

Ostrich eggshell beads: hole drilling technology at Little Muck Shelter, South Africa

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Abstract:

Ostrich eggshell beads (OES) are commonly found in forager sites across sub-Saharan Africa. Although they have received a reasonable amount of investigation, the drilling technology used to perforate OES beads has received little attention. As a result, not much is known about this technology. Providing a basic tool form for these drills could be useful for future researchers to identify such tools in assemblages, or to prompt revisiting older assemblages to identify these types of tools, which might have been overlooked or misidentified. This study made use of experimentation and use-wear to determine the types and shapes of materials most effective for perforating OES. It was determined that early foragers most likely used micro-lithic drills made from small, but thick, flake blanks that were retouched along the laterals to create a near symmetrical point with a tetrahedral tip. At Little Muck Shelter the base of the flake was also shaped to resemble a tang that likely aided hafting. This tool form can act as a basis to help researchers identify similar technology which can be studied and help broaden our understanding of the complexity of forager technology.

Keywords: Drills, Ostrich eggshell beads, Use-wear, Little Muck Shelter, southern Africa.

Highlights

- Materials used for drilling ostrich eggshell (OES).
- Shapes of drill tips used for OES drilling.
- Microlithic drill tool type.
- Drills used at Little Muck Shelter.

Introduction

There are many traits that define modern human behaviour (McBrearty and Brooks 2000), one of them being the use of personal ornamentation. The earliest known personal ornamentation (and possibly trade) was made from marine shells (*Nassarius kraussianus*) during the Middle Stone Age (MSA) at Blombos cave, South Africa, roughly dating between 75 and 78ka (d'Errico *et al.* 2005). This was determined with morphometric, taphonomic, microscopic and experimental analyses indicating that these shells were purposely perforated, strung up, and possibly worn (d'Errico *et al.* 2005; d'Errico *et al.* 2009; Vanhaeren *et al.* 2013; Hatton *et al.* 2020). Similar MSA marine shell beads made from *Afrolittorina africana* were found at Sibudu Cave, South Africa dating between 70 and 60ka (d'Errico *et al.* 2008) and at Border Cave (*Nassarius kraussianus*) dating to 42ka, alongside some of the earliest beads made from ostrich eggshell (OES) in South Africa (d'Errico *et al.* 2012). Archaeological discoveries to date indicate that OES bead technology originated in eastern Africa towards the end of the MSA and the beginning of the Later Stone Age (LSA) with the earliest OES beads found at Magubike Rockshelter, Tanzania, dating to roughly 50ka (Miller and Willoughby 2014) and later spreading southward into southern Africa (Miller and Wang 2022).

Most research conducted on OES beads focused on variation in bead styles (Miller 2019; Hatton *et al.* 2022), shapes (d'Errico *et al.* 2012), diameter (Miller and Sawchuk 2019), sizes (Jacobson 1987; Miller 2019) and manufacturing techniques (Kandel and Conard 2005; Orton 2008), as well as determining and understanding the movements of exchange networks across Africa in the past 50 000 years (Stewart *et al.* 2020; Miller and Wang 2022). However, very little research has been conducted on the technology used to perforate the shell, with mainly ethnographic accounts indicating that iron awls were used (Bleek 1928; Schapera 1930; Lee and DeVore 1976; Marshall 1976; Silberbauer 1981; Wingfield 2003; Hitchcock 2012). Nevertheless, before the introduction of iron, foragers would have had to make use of other tools to perforate OES pieces. The most likely candidates are drills made from lithics, however, lithic tools that resemble drills can and were often used for drilling a multitude of different materials (Coşkunsu 2008) and could be used in a variety of activities such as perforating (Coşkunsu 2008; Miller and Redmond 2016; Bates *et al.* 2022) and possibly engraving or etching. In addition, other materials not made from stone can be used for drilling shell, such as sea-lion whiskers or specific bones from swordfish, which were used with abrasives to drill holes into long thin tubular beads made from the Pismo clam (*Tivela stultorum*) at the

Californian coastal area (Arnold and Rachal 2002). Raymond *et al.* (2022) demonstrated that even cactus thorns (*Melocactus intortus*) could be used as drills for making perforations in harder materials such as stone. Therefore, isolating any drills that were used specifically to drill OES beads in an assemblage could be challenging. The aim of this study is to isolate the drills used for making OES beads at Little Muck Shelter (LMS), South Africa, by making use of experimentations and accompanying use-wear. The drilling technology at LMS will be described and discussed, which will be useful for identification of such drills in other assemblages and aid in identifying a more complete set of behaviour patterns and their respective technological indicators. Moreover, this study suggests a new tool type that had not been previously identified.

