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ARCHAEOLOGIES OF THE INDIAN OCEAN

12

SOUTH ASIAN ARCHAEOLOGY AND ART 2012

Volume 1

Man and environment in Prehistoric and Protohistoric South Asia: New Perspectives

Publication soutenue par la Région Île de France indicopleustoi

Indicopleustoi
archaeologies of the indian ocean

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Man and environment in Prehistoric and Protohistoric South Asia:

New Perspectives

Edited by

Vincent Lefèvre, Aurore Didier and Benjamin Mutin

BREPOLS

Illustration de couverture : Sibri: Architectural remains cut by a grave.

Crédits photographiques Mission archéologique de l'Indus—Catherine Jarrige.

D/2015/

ISBN

Printed in the E.U. on acid-free paper

TABLE OF CONTENTS

Volume 1

ANALYSIS OF THE ERNESTITE STONE DRILLS FROM DHOLAVIRA EXCAVATIONS

V. Nandagopal Prabhakar

Dholavira, locally known as Kotada, is located in the Khadir island of Kachchh (*fig. 1*). The excavations at Dholavira brought to light seven stages of cultural occupations termed Stages I-VII, recording the establishment, rise and fall of the Harappan settlement (Bisht 1991). The Harappan settlement is demarcated into various divisions as "castle", "bailey", "middle town", "lower town", "ceremonial ground", etc. by the excavator (Bisht 1991) (*fig. 2*).

Kachchh is rich in minerals such as chalcedony, chert, ochres, white clay, Fuller's earth (*mung mitti*), glass-sand, salt, gypsum, different rocks and building materials that might have been exploited by the Harappans (Bisht 1989, 267). Bead making at Dholavira has been attested right from the earliest period onwards (Bisht 1991, 71-82). The bead industry, which made its humble beginning during the Stages I and II, diversified in the mature Harappan period represented by Stages IV and V. Stage VI also preserves evidence of bead manufacturing at this site during the late Harappan period. Also remarkable is the large quantity of drills recovered from the excavations at this site.

The majority among the drills is made from "ernestite", tentatively named by Kenoyer and Vidale (1992). These drills came from various localities of the site. However, the Middle Town yielded the majority of them, thus indicating concentration of bead industries in this part of the city. Furthermore, evidence for bead working (beads in various stages of manufacturing, bead polishers, drills, etc.) was found in localities in the Middle Town, Bailey and Lower Town. The evidence of a bead working area during Stages IV and V was brought to light near the eastern gate of Middle Town while two bead-working areas were revealed during Stage VI, one near the northern gate of Bailey and another one near the western gate of Castle. Over 1200 drills from Dholavira were subjected to a detailed documentation and microscopic analysis to understand the distribution patterns, morphology and nature of findings. The results of this study are presented here.

Beads and Drills in Harappan Context

Beads occupy an important position in antiquity record. In the Indian sub-continent, beads of turquoise, steatite, shell, dentalium, calcite and lapis lazuli are noticed as early as the Neolithic levels of Mehrgarh (7th-4th millennia BCE) (Jarrige *et al*. 1995). The presence of turquoise beads from the Neolithic levels is a clear evidence of long distance contacts, as turquoise had to be procured from either Iran or Central Asia, nearly 1500 km from Mehrgarh (Jarrige *et al*. 1995). The Chalcolithic levels at Mehrgarh show the presence of used and unfinished drills of pthanite (*sic pthanite*) among the debitage of semi-precious stones like chalcedony, agate, carnelian and turquoise (Jarrige *et al*. 1995). Through the course of transition from Neolithic to the Indus levels, harder and harder stones were introduced, while the length of the beads also increased (Barthélémy de Saizieu and Rodière 2005). The Harappan period witnessed an explosion in bead industry. The Harappans were highly advanced in raw material procurement, production and distribution of various kinds of beads. The Harappans exploited a wide variety of semi-precious stones for bead manufacturing. A recent study (Law 2005) from Harappa indicates that, during the mature Harappan phase at Harappa, nearly 40 different kinds of rocks and minerals were exploited by the Harappans from different geographic zones.

E.J.H. Mackay (1937) first studied stone bead manufacturing and drilling technologies in the course of his work at Mohenjo-daro and Chanhu-daro. Mackay found a variety of unfinished stone beads in various stages of manufacture from Chanhu-daro, which has led to a fair understanding of the bead manufacturing technology involved in the production of the long barrel-cylinder beads (Mackay 1937). Mackay also found a large number of stone drills from Chanhu-daro, both broken and complete. The complete ones average 3.81 cm in length and 2.54 mm to 3.048 mm in diameter (Mackay 1937). The beads were also bored first and then given polish, as has been evidenced from Chanhu-daro examples (Mackay 1937). The raw material for these stone beads came largely from Gujarat region of India as evidence from the agate-carnelian sources from Ratanpur in Rajapipla, Kapadvanj, Jamnagar, Khandek and Medhok or Mardak Bet (Bisht 1989) and of these many of the agate-carnelian specimens from Harappa were derived from Mardak Bet (Law 2011) (*fig. 3*). Sites from Gujarat have also yielded evidence for bead manufacturing activities.

S.R. Rao reports the presence of a probable bead factory from Lothal based on the presence of a large number of cores, flakes, ground and un-perforated beads scattered in the courtyard and the surrounding rooms (Rao 1985). Rao suggests that the agate for making carnelian at Lothal came from the Rajapipla mines. Rao also compares modern bead making lapidaries and techniques of Khambhat with that of bead factory at Lothal (Rao 1979, 1985). The studies on the modern bead manufacturing at Khambhat conducted by Kenoyer *et al*. indicate two types of diamond tipped drills, namely *tekni* (a single rounded diamond chip to create a depression to facilitate the second drill that makes the actual boring) and *sayedi*, which has two tiny rounded diamonds set at right angles at the tip end (Kenoyer *et al*. 1991). As diamond was unknown during protohistoric period, drills of chert and types of mottled green jasper were in use, and much time was consumed in drilling the hard stones using these drills.

