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# Terminal Pleistocene Human Occupation of the Qomolangma Region: New Evidence from the Su-re Site

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**Abstract:** Lithic artifacts are crucial for elucidation of the temporal and spatial patterns of prehistoric human occupation of the Tibetan Plateau. Core-and-flake technology is particularly noteworthy, as it is distinguished by its broad temporal span and widespread distribution across the plateau. In this study, we present the results of a reassessment of the lithic assemblage from the Su-re site in Tingri County, Shigatse City, Xizang Autonomous Region, China. Its resemblance to lithic assemblages from Southwestern China implies a close relationship between the plateau and its southeastern vicinity, contributing to the diversification of technology and prehistoric humans on the Tibetan Plateau. Moreover, gneissic pebbles transported by glacial meltwater in the Tingri Graben—the most suitable raw material available in the vicinity—explains the presence of prehistoric humans in the inhospitable Qomolangma region.

**Keywords:** Su-re site; South Tibetan Plateau; Qomolangma region; Terminal Pleistocene; core-and-flake industry

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## 1. Introduction

The successful human adaptation to the world's highest upland, the Tibetan Plateau (TP), stands as a significant milestone in human evolution, overcoming challenges to health, subsistence, and living conditions [1]. Recent archaeological finds suggest that blade technology, which is considered a hallmark of high mobility, emerged in the interior TP (>4500 masl) ca. 45–30 ka BP [2,3]. Furthermore, hunter–gatherers bearing microblade technology demonstrated the ability to undertake extensive, long-term occupation of the TP hinterland during the Terminal Pleistocene [4,5]. These discoveries shed light on the potential of modern humans to inhabit extreme high-altitude (>4500 masl) environments since the Late Pleistocene. Additionally, core-and-flake lithic technology is also prevalent on the TP, but remains under-researched. Core-and-flake technology, including both pebble and flake tool industries, are distributed mainly in two geomorphological environments on the TP: (1) the transition zone from the western Loess Plateau to the northeastern Tibetan Plateau, characterized by loessic taphonomic conditions [6], and (2) fluvial and lacustrine terraces, such as those surrounding Qinghai Lake, Siling Co, and the Tongtian, Senge Tsangpo, and Yarlung Tsangpo Rivers [7–10], among others. These river and lake basins yielded not only lithic raw material (pebbles), fresh water, and various food resources, but also a relatively temperate regional climate, creating an ideal living environment for our human ancestors. It is noteworthy that core-and-flake technology in the Tibetan hinterland occurs predominantly in the Changtang Reserve in the northern and western parts of the plateau, though it is rare in Southern Xizang, including the northern Himalayan Massif and its montane outliers (Figure 1a). This phenomenon may be attributed to glacial hazards (floods, landslides, and unstable moraines) [11], as well as a scarcity of animal and plant resources to support a viable subsistence base.

