Journal of Archaeological Science 38 (2011) 3415–3424

Contents lists available at SciVerse ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Multi-scale tribological analysis of the technique of manufacture of an obsidian bracelet from Aşıklı Höyük (Aceramic Neolithic, Central Anatolia)

L. Astruc [a,*], R. Vargiolu [b], M. Ben Tkaya [b], N. Balkan-Atlı [c], M. Özbaşaran [c], H. Zahouani [b]

[a] Institut Français d'Etudes Anatoliennes, CNRS/USR 3131, Nuru Ziya Sokak, 10 P.K. 54, 34433 Beyoğlu, Istanbul, Turkey
[b] Université de Lyon, Ecole Nationale d'Ingénieurs de Saint Etienne, Ecole Centrale de Lyon, CNRS/UMR 5513, Laboratoire de Tribologie et Dynamique des Systèmes, 36 avenue Guy de Collongue, 69131 Ecully, France
[c] Istanbul Üniversitesi, Edebiyat Fakültesi, Arkeoloji Bölümü, Prehistorya Anabilim Dalı, Ordu Cadesi, Laleli, 34134 Fatih, Istanbul, Turkey

ARTICLE INFO

Article history:
Received 12 May 2011
Received in revised form
17 July 2011
Accepted 30 July 2011

Keywords:
Tribology
Obsidian
Polishing
Ornaments
Neolithic
Anatolia
Aşıklı Höyük

ABSTRACT

Tribological analysis is employed in a pilot study of the technological steps involved in the manufacture of a polished obsidian bracelet from Aşıklı Höyük, an Aceramic Neolithic site in Central Anatolia (8300–7500 cal. B.C.). The study includes morphological analysis of the bracelet, based on profile measurements, and identifications of wear variations indicated by surface topographic features and parameters. The manufacturing skill that is revealed suggests early appearance of a regional tradition of obsidian working, which reached its full development in the 6th millennium cal. B.C. with the production of various ornamental objects, including mirrors and vessels. The cultural record and location of Aşıklı Höyük make the site important for our understanding of the technological developments during the early Neolithic in Anatolia.

1. Introduction

Artifacts of personal adornment, mirrors, and vessels made from polished obsidian occur in Anatolian sites of the 7th and 6th millennia cal. B.C. and are considered expressions of remarkable stone craft skills developed during this period (Healey, 2000, 2007; Vedder, 2005). Recently, a fragment of obsidian bracelet with highly polished surface and complex morphology (Fig. 1), dating back to the 8th millennium cal. B.C., was discovered at Aşıklı Höyük in Central Anatolia, indicating a greater antiquity for the practice of obsidian polishing.

Aşıklı Höyük is a 3.5–4 ha settlement mound situated at an elevation of about 1100 m above sea level in the Melendiz valley in Aksaray province, within the territory of ancient Cappadocia (Fig. 2; Esin and Harmankaya, 1999, 2007; Esin et al., 1991; Todd, 1966). At distances of 19 and 25 km from the site are located, respectively, Nenezi Dağ and Göllü Dağ, two of the main sources of the obsidian traded in the eastern Mediterranean region during the Neolithic period (Cauvin et al., 1998; Renfrew et al., 1966). Aşıklı Höyük preserves more than 10 m of well stratified deposits assigned to the Aceramic Neolithic and dated by more than 80 ^{14}C dates to about 8300–7500 cal. B.C. Excavations conducted in 1989–2000 by Ufuk Esin (Istanbul University) covered a total area of 1.6 ha, making Aşıklı Höyük one of the most extensively investigated Neolithic settlements in Anatolia. Work continued on a smaller scale until 2004 under the direction of Nur Balkan and concentrated on the earliest phases of occupation. In 2010, excavations resumed under Mihriban Özbaşaran and continue to date. The finds include well-preserved mudbrick (*kerpiç*) architecture; human burials; as well as large collections of faunal and botanical remains, stone tools, and ornaments. A general stability in the subsistence economy of the village, with some diachronic changes in resource use and selection, has been observed. Specifically, the importance of wild and domestic cereals, wild grasses, legumes, and fruits in the diet (van Zeist and de Roller, 1995, 2003) and an unusual level of control over wild ovicaprids, which pinpoints "proto-domestication" (Buitenhuis, 1997), have been noted. The stone industries were produced by means of uni- and bidirectional debitage from obsidians from Göllü Dağ and, to a lesser degree, Nenezi Dağ (Abbès

* Corresponding author. Tel.: +90 2122441717x143; fax: +90 2122528091.
E-mail addresses: laurence.astruc@laposte.net (L. Astruc), Roberto.Vargiolu@ec-lyon.fr (R. Vargiolu), Mohamed.Ben-Tkaya@ec-lyon.fr (M. Ben Tkaya), nbalkan@istanbul.edu.tr (N. Balkan-Atlı), ozbasaranmihriban@gmail.com (M. Özbaşaran), Hassan.Zahouani@ec-lyon.fr (H. Zahouani).

0305-4403/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jas.2011.07.028

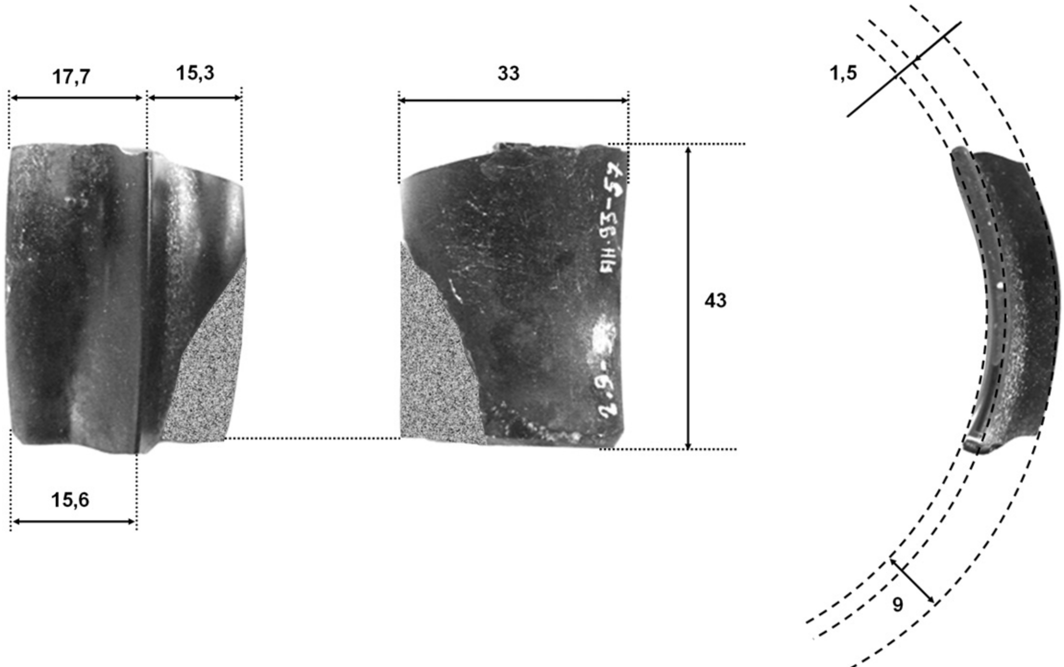


Fig. 1. Fragment of obsidian bracelet from Aşıklı Höyük. The casted missing edge appears light in color. Dimensions are in mm.

et al., 1999; Balcı, 2010; Balkan-Atlı, 1994; Yıldırım-Balcı, 2007). The ornaments were mainly beads made from limestone and volcanic rocks and used for bracelets and necklaces or pendants. Obsidian was only identified on the specimen examined below, the sole solid bracelet from the site. Contrary to the beads, which were found in burial contexts, the obsidian bracelet was recovered from Building T of the "Public Area", a communal space in the southern part of the site (Fig. 3).