In the course of their studies at Khambhat, Kenoyer and Vidale (1992) also carried out a more comprehensive experiment on the usage of stone drill. They suggested two new terms for the identification and classification of cylindrical drills with a dimpled tip. They are “tapered cylindrical drills” and “constricted cylindrical drills” based on the morphology of the drills (ibid.). While the former has a very wide distribution and presence in the regions from Mesopotamia to the Indus, the latter is “a unique form of standardized and specialized tool developed by the artisans of the Indus Valley for perforation of long beads made of agate/ carnelian and jasper” (ibid.). Detailed microscopic investigations were carried out on stone drills obtained from Mohenjo-daro and Harappa by Kenoyer and Vidale (1992). They suggested the name “ernestite” for the type of stone drills that were used for drilling agate beads. They describe ernestite as “… a fine grained metamorphic rock composed primarily of quartz, sillimanite, mullite, hematite and titanium-oxide phases”. Of these, mullite is extremely rare in nature, but is produced in modern high temperature ceramic materials (Kenoyer 2003). Kenoyer (2003) also suggests that presence of mullite in Harappan drill bits may be a byproduct due to intentional heating of the original rock. Ernestite is found in many colours and often multi-coloured ones are found. The material has been subjected to detailed analysis by Kenoyer and Vidale (1992).

Law (2011) describes ernestite as follows: “Ernestite is an extremely fine-grained stone mottled with dark-brown to black patches and dendritic veins in a khaki-coloured matrix”. Law carried out XRD and EMPA studies on four ernestite samples obtained from Mound E of Harappa. The diffraction peaks of two samples indicate that ernestite is composed mainly of quartz and mullite-sillimanite along with minor presence of hematite (iron oxide) and rutile (titanium oxide). The remaining two samples showed the presence of cystobalite and mullite and absence of quartz, hematite and rutile. The XRD studies of two samples from Dholavira indicate phases of mullite-sillimanite, similar to other previous studies (Prabhakar *et al*. 2012). The source of ernestite is yet to be identified. However, the abundance of ernestite drill bits and raw materials (*fig. 4*) from sites in Gujarat in comparison to other Harappan sites (Prabhakar *et al*. 2012) indicates that a source is located in or near Gujarat.

Kenoyer (2005) in his study of beads from Harappa has identified the following major types of perforations of stone beads; pecking, drilling with tapered cylindrical stone drills, drilling with constricted cylindrical stone drills, drilling with solid copper drill with abrasives, and drilling with tubular copper drill with abrasives. Tapered cylindrical drills were made of chert, agate, jasper (Kenoyer 2005), and a green stone that has now been identified as pumpelleyite (as opposed to pthanite) (Barthélémy de Saizieu and Rodière 2005).

Drills from Dholavira

A total number of 1212 drills were documented and recorded during the course of the study of the materials from Dholavira excavation. Prabhakar *et al*. (2012) discuss the methodology which is a modified version of the format developed by Kenoyer for bead studies at Harappa (*fig. 5*).

Digital documentation of the drills was made by directly scanning them on a flat-bed scanner at 1200 dpi in groups, generally 20 to 25 in one scan. Then these were cleaned and separated from the group scan, and individual images created. The spatial analysis of the distribution of drills across various divisions of the Dholavira indicates that the maximum number of drills bits (61.42%) is from Middle Town followed by Castle (21.98%), Bailey (12.16%) and Lower Town (3.91%) (*fig. 6*). This may also suggest that the drill working areas were concentrated in the Middle Town area which thus consisted of a specialised craft working hub in Dholavira. The temporal distribution indicates a phenomenal rise of drills bits (82%) during Mature Harappan period represented by Stages IV and V.

That the bead making industry continued at Dholavira is substantiated by the presence of a considerable number of drills in Stage VI (12.51%) and also by the presence of two bead working areas, one immediately west of the northern gate of Bailey and another one near the western gate of Citadel area. Out of the 1212 drills, eight are of chert and two of vesuvianite, the remaining 1202 are of ernestite. The ernestite drills represent 99.17% of the total collection, while chert and vesuvianite represent 0.660% and 0.165% respectively.

Results from the analysis

The results from the analysis of drills at Dholavira in terms of statistics and typology have brought to light some interesting and revealing facts. An overwhelming preference for ernestite drills has been observed here (99.17%). This may not completely overrule the presence of chert drills as indicated by their small presence. The broad drill types noticed are cylindrical drills, tapered cylindrical, constricted cylindrical, re-used, re-sized and pointed drills (*fig. 7*).

Since only one specimen of pointed drill type is noticed in the collection, it is possible that this type of drill was also used in other activities. For example, the pointed drill could have been used to punch the initial hole on the bead blank, which served as a firm grip for further drilling. However, this is only a speculation as only one such drill was encountered. Among the ernestite drills, the dominant types are tapered cylindrical drills, which represent 56.2% of the total collection, followed by cylindrical drills (23.1%), and constricted cylindrical drills (19.1%). Additionally some drill bits are re-used (0.9%), re-sized (0.6%) and pointed (0.1%). Of the total collection only 41.6% are complete drills, while the remaining 58.4% are broken and incomplete ones. The large percentage of broken and incomplete drills is a clear indication of industrial waste.

Drills with missing tips constitute 40.53% of the collection and include those that are broken or partially broken. The drills with a dimple tip are most common (23.01%), followed by convex ground tip (12.29%), truncated ground tip (6.48%), nipple tip (5.64%), and chipped flat tip (4.73%). The dimple tip is produced from heavy drilling, and the other tips are the result of initial drilling, or some intermediary stage. The other varieties of tips which include chipped convex, convex faceted, flat beveled, dimple beveled, dimple-nipple, and faceted are present in very small percentages. The larger percentage of broken tips as well as dimple tips clearly shows that 63.54% of the drills were extensively used and were discarded when they could no longer be reshaped. The maximum length of the drills varies from 3.34 to 30.89 mm, while the length of complete drills varies from 6.33 to 30.89 mm. Out of a total of 1204 drills almost half of the drills (501) are complete. This indicates that bead drilling was done very carefully to optimise the use of the drill bit until it was too short to be used again. The width of the drills varies from 1.25 to 5.33 mm with a mean width of 2.79 mm.