Drilling technology

The method for perforating earlier marine shells found in South Africa was tested by d'Errico *et al.* (2005) and they determined that the marine shells were likely perforated through the aperture with a sharpened bone point. Tátá *et al.* (2014) concluded that a similar technique for marine shell beads found in Portugal was used and so did Stiner *et al.* (2013) for marine beads found in Turkey, in that, a pointed bone or antler was either used with direct pressure or punched through from the internal aperture of the marine shell. It is theoretically possible to perforate an OES piece making use of pressure, punching, pecking, gouging, or scooping, however, these methods are not documented for OES beads and instead the vast majority show evidence of rotatory drilling (Werner and Miller 2018).

Drilling technology pertaining to shell bead making is not covered extensively and the research that has been conducted focusses instead on use-wear that develops on experimental drill bits (Yerkes 1983; Moss 1983; Stemp *et al.* 2009; Beyin 2010), the characteristics of the perforation on the bead (Werner and Miller 2018), and raw materials used for drills (Nigra and Arnold 2013). Little research is available on OES drill technology itself with the only accounts being ethnographic (Bleek 1928; Schapera 1930; Silberbauer 1981; Wingfield 2003; Hitchcock 2012), which describe the technology for the last few hundred years. Wingfield (2003:57) depicts the process of OES bead making at D'Kar in Botswana in detail describing the drill as “a long piece of wood with a nail-sized piece of flattened metal attached at one end”. The drill

is placed on the concave side of the shell piece and the drill is then rolled between the palms of the hands with some downward pressure.

The production of lithic drills was covered by [Nguyen and Clarkson \(2013\)](#) for a Late Neolithic site in Vietnam where flake blanks were specifically produced, usually similar in size, elongated and thick. The edges of the flake were pressure flaked to reduce the width along the edges till the tip of the tool resembled a tetrahedral or pyramidal point (such as in Figure 1A). Drills were “symmetrical in cross-section” thus “more resilient to breakage” ([Nguyen and Clarkson 2013:37](#)). However, the materials or activities the drills were used for was not determined, but the authors speculate that it might have been for drilling shell beads.

Drilling technology for stone bead creation has been discussed to a greater extent ([Gwinnett and Gorelick 1998](#); [Kenoyer 2003](#); [Coşkunsu 2008](#); [Wright *et al.* 2008](#); [Shoda *et al.* 2013](#); [Prabhakar 2016](#); [Raymond *et al.* 2022](#)). Various types of drills used in Europe and Asia for stone beads from the Palaeolithic to present day were outlined by [Gwinnett and Gorelick \(1998\)](#). They made use of silicone impressions from stone beads as well as their own experiments to determine what type of tool was used to drill the holes. They made use of a variety of drills, abrasives, and lubricants to determine distinct hole shapes, grooves, and marks for comparison to the archaeological beads. Drills from the Mesolithic period in Asia (12 000 BCE) were microliths made from flint and probably hafted due to their size. These drills were polyhedral in shape (Figure 1A) with the lateral edges acting as cutting edges. Drills from the Neolithic (8 000 - 4 000 BCE) show a change towards grinding and the use of abrasives (Figure 1B). Harder rock was eventually used as drills and abrasives, such as ernestite, which is harder than 7 on the Mohr scale and is harder than most silica-based rock often used for the beads ([Kenoyer 2003](#); [Prabhakar 2016](#)). Around 4 000 BCE. the first introduction of metal appears with copper rods that were used together with abrasives to drill holes into stone beads. Copper was likely used due to its malleability which would allow for easier shaping of drills, and it could embed and hold abrasives during the drilling process ([Gwinnett and Gorelick 1998](#)). A shift towards iron rods with polyhedral shapes was made during the iron age.

Even though metal is present at LMS, no awls or pointed pieces have been recovered and are mainly part of bangles. In addition, no metal is present in layers dominated with OES beads. It is thus clear that foragers made use of something else to drill the apertures of OES beads.