The bracelet was made from high quality green obsidian. Since it is a museum piece that cannot be transported for study, the source of the obsidian has not been identified through geochemical analysis. Green obsidians of different aspects are found on the nearby Nenezi Dağ as well as Nemrut Dağ and the Bingöl region in Eastern Anatolia, 400–550 km away from Aşıklı Höyük. If these two latter sources were employed, the possibility that the bracelet was obtained through exchange should be considered. In that case, it would predate the earliest imports of Eastern Anatolian obsidian in Central Anatolia, now known from Çatalhöyük and dated at 7000–6300 cal. B.C. (Carter et al., 2008). Identifying the technology devised to produce the Aşıklı Höyük specimen is fundamental for understanding the appearance of the obsidian polishing craft. In this paper, we use tribological analysis in order to identify and classify the manufacturing technique. This analysis is selected because of its suitability to studies of the wear on stone. It also permits observations to be carried out on replicas of objects from museum collections, which cannot be directly analyzed.

2. Description of the bracelet fragment

The fragment lacks part of an edge, which was completed with resin during restoration (Fig. 1). Its length is 43 mm and its maximum width 33 mm. The internal diameter is estimated 100 mm (with an approximation error of 5%), which confirms that the object could be worn on the wrist or the arm as bracelet. Based on these measurements, a minimum volume of 315 cm^3 of obsidian was estimated necessary to make the bracelet.

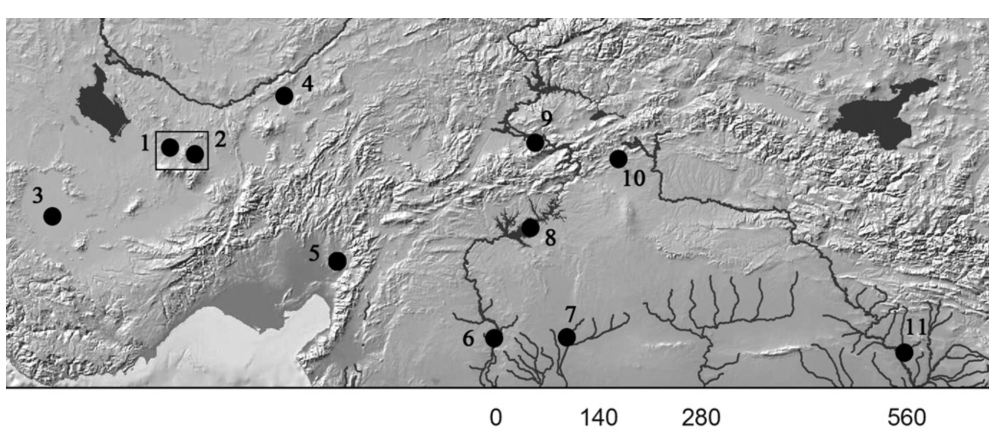


Fig. 2. Locations of sites mentioned in the text: 1. Aşıklı Höyük; 2. Kömürcü-Kaletepe; 3. Çatalhöyük; 4. Kültepe; 5. Domuztepe; 6. Tell Halula; 7. Tell Sabi Abyad; 8. Kumartepe; 9. Cafer Höyük; 10. Çayonü; 11. Arpachiyah. The small square sets the locations of Nenezi Dağ and Göllü Dağ.

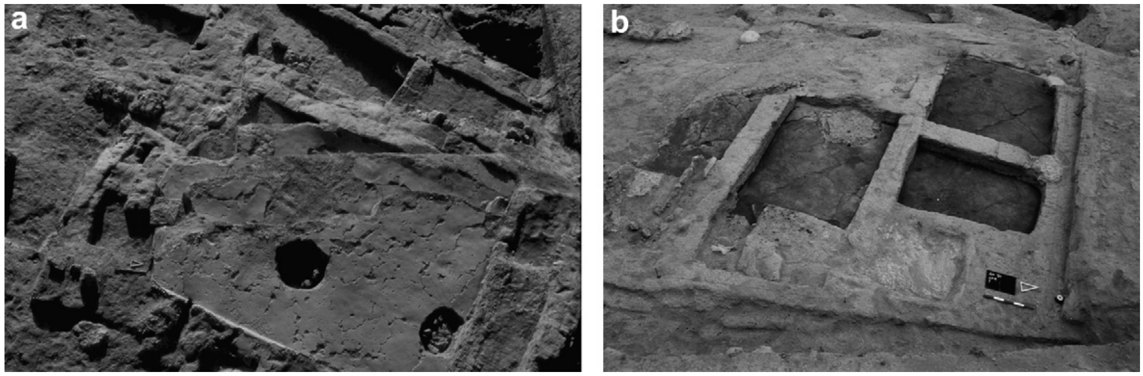


Fig. 3. (a) Plastered and painted floor from the second building phase of Building T, with which the obsidian bracelet has been associated; (b) mudbrick foundation walls associated with the floor.

An annular ridge, shaped on the outer surface of the bracelet, divides its width into two unequal parts measuring 17.7 and 15.3 mm and described below as zones A and B, respectively. The apex of the ridge is rounded and its slopes become concave toward the base, the breadth of which is 10 mm. The maximum thickness of the fragment, at the level of the ridge, is 9 mm and the minimum thickness, near the edges of the bracelet, which were thinned during the manufacture, 1.5 mm. Macroscopically, the object's surface appears highly smoothed and glossy. Observation with a 10× hand-lens permits to identify zones with different degrees of polishing and surface morphology. The external surface is shiny with narrow, dotted or continuous, concentric striations which run parallel to the bracelet's edges and the annular ridge. On the same surface, the thinned edges exhibit a relatively mat abraded surface, which is 3–5 mm in width. The abrasion consists of slightly oblique, narrow, and shallow striations with mat bottoms and irregular edges. The ridge is shiny with oblique striations. The apex was rounded by grinding narrow facets. The inner side of the bracelet is also smoothed but appears less shiny because of the presence of mat striations and pits caused by post-depositional damage.

3. Methodology

Tribological techniques developed for industrial applications permit a multi-scale analysis and provide adequate explanations of the wear and deformation of solid materials (Georges, 2000). They combine qualitative and quantitative methods in order to assess wear variations and conditions. Therefore, tribological analysis enhances our understanding of the wear on ancient tools, traditionally studied using a qualitative approach (see, e.g., Keeley, 1980; Gassin, 1996; Plisson and van Gijn, 1989). In this study, we use surface topography and profile measurements in order to evaluate the control of the bracelet's symmetry during the manufacture, and identify variations in surface topography, issued from different stages of the production sequence (e.g., D'Errico et al., 2000). This analysis allowed us to evaluate the manufacturing skills involved in the production. For optical observation of the wear, two different scales of measurement were employed: macro-scale analysis with a confocal microscope allowing for measurements of maximum lateral resolution of 10 nm and a resolution in Z of 3 mm (Fig. 4a) and micro-scale analysis carried out with an interferometer which permits measurements of a maximum lateral resolution of 2 nm with a resolution in Z of 1 mm (Fig. 4b). In both cases, the size of the measured areas was adapted to the worn surface. The study was conducted on selected areas of the bracelet, replicated using Silflo® silicone, which is a high quality impression material. Positive casts were then made in UREOL FC 52 AB resin. Cast reliability was evaluated by several optical measurements of the topography of the worn surfaces. To compare topographies, we use the statistical parameters of Mean Roughness (Spa) and Porosity (i.e., surface area of pores by surface unit), and automatic detection of striations (Stout et al., 1993; Zahouani, 1998; Zahouani et al., 1999). Our analysis was conducted in the Laboratoire de Tribologie et Dynamique des Systèmes, Ecole Centrale de Lyon. Since 1996, this laboratory undertakes basic research on ancient stone technology in collaboration with CNRS and university archeologists (Anderson et al., 1998, 2006; Astruc and Vargiolu, 2004; Astruc et al., 2001, 2002, 2003; Morero et al., 2008; Procopiou et al., 1998; Vargiolu et al., 2007).