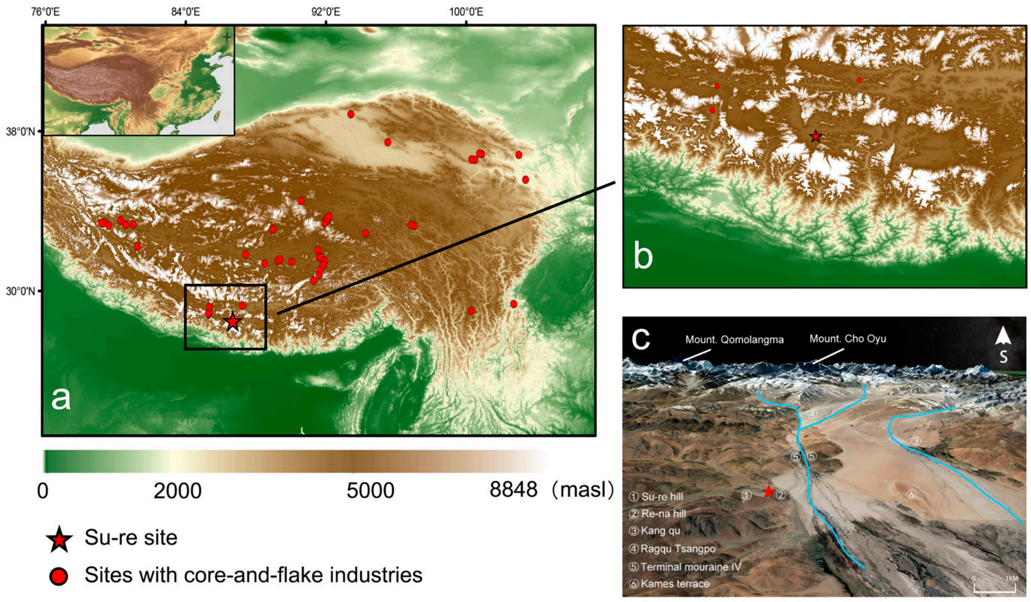


**Figure 1.** (**a**) The distribution of core-and-flake industries on the Tibetan Plateau; (**b**) location of the Su-re site; (**c**) oblique aerial view of the Tingri Graben and Qomolangma-Cho Oyu massif (Google Earth). Blue lines refer to two rivers, Ragqu Tsangpo and Kang qu.

We present new findings from the Su-re Paleolithic site (28°30′42.4″ N, 86°40′15.40″ E, 4420 masl) in the Qomolangma Reserve in the northern foothills of Cho Oyu and Qomolangma (Sagarmatha or Mount Everest) to enhance our comprehension of the prehistoric peopling of the Tibetan Plateau (TP) (Figure 1b,c). Our systematic investigation reveals that at least two prehistoric occupations occurred at Su-re since the Terminal Pleistocene, underscoring the remarkable adaptive capabilities of prehistoric humans in this challenging environment. Additionally, a lithic analysis of the flake tool assemblage highlights its close affinity with lithic industries in Southwestern China, suggesting a potential southeastern dispersal route onto the plateau. Our objectives are to offer fresh insights into core-and-flake technology, the dispersal patterns of human groups in the hinterland of the TP, and their adaptation to the region's harsh periglacial environment [11].

## 2. Materials and Methods

### *2.1. Site Background*

The Su-re site in Tingri County, Shigatse City, lies in the northern foothills of Cho Oyu and Qomolangma, an area that has experienced frequent glaciation. At present, the region exhibits a semi-arid continental climate (Köppen and Geiger classification BSk), influenced by both the Indian Monsoon and westerlies [12]. Discovered in 1966, the Su-re site is named after the hill where it is located. A total of 44 lithic artifacts were collected and studied as a core-and-flake industry showing a close affinity with Upper Paleolithic industries in Southwestern China [13]. In the 2010s, geologists studied surface collections of quartzite lithic artifacts and applied optically stimulated luminescence (OSL) dating to determine the latest burial age of these artifacts. The results revealed a cluster of the oldest burial age to have been between 5.2 and 5.5 ka BP [14,15]. In addition to the direct dating of lithic artifacts, an analysis of landscape dynamics in the Tingri Graben was undertaken, suggesting that humans utilizing pottery and sling projectiles may have inhabited the Su-re site around the beginning of cal 3.9 ka BP. Climatic conditions in the Tingri area were inferred to have been warm and moist enough to support vegetation expansion and soil formation between approximately 6.7 and 3.9 ka BP [16]. A joint archaeological team from the Cultural Relics Conservation Institute of the Xizang Autonomous Region and the Institute of Vertebrate Paleontology and Paleoanthropology of the Chinese Academy of Sciences reinvestigated Su-re in 2012 and 2020 and carried out formal excavations there in 2021 to clarify the complexity of human activities and their technologies.

### *2.2. Materials and Methods*

A 16-square-meter trench opened in a gully between Su-re Hill and Re-na Hill revealed five stratigraphic layers (Figure 2). Layer 1 consisted of brown, loose topsoil with abundant modern plant roots. Layer 2 was characterized by yellow-gray interbedded layers of fine sand and gravel, indicative of low-energy water flow. Layer 3 was a reddish paleosol eroded by Layer 2, in which a few scouring channels filled with grayish sand were observed, which also indicated erosion caused by low-energy water flow. Layer 4 comprised yellowish fine sand showing signs of freeze–thaw action. Finally, Layer 5 comprised a thick red paleosol with some sub-angular pebbles. To reconstruct the chronology of this depositional sequence, radiocarbon dating methods were applied.