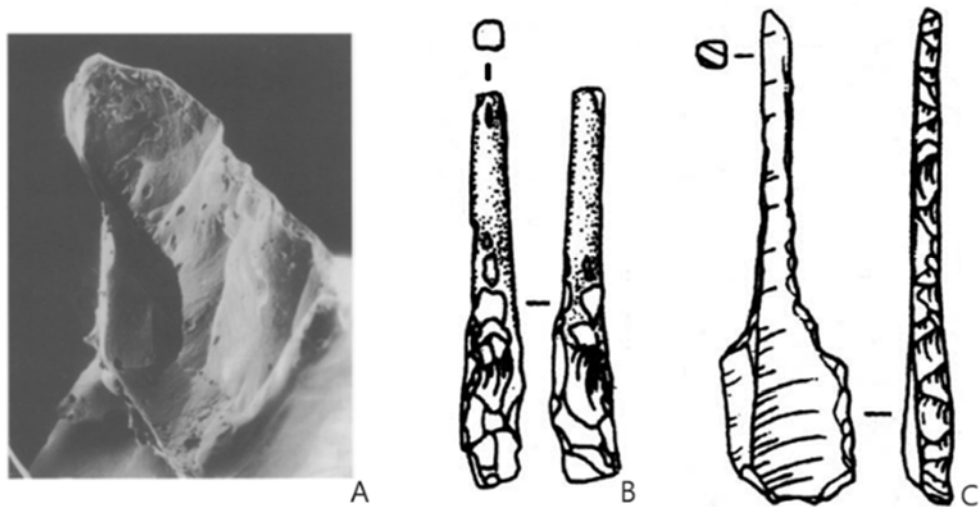


Figure 1: Examples of lithic drills and perforators. A: Micrograph of a flint microlith showing a polyhedral shaped tip with cutting edges; B: Flint drill used with abrasives to drill stone; C: Perforator made from a burin. Adapted from A: [Gwinnett and Gorelick \(1998:52\)](#) and B, C: [Coşkunsu \(2008:28\)](#).

Little Muck Shelter

Little Muck Shelter (LMS) is situated in a sandstone ridge in the Limpopo Valley, South Africa. The shelter has a steep ceiling that drops down into a recess providing a decent amount of shelter from the outside elements. Surrounding this area is exposed bedrock upon which are engraved hollows, grooves, cupules, and gaming boards. The shelter's backwall contains numerous paintings produced by foragers that include giraffe, elephants, antelope, and human figures, and there is a rich archaeological deposit from forager and farmer uses from the final centuries BC until the 19th century CE. The site was first occupied by Later Stone Age foragers a few hundred years before IA farmers migrated to the area from approximately 200 BCE, followed by a contact period with early Happy Rest Iron Age farmers migrating to the area (350–900 CE). The most intensive period of occupation at the site happened between 900 and 1000CE (Zhizo) before the sequence shows a decline in LSA artefacts. The site was then likely appropriated by farmer and or herder communities around 1000-1300CE (K2/Mapungubwe) for boys' initiation ([Hall and Smith 2000](#)) with the occasional activity from foragers still present ([Forssman et al. 2023](#)). The first excavations were led by [Hall and Smith \(2000\)](#) in 1998 who showed a tightly controlled series of changes at the site that included a notable increase in scrapers from the moment of contact with farmers. The site was later re-excavated by the

Hunter-Gatherer Archaeological Research Project (HARP) who conducted excavations from 2020 till 2023. The most abundant tools at LMS are scrapers, which were studied by [Sherwood and Forssman \(2023\)](#) who confirmed a change in forager activities at the site after contact with Iron Age farmers as suggested by [Hall and Smith \(2000\)](#). The site also has a sizable number of OES debris and beads, which is visible throughout its occupational sequence (200BCE-1300CE). Despite the numerous beads, drills have not yet been identified at the site even though all stages of bead manufacturing are present, hence the reason for this study.

Methodology

To determine how OES drills might be present, two sets of experiments were conducted. The first set was to determine what materials and what forms of such materials work best for drilling holes into OES pieces. Set 2 comprised of experimental stone drills used to create apertures in 200 OES pieces to test the effectiveness of two different pathways used to create OES beads for another research paper ([Sherwood and Forssman in preparation](#)).

