BEADMAKING IN IRAN IN THE EARLY BRONZE AGE

Derived by Scanning Electron Microscopy

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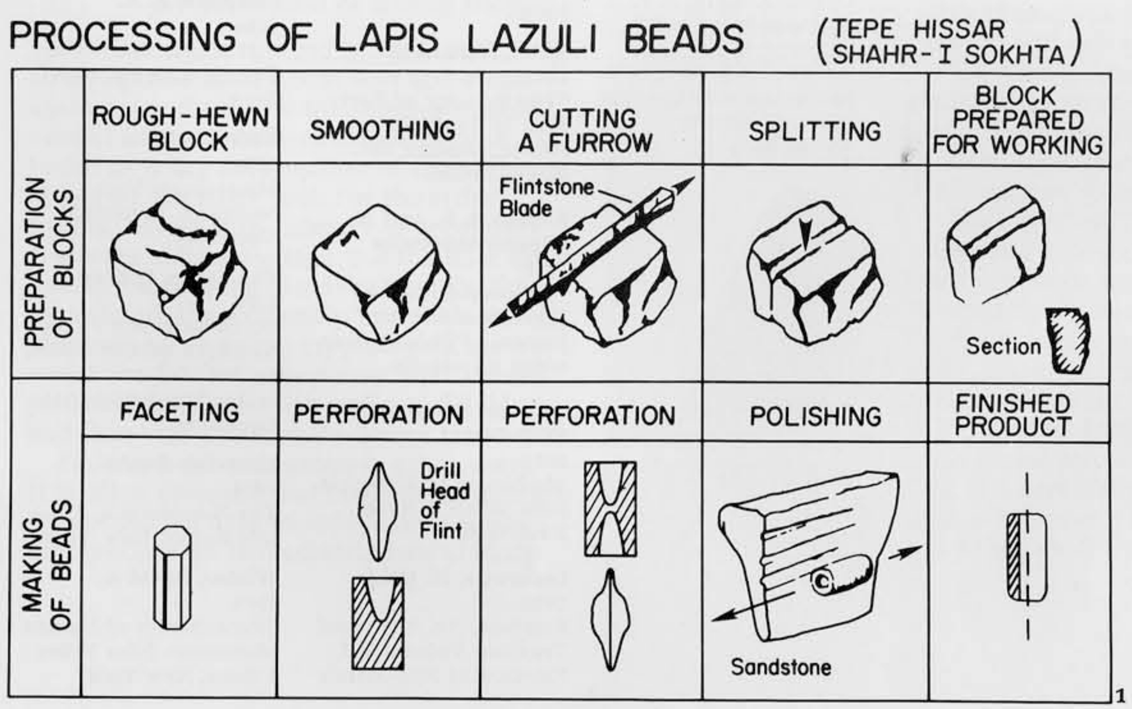
INTRODUCTION

The techniques used to manufacture the ubiquitous bead occupy a significant place in the development of lapidary technology. Fashioned from rough stone whose hardness ranged predominantly from 1 to 7 on the Mohs scale, beads are believed to have been made by chipping, splitting, sawing, facetting, rounding and polishing into a variety of sizes and shapes. The process also included the drilling of a hole for mounting and it is not uncommon to find holes less than 0.5 mm. in diameter. While modern lapidary techniques have significantly improved the rate of bead production, there still remain workshops making beads in a style and manner held constant over the centuries.

The makers of drilled objects, such as beads and seals, probably shared in a similar technology of the time with each benefitting from new innovations. While many speculate on the method of manufacture of beads and seals, few have attempted to reconstruct the stages and methods involved by critically examining artifacts and tools likely used in their fabrication. The paucity of information relates, at least in part, to the lack of recovering tools at sites where beads and seals were manufactured. Tosi and Piperno (1973) in writing of their findings at Shahr-i Sokhta have addressed the question of technological specialization and lithic technology behind the lapis lazuli trade in the 3rd millennium B.C. From the microscopic examination of beads and liths recovered from Shahr-i Sokhta and Tepe Hissar they reconstructed a possible sequence of stages in the manufacture of beads from stones with Mohs values ranging from 1 to 7. Their finding of traces of lapis on microliths led them to conclude that these were used to drill lapis beads. Figs. 1 and 2 show a reconstruction (based on translation of Tosi's work) which shows the stages in processing lapis lazuli (Mohs 5) and chalcedony (Mohs 7) beads.

Several questions remain from Tosi's findings and description. For example, (1) was the use of drilling continuous or discontinuous? (2) was an abrasive used? (3) what was the nature of the drills? In an attempt to shed more light on the process of early bead manufacture we embarked upon a study of beads from Shahr-i Sokhta and Tepe Hissar provided through the generous cooperation of Tosi. Our methods of examination involved the use of scanning electron microscopy and experimentation and form a part of our continuing effort to develop a history of ancient lapidary technology. A description of the scanning electron microscope and its advantages together with our methods of examination have been published previously in *Expedition* (Winter 1978).



1, 2
Translated from Tosi, these diagrams show his reconstruction of the stages in bead manufacture from lapis lazuli and chalcedony.

ARTIFACT SAMPLE

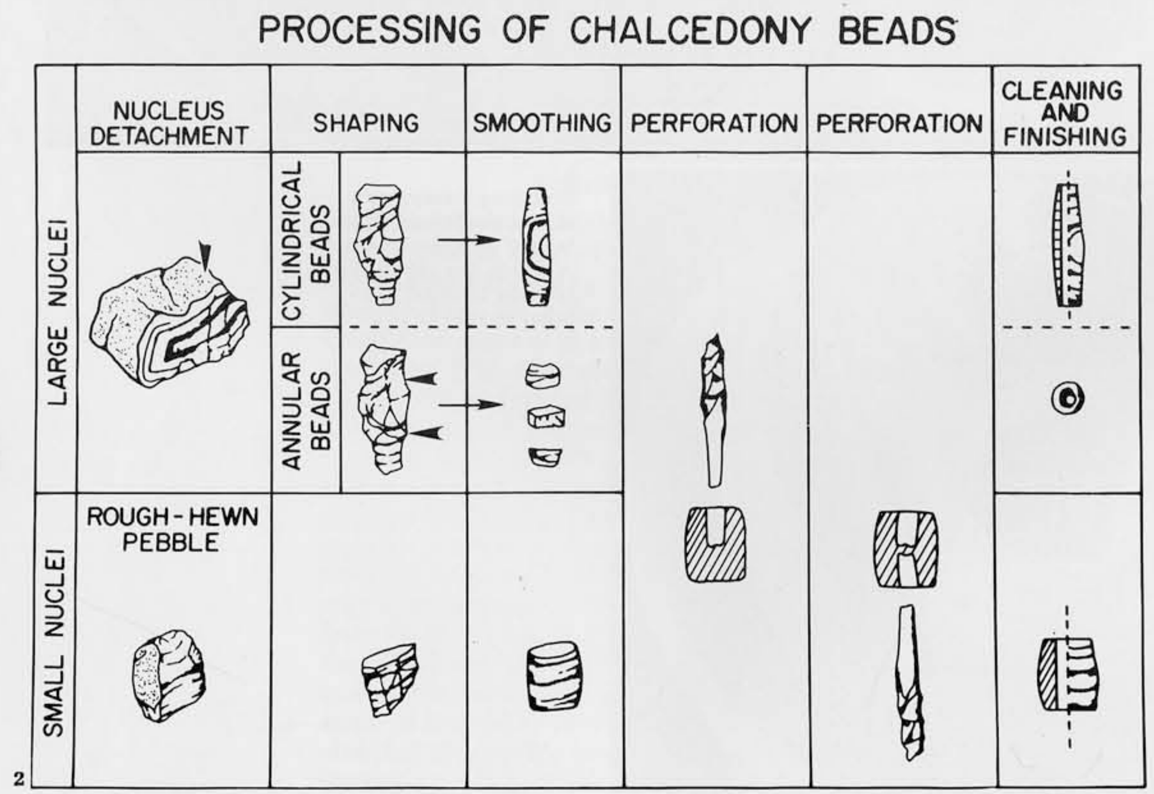
Forty-nine beads in various stages of preparation and twenty-two liths dated *ca.* 2800-2200 B.C. were available from Shahr-i Sokhta with an additional fifteen beads and five liths from Tepe Hissar, also of the same dating. The artifacts were photographed and models were made of them for examination in the scanning electron microscope (SEM). We chose to classify the beads into three broad groups according to their hardness. Fig. 3 shows the classification and the numbers of beads available for study with respect to composition.