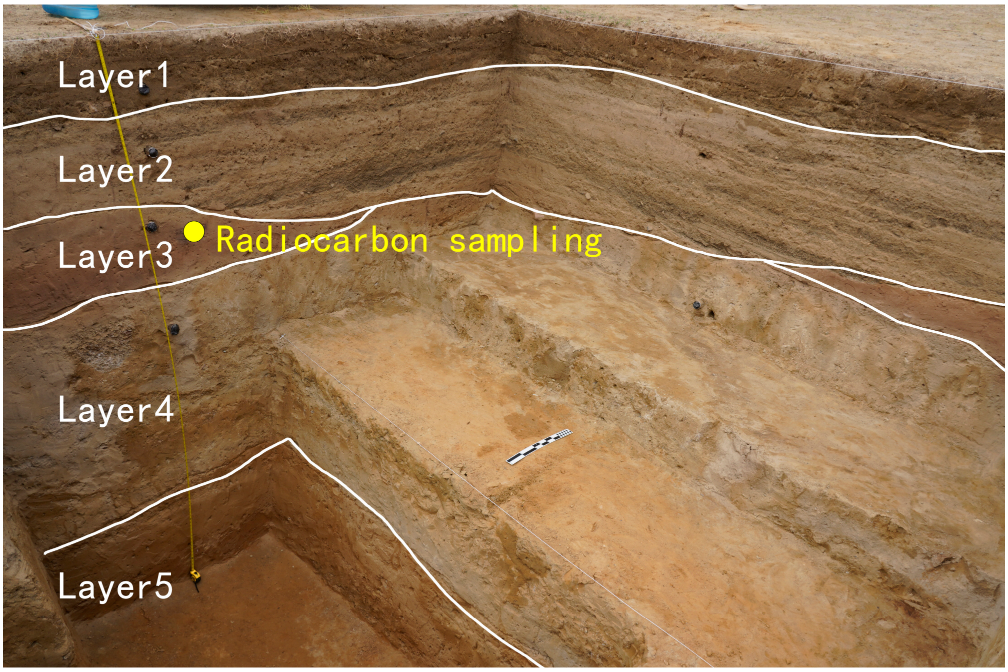


**Figure 2.** Section and sedimentary sequence at the Su-re site.

A total of 472 lithic artifacts was analyzed, 15 of which came from excavated deposits. The remaining 457 were collected from the surface on the middle slope of Su-re Hill. The assemblage mainly comprises gneissic pebbles except for a few artifacts fabricated with white or pale-green quartzite sourced in the nearby mountains. A techno-typological perspective was used to study the lithic assemblage with the goal to reconstruct the technological behavior through the *chaîne opératoire* approach [17].

## 3. Results

### *3.1. Geomorphology of the Su-re Site*

Based on field observations and radiocarbon results, our excavation yielded very few lithic artifacts, all of which were found in secondary alluvial and colluvial deposits representing only the most recent burial chronology. Consequently, analyzing the chronology of the Su-re site, we employed paleoenvironmental reconstruction and cross-cultural comparison, in conjunction with dating results of natural sections of terraces [16]. The archaeological team conducted excavations and dating of trench SRT1, located on the southern slope of Su-re Hill.

Based on these sections and corresponding radiocarbon dates, the approximate depositional environments around the Su-re site following the Last Glacial Maximum (LGM) were as follows:

1. Between 600 and 500 years ago—characterized by layers of fine sand and gravel with alternating structures (Layer 2), which were affected by frequent but weak hydraulic processes.
2. Between 6000 and 3000 years ago (Layer 3; Table 1)—paleosol development, albeit still subject to hydraulic processes.
3. Between 11,000 and 10,000 years ago (Layer 4)—the vicinity of the site experienced some freeze–thaw action.
4. Approximately 15,000 years ago (Layer 5)—corresponding to the Bølling–Allerød Interstadial, characterized by paleosol development.

