Article
Understanding the Quadruple Flutes of Teotihuacan, Mexico
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Abstract: This paper presents the results of a study on the quadruple flutes (multiple pipes) from the UNESCO World Heritage Centre of Teotihuacan, Mexico, based on a thorough examination of the fragmented, restored and partly reconstructed archaeological finds and the manufacture and subsequent test of a series of playable reproductions with a refined reconstructive design. For the latter, organological features, such as the diameter, number and position of the fingerholes/ tone holes and the length of the individual pipes of the restored finds are challenged and a new design is proposed that might be closer to the original construction of the Teotihuacan instruments. The study reveals a better understanding of the particular construction, acoustics and musical possibilities of the Teotihuacan quadruple flutes.

Keywords: Teotihuacan; musical instruments; sonic artefacts; aerophones; multiple pipes; quadruple flutes; organology; acoustics; pre-Columbian; Mesoamerica

1. Introduction

The UNESCO World Heritage Centre of Teotihuacan, situated in the Central Mexican Highlands at an altitude of 2280 masl, was a civic-religious centre established in the Late Preclassic period of Mesoamerica around 150 BCE and one of the most powerful cultures during the Classic period between 200–650 CE. Although Teotihuacan has been the subject of intense research since the first archaeological investigations carried out in the end of the 19th century, the musical instruments of the site have been the subject of only a very small selection of dedicated studies so far [1–5].

The present study is the result of an ongoing research project on the sonic environment of Teotihuacan, in which the instruments of the site are studied within the acoustic ecology of the site. One part of the project consists of a survey of the archaeological finds preserved in various institutions in terms of their organology and, if the condition of the original objects allows for experimental playing, inherent acoustic parameters. As the full array of sonic artefacts reported for Teotihuacan is not preserved and not all finds can be tested because of their fragmented or fragile condition, another part of the project is the reproduction of an array of Teotihuacan sound-producing instruments in the form of replicas. In addition, the archaeological contexts of the finds and the Teotihuacan music iconography are being revised, among other factors supporting interpretation of the playing postures and cultural contexts in which the instruments were sounded.

In this paper, the extant finds of the Teotihuacan quadruple flutes are discussed, particularly with regard to the organological design of the two most complete archaeological finds, the so-called Zacuala and Anahuacalli-1 quadruples. In the course of the present research, it has been noted that the current dimensions in terms of the individual length of the pipes and the placement (or omission) of some of the fingerholes/ tone holes of the restored and partly reconstructed flutes have to be challenged. According to the restoration history of the finds, a comparative study of the organological features present in the extant triple and quadruple flutes from the Gulf Coast and the Maya Area, and tests carried out with a number of reproductions, a refined reconstructive design of the instruments is proposed. The performance possibilities, the acoustic parameters of the instruments and
possible implications on the sonic ecology of the site are discussed in greater detail in a complementary paper [5].

2. Materials and Methods

For the reproduction of the Teotihuacan quadruple flutes and their subsequent testing in terms of organological function, acoustics, playing techniques and musical possibilities, the methodological approaches of experimental music archaeology have been applied (theoretical considerations and methodologies are discussed in [6] and constantly further developed, especially regarding archaeoacoustic studies and experimental approaches). Within this process, a series of playable instruments, in particular replicas (exact copies of well-preserved finds), reconstructions (exact copies of fragmented finds with hypothetically reconstructed parts) and experimental models (exact copies of the acoustically relevant organological parts designed for functional tests), were produced accurately according to the original material (in the case of ceramic objects: low-fire clay, water), tools (in the case of the quadruple flutes: wooden bars for the tubes, sticks of different shape and a blade) and workmanship (in the case of ceramic flutes: modelling, burning in the open fire and larger objects in a brick stove). The production of a series of copies per instrument type was aimed at better understanding the organology involved in the construction of the instruments, particularly in relation to the way sound is generated and which particular sonic characteristics are produced. The experimental process proved to be very fruitful, as a large amount of specific data has been compiled with regard to the manufacture and performance of the documented instruments, revealing aspects of the organological and acoustical knowledge developed in Teotihuacan.