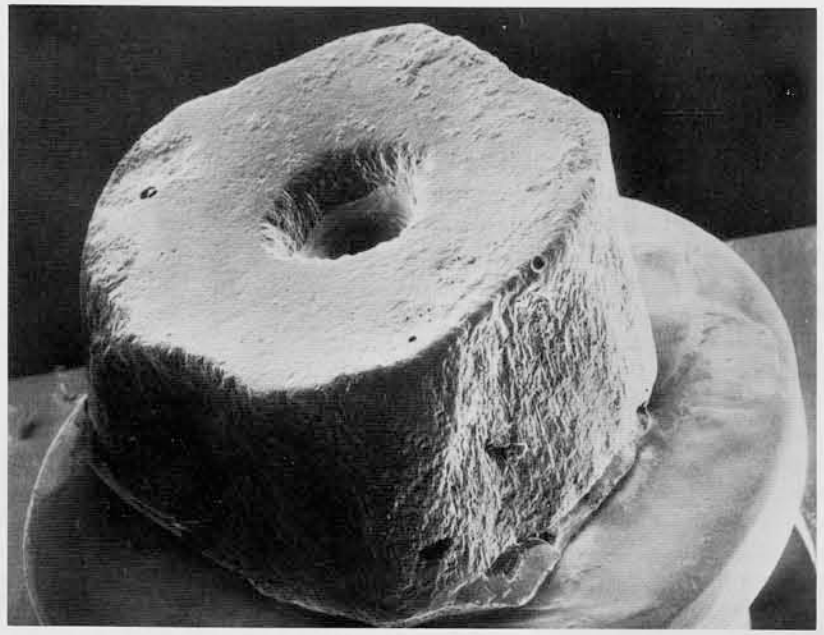
BEAD COMPOSITION

SOFT MOHS 1-3		MEDIUM MOHS 4-6		HARD MOHS 7-10	
Alabaster	(7)	Aragonite	(2)	Carnelian	(3)
Limestone	(17)	Lapis	(9)	Chalcedony	(11)
Sherds	(2)	Turquoise	(9)	Jasper	(4)
Steatite	(1)	Breccia	(1)	Rock Crystal	(1)

Parenthesis indicates number available in sample

3
Tables show classification of bead sample according to Mohs hardness and the numbers of beads available with respect to substrate. Quartz, with a Mohs value of 7, was the hardest bead found.



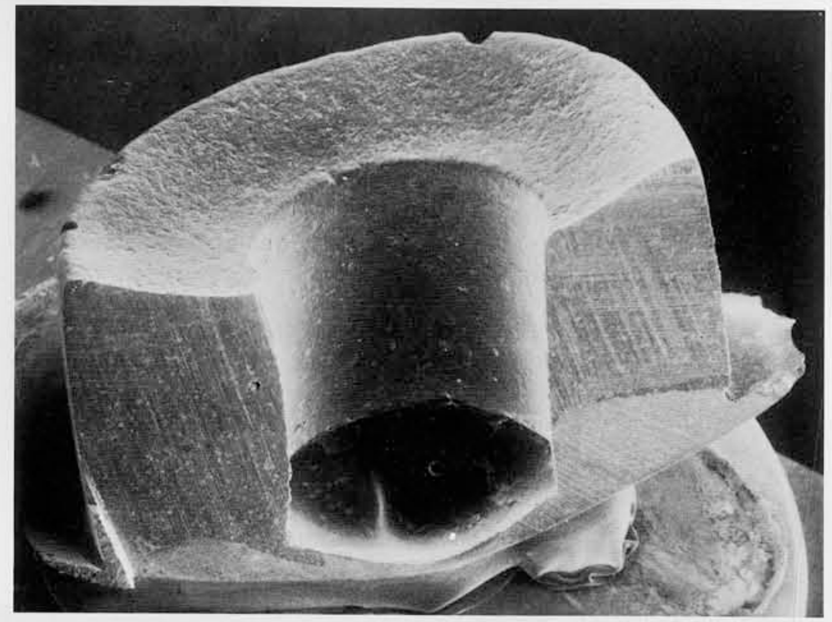


4
Scanning micrographs of an early stage in soft stone bead manufacture in which the bead is irregularly polygonal. Note that perforation has been done at this early stage, (x 11).

5
Scanning micrograph of a finished, annular bead. The outer surface is relatively smooth and free of scratch marks. Some pitting is present, (x 11).

6
Scanning micrograph shows the irregular surface of an annular bead in which the perforation is of an unusual bilobular shape, (x 12).

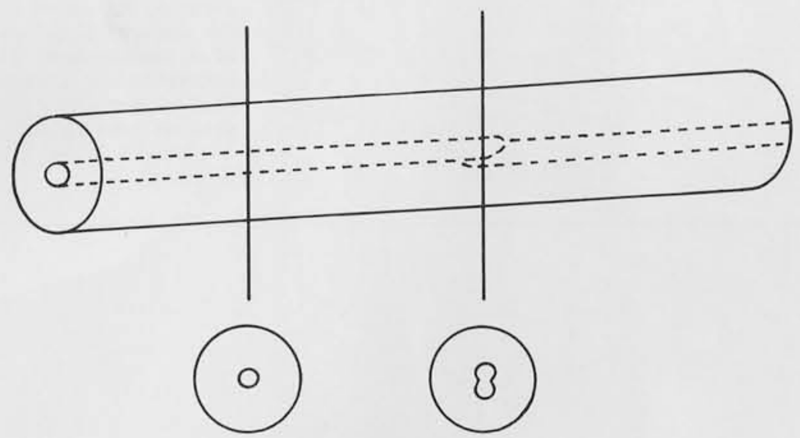
7
Scanning micrograph shows the presence of abrasion anomalies on the perforated surface of an annular bead. The anomalies are relatively shallow, parallel grooves running predominantly in one direction.



8
Scanning micrograph showing a concave appearance to the surface surrounding the bead perforation. The reason for such a shape is unclear except to note that it would accommodate a spherical bead, (x 12).