Coming to the bit lengths, evidence for a clear bit is observed in 528 drills, and the bit length varies from 2.44 to 29.72 mm with a mean of 8.36 mm. The tapered cylindrical drills are better represented with bit lengths followed by cylindrical and constricted cylindrical ones. The base length could be measured in 691 cases, and it varies from 3.13 to 18.77 mm with a mean of 7.1 mm. In the case of base also, the tapered cylindrical drills have an overwhelming 85.24% cases where the base is preserved. Evidence of a clear tip could be noticed in the case of 708 drills.

The tip width varies from 1.7 to 3.5 mm with a mean of 2.42 mm. Evidence for the presence of minimum width is noticed in the case of 173 drills and the width varies from 1.40 to 2.70 mm with a mean of 2.04 mm. The base widths of drills are observed in 759 cases, and it varies from 1.63 to 4.15 mm with a mean of 2.74 mm. 892 drills have proximal ends and their widths vary from 1.45 to 5.25 mm with a mean of 2.51 mm.

Results from microscopic analysis of drills

The drills were also subjected to microscopic analysis with the aid of a Dinolite USB Microscope for understanding the various surface morphological variations due to their usage.

The different portions of the tips like shaft, drill portion, tip, etc., were examined under a microscope. Furthermore, microscopic examination was also conducted on drills in various stages of manufacture. The analysis of drill rough outs indicates that chips were removed along their longer axis (*fig. 8a-b*) and that they were then ground-facetted longitudinally.

This also tallies well with the description given by Kenoyer and Vidale (1992) on the analysis of drills from Harappa. The evidence for creating a facetted side is clearly found on the surface of the drills in the form of striations due to various angles of grinding on a harder surface (*fig. 8c-e*). These striations do not follow any regular pattern, and this indicates a grinding pattern as per the necessity to meet the requirements of a facetted drill blank. The presence of a stone with negative grooves from Dholavira (*fig. 9*) also suggests its usage for grinding drills, most probably of ernestite. The analysis of drills from Dholavira also helps in understanding the nature of unworked tip, which is a chipped-flat edge (*fig. 10a*), with a raised edge (*fig. 10b*), with a facetted edge having triangular cross-section (*fig. 10c*) and a pointed tip with prismatic cross-section (*fig. 10d*). That the tip of drills was grounded and fashioned to have a desired shape (*fig. 10e*) is clearly understood through the microscopic analyses, which could not have been observed through naked eye.

The shaft of the drill might have been fashioned with a facetted cross-section in order to have a clear grip with the hafting tool. Some of the drill shafts also display deliberate chipping on at least two facets (*fig. 10f*). The rough edges thus created could have facilitated a firm grip with the hafting tool in order to have a smooth drilling of beads. The drill tips underwent a series of surface modifications due to the intensive heat and grinding during the course of drilling holes in the bead. The surface of the drills also underwent wear and tear during the course of surface modifications, some of which could be seen clearly under a microscope. However, the order in the formation of these different patterns is yet to be understood in the absence of a detailed experimental analysis of ernestite drill manufacturing as well as drilling the agate beads. This is partially because ernestite raw materials are rare from archaeological record and their provenance is yet to be determined. The various surface modifications of the tip that have been noticed and documented are flat, truncated ground, convex ground, nippled and dimpled (*fig. 11a-f*). From the analysis of drill tips, it is also surmised that the dimpled tip could be the final stage of a continuous usage of drill before it is broken/snapped (*fig. 11g-i*).

The drill record from Dholavira presents several examples of breakage at the tip point when the dimpled stage is reached (*fig. 12a-c*). Furthermore, the microscopic analysis also helped in understanding the imprints of internal dynamics from rotatory motion of drills inside the bead holes in the form of deep striations, both clockwise and anti-clockwise tallying with the similar movement of drills (*fig. 12d-f*). The breakage of spalls starting from the tip portion and proceeding in a radial pattern along the length of drill indicates the event while it is in use in a rotatory motion (*fig. 12g*). The evidence of breakage at the central portion of drills indicates a sudden snap, caused again by the rotatory motion of the drills, the snap being due to the intense pressure on the drills which was stuck inside the bead holes along with byproducts of drilling and abrasives (*fig. 12h-j*).

Conclusion

An attempt was made in this study to document and analyse the ernestite stone drills from Dholavira, the largest collection so far from a Harappan site. The study of ernestite stone drills from Dholavira is the first of its kind from a Harappan site, in terms of statistical as well as surface morphological studies. The statistical studies along with the spatio-temporal studies have revealed the mastering of ernestite drilling technology during the mature Harappan phase. The presence of large numbers of ernestite stone drills along with several examples of raw materials at Dholavira is a clear indication of its prominent role in bead manufacturing industry of the Harappans, which might have contributed even in the overseas trade. The study also shows that the prominent working areas were complemented by the presence of bead workshops at Dholavira. The large collection of drills with evidence of re-used and re-sized ones indicates large-scale utilisation of ernestite material even to its smallest possible level due to its rarity and the fact that it is a remarkable drilling tool when compared to other stone drills. The morphological studies with the aid of a microscope were most revealing in understanding the various stages starting from the manufacture of drills to its usage and discard. The modifications of the tip were most revealing which also indicates that replication of drills and study of the experimental products in comparison with the archaeological ones is a necessity and provides a better understanding on these modifications.

Several ernestite stone drills from Harappan sites in Gujarat await similar study. The study of these materials would provide us with a more comprehensive understanding of the bead drilling mechanism of the Harappans. The methodology used in the present study can be used for other sites.

