. The burning corresponds to a layer of the final occupation, since the upper layer shows the gradual deposition of materials accumulated during abandonment that seals the archaeological site. In the case of El Cóporo, a later occupation was detected by nomadic groups that reused the fragmented roof blocks to build a new hearth. This event sits on top of the layers of site occupation and subsequent abandonment. At the same time, a stairway on the north platform of the Plaza del Ocaso was apparently looted during pre-Hispanic times. Traces of fire were located in the Montes and Cóporo complexes, which indicated a generalized fire event that spread throughout the entire settlement. Traces of fire are also evident throughout the site in La Quemada, and the composition of the stratigraphic layers is similar to composition observed in Cóporo. There is also a posterior occupation, as indicated in El Cóporo, where later groups took advantage of the walls to construct simple shelters [15].

At the Plazuelas archaeological site, the remains of a burned floor have also been found, but rather than arguing a widespread fire consumed the city in its last phase of occupation, it is mainly suggested that this indicates the massive destruction of certain buildings [24,25,27]. This phenomenon occurred in the same way at the Cerro Barajas site (state of Guanajuato), where a planned abandonment with rituals of closure was proposed [32,52]. On the other hand, at the sites of El Ocote, La Palma and El Cerrito de Los Agaves, there is evidence of burned floors without signatures of the existence of a ritual abandonment.

Using our new dates, we suggest that there was a widespread fire in La Quemada and Cóporo perhaps linked to the abandonment of the settlement. Although the fire in Plazuelas is not so evident, archeological evidence points to ritual abandonment. A similar situation appears at the site of Cerro Barajas. This abandonment occurred in the transition between the Epiclassic to the early Postclassic, that is, between the years 900 and 1000 AD, which is in accordance with the hypothesis of a stepwise abandonment in the Bajío that started at 900 AD due to drought [24].

Judging from the data presented here, we consider that in La Quemada, Cóporo, Plazuelas and Cerro Barajas there was a differential or gradual abandonment (in Schiffer's terms, see Schiffer, 1988 and López, 2003) [51,53]. On the other hand, in Lo de Juárez, Ocote, La Palma and Los Agaves, we still lack the reliable data with which to draw conclusions on the past's incendiary events firmly. It has been pointed out that the Epiclassic was a period of political destabilization with marked militarism [54]. Upon abandoning these Epiclassic sites, the settlers returned to their places of origin where they already had commercial, social or kinship relationships.

The ancient metropolis of Teotihuacán was a reference point for cultural developments in Mesoamerica, and the northern frontier was no exception. Teotihuacán is considered the best-planned and largest pre-Hispanic city in Mesoamerica. One of the causes related to the decline of the Teotihuacán is the so-called "Big Fire". Previous archaeomagnetic study conducted by Soler-Arechalde et al. (2006) [55] on both burned and unburned *stuccos* of Teotihuacán provided an age estimate of around 575 AD well before northern border depopulation. However, recent new data [46] suggest that Teotihuacán experienced various fire episodes probably caused and controlled during public acts loaded with symbolic value, such as rituals for the termination of a cycle or those related to the beginning of a new constructive stage. The Teotihuacán state and the small territorial political units of the north center (Querétaro and Tunal Grande) correspond to the periods of initial settlement, colonization, stabilization, population movements and new settlements, territorial reorganization and collapse [56]. The demographic rearrangement and migrations in the Mesoamerican northern border in the 11th century were analyzed by Manzanilla (2005) [8,57]. The migration of groups during this century from the center of Mexico to the north and their subsequent return to their place of origin has been discussed [54,58–61]. The Mesoamerican northern frontier was a place of mobility and interaction throughout its history [60] between 600 and 900 AD. The history of the origin and abandonment of this territory, however, is still not well reconstructed [62–69].

Mexico's northern boundary expansion, apogee and subsequent demise have been analyzed in many studies by Pedro Armilla at the site of La Quemada. He proposed that climate changes during the early Postclassic period in combination with social conflicts resulted in decline and abandonment [9–12]. The climate hypothesis, however, has become very controversial during the last decades. Elliot et al. (2010) [67] carried out phytolith, organic carbon and magnetic susceptibility analyses of a 4000 yr alluvial record of climate and human land use from the Malpaso Valle and argued that early occupation already existed around 500 BC in arid conditions. A similar climate persisted during the Classic period until at least the Postclassic period (see also Somerville, 2015) [65] also hypothesized that anthropogenic landscape degradation influenced the social and geographic changes of the septentrional frontier rather than climatical variation (see also [69]).

On the other hand, the expansion and retraction of the septentrional frontier emerged as the hypothesis for the prolonged bellicose relations with nomadic groups (mainly the Chichimecs) [9,11,13,15]. It is pertinent to note J. Charles Kelley viewed La Quemada as an early Postclassic bastion fortress built to protect against Chichimec intrusions from the Tarascan territory to the south (see review in [70,71]. However, it was detected an extensive Classic period occupation of the area that he called the "American Southwest" (see [71]. In this context, Schöndube [72] regarded West Mexico's integration into Mesoamerica as a late occurrence dated to the early Postclassic period. Jimenez Betts [70] carried out the most detailed assessment of the septentrional frontier. This author considered that the Mesoamerican world system could not be understood in isolation, and that "Central Mesoamerica had a sequence of rise and fall of state level polities, which during periods of upswing in state development correlated with an increase in the geographical scale of interregional communication and integration. Broadscale interaction interconnected many regions through links with polities of different levels of complexity, in some cases involving core/periphery relations. When state level societies faced disintegration and demise, the long-distance interregional relationships loosened and frayed". Jimenez Betts [70] suggested that the early Postclassic period in West Mexico had three main events that need attention: (1) the demise of the Epiclassic period inland; (2) the rise of the Aztatlan network along the Pacific Coast, west of the Sierra Madre Occidental; and (3) an unresolved problem concerning the nature of Toltec presence in this region of Mesoamerica. Moreover, an all-inclusive analysis requires considerations that account for the developments in Central Mexico at around 900 AD with the rise of Tula and the decline of Teotihuacán.

5. Conclusions

- Archaeomagnetic data from the northern border of Mesoamerica were revaluated in light of new global geomagnetic models and local paleosecular variation curves. The studied burned archaeological structures belong to Aguascalientes (El Ocote), Guanajuato (El Cóporo, Lo de Juárez and Plazuelas), Jalisco (Cerro de Los Agaves, La Palma-Sierra Manantlán and El Palacio de Ocomo) and Zacatecas (La Quemada).
- The in situ archaeological artifacts consisted of burned floors in the vast majority of cases, but also some fire pits and hearths carrying thermoremanent magnetization.
- Available archaeomagnetic age intervals were recalculated considering the geomagnetic models SHA.DIF.14K [41]. and SHAWQ.2K (Campuzano et al., 2019 [44], as well as the two regional paleosecular variation curves for Mesoamerica by Mahgoub et al. (2019) [45] and García-Ruíz et al. (2022) [46].
- A bootstrap resampling method was used to obtain an optimal age range for each studied structure. These new absolute chronological intervals indicate that the last fire exposure of the vast majority of analyzed artifacts corresponds to the Mesoamerican early Postclassic.
- A recent detailed study by Wogau et al. (2019) [69] on the relationship between climatic-environmental changes and their cultural implications on the northern Mesoamerican frontier through high-resolution paleoclimate and paleoenvironmental reconstruction using laminated sediments from La Alberca maar lake (Guanajuato) evidenced two drought events around ~700–790 AD and ~810–880 AD. This supports Armillas's theory that climate conditions together with potential social conflicts caused the accelerated depopulation of the northern Mesoamerican border in agreement with archaeomagnetic data.

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References

1. Kirchoff, P. Mesoamérica. Sus límites Geográficos, Composición étnica y Características Culturales. Suplemento de la revista Tlatoani *Actas Americanas No.1*. Mexico City, 1943; pp. 92–107. Available online: https://revistas.inah.gob.mx/index.php/dimension/article/view/8334 (accessed on 29 September 2022).
2. Kirchoff, P. Relaciones entre el área de los recolectores cazadores del Norte de México y las áreas circunvecinas. In *III Mesa Redonda*; El norte de México y el sur de los Estados Unidos, Sociedad Mexicana de Antropología: Mexico City, Mexico, 1944; pp. 255–258.
3. Kirchoff, P. Gatherers and Farmers in the Greater Southwest: A Problem in Classification. In *American Anthropologist*; Wiley: New York, NY, USA, 1954; pp. 529–550.
4. Mendizábal, M.O. Colonización del Oriente de Jalisco y Zacatecas. In *III Mesa Redonda*; El norte de México y el sur de los Estados Unidos, Sociedad Mexicana de Antropología: Mexico City, Mexico, 1944; pp. 40–49.
5. Jiménez, W. Tribus e idiomas del norte de México. In *El Norte de México y el Sur de los Estados Unidos*; 1944; Available online: https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1607-050X2016000100172 (accessed on 29 September 2022).
6. Margain, C.R. Zonas arqueológicas de Querétaro, Guanajuato, Aguascalientes y Zacatecas. In *El Norte de México y el Sur de los Estados Unidos. III Mesa Redonda El Norte de México y el sur de los Estados Unidos*; Sociedad Mexicana de Antropología: Mexico City, Mexico, 1944; pp. 145–148.
7. Braniff, B. Secuencia arqueológica en Guanajuato y la cuenca de México: Intento de correlación. In *Teotihuacán, XI Mesa Redonda de la Sociedad Mexicana de Antropología*; La Sociedad: Mexico City, Mexico, 1972; pp. 273–323.
8. Manzanilla, L. *Reacomodos Demográficos del Clásico al Posclásico en el Centro de México*; Instituto de Investigaciones Antropológicas UNAM: Mexico City, Mexico, 2005.
9. Armillas, P. Condiciones ambientales y movimiento de pueblos en la frontera septentrional de Mesoamérica. In *Homenaje a Fernando Miranda. Publicaciones del Seminario de Estudios Americanistas y del Seminario de Antropología Americana*; Universdad de Madríd y Sevilla: Sevilla, España, 1964; pp. 62–82.
10. Armillas, P. The Northern Mesoamérica. In *Prehistoric Man in the New Word*; Jennings, J., Norbeck, E., Eds.; The University of Chicago Press: Chicago, IL, USA, 1964; pp. 291–329.
11. Armillas, P. The arid frontier of mexican civilization. In *Transaction the New York Academy of Sciences*; Series II; Wiley: New York, NY, USA, 1969; Volume 31, pp. 697–704.
12. Braniff, B. Oscilación de la frontera Septentrional Mesoamericana. In *The Archaelogy of West México*; Bell, B., Ed.; Sociedad de Estudios Avanzados de Occidente de México: Ajijic, Mexico, 1974; pp. 40–50.
13. Braniff, B. Oscilación de la frontera Septentrional Mesoamericana: Un nuevo ensayo. In *Arqueología No. 1, Dirección de Arqueología*; INAH: Mexico City, Mexico, 1989; pp. 99–114.
14. Castañeda, B.; Crespo, A.M.; Flores, L.M. Tunal Grande: Frontera de equilibrio para Mesoamérica. In *Boletín de Antropología, Nueva Época No. 34*; INAH: Mexico City, Mexico, 1991; pp. 22–29.
15. Hers, M.A. *Los Toltecas en Tierras Chichimecas*; IIE-UNAM: Mexico City, Mexico, 1989.
16. Hers, M.A. Colonización Mesoamericana y Patrón de Asentamiento en la Sierra Madre Occidental. In *Origen y Desarrollo del Occidente de México*; Boehm de Lameiras, B., Weigand, P.C., Eds.; Librería COLMICH: Zamora, Mexico, 1992; pp. 103–136.
17. Kelley, J.C. Archaeology of the Northern Frontier Zacatecas and Durango. In *Handbook of Middle American Indians*; Wauchope, E., Ed.; University of Texas Press: Austin, TX, USA, 1971; Volume 11, pp. 768–801.
18. Kelley, J.C. Speculation on the culture history of Northwest Mesoamerica. In *The Archaelogy of West México*; Bell, B., Ed.; Sociedad de Estudios Avanzados de Occidente de México: Ajijic, Mexico, 1974; pp. 19–39.
19. Kelley, J.C. Alta Vista: Outpost of Mesoamerica Empire on the Tropic of Cancer. In *Las Fronteras de Mesoamérica*; XIV Mesa Redonda de la Sociedad Mexicana de Antropología: Mexico City, Mexico, 1976; pp. 21–40.
20. Weigand, P.C. *La Prehistoria en el Estado de Zacatecas. Anuario de Historia*; Departamento de Investigaciones Histó-ricas, Universidad Autónoma de Zacatecas: Zacatecas, Mexico, 1978; pp. 203–248.
21. Brambila, R.; Castañeda, C.; Crespo, A.; Duran, T.; Flores, L.; Saint-Charles, J.C. Problemas de las sociedades prehispánicas del Centro Occidente de México. Resumen. In *Primear Reunión Sobre Sociedades Prehispánicas en el Centro Occidente de México, Memoria*; Cuaderno de Trabajo No. 1; INAH: Mexico City, Mexico, 1988; pp. 11–22.
22. Castañeda, C.; Crespo, A.M.; Contreras, J.A.; Saint Charles, J.C.; Durán, T.; Flores, L.M. Interpretación de la Historia del Asentamiento en Guanajuato. In *Primera Reunión Sobre Sociedades Prehispánicas en el Centro Occidente de México. Memorias. Cuaderno de Trabajo*; No. 1; INAH: Mexico City, Mexico, 1988; pp. 322–356.

23. Nalda, E. Proposiciones Para un Estudio del Proceso de Contracción de Mesoamérica. In *Las Fronteras de Mesoamérica*; XIV Mesa Redonda de la Sociedad Mexicana de Antropología, Tomo I: Villahermosa, Mexico, 1976; pp. 51–60.
24. Castañeda, C.; Quiroz, J. Plazuelas y la tradición Bajío. In *Tradiciones arqueológicas. Efraín Cárdenas García Coordinador General*; El Colegio de Michoacán, Gobierno de Estado de Michoacán: Mexico City, Mexico, 2004.
25. Castañeda, C.; Plazuelas, G. *Zona Arqueológicas en Guanajuato. Cuatro Casos: Plazuelas, Cañada de la Virgen, Peralta y El Cóporo*; IEC, INAH: Guanajuato, Mexico, 2007; pp. 21–67.
26. Castañeda, C. Los movimientos de poblaciones en el suroeste de Guanajuato. In *Migraciones e Interacciones en el Septentrión Mesoamericano*; García, E.C., Ed.; El Colegio de Michoacán: Zamora, Mexico, 2017; pp. 119–138.
27. Aramoni, M. *El Mundo Prehispánico de Guanajuato. Plazuelas. Lugar de la Serpiente de Fuego*; INAH: Mexico City, Mexico, 2014.
28. Morales, J.; Castañeda, C.; Cárdenas, E.; Goguitchaichvili, A. New evidence of the date of abandonment of the plazuelas archaeological site in Guanajuato, Mexico through archaeomagnetic dating of a burned floor. *Arqueol. Iberoam.* **2015**, *28*, 40–45.
29. Torreblanca, C. *El Cóporo. Una Antigua Ciudad Bajo la Nopaler*; IEC INAH: Guanajuato, Mexico, 2015.
30. García-Pimentel, A.; Goguitchaichvili, A.; Torreblanca, C.; Cejudo, R.; Kravchinsky, V.; García, R.; Morales, J.; Cervantes, M. The memory of fire in El Cóporo (Northern Mesoamerica): Apogee and abandonment. *J. Archaeol. Sci. Rep.* **2020**, *30*, 102274. [CrossRef]
31. López-Delgado, V.; Goguitchaichvili, A.; Torreblanca, C.; Cejudo, R.; Jimenez, P.; Morales, J.; Soler, A.M. La Quemada: Decline and abandonment in two stages on the classic period northern frontier of Mesoamerica. *J. Archaeol. Sci. Rep.* **2019**, *24*, 574–581. [CrossRef]
32. Pereira, G.; Migneon, G.; Michelet, D. Transformaciones demográficas y culturales en el centro norte de México en vís-peras del posclásico: Los sitios del Cerro Barajas (Suroeste de Guanajuato). In *Reacomodos Demográficos del Clásico al Posclásico en el Centro de México*; Manzanilla, L., Ed.; IIA-UNAM: Mexico City, Mexico, 2005; pp. 123–136.
33. Carrancho, A.; Gogichaishvili, A.; Kapper, L.; Morales, J.; Soler Arechalde, A.M.; Tema, E. Geomagnetic applications in archeology: State of the art and recent advances. In *New Developments in Paleomagnetism Research*; Nova Science Publishers, Inc.: New York, NY, USA, 2015; pp. 53–98.
34. Brown, M.C.; Hervé, G.; Korte, M.; Genevey, A. Global archaeomagnetic data: The state of the art and future challenges. *Phys. Earth Planet. Inter.* **2021**, *318*, 106766. [CrossRef]
35. Cejudo, R.; García-Ruiz, R. Intervención arqueomagnética en El Ocote (Aguascalientes, México): Implicaciones cronológicas absolutas. *Arqueol. Iberoam.* **2019**, *44*, 3–9. [CrossRef]
36. Pomedio, C.; López, V.; Goguitchaichvili, A.; Cejudo, R.; Morales, J.; Soler-Arechalde, A.; Cervantes-Solano, M.; García, R. Estudio arqueomagnético del Piso Quemado en la Palma, Valle de Cuzalapa, Sierra de Manantlán (Jalisco). *Boletín Soc. Geológica Mex.* **2021**, *74*, 1. [CrossRef]
37. Esparza, R.; López, V.; Cejudo, R.; Goguitchaichvili, A.; Yoshida, T.; Rétiz, M.; Rodríguez, F.; Cervantes-Solano, M.; Morales, J.; Bautista, F. Estudio petromagnético y arqueomagnético del sitio El Cerrito de Los Agaves en la parte Suroriental de los Altos de Jalisco. *Boletín Soc. Geológica Mex.* **2020**, *73*, A210121.1–A210121.12. [CrossRef]
38. López-Delgado, V.; Rodríguez, L.; Goguitchaichvili, A.; Morales, I.; Cejudo, R.; Morales, J.; Soler, A.M.; Bautista, F.; García, R. De Chupícuaro al despoblamiento de la frontera septentrional. Evidencia arqueomagnética del sitio Lo de Juárez, Guanajuato, México. *Boletín Soc. Geológica Mex.* **2021**, *73*, A050121. [CrossRef]
39. Morales, I. "Lo de Juárez", una unidad habitacional prehispánica en la cuenca del río Guanajuato. Aproximación a la dinámica doméstica y sociopolítica de los habitantes del Irapuato, prehispánico. Bachelor's Thesis, Unidad Académica de Antropología de la UAZ, Zacatecas, Mexico, 2020.
40. Pavón-Carrasco, F.J.; Rodríguez-González, J.; Osete, M.L.; Torta, J.M. A matlab tool for archaeomagnetic dating. *J. Archaeol. Sci.* **2011**, *38*, 408–419. [CrossRef]
41. Pavón-Carrasco, F.J.; Osete, M.L.; Torta, J.M.; De Santis, A. A geomagnetic field model for the Holocene based on archaeomagnetic and lava flow data. *Earth Planet. Sci. Lett.* **2014**, *388*, 98–109. [CrossRef]
42. Pelz, A.M.; Jiménez, J. Arqueología en Aguascalientes. El Ocote. In *La reinvención de la Memoria. Ensayos para una Historia de Aguascalientes*; Tomo, I., González Esparza, V.M., Eds.; Col. Nueva Historia; Instituto de Cultura de Aguascalientes: Aguascalientes, Mexico, 2007; pp. 83–107.
43. Esparza, C.; Goguitchaichvili, A.; López, V.; Cejudo, R.; Morales, J.; Bautista, F.; Kravchinsky, V.; Garcia, R. Ball court in la quemada, northern Mesoamerica: Absolute chronological contributions through the archeomagnetic study of associated fire pits. *J. Archaeol. Sci. Rep.* **2020**, *33*, 102558. [CrossRef]
44. Campuzano, S.A.; Gómez-Paccard, M.; Pavón-Carrasco, F.J.; Osete, M.L. Emergence and evolution of the South Atlantic Anomaly revealed by the new paleomagnetic reconstruction SHAWQ2k. *Earth Planet. Sci. Lett.* **2019**, *512*, 17–26. [CrossRef]
45. Mahgoub, A.N.; Juárez-Arriaga, E.; Böhnel, H.; Manzanilla, L.R.; Cyphers, A. Refined 3600 years palaeointensity curve for Mexico. *Phys. Earth Planet. Inter.* **2019**, *296*, 106328. [CrossRef]
46. García-Ruiz, R.; Goguitchaichvili, A.; Pavón-Carrasco, F.J.; Soler, A.M.; Pérez-Rodríguez, N.; Osete, M.L.; Kravchinsky, V. Fluctuations of magnetic inclination and declination in Mexico during the last three millennia. *Quat. Geochronol.* **2022**, *71*, 101309. [CrossRef]
47. Efron, B. Computers and the theory of statistics: Thinking the unthinkable. *SIAM Rev.* **1979**, *21*, 460–480. [CrossRef]
48. Jayakumar, K.; Sankaran, K.K. On a generalization of uniform distribution and its properties. *Statistica* **2016**, *76*, 83–91.

49. González-Hernández, I.J.; Simón-Marmolejo, I.; Granillo-Macías, R.; Santana-Robles, F.; Rondero-Guerrero, C.; Soto-Campos, C.A. Simulación de la distribución uniforme generalizada. *Ingenio Concienc. Boletín Científico Esc. Super. Ciudad. Sahagún* **2020**, *7*, 23–28. [CrossRef]
50. Hernández-Abreu, E.; Martínez-Pérez, M. El Método Bootstrap en la Estimación de Incertidumbres. In *Boletín Científico Técnico Inimet, Núm. 1*; Instituto Nacional de Investigaciones en Metrología Ciudad de La Habana: la Habana, Cuba, 2012; pp. 8–16.
51. López, F. Los procesos de abandono. Lo blanco y lo negro de la interpretación arqueológica. In *Trace. Abandono de Asentamientos Prehispánicos Hispánicos, Junio*; No. 43; CEMCA: Mexico City, Mexico, 2003; pp. 56–69.
52. Gérald, M. Abandonos Planificados, Rituales de Vasijas Matadas o de Clausura y Ocupaciones Posteriores. In *Trace. Abandono de Asentamientos Prehispánicos Hispánicos, Junio, No. 43*; CEMCA: Mexico City, Mexico, 2003; pp. 97–115.
53. Schiffer, M.B. Existe una "premisa de pompeya" en arqueología? *Boletín Antropol. Am.* **1988**, *18*, 5–31.
54. Nelson, B.; Crider, D. Posibles pasajes migratorios en el norte de México y el suroeste de los Estados Unidos durante el Epiclásico y el Posclásico. In *Reacomodos Demográficos del Clásico al Posclásico en el Centro de México*; Manzanilla, L., Ed.; IIA-UNAM: Mexico City, Mexico, 2005; pp. 75–102.
55. Soler-Arechalde, A.M.; Sánchez, F.; Rodriguez, M.; Caballero-Miranda, C.; Goguitchaishvili, A.; Urrutia-Fucugauchi, J.; Manzanilla, L.; Tarling, D.H. Archaeomagnetic investigation of oriented pre-Columbian lime-plasters from Teotihuacan, Mesoamerica. *Earth Planets Space* **2006**, *58*, 1433–1439. [CrossRef]
56. Crespo, A.M. La Expansión de la Frontera Norte (y la Cronología Oficial Para Teotihuacán). In *Los Ritmos de Cambio en Teotihuacán: Reflexiones y Discusiones de su Cronología*; Brambila, R., Cabrera, C., Eds.; INAH: Mexico City, Mexico, 1998; pp. 323–334.
57. Cárdenas, G.E. *Migraciones e Interacciones en el Septentrión Mesoamericano*; El Colegio de Michoacán: Mexico City, Mexico, 2017.
58. Hers, M.A. Imágenes Norteñas de los Guerreros Toltecas-Chichimecas. In *Reacomodos Demográficos del Clásico al Posclásico en el Centro de México*; Manzanilla, L., Ed.; IIA-UNAM: Mexico City, Mexico, 2005; pp. 11–56.
59. Carot, P. Reacomodos Demográficos del Clásico al Posclásico en Michoacán: El Retorno de los que se Fueron. In *Reacomodos Demográficos del Clásico al Posclásico en el Centro de México*; Manzanilla, L., Ed.; IIA-UNAM: Mexico City, Mexico, 2005; pp. 103–121.
60. Brambila, P.; Crespo, A. Desplazamientos de Poblaciones yc Creación de Territorios en el Bajío. In *Reacomodos Demográficos del Clásico al Posclásico en el Centro de México*; Manzanilla, L., Ed.; IIA-UNAM: Mexico City, Mexico, 2005; pp. 155–173.
61. Carot, P.; Hers, M.A. De Teotihuacán al Cañón de Chaco: Nueva Perspectiva Sobre las Relaciones Entre Mesoamérica y El Suroeste de los Estados Unidos. In *Anales del Instituto de Investigaciones Estéticas*; Número 98; UNAM: Mexico City, Mexico, 2011; Volume XXXIII, pp. 5–53.
62. Brown, R.B. *Paleoecología y Arqueología en la Frontera Norte de Mesoamérica: Un análisis. Cuaderno de Trabajo No. 13, Dirección de Arqueología*; INAH: Mexico City, Mexico, 1991.
63. Park, J.J. Holocene environmental change and human impact in Hoya Rincon de Parangueo, Guanajuato, Mexico. *Korean J. Ecol.* **2005**, *28*, 245–254. [CrossRef]
64. Elliott, M. Classic Period Wood Use at Monumental Center in Northwestern Mesoamerica. In *Archaeological Charcoal: Natural or Human Impact on the Vegetation*; SAGVNTVW EXTRA-11; 2011; pp. 117–118. Available online: https://www.sapac.es/charcoal/saguntum/extra11/se11_117.pdf (accessed on 29 September 2022).
65. Elliott, M. An anthracological approach to understanding Late Classic period cultural collapse in Mesoamerica's northwestern frontier. In *Wood and Charcoal: Evidence for Human and Natural History, 13*; Badal, E., Carrión, Y., Macias, M., Eds.; Maria Ntinou Departament de Prehistòria i d'Arqueologia, Universitat de Valencia: Valencia, Spain, 2012; pp. 217–225.
66. Elliott, M.; Nelson, B.; Fisher, C. Vinculando la Historia de Asentamientos Humanos con la Evolución Socio-Ecológica del Paisaje en Mesoamérica Septentrional: Una Perspectiva Desde el sur de Zacatecas. In *Espaciotiempo: La Arqueología en el Norte de México, No. 3*; Coordinación de Ciencias Sociales y Humanidades de la UASLP: San Luis Potosí, Mexico, 2008; pp. 107–122.
67. Elliott, M.; Fisher, C.T.; Nelson, B.A.; Garza, R.S.M.; Collins, S.K.; Pearsall, D.M. Climate, agriculture, and cycles of human occupation over the last 4000 yr in southern Zacatecas, Mexico. *Quat. Res.* **2010**, *74*, 26–35. [CrossRef]
68. Dominguez, G.; Castro, V. Cambios climáticos y sus efectos en el ambiente durante el Holoceno en el Bajío. In *Migraciones e Integraciones en el Septentrión Mesoamericano*; García, E.C., Ed.; El Colegio de Michoacán: Zamora, Mexico, 2017; pp. 27–40.
69. Wogau Kurt, H.; Arz, H.; Böhnel, H.; Nowaczyk, N.; Jungjae, P. High resolution paleoclimate and paleoenvironmental reconstruction in the Northern Mesoamerican Frontier for Prehistory to Historical times. *Quat. Sci. Rev.* **2019**, *226*, 1–20.
70. Jimenez Betts, P. Orienting West Mexico, The Mesoamerican World System 200–1200 CE. Doctoral Thesis, Department of Historical Studies, University of Gothenburg, Gothenburg, Sweden, 2018; p. 268.
71. Jimenez Betts, P. Llegaron, se pelearon y se fueron: Los modelos, abusos, y alternativas de la migración en la arqueología del norte de Mesoamérica. In *Reacomodos demográicos del Clásico al Posclásico en el Centro de Mexico*; Manzanilla, L., Ed.; IIA/UNAM: Mexico City, Mexico, 2015; pp. 57–74.
72. Schöndube, B.O. Epoca prehispánica. In *Historia de Jalisco: Vol. 1, Desde los Tiempos Prehistóricos Hasta ines del Siglo XVII*; Muriá, J.M., Ed.; Gobierno de Jalisco: Guadalajara, Mexico, 1980; pp. 113–257.

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Article

The Becoming of a Prehistoric Landscape: Palaeolithic Occupations and Geomorphological Processes at Lojanik (Serbia)

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Abstract: Accomplishing long-term plans to harvest and modify natural resources has been a crucial skill for the survival of our species since early Prehistory. Research on this first step of production mostly focuses on the provenience study of lithic artifacts uncovered at archaeological sites, using petrographic and geochemical analyses to correlate the artifacts with potential geological outcrops. Although fundamental for understanding key aspects of landscape use and mobility, regional raw material economy, and extraction technology, Palaeolithic raw material sources have been less intensively investigated, as they are often difficult to locate and challenging to tackle with traditional archaeological approaches. Lojanik in the Central Balkans is one of the largest Prehistoric quarrying areas known in Europe, showing numerous lithic raw material outcrops exploited from the Middle Palaeolithic to the Chalcolithic periods, over an area of 18 hectares. In this paper, we present the results from our renewed research program in this region. Combining airborne LIDAR mapping, geomorphological and archaeological survey, and techno-typological analysis of lithic artifacts, we were able to reconstruct the geomorphological evolution of the landscape and its use by prehistoric societies.

Keywords: archaeological survey; LiDAR; geomorphology; lithic analysis; Middle Palaeolithic; Upper Palaeolithic; Serbia

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1. Introduction

The capacity of humans to exploit natural resources has been crucial for their survival throughout history. It illustrates their cognitive capacity for long-term planning, selection, predetermination, and resource management. To understand Prehistoric societies, it is important to study the way they acquire and manage their raw materials, especially the lithic component, which represents an important part of the remains recovered from this period.

The study of lithic raw material procurement in Europe is usually focused on petrography in order to identify the type of raw material and possible outcrops. Palaeolithic mines and quarries have seldom been extensively studied for themselves, especially for Lower (ca. 3.3 million years ago–300,000 years ago) and Middle Palaeolithic (ca. 300,000–30,000 years ago). However, they are important assets when trying to understand regional economic systems, as they allow us to study landscape use and mobility, raw material economy, and lithic technology.

Being a corridor for human migrations [1–9], the Balkan peninsula presents a perfect area for the study of the evolution of human interaction with their environment, as we should expect ancient societies to gravitate around and exploit areas rich in lithic raw material—an invaluable resource during prehistoric times. Zones of raw material extraction show evidence of a long-standing relationship between humans and their landscape, and how it changes with different human species or cultural groups. Despite this advantageous position, the archaeological record of this region is not as rich in Palaeolithic sites as one could expect, and the region is often absent from general interpretations. Neanderthal occupation patterns are difficult to theorise due to uneven research, and our understanding of their typo-technological solutions remains limited [10]. A surprising characteristic of the Balkans is the rarity of Middle Palaeolithic elements that can be linked to the Levallois concept of reduction (as defined by [11–13]), which is the most widespread reduction system for this period in Europe and the Near East [14]. Although rare and poorly dated Levallois artefacts have been identified in some sites, most Middle Palaeolithic assemblages in the Balkans are characterised by a more expedient, Discoid-based industry throughout the Danube corridor, as well as Micromousterian and Denticulate Mousterian along coastal areas [15]. These variations are still difficult to explain due to the lack of absolute dates and the fact that vast areas of the Balkan peninsula remain under investigated. In Serbia especially, research was mostly concentrated on cave sites of intermediate mountain landscapes, while it is probable that Palaeolithic populations occupied more densely the valleys and basins.

The Lojanik complex is an open-air locality of west-central Serbia on the right bank of the Ibar river, 200 km south of Belgrade (Figure 1), where numerous lithic raw material outcrops have been identified over an area of twelve hectares [16,17]. The outcrops were exploited during later Prehistory (Neolithic and Chalcolithic, which date in the region from ca. 6500 to 1000 years BC), but some artefacts showed Middle Palaeolithic traits. The recent discovery of clear Levallois elements (cores and preferential products) in some of the different sites of Lojanik confirms that the site was exploited as early as the Middle Palaeolithic era [17]. As we mentioned previously, this Levallois component is a very rare occurrence in the central Balkans, making Lojanik a key raw material industrial complex for the comprehension of raw material extraction strategies and their evolution from the Middle Palaeolithic to Chalcolithic.

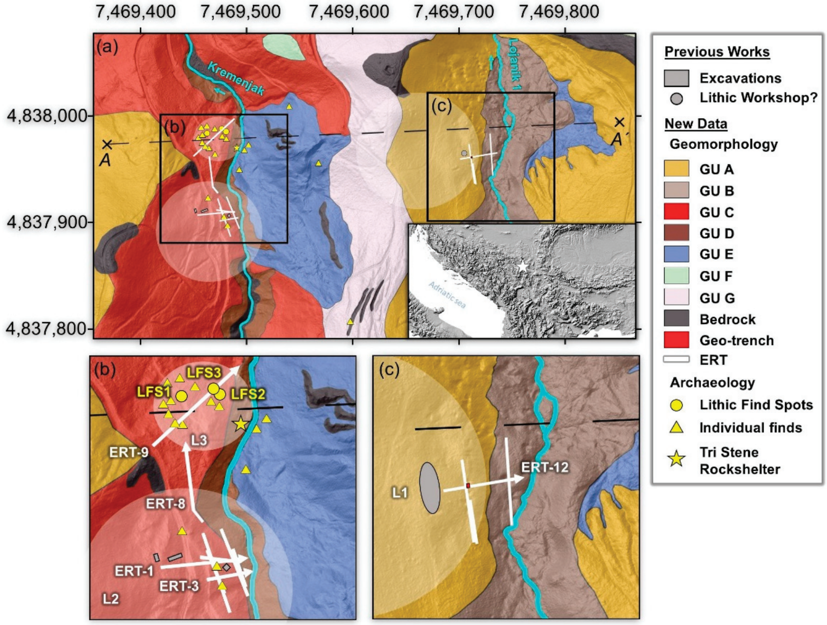

Figure 1. *Cont.*

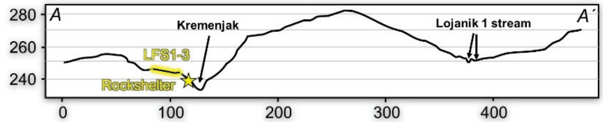

Figure 1. Study region: (**a**) Geomorphological map displaying the main Geological Units (GU) mapped during our survey, based on the LiDAR data. (**b**) Detail from the Kremenjak Valley showing Lojanik 2 (L2), our Lithic Find Spots (LFS) from Lojanik 3 (L3), and the Electrical Resistivity Tomographies (ERT) displayed in Figure "ERT1". (**c**) Detail from the Lojanik 1 Valley displaying Lojanik 1 (L1), our Geotrench, and the ERT data exhibited in Figure "ERT2". A–A′ topographic section across the two valleys, location in detail (**a**).

In this article, we present the results of our 2022 field study, which encompass different field and laboratory methodologies, designed to provide an understanding of prehistoric human behaviour on a regional, micro-regional, and local scale.

2. Materials and Methods

2.1. Study Area

The Lojanik complex is an open-air locality that encompasses hills and valleys, which developed along faults [18] and drain into the Ibar River—an important axis of communication from Prehistory to today, crossing south to north from Montenegro until the West Morava River. Prehistoric societies have been documented in the region, which is regarded as part of important migratory routes for Prehistoric humans [16,19,20].

The geological history of Lojanik is unique, as it was formed by the silicification of an ancient forest by a cataclysmic event during the Miocene [21]. The petrified wood created by these processes has been exploited since prehistorical times until today as sharpening material for knives and agricultural tools, such as scythes [16]. This opalised wood was also a good quality knapping material, and its use by prehistoric humans has been attested in the nearby late-Neolithic site of Divlje Polje, leading to surveys of the Lojanik complex to understand the origin of the material [22,23]. In the frame of research about the Neolithic and Mesolithic occupations of the West Morava Valley, it was demonstrated that Lojanik opal was found in other localities in the surroundings, such as the Early Neolithic settlement of Crkvine, shedding new light onto the interpretation of Neolithic mobility and territories in the region [24]. From 2016 to 2021, Lojanik has been systematically surveyed to understand the raw material exploitation techniques from the Palaeolithic until today [24]. The first area to be surveyed, Lojanik 1, is located on the west flank of a seasonal unnamed stream—that we call "Lojanik 1 stream" (Figure 1)—and is characterised by surface scatters of artefacts which have been surveyed and 3D scanned to understand their organization [25]. From 2017, another locus has been surveyed on the west slope of the Kremenjak Valley (fig.), Lojanik 2, which was tested with three trenches (A, B and C). Recent research has demonstrated that a division of the space had been implemented in some localities, with distinct extraction, workshop, and discard zones [25]. In 2017, the discovery of a Levallois recurrent centripetal core opened new perspectives of interpretation and demonstrated the significance of the Lojanik complex, since Levallois elements are very scarce in the Central Balkans Palaeolithic record [17]. Our 2022 field study was organised to better understand the status of this Levallois component and the earliest Palaeolithic occupations of the site.

2.2. Methods

To locate new archaeological occurrences and establish a correlation between surface finds and geomorphological processes, we combined remote sensing, geomorphological and archaeological surveys, geophysical prospections, as well as geological excavations.

An airborne Light Detection And Ranging (LiDAR) survey [26] was performed on the study region to penetrate the dense forest coverage and obtain high resolution (0.25 m) topographic data of the ground surface. The use of airborne LiDAR has already been attested in numerous sites to define architectural features of later time periods, e.g., [27–29], but its use in the study of prehistoric landscapes is yet to be developed. The data obtained has helped us to produce a targeted pedestrian survey, aimed at reconstructing the geological and depositional environment of the area, as well as defining archaeological features present here.

The LiDAR results were analysed with the software SAGA (SAGA User Group Association, Hamburg, Germany) and QGIS (QGIS.org, %Y. QGIS Geographic Information System. QGIS Association. http://www.qgis.org (accessed on 10 November 2022)) to produce topographic [30], slope/aspect [31–35], and hillshading maps [36], as well as topographic cross-sections of selected features (QGIS Profile Tool). These maps and cross-sections enabled us to locate key, potential landforms, such as breaks-in-slope, gullies, bedrock outcrops, and pits. We expected that these features had high potential to yield archaeological material and could be used to explore the relation between archaeological occurrences and different geomorphological processes. For instance, breaks-in-slope might correspond to bedrock or river terraces and, thus, might preserve intact archaeological deposits (e.g., [37,38]). Gullies' margins provide natural sediment exposure, which can be surveyed to investigate the occurrence of buried archaeology-bearing deposits in the landscape (e.g., [39,40]). Opal outcrops were likely exploited by the Prehistoric people of Lojanik for quarrying [16,25]. Additionally, bedrock outcrops have been commonly used as shelters by Prehistoric humans (e.g., [41,42]), thus locating them was an important step of our study. Lastly, the excavation of pits to extract raw materials has been a well-established practice since at least the Neolithic period [43–46], probably also at Lojanik [16]. Therefore, identifying human-made pits was important to document phases of landscape use and raw material extraction in our study area.

We focused our fieldwork on two areas that appeared more promising from an archaeological point of view, located in the vicinity of the previously surveyed sites of Lojanik 1 and Lojanik 2 (Figure 1). With targeted surveys, we located in the field the potential landforms detected by LiDAR, we cleared the vegetation that was covering them and documented them with photos and occasionally with photogrammetry (using the software Metashape). Within each sediment exposure, we distinguished separate geological layers (GL) based on lithological properties. These included depth, transition to the next lower sediment [47], and amount of coarse (>2 mm) and fine fraction (<2 mm [48]). For the coarse fraction, we described colour, composition, frequency [48], size (ISO 14688-1:2002 standard), shape [49], roundness [50], sorting [51], and orientation. For the fine fraction we reported Munsell colour and texture, which was estimated in the field "by feel", following the protocol published by Vos et al. [52]. For simplicity, when presenting the result of our surface mapping, we grouped the GLs identified in the field into facies, named geological units (GU).

To gain insights about their underground geometry, depth to bedrock, and lithology, we surveyed with geophysical methods a representative group of landforms, such as breaks-in-slope, potential rock outcrops, and potential man-made pits. Electrical Resistivity Tomography (ERT) is a non-invasive geophysical method employed to reconstruct the lithological properties of the subsurface by measuring and modelling its electrical resistivity (e.g., [53,54]). Previous studies have demonstrated the ability of ERT methods to map the bedrock topography (e.g., [55,56]), detect human-made pits and ditches (e.g., [57,58]), as well as provide insights on the landscape evolution of river valleys (e.g., [59,60]). In the field, we collected 14, 2D, freely oriented ERT profiles using a Lippmann 4-point light 10 W resistivity meter connected to a chain of 20 electrodes, which we inserted in the ground along straight lines. ERT data were acquired with electrode spacing of 1 m along the transects ERT-2, 3, 7, and 11, while an electrode spacing of 2 m was used along the remaining survey lines from ERT-1 to ERT-14. ERT-9, which covers a length of 55 m, was acquired following a roll-along protocol. All ERT data were acquired using Dipole–Dipole, Wenner, and Schlumberger arrays. All measurements were evaluated as both separate and joint inversions [61] with the software ResIPy [62]. In this paper we present the results of the jointed inversion, as these have higher data sensitivity.

Due to restrictions in our fieldwork permit, excavation was limited exclusively to the re-opening of one of the many, partly refilled pits, that we identified downslope from the site of Lojanik 1. A small (1 × 0.5 m) geological trench was dug to re-open half of this pit down to its bottom, this allowed us to corroborate our interpretation of the ERT data and investigate formation and geomorphological context of this man-made feature. Its infilling was removed, respecting the morphology of sedimentary contacts, and retrieving all identified archaeological materials. The GLs we distinguished in the field were described following the same protocol used for the natural sediment exposures (see above).

Key geomorphological features were also surveyed for archaeological materials. The LiDAR data allowed us to select places of interest where artefacts could be more visible such as breaks-in-slope or bedrock outcrops. We also closely monitored places where the sediment could have unearthed artefacts by recent movement, such as around tree roots or sediment exposed by either erosion or recent human modifications of the landscape, e.g., roads and hiking trails. When a locus was identified, we intensively surveyed its surroundings. We did not collect the artefacts, but set up a data recording strategy based mainly on the three-dimensional modelling of the diagnostic artefacts directly in the field by structure-from-motion methods using a portable field setup and the software Metashape. The coordinates of each locus were recorded with a Differential GPS (DGPS), with the ReachView 3 survey app.

Three types of loci were distinguished:

- Isolated artefacts;
- Findspots, which are clusters of artefacts scattered on less than 1 square meter;
- Find areas, which are larger scatters, and can include different findspots.

We collected typo-technological data with the E5 program developed by OldStoneAge. We took a peculiar interest in diagnostic artefacts, such as cores or predetermined flakes, that would allow us to precisely attribute the artefact to a specific technocomplex, as this study does not aim to be exhaustive but to draw a first picture of the history of the human occupations in Lojanik.

3. Results

3.1. Geoarchaeological Results

a Geomorphological mapping

From a geomorphological point of view, the Kremenjak Valley, where Lojanik 2 is located, and the unnamed valley where Lojanik 1 is situated (from here on "Lojanik 1 Valley") appear dissimilar. The first valley is narrow ("V" shaped), exhibits steep flanks (up to 40–70°), and shows frequent active and relict erosional features, such as gullies and scarps, likely resulting from the formation of debris flows [63]. The lack of run-out lobes downslope from the scarps indicates that the Kremenjak, while dry in spring and summer, has enough water discharge in fall and winter to remove sediments and possibly even carve the bedrock outcropping from its riverbed. On the other hand, the Lojanik 1 Valley is more open ("U" shaped), is completely dry in spring/summer, and has a shallower bottom (15 m above the Kremenjak stream). This valley also exhibits gentler flanks (up to 20–55°) and rare geogenic erosional landforms. Up to 30 m downslope and 80 m north from the archaeological area Lojanik 1, the western flank of the Lojanik 1 Valley is carved by numerous, subcircular, human-made pits. The size of these features changes along the hillside, with the smaller ones (ca. 3 m in diameter, 40 cm in depth) located in the upper part of the slope and the larger ones (ca. 6 m in diameter, 1.5 m in depth) situated at the valley bottom.

The two valleys appear also different from a sedimentological point of view. GU A (Figure 2a) is the sole lithological unit we documented in both valleys, covering the western hilltop above the Kremenjak and most of the flanks of the Lojanik 1, including the majority of the archaeological area Lojanik 1. This unit is made from frequent, triaxial to equiaxial, subangular to subrounded fossilised wood, serpentinised peridotites, and very rare opal embedded in yellowish brown (10 YR 5/3–5/6) to light olive brown silty clay (2.5 Y 5/3–5/6). This sediment appears from moderately compacted to loose, depending on the density of the vegetation cover. Aside from GU A, the Lojanik 1 Valley is mostly entirely filled with common, fine to medium, triaxial to equiaxial, subangular to subrounded, serpentinised peridotites embedded in poorly compact silty clay, which range in colour from very dark greyish brown (10YR 3/2) to strong brown (7.5 YR 4/3–4/6; Unit B; Figure 2b). This deposit appears laterally eroded and redeposited by the stream. Most of the sediments we observed along the slopes of the Kremenjak Valley correspond to common, fine to medium, fresh to highly weathered, subangular to subrounded fragments of peridotites, fossilised wood, and opal. These gravel-sized components are buried in moderately compact clay-rich matrixes, which show reddish brown (5 YR 4/3–4/4) to yellowish brown (5 YR 4/6) colours (GU C; Figure 2c). Most of the archaeological area of Lojanik 2 and Lojanik 3 (LFS1, LFS2, LFS3) falls within this lithological unit. Sediments with high clay content and moderate sorting similar to those we documented in GU C might have been accumulated by water-driven sedimentary processes. These could be related to fluvial or colluvial processes. The first hypothesis appears to be supported by the occurrence of breaks-in-slope of possible fluvial origin in the areas of Lojanik 2 and Lojanik 3. On the other hand, the hypothesis that at least part of GU C was accumulated by colluvial mud flows [64,65] cannot be ruled out based on our lithological data. The lower slopes of the Kremenjak Valley are covered with loose sediments, made from frequent, subangular, triaxial bedrock fragments embedded in very rare, dark yellowish brown to dark brown (10 YR 4/4–7.5 YR 3/3) silty sand to silty clay (GU D). Active gullies carving into both GU C and GU D are common, as well as opal-rich peridotite outcrops. Through surface mapping we were unable to verify whether all these outcrops corresponded to bedrock or boulders that fell from a large bedrock outcrop located upslope from the area Lojanik 3 (Figure 2f). Slope instability is clearly higher along the eastern flank of the valley, where we observed very loose, dry, locally de-vegetated, yellowish brown to light olive brown (10 YR 5/6–2.5 Y 5/4) scree deposits (GU E; Figure 2d). The higher immaturity of these sediments in comparison with those accumulated along the opposite valley flank (GU C) suggests that these scree deposits might have formed more recently, possibly as result of the extensive modern logging and quarrying activity conducted along this slope. Alternatively, this stark difference in lithology might reflect different moisture availability along the two slopes. Aside from a localised fluvial deposit composed of well-rounded, triaxial to oblate, polished, fine to medium gravel of limestone and sandstone embedded in a red clay (2.5 YR 4/6; GU F; Figure 2e), most of the ridge separating the Kremenjak and Lojanik 1 valleys exhibits outcropping bedrock. This is only locally covered with compact, possibly authigenic, clay (GL G), which appears light olive brown (2.5 Y 5/3) to light yellowish brown in colour (2.5 Y 6/3).

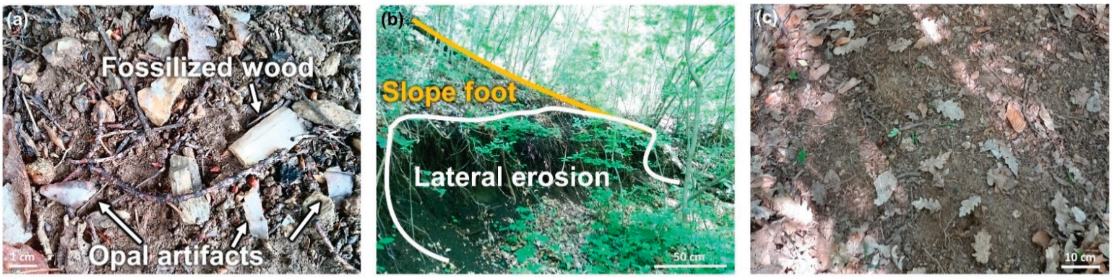

Figure 2. *Cont.*

Figure 2. Geological units detailed in the text: (**a**) Unit A, in the Lojanik 1 area; (**b**) Unit B, at the Lojanik 1 Valley bottom, with an example of stream lateral erosion; (**c**) Unit C, in the Lojanik 3 area, close to LFS1; (**d**) Unit E, on the eastern slope of the Kremenjak Valley; (**e**) Unit F; (**f**) Bedrock outcrop, between Lojanik 2 and 3.

b. Tri Stene Rockshelter

Some 40 m North from the archaeological area Lojanik 2, within the larger GU D, we identified a 2 m high exposure which was likely uncovered by the Kremenjak River through lateral erosion (Figure 3). This sequence, sheltered by opal-rich peridotite rocks, stood out from other sedimentary exposures we observed throughout our survey, as it appeared stratified and contained stone tools. The top of this sequence is made from frequent, subangular to subrounded, triaxial, fine to medium gravel of peridotite and opal (including lithic artifacts) embedded in a loose, extensively bioturbated silty sand. Based on the fine fraction colour, we could distinguish three separate sediments within this larger deposit: a central dark yellowish-brown unit (10 YR 4/4; GL 1001) sandwiched between an upper and lower dark brown layer (7.5 YR 3/3; GL 1000 and GL 1002). These sediments appeared to be the downslope continuation of colluvial lobes descending from the higher portion of the hillside. Below them, underneath a sharp contact, we distinguished rare subrounded peridotite gravel with rare lithic artifacts made from opal, embedded in a compact, strong to dark brown clayey silt (7.5 YR 4/6–3/3; GL 1003). This layer covered (from top to bottom): a very loose brown clayey silt (7.5 YR 4/4; GL 1004) poor in archaeological finds; a compact brown to strong brown (7.5 YR 4/3–5/6) silty clay, with common subangular peridotite and rare lithics (GL 1005); and common, weathered gravel and stone tools embedded in (10 YR 3/3) silty clay (GL 1006). Modern bioturbation appeared intensive in this lowermost layer, likely because of the higher moisture content caused by the water stand oscillations of the Kremenjak River. We plan to determine the chronology of the sequence through luminescence dating. Samples for these analyses have already been collected from layers GL 1005 and GL 1006.

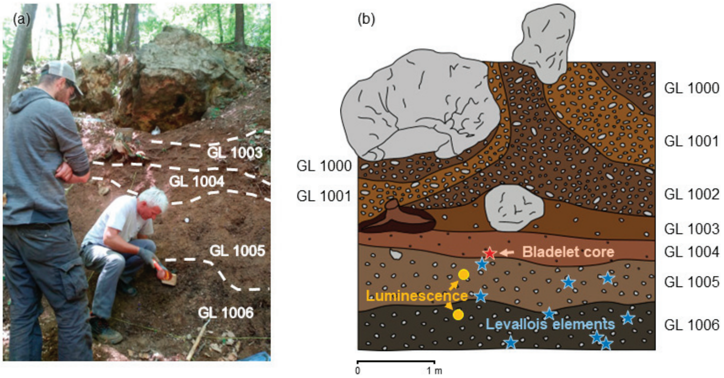

Figure 3. *Cont.*

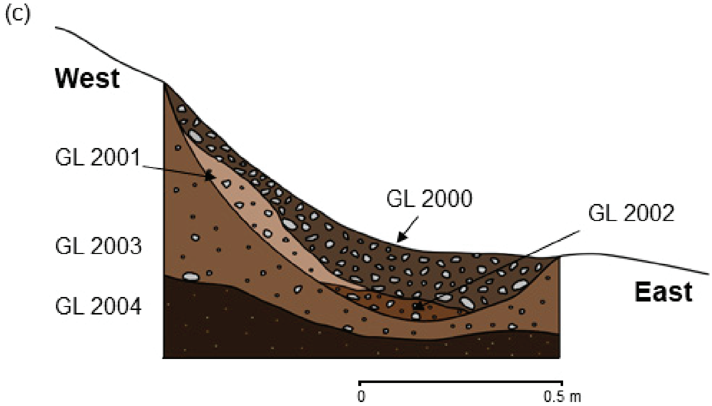

Figure 3. Stratigraphic data: (**a**) Tri Stene Rockshelter during luminescence sampling, analysis underway; (**b**) Schematic drawing of the lithological units and location of key archaeological materials identified at Tri Stene Rockshelter; (**c**) Schematic cross-section drawing from Geo-trench 1.

c. Electrical resistivity tomography

To gain insights into the nature of features detected during our geomorphological mapping (such as breaks-in-slope and potential bedrock outcrops) and collect preliminary data about the formation of Kremenjak and Lojanik 1 valleys, we acquired ERT data along freely oriented lines. Across the western flank of the Kremenjak Valley, we detected a laterally continuous, stratified sequence (Figure 4). From top to bottom, we identified a potential lithological unit exhibiting resistivity between 1.8 and 3 log10 Ωm (ERT-A). This body outcrops at the ground surface and reaches a maximum depth of 3 m. Considering electrical properties [66,67] and location across the slope, ERT-A likely corresponds to the numerous opal rich peridotite rocks we observed during our geomorphological mapping in the archaeological areas Lojanik 2 and 3. Our ERT data demonstrate that these rocks are not bedrock outcrops but rather loose boulders, which likely accumulated during rockfalls. Underneath ERT-A, we documented a resistive unit (1.4 to 1.8 Ωm; ERT-C) sandwiched in between two conductive layers (0.7 to 1.1 Ωm; ERT-B and ERT-D). Based on published reference data [60,68–71], we interpret these potential lithological bodies as boulder/gravel- and clay-rich sediments, respectively. The geometry of these deposits appears to be better resolved in the 1 m spaced tomographies. In particular, in ERT-3, these sediments appear sub-horizontal and truncated by an erosional surface, which was subsequently buried by ERT-A. This suggests that ERT-B, ERT-C and ERT-D might correspond to incised and locally reworked river terraces [59,60,72]. This part of the sequence has a maximum thickness of 10–15 m and rests on top of a unit that exhibits resistivity between 1.5 and 1.8 Ωm (ERT-E). Considering its electrical properties [60,68–71] and its position in the landscape, we hypothesise that ERT-E corresponds to the bedrock that we observed outcropping at the rockshelter and at the valley bottom. Remarkably, ERT-E appears to delimit a laterally continuous depression, which is elongated in the north–south direction and located some 20 to 40 m west from the present course of the Kremenjak. Considering the estimated depth of this feature, it is likely that, prior to the accumulation of ERT-D, the Kremenjak River carved the valley floor either down to or deeper than the current valley bottom.

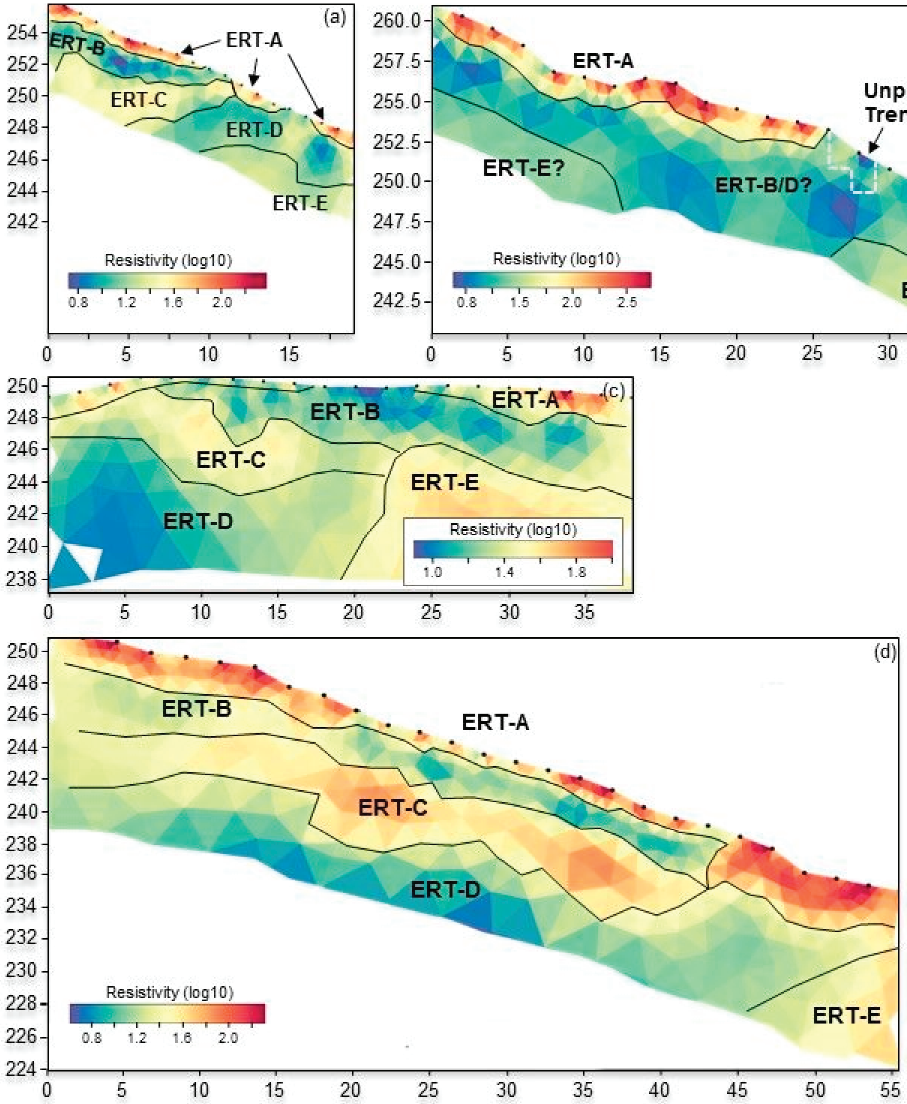

Figure 4. Electrical Resistivity Tomography (ERT) results from the Kremenjak Valley: (**a**) profile ERT-3; (**b**) ERT-1; (**c**) ERT-8; (**d**) ERT-9. All the subpanels display jointed inversions of resistivity measurements acquired with Dipole–Dipole, Wenner, and Schlumberger arrays. The location of these profiles is displayed in Figure 1b.

The potential lithological units we detected along and downslope from the Lojanik 1 area are generally more conductive and less laterally continuous than those identified in the Kremenjak Valley (Figure 5). From top to bottom, we distinguished an uppermost potential lithological body, which outcrops at the ground surface and reaches a maximum depth of 4 m (ERT-F). Based on its resistivity (1.2 to 1.5 Ωm), ERT-F probably corresponds to gravels and boulders deposited along the slope by rockfalls and colluvial processes [60,73,74]. This unit is often laterally discontinuous and alternates with pockets of highly conductive sediments (<1 Ωm; ERT-G), which likely correspond to clay-rich deposits. These features are usually localised within or in proximity of the many man-made pits situated along the slope. Underneath ERT-F and ERT-G, we detected moderately conductive materials (0.7–0.9 Ωm), comparable with silty clay deposits [60,68–70], on top of a more resistive (1–1.2 Ωm) and laterally discontinuous unit (ERT-I), which might have been shaped by river processes.

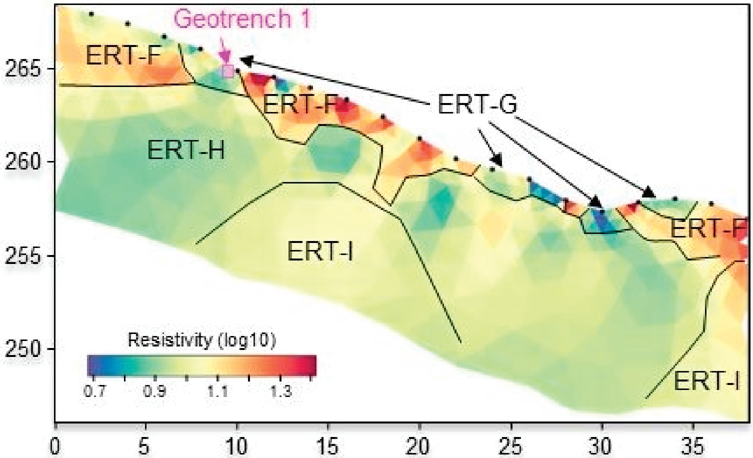

Figure 5. Electrical Resistivity Tomography (ERT) profile ERT-12 from the Lojanik 1 Valley, for the precise location of this transept see Figure 1c. The image displays the jointed inversion of resistivity measurements acquired with dipole–dipole, Wenner, and Schlumberger arrays.

d. Geo-trench 1

In Geo-trench 1, we exposed a 40 cm deep sequence which enabled us to partly re-open one of the numerous pits we identified downslope from the Lojanik 1 area and confirm the interpretation of the ERT we acquired along this slope. During excavation, we distinguished, from top to bottom, an uppermost infilling (GL 2000) made from frequent, subangular to subrounded, triaxial to equiaxial, fine to medium gravel-sized fragments of peridotites and fossilised wood, as well as common lithic artifacts made from opal, which are all embedded in a greyish brown to dark brown (10 YR 5/2–3/2) clayey silt (Figure 3c). Composition, lack of sorting, and geometry (5 cm thick upslope and 25 cm thick downslope) revealed that this sediment likely originated from the erosion of the surface sediments and archaeological materials documented uphill, corresponding to the archaeological area Lojanik 1. High compaction, subangular aggregation, and high frequency of roots suggest that this deposit was overprinted by the development of a modern A horizon. Below GL 2000, localised on the upslope areas of the geo-trench, we unearthed a mostly sterile, loose, light yellowish brown to brownish yellow (10 YR 6/6–6/4) sandy silt, in which only rare subrounded, equiaxial, fine gravel-sized fragments of peridotites and fossilised wood are buried (GL 2001). As discussed for GL 2000, the location and geometry of this deposit suggest that it probably corresponds to a colluvial sediment. Separated by a sharp contact from the above GL 2001, GL 2003 is composed of common, subangular to subrounded, triaxial, fine and medium gravel fragments buried in a dark brown to dark yellowish brown (10 YR 3/3–3/4) silty clay. Only rare potential lithic artifacts were observed in this deposit. Underneath GL 2003, we detected two sediments (GL 2002 covering GL 2004) that appeared laterally continuous across our excavation area and thus might correspond to the original bottom of the pit. Given the limited size of our trench and the much wider diameter of the pits situated at the bottom of the valley, however, we cannot exclude that these as well as the above sediments are the infillings of a larger depression. In any case, while GL 2002 appeared similar to the upper sediments unearthed in the Geo-trench 1, being made from brown to yellowish brown clayey silt (10 YR 4/3–5/4), GL 2004 showed a very different composition. This layer contained common, highly weathered, yellowish red (5 YR 4/6), brownish yellow (10 YR 6/6), and black (10 YR 2/1) peridotite sand-sized fragments embedded in a well-sorted, black (2.5/1 2.5 YR) clay. Remarkably, such deposit is comparable with sediments unearthed in the unpublished trench B situated in the archaeological area Lojanik 2. This field observation might indicate that, below the surface sediments, similar deposits accumulated in both the Lojanik 1 and Lojanik 2/3 areas, which today appear dissimilar due to more intensive (and possibly more recent) aggradation in the Lojanik 1 valley. This working hypothesis remains to be further tested with additional excavation and absolute dating of the deposits in both valleys.