As the experimental models and refined reconstructions are produced manually and from clay, which is always subject to variable shrinking during the process of drying, it is virtually impossible to match the dimensions of the original finds in an exact way, especially for larger and in, organological terms, more complex instruments such as the quadruple flutes. This has no greater effect on the general sound characteristics and playing possibilities of the particular instruments, but it complicates the matter of testing organological and acoustical details observed in the original artefacts. The results obtained are therefore limited, especially as it is too time consuming and costly to manually reproduce a greater range of models designed for acoustic tests and comparison. Currently available technologies, such as software for acoustic analysis [7], computed tomography, virtual modelling and 3D printing [8], offer new opportunities for further research. The latter technologies also proved to be valuable tools to the present research.

3. Results

3.1. Quadruple Flute Organology

The Teotihuacan quadruple flutes are among the most elaborate ceramic fipple flute instruments documented for Mesoamerica. The extant finds, apart from three partly preserved quadruples most frequently broken mouthpieces [2,4,9,10] 1 and a series of miniature representations in the form of ceramic plaques [2,9,11–14] 2 were excavated predominantly close to the civic-religious centre of the site. The finds point to a standardized production of these flutes in terms of morphology and, in terms of size, to the employment of a family of larger (“alto”) and smaller (“soprano”) instruments.

In organological terms, the multiple flutes are composed of a mouthpiece and four long tubular resonators equipped with a number of fingerholes and/or tone holes (Figure 1a). The typical mouthpiece is characterized by two blow holes and two bifurcated airducts with four exit slits (Figure 1b). The four apertures are in general much longer than wider, equipped with convex side walls (presenting no frames) and slightly curved edges (Figure 2a). Inside the pipes a curved or bended ramp can be observed, extending from the exit slits of the airducts to the bottom of the pipe (Figure 2b). Cross sections of a virtual flute model provide visual possibilities demonstrating these partly non-visible organological features of the instruments (Figure 3). The configuration of the airduct–aperture assemblage
is particularly unique when compared with more conventional forms applied in the ceramic fipple flute organology from Mesoamerica, presenting single airducts and apertures of rectangular, trapezoid, circular or oval shapes. Notably, the particular configuration is also not found in the multiple flutes from other pre-Columbian cultures, and thus represents a distinctive feature exclusively related to the Teotihuacan quadruple flutes.

Figure 1. (a) The organological components of a Teotihuacan quadruple flute (experimental model); (b) mouthpiece configuration with two bifurcated airducts. Photos by Adje Both.

Figure 2. (a) Characteristic form of the Teotihuacan quadruple flute apertures: (1) top side of the airduct at exit; (2) edge; (3) side walls; (b) cross section of the Teotihuacan airduct–aperture assemblage with curved ramp. Drawings by Adje Both.

The two rightmost pipes of the instruments, which are likely to represent the “melody” pipes or “chanters” (identified as pipes A and B, for reference, see Figure 1), are always equipped with three more-or-less equidistant fingerholes placed in the central part (A1; A2; A3; B1; B2; B3) and a tone hole placed in the lower part of the pipes (A4; B4). As a general principle, the fingerhole groups in the central part are not aligned in parallel but slightly shifted, with the fingerholes of pipe A placed three-to-five millimetres higher than those of pipe B (always measured from the centre of each fingerhole). The tone holes in pipes A and B are also not aligned in parallel, but shifted in the opposite direction, with the hole of pipe A placed slightly lower than the one of pipe B. In acoustical terms, the tonal deviation as a result of the shifted position of the fingerholes is thus counterbalanced, but due to small measurement deviations in terms of the distances between the respective edges and the holes and their diameter, the pipes are hardly to be played in unison, resulting in the production of beats with various degrees of roughness [5] (p. 529). The two leftmost or “drone” pipes (C and D, see Figure 1) are equipped with one or two fingerholes each.
(C1; C2; D1), placed in the lower part for adjusting the drone frequencies. It should be mentioned, however, that the organological identification of the pipes and the holes with respect to their usage must be carried out cautiously and that the definitions given above are preliminary. According to the way the instrument is supported and the fingering technique applied, pipes C and D can also be turned into melody pipes with a limited tonal range, and the tone holes of pipes A and B could also be used as fingerholes.