Experiments: set 1

Six different materials were used for drilling OES beads, varying from soft to hard, to test their effectiveness. Effectiveness here refers to a drill's ability to perforate an OES piece. All drill tips were hafted into a handle to help with control and grip of the tool, as drill tips can be quite small and would be difficult to manipulate effectively if only gripping them with fingertips. Steel was used to represent iron (metal), which was difficult to source in pure form, but commonly used in the last few hundred years. Most importantly it represents the upper hardness control. Three steel tips were prepared with different shapes to test the effectiveness of the tip shape (Figure 2). The tip of the first one (Figure 2A) was shaped into a pointy cone with no angular edges; the second (Figure 2B) was shaped like a pyramid and the third (Figure 2C) much like a flat-head screwdriver. Three toothpicks (made from pine) were used to represent wood, one tip was shaped into a sharply pointed cone and the other two shaped into pyramids to have angularity to the laterals (Figure 3AC). Three porcupine quills were used (*Hystrix africae australis*), two with the distal tip (tip furthest from the animal) and one with the root tip. No shaping was done prior to use. Three bone drills were used, one with a conical tip, one with a flat rounded tip and one with a heat-treated tetrahedral tip. Seven enamel drills were used from porcupine teeth (*Hystrix africae australis*). The initial sample size was three, but four extras were added to test the material further as the results from the first three were inconsistent.

Four enamel tips resembled a cone cut in half, one with a heat-treated root tip (dentine) that was scraped into a conical point. One with a square tip and one with a thin long sharply pointed tip. Seventeen stone pieces were used to test lithic material for a variety of shapes, as well as, to test if certain lithic materials perform better than others. Ten pieces were made from quartz, and the remaining seven were made from agate, red jasper, picture jasper, chert, quartzite, hornfels and igneous (Ventersdorp lava). These materials were chosen as they are the most frequently used materials by Later Stone Age peoples residing in South Africa. Flakes were struck off cores with a cobble using freehand percussion and selected if they had a pointed tip and ranged in sizes between 1 and 2cm in length. Three orange slice segments were hafted with one of the pointed ends intended for use. The remainder were various triangular shapes with different thickness.

Drilling was performed by hand by twisting the drill back-and-forth while applying low pressure at first and then working up to higher pressure. The drill tip in Figure 3H was used with both a rolling action between the hands and a bow drill, with retouching the tip between tests, to evaluate the differences in techniques and their respective speed.

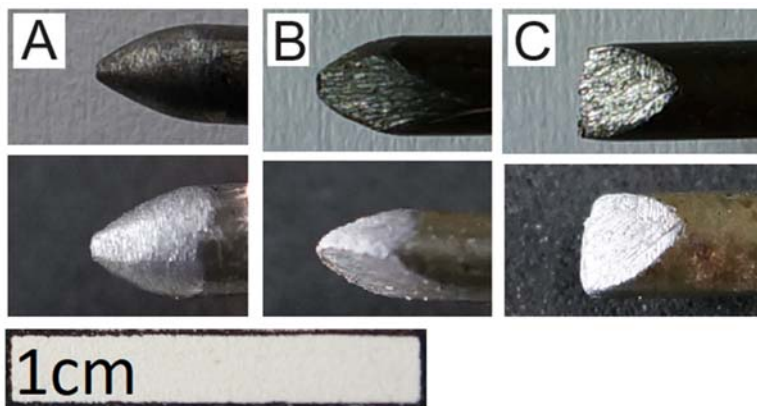


Figure 2: Steel drill tips. before use (top row); after use (bottom row).



Figure 3: Drill tips for wood (AC), quill (AB), bone (Y-AA), enamel (R-X), and stone (A-Q) showing before and after use.

Experiments: set 2

The previous set of experiments (set 1) isolated the best materials and tip geometry to use for drilling OES beads. These findings, along with literature on the topic (Gwinnett and Gorelick 1998; Nguyen and Clarkson 2013), were used to create drill tips for another set of experiments testing the different techniques used to create OES beads at LMS. The drills are discussed in this paper as set 2 of the experiments and the results of the OES bead creation, which assesses the effectiveness of using different pathways in the bead making process (the whole bead manufacturing process), are discussed in another paper (Sherwood and Forssman in preparation).