3.2. Evidences of Human Activity

Across the zones that were surveyed, we found scatters of lithic material, of which some could be correlated to the Middle Palaeolithic period, and others to a more recent prehistoric material (Upper Palaeolithic or Neolithic).

a. Lojanik 1

The area of Lojanik 1 had been already extensively researched by previous field missions on its higher elevation and at the hilltop [25]. We focused our interest on the lowest level of the valley, next to the stream, where the LiDAR data allowed us to identify a series of aligned human-made pits that could be attributed as mining shafts. In order to understand the stratigraphy of these pits, we dug a small geological trench, which yielded very few artefacts; the only diagnostic element found in this pit is a large tablet to rejuvenate a blade core (Figure 6c), which was found in GL 2004, and possibly came from below the bottom of the pit. This artifact is specific to volumetric blade productions and mostly associated with the Upper Palaeolithic (ca. 40,000 to 10,000 years ago) or Neolithic periods, although it can also be present in Middle Palaeolithic technocomplexes. However, the pit seemed to be much more recent, and could be linked with modern mining activities for obtaining the petrified wood.

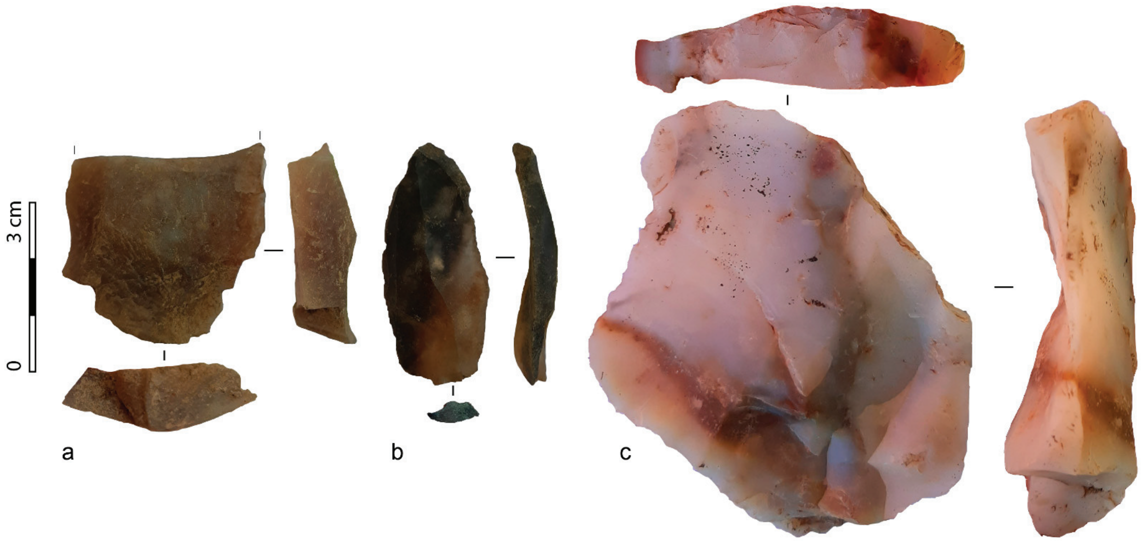

Figure 6. Lojanik 1, lithic artefacts: (**a**) fragment of blade detached with hard hammer; (**b**) potentially Levallois laminar blank; (**c**) core tablet from Geo-trench 1.

A few meters west from the pit, on the middle part of the slope, an important scatter of lithic artefacts had been identified as a workshop during previous surveys. We could not confirm the “workshop” interpretation of this scatter, but we identified Levallois products or production of laminar blanks with a hard hammer (Figure 6a,b). We also found evidence of the production of laminar blanks with a soft hammer, also common in Upper Palaeolithic or more recent Prehistoric assemblages (such as Neolithic or Chalcolithic).

b. Lojanik 2

First documented in 2017, Lojanik 2 is a sloped area on the west bank of the Kremenjak Valley, which was tested with three archaeological trenches (A, B and C) prior to our survey. For this reason, we did not extensively survey this zone, and only identified a small number of artefacts this year, which made us revisit the material uncovered in the previous campaigns.

The artefacts found at Lojanik 2 display a lithic industry characterised by two major components: Levallois and laminar. The features of some of the artefacts, such as the hierarchy of the core faces as well as the organisation of the lateral and distal convexities, fit entirely within the Levallois concept. Looking at the cores, recurrent centripetal and centripetal preferential Levallois production seem to be the preferred method of reduction (Figure 7a), while other methods, such as the unidirectional preferential, seem to only be hinted at [13]. While the number of this kind of artefacts is not vast, the lack of platform preparation is noticeable. This is especially visible in one of the pieces documented during the survey, where the maker decided to keep the natural platform on the core (Figure 7b).

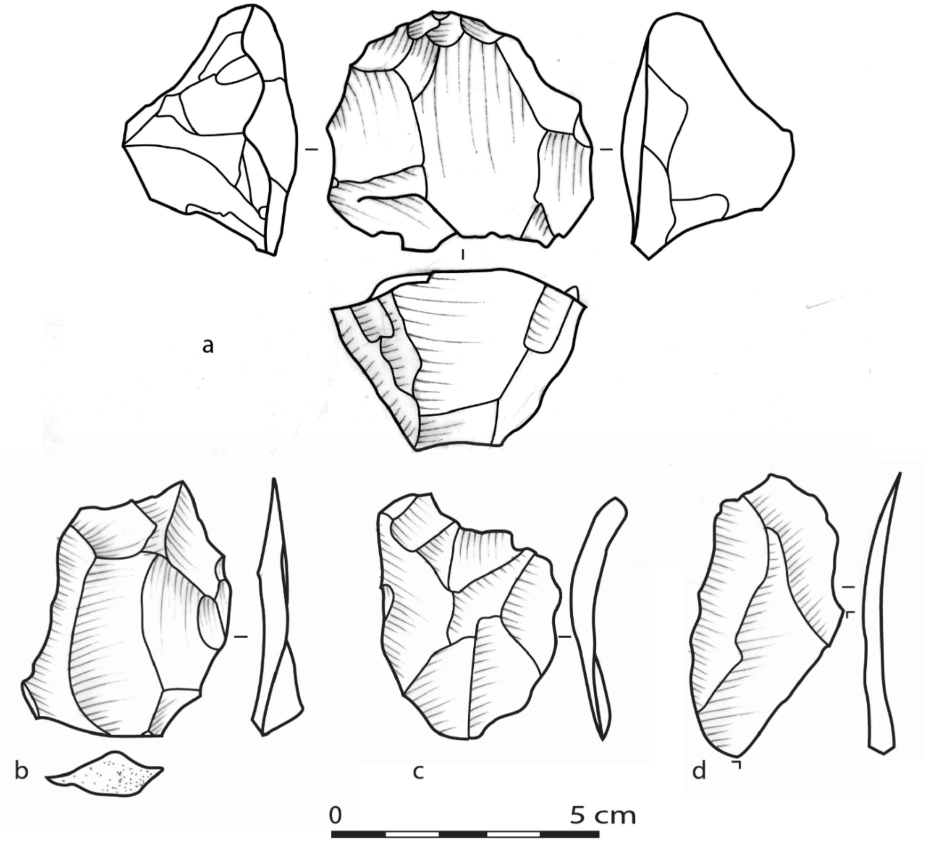

Figure 7. Lojanik 2, Levallois elements: (**a**) Preferential Levallois core (found in 2022); (**b**–**d**) Levallois flakes (from previous surveys).

The reduction of laminar elements seems to be coordinated in a uniform fashion, and the blade core platforms are prepared by faceting, implying they were possibly made by hard hammer percussion. Other traits that we can recognise are bidirectional production of thick laminar blanks or elongated flakes, while some of the pieces display a lateral or posterolateral shaping of the cores (Figure 8a,b and Figure 9c–e). Negatives on the cores, as well as flake morphology, imply a tendency towards pointed blade production (Figures 8 and 9a,d,e), but the artefacts are not numerous enough to back this claim without further research. Apart from the two burin cores, the production of bladelets has not been recognised (Figure 9b,f).

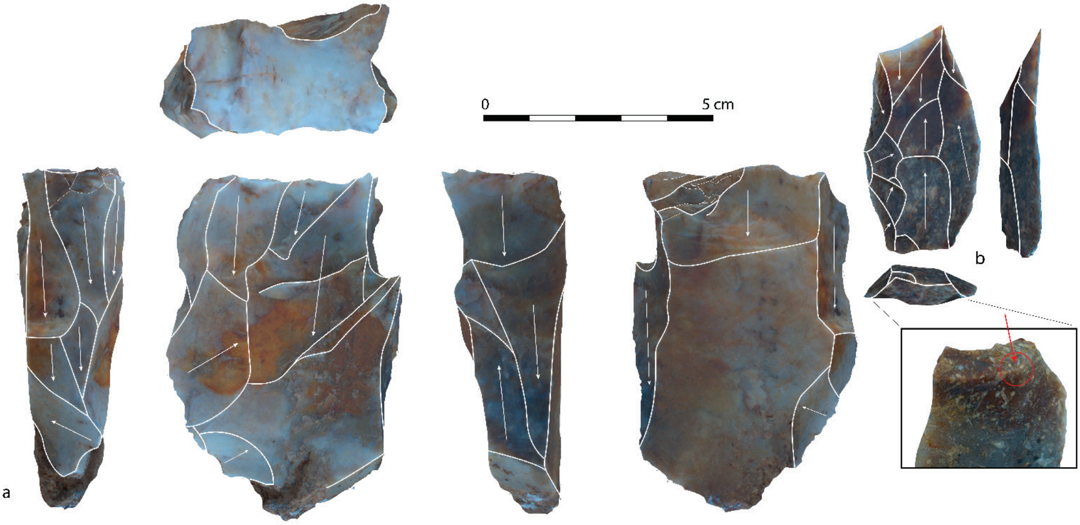

Figure 8. Lojanik 2, lithic artefacts found in 2022: (**a**) narrow-faced blade core; (**b**) blade.

c. Lojanik 3

Lojanik 3 is a find area located on a slope of the Kremenjak valley, north of Lojanik 2. It was identified as a find area due to the concentration of scatters of artefacts (findspots) that we encountered, usually organised as small mounds in various elevations of the slope.

LFS1 (Lojanik FindSpot 1) is a locus which forms a small mound, situated on the edge of a small pedestrian path, next to a boulder. On the findspot we could identify numerous lithic artefacts, of which a majority were small in size compared to the material identified in the other loci. Although most of the artefacts are non-diagnostic flakes, some of them present scars of bladelet production (Figure 10), which occur in Upper Palaeolithic assemblages.

LFS2 and LFS3 are two scatters of artefacts located lower on the slope. LFS2 material is dominated by the production of large artefacts, with a tendency to elongation, which are detached following a direct percussion with a hard hammer (Figure 10). This way of producing large flat flakes and laminar blanks is widely documented in Middle Palaeolithic contexts and is correlated to the Levallois reduction concept. In LFS2, we identified a preform of a volumetric laminar core (Figure 11), which could be associated either with Middle or Upper Palaeolithic.

The rockshelter exposure described above ("Tri Stene Rockshelter") is also part of Lojanik 3, on the southern part of the find area. It has yielded over 70 well-preserved artefacts. The artefacts are in their great majority obtained through direct percussion with a hard hammer. Most of the products display scars that are related to a unipolar reduction, but multipolar, bipolar, and centripetal reduction are also well represented. Nine of these artefacts show characteristics that fits in the Levallois *chaîne opératoire* of reduction, such as a visible organisation of the convexities for the production of predetermined flakes, hard hammer percussion following a fracture plane parallel to the plane of intersection, and for one flake a very typical *chapeau de gendarme* facetted platform (Figure 12b). Elongated products are highly represented in this locus, with more than 10 blades and laminar blanks. This corresponds to what we have seen in other loci, such as LFS2 and LFS3, as well as Lojanik 2.

On the top of the sequence, one artefact displayed unique characteristics compared to the rest of the rockshelter assemblage. This small flake shows scars of bladelet production on its distal side and could be described as a carinated endscraper (Figure 12a) which would be typically found during the Upper Palaeolithic period.

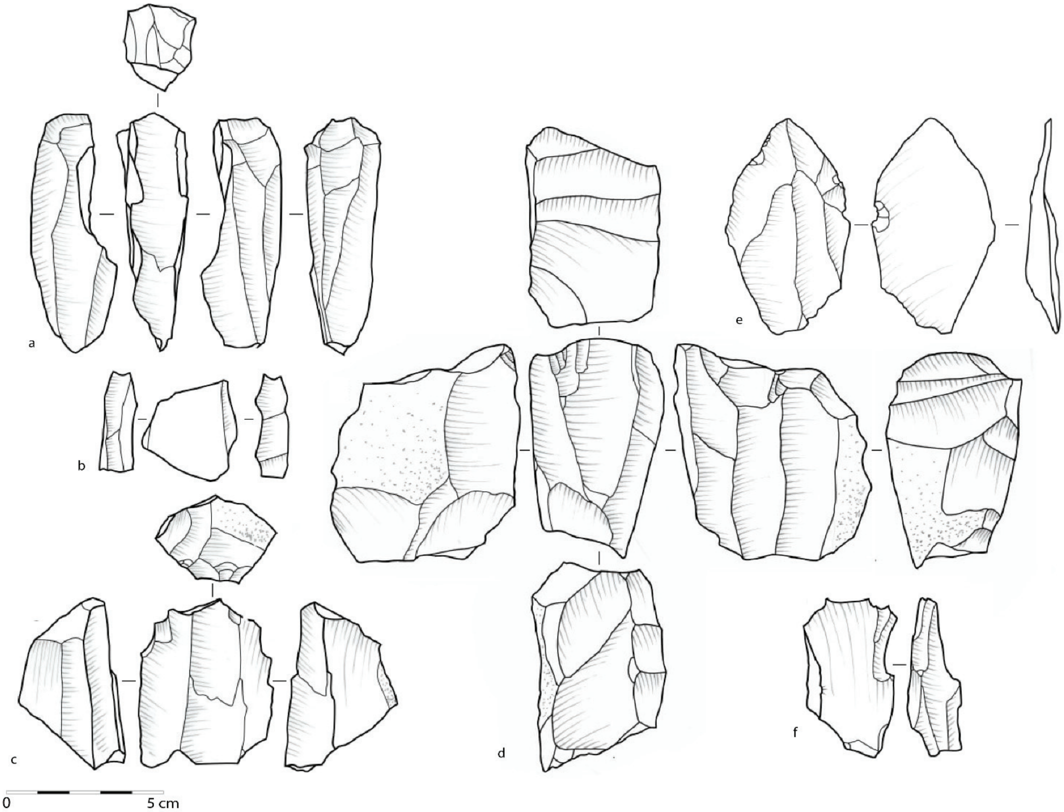

Figure 9. Lojanik 2, lithic artefacts from previous surveys: (**a**,**c**,**d**) blade cores; (**b**,**f**) burin cores; (**e**) laminar flake.

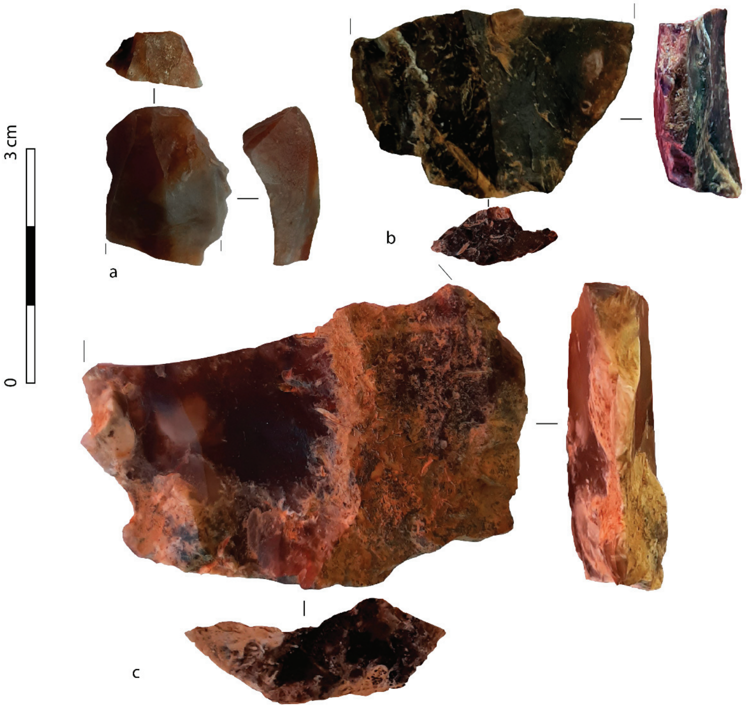

Figure 10. Lojanik 3, lithic artefacts: (**a**) bladelet core from LFS1; (**b**,**c**) fragmented large laminar blanks from LFS2.

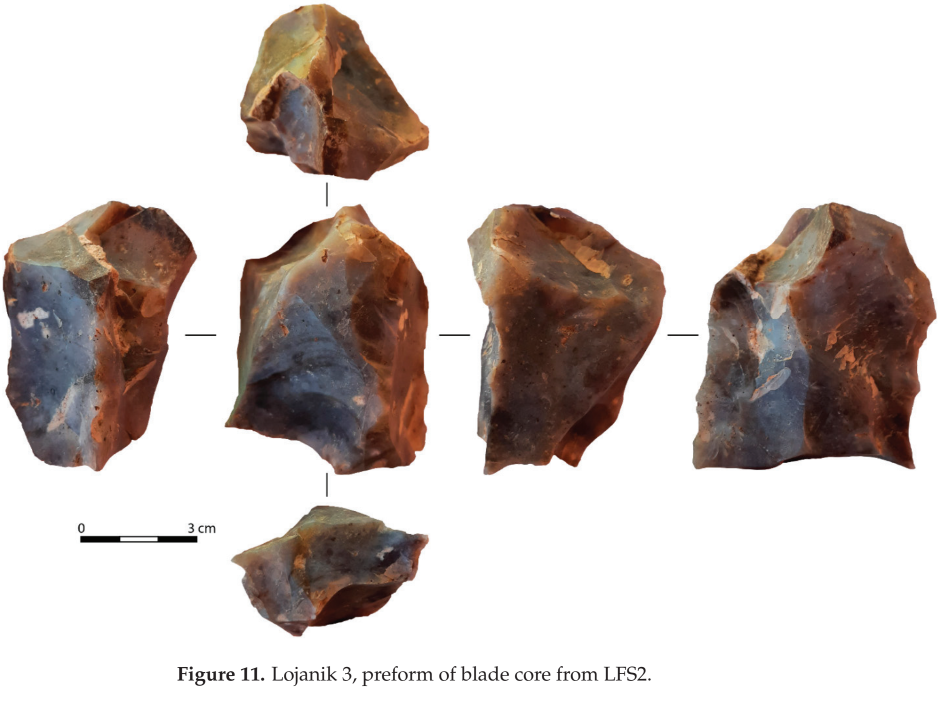

Figure 11. Lojanik 3, preform of blade core from LFS2.

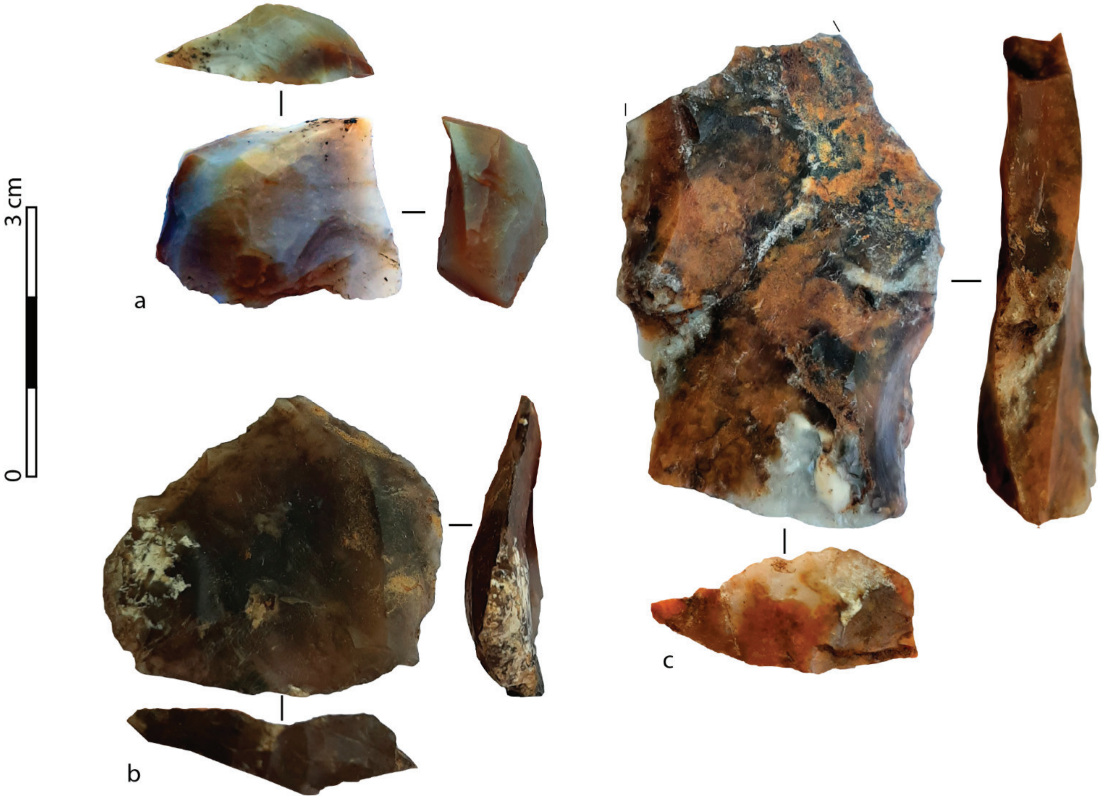

Figure 12. Lojanik 3, lithic artefacts from the Tri Stene Rockshelter: (**a**) carinated endscraper; (**b**) Levallois flake with facetted platform; (**c**) laminar blank.

4. Discussion

The results from the 2022 survey at Lojanik are quite promising for the study of prehistoric occupation in the central Balkans. This study has its limitations, as most of the material comes from the ground surface of a region that has been affected by intensive human modifications, such as modern quarrying and forestry, and the landscape is scarred by erosional landforms (e.g., gullies and scarps). Despite these constraints, we were able to formulate hypotheses about the geomorphological evolution of this landscape and its use by prehistoric societies.

4.1. Phases of Landscape Evolution

Here, we summarise the key phases of landscape evolution we hypothesised based on the geoarchaeological data presented in this paper.

a. The Kremenjak Valley

i. Bedrock incision (Mio-Pleistocene?)

Our ERT data suggest that the bedrock at the bottom of the Kremenjak Valley was carved by river erosion nearly down to the elevation of the current riverbed (see depression on top of ERT-E in Figure 4). Based on the chronology of river terraces in the Ibar Valley [18,75], this deepening of the base level of the Kremenjak River possibly occurred between the end of the Miocene and the early Pleistocene and might have been triggered by tectonic activity [18].

ii. *Aggradation, formation of river terraces, and accumulation of Palaeolithic stone tools (Pleistocene)*

The bedrock incision was filled with sub-horizontal and alternating fine and coarse sediments (ERT-B to ERT-D in Figure 4), which were subsequently truncated and partly moved downslope by erosional processes. The geometry and elevation of one of these beds (ERT-C, 20 m above today valley bottom in Figure 4a) are compatible with a terrace of the Ibar River in the area of Mataruška spa, which was dated to the Pleistocene [75]. The materials unearthed in the unpublished Trench B of Lojanik 2 as well as the lithic artifacts collected during our survey in this archaeological locality and in the areas of Lojanik 3 probably come from this river terrace, or from deposits formed after its erosion and reworking. Therefore, it is possible that foragers producing Middle and Upper Palaeolithic stone tools exploited this landform. This hypothesis remains to be further tested with detailed archaeological, geoarchaeological, and geochronological analyses of Trench B, as well as coring and excavations in Lojanik 3.

iii. *River valley incision, slope erosion, rockfall, and river lateral erosion (late Pleistocene to modern)*

As mentioned above, the potential river terrace that formed in the area of Lojanik 2 and 3 was subsequently truncated during at least two separate erosional phases. The first was followed by rockfall(s), during which gravel-sized up to boulder-sized opal-rich peridotite rocks were deposited along the slope (corresponding to ERT-A in Figure 4), while the second is still ongoing and led to the configuration of today's slope topography. The shift from slope aggradation to erosion was probably triggered by a phase of river valley incision. Causes and timing of these processes remain to be investigated. Slope erosion also led to the accumulation of the upper sediments we observed at the rockshelter (GL 1000 to GL 1004), while we cannot exclude that the lower part of the sequence (GL 1005 and 1006) was accumulated during the previous phase of landscape evolution.

Our geomorphological mapping revealed that today the slopes of the Kremenjak Valley are actively eroded by gullying and debris flows, which are more active on the eastern valley flank likely due to more intensive human activity. On the other hand, at the valley bottom, lateral erosion is probably more intensive than incision, leading to the formation of natural exposures, such as the one visible at the rockshelter.

b. The Lojanik 1 Valley

i. *Bedrock Incision (Mio-Pleistocene?)*

Our ERT data seem to indicate the occurrence of a bedrock depression at the bottom of the Lojanik 1 Valley (top of ERT-I in Figure 5). This landform is some 20 m higher in elevation than the one we observed at the bottom of the Kremenjak Valley (top of ERT-E inFigure 4) and up to 6 m higher than the potential river terrace ERT-C (Figure 4a). This difference in elevation might indicate that the lowermost incision of the Lojanik 1 Valley did not form during the genesis of either landform of the Kremenjak Valley, or, alternatively, that river landforms across this region were vertically displaced due to tectonic activity. Geochronological research is necessary to clarify this point.

ii. *River valley aggradation and accumulation of Palaeolithic stone tools (Pleistocene)?*

Lithological and archaeological data from the bottom of our Geo-trench 1 (GL 2004) seem to indicate that the depression carved in ERT-I was filled with sediments and archaeological materials similar to those reported from the unpublished Trench B in Lojanik 2, which intercepted deposits corresponding to ERT-B/D (Figure 4). Therefore, it is possible that hunter-gatherers producing Middle and Upper Palaeolithic stone tools visited Lojanik 1, 2, and 3 when these exhibited similar environments (possibly low energy river terraces). This hypothesis remains to be tested with further research.

iii. *Slope erosion followed by rockfall, and further accumulation of stone tools (late Pleistocene to Holocene?)*

Based on our ERT data, the archaeology bearing clay-rich deposits accumulated in the Lojanik 1 area were eroded and covered with highly resistive sediments (ERT-F in Figure 5). For the most part, these correspond to gravel-rich sediments that outcrop at the ground surface and exhibit Middle or early Upper Palaeolithic stone tools. Colluviation and human visit to the (upper areas) of the slope might have lasted until the Late Neolithic, as suggested by previous lithic studies [25].

iv. *Human-made pitting triggering slope erosion and further river valley aggradation (Holocene to modern times)*

These coarse deposits were partly excavated in historical to modern times during quarrying activity searching for sediments and bedrock formations rich in silicified wood (reconstruction based on interview with Mr. Dragotinović, who was a worker during these activities until the 1980s). Such intensive destruction of the landscape destabilised the slopes, locally triggering debris flows and causing the erosion of archaeological materials. This process, in combination with the mostly dry stream at the foot of the slope, led to the (ongoing) infilling of the valley.

4.2. Phases of Human Occupation

The results of the survey, as well as the lithic analysis, have demonstrated three possible chronological chapters of human occupation at Lojanik, while other periods did not yield as many pieces of evidence, occurring only occasionally. The earliest evidence of occupation can be correlated to the Middle Palaeolithic, perceived from the abundance of Levallois-like artefacts on the surface of at least two of the defined areas—Lojanik 2 and Lojanik 3. These two areas also yielded a few significant Upper Palaeolithic artefacts, such as bladelet cores, but these are unfortunately not diagnostic and not numerous enough to be able to correlate them with a specific Upper Palaeolithic tradition. Finally, the third chapter of human exploitation is illustrated by the modern mining, visible in the possible mining shafts in Lojanik 1 Valley, as well as quarrying on the eastern slope of the Kremenjak Valley.

a. Lojanik 1

Previous studies on the Lojanik 1 valley have indicated that the site was exploited following a planned organization, with a division of activities between zones of acquisition of raw material, upslope, workshop areas, downslope, and discard zones [25]. The chronological range is very wide, from the Middle or early Upper Palaeolithic to the late Neolithic. The artefacts that can be linked to the earliest occupation seem to be located downslope, around the workshop zone (Figure 1), while Neolithic artefacts have been identified upslope and on top of the hill.

b. Lojanik 2

In Lojanik 2, the discovery of Levallois cores and artefacts during previous studies has indicated that this area was occupied since the Middle Palaeolithic era [17]. However, artefacts identified in 2022, such as a bidirectional narrow-faced blade core (Figure 8), in combination with previously unearthed material from past studies, such as burins and bidirectional blade cores (Figure 9), caused us to question this attribution. Indeed, they are presenting the defining features of Initial Upper Palaeolithic [76–78]: bidirectional production of laminar elements and platforms prepared by faceting, as well as the production of burin cores, by direct percussion with a hard hammer. This notion could actually be strengthened by the presence of Levallois artefacts, which is considered another defining feature of this phenomenon. For this reason, the provenience of Levallois artefacts found on the surface cannot be decided with certainty, as it is considered common for both Middle Palaeolithic and the Initial Upper Palaeolithic. The context of the finds greatly limits our ability to attribute these artefacts to a specific time period with certainty, as it is currently impossible to discriminate between two possible interpretations of occupation for Lojanik 2:

- Either a first Middle Palaeolithic occupation, when the Levallois elements were abandoned at the site, followed by an Initial Upper Palaeolithic occupation, characterised by burins and blade cores.
- Or, only an Initial Upper Palaeolithic occupation, with the combination of Levallois, blade cores and burins.

c. Lojanik 3

In Lojanik 3, the assemblage is dominated by Levallois elements, with a tendency towards elongation. No typical Initial Upper Palaeolithic artefact has been identified during this preliminary study, but some elements indicated the presence of at least one Upper Palaeolithic occupation (e.g., Figures 10 and 12). We can note that LFS1, upslope, yielded typical Upper Paleolithic artefacts (e.g., Figure 10) and small-scale artefacts, while LFS 2 and 3, downslope, yielded large artefacts that can be linked with Levallois and hard hammer volumetric blade reduction. This could be due to modern modifications of the slope, pulling the larger artefacts downslope towards the Kremenjak River, or could illustrate a chronological sequence, with a first occupation downslope during the Middle Palaeolithic, when the valley was lower, then a period of sedimentation, and then a later, Upper Palaeolithic occupation on top of the new deposits.

In the Tri Stene Rockshelter, the upper layers, GL 1000 to GL1002, did not yield noticeable archaeological material, and are probably colluvial lobes that stretch across the lower part of the slope, as mentioned earlier. GL 1003 and downwards seem to be less disturbed, and show an alternation of archaeological and sterile layers, which could indicate an intact sequence. The artefacts positions could also confirm this, with the presence of the more recent artefact, the bladelet core, on the top of the archaeological sequence, while the Levallois elements are more concentrated at the bottom of the exposure. If this is the case, it would mean that the valley was already carved down to the bedrock while the first Levallois-making groups occupied the area.

Thus, the Lojanik 3 assemblage as a whole seems to indicate at least two periods of occupation:

- First, Levallois-making hunter-gatherers occupied the valley near the stream, probably taking advantage from the exposed bedrock to easily exploit the raw material;
- Then, Upper Palaeolithic groups came to occupy the site; at this time the bedrock would not be as exposed and thus not as easily accessible. However, they could have exploited bedrock outcrops that are located higher on the slope, such as the one we identified during our survey (Figure 2f), or boulders that have been detached from the same outcrop and rolled down the slope.

d. Techno-typological summary of the Kremenjak Valley assemblages

Lojanik 2 and Lojanik 3 show a similar pattern of techno-typological features observed on the artefacts. Both of them have a high proportion of both Levallois artefacts and laminar production. Due to the nature of the context of these artefacts as well as their uniqueness on the regional level, their chronological and cultural interpretation is limited. However, due to the presence of some very diagnostic elements, we can make strong assumptions about their cultural attribution. While these assumptions could potentially be of great significance, we should remain conservative on our interpretation. Having this in mind, the presence of Levallois or Levallois-like elements is unambiguous, making Lojanik a clear outlier in the Central Balkans at this point. The nature of the laminar production is less obvious since its ambiguity presents a challenge for interpretation.

4.3. Landscape Use in the Kremenjak Valley

The information gathered from Lojanik 2 and 3 indicate a repeated occupation in the Kremenjak area, possibly with different human species returning to the site over a long period of time. The lack of evidence for other periods could be a product of active geological processes as well as different behaviours concerning raw material economy during later prehistory. Each side of the valley of Kremenjak seems to show a different depositional environment, which is in corelation with the distribution of artefacts. The eastern slope (Figure 1, GU E) displays a greater instability and artefacts are only seldom found in this area. The western slope, on the other hand, presents a more stable depositional environment, and even with the recent human activities, erosion, and reworking, shows a much better preservation of artefacts.

The major difference between Lojanik 2 and Lojanik 3 is seen in the context of the finds. Lojanik 3 seems to have suffered recent modifications due to the levelling of terrain and clearing of smaller forest paths, which have in fact made the artefacts more visible. While we recognise that a lot of them are in a secondary context, the artefacts do not seem to be displaced over great distances, as the piles created by these activities do not require long distance transportation of the sediment. In addition, the artefacts seem to be well preserved, with sharp edges and few post-depositional alterations [79]. The exception in this area is the Tri Stene Rockshelter, which does not seem to be affected by recent human activities but has still been modified by the movement of the Kremenjak stream.

Both areas are located downslope of a large outcrop of good-quality opal, from which boulders have been detached and rolled down, where the raw material is accessible. Upslope from this outcrop, surface finds are extremely rare, and good quality raw material sources decrease sharply. It is thus possible that, although reworked, Lojanik 2 and Lojanik 3 reflect more intensive forager visits in a portion of the landscape where good-quality lithic raw material was readily accessible.

5. Conclusions

The Lojanik complex is a crucial site for the understanding of lithic raw material procurement and landscape use in the Prehistory of the Balkans. Despite the recent modifications of the landscape, due to modern mining, we were able to reconstruct patterns of human occupation in relation with the geomorphological processes affecting the valleys. The promising results of the 2022 survey demonstrate how LiDAR data can be used in the context of Prehistoric archaeology to locate sites and areas of interest even in the absence of large-scale modifications of the ground—such as buildings or enclosures for later periods. Our work represents a step forward for the research on Prehistoric occupations in the Balkans, notably with the identification of Levallois elements, an exceptionally rare occurrence in the region. Future investigations will include archaeological excavations and geoarchaeological and chronological analyses, in hopes of portraying a comprehensive picture of human settlement patterns and cultural behaviours in the central Balkans Prehistory.

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Data Availability Statement: The results of the archaeological survey are currently archived by C. Lesage and A. Barbieri at ICArEHB (Portugal), as well as V. Bogosavljević Petrović at the National Museum of Belgrade (Serbia). These include GPS data points, digital mapping, and LiDAR data, fieldnotes, lithic database, field and material pictures, and ERT database. Artifact collections are the property of the National Museum Kraljevo (Serbia).

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References

1. Van Andel, T.H.; Tzedakis, P.C. Palaeolithic Landscapes of Europe and Environs, 150,000–25,000 Years Ago: An Overview. *Quat. Sci. Rev.* **1996**, *15*, 481–500. [CrossRef]
2. Tzedakis, P.C. The Balkans as Prime Glacial Refugial Territory of European Temperate Trees. In *Balkan Biodiversity*; Springer: Berlin/Heidelberg, Germany, 2004; pp. 49–68.
3. Hewitt, G.M. Post-Glacial Re-Colonization of European Biota. *Biol. J. Linn. Soc.* **1999**, *68*, 87–112. [CrossRef]
4. Weiss, S.; Ferrand, N. *Phylogeography of Southern European Refugia*; Springer: Berlin/Heidelberg, Germany, 2007.
5. Dennell, R.W.; Martinón-Torres, M.; de Castro, J.M.B. Hominin Variability, Climatic Instability and Population Demography in Middle Pleistocene Europe. *Quat. Sci. Rev.* **2011**, *30*, 1511–1524. [CrossRef]
6. Feliner, G.N. Southern European Glacial Refugia: A Tale of Tales. *Taxon* **2011**, *60*, 365–372. [CrossRef]
7. Dogandžić, T.; McPherron, S.; Mihailović, D. Middle and Upper Paleolithic in the Balkans: Continuities and Discontinuities of Human Occupations. *Palaeolithic Mesolith. Res. Cent. Balk.* **2014**, *83*, 83–94.
8. Stojak, J.; McDevitt, A.D.; Herman, J.S.; Searle, J.B.; Wójcik, J.M. Post-Glacial Colonization of Eastern Europe from the Carpathian Refugium: Evidence from Mitochondrial DNA of the Common Vole Microtus Arvalis. *Biol. J. Linn. Soc.* **2015**, *115*, 927–939. [CrossRef]
9. Jones, E.L. What Is a Refugium? Questions for the Middle–Upper Palaeolithic Transition in Peninsular Southern Europe. *J. Quat. Sci.* **2021**, *37*, 136–141. [CrossRef]
10. Dogandžić, T.; Đuričić, L. Lithic Production Strategies in the Middle Paleolithic of the Southern Balkans. *Quat. Int.* **2017**, *450*, 68–102. [CrossRef]
11. Boëda, E. Approche Technologique Du Concept Levallois et Évaluation de Son Champ d'application: Étude de Trois Gisement Saaliens et Weichseliens de La France Septentrionale. Ph.D. Thesis, Université Paris X, Nanterre, France, 1986.
12. Boëda, E. De La Surface Au Volume: Analyse Des Conceptions Des Débitages Levallois et Laminaire. In *Proceedings of the Actes du Colloque International de Nemours, 1988*; Mémoires du Musée de Préhistoire d'Ile-de-France: Nemours, France, 1990; Volume 3, pp. 63–68.
13. Boëda, E. Levallois: A Volumetric Construction, Methods, A Technique. In Proceedings of the Monographs in World Archaeology n°23; Prehistory Press: Philadelphie, PA, USA, 1995; pp. 41–68.
14. Jaubert, J. *Chasseurs et Artisans Du Moustérien*; La Maison des Roches: Paris, France, 1999.
15. Mihailović, D. Push-and-Pull Factors of the Middle to Upper Paleolithic Transition in the Balkans. *Quat. Int.* **2020**, *551*, 47–62. [CrossRef]
16. Bogosavljević Petrović, V.; Marković, J. Raw Material Studies of West Central Serbia. *J. Lithic Stud.* **2014**, *1*, 55–71. [CrossRef]
17. Bogosavljević Petrović, V.; Petrović, A.; Galfi, J.; Jovanović, D.; Radonjić, Đ. Grey Zones of Production: Discussing the Technology of Tools at the Lojanik Quarry in West-Central Serbia. *J. Lithic Stud.* **2018**, *5*, 2. [CrossRef]
18. Marković, B.; Urošević, M.; Pavlović, Z.; Terzin, V.; Jovanović, Ž.; Vujisić, T.; Rakić, M. SFRJ, 1:100.000, Tumač Za List Kraljevo, K 34-6. 1963.
19. Mihailović, D.; Bogosavljević Petrović, V. Samaila—Vlaška Glava, Paleolitsko Nazalište Na Otvorenom Prostoru (in Serbian; Samaila—Vlaška Glava, Open-Air Palaeolithic Site). *Naša Prošlost* **2009**, *10*, 21–44.
20. Mihailović, D.; Milošević, S.; Radović, P. New Data about the Lower and Middle Palaeolithic in Western Morava Valley. In *Palaeolithic and Mesolithic research in the central Balkans*; Serbian Archaeological Society: Belgrade, Serbia, 2014; pp. 57–67.
21. Stevanović, P.; Pavlović, M.B.; Eremija, M. Čačansko-Kraljevački (Ili Zapadnomoravski Basen). In *Geologija Srbije, II-3. Stratigrafija-Kenozoik*; Institut za regionalnu geologiju i paleontologiju Rudarsko-geološkog fakulteta: Belgrade, Serbia, 1977; pp. 270–275.
22. Bogosavljević Petrović, V. *Okresama Kamena Industrija Sa Neolitiskih Naselja Divlje Polje i Trsine (Chipped Stone Industries from the Neolithic Sites of Divlje Polje and Trsine)*; Magistarski rad No 3/316; Filozofski fakultet, Univerzitet u Beograd: Belgrade, Serbia, 1990.
23. Bogosavljević Petrović, V. Razvoj Industrije Okresanog Kamena u Vinčanskoj Kulturi Na Teritoriji Srbije (Evolution of the Chipped Stone Industry in the Vinča Culture in the Territory of Serbia). Ph.D. Dissertation, Filozofski fakultet Univerzitet u Beograd, Belgrade, Serbia, 2015.
24. Bogosavljević Petrović, V.; Starović, A. The Context of the Early Neolithic in Serbia: Hidden Reflections of Mesolithic Continuity? *Glas. Srp. Arheol. Društva* **2016**, *32*, 7–50.
25. Bogosavljević Petrović, V.; Starović, A.; Jovanovic, D.; Pendić, J. Micro-Regional Quarry-Settlement in the West-Central Serbia: Preliminary Lojanik 2016 Fieldwork Report. *Glas. Srp. Arheol. Društva* **2018**, *33*, 21–46.
26. Dong, P.; Chen, Q. *LiDAR Remote Sensing and Applications*; CRC Press: Boca Raton, FL, USA, 2017.

27. Chase, A.; Chase, D.; Chase, A. Ethics, New Colonialism, and Lidar Data: A Decade of Lidar in Maya Archaeology. *J. Comput. Appl. Archaeol.* **2020**, *3*, 51–62. [CrossRef]
28. Evans, D. Airborne Laser Scanning as a Method for Exploring Long-Term Socio-Ecological Dynamics in Cambodia. *J. Archaeol. Sci.* **2016**, *74*, 164–175. [CrossRef]
29. Inomata, T.; Triadan, D.; Vázquez López, V.A.; Fernandez-Diaz, J.C.; Omori, T.; Méndez Bauer, M.B.; García Hernández, M.; Beach, T.; Cagnato, C.; Aoyama, K. Monumental Architecture at Aguada Fénix and the Rise of Maya Civilization. *Nature* **2020**, *582*, 530–533. [CrossRef]
30. Shepard, D. A Two-Dimensional Interpolation Function for Irregularly-Spaced Data. In Proceedings of the 1968 23rd ACM National Conference, New York, NY, USA, 27–29 August 1968; pp. 517–524.
31. Haralick, R.M. Ridges and Valleys on Digital Images. *Comput. Vis. Graph. Image Process.* **1983**, *22*, 28–38. [CrossRef]
32. Zevenbergen, L.W.; Thorne, C.R. Quantitative Analysis of Land Surface Topography. *Earth Surf. Process. Landf.* **1987**, *12*, 47–56. [CrossRef]
33. Evans, I.S. *An Integrated System of Terrain Analysis and Slope Mapping*; University of Durham: Durham, UK, 2006.
34. Olaya, V. Basic Land-Surface Parameters. In *Geomorphometry: Concepts, Software, Applications. Developments in Soil Science*; Hengl, T., Reuter, H.I., Eds.; Elsevier: Amsterdam, The Netherlands, 2006; Volume 33, pp. 141–169.
35. Travis, M.R.; Elsner, G.H.; Iverson, W.D.; Johnson, C.G. *VIEWIT: Computation of Seen Areas, Slope, and Aspect for Land-Use Planning*; USDA Forest Service General Technical Report.; Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station: Berkeley, CA, USA, 1975; Volume 11, 70p.
36. Tarini, M.; Cignoni, P.; Montani, C. Ambient Occlusion and Edge Cueing for Enhancing Real Time Molecular Visualization. *IEEE Trans. Vis. Comput. Graph.* **2006**, *12*, 1237–1244. [CrossRef]
37. Bridgland, D.R. River Terrace Systems in North-West Europe: An Archive of Environmental Change, Uplift and Early Human Occupation. *Quat. Sci. Rev.* **2000**, *19*, 1293–1303. [CrossRef]
38. Cunha, P.P.; Martins, A.A.; Buylaert, J.-P.; Murray, A.S.; Gouveia, M.P.; Font, E.; Pereira, T.; Figueiredo, S.; Ferreira, C.; Bridgland, D.R.; et al. The Lowermost Tejo River Terrace at Foz Do Enxarrique, Portugal: A Palaeoenvironmental Archive from c. 60–35 Ka and Its Implications for the Last Neanderthals in Westernmost Iberia. *Quaternary* **2019**, *2*, 3. [CrossRef]
39. Shea, J.J. The Middle Stone Age Archaeology of the Lower Omo Valley Kibish Formation: Excavations, Lithic Assemblages, and Inferred Patterns of Early Homo Sapiens Behavior. *J. Hum. Evol.* **2008**, *55*, 448–485. [CrossRef] [PubMed]
40. Schilt, F.; Miller, C.E.; Wright, D.K.; Mentzer, S.M.; Mercader, J.; Moss, P.; Choi, J.-H.; Siljedal, G.; Clarke, S.; Mwambwiga, A. Hunter-Gatherer Environments at the Late Pleistocene Sites of Mwanganda's Village and Bruce, Northern Malawi. *Quat. Sci. Rev.* **2022**, *292*, 107638. [CrossRef]
41. Straus, L.G. Underground Archaeology: Perspectives on Caves and Rockshelters. *Archaeol. Method Theory* **1990**, *2*, 255–304.
42. Skeates, R.; Bergsvik, K.A. Caves in Context: The Cultural Significance of Caves and Rockshelters in Europe. In *Caves in Context*; Oxbow Books: Oxford, UK, 2012; pp. 1–304.
43. Becker, C.J. Flint Mining in Neolithic Denmark. *Antiquity* **1959**, *33*, 87–92. [CrossRef]
44. Bosch, P.W. A Neolithic Flint Mine. *Sci. Am.* **1979**, *240*, 126–133. [CrossRef]
45. Camprubí, A.; Melgarejo, J.-C.; Proenza, J.A.; Costa, F.; Bosch, J.; Estrada, A.; Borell, F.; Yushkin, N.P.; Andreichev, V.L. Mining and Geological Knowledge during the Neolithic: A Geological Study on the Variscite Mines at Gavà, Catalonia. *Epis. J. Int. Geosci.* **2003**, *26*, 295–301. [CrossRef]
46. Leopold, M.; Völkel, J. Neolithic Flint Mines in Arnhofen, Southern Germany: A Ground-penetrating Radar Survey. *Archaeol. Prospect.* **2004**, *11*, 57–64. [CrossRef]
47. FitzPatrick, E.A. *Soils. Their Formation, Classification and Distribution.*; Longman: London, UK, 1980.
48. Chilingar, G.V.; Bissell, H.J.; Wolf, K.H. Diagenesis of Carbonate Rocks. In *Developments in Sedimentology*; Elsevier: Amsterdam, The Netherlands, 1967; Volume 8, pp. 179–322.
49. Zingg, T. Beitrag Zur Schotteranalyse. Ph.D. Dissertation, ETH, Zurich, Switzerland, 1935.
50. Powers, M.C. A New Roundness Scale for Sedimentary Particles. *J. Sediment. Res.* **1953**, *23*, 117–119. [CrossRef]
51. Stoops, G. *Guidelines for Analysis and Description of Soil and Regolith Thin Sections*; John Wiley & Sons: Hoboken, NJ, USA, 2021; Volume 184.
52. Vos, C.; Don, A.; Prietz, R.; Heidkamp, A.; Freibauer, A. Field-Based Soil-Texture Estimates Could Replace Laboratory Analysis. *Geoderma* **2016**, *267*, 215–219. [CrossRef]
53. Telford, W.M.; Telford, W.M.; Geldart, L.P.; Sheriff, R.E. *Applied Geophysics*; Cambridge University Press: Cambridge, UK, 1990.
54. Binley, A.; Kemna, A. DC Resistivity and Induced Polarization Methods. In *Hydrogeophysics*; Rubin, Y., Hubbard, S.S., Eds.; Springer: Dordrecht, The Netherlands, 2005; pp. 129–156.
55. Diallo, M.C.; Cheng, L.Z.; Rosa, E.; Gunther, C.; Chouteau, M. Integrated GPR and ERT Data Interpretation for Bedrock Identification at Cléricy, Québec, Canada. *Eng. Geol.* **2019**, *248*, 230–241. [CrossRef]
56. Coulouma, G.; Samyn, K.; Grandjean, G.; Follain, S.; Lagacherie, P. Combining Seismic and Electric Methods for Predicting Bedrock Depth along a Mediterranean Soil Toposequence. *Geoderma* **2012**, *170*, 39–47. [CrossRef]
57. Tsokas, G.N.; Tsourlos, P.I.; Vargemezis, G.; Novack, M. Non-destructive Electrical Resistivity Tomography for Indoor Investigation: The Case of Kapnikarea Church in Athens. *Archaeol. Prospect.* **2008**, *15*, 47–61. [CrossRef]

58. Nowaczinski, E.; Schukraft, G.; Hecht, S.; Rassmann, K.; Bubenzer, O.; Eitel, B. A Multimethodological Approach for the Investigation of Archaeological Ditches–Exemplified by the Early Bronze Age Settlement of Fidvár Near Vráble (Slovakia). *Archaeol. Prospect.* **2012**, *19*, 281–295. [CrossRef]
59. Chambers, J.E.; Wilkinson, P.B.; Wardrop, D.; Hameed, A.; Hill, I.; Jeffrey, C.; Loke, M.H.; Meldrum, P.I.; Kuras, O.; Cave, M. Bedrock Detection beneath River Terrace Deposits Using Three-Dimensional Electrical Resistivity Tomography. *Geomorphology* **2012**, *177*, 17–25. [CrossRef]
60. Barbieri, A.; Bachofer, F.; Schmaltz, E.M.; Leven, C.; Conard, N.J.; Miller, C.E. Interpreting Gaps: A Geoarchaeological Point of View on the Gravettian Record of Ach and Lone Valleys (Swabian Jura, SW Germany). *J. Archaeol. Sci.* **2021**, *127*, 105335. [CrossRef]
61. de la Vega, M.; Osella, A.; Lascano, E. Joint Inversion of Wenner and Dipole–Dipole Data to Study a Gasoline-Contaminated Soil. *J. Appl. Geophys.* **2003**, *54*, 97–109. [CrossRef]
62. Blanchy, G.; Saneiyan, S.; Boyd, J.; McLachlan, P.; Binley, A. ResIPy, an Intuitive Open Source Software for Complex Geoelectrical Inversion/Modeling. *Comput. Geosci.* **2020**, *137*, 104423. [CrossRef]
63. Nettleton, I.M.; Martin, S.; Hencher, S.; Moore, R. Debris Flow Types and Mechanisms. In *Scottish Road Network Landslides Study*; Transport Scotland: Edinburgh, Scotland, 2005; pp. 45–67.
64. Bertran, P.; Texier, J.-P. Facies and Microfacies of Slope Deposits. *Catena* **1999**, *35*, 99–121. [CrossRef]
65. Blikra, L.H.; Nemec, W. Postglacial Colluvium in Western Norway: Depositional Processes, Facies and Palaeoclimatic Record. *Sedimentology* **1998**, *45*, 909–960. [CrossRef]
66. Savin, C.; Robineau, B.; Monteil, G.; Beauvais, A.; Parisot, J.C.; Ritz, M. Electrical Imaging of Peridotite Weathering Mantles as a Complementary Tool for Nickel Ore Exploration in New Caledonia. *ASEG Ext. Abstr.* **2003**, *2003*, 1–5. [CrossRef]
67. Bondar, K.M.; Sokhatskyi, M.P.; Chernov, A.; Popko, Y.; Petrokushyn, O.; Baryshnikova, M.; Khomenko, R.; Boyko, M. Geophysical Assessment of Verteba Cave Eneolithic Site, Ukraine. *Geoarchaeology* **2021**, *36*, 238–251. [CrossRef]
68. Reynolds, J.M. *An Introduction to Applied and Environmental Geophysics*; John Wiley & Sons: Hoboken, NJ, USA, 2011.
69. Verdet, C.; Sirieix, C.; Marache, A.; Riss, J.; Portais, J.-C. Detection of Undercover Karst Features by Geophysics (ERT) Lascaux Cave Hill. *Geomorphology* **2020**, *360*, 107177. [CrossRef]
70. Testone, V.; Longo, V.; Mameli, P.; Rovina, D. Geophysical Prospection Pilot in Rock-Cut Tombs: The Case Study of Anghelu Ruju Necropolis (Sardinia). *Archaeol. Prospect.* **2018**, *25*, 271–277. [CrossRef]
71. Barbieri, A.; Regala, F.T.; Cascalheira, J.; Bicho, N. The Sediment at the End of the Tunnel: Geophysical Research to Locate the Pleistocene Entrance of Gruta Da Companheira (Algarve, Southern Portugal). *Archaeol. Prospect.* **2022**. [CrossRef]
72. Nett, J.J.; Chu, W.; Fischer, P.; Hambach, U.; Klasen, N.; Zeeden, C.; Obreht, I.; Obrocki, L.; Pötter, S.; Gavrilov, M.B.; et al. The Early Upper Paleolithic Site Crvenka-At, Serbia–The First Aurignacian Lowland Occupation Site in the Southern Carpathian Basin. *Front. Earth Sci.* **2021**, *9*, 599986. [CrossRef]
73. Hussain, Y.; Hamza, O.; Cárdenas-Soto, M.; Borges, W.R.; Dou, J.; Rebolledo, J.F.R.; Prado, R.L. Characterization of Sobradinho Landslide in Fluvial Valley Using MASW and ERT Methods. *REM Int. Eng. J.* **2020**, *73*, 487–497. [CrossRef]
74. Fankhauser, K.; Guzman, D.R.L.; Oggier, N.; Maurer, H.; Springman, S.M. Seasonal Response and Characterization of a Scree Slope and Active Debris Flow Catchment Using Multiple Geophysical Techniques: The Case of the Meretschibach Catchment, Switzerland. In Proceedings of the EGU General Assembly Conference Abstracts, Vienna, Austria, 12–17 April 2015; p. 11833.
75. Pavlović, M.B.; Stevanović, P.; Eremija, M. Чачанско—Краљевачки (Или Западноморавски) Басен (Čačak-Kraljevo (or West Morava) Basin). In *Геологија Србије*; Zavod za regionalnu geologiju i paleontologiju Rudarsko—Geološkog fakulteta, Univerzitet u Beogradu: Beograd, Serbia, 1977; Volume 3, pp. 270–275.
76. Kuhn, S.; Zwyns, N. Rethinking the Initial Upper Paleolithic. *Quat. Int.* **2014**, *347*, 29–38. [CrossRef]
77. Kuhn, S.L. In What Sense Is the Levantine Initial Upper Paleolithic a "Transitional" Industry. In *The Chronology of the Aurignacian and of the Transitional Technocomplexes. Dating, Stratigraphies, Cultural Implications*; Instituto Português de Arqueologia Lisbon: Lisboa, Portugal, 2003; Volume 33, pp. 61–70.
78. Marks, A.E.; Ferring, C.R. The Early Upper Paleolithic of the Levant in The Early Upper Paleolithic. Evidence from Europe and the Near East. *BAR Int. Ser.* **1988**, *437*, 43–72.
79. Dibble, H.L.; Chase, P.G.; McPherron, S.P.; Tuffreau, A. Testing the Reality of a "Living Floor" with Archaeological Data. *Am. Antiq.* **1997**, *62*, 629–651. [CrossRef]

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Article

Mountain Landscape and Human Settlement in the Pindus Range: The Samarina Highland Zones of Western Macedonia, Greece

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Abstract: Past human mountain settlement patterns and resource and high-altitude landscape exploitation are underexplored research fields in archaeology. This study presents data gathered during more than 20 years of fieldwork in the Pindus range of Western Macedonia (Greece), focusing in particular on Holocene land use. The investigated territory is located around the Vlach town of Samarina. The area is partly bounded by Mounts Vasilitsa, Gurguliu, Bogdani and Anitsa, and their interconnecting watersheds between ca. 1400 and 2000 m a.s.l. This research led to the discovery of many sites and findspots of lithic and ceramic artefacts attributed to the Middle and Upper Palaeolithic, Mesolithic, Late Neolithic, Chalcolithic, Bronze Age, and several Historical periods. The radiocarbon results show an unexpected *longue durée* of Holocene human landscape use. The number of sites, their distribution, location, and subsistence strategies exhibit shifts between the Middle Palaeolithic and different periods of the Holocene, which are closely related to the exploitation of the mountain environment and its resources. Moreover, typical knapped stone artefacts have been used as a proxy for dating the glacial landforms which characterise the Samarina highland zone; we correlate them to the better-known moraine systems of Mount Tymphi in Epirus and contribute to the reconstruction of the Pleistocene glacial landscapes of the Pindus Range.

Keywords: mountain environment; human landscape; prehistoric settlement; Pindus range; north-western Greece

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1. Introduction

This paper discusses the results of surveys and excavations carried out jointly by Aristotle University, Thessaloniki (Greece), and Ca' Foscari University, Venice (Italy) between 1999 and 2021 in the mountains of the north Pindus range, a remote and somewhat neglected region of Western Macedonia [1]. The research was aimed at surveying and exploring the archaeological potential of the high-altitude landscapes around the Vlach town of Samarina (ca. 1450 m a.s.l.), at the eastern piedmont of Mount Gurguliu (Gorgul'u) [2–5]. The initial purpose of the project was to search for high-altitude Mesolithic sites, in light of results achieved since the end of the 1960s in the Italian Alps, where dozens of early Holocene hunter-gatherer sites attributed to different Mesolithic periods were discovered [6–8]. This is a very important agenda because our knowledge of the Early Holocene archaeology of the entire Balkan Peninsula is elusive, especially with regard to the territories of the interior and the mountain zones [9–13]. Therefore, this paper will focus, in particular, on the Holocene archaeology of the Samarina highland zone, though we will also consider Mount Vasilitsa moraines, where artefacts of different ages have been discovered.

The Pindus archaeological surveys were carried out in the Samarina highlands (Figure 1). They covered a previously uninvestigated mountain landscape of north-western Greece, which has been exploited for centuries by groups of Vlach shepherds for their seasonal pastoral transhumance [14–17]. This territory is very different from those often investigated by archaeologists in the southern periphery of the Balkan Peninsula [18,19]. During twenty-two years of fieldwork, we systematically GPS-recorded every single archaeological find visible from the ground surface. Apart from the presence of impressive chert outcrops, which were exploited mainly by Neanderthal groups [20], the surveys led to the discovery of many Middle Palaeolithic sites, lithic workshops, clusters and scattered artefacts [21], a few Upper Palaeolithic and Mesolithic findspots [22,23], Late Neolithic, Chalcolithic, Bronze Age, and Historical sites and artefacts [24], some of which have been radiocarbon-dated mainly from identified charcoal samples (Figures 2 and 3; Table 1) [25]. Moreover, test trenches have been opened at five sites to investigate the presence of archaeological deposits in situ (Figure 1).

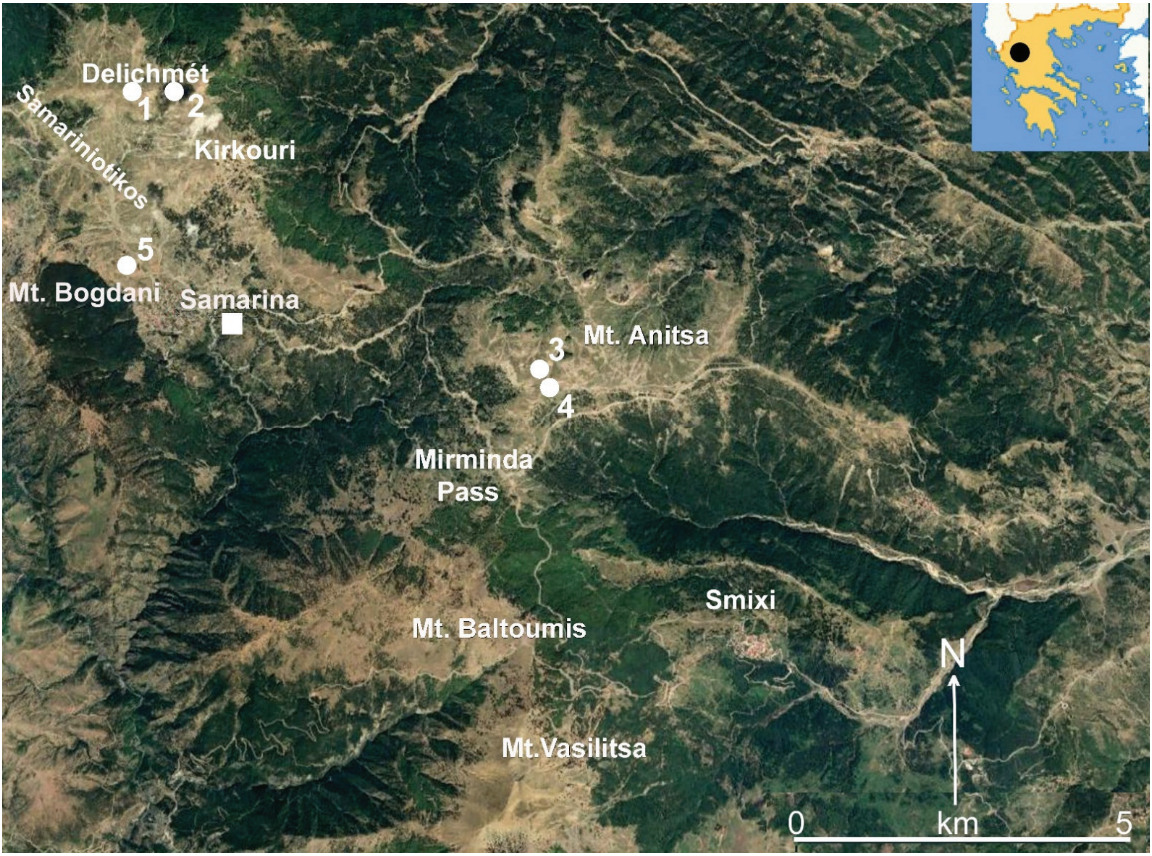

Figure 1. Map of the surveyed area showing the most important localities reported in the text, and the sites where test trenches were opened: Sam-8 (n. 1), Sam-5 (n. 2), Sam-29 (n. 3), Sam-23 (n. 4), and HC (n. 5) (drawing by P. Biagi).