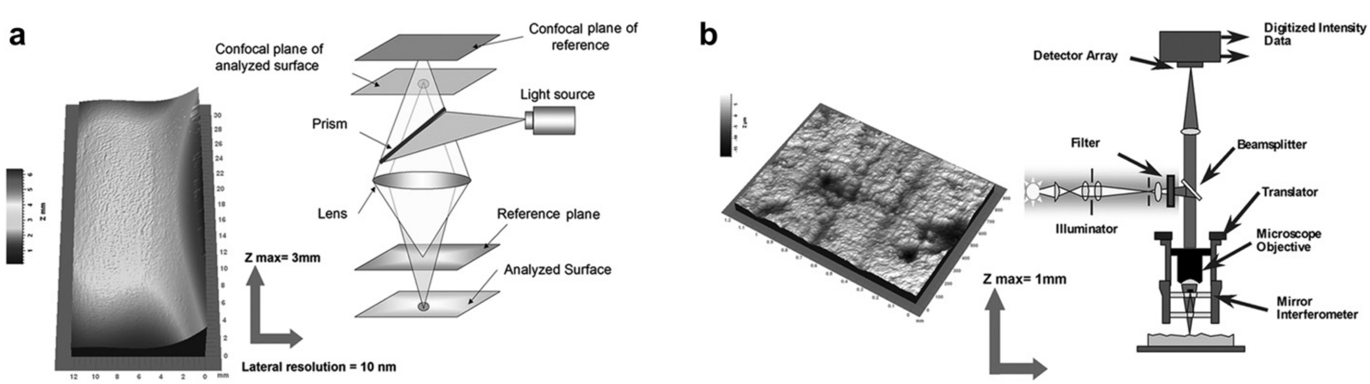


Fig. 4. Instruments used for optical observation at the (a) macro- and (b) micro-scales.

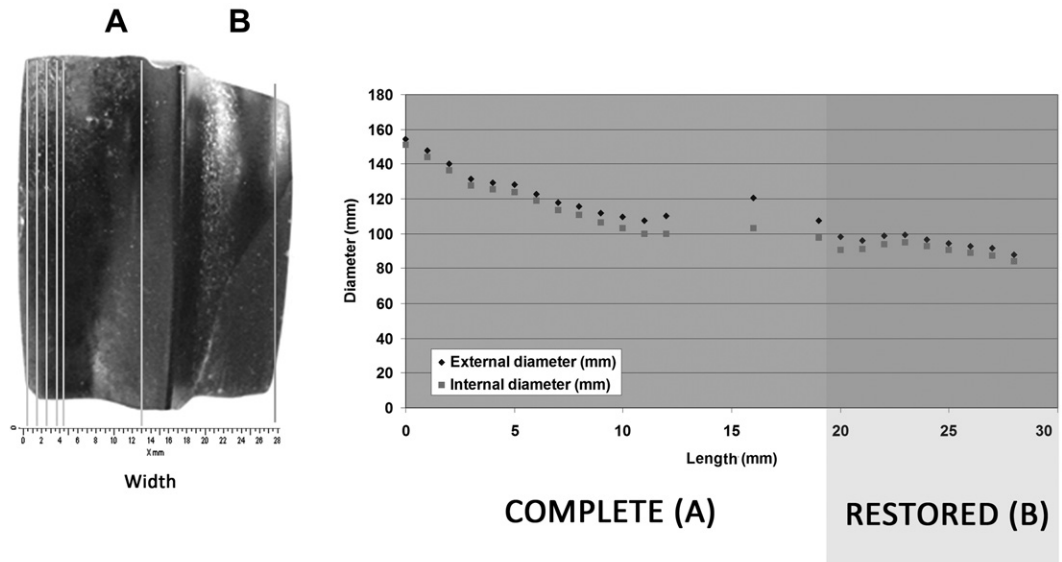


Fig. 5. Extraction of topographical profiles, evaluation of the degree of symmetry, and estimation of the internal and external diameters of the bracelet.

3.1. *Degree of symmetry of the bracelet*

The height of the circular arc of the bracelet was calculated by extracting topographical profiles along the external diameter of the object (Fig. 5). Measurements were taken every 1 mm within zone A and zone B. Values vary between 1.5 and 2.2 mm for the former zone and indicate that the control of the bracelet's symmetry during the manufacture was very high but not complete. The measurements within zone B show that the restoration did not respect the artifact's profile.

Transverse profiles show the same degree of symmetry control. The concavities formed on the slopes of the annular ridge have very similar angles ($a_1 = 125°$ and $a_2 = 124°$; Fig. 6), but the radius of curvature is 7.3 mm on zone A and 5 mm on zone B. This difference is significant when the transverse profiles are compared to reconstructed symmetrical profiles (Fig. 7a).

Asymmetry indicated by differences in the radius of curvature of the ridge slopes and the width of zones A and B is related to variations in surface state (Fig. 7b). The 2D images of areas of 8.5 × 4.5 mm, obtained with the interferometer, show, for zone A, a smooth, highly polished surface without peculiar defects and, for zone B, a comparatively rough surface with longitudinal striations. This difference is more clearly shown by the extracted profiles, very regular and with low amplitude in the first case, irregular and pitted in the second. To quantify the difference we used the parameter of Spa which is 0.67 μm for the smooth surface and 2.1 μm for the rough one (Fig. 7c). Spa, Porosity, and striation patterns allowed us to examine if different surface states correspond to different stages of manufacture.

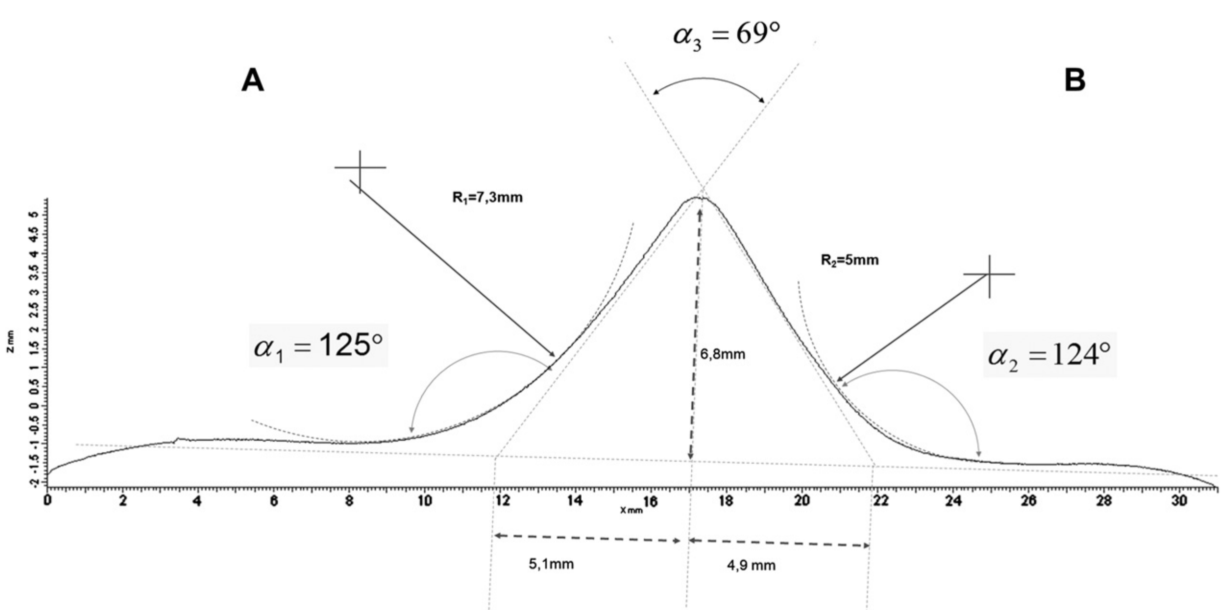


Fig. 6. Annular ridge: transverse profile and dimensions. The angle (a) and radius of curvature (R) of the concave slopes are indicated.