FINDINGS

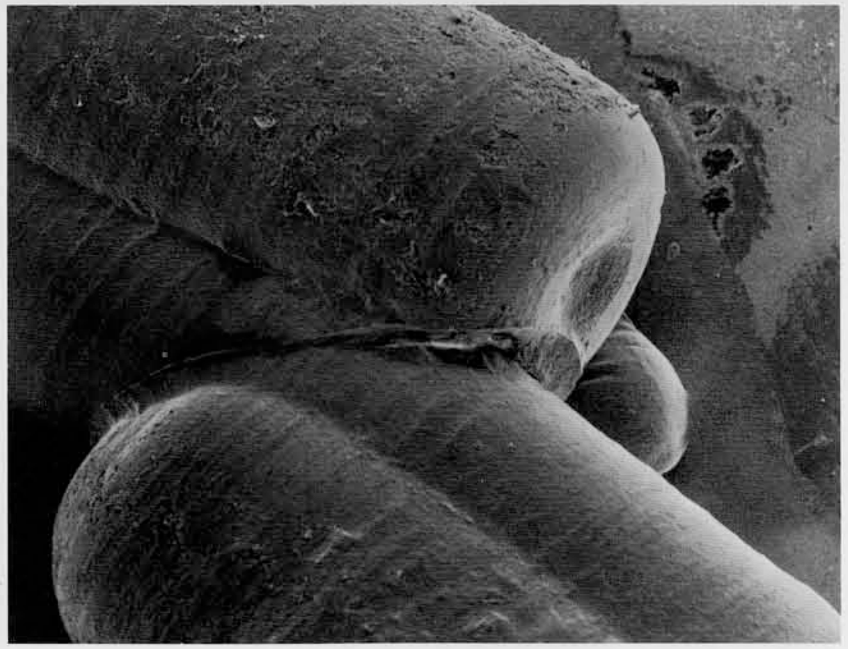
(a) *Soft Stones* (Mohs 1-3): Intact beads and fragments showed topographical detail and shapes suggesting various stages of manufacture. With the exception of bead fragments, most of the beads were either polygonal (Fig. 4) or round, disk shaped. Most were perforated (Fig. 5). The surface surrounding the perforation was either irregular, gouged with some smooth regions (Fig. 6), flat and grooved (Fig. 7), or concave (Fig. 8). The grooves were parallel, shallow and numerous, commonly running in one direction. These grooves may have arisen either from sawing or from flattening and smoothing by passing the bead back and forth in one direction over an abrasive such as sandstone. That some of the beads may have been made by cleaving or splitting could account for the irregular surface of the bead seen in Fig. 6.

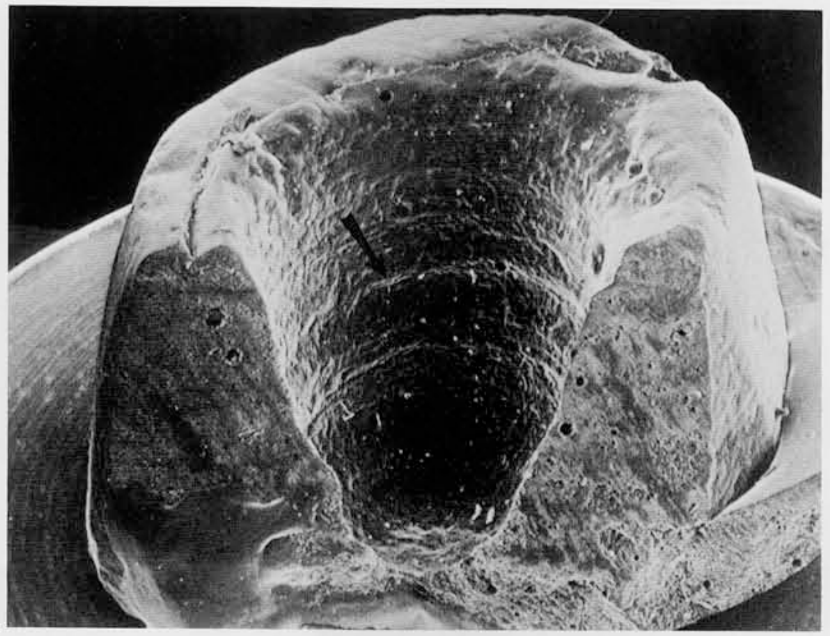


9
Reconstruction of the process of annular bead making from a long cylinder. The fact that drilling was done in the early stages, and in this case with axial misalignment, would account for the bilobular shape of the bead perforation seen in Fig. 6.

10
Scanning micrograph of an imprint of the bore of the chalcedony seal. Note the misalignment of the bore holes at a point toward the center of the seal, (x 30).

This latter bead also showed an unusual shaped perforation which in cross-section appeared bilobular. Such a shape can be accounted for by referring to Fig. 9. In this reconstruction it will be noted that a long cylindrical form is drilled from each end but the drill holes are misaligned and do not meet precisely in the center. This is not an uncommon finding in the bores of seals (Fig. 10). If segments are cut from the cylindrical form, then one taken from the center region will show a bilobular perforation similar to that shown in Fig. 6.





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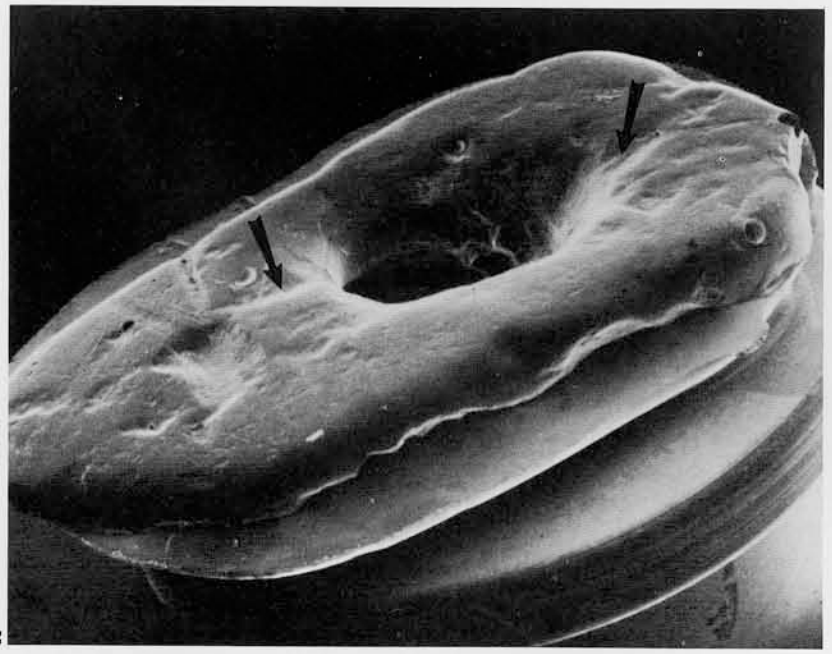
11
Scanning micrograph showing concentric, shallow abrasion grooves (arrow) on the wall of the bead perforation. The model has been cut to display the inner wall, (x 11). Note the resemblance to the pattern produced in experimental drilling with flint (see Fig. 27).

12
Scanning micrograph of a flat, irregular limestone bead in which two grooves can be seen (arrows). It is speculated that these were a manifestation of a step in the initiation of drilling, (x 11).

The typical cutting anomalies left on the walls of the hole during perforation of soft stone beads can be seen in Fig. 11. In this cylindrical alabaster bead there is an incompletely drilled hole. The model has been cut to display the bore. The shape is conical with circumferential grooves around the wall. The size and separation of the grooves vary, with the bottom of the hole being relatively smooth and rounded. These characteristics are consistent with those found when similar stones are drilled with shaped flint tools and we have been able to reproduce them experimentally. The grooves reflect prominent cutting edges on the lith. The smooth, rounded base suggests wear of the lith at its leading edge. The leading edge of the lith, in contact with the base, would be that part which had received most use in the drilling.