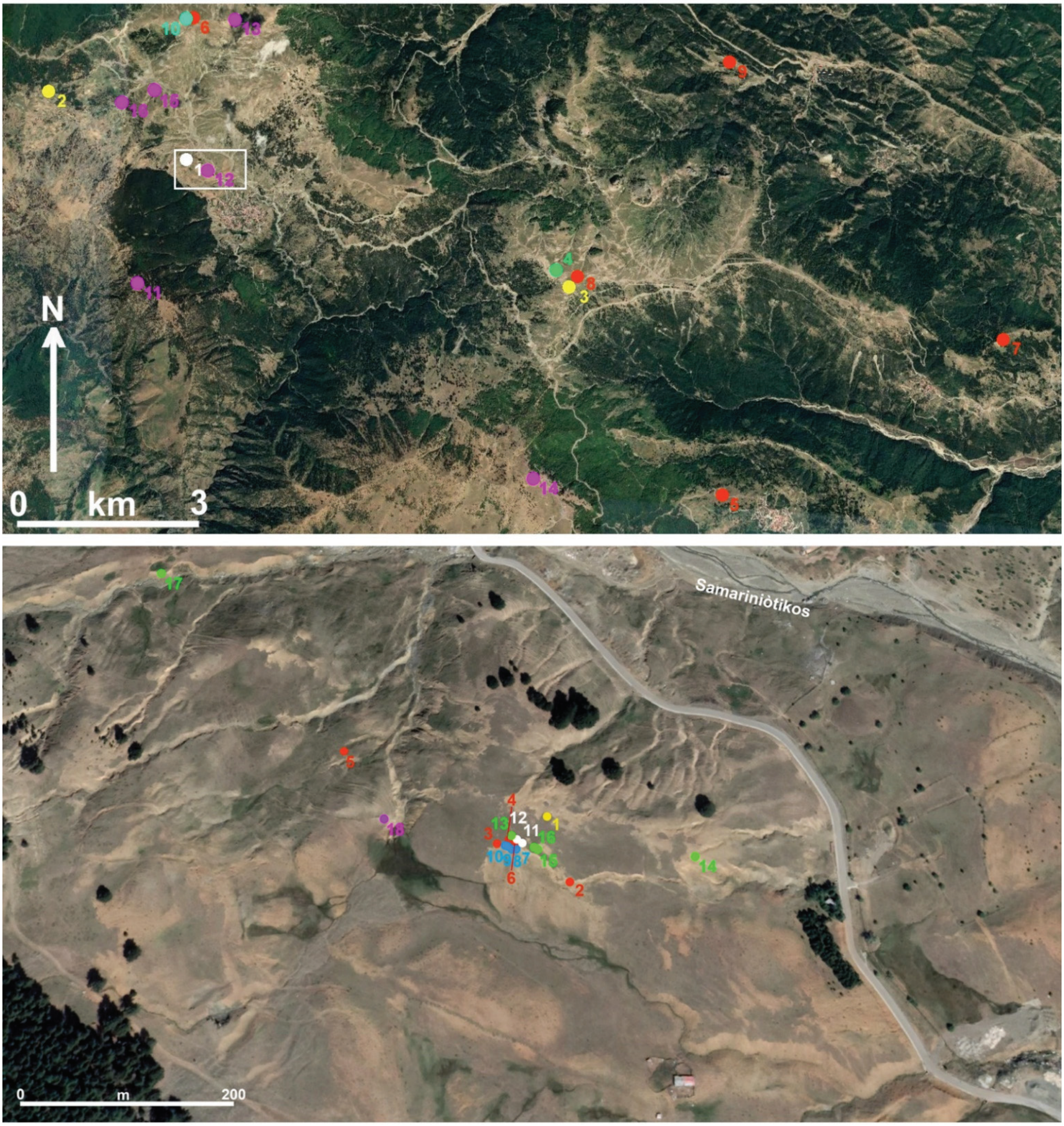

Figure 2. Distribution map of the radiocarbon-dated sites in the study area: HC-CH-20 (n. 1), BGD-1 (n. 2), NTS-25 (n. 3), Sam-23 (n. 4), SMX-1 (n. 5), Sam-8/2 and 8/4 (n. 6), KRN-45 (n. 7), Sam-29 (n. 8), AA-1 (n. 9), Sam-8/1 and 8/3 (n. 10), GRG-1 (n. 11), Samarina HC-5 and HC-4/CH1 (n. 12), Sam-5 (n. 13), VSL-1 (n. 14), SMR-1W (n. 15), and GVL-1 (n. 16). Mesolithic (white dot), Neolithic (blue dot), Chalcolithic (yellow dot), Bronze Age (red dot), Historical periods (violet dot). The white rectangle marks the location of the Historical Camp (HC) (top). Distribution map of the radiocarbon-dated tree-pits in the Historical Camp (HC): HC-102 (n. 1), HC-CH16 (n. 2), HC-115 (n. 3), HC-145 (n. 4), HC-CH9 (n. 5), HC-111 (n. 6), HC-144 (n. 7), HC-5/CH2 (n. 8), HC-146 (n. 9), CHR-4 (n. 10), CH-3 (n. 11), HC-105 (n. 12), HC-147 (n. 13), Grevena-1 (n. 14), HC-143 (n. 15), HC-107 (n. 16), HC-133 (n. 17), and CHR-5 (n. 18). Chalcolithic (yellow dot), Bronze Age (red dot), Iron Age (blue dot), Roman Age (white dot), Byzantine period (green dot), Medieval period (violet dot) (bottom) (drawings by P. Biagi and E. Starnini).

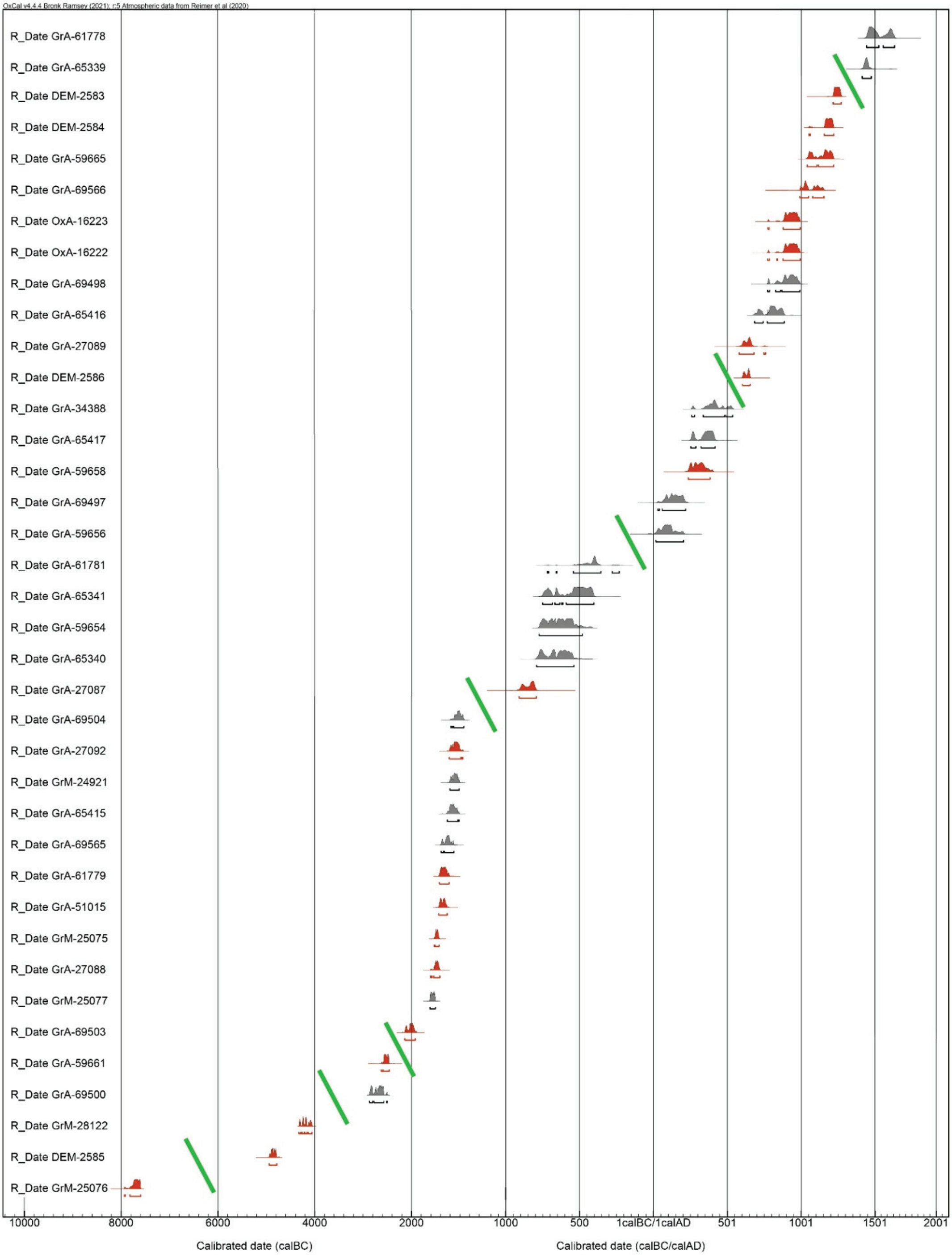

Figure 3. Plot of all the calibrated dates from the Samarina highlands. Grey histograms: HC tree-pits, red histograms: archaeological sites. The oblique green bars mark the discontinuity between different periods. Calibrations according to OxCal 4.4 [26].

Table 1. List of all the radiocarbon-dated sites reported in the text. The HC tree-pit results are marked in grey (NA = Not Available). Calibrations according to OxCal 4.4.

Reference	Context	Coordinates	Altitude (m)	Laboratory Number	Uncal BP	*Taxon*	Cal BC/AD (95.4%)	Δ^{13}C	Figure
CHR-5	tree-pit	40°06′42.7″ N–21°00′24.9″ E	1547	GrA-61778	385 ± 35	*Fagus sylvatica*	1443–1663 AD	−25.73 ± 0.15	2 bottom, n. 18
HC-133	tree-pit	40°06′52.1″ N–21°00′14.5″ E	1528	GrA-65339	455 ± 30	*Pinus nigra*	1414–1475 AD	−25.35	2 bottom, n. 17
GVL-1	colluvial charcoal	40°07′20.1″ N–20°59′32.3″ E	1531	DEM-2583	805 ± 21	*Quercus* sp.	1218–1271 AD	NA	2 top, n. 16
SMR-1W	charcoal horizon	40°07′31.9″ N–20°59′53.6″ E	1522	DEM-2584	876 ± 19	*Fagus sylvatica*	1053–1222 AD	NA	2 top, n. 15
HC-4/CH1	burning pit?	40°06′41.1″ N–21°00′33.1″ E	1536	GrA-59665	895 ± 30	*Juniperus* sp.	1043–1220 AD	−26.765	2 top, n. 12
VSL-1	fireplace	40°04′12.4″ N–21°04′19.9″ E	1774	GrA-69566	995 ± 30	*Pinus nigra*	992–1154 AD	−23.85 ± 0.11	2 top, n. 14
Sam-5/1	fireplace	40°08′10.4″ N–21°00′53.5″ E	1778	DEM-1918/OxA-16223	1127 ± 25	undet. charcoal	775–994 AD	−26.7	2 top, n. 13
Sam-5/2	fireplace	40°08′10.4″ N–21°00′53.5″ E	1778	DEM-1917/OxA-16222	1129 ± 26	undet. charcoal	775–994 AD	−24.1	2 top, n. 13
HC-107	tree-pit	40°06′41.8″ N–21°00′31.3″ E	1541	GrA-69498	1140 ± 30	*Pinus nigra*	774–992 AD	−23.75 ± 0.11	2 bottom, n. 16
HC-143	tree-pit	40°06′41.9″ N–21°00′31.3″ E	1552	GrA-65416	1225 ± 30	*Pinus nigra*	671–876 AD	−24.27	2 bottom, n. 15
Sam-8/3	colluvial charcoal	40°08′10.7″ N–20°00′22.0″ E	1782	GrA-27089	1395 ± 40	*Pinus nigra*	580–759 AD	−22.60	2 top, n. 10
Samarina HC-5	burning pit	40°06′41.3″ N–21°00′33.9″ E	1567	DEM-2586	1414 ± 18	*Juniperus* sp.	604–655 AD	NA	2 top, n. 12
Grevena-1	tree-pit	40°06′41.5″N–21°00′37.5″ E	1524	GrA-34388	1655 ± 35	undet. charcoal	260–537 AD	−21.54	2 bottom, n. 14
HC-147	tree-pit	40°06′42.1″ N–21°00′29.6″ E	1547	GrA-65417	1700 ± 30	*Pinus nigra*	254–419 AD	−24.02	2 bottom, n. 13
GRG-1	small kiln	40°05′33.4″ N–20°59′55.1″ E	1939	GrA-59658	1755 ± 30	*Pinus sylvestris*	236–384 AD	−23.136	2 top, n. 11
HC-105	tree-pit	40°06′42.2″ N–21°00′31.4″ E	1540	GrA-69497	1905 ± 30	*Pinus heldreichi*	31–219 AD	−27.96 ± 0.11	2 bottom, n. 12
CH-3	tree-pit	40°06′42.2″ N–21°00′31.2″ E	1546	GrA-59656	1935 ± 30	*Pinus* sp.	17–205 AD	−25.07 ± 0.15	2 bottom, n. 11
Chr-4/CHR-4	tree-pit	40°06′42.2″ N–21°00′29.8″ E	1544	GrA-61781	2340 ± 40	*Pinus nigra*	718–232 BC	−26.61 ± 0.15	2 bottom, n. 10
HC-146	tree-pit	40°06′42.2″ N–21°00′30.0″ E	1548	GrA-65341	2430 ± 35	*Pinus nigra*	751–404 BC	−22.64	2 bottom, n. 9

Table 1. *Cont.*

Reference	Context	Coordinates	Altitude (m)	Laboratory Number	Uncal BP	*Taxon*	Cal BC/AD (95.4%)	Δ^{13}C	Figure
HC-5/CH2	tree-pit	40°06′42.0″ N–21°00′31.0″ E	1548	GrA-59654	2485 ± 30	*Pinus* sp.	774–481 BC	−23.325	2 bottom, n. 8
HC-144	tree-pit	40°06′41.9″ N–21°00′31.1″ E	1550	GrA-65340	2515 ± 35	*Pinus nigra*	791–589 BC	−23.79	2 bottom, n. 7
SAM-8/1	colluvial charcoal	40°08′10.7″ N–20°00′22.0″ E	1782	GrA-27087	2680 ± 40	*Salix* sp.	909–793 BC	−24.81	2 top, n. 10
HC-111	tree-pit	40°06′42.1″ N–21°00′30.5″ E	1542	GrA-69504	2860 ± 35	*Pinus nigra*	1187–919 BC	−23.20 ± 0.11	2 bottom, n. 6
SAM-8/4	colluvial charcoal	40°08′10.7″ N–20°00′22.0″ E	1782	GrA-27092	2900 ± 40	*Abies* sp.	1218–937 BC	−27.08	2 top, n. 6
HC-CH9	tree-pit	40°06′45.0″ N–21°00′22.9″ E	1546	GrM-24921	2912 ± 26	*Pinus nigra*	1205–1015 BC	−24.67 ± 015	2 bottom, n. 5
HC-145	tree-pit	40°06′42.2″ N–21°00′30.7″ E	1552	GrA-65415	2940 ± 35	*Pinus nigra*	1260–1017 BC	−23.37	2 bottom, n. 4
HC-115	tree-pit	40°06′42.1″ N–21°00′29.9″ E	1542	GrA-69565	3010 ± 35	*Pinus nigra*	1389–1125 BC	−23.31 ± 0.11	2 bottom, n. 3
AA-1	charcoal horizon	40°07′45.0″ N–21°07′07.1″ E	1112	GrA-61779	3070 ± 40	*Quercus caducifolia*	1423–1223 BC	−23.81 ± 0.15	2 top, n. 9
Sam-29, Anitsa	charcoal	40°05′36.5″ N–21°05′09.8″ E	1705	GrA-51015	3095 ± 35	*Quercus* sp.	1436–1264 BC	−25.76 ± 0.15	2 top, n. 8
KRN-45	charcoal lens	40°05′05.0″ N–21°10′16.0″ E	1333	GrM-25075	3218 ± 26	*Quercus* sp.	1528–1430 BC	−23.96 ± 0.15	2 top, n. 7
Sam-8/2	colluvial charcoal	40°08′10.7″ N–20°00′22.0″ E	1782	GrA-27088	3220 ± 40	*Fagus* sp.	1607–1414 BC	−23.61	2 top, n. 6
HC-CH16	tree-pit	40°06′40.8″ N–21°00′32.5″ E	1537	GrM-25077	3297 ± 26	*Pinus nigra*	1618–1507 BC	−26.74 ± 0.15	2 bottom, n. 2
SMX-1	charcoal from pit	40°03′41.4″ N–21°06′50.1″ E	1367	GrA-69503	3645 ± 35	*Pinus* sp.	2137–1923 BC	−23.15 ± 0.11	2 top, n. 5
Sam-23, Anitsa	charcoal horizon	40°05′44.0″ N–21°04′53.6″ E	1666	GrA-59661	4005 ± 35	*Juniperus* sp.	2623–2461 BC	−23.228	2 top, n. 4
HC-102	tree-pit	40°06′43.1″ N–21°00′31.8″ E	1541	GrA-69500	4105 ± 35	*Pinus nigra*	2868–2501 BC	−26.95 ± 0.11	2 bottom, n. 1
NTS-25, Anitsa	charcoal	40°05′33.0″ N–21°05′08.0″ E	1704	GrM-28122	5356 ± 26	*Fraxinus* sp.	4325–4055 BC	−25.73 ± 0.15	2 top, n. 3
BGD-1	fireplace	40°07′26.9″ N–20°58′36.8″ E	1892	DEM-2585	5972 ± 27	undet. charcoal	4944–4783 BC	NA	2 top, n. 2
HC-CH20	tree-pit?	40°06′46.3″ N–21°00′19.8″ E	1546	GrM-25076	8705 ± 35	*Salix* sp.	7934–7596 BC	−26.20 ± 0.15	2 top, n. 1

Table 1. *Cont.*

Reference	**Context**	**Coordinates**	**Altitude (m)**	**Laboratory Number**	**Uncal BP**	***Taxon***	**Cal BC/AD (95.4%)**	**Δ^{13}C**	**Figure**
HC-CH18	tree-pit	40°06′46.2″ N–21°00 19.5″ E	1546	failed, too small sample	NA	*Pinus* sp.	NA	NA	NA
HC-149	tree-pit	40°06′51.8″ N–21°00 17.3″ E	1532	failed, too small sample	NA	*Pinus nigra*	NA	NA	NA
HC-148	tree-pit	40°06′52.4″ N–21°00 16.8″ E	1532	failed, too small sample	NA	*Pinus nigra*	NA	NA	NA

During the last three decades, the territory around Samarina has been affected by the development of tourist infrastructures, construction of new roads, hotels and ski resorts mainly around Mount Vasilitsa, and a small dam near Polyneri, which heavily damaged part of the landscape despite their location inside the North Pindus National Park, which was established in 2005 [27].

In particular, the construction of many paved and unpaved roads triggered deep erosion along hillslopes. In contrast, the building of some infrastructures has favoured the discovery of archaeological finds. Moreover, the visibility of traces of past human activities is enhanced by extensively deforested zones, which are at present exploited for pastoral activities. Intensive grazing by flocks of sheep and goats produced patches of bare ground that increase the visibility of archaeological materials otherwise buried under the sward.

2. The Pindus Mountain Landscape: Environment and Resources

2.1. Holocene Climate and Vegetation

The investigated area covers a territory of some 80 square kilometres, from the village of Polyneri (ca. 1000 m a.s.l.) to the Mounts Bogdani-Gurguliu ridge (ca. 2000 m a.s.l.). The sharp variability in exposure, steepness, hydrology and geological substratum is the key natural control on the vegetation structure. Adding to these, diverse economic use of the territory (forests, pastures) has played an important role in shaping the present landscape.

Out of 15 forest types of the whole North Pindus National Park, only five are more extensively found today around Samarina. At lower altitudes up to 1200 m a.s.l., the prevailing forest is formed by deciduous oaks (mostly *Quercus frainetto*), followed by the black pine (*Pinus nigra*) and beech (*Fagus sylvatica*) with scattered stands of fir (*Abies borisii-regis*). The Bosnian pine (*Pinus heldreichii*) forms the treeline up to 2000 m a.s.l. However, at least 50% of the area is covered with pastures, opened in the past by Vlach transhumant herders (seasonal transhumance with summer pastures in Samarina, winter pastures in Thessaly) [17].

Dating this human-made landscape requires a better knowledge of Vlach history in the past millennia and the local history of Holocene climate change. As for the first point, reference can only be found either in the ethnographic reports from the few ancient travellers who, for different reasons, crossed this remote land (mostly historians and military topographers) or in the archaeological surveys [2,18,28,29].

For the reconstruction of the Holocene climate history, the following datasets are available (1) a good series of recent dendroclimatological data, covering the last two millennia; (2) a radiocarbon-dated pollen diagram, referring to a longer span of time, from 1340 BC to 700 AD; and (3) 20 radiocarbon-dated pieces of pine, juniper and beech charcoals from three-pits and burning structures recovered from the Historical Camp (henceforth HC) north-north-west of Samarina, spanning from 7934–7596 BC to 1443–1663 AD (Table 1).

Pinus heldreichii, the so far oldest European dendrochronologically dated tree [30], has recently provided a unique opportunity to establish a proxy climate record back to the 6th century BC. The studied cores were obtained from trees from Mount Smolikas and Valia Kalda in Western Macedonia [31,32] and Mavrovouni (Metsovon) in Epirus [33]. Tree-ring width climate signals detected in the longer core correlate to the climatic results obtained with the densitometry approach from other Smolikas black pine samples [34].

These recent data show that a significant warm period occurred between 876–905 AD, followed by an exceptionally cold phase (997–1026 AD), not yet detected in Central Europe curves, at the middle of the Medieval Warm Period. This was clearly warmer than the following Little Ice Age. Tree ring densitometry points to the existence of severe dry periods at 1350–1379 AD and 913–942 AD, and wetter phases at 862–891 AD and 1522–1551 AD [35]. For the BC periods, we have only one high-altitude pollen sequence in the Smolikas area. It was obtained from a sediment core taken from Lake Gomara, a small basin on the southern slopes of Mount Baltoumis (1749 m a.s.l.) [36] (Figure 4). Starting in 1340 BC, the pine forest was gradually replaced by beech after ca. 890 BC, perhaps through reduced disturbance and/or increased precipitation. A herbaceous pollen spike at ca. 80 BC followed the deposition of volcanic ash. Pinewood replaced beech forest at ca. 330 AD.

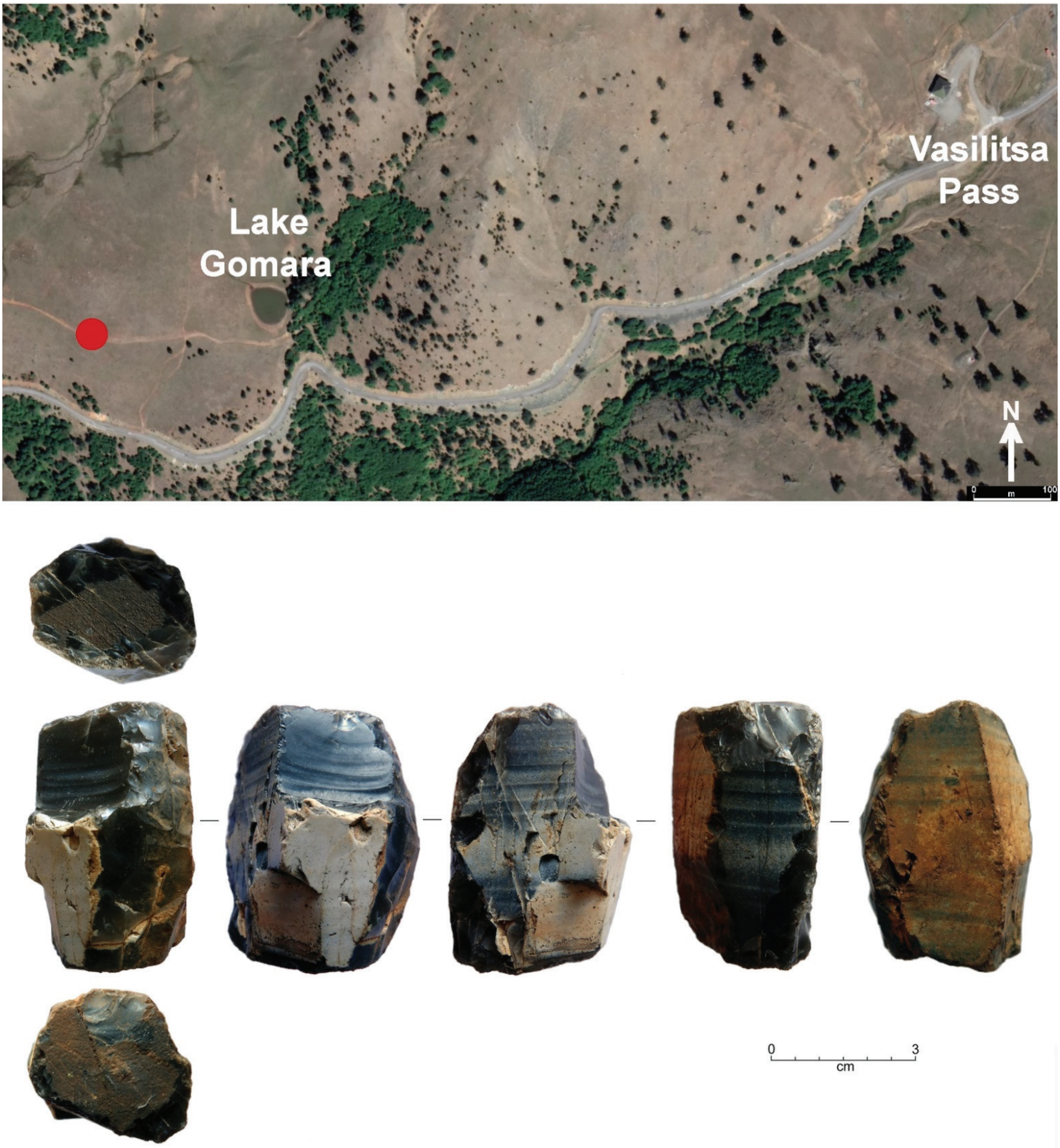

Figure 4. Lake Gomara, along the southern slope of Mount Baltoumis (**top**), and location of the pre-core of Vikos "black chert" recovered from the surface ca. 200 m west of the small basin (red dot) (**bottom**) (photographs by E. Starnini, 2022).

Two periods of accelerated erosion coincide with the pine wood phases and possibly with anthropogenic burning and grazing (early Vlach presence?). They are separated by a period of abandonment when the climate was probably wetter.

The radiocarbon dates obtained from charcoal from the Samarina HC structures and tree-pits (Figure 2) show the early presence (7934–7596 BC) of *Salix* sp., clearly pointing to the presence of water (a warm and wet phase?). Towards the beginning of the 3rd millennium BC the pine forest (mostly *Pinus nigra*, rarely *P. heldreichii*) permanently covered the area with some occurrences of beech (*Fagus sylvatica*) during the Bronze Age and Middle Ages. The Byzantine presence of juniper charcoal (from the seventh century up to 1043–1220 AD) shows the local opening of the conifer forest, which may indicate a pastoral economy.

Other interesting records come from the wider surveyed area. Charcoal of ash (*Fraxinus* sp.) at Anitsa clearly shows the existence of a warm period during the Late Neolithic, around 4325–4055 BC. Deciduous oak was frequent during the Bronze age along the lower slopes and valley bottom between 1100–1300 m up to Mount Anitsa (1705 m a.s.l.).

2.2. Lithic Resources

In general, ophiolithic rocks predominate in the surveyed area (Mounts Smolikas, Flampouro, Vasilitsa). The ophiolites consist mainly of peridotites and serpentinites accompanied by red cherts. In contrast, the southern and western parts of the Northern Pindus National Park (Tymphi, Trapezitsa and Mitsikeli massifs) and some areas in the north-east (Orliakas) are dominated by limestone [37,38]. One of the most important knappable lithic resources is represented by dark grey-cream yellow siliceous limestone and chert in the form of rounded nodules occurring in seams in the limestone formation around Samarina. This raw material has been intensively exploited mainly by Middle Palaeolithic hunters [20], more rarely in later periods.

The first chert outcrops were discovered during our survey along the Delichmét ridge (Figure 1), between La Greklu saddle (1740 m a.s.l.) and Mount Kirkuri (1850 m a.s.l.) in 1999. In 2011, more chert outcrops were recorded along the eastern part of the same watershed. Smaller findspots were also recorded along the upper part of the left, north-north-western slope of the upper Samariniòtikos River Valley, south of Delichmét. Other occurrences were discovered in the south-western slopes of Mount Kirkuri, all along smaller riverbeds, and in the deposits of two left tributaries of the Samariniòtikos River. More chert deposits and large nodules were discontinuously recorded all along the Holy Cross Church ridge (1662 m a.s.l.) and near the top of Mount Anitsa (1705 m a.s.l.). Two chert samples, collected from the outcrops located close to Delichmét have been analysed in thin section and SEM-EDS. They showed that they consist of a non-calcareous chert of medium-quality from the point of view of its knapping properties [21].

However, despite its abundance, this raw material has been rarely employed for knapping artefacts during the Holocene. In contrast, better quality, more vitreous cherts were preferred, whose provenance remains to be identified in most cases. The data achieved during our surveys show that the final Pleistocene and Holocene assemblages of the Samarina highlands, were obtained almost exclusively from non-local, good-quality cherts and flints whose chronological attribution is based almost exclusively on the techno-typological characteristics of the lithic artefacts. In some cases, the presence of cortical parts shows that they were collected as pebbles and nodules, perhaps from secondary deposits.

At present, we have just a few data regarding the presence of raw material chert outcrops in Western Macedonia and their prehistoric exploitation. However, according to data available from Dispilio, an important Late Neolithic–Bronze Age lake-dwelling settlement excavated along the southern shore of Lake Orestiadas (Kastoria) [39,40], radiolarian and other varieties of chert were widely utilised in the Neolithic, during which were exploited local and regional raw materials available within a radius of ca. 50–60 km. From Dispilio, O. Kakavakis reports the presence of fine-textured radiolarian chert, otherwise known as chocolate flint, whose outcrops occur in the Pindus Range [41].

Moreover, “black chert” is known from the Vigla limestone outcropping in the Vikos Gorge, near the village of Papingo in the Vikos-Aoos Geopark of the Tymphi Massif (Epirus), in the north-western part of the Pindus Range [42]. Artefacts made from this raw material have been visually identified among the knapped stones recovered mainly from the Late Neolithic–Bronze Age sites discovered around Samarina during our surveys. In particular, the raw material employed for making several artefacts collected from the Mounts Anitsa, Vasilitsa, Bogdani and other Late Neolithic-Bronze Age sites (Figures 5–7), is visually identical to the sample named Vikos07 (see [43], Figure 10). It consists of a high-quality, translucent "black chert" from the Vigla limestone, employed by the hunter-gatherers who occupied the Boïla Rock-shelter in Epirus, which was in use at the very end of the Pleistocene and the beginning of the Holocene [43]. Dark cherty flint has been recorded in the sediments of the Voidomatis River in Epirus and was intensively used by Late Upper Palaeolithic hunters on the slopes of Mount Tymphi [44,45].

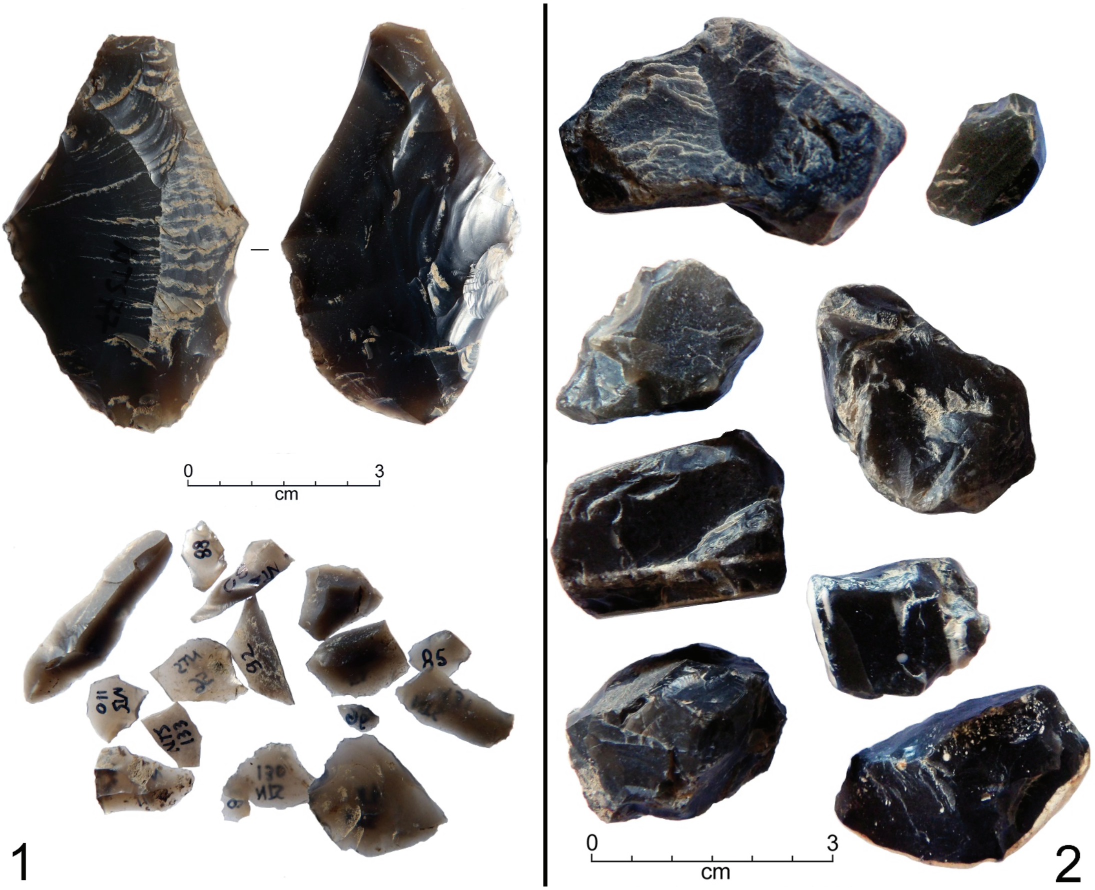

Figure 5. Mount Anitsa: bifacial rough-out (NTS-77) and debitage microflakelets of the same variety of non-local Vikos "black chert" (n. 1). The NTS lithic manufacturing spot has been radiocarbon dated to 5356 ± 26 BP (GrM-28122: NTS-25) by one *Fraxinus* charcoal fragment. Geological samples of Vikos "black chert" from the Vikos Gorge outcrops in Epirus (n. 2) (photographs by E. Starnini, 2022).

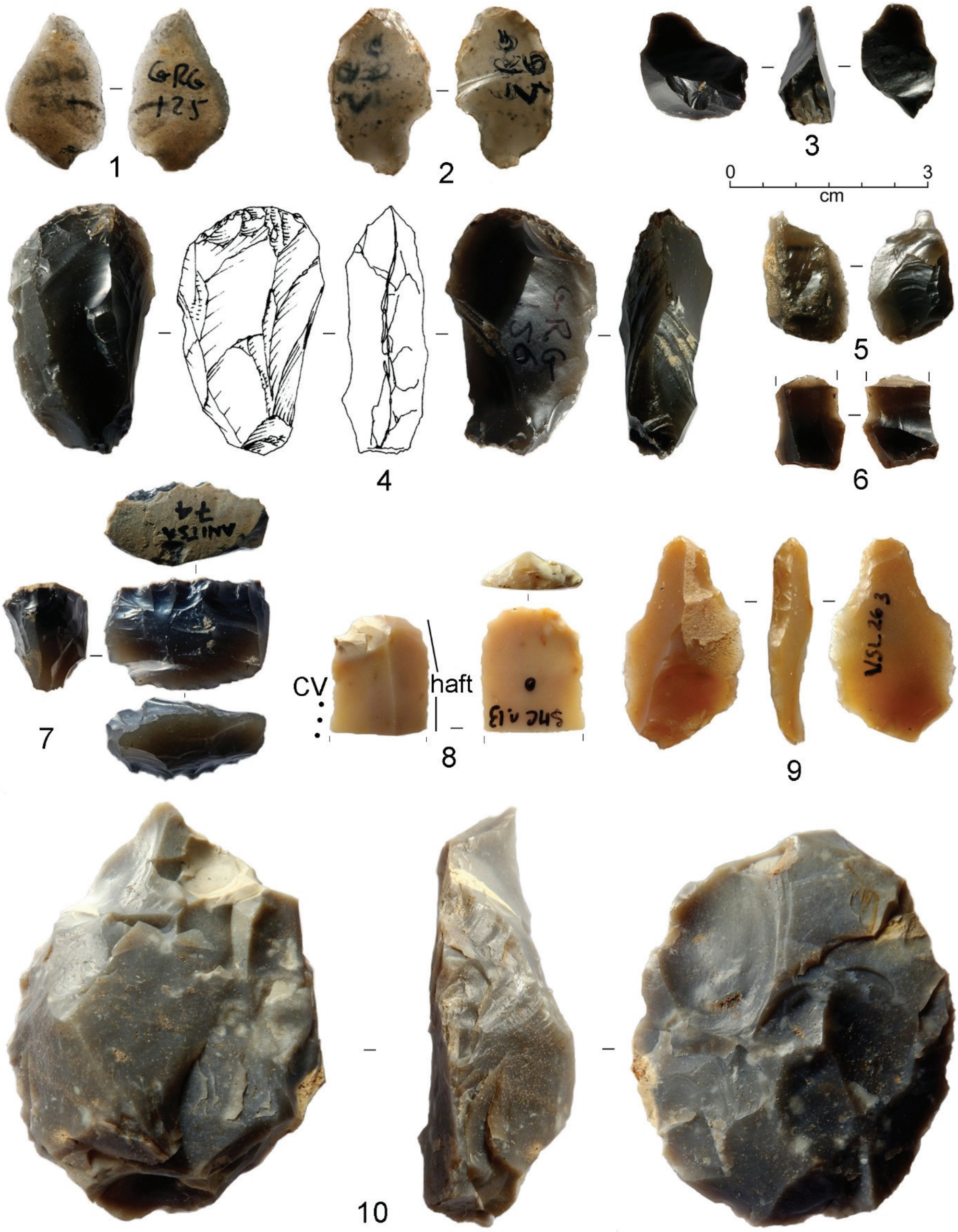

Figure 6. Non-local artefacts made from Vikos "black chert" from different sites: GRG-125 (n. 1), GRG-46 (n. 2), GRG-121 (n. 3), GRG-156 (n. 4), GRG-39 (n. 5), GRG-144 (n. 6), Anitsa-74 (n. 7: microbladelet core), and VSL-305 (n. 10: microflakelet core or preform of a bifacial point), and blonde non-local chert SMC-13 (n. 8: hafted, long-end scraper used for cutting vegetation (CV), VSL-263 (n. 9: straight perforator heavily worn and broken) (photographs by E. Starnini).

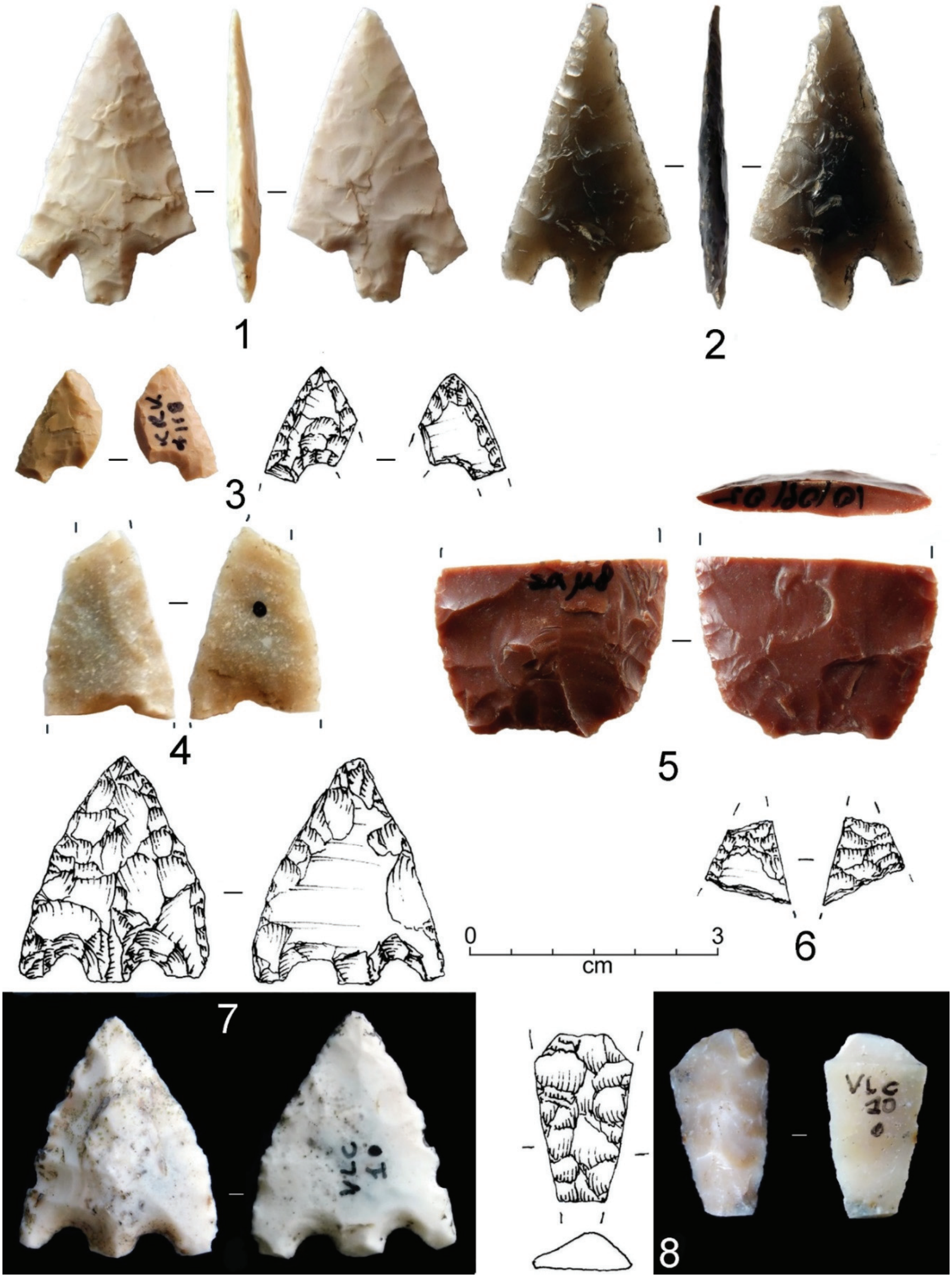

Figure 7. Triangular, barbed-and-tanged arrowheads with flat invasive or covering bifacial retouch from Kirkuri (KRK-28, n. 1), Sam-8 (n. 2), Mirminda Pass (VLC-1, n. 7); hollow-based arrowhead from Kirkuri (KRK-118, n. 3); fragments of arrowheads from Kirkuri (KRK-14, n. 4; KRK-92, n. 6) and the Mirminda Pass (VLC-10, n. 8); proximal fragment of dagger obtained by flat, covering bifacial retouch from Sam-8 (n. 5) (photographs by E. Starnini; drawings by P. Biagi; inking by G. Almerigogna).

The presence of chert types of different colours has been ascertained from other localities of central and western Epirus (see [43]: Figure 7). Finally, red radiolarite suitable for knapping occurs in the Avdella Mélange in the northern Pindus Range, ca. 14 km south-east of Samarina [46]. However, red radiolarite boulders have been observed in the diamicton along the slopes of Mount Vasilitsa, together with serpentinite blocks. Therefore, this raw material can be considered of local occurrence. Several red radiolarite artefacts were also recovered during the surveys, although, according to their techno-typological features, most of them can be attributed to the Middle Palaeolithic.

Imports of far-distant raw materials are represented by two obsidian flakes. The first Carpathian 1 specimen comes from Mount Vasilitsa Site 1 (VSL 1), along the northern upper slopes of Mount Baltoumis (40°04′12.7″ N, 21°04′20.5″ E: VSL-139, 1771 m a.s.l.), the second, a Melos piece, from the upper ridge of Mount Bogdani (GRG-19: 40°07′20.21″ N, 20°58′21.15″ E, 1960 m a.s.l.) (Figure 8). They were characterised by non-destructive XRF and LA-ICP-MS at the CNRS-IRAMAT Laboratory, Orléans (F) by B. Gratuze.

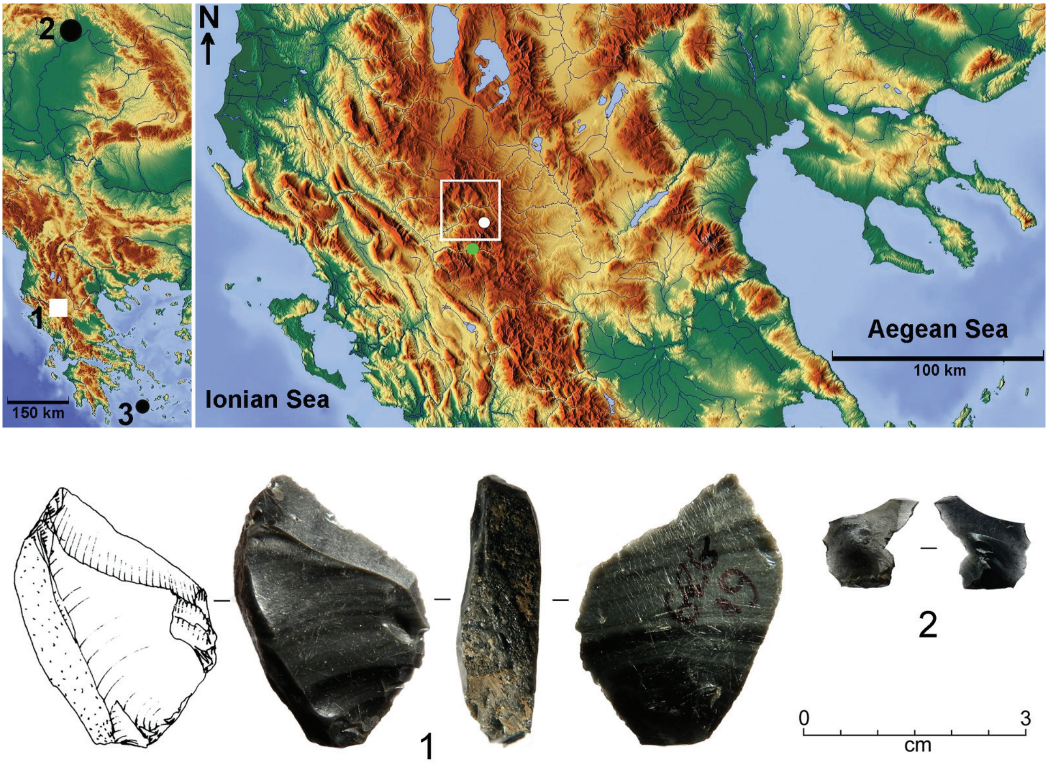

Figure 8. Unretouched obsidian flakelets from Melos Demenegaki (GRG-19, n. 1) and Carpathian 1b, Cejkov (VSL-139, n. 2) (**bottom**), and locations of the two obsidian outcrops (Carpathian 1, n. 2; Melos, n. 3). The green dot marks the location of the Vikos Gorge mentioned in the text; the white dot shows the location of Samarina (**top**) (photographs by E. Starnini; drawings by P. Biagi; inking by G. Almerigogna).

Finally, a few polished greenstone implements were recovered during our surveys. Due to their shape and size, they can be interpreted as woodworking tools, unsuitable for felling trees (Figure 9). They are represented by two chisels whose typology suggests a Neolithic age. The detailed identification of the rocks employed in their manufacture needs a petrographic analysis, although geological formations bearing potential raw materials suited for the production of polished stone tools are present in the region.

Figure 9. Polished greenstone chisels from Mount Vasilitsa (VSLA-61: n. 1) and Sam-8 (n. 2) (photographs by E. Starnini).

3. Research Aims, Methods and Strategy

Mountain archaeology [47–49] is still an under-practiced field, partly because it presents challenging environmental and logistical conditions and climate variability, which make highland zones suitable for systematic archaeological work for only a few months a year. It is a time-consuming and harsh fieldwork; high-altitude weather conditions can change dramatically within a few minutes [50]. In many cases, archaeologists have to move up- and downslope and walk for hours to operate in areas which are often difficult or impossible to access with vehicles. There is little doubt, however, that the study of human adaptation to highland environments is an important and promising avenue for archaeological research [51]. With all of this in mind, our project started with the systematic exploration of the highland zones around the small town of Samarina.

The Samarina archaeological surveys were conducted on foot by 3–5 people, walking along watersheds, slopes and river valleys, 2–3 weeks per year. The first areas to be explored were those around small lakes and watering holes close to passes and saddles which, following the experience gathered during fifty years of fieldwork in the Italian Alps [52,53], are the most suitable landscapes for the preservation of traces of past human activity or seasonal occupations.

As shown by the Alpine case studies cited above, relict glacial landscapes represent an ideal environment for the summer settling of Early Holocene hunter-gatherers who moved from valley bottom base camps, up to alpine grasslands for purposes which are still widely debated, one of which is hunting in the open landscape located just above the upper tree-line [54,55].

The high-altitude Samarina stations were systematically revisited throughout a period of more than twenty years. Following our experience, mountain surveys need to be repeated many times with different weather and light conditions to retrieve fully reliable and detailed results. Moreover, the sites can yield either many or no artefacts in an unpredictable pattern [56]. This depends on many variables among which are the quantity of seasonal rain/snow, the intensity of trampling by grazing flocks, depth of buried materials, and soil cover characteristics and thickness. Therefore, it is necessary to re-visit the same localities several times to confirm the presence/absence of archaeological sites/finds, and to collect diagnostic artefacts to establish their chronology. During our surveys, every single artefact, or findspot, has been located according to its coordinates taken with a Garmin-GPS to build distribution maps with the help of Google Earth images, and databases "*for gaining information necessary to the analytic determination of what cultural items are, spatial and temporally clustered one with another and with other artifactual material*" ([57], p. 430).

One of the first targeted areas was a small glacial basin located at 1357 m a.s.l. just above the Vlach village of Smixi (Smiksi). The lake is partly delimited by the lowermost fringes of the impressive moraines that slope down from the northern flanks of Mount Vasilitsa (Figure 10 top). The first visit to Smixi Lake in Autumn 1999 was highly productive and a typical Middle Palaeolithic chert artefact was collected from the surface close to the southern shore of the shallow basin (Figure 10 bottom). This encouraged us to continue the research that year leading to the unexpected discovery of impressive good-quality chert outcrops along the watershed between the saddle of La Greklu, in the west, and Kirkuri, in the east [20]. Closer observations made in the following years showed that the chert seam extends farther east and is marked by the presence of chert knapping areas and extractive traces all along its development, most of which have been attributed to Middle Palaeolithic exploitation [21].

The surveys were extended in subsequent years to an area of ca. 80 square km from the saddle that separates Western Macedonia from Epirus, in the north-west (La Greklu: 1740 m a.s.l.), to the village of Filippei (ca. 1400 m a.s.l.), in the south-east. This territory is delimited by the ridges of Mounts Bogdani, Gurguliu and Vasilitsa, in the west, and the northern watershed that extends from La Greklu, across Delichmét, Kirkuri, Mount Anitsa, the Mirminda Pass and farther south. During the first few years, test trenches (2 × 3 m wide) were opened at five sites, which were considered to be particularly important due to the presence of thin charcoal horizons along the profiles revealed by road constructions. The scope of the excavation trenches was to check for the presence of archaeological horizons in situ and establish their chronology by radiocarbon dating. A few valley-bottom sites were briefly visited, among which is Agios Athanasios, along the right terrace of the Venetikos River Valley (ca. 1120 m a.s.l.) (Figure 11). This locality yielded evidence of a late Bronze Age village from which an oak charcoal lens was radiocarbon dated to 3095 ± 35 BP (GrA-61779: AA-1).

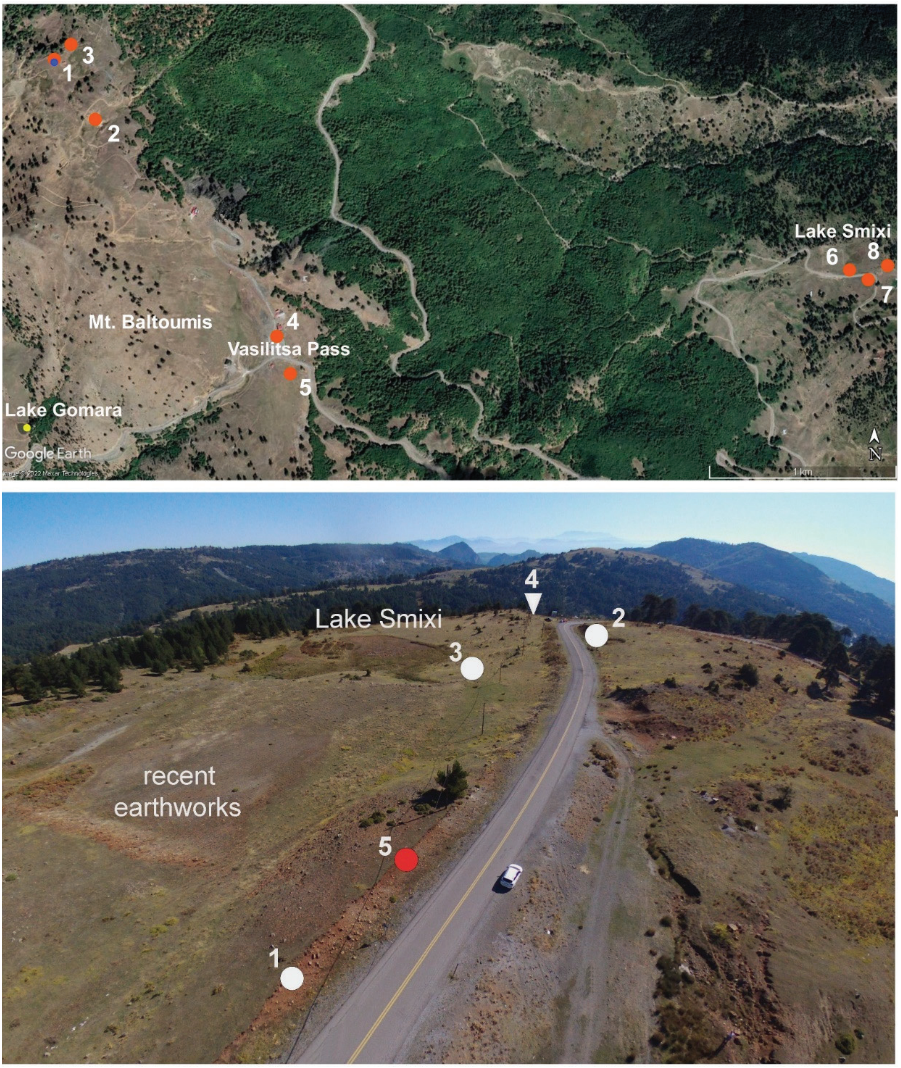

Figure 10. Distribution map of the prehistoric sites discovered in the Vasilitsa Pass (VSL 4 and VSL 5: nn. 4 and 5), along the northern slope of Mount Baltoumis (VSL 1, VSL 2 and VSLA: nn. 1–3), and Lake Smixi (nn. 6–8) (**top**). Lake Smixi location of the finds: refitting Levallois flakes (n. 1), Mousterian discoid cores and pre-core (n. 2), Upper Palaeolithic retouched point (n. 4), early Bronze Age small pit radiocarbon-dated to 3645 ± 35 BP (GrA-69503: SMX-1) from one pine charcoal fragment (n. 5) (**bottom**). The white dots and the triangle refer to the Palaeolithic artefacts, the red dot to the Bronze Age pit (drawing by P. Biagi).

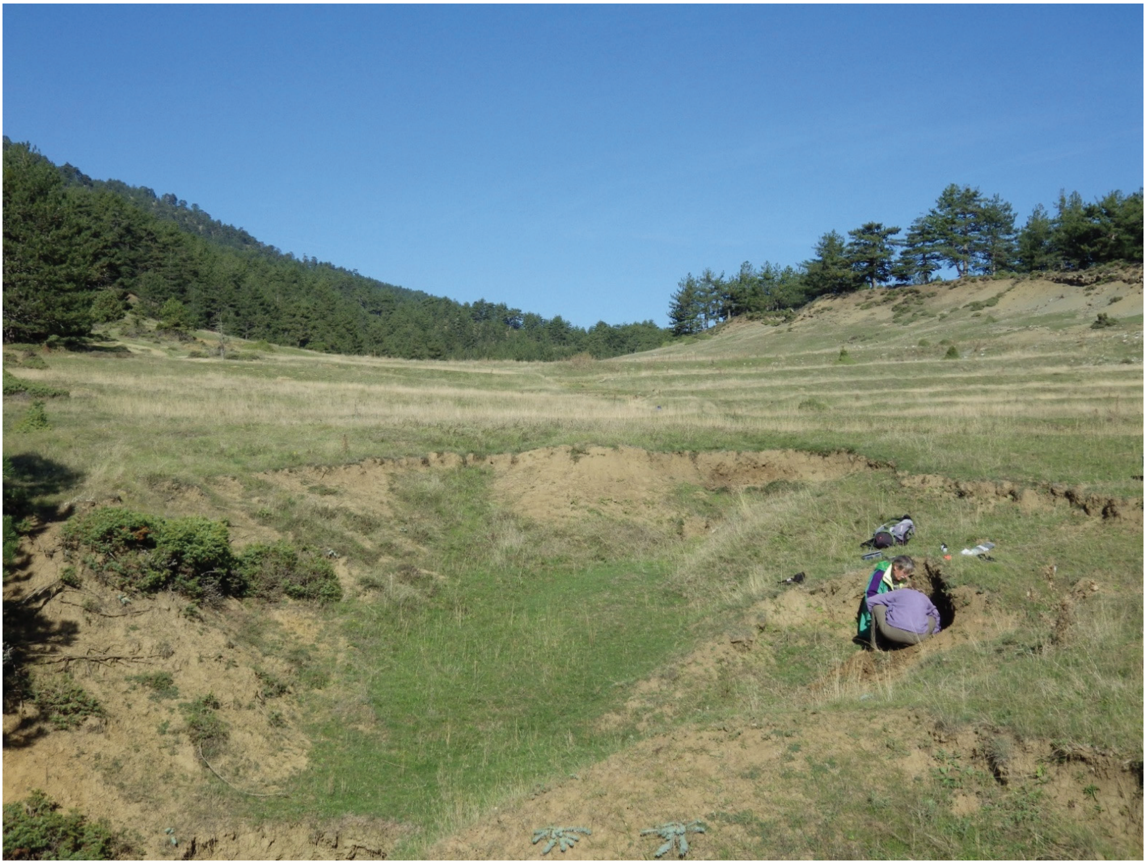

Figure 11. Agios Athanasios: Sampling charcoal from a profile exposed by erosional processes within the Bronze Age site (AA) located on a terrace of the Venetikos River Valley, which yielded the result of 3070 ± 40 BP (GrA-61779: AA-1) (photograph by P. Biagi, 2014).

Unexpectedly, the surveys yielded mostly traces of different types of Middle Palaeolithic activities and settlements up to an altitude of ca. 1900 m a.s.l. along the upper ridges of Mounts Gurguliu and Bogdani (Figure 12). However, material culture remains, and radiocarbon results confirm that the earliest Holocene exploitation of the Samarina highlands took place during the Preboreal Mesolithic [23], continuing with several interruptions up to the present. The Holocene human settlement of this landscape intensified mainly between the Late Neolithic and the Late Bronze Age, most probably due to the growing importance of pastoral activities. This observation is supported by several proxies, among which are the recovery of characteristic archaeological finds, and a number of radiocarbon dates, which help us to better understand why the exploitation of this territory intensified again well after the end of the last glaciation (Table 1).

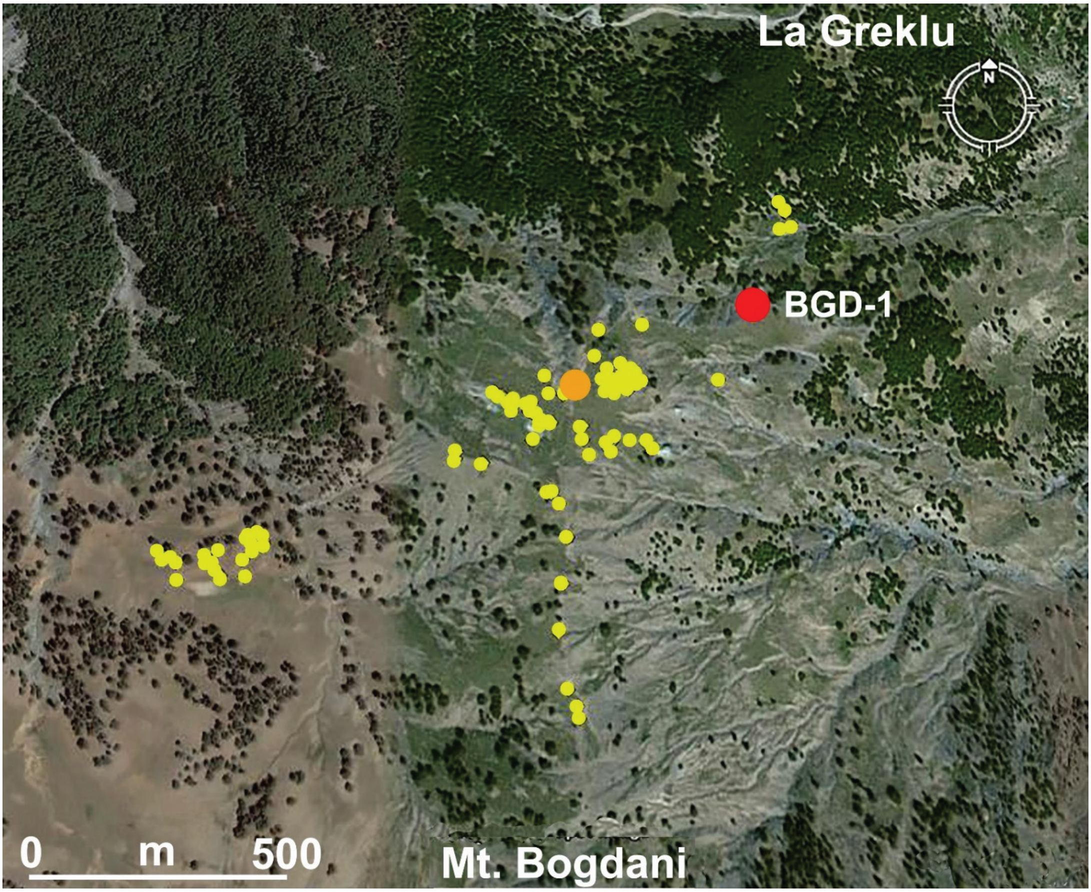

Figure 12. Distribution map of all the Palaeolithic and Holocene knapped stone artefacts collected in 2008 along the northern slopes and ridge of Mount Bogdani (yellow dots). The orange dot marks the location of the Melos obsidian flakelet (GRG-19), the red dot the Late Neolithic fireplace BGD-1, which was radiocarbon-dated to 5972 ± 27 BP (DEM-2585) (drawing by C. Franco and P. Biagi).

