Barthélemy de Saizieu, Blanche – Rodière, Jean

# Bead-Drilling: A Look from Mehrgarh and Nausharo: Preliminary Results of Micro-trace Analyses.

in: Franke-Vogt, Ute – Weisshaar, H.-J (Hrsg.), South Asian archaeology 2003: proceedings of the Seventeenth International Conference of the European Association of South Asian Archaeologists, 7–11 July 2003, Bonn 39–48.

DOI: https://doi.org/10.34780/mvc3-3u6b

**Herausgebende Institution / Publisher:**
Deutsches Archäologisches Institut

B. Barthélemy de Saizieu / J. Rodière

# Bead-Drilling: A Look from Mehrgarh and Nausharo. Preliminary Results of Micro-trace Analyses

## Introduction

In the manufacturing process of beads, perforation appears as one of the more delicate operations. It has been a major topic of research concerning craft techniques particularly in the Indus Valley, with the increased development of hard-stones beads in the urban phase (2500–2000 BC)[1]. It has also been assumed that beads craft, or crafts in general, could have played an economic role in the socio-political organisation of the Indus civilization at this time.

The difficulty levels in perforating vary on the one hand according to the properties of the materials used, on the other hand according to the shapes and the size of the beads. As we can expect, the harder the materials and the longer the beads, the higher the difficulties, but, also, whatever the materials, the smaller the diameter of the drill-holes, the higher the required skill and precision.

Studies based both on the micro-trace analysis of drill-holes of archaeological beads and on various experimentations have suggested the use of different means, i. e. of different tools, such as drills made of stones, of metal, of wood or else of bone with the possible addition of abrasive and lubricant, and also the use of different devices, such as hand-moved power (palm-drill) or mechanical-moved power driven by bow-drill or pump-drill[2].

But, if these different suggestions allow us to understand how materials of different hardness were perforated and different size drill-holes were made, they do not explain the homogeneity or the variability of perforations observed at one site. This question of variability is here raised for the Mehrgarh and Nausharo sites, occupied from Neolithic to Indus Periods (Jarrige 1996).

As a matter of fact, besides aesthetical, symbolic or economical factors, the materials used and the shapes were probably determined by technical factors, too, such as constraints of perforation. At Mehrgarh and Nausharo, besides a massive use of steatite[3] as early as the Late Aceramic Neolithic till the Indus Periods, an increasing diversity of materials is observed. Among this diversity, one can notice in particular an increasing number of hard-stone beads (fig. 1), accompanied by increasingly longer and longer shapes (Barthélemy de Saizieu 2004). So, what do the perforations of the beads reveal in comparison with this evolution? We will characterize the different drilling techniques in terms of constraint of raw materials and bead morphology. This is a necessary first step before interpreting the variability of drilling techniques in terms of cultural choices.

## Method of analysis

Before presenting the results, let us introduce the analytical techniques, which have been used: a careful observation under binocular lenses to choose a bead sample was followed by a micro-trace analysis of drill-holes with a Scanning Electron Microscope (SEM).

The sample includes beads broken longitudinally, along the drilling axe, and complete beads. For the latter beads, a silicon impression of the drill-hole was necessary. These impressions were made according to a technique, which is now well known, i. e. with a resin currently used by dentists to get the best resolution possible (Gorelick/Gwinnet 1983; Gwinnet/Gorelick 1979; Kenoyer 1997). In several cases, however, it was extremely difficult to obtain exact mouldings, in particular with very tiny beads and/or, whatever lengths, with extremely thin holes, or holes narrowed at the centre or else with beads which were unfortunately coated by a

[1] Mackay 1937; 1943; Possehl 1981; Kenoyer 1997; in press; Kenoyer/Vidale 1992.

[2] Gwinnet/Gorelick 1979; 1981; 1987; Gorelick/Gwinnet 1981; 1983; 1989; 1990.

[3] Along this massive use of steatite, a quasi systematic use of treatments (glazing or only heating) as early as the Early Chalcolithic has also been observed (Barthélemy de Saizieu/Bouquillon 1994, 1997; Bouquillon/Barthélemy de Saizieu 1995).

| SITES | Mehrgarh (MR) | | | | | Nausharo (NS) | |
|---|---|---|---|---|---|---|---|
| Periods<br>Lenghts & Number | Aceramic | Ceramic | Ancient Chalcolithic | Recent Calcolithic | Pre-Indus | Pre-Indus | Indus |
| | I | II | III | IV-V | VI-VII | I | II-IV |
| **L<Ø (number)** | 4 | 1 | 23 | 1 | 24 | 6 | 17 |
| Drill-hole Lg. (minim.& max. in mm) | 1,5 to 3 | ? | 1,2 to 9 | 4,2 | 1,8 to 4 | 0,5 to 5,4 | 2 to 5,7 |
| **L≤8mm (L≥ Ø) (number)** | - | - | 1 | 1 | 6 | 2 | 30 |
| Drill-hole Lg. (minim.& max. in mm) | | | 7 | 5 | 5,5 to 8 | 3,7 to 5,2 | 2,7 to 8 |
| **L≥8mm (number** | - | - | 5 | 2 | 20 | 9 | 71 |
| Drill-hole Lg. (minim.& max. in mm) | | | 9 to 15 | 15 to 25 | 8,5 to 32 | 9 to 28 | 9 to 66 |
| **TOTAL of hardstones beads** | **4** | **1** | **30** | **4** | **50** | **17** | **118** |
| Total of beads | 9 336 | 168 | 3 001 | 47 | 1 556 | 1 241 | 3 788 |

*Fig. 1.* Quantitative distribution of hardstone beads according to the knapped lengths from the Neolithic to the Indus period at Mehrgarh and Nausharo.

| | **Aceramic Neolithic** | **Ancient Chalcolithic** | **Recent Chalcolithic Pre-Indus period** | **Indus periods** |
|---|---|---|---|---|
| **Sites/periods** | **MR period I** | **MR period III** | **MR period VII-NS period I** | **NS periods II-IV** |
| Beads | 10 steatite<br>1 shell<br>4 calcite<br>2 turquoise | 1 steatite<br>2 lapis-lazuli<br>2 carnelian<br>1 garnet | 1 serpentine<br>1 calcite<br>1 turquoise<br>2 carnelian | 1 calcite<br>1 limestone<br>2 carnelian |
| **Total** | 17 | 6 | 5 | 4 |

*Fig. 2.* Composition of the beads sampling studied by scanning electron microscope.

preservation resin. So, if the sampling has been chosen to be as representative as possible of different materials and periods, this representativity is nevertheless limited by the moulding constraints on the one hand, and by the available data on the other hand.