![Virtual flute model](image)

**Figure 3.** Virtual flute model, created by Jared Katz (2021): (a) top view showing the airduct-aperture assemblage; (b) cross section of the mouthpiece. Sections created by Stephen Knowles.

While pipes A–C are usually of the same length, pipe D is somewhat longer, thus producing tones in a lower frequency range than the other pipes. This particular feature is frequently seen in the quadruple flute miniatures from Teotihuacan mentioned above. In the sound artefacts, pipe D is also special in the sense that it is sometimes equipped with a much larger aperture than the apertures related to pipes A–C, and the ramp may be bended instead of being curved. Pipes A–C are usually half-stopped by slightly dented walls or an attached disk with a central opening, while pipe D could also present a conical constriction at the distal end. These elements serve to ensure that the pitch of the instrument is lower than if the pipes were open. As the distal end of pipe D has not been preserved in any of the extant sound artefacts from Teotihuacan, its exact configuration is unknown.

Some of the above described organological features are also observed in a series of roughly contemporary or slightly later multiple flutes from the Gulf Coast and the Maya Area, in particular the triple flute from Tenenexpan, Veracruz [15], the triple flutes from Jaina, Campeche, and Copan, Honduras [16] and the quadruples from Jaina, Campeche, and Baking Pot, Belize [2], suggesting mutual interchanges and certain continuities in terms of instrument design and musical knowledge. The comparison with these instruments is of particular help to get a better picture of the Teotihuacan quadruple flute organology, as not all parts of the extant finds from Teotihuacan are preserved (see Section 3.4). It should be noted that the triple and other multiple flutes from Mesoamerica are of equal importance than the quadruples, especially as the rightmost chanter of the triple flutes has been simply duplicated in the quadruple flutes (probably, as a reference to the West Mexican double pipes with groups of three fingerholes), while the longer configuration of the leftmost drone pipe was always maintained.
3.2. The Three Best-Preserved Teotihuacan Quadruple Flutes

Only three sonic artefacts are known, which are preserved partly intact. The first, larger instrument has been excavated in Burial 30 of Zacuala Palace, forming part of the main temple of the compound (Figure 4a) [2] (p. 70–73, Figure 3), [9] (p. 207, Lám. CVIII), [17] (p. 347, Cat. 165), [18] (p. 48–49, Figure 28), [19] (p. 131, Figure 10). For a better distinction, this flute is called the Zacuala quadruple. The flute was subject of at least three restoration/reconstruction attempts roughly carried out between 1959–1965 by Carlos Sigüenza, the second before 2005 and the last over 2005–2008 under the direction of Felipe Solis. Its current measurements are 74.5 cm in length, 13.2 in width and 3.8 cm in height. According to our examination of the artefact, it is made from granular paste, with temper containing mica (or muscovite, a phyllosilicate mineral) and crumbled shell (pieces of the latter are observed at the partly fractured distal end of the mouthpiece). The finish presents an ochre–yellowish engobe applied on both sides of the pipes that has been partially polished along the shafts of the pipes (comparable to the ochre ground on the Teotihuacan red-on-ochre ware or ceramic Group 8 established by Séjourné [20]).

The mouthpiece originally did not present any application of engobe, which is hardly detected today as, in the course of the second restoration/reconstruction attempt of the instrument, the natural surface colour of the fired clay had been adjusted to the colour of the pipes. Notably, the object is manufactured from the same paste and also has the same finish as the Anahuacalli quadruples (see below). The feature of ware from granular paste with ochre–yellowish engobe is also shared with other Teotihuacan instruments, such as the ceramic horn in the form of a marine shell from Tetitla, Burial 32 5 (p. 518–520).

The second, much smaller flute, called Anahuacalli-1, is from the Diego Rivera collection and has no archaeological background information, except that it is from Teotihuacan (Figure 4b). This instrument was fragmented and the subject of one restoration/reconstruction attempt carried out before 1955, when published for the first time [21] (p. 140). The actual measurements are 43.0 cm in length, 10.4 cm in width and 2.7 cm in height. Its current condition is poor, as some of the reconstructed sections have come apart and further damages have been incurred to the preserved original parts.