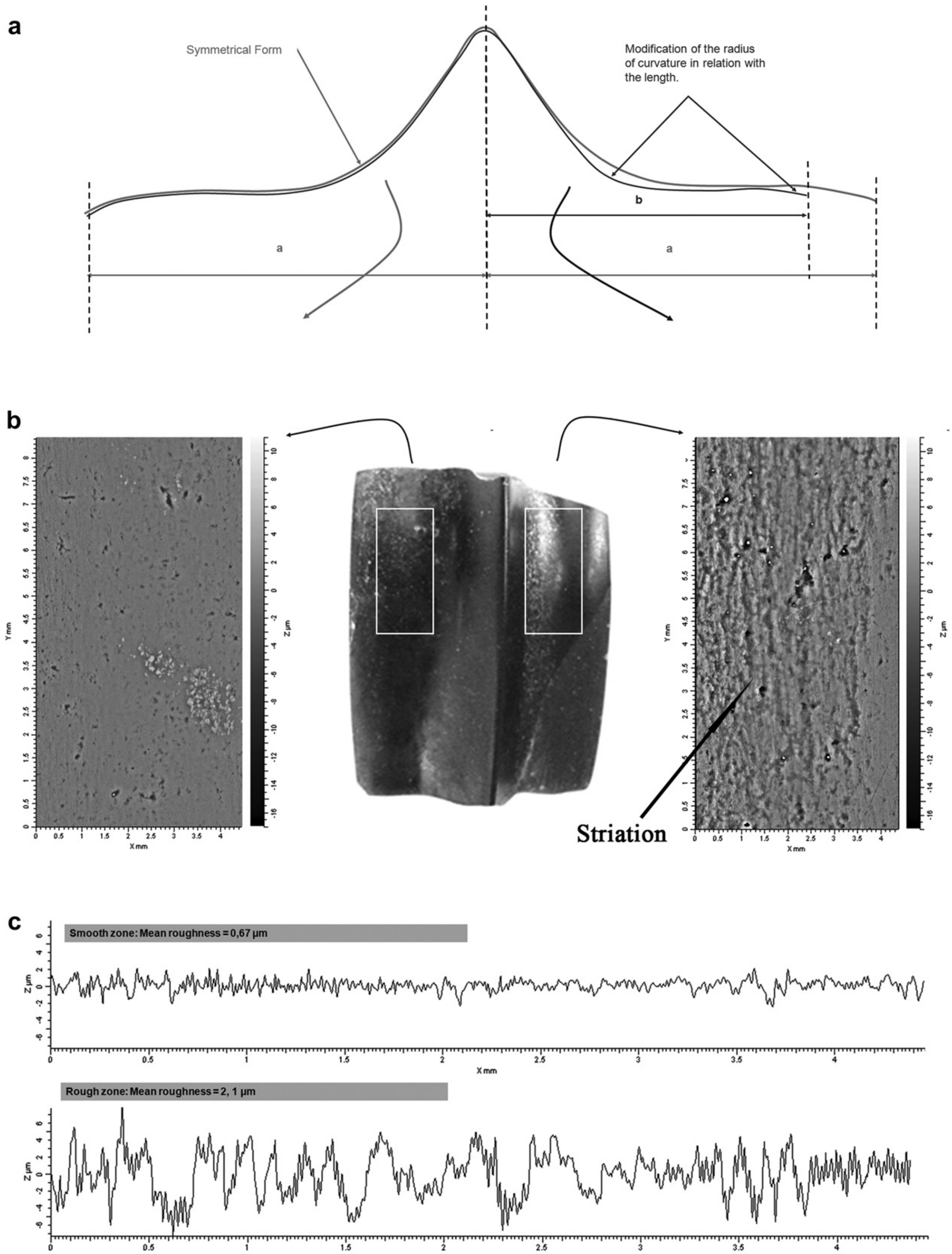
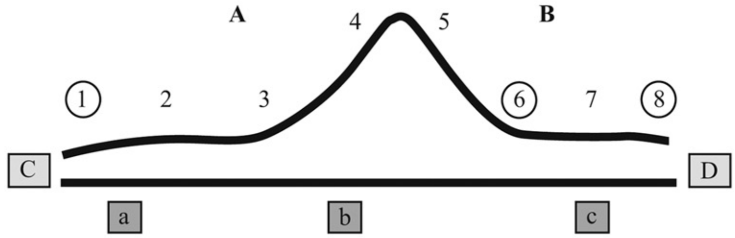


Fig. 7. Annular ridge: transverse profile and surface state.

Table 1
Porosity and Mean Roughness for 13 areas sampled on the external and internal surfaces and on the edges of the bracelet.



	6	a	1	8	D	3	b	C	4	c	2	5	7
Porosity (%)	23.20	22.50	15.90	9.18	6.90	6.66	5.70	4.80	4.48	4.10	3.37	1.12	0.20
Mean Roughness (in μm)	2.31	2.70	1.76	1.15	1.01	0.87	0.80	0.89	0.73	1.20	0.70	0.50	0.49

3.2. Comparative study of surface topographies

Eight areas of 900 × 900 μm (1–8; Table 1) were sampled for study on the outer side of the bracelet and three (a–c) on the internal.

3.2.1. Porosity and Spa

Wear features, Porosity, and Spa differentiate areas 1, 8, and 6 from areas 2–5 and 7 (Table 1; Figs. 8 and 9). Porosity on areas 1, 8, and 6 shows a greater number of depressions, identified as pecking marks used to roughout the bracelet. Spa demonstrates different amounts of polishing of the object's surface at the final stage of the production and permits to classify the sampled areas according to the degree of finishing, from the lowest to the highest, as follows: 6, 1, 8, 3, 4, 2, 5, and 7. Areas 5 and 7 within zone B show the highest degree of polishing and area 6 the lowest owing to the presence of a flaw produced in a previous stage of the work. The degree of polishing is low on the thinned areas 1 and 8 along the bracelet's edges and intermediate on the edges themselves, C and D, and the areas 3, 4, and 2 within zone A. On the inner side of the bracelet, area a shows increased porosity, comparable to that of area 6. Areas b and c present an intermediate degree of finishing, similar to that of areas 3, 4, and 2. The inner side of the ring exhibits a rather mat aspect as a result of post-depositional damage (see also section 2).

3.2.2. Striation patterns

All of the 3D images extracted exhibit polishing striations. In zones A and B, the striations have the same orientation. Striation orientation, depth, and width were observed using automatic detection of striations. This analysis provided information about the finishing of the bracelet, the external surface of which displayed parallel striations with specific orientations of 80–100° on zone A and 80° on zone B (Fig. 10). These orientations indicate very similar movements used for polishing. The lowest density of striations, which indicates thorough polishing, was observed on zone B (2.5%), specifically the areas with the lowest Spa, with the exception of area 6. Zone B shows the highest degree of polishing.

On the ridge, the depths and widths of the striations are similar but their orientation varies (Fig. 11). The angles measured for the slope of zone B fluctuate between 20° and 50°. On the opposite slope, they are 20–30° and 140°. These variations show that the craftsman employed different movements to finish curved forms. The tools and abrasives employed were the same.

The inner side of the bracelet was less polished. The orientation of the striations averages 70° and their widths and depths are generally greater than on the outer side. Such differences may reflect variations in the time of working, the grain size of the abrasive material, and the amount and type of lubricants used for polishing.

4. Identification of the manufacturing process

The nature and distribution of the wear marks indicate that three techniques were employed consecutively to shape and finish the bracelet. These techniques are: pecking, grinding, and polishing. Each technique is responsible for partial or complete obliteration of the marks produced by previous work. Therefore, it is

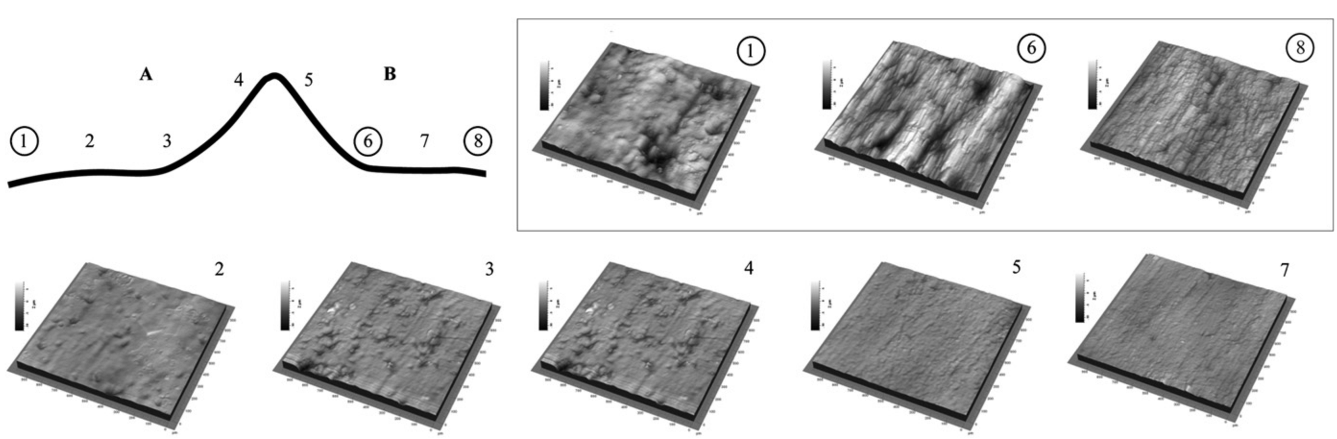


Fig. 8. 3D images of the areas sampled on the external surface of the bracelet. The less smoothed surfaces are shown at the upper right side of the figure.