The micro-trace analysis of the drill-holes was carried out with the SEM Philips of the Centre de Recherche et de Restauration des Musées de France. Indeed, this SEM has the following advantage: Pressure in the chamber can be adjusted between 0,1 and 0,5 mbar in order to observe directly small objects (till about 15 cm), in particular small objects made out of materials with a very low conductivity, without any treatment (i. e. without metallization to improve their conduction). It makes it possible in particular to observe materials such as bone, ivory, wood or lithic material. Coupled with the X-Ray EDS system for chemical analyses, this SEM gives thus the possibility to have the best possible observations and the chemical composition without doing any damage to archaeological objects.

The sampling studied till now includes 32 beads (fig. 2), of which the drill-holes could be directly studied when the beads were broken; or they were studied indirectly from a silicon impression. The following results are based both on the sampling data and on complementary data provided by visual observations of the whole assemblage of the Mehrgarh and Nausharo beads.

## Results

Based on the general shape, on the surface aspects of the interior walls and on the traces left by the tools used, four main types of perforations have been distinguished, each of them including one or several different patterns according to the operations achieved.

### *First type (fig. 3)*

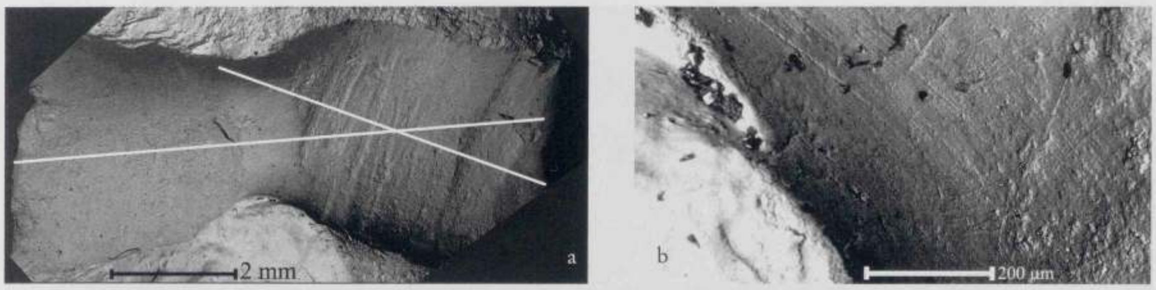
The first type of perforation implies that drilling was carried out from the two opposite sides by rotary grinding, with a conical borer-tip. This borer could also have been driven by a hand rotary motion, at least in several cases belonging to this type. The different features that determine this type are the following:

- A biconical profile with a narrowing at the centre, that is to say at the joining area of the two opposite holes,
- Irregular grinding rings on the inner walls of each opposite hole (fig. 3, 1–3); these circular grooves are not only of variable depth and distance but sometimes they overlap each other and they are not parallel, except in a few cases.

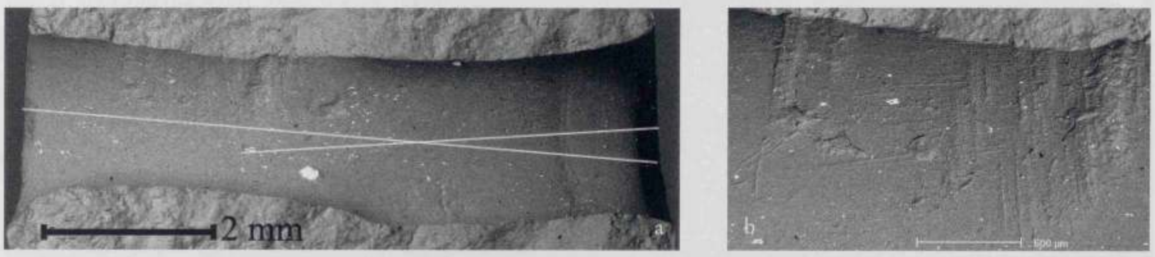
Furthermore, the opposite drilling-axes are often asymmetric and quite oblique. In several cases, the drilling has even been performed from each of the two ends in several steps (fig. 3, 3) with, each time, a change of the direction of the tool, which implies discontinuous movements.

According to the way the perforation was or was not restarted in a last step, three patterns can be distinguished:

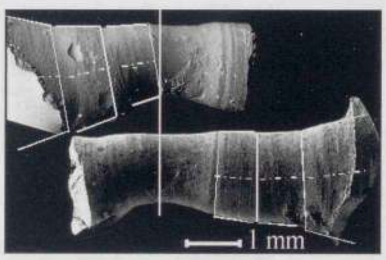
a) The first pattern is characterized by a restarting of the drill-hole centre. Indeed, longitudinal lines can be noticed at the junction of the two



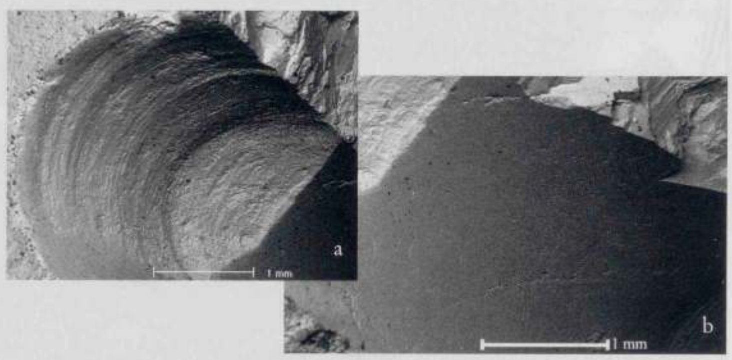

1 – Calcite, Neolithic period I. Type 1: 1st pattern (a: white lines = drilling axes; b: detail of the restarting by linear filing at the centre (junction of the two opposite drill-holes).