Acknowledgements

The present study would not have been possible without the help and guidance of R.S. Bisht, excavator of Dholavira. The study was also possible due to the guidance of J.M. Kenoyer, whose methodology was used in documenting and recording the drills. R.W. Law also provided valuable help and guidance at various stages of documentation of the drills.

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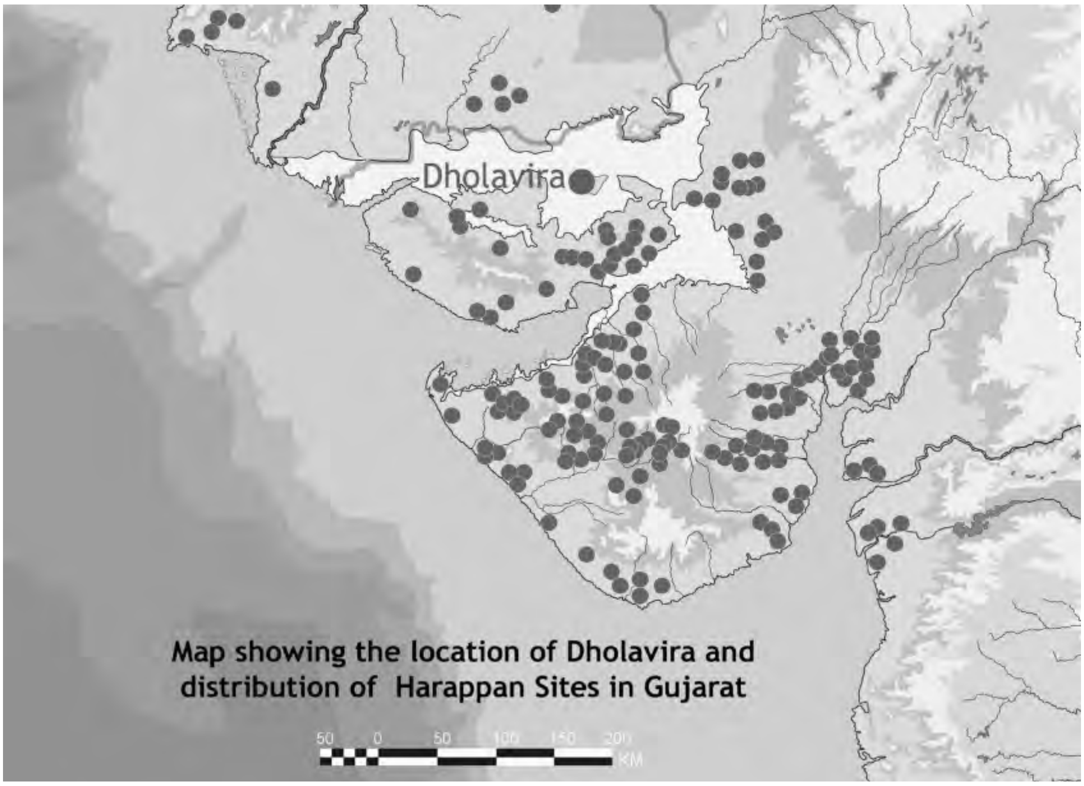


Fig. 1—Map showing the location of Dholavira and distribution of Harappan sites in Gujarat.

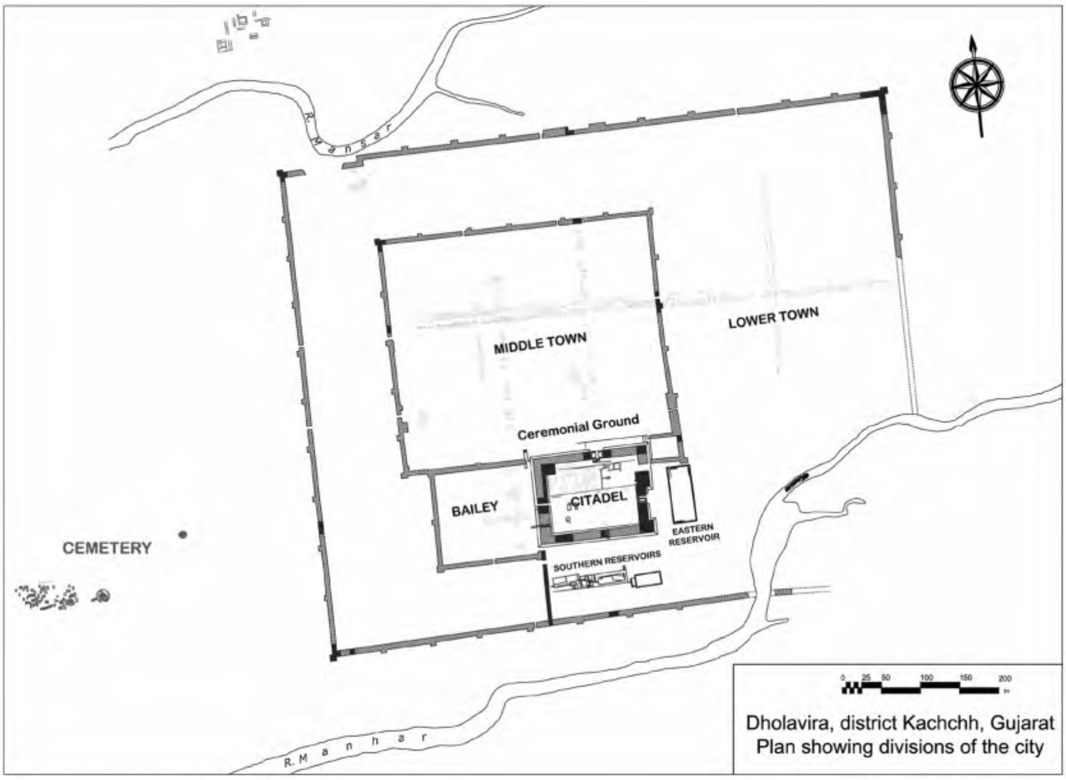


Fig. 2—Dholavira, district Kachchh, Gujarat, plan showing divisions of the city.