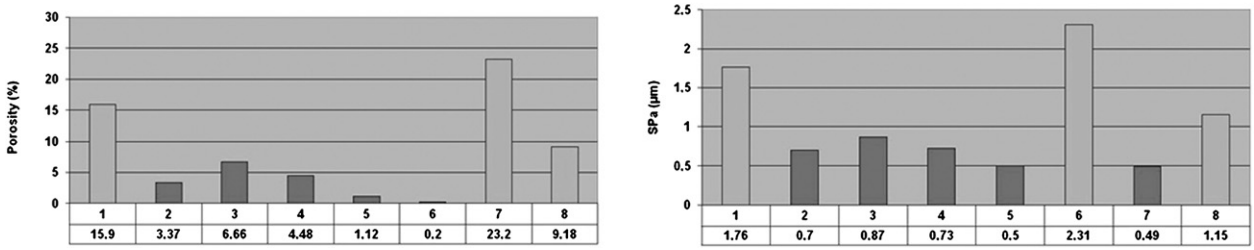
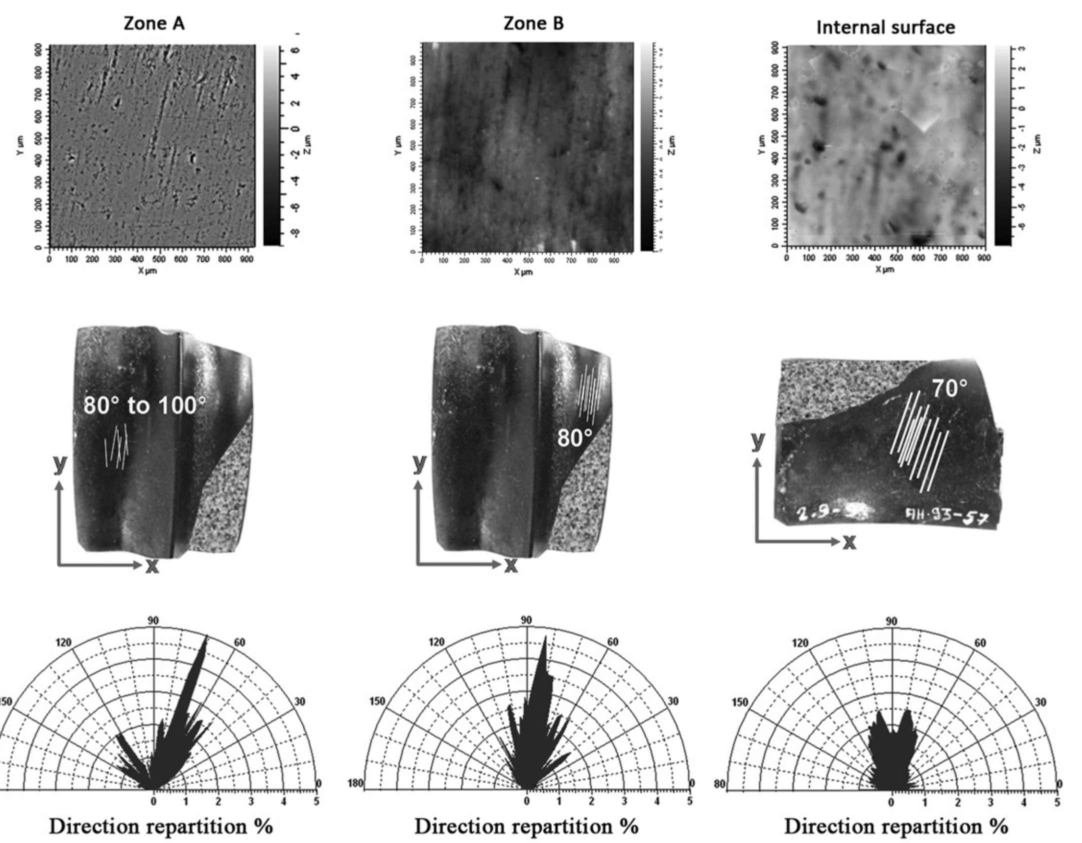


Fig. 9. Porosity and Mean Roughness for the areas sampled on the external surface of the bracelet.

possible that flaking was used prior to or in combination with pecking in order to obtain the volume of obsidian required to make the bracelet and that flake negatives were removed during pecking and grinding. Drilling was also perhaps used to make the hole of the bracelet. It must be noted, however, that perforation marks are not preserved on the bracelet and drilling is only known from Bronze Age sites, where it was employed to hollow vessels (Healey, 2000).

Pecking, identified on areas 6 and 1 (cf. Porosity; Fig. 8), was employed to shape the annular ridge. Pecking is a well-known stage of the production of mirrors and vessels in the 6th millennium cal. B.C. in Eastern Anatolia (Domuztepe; Healey, 2000), and of vessels in the Hittite period in Central Anatolia (Kültepe; personal observation, Kayseri Museum). Grinding was used after pecking. The abrasion marks are best preserved on area 6 which is rough (cf. Spa) with wide striations. Areas 1 and 8 were probably more intensively ground. Our data do not permit distinction between coarse and fine grinding (Vedder, 2005). Finally, the glossy surface of the bracelet (Fig. 8, all areas) was obtained by polishing: the surface became more homogeneous using finer abrasives. Areas 2, 3, 4, 5, and 7 indicate only slightly different degrees of finishing.

In sum, different tools and abrasives were used for grinding and polishing. Differences in striation patterns indicate different movements employed for polishing. The formation of concentric striations with consistent orientation and the profiles extracted point to use of mechanical devices for grinding and polishing. These data differentiate the Aşıklı Höyük bracelet from the Çatalhöyük mirrors (6520–6220 cal. B.C.; Cessford, 2001; Vedder, 2005). The manufacture of these objects involved flaking and "a relatively simple technology in a manner analogous to the production of contemporary ground-stone tools and other items" (Vedder, 2005: 597). The tools used to obtain the complex form of the Aşıklı Höyük bracelet indicate higher technical input. Experiments showed that approximately