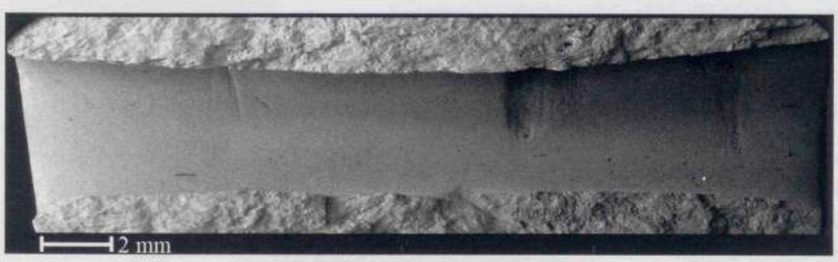

2 – Steatite, Neolithic period I. Type 1: 2nd pattern (a: white lines = drilling axes; b: detail of the left drill-hole with irregular grinding rings and linear striae due to a restarting of drilling by filing in a last step).



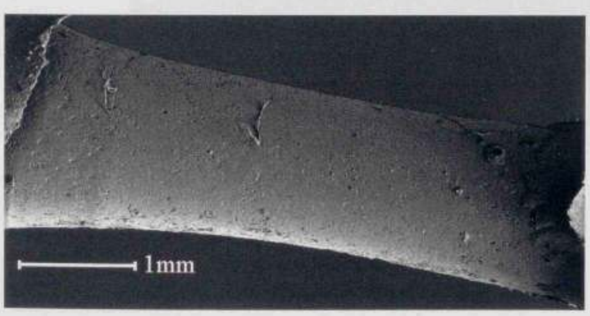

3 – Turquoise, Neolithic period I. Type 1: 1st pattern (moulding, white lines = drilling axes).




4 – Calcite, Neolithic period I. Type 1: 2nd pattern showing a very strong obliquity of the two opposite drilling-axes (a: detail of the left drill-hole; b: detail of the drill-hole centre from the right side).

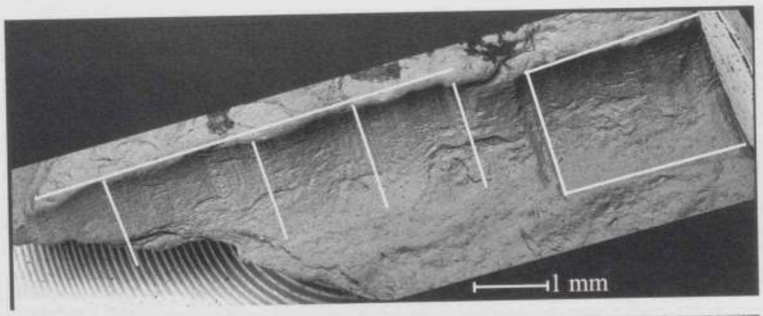



5 – Calcite, Neolithic period I. Type 1: 2nd pattern (erasing of the grinding rings excepted the deeper ones by a complete restarting by linear filing).

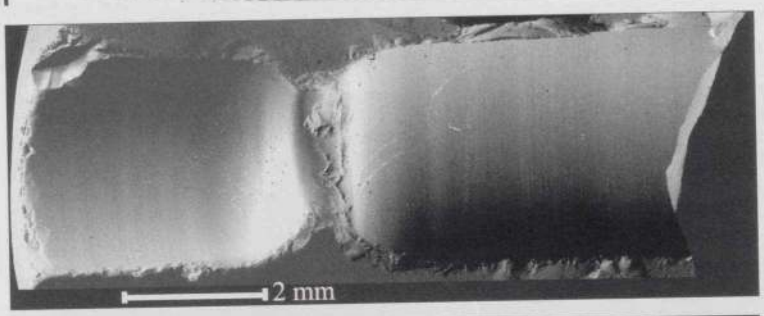



6 – Turquoise, Neolithic period I (moulding). Type 1: 3rd pattern (?, ambiguous case).

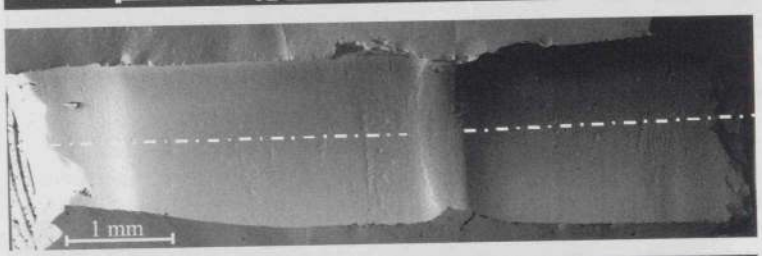
*Fig. 3.* Examples of the first type of perforation. From original pictures (SEM): J. Rodière.



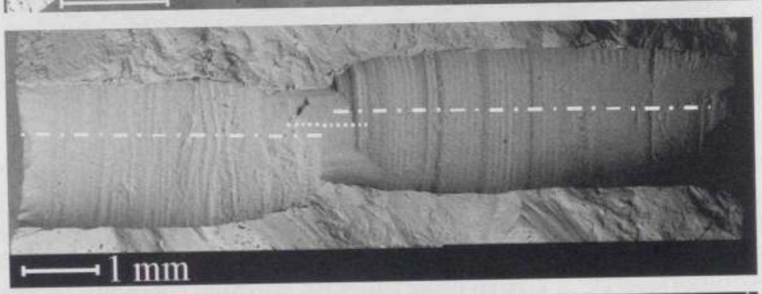

1 – Steatite, Chalcolithic MR period III. Type 2: 1st pattern (from the left side): perforation in at least four steps.