One of the steatite beads (Fig. 12) showed a feature consistent with other observations in which drilling was commenced by scoring or pecking the surface to prevent the drill tip from wandering during early stages of perforation. The shallow groove on each side of the hole is consistent with Semenov's observation of a similar phenomenon seen in the drilling of shells. A criss-cross of grooves provides a center spot to guide and hold the drill and abrasive.



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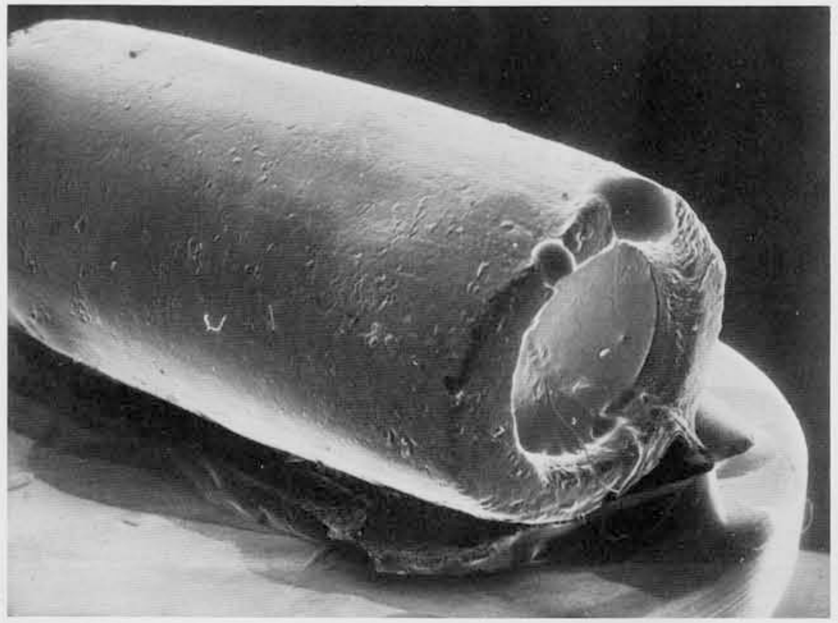
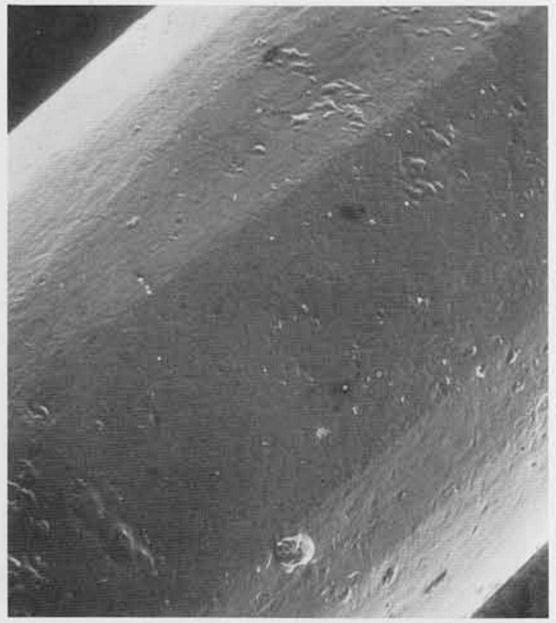




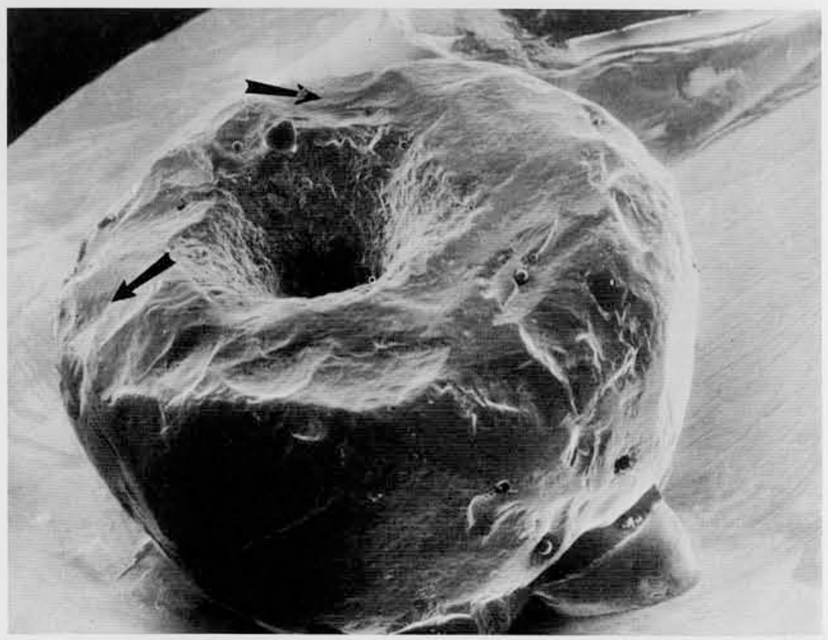
13
Scanning micrograph of a tubular lapis bead in the final stage of manufacture. The bead is rounded and has a notable absence of abrasion grooves. It appeared polished to the unaided eye, (x 10).

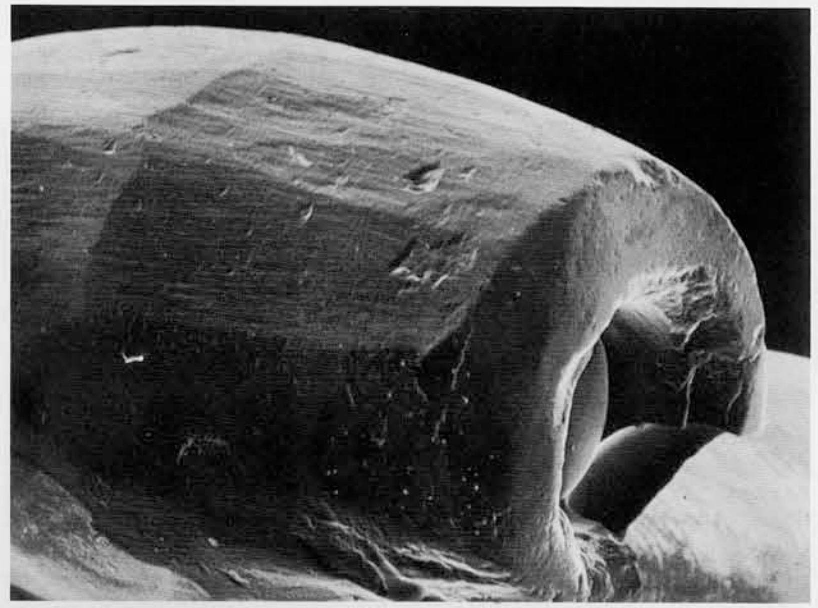
14
Scanning micrograph of a tubular lapis lazuli bead at a stage where shaping by facetting was being done, (x 18).

15
Scanning micrograph of a chalcedony bead showing evidence of chipping (arrows) to produce a desired shape. The bead has been perforated at this early stage, (x 12).

(b) *Medium Stones* (Mohs 4-6): The beads in this group showed features similar to those reported for the soft stones. The group contained beads which were more varied in shape, with several apparently completed tubular beads (Fig. 13). A close examination of these beads showed evidence of facetting (Fig. 14), a feature not found on the soft stones. The facets, which ran in the long dimension of the bead, showed little evidence of grooves. These were probably removed during the polishing stages subsequent to shaping. To the unaided eye, the beads had a polished appearance.