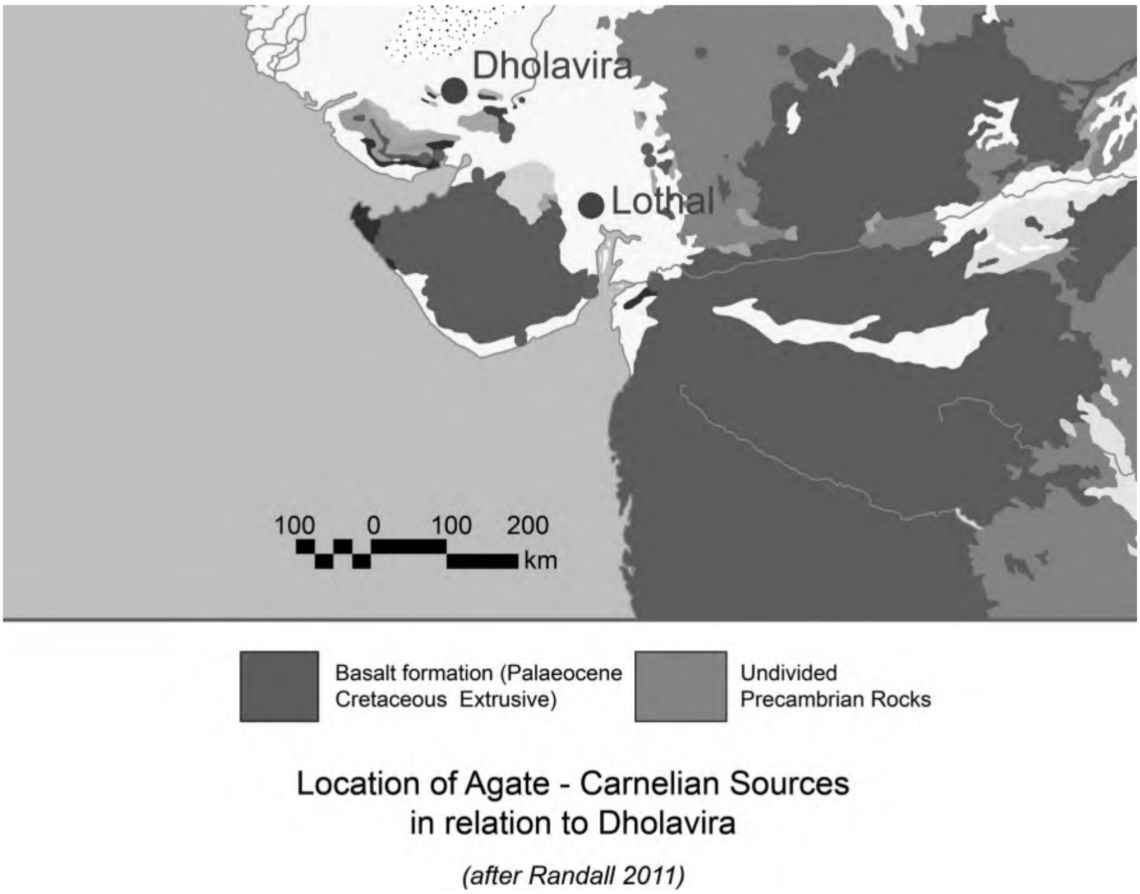


Fig. 3—Location of agate-carnelian sources.