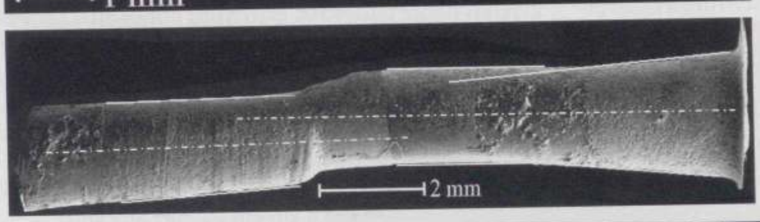

2 – Carnelian, Chalcolithic MR period III. Type 2: 1st pattern.



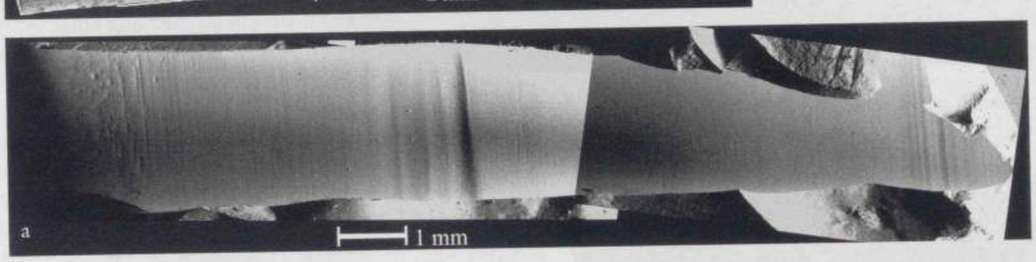

3 – Carnelian, Pre-Indus MR period VII. Type 2: 1st pattern.

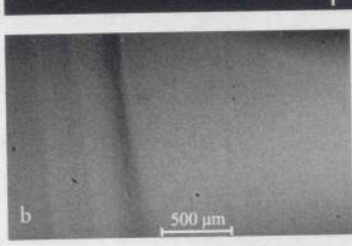



4 – Serpentine, Pre-Indus NS period I. Type 2: 1st pattern.



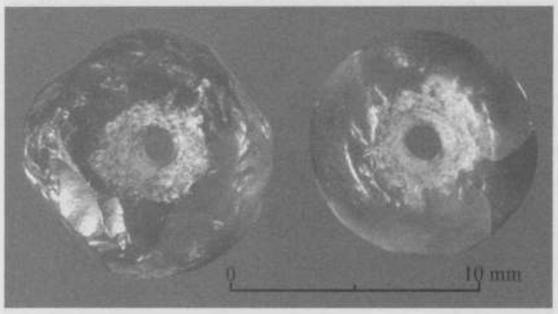

5 – Limestone, Indus NS period III. Type: 2nd pattern.



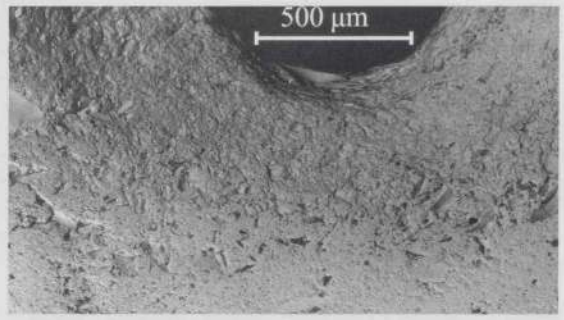




6 – Carnelian Pre-Indus NS period VII. Type 2: 2nd pattern (a: complete drill-hole; b: detail of the furrow at the junction of the two opposite holes).

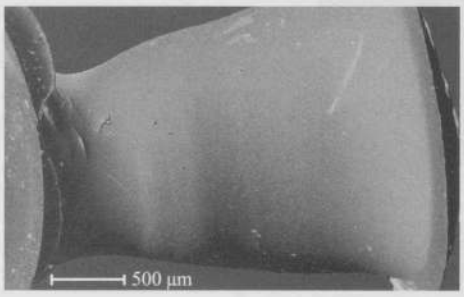
*Fig. 4.* Examples of the second type of perforation. From original pictures (SEM): J. Rodière.



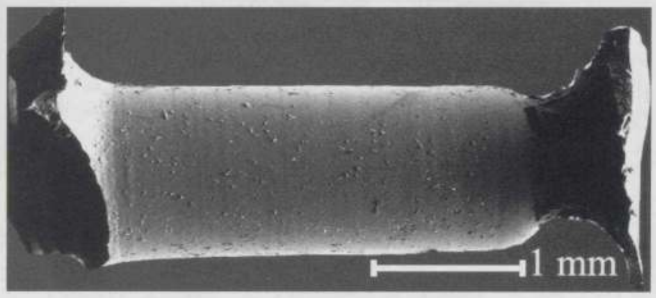

1– Carnelian, Indus period NS III (on the left) & Pre-Indus period NS I (on the right). Type 3: pecking technique.



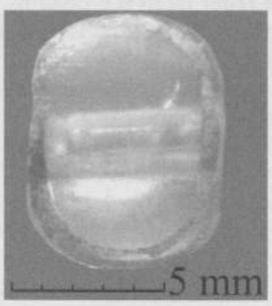

2 – Garnet, Chalcolithic MR period III. Type 3: detail of the surface.




3 – Carnelian, Chalcolithic MR period III (moulding). Type 4: pecking technique from the left side, rotary grinding from the opposite side.




4 – Carnelian, Pre-Indus NS period I (moulding). Type 4: rotary grinding from the left side, pecking from the opposite side.

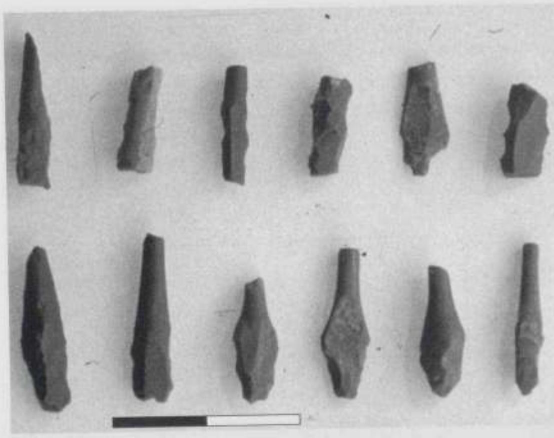



5 – Carnelian, Indus NS period III. Other example of the Type 4 perforation.