(c) *Hard Stones* (Mohs 7-10): Intact beads and fragments represented several stages in fabrication. While many beads appeared irregular in shape, most were either rounded (Fig. 15) or tubular (Fig. 16). Close examination of the surface showed numerous areas of chipping (Fig. 17) and cleaving to develop facets (Fig. 18), a characteristic unique to the hard stones. These early stages of fabrication appeared to be followed by shaping using other methods. Abrasion anomalies on many of the beads suggest moving them across an abrading stone in a manner similar to that





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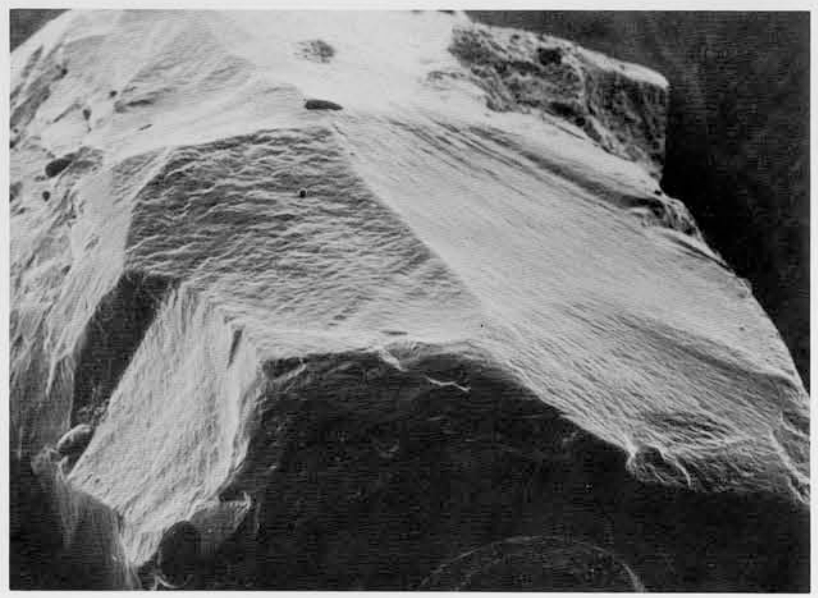
Scanning micrograph of a chalcedony bead showing a facetting stage, (x 11).

17
Scanning micrograph showing areas of chipping resulting from early shaping of hard stone beads, (x 20).

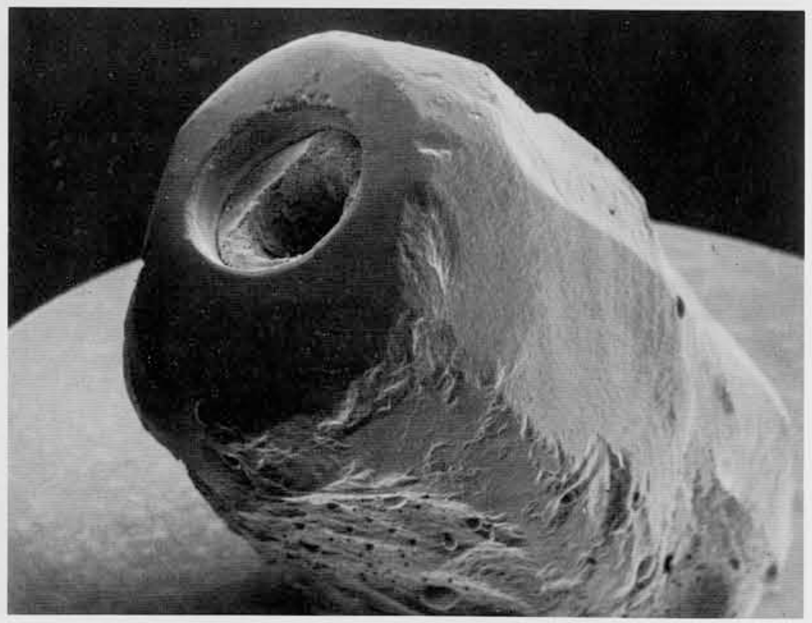


18
Scanning micrograph showing an early stage in chalcedony bead manufacture, (x 18).

observed for the soft stones. The presence of regular, closely packed shallow grooves (Fig. 19) was a common finding.

The beads were obviously drilled in the early stages of their fabrication (Fig. 20). This conclusion is drawn from seeing several drilled beads still in a rough state of fabrication. The walls of the holes showed striking differences from those seen with beads made from soft and medium hardness stones. To the unaided eye the walls were shiny and polished. By reflecting light from different angles into the bores it was possible to discern faint lines. Using the SEM it was evident that numerous, shallow, fine concentric grooves (Fig. 21) were present on the walls. In this particular figure there is a change in bore size toward the bottom of the hole. This can be explained by the use of two drills of different size (Fig. 22). It was perhaps not uncommon in drilling hard stones like chalcedony and carnelian to experience high rates of tool wear. Such drillings would have required the use of an abrasive since the hardness of knapped flint and jasper would have made it impossible to cut them without an abrasive. It was not uncommon to find a bevel at the entrance to the drill hole (Fig. 23). This phenomenon is also present in seals made from similar stones. One plausible explanation is that the bevel represents the remnant shape of a shallow well created for the purpose of containing and confining abrasive—a procedure necessary in the early stages of drilling. As the hole deepens it acts as its own well for accommodating the abrasive. The original well could have been made with a large drill judging by the angle of divergence of the bevel. This phenomenon was seen only on the hard stone.

19
Scanning micrographs showing parallel, shallow abrasion grooves running along the facets predominantly in one direction, (x 13).



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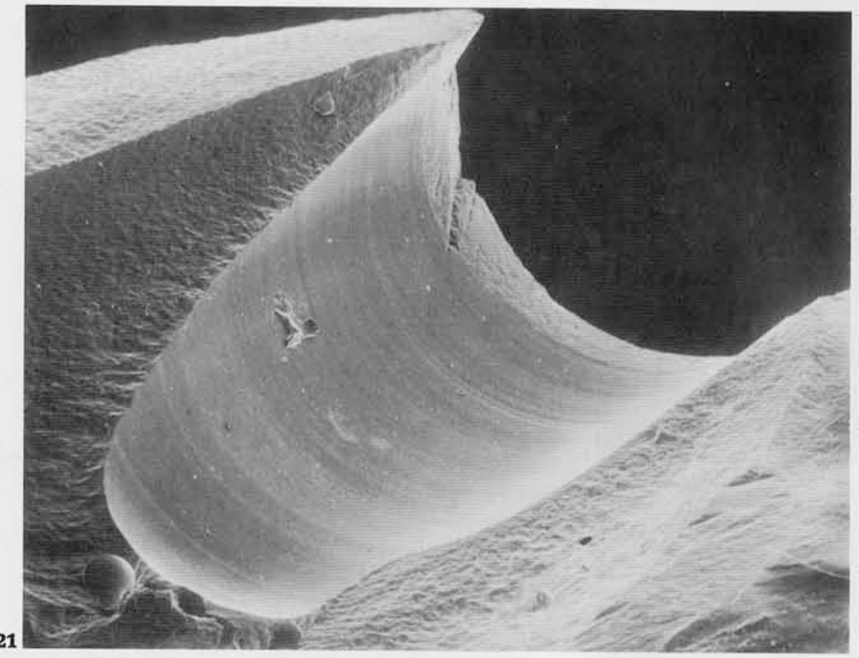
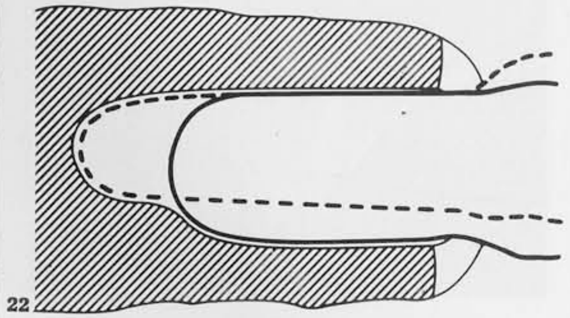
Scanning micrograph showing that perforation was done in the early stages of bead manufacture from hard stones. The rough shape of the bead is evident, (x 25).