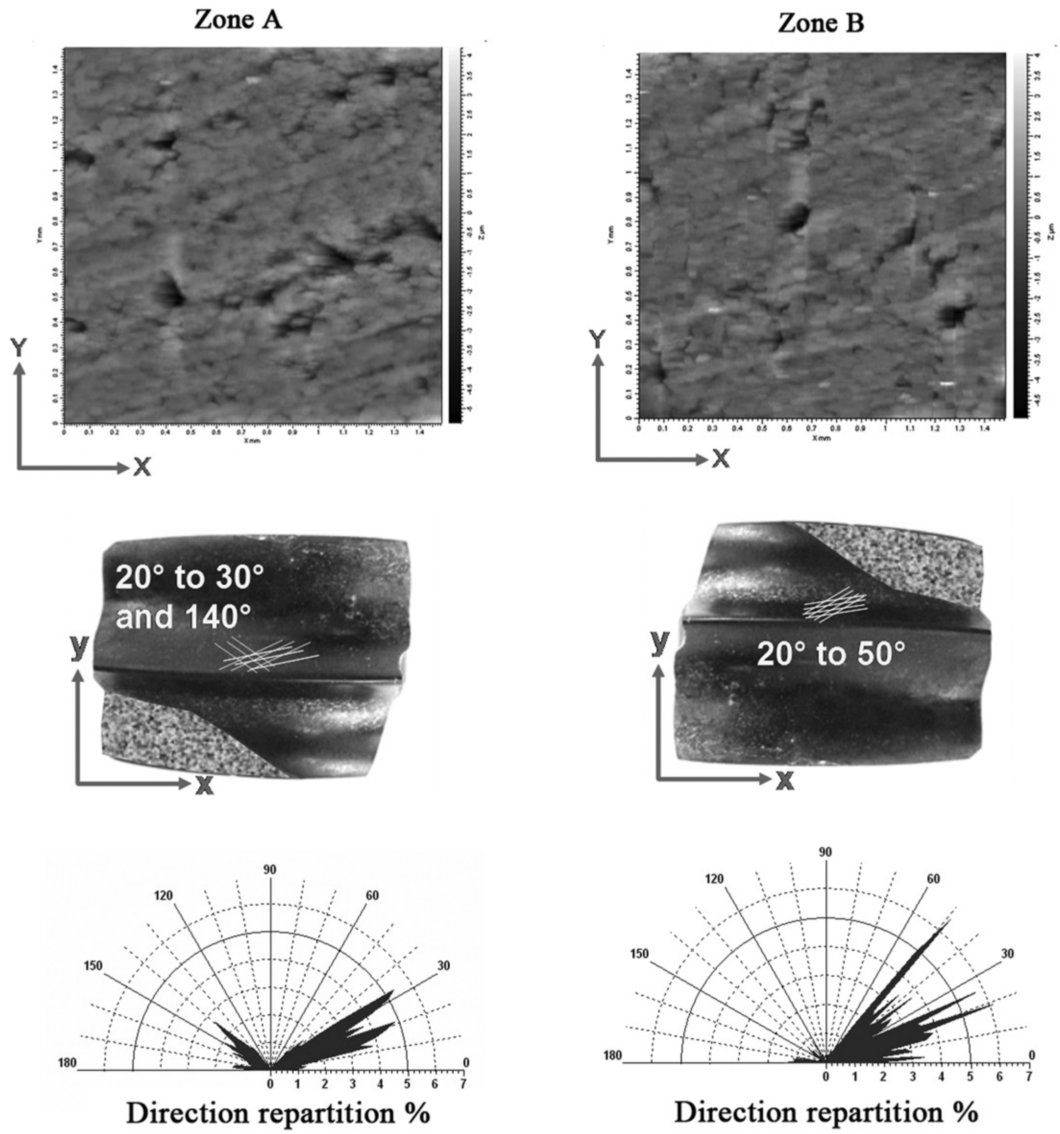


A	0 -> 2 µm	2 -> 4 µm	> 4 µm
Density (%)	91.91	7.68	0.41
Depth (µm)	0.69	2.58	4.8
Width (µm)	30.9	64	85.5

B	0 -> 2 µm	2 -> 4 µm	> 4 µm
Density (%)	100	0	0
Depth (µm)	0.49	0	0
Width (µm)	51.08	0	0

Internal surface	0 -> 2 µm	2 -> 4 µm	> 4 µm
Density (%)	78.48	18.83	2.69
Depth (µm)	1.09	2.56	5.78
Width (µm)	238	271	264

Fig. 10. Automatic detection of striations on three areas of the bracelet. The mean depths and widths calculated for three classes of depths are indicated.



A	0 -> 2 µm	2 -> 4 µm	> 4 µm
Density (%)	**87.69**	**11.46**	**0.85**
Depth (µm)	**1.02**	**3.17**	**4.23**
Width (µm)	**75.70**	**88.30**	**82.30**

B	0 -> 2 µm	2 -> 4 µm	> 4 µm
Density (%)	**94.31**	**5.69**	**0**
Depth (µm)	**1.01**	**2.66**	**0**
Width (µm)	**84.36**	**113.16**	**0**

Fig. 11. Automatic detection of striations on the slopes of the annular ridge. The mean depths and widths calculated for three classes of depths are indicated.

7 h of work were required to obtain a good mirror surface. The time spent in the shaping of the bracelet is not as yet estimated.

5. Discussion

Our study produced evidence for skilled work of the obsidian bracelet from Aşıklı Höyük. This evidence is:

- The choice of high quality obsidian
- The use of different movements and abrasive materials for making the bracelet
- The creation of a complex form and the control of symmetry during the shaping
- The near absence of manufacturing errors and the ability to deal with defects

The artisan could maintain a constant angle while pecking and grinding and control the radius of curvature on the slopes of the ridge despite width differences between zones A and B and the flaw on zone B. The use of mechanical devices for grinding and polishing is also anticipated and experimentation can help identify the tools and abrasives employed. These results are consistent with the idea that the bracelet was not produced by a novice but an experienced artisan and cannot therefore be an isolated product. Intra- and inter-site comparisons of stone ornaments and other artifacts sites provide a basis for research into the variability and development of the stone-working techniques. Moreover, differences in the raw materials, morphology, and manufacturing techniques of the ornaments embody behavioral and cultural variability and manufacturing processes connected to distribution and consumption patterns allow the archaeologists to comprehend social relations and interaction (e.g., Alarashi, Chambrade, 2010). At Aşıklı Höyük, the raw materials, shapes, and uses of the beads indicate diversity in ornament production. Apart from local limestone and volcanic rocks of different colors and hardnesses, beads were also sometimes made from native copper, marine shell, and deer teeth (Esin, 1995). Evidence for skilled work is scarce. Ten beads made from cornelian (a material harder than obsidian) and found in a burial show high technical input in manufacture. It is unlikely that these beads are local products, since there are no cornelian sources in Central Anatolia. They are highly polished and bear a carefully drilled bi-conical perforation made with a mechanical device. The technical input is in this case more important than for the cornelian disk beads from the 6th millennium cal. B.C. Kumartepe workshop in Eastern Anatolia, which present conical perforations made using mechanical drilling and indirect percussion with *tamponoir* (Calley and Grace, 1988). The morphology and perforations of some of the Aşıklı Höyük cornelian beads resemble those of the yellowish chalcedony bead found together with a copper lunula pendant in burial 4 J-E32 at Tell Halula in the Middle Euphrates valley, dated at about 7500 cal. B.C. (Molist et al., 2009: Fig. 4). Both Tell Halula and Aşıklı Höyük produced evidence of use of metal ornaments and acquisition through exchange of high quality stone beads in the 8th millennium cal. B.C. These objects were found in burials. As was noted above, the form and depositional context of the Aşıklı Höyük bracelet are unique for the site. Although the bracelet cannot be associated with specific finds in Building T, the communal character of the structure let us hypothesize that this personal ornament was used to represent the user's special status or role.

Several different stone artifacts also show acquired technical know-how and skilled production in Anatolia during the period under examination. These artifacts are considered to be markers of individual identities and differentiate Central from Eastern Anatolia. They include the highly standardized obsidian blades produced from naviform cores on the Kaletepe-Kömürcü workshop, dated at 8290–7960 cal. B.C. (Balkan-Atlı and Binder, 2001; Binder, 2002); the projectile points of Central Anatolia, which bear sometimes marks of hunters or knappers, dated to the 8th-7th millennia cal. B.C. (Ataman, 1988; Balkan-Atlı et al., 1999, 2008, 2009; Carter, 2000); and the large blades produced by pressure with lever and dated in Eastern Anatolia as early as 8500 cal. B.C. and in High Mesopotamia in the 7th millennium (Altınbilek et al., in press; Astruc, 2011; Binder, 2007). Identity markers are also the 7th millennium cal. B.C. mirrors of Çatalhöyük and the 6th millennium cal. B.C. vessels, links, and pendants of the Halafian Culture of Domuztepe and Tell Arpachiyah (Healey, 2000). Evidence about the manufacture and distribution of stone bracelets is scant. Fragments of obsidian bracelets have been found in the Pottery Neolithic levels at Çayonü Tepesi in the High Valleys (Aslı Erim-Özdoğan, personal communication 6/06/2011) but have not been analyzed. Stone bracelets with complex forms were analyzed from the 7th millennium cal. B.C. contexts at Cafer Höyük (Maréchal, 1985). The analysis showed that complex morphologies are culture-specific. The Aşıklı Höyük bracelet may then come from Eastern Anatolia.