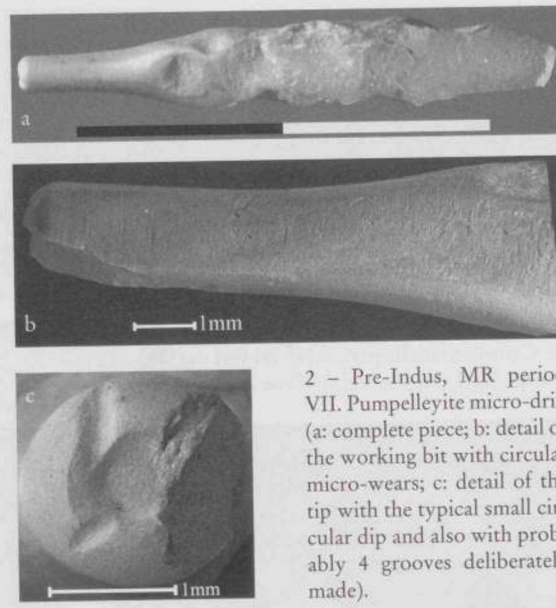
*Fig. 5.* Examples of the third and fourth types of perforation. From original pictures: B. de Saizieu (1, 5) et J. Rodière (SEM, 2–4).

opposite holes (fig. 3, 1. 3). These linear striae are characteristic of a filing, i. e. of a local restarting of drilling by linear grinding. This filing was probably intended to widen the typical central narrowing due to a bipolar and biconical drilling, and, therefore, to connect the hole-extremities best. This pattern is represented mainly in Neolithic beads (calcite, steatite, turquoise) and also by two Chalcolithic beads made of lapis lazuli.

b) The second pattern is different from the first one by the presence of longitudinal lines not only at the centre, but also all along, or nearly all along, the walls (fig. 3, 2. 4–5). As shown by several examples, these longitudinal lines which indicate a complete or quasi-complete restarting of drilling by filing, tend to erase the characteristics of the first steps of drilling, i. e. the traces of the rotary grinding. Sometimes, the drill-hole may appear different at first sight with its very regular outline without any discontinuity at the centre, but in fact this regularity and this continuity are only the result of a complete restarting by linear filing which has completely erased the traces of the rotary grinding, excepted the deeper ones (fig. 3, 5). These few remaining circular grooves are rather interwoven and irregular. They thus allow us to suggest that the complete restarting by filing was probably intended to even and to smooth the walls of drill-holes appearing to be too irregular. In other cases, the longitudinal filing was probably carried out to correct the too strong obliquity of the opposite drilling axes (fig. 3, 4). Owing to this obliquity, the two opposite conical holes can then be very badly connected: they formed too marked an "elbow" or maybe they did not meet at all. This 2nd pattern has been observed until now exclusively on Neolithic



1 – Chalcolithic, MR period III. Green stones micro-drills. One of them (1st rank at the extreme right) has been identified as Pumpelleyite.




2 – Pre-Indus, MR period VII. Pumpelleyite micro-drill (a: complete piece; b: detail of the working bit with circular micro-wears; c: detail of the tip with the typical small circular dip and also with probably 4 grooves deliberately made).

*Fig. 6.* Green stones drills. From original pictures: C. Jarrige (1), D. Bagault, CRRMF (2a) et J. Rodière (SEM, 2b–c).

beads, and more particularly, on soft stone beads: calcite and steatite, of whatever shapes and sizes.

c) A third pattern is yet observed, which is up to now represented by one example only; it has been drilled in a turquoise bead in the Neolithic Period (fig. 3, 6). The drill-hole of this bead was apparently performed exclusively by rotary grinding without restarting by filing. However, the traces observed on the drill-hole moulding are here extremely difficult to characterize because this bead has been covered with a paraloid preservation resin when it was found. So, one cannot determine exactly to which drilling technique it corresponds. One can only mention that if this bead represents a different drilling technique than the bead samples studied, it appears to be an exception compared to the other drill-holes of the Neolithic Period.

Except this singular pattern, all the features that characterize the first type of perforation, whether the first or the second pattern, involve very likely a drilling achieved by a hand rotary grinding, maybe by mechanical rotary grinding in a few cases according to the greater regularity observed, but in any case, a low and discontinuous rotary motion (with changes of direction) was involved.

### *Second type (fig. 4)*

The second type of perforation corresponds to a drilling technique, which was performed by rotary grinding from the two opposite ends but with a quasi-cylindrical borer-tip driven by a mechanical motion. The characteristics, which determine this type, are as follows:

- A cylindrical or near cylindrical profile, i. e. sometimes a very slight taper from the opening to the centre, with a more or less clear narrowing or discontinuity at the drill-hole centre,
- Regular grinding rings on the inner walls of each opposite hole; these rings may be of variable depth and distance but are always parallel to each other. This indicates complete rotation movements and therefore a drilling carried out by a continuous or at least by series of continuous rotations. Indeed, the series of parallel circular grooves or lines can be either continuous all along the walls, or discontinuous and alternating with smooth areas. In this latter case, it shows very well the drilling from one side or from both sides in several steps by series of continuous rotary motions (fig. 4, 1).

At last, the opposite drilling-axes are more symmetrical than those of the first type of perforation. They are always parallel, in spite of a slight misalignment in some cases (fig. 4, 4–5). Two different patterns can also be distinguished depending on whether or not the drilling was restarted in a later step.

a) In the first pattern, the presence of longitudinal lines at the junction of the two opposite holes reveals a restarting of the perforation by filing. However, this filing remains limited to the central part of the boring. It could have been intended either to break through the joining point of the two opposite holes (fig. 4, 2–3) or else to widen the central boring (fig. 4, 4).