4. Glacial History of Greece—Overview

The mountains of Greece have been glaciated several times during the Quaternary, with well-preserved evidence from multiple glacial cycles. Glaciers were extensive in some mountain areas forming ice caps and ice fields with valley and cirque glaciers in others [58–60].

The most extensive glaciers formed on the highest mountains, from Smolikas and Tymphi in the northern Pindus [61,62] to the Peloponnese in the south and on Mount Olympus in the north-east [63].

These glaciers had a major influence on rivers' runoff and sediment supply to rivers [64] and supplied water to areas far downstream, sometimes beyond glaciated catchments through karstic drainages, such as at Lake Ioannina in Epirus [65,66].

Recent research has suggested that glaciers may have been even larger than previously thought, and substantial glaciers also formed on the lower mountains of northern Greece such as Mavrovouni [67] and also Vasilitsa [68].

These two mountains are similar in that they are formed in ophiolite rocks and supported valley and cirque glaciers on their northern slopes. On Vasilitsa, three cirque basins are etched into the north-east-facing slopes and there is evidence of multiple phases of glaciation in this area.

During the last glacial cycle, glaciers existed in the Greek mountains at a time when anatomically modern humans (AMH) were present in Greece [69,70]. The presence of stone tools from Middle Palaeolithic humans on moraines in Greece, such as at Vasilitsa, is important not only for understanding human occupation of the mountains, but also for providing additional independent age control on the glacial record.

For example, the oldest and most extensive glaciers in Greece are Middle Pleistocene in age and pre-date the last glacial cycle [60,71]. The presence of Levallois Mousterian artefacts on moraines, associated with Neanderthals pre-dating the AMHs who occupied the Pindus Mountains in the last glacial cycle [21,22,72], is especially noteworthy. These artefacts confirm that the oldest moraine surfaces are much older than the Last Glacial Maximum.

The fact that such artefacts are frequently found on moraines could suggest that these landscapes were attractive as they provided open and elevated vantage points for humans. The presence of moraine-dammed glacial lakes nearby, as is the case in Vasilitsa, would have offered a reliable water supply.

5. Results: The Natural and Human Landscape

This section discusses the most important Holocene archaeological sites discovered in the area, starting from Mount Vasilitsa (VSL and VSLA sites), moving north to the northern Mount Bogdani watershed (GRG) and the La Greklu-Delichmét ridge (a few Sam sites), Kirkuri (KRK), Anitsa (Anitsa and NTS sites), the Mirminda Pass and the watershed up to Mount Anitsa (VLC) and, finally, the Historical Camp (HC), just to the north-north-west of Samarina (Figure 1).

5.1. Evidence of Glaciers on Mount Vasilitsa

The glacial deposits on Mount Vasilitsa (2248 m a.s.l.) extend down to an elevation of ca. 1320 m a.s.l., just above the village of Smixi on the north-eastern slopes [73].

Good exposures are present in several places where sections are cut by roads and tracks, revealing a matrix-supported diamicton, and large perched rocks occur in many areas on a series of undulating moraine ridges.

The moraines resemble the glacial deposits noted elsewhere in ophiolite terrains such as those on Mount Smolikas [59,60] and Mavrovouni [67]. The lowest set of moraines on Vasilitsa are named the Smixi Member (Figure 13).

Further up-valley, moraine ridges impound a small lake on the north-eastern slopes at ca. 40°03′16″ N, 21°05′23″ E, 1750 m a.s.l. Two more ridges are present to the south-west of the lake. These sediments and landforms are named the North Vasilitsa Member and are interpreted as end and recessional moraine ridges formed in front of a former cirque glacier.

Moraine ridges also exist further south and impound a lake at ca. 40°02′52″ N, 21°05′40″ E, 1790 m a.s.l. (Figure 14). Here, at least three moraine ridge crests can be defined. These landforms are identified as the Central Vasilitsa Member. Hummocky, boulder-covered moraines are present up-valley of these ridges and probably formed during glacier retreat. A boulder ridge is also evident in the shallow valley to the southeast at ca. 1730 m a.s.l. and appears to represent the terminus of an off-shoot glacier which had the same source as the glacier which produced the lake moraines described above.

In the highest cirques on Vasilitsa, arcuate boulder moraines dam another lake (probably ephemeral) at ca. 2000 m a.s.l. and this youngest moraine unit is identified as the Vasilitsa Summit Member. These moraine ridges represent a discrete glacial advance during a later glacial phase. East of the summit of Vasilitsa, moraine ridges also exist in a small hollow at ca. 40°02′20″ N, 21°05′50″ E, 1730 m a.s.l. These deposits represent the East Vasilitsa Member. As this is the sole unit, these deposits also represent the East Vasilitsa Formation. Two main crests can be identified. No moraines were located down-valley, although lower glacial deposits may have been eroded [68].

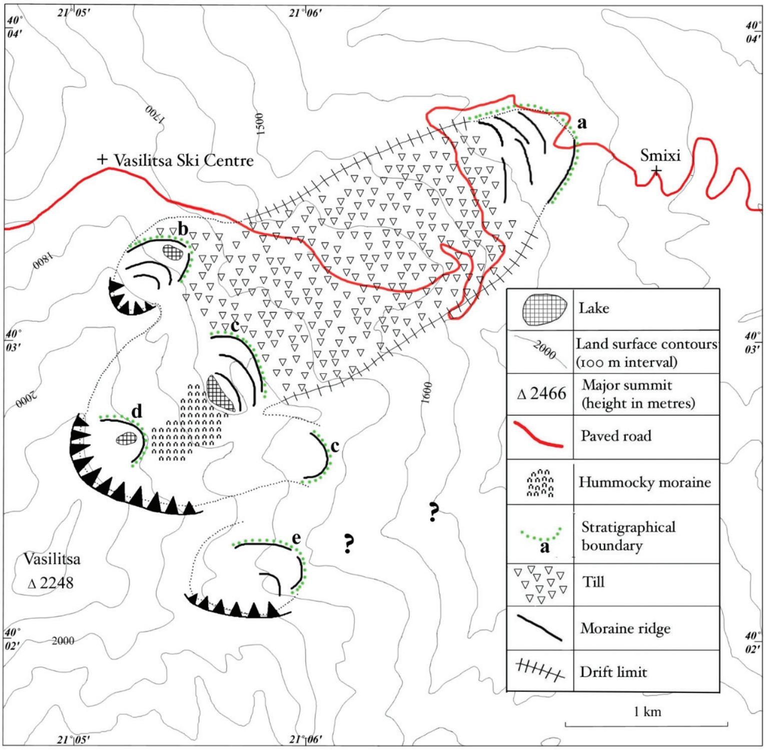

Figure 13. Geomorphological map of the Mount Vasilitsa area. The stratigraphical units marked (**a**–**d**) represent the Vasilitsa Formation: (**a**) Smixi Member, (**b**) North Vasilitsa Member, (**c**) Central Vasilitsa Member, (**d**) Vasilitsa Summit Member. The stratigraphic unit marked (**e**) represents the East Vasilitsa Member, the sole unit of the East Vasilitsa Formation (drawing by P. Hughes).

Figure 14. A section through the Smixi Member moraines at ca. 40°03′10″ N, 21°05′50″ E, 1690 m a.s.l. Note the large boulders on the surface of the moraine, which are a common feature in this area (**left**). A moraine impounding a lake to the east of Mount Vasilitsa at ca. 40°02′52″ N, 21°05′40″ E, 1790 m a.s.l. (**right**) (photographs by P. Hughes, May 2003).

The stratigraphy of the glacial sequence on Vasilitsa is summarised in Table 2. The lowest and most extensive moraines are Middle Pleistocene in age whilst only the highest cirque moraines were formed by small glaciers during the Late Pleistocene (Last Glacial Cycle). All of the chert artefacts reported in this paper have been found on the Middle Pleistocene moraines.

Table 2. Chronostratigraphy and morpho-lithostratigraphy of the moraine sequence in the north-eastern valley of Mount Vasilitsa. From Hughes (2004).

Chronostratigraphy/Age	**Morpho-Lithostratigraphy (Moraine Sequence)**		
Tymphian Stage, MIS 5d-2 110,000–11,700	Unit 3	Vasilitsa Summit Member East Vasilitsa Member	VASILITSA & EAST VASILITSA FORMATIONS
Vlasian Stage, MIS 6a 190,000–130,000 years ago	Unit 2	North Vasilitsa Member Central Vasilitsa Member	
Skamnellian Stage, MIS 12 480,000–430,000 years ago	Unit 1	Smixi Member	

The lowest moraines of the Smixi Member formed during the Skamnellian Stage in the Greek glacial chronostratigraphy, which is equivalent to Marine Isotope Stage (MIS) 12, ca. 480–430,000 years ago [59].

The North and Central Vasilitsa Member moraines formed during the Vlasian Stage in the Greek glacial chronostratigraphy, which is equivalent to MIS 6a, ca. 190–130,000 years ago. The Vasilitsa Summit and East Vasilitsa Member cirque moraines belong to the Tymphian Stage in the Greek glacial chronostratigraphy, which is equivalent to MIS 5d-2, ca. 110,000–11,700 years ago.

In neighbouring mountains, the maximum extent of glaciers during this Last Glacial Cycle occurred ca. 30–25,000 years ago [67,74] (Figure 14). However, glaciers were present in the Pindus Mountains throughout the Last Glacial Cycle and oscillated in response to dramatic millennial-scale climate change. Neanderthals and, later, anatomically modern humans occupying the mountain early in the Last Glacial Cycle would have experienced open mountain terrain, late-lying snow and small cirque glaciers.

This open alpine terrain would have been attractive for hunting mountain fauna such as ibex and chamois [75]. For example, there is evidence from rock shelters on nearby Mount Tymphi that AMHs used these sites as bases from which to hunt ibex and chamois in the nearby open uplands [64,76,77]. Whilst the evidence from Mount Tymphi is of later Upper Palaeolithic AMH activity, it is likely that Neanderthals in this region were also hunting these animals on the glaciated landscapes on Vasilitsa and nearby glaciated areas such as Samarina.

It is certainly worth noting that Yravedra and Cobo-Sánchez [78] reported the importance of ibex and chamois in both Neanderthal and Modern human hunting behaviour in south-eastern Europe.

5.2. Vasilitsa Sites (VSL and VSLA)

Five sites in this area yielded artefacts attributable to different prehistoric periods. They were discovered along the northern slopes of Mount Baltoumis (2027 m a.s.l.), a secondary peak separated by Mount Vasilitsa by a wide saddle, and the Vasilitsa Pass itself (Figure 10 top).

Only three of them can be attributed to the Late Neolithic or the Early Bronze Age (VSL 1 and 2 and VSLA), although the assemblages show that the area was visited during different Pleistocene periods mainly by Middle Palaeolithic hunters. The chronology of the Vasilitsa Holocene sites is difficult to define due to the absence of radiocarbon datable material. None of the sites has been excavated and all the artefacts come from surface collections.

Site VSL 1 yielded the most important assemblages. It is located on a terrace delimited by a small pond, (Figure 10 top, n. 1; Figure 15 top). The site is located at 1770 m a.s.l. and extends over a surface of ca. 2000 square metres. It consists of a large patch of bare ground which is subjected to erosion due to summer grazing and human disturbance caused by the presence of ski infrastructure. One *Pinus nigra* charcoal fragment collected from a small fireplace discovered against a rock outcrop in the centre of the site gave a Late Byzantine age (VSL-1, GrA-69566: 995 ± 30 BP).

Figure 15. Panoramic view of the archaeological sites discovered along the northern slopes of Mount Baltoumis: VSL 1 (**top**), and VSL 2 with Mount Anitsa in the background (**bottom**) (photographs by P. Biagi, 2019).

The site yielded several Holocene knapped stone artefacts, most of which are made from non-local, Epirotic chert, and one obsidian microflakelet which has been characterised as coming from the Slovak Carpathian 1 source (Figure 8, n. 2). The colours of the chert artefacts vary from black to blonde, brown, pinkish, light and dark grey. They consist of bladelet cores, technical pieces (crested blades), prismatic bladelets, and long and short-end scrapers (Figure 16, n. 3). Among the other tools are one straight perforator (Figure 6, n. 9), side scrapers, sickle inserts with sickle gloss, and arrowheads with bifacial invasive or covering flat-retouch (Figure 16, nn. 1, 2, 4 and 5; Figure 17, nn. 2 and 3), and other tools with cut or scrape wood, and cut hide use wears (Figure 16, nn. 6 and 7).

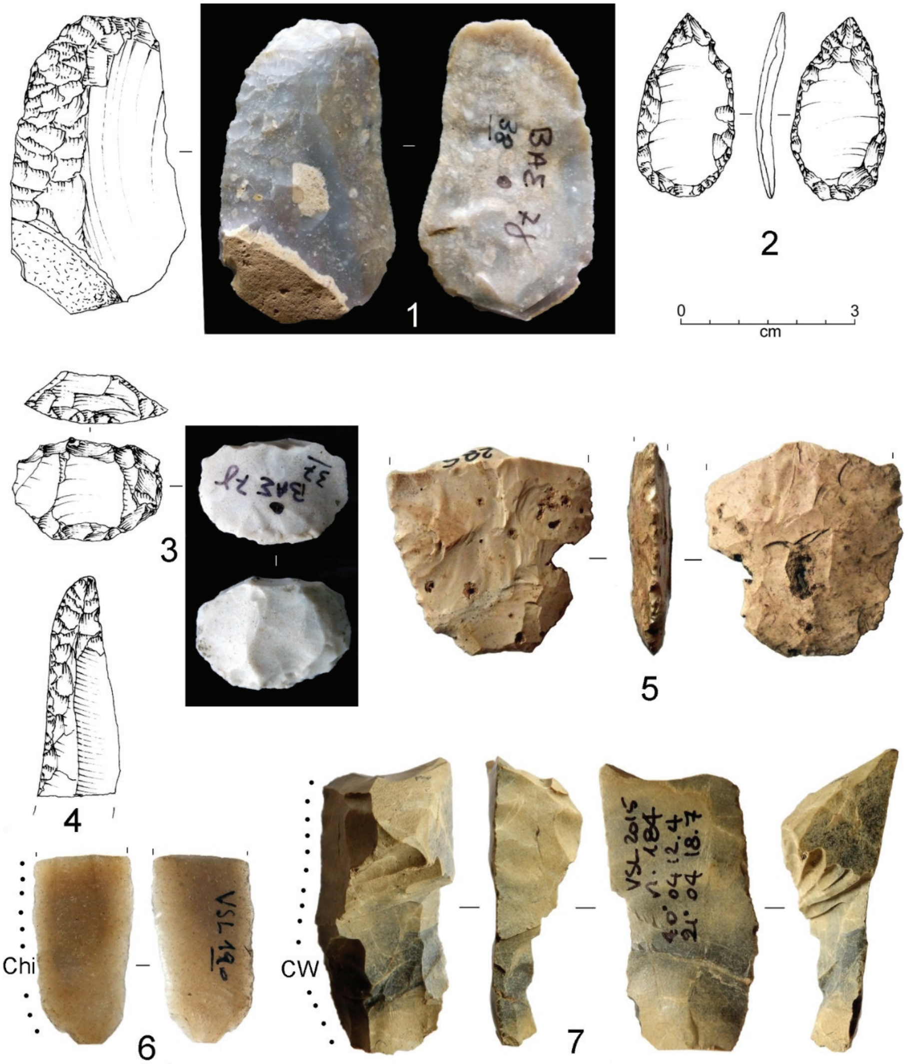

Figure 16. Mount Vasilitsa: Holocene knapped stone artefacts made from non-local chert: Site VSL 1: Flat-retouched side scraper (n. 1), bifacial arrowhead (n. 2), short end scraper (n. 3), flat-retouched bladelet (n. 4), proximal fragment of flat-retouched, bifacial dagger (VSL-285, n. 5) and artefacts with utilisation traces (VSL-190, cut hide (Chi), n. 6; and VSL-184, cut wood (CW), n. 7) (photographs by E. Starnini).

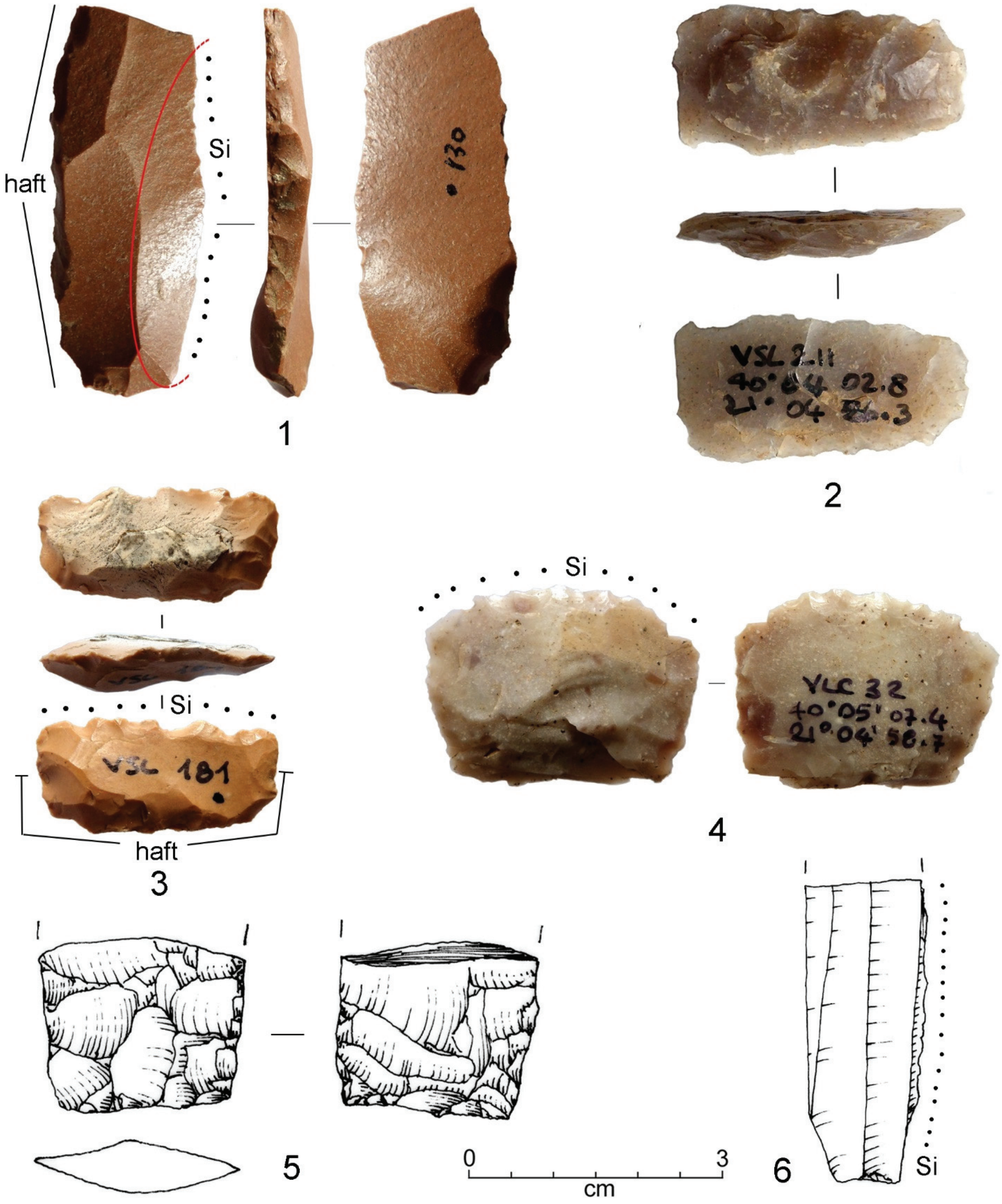

Figure 17. Sickle inserts from various localities: Mount Anitsa: hafted, snapped, abrupt-retouched bladelet with opposed oblique sickle gloss (Si), of reddish-brown radiolarite (Anitsa-130, n. 1); Mount Baltoumis: flat-retouched, bifacial insert of radiolarian chert (VSL-211, n. 2); Mount Baltoumis: hafted, flat-retouched, bifacial sickle insert (Si) with notched, resharpened working edge, hafted and reshaped, made of radiolarian chert (VSL-181, n. 3); Mirminda Pass, flat-retouched, bifacial insert with sickle gloss (Si) (VLC-32, n. 4); fragment of bifacial dagger (Sam-33, n. 5); unretouched bladelet with sickle gloss (Si) (Sam-23, n. 6) (photographs by E. Starnini; drawings by P. Biagi, inking by G. Almerigogna).

The assemblage includes two transverse arrowheads (Figure 18, n. 2), one of which had been hafted and used for cutting hard material (Figure 18, n. 1), one lunate fragment with impact traces (VSL-130). Green radiolarite was also utilised on a small scale, as well as light green soapstone (steatite) for making beads (Figure 19, n. 4). Other tools show wear traces of hafting and scraping wood and hide (Figure 19, nn. 2 and 3).

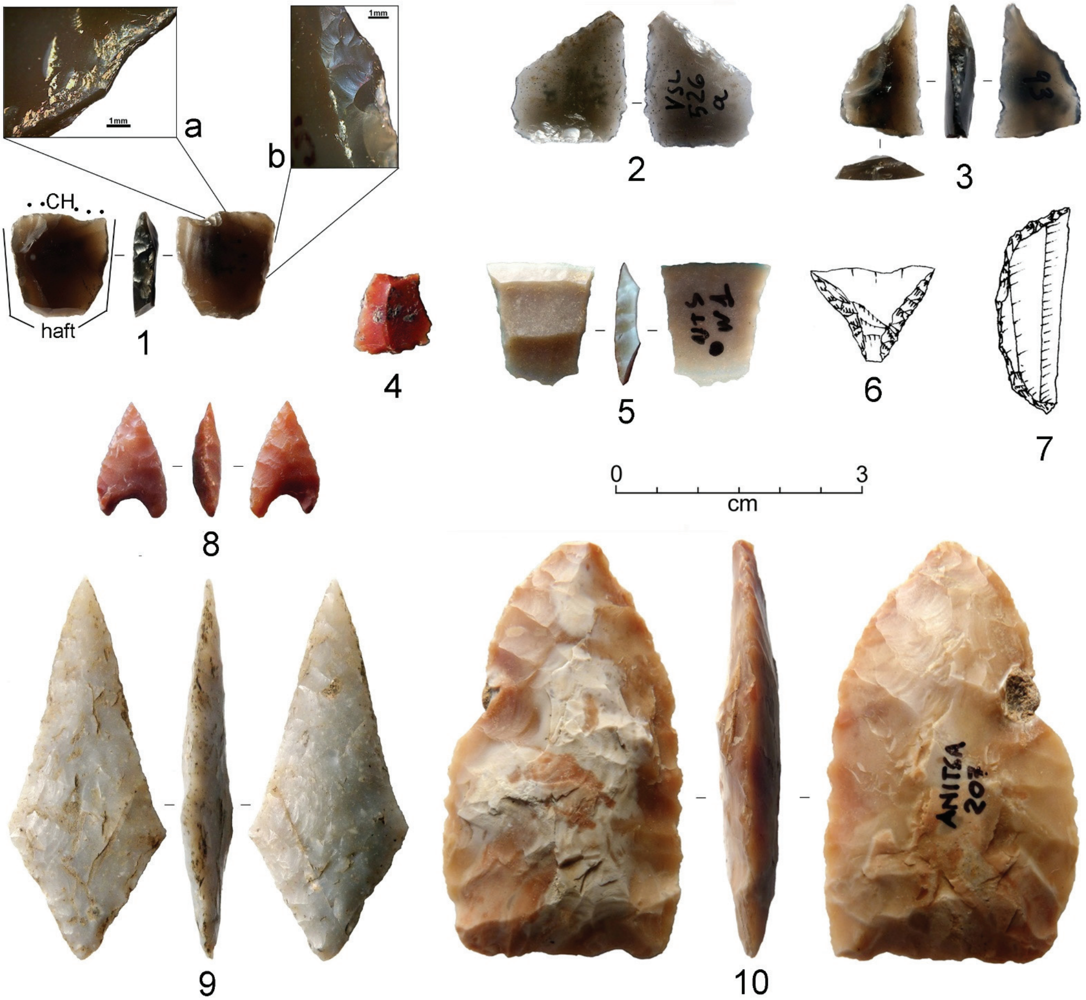

Figure 18. Different types of non-local chert geometric microliths from different sites: VSL-145 (n. 1: Vikos "black chert": wear traces: cut hard (CH), (**a**); hafting, (**b**), VSL-526a (n. 2: Vikos "black chert"), VLC-93 (n. 3: Vikos "black chert"), Sam-23 (n. 4), NTSW-4 (n. 5), Sam-11 (n. 6), and KRK-88 (n. 7); non-local chert arrowheads from Mount Anitsa northern upper slope (Anitsa-26: n. 8; Anitsa-111, n. 9; Anitsa-207, n. 10) (photographs by E. Starnini; drawings by P. Biagi; inking by G. Almerigogna).

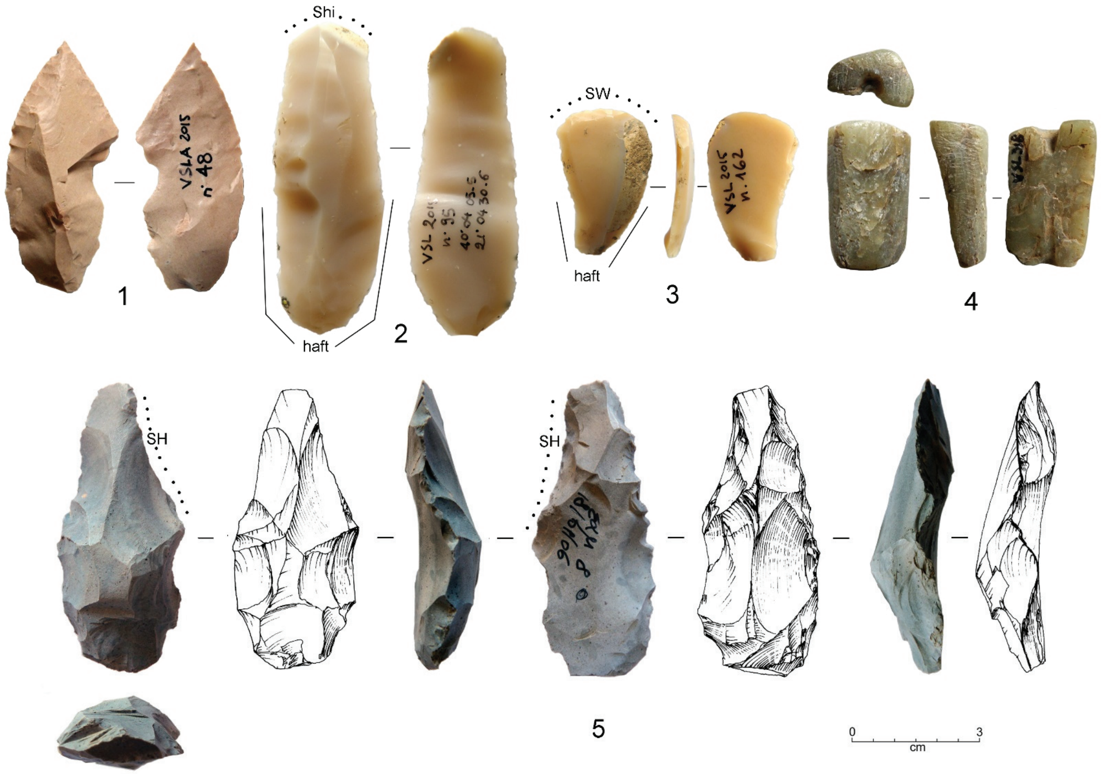

Figure 19. Flat-retouched, unifacial point from Mount Baltoumis Site 3 (VSLA-48, n. 1) made from non-local chert, hafted long-end scraper with scrape hides (Shi) traces of wear made from non-local blonde flint (VSL-95, n. 2), hafted long-end scraper with scrape wood (SW) traces of wear made from non-local blonde flint (VSL-162, n. 3), cylindrical soapstone bead with unfinished, bidirectional perforations, broken, during manufacture, from Mount Baltoumis Site 1 (VSL-318, n. 4), and bifacial artefact with scrape hard (SH) wear traces from Sam-8 (n. 5) (photographs by E. Starnini).

Site VSL 2 is located ca. 350 m south-east of Site 1, close to a small pond which attracts grazing flocks for their daily watering (Figure 10 top, n. 2; Figure 15 bottom). The assemblage was collected from a surface of ca. 1500 square metres. It consists of Middle Palaeolithic and Holocene artefacts exhumed by erosion due to pastoral land use.

Site 3 (VSLA: Figure 10 top, n. 3) is a small findspot discovered along the eastern, eroded and deeply incised slope of Mount Baltoumis, ca. 100 m north-east of Site 1. The assemblage is represented almost exclusively by Middle Palaeolithic artefacts, although a very few Late Neolithic tools were also found. The most representative is one greenstone chisel (Figure 9, n. 1), which finds generic parallels with some types from Servia ([79]: Plate 4.6), and one flat retouched point made from non-local pale red chert (Figure 19, n. 1).

5.3. The Smixi Moraine Ridges

One of the first areas targeted for our survey is a small glacial basin located at 1357 m a.s.l. just above the village of Smixi. A seasonal pond occupies a small depression in the pasture, whose southern side is delimited by the lower moraine of the Smixi Member which slopes down from the eastern flanks of Mount Vasilitsa. In some exceptionally wet years, the shallow basin is also filled with water during the summer season. The lowermost moraine ridge has been cut in several points by the road that connects the village of Smixi with the Vasilitsa Pass. Ground visibility is good, most of the area is deforested, and intensive grazing has eroded the grass cover in many areas.

The surveys conducted around the lake and along the moraine ridges which border it yielded some important traces of prehistoric activity mainly along the sections created by constructions of the new asphalt road (Figure 10 bottom). They consist of three Middle Palaeolithic refitting flakes (Figure 20, nn. 1–4), 2 Mousterian discoidal cores with centripetal detachments (Figure 20, nn. 5 and 6), and one pre-core (Figure 21, n. 1) made of local whitish chert. All these artefacts are important for the definition of the chronology of the lowermost moraines of Mount Vasilitsa (Figure 14). The three conjoining Levallois flakes are very fresh, covered with a reddish patina, which shows that they were embedded within the red clayey soil deposits of the moraine most probably since the Late Pleistocene.

Figure 20. Lake Smixi: Middle Palaeolithic, Levallois refitting flakes (nn. 1–4) and discoid cores made from local chert (nn. 5 and 6) from the Smixi Member moraines south of the small basin (photographs by E. Starnini).

Figure 21. Lake Smixi: Middle Palaeolithic pre-core (n. 1) and probable Upper Palaeolithic point on a blade (n. 2) made from local chert (photographs by E. Starnini).

One unique Palaeolithic tool made of local chert was collected a few metres away from the lake, along the slope down to the village of Smixi. It is a point made from a long blade with a facetted butt and direct, bilateral retouch (Figure 21, n. 2). This tool has no parallel with any Palaeolithic artefact retrieved from the surveyed Samarina region. Its cultural and chronological attributions are difficult to define, although the technology of the laminar blank would suggest an Upper Palaeolithic age.

A small pit discovered along the open profile of the southernmost ridge of the moraine yielded a few ceramic potsherds and pine charcoal fragments (Figure 10 bottom, n. 5) The latter were radiocarbon-dated to 3645 ± 35 BP (GrA-69503: SMX-1). The result shows that the moraines that surround Smixi Lake were briefly visited also around the beginning of the Bronze Age (see Table 1: SMX-1).

5.4. La Greklu-Delichmét Watershed

The watershed that extends between La Greklu and Delichmét is marked by very impressive chert outcrops. Two important sites were partly excavated: Sam-8 (40°08′10.7″ N, 20°00′22.0″ E: 1782 m a.s.l.) (Figure 1, n. 1) and Sam-5 (40°08′14.4″ N, 21°00′53.5″ E: 1778 m a.s.l.) (Figure 1, n. 2).

The 2 × 3 m. trench opened in 2003 in Sam-8, a site whose surface is gently inclined towards north-west ca. 3–4°, yielded evidence of a complex evolution of soil formations. It showed that this part of the watershed was deforested during the Bronze and Iron Ages (see Figure 3; Table 1). This led to the incision and disturbance of the lower-lying Pleistocene deposit, characterised by polygonal patterns [24], which yielded a few Middle Palaeolithic artefacts. Unique lithic tools were collected from the Holocene horizon, which was partly damaged by the construction of a new road.

They include one greenstone chisel (Figure 9, n. 2), which finds some parallels in a few Bronze Age specimens from Servia ([79], Figure 4.6) and one bifacial artefact made from local chert (Figure 19, n. 5). One triangular, barbed-and-tanged, bifacial arrowhead made from Vikos "black chert" (Figure 7, n. 2.) was recovered in situ along the profile of the site which continues for ca. 20 m and is marked by a line of small charcoal pieces and lithic artefacts.

Quite a different situation was recorded from Sam-5. One 2 × 3 m test trench was opened in 2004 close to the limestone outcrop locally called Delichmét, and to the point where a few Late Mesolithic artefacts were collected along both sides of the new road [23]. The excavation yielded only a few historic ceramic potsherds, among which is a double-pierced handle, and a small fireplace, which was radiocarbon-dated to the Byzantine period (DEM-1917/OxA-16222: 1129 ± 26 BP, and DEM-1918/OxA-16223: 1127 ± 25 BP). In a profile cleaned in the Pleistocene deposit below the Historic occupation, evidence of buried Middle Palaeolithic artefacts was observed. The trench did not yield any evidence of Mesolithic occupation.

5.5. Kirkuri (KRK)

Kirkuri is a rounded peak (1855 m a.s.l.) with one wide area of bare ground on its top (Figure 22) caused by overgrazing and the construction of transmission antennas. The survey of this peak yielded various types of Palaeolithic and Holocene knapped stone artefacts [22].

Figure 22. The top of Mount Kirkuri from the south, from which come lithic artefacts of different cultural periods and Bronze Age arrowheads (photograph by E. Starnini, 2013).

Among the latter, the area yielded four fragmented arrowheads made from non-local chert, by bifacial, covering, flat retouch. They consist of one, almost complete, barbed-and-tanged, triangular type (Figure 7, n. 1), two have a concave base (Figure 7, n. 3 and 4), and one is too small a fragment to have an idea of its original shape (Figure 7, n. 6). From a techno-typological point of view, all the Kirkuri arrowheads can be attributed to the Bronze Age.

5.6. Mount Anitsa (Anitsa and NTS)

Mount Anitsa has played an important role in the prehistory and recent history of the Samarina region, for reasons that can be partly explained by the events that took place during WWII [80]. The reasons why the conquest of Mount Anitsa was so important for the end of the war are to be found in the strategic location and shape of the mountain, which gives access to the Western Macedonian Plain, in the east, and offers good visibility from which all the valleys around can be controlled. Given these features, it is not surprising that a Middle/Late Bronze Age site (Sam-29) was established on its top (1705 m a.s.l.). The 2 × 3 m excavation trench opened in 2007 did not yield any evidence of archaeological features. A few characteristic Bronze Age fine-ware shards were recovered [81], and a few *Quercus* sp. charcoal pieces, one of which was radiocarbon-dated to 3095 ± 35 BP (GrA-51015).

Important discoveries were also made on the upper slope of the same mountain, facing south. Dozens of shatters and hyper-microflakelets knapped from Vikos “black chert” were found scattered over a surface of ca. 5 square metres associated with a partly retouched large flake of the same raw material, most probably the rough-out of an arrowhead (Figure 5, n. 1). These finds suggest the presence of an in situ chert manufacturing area. A few tiny pieces of *Fraxinus* sp. charcoal recovered from 25 cm of depth in association with Vikos “black chert” artefacts, yielded an age of 5356 ± 26 BP (GrM-28122: NTS-25). The radiocarbon date shows that the workshop was active during the Late Neolithic. The presence of one microlithic isosceles trapeze obtained by two parallel, abrupt truncations from a bladelet with trapezoidal cross-section supports this conclusion (Figure 18, n. 5).

All of the higher north-western flanks of Mount Anitsa sloping down to an unnamed narrow valley, which separates Anitsa from the Skourdza peak (1799 m a.s.l.), yielded many Middle Palaeolithic and Late Holocene artefacts scattered along the slope. Among the latter are different types of non-local chert bifacial arrowheads (Figure 18, nn. 8–10), one end scraper, a few bladelets with parallel sides, among which is a sickle insert with hafting traces on a snapped, abrupt-retouched bladelet (Figure 17, n. 1), and a few unretouched artefacts knapped from Vikos “black chert” (Figure 6, n. 7). Along the same slope, the site called Sam-23 is located at ca. 1666 m a.s.l., close to a spring. The site has been attributed to the Chalcolithic mainly due to a radiocarbon date obtained from a juniper charcoal fragment (GrA-59661: 4005 ± 35 BP). The 2 × 3 m trench opened in 2004 did not yield any archaeological features. Among the collected lithics are two significant artefacts made from non-local chert. They consist of a sickle bladelet on a snapped, unretouched, blank with a trapezoidal cross-section (Figure 17, n. 6), and one atypical, asymmetric geometric armature obtained by two opposed marginal truncations (Figure 18, n. 4).

5.7. The Mirminda Pass (VLC)

Another watershed, which has yielded many artefacts of different ages, extends between the Mirminda Pass (1556 m a.s.l.), in the south, and Mount Anitsa, in the north-north-east (Figure 1). The Mirminda Pass must be crossed to reach the Samarina basin moving from the Grevena lowland and the Aliakmon River. Due to its location, the pass probably played a very important role in prehistory, because it separates two important rivers, the first of which flows into the Ionian Sea, to the west, and the second into the Aegean, to the east. Just north of the Mirminda Pass, a few important tools were recovered: one triangular, tanged-and-barbed, flat-retouched, bifacial arrowhead made from patinated dark bluish-grey chert (Figure 7, n. 7), and the tang of another arrowhead made by flat unifacial retouch (Figure 7, n. 8). Other finds were collected along the watershed, though most of them come from a sheltered area close to Mount Anitsa. Among them is one insert with sickle gloss (Figure 17, n. 4), and a few Vikos "black chert" artefacts, among which is one truncation (Figure 18, n. 3). The assemblage includes also two quartzarenite pebbles, which were most probably employed as hammerstones or fabricators.

5.8. The Historical Camp (HC)

The so-called Historical Camp (HC) is located just north-north-west of Samarina at ca. 1530–1550 m a.s.l., east of a Middle Pleistocene moraine ridge that slopes down from Mount Gurguliu. The area, from which come some 300 artefacts, many of which have been attributed to the Middle Palaeolithic, though also to different Holocene periods, looks almost flat, although it is incised by several gullies (Figure 23 top). A small pond marks the northernmost edge of the HC (Figure 23 bottom).

Figure 23. Historical Camp (HC): views from the lower slopes on Mount Gurguliu. Note Mount Kirkuri in the background and the location of the HC site excavation trench along the edge of the erosion gully, in the centre of the top photograph. Mount Kirkuri is visible in the background (photographs by P. Biagi, 2006).

A 2 × 3 m test trench was opened close to the deepest gully (40°06′41.3″ N, 21°00′33.9″ E). It yielded structures which were attributed to the historical campsite but it was devoid of material culture remains. The structures consisted of two diverging postholes and two shallow pits filled with juniper carbonised branches, one of which was radiocarbon-dated to the Byzantine period (DEM-2586: 1414 ± 18 BP) (Figure 24).

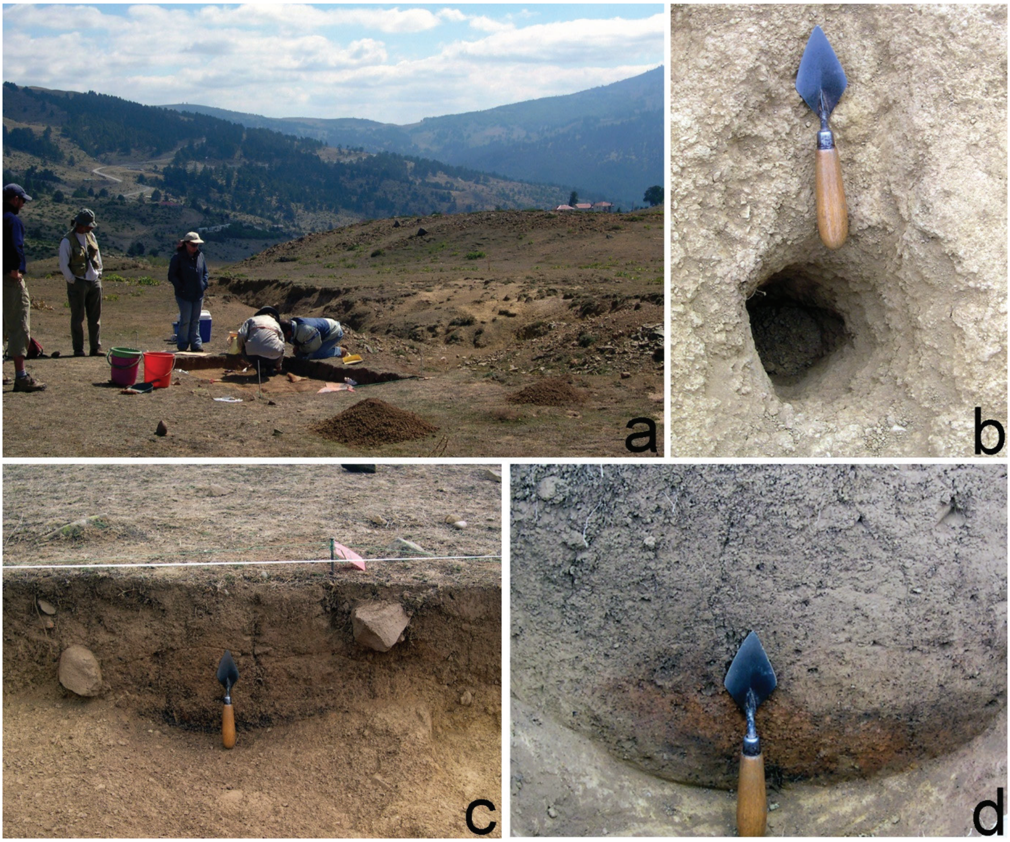

Figure 24. Historical Camp (HC): excavations underway in the seventh-century AD site. The 2 × 3 m test trench (**a**), inclined posthole (**b**), shallow burning pits or fireplaces with charcoals of small juniper branches (**c**,**d**), the second of which has been radiocarbon-dated to 1414 ± 18 BP (DEM-2586) (photographs by P. Biagi, 2006).

The same HC area yielded at least 80 "black spots", buried by ca. 20 cm of colluvial sediments, which were interpreted as remains of burnt tree-pits related to intentional deforestation episodes [82]. The features show evidence of anthropogenic thermal impact and contain a few charcoal pieces [25].

One was excavated (HC-5: Figure 25) and 18 were sampled for radiocarbon-dating. The radiocarbon ages show that the deforestation of the territory took place in different periods of the Holocene (see Figure 2 bottom and Table 1) and continued into the nineteenth century ([2], see p. 45).

Figure 25. Historical Camp (HC): the excavation carried out at pine tree-pit HC-5 which was radiocarbon-dated to 2485 ± 30 BP (GrA-59654) (photographs by P. Biagi, 2010).

6. Discussion

The occurrence of high-altitude archaeological sites of the Late Holocene age has only rarely been reported in the Balkan Peninsula [10]. The surveys made around Samarina have shed new light on the potential for discovering sites of this period at high elevations and for establishing why and when these landscapes were visited or settled.

In our case, knapped stone artefacts play an important role because potsherds, bones and other archaeological remains in most cases have been destroyed by the acidity of the mountain soil [14,83]. A few important points can be noted about lithics in the Samarina mountain zone. They show (1) the importance of non-local chert for understanding regional connections and ancient pathways, and the geographic location and distance of the lithic sources exploited during the Late Holocene; (2) the reason why a few types of knapped stone artefacts repeatedly recur in some specific areas; (3) their significance, and the role they played in the economic subsistence of the sites from which they have been retrieved; and (4) the presence of artefacts made from exogenous materials probably transported from very distant sources. We expand on each of these themes below.

(1) Almost all the lithic artefacts from the Holocene Samarina sites are made from non-local, good-quality, knappable material. Apart from the Vikos "black chert", other non-local chert types were utilised, though their sources have not been yet identified. One probable pre-core of Vikos "black chert" was collected from the surface ca. 1 km west of the Vasilitsa Pass, close to the Gomara Lake (Figure 4 bottom). Artefacts and debitage flakes made from this chert, whose outcrops are well-known in Epirus, ca. 25–30 km south-west of the study area, have been recovered from many sites of the Samarina highlands (see for example Mounts Vasilitsa, Anitsa, the watersheds around Delichmét and the Mirminda Pass and others). The Vikos "black chert" pre-core most probably punctuates one of the routes which were followed to transport this raw material and reinforces the impression that it was transported as blocks or rough-outs and not as finished tools. This interpretation is confirmed by the Mount Anitsa NTS debitage waste spot, which was radiocarbon-dated to the Late Neolithic (GrM-28122), and the recovery of many debitage flakelets and a few cores from the Mount Baltoumis site VSL 1. The triangular tanged-and-barbed arrowhead collected along the profile of site Sam-8, which finds a close parallel from Dispilio ([84], Figure 7), was made from this type of exogenous chert (Figure 7, n. 2);

(2) The knapped stone artefacts are represented mainly by long and short-end scrapers, sickle inserts and flat-retouched arrowheads. Different types of sickle inserts were recovered (Figure 17), two of which show the characteristic, shining, sickle gloss (Figure 17, nn. 1 and 6). One specimen has been resharpened (Figure 17, n. 4), and one has a notched working edge (Figure 17, n. 3). The typological variability of the sickle inserts has been discussed in several papers and explained as being due to their chronology, function, harvesting method and production technology [85–87].

(3) Other characteristic tools consist of arrowheads, all made from non-local chert. Unfortunately, we know very little about the techno-typology and chronology of the flat-retouched arrowheads from Greece, mainly because, apart from a few exceptions, they have never been studied in detail [88–90]. This contrasts with the evidence from other parts of Europe, where these items and their variability have been studied in detail to interpret the changes and complexity of societal structure mainly during the Chalcolithic and Bronze Age periods [91,92].

(4) Arrowheads and daggers were utilised for different uses, one of which was undoubtedly hunting. They were recovered along most of the watersheds and some of the highest and most strategic points. The presence of lithic arrowheads at high elevations is not surprising, although the Samarina samples are the first ever published from the Greek mountains. A large quantity of chert and obsidian arrowheads are attested in the Aegean since the Neolithic. Many have been found in Thessaly and other regions of northern Greece, although during the Bronze Age chert arrowheads were still used in several parts of the Greek mainland and Crete [93].

(5) The artefacts from the Mount Baltoumis sites (VSL) show that different activities were performed at high altitudes, including agriculture, hunting and woodworking. Chert tools, and also prestige items were produced within Site 1. This is shown by

the presence of exhausted cores, debitage pieces and one broken steatite bead with unfinished perforations (Figure 19, n. 4). Some lithic artefacts were hafted (Figure 18, n. 1) or used for cutting hide (Figure 16, n. 6), wood (Figure 16, n. 7) and piercing (Figure 6, n. 9).

(6) As reported above, two obsidian flakes have been collected from site VSL 1 (VSL-139) and the northern watershed of Mount Bogdani (GRG-19) (Figure 8). These undiagnostic finds, although their chrono-cultural attribution is difficult to define, reopen the question of the distribution and spread of archaeological obsidian in continental Greece. The first, which preserves part of the cortex on one side, comes from the Island of Melos, and the second from the Slovak source Carpathian 1. Both finds are very important because they were collected from territories located out of the distribution limit currently known for both Melian and Carpathian 1 obsidian [94]. Quite unexpectedly, they show that the Samarina mountain sites were part of the long-distance obsidian distribution network. Both are knapping by-products, which can be considered proxies for the circulation of obsidian nodules rather than finished products. The occurrence of both Carpathian and Aegean obsidian in Western Macedonian was previously known only from the sites of Mandalo and Dispilio [95–97].

7. Conclusions

The surveys conducted in the Samarina highlands during the last 20 years have led to the discovery of many traces of human activities attributable to the Late Holocene [98], more precisely to prehistoric periods between the Late Neolithic and the end of the Bronze Age. However, recent discoveries have shown that groups of Epipalaeolithic and Early Mesolithic hunter-gatherers were the first to move up to the north Pindus Range most probably during the warm interstadials that characterise the end of the Pleistocene and also around the beginning of the Holocene [22]. The Preboreal Mesolithic presence is confirmed by the recovery of one characteristic microlithic point made from Vikos "black chert", and one radiocarbon date obtained from *Salix* charcoal recovered from two distinct, though neighbouring points of the HC site (HC-CH20: GrM-25076). Moreover, the discovery of a few Epipalaeolithic and Early Mesolithic artefacts would help confirm the suggested hypothesis that north-western Greece and neighbouring Albania were "*parts of a mobility system of hunter-gatherer tied to the systemic habitat of prehistoric populations*" ([99], p. 76).

Apart from the Early Holocene finds, which include also a few typical early Atlantic Late Mesolithic artefacts [23], the Samarina highlands started to be more systematically inhabited during the Late Neolithic. Two radiocarbon dates from charcoal pieces obtained from a small fireplace discovered along the northern piedmont of Mount Bogdani (BGD-1: DEM-2585), and from a thin charcoal horizon from one of the Mount Anitsa profiles (NTS-25: GrM-28122), confirm this view. The results show that Late Neolithic farmers started to move up to the north Pindus mountains during two different times in the sixth millennium BP. The evidence provided by the two dates are reinforced (1) by the presence of a small Vikos "black chert" knapping floor at ca. 1700 m a.s.l. (NTS), most probably for the production of a flat, bifacial point, and (2) the recovery of a Carpathian 1 obsidian flakelet ca. 300 m south-west of the BGD-1 fireplace, along a Mount Bogdani ridge that yielded many other non-local Holocene chert artefacts.

These data show that Vikos "black chert" has been exploited here since the early Holocene and transported to the Samarina highlands, a movement that continued and increased throughout the entire Chalcolithic and the Bronze Age. Moreover, they show the importance of the relationships that developed with the Epirus middle-altitude mountain landscapes.

The discovery of a few Bronze Age high-altitude sites, structures (pits), and material culture remains, among which are different types of lithic artefacts and ceramic potsherds, is also important. According to the available radiocarbon chronology, the area started to be seasonally (?) frequented during the early Bronze Age (SMX-1: GrA-69503), to continue until the end of the same period. It is important to note the presence of one large valley bottom settlement at Agios Athanasios (ca. 1110 m a.s.l.), along the right terrace of the Venetikos River. This discovery is important for several reasons. The Venetikos joins the Aliakmon River ca. 50 km south-east of the site, to flow into the Aegean Sea. This means that this river system has nothing in common with the Epirus Vikos chert supply zone, and the route through which this important knappable source was transported. Moreover, Agios Athanasios (AA) is the only Bronze Age valley bottom site known in the study area, though it is likely that many others exist. In this regard, the discovery of a radiocarbon-dated charcoal lens associated with a few potsherds, near Koutroulia, close to the village of Filippei, at ca. 1330 m a.s.l. (KRN-45: GrM-25075), an area which again faces south-east, is of great interest.

Despite the two middle-altitude occurrences, it is important to emphasise that most of the Chalcolithic and Bronze Age sites have been found at high elevations. The settlement that was partly excavated and located on the top of Mount Anitsa (Sam-29: GrA-59015) is a typical observation point from which the entire surrounding region can be controlled. More Bronze Age sites are well-known in other key areas, among which are La Greklu and Mount Vasilitsa. The first, which is still undated, yielded a few potsherds, while the chronology of Mount Baltoumis sites VSL-1 and VSL-2 is not well-defined. Some of the lithic artefacts from these two sites are most probably attributable to this period (Figure 17, nn. 2 and 3). One of the sickle inserts can be compared with very similar bifacial sickles on flakes with a notched working edge from other early Bronze Age sites excavated in Western Macedonia and in the Peloponnese [100].

The available evidence shows that the Bronze Age high-altitude sites were part of a complex network, which involved movements from the valley bottoms and middle-altitude territories of Western Macedonia and Epirus to the Samarina highlands. Moreover, the recovery of many flat-retouched chert arrowheads along watersheds and their presence within Bronze Age sites (Sam-8: Figure 7, n. 2), show that the footpaths on the Samarina ridges were already opened, the visibility was good for hunting, and the entire area could be easily crossed on foot at least by the beginning of the Bronze Age, most probably also during the Chalcolithic. This is suggested by the presence of one site of this age along the upper slopes of Mount Anitsa (Sam-23: GrA-59661), where hunting activities are evidenced also by the presence of one lunate armature with impact fracture traces. Another point to note is the systematic occurrence of Bronze Age findspots close to springs or water sources, which are numerous all over the study region. A distinctive Bronze Age example is the flat-retouched transversal arrowhead labelled Sam-11 (Figure 18, n. 6) recovered from an area of springs, just south of La Greklu Pass, at ca. 1600 m a.s.l.

Figure 3 shows the results obtained from the archaeological sites and the Historical Camp tree-pits, which mark the periods during which the deforestation of the HC area took place. The calibration plot shows evident discontinuities between the most important cultural periods, which are represented by gaps within both groups of dates, for example between the Late Neolithic and the Bronze Age, and again between the Bronze, Iron and Roman Ages. Though we know very little about the Iron Age, pit-graves of this period containing different ceramic and bronze items were found at Spelaion (ca. 950 m a.s.l.), some 25 km south-east of Samarina [101]. Regarding the Roman period, charcoal pieces from a small Roman Age smelting kiln at 1939 m a.s.l. along the western upper slope of Mount Gurguliu, yielded an age of 1755 ± 30 BP (GrA-59658). This evidence is intriguing, despite our very limited knowledge of activities of this age in the study area that undoubtedly took place in the early Roman Imperial period, most probably due to the presence of the important Egnatia Odos, which crossed this mountain region, and the recovery of small metal slags along the slopes of the same mountains, though their age could not be ascertained. The existence of Roman (?) smelting ore ([2], p. 177) and coinage mint are reported to be practised until a few centuries ago at the edge of Valia Kalda along the southern slopes of Mount Smolikas.

The discovery of Byzantine fireplaces at Delichmét (Sam-5: DEM-1918/OxA-16223 and DEM-1917/OxA-16222), VSL-1 (GrA-69566), and other places show that the Samarina highlands were also settled in this period, as they were during the Roman Imperial rule. This evidence contrasts with the lack of radiocarbon results attributable to the Hellenistic period, which is otherwise represented by two important middle-altitude settlements along the Smixiotikos River, both known as Kastrì [102].

To sum up, the results obtained during this long-term research programme carried out in the Samarina highlands have shown the great potential of such surveys to enhance archaeological knowledge in unexplored mountain areas, and to help frame it within a wider cultural network. It is important to state that the territory we have explored has been exploited for centuries by seasonal Vlach transhumant shepherds, whose presence has led to deforestation and grazing, and the consequent exposure of many open spaces, which would otherwise be covered with thick forests and reduced visibility. In this respect, it is important to point out that the investigated territory is not only unique, but also represents an ideal landscape for conducting archaeological research. The amount of data collected so far is very significant from this point of view.

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References

1. Hammond, N.G.L. *Epirus: The Geography, the Ancient Remains, the History and the Topography of Epirus and Adjacent Areas*; Clarendon Press: Oxford, UK, 1967.
2. Wace, A.J.B.; Thompson, M.S. *The Nomads of the Balkans: An Account of Life and Customs among the Vlachs of the Northern Pindus*; Biblo & Tannen: Cambridge, UK, 1913.
3. Winnifrith, T.J. *The Vlachs: The History of a Balkan People*; Duckworth: London, UK, 1987.
4. Koukoudis, A.I. *The Vlachs: Metropolis and Diaspora*; Zitros: Thessaloniki, Greece, 2003.
5. Russell, J.; Cohn, R. *Alchiviad Diamandi di Samarina*; Bookvika Publishing: Edinburgh, UK; Lennex Corp.: Edinburgh, UK, 2012.
6. Broglio, A. Mountain sites in the context of the North-East Italian Upper Palaeolithic and Mesolithic. *Preist. Alp.* **1992**, *28*, 293–310.
7. Biagi, P.; Nandris, J. (Eds.) *Highland Zone Exploitation in Southern Europe*; Monografie di Natura Bresciana; Museo Civico di scienze naturali di Brescia: Brescia, Italy, 1994; Volume 20, pp. 7–338.
8. Franco, C. *La Fine del Mesolitico in Italia. Identità Culturale e Distribuzione Territoriale degli Ultimi Cacciatori-Raccoglitori (The end of the Mesolithic in Italy. Cultural Identity and Territorial Distribution of the Last Hunter-Gatherers)*; Società per la Preistoria e Protostoria della Regione Friuli-Venezia Giulia, Quaderno 13, Centralgrafica: Trieste, Italy, 2011. (In Italian)
9. Francis, K.; Vulpi, V. The Italian notebooks and reports and their English translations. In *Explorations in Albania. The Notebooks of Luigi Cardini, Prehistorian with the Italian Archaeological Mission*; Francis, K., Ed.; The British School at Athens: London, UK, 2005; Supplementary Volume NO. 37, pp. 11–182.
10. Schon, R.; Galaty, M.L. Diachronic Frontiers: Landscape Archaeology in Highland Albania. *J. World-Syst. Res.* **2006**, *XII*, 231–262. [CrossRef]
11. Mihailović, D. (Ed.) *Palaeolithic and Mesolithic in the Central Balkans*; Serbian Archaeological Society: Belgrade, Serbia, 2014.
12. Bobînă, B. Mountain Archaeology in Romania: The Status of Research. *Terra Sebus. Acta Musei Sabesiensis* **2015**, *7*, 149–164.
13. Beck, J.; Ciugudean, H.; Quinn, C.P. Bioarchaeology and Mountain Landscapes in Transylvania's Golden Quadrangle. *Bioarchaeol. Int.* **2020**, *4*, 89–110. [CrossRef]

14. Halstead, P. Present to past in the Pindhos: Diversification and specialisation in mountain economies. In *Archeologia della Pastorizia in Europa Meridionale*; Maggi, R., Nisbet, R., Barker, G., Eds.; Rivista di Studi Liguri: Bordighera, Italy, 1990; Volume 56, pp. 61–80.
15. Chang, C. Pastoral Transhumance in the Southern Balkans as a Social Ideology: Ethnoarcheological Research in Northern Greece. *Am. Anthropol.* **1993**, *95*, 687–703. [CrossRef]
16. Chang, C.; Tourtellotte, P.A. Ethnoarchaeological Survey of Pastoral Transhumance Sites in the Grevena Region, Greece. *J. Field Archaeol.* **1993**, *20*, 249–264. [CrossRef]
17. Ntassiou, K.; Doukas, I.D. Recording and mapping traditional transhumance routes in the South-Western Macedonia, Greece. *GeoJournal* **2019**, *84*, 161–181. [CrossRef]
18. Dakaris, S.I.; Higgs, E.S.; Hey, R.W.; Tippett, H.; Mellars, P. The Climate, Environment and Industries of Stone Age Greece: Part I. *Proc. Prehist. Soc.* **1964**, *30*, 199–244. [CrossRef]
19. Runnels, C.; Korkuti, M.; Galaty, M.L.; Timpson, M.E.; Whittaker, J.C.; Stocker, S.R.; Davis, J.L.; Bejko, L.; Mucaj, S. The Palaeolithic and Mesolithic of Albania: Survey and excavation at the site of Kryegjata B (Fier District). *J. Mediterr. Archaeol.* **2004**, *17*, 3–29. [CrossRef]
20. Biagi, P.; Nisbet, R.; Michniak, R.; Efstratiou, N. The Chert Outcrops of the Pindus Range of Western Macedonia (Greece) and their Middle Palaeolithic Exploitation. *Quarry* **2015**, *11*, 3–16.
21. Biagi, P.; Nisbet, R.; Starnini, E.; Efstratiou, N.; Michniak, R. Where Mountains and Neanderthals Meet: The Middle Palaeolithic Settlement of Samarina in the Northern Pindus (Western Macedonia, Greece). *Eurasian Prehistory* **2017**, *13*, 3–76.
22. Biagi, P.; Nisbet, R.; Efstratiou, N. Late Palaeolithic and Early Mesolithic finds from the Pindus Mountains of western Macedonia (Greece). *Antiq. Proj. Gallery* **2015**, *346*. Available online: https://www.antiquity.ac.uk/projgall/biagi346 (accessed on 25 July 2016).
23. Biagi, P.; Efstratiou, N.; Starnini, E.; Nisbet, R. Traces of Mesolithic occupation in the Pindos Mountains of western Macedonia (Greece). *Mesolith. Misc.* 2023; 30, *in press*.
24. Efstratiou, N.; Biagi, P.; Elefanti, P.; Karkanas, P.; Ntinou, M. Prehistoric exploitation of Grevena highland zones: Hunters and herders along the Pindus chain of western Macedonia (Greece). *World Archaeol.* **2006**, *38*, 415–435. [CrossRef]
25. Biagi, P.; Nisbet, R. Archeologia della pastorizia dei Vlah di Samarina (Macedonia Occidentale, Grecia) (Archaeology of the pastoralism of the Vlachs of Samarina (Western Macedonia, Greece). In *Un Accademico Impaziente. Studi in Onore di Glauco Sanga*; Ligi, G., Pedrini, G., Tamisari, F., Eds.; Edizioni dell'Orso: Alessandria, Italy, 2018; pp. 581–593. (In Italian)
26. Reimer, P.J.; Austin, W.E.N.; Bard, E.; Bayliss, A.; Blackwell, P.; Bronk Ramsey, C.; Butzin, M.; Cheng, H.; Edwards, R.L.; Friedrich, M.; et al. The IntCal20 Northern EmisphereRadiocarbon Age Calibration Curve (0–55 cal kBP). *Radiocarbon* **2020**, *62*, 725–757. [CrossRef]
27. *Management Unit of Northern Pindos National Park*; National System of Governance of Protected Areas, Natural Environment and Climate Change Agency (N.E.C.C.A.): Athens, Greece, 2021–2022.
28. Pouqueville, F.-C.H.-L. *Voyage de la Grèce*, 2nd ed.; Firmin Didot: Paris, France, 1826.
29. Leake, W.M. *Travels in Northern Greece*; J. Rodwell: London, UK, 1835.
30. Konter, O.; Krusic, P.J.; Trouet, V.M.; Esper, J. Meet Adonis, Europe's oldest dendrochronologically dated tree. *Dendrochronologia* **2017**, *42*, 12. [CrossRef]
31. Klippel, L.; Krusic, P.J.; Brandes, R.; Hartl-Meier, C.; Trouet, V.; Meko, M.; Esper, J. High-elevation inter-site differences in Mount Smolikas tree-ring width data. *Dendrochronologia* **2017**, *44*, 164–173. [CrossRef]
32. Klippel, L.; Krusic, P.J.; Brandes, R.; Hartl, C.; Belmecheri, S.; Dienst, M.; Esper, J. A 1286-year hydro-climate reconstruction for the Balkan Peninsula. *Boreas* **2018**, *47*, 1218–1229. [CrossRef]
33. Christopoulou, A.; Fyllas, N.M.; Gmińska-Nowak, B.; Özarslan, Y.; Arianoutsou, M.; Brandes, R.; Ważny, T. Exploring the past of Mavrovouni forest in the Pindus Mountain range (Greece) using tree rings of Bosnian pines. *Trees* **2022**, *36*, 153–166. [CrossRef]
34. Esper, J.; Klippel, L.; Krusic, P.J.; Konter, O.; Raible, C.C.; Xoplaki, E.; Luterbacher, J.; Büntgen, U. Eastern Mediterranean summer temperatures since 730 CE from Mt. Smolikas tree-ring densities. *Clim. Dyn.* **2020**, *54*, 1367–1382. [CrossRef]
35. Esper, J.; Konter, O.; Klippel, L.; Krusic, P.J.; Büntgen, U. Pre-instrumental summer precipitation variability in northwestern Greece from a high-elevation Pinus heldreichii network. *Int. J. Climatol.* **2021**, *41*, 2828–2839. [CrossRef]
36. Chester, P.I. Late Holocene Vegetation History of Grevena Province, Northwestern Greece. Ph.D. Thesis, Victoria University of Wellington, Wellington, New Zealand, 1988, unpublished. Available online: http://hdl.handle.net/10063/507 (accessed on 30 June 2021).
37. Ntokos, D. Synthesis of Literature and Field Work Data Leading to the Compilation of a New Geological Map—A Review of Geology of Northwestern Greece. *Int. J. Geosci.* **2017**, *8*, 205–236. [CrossRef]
38. Wong, K.; Draper, K.; Feng, L.; Hawkins, P.; Oakley, S.; Zheng, X.X. The geology of Mount Orliakas and the Pindos Ophiolite, Greece. *Bull. Geol. Soc. Greece* **2019**, *54*, 144–177. [CrossRef]
39. Hourmouziadis, G. *Dispilio, Kastoria a Prehistoric Lakeside Settlement*; Codex: Thessaloniki, Greece, 1966. (In Greek)
40. Facorellis, Y.; Sofronidou, M.; Hourmouziadis, G. Radiocarbon Dating of the Neolithic Lakeside Settlement of Dispilio, Kastoria, Northern Greece. *Radiocarbon* **2014**, *56*, 511–528. [CrossRef] [PubMed]
41. Kakavakis, O. In search of social networks during the Neolithic Period in Macedonia (Northern Greece): The case of chipped stone industries. In *A Century of Research in Prehistoric Macedonia 1912–2012*; Stefani, E., Merousis, N., Dimoula, A., Eds.; Archaeological Museum: Thessaloniki, Greece, 2014; pp. 599–606.