6. Conclusions

Multi-scale analysis of wear variations on the obsidian bracelet from Aşıklı Höyük revealed a complex manufacturing method. The bracelet's symmetry, the movements executed during the manufacture, as well as the probable use of mechanical devices for grinding and polishing open the possibility to discuss the production of this artifact in relation to technological specialization in Anatolia during the early Neolithic. The form and anticipated sources of the raw material of the Aşıklı Höyük bracelet point to long distance trade. Aşıklı Höyük is one of the few excavated sites for the 9th-8th millennia cal. B.C. in Central Anatolia and the most extensively investigated one. Continuation of scientific work on the stone artifacts from various sites in Anatolia is necessary in order to discover patterns of production and distribution. In particular, comparisons with other sites can help identify different forms of social differentiation in Central and Eastern Anatolia during the Neolithic (Hodder, 2006: 179).

Acknowledgements

This work is part of the ANR-08-BLAN-0318 program "Obsidiennes, Pratiques techniques et sociales en Anatolie" (France), directed by L. Astruc. The program is collaboration between IFEA and ECL (France) and Istanbul University (Turkey). L. Astruc and R. Vargiolu's work at Aşıklı Höyük in 2009-10 was partly supported by the Istanbul University Research Fund (project no 3343, 6647). L. Astruc, R. Vargiolu, M. Ben Tkaya, and H. Zahouani thank N. Balkan-Atlı and M. Özbaşaran for invitation to study the obsidian bracelet from Aşıklı Höyük. Thanks also to the Department of Cultural Assets and Museums of the Ministry of Tourism and Culture of Turkey and to the Director of the Archaeological Museum of Aksaray for permission to study the object. We appreciate the comments and suggestions of R. Christidou on an earlier draft of the manuscript.

References

Abbès, F., Balkan Atlı, N., Binder, D., Cauvin, M.-C., 1999. Etude technologique préliminaire de l'industrie lithique d'Aşıklı Höyük. TÜBA-AR 2, 117–137.

Alarashi, H., Chambrade, M.-L., 2010. Outils géographiques appliqués à l'étude de la provenance des matériaux utilisés pour la parure néolithique: l'exemple du site de Mureybet. In: Alarashi, H., Chambrade, M.-L., Gondet, S., Jouvenel, A., Sauvage, C., Tronchère, H. (Eds.), Regards croisés sur l'étude archéologique des paysages anciens. Nouvelles recherches dans le bassin méditerranéen, en Asie centrale et au Proche et au Moyen-Orient. Travaux de la Maison de l'Orient et de la Méditerranée 56, Lyon, pp. 95–106.

Altınbilek, C., Astruc, L., Binder, D., Pelegrin, J. Pressure blade production with a lever in the early and late Neolithic of the Near East, in: Desrosiers, P.M. (Ed.), The emergence of pressure blade making: from origin to modern experimentation. Springer, New York, in press.

Anderson, P., Astruc, L., Vargiolu, R., Zahouani, H., 1998. Contribution of quantitative analysis of surface states to a multi-method approach for characterising plant-processing traces on flint tools with gloss. In: Antoniazzi, A., Arsuaga Ferreres, J.L., Bermudez De Castro, J.M., Carbonell I Roura, E., Cavallini, E., Fontana, F., Gutiérrez Sàez, C., di Lernia, S., Longo, L., Manzi, G., Milliken, S., Oosterbeek, L., Pavukova, V., Peresani, M., Peretto, C., Pesce Delfino, V., Pizchelauri, K., Prati, L., Sala I Ramos, R. (Eds.), Proceedings of the XIIIth Congress of the International Union of Prehistoric and Protohistoric Sciences, vol. 6.2. ABACO, Forli, pp. 1151–1160.

Anderson, P.C., Georges, J.M., Vargiolu, R., Zahouani, H., 2006. Insights from a tribological analysis of the tribulum. Journal of Archaeological Science 33 (11), 1559–1568.

Astruc, L., 2011. A note on the complexity of lithic assemblages, in: Healey, E., Campbell, S., Maeda, O. (Eds.), The state of the stone: terminologies, continuities and contexts in Near Eastern lithics, The proceedings of the sixth PPN conference on chipped and ground stone artefacts in the Near East, Manchester, 3-5 March 2008, with papers from the fourth international workshop on chipped lithic industries, Niğde, Cappadocia, Turkey, 4-8 June 2001 (coordinated by Nur Balkan-Atlı). SENEPSE 13, Ex Oriente, Berlin, pp. 257–264.

Astruc, L., Vargiolu, R., 2004. La tribologie, Dossiers de l'Archéologie 290 (février).

Astruc, L., Jautée, E., Vargiolu, R., Zahouani, H., 2001. La texture des matières siliceuses et son influence sur la nature et le développement des traces d'usure: apports des méthodes expérimentales. L'exemple des cherts de la formation de Lefkara (Chypre). In: Bourguignon, L., Ortega, I., Frère-Sautot, M.-Ch (Eds.), Préhistoire et approche expérimentale. Editions Monique Mergoil, Montagnac, pp. 205–224.

Astruc, L., Le Brun, A., Vargiolu, R., Zahouani, H., 2002. La pierre dans tous ses états: les multiples aspects de l'artisanat de la pierre à Chypre au Néolithique précéramique. Archéologia 388, 54–65.

Astruc, L., Vargiolu, R., Zahouani, H., 2003. Wear assessments of prehistoric instruments. Wear 255, 341–347.

Ataman, K.A., 1988. The chipped stone assemblage from Can Hasan III: a study in typology, technology and function. Unpublished Ph.D. dissertation, Institute of Archaeology, University College, London.

Balcı, S., 2010. Obsidian-source-technology-settlement relations: Aşıklı Höyük (Central Anatolia) case, in: Matthiae, P., Pinnock, F., Nigro, L., Marchetti, N. (Eds. with the collaboration of Romano, L.), Proceedings of the 6th international congress on the archaeology of the ancient Near East, Università di Roma "La Sapienza", 5–10 May 2009, vol. 3, Islamic session, poster session. Harrassowitz Verlag, Wiesbaden, pp. 3–23.

Balkan-Atlı, N., 1994. The typological characteristics of the Aşıklı Höyük chipped stone industry. In: Gebel, H.G., Kozlowski, S.K. (Eds.), Neolithic chipped stone industries of the Fertile Crescent, Proceedings of the first workshop on PPN chipped lithic industries, Berlin, 1993, pp. 209–221.

Balkan-Atlı, N., Binder, D., 2001. Les ateliers de taille d'obsidienne: fouilles de Kömürcü-Kaletepe 2000. Anatolia Antiqua/Eski Anadolu 9, 193–205.

Balkan-Atlı, N., Binder, D., Cauvin, M.-C., 1999. Obsidian: trade, sources and workshops in Central Anatolia. In: Özdoğan, M., Başgelen, N. (Eds.), Neolithic in Turkey. The cradle of civilization. Arkeoloji ve Sanat Yayınları, Istanbul, pp. 133–146.

Balkan-Atlı, N., Kuhn, S., Astruc, L., Çakan, D., Dinçer, B., Kayacan, N., 2008. Göllü Dağ 2007 survey. Anatolia Antiqua/Eski Anadolu 16, 293–312.

Balkan-Atlı, N., Kuhn, S., Astruc, L., Kayacan, N., Çakan, G., Dinçer, B., 2009. Gollü Dağ 2008 survey. Anatolia Antiqua/Eski Anadolu 17, 293–312.

Binder, D., 2002. Stones making sense: what obsidian could tell about the origins of Central Anatolian Neolithic. In: Gérard, F., Thissen, L. (Eds.), The Neolithic of Central Anatolia. Ege Yayınları, Istanbul, pp. 79–90.

Binder, D., 2007. PPN pressure technology: views from Anatolia. In: Astruc, L., Binder, D., Briois, F. (Eds.), Les communautés du Néolithique précéramique d'Eurasie: de l'analyse de la diversité des systèmes techniques à la caractérisation des comportements sociaux, Actes du 5ème colloque international sur les industries lithiques proches-orientales, Fréjus, 29 février-5 mars 2004. APDCA, Antibes, pp. 235–243.

Buitenhuis, H., 1997. Aşıklı Höyük: a protodomestication site. Anthropozoologica 25–26, 655–662.