*Fig. 7.* Drilling techniques of small carnelian ring-beads from the Neolithic to the Indus periods.

| Sites/Periods | Perforation of small carnelian rings : techniques used | | | TOTAL |
|---|---|---|---|---|
| | Pecking | Rotary grinding | Mixed technique | |
| MR period I | 4 | | | 4 |
| MR period II | 1 | | | 1 |
| **MR period III** | 6 | **<u>10</u>** | 1 | 17 |
| MR period IV-V | | 2 | | 2 |
| MR period VI-VII | **<u>23</u>** | 1 | | 24 |
| NS I (Pre-Indus) | 4 | | | 4 |
| NS II-IV (Indus) | 14 | | | 14 |

*Fig. 8.* Types of perforation along time (h.: hardness on the Mohs scale).

| **Periods**<br>**Perforation types** | **Neolithic** | **Ancient Chalcolithic** | **RecentChalcolithic /Pre-Indus** | **Indus** |
|---|---|---|---|---|
| **1 : hand(?) rotary grinding** | For all the materials (h.<7) whatever shapes and sizes<br>⇓<br>**T.1 : DOMINANT** | For materials (h.<7) whatever shapes and sizes but not all of them<br>⇓<br>**T.1 : DECREASE** | No use ? | No use |
| **2 : mechanical rotary grinding** | No use | For materials (h.>7 & <7) whatever shapes and sizes<br>⇓<br>**T.2 : NEW TECHNIQUE** | For all the materials (h.>7 & < 7) whatever shapes, excepted the small carnelian rings<br>⇓<br>**T.2 : DOMINANT** | Idem<br>⇓<br>**T.2 : DOMINANT** |
| **3 : pecking** | For carnelian (h.>7) used exclusively in the shape of small rings | For a few carnelian rings only<br>⇓<br>**T.3 : DECREASE** | For all the small carnelian rings<br>⇓<br>**T.3 : SPECIFIC** | Idem<br>⇓<br>**T.3 : SPECIFIC** |
| **4 : mixed technique** | | Rare : 1 case (carnelian) | Rare: 1 case (carnelian) | Rare: 6 cases (carnelian) |

b) The second pattern is characterized by drill-holes, which have not been restarted by filing. The junction of the two opposite holes is only marked by a narrowing, a slight shift (fig. 4, 5) or a deep groove, in fact a kind of furrow (fig. 4, 6).

Whether the 1st or 2nd pattern was present, this type of perforation concerns soft stone beads, such as serpentine or calcite, as well as the hard stone beads, such as carnelian, but it appears only during the Early Chalcolithic Period, i. e. Period III of Mehrgarh, at the same time as the first "long" carnelian beads (i. e. carnelian beads whose length is longer than their diameter).

## *Third type (fig. 5, 1–2)*

The third type of perforation determines the pecking technique. It is characterized by conical holes, carried out from both ends. On these conical walls, a series of small cavities and conchoidal fractures or scars are observed (fig. 5, 2). Now well known, this pecking technique corresponds to a hand-perforation, exclusively applied on small hard stone beads. These beads correspond to ring-beads whose length is smaller than their diameter and varies between approximately 2 and 8 mm (fig. 5, 1). Thus, this technique concerns all carnelian beads from the Neolithic Period, which are then exclusively small rings-beads (fig. 7) and from the Early Chalcolithic Period, a few small carnelian rings only and garnet beads. One should note here that, in this Early Chalcolithic Period, garnet, a harder mineral than carnelian, is not only as rare as the carnelian was in the Neolithic Period, but also that it was used exclusively for small ring-shaped beads similar to the Neolithic carnelian beads. One should also note the following specific features: during the Chalcolithic (Period III of Mehrgarh), with the adaptation of the perforation technique by rotary grinding to carnelian which made the production of "long" carnelian beads possible, only a few small carnelian rings were still perforated by pecking (fig. 7), while most beads were drilled in the same technique as the long ones. During the following periods, the pecking technique was still used for the small carnelian ring beads, with only one exception (fig. 7).

## *Fourth type (fig. 5, 3–5)*

The fourth and last type of perforation is characterized by the association of the two techniques. It still corresponds to a bipolar perforation, but while one side was perforated by pecking, the other side was drilled by rotation. This type, as the third one, concerns exclusively small carnelian beads, but not only ring-beads. It appears, as the second type, from the Early Chalcolithic Period onwards, that is Period III of Mehrgarh. This mixed technique, however, remains rare. One single example is noted for the Early Chalcolithic (fig. 5, 3), another one for the Pre-Indus Period of Nausharo (fig. 5, 4), and six examples for the Indus Period (fig. 5, 5). Among these eight beads, one could notice the following and common feature: the hole drilled from one side by rotary grinding is the longer one, it goes through almost the whole length of the bead, while the pecking carried out from the opposite side, as we can expect, was done on a tiny length. This can be confused, at first sight, with a unipolar drilling. Unfortunately one cannot determine from which side the drilling was begun, i. e. whether the pecking technique was used as the last step to finish the drill-hole carried out by rotary grinding from the opposite side, or the opposite way around.

Concerning the drill-hole performed by rotary grinding, the shape is different between the Chalcolithic example, which has a conical profile (fig. 5, 3) and the other pieces, which have a cylindrical profile (fig. 5, 4–5). This difference seems to be due to the shape of the tool used rather than to the motion involved. Indeed, in all cases, the thinness and the extreme regularity of the grinding rings found on the walls indicate a drilling carried out by a continuous rotary movement, or at least by a regular speed and precise alternative movements.

## Résumé and Interpretation

Thus, in summary, four main types of perforations were distinguished on the basis of the techniques (pecking or rotary grinding) and the motion powers (hand or mechanical) applied for drilling. Each type implies the use of different devices and tools.

The perforations performed by pecking were most likely made by a stone-tool, probably made of flint, as demonstrated by Chevalier/Inizan/Tixier (1982). This tool did apparently not vary a lot through time, as shown by the perforations of the small carnelian beads from the Neolithic to the Indus Periods: whatever the period, the characteristics of these perforations remain the same (same shape, same surface aspects, same size).

As for type 1 and type 2, they imply, as we have already suggested, different motion powers, that is a hand-power for the type 1, or at least for most of the examples belonging to this type[4], and a mechanical power, driven by a bow or a pump drill for example, for the type 2. The differences in shapes also imply different tools.