42. Elefanti, P.; Marshall, G.; Stergiou, C.L.; Kotjabopoulou, E. Raw material procurement at Boïla Rockshelter, Epirus, as an indicator of hunter-gatherer mobility in Greece during the Late Upper Palaeolithic and Early Mesolithic. *J. Archaeol. Sci. Rep.* **2021**, *35*, 102719. [CrossRef]
43. Kotjabopoulou, E.; Panagopoulou, E.; Adam, E. The Boïla Rockshelter: A Preliminary Report. In *Klithi: Palaeolithic Settlement and Quaternary Landscapes in Northwest Greece. Volume 2: Klithi in Its Local and Regional Settling*; Bailey, G.N., Ed.; McDonald Institute for Archaeological Research: Cambridge, UK, 1997; pp. 427–437.
44. Lewin, J.; Macklin, M.G.; Woodward, J.C. Late Quaternary Fluvial Sedimentation in the Voidomatis Basin, Epirus, Northwest Greece. *Quat. Int.* **1991**, *35*, 103–115. [CrossRef]
45. Adam, E. To Know and To Have: Raw Material Availability and Upper Palaeolithic Stone Assemblage in Epirus. In *Klithi: Palaeolithic Settlement and Quaternary Landscapes in Northwest Greece. Volume 2: Klithi in Its Local and Regional Settling*; Bailey, G.N., Ed.; McDonald Institute for Archaeological Research: Cambridge, UK, 1997; pp. 481–496.
46. Ozsvárt, P.; Dosztály, L.; Migiros, G.; Tselepidis, V.; Kovács, S. New radiolarian biostratigraphic age constraints on Middle Triassic basalts and radiolarites from the Inner Hellenides (Northern Pindos and Othris Mountains, Northern Greece) and their implications for the geodynamic evolution of the early Mesozoic Neotethys. *Int. J. Earth Sci.* **2012**, *101*, 1487–1501. [CrossRef]
47. Stirn, M.A. Why all the way up there? Mountain and high-altitude archaeology. *SAA Archaeol. Rec.* **2014**, *14*, 7–10.
48. Ballbè, E.G.; Conte, I.C.; Mazzucco, N.; Casas, D.G.; Gomez, L.O.; Anton, D.R. Surface surveying in high mountain areas, is it possible? Some methodological considerations. *Quat. Int.* **2016**, *402*, 35–45. [CrossRef]
49. Biagi, P.; Nisbet, R.; Starnini, E. High-Altitude Archaeology in Southeastern Europe. In *Encyclopedia of Global Archaeology*; Smith, C., Ed.; Springer Nature: Cham, Switzerland, 2019; pp. 5033–5051. [CrossRef]
50. Morgan, C. Was it Euphoria or Oxygen Deprivation? Reflexions on Conducting Research in Alpine Settings. *SAA Archaeol. Rec.* **2014**, *14*, 31–35.
51. Tzortzis, S.; Delestre, X. *Archéologie de la Montagne Européenne*; Bibliothèque d'Archéologie Méditerranéenne et Africaine: Paris, France, 2010.
52. Biagi, P.; Starnini, E. Human settlement and environmental exploitation of Valcamonica-Valtrompia watershed from the beginning of the Holocene to the Middle Ages. *Nat. Brescia* **2015**, *39*, 249–259.
53. Biagi, P.; Starnini, E. Archeologia d'alta quota: Alcuni esempi dalle Alpi centrali (Highland Zone Archaeology: Some Examples from the Central Alps). In *Una Preziosa Eredità. Scritti in Ricordo di Arturo Palma di Cesnola*; Sarti, L., Martini, F., Eds.; Museo e Istituto Fiorentino di Preistoria: Florence, Italy, 2021; Volume 24, pp. 261–275. (In Italian)
54. Steward, J.H. Causal Factors and Processes in the Evolution of Pre-farming Societies. In *Man the Hunter*; Lee, R.B., DeVore, I., Eds.; Aldine: New York, NY, USA, 1968; pp. 321–334.
55. Binford, L.R. Long-term Land-use patterning: Some Implications for Archaeology. In *Working at Archaeology*; Binford, L.R., Ed.; Academic Press: New York, NY, USA, 1981; pp. 379–386.
56. Schiffer, M.B.; Sullivan, A.P.; Klinger, T.C. Field Techniques and Research Design. *World Archaeol.* **1978**, *10*, 1–28. Available online: https://www.jstor.org/stable/124409 (accessed on 29 June 2021). [CrossRef]
57. Binford, L.R. A Consideration of Archaeological Research Design. *Am. Antiq.* **1964**, *29*, 425–441. Available online: https://www.jstor.org/stable/277978 (accessed on 29 June 2021). [CrossRef]
58. Leontaritis, A.D.; Kouli, K.; Pavlopoulos, K. The glacial history of Greece: A comprehensive review. *Mediterr. Geosci. Rev.* **2020**, *2*, 65–90. [CrossRef]
59. Hughes, P.D.; Woodward, J.C.; Gibbard, P.L.; Macklin, M.G.; Gilmour, M.A.; Smith, G.R. The glacial history of the Pindus Mountains, Greece. *J. Geol.* **2006**, *114*, 413–434. [CrossRef]
60. Hughes, P.D.; Gibbard, P.L.; Woodward, J.C. Middle Pleistocene glacier behaviour in the Mediterranean: Sedimentological evidence from the Pindus Mountains, Greece. *J. Geol. Soc.* **2006**, *163*, 857–867. [CrossRef]
61. Pope, R.J.; Hughes, P.D.; Skourtsos, E. Glacial history of Mt Chelmos, Peloponnesus, Greece. *Geol. Soc. Lond. Spec. Publ.* **2017**, *433*, 211–236. [CrossRef]
62. Pavlopoulos, K.; Leontaritis, A.; Athanassas, C.D.; Petrakou, C.; Vandarakis, D.; Nikolakopoulos, K.; Stamatopoulos, L.; Theodorakopoulou, K. Last glacial geomorphologic records in Mt Chelmos, North Peloponnesus, Greece. *J. Mt. Sci.* **2018**, *15*, 948–965. [CrossRef]
63. Smith, G.W.; Damian Nance, R.; Genes, A.N. Quaternary glacial history of Mount Olympus, Greece. *Geol. Soc. Am. Bull.* **1997**, *109*, 809–824. [CrossRef]
64. Woodward, J.C.; Hamlin, R.H.B.; Macklin, M.G.; Karkanas, P.; Kotjabopoulou, E. Quantitative sourcing of slackwater deposits at Boïla rockshelter: A record of lateglacial flooding and Paleolithic settlement in the Pindus Mountains, Northwest Greece. *Geoarchaeol. Int. J.* **2001**, *16*, 501–536. [CrossRef]
65. Wilson, G.P.; Reed, J.M.; Frogley, M.R.; Hughes, P.D.; Tzedakis, P.C. Reconciling diverse lacustrine and terrestrial system response to penultimate deglacial warming in southern Europe. *Geology* **2015**, *43*, 819–822. [CrossRef]
66. Wilson, G.P.; Frogley, M.R.; Hughes, P.D.; Roucoux, K.H.; Margari, V.; Jones, T.D.; Leng, M.J.; Tzedakis, P.C. Persistent millennial-scale climate variability in Southern Europe during Marine Isotope Stage 6. *Quat. Sci. Adv.* **2021**, *3*, 100016. [CrossRef]
67. Leontaritis, A.D.; Pavlopoulos, K.; Marrero, S.M.; Ribolini, A.; Hughes, P.D.; Spagnolo, M. Glaciations on ophiolite terrain in the North Pindus Mountains, Greece: New geomorphological insights and preliminary ^{36}Cl exposure dating. *Geomorphology* **2022**, *413*, 108335. [CrossRef]

68. Hughes, P. Quaternary Glaciation in the Pindus Mountains, Northwest Greece. Ph.D. Thesis, The University of Cambridge, Cambridge, UK, 2004, unpublished.
69. Bailey, G.N.; Lewin, J.; Macklin, M.; Woodward, J. The "Older Fill" of the Voidomatis Valley, North-west Greece and Its Relationship to the Palaeolithic Archaeology and Glacial History of the Region. *J. Archaeol. Sci.* **1990**, *17*, 145–150. [CrossRef]
70. Bailey, G.N. (Ed.) *Klithi: Palaeolithic Settlement and Quaternary Landscapes in Northwest Greece. Volume 1: Excavation and Intra-Site Analysis at Klithi*; McDonald Institute for Archaeological Research: Cambridge, UK, 1997.
71. Woodward, J.C.; Macklin, M.G.; Smith, G.R. Pleistocene glaciation in the mountains of Greece. In *Quaternary Glaciations—Extent and Chronology: Part 1*; Ehlers, J., Gibbard, P.L., Eds.; Elsevier: Amsterdam, The Netherlands, 2004; pp. 155–173.
72. Efstratiou, N.; Biagi, P.; Angelucci, D.E.; Nisbet, R. Middle Palaeolithic chert exploitation in the Pindus Mountains of western Macedonia, Greece. *Antiq. Proj. Gallery* **2011**, *328*, 1–3. Available online: http://www.antiquity.ac.uk/projgall/biagi328/ (accessed on 29 June 2021).
73. IGME. *Geological Map of Greece, Northern Part*, 2nd ed.; Institute of Geological and Mineral Exploration: Athens, Greece, 1983.
74. Allard, J.L.; Hughes, P.D.; Woodward, J.C.; Fink, D.; Simon, K.; Wilcken, K.M. Late Pleistocene glaciers in Greece: A new 36Cl chronology. *Quat. Sci. Rev.* **2020**, *245*, 106528. [CrossRef]
75. Bailey, G.N. Klithi: A Synthesis. In *Klithi: Palaeolithic Settlement and Quaternary Landscapes in Northwest Greece. Volume 2: Klithi in Its Local and Regional Settling*; Bailey, G.N., Ed.; McDonald Institute for Archaeological Research: Cambridge, UK, 1997; pp. 655–677.
76. Woodward, J.C. Late Pleistocene rockshelter sedimentation at Klithi. In *Klithi: Palaeolithic Settlement and Quaternary Landscapes in Northwest Greece. Volume 2: Klithi in Its Local and Regional Settling*; Bailey, G.N., Ed.; McDonald Institute for Archaeological Research: Cambridge, UK, 1997; pp. 361–376.
77. Allard, J.L.; Hughes, P.D.; Woodward, J.C. Heinrich Stadial aridity forced Mediterranean-wide glacier retreat in the last cold stage. *Nat. Geosci.* **2021**, *14*, 197–205. [CrossRef]
78. Yravedra, J.; Cobo-Sánchez, L. Neanderthal exploitation of ibex and chamois in southwestern Europe. *J. Hum. Evol.* **2015**, *78*, 12–32. [CrossRef]
79. Mould, C.A.; Ridley, C.; Wardle, K.A. The Stone Small Finds. In *Servia I*; Ridley, C., Wardle, K.A., Mould, C.A., Eds.; The British School at Athens: London, UK, 2000; Volume 32, pp. 112–190.
80. Catania, S. *The Italian Invasion of Greece in 1940: When Operational Art Does Not Close the Gap between Tactical Engagements and Strategic Objectives*; School of Advanced Military Studies, US Army Command and General Staff College: Fort Leavenworth, KS, USA, 2019.
81. Efstratiou, N. Mountain Archaeology in the Pindus. *Egnatia* **2008**, *12*, 45–63. (In Greek)
82. Langohr, R. Types of tree windthrow, their impact on the environment and their importance for the understanding of archaeological excavation data. *Helinium* **1993**, *XXXIII*, 36–49.
83. Schmidtlein, S.; Ewald, J. Landscape Patterns of Indicator Plants for Soil Acidity in the Bavarian Alps. *J. Biogeogr.* **2003**, *30*, 1493–1503. [CrossRef]
84. Tsankouli, C. The Lithic Assemblage. In *Dispilió 7500 Years of Life*; Chourmouziadis, G.C., Ed.; University Studio Press: Thessaloniki, Greece, 2002; pp. 145–154. (In Greek)
85. Rosen, S.A. *Lithics After the Stone Age. A Handbook of Stone Tools from the Levant*; Altamira Press: Walnut Creek, CA, USA, 1997.
86. Mazzucco, N.; Guilbeau, D.; Petrinelli-Pannocchia, C.; Gassin, B.; Ibáñez, J.J.; Gibaja, J.F. Harvest time: Crop-reaping technologies and the Neolithisation of the Central Mediterranean. *Antiq. Proj. Gallery Antiq.* **2017**, *91*, e2. [CrossRef]
87. Ibáñez, J.J.; Anderson, P.A.; Arranz-Otaegui, A.; González-Urquijo, J.; Jorgensen-Lindahl, A.; Mazzucco, N.; Pichon, F.; Richter, T. Sickle gloss texture analysis elucidates long-term change in plant harvesting during the transition to agriculture. *J. Archaeol. Sci.* **2021**, *136*, 105502. [CrossRef]
88. Runnels, C. The Bronze-Age Flaked-Stone Industries from Lerna: A Preliminary Report. *Hesperia* **1985**, *54*, 357–391. [CrossRef]
89. Andreasen, N. The Chipped Stone Artefacts from Neolithic Avgi: Some Observations from the Continued Study of the West Sector in 2011. Available online: http://www.neolithicavgi.gr/?page_id=492 (accessed on 29 June 2021).
90. Kita, A. Lithotechnica from Dispilio. Ph.D. Thesis, Aristotle University Thessaloniki, Thessaloniki, Greece, 2020, unpublished (In Greek).
91. Nicolas, C. Arrows of power at the dawn of metallurgy, from Brittany to Denmark (2500-1700 BC). *Proc. Prehist. Soc.* **2017**, *83*, 247–287. [CrossRef]
92. Nicolas, C. The production and use of archery-related items as a reflection of social changes during the Late Neolithic and the Early Bronze Age in Europe. In *Habitus? The Social Dimension of Technology and Transformation*; Scales of Transformation in Prehistoric and Archaic Societies; Kradow, S., Müller, J., Eds.; Sidestone Press: Leiden, The Netherlands, 2019; Volume 3, pp. 115–140.
93. Runnels, C.N.; Payne, C.; Rifkind, N.V.; White, C.; Wolff, N.P.; LeBlanc, S.A. Warfare in Neolithic Thessaly: A Case Study. *Hesperia* **2009**, *78*, 168–194. [CrossRef]
94. Georgiadis, M. The Obsidian in the Aegean beyond Melos: An Outlook from Yali. *Oxf. J. Archaeol.* **2008**, *27*, 101–117. [CrossRef]
95. Kilikoglou, V.; Bassiakos, Y.; Grimanis, A.P.; Souvatzis, K.; Pilali-Papasteriou, A.; Papanthimou-Papaefthimiou, A. Carpathian obsidian in Macedonia, Greece. *J. Archaeol. Sci.* **1996**, *23*, 343–349. [CrossRef]
96. Milić, M. PXRF characterisation of obsidian from central Anatolia, the Aegean and central Europe. *J. Archaeol. Sci.* **2014**, *41*, 285–296. [CrossRef]

97. Milić, M. Obsidian Exchange and Societies in the Balkans and the Aegean from the Late 7th to 5th Millennia BC. Ph.D. Thesis, UCL, London, UK, 2016, unpublished.
98. Wanner, H.; Beer, J.; Bütikofer, J.; Crowley, T.J.; Cubasch, U.; Flückiger, J.; Goosse, H.; Grosjean, M.; Joos, F.; Kaplan, J.O.; et al. Mid- to Late Holocene climate change: An overview. *Quat. Sci. Rev.* **2008**, *27*, 1791–1828. [CrossRef]
99. Richter, J.; Gjipali, I.; Hauch, T.C.; Ruka, R.; Vogels, O.; Metalla, E. The Early Prehistory of Albania: First Results of the "German-Albanian Palaeolithic" (GAP) Programme. In Proceedings of the International Congress of Albanian Archaeological Studies, Tirana, Albania, 21–22 November 2014; Përzhita, L., Gjipali, I., Hoxha, G., Muka, B., Eds.; Centre for Albanian Studies, Institute of Archaeology: Tirana, Albania, 2014; pp. 65–82.
100. Karageorgiou, S.; Kostaki, A.; Vavelidis, M.; Andreou, S. Raw material sources of knapped stone tools from the excavation of the Early Bronze Age site at Toumba Thessaloniki, Greece. *J. Lithic Stud.* **2016**, *3*, 439–454. [CrossRef]
101. Rhomiopoulou, K. Early Iron Age pit-graves from east Pindus. In *Spileo, Grevena 1200 BC, 2000 AD*; Sullogos Spilioton Thessalonikis: Thessaloniki, Greece, 1999; pp. 25–31. (In Greek)
102. Drougou, S.; Kallini, C. Kastri near Polyneri, Grevena prefecture, 2001. *Archaiologiko Ergo Sti Makedonia Kai Thrak.* **2001**, *15*, 587–592. (In Greek)

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Article

The Soils of Early Farmers and Their Neighbors in the Southern Buh Catchment (Ukraine): Micromorphology and Archaeological Context

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Abstract: The problems regarding hunter-gatherer/early farmer interactions are quite an important topic in southeast European archaeology. According to the available data, the two economic subsistence systems have coexisted for some 2000 years during the 6th–4th millennia cal BC (Telegin 1985; Lillie et al., 2001). In some areas, hunter-gatherer and early farmer sites are located just a few kilometers apart. The Southern Buh River valley has yielded evidence of Linear Pottery culture, early Trypillia and Trypillia B1 Neolithic settlements as well as hunter-gatherer sites with pottery attributable to the so-called sub-Neolithic or para-Neolithic (Haskevych et al., 2019; Kiosak et al., 2021). Trial-trenches have been opened within some of these sites, which have been radiocarbon-dated from Bern University laboratory (LARA). Soil samples for micromorphological analysis have been collected from these sites to interpret their paleogenetic formation. The soil development is attested since, at least, the beginning of the 5th mill BC, followed by the developed of chernozem soils, which was interrupted by an erosional episode in the end of 5th millennium BC. The available data show that the soils of early farmers arable as are the present day ones. The early farmers were able to exploit relatively heavy soils to cultivate wheat and barley as early as 5250–5050 cal BC. In contrast, the sites of ceramic hunter-gatherers were often located on the soils which formed under wet conditions along seasonally flooded riverbanks, which were almost unsuitable for agricultural practices.

Keywords: Neolithization of eastern Europe; Ukraine; radiocarbon dates; soil micromorphology; paleopedogenesis

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1. Introduction

Chernozem is a dominant type of soil in Ukraine nowadays. It covers more than 65 percent of the country's arable land. This soil is extremely rich in nutrients and very fertile [1]. That is why Neolithic farmers prefer it in many regions [2]. However, the formation of chernozems is thought to result from direct or indirect anthropic influence on ecosystems [3–6]. Thus, the first agriculturalists in this region could rely on other types of soil, especially in the early phases of their arrival in a certain region [7,8]. The sedimentary conditions of southern Ukraine, where high rates of accumulation sometimes enable partial preservation of past Holocene soils under modern-day soils [9], permit us to estimate directly the type of soils used by early farmers.

In Ukraine, the earliest evidence of agriculture was found in the sites of Linear Pottery culture [10,11]. However, there was a complex situation in Ukraine during the second half of the sixth–fifth millennia BC [12,13]. In the west, vast territories saw the arrival of the first farmers (LPC, then Trypillia culture). During the same time period, sites of hunter-gatherers equipped with pottery (attributed to numerous local cultural aspects) flourished to the east of "agricultural frontier" [14,15]. Thus, in Ukraine there are many regions where early farmers' settlements neighbor sites of ceramic hunter-gatherers [16–18].

This research was carried out in the Southern Buh catchment (SBC, Figure 1): the region in southwest Ukraine that yielded sites of groups with the agriculture-based economy (Linear Pottery culture, LPC, and Trypillian culture, [19,20]) as well as sites of mobile groups with extractive economy equipped with pottery (Figure 2). Thus, their soil preferences can be directly compared here. Previously, the pedological analysis had been implemented in several hunter-gatherers' sites in the SBC, with indecisive results: some sites contained traces of buried chernozems (Dobrianka 1 and 3, [21]), while the sediments from other sites (Gard and Lidyna Balka, [22]) were rather related to the floodplain pedogenesis. In the Trypillian settlement of Sabatynivka 1, the soil sections revealed a buried soil of chernozem type dating to the 5th mill. BC [23]. However, pedological research had been carried out in an opportunistic way, reflecting the ongoing archaeological projects. Thus, the authors propose a systematic program of pedological investigation in the SBC, encompassing both recently excavated and historic sites. In this paper, the results of pedological analysis on three settlements of the early farmers are compared with observations on two sites of the ceramic hunter-gatherers.

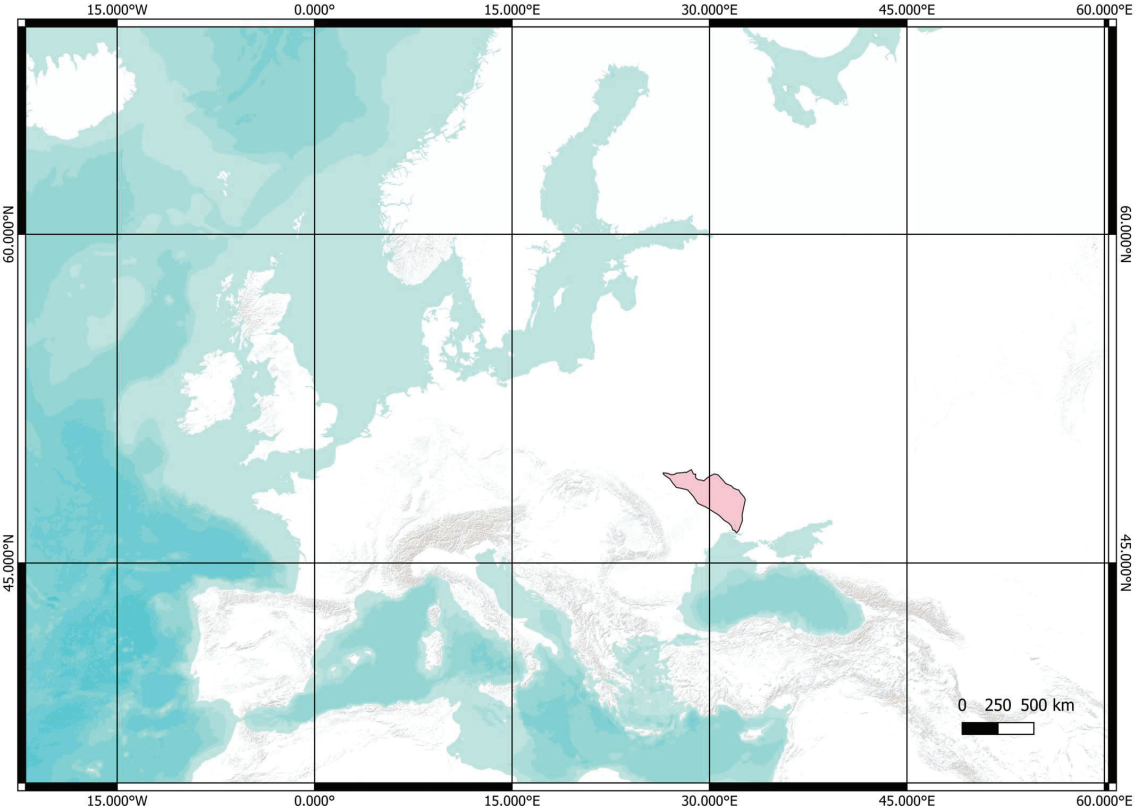

Figure 1. The Southern Buh catchment (pink area) on the map of Europe. Topo—ESRI Terrain. Elaboration—DK.

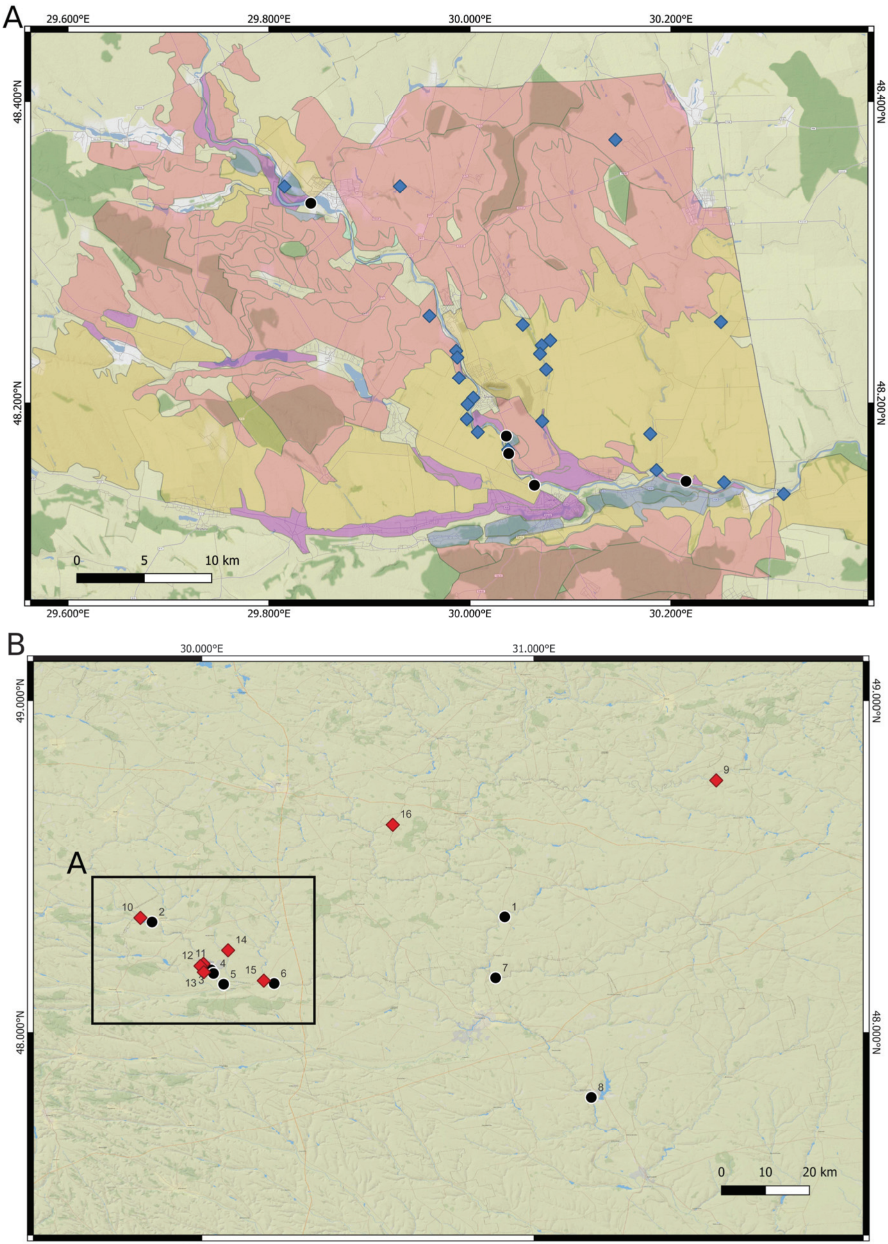

Figure 2. (**A**): An example of modern soils cover in the middle Southern Buh. Diamonds—early farming sites, circles—hunter-gatherers' sites. Yellow areas—chernozems, reddish—forest soils, purple—meadow soils, blue—sands. (**B**): The sites of hunter-gatherers (black dots) and early farmers (red diamonds) in the Southern Buh catchment. 1—Dobrianka 1 and 3, 2—Haivoron-Polizhok, 3—Zavallia, 4—Zhakchyk, 5—Savran, 6—Melnychna Krucha, 7—Mykolyna Broiaka, 8—Gard and Lidyna Balka, 9—Likareve, 10—Haivoron, 11—Kamyane-Zavallia 1, 12—Kamyane-Zavallia, 13—Hnyla Skelia, 14—Mohylna 3, 15—Sabatynivka 1, 16—Nebelivka. A—area depicted in Figure 2A. Topo—ESRI National Geographic. Elaboration—DK.

2. Region

The region of study (Figure 1) is situated along the Southern Buh River and its tributaries. The Southern Buh River is a natural connection between the hilly landscapes of the Podillia and Dnieper uplands on the one hand and the much flatter terrain of the steppe Black Sea lowland on the other hand. The region is characterized by the alteration of flooding watersheds with deep (up to 80–90 m), sometimes canyon-like valleys of rivers and gullies [24]. The slopes of gullies and rivers are often wooded. The river terraces are often not visible along the Southern Buh River course, and there is only a single cliff between a narrow strip of floodplain and a hilly loess plateau above [25]. The current vegetation patterns of the region are classified as a broadleaf forest, meadow-steppe landscape, and steppe when moving downstream [26].

The Southern Buh River is crossed in many places by rapids, mostly made of large granite blocks. They formed favorable fishing locations since prehistory [27].

The underlying Quaternary bedrock is represented mainly by loess [9]. The loess soils, preferred by early farmers of LPC in Central Europe [28], are so widespread here that it can be challenging to search for patches free of them. Thus, "loess islands" as an explanatory concept of LPC patchy character of settlement loses much of its heuristic value in Ukraine.

Nowadays, the soils of the SBC are mostly chernozems [25], Figure 2A. They are classified into three broad groups: (1) typical, deep (80–120 cm of the profile), with a small content of humus (4–6%), sometimes carbonized; (2) podzolized; (3) regraded. Podzolized and regraded chernozems are soils formed under deciduous vegetation and cultivated only relatively recently (since the 1950s). The region also has dark-grey and grey forest soils, mostly preserved under modern-day forests and nearby [29]. They cluster together with the two types of chernozem mentioned earlier (2 and 3).

The meadow soils (often meadow chernozems) were developed in the floodplains. This process occurred mainly in the vast stretches of wet lowland formed by the conjunction of the Southern Buh and its major tributaries (Savranka, Mohylianka). The sands and sandy soils are presented in the region in several pockets. The largest pockets are along the Savranka river and by the town of Haivoron [29].

Thus, the SBC exhibits a great variety of soils. Most soils are very fertile; however, they require somewhat different agricultural treatments to be productive. The modern dominance of chernozems is a relatively recent artifact of heavy cultivation [1].

In prehistory, humans settled in the region since the Paleolithic [30]. The Mesolithic sites are known in the region [27,31,32]. However, their chronology and cultural attribution are often uncertain. Later on, the region was occupied by groups of hunter-gatherers already equipped with pottery with the mostly extractive economy (called sub-Neolithic [33] or para-Neolithic [34]). The sub-Neolithic or para-Neolithic is defined by D.L. Haskevych as "cultures situated east [outside—D.K.] of the agricultural frontier", where "influence of farming groups on their hunter-gatherer neighbours can be seen only in the sporadic exchange of prestigious goods, as well as in attempts to imitate the decorations and forms of pottery from the Criş Vinča, and Trypillia and some other Western cultures" [14]. The chronology of these groups is yet to be clarified. There were foragers' sites with ceramic fragments by the second quarter of the sixth mill. BC [35] and some sites of this type existed in the early fifth mill. BC [36].

3. State of the Art

The empirical archaeological data on the cultural landscape in the region is sparse. The palaeobotanical analysis indicates that the alluvial deciduous forest composed of ash, oak, and elm existed on the Southern Buh riverbank in the SBC by the late seventh mill. BC and continued to exist well into LPC time, the last quarter of the sixth mill. BC [10]. At LPC Kamyane-Zavallia (Figure 2B: 12), *Triticum* cf. *dicoccum, T.* cf. *monococcum*, and cf. *Hordeum* remains demonstrated cereal use onsite. Among the weed macro remains identified at Kamyane-Zavallia, *Chenopodium album* type and *Fallopia convolvulus* can grow in cereal plots and field edges, thus showing that arable fields had replaced some parts of the forest by this time [10]. Thus, the agricultural landscape appeared in the SBC by 5250–5050 BC. The extensive data came from the Trypillian mega-site of Nebelivka (early fourth mill. BC) situated in the very north of the SBC [37–39]. Pollen analysis suggested a prolonged agricultural usage of territory around the mega-site, starting in the late fifth mill. BC [40].

No pollen cores covered the study period in the SBC. But, essential pollen cores 100 km to the west (Dovjok) and 130 km to the southeast (Troitske) contained data on the floral composition highly consistent with the paleobotanic observations [41,42].

The pedological analyses were carried out by Zh.M. Matviishyna and her students at several sites [43]. They revealed that buried soils, when preserved, belonged to several morphological types similar to those existing in the region today [21,22,44,45]. Shorter profiles of the late 5th mill BC soils made them similar to the "chernozems of southern type" developing under open grassland conditions. Thus, this observation probably reflects the existence of deforested patches in the landscape by 4350–4200 BC [23].

4. Sites and Methods

In the Southern Buh catchment, early farming settlement is represented by the sites of the Linear Pottery culture, early Trypillia, and Trypillia B1. The sections were studied on sites of these successive cultural aspects: Kamyane-Zavallia (LPC), Mohylna 3 (Trypillia A), and Kamyane-Zavallia 1 (Trypillia B1, Figure 2). The research was complemented by an analysis of two sites of ceramic hunter-gatherers (Melnychna Krucha and Mykolyna Broiaka, Figure 2: 6, 7). The sites were dated by radiocarbon method in the laboratory of Bern University (LARA) employing the MICADAS equipment [46,47]. Collagen extraction was performed according to Szidat et al. [47], which was extended with an additional ultrafiltration step. The results were calibrated with OxCal software [48], Version 4.4.4, based on the IntCal20 calibration curve [49].

Here and thereafter, we differentiate clearly between conventional radiocarbon ages (cited "BP"), calibrated ^{14}C dates (cited "calBC") and estimates interpolated from ^{14}C dates, typological seriation and stratigraphies (cited "y. BC").

The sections were studied by the micromorphological analysis in order to reconstruct the processes of pedogenesis. Thin sections were prepared in the geochemistry of isotopes laboratory of NASU by mechanical treatment without an application of HCl solution till the samples were 0.02–0.03 mm thin. The polarization microscope Min-8 aided the microscopic observation with a magnification of ×70. The details of the method employed for identifying soil structure were elaborated on in the paper [50]. The content of organic carbon was defined by the Tiurin method in modification of TSINAO [51]. Then, humus content was calculated by an application of coefficient 1.724. Granulometric analysis was performed using the Kachynskyi method [52]. Several cycles of soil development were defined for the region in question in line with the palaeoclimatological approach of M. Veklych [53]. The soil's nomenclature corresponds to the WRB scheme [54]. At the same time, local terms [29] are used when we cite the results of published research for clarification (together with internationally recognized WRB terminology) and when the international terms are not enough to describe the situation under discussion.

5. Results

5.1. Early Farming Sites

5.1.1. Kamyane-Zavallia

Kamyane-Zavallia (48°10′51″ N; 30°0′25″ E) is the easternmost excavated site of LPC. It is situated on the right bank of the Southern Buh River in front of the town of Zavallia. Excavations covered an area of 130 sq. meters in 2013–2016 and over 400 sq. meters in 2019. Finds are numerous: over 2000 potsherds, some 5000 bone fragments, plant macro-remains (charcoal, very few seeds), pieces of burnt clay, and over 500 lithics. Two radiocarbon dates from pit 1 of Kamyane-Zavallia, fall within the last three centuries of the sixth millennium BC, more precisely between 5300–5032 and 5210–4952 cal BC (6200 ± 40 BP, Poz-67121 and

6130 ± 40 BP, Poz-67554, Table 1) [10,55]. Sections 1 and 2 were studied at the northern edge of excavation pit 1 (2014–2016). Section 1 revealed sparse archaeological finds (small, rounded potsherds); thus, it is situated in the site's periphery. Section 2 cut a Neolithic pit (pit 1, which was dated by radiocarbon analysis, see above). Sections 1 and 2 were compared with the "natural" sections revealed in a cliff of the river-bank nearby as well as in the walls of stone quarry. Sections revealed similar sequences (Figure 3), which is characterized in Supplementary Table S1.

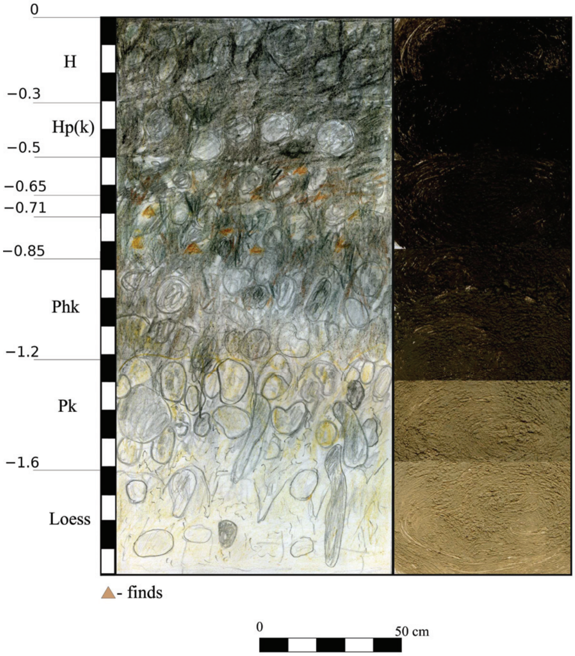

Figure 3. Kamyane-Zavallia. Soil-section 1. Captions: see Supplementary Table S1. Left column: soil horizons' indices; central column: schematic drawing; right column: photos of the actual soil textures from the respective horizons of the section.

Table 1. Relevant radiocarbon dates.

Lab No.	Site	Material	Context	Age_Uncal (y BP)	±1s (y)	Period/Culture	CalBC (1 σ)	CalBC (2 σ)	Reference
BE-7636	MK-SU4	Animal bone	Cultural layer	8368	23	Kukrek	7509–7379	7520–7357	Kiosak et al., 2021
BE-7635	MK-SU4	Animal bone	Cultural layer	8311	24	Kukrek	7454–7345	7480–7315	Kiosak et al., 2021
BE-10309	MK-SU4	Animal bone	Cultural layer	8344	23	Kukrek	7483–7362	7497–7347	Kiosak et al., 2021
Poz-67496	MK-SU3	Angiosperm	Cultural layer	7520	50	Late Mesolithic	6448–6361	6461–6252	Kiosak, Salavert 2018
BE-7639	MK-SU3	Animal bone	Under the shell pile	7436	23	Late Mesolithic	6367–6256	6381–6241	Kiosak et al., 2021
BE-10308	MK-SU3	Animal bone	Cultural layer	7404	23	Late Mesolithic	6352–6233	6365–6230	Kiosak et al., 2021
Poz-67497	MK-SU3	Ash charcoal	Cultural layer	7380	40	Late Mesolithic	6356–6216	6380–6100	Kiosak, Salavert 2018
BE-7637	MK-SU2	Animal bone	Bone scatter	6980	24	Para-Neolithic	5962–5815	5976–5787	Kiosak et al., 2021
BE-7641	MK-SU2	Antler	Bone scatter	6986	24	Para-Neolithic	5966–5841	5977–5794	Kiosak et al., 2021
BE-7638	MK-SU2	Animal bone	Bone scatter	6985	22	Para-Neolithic	5963–5841	5976–5798	Kiosak et al., 2021
BE-7640	MK-SU2	Antler	Cultural layer	6812	24	Para-Neolithic	5722–5674	5736–5651	Kiosak et al., 2021

Table 1. *Cont.*

Lab No.	Site	Material	Context	Age_Uncal (y BP)	±1s (y)	Period/Culture	CalBC (1 σ)	CalBC (2 σ)	Reference
Ki-14790	Gard	Pottery carbon	Lower layer	6630	90	Para-Neolithic	5630–5490	5721–5385	Tovkailo 2014
Ki-14789	Gard	Pottery carbon	Lower layer	6480	80	Para-Neolithic	5520–5360	5612–5310	Tovkailo 2014
Ki-14791	Gard	Pottery carbon	Upper layer	6710	80	Para-Neolithic	5710–5560	5734–5489	Tovkailo 2014
Ki-14792	Gard	Pottery carbon	Upper layer	6520	80	Para-Neolithic	5560–5370	5618–5338	Tovkailo 2014
Ki-14793	Gard	Pottery carbon	Upper layer	6400	90	Para-Neolithic	5480–5310	5546–5210	Tovkailo 2014
BE-18269	MB	Animal bone	House 1, 280 cm deep	6762	27	Para-Neolithic	5708–5631	5719–5625	Kiosak et al. sbm
BE-18270	MB	Animal bone	sq. 2-E, 268 cm deep	5731	26	Para-Neolithic	4647–4505	4678–4493	Kiosak et al. sbm
Ki-9833	Dobrianka-1	Pottery carbon	Cultural layer	6530	140	Para-Neolithic	5616–5370	5714–5224	Zalizniak et al., 2013
Ki-9834	Dobrianka-1	Pottery carbon	Cultural layer	6360	150	Para-Neolithic	5490–5080	5616–4991	Zalizniak et al., 2013
OxA-17490	Dobrianka-3	Animal bone	Cultural layer	9115	45	Mesolithic	8420–8272	8454–8252	Lillie et al., 2009
OxA-222-33 *	Dobrianka-3	Human bone	Burial	7227	40	Mesolithic	6202–6028	6210–6018	Lillie et al., 2009
Ki-11105	Dobrianka-3	Animal bone	Cultural layer	7400	130	Para-Neolithic	6411–6106	6474–6016	Zalizniak et al., 2013
Ki-11104	Dobrianka-3	Animal bone	Cultural layer	7320	130	Para-Neolithic	6354–6058	6441–5933	Zalizniak et al., 2013
Ki-11108	Dobrianka-3	Animal bone	Cultural layer	7260	170	Para-Neolithic	6354–5987	6452–5808	Zalizniak et al., 2013
Ki-11106	Dobrianka-3	Animal bone	Cultural layer	7070	150	Para-Neolithic	6068–5777	6232–5642	Zalizniak et al. 2013
Ki-11107	Dobrianka-3	Animal bone	Cultural layer	7050	160	Para-Neolithic	6056–5756	6232–5642	Zalizniak et al., 2013
GrA-33115	Dobrianka-3	Animal bone	Cultural layer	4400	35	Para-Neolithic	3088–2928	3308–2910	Biagi et al., 2007
GrA-33117	Dobrianka-3	Animal bone	Cultural layer	3595	35	Para-Neolithic	2013–1902	2113–1831	Biagi et al., 2007
Poz-67121	KZ	Bone	Pit 1	6200	40	LPC	5207–5058	5212–5042	Kiosak 2017
Poz-67554	KZ	Acer sp. Charcoal	Pit 1	6130	40	LPC	5287–5079	5296–5072	Kiosak 2017
BE-7649	MIII	Bone	Close to Ploschadka	5712	22	Trypillia A3	4580–4501	4616–4466	Kiosak et al., 2021
BE-16908	MIII	animal bone	Soil-section 1	5699	26	Trypillia A3	4549–4459	4607–4453	Kiosak et al., sbm
BE-16909	MIII	animal bone	Soil-section 1	5679	27	Trypillia A3	4539–4458	4599–4447	Kiosak et al., sbm
BE-7652	KZ 1	Bone	Inner ditch	5346	21	Trypillia B1	4252–4076	4315–4056	Kiosak et al., 2021
BE-7651	KZ 1	Bone	Inner ditch	5424	21	Trypillia B1	4331–4263	4337–4251	Kiosak et al., 2021

MK—Melnychna Krucha, SU—stratigraphic unit, MB—Mykolyna Broiaka, MIII—Mohylna 3, KZ—Kamyane-Zavallia. * Kyiv radiocarbon dates on the potsherds have shown a poor agreement with dates from other laboratories and should be treated with extreme caution [14].

The modern soil observed in section 1 is characterized by a developed profile with well-defined horizons, intense humification, a clear granular–blocky structure, and carbonates in the lower horizons (Figures 3 and 4). These traits enable us to define this soil as typical chernozem, accumulative, thick, made of light loam, formed on loess-like loams [9] of the first river terrace of the Southern Buh.

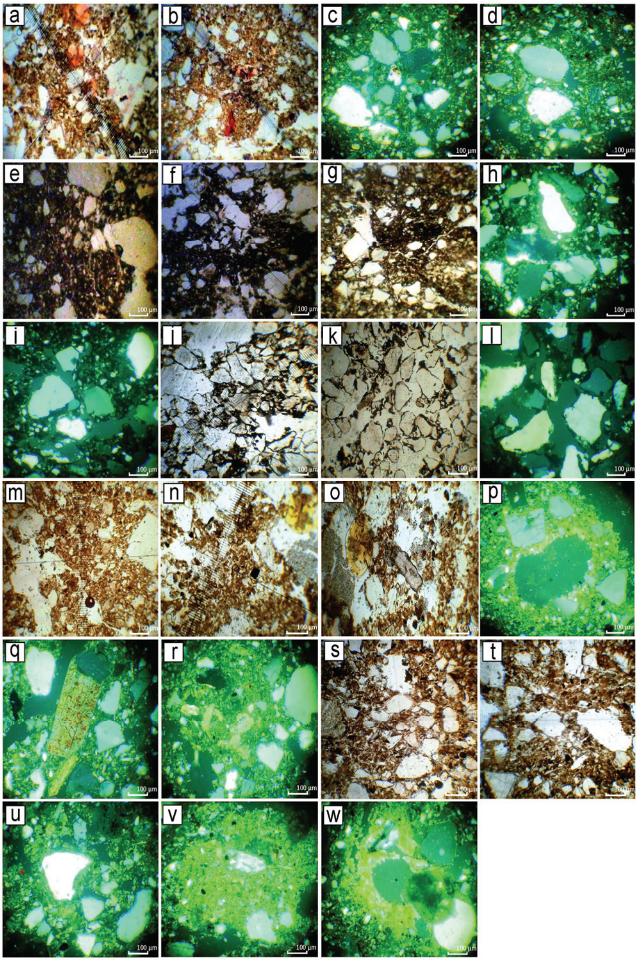

Figure 4. Kamyane-Zavallia. Soil micromorphology. Captions: see Supplementary Table S1. (**a**,**b**,**e**–**g**,**j**,**k**,**m**–**o**,**s**,**t**)—PPL (plane-polarised light); (**c**,**d**,**h**,**i**,**l**,**p**–**r**,**u**–**w**)—XPL (cross-polarized light). Magnification 1:70. Elaboration—ZM.

Section 2 revealed the same sequence but distorted by a pit of Neolithic (pit 1/9 of excavation trench 1). This pit and other pits in excavation trench 1 were traced from −0.55 m–0.6 m depth from the lower part of the horizon Hp(k). The modeling of artifact distribution in three dimensions confirms this observation [56]. The stone pavement of Linear Pottery culture was found by pit 1. The foundations of stones stood at the same depth [20]. In section 1, the sparse finds of Neolithic potsherds came from the same depth. Thus, the horizon of Neolithic activity corresponds to the lower part of the horizon Hp(k). So, the soil of LPC was reworked by further pedogenetic processes and the LPC remains were covered by the younger soil. However, it left a visible trace: humus shells of mineral grains were observed in thin sections of the sample coming from this layer. One of the authors (Zh.M.) reconstructs the soil of the Neolithic period as chernozem with three horizons H, Phk, Pk, 0.6–0.7 m thick. While the exact character of this soil is not yet apparent, it is evident that it contained a high content of humus, being arable, at least as the modern soil is. Moreover, considering that the analyzed sample comes from the horizon covering the layer of Neolithic activity (0.65–0.75 m), these observations can also relate to younger phases of the Neolithic, which are consistent with the results obtained in the nearby Trypillian settlement of Kamyane-Zavallia 1.

5.1.2. Mohylna 3

Mohylna 3 (48°14′32″ N; 30°4′45″ E) is a Trypillia A site situated on the eastern slope of a no-name tributary of the Mohylianka river (left tributary of the Southern Buh River). It is a large site with an area covering over 15 ha. Geomagnetic prospection covered seven hectares of the site's area in 1993 [57]. The extensive collections of pottery, chipped stone artifacts, and figurines were gathered on the site's surface and described on numerous occasions. N.B. Burdo noted that Mohylna 3 could hold a recent relative position in the typo-chronology of Early Trypillia [58]. The site's small faunal collection mostly comprise fragmented cattle bones (definition of O.P. Siekerska, [34]). The numerous remains of cultivated plants were detected in imprints on potsherds and daub coming from the sites of Trypillia A [14], also situated near Mohylna 3. Thus, the site's inhabitants practiced farming and herding.

Mohylna III is dated to 4616–4447 calBC (2σ) (BE-7649, 5712 ± 22 BP; BE-16908, 5699 ± 26 BP; BE-16909, 5679 ± 27 BP; Figure 2B: 14, Table 1). The latter two dates (BE-16908 and BE-16909) come from animal bones that were selected from the horizon 0.55–0.78 m deep in soil-section 1.

Soil-section 1 was situated on the very northern edge of the Trypillian site, where a deep gully created a cliff suitable for detailed examination. It was situated close to robbers' illegal excavation pit that destroyed a fired-clay dwelling (ploschadka) of Trypillia A. Despite the absence of construction elements in the test trench, it is evident that most artifacts should be linked with the dwelling. The "natural" section (soil-section 2) was examined in the cliff of the upper terrace of the Mohylianka river, some 600 m upstream. Both sections yielded comparable sequences.

Under the arable layer (Figure 5), there was the upper soils (0.0–0.57 m), transitional horizon (0.75–0.80 m), the lower soil (0.8–1.7 m) with genetic horizons (H(p)k, Hpk, Phk, Pk), and the mother-rock (Pk)—white pale loess (1.7–2.0 m and below). The soils are made of terrace deposits of the Mohylna river valley. The soil profile is saturated by $CaCO_3$ from the very surface to the bottom of the section in the shape of solved carbon and many micellar carbonates. Humus distribution (Figure 6) and granulometric composition (Figure 7) reflect several cycles of pedogenesis. The modern soil is gleyic chernozem, with micellar carbonates and a deep humic horizon. The finds of Early Trypillian artefacts were detected in the horizon 0.65–0.9 m deep. The same observation was made during an extensive archaeological test-trenching [34]. Thus, Trypillian activity happened on the surface of the lower soil. The process of soil formation can be reconstructed as follows (from bottom to top):

1. Formation of pale white loess—cold periglacial steppe, likely of Buh phase.
2. Early Holocene deposits altered by further pedogenesis.
3. The lower soil, already well-developed by the foundation of the Early Trypillian site, probably of chernozem type with brownish coloring and structural peculiarities transitional to kastanozems formed under arid conditions.
4. Erosional event—carbonate-rich light horizon at 0.75–0.8 m.
5. At least two cycles of pedogenesis of modern-day gleyic chernozem.

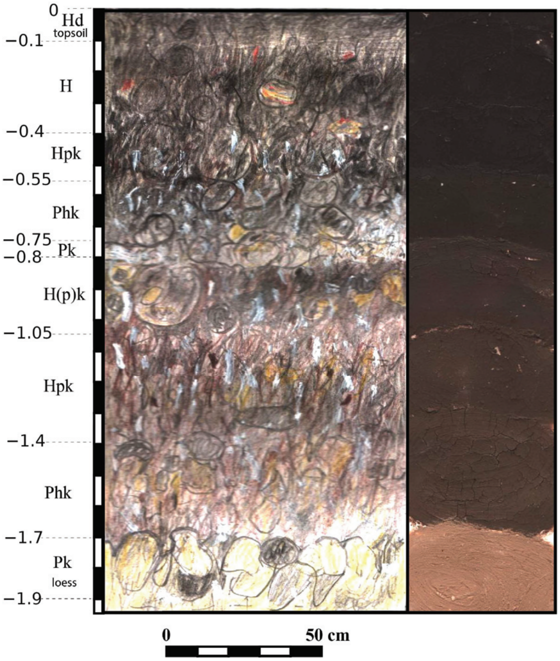

Figure 5. Mohylna 3. Soil-section 1. Captions: see Supplementary Table S2. Left column: soil horizons' indices, dotted lines indicate changes of horizons; central column: schematic drawing; right column: photos of actual soil textures from respective horizons of the section, taken afield by gluing a respective sample to a sheet of paper; Elaboration—ZM.

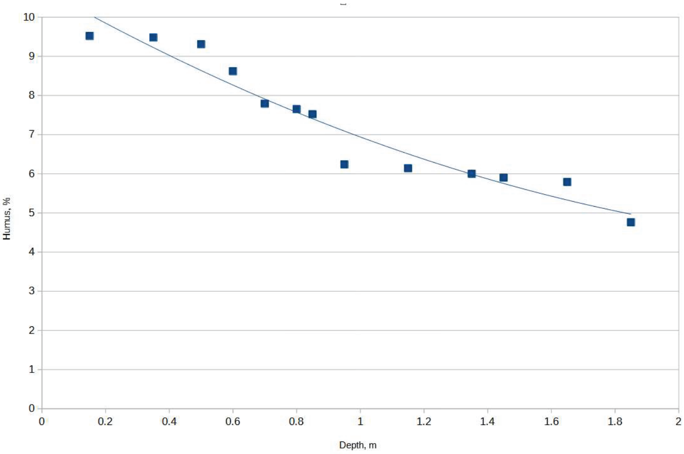

Figure 6. Humus content in the section 1 of Mohylna 3. Analysis by H.P. Zadverniuk. Elaboration—DK.

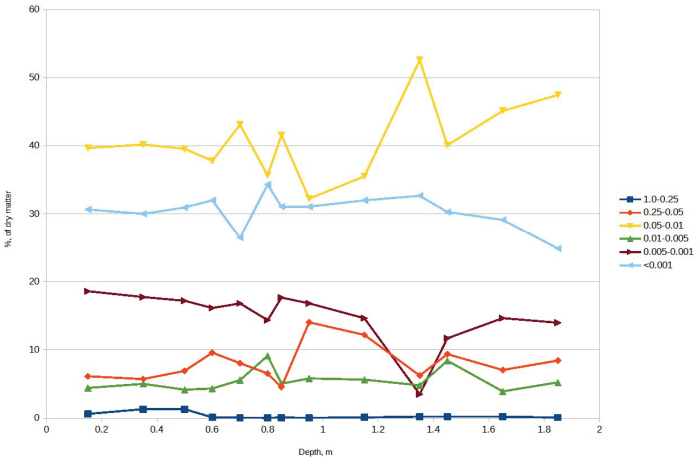

Figure 7. Granulometry of soils in the section 1 of Mohylna 3. Analysis by O.O. Halahan. Legend: sizes of particles in mm. Elaboration—DK.

5.1.3. Kamyane-Zavallia 1

Kamyane-Zavallia 1 (48°12′12″ N; 30°0′12″ E, Figure 2B: 11) is a site of the first stage of developed Trypillia (Trypillia B1). It is situated on a flat promontory of the first terrace of the right bank of the Southern Buh River. The site yielded ceramic groups similar to Trypillia A and small potsherds with painted decorations indicative of the Trypillia B1 (Cucuteni A3–4) stage. The lithic inventory comprise minor flat bifacial projectile points, a characteristic of developed Trypillia. The site belongs to the same local group with the nearby Trypillian sites excavated on the larger area: Sabatynivka 1 and Berezivska HES [59]. Both latter sites yielded abundant evidence of the agriculture: remains of domestic animals and cultivated plants [14,23]. The site of Kamyane-Zavallia 1 consisted of the habitation zone surrounded by two ditches [19]. Two animal bones from the inner ditch filling were selected for radiocarbon analysis. They yielded dates of 4337–4056 calBC, 2σ (Table 1) [59].

The soil-section was studied in the test-trench 3, opened outside the Trypillian ditch (Figure 8), thus in the archaeological site's periphery. The "on-site" observations were controlled by examination of the modern cliff of the Southern Buh river in the vicinity of the site.

The soil profile with horizons H, Hp, Ph, P, and absence of carbonates are characteristic of mollic fluvisols formed on the alluvial silty loam (Figures 8 and 9).

In this case, pedogenesis occurred in the high meadow plain on a sandy substrate. The most intense humus horizon is not the upper layer here, but the horizon from 0.3–0.7 m deep, especially the lower part of it (Figure 9, Supplementary Table S3). The available soil profile can be explained if the late Atlantic period mollic fluvisol was a substrate for the formation of modern soil and was only partially altered during this process. The artifacts of the Trypillian period were primarily attested in the humus (upper) horizon of the late Atlantic soil. The soil contained more humus than modern soil, so it was probably at least as arable as modern soil. The soil is relatively light for working because it was formed on the alluvial sands of the high meadow terrace. This sandy substrate is in clear contrast with the mostly loess substrate of the soils, which LPC farmers selected.

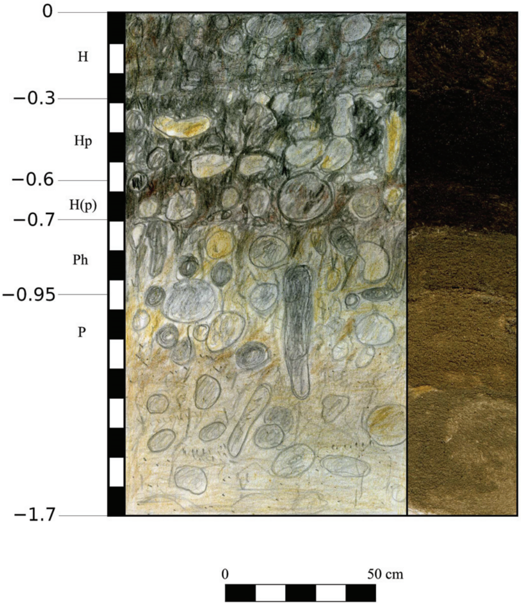

Figure 8. Kamyane-Zavallia 1. Soil-section 1. Captions: see Supplementary Table S3. Left column: soil horizons' indices, dotted lines indicate changes of horizons; central column: schematic drawing; right column: photos of actual soil textures from respective horizons of the section, taken afield by gluing a respective sample to a sheet of paper. Elaboration—ZM.

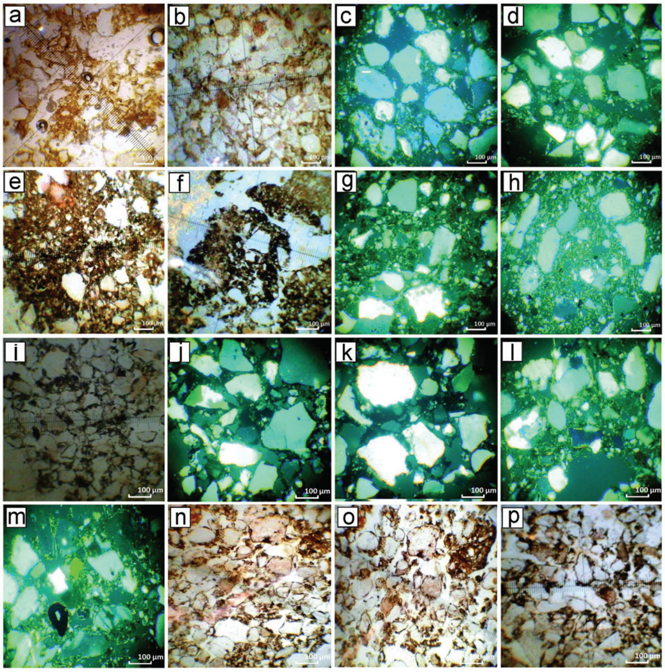

Figure 9. Kamyane-Zavallia 1. Soil micromorphology. (**a**,**b**,**e**,**f**,**i**,**n**–**p**)—PPL, (**c**,**d**,**g**,**h**,**j**–**m**)—XPL. Magnification 1:70. Elaboration—ZM.

5.2. Sites of Hunter-Gatherers

5.2.1. Melnychna Krucha

Melnychna Krucha (48°8′49″ N; 30°13′1″ E, Figure 2B: 6) is a stratified site that yielded finds dating from the Mesolithic till the Iron Age. It is situated on the left northern bank of the Southern Buh River in the meadow plain. The site was discovered by S. I. Chub in 1930 and was excavated on several occasions from 1931 to 1949 [60]. The recent excavation project (2012–2018, jointly with prof. N. Kotova, Institute of Archaeology, Kyiv; and prof. W. Tinner, University of Bern) revealed a complex sequence with some stratigraphic units.

Stratigraphic unit (SU) 1a contained dispersed potsherds and bones of the late Bronze Age and Iron Age, while SU1b yielded potsherds of the Eneolithic period (late fifth–early fourth mill. BC, [61,62]).