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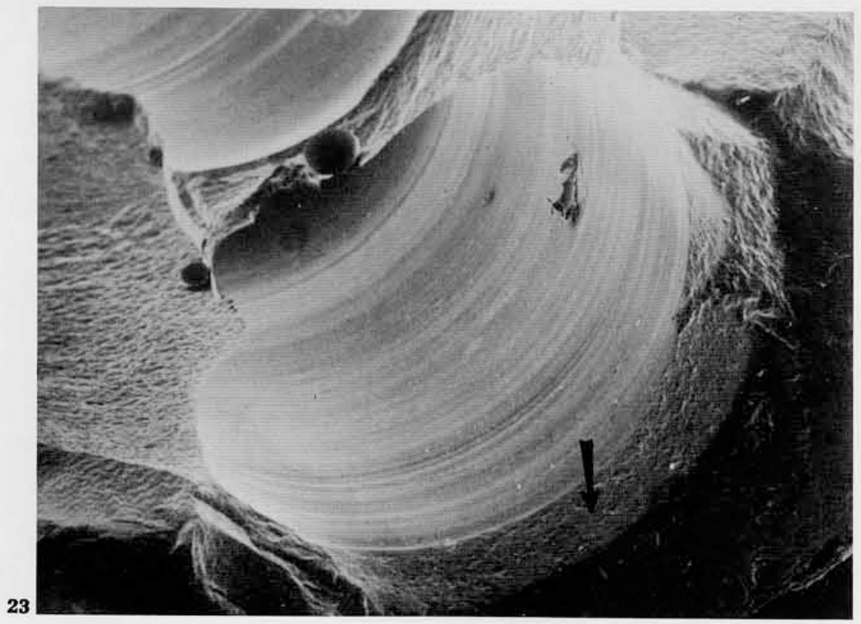
Scanning micrograph of the bore of a carnelian bead in which numerous, shallow, parallel concentric abrasion lines mark the wall of the bore. The change in diameter toward the bottom of the hole suggests the use of two drills. The fineness of the lines contrasts with soft stone patterns and requires further research.

22
Diagrammatic representation of drilling using two drills of different diameter. These would account for the phenomenon seen in Fig. 20.



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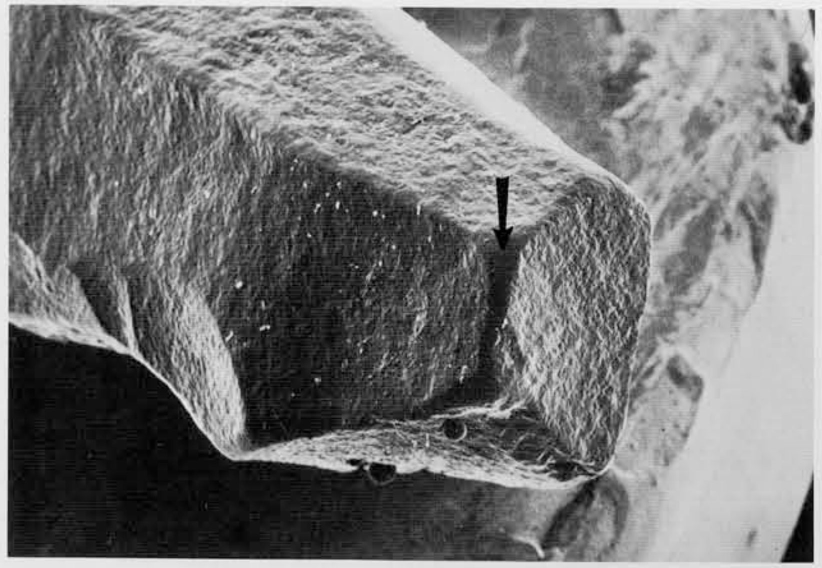
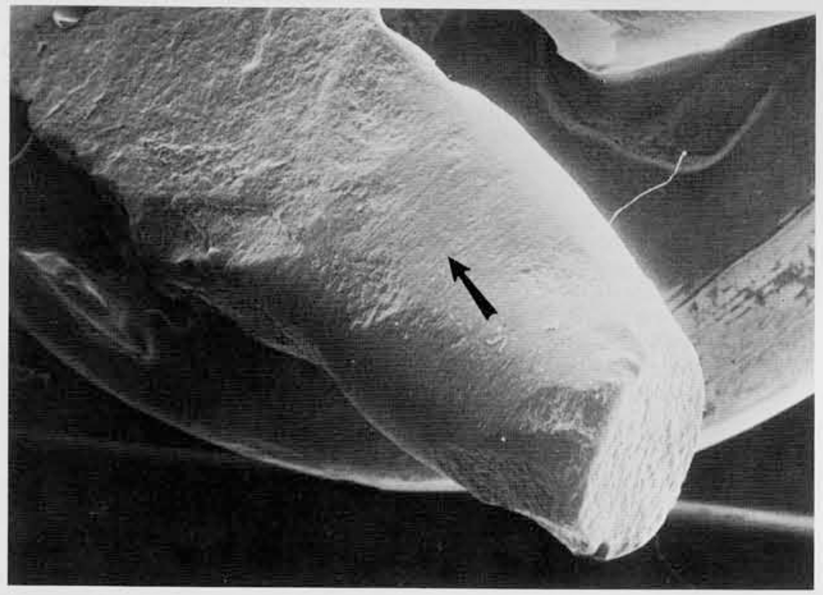
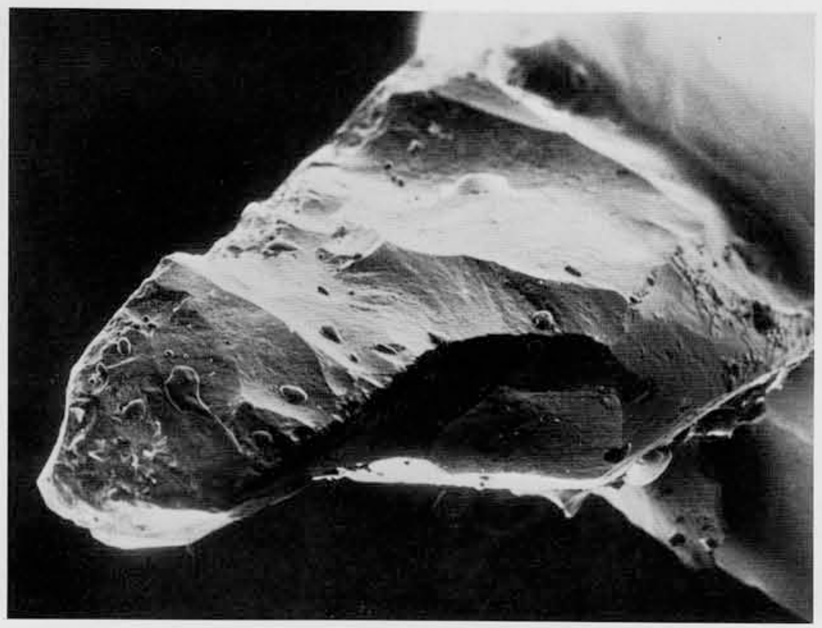
Scanning micrograph showing a bevel (arrow) at the entrance to the perforation of a carnelian bead, (x 13).