For type 1, whose drill-holes have a biconical shape, we may suppose the use of stone-drills, and more particularly of flint tools.

Indeed: 1) Flint borers are numerous, in particular during the Neolithic Periods, and they are represented by a rather great variety of shapes, in particular as for the length and the taper of the tip (Lechevallier 2004).

2) Previous studies have shown that flint, that has a hardness of 7 on the Moh's scale, can easily drill stones that are less hard (Gwinnet/Gorelick 1981, 1987, 1990).

3) At Mehrgarh, borings of type 1 were found only with beads whose hardness is up to 6 on the Moh's scale.

So, for these different reasons, flint borers seem to be the best adapted tools for type 1 borings.

As for type 2, whose drill-holes have a quasi-cylindrical shape, it involves the use of tools with quite long and cylindrical, or very slightly tapering drill-heads.

The best candidates could be the new stone drills, which appear from the Early Chalcolithic Period onwards (fig. 6, 1). These are the famous green stone drills, now well known since the works of Piperno (1973, 1976, 1983) and named "tapered cylindrical drills" in the typology developed by Kenoyer/Vidale (1992).

Indeed, they differ from the flint borers through their particular shape (Piperno 1973, 1976, 1983) and mineralogy. The material, from which they were made, was often wrongly named phtanite. According to the mineralogical analysis carried out on one example from the Early Chalcolithic Period, the mineral used is Pumpelleyite, whose hardness is the same as flint, 7 on Moh's scale. Unfortunately, we do not know the exact properties of this mineral but it should very likely have better perforating qualities than flint and a better efficiency, in particular with chalcedony seeing that the first carnelian beads pierced by rotary grinding, and therefore the first "long" carnelian beads, appear at the same time as these new drills and as the perforations of type 2.

Furthermore, it has been shown that these borers, when driven by a mechanical device such as a bow drill, can drill both soft stones and hard stones, and in particular drill hard stones with a drill-tip which was already used for softer materials and which has become cylindrical, thus, the sides of these drill-tips are no longer jagged but rounded (Kenoyer/Vidale 1992).

One of these borers has been more specifically studied (fig. 6, 2 a). It belongs to Mehrgarh Period VII (Late Chalcolithic/Pre-Indus). The mineral is also Pumpelleyite. The cylindrical shape and the micro-wears of the bit attest its use (fig. 6, 2 a–b). The bit shows circular micro-wears up to about 4 mm from the leading edge and a diameter along the used part (along 4 mm), which varies between 2,1 to 3 mm. This is quite compatible with the diameter of some cylindrical drill-holes. If the shape observed today is a result of its wear, it is also the result of a voluntary modification, as shown by its tip. The studied sample has, in fact, not only the small circular dip, intended to increase both the cutting

[4] If a hand motion power seems evident for most of the examples studied till now, which illustrate type 1, however, one can ask oneself whether a mechanical motion power was not used for a few biconical drill-holes of type 1, at least among the most regular ones, and in particular for the drill-hole of the turquoise bead which illustrates here the third pattern distinguished. But in all cases, if a mechanical power was used for some drill-holes belonging to type 1 borings, this power implies slow rotary motions, even very likely irregular and discontinuous motions, which are completely different from those produced by the motion power used for the type 2 borings.

angle of the tip and the tensile strength after several uses, but it also has three, probably even four deep and oblique grooves made deliberately around the small dip (fig. 6, 2 c). These oblique grooves were all made in the same direction, i. e. they turn clock wise around the small dip to the way of spiral arms, to allow the abrasive powder to run out of the border. Till now this feature was never observed with this kind of tool in the pre-Indus or Indus Period, but it reveals once again the ingenuity of the Indus craftsmen.

Concerning the question whether or not an abrasive was used, even though this is not the subject here, attention must be drawn to the fact that, whether type 1 or type 2 perforations, as the drilling proceeds, the drilled material itself is reduced to finer and finer particles which themselves act as an abrasive. Thus, the material itself can constitute its own abrasive; therefore the use of other abrasives is not absolutely necessary. According to this self-abrasive property, one should also notice that the harder the material drilled, the higher is its abrasive power and, therefore, the thinner will the grinding rings be.

This leads us to suppose that the differences observed between grooves and thin lines may not necessarily be due to the use of different tools, i. e. of tools made of materials of different hardness (stones or copper, for example, with the addition of an external abrasive), but to the hardness of the drilled material itself.

Whatever type of perforations was carried out by rotary grinding, i. e. type 1 or type 2, the softer the material is, the deeper and more visible the grinding rings are (fig. 3, 1. 4 a; 4, 1. 4) and, on the opposite, the harder the material, the thinner the grinding rings are (fig. 4, 2. 3. 6). These rings are sometimes so thin that they cannot be detected by the naked eye.

## Conclusion

Even though the results presented here are still preliminary, they allow us to observe the following evolution:

In the Neolithic Period, two types of perforations are practised: type 1 and type 3. Type 1 was used for all materials, whatever shapes, except for carnelian, while type 3, on the contrary, concerns exclusively the small carnelian beads (fig. 8). Type 1 appears to be the predominant technique.

In the Early Chalcolithic Period, the four main types of perforation defined here are observed. Type 1 keeps on being used for beads made of materials up to 6 on the Moh's scale, but not for all of them. Type 2 appears with the first long carnelian beads, but was also used with softer materials and for most of the small carnelian beads. Type 3 is limited to a few small hard stone beads. Type 4, finally, which is only a combination type 2 and 3 borings, remains exceptional and is only used for small carnelian beads.

During the Late Chalcolithic or pre-Indus Period, type 1 types seem to have disappeared. Type 2 then appears as the dominant technique, used for all the materials whatever their shape, with the exception of the small carnelian ring-beads. Type 3 drillings are frequently used for these beads and even become specific for all small carnelian beads. Type 4 remains as rare as during the previous period. One could probably say that type 2 was improved, according to the increasing length of the hard stone beads (cf. fig. 1).

During the Indus Period, the variability of drilling techniques is very similar to the Pre-Indus times, even though the type 2 boring was probably improved again, in particular with the emergence of a new stone drill adapted to the production of the very long carnelian beads (Kenoyer/Vidale 1992; Sela/Roux 2000).