SU2 consisted of a dense scatter of bones, debris of decortification of several concretions of yellow-wax flint layer of lithics, and eight potsherds. This habitation belonged to local pottery-bearing groups, with subsistence still primarily based on fishing, hunting, and gathering. The recovered bones mostly belonged to red deer and wild boar (definition of O.P. Siekerska [35]). The archaeobotanical analysis combined with flotation failed to recover remains of cultivated plants coming from this unit [10]. Three very consistent radiocarbon dates date it to 5966–5787 cal BC (BE-7641: 6986 ± 24 BP; BE-7638: 6985 ± 22 BP; BE-7637: 6980 ± 24 BP, Table 1), while a single determination is younger than the rest—5736–5651 cal BC (BE-7640: 6812 ± 24 BP, [35]).

SU3 contained lithic artifacts, fragmented animal bones, turtle shell plates, avian bones, fish vertebrae, and bones of small mammals. The lithic inventory is microlithic with some microcores, end-scrapers on flakes, backed bladelets, and an isosceles trapeze [32]. Four radiocarbon dates come from SU3, dating to the last half of the seventh mill. BC, namely 6461–6100 cal BC (Poz-67496: 7520 ± 50 BP, BE-7639: 7436 ± 23 BP, BE-10308: 7404 ± 23 BP, Poz-67497: 7380 ± 40 BP, Table 1, [35]).

The lowermost layer (SU4) contained fragmented auroch bones and lithic implements. The chipped stone inventory included:

- Conical cores for fine bladelets and microblades;
- Multiple burins on blade's spalls;
- Blade fragments with ventral trimming and retouch (so-called Kukrek inserts, [27,63,64]);
- Points with partial abrupt retouch forming a distal acute tip and a notch on the opposite end by a bulb [32].

Three dates come from this unit. They encompass 7520–7315 cal BC, (BE-7636: 8368 ± 23 BP, BE-10309: 8344 ± 23 BP, BE-7635: 8311 ± 24 BP, Table 1, [35]).

Thus, the Melnychna Krucha is a "long" sequence, covering the eighth–fifth/fourth mill. BC.

Paleopedological analysis was carried out on the eastern wall of square 6 of the excavation pit of Melnychna Krucha and on the nearby cliff of the Southern Buh Riverbank outside the archaeological site. Both sections ("archaeological" and "natural") yielded the same sequence. The general depth of sediments is over 4 m. The rapid accumulation rates led to the repeated burying of the ancient soils, avoiding their complete alteration in the younger pedogenesis. There are three consecutive soils in the sequence (Figure 10).

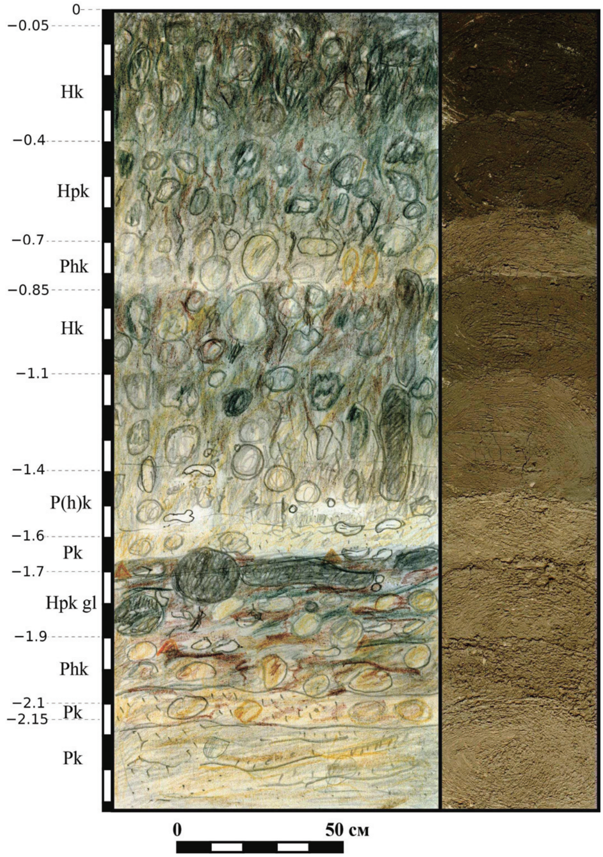

Figure 10. Melnychna Krucha. Soil-section 1. Captions: see Supplementary Table S4. Left column: soil horizons' indices, dotted lines indicate changes of horizons; central column: schematic drawing; right column: photos of actual soil textures from respective horizons of the section, taken afield by gluing a respective sample to a sheet of paper. Elaboration—ZM.

Sections revealed a complex soil sequence up to 4 m deep. There are three consecutive pedogenesis cycles, reflected in respective soils with developed profiles. The upper soil (0.0–0.85 m) comprises four genetic horizons (Supplementary Table S4, Figures 11–13) and is clearly separated from the underlying sediments by a well-visible lighter horizon of light dusty loam. The middle soil (0.85–1.7 m) is a light loam with upper horizons rich in humus formed on the lower horizons of light yellow color and loess-like texture. In the excavation pits the horizons corresponding to the middle soil contained artefacts of Eneolithic (the late 5th–early 4th mill. BC, definition of N.S. Kotova [21]). The lower soil (1.7–1.9 m) is a light sandy loam with humus-rich upper horizon—Hpk (gl)—1.7–1.9 m—humus horizon with interchanging layers of grey and brownish-grey stripes 5–7 cm wide. The stripped pattern indicates periodic flooding. In the vicinity of Melnychna Krucha, accumulative processes shaped the formation of a high meadow plain from alluvial material with partial redeposition of the latter under the subaerial conditions. It resulted in the development of a soil sequence thicker than the soils of similar age in the higher river terraces and watershed plateaus. The active deposition enabled us to define three soils separated by illuvial carbonate horizons.

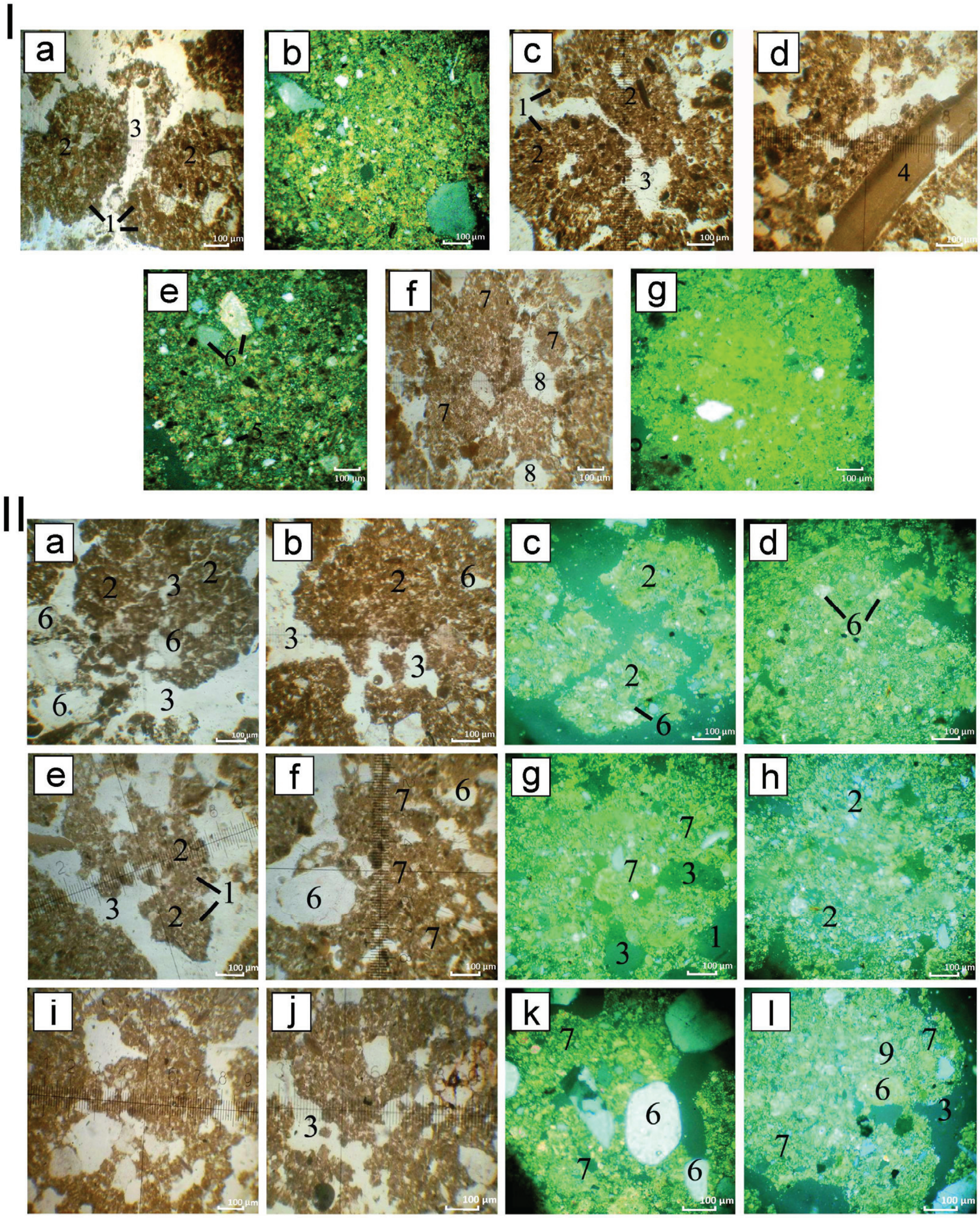

Figure 11. Melnychna Krucha. Micromorphology of soils in the section 1. **I**—upper soil, (**a**,**c**,**d**,**f**)—PPL; (**b**,**e**,**g**)—XPL. **II**—middle soil: Captions: see Supplementary Table S1. Left column: soil horizons' indices; central column: schematic drawing; right column: photos of the actual soil textures from the respective horizons of the section. (**a**,**b**,**e**,**f**,**i**,**j**)—PPL, (**c**,**d**,**g**,**h**,**k**,**l**)—XPL. Magnification 1:70. Elaboration—ZM.

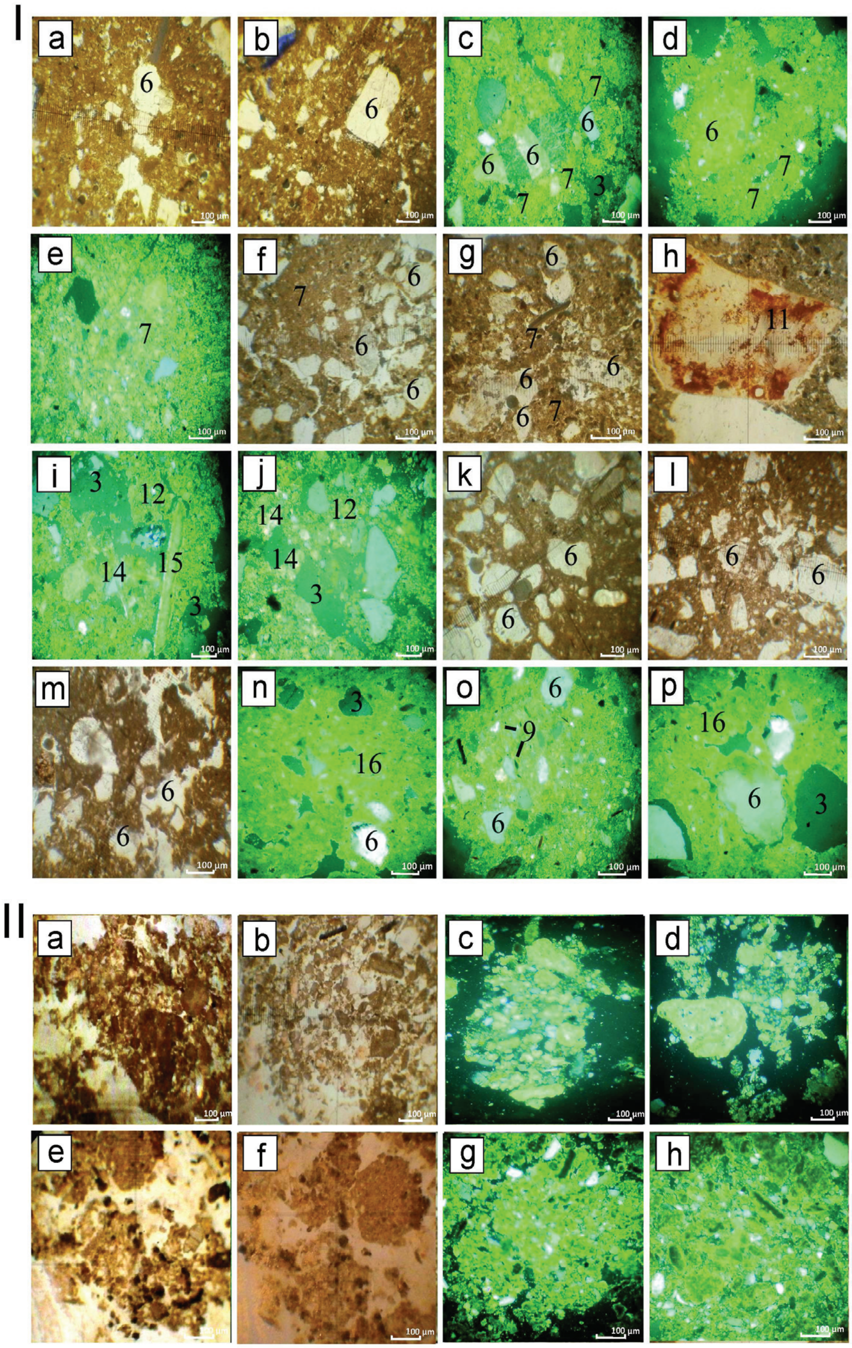

Figure 12. Melnychna Krucha. Micromorphology. **I**—lower soil of the section 1, (**a**,**b**,**f**–**h**,**k**–**m**)—PPL; (**c**–**e**,**i**,**j**,**n**–**p**)—XPL. **II**—soils of the section 2. Captions: see Supplementary Table S4. Left column: soil horizons' indices; central column: schematic drawing; right column: photos of the actual soil textures from the respective horizons of the section. (**a**,**b**,**e**,**f**)—PPL, (**c**,**d**,**g**,**h**)—XPL. Magnification 1:70. Elaboration—ZM.

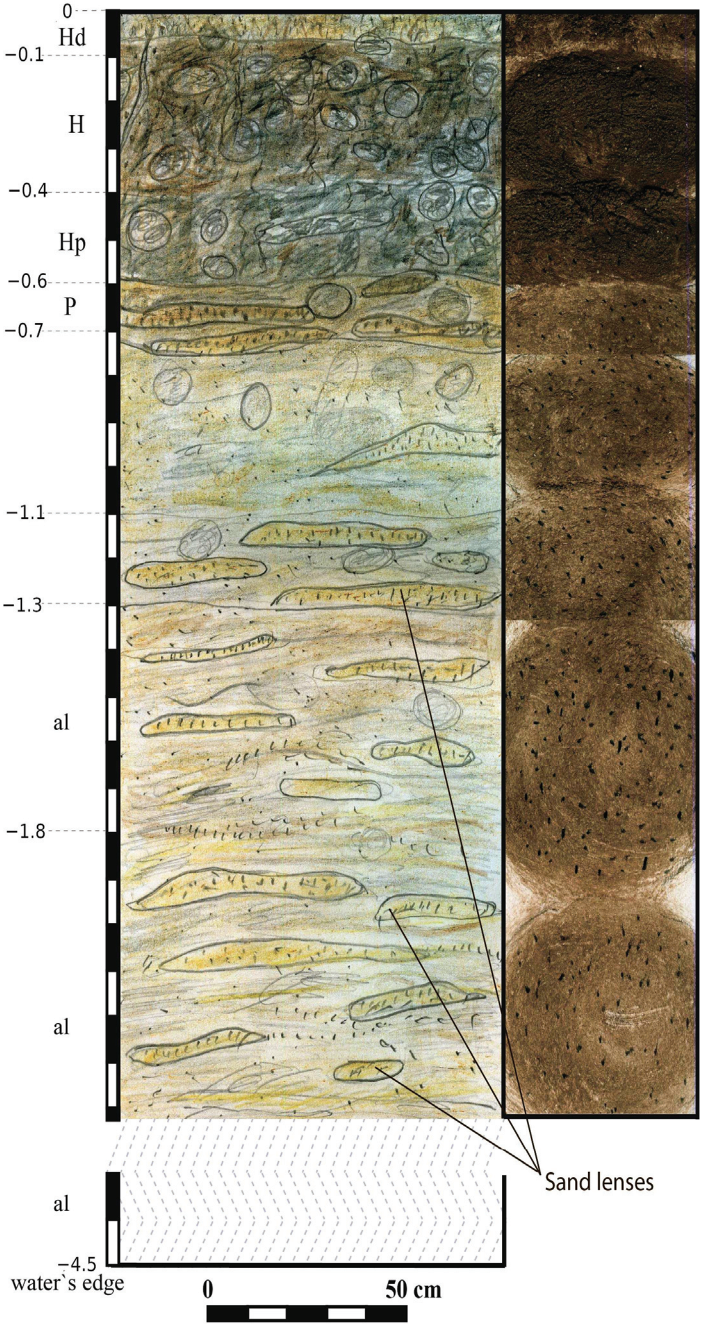

Figure 13. Melnychna Krucha. Soil-section 2. Captions: see Supplementary Table S4. Left column: soil horizons' indices, dotted lines indicate changes of horizons; central column: schematic drawing; right column: photos of actual soil textures from respective horizons of the section, taken afield by gluing a respective sample to a sheet of paper. Elaboration—ZM.

The upper and middle soils were formed under subaerial conditions, while the lower soil developed in a very moist environment, which was probably periodically flooded. The margin between the middle and lower soils is clear and likely represents an erosion event. It also corresponds to an interruption of soil formation processes, when organic matter was largely reduced, and instead, yellow dust and sand formed the lowermost horizon of the middle soil. The upper and middle soils resemble calcaric fluvisols formed under steppe vegetation on light clay loam of alluvial origin. In contrast, the lower soil is gleyic podzol from a taxonomic point of view and was formed under hydromorphic conditions.

The SU2 (ceramic hunter-gatherers) remains are associated with the lowermost part of the middle soil (horizons Pk and P(h)k), SU3 (the late Mesolithic) with the upper horizon of the lower soil (horizon Hpk (gl)), while SU4 (the middle Mesolithic) was uncovered in the lower horizons of the lower soil (Phkgl and Pkhorizons). Thus, both stratigraphic units of Mesolithic age were developed under wet, periodically watered conditions, along the river beach. The ceramic hunter-gatherers of SU2 settled on the hydromorphic soil barely suitable for any meaningful agricultural activity.

5.2.2. Mykolyna Broiaka

Mykolyna Broiaka (48°09′50′′ N 30°53′02′′ E, Figure 2B: 7) is a site of ceramic hunter-gatherers. It was found by local inhabitants and excavated by P. Kharlampovych in 1932 [65] and by V. Danilenko and M. Shamglii in 1955 [27]. Both excavations revealed a complex stratigraphy: two layers of ceramic hunter-gatherers material culture at a certain distance from the riverbank in 1955 [27] or a probable Eneolithic horizon above the shell-midden with hunter-gatherers potsherds and lithics in 1932 [66]. Two radiocarbon dates come from this site: from the lower layer—5719–5625 cal BC (Be-18269, 6762 ± 27 BP), and from the upper stratigraphic unit—4678–4493 cal BC (BE-18270, 5731 ± 26 BP, Table 1), probably corresponding to the shell-midden in excavations of 1932.

There were two studied soil sections: section 1 by the site of an older excavation of 1932 and section 2 in a natural context some 200 m downstream. Both sections cut a cliff (0.7 m high) of a meadow terrace rising above the lower floodplain about 20 m wide. Section 1 revealed a modern soil (0.0–0.5 m) of gleyic mollic fluvisol type. Underneath, there was a sequence of dark loose horizons of clay loam (20–50 cm thick) separated by white-yellow-grey dense horizons 5–10 cm thick, indicating events of prolonged flooding (Figure 14). In general, the sequence was formed in hydromorphic regime. The section cut the shell-midden at a depth of 1.8–1.9 m, which corresponds well with the depth reported in the 1932 excavation. Thus, we can establish the stratigraphic position of the horizon related to activity of ceramic hunter-gatherers in the section 1. It is embedded between humic (Figure 15) sediments formed under hydromorphic regime, under conditions of periodical flooding. The latter is clearly reflected in periodic changes in granulometry of sediments (Figure 16).

Section 2, which was situated outside the archaeological site, confirmed this observation yielding a sequence of soils formed under conditions of periodic flooding, probably corresponding to the upper six horizons observed in section 1 (See descriptions of sections, Supplementary Table S5). Thus, the site of ceramic hunter-gatherers was situated on the beach of the riverbank and was flooded periodically. They settled on the marshy alluvial sediments barely suitable for arable agriculture.

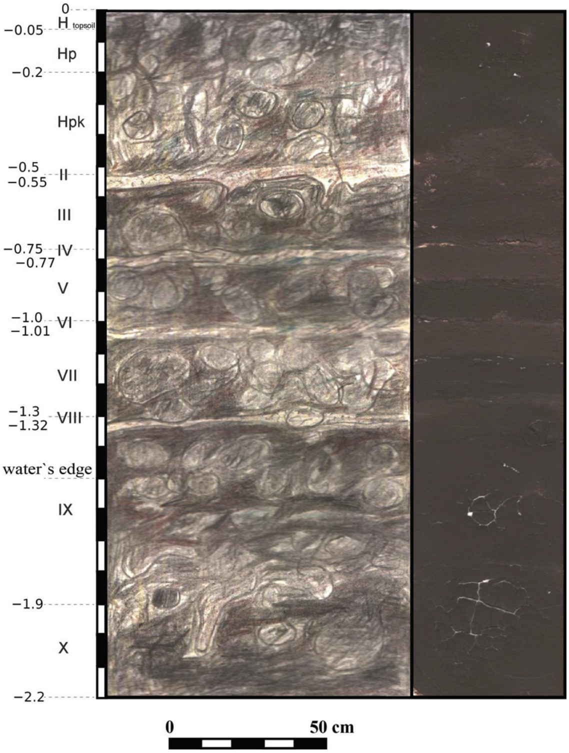

Figure 14. Mykolyna Broiaka. Soil-section 1. Captions: see Supplementary Table S5. Left column: soil horizons' indices, dotted lines indicate changes of horizons; central column: schematic drawing; right column: photos of actual soil textures from respective horizons of the section, taken afield by gluing a respective sample to a sheet of paper. Elaboration—ZM.

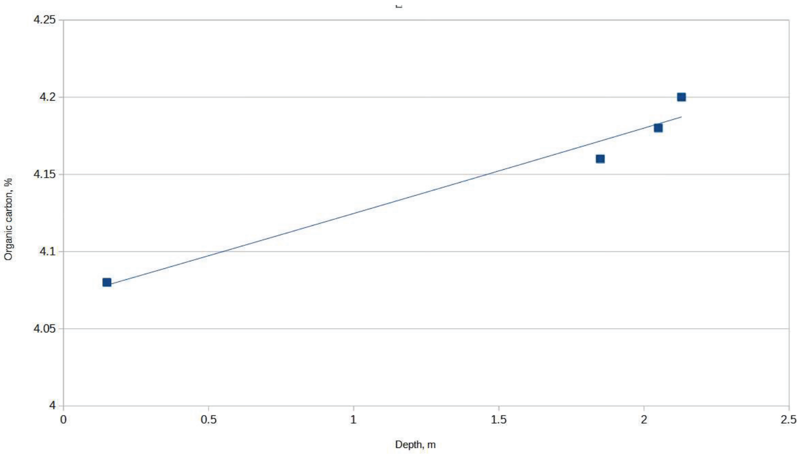

Figure 15. Mykolyna Broiaka. Organic carbon content in soil-section 1. Analysis by H.P. Zadverniuk. Elaboration—DK.

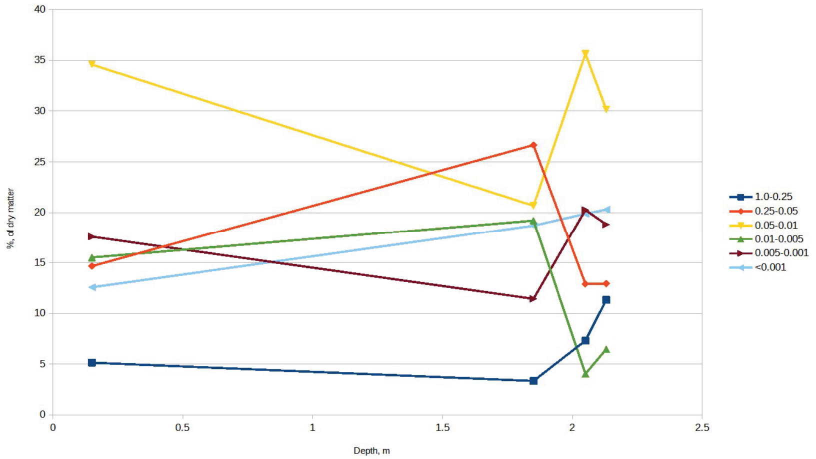

Figure 16. Mykolyna Broiaka. Granulometry in soil-section 1. Legend: sizes of particles, in mm. Analysis by O.O. Halahan. Elaboration—DK.

6. Discussion

Neolithic farmers had certain patterns of soil exploitation, which were well established in central and southern Europe [28,67,68]. However, the geographical correspondence between Neolithic sites and the modern soil distribution can be misleading, because soils underwent a prolonged evolution, which could have altered their character in some regions. Particular sedimentary conditions exist at many Neolithic sites in the south of eastern Europe. The archaeological remains are covered by a thick (sometimes over 1 m) layer of later Holocene deposits. On the one hand, this situation makes any large-scale excavation of these sites a complex enterprise [69]. On the other hand, it opens the possibility to study the soil sequences looking for trends of pedogenesis during the Holocene [70].

The earliest agriculture in the Southern Buh catchment is attested by finds of archaeobotanical remains in the LPC settlement of Kamyane-Zavallia [10]. The pedological analysis of the soil sections at this site revealed traces of a fertile, humic, short-profiled soil formed on the loess. The modern soil at the site is fertile chernozem, morphologically light clay loam. Micromorphological analysis indicates the feeble presence of buried soil at a depth of the expected walking surface (−50–−85 cm). It is dark grey or blackish, loose with evident blocky–granular, light clay loam. Under microscope, it is well visible that every sand grain is surrounded by a humic–clayish cover, thus indicating fertility comparable with the modern local soil. This arable soil existed during LPC time or slightly post-dated the LPC habitation.

In the Mohylna 3 site, the Early Trypillian farmers exploited a fertile soil of chernozem type transitional to kastanozems by its structural characteristics, indicating arid conditions when it was formed. The buried soil is rich in humus and organic carbon.

The Trypillia B1 (4400–4200 BC) farmers built their settlements by mollic fluvisol formed on sandy alluvial deposits (Kamyane-Zavallia 1, this work) or by chernozem formed on alluvial silts (Sabatynivka 1, [23]). The buried soils contained humus horizons 25–30 cm thick, thus being fertile. The groups of later stages of Trypillia from the nearby portions of the Dnieper River basin also exploited chernozem soils (Likareve, Trypillia B2; [44,45,71]). In the site of Sabatynivka 1, the development of chernozem was stopped by erosional event of the late fifth mill. BC [23]. Similar chronology maybe applicable also to lower soils of Mohylna 3 and Kamyane-Zavallia 1.

Contrary to the above-described pattern, the ceramic hunter-gatherers settled on soils of other types. Their remains were found in the erosional event layer above silty alluvial deposits at Melnychna Krucha and inside marshy–fluvial layered sediments at Mykolyna

Broiaka. Although the modern soils on both sites are arable and exploited for agriculture, it seems that the soils available in sixth–fifth mill. BC were not suitable for agriculture, and humans settled on the riverbanks pursuing other economic needs, probably fishing, hunting, and gathering.

This observation can be checked by a reference to four other sites of local hunter-gatherers studied by pedological approach. The sites of Dobrianka 1 and 3 [18,72] were investigated in the valley of Velyka Vys river (a second-order tributary of Southern Buh). They seem to contradict the observation under discussion, because Zh.M. Matviishyna reconstructed chernozems as the buried soils corresponding to "Neolithic" period layers at these sites [21]. However, we should consider the complexity of the taphonomic situation on both sites [73]. The dating efforts yielded dates of the early Holocene [74], late seventh mill. BC [18], as well as some Bronze Age dates [75] coming from the same depth (Table 1). So, the chernozems could be formed later with the altered materials of the "Neolithic" cultural layer.

The site of Gard yielded a sequence about 3 m deep. This site's lower layer is a para-Neolithic layer, rich in lithic implements and pottery with some imports of the late Criş culture (5600–5400 BC) [76]. It is a H(p) horizon of mollic fluvisol. This soil formed under wet conditions on alluvial sandy loam. The upper layer of Gard contained the "Late Neolithic" layer, where hunter-gatherers' ceramics and Trypillia A potsherds were found in large quantities [16]. This soil is formed in subaerial conditions and is suitable for some limited agriculture. In the Lidyna Balka site, the soil corresponding to the para-Neolithic horizon is gleyic mollic fluvisol, also formed under quite wet conditions [22].

The local hunter-gatherer groups of the Southern Buh River valley were treated as Neolithic when their culture was discovered [27,77]. R. Tringham suggested that they were fishers, hunters, and gatherers acquainted with agriculture and herding [78]. Later on, this model was elaborated by D. Telegin [36,79,80] and N. Kotova [15,81,82]. M. Zvelebil and M. Lillie suggested they were hunters in the availability phase [83]. Recently, a growing amount of data sheds doubt on the acquaintance of the indigenous groups of the Southern Buh River with an agriculture-based economy. The imprints of domestic plant seeds and pericarps in shards of para-Neolithic pottery were reexamined, and no compelling evidence of domesticates was found [14,84]. The archeozoological collections contained either no domestic animal bones or were mixed with later materials, thus casting doubt on the evidence of herding [85]. The flotation efforts on the sites of ceramic hunter-gatherers failed to produce the remains of domestic plants, despite good preservation of archaeobotanical remains [10,86]. In the catchment of the Dnieper River, isotope studies on the human bones demonstrated a late (fifth mill. BC) arrival of herding in the region [87]. The settlement pattern studies have demonstrated that local hunter-gatherers tended to settle by the river rapids in meadow plains and on river islands, where agriculture is impossible even today. At the same time, early farming sites cluster on the first terraces by small streams and gullies in places suitable for agriculture [88–90]. Thus, nowadays, it seems that, by the arrival of LPC farmers, indigenous groups practiced an exclusively extractive economy in southern Ukraine [11].

Our results on buried soils from hunter-gatherers' sites reinforce this observation. In four of seven reported cases, para-Neolithic remains were found to be associated with soils formed under periodical flooding, barely suitable for agriculture. A single case (upper horizon of Gard) yielded soil suitable for limited agricultural activities such as gardening [22]. Moreover, two cases when chernozems were attested with artifacts of ceramic hunter-gatherers can be effectively doubted on taphonomic grounds. It seems we cannot be sure about the chronology of these soils. In contrast, every early farming site under study yielded fertile soil: three cases of chernozems of different types and a single case of mollic fluvisol, rich in humus with a developed profile.

The issue of hunter-gatherers/early farmers interaction is particularly vivid in the south of eastern Europe. Here, two subsistence systems coexisted for millennia in six–fourth mill. BC. Sometimes, in a single microregion, there are sites of hunter-gatherers, and those of early farmers separated just by a few kilometers of distance. This is the case in the Southern Buh valley, where LPC sites of Kamyane-Zavallia and Hnyla Skelia stood less than 4 km from hunter-gatherers sites of Zavallia and Zhakchyk, the Trypillia A settlement of Haivoron stood near the hunter-gatherers' site Haivoron-Polizhok, and Trypillia B1 sites neighbored the hunter-gatherers' sites of Melnychna Krucha and Savran. In the 1980s, the issue of possible coexistence between hunter-gatherers and agrarian communities was taken into account in relation to the first reliable absolute dates for the period in question [36,80]. In recent years this topic definitely became part of the broader discussion of the Neolithization of eastern Europe [33,63,90–92]. Significant new information also playing a crucial role in these discussions comes from sites recently discovered particularly in the Southern Buh catchment [20,38]. These discoveries, combined with the application of fine-tuned radiocarbon dating and geoarchaeological studies, are now gradually widening the gap between both societies in question.

The observation of the soil preferences enables us to argue that the early farmers (LPC and Trypillia) and indigenous hunter-gatherers equipped with pottery had different spatial organization; the former looked for arable fields while the latter for good fishing places. These differences could be evidence of different mobility cycles within the same space, utilized in different economic ways. Their economic needs intersected only partially, and thus, there was limited competition for spatially distributed resources. Indeed, this model is a simplification. The economic cycles of both cultures were quite complex and could not have depended only on the exploitation of single locations. However, the tendency is evident nowadays: the hunter-gatherers' sites are often found on periodically flooded soils, while early farmers often relied on chernozems.

7. Conclusions

In this work, we studied the geographical correspondence between sites of several Neolithic cultures and the past soil distribution. In order to carry out the comparison, we compiled the radiocarbon database (Table 1) and conducted paleopedological research on three sites of early farmers and two sites of indigenous groups with an extractive economy. The results indicate a variable pattern of soil exploitation.

The soil development has been attested since, at least, the beginning of the fifth mill. BC, followed by the development of chernozem soils, which were interrupted by an erosional episode at the end of fifth millennium cal BC. Paleopedological analysis has shown that past soils can significantly differ from modern-day soils at the same site. Sometimes, these discrepancies are crucial for our interpretation of an economic basis of past societies (Melnychna Krucha being the most evident example).

The available data show that the soils of early farmers are arable as are the present-day ones. The early farmers were able to exploit relatively heavy soils to cultivate wheat and barley as early as 5250–5050 cal BC. Early farmers' sites stood on chernozem soils (three cases), or on chernozem-type soil (a single case) and on a mollic fluvisol (a single case). There is no evidence to suggest that the chernozem soils were ploughed rather than worked by sticks and hoes, nor did this paper aim to provide such an evidence. In contrast, the sites of ceramic hunter-gatherers were often located on soils that formed under wet conditions along seasonally-flooded riverbanks, which were almost unsuitable for agricultural practices, namely on silty alluvial deposits (three cases), or on marshy–fluvial layered sediments (a single case) or on a mollic fluvisol (a single case), while two cases were dismissed as dubious from post-depositional perspective.

The database (twelve sites) is yet limited and the further research can change the observed pattern. At the moment, we can suppose that early farmers and ceramic hunter-gatherers had drastically different preferences in soil selection. Early farming sites were often situated on arable soils, while hunter-gatherers paid little attention to fertility of an underlying soil when choosing a location for a site. Surely, sites could have been located at a certain distance from paleofields. However, combining different lines of inquiry (archaeobotanical and paleozoological data, observations on sites' topography), the presented data contradict the hypothetical model of limited agriculture practiced by the ceramic hunter-gatherers in the Southern Buh river basin.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land12020388/s1, Supplementary Table S1: Soil section 1 of the Kamyane-Zavallia site, Supplementary Table S2: Soil section 1 of the Mohylna 3 site, Supplementary Table S3: Soil section 1 of the Kamyane-Zavallia 1 site, Supplementary Table S4: Soil section 1–2 of the Melnychna Krucha site, Supplementary Table S5: Soil section 1 of the Mykolyna Broiaka site.

Author Contributions: Conceptualization, D.K. and Z.M.; methodology, Z.M.; software, D.K.; fieldwork, D.K. and Z.M.; sections' description, Z.M.; micromorphology, Z.M.; radiocarbon dates' interpretation, D.K.; archaeological contexts, D.K.; writing—original draft preparation, D.K.; writing—review and editing, Z.M.; funding acquisition, D.K. All authors have read and agreed to the published version of the manuscript.

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References

1. Pozniak, S. Chernozems of Ukraine: Past, Prezent and Future Perspectives. *Soil Sci. Annu.* **2019**, *70*, 193–197. [CrossRef]
2. Saile, T. On the Bandkeramik to the East of the Vistula River: At the Limits of the Possible. *Quat. Int.* **2020**, *560–561*, 208–227. [CrossRef]
3. Dreibrodt, S.; Hofmann, R.; Dal Corso, M.; Bork, H.-R.; Duttmann, R.; Martini, S.; Saggau, P.; Schwark, L.; Shatilo, L.; Videiko, M.; et al. Earthworms, Darwin and Prehistoric Agriculture-Chernozem Genesis Reconsidered. *Geoderma* **2022**, *409*, 115607. [CrossRef]
4. Schmidt, M.W.I.; Skjemstad, J.O.; Gehrt, E.; Kögel-Knabner, I. Charred Organic Carbon in German Chernozemic Soils. *Eur. J. Soil Sci.* **1999**, *50*, 351–365. [CrossRef]
5. Gerlach, R.; Baumewerd-Schmidt, H.; van den Borg, K.; Eckmeier, E.; Schmidt, M.W.I. Prehistoric Alteration of Soil in the Lower Rhine Basin, Northwest Germany—Archaeological, ^{14}C and Geochemical Evidence. *Geoderma* **2006**, *136*, 38–50. [CrossRef]
6. Gerlach, R.; Fischer, P.; Eckmeier, E.; Hilgers, A. Buried Dark Soil Horizons and Archaeological Features in the Neolithic Settlement Region of the Lower Rhine Area, NW Germany: Formation, Geochemistry and Chronostratigraphy. *Quat. Int.* **2012**, *265*, 191–204. [CrossRef]
7. Lorz, C.; Saile, T. Anthropogenic Pedogenesis of Chernozems in Germany?—A Critical Review. *Quat. Int.* **2011**, *243*, 273–279. [CrossRef]
8. Von Suchodoletz, H.; Tinapp, C.; Lauer, T.; Glaser, B.; Stäuble, H.; Kühn, P.; Zielhofer, C. Distribution of Chernozems and Phaeozems in Central Germany during the Neolithic Period. *Quat. Int.* **2019**, *511*, 166–184. [CrossRef]
9. Matviishyna, Z.M.; Doroshkevych, S.P. Micromorphological Peculiarities of the Pleistocene Soils in the Middle Pobuzhzhya (Ukraine) and Their Significance for Paleogeographic Reconstructions. *J. Geol. Geogr. Geoecology* **2019**, *28*, 327–347. [CrossRef]
10. Salavert, A.; Gouriveau, E.; Messager, E.; Lebreton, V.; Kiosak, D. Multi-Proxy Archaeobotanical Analysis from Mesolithic and Early Neolithic Sites in South-West Ukraine. *Environ. Archaeol.* **2020**, *26*, 349–362. [CrossRef]
11. Motuzaite-Matuzeviciute, G.; Telizhenko, S. The First Farmers of Ukraine: An Archaeobotanical Investigation and AMS Dating of Wheat Grains from the Ratniv-2 Site. *Archaeol. Litu.* **2016**, *17*, 100–111. [CrossRef]
12. Potekhina, I.; Telegin, D. On the Dating of the Ukrainian Mesolithic-Neolithic Transition. *Curr. Anthropol.* **1995**, *36*, 823–826. [CrossRef]
13. Telegin, D.Y.; Lillie, M.; Potekhina, I.D.; Kovaliukh, M.M. Settlement and Economy in Neolithic Ukraine: A New Chronology. *Antiquity* **2003**, *77*, 456–470. [CrossRef]
14. Endo, E.; Nasu, H.; Haskevych, D.; Gershkovych, Y.; Videiko, M.; Yanevich, O. Re-Identification of Plant Impressions on Prehistoric Pottery from Ukraine. *J. Archaeol. Sci. Rep.* **2022**, *42*, 103364. [CrossRef]
15. Kotova, N.S. *Neolithization in Ukraine*; John and Erica Hedges Ltd.: Oxford, UK, 2003.
16. Tovkailo, M. *Neolithic of Steppe Buh Region [Neolit Stepovogo Pobuzhzhia]*; Shliakh: Kyiv, Ukraine, 2005; p. 160.
17. Okhrimenko, G.V. *Kamyana Doba Na Terytorii Pivnichno-Zahidnoji Ukrajiny (XII-III Mill.BC) [Stone Age on the Territory of North-Western Ukraine (XII-III Mill. BC)]*; VAT "Volyns'ka Oblasna Drukarnia": Lutsk, Ukraine, 2009; p. 520.

18. Zaliznyak, L.; Tovkailo, M.T.; Man'ko, V.O.; Sorokun, A.A. Stojanky Bilia Hutora Dobryanka t'a Problema Neolityzatsii Bugo-Dnistrovs'kogo Mezhyrichia [Sites in the Vicinity of the Dobryanka Hamlet and Issue of Bug-Dniester Interfluvial Neolithization] (In Ukrainian). *Kamiana Doba Ukr. [Кам'яна доба України]* **2013**, *15*, 194–257.
19. Saile, T.; Posselt, M.; Dębiec, M.; Kiosak, D.; Tkachuk, T. Zwei Magnetometerprospektionen Auf Ukrainischen Fundstellen Des Cucuteni-Tripolje-Komplexes an Dnjestr Und Südlichem Bug. *Archäologisches Korresp.* **2016**, *46*, 465–477.
20. Kiosak, D. Kamyane-Zavallia, the Eastermost Linear Pottery Culture Settlement Ever Excavated. *Spraw. Archeol.* **2017**, *69*, 253–270. [CrossRef]
21. Matviishyna, Z.M.; Parkhomenko, O.G. Hrunty Neolitychnykh Stoianok Bilia Sela Dobrianka Na Cherkaschyni Iak Indykator Davnih Paleolandshaftiv [Soils of Neolithic Sites by Vill. Dobrianka as an Indicator of Past Landscapes]. *Kamiana Doba Ukr.* **2007**, *10*, 181–190.
22. Matviishyna, Z.M.; Fomenko, V.M.; Tovkailo, M.T.; Doroshkevych, S.P. Paedological Studies of Multilayered Sites Gard and Lidyna Balka in Southern Buh Steppe Region. *Kamiana Doba Ukr.* **2015**, *16*, 190–203.
23. Lobanova, M.A.; Matviishyna, Z.M.; Kiosak, D.V. The Issue of the Stratigraphy of the Site Sabatinovka i and the Enviromental Settings of the Southern Bug Region in the Eneolithic—Late Bronze Age. *Strat. Plus* **2021**, *2021*, 31–52. [CrossRef]
24. Marynych, O.M. (Ed.) *Geografichna Enzyklopedia Ukrainy [Geographic Encyclopedia of Ukraine]*; T. 1 A-ZH; Ukrainska Radianska Enzyklopedia Imeni M.P. Bazhana: Kyiv, Ukraine, 1990.
25. Doroshkevych, S.P. *Pryroda Seredniogo Pobuzhzhia u Pleistotseni Za Danymy Vyvchennia Vykopnykh Hruntiv [Nature of Middle Buh Region in Pleistocene after the Data of Research on Buried Soils]*; Naukova Dumka: Kyiv, Ukraine, 2018.
26. Loza, Y. *Istorychnyi Atlas Ukrainy. Naidavnishe Mynule. Rus (Kyivska Derzhava, Halytsko-Volynska Derzhava)*; Mapa: Kyiv, Ukraine, 2010.
27. Danilenko, V.N. *Neolit Ukrainy: Glavy Drevnejshej Istorii Jugo-Vostochnoj Evropy [Neolithic Ukraine: Issues of Ancient History of South-East Europe]*; Naukova Dumka: Kyiv, Ukraine, 1969; p. 258.
28. Petrasch, J. Settlements, Migration and the Break of Tradition: The Settlement Patterns of the Earliest Bandkeramik and the LBK and the Formation of a Neolithic Lifestyle in Western Central Europe. *Quat. Int.* **2020**, *560–561*, 248–258. [CrossRef]
29. Krupskoi, N.K.; Polupan, N.I. (Eds.) *Atlas Pochv Ukrainskoi SSR [Atlas of Soils of the Ukrainian SSR]*; Urozhai: Kyiv, Ukraine, 1979.
30. Stepanchuk, V.; Ryzhov, S.; Rekovets, L.; Matviishina, Z. The Lower Palaeolithic of Ukraine: Current Evidence. *Quat. Int.* **2010**, *223–224*, 131–142. [CrossRef]
31. Gaskevych, D.L. Problemy Radiovugletsevogo Datuvannia Bugo-Dnistrovskoji Neolitychnoji Kul'tury [Issues of the Radiocarbon Dating of Bug-Dniester Neolithic Culture]. *Arheologija* **2014**, *4*, 3–17. (In Ukrainian)
32. Kiosak, D. The Mesolithic of the North Pontic Region and the Transition to the Neolithic. *Eurasian Prehistory* **2019**, *15*, 279–292.
33. Haskevych, D.; Endo, E.; Kunikita, D.; Yanevich, O. New AMS Dates from the Sub-Neolithic Sites in the Southern Buh Area (Ukraine) and Problems in the Buh-Dnister Culture Chronology. *Doc. Praehist.* **2019**, *46*, 216–245. [CrossRef]
34. Kiosak, D. *Lithic Industries of Early Farmers between Carpathians and Dnieper: Social Context and Organization of Production*; Odesa "I.I. Mechnikov" National University: Odesa, Ukraine, 2019.
35. Kiosak, D.; Kotova, N.; Tinner, W.; Szidat, S.; Nielsen, E.; Brugger, S.; de Capitani, A.; Gobet, E.; Makhortykh, S. The Last Hunter-Gatherers and Early Farmers of the Middle Southern Buh River Valley (Central Ukraine) in VIII-V Mill. BC. *Radiocarbon* **2021**. [CrossRef]
36. Telegin, D.J. Neolithic Cultures of the Ukraine and Adjacent Areas and Their Chronology. *J. World Prehistory* **1987**, *1*, 307–331. [CrossRef]
37. Gaydarska, B. (Ed.) *Early Urbanism in Europe: The Trypillia Megasites of the Ukrainian Forest-Steppe*; De Gruyter Open Poland: Warsaw, Poland; Berlin, Germany, 2020; p. 576.
38. Gaydarska, B.; Nebbia, M.; Chapman, J.; Caswell, E.; Arbeiter, S.; Ovchinnikov, E.; Gaskevych, D.; Lazăr, C.; Ignat, T.; Boyce, A.; et al. The Finds. In *Early Urbanism in Europe: The Trypillia Megasites of the Ukrainian Forest-Steppe*; De Gruyter: Warsaw, Poland; Berlin, Germany, 2020; pp. 265–414.
39. Chapman, J. The Standard Model, the Maximalists and the Minimalists: New Interpretations of Trypillia Mega-Sites. *J. World Prehistory* **2017**, *30*, 221–237. [CrossRef]
40. Albert, B.; Innes, J.; Krementskiy, K.; Millard, A.R.; Gaydarska, B.; Nebbia, M.; Chapman, J. What Was the Ecological Impact of a Trypillia Megasite Occupation? Multi-Proxy Palaeo-Environmental Investigations at Nebelivka, Ukraine. *Veg. Hist. Archaeobotany* **2020**, *29*, 15–34. [CrossRef]
41. Bezusko, L.G. Novi Palinologichni Haraketerystyky Vidkladiv Holocenu Bolota Troitske (Mykolaivska Oblast, Ukraina) [New Pollen Characteristics of Holocene Deposits from Troitske Bog (Mykolaiv Region, Ukraine)]. *Ukr. Bot. Zhurnal* **2010**, *67*, 560–576.
42. Kremenetski, C.V. Holocene Vegetation and Climate History of Southwestern Ukraine. *Rev. Palaeobot. Palynol.* **1995**, *85*, 289–301. [CrossRef]
43. Kushnir, A.; Leiberiuk, O. Database of Paleosoil Research of the Holocene within the Plains of Ukraine on the Basis of GIS Technology. *Ukr. Geogr. J.* **2022**, *2022*, 47–52. [CrossRef]
44. Matviishyna, Z.M.; Doroshkevych, S.P.; Kushnir, A. Reconstruction of Trypillian Time Landscapes Using Paleopedological Studies. *Visnyk Lviv Univ. Ser. Geogr.* **2014**, *48*, 107–116. [CrossRef]
45. Matviishyna, Z.M.; Doroshkevych, S.P. Reconstruction of Natural Atlantic Holocene Stage Condisionts Based on the Paleosoil Research of Trypillia Settlement. *Ukr. Geogr. J.* **2016**, *2*, 19–25. [CrossRef]

46. Szidat, S.; Salazar, G.A.; Vogel, E.; Battaglia, M.; Wacker, L.; Synal, H.-A.; Türler, A. ^{14}C Analysis and Sample Preparation at the New Bern Laboratory for the Analysis of Radiocarbon with AMS (LARA). *Radiocarbon* **2014**, *56*, 561–566. [CrossRef]
47. Szidat, S.; Vogel, E.; Gubler, R.; Lösch, S. Radiocarbon Dating of Bones at the LARA Laboratory in Bern, Switzerland. *Radiocarbon* **2017**, *59*, 831–842. [CrossRef]
48. Bronk Ramsey, C.; Lee, S. Recent and Planned Development of the Program OxCal. *Radiocarbon* **2013**, *55*, 720–730. [CrossRef]
49. Reimer, P.J.; Austin, W.E.N.; Bard, E.; Bayliss, A.; Blackwell, P.G.; Bronk Ramsey, C.; Butzin, M.; Cheng, H.; Edwards, R.L.; Friedrich, M.; et al. The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0–55 Cal KBP). *Radiocarbon* **2020**, *62*, 725–757. [CrossRef]
50. Matviishyna, Z.M.; Kushnir, A.S. Geoarchaeological Approach in Paleosoil Research of Archaeological Sites. *Ukr. Geogr. J.* **2018**, *4*, 10–15. [CrossRef]
51. Mebius, L.J. A Rapid Method for the Determination of Organic Carbon in Soil. *Anal. Chim. Acta* **1960**, *22*, 120–124. [CrossRef]
52. Rząsa, S.; Owczarzak, W. Methods for the Granulometric Analysis of Soil for Science and Practice. *Pol. J. Soil Sci.* **2013**, *46*, 1–50.
53. Veklych, M.F. *Problemy Paleoklimatologii [Issues of Paleoclimatology]*; Naukova Dumka: Kyiv, Ukraine, 1987; p. 190.
54. IUSS Working Group. *WRB World Reference Base for Soil Resources*, 4th ed.; IUSS: Vienna, Austria, 2022.
55. Kiosak, D.; Salavert, A. Revisiting the Chronology of Two Neolithic Sites in Eastern Europe: New Radiocarbon Dates from Melnychna Krucha and Kamyane-Zavallia (Southern Buh Region, Ukraine). *Rev. Archeol.* **2018**, *XIV*, 116–131.
56. Kiosak, D.; Radchenko, S. 3-D Pit: Linear Pottery Culture Long Pit Reconstructed through Point-Cloud Analysis. *Digit. Appl. Archaeol. Cult. Herit.* **2021**, *21*, e00188. [CrossRef]
57. Peresunchak, O.S.; Burdo, N. Kolektsia Plastyky Iz Ranniotrypil's'kogo Poselennia Mohyl'na III [Collection of Plastics from Early Trypillian Site of Mohyl'na III]. In *Kul'turnyi Kompleks Cucuteni-Trypillia ta Yogo Susidy. Zbirka Naukovykh Prats' Pamiati Volodymyra Krutsa*; Diachenko, O., Menotti, F., Ryzhov, S., Buniatian, K., Kadrow, S., Eds.; Astroliabia: Lviv, Ukraine, 2015; pp. 357–366.
58. Burdo, N.B. Ranniotrypils'ki Pamiatky Mizh Selamy Mohylna Ta Zhakchyk Na Kirovogradschyni [Early TrypillieanTrypillian Sites between Villages Mohyl'na and Zhakchik in the Kirovograd Region]. *Archaeom. Ta Ohor. Istoryko-kul'turnoji Spadschyny* **1997**, *1*, 67–71.
59. Kiosak, D.; Lobanova, M. On the Chronology of the Sabatynivka Group of the Cucuteni-Trypillia Cultural Complex (Central Ukraine). *Spraw. Archeol.* **2021**, *73*, 25–46. [CrossRef]
60. Gaskevych, D.L. Melnychna Krucha—Bagatosharova Pamiatka Pervisnoji Doby Na Pivdni Lisostepovogo Pobuzhzhia [Melnychna Krucha—Multilayered Site of Prehistoric Time in the South of Forest-Steppe Southern Bug Region]. *Arheol. I Davnia Istor. Ukr.* **2012**, *8*, 13–22.
61. Reingruber, A.; Rassamakin, Y.Y. Zwischen Donau Und Kuban: Das Nordpontische Steppengebiet Im 5. Jt. v. Chr. In *Der Schwarzmeer Raum vom Neolithikum bis in die Früheisenzeit (6000-600 v. Chr.): Kulturelle Interferenzen in der Zirkumpontischen Zone und Kontakte mit ihren Nachbargebieten*; Nikolov, V., Schier, W., Eds.; Leidorf: Rahden-Westf, Germany, 2016; pp. 273–311.
62. Rassamakin, Y.Y. Mohylnyky Ihren (Ohrin) 8 Ta Oleksandria Doby Eneolitu: Problemy Datuvannia Ta Kulturnoi Nalezhnosti [Cemeteries of Ihren (Ohrin) 8 and Olexandriia of Eneolithic Epoch; the Issue of Dating and Cultural Attribution]. *Arkheologija* **2017**, *4*, 26–48. [CrossRef]
63. Kiosak, D.; Kotova, N.; Radchenko, S.; de Capitani, A.; Gobet, E.; Makhortykh, S.; Nielsen, E.; Szidat, S.; Tinner, W.; Tuboltsev, O.; et al. Chipped Stone Assemblage of the Layer B of the Kamyana Mohyla 1 Site (South-Eastern Ukraine) and the Issue of Kukrek in the North Meotic Steppe Region. *Open Archaeol.* **2022**, *8*, 85–113. [CrossRef]
64. Telegin, D.J. Pro Nomenklaturnyh Spysok Kremianykh Vyrobiv Doby Mezolitu-Neolitu [On the Nomenclature List of Flint Implements of Mesolithic-Neolithic]. *Arkheologija* **1976**, *8*, 21–45.
65. Kharlampovych, P.V. Neolitychna Statsiia "Mykolyna Broiaka" Na Richtsi Chornyi Tashlyk [Neolithic Site 'Mykolyna Broiaka' on the Chornyi Tashlyk River]. *Kamiana Doba Ukr. [Кам'яна доба України]* **1932**, *7*, 228–234.
66. Polischuk, L.Y.; Kiosak, D. Нові Матеріали До Історії Археологічного Вивчення Південного Побужжя Novi Materialy Do Istorii Arkheologichnogo Vyvchennia Pivdennogo Pobuzhzhia [New Materials on the History of Archaeological Research in the Southern Buh Region]. In *Starodavne Prychornomoria*; Nemchenko, I.V., Ed.; ONU "I.I. Mechnikov": Odesa, Ukraine, 2018; pp. 436–445.
67. Zimmermann, A.; Wendt, K.P.; Frank, T.; Hilpert, J. Landscape Archaeology in Central Europe. *Proc. Prehist. Soc.* **2009**, *75*, 1–53. [CrossRef]
68. Hofmann, D.; Banffy, E.; Gronenborn, D.; Whittle, A.; Zimmermann, A. Als Die Menschen Sesshaft Wurden: Die Jungsteinzeit in Süd- Und Mitteldeutschland. In *Spuren des Menschen: 800 000 Jahre Geschichte in Europa*; Bánffy, E., Hofmann, K.P., von Rummel, P., Eds.; WBG Theiss in Wissenschaftliche Buchgesellschaft (WBG): Darmstadt, Germany, 2019; pp. 110–133.
69. Saile, T.; Dębiec, M.; Posselt, M.; Ţerna, S.; Kiosak, D. Zur Bandkeramik Zwischen Pruth Und Südlichem Bug. *Praehist. Z.* **2016**, *91*, 1–15. [CrossRef]
70. Dmytruk, Y.; Matviyishyna, Z.; Kushnir, A. Evolution of Chernozem in the Complex Section at Storozheve, Ukraine. In *Soil as World Heritage*; Dent, D., Ed.; Springer: Dordrecht, The Netherlands, 2014; pp. 91–100. ISBN 978-94-007-6187-2.
71. Ryzhov, S.; Shumova, V. Likareve Settlement and Its Place among Trypils'ka Culture Monuments of Middle Stage. *Magisterium* **2011**, *45*, 25–29.

72. Zaliznyak, L.L.; Man'ko, V.O. Stoyanky Bilia s. Dobryanka Na r. Tikych t'a Deiaki Problemy Neolityzatsii Seredniogo Podniprovia [Sites in the Vicinity of Dobryanka Village on the River Tikych and Some Issues of Neolithization of Middle Dnieper Region]. *Kamiana Doba Ukr.* **2005**, *4*, 137–168. (In Ukrainian)
73. Kotova, N.S. *Drevnejshaja Keramika Ukrainy [The Most Ancient Pottery in Ukraine]*; Maidan: Kyiv/Kharkiv, Ukraine, 2015.
74. Lillie, M.; Budd, C.; Potekhina, I.D.; Hedges, R.E.M. The Radiocarbon Reservoir Effect: New Evidence from the Cemeteries of the Middle and Lower Dnieper Basin, Ukraine. *J. Archaeol. Sci.* **2009**, *36*, 256–264. [CrossRef]
75. Biagi, P.; Zaliznyak, L.; Kozlowski, S. Old Problems and New Perspectives for the Radiocarbon Chronology of the Ukrainian Mesolithic? In Proceedings of the UNESCO-IUGS-IGCP-INQUA IGCP 521-481 Joint Meeting and Field Trip, Gelendzhik, Kerch, Russia, 8–17 September 2007; Tipografia Rossel'chozakademii: Moscow, Russia, 2007; pp. 27–30.
76. Tovkailo, M.T. Neolitizatsija Jugo-Zapadnoj Ukrainy v Svete Novyh Issledovanij Poselenija Gard [Neolithization of South-Western Ukraine in the Light of New Investigations of Gard Settlement]. *Strat. Plus* **2014**, 183–245. (In Russian)
77. Markevich, V.I. *Bugo-Dnestrovskaja Kul'tura Na Territorii Moldavii [Bug-Dniester Culture in Moldova Territory]*; Stiinta: Chisinau, Moldova, 1974; p. 174.
78. Tringham, R. *Hunters, Fishers and Farmers of Eastern Europe 6000–3000 B.C.*; Hutchinson & Co. Ltd.: London, UK, 1971; p. 145.
79. Telegin, D.J. Reviw of Markevich V.I. Bugo-Dnestrovskaja Kul'tura Na Territorii Modavii. *Arheol* **1977**, *23*, 89–91. (In Ukrainian)
80. Telegin, D.J. Voprosy Kul'turno-Hronologicheskogo Chlenennija i Sinchronizatsii Pamiatnikov Neolita [Issues of Cultural and Chronological Division and Synchronization of Neolithic Sites]. In *Arheologija Ukrainskoj SSR.*; T.1 Pervobytnaia Arheologija; Telegin, D.J., Ed.; Naukova dumka: Kyiv, Ukraine, 1985; pp. 110–118.
81. Kotova, N.S. First Cattle-Breeders of the Steppe Ukraine (the Mesolithic-Early Eneolithic). In *Nomadism and Pastoralism between Vistula and Dnieper (Neolithic, Eneolithic and Bronze Age)*; Kosko, A., Szmit, M., Eds.; Wydawnictwo Poznańskie: Poznan, Poland, 2004.
82. Kotova, N.S. The Neolithization of Northern Black Sea Area in the Context of Climate Changes. *Doc. Praehist.* **2009**, *36*, 159–174. [CrossRef]
83. Zvelebil, M.; Lillie, M. Transition to Agriculture in Eastern Europe. In *The Europe's First Farmers*; Price, T.D., Ed.; Cambridge University Press: Cambridge, UK, 2000; pp. 47–92.
84. Endo, E.; Nasu, H.; Gaskevic, D.; Videiko, M.; Yanevich, O. Re-Examination of Cereals in Ukraine during Neolithic to Eneolithic, Using Replica-SEM Method (Preliminary Report). In Proceedings of the 32th Conference of the Japanese Association of Historical Botany, Miyazaki, Japan, 3 December 2017; pp. 21–22. (In Japanese).
85. Benecke, N. Archeozoological Studies on the Transition from the Mesolithic to the Neolithic in the North Pontic Region. *Anthrpozoologica* **1997**, *25–26*, 631–641.
86. Motuzaite-Matuzeviciute, G. *The Adoption of Agriculture: In Prehistoric Ukraine*; Potekhina, I.D., Lillie, M., Eds.; From the First Hunters to the First Farmers; Oxbow Books: Oxford, UK, 2020; pp. 309–326. ISBN 978-1-78925-458-7.
87. Budd, C.; Potekhina, I.; Lillie, M. Continuation of Fishing Subsistence in the Ukrainian Neolithic: Diet Isotope Studies at Yasinovatka, Dnieper Rapids. *Archaeol. Anthropol. Sci.* **2020**, *12*, 64. [CrossRef]
88. Dolukhanov, P.M. *Ecology and Economy in Neolithic Eastern Europe*; Duckworth: London, UK, 1979; p. 212.
89. Kiosak, D. Settlements and Indigenous Populations at the Easternmost Fringe of the Linear Pottery Culture. *Eurasia Antiq.* **2014**, *20*, 117–141.
90. Haskevych, D. Beside or by Turn? The Buh-Dnister Foragers and the Linear Band Pottery Farmers on the Southern Buh River (Ukraine). *SASprawozdanie Archeol.* **2021**, *73*, 9–55. [CrossRef]
91. Kotova, N.; Demchenko, O.; Kiosak, D. Innovations of the Beginning of the Sixth Millennium BC in the Northern Pontic Steppe. *Open Archaeol.* **2021**, *7*, 1529–1549. [CrossRef]
92. Kiosak, D.; Kotova, N.; Demchenko, O.; Bardec'kyi, A.; Werra, D.H. Verifying the Chronology of Ukrainian Neolithic. *Praehist. Z.* 2023; *accepted to publication*.

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Article

New Absolute Chronological Constraints to La Playa (Sonoran Desert) Archaeology between the American Southwest and Mesoamerica—From Long Period Human Resilience to Apparent Abandonment

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Abstract: Sonoran Desert archaeological settlement is one of the most representative sites in Northwestern Mexico/Southwestern United States of the Early Agriculture period because of various cultural processes involved, such as the introduction of the first cultigens and the construction of Pit Houses. These early desert village settlements used geomorphological features of the local landscape to facilitate their sophisticated form of agriculture. Most of the features and artifacts at the site are associated with the Early Agricultural period of 3150-1900 cal B.P., while most occupation dates are in the Cienega phase (2800-1900 cal B.P.). Later stages are poorly documented because of the apparent reduction in population, less marked archaeological features, and extreme erosion processes. Systematic archaeological excavation revealed evidence of completely burned Pit Houses. We analyzed 56 samples belonging to four Pit Houses and one different combustion feature (Kiln or *Horno*, as they are locally known) in different areas of the settlement. The experimental procedure included continuous susceptibility vs. temperature measurements and step-wise alternating field demagnetizations. Only 36 samples yielded technically acceptable determinations that allowed the determination of archaeomagnetic directions. Statistically indistinguishable results were obtained from all five studied features. This finding reinforces archaeological evidence of ritual-related paraphernalia and/or apparent abandonment or, at least, migration.