RECONSTRUCTION OF THE PROCESS OF EARLY BEAD MAKING

The findings from this study corroborated some but not all of those made by Tosi and lent support to some of his conclusions. In addition, there were obviously some technological parallels in the making of beads from stones with different Mohs hardness, as well as some notable differences.

Whether made from soft, medium or hard stones, the process of bead making probably began by detachment of small pieces from larger chunks of stone. The segmentation could have been done by sawing or mechanical splitting. The pieces would then be selected according to size and shape requirements. There was evidence from this study to support the fact that some beads made from soft stones, such as alabaster, were cut or cleaved into annular shapes from previously drilled cylindrical forms. The observation of a bilobular perforation (see Fig. 6) was clear evidence for this stage.

Drilling was an early step in the manufacture of beads. It is logical to do this since the friable, small beads might readily break during drilling, thus wasting many hours of work devoted to shaping, smoothing and polishing. We place drilling of hard beads, such as those made from chalcedony, at a step earlier than indicated by Tosi. He indicated that drilling followed smoothing. We found several beads in very early stages of manufacture in which complete perforation had been done.

An examination of the *macroliths* available for this study, which were either of flint or jasper chert, showed evidence of use. These were clearly too large to have been used for the beads in this sample. On the other hand, the diameters of the *microliths* were consistent with those of the tiny perforations in the beads of which some were less than 1 mm. in diameter. On the *macroliths*, the extent of wear varied. In some, portions of the leading edge were rounded (Fig. 24) with other cutting projections still sharp and intact. In others, the *macrolith* appeared tubular (Fig. 25), perhaps deliberately shaped for use with an abrasive.

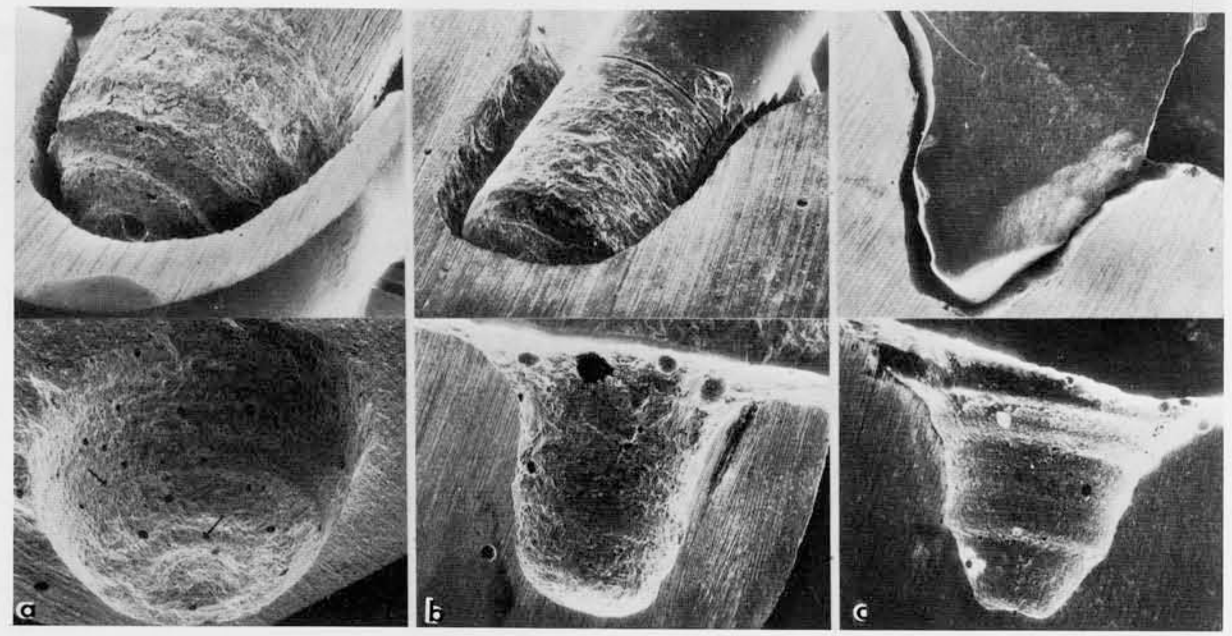
Microliths (Fig. 26) with cutting projections produced by knapping could have been responsible for the abrasion anomalies and other characteristics seen in the bores of soft and medium stones. The hardness of flint with respect to stones in the 1-6 Mohs range could sustain cutting edges for a good length of time, particularly on stones such as steatite, alabaster and limestone. We have confirmed this experimentally and find no reason to doubt a similar effectiveness of flint in drilling lapis. The abrasion patterns in the bores of lapis and soft-stone beads were consistent with those left by a flint drill. On soft stones we can be confident of the use of a flint drill since wood and metal drill tips produce a different pattern. We have determined this experimentally. The abrasion patterns left in soft stones by copper and wood, for example, differ significantly from those of flint (Fig. 27). Furthermore, wood and copper drills hardly reach the efficiency of flint even when an abrasive is used.

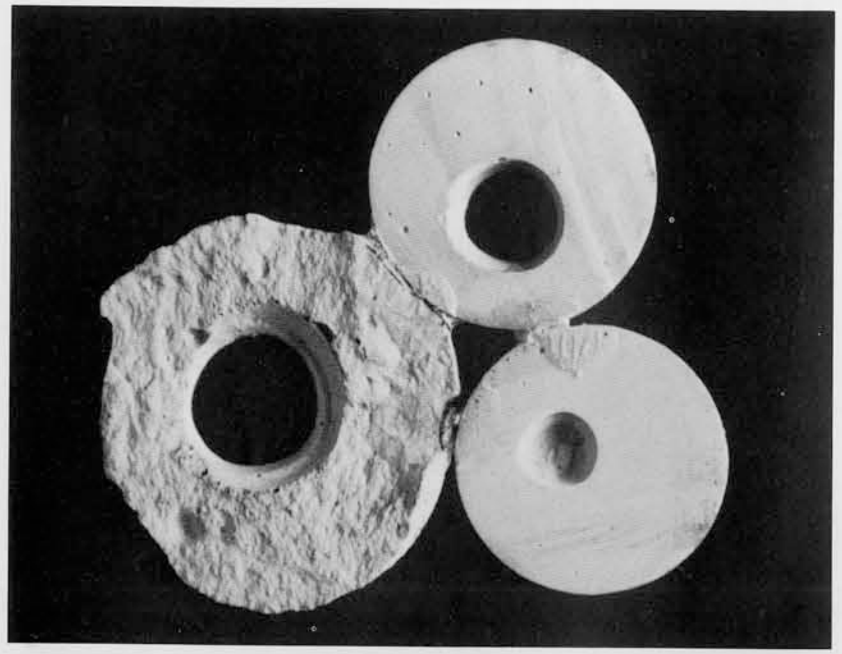
24
Scanning micrograph showing wear (arrow) on the leading edge of a lith, (x 11).