This variability of drilling techniques through time implies constraints of materials and shapes. In particular, it explains why carnelian was only used in the shape of small rings in Neolithic times but was knapped in various and longer and longer shapes from the Chalcolithic to the Indus Periods. However, one wonders whether the innovation implied by type 2 boring led to the demand and manufacture for ever longer beads or, in the opposite, if the demand for longer beads led to the technical innovations. Very likely, the evolution observed is the result of reciprocal interactions between technical and cultural factors.

Indeed, besides constraints of materials and shapes, the variability of perforations observed could also reflect cultural choices, as shown for example by the exclusive use of type 3 borings for all small hard stone beads from the Pre-Indus Period onwards. One may ask oneself, why these small beads were not drilled by type 2 borings, which was used for most of them during the previous Chalcolithic Period, and as it was the case for the long beads. What does this technical difference between small and long carnelian beads mean? As it cannot be explained by material constraints, one may suppose a socio-economical factor related to the emergence of a specialized craftsmanship, or/and a cultural factor that attributed different values to long and to small beads (Roux 2000). The analysis of a larger sample of beads, associated with some experimentations and the micro-wear analysis of stone drills, would, however, be necessary to improve these first results.

## Acknowledgements

We would like to thank Anne Bouquillon from the CRRMF and Valentine Roux (UMR 7055, CNRS) for their helpful remarks, their constructive critiques and their encouragements.

Bibliography

Barthélemy de Saizieu, B.
2004 Les Perles et Pendentifs de Mehrgarh. Monographie. Fouilles 1974–1985. Paris.

Barthélemy de Saizieu, B./Bouquillon, A.
1994 Steatite Working at Mehrgarh during the Neolithic and Chalcolithic Periods: quantitative distribution, characterisation of material and manufacturing processes. In: Parpola, A./Koskikallio, P. (eds.), South Asian Archaeology 1993. Helsinki, 47–59.
1997 Evolution of Glazed Materials from the Chalcolithic to the Indus Period Based on the Data of Mehrgarh and Nausharo. In: Allchin, B. (ed.), South Asian Archaeology 1995. Cambridge, 63–76.

Beck, H. C.
1940 Report on Selected Beads from Harappa. In: Vats, M. S. (ed.), Excavations at Harappa. New-Delhi, 392–431.

Bouquillon, A./Barthélemy de Saizieu, B.
1995 Glazed Steatite Beads from Mehrgarh and Nausharo (Indus Valley). In: Druzig, J./Vandiver, P. (eds.), Materials Issues in Art and Archaeology. Materials Research Society Symposium Proceedings, vol. 352. Pittsburg, 527–538.

Chevalier, J./Inizan, M. L./Tixier, J.
1982 Une technique de perforation par percussion de perles en cornaline (Larsa, Iraq). In: Paléorient 8/2, 55–65.

Gorelick, L./Gwinnet, A. J.
1981 The Origin and Development of the Ancient Near Eastern Cylinder Seal. In: Expedition 23/4, 17–30.
1983 Ancient Egyptian Stone-Drilling. In: Expedition 25/3, 40–47.
1989 "Collars" in the Holes of Near Eastern Cylinder Seals. In: Archeomaterials 3, 39–46.
1990 Innovative Lapidary Craft Techniques in Neolithic Jarmo. In: Archeomaterials 4, 25–32.

Gwinnet, A. J./Gorelick, L.
1979 Ancient Lapidary. In: Expedition 22/1, 17–32.
1981 Beadmaking in Iran in the Early Bronze Age. In: Expedition 24/1, 10–23.
1987 The Change from Stone Drills to Copper Drills in Mesopotamia. In: Expedition 29/3, 15–24.

Jarrige, J.-F.
1996 Les fouilles de Nausharo au Balochistan pakistanais et leur contribution à l'étude de la civilisation de l'Indus. In: Académie des inscriptions et belles-lettres, Comtes rendus des séances de l'année 1996. Paris, 821–878.

Kenoyer, J. M.
1997 Trade and technology of the Indus Valley: new insights from Harappa, Pakistan. In: World Archaeology 29/2, 262–280.
in press Bead Technologies at Harappa, 3300–1900 B.C.: A comparative summary. In: Jarrige, C. (ed.), South Asian Archaeology 2001. Paris.

Kenoyer, J. M./Vidale, M.
1992 A new look at stone drills of the Indus Valley Tradition. In: Vandiver, P./Druzik, J./Wheeler, G./Freestone, I. (eds.), Materials Issues in Art and Archaeology III. Materials Research Society Symposium Proceedings, vol. 67, 495–518.

Lechevallier, M.
2004 L'industrie lithique de Mehrgarh. Fouilles 1974–1985. Paris.

Mackay, E.
1937 Bead Making in Ancient Sind. In: Journal of American Oriental Studies 57, 1–17.
1943 Chanhu-Daro Excavations 1935–36. New Haven.

Piperno, M.
1973 Micro-Drilling at Shahr-i Sokhta; the making and use of the lithic drill-heads. In: Hammond, N. (ed.), South Asian Archaeology 1971. London, 120–129.
1976 Grave 77 at Shahr-i Sokhta: Further Evidence of Technological Specialization in the 3rd Millennium B. C. In: East and West 26/1–2, 9–12.
1983 Bead-Making and Boring Techniques in 3rd Millennium Indo-Iran. In: Tosi, M. (ed.), Prehistoric Sistan. Reports and Memoirs vol. XIX/1. Rome, 319–325.

Possehl, G. L.
1981 Cambay Beadmaking. In: Expedition 23/4, 39–47.

Roux, V.
2000 Cornaline de l'Inde. Des pratiques techniques de Cambay aux techno-systèmes de l'Indus. Paris.

Sela, A./Roux, V.
2000 La perforation des perles en calcédoines: approche mécanique des techniques harappéennes. In: Roux, V. (ed.), Cornaline de l'Inde. Des pratiques techniques de Cambay aux techno-systèmes de l'Indus. Paris, 171–204.