**Table 1.** Radiocarbon dating results for the Su-re site.

| Lab. No. | Sampling Locality | Material | uncal. BP (yBP) | yrs. cal.BP (years cal.BP) | δ13C (‰) | Layer | Reference |
|---|---|---|---|---|---|---|---|
| Beta-570211 | Su-re | Unidentified charcoal | 2780 ± 30 | 2952–2793 * | −21.1 | Layer 3 | This study |
| Beta-570213 | Su-re | Unidentified charcoal | 2760 ± 30 | 2929–2779 * | −21.0 | Layer 3 | This study |
| Beta-570215 | Su-re | Unidentified charcoal | 2830 ± 30 | 3007–2855 * | −21.3 | Layer 3 | This study |
| Poz-99983 | Su-re | Sediment | 5200 ± 35 | 5903–6168 * | −25.1 ± 1.0 | Paleosol (equal to Layer 3) | [16] |
| CEDAD_ LTL16960A | Su-re | Sediment | 5881 ± 50 | 6562–6844 ** | −32.9 ± 0.6 | Paleosol (equal to Layer 3) | [16] |
| Poz-100148 | Su-re | Sediment | 3925 ± 30 | 4249–4438 ** | −20.5 ± 0.3 | Paleosol (equal to Layer 3) | [16] |
| CEDAD_ LTL16961A | Su-re | Unidentified charcoal | 2792 ± 45 | 2781–3000 ** | −23.5 ± 0.3 | Paleosol (equal to Layer 3) | [16] |
| Poz-71933 | Su-re | Sediment | 5560 ± 40 | 6289–6411 ** | −29.4 ± 1.0 | Paleosol (equal to Layer 3) | [16] |

* Calibrated with IntCal 20. ** Calibrated with IntCal 13.

Following prolonged investigation, Kuhle [18–20] categorized glacial activity in the Cho Oyu to Mount Everest region into four stadia during the Last Glacial. Adding Kuhle’s findings to our own enables the reconstruction of the development of glaciers and rivers around the Su-re site: during stadia 1–2 (17–14.25 ka BP), glaciers began to develop on the northern flank of Cho Oyu, albeit with very limited activity. During stadia 3–4 (14.25–13 ka BP), the terminal moraine of the glacier nearly reached the Su-re site, with a large moulin forming in the center of the glacier’s outlet, subsequently evolving into a rhomboidal glacial kames terrace (Figure 1c: ⑥). Subsequently, meltwater from Labuche Kang flowed into the Kangqu River with a valley width (consisting of leucogranite) exceeding 10 km. After stadial 4, the Ragqu Tsangpo River developed, flowing through the terminal moraine formed during stage 4. Compared to the Kangqu River, the Ragqu Tsangpo is narrower, with a width of only 2 km and a river level of approximately 4415 masl. The river gravel includes leucogranite and gneiss, which was the principal raw material used by the area’s ancient inhabitants for fabricating stone tools.

### 3.2. The Su-re Lithic Assemblage

Chipped stone artifacts are represented by cores, flakes, chunks, debris, and shatter (Table 2). Only 15 gneiss flakes were recovered from Layer 3, but their raw material, degree of erosion, size, and typology are the same as those from the surface collection. Flake tools are defined here as blanks that have been modified into tools through retouch or edge modification [21]. Alternating knapping is defined as a process through which both faces are flaked in a single sequence by continuously changing the orientation of the core and flaking planes [22]. Broad-faced cores are classified as unidirectional or bidirectional nuclei made on flakes and exhibiting occasional lateral trimming [23].