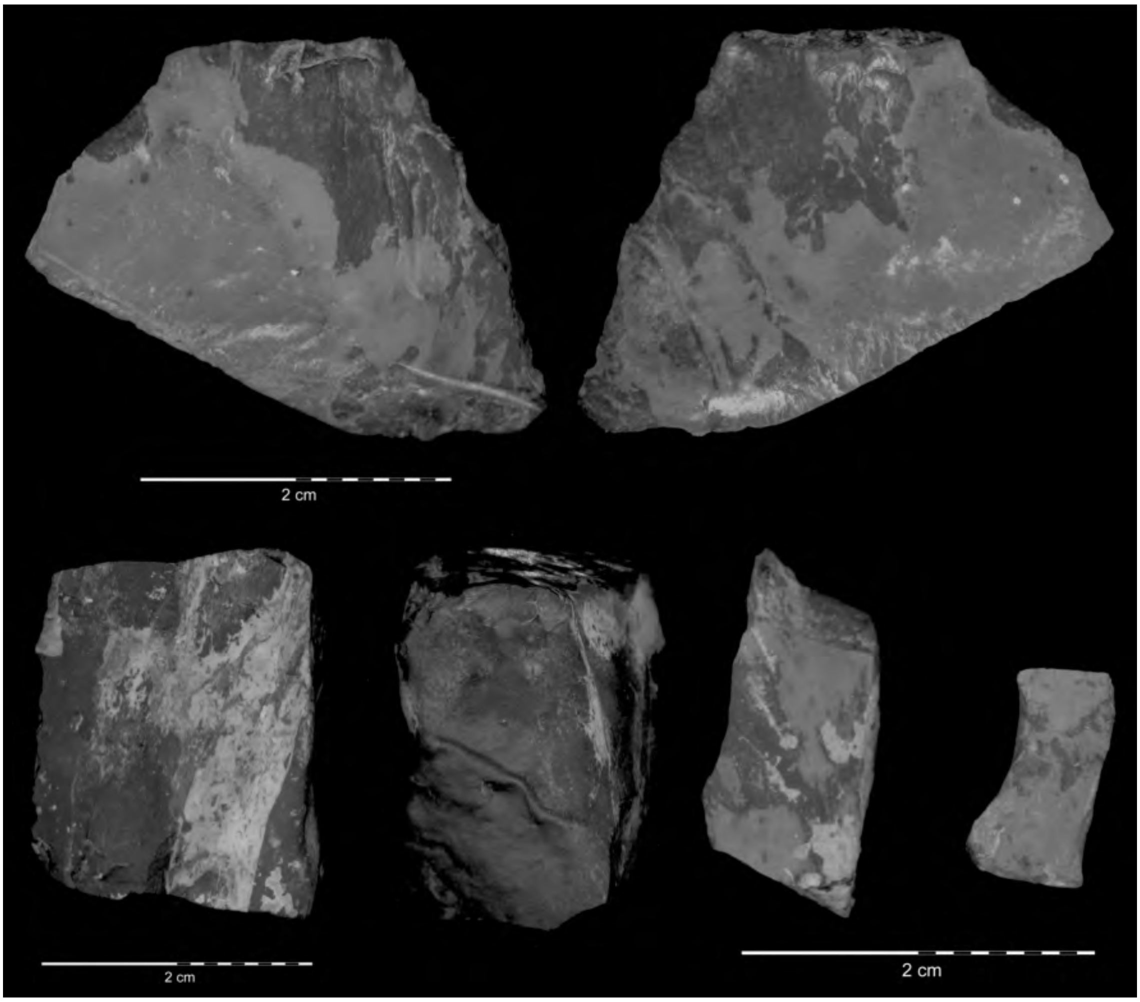


Fig. 4—Raw material of ernestite, Dholavira.

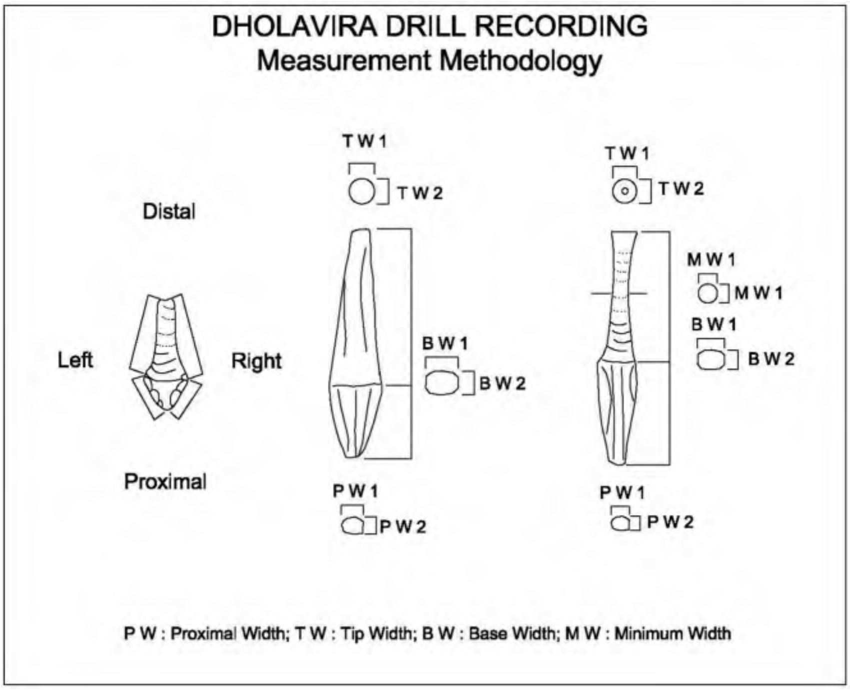
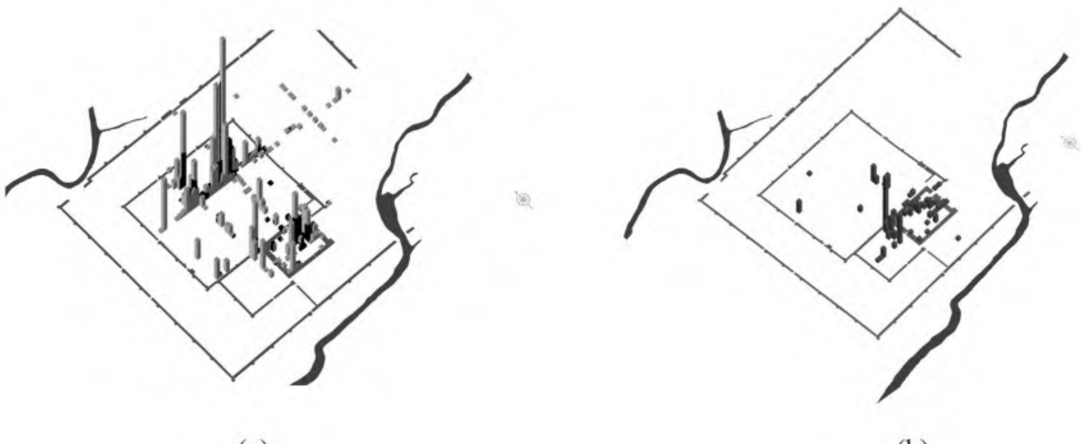


Fig. 5—Measurement methodology used to record the drills, Dholavira.



(a) (b)

Fig. 6—Distribution of drills during Stages IV, V and VI, Dholavira.