Despite metal being the most effective by taking less time and effort to drill holes and only requiring resharpening after drilling dozens of holes, the lack of metal implements present alongside OES beads at LMS indicated that stone was the most likely to have been used to drill OES pieces. Set 1 of experiments indicated that enamel, bone, quill, and wood performed inconsistently or not at all further indicating that lithic drills were likely used. In addition, the aperture geometry of LMS beads more closely resembled that of experimental apertures made by lithic drills as seen in Figure 4, in that the aperture has a capsule-like shape rather than a cone or cylinder, a smaller hole and smoother more symmetrical edges. LSA lithics discovered at the site are predominantly made from cryptocrystalline silicate (CCS) materials, and formal tools, retouched or shaped pieces are only made from such materials. Experiments in set 1 indicated that the most commonly used lithic material types in the South African LSA were able to perforate OES, thus lithic material types used at the site was chosen for experiments in set 2. Silica-based materials such as quartz, chert, jasper and agate, not all sourced from the local geology, but rather various locations in South Africa and Lesotho from the authors personal collection, were used for drills in this experimental set. A total of 29 lithic drills was used with the drills that performed most consistently shown in Figure 5. A variety of cryptocrystalline (CCS), or silica-based rock, was knapped (freehand hard hammer percussion) to obtain flakes that were thick (dorso-ventrally) and between 1 and 2cm long. The tip of the flake was pressure flaked with a bone point to approximate a tetrahedral tip, even though not all were perfectly symmetrical. The base of the flake was only retouched to assist hafting where necessary. All drill tips were hafted into the hollow end of a reed joint (*phragmites australis*) and secured with clay which was sundried for two days. Three quarters (150) of all holes were drilled with a bow drill for efficiency (experiments in set 1 indicated that bow drilling was

faster) and the remaining quarter (50) was drilled by rolling the hafted drill between the hands in a back-and-forth motion.

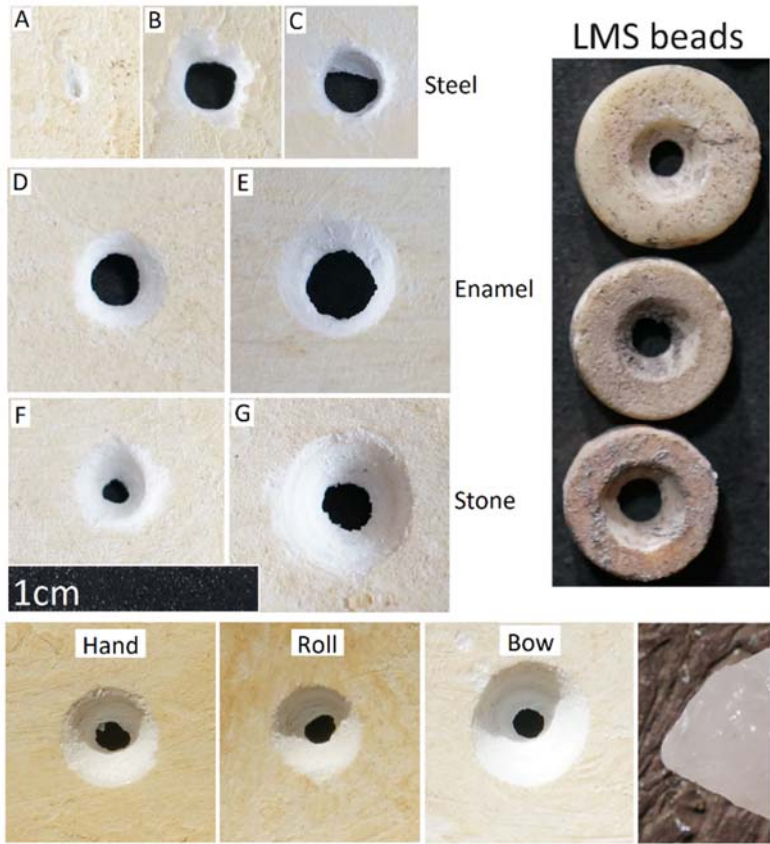


Figure 4: Hole shapes using steel, enamel, and stone. Hole shapes using different techniques with a stone tip.



Figure 5: Drills that performed the most consistently in set 2 of experiments. Used end facing left; hafted end facing right.

Results

Experiments: set 1

Wood, quill, and bone were not able to drill holes into OES pieces as these materials were too soft to successfully cut and grind into the eggshell. The tips, even with some angularity, deformed under pressure leaving only scratch marks on the surface of the eggshell. A piece of bone was heat treated to determine if this had an improvement on a bone's ability to drill a hole, but this made the material exceedingly brittle, and it crumbled under very little pressure (Figure 3AA).