Keywords: Early Agricultural Settlements; American Southwest; North America; Pit Houses; Absolute Chronology; Archaeomagnetism; ritual closure; abandonment

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1. Introduction

The Early Agricultural period in the Southwestern United Sites and Northwestern Mexico is characterized by the first residential settlements and fast population growth [1–3]. Abundant precipitation and, apparently, lower temperatures around 5000 B.P. attracted hunter-gatherers to the Sonoran Desert and allowed access to fertile floodplains [1,4–6]. Among scattered regional sites, La Playa is the largest archaeological landscape in northern Sonora, northwest Mexico [7–9].

La Playa, located in the municipality of Trincheras, Sonora (Figure 1), is considered one of the most representative sites in Northwestern Mexico/Southwestern United States of the Early Agriculture period [2,8,10–12]. It is characterized by various cultural processes: the introduction of the first cultigens in the region, the development of techniques for irrigation canals, the technology of the projectile points, and the construction of Pit Houses.

The latter is poorly represented in the archaeological record due to the strong erosion that affects the site, making it a challenge to find the few specimens suitable for investigations.

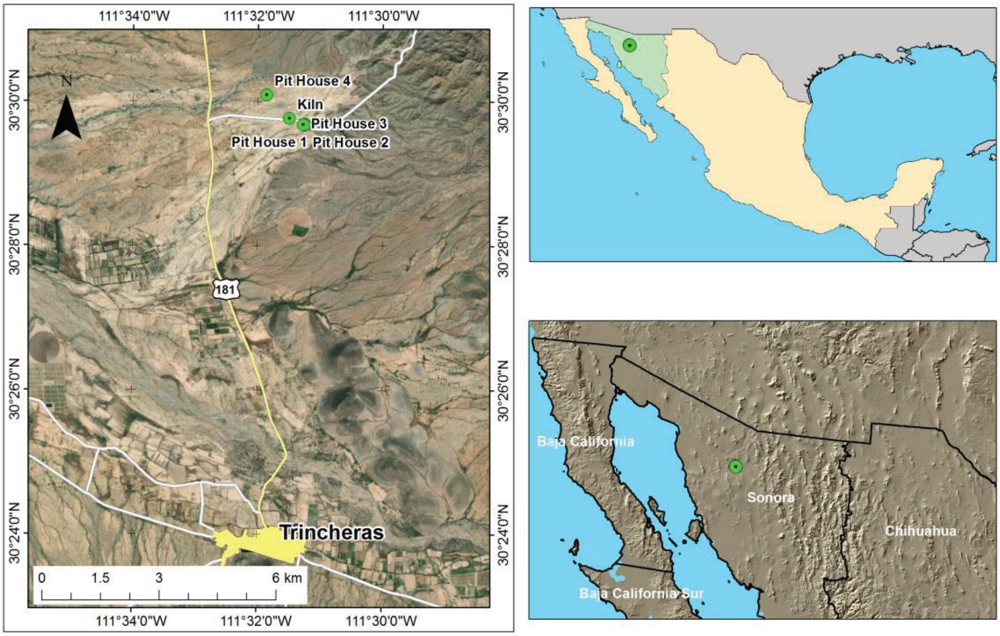


Figure 1. La Playa archaeological site in the municipality of Trincheras, State of Sonora, Mexico showing the locations of Pit Houses and Kiln (*Horno*). The data are obtained from INEGI (INSTITUTO NACIONAL DE ESTADISITICA E GEOGRAFIA), while ArcMap was used to draw schematic maps.

La Playa site shows a complex stratigraphy and geomorphology, which has been constantly altered by hydric and wind agents. While long-term environmental trends promote stable adaptations, more rapid climate changes require human groups to use more rapid resilience strategies. The first farmers in the Sonoran Desert employed the construction of canals to transport water flows from low-intensity streams to irrigate their crop fields ~3000 years ago. These early desert village settlements used geomorphological features of the local landscape to facilitate their sophisticated form of agriculture.

The settlement is a multi-component site that contains evidence of occupation from the Paleoindian and Middle Archaic periods, as well as continuous occupation from the Late Archaic to the mid-20th century. Most of the features and artifacts at the site are associated with the Early Agricultural period of 3150-1900 cal B.P., and most occupation dates are in the Ciénega phase (2800-1900 cal B.P.). There is later evidence of sporadic occupation of Trincheras from 150-1450 A.D. Maize is known to appear in the Southwest around 4100 cal B.P. [13]. During the Early Agricultural period, farmers began to rely more significantly on cultivated plants as an essential part of their diet.

Huckell [14] redefined the Early Agricultural period to distinguish agricultural use from the earlier Late Archaic period. Under this definition, the Archaic period represents the period from after the Paleo-Indian until the use of pottery. Still, the term also refers to the widespread hunter-gatherer-forager subsistence economy. The term Early Agricultural period is used to recognize the presence of domesticated crops in the diet. It is characterized by a subsistence economy based on mixed feeding. The term Late Archaic is retained for sites with contemporary dates that show evidence of a generalized hunting and gathering economy [10,14,15].

The Early Agricultural period, defined by the more intensive use of agriculture, includes new food production strategies and also signifies a change in the material culture, the intensity of settlement occupation patterns, and land [14]. This does not necessarily mean that the forage farming groups were dependent on agriculture for their subsistence, nor were they completely sedentary. The transition from foraging to agriculture was not immediate. Early Agricultural period sites vary in the degree of sedentarization and dependence on agriculture. In general, the period is characterized by dwelling structures of Pit Houses of various sizes, although they are generally a few meters in diameter; elements in walls, stone ovens for firing, hearths, polished metate lithics, pestles, mortars, diagnostic projectile points, stone trays, ornaments in seashells, and ceramic figurines are all included [12,15]. Compared to the San Pedro phase, the Ciénega phase (2800-1800 cal B.P.) sites indicate greater sedentarization and dependence on agriculture, showing more formal structures, a greater diversity of artifacts, a greater number of storage pits, and more storage capacity at the same time. Sometimes, they contain larger communal structures, possibly due to the increase in the population or their greater concentration due to being more sedentary populations [15,16]. Extensive water canal use during the Ciénega phase has been documented, which, in the Tucson Basin, has been dated to 3450-2450 cal B.P. [17,18]. These irrigation canals made agriculture possible in more than one season and possibly throughout the year, as well as the introduction of new crops, which may have contributed to population growth [19]. Using magnetic gradiometry, Cajigas [20] detected approximately 3 km of intact irrigation canals, almost 8700 m^2 of agricultural fields, and 12 circular structures.

After almost two decades of investigating the site and not finding any element with habitation characteristics, in 2010, a strip of sediment with high carbon content and associated artifacts was identified. Similarly, the nearby areas also record the presence of fragments of burnt soil, charred material, and some artifacts. The excavation of these structures revealed the existence of semi-complete and entirely burned Pit Houses, which represent excellent archaeomagnetic targets and, thus, the possibility to date the last firing event. Beyond this main objective, we will try to estimate whether this apparently intentional generalized firing episode at the end of the Ciénega phase (the period of major settlement patterns) relates to ritual aspects or environmental changes.

2. Chronological Framework and Sample Provenance

Besides the series of evidence indicating that the La Playa site spans approximately 10,000 years of human presence, the major occupation can be restricted to a relatively short interval [21]: the Late Archaic/Early Agriculture Period (1500-1200 B.C. to 150 A.D.). There is now a general agreement among the archaeologists that the Early Agricultural period in the Sonoran Desert is divided into the San Pedro and Cienega phases [3,5,21]. Mabry [6,12], however, mentioned an *unnamed phase* (approximately 2100-1200 B.C.) preceding the San Pedro phase (1200-800 B.C.). This author also proposed to divide the Ciénega phase into Early (800-400 B.C.) and Late (400 B.C.-A.D. 40) phases [21]. Carpenter et al. [22] and Martinez–Lira et al. [21], among others, argue that the population at La Playa was essentially sedentary because of the recovery of multiple activity areas, the clear evidence of maize farming, the numerous human burials, as well as the distribution and density of archaeological artifacts [21,22]. Copeland et al. [7], in turn, support the idea that archaeological remains from the Ciénega phase (2800-1800 cal B.P.) identify increases in village size and complexity, as well as more technologically complex artifacts [23]. In addition, the archaeological record from the San Pedro phase (3600-2800 cal B.P.) includes large, un-notched blades, various stone tools, and shell decorations [7,24].

The most common archaeological features at La Playa include Pit Houses (Figure 2a) and burials, including human inhumation and cremation. Some pits and *hornos* (kilns) were also discovered during the last decades. Pit Houses should be considered as particular structures since they were found completely burned and, thus, were susceptible to carrying thermoremanent magnetization acquired during the cooling from high temperatures. The same is true for the *horno* samples. There were four Pit Houses (Figure 2) and one Horno (Figure 3) sampled under this investigation, while their excavation details may be described as follows:

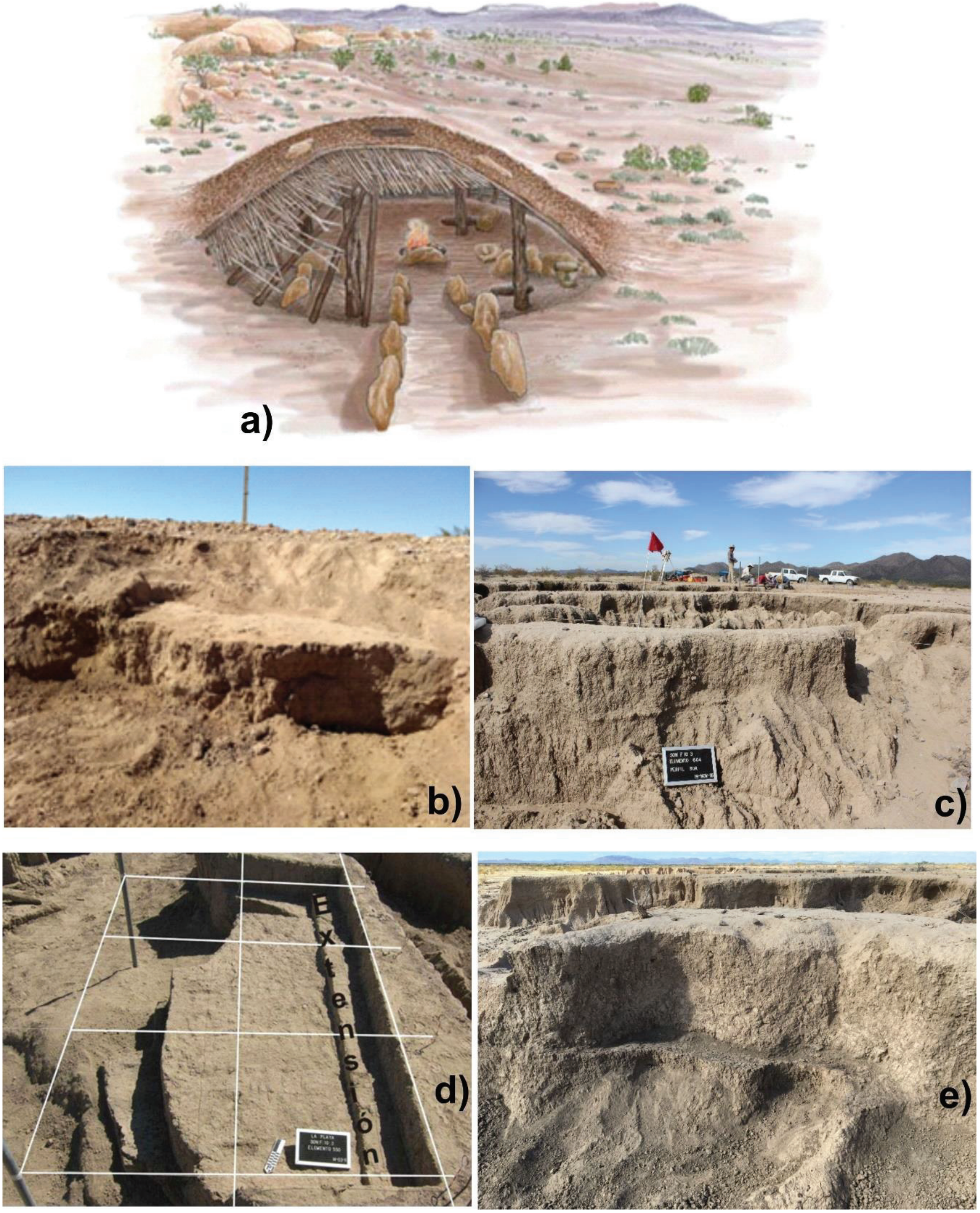


Figure 2. Reconstruction of Pit House, Illustration by Joyce Heuman Kramer; Crow Canyon Archaeological Center (Basketmaker II pithouse (https://www.crowcanyon.org/EducationProducts/peoples_mesa_verde/basketmaker_II_housing.asp, accessed on 7 January 2023) (**a**) and burned features discovered during the excavations (**b**–**e**), see text for more details.

Figure 3. Remains of combustion feature (kiln or *horno*).

Feature 602 (30°29′40.94″ N, 111°31′14.91″ W—Pit House 1, Figure 2b) is located in the vicinity of *Viejo Campamento* area, to the south of the road and to the west of structure 550. Before excavation, only a well-consolidated floor of approximately 4 cm was visible, and only the western limit was observed. The excavation was carried out by metric levels of 10 cm. During the excavation process, the sediment became more compact and darker. No material was recovered from the levels above the floor. Sampled area is the one that contained most of the burned soil observed in the profile, so this square was excavated until reaching contact with the base approximately 30 cm below the surface. In the west profile of the square, at a depth of 20 cm, a charcoal fragment was recovered with no association to any other artifact.

Feature 604 (30°29′40.32″ N, 111°31′14.79″ W—Pit House 2, Figure 2c) is also located in the *Viejo Campamento* area, south of element 602, in an erosion gully approximately 60 cm wide, with an east–west orientation. In the southwest profile, the remains of another floor were identified at a depth of 40 cm. The burned floor level was reached after 4 metric levels of 10 cm, revealing an extremely compact surface with a semicircular limit of 95 cm wide by 43 cm long. No artifacts were recovered in contact with the ground and the walls. Again, what was preserved of the structure was too little to be able to obtain the total dimensions of this pit, since everything was located in the south part and had already eroded. Very few materials were recovered from the excavation of this item: two complete chalcedony flakes and a decorated *Trincheras* type sherd. The area was also scoured trying to locate artifacts that may have eroded from the house; however, no material was recovered.

Feature 614 (30°30′5.35″ N, 111°31′51.43″ W—Pit House 4, Figure 2d) is located in the north of the *Los Entierros* area in an erosion gully approximately 2 m wide. A partially preserved burned floor was detected in the eastern profile under 60 cm of the surface. Above the floor, there was a 7 cm layer of ash that covered it entirely. In the already eroded area, there were many artifacts such as metate hands, bone fragments, and burned soil that possibly belonged to the already eroded parts of this structure. This structure has an irregular, 1.20 m diameter circular shape. The eastern part was totally eroded, and in the rest of the element, it was not possible to differentiate the walls of the sediment in which the element was excavated. Only one 16 cm diameter post hole was recognized, which would be located to the east of the feature, very close to the eroded area. The ash layer was detected at 60 cm deep. More materials were recovered from these levels than the elements described above. Most were bone fragments and small coals. The 5 cm thick ash layer had very low compaction. Mixed with the ash were fragments of burnt earth; however, and unlike previous levels, no coal fragments were recovered. Below the ash was the floor, which was burned and best preserved in the center of the excavated area. Once again, the walls, to the south and to the north, were not delimited and a small elevation (border) was barely visible, similar to that of Structure 602.

Feature 550 (30°29′40.57″ N, 111°31′16.41″ W—Pit House 3, Figure 2e) is particular because its systematic excavation began in November 2010 when it was located in one of the runoffs of the area called *Viejo Campamento*. It has been proposed that these areas are associated with the settlements of the Early Agricultural Period (800 B.C. to A.D. 200) [25]. This completely charred house revealed a perfectly preserved floor covered by a thin charcoal layer. About 3 to 4 cm post holes in the wall of the house were also detected. This was interpreted as the ocotillo tree frame that makes up the architectural structure of the pit house. The structure seems completely collapsed during the intense firing episode and was what allowed its identification. After the first 30 cm excavated, the delimitation of the house was very clear, marking a circumference that revealed the compacted walls. Almost in contact with the floor of the house, we were able to locate several circular spots, of between 2.5 and 3 cm, with fragments of coal inside. The characteristics of this evidence allowed us to suppose that it was about the secondary posts of the structure that gave shape and supported the walls of this house pi house.

Feature 619 (30°29′45.85″ N, 111°31′29.64″ W) Horno (Figure 3) is located in the *Hornos Alineados* area, a few meters from the dirt road to El Ocuca village. On the surface, it was observed as a concentration of rocks fragmented by fire, with some flakes and pieces of polished lithic ground stone, with an approximate diameter of 1 m and a height of 30 cm. At the base of the concentration of rocks, it was possible to appreciate a crust of burned earth that delimited the wall of the structure formed by blocks. It has a maximum diameter of 65 cm and a frustoconical shape.

Magnetically oriented hand samples leveled with plaster (*Platre de Paris)* were collected from four burned soils belonging to Pit Houses and one Horno. Due to a relatively small sampling area, two or three oriented monoliths were taken from each structure, while at least eight 2 cm cubic specimens were cut from each hand sample.

3. Laboratory Techniques

Prior to magnetic treatments, we carried out susceptibility against temperature measurements in a continuous way and aimed to reveal major magnetic carriers and estimate their thermal stability. AGICO MFK1 susceptibility meter equipped with a furnace was employed for such a purpose using crushed virgin specimens. They were heated (under the air) until about 600 °C and cooled down to the room temperature using the rate of 20 °C per minute rate. As natural remanent magnetization measurements are concerned, samples were placed for 15 days in free magnetic fields of $\mu-$metal shield in order to diminish the effect of potential viscous remanent magnetization.

All remanences were recorded using JR6 AGICO spinner magnetometer at the facilities of National Archaeomagnetic Service of National University of Mexico. Due to the fragility of the great majority of samples, we adopted alternating field treatment to reveal primary, characteristic thermoremanent magnetization. For this purpose, an AGICO LDA3 demagnetizer was used with maximum available peak alternating field of 90 mT. The characteristic remanent magnetization (ChRM) of each specimen was calculated by principal component analysis, based on at least five aligned points of the demagnetization process [26]. The calculation of the mean directions, as well as their associated precision parameters, was carried out following Fisher’s statistics [27].

4. Main Results

There are two types of behaviors that may be recognized on the analysis of continuous thermomagnetic curves. The majority of samples exhibit evidence for two magnetic phases during heating (Figure 4, samples SH02 and SH03). The low temperature phase is rather well-defined, showing an important susceptibility drop between 340 and 415 °C, while the second phase correspond to magnetite judging from its Curie temperature. This behavior is commonly interpreted as the inversion of thermally unstable titanomaghemites into almost pure magnetite [28]. The particular case is reported for one sample from Pit House 4 (Figure 4, SH04). The low temperature phase is presented here as well, while heating at higher temperatures produces an important neoformation of magnetite most probably from the non-magnetic matrix. Due to the marked irreversibility and thermal instability observed on continuous thermomagnetic curves, no paleointensity determination was intended.

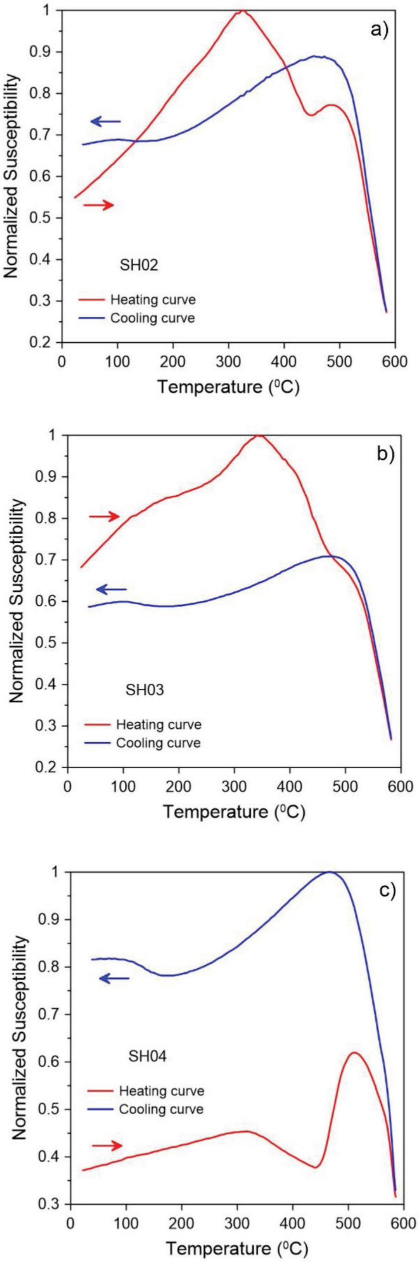


Figure 4. Representative continuous thermomagnetic measurements for La Playa representative samples. The Red (blue) branch corresponds to the heating (cooling) cycle.

Characteristic remanent magnetization is obtained from 36 out of 59 analyzed samples belonging to four Pit Houses and one Horno exhibiting very similar demagnetization patterns (Figure 5). The major part of thermoremanence is removed when applying 80 mT peak alternating field, while median destructive field values range between 25 and 35 mT. These factors attest that the main magnetic carriers are ferrimagnetic grains, and hematite contribution in total remanence is very limited. All individual paleodirection determinations are based on at least five aligned demagnetization steps with the maximum angular deviation (MAD) values within 2.4°. The mean archaeomagnetic directions are reasonably well-defined for all 5 cooling units (4 burned floors belonging to Pit Houses and 1 Horno) for 4 out of 5 of the studied burned features (Figure 6) with a cone of confidence α_{95} between 2.2° and 7.2°. Only Pit House 4 yielded higher α_{95} of 7.2°, which attests rather scattered archaeodirections (Figure 6).

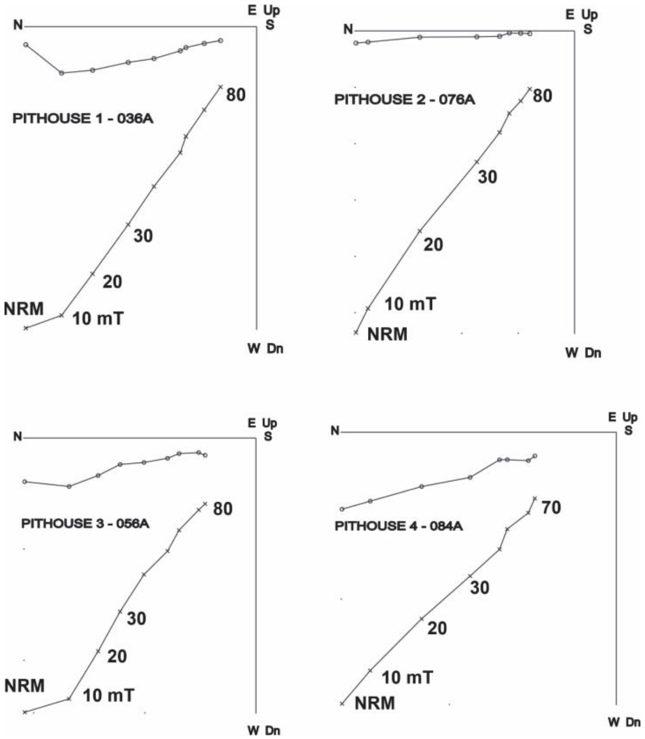
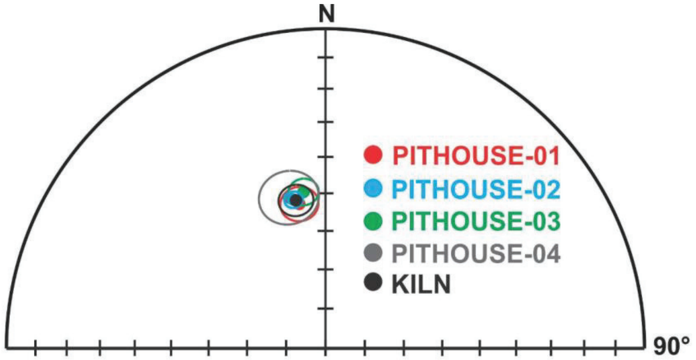


Figure 5. Representative orthogonal diagrams of alternating field treatments for La Playa representative samples.

Statistically undistinguishable paleodirections were obtained from all five studied features (Figure 6) with their α_{95} completely overlapping. Thus, it is evident that all four Pit Houses and one Horno were burned within the same time interval. Mean paleodirections obtained for Pit House 1 are Dec = 349.7°, Inc = 52.2°, α_{95} = 4.6°, k = 145 determined on 8 out of 12 analyzed samples (Figure 6), Pit House 2 provided Dec =347.8°, Inc = 50.8°, α_{95} = 2.2°, k = 544, 9 out of 14 samples; Pit House 3—Dec = 352.0°, Inc = 49.2°, α_{95} = 3.6°, k = 277, 7 out of 12 samples; Pit House 4—Dec = 346.3°, Inc = 49.9°, α_{95} = 7.2°, k = 114, 5 samples out of 9 analyzed. Horno yielded Dec = 348.7°, Inc = 51.1°, α_{95} = 4.2°, k = 210, 7 out of 12 samples.



Pit House 1 - Dec=349.7°, Inc =52.2°, α_{95} =4.6°, k =145, 8/12.

Pit House 2 - Dec=347.8°, Inc =50.8°, α_{95} =2.2°, k =544, 9/14.

Pit House 3 - Dec=352.0°, Inc =49.2°, α_{95} =3.6°, k =277, 7/12.

Pit House 4 - Dec=346.3°, Inc=49.9°, α_{95} =7.2°, k=114, 5/9.

Kiln - Dec=348.7°, Inc=51.1°, α_{95} =4.2°, k=210, 7/12.

Figure 6. Equal area projection of mean archaeomagnetic directions for four Pit Houses and one kiln (horno).

5. Discussion and Concluding Remarks

The time interval 1000 BC and 500 AD was selected for archaeomagnetic dating purposes based on available archaeological and relative chronological evidences. Unfortunately, this interval is characterized by little available data on local paleosecular reference curves [29,30] and, thus, cannot be correctly used for precise age determination. The same is true for recent global geomagnetic models SHAWQ2K and SHAWQ-Iron Age with additional inconvenient that they represent two different tome intervals [31,32]. Thus, we still prefer to us the model SHADIF14k and MATLAB software from Pavón–Carrasco et al. [33,34]. Dating details and probable intervals obtained at a 95% confidence level are shown in Figures 7 and 8. As expected, the possible dating intervals are very similar (Pit House 1—196 to 48 B.C.; Pit House 2—151 to 88 B.C.; Pit House 3—171 to 87 BC: Pit House 4—206 to 47 B.C.).; Horno—171 to 72 B.C.

Systematic archaeological surveys during the last decades have documented numerous cultural features at La Playa, corresponding to the biggest Early Agricultural period regional settlement [7–9].

Recently available, high standard radiocarbon ages from archaeological contexts at La Playa show that it reached maximum occupancy during the Early Agricultural period, especially during the Cienega phase, which ended roughly between (1 to AD 200) [7]. This pattern is similarly observed at contemporaneous sites in southern Arizona, as Cienega phase villages reach population maximums prior to shifting settlement patterns and the beginning of the Hohokam cultural sequence (in Arizona) [7,35].

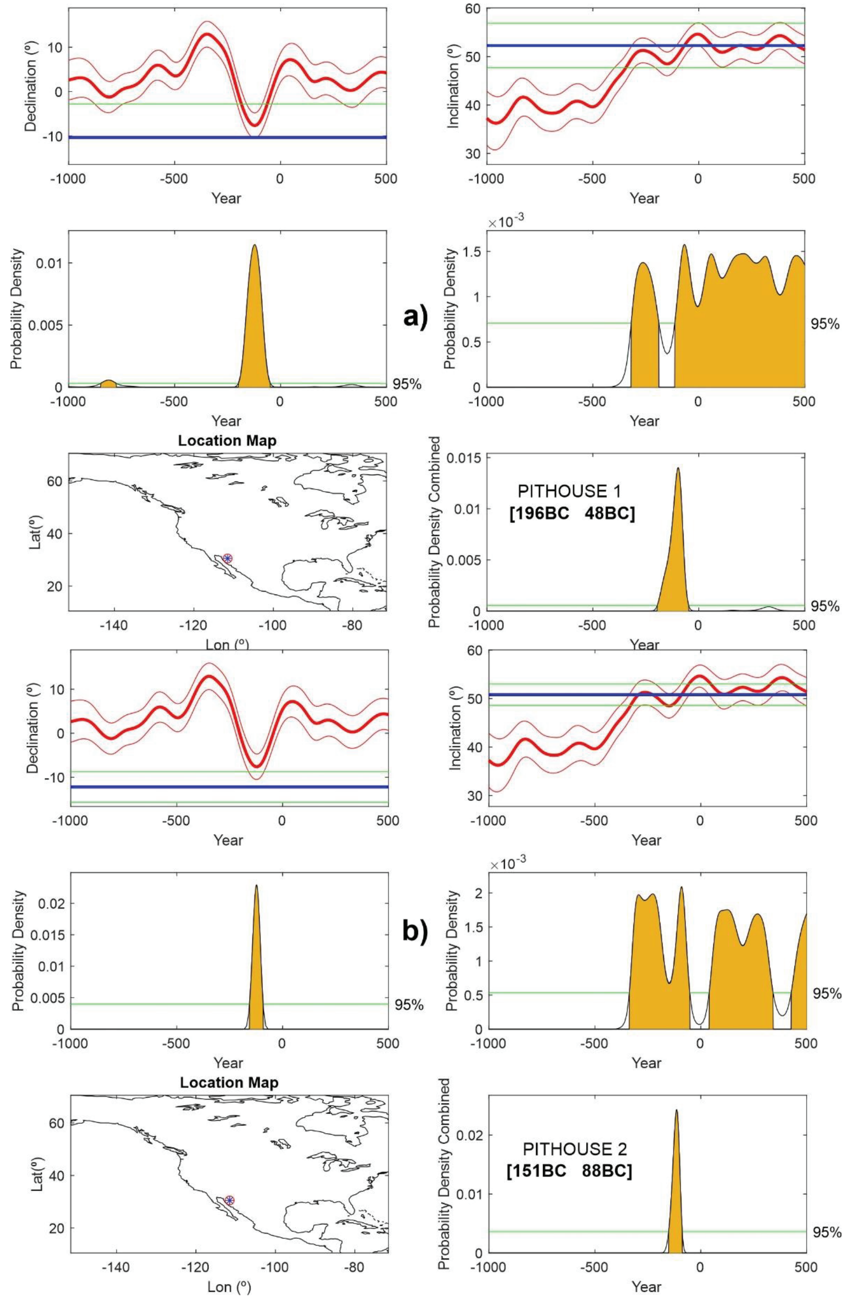


Figure 7. Archaeomagnetic dating using SHA.dif.14k global geomagnetic model [33,34] for Pit House 1 and 2.

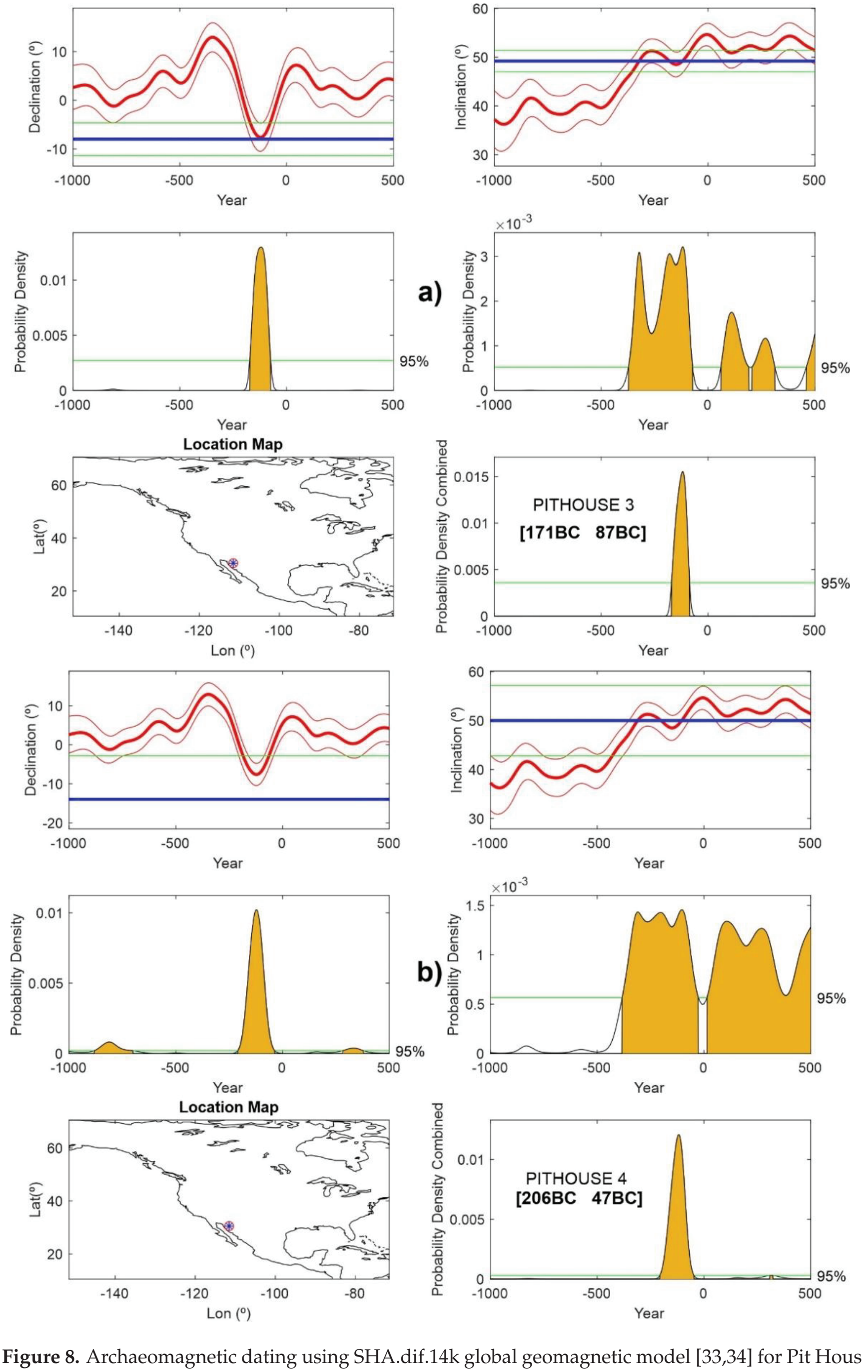


Figure 8. Archaeomagnetic dating using SHA.dif.14k global geomagnetic model [33,34] for Pit House 3 and 4.

Probably, the most interesting archaeological features at La Playa are semi-preserved Pit Houses. Regarding the construction techniques with which the houses were built, up to now, we can say that the walls were excavated with a circular cutting instrument—surely some wooden stick, judging by the marks left. This instrument was one of the tools used in the excavation of the area destined for the element where the marks of the "excavator stick" are perceptible.

It is now known that residents of the Tucson Basin used wooden shovels and pottery shards. These elements were apparently used to dig the floor to a depth of 50 or 60 cm from the surrounding ground level. The technique used to build this type of house consisted, once the required depth was achieved, of assembling the main structure with mesquite or ironwood trunks that allowed the roof to be supported; between these main posts, ocotillo rods were placed to shape the exterior walls of the house. It seems that the roof was formed by reeds, or there was probably a kind loft inside the house. It is very possible that, in the central part of the floor, there was a stove just aligned with the entrance of the house; however, the erosion of almost half of the structure does not allow us to confirm the above. It is evident that this house corresponds to the Ciénega—Late Phase of the Early Agriculture Period due to the association with the four Ciénega Larga style points found, which has been confirmed with radiometric dates (28 ± 14 AD). The age estimation was carried at AMS facilities of Arizona University. Laboratory code—UA-AA93711, Material dated—wood, uncalibrated ^{14}C date—1900 ± 30 BP, ^{13}C o/100–121, calibrated age interval using OxCal 4.2–28 AD (95.4%) 215 AD.

If the house was preserved due to an unplanned fire or if there was a ritual closing of this element, it is something that we will hardly be able to corroborate, although we are inclined towards the latter due to the presence of the four Ciénega Larga style points placed towards the north of the entrance of the house. What seems important to us to highlight is that we do not believe that it was just any house but, rather, the place of residence of a member of the community who had access to ritual-related paraphernalia. In any case, simultaneous intentional burning of different Pit Houses revealed by the present archaomagnetic survey reinforce the ritual closure hypothesis. Whether this event may be considered as abandonment of site needs more precise analysis in order to make any firm conclusions. Still, the poorly documented post Cienega phase seems to have significantly reduced activities and far fewer archaeological features.

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References

1. Byrd, R. Biological Interaction of the First Forager-Farmers in the Sonora Desert. Ph.D. Thesis, The University of Arizona, Tucson, AZ, USA, 2012.
2. Carpenter, J.P.; Sánchez, G.; Villalpando, M.E. Of maize and migration: Mode and tempo in the diffusion of Zea mays in Northwest Mexico and the American Southwest. In Traditions, Transitions, and Technologies: Themes in Southwestern Archaeology, Proceedings of the 2000 Southwest Symposium, Boulder, CO, USA, 2–4 April 2000; Schlanger, S.H., Ed.; University Press of Colorado: Boulder, CO, USA, 2002; pp. 245–256.
3. Huckell, B.B. *Of Marshes and Maize: Preceramic Agricultural Settlements in the Cienega Valley, Southeastern Arizona*; University of Arizona Press: Tucson, AZ, USA, 1995; p. 188.

4. Huckell, B.B.; Huckell, L.W. Crops come to the desert: Late preceramic agriculture in southeastern Arizona. In Proceedings of the 53rd Annual Meeting of the Society of American Archaeology, Phoenix, AZ, USA, 7–10 March 1988.
5. Huckell, B.B. The archaic prehistory of the North American Southwest. *J. World Prehistory* **1996**, *10*, 305–373. [CrossRef]
6. Mabry, J.B. Changing knowledge and ideas about the first farmers in southeastern Arizona. In *The Late Archaic across the Borderlands: From Foraging to Farming*; Vierra, B.J., Ed.; University of Texas Press: Austin, TX, USA, 2005; pp. 41–83.
7. Copeland, A.; Quade, J.; Watson, J.T.; McLaurin, B.T.; Villalpando, E. Stratigraphy and geochronology of La Playa archaeological site, Sonora, Mexico. *J. Archaeol. Sci.* **2012**, *39*, 2934–2944. [CrossRef]
8. Carpenter, J.; Sanchez, G.; Villalpando, M.E. *The Late Archaic/Early Agricultural Period in Sonora, Mexico*; Vierra, B.J., Ed.; University of Texas Press: Austin, TX, USA, 2005; pp. 13–40.
9. Carpenter, J.; Villalpando, E.; Sánchez, G. La Playa: An Early Agricultural period landscape. *Archaeol. Southwest* **2009**, *23*, 14.
10. Diehl, M.W. Morphological observations on recently recovered Early Agricultural period maize cob fragments from Southern Arizona. *Am. Antiq.* **2005**, *70*, 361–375. [CrossRef]
11. Mabry, J.B. The role of irrigation in the transition to agriculture and sedentism in the Southwest: A risk management model. In *Traditions, Transitions, and Technologies: Themes in Southwestern Archaeology, Proceedings of the 2000 Southwest Symposium, Boulder, CO, USA, 2–4 April 2000*; Schlanger, S.H., Ed.; University Press of Colorado: Boulder, CO, USA, 2002; pp. 178–199.
12. Mabry, J.B.; Doolitte, W. Modeling the early agricultural frontier in the Desert Bordelands. In *Archeology without Border*; McBrinn, M.E., Webster, L.D., Eds.; University Press of Colorado: Boulder, CO, USA, 2008; pp. 55–70.
13. Cordell, L.; McBrinn, M.E. *Archaeology of the Southwest. Walnut Creek*; Left Coast Press: Walnut Creek, CA, USA, 2012.
14. Huckell, B.B.; Huckell, L.W.; Fish, S.K. *Investigations at Milagro, a Late Preceramic Site in the Eastern Tucson Basin*; Technical Report No. 94-5; Center for Desert Archaeology: Tucson, AZ, USA, 1995; 72p.
15. Roth, B.J.; Wellman, K. New insights into the Early Agricultural period in Tucson Basin: Excavations at the Valley Farms site (AZ AA:12:736). *Kiva* **2002**, *67*, 59–79. [CrossRef]
16. Mabry, J.B. Early farming societies in the desert southwest. *Archaeol. Southwest* **2009**, *23*, 18–19.
17. Nials, F.L. Canal geomorphologies. In *Las Capas: Early Irrigation and Sedentism in a Southwestern Floodplain*; Mabry, J.B., Ed.; Anthropological Papers No. 28; Center of Desert Archeology: Tucson, Tucson, AZ, USA, 2008; pp. 149–165.
18. Herr, S. The latest research on the earlies farmers. *Archaeol. Southwest* **2009**, *23*, 1–3.
19. Mabry, J.B.; Holmlund, J. *Canals. Archaeological Investigations of Early Village Sites in the Middle Santa Cruz Valley: Analyses and Synthesis*; Mabry, J.B., Ed.; Anthropological Papers No. 19; Center of Desert Archeology: Tucson, AZ, USA, 1998; pp. 283–298.
20. Cajigas, R. An integrated approach to surveying an Early Agricultural period landscape: Magnetic gradiometry and satellite imagery at La Playa, Sonora, Mexico. *J. Archaeol. Sci. Rep.* **2017**, *15*, 381–392. [CrossRef]
21. Martinez-Lira, P.; Corona, E.; Arroyo-Cabrales, J.; Carpenter, J. Bird Bundles from La Playa, Sonora, Mexico. In *Feathers, Grit and Symbolism: Birds in the Ancient Old and New Worlds*; Grupe, G., Peters, J., Eds.; Leidorf: Rahden/Westf, Germany, 2005; pp. 201–206.
22. Carpenter, J.P.; Villalpando, M.E.; Sánchez, G.; Martínez, N.; Montero, C.; Morales, J.J.; Villalobos, C. *Proyecto Arqueológico La Playa: Quinto Informe de la Temporada Verano 2002, Análisis de los Materiales Arqueológicos y Propuesta para la Temporada Invierno 2003*; Unpublished site report submitted to INAH (Instituto Nacional de Antropología e Historia); INAH: Hermosillo, Mexico, 2003.
23. Watson, J.T. Changes in food processing and occlusal dental wear during the Early Agricultural period in Northwest Mexico. *Am. J. Phys. Anthropol.* **2008**, *135*, 92–99. [CrossRef]
24. Carpenter, J.; Sánchez, G. Preliminary investigations at La Playa, Sonora, Mexico. *Archaeol. Southwest* **1999**, *13*, 6.
25. Villalpando, C.E.; Carpenter, J.P.; Watson, J. *Proyecto Arqueológico La Playa (SON:F:10:3)*; Informe de Trabajo 2011–2012, mecanuscrito, Archivo Técnico Coordinación Nacional de Arqueología INAH; INAH: Hermosillo, Mexico, 2012.
26. Kirschvink, J.L. The least-squares line and plane and the analysis of palaeomagnetic data. *Geophys. J. Int.* **1980**, *62*, 699–718. [CrossRef]
27. Fisher, R.A. Dispersion on a sphere. Proceedings of the Royal Society of London. *Ser. A Math. Phys. Sci.* **1953**, *217*, 295–305. [CrossRef]
28. Özdemir, Ö. Inversion of titanomaghemites. *Phys. Earth Planet. Inter.* **1987**, *65*, 125–136. [CrossRef]
29. Mahgoub, A.N.; Juarez-Arriaga, E.; Böhnel, H.; Manzanilla, L.; Cyphers, A. Refined 3600 years palaeointensity curve for Mexico. *Phys. Earth Planet. Inter.* **2019**, *296*, 106328. [CrossRef]
30. García-Ruiz, R.; Goguitchaichvili, A.; Pavón-Carrasco, F.J.; Soler, A.M.; Pérez-Rodríguez, N.; Osete, M.L.; Kravchinsky, V. Fluctuations of magnetic inclination and declination in Mexico during the last three millennia. *Quat. Geochronol.* **2022**, *71*, 101309. [CrossRef]
31. Campuzano, S.A.; Gómez-Paccard, M.; Pavón-Carrasco, F.J.; Osete, M.I. Emergence and evolution of the South Atlantic Anomaly revealed by new paleomagnetic reconstruction SHAWQ2k. *Earth Planet. Sci. Lett.* **2019**, *52*, 17–26. [CrossRef]
32. Osete, M.L.; Molina-Cardín, A.; Campuzano, S.A.; Aguilella-Arzo, G.; Barrachina-Ibañez, A.; Falomir-Granell, F.; Oliver Foix, A.; Gómez-Paccard, M.; Martín-Hernández, F.; Palencia-Ortas, A.; et al. Two archaeomagnetic intensity maxima and rapid directional variation rates during the Early Iron Age observed at Iberian coordinates. Implications on the evolution of the Levantine Iron Age Anomaly. *Earth Planet. Sci. Lett.* **2022**, *533*, 116047. [CrossRef]
33. Pavón-Carrasco, F.J.; Rodríguez-González, J.; Osete, M.L.; Torta, J.M. A Matlab tool for archaeomagnetic dating. *J. Archaeol. Sci.* **2011**, *38*, 408–419. [CrossRef]

34. Pavón-Carrasco, F.J.; Osete, M.L.; Torta, J.M.; De Santis, A. A geomagnetic field model for the Holocene based on archaeomagnetic and lava flow data. *Earth Planet. Sci. Lett.* **2014**, *388*, 98–109. [CrossRef]
35. Wallace, H.D. Hohokam beginnings. In *The Hohokam Millenium*; Fish, S.K., Fish, P., Eds.; School for Advanced Research Press: Santa Fe, NM, USA, 2007; pp. 13–21.

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Article

Archaeology of the Landscape of Metalworking Sites in Italian Alpine Areas (Orobic Alps) between the Middle Ages and the Modern Era

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Abstract: The article introduces features of iron-working in the north-western Italian Alpine region (specifically, the Valtellina side of the Bergamesque or Orobic Alps) during the Middle Ages by comparing historical data and archaeological sources. This will help shed light on the organisation of the production process, starting from iron ore mining, proceeding to examine the transformation phases and culminating in the conversion of the ore into ingots or bars to produce tools for agricultural or wood-cutting activities. The article follows two distinct paths, initially presenting the main stages of iron-working in Valtellina until the second half of the eighteenth century, followed by an analysis of the mining complex of Val Venina where an extremely important metal-working site is situated. Two separate mining zones were identified, the first deep underground and the second an opencast working site. Furthermore, a series of rooms made of dry-stone walling that provided accommodation for the miners have been brought to light, as well as mineral deposits and stables for the animals required to carry out the activities described by Melchiorre Gioia in his volume "Statistica del Dipartimento dell'Adda" and indicated in the land registers of the Lombardy-Veneto regions carried out in 1815 and 1863.

Keywords: metalworking; Italian Alpine areas; iron-working; mining complex; mineral deposits; blacksmiths; windchests

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1. Introduction: The Iron Mining Landscape in the Italian Alpine Areas

The history of mining and iron-working in the western Italian Alpine region during the late Middle Ages and the early modern period, especially in areas of Lombardy, has recently been the subject of numerous studies. On several specific points, this research has added to the data from the work of Rolf Sprandel [1], focusing much more closely than in previous studies on trading relationships and economic development. Since this renewed interest can be combined with a careful re-reading of documents related to local metal working and the results of new excavations and surveys, it is now possible to offer an initial overview—albeit fraught with difficulties—of the economic importance of the production, working and commercialisation of iron in Lombardy in the late Middle Ages and the early modern period [2].

The decision to study the landscape of the Orobic Alps in Valtellina stems from various considerations, beginning with an observation made by Massimo Zucconi. If history involves the study of the origins, development and decline of civilisations, he argues "[then] the forms and techniques of production offer the most interest way of analysing the transformations that have taken place over the centuries" [3]. The areas of Valtellina examined in this study have a fascinating and extremely important mining tradition, which has affected life in the territory since the Middle Ages. The area has a low settlement density and consists largely of woodland in which mining, agricultural, woodland and pastoral resources have profoundly influenced the life of local communities and where the landscape has undergone numerous transformations as a result of the processes that made their usage possible [4]. The interpretation of mining landscapes and the phases of their exploitation vary but the geographical features of Valtellina and the formation of the first urban settlements in the Middle Ages confirm the arguments put forward by Ilaria Burzi: "[. . .] the theme of the areas of mining activities does not concern the individual components, quarries and mines, but the entire context to which they belong which explains the need to refer to "landscapes". If a landscape can be considered the physical expression of action during the existence of a society, its way of operating and administering the territory, then mining landscapes represent a significant example of the transformational processes carried out by humans–activities related to extraction–and by nature" [5].

My main goal shall therefore be to analyse these distinctive landscapes without confining them to cognitive processes per se, but instead trying to preserve the ties to the territory to which they belong and in which they are set, in order to treat them as landscapes that can be understood and appreciated by everyone. This is because, if the landscape is considered as the living space of its communities, shaped and constructed by them over the centuries, these mining areas, which have now fallen into disuse, should be considered "[. . .] not just a recoverable non-place but a total and practical opportunity for the redevelopment and socio-economic rehabilitation of the whole territorial context in which they are situated" ([5], p. 11).

This article will explore several mining areas of Valtellina, currently reduced to ruined stone structures (furnaces, dwellings, storerooms and stables), silent witnesses of the efforts of the miners, mule drivers and workmen deemed to be magical places, containers of the history, stories and working experiences of entire communities of the past. The preservation of all these contexts, both the areas where the mining and extraction activities profoundly affected the appearance of the natural landscape and the workshops in which the semi-finished products took shape, represents the only way of attracting the attention and interest of local institutions in order to encourage them to change their approach towards the planning of a mining area that has the potential to become a tourist attraction and an educational resource ([4], pp. 14–15).

2. Materials and Methods: Survey, Historical Cartography and GIS

The research activities of the Department of Historical Studies of the University of Turin focused on the territory of the municipalities of Piateda and Fusine, in central Lombardy (N Italy) (Figure 1), where an accurate graphic and photographic documentation of what remains of this extraordinary remote past in Ambria in Val Venina (Piateda) and in the Cervia and Madre (Fusine) valleys was carried out. The first phase of the research, dedicated to reconnaissance and a preliminary consultation of sources, revealed the absence of the investigated sites in contemporary cartography, which is why the working group's first objective was to survey and georeference the individual items of evidence.

The specific contexts did not provide fiducial or reference points through a common indirect survey with a total station could be implemented: the results would have been recorded but there would have been no possibility of contextualising them. The total station, moreover, being composed of heavy elements and very sensitive to abrupt movements, would not have been suitable for the type of route that had to be taken on foot, off-path, to reach the places in question; the risk of surveying with an uncalibrated instrument would have been too high.

Having assessed these impossibilities, the only way to carry out an indirect, georeferenced survey was to use a GPS (Navigation Satellites Timing and Ranging Global Positioning System) satellite positioning system, which, through a dedicated network of orbiting artificial satellites, provides a mobile terminal with information on its geographical coordinates. The terminal is placed on the individual points to be surveyed, obtaining their x-y-z coordinates; these data are then graphically transformed into points in space that together delineate the morphology of the survey object. This proposal, too, encountered an obstacle of no small magnitude at an early stage of analysis: the areas concerned are completely lacking in GSM (Global System for Mobile Communications) coverage, a system that is used by the instrument to increase the accuracy of the satellite data received, in the absence of which there can be a very high degree of reliability discrepancy. The solution was found by opting for a type of GPS instrument that bridged the lack of GSM coverage with the help of two receivers, called Base and Rover. Through this system it was possible to proceed with an RTK (Real Time Kinematic mode)-type survey, determining and displaying in real time and in rapid succession the x-y-z coordinates of many points (detailed survey). The Rover station on a pole was placed on the points to be surveyed, connected to the satellite system and linked via Bluetooth to the Base station; the latter, positioned on a point of known coordinates (known point), refined the data from the same satellites. In this way, accuracies of up to half a centimeter were achieved. The size of the constituent elements of the GPS instrument made it possible to transport them easily and to survey all the evidence found in both Fusine (Val Cervia-Val Madre) and Piateda (Ambria-Val Venina).

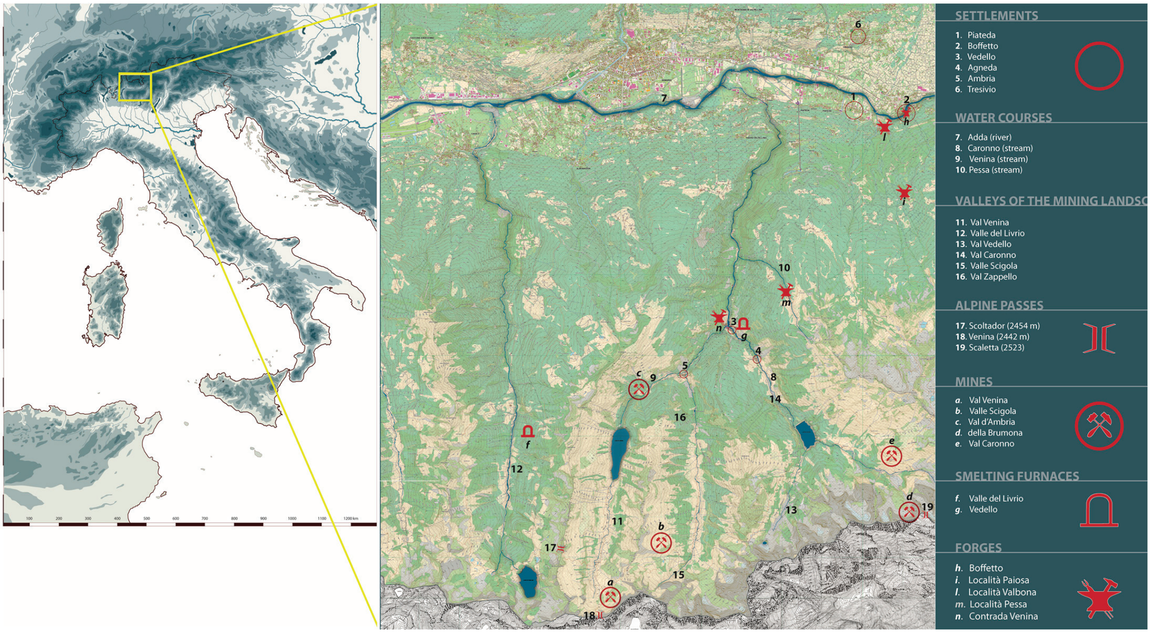


Figure 1. Map of the territory analysed in the study with specific reference to the extraction and production sites (map by the Author).

The Vitalengo mine, in the locality of Flere (Val Cervia), was surveyed precisely along its entire section, providing a graphic elaboration aimed at highlighting the relationship between mining activity and the orography of the terrain. The careful survey made it possible to geolocate and describe the remains of a masonry structure functional to the mining area and two roasting ovens located in the area, providing archaeologists with orthogonal projections and sections useful for analysis and comparison. A few hundred metres from the Vitalengo context, the remains of partially collapsed buildings were identified, which can be considered miners' dwellings and/or the shelter of animals/work tools, along with an additional roasting oven with adjacent masonry structures.

In Ambria, in the locality of Le Gere, at the foot of the Scale di Venina path, an oven was identified that was reported on some historical maps, though its existence was unknown in the present day. The structure, probably a roasting oven, was geolocated and only partially surveyed due to the presence of invasive vegetation.

Subsequently, the known evidence forming part of the Val Venina mining site was surveyed, in particular the imposing circular structure (a roasting oven) positioned at the base of the production context, the mouth of an underground tunnel (with a masonry access corridor in front) and the remains of structures attributable to miners' dwellings and/or the shelter of animals/work tools (Figure 2).

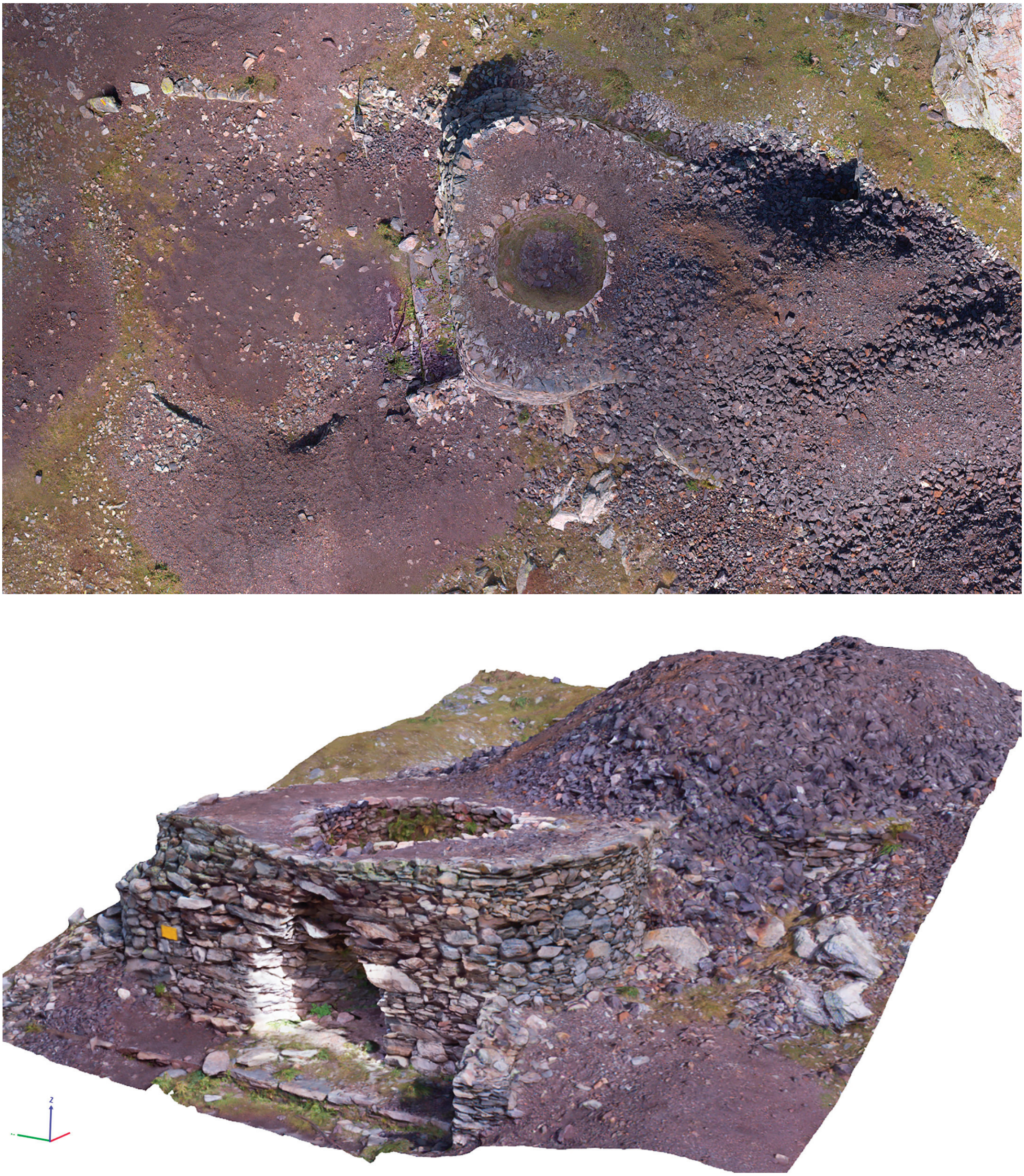


Figure 2. Piateda (SONDRIO), mining site in Val Venina. Roasting furnace. Aerial photogrammetric survey and three-dimensional restitution.

It is necessary to point out that, given the particular context, the survey activities were preceded by a careful reconnaissance campaign supported by multidisciplinary expertise and geared towards the identification of the survey priorities. Data acquisition was completed by means of aerophotogrammetry, and the GPS tool was used to georeference the drone footage during this phase as well. The first part of this operation was dedicated to planning; the areas to be surveyed were identified, the drone's take-off and landing points were chosen (a not insignificant detail given the orography), the best positions of the ground control stations were defined, and possible flight obstacles were identified. Teamwork between the aerophotogrammetric survey operator, the survey architect and the archaeologist was necessary to agree on the positioning of the GCPs (Ground Control Points), i.e., the points on the ground whose geographical coordinates were precisely known and which were used to scale the aerophotogrammetric survey. These points, being 60 × 60 cm panels, are fundamental for the aerophotogrammetric survey operator but, if located too close to the archaeological evidence, they risk interfering with the reading of the structures, thereby undermining the purpose for which this operation is carried out. The photographs were taken both with a nadiral camera (pointed towards the ground) and with a camera oriented frontally or inclined with respect to the horizon, in order to subsequently enable a three-dimensional rendering and thus to describe the relationship of the structures with the landscape context (Figure 1). The meticulous fieldwork made it possible to gather important and unpublished information on the state of the sites at altitude, but it was essential to supplement this with precise cartographic research in order to bring out the historical identity of the sites surveyed and the points of contact with the historical-urban analysis of the centres in which the activity of the forges took place.

The study of historical cartography was undertaken on the basis of the work carried out on the occasion of the exhibition held in Sondrio in 2006 [6] and Oscar Sceffer's research, aimed at outlining the cartographic landscape of Rhaetia between the 16th and 19th centuries [7]. It is important to point out that map publishing developed as a consequence of the start of printing between the end of the 15th century and the beginning of the following century and that the first regional maps date back to the 16th century, a period to which the maps of Valtellina can also be attributed.