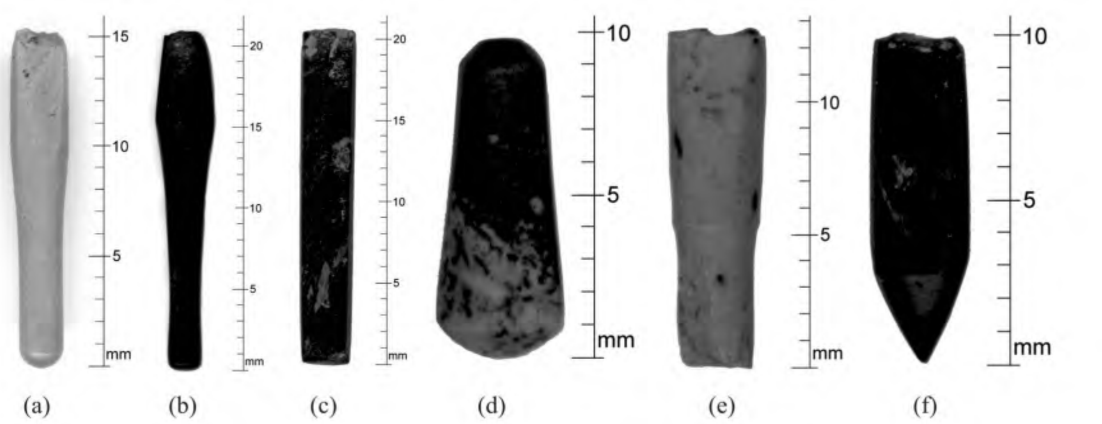


Fig. 7—Types of drills, Dholavira; 7a: Tapered (Drill no.69 (1999)); 7b: Constricted cylindrical (Drill no.1855 (2000)); 7c: Cylindrical (Drill no.2332 (2000)); 7d: Re-used (Drill no.1502 (2000)); 7e: Re-sized (Drill no.14680); 7f: Pointed (Drill no.26170).

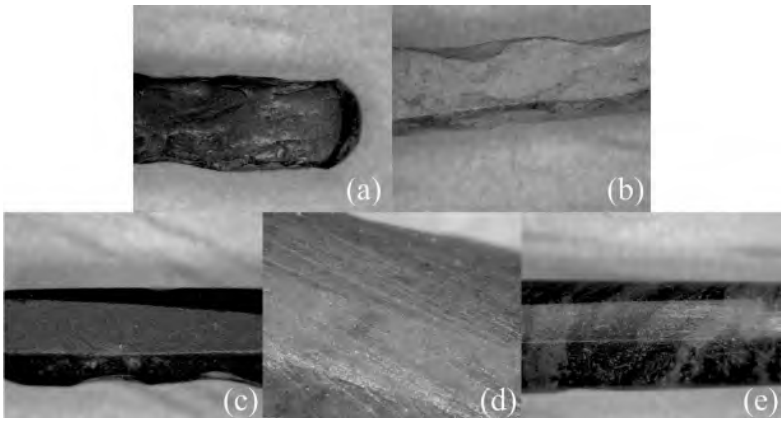


Fig. 8—Drill showing removal of chips (8a: Drill no.122K; 8b: Drill no.1325) and grounded surface and facetted profile, Dholavira (8c: Drill no.3112; 8d: Drill no.105; 8e: Drill no.4420).

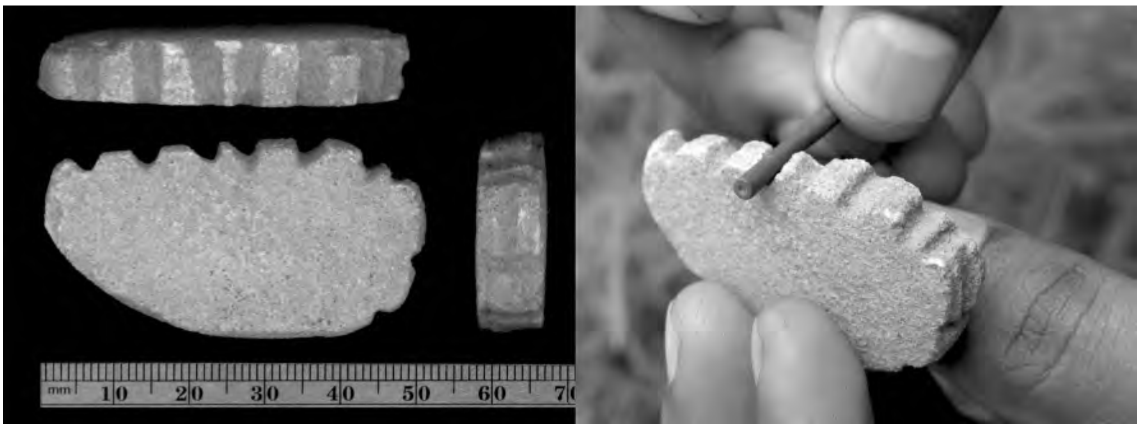


Fig. 9—Stone with grooves for fashioning drills, Dholavira.

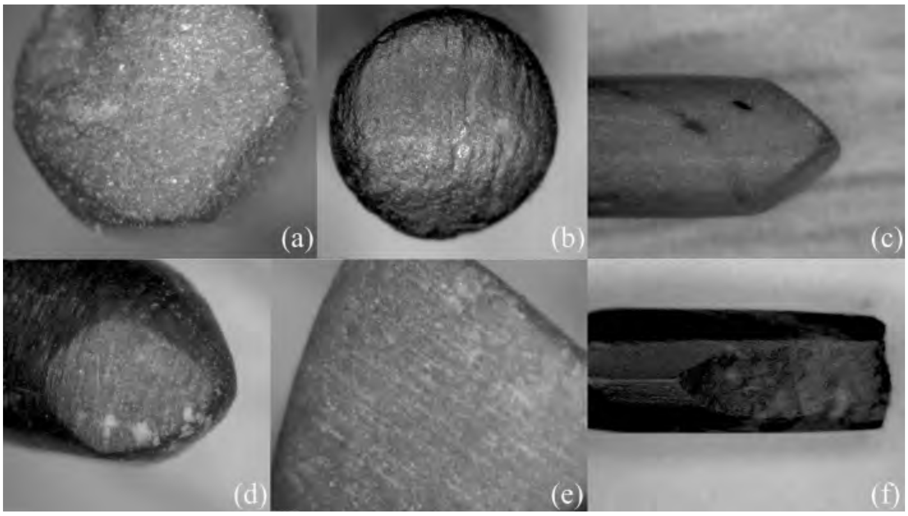


Fig. 10—Drill tip with flat edge (10a: Drill no.4144); raised edge (10b: Drill no.3112); facetted with triangular cross-section (10c: Drill no.4832); pointed with prismatic cross-section (10d: Drill no.3205A); showing purposeful grinding to fashion the desired shape (10e: Drill no.4832); showing removal of chips to facilitate proper hafting (10f: Drill no.26170).