The third quadruple flute, called Anahuacalli-2, is from the same collection but preserved only in a larger fragment consisting of the mouthpiece and the upper part of the tubes, including some of the fingerholes of pipes A and B (Figure 4c). The latter instrument is virtually identical to the Anahuacalli-1 quadruple in terms of its morphology, size, organological details and wear marks of its preserved parts. In both instruments a dark discoloration in the distal end of the mouthpiece has been observed, apparently resulting from extensive playing. Additionally, greyish-black spots of an unidentified substance are dispersed on the surface of both mouthpieces. According to these features, it can be assumed that the Anahuacalli quadruples stem from the same archaeological context, most possibly a burial. The two latter instruments belong to the soprano size of the Teotihuacan quadruple flutes.
Figure 4. Quadruple flute finds from Teotihuacan, actual condition of the fragmented, restored and partly reconstructed artefacts: (a) Zacuala Palace (Museo Nacional de Antropología, Mexico City, Inv. 10-223540), actual length: 74.5 cm; (b) Diego Rivera collection, “Anahuacalli-1” (Museo Anahuacalli, Mexico City, Inv. 51125), actual length: 43.0 cm; (c) fragment from the Diego Rivera collection, “Anahuacalli-2” (Museo Anahuacalli, Mexico City, Inv. 45540), length: 28 cm. Drawings by Adje Both.

3.3. Previous Reconstruction Attempts and Current Playing Condition of the Finds

As mentioned before, the Zacuala quadruple was subject to at least three restoration/reconstruction attempts, which are not fully correct according to current research. Notably, the reconstructions resulted in differing total lengths of the sonic artefact, ranging between 63.5 cm in the first stage and, after a prolongation of the length of pipe D, 74.5 cm in the last reconstruction. On the other hand, the width of 13.2 cm and the height of 3.8 cm were always maintained and correspond to the original size (the height equivalent to the maximum outer diameter of the pipes). From the preserved part of the original find only a sketch has been published (Figure 5). The sketch does not include several parts of the distal end of some of the pipes, one fragment still presenting a fingerhole/tone hole inserted erroneously on the inferior side of the instrument (in pipe A in the first reconstruction and in pipe C in the second reconstruction). In the first reconstruction, pipes A–C have been given the same length, with the length of pipe D only a few millimetres larger. For the second reconstruction, the length of pipe D has been enlarged, and for the last attempt even more. During the second reconstruction attempt also the diameter of some of the fingerholes, originally presenting between 4.5–5.5 mm, has been substantially modified, resulting in diameters between 2.9–5.5 mm. According to the pre-Columbian flute design, usually presenting only small deviations of the fingerhole diameters of not more than 0.5–1.0 mm in one and the same instrument, the present condition must be challenged. In addition, due to the lack of knowledge on comparative material, the fingerholes and tone holes of the unpreserved parts in pipe A (A4), B (B4), and C (C1; C2) were never
included. The fingerhole/tone hole currently situated on the inferior side of pipe C, most probably corresponds to A4, and the corresponding fragment to pipe A. The Anahuacalli-1 quadruple also has not been restored fully and satisfyingly, especially in terms of the length of pipe D and the omission of some of the fingerholes of pipes B (B2; B3), C (C1) and D (D1).

Figure 5. Sketch of the Zacuala quadruple before restoration/reconstruction. Redrawn by Claudia Zeißig after [19] (p. 131, Figure 10).

According to our recent examination of the original finds, the instruments cannot be fully sounded in their actual state [5] (p. 526). For the Zacuala quadruple, only pipes A–C could be individually tested, while pipe D is mute due to invisible damage or inappropriate restoration. Due to the same reasons, also not all fingering positions of pipe A are playable. In the Anahuacalli-1 quadruple only pipes B and C are playable, while pipes A and D are mute. In addition, as the playable pipes of the latter flute are fractured at the upper part close to the window, only frequencies much higher than in the original intact flute can be produced and the values obtained are therefore irrelevant.