**Table 2.** Lithic assemblage of Su-re site.

| Procedure | | Category | Number |
|---|---|---|---|
| Knapping | Core | Broad-faced unidirectional core | 3 |
| | | Broad-faced bidirectional core | 1 |
| | | Alternating core | 2 |
| | | Multiplatform core | 2 |
| | | Other | 15 |
| | Flake | Complete | 305 |
| | | Incomplete (broken and split) | 63 |
| | Chunk | | 38 |
| | Debris | | 29 |
| | Shatter | | 14 |
| | Total | | 471 |
| Retouching | Retouched items | Side scraper | 63 |
| | | Notch | 8 |
| | | Point | 19 |
| | | Denticulate | 6 |
| | | Notch-denticulate | 1 |
| | | Miscellaneous | 4 |

More than three-quarters of the Su-re cores are made from gneissic river pebbles (n = 17). Quartzite and flint were also used, the latter exhibiting clear evidence of microblade technology. Cores made on gneiss are smaller (average maximum length = 53.64 mm) than those fabricated on quartzite (average maximum length = 83.45 mm), while yielding more flakes per core (average = 7.9). The lower cortex rate also implies a longer knapping sequence during the exploitation of gneiss pebbles. Based upon preliminary knapping experiments, gneiss pebbles are difficult to knap even by means of direct hard hammer percussion and were thus unlikely to have been reduced through soft hammer or indirect percussion techniques assumed by previous researchers [24,25]. Broad-faced and alternating cores reflect special knapping strategies (Figure 3: 2–5; 8), together with length/width ratios of flakes that mainly fall from 1 to 2, showing an inclination to exploit the relatively wider plane to obtain broader rather than elongated flakes. Intentional platform modifications such as platform retouch and rejuvenation were identified, indicating a highly controlled knapping technique.

The proportion of retouched items in the Su-re assemblage is relatively high (n = 101, 21.44%) considering that most artifacts came from the surface, and half show two or more retouched edges with an average retouch ratio per edge of 0.82. These mainly flake-based tools were divided into side-scrapers, points, notches, denticulates, notch-denticulate, and miscellaneous, according to a traditional typological approach. The non-standardized morphology and high retouch ratio imply intensive blank use and the production of multifunctional implements despite severe abrasion and the impossibility of conducting use-wear analysis. Most removals are scalar and shallow with only a few that are stepped or truncated. More than two-thirds of retouched edges were unidirectionally retouched, while alternate and alternating removals producing sinuous edges were also apparent.