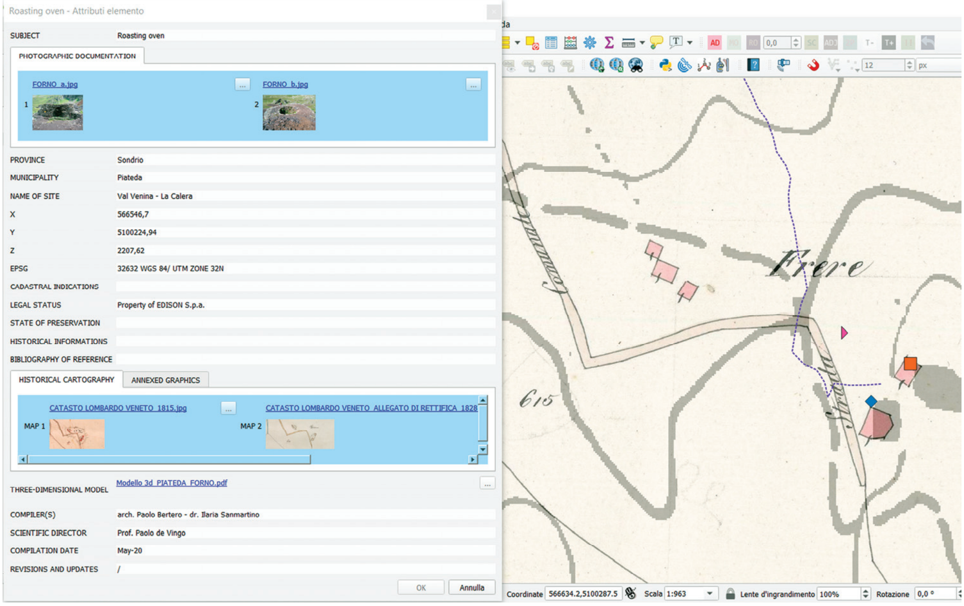
In early 17th century cartographic documentation from the Graubünden period, it was possible to find the location of Vitalengo and Venina in the "terzero di mezzo" and the indication of the Alpine passes connecting Val Madre, Val Cervia and Val Venina with the Valle Brembana in the Bergamo area [8]. The 19th century cartography identified the sites of La Calera in Val Venina, the Forno di Vedello (whose structure was later incorporated into a building, brought to light by the alluvial flood of the Caronno torrent in 1987) and, as described above, the structure of initial material processing in Ambria, in the locality of Le Gere. The research found elements for more in-depth analysis thanks to the study of the 19th century Catasto Lombardo Veneto (Lombardy-Venetia land register), preserved in the State Archives of Milan (first draft of 1815) and Sondrio (second draft of 1853 and subsequent amendments). The collections consist of hundreds of watercolour cadastral maps at a scale of 1:2000 of high formal quality: the "Book of Parcels", the "Register of Possessors", the "Register of Map Numbers" and the "Description and Estimate Table". This census activity was undertaken in Valtellina in 1807; after the fall of Napoleon I, the operations were continued by the succeeding Habsburg government and concluded in 1853. The Catasto Lombardo Veneto is of the geometric parcel type in that it subdivides the territory into parcels defined on the map, classifying them according to pre-established criteria that take into account the intended use, types of cultivation and the value of land and buildings [9]. The study of this census tool made it possible to identify the forges present in the 19th century in the territory of Fusine and Piateda, where iron was transformed into finished products; by means of cartographic filtering operations with a GIS software, again starting from the Catasto Lombardo Veneto, the study of the system of irrigation ditches that supplied mechanical energy to the activities was further investigated.

The analysis of the Registers of the Catasto Lombardo Veneto not only offered valuable information on the owners of the forges, but also made it possible to study the urban contexts graphically described on the maps within which these production sites were set up. As was customary, in Fusine as in Piateda (locality Boffetto), the owners of the forges also managed the adjacent buildings, which in most cases were used as residences and sometimes registered as "*mulino da grano ad acqua*" (water-powered grain mills), the latter identifiable on the maps because they were tangent to the water channels. Furthermore, it was particularly interesting to find that in the 19th century the structures visible in Val Venina in locality La Calera were larger in number than today; they were probably intended to house workers or shelter equipment and their number confirms the significant size of the mining site [10] (Figure 3). The data from the activities described, using the GIS (Geographic Information System) tool, were merged with those that surfaced in the historical research in order to make them easily implementable and ready for immediate consultation and thus enable the study of the entire Orobic landscape.

Figure 3. Piateda (SONDRIO), mining site in Val Venina. Detail of the GIS processing with superimposition of the geo-referenced evidence on the Lombardo Veneto Cadastre of 1815 and on the Regional Technical Map. Dotted line shows the present pathway, orange square shows the workers' house and shelter, blue lozenge shows the roasting oven.

Using an Open-Source GIS software and the Regional Technical Map as a cartographic basis, the evidence under study was positioned, appropriately differentiated according to its identity (vector data), such as mines, roasting furnaces, and elevated and outcropping structures. By means of cartographic filtering, it was possible to trace the vectors representing the historical routes and Alpine passes relevant to the iron industry; this will make it possible, in the future, with a greater number of case studies, to carry out thematic research and make the appropriate comparisons. It should be noted that, thanks to the survey campaigns, each element was georeferenced and thus positioned on the GIS using real coordinates (prior to this work, no structure had been mapped).

For each piece of evidence, moreover, a master data sheet was prepared, including historical and photographic documentation, graphics and the three-dimensional model; for access and consultation, simply select the symbol that identifies the object on the map and represents the type of evidence (Figure 4). The historical cartography has been included in the system at full scale (raster data) and consequently the researcher can either compare a given map with the current situation or compare two or more historical maps at the same scale. Obviously, the vectors identifying the surveyed evidence can be superimposed on the historical maps, providing interesting keys to interpretation. This work must be considered a starting point in the graphic documentation and GIS processing of the data regarding the archaeo-mineral landscape of the Orobic side of the Valtellina, but we are equally convinced that the potential of these operations is high and spendable both in research and in enhancement initiatives.



Roasting oven - Attributi elemento

SUBJECT	Roasting oven
PHOTOGRAPHIC DOCUMENTATION	1 FORNO_a.jpg 2 FORNO_b.jpg
PROVINCE	Sondrio
MUNICIPALITY	Piateda
NAME OF SITE	Val Venina - La Calera
X	566546,7
Y	5100224,94
Z	2207,62
EPSG	32632 WGS 84/ UTM ZONE 32N
CADASTRAL INDICATIONS	
LEGAL STATUS	Property of EDISON S.p.a.
STATE OF PRESERVATION	
HISTORICAL INFORMATIONS	
BIBLIOGRAPHY OF REFERENCE	
HISTORICAL CARTOGRAPHY	MAP 1 CATASTO LOMBARDO VENETO_1815.jpg MAP 2 CATASTO LOMBARDO VENETO_ALLEGATO DI RETTIFICA_1828
THREE-DIMENSIONAL MODEL	Modello 3d_PIATEDA_FORNO.pdf
COMPILER(S)	arch. Paolo Bertero - dr. Ilaria Sanmartino
SCIENTIFIC DIRECTOR	Prof. Paolo de Vingo
COMPILATION DATE	May-20
REVISIONS AND UPDATES	/

Coordinate 566634.2,5100287.5 Scala 1:963 Lente d'ingrandimento 100% Rotazione 0,0 °

Figure 4. Piateda (SONDRIO), mining site in Val Venina. Roasting furnace. Detail of the data sheet of the GIS processing.

3. History and Archaeology of Iron in the Alpine Areas

The practice of separating iron from its ore is attested in the European area from the 9th century BC. [11,12]. In the early Middle Ages, the transformation process took place in a closed furnace where layers of ore and natural coal were arranged; the coal was ignited while air was supplied by hand-operated bellows to fuel combustion. From the furnace, bloom was extracted, a spongy material that, in addition to iron, contained fragments of coal and ore and some pieces of steel, an iron alloy with a very low carbon content. The bloom was worked by continuous heating and subsequent hammering until it was transformed into an alloy of iron and steel. The spread of iron ore throughout all areas of Europe, including Italy, coincided over a period of almost 1500 years with a large number of processing sites and a considerable variety of smelting plants. All these apparatuses, semi-underground or sleeve furnaces, with slag collection at the top or bottom, were of a closed type and human presence was only required to check that combustion was taking place in a regular manner [13,14].

In the course of the late medieval centuries, Italian and European iron manufacturing experienced a new productive impulse thanks to the affirmation of new processes that allowed for an extraordinary increase in the exploitation of the ore: furnaces and forges to obtain iron and steel; furnaces for the production of raw iron (pig iron) and forges with open hearths; ironworks with open hearths for iron processing. Three different methods that, in no casual relation to the respective contexts in which they developed, and which underwent various improvements during the 17th and 19th centuries, always remained distinct from each other. The European development of iron manufacturing, a direct consequence of the application of the horizontal-axis water wheel first to the movement of hammers and then to that of bellows, coincided with an extraordinary increase in production capacity and the extraction of ore ([13], p. 200) [15].

In the early Middle Ages, written sources confirm that in the Alpine areas close to Valtellina, Valcamonica (in the Brescia area), Valseriana and Valle Scalve (in the Bergamo area), iron mining and metallurgy were already organised and operational to extract and process raw ore. In the area of Bienno in Valcamonica, the excavation of the site of Ponte Val Gabbia III has shown that workers capable of voluntarily decarburising pig iron existed as early as the 5th–6th century, providing a fundamental impulse to the technological perfection of iron metallurgy [16–18]. While the transition from the direct to the indirect method represented a decisive technical innovation for the development of the iron and steel industry, it was not until the 13th century that important economic, political, administrative and legislative implications arose. The cognitive progression of both civil and military engineering skills favoured the introduction of new ore mining and metalworking techniques that would lead, especially in German areas, to the renewal and strengthening of the entire metallurgical mining sector [19].

Medieval historical sources concerning the exploitation of iron mines in the Valtellina territory do not attest to a uniform use of these resources, since the most significant mining activities are documented, from the 13th century onwards, in the entire Bormiese area (Alta Val Zebrù), in Valdidentro, in the Livigno valley and in Val Fraele [20]. The northern Valtellina sector is in fact characterised by the presence of rich limonite deposits, with the exception of Val Zebrù, where magnetite veins are found. Archaeological data show that urban centres, including Sondrio, received substantial quantities of semi-finished products to supply the workshops of local blacksmiths in the form of iron blocks, of standardised weight, defined in documents known as “*broza*” in Bormio, “*quadrones*” or “*regones*” in the lower Valtellina [21].

In 1325, Giacomo Capitanei ceded all his rights over the metalliferous veins in the Zero valley (Val Cervia) to ser Amedeo del fu dominus Ardizzone de Vallevi. In November 1452, Giacomina Capitanei, of the same Sondrio family, with the consent of her husband Antonio Beccaria, granted the brothers Donato and Biasino de Vallelevi the mountains of the Val Madre and Val Cervia in perpetual lease, and specifically the possibility of digging and owning all the existing iron veins, requiring them to pay, for the right acquired, an annual fee in baked iron [22].

Sources also confirm significant excavation operations in the southern Valtellina region from the 14th century onwards. In the first case (Val Tartano), we are referring to the metalliferous veins located between the Valle dei Lupi and the Dordona pass, known in the local toponymy as Caxirolo, where mining activities appear in certain deeds of Simone della Porta, notary of Talamona. A first document of sale from 1344 concerns mining activities carried out in Dordona with which “[...] *Guarischi de Fondra qui stat in loco de Talamona*” sells to Vincenzo del fu Pietro “[...] *de octo partibus una pars pro indiviso metali unius a fero siti in loco et territorio de Talamona ubi dicitur in Dordona*”, while a second notarial deed of 1345 indicates a mining site identified as “*vene de Caxirolo*” [23]. For the second area (Val Gerola) in the vicinity of Lake Inferno, just beyond the settlement centre of Gerola at an altitude of between 2000 and 2143 m. a.s.l., both open-pit and tunnel cultivations of hematite and siderite have been surveyed and studied, the mining of which can be dated to between the 15th and 16th centuries. This is confirmed by a sub-vertical trench extending over a length of 110 m, 8–10 m deep and approximately 1.85 m wide. In this mining complex, a covered, dry-built gallery was documented, functioning as a connecting sleeve to a stone structure, probably temporary accommodation for the workers who worked in the excavation of the iron veins [24].

4. Documentary Sources and Iron Metallurgy in the Orobic Alps: A New History

In the Orobic Valley in Valtellina, the memory of an important productive past linked to iron-working emerges from the evidence of many historians of Lombardy, such as Carlo Amoretti (1724), Francesco Saverio Quadrio (1755), Carlo Cantù (1829), Annibale Saluzzo (1845) and Francesco Giordano (1864), even though only Amoretti, Quadrio and Cantù attribute the most intensive period of mining to the historical phase that corresponds to the period of rule by the Sforza, Dukes of Milan (1450–1499).

Enrico Besta, referring to one of these testimonies, that of Francesco Saverio Quadrio, recalls that the metalliferous deposits in the Belvisio and Ambria valleys “from which much iron was extracted [...] that had been famous under the Visconti” had by then been reduced, in the first half of the 18th century, “[...] to large excavations full of water [...]” [25] ([20], pp. 6–7).

Each circumstance that undergoes a phase of maximum growth always requires a pre-existing substratum on which to deposit itself, grow and develop. The same can be said for iron-working in this area because, even though the medieval period, beginning from the second half of the thirteenth century, has always been considered to mark the beginning of the phase of Alpine metalworking, several documents from the rectory (*canonica*) of Santa Eufemia (Isola Comacina) dating to 999 and 1006 testify to the development of this activity during a period over three centuries earlier. A notarial deed refers to the name of *Iohannes* and identifies him as the *ferarius* (i.e., the smith), an inhabitant of the *vicus* of *Cose*, a village situated at the foot of the Orobic Alps, close to Lake Como and Lake Valchiavenna, an early indication of a profession linked to iron metalworking that was already underway and thriving in the territory. The same is true for the area of the *carbonaria*, referred to in an interesting document dating to 1085 that records the sale of a chestnut wood in Morbegno, because it implies the presence of the production of charcoal, an essential fuel source for the working of iron ore [26]. The result of this production platform is confirmed in 1276 when the Bishop of Como granted Goffredo *de Capitanei* the right to exploit the metalliferous deposits under the jurisdiction of the parish churches (*pievi*) of Berbenno and Sondrio, in 1378 with the promise of Oldarico to deliver Arrighino de Bordogna “[. . .] 250 *centinaria feri crudi boni neti puri de illo castro Ambrie* [. . .]” and in 1382 with the presence of a production site at Vedello (see *infra*) with facilities that ensured the indirect reduction process of iron ore “[. . .] *pro faciendo et colando venam faciendi ferum* [. . .]” [27]. This timeframe leaves no room for doubt about the territory’s capacity to pave the way and then, immediately afterwards, to begin the cycle of Alpine ironworking, developing mining and smelting activities both to the east of Piateda in the valleys of Belviso, Caronella, Bondone and Arigna and to the west in the valleys of Livrio, Cervia, Madre, Ambria, Tartano and Gerola.

5. Mines and Roasting Ovens in the Orobic Alps

The first structure, identified as a roasting furnace, was identified along a mule track that leads up from Ambria to the Venina Pass (2442 m. a.s.l. in the direction of Val Brembana) and the Scoltador Pass (2454 m. a.s.l. towards the Livrio valley), in the *Li gèeri* area, just before the point where the path begins the steep climb of the *Scale di Venina*. Although the site has been largely destroyed and covered by thick invasive vegetation, it was possible to identify the loading opening and a small opening at the base, preserved partly by the dense vegetation: these are the distinctive features of a structure designed to ensure the initial “roasting” of the iron ore (Figure 5). The *regrana* (furnace) is not mentioned in local historical records. However, its presence at this point is mentioned both in the land register of the Catasto Lombardo Veneto (1815) (Figure 6) where it is described in detail, and by the placename *Fornace*, marked a few years later on military maps drawn by Austro-Hungarian engineers (1818–1829) (Figure 7). Nevertheless, given the current state of research, questions still remain about the provenance of the iron ore that was roasted in this structure, since the distance between this site and the mine of Val Venina, equipped with a structure capable of working significant amounts of iron ore, would appear to be too long and therefore economically unfavourable in terms of the cost of transporting the raw material. It is therefore more likely that the furnace was supplied by one or more deposits situated in the vicinity that have yet to be identified [28].

Figure 5. Piateda (SONDRIO), Località "*Li gèeri*", roasting oven buried beneath invasive natural vegetation: detail of the slag outlet at the base of the oven.

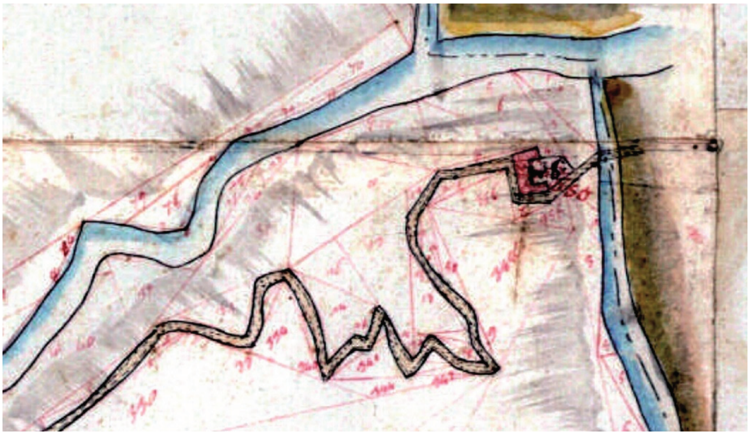


Figure 6. Extract from the cadastral map of the land registry (Catasto) of the kingdom of Lombardy-Venetia (1815). Plan of the roasting oven in località "*Li gèeri*" (image by the Author).

The mining context of Val Venina is situated in the uplands at an altitude of 2207 m. a.s.l., just beneath the head of the valley that separates the side facing the Orobic Alps from the one facing the Bergamesque Alps. This is the spot where discoveries were made of the remains of a productive complex consisting of several mines, structures for the initial working of the iron ore and the ruins of cabins and huts used for housing workers, mule drivers and animals. The structures were accurately mapped in the surveys conducted by the Catasto Lombardo Veneto, both in the version drawn up in 1815 and in the one done in 1853 (with subsequent amendments), where the area is marked with the placename *Frere*, an indication of the presence of iron mines [29].

Two extraction areas, one an underground mine and the other an open-pit mine, were identified during surveys carried out in situ. The first is situated in the westernmost part of the area, a few metres away from the miners' cabins and the blast furnace, access to which was through a narrow entrance, preceded by a long corridor (17 m × 1 m) bordered on the sides by dry-stone walls, which have now partly collapsed (Figure 8). It is probably the nineteenth-century mine described by Melchiorre Gioia in the *Statistica del Dipartimento dell'Adda* "[. . .] uno scavo interno al monte [. . .]" (an excavation within the mountain), used already in antiquity and divided into several tunnels preceded by a large space [30].

Figure 7. Extract from the second military survey of the Hapsburg Empire (1818–1829) with an indication on the map of the placename "Fornace" (image by the Author).

Figure 8. Piateda (SONDRIO), mining complex of Venina. View of the underground entrance to the mine with the access corridor outside (image by the Author).

In the northernmost part of the site, there are four rooms made of dry-stone walling. The roofs of the rooms no longer survive, but the elevations, arranged around the sides of a large block of rock emerging from the ground, are partly preserved. The structures situated to the left of the boulder, partly interconnected by means of openings, can be interpreted as the cabins of the miners, while the room located on the opposite side of the rock was probably a charcoal shed or "coal house"; the building displays a fairly poor construction technique and was probably less well insulated compared to the others, since the western façade consisted only of the rockface. A fourth small room, conceivably a storeroom for equipment, was built north-west of the boulder in the space created between the boulder and the masonry structure that was built against it (Figure 9).

Figure 9. Piateda (SONDRIO), mining complex of Venina. 3D view of the buildings related to mining activity (image by the Author).

Melchiorre Gioia's book *Filosofia della Statistica* describes how a company working in Val Venina consisted of 15–20 miners, called "frerini", coordinated by a chief excavator ("capo scavatore"); some of them were involved in mining activities, others were responsible for transporting the iron ore to the roasting furnaces, while others were in charge of separating and cleaning the heated seams. The numbers were bolstered by mule drivers who, during the summer months, transported the roasted iron ore to the smelting furnace in Vedello ([30], p. 368). Apart from those involved in transporting the coal and the iron ore, the workers were not local and mostly came from the Bergamasque department of Serio. Mining work was generally carried out in the winter months when ice restricted the amount of water leaking into the tunnels, causing hardship for the miners; the workers spent long periods of isolation in the buildings adjoining the quarries and mines, equipped with sufficient foodstuffs and wood for their needs. During the other months, they performed other activities linked to the working and transformation of the raw material (selection, crushing, roasting and seasoning) in order to organise the transport of the ore down into the valley ([24], p. 47).

The second open-pit mine was identified in the easternmost part of the site on the slope that separates the valley from Val Zappello, where the mine resembles a sub-vertical trench just over 20 m long with an average width of 2 m. Holes (with a diameter of about 30 mm) were identified along the walls of the mine face and were used to insert explosives. This work can be attributed to the final phase of mining operations when in 1939 the "Società Anonima Stabilimenti Elettrosiderurgici Carlo Tassera (Breno, Italy)" asked the town council of Piateda for authorisation to use explosives to loosen the rock [31].

Lastly, the most easily recognisable structure at the site is the large roasting furnace placed at the front of the entrance to the area, marked on the cadastral map of Lombardo Veneto (1815) with a feature that clearly refers to the one preserved today. The structure is made of dry-stone walling with dimensions that reach a maximum of about 4 m high × 10 m wide; the eastern part of the construction appears to be built against a natural knoll behind, upon which there is a large mound of abandoned iron ore (Figure 10). The central part of the structure contains a large belly in the form of a shaft that tapers at the base, with a circular mouth with a diameter of 4.5 m and an overall height that must have corresponded to about 3 m, although the precise dimensions cannot be determined due to the presence of debris and residual iron ore in the inner cavity. At the centre of the huge façade there is a deep arched opening, in the lower part of which there is a second, smaller quadrangular opening. Two dry-stone walls marked the limits of the flat area in front of the furnace, although only a few courses of the walls are still preserved ([28], p. 232).

Figure 10. Piateda (SONDRIO), mining complex of Venina. View from the west of the open-pit mine (photograph by Ilaria Sanmartino).

The structure was used to roast the iron ore, in other words to carry out an initial "cooking" designed to eliminate most of the impurities that could be altered in the heat within the excavated cavity. By the end of the process, the iron ore had lost roughly 25% of its initial weight, facilitating the transport of the material to the reduction sites. The central space of the furnace was filled with layers of charcoal and iron ore, eventually reaching 3/4 of the total volume; loading operations were facilitated by the large loading opening of the furnace and by the ledge provided by the knoll situated behind it. The roasting process took several hours until the charcoal had been used up, and the workers in charge of the furnace had to monitor the opening at the base on a constant basis to ensure that the fire did not go out or overheat. Once the combustion phase had ended, the iron ore was deposited on the bottom and, once it had cooled, was extracted using shovels through a small opening. The seam subsequently underwent a lengthy period of weathering in the open air so that the elements removed the impurities still present in the ore, after which it was crushed into small pieces and transported down into the valley, where it was reduced in smelting furnaces. These operations were carried out in the area in front of the furnace, where plentiful levels of small pieces of roasted iron ore are still scattered over the whole area. These activities, like the ones that preceded the roasting phase (selection and initial crushing of the seam), formed part of the tasks undertaken in the summer months close to the mine. Even though the material structures used in the process have undergone numerous technological transformations over the centuries, the methods for preparing the iron ore remained largely unchanged [32].

A second roasting furnace, which can be identified as a structure in the easternmost sector of the site, situated a few metres away from the open-pit mine, has been largely stripped (possibly due to the reuse of the stone employed in its construction) and obstructed by debris and iron ore refuse. Nevertheless, a visible furnace remains, observable through aerial photography, bearing a striking resemblance to the plan of the furnace described above, albeit on a slightly smaller scale (9 m × 5 m). The structure is not included in the cadastral map of the Catasto Lombardo Veneto (1815), so its use may date back to an earlier phase. The furnace may well have been abandoned due to malfunctioning or abandoned to construct the existing one, which was sufficient and more practical for the productive needs of the site ([28], p. 234).

6. Iron Metallurgy in the Orobic Alps: The Vedello Blast Furnace

The settlement of Vedello (1032 m) is situated in the point in which Val d'Ambria is divided between the branching of the Ambria and Venina rivers to the west and the Caronno and Vedello rivers to the east, at the confluence between the Venina and Caronno rivers. The construction of a smelting furnace at this point was strategically important due to its proximity to the areas supplying the materials required: the iron ore and the wood charcoal came from the mines and woodlands in the valleys above Vedello, where all the routes (paths and mule tracks) used for transport converged, while the confluence of Venina rivers in the Caronno river guaranteed the water capacity required to power the bellows of the plant.

The first indirect reference to the furnace can be found in a document of 1212, where *Morescus Magani de Furnis de Vedello de Trisivio* appears as a witness in the deed of the sale of land between two inhabitants of Tresivio [33]. It is not until the end of the following century that we have more detailed information about the structure and its location in the district of Vedello, when the roasting furnace crops up in a series of notarial deeds regarding the sale of the furnace itself or other adjoining property. The boundaries mentioned in a deed of 1382 indicate that the structure was situated "*a mane flumen Caronni, a meridie ser Taloli de Ambria accessium mediantem mediante, a sero via communis et a nullaora suprascriptum flumen Caronni in parte et in parte via communis*". In 1470, the furnace is mentioned in a notary deed regarding the sale "*de piazo uno in territorio de Trixiviomonte in contrada de Vedello prope furnum cui coheret* [. . .] *et ab altera suprascriptum seu carbonile ipsius furni strata mediante*" and seven years later, in 1477, another document describes how "*in valle de ambria in contrada de vedello quibus omnibus coheret a mane communis vide licet plaza et carbonilia furni a ferro a meridie assero strata et a nullaora flumen caroni*" ([27], pp. 90–91).

The furnace therefore bordered the Caronno river to the east, the property of an inhabitant of Ambria to the south, the municipal road to the west and the Caronno river and part of the municipal road to the north. The position is the same as the one on which a new furnace was built in 1803, as is indicated by the structure surveyed in the land register compiled by the Catasto Lombardo Veneto (1815). It was in this spot, following heavy flooding in 1987, beneath what corresponded to the "Privativa Tavelli", that the Caronno burst its banks, bringing to light ruins belonging to the nineteenth century structure, subsequently incorporated into the retaining wall built to stop floodwater (Figure 11).

The information contained in late fourteenth-century documents shed light on the technological features of iron working at the structure in Vedello. More specifically, the reference *pro faciendo et colando venam faciendi ferum* indicates that the blast furnace was capable of ensuring the indirect reduction of iron; the plant therefore had stable structures that were fairly sizeable. This technological innovation, which originated in the valleys near Brescia where the production and spontaneous decarburisation of pig iron had been practised since the fifth/sixth century, became firmly established from the thirteenth century onwards in the Lombard Alps before spreading to the rest of Italy and subsequently, when the production process was at its height, to many areas in Europe [16].

In the territory of Valtellina, the first evidence for the adoption of this procedure dates to 1269 in the area of Bormio (furnace at Semogo), and it subsequently spread throughout most of the Orobic valleys such as Val Gerola (furnace at Costa, 1294: furnaces in *Cagamozio*, 1326), in Val Tartano (1347, furnace at Consegio in Talamona, 1348), in Val Cervia (furnace at Cedrasco, 1378) and in the same year in the nearby Livrio Valley ([30], p. 364) [34–37]. Using this procedure, it became possible to split the production process into two phases. During the first phase of the production cycle, the skilled workforce used a blast furnace to smelt the iron ore in order to obtain pig iron (known as *ferrazzo*, *ferro grosso* or *ferrum crudum*) while, in a subsequent phase, they transformed it into iron (*ferro cotto*, *ferrum coctum*) or steel through a process of decarburisation (i.e., a second "cooking"), which took place in refining forges known as "fucine grosse", where the iron was beaten with a drop hammer to create semi-finished products of various types. By using the indirect smelting process, it became possible to produce pig iron in a continuous cycle without the need to interrupt combustion, as was the case for the traditional direct smelting process (*bassofuoco*), in order to obtain the metal bloom and introduce fresh charcoal and iron ore. This procedure also enabled the extraction of a greater percentage of iron from the ore, considerably reducing the amount that was lost during the production process ([32], p. 101) [38–41] ([13], pp. 205–206).

Figure 11. Vedello (SONDRIO), Privativa Tavelli damaged by the flood of 1987. Beneath the structure are the probable ruins of the smelting furnace which emerged during flooding when the Caronno river burst its banks (photograph by Marino Amonini).

In 1584, the blast furnace at Vedello was operational, as is shown by the equipment listed in the will of Castellino Beccaria (work tools, seven mules for transporting the iron ore or the charcoal and fifteen carts loaded with hay to feed the pack animals); in the following years it was predicted that the structure would operate at full capacity, thanks to the capital—the princely sum of 2000 gold *scudi*—invested by the company set up by the Beccaria and Morandi families to run it ([27], p. 83).

A document dating to 1591—in which the Beccaria brothers sold the blast furnace to Alessandro Carcano—is the first source that provides a detailed description of the smelting process. The building had a rectangular base and was arranged on two storeys: the lower vaulted level measured about 10 m × 5.5 m, while the upper storey measured about 10 m × 8 m; the roof was made of wooden planks. Entry to the furnace room was via a large door with a chain and lock, while the upper floor, which also had an entrance, did not have any specific security system. The inner part of the furnace contained the *caneccio*, the local term for the reduction tower or stack in which the iron ore was reduced; the measurements of the structure are not given, but the overall height reached the upper floor, where the loading opening was located [42,43]. The actual smelting process was preceded by a phase of heating the furnace during which the *caneccio* (stack), filled only with charcoal, was lit for the whole day to eliminate damp within the structure. It was during this preparatory period, which could last up to several weeks, that the ironmaster in charge of the furnace demonstrated his expertise. He was entrusted with the task of obviating or solving the technical problems that might crop up during the smelting process because, once lit, the furnace remained active for months at a time [44]. After the preliminary checks had been carried out, the iron ore was loaded into the stack (*caneccio*), alternating with layers of charcoal. Inside the furnace, the iron ore underwent a series of chemical and physical reactions and processes according to the temperatures produced at the different heights of the structure. The smelting point was reached in the zone of the *presura*, the lower part of the furnace where air was pumped using bellows; at this point, the bosh narrowed considerably in the lower part of the furnace and the iron ore, restricted by the bottleneck, formed a sort of vault through which the slag (*loppa*) and the pig iron could be collected and poured. Firstly, the slag floating on the crucible was poured off using special tools with duck-billed spouts (*raspirolle* and *lacciaroli*) and the pig iron, dragged into a pool of running water (*pozzo*), known as a *rampino*, was subsequently drained ([22], pp. 232–233).

The ironmaster's tasks included the preparation of the iron ore for smelting, generally from different seams, checking the exposure to the fire of the right quantity of ore and regulating the constant flow of air into the furnace to ensure that the iron-making process took place at a steady rate. At Vedello the ventilation system involved a pair of bellows (*mantici*), described as new and equipped with all the mechanisms required for their efficient functioning; the air was introduced into the furnace via a single tuyere (*canna*). The bellows were activated by the force of running water, channelled from the Caronno river through a system of canals (*canali aquedutti*). The air supplied by the bellows was regulated by the flow of the water to the wheel (*rota*) fitted with a wooden shaft with an iron rim (*arbore con vere dieci di ferro*) which transferred the movement to the drive shafts of the bellows (*braccioli*). The furnace complex included other rooms, including a large storeroom used to store the charcoal (*carbonile*) capable of containing from 400 to 500 sacks of fuel, and a well-guarded room for storing iron ore (*venaiola*).

At Vedello, there was a fairly large complex equipped not only with the furnace and the machinery required for it to function, but also permanent ancillary buildings, as well as accommodation for the workers, even though this is not mentioned in the document. The costs of running the furnace must have been high, including the sourcing of supplies (iron ore and charcoal) with relative transport expenses, the payment of the workforce (employed in all phases of the production process) and the frequent maintenance of the structures and machinery of the *caneccio*. Unfortunately, the available documentation does not provide precise indications about the names and origins of the workers who constructed the furnace, or the number and tasks of the people who were in charge of its functioning; there is also a lack of data about productive capacity, even for the years between the sale of 1591 and 1803, when it is known that a new furnace was constructed by the company directed by Gaspare Sacchi, designed to exploit the mines in the territory of Piateda ([28], p. 244).

Moving westwards towards Piateda, the research focused on the territory of Fusine, particularly on the uplands of Val Cervia where, at an altitude of over 2000 m above the peak of Cima Vitalengo, a series of structures linked to mining and initial working of the iron ore have been documented. The ruins of a siderite mine, probably the same one that appears on an old map of the uplands of Val Cervia made in 1688, are visible on the eastern slope in the district of *Le Flerie* [45] (Figure 12). It is a large open-pit mine covering an overall area of over 115 m with a difference in height of about 80 m. The mine consists of a large subvertical trench that corresponds to the layout and thickness of the seam, with an average thickness of 2 metres and average depth of 5–7 metres, even though the latter measurement cannot be calculated precisely due to the quantity of material that has collapsed onto the mine floor [46] (Figure 13).

The siderite deposit, which almost certainly constituted the working face, is situated in the highest part of the mine situated at an altitude of 2282 m. a.s.l. and is still clearly visible. The technique employed appears to be cut-and-fill stoping ("gradini rovesciati"): mining operations began on the lowest part and subsequently, sometimes using wooden scaffolding, work proceeded by removing the upper part and leaving useless and waste rock on the floor. In order to avoid dangerous collapses, parts of the rock were often left to act as supports between the faces of the mine; one of these is still present in the final part of the mine at the point where the trench narrows significantly. As far as techniques are concerned, it is reasonable to suppose that mining was conducted using pickaxes or using the traditional system of pick and chisel because the mine faces are smooth, the rock is not fragmented and there are no signs of holes. Besides this method, fire may have been used to "cook" (roast) the rock and facilitate its removal. In the upper part of the mine, the faces are irregular and extremely fragmented, probably due to the use of explosives and therefore more recent mining operations compared to the extraction carried out below ([46], p. 323).

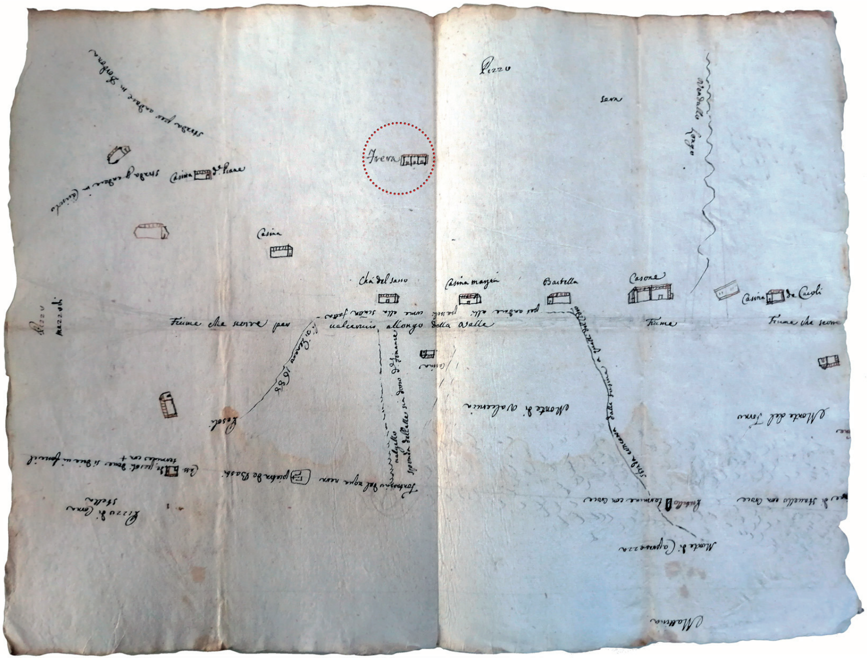


Figure 12. Map of Val Cervia (1688); the Vitalengo mine is shown in red (image by the Author).

Figure 13. Fusine (SONDRIO), Val Cervia, the initial section of the Vitalengo mine.

Once it had been extracted, the mined ore was probably left in the area in front of the entrance to the mine, bordered by two dry-stone walls, which have been partly preserved. Here, the iron ore underwent initial selection and crushing (using sharp tools), with the aim of eliminating the largest possible amount of country rock surrounding the iron ore. Before it was sorted, the mined ore could be left to season at the edges of the mine so that weathering and frost shattering could act upon the interfaces between the ore and the rock, leading to natural detachment. Like the situation encountered at Piateda, the iron ore underwent an initial process of "roasting" in specially made shaft furnaces known as *reglane* (the Bergamesque dialect term), carried out in the immediate vicinity of the mines in order to facilitate the journeys made by porters and pack animals and, as a consequence, to reduce transport costs as far as possible ([32], p. 101).

Two roasting furnaces were found close to the mine, just beyond the steep ravines that border it to the north and the south. They are extremely similar in shape and size and both have been partly damaged by collapses caused by landslides. The structures identified in Val Cervia, which are fairly similar to each other, consist of a large chamber embedded into the slope, with slightly splayed faces made of dry-stone walling and partly made by exploiting the natural rock (now no longer visible due to earth and debris accumulated in the chambers). The façade of the furnace is supported by a retaining wall, built both to counteract the steep overlying slope and to improve the thermal insulation of the production site; on the downstream side, and therefore in the direction of the mountainside most exposed to air currents, it forms in both structures two massive projecting parts, slightly diverging from each other, in which the slag outlet is located ([46], p. 324) (Figure 14).

Figure 14. Fusine (SONDRIO), Val Cervia, roasting furnace to the north of the mine.

The circular loading opening is free and facilitated the loading operation from the upper side, exploiting the ledge provided by the foundation wall. The shaft has diameters of 2.30 m and 2.50 m, while the overall height, as far as it is still visible, is over 2 m. In the furnace to the north of the mine (2230 m), it is possible to identify the small slag outlet placed at the base of the façade of the structure, quadrangular in shape and a few decimeters wide (0.25 m × 0.30 m), through which the roasted material was unloaded (Figure 15).

In the second structure (2177 m), where the furnace chamber is easier to inspect, thanks to the fact it is more deeply interred, there are visible traces of reddening and corrosion on the inner walls of the belly, which formed as a result of the prolonged use of the structure (Figure 16).

The two locations of the mining and roasting operations were connected by a mule track that, in the steepest parts, is just a basic path but was carefully paved in the more level parts; part of the paved track outside the furnace situated to the south of the mine is still visible. The path that begins from the second furnace, situated further north, is also clearly visible; with only a slight difference in height, the path rises, diagonally cutting the slope of the mountainside until it reaches the crest that separates Val Cervia from Val

Madre. Here, just below the peak of cima Vitalengo (2407 m a.s.l.), at an altitude of 2302 m, are the ruins of the cabin used as accommodation by the miners and other workers.

The site, which occupies a surface area of about 1400 m^2, is situated on a fairly level saddle along the ridge separating the two valleys in a favourable position, which could receive sunlight throughout the day, especially in winter, and was not exposed to the dangers caused by avalanches and landslides, which were undoubtedly frequent phenomena in this upland terrain (Figure 17). The context consists of five buildings of which the only surviving features are parts of the perimeter walls that are made of dry-stone walling and, in some cases, take advantage of the outcropping rock that acts as natural walls. The cabins situated in the highest part (buildings 1 and 2), whose elevations are the most clearly interpretable, were probably used as accommodation for the workers, a hypothesis indicated by the dimensions of the two structures, larger than the others (about 6–7 m wide), and by the bonding of the masonry, which was carefully constructed with regular courses. The inner southern façades of both buildings still preserve small niches made in the masonry, possibly used for oil lamps to provide lighting for the rooms.

Figure 15. Fusine (SONDRIO), Val Cervia, roasting furnace to the north of the mine. Detail of the façade of the combustion chamber of the furnace with a small opening at the centre for unloading the iron ore.

Figure 16. Fusine (SONDRIO), Val Cervia. roasting furnace to the south of the mine. Detail of the combustion chamber which has partly collapsed and been filled with debris.

Figure 17. Fusine (SONDRIO), general view from the south of the miners' cabins on the watershed dividing Val Madre (on the left) from Val Cervia (on the right).

The position of the structures offered a complete view of the area below, as well as of the whole valley. The remains of two other buildings are visible at a distance of about ten metres away from the ones described above: only the foundations of the easternmost structure (building 3) are preserved, except for a few stretches of walls with a few courses still intact, while the elevations of the perimeter walls (maximum height c. 1 m) of the second structure (building 4), since it is partly incorporated within the bedrock, are still partially visible. While the function of the former building is unclear, the long plan of the second structure (c. 14 m × 7 m), divided into at least three rooms, subdivided by partition walls, could indicate the presence of a storehouse, used to preserve provisions for the workers or as a coal house or woodstore, as well as a place for keeping fodder for the pack animals. Outside building 4 is a clearing where numerous small roasted fragments of siderite were found. This was probably an area where the initial selection of the ore was made, followed by manual crushing. These operations were carried out in the summer months when, in most cases, mining work was unfeasible. Lastly, beyond the storehouse, in the northernmost part of the area, is the last structure of the site (building 5), the walls of which are also preserved to a maximum height of just over a metre. The building has a less regular plan than the others, due to the outcropping rock, partly used as a support for constructing the perimeter walls. This evidence, together with the construction technique of the walls—much more irregular and slapdash than the other huts and therefore with a lower capacity for thermal insulation—suggests that the structure may have been used as a shelter for pack animals or as a storeroom for work tools and a space for keeping and repairing mining equipment.

Lastly, on the right slope of Val Madre, between Casera Vitalengo and the hut of Vendullungo, another roasting furnace was discovered, with several adjoining structures made of dry-stone walling (2156 m). The complex, which is fairly well preserved, displays the same construction technique as the structures recorded in Val Cervia, although it is larger. The shaft into which the iron ore was loaded, alternating with charcoal or wood (unfortunately covered in debris), reaches a height of 3 metres, while the stack has a maximum diameter of 4 metres. Traces of other buildings, of which very little of the elevations is preserved, have been found on the outer side of the structure, probably used for ancillary buildings for the furnace, such as storerooms for equipment and charcoal. It is harder to establish from which deposit the raw material for the production site came from. Although the most plausible hypothesis is that there was a mine in the immediate vicinity of the complex (yet to be located), it cannot be excluded that the furnace, which is likely to be more recent than the *reglane* described above, is related to a subsequent phase of extraction from the mine in Val Cervia, related to the opening of the smelting furnace in Val Madre that took place in the early eighteenth century [47].

7. Discussion: What Now Remains of Orobic Metallurgy

With regard to the areas of Valtellina in the late sixteenth century, the only relatively precise evidence for reconstructing the type of furnace adopted for iron working comes from a single complex (1591), situated at Vedello. On the basis of the available data, it would appear that the facilities were contained within a single building, and therefore not in open areas, and that the most commonly used early type of blast furnace was the *cannecchio* used in the areas of Brescia and Bergamo, powered by hydraulic energy. The construction of ironworking structures of this type required considerable technical expertise, significant precision and care in the preparation of hydraulic infrastructure, channels and a wheel for providing the power supply for the complex [48]. The documents reveal strict spatial organisation limited by the position of the drive shafts of the hydraulic wheels.

The reconstruction of the technology used in the ironworking complexes in the Valtellina area and, more generally, the possibility of understanding the organisational and management system of medieval metallurgy, has proved to be extremely difficult and complex due to the lack of documentary evidence. Surveys carried out in the area suggest the prolonged use of preserved production sites, while the destruction due to natural phenomena of one of the oldest ironworks—the one at Verdello described in the documentary sources—has significantly hindered attempts to provide precise dates for the production sites, which consisted essentially of roasting furnaces situated at medium-to-high altitudes in Alpine environments. The same observations hold true for the forges, considering that in the specific case of Fusine, of all the ones listed in the sources, the only surviving forge belonged to the Bazzi family.

It is also worth adding that when the identification of a mine is accompanied by a date engraved close to its entrance and a direct relationship is plausible, the written sources provide scant evidence about the exploitation of the seams of iron ore and it is unclear whether the date given (*1640* for the deposit in the Scigola Pass and *1657* for the Scaletta Pass) refers to the initial or final phase of the mining operations. In the cases examined here, it is extremely likely that the engravings were made with two stone hammers or with an iron hammer and chisel. In the first case (Scigola Pass), the engravings are arranged in two distinct panels alongside each other. The upper part of the first panel contains four numerals “1 6 4 0” while the lower part has two traces with a curved profile followed by a circular design next to a short perpendicular rod surmounted by a point in the form of a “[c?]” or “I”. In the panel next to the previous one, it is possible to discern a circular design beyond which is a Greek cross reinforced with two Latin crosses on the outer edges parallel to the rockface “o †+†” (Figure 18).

Figure 18. Scigola Pass (SONDRIO), graphic composition engraved with a time reference (Photograph by Marino Amonini).

In the second case (Scaletta Pass), there is a single field divided into two parts: the upper one has four numerals “1 6 5 7”, with curvilinear engraving, while the one below features the letter J (?) followed by an E arranged parallel to the rockface and a Latin cross grafted onto the shorter part of the vowel with two small cylinders inserted on the short arm, accompanied by a P (Figure 19). The height and inaccessible nature of the two contexts prevent the precise identification of the author, or authors, of these precious historical sources. The altitudes of the engravings are beyond the limits of pasture for livestock in the Orobic valley of Valtellina, generally between 1400 m and 2200 m, but it is equally true that the two passes are the crossing points between two opposing Alpine mountainsides. This suggests that the shepherds involved in transhumance or moving livestock between the Orobic valley and the Bergamesque valley were responsible for the engravings, but it does not shed light on their meaning, which remains incomprehensible.

If, on the other hand, the executors were the workers involved in extracting material from the seams of iron ore, then it is possible that the first series of numerals corresponds to “1640” and the second to “1657” and that they therefore represent the initial or final dates of mining activity. The few signs that have been identified may be interpreted as alphabetic letters and therefore constitute the initials of the name of a person, accompanied by symbols related to identity or origin, so that the ownership of both mines—Melchiorre Gioia alludes to the excellent quality of the iron ore and therefore to the greater economic importance compared to other extraction sites—was visible; no one could consider them to be abandoned and the owners were therefore easily identifiable ([28], pp. 227–229).

The hypothesis that the mining sites of Valtellina were exclusively for personal use, a view that was widely shared until a few years ago, has been completely disproved. Furthermore, the greater originality and effectiveness of our research can be recognised through the capacity to extend the chronology, differentiating between eras and areas, following a temporal transformation of the economic, social and technological aspects, without which it would be impossible to recognise and understand the mining landscape of Valtellina. Historians of mining and ores underestimate the importance of archaeological evidence, while archaeologists frequently play down the significance of the written sources.

Archival sources suggest the active presence of numerous players—with a key role played by local aristocratic families (the Curtoni, Ruffoni, Quadrio, Beccaria and Capitanei families during the Middle Ages)—and a surprising level of productive complexity within an economic context mainly related to trade and the supply of production units situated beyond the Orobic valley of Valtellina.

Figure 19. Scaletta Pass (SONDRIO), graphic composition engraved with a time reference (Photograph by Marino Amonini).

It is worth underlining that the commercial importance of metalworking was not confined to purely local productive decisions but was targeted at a much wider market than hitherto believed. On the basis of the evidence of notarial deeds, it can be concluded that the internal market was the main point of reference between the eleventh and sixteenth centuries, although it was not the only one for ironworking artisans in the Valtellina area. It was an extremely extensive commercial environment involving aristocratic families with considerable purchasing power, a fairly sizeable population, numerous clerics and a steady stream of merchants (*mercatores*) and pilgrims along the main Alpine routes. However, the relative prosperity of the artisans (often owning a house and a vineyard) did not stem from the success of their products but rather from the possibility of devoting themselves to other activities, especially in the agricultural and woodland-cum-pastoral spheres [49]. This reflects the presence of a high degree of specialisation in conjunction with significant capital investment in production by local aristocratic families or individual merchants (*mercatores*) who realised that the possibility of selling raw or semi-finished material to Milan or Bergamo could provide a much more reliable source of income and profit than involvement in financial operations, from which they seem to have distanced themselves.

8. Conclusions: From Decommissioning to Optimal Use: A Long Process of Transformation

Although the mining activities in this territory witnessed fluctuating levels of productivity over the centuries, a transformation towards full-scale industrialisation never took place, or at least the conditions never emerged whereby the mining resources could become part of this kind of process. The rapid involution of a system that had functioned satisfactorily for at least five centuries may have been caused by several factors that acted as destabilising elements in the second half of the nineteenth century, leading to the abandonment of the production sites: the difficulty of obtaining raw material, due to the natural localisation of the various mines; natural phenomena such as landslides at high altitude involving roasting furnaces and river flooding, which devastated the smelting furnaces; the reduction in the number of workers, mule-drivers and porters; the impossibility of adjusting the system to embrace the innovations brought about by the Industrial Revolution; the decision of communities to preserve the woodland areas that had been "used up" over the centuries to provide fuel for activities regulated according to ancient principles and methods; and lastly, in all likelihood, the exhaustion of the main seams for extracting iron ores.

In the light of a seriously damaged mining landscape, the decision was taken to carry out a detailed survey of the mining sites in the Alpine areas of the *comuni* of Piateda and Fusine as part of the initial phase of a joint initiative organised by the Department of History in conjunction with two local administrations in charge of preserving significant parts of this ancient productive heritage. The landscape is of the utmost importance because the analysis of the features of these "monuments to human labour" and the determination of the different phases of ironworking to which they belong can transform them from being a strategic resource, which they once were in antiquity, to being an asset that could be used to enhance the landscape in which they are situated. These structures will no longer be silent witnesses to the passing of time, subject to dilapidation, neglect and abandonment, but key elements in a new relationship between the community and the environment: a virtuous circle in which their enhancement may yield notable benefits, not just from an economic standpoint but also from a moral and spiritual perspective, capable of making new generations responsible for the traditions to which they belong and aware of the sacrifices of those who preceded them, and therefore capable of constructing and creating the present while also looking to the future.

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References

1. Sprangel, R. *Das Eisengewerbe im MittelalterI*; Anton Hiersemann Verlag: Stoccarda, Germany, 1968; p. 110.
2. Comba, R. Produzioni metallurgiche nel Piemonte sud-occidentale. In *La Sidérurgie Alpine en Italie (XII^e–XVII^e)*; Braunstein, P., Ed.; Collection de l'École Française de Rome, 290; École Française de Rome: Rome, Italy, 2001; p. 49.
3. Zucconi, M. L'identità mineraria dell'Italia. Contributi per un progetto di valorizzazione culturale integrata. In *Linee Guida per la Tutela, Gestione e Valorizzazione di Siti e Parchi Geo-Minerari. Proposte e Prospettive per la Crescita e la Sostenibilità del Settore*; ISPRA: Rome, Italy, 2008; pp. 11–16.
4. de Vingo, P. Il Paesaggio Minerario Della Valtellina Orobica: Un Patrimonio da Esplorare, da Conoscere e da Valorizzare. In *Le Radici della Terra: Le Miniere Orobiche Valtellinesi da Risorsa Economica a Patrimonio Culturale delle Comunità tra Medioevo ed Età Contemporanea*; de Vingo, P., Ed.; FrancoAngeli: Milano, Italy, 2022; pp. 7–8.
5. Burzi, I. *Nuovi Paesaggi E Aree Minerarie Dismesse*; Florence University Press: Florence, Italy, 2013; p. 10.
6. Sceffer, O. *Cartografia Antica della Rezia: Valtellina, Valchiavenna, Grigioni*; Bonazzi: Sondrio, Italy, 2006.
7. Bianchi, S. *Valtellina Valchiavenna e Grigioni Sotto la Lente—Antica Cartografia dal XVI al XVIII Secolo*; Priuli & Verlucca: Scarmagno, Italy, 2007.
8. Bertero, P. Rilievo, cartografia storica e georeferenziazione. In *Le Radici Della Terra: Le Miniere Orobiche Valtellinesi da Risorsa Economica a Patrimonio Culturale delle Comunità tra Medioevo ed Età Contemporanea*; de Vingo, P., Ed.; FrancoAngeli: Milano, Italy, 2022; p. 156.
9. Della Ferrara, L. Estimo descrittivo e catasto particellare in Valtellina dal XVI al XIX secolo. L'esempio di Chiuro. *Boll. Della Soc. Stor. Valtellin.* **2018**, *71*, 45–56.
10. Archivio di Stato di Milano/State Archives of Milano. *Catasto Lombardo Veneto, Distretto di Ponte, Comune Censuario di Ambria, Mappa originale del Comune Censuario di Ambria, 1815*; Archivio di Stato di Sondrio: Sondrio, Italy, 1847.
11. Dillmann, P.; Schwab, R.; Bauvais, S.; Brauns, M.; Disser, A.; Leroy, S.; Gassmann, G.; Fluzin, P. Circulation of iron products in the North-Alpine area during the end of the first Iron Age (6th–5th c. BC): A combination of chemical and isotopic approaches. *J. Archaeol. Sci.* **2017**, *87*, 108–124. [CrossRef]

12. Pagès, G.; Dillmann, P.; Vega, E.; Berranger, M.; Bauvais, S.; Long, L.; Fluzin, P. Vice-versa: The iron trade in the western Roman Empire between Gaul and the Mediterranean. *PLoS ONE* **2022**, *17*, e0268209. [CrossRef] [PubMed]
13. Baraldi, E. Una nuova età del ferro: Macchine e processi della siderurgia. In *Il Rinascimento Italiano e L'EUROPA. Produzioni e Tecniche*; Braunstein, P., Molà, L., Eds.; Angelo Colla: Verona, Italy, 2007; p. 199.
14. Rosenthal, P.; Morin, D. Roman and Medieval Iron Mining and Smelting at High Altitudes in the South-Western Alps: Mercantour and Ubaye Mountains (Alpes-Maritines, Alpes-de-Haute-Provence, France). In *Mining in European History and its Impact on Environment and Human Societies, Proceedings for the 1st Mining in European History-Conference of the SFB-HIMAT, Innsbruck, Austria, 12–15 November 2009*; Anreiter, P., Goldenberg, G., Hanke, K., Leitner, W., Mathis, F., Nicolussi, K., Oeggl, K., Pernicka, E., Prast, M., Schibler, J., et al., Eds.; Universität Innsbruck: Innsbruck, Austria, 2010; pp. 109–114.
15. Bindler, R.; Segerström, U.; Jensen-Pettersson, M.-I.; Berg, A.; Hansson, S.; Holmström, H.; Olsson, K.; Renberg, I. Early medieval origins of iron mining and settlement in central Sweden: Multiproxy analysis of sediment and peat records from the Norberg mining district. *J. Archaeol. Sci.* **2011**, *38*, 291–300. [CrossRef]
16. Cucini Tizzoni, C.; Tizzoni, M. Alle origini dell'altoforno i siti della Val Gabbia e della Val Grigna a Bienno in Valcamonica. In *Musei del Ferro in Europa e in Italia: La Ricerca Storica e le Esperienze di Conservazione e Valorizzazione, Atti del Convegno Brescia-Tavernole sul Mella, 24–25 Settembre 2004*; Poggio, P.P., Simoni, C., Eds.; Grafo: Brescia, Italy, 2006; pp. 24–26.
17. Thiele, A. From the Soil to the Iron Product—The Technology of Medieval Iron Smelting. *EXARC J.* **2014**. Available online: https://exarch.net.ark://88735/10160 (accessed on 29 April 2023).
18. Wrona, P.; Rózanski, Z.; Grzegorz, P.; Niewiadomski, P.A.; Veiga, P.J. Historical Outline of Iron Mining and Production in the Area of Present-Day Poland. *Mineral* **2021**, *11*, 1136. [CrossRef]
19. de Vingo, P. Tempo delle miniere e tempo dei minatori nelle Alpi orobiche valtellinesi. In *Le Radici della Terra: Le Miniere Orobiche Valtellinesi da Risorsa Economica a Patrimonio Culturale delle Comunità tra Medioevo ed Età Contemporanea*; de Vingo, P., Ed.; FrancoAngeli: Milano, Italy, 2022; p. 62.
20. Besta, E. L'estrazione e la lavorazione dei metalli nella Valtellina Medioevale. In *Atti e Memorie del Terzo Congresso Storico Lombardo, Cremona, 29–31 Maggio 1938*; Regia Deputazione di Storia Patria per la Lombardia; Giuffrè Editore S.p.A.: Milano, Italy, 1939; pp. 4–6.
21. Bagiotti, T. *Storia Economica della Valtellina e della Valchiavenna*; Banca Popolare di Sondrio: Sondrio, Italy, 1958; p. 178.
22. Dell'Avanzo Stefani, L. L'estrazione e la lavorazione del ferro a Fusine. *Boll. Della Soc. Stor. Valtellin.* **1989**, *42*, 236.
23. Marchesi, C. Talamona alla metà del trecento: Economia e società alla luce degli atti di Simone della Porta. *Boll. Della Soc. Stor. Valtellin.* **1993**, *42*, 35–36.
24. Tizzoni, C. Dieci anni di ricerche sulla siderurgia lombarda: Un bilancio. In *La Sidérurgie Alpine en Italie (XII^e^–XVII^e^)*; Braunstein, P., Ed.; Collection de l'École française de Rome, 290; École française de Rome: Rome, Italy, 2001; pp. 46–47.
25. Quadrio, S. *Dissertazioni Critico-Storiche Intorno Alla Rezia di Qua Dalle Alpi Oggi Detta Valtellina*; Giuffrè Editore S.p.A.: Milano, Italy, 1755; pp. 24–25.
26. Pezzola, R. Tra paesaggio costruito e paesaggio documentario. Stato e prospettive delle ricerche sulla metallurgia orobica in Valtellina (secoli X–XV). In *Le Radici della Terra: Le Miniere Orobiche Valtellinesi da Risorsa Economica a Patrimonio Culturale delle Comunità tra Medioevo ed Età Contemporanea*; de Vingo, P., Ed.; FrancoAngeli: Milano, Italy, 2022; p. 26.
27. Prandi, F. (Ed.) *Inventario dei Toponimi Valtellinesi e Valchiavennaschi: Territorio Comunale di Piateda*; Società Storica Valtellinese: Sondrio, Italy, 2012; Volume 37, pp. 80–81.
28. de Vingo, P.; Sanmartino, I. Le strutture del ciclo minerario-metallurgico nel territorio di Piateda tra fonti scritte ed evidenze materiali. In *Le Radici della Terra: Le Miniere Orobiche Valtellinesi da Risorsa Economica a Patrimonio Culturale delle Comunità tra Medioevo ed Età Contemporanea*; de Vingo, P., Ed.; FrancoAngeli: Milano, Italy, 2022; pp. 236–237.
29. Archivio di Stato di Sondrio. *Catasto Lombardo Veneto, Distretto di Ponte, Comune Censuario di Ambria, foglio 30, 1853*; Archivio di Stato di Sondrio: Sondrio, Italy, 1853.
30. Sofia, F. (Ed.) *Statistica del Dipartimento Dell'adda. Riproduzione Anastatica del Manoscritto di Melchiorre Gioia ed Edizione Critica*; Annali di Statistica; 2000; Volume XXII, pp. 363–367.
31. Archivio Storico Comune di Piateda. *b. 83, Titolo XI, clas. 2, fasc. 1*; Miniera Carlo Tassara: Collio, Italy, 1939.
32. Cima, M. *Archeologia del Ferro. Sistemi Materiali e Processi Dalle Origini Alla Rivoluzione Industriale*; Edizioni Nautilus: Torino, Italy, 1991; p. 101.
33. Antonioli, G. Spunti per la storia dell'onomastica e delle istituzioni valtellinesi e valchiavennasche emergenti dall'analisi delle pergamene del monastero comasco di S. Abbondio (1100–1252). In *Itinerari Linguistici Alpini, Atti del Convegno di Dialettologia in Onore del Prof. Remo Bracchi, Bormio, 24–25 Settembre 2004*; Pfister, M., Antonioli, G., Eds.; Istituto di Dialettologia e di Etnografia Valtellinese e Valchiavennasca: Tirano, Italy, 2005; pp. 421–422.
34. Mainoni, P. Aspetti del dominio visconteo in Valtellina: La famiglia degli Ambria. *Nuova Riv. Stor.* **1979**, *LXIII*, 536.
35. Arnoux, M. Innovation technique, intervention publique et organisation du marché: Aux origines du district sidérurgique de la Valteline (XIII^{e}–XIV^{e} siècles). In *La Sidérurgie Alpine en Italie (XII^{e}–XVII^{e})*; Braunstein, P., Ed.; Collection de l'École Française de Rome, 290; École française de Rome: Rome, Italy, 2001; p. 223.
36. Baraldi, E.; Calegari, M. Pratica e diffusione della siderurgia «indiretta» in area italiana (secc. XIII–XVI). In *La Sidérurgie Alpine en Italie (XII^{e}-XVII^{e})*; Braunstein, P., Ed.; Collection de l'École française de Rome, 290; École française de Rome: Rome, Italy, 2001; pp. 181–182.

37. Ruffoni, C. Comunità operose. In *Le Antiche Attività Nelle Valli del Bitto*; Bianchi Fanciulli Officina Grafica: Morbegno, Italy, 2012; pp. 33–40.
38. Tizzoni, C. Miniere e metallurgia in alta Val Brembana—Bergamo (secoli XII–XVI). *Bergomum* **1994**, *2*, 85–87.
39. Baraldi, E. Il modo indiretto di produrre il ferro in Italia dalla fine del Medioevo (XIII-XVI secolo). *Int. J. Ital. Assoc. Metall.* **2000**, *1*, 35–36.
40. Baraldi, E. Ordigni e parole dei maestri da forno bresciani e bergamaschi: Lessico della siderurgia indiretta in Italia fra XII e XVII secolo. In *La Sidérurgie Alpine en Italie (XII^e-XVII^e)*; Braunstein, P., Ed.; Collection de École française de Rome, 290; École française de Rome: Rome, Italy, 2001; pp. 181–182.
41. Tizzoni, M. La siderurgia preindustriale. In *Metodi e pratica della cultura materiale: Produzione e consumo dei manufatti*; Giannichedda, E., Ed.; Istituto Internazionale di Studi Liguri: Bordighera, Italy, 2004; pp. 174–178.
42. Marchesi, G.; Mura, L. Il forno fusorio di Livemmo (BS). *Archeol. Mediev.* **2006**, *XXXIII*, 525–527.
43. Mura, L. Le indagini archeologiche. In *Il Forno Fusorio di Livemmo, Pertica Alta: Lo Studio, il Lavoro e L'inventiva*; Marchesi, G., Ed.; Fondazione Civiltà Bresciana: Brescia, Italy, 2009; pp. 57–71.
44. Cima, M. Il cannecchio bresciano tra forno a manica e altoforno. In *Dal Basso Fuoco All'altoforno, Atti del 1° Simposio Valle Camonica 1988, La Siderurgia Nell'antichità, Breno-Boario Terme, 13–16 Ottobre 1988*; Cuomo di Caprio, N., Simoni, C., Eds.; Grafo: Brescia, Italy, 1991; p. 283.
45. Da Prada, G. (Ed.) La Magnifica Communità et li Homini delle Fusine. L'alpeggio Valcervo dal 1620 ai Nostri Giorni con Riferimenti a Cedrasco. Parrocchia di Fusine: Fusine, Italy, 1985; Volume IV, pp. 10–11.
46. de Vingo, P.; Sanmartino, I. Estrazione, preparazione e gestione del ciclo minerario-metallurgico a Fusine e nel so territorio tra fonti storico-archivistiche e strutture produttive. In *Le Radici della Terra: Le Miniere Orobiche Valtellinesi da Risorsa Economica a Patrimonio Culturale delle Comunità tra Medioevo ed Età Contemporanea*; de Vingo, P., Ed.; FrancoAngeli: Milano, Italy, 2022; p. 322.
47. Zoia, D. Le proprietà. In *Economia e Società in Valtellina e Contadi Nell'età Moderna*; Scaramellini, G., Zoia, D., Eds.; Fondazione Gruppo Credito Valtellinese: Sondrio, Italy, 2006; Volume I, p. 255.
48. Cortese, M.E.; Francovich, R. La lavorazione del ferro in Toscana nel Medioevo. *Ric. Stor.* **1995**, *25*, 447–448.
49. de Vingo, P. Utensili da lavoro, armi, oggetti della vita quotidiana e religiosa della Valtellina tra Mediovo e prima età moderna. In *La Valtellina Nei Secoli. Studi e Ricerche Archeologiche*; Ricerche e Materiali Archeologici; Mariotti, V., Ed.; SAP Società Archeologica: Mantova, Italy, 2015; pp. 678–680.

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