3.4. Manufacture and Design of Playable Reproductions with Copied and Reconstructed Parts

As the original restored and reconstructed flutes are malfunctioning and the organological details of the actual restorations/reconstructions are challenged, in particular the lengths of the individual pipes, the diameter of the fingerholes/tone holes, their number and respective placement, a series of reproductions from clay was produced by the instrument maker Osvaldo Padrón Pérez, corresponding to revised reconstructions of the instruments. For the actual reproduction process the following steps were followed:

1. producing four tubes with flat pieces of clay wrapped around wooden bars;
2. joining the four tubes by filling an amount of clay in between the tubes in the upper and lower section of the pipes and in between the tubes on the inferior side;
3. cutting the four apertures in the tubes;
4. producing the mouthpieces in two parts (a larger lower and a smaller upper section, the latter presenting the blow holes): the inferior side of the lower section with four flat sticks in the size of the airducts, then covered by the superior side of the lower section; the same repeated with the upper section;
5. joining the lower section of the mouthpiece with the tubes by bringing the remaining sticks in line with the edges; carefully removing the sticks and testing the sound; for support adding clay at the joint of the inferior side of the mouthpiece and the four tubes;
6. joining the upper section of the mouthpiece with the lower section; removing the sticks and testing the sound; eventually adjusting the position of the mouthpiece so that all airducts are aligned well with the apertures, especially the edges;
7. bringing the form of the aperture into shape and testing the sound; eventually slightly adjusting the airduct-aperture configuration;
8. perforating the fingerholes/tone holes with a reed tube by measuring the position of the fingerhole A2 and from there on deducting all other fingerholes/tone holes; then testing the sound; eventually slightly adjusting the individual size of the fingerholes/tone holes;
9. finishing by smoothing the entire surface, eventually applying engobe and partially polishing the surface.
10. drying and firing. With the respective preparation, construction and drying processes of the individual pieces, at least three work days of 4 to 5 h each are required for production, and then at least a couple of days for the drying process, before the instrument can be fired.

For a better reference, the obtained models are labeled “Zacuala/2020-1”, “Zacuala/2020-2”, “Zacuala/2021”, “Anahuacalli-1/2020” and “Anahuacalli-1/2021” (Figures 6 and 7). Further models are 3D-printed reconstructions designed for acoustic tests, based on a CT scan made from the Zacuala/2020-2 quadruple and the creation of a virtual model with adjusted measurements carried out by Jared Katz and Stephen Knowles (Figure 8).

![Figure 6. Quadruple flute reconstructions made by Osvaldo Padrón Pérez (2020): (a) “Zacuala/2020-1”, length: 71.0 cm; (b) “Zacuala/2020-2”, length: 66.5 cm; (c) “Anahuacalli-1/2020”, length: 46.0 cm. Note the varying length of pipe D and the different placements of the fingerholes/tone holes in the lower part of the pipes. Photos by Adje Both.](image)

In terms of the length of pipes A–C of the Zacuala quadruple, the first restoration/reconstruction attempt of the original has been considered closer to the Teotihuacan instrument design than the later reconstructions, especially due to the discovery of a possible method for calculating the placement of the fingerhole groups in pipes A and B, carried out by dividing the distance between the edge and the distal end of pipe A by two and thus defining the position of the central fingerhole of the group (A2), to be perforated more or less exactly in the centre of pipe A. With little deviations, this feature is observed in the first reconstruction of the Zacuala quadruple and in the Anahuacalli-1 quadruple. Once that the position of A2 had been defined, the position of all other holes of the two fingerholes groups was likely to be applied according to the makers’ right hand and the standard playing posture of covering A1–B1 with the forefinger, A2–B2 with the middle finger, and A3–B3 with the ring finger (Figure 9). This principle also has been followed in the manufacture of the reconstructions discussed here. All fingerholes were made with a diameter between 0.35–0.45 cm (Anahuacalli-1 quadruple) and 0.45–0.55 cm (Zacuala quadruple), such as in the original finds (for the Zacuala quadruple, according to the condition observed before the second reconstruction attempt).
Note the varying length of pipe D and the different placements of the fingerholes/tone holes in the lower part of the pipes. Photos by Adje Both.

Figure 7. Quadruple flute reconstructions made by Osvaldo Padrón Pérez (2021): (a) “Zacuala/2021”, length: 66.0 cm; (b) “Anahuacalli-1/2021”, length: 47.5 cm. Photos by Adje Both.

Figure 8. 3D-print of a quadruple flute virtual model corresponding to the upper part of the instrument, made by Stephen Knowles (2021), length: 25.5 cm. Photo by Adje Both.