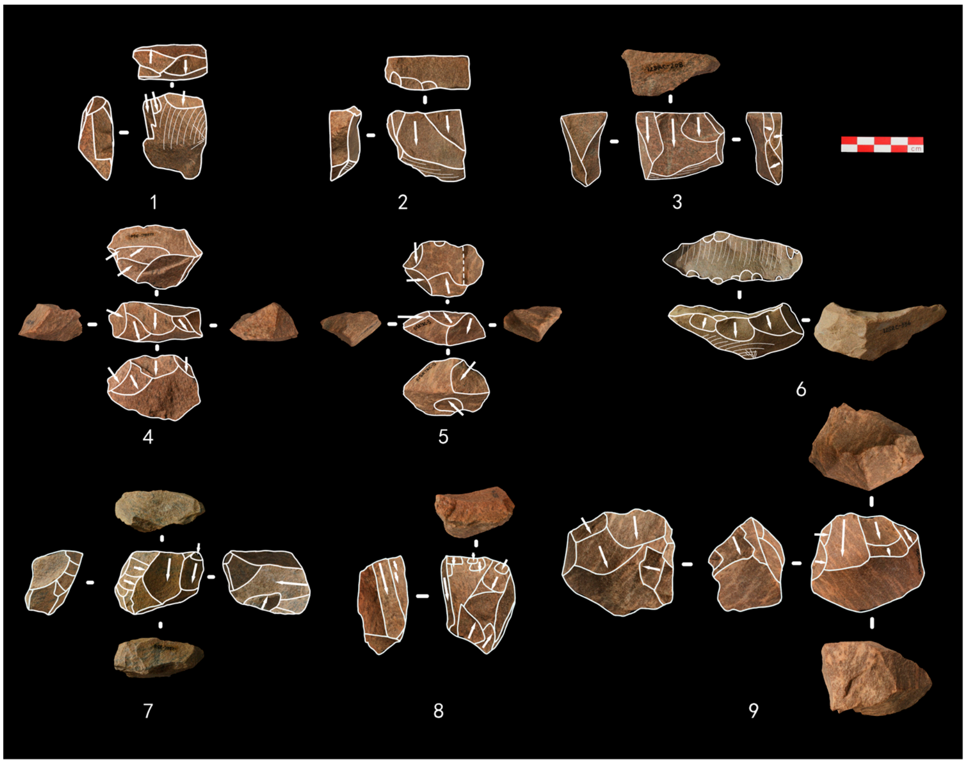


**Figure 3.** Cores from the Su-re site: 1, 6, narrow-faced cores; 2–3, 8, broad-faced cores; 4–5, cores produced by alternating knapping; 7, 9, multi-platform cores.

The lithic raw materials utilized at Su-re derive primarily from sources located within a 5 km radius of the site, indicating the relatively local activity range of its ancient human inhabitants. Gneiss presented substantial challenges as the dominant lithic raw material employed at Su-re but is nonetheless optimal in comparison with other available rock types. The deliberate choice of such a hard raw material underscores the profound understanding of material properties exhibited by Su-re's ancient inhabitants. Furthermore, the Su-re lithic assemblage displays a heightened depletion of cores and an abundance of complete flakes in contrast to experimentally produced examples, attesting to the adept craftsmanship of the site's ancient population that was fully capable of knapping usable artifacts despite confronting low-quality raw materials.

The Su-re assemblage is based on flake tools and can be categorized within Boëda's D-type system, which could not only produce flakes but also blades such as Chatelperronian or Aurignacian blades. Triangular flakes and pseudo-Levallois points were found, although cores lacked an integrated structure and preparation [26,27]. Various production methods were employed in the Su-re assemblage, including platform preparation and rejuvenation. This manifested chiefly in the maintenance and rejuvenation of striking platforms, alongside the deliberate creation of new platforms (Figure 4: 11–12). Throughout flake production, a prevalence of unidirectional sequences employing hard-hammer direct percussion is evident, aimed at leveraging ridges created by former flake scars to continue flaking. Noteworthy among the targeted products (flakes) are artifacts resembling blades and Levallois points (Figure 4: 1–2; 7–10), which are consistent with the distinctive attributes of the D-type system and principally attributable to the meticulous control exercised by prehistoric humans during the production process.