Calley, S., Grace, R., 1988. Technology and function of micro-borers from Kumartepe (Turkey). In: Beyries, S. (Ed.), Industries lithiques, tracéologie et technologie. Aspects archéologiques. British Archaeological Reports, International Series 411(1), Oxford, vol. 1, pp. 69–81.

Carter, T., (with contributions by Spasojevic, A., Underbjerg, H.), 2000. Chipped stone/Işlenmiş taş, in: Çatalhöyük 2000 archive report. http://www.catalhoyuk.com/archive_reports/2000/ar00_08.html (accessed 04 25 2011).

Carter, T., Dubernet, S., King, R., Le Bourdonnec, F.-X., Mili·, M., Poupeau, G., Shackley, M.S., 2008. Eastern Anatolian obsidians at Çatalhöyük and the reconfiguration of regional interaction in the early Ceramic Neolithic. Antiquity 82 (318), 900–909.

Cauvin, M.-C., Gourgaud, A., Gratuze, B., Poidevin, J.L., Poupeau, G., Chataignier, C. (Eds.), 1998. L'obsidienne au Proche et Moyen Orient: du volcan à l'outil. British Archaeological Reports International Series 738, Oxford.

Cessford, C., 2001. A new dating sequence for Çatalhöyük. Antiquity 75 (290), 717–725.

D'Errico, F., Roux, V., Dumont, Y., 2000. Identification des techniques de finition des perles en roches dures par l'analyse microscopique et rugosimétrique. In: Roux, V. (Ed.), Les perles de Cambay. Des pratiques techniques aux technosystèmes de l'Orient ancien. Editions de la Maison des Sciences de l'Homme, Paris, pp. 97–169.

Esin, U., 1995. Early copper metallurgy at the pre-pottery site of Aşıklı. In: Readings in prehistory. Studies presented to Halet Çambel. Graphis Yayınları, Istanbul, pp. 61–77.

Esin, U., Harmankaya, S., 1999. Aşıklı. In: Özdoğan, M., Başgelen, N. (Eds.), Neolithic in Turkey. The cradle of civilization. Arkeoloji ve Sanat Yayınları, Istanbul, pp. 115–132.

Esin, U., Harmankaya, S., 2007. Aşıklı Höyük. In: Özdoğan, M., Başgelen, N. (Eds.), Türkiye'de Neolitik Dönem. Arkeoloji ve Sanat Yayınları, Istanbul, pp. 255–272.

Esin, U., Bıçakçı, E., Özbaşaran, M., Balkan Atlı, N., Berker, D., Yağmur, I., Atlı, A.K., 1991. Salvage excavations at the pre-pottery site of Aşıklı Höyük in Central Anatolia. Anatolica 17, 124–174.

Gassin, B., 1996. Evolution socio-économique dans le Chasséen de la grotte de l'Eglise supérieure (Var). Apport de l'analyse fonctionnelle des industries lithiques. Monographie du CRA 17. CNRS Editions, Paris.

Georges, J.M., 2000. Frottement, usure et lubrification. CNRS Editions, Paris.

Healey, E., 2000. The role of obsidian in the late Halaf. Unpublished Ph.D. dissertation, University of Manchester.

Healey, E., 2007. Obsidian as an indicator of inter-regional contacts and exchange: three case-studies from the Halaf period, Anatolian Studies 57, Transanatolia: Bridging the gap between East and West in the archaeology of ancient Anatolia 171–189.

Hodder, I., 2006. The leopard's tale. Revealing the mysteries of Çatalhöyük. Thames and Hudson Ltd., London.

Keeley, L.H., 1980. Experimental determination of stone tool uses: a microwear analysis. University of Chicago Press, Chicago.

Maréchal, C., 1985. Les bracelets néolithiques en pierre de Cafer Höyük (Turquie). Cahiers de l'Euphrate 4, 109–115.

Molist, M., Montero-Ruiz, I., Clop, X., Rovira, S., Guerrero, E., Anfruns, J., 2009. New metallurgic findings from the pre-pottery Neolithic: Tell Halula (Euphrates valley, Syria). Paléorient 35 (2), 33–48.

Morero, E., Procopiou, H., Vargiolu, R., Zahouani, H., 2008. Stone vase drilling in Bronze Age Crete. British Archaeological Reports, International Series 1783, Oxford. In: Longo, L., Skakun, N. (Eds.), "Prehistoric Technology" 40 years later: functional studies and the Russian legacy, Proceedings of the international congress, Verona (Italy), 20-23 April 2005, pp. 479–482.

Plisson, H., Gijn van, A.L., 1989. La tracéologie, mode d'emploi. L'Anthropologie 93 (3), 631–642.

Procopiou, H., Jautée, E., Vargiolu, R., Zahouani, H., 1998. Petrographic and use wear analysis of a quern of Syvritos Kephala. In: Antoniazzi, A., Arsuaga Ferreres, J.L., Bermudez De Castro, J.M., Carbonell I Roura, E., Cavallini, E., Fontana, F., Gutiérrez Sàez, C., di Lernia, S., Longo, L., Manzi, G., Milliken, S., Oosterbeek, L., Pavukova, V., Peresani, M., Peretto, C., Pesce Delfino, V., Pizchelauri, K., Prati, L., Sala I Ramos, R. (Eds.), Proceedings of the XIIIth Congress of the International Union of Prehistoric and Protohistoric Sciences, vol. 6.2. ABACO, Forli, pp. 1183–1192.

Renfrew, C., Dixon, J.E., Cann, J.R., 1966. Obsidian and early cultural contact in the Near East. Proceedings of the Prehistoric Society 32, 30–72.

Stout, K.J., Sullivan, P.J., Dong, W.P., Mainsah, E., Luo, N., Mathia, T.G., Zahouani, H., 1993. The development of methods for the characterisation of roughness in three dimensions. Commission of the European Communities, Brussels (ISBS 7044 13132).

Todd, I.A., 1966. Aşıklı Hüyük: a protoneolithic site in central Anatolia. Anatolian Studies 16, 139–163.

Vargiolu, R., Morero, E., Boleti, A., Procopiou, H., Pailler-Mattei, C., Zahouani, H., 2007. Effects of abrasion during stone vase drilling in Bronze Age Crete. Wear 263 (1–6), 48–56.

Vedder, J.F., with a contribution by Swogger, J.G., 2005. The obsidian mirrors at Çatalhöyük. In: Hodder, I. (Ed.), Changing materialities at Çatalhöyük: reports from the 1995–99 seasons. McDonald Institute for Archaeological Research, Cambridge, pp. 597–619.

Yıldırım-Balcı, S., 2007. Orta Anadolu obsidyen teknolojisi: Aşıklı Höyük modeli, tekno-kültürel kökeni ve evrimi. Yayımlanmamış Doktora Tezi, İstanbul Üniversitesi Sosyal Bilimler Enstitüsü.

Zahouani, H., 1998. Spectral and 3D motifs identification of anisotropic topographical components. Analysis and filtering of anisotropic patterns by morphological rose approach. International Journal of Machine Tools and Manufacture 38 (5–6), 615–623.

Zahouani, H., Lee, S.-H., Vargiolu, R., Mathia, T.G., 1999. The multi-scale mathematical microscopy of surface roughness. Incidence in Tribology. In: Dowson, D., Priest, M., Taylor, C.M., Ehret, P., Childs, T.H.C., Dalmaz, G., Berthier, Y., Flamand, L., Georges, J.M., Lubrecht, A.A. (Eds.), Lubrication at the frontier: the role of the interface and surface layers in the thin film and boundary regime, Proceedings of the 25th Leeds-Lyon symposium on tribology, Institut national des sciences appliquées, Lyon, 8-11 September 1998. Tribology Series 36. Elsevier Science B.V., The Netherlands, pp. 379–390.

Zeist van, W., Jan de Roller, G., 1995. Plant remains from Aşıklı Höyük, a pre-pottery Neolithic site in central Anatolia. Vegetation History and Archaeobotany 4, 179–185.

Zeist van, W., Jan de Roller, G., 2003. Some notes on the plant husbandry of Aşıklı Höyük. In: Zeist van, W. (Ed.), Reports on archaeobotanical studies in the Old World, Barkhuis, Gröningen, pp. 115–142.