Especially important for reconstructing the particular Teotihuacan quadruple organology in terms of the number of the fingerhole/tone holes and their respective placement are the position of the preserved holes of pipes A, B and C of the Zacuala and pipes A–C of the Anahuacalli-1 quadruples, and the organological features of the above mentioned multiple flutes from the Gulf Coast and the Maya Area (see Section 3.1). In the Zacuala models the missing fingerhole/tone hole of pipe A (A4) was placed by taking into account the position of the inferior hole currently found in pipe C of the sonic artefact (thus, in terms of its relation to the pipe following the first reconstruction attempt). Then, the array of fingerholes/tone holes in the lower section of the pipes A–C of the Anahuacalli-1 quadruple has been duplicated, presenting the holes B4 and C2 in line in a somewhat higher position than the hole A4.
Figure 9. Suggestion for the standard fingering positions of the right hand (left) and the left hand (right). Photo by Adje Both.

For defining the position of the unpreserved fingerholes of pipes C (in the Zacuala quadruple) and C–D (in the Anahuacalli quadruple), two approaches were followed and brought in line. Important information was obtained by the accidental (and later also intentional) break of several reproductions (Figure 10), resulting in comparable fractures present in the Zacuala and the Anahuacalli quadruples (for the former flute, some lines of breakage are still observable on the photos of the first restoration/reconstruction attempt, still preserving the original finish). The fractures in both the extant finds and the reproductions clearly demonstrate that the instruments break most likely at the weakest parts, which are the joints between the mouthpiece and the pipes and the hole positions.

Figure 10. (a) and (b) Broken quadruple flute reproductions made by Osvaldo Padrón Pérez (2020) showing fractures comparable to the original finds. Photos by Adje Both.

In addition, when comparing the fingerhole placement of the two leftmost pipes in the multiple flutes from other cultures it has been observed that the distance of the two holes of pipe C is either comparable to or only slightly smaller than the distance between
the first and the third hole of the three-fingerhole groups, suggesting that the middle finger of the left hand was meant to support the instrument without operating a fingerhole. C1 was then likely to be operated by the fore finger of the left hand, C2 with the ring finger and D1 with the little finger (Figure 9). On the basis of these considerations, the position of some of the unpreserved fingerholes/tone holes in the lower part of the pipes could be well calculated. However, questions regarding the variability of the position of some of the fingerholes/tone holes remain unsolved.

The length of pipe D and the shape of its exit is still the most uncertain part in the Zacuala and the Anahuacalli-1 quadruples. Therefore, different versions have been applied and tested. The pipe has been produced very large, such as in the Zacuala Palace/2020-1 model (Figure 5), presenting a long pipe close to the Tenenexpan triple, or not as large, such as in the Zacuala Palace/2021 and the Anahuacalli-1/2021 models (Figure 6). In addition, the characteristic form of the distal end of pipe D with a conical constriction was taken from the Gulf Coast and Maya instruments in the 2020 models and left out in the 2021 models. Such as the length of the tube, this feature has an effect on the lower frequency generated by pipe D.

While the length of the individual pipes certainly has an impact on the fundamental frequencies, it has been noted that small deviations in terms of the length of the pipes and the shape of their exit, the diameters of the fingerholes/tone holes and their position has no greater effect on the general acoustics, which is always characterized by the production of tone clusters and, according to the cross-fingering techniques applied, intervals corresponding to dyads or triads (in rare cases also four-note chords) [5] (p. 525). On the other hand, even minimal measurement deviations, which are likely to occur between one or the other instrument due to the fact that they are made from clay and produced manually, result in a great range of beats with various degrees of roughness. These acoustic features certainly correspond to the main sonic characteristics of the quadruple flutes.

By experimenting with the 3D print of the upper part of the Zacuala/2020-2 flute mentioned above, additional information on the particular airduct-aperture assemblage and its related acoustics has been discovered. While playing the printed model, it has been noted that it sounds only when stopping the pipes at the distal ends. Apparently, the operational function of airducts directed to the characteristic apertures of the quadruple flutes is closely related to the greater volumetric capacity of the pipes, while pipes of less volume simply would not react in the combination of such parameters.