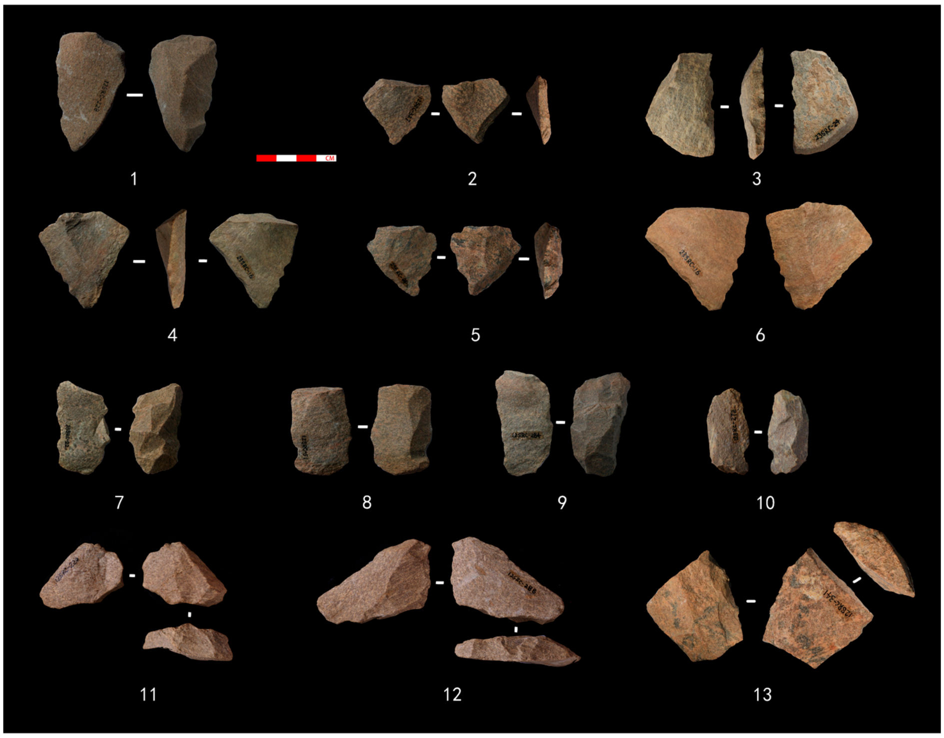


**Figure 4.** Flakes and retouched pieces from the Su-re site: 1–2, triangular flakes; 3, side-scraper; 4–6, denticulates made on triangular flakes; 7–9, elongated flakes; 10, notch made on elongated flake; 11–12, core rejuvenation flakes; 13, point with truncation.

In addition to core-and-flake products, two flint microblade technology products were also collected at Su-re. Both their lower degree of abrasion and distinct technological characteristics indicate that they are not contemporary with the gneissic artifact assemblage.

## 4. Discussion

### *4.1. Human–Environment Interactions in the Qomolangma Region*

Four glacial stadia have been recognized in the Tingri Graben during the Late Glacial [18–20]. Moraines were limited to the northern foothills of Cho Oyu between 17 and 14 ka BP and extended to the vicinity of the Su-re site between 14 and 13 ka BP, developing a massive kames terrace containing a large amount of Himalayan leucogranite and pyroclastic rock 5 km west of the site. The gneissic pebbles used by the ancient inhabitants of Su-re only form on the Ragqu Tsangpo floodplain, which destroyed the moraines that developed 14–13 ka ago. Therefore, artifacts made on gneissic pebbles are unlikely to have appeared before 14–13 ka ago. As for their latest chronology, core-and-flake and microblade products from Su-re exhibit distinct differences in degree of weathering and in their technological characteristics, and it is possible that the core-and-flake artifacts and products of microblade technology recovered at Su-re are associated with different human groups. Since microblades in Southern Xizang apparently existed no earlier than ca. 6.6–4.5 ka BP [28], core-and-flake assemblages should have been present earlier than the Middle Holocene. This hypothesis is supported by results obtained from surface OSL dating of quartzite lithic artifacts at Su-re, which indicate the latest date of burial was ca. 5.5 ka ago [16].

Lithic bearing sites in Southern Xizang are very scarce, concentrated primarily in the Yarlung Tsangpo Valley, and are exceedingly rare in glacial environments. We conducted field surveys within a 50 km radius of the Su-re site but identified no other core-and-flake localities. Lithic artifacts were not even found near Paiku Co, a large (ca. 275 km$^2$) brackish lake about 100 km west of the Su-re site, currently supporting abundant faunal and floral resources. High-altitude periglacial environments pose significant challenges to human survival, including oxygen deficiency, scarce biological resources, and variable climates. Nevertheless, the ancient humans inhabiting the Su-re site chose to occupy glacial areas in the northern foothills of Cho Oyu and Mount Qomolangma. A major contributing factor to this choice may have been the scarcity of suitable lithic raw materials in the surrounding areas. The primary rock types in this region are Himalayan leucogranite and volcanic breccia, among others, characterized by abundant mineral crystallization and fractures, which make them less suitable for lithic production. However, the area near the Su-re site not only contains gneissic pebbles and quartzite rocks, which are easier to knap, but are also located where two rivers conjoin and provide abundant fresh water. Su-re was, therefore, an optimal choice for ancient human occupation. As for the microblade technology, a few artifacts were collected near Paiku Co, Ting-ri, and Su-re, which appeared after 6.6 ka [29,30]. It was found that high quality, non-local raw materials such as obsidian and flint were used, indicating that the populations using microblades were capable of long-distance transportation or trade [30].