The most effective (consistent and fast) tools for drilling holes were steel tips, more specifically, the steel tips that had some angularity to their lateral sides (Figure 2 middle and right). The conical tip was able to make a shallow depression, but then just ended up compressing the material and polishing its surface (Figure 4A). This is because without sharp lateral edges there is nothing cutting away the material allowing the drill tip to progress downward. Both the pyramidal and flat tips were capable of drilling holes, where the pyramidal tip resulted in a rough conical shaped hole (Figure 4B) and the flat tip resulted in a cylindrical hole (Figure 4C), as also seen with experiments done by [Werner and Miller \(2018\)](#). Stone and enamel were also capable of drilling holes but depended on the technique used and the presence of angular lateral cutting edges. Enamel tips could sustain a much larger amount of downward pressure and were the only material resulting in breakages of blanks during the creation of the holes when too much downward pressure was applied. However, the sharp edges on enamel tend to become round and smooth quickly resulting in having to resharpen the edge multiple times while drilling a single bead as the rounded surfaces only end up polishing the depression in the shell. Teeth fragments can therefore be used to drill holes into OES pieces but perform inconsistently and require a lot of constant maintenance of the lateral edges, thus it is not the most reliable material to use. Heat treatment of a tooth fragment (root) had the same result as on bone where the dentin became very brittle and crumbled when used to drill.

All lithic drills were consistently effective for drilling holes when using the correct technique. This first set of experiments indicated that all the stone varieties could drill a hole successfully, but crumble under too much pressure/force. It should be noted that many of these drills were thin (dorso-ventrally compared to their width) pointed flakes with minimal retouch. Force was not specifically measured with an apparatus but gauged by the craftsperson based on sensory

input. This force can vary from drill to drill and was judged after the use of a few test pieces before experimentation began. The drills were first slowly twisted back-and-forth with very little downward pressure till an indent became apparent in the OES piece. Downward force was gradually increased while twisting the drill back-and-forth till the tip was unusable or the hole was successfully drilled. Initially a few flakes would break away from the tip of the drill creating a twisted appearance as can be seen in Figure 6A. This likely happens due to the initial drilling motion pushing off flakes near the drill tip from pressure and torque on one dorso-lateral side and one ventro-lateral side, and then stabilizing (only for thin flakes). The direction of the twist depends on whether the initial rotation starts clockwise or counterclockwise but remains stable even with a back-and-forth motion. When too much downwards pressure was applied, the tip would start to flake away (pressure flaking), creating a shape seen in Figure 6B, then turn into a flat platform that resembles bipolar flaking when even more force is directed downwards (Figure 6C). Drill tips that were thicker and shaped like a pyramid or tetrahedron (when viewed head on) tended to round down into a cone or capsule shape (Figure 6D). These drill tips were able to handle more downward force and were able to drill more holes before needing retouch and or discard.

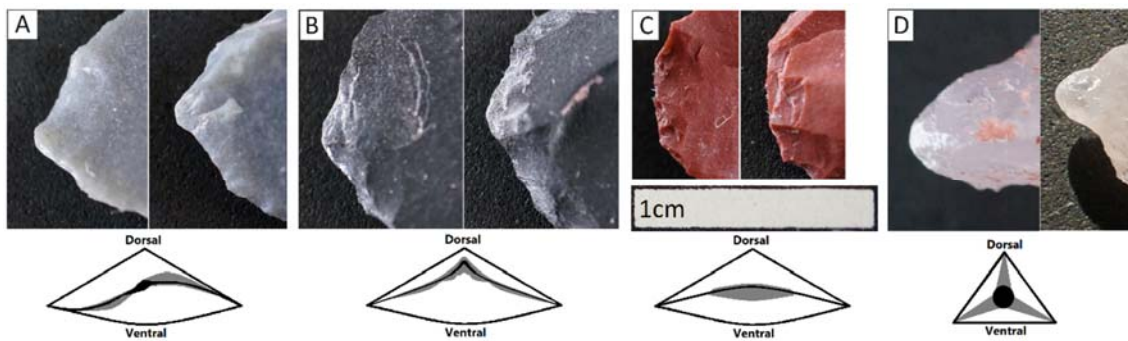


Figure 6: Macro use-wear types on drill tips.