4. Discussion

Considering all available information presently at hand, our understanding on the quadruple flute organology and its related acoustics, construction techniques, playing postures and musical possibilities has been considerably enhanced. The information could not only be compiled on the basis of an analysis of the original sound artefacts in terms of measurements and morphology. A deeper understanding of the finds could only be obtained by undertaking the effort of accurately reproducing the instruments and facing the challenge of reconstructing the damaged and missing parts. A comparable process had not been carried out on the originals in the past, leading to unsatisfactory restoration/reconstruction results in terms of organological parameters and playing conditions. The obtained models produced for the project are believed to be much closer to the original design of these instruments, and therefore also the acoustics closer to the original sonic ecology of Teotihuacan. Taking the particular organological features of the quadruple flutes into account, it becomes clear that these aerophones represent the physical remnants of a once elaborated music culture with the development of a specific instrument design and related highly specialized constructive and acoustic knowledge.

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Notes
1. So far documented are approximately 40 fragmented mouthpieces from the Teotihuacan Mapping Project at the Research Laboratory of the Arizona State University, San Juan Teotihuacán (RL-ASU), for a selection see [2] (p. 74–76, Figure 5); finds from Atetelco, La Ventilla and other excavation sites at the Ceramicoteca of the Zona de Monumentos Arqueológicos de Teotihuacán, San Martín Teotihuacán (C-ZMAT, Inv. 10-600289; 10-599889; Elem. 18987; 57888; further finds without inventory no.), for a selection see [2] (p. 71, 74–76, Figure 2); finds from Zacualt, Yahualua and Tetitla, see [9] (p. 236, Figure 126), [10] (p. 106, Figure 83D,E); and two finds from Teopancazco, see [4] (p. 202, 205, Figures. 4.47–4.48). For a distribution map, based on the finds stored in the RL-ASU and the C-ZMAT, see [2] (p. 83, Figure 9).
2. The miniatures are produced with a flat inferior side and the superior side simulating the instrument in relief, frequently simulating the fingerholes, apertures, and decoration, see [2] (pp. 76-81: Figures 6–8); [9] (pp. 237–238, 240, Figures 127–129); [11] (p. 379, Figure 268); [12] (p. 13, Table 4); [13] (p. 46, Photo 129); [14] (p. 3, Photo 130). A series of finds is stored in the RL-ASU and the C-ZMAT; one further find in the Museo Nacional de Antropología, Mexico City (MNA), the latter without inventory number.
3. Samuel Marté gave the length of 53.5 cm for the first restoration/reconstruction [18] (pp. 48–49, Figure 28), but when bringing his top view photograph to scale (and taking into account the photographic distortion of the object resulting from the position of the photographer and the angle of her or his camera) it becomes clear that a typo occurred, as an instrument of 53.5 cm in length would present a width of not more than 10.8 cm. When bringing the photograph to the scale of 63.5 cm in length and recompute the photographic distortion, the width of 13.2 cm is matched.

References
4. Zalaquett Rock, F.A.; Espino Ortiz, D.S.; Vázque Campa, V. Instrumentos sonoros procedentes de las excavaciones de Teopancazco. In Teopancazco Como Centro de Barrio Multiétnico de Teotihuacán: Los Sectores Funktionales y el Inter cambio a Larga Distance; Manzanilla, L.R., Ed.; UNAM: Mexico City, Mexico, 2018; pp. 181–212.
7. Hagel, S. Assessing Unknown Parameters of Instrument Finds by Writing Software. In From Digitalisation and Virtual Reconstruction of Ancient Musical Instruments to Sound Heritage Simulation and Preservation; Angela, B., Ed.; Archeologia e Calcolatori 32.1; Edizioni All'Insegna del Giglio: Sesto Fiorentino, Italy, 2021; pp. 403–421. [CrossRef]
10. Séjourné, L. Un Palacio en la Ciudad de los Dioses [Teotihuacan]; INAH: Mexico City, Mexico, 1959.
18. Martí, S. Alt-Amerika; Musikgeschichte in Bildern, Volume 2; Musik des Altertums, Lieferung 7; VEB Deutscher Verlag für Musik: Leipzig, Germany, 1970.