In summary, access to suitable tractable lithic raw materials and their development in this glacial environment, combined with cultural factors, suggest that the occupation of the Su-re site by a population of ancient humans bearing core-and-flake technology likely took place during the Terminal Pleistocene to Early Holocene.

### *4.2. Core-and-Flake Technology on the Tibetan Plateau*

The Su-re lithic assemblage can be classified into Type D of Boëda's system [26,27]. It belongs to the core-and-flake technocomplex, but is far from "simple." Intentional platform modification and dorsal ridge use, the frequent alteration of striking direction, and intensive retouch all demonstrate a mastery of knapping techniques and the capability of accommodating low-quality lithic raw materials. On the other hand, this pattern also suggests that gneissic pebbles are still a better choice despite their low quality when compared with local quartzite blocks or Himalayan leucogranite pebbles in this glacial environment, so ancient humans tried to maintain striking platforms and exploit pebbles as fully as possible.

Compared to the Late Pleistocene lithic complexes of North China, the Su-re assemblage lacks prepared funnel-shaped cores and elongated flakes. Alternate and alternating retouch are also rare in North China [31,32]. However, Terminal Pleistocene assemblages in Southwest China represented by the Fulin locality in western Sichuan Province exhibit some similarity with the Su-re site, including the preparation of some cores, sinuous edges on retouched pieces, and a few artifacts exhibiting abrupt retouch [33,34]. The flake tool industries of South Asia during this period are too few to allow useful comparisons due to a paucity of excavations and analytical publications.

Although core-and-flake technology on the Tibetan Plateau has always been regarded as simple and coarse, it has long remained under-explored. The Su-re flake tool industry is the first systematically studied lithic industry in the hinterland of the TP, whose complexity demonstrates the mastery of knapping techniques achieved by these prehistoric humans.

In the 1990s, most scholars associated core-and-flake technocomplexes with those in North China [35–37]; meanwhile, others claimed that both flake tool and pebble tool industries may have originated in Southwest China, subsequently dispersing along the Yarlung Tsangpo River [24,25,38]. Recent discoveries on the TP indicate that two flake tool industries and one pebble tool industry can be recognized:

(1) The most widely distributed Terminal Pleistocene-to-Early Holocene flake tool industries can be found in Western, Southern, and Northern Tibetan Plateau, such as at the Su-re and Ge-ting sites [39]. This category does not exhibit clear evidence of laminar or discoidal knapping sequences, and no obvious core preparation can be identified, although some specific knapping strategies employed during both core-on-flake and core-on-pebble approaches can be seen. The target products (flakes) are sometimes triangular or elongated but are in most cases irregular.

(2) A special group of "Quina" style Middle Paleolithic retouched tools have been found in North Tibetan Plateau that are especially associated with lacustrine en-

vironments [40]. Multilayer, intensive, stepped, and thinning retouch can be identified on many tools, but this whole assemblage remains unclear and has not thus far been adequately studied.

(3) A pebble tool technocomplex has been found on the terraces of large rivers such as the Yarlung Tsangpo and Langchen Tsangpo. Typical lithic artifacts include choppers and chopping tools, including end choppers, side choppers, and discoids. Discoids are fashioned on flat and circular river pebbles, with centripetal removals retaining one unretouched side, perhaps to facilitate handling [41]. Such tools resemble discoids found in the Siwalik Hills of northeast Pakistan, Northern India, and southwest Nepal [42], while side and end choppers appear closely related to pebble tools found in Southwest China [43,44]. No Hoabinhian-style tools (e.g., "sumatraliths", core-axes) or techno-typological characteristics thereof have yet been recognized in Xizang. At present, all such pebble tools have been surface collected and have no reliably associated chronometric dates.

Long correctly considered a harsh and challenging environment for human beings, the Tibetan Plateau has nonetheless yielded varied prehistoric lithic assemblages. Although the chronology of these assemblages is still problematic, the variety and complexity of these lithic technocomplexes exceed earlier expectations and the study of these lithic industries promises further intriguing results.

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**Data Availability Statement:** The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

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