25
Scanning micrograph of a cylindrical macrolith on which can be seen concentric abrasion anomalies (arrow) suggesting rotational use, (x 13).

26
Scanning micrograph of a microlith showing a number of sharp cutting edges formed in the knapping of the flint, (x 18).

27
Scanning micrographs showing a comparison of (a) wood, (b) copper and (c) flint cutting characteristics on steatite, (x 10). The slight elevation produced by the flint was due to an oblique fracture on the tip of the drill. The pattern shown for wood and steatite closely resembles that of a stamp seal from the Jemdt Nasr period which we have reported previously (Gorelick and Gwinnett 1979).





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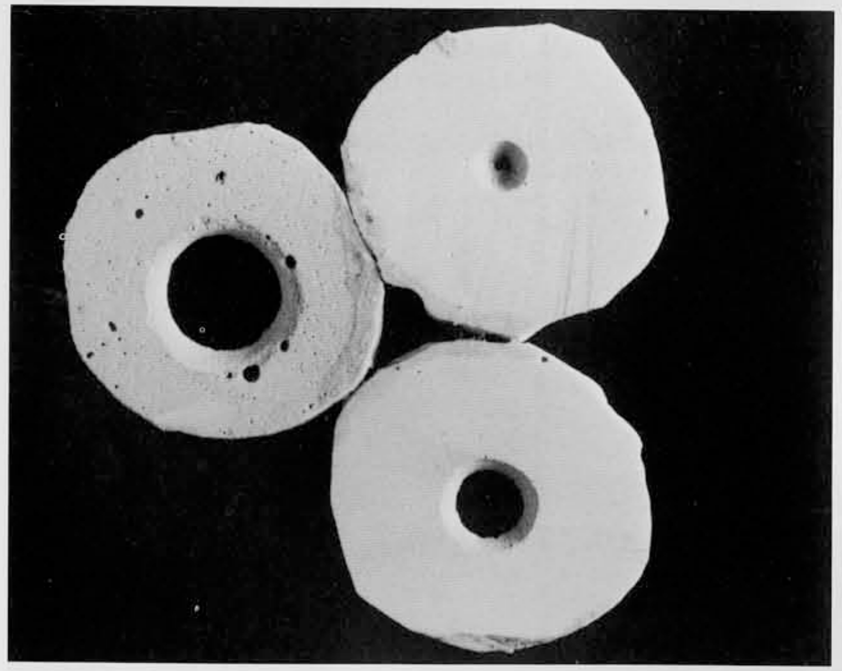
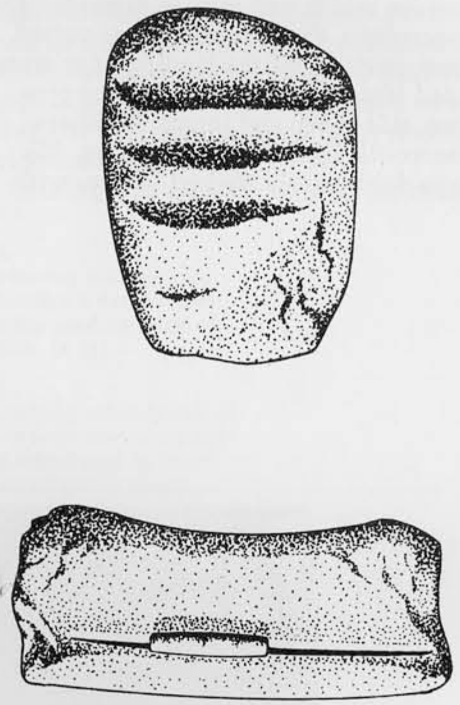


b

28
Two models sectioned through drill holes created by (a) hand drilling and (b) rotational drilling. Note the asymmetry of the hole drilled by a hand-held flint drill which produced a notch (arrow). The drilling was done on marble.

Our present experimentation also leads us to conclude that continuous and discontinuous drilling motion cannot be differentiated on the basis of the examination of the drill hole. However, a hand-held drill in which incomplete rotation of the drill is likely due to limitations of wrist movement can be differentiated from cases in which at least one complete revolution of a drill tip occurs. In the latter a completely circular opening is present while the former results in asymmetry (Fig. 28).

In the sample the rounded, cylindrical *microliths* had no cutting edges. A reasonable hypothesis is that such shaped liths were used to keep an abrasive, under pressure, at the drilling interface in making the perforation. The concentric abrasion marks on the side of some of these liths suggest that they were in fact rotated and



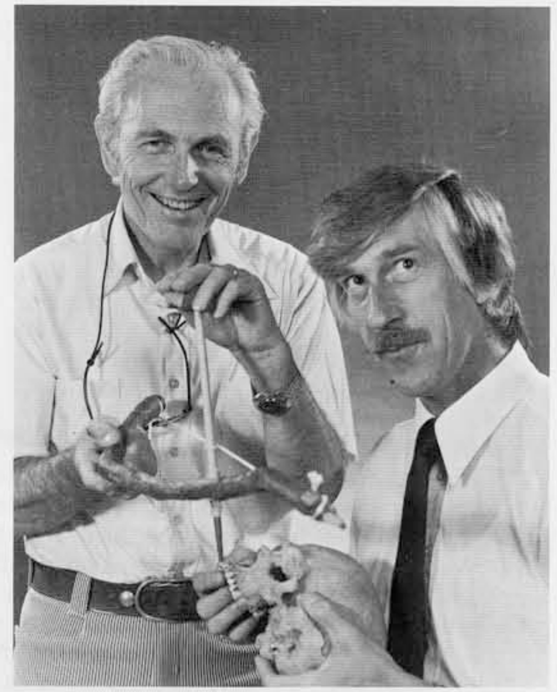
29
A diagrammatic representation of grooved sand-stones used to shape beads. The bead was held firmly and moved back and forth in the groove.

probably in the presence of an abrasive. Piperno (1976) has already made reference to such liths in which some showed a slight indentation in the leading edge. We have equated such a shape with an observation we made in the bore of a seal made from chalcedony (see Fig. 10). The depression would serve to increase the surface of the drill tip at the drilling interface and would improve cutting efficiency by also keeping abrasive at the site. Was the depression due to wear or was it created deliberately? We have run drill tips made from flint for several hours on hard stones in the presence of a fine sand abrasive and have not been able to produce wear of the drill tips in a shape matching the depression. We feel that further research is needed here.

The early shaping of the beads appeared to center on making polygonal or multifacetted forms. In hard stones, the finding of conchoidal fracture patterns supported the conclusion that shaping was done by chipping and cleaving using sharp blows. Final shaping probably involved the use of abrasive stones of different coarseness in which the beads were held in some manner and moved back and forth. The dominant, single direction of abrasion grooves suggests fixation and movement of the beads in one direction over fixed abrading particles such as might be contained in sandstones. Numerous examples exist of this procedure, which is illustrated in Fig. 29. The beads may also have been strung and rolled across an abrading surface though no evidence of concentric lines on the outer surface of the beads could support this action.

How the beads were finally polished remains speculative except to note that tumbling in bags and placement in streams have been suggested. Several of the beads examined appeared polished to the unaided eye. Many did not show scratches under critical examination in the SEM. In some however, occasional scratches were present which may represent residual grooves made during early shaping stages and not totally removed during polishing.

In conclusion, the scanning electron microscope has elucidated the basic steps in early bead manufacture, and has established that different methods were used for stones of different hardness.



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