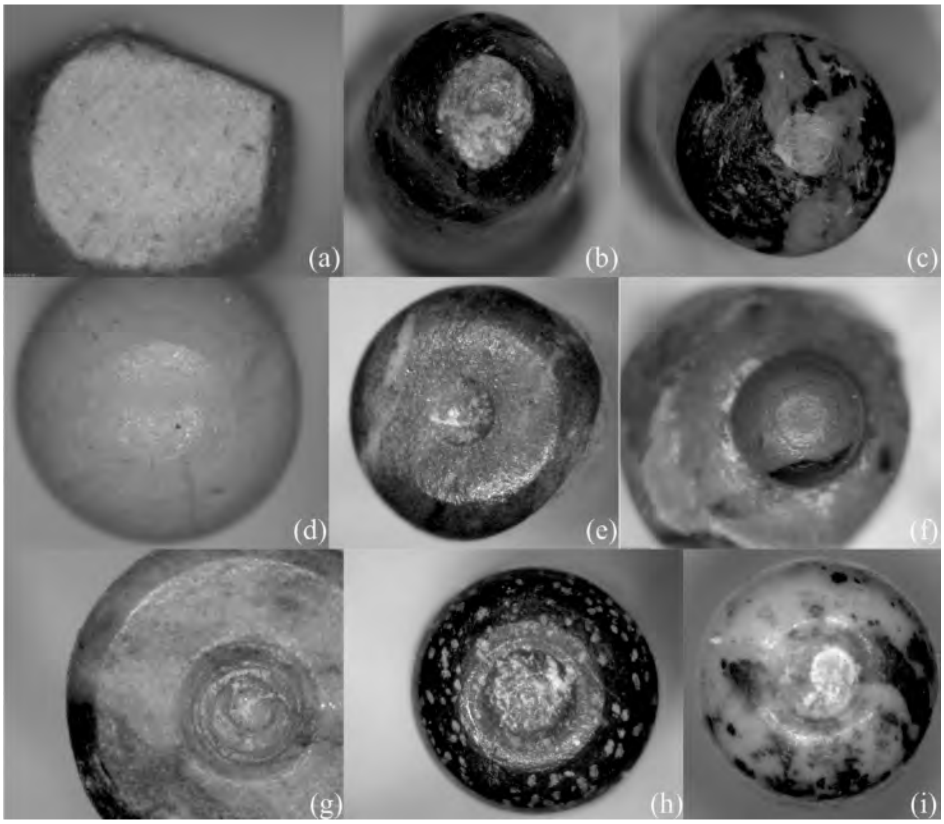


Fig. 11—Drills with different tip profiles, Dholavira; 11a: Flat tip (Drill no.1178); 11b: Truncated ground (Drill no.4170); 11c: Truncated ground approaching a convex ground (Drill no.10515A); 11d: Convex ground (Drill no.69 (1999)); 11e: Dimpled (Drill no.116 (1999)); 11f: Nippled (Drill no.1490F); 11g-h: Dimpled tip profiles (Drill no.4093; Drill no.4762 (2002); Drill no.9400B).

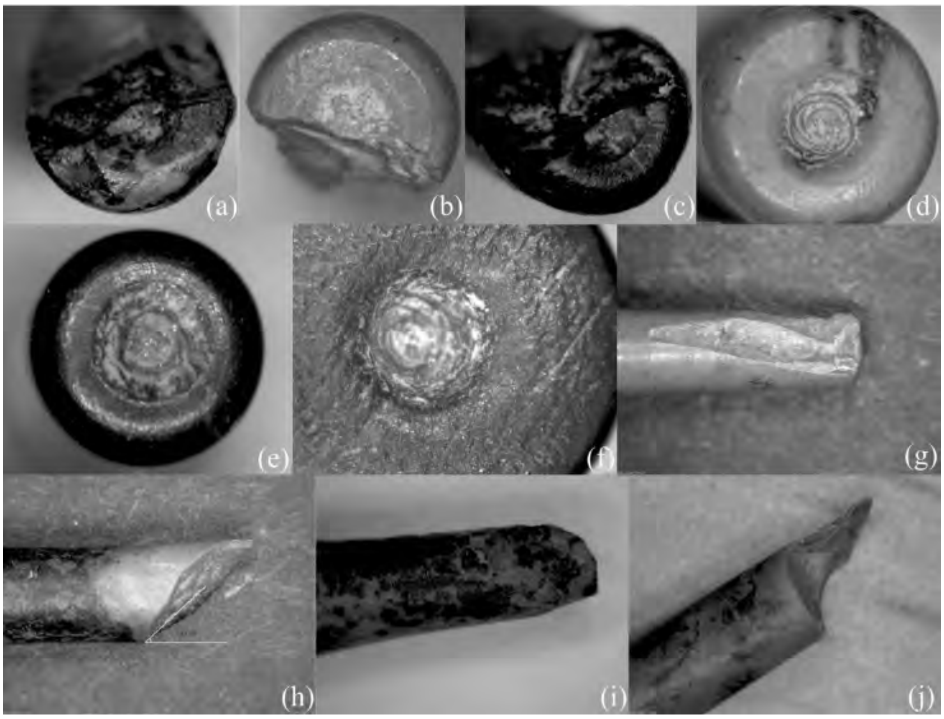


Fig. 12—Drills with dimpled tip profiles and breakage along the tips (12a: Drill no.9237; 12b: Drill no.9857A; 12c: Drill no.6229); dimpled tips showing the striations (12d: Drill no.2239; 12e: Drill no.3801; 12f: Drill no.12364); broken tip, the detached spalls move in a radial pattern (12g: Drill no.9857A); broken at the centre (12h: Drill no.12390; 12i: Drill no.4192; 12j: Drill no.3435 (2002)).