Experiments: set 2

Experiments in set 1 determined that thicker flakes made from stone with tetrahedron shaped tips were most effective (bar metal) for drilling holes into OES pieces, thus these drills were created and used in another experiment to determine the most effective technique for creating OES beads (Sherwood and Forssman in preparation). These drills (Table 1 and Figure 5) were

able to consistently drill holes into multiple OES pieces, with the only limiting factor in success being the hafting of the drill tip, which works optimally if the drill is secure enough to handle moderate downward pressure and rotational force, as well as having the tip directly overhead and in line with the shaft (Figure 7). A drill that was not securely hafted would shift around and a drill tip that was off-centre created an imbalanced rotation making the process challenging and more time costly. The drills with a lower number of beads drilled in Table 1 were limited by the hafting quality rather than the material type used and were retired when dislodging from the stick.

Table 1: Number of holes drilled with each drill tip from experimental set two.

Drill no.	Holes drilled	Drill no.	Holes drilled
1	12	1a	22
2	9	2a	4
3	15	3a	4
4	3	4a	3
5	10	5a	10
6	11	6a	3
7	5	7a	6
8	3	8a	6
9	3	9a	8
10	3	10a	5
11	8	11a	5
12	3	12a	5
13	6	13a	4
14	3	14a	15
15	2		

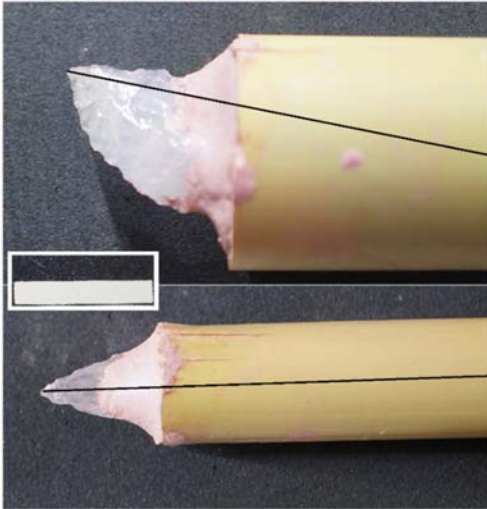


Figure 7: Drill tip orientation relative to the shaft.

Use-wear and LMS drills:

Use-wear on drills from experimental set 2 were evaluated and photographed with a stereoscope (Nikon SMZ 745 T, 50X magnification and a Nikon camera with accompanying software) to isolate wear that could be used to help identify OES drills from LMS. The use-wear that developed depended on the extent of tool use, as well as how much downward pressure was exerted on the tool tip. A drill that was used to make one perforation while rolling the hafted drill between hands shows wear development as a rounding of the tip and part of the laterals, with elongated (sometimes wavy) pits forming on the very tip of the drill (Figure 8:1). Drills that were used in a bow exhibit more extensive pitting on the very tip, likely due to more downward pressure being applied (Figure 8:5), and when too much pressure is applied the entire tip can break off (Figure 8:2). Drills used with either technique eventually round and start to resemble drill tips such as in Figure 8(3 and 4).

The angular surfaces along the lateral edges of the tip that contact the OES piece abrade away over time rounding these surfaces. Pits are formed predominantly on the very tip of the tool and are likely caused by weakness in the internal crystal structure of the cryptocrystalline rock that breaks with the downward and rotational forces and dislodges. The wavy pattern of the pits observed on some of the pieces could be due to the alternating rotation of the drill. The rounded surfaces are coarse rather than polished, as with every rotation the surface is grinded

against the OES material and slowly abraded away rather than polished. This is clearer in Figure 8 (3 and 4) where, after extensive use the entire tip is rounded with most angularity removed. Interestingly these drills are still capable of making a perforation as the continuous removal of small crystal structures from the rock acts as abrasives helping the process, however, this is slower and results in a wider perforation, often more capsule shaped instead of a cone.

Lithics in square J42B at LMS were carefully evaluated to find pieces that were deliberately shaped and looked as though they could be used for drilling, based on what was observed from drills in the experiments. This square was selected as it had a sizable amount of OES debris and beads present. A few promising pieces were isolated, and their use-wear was evaluated in the same manner as those from the experiments. The piece in Figure 8A shows retouch on either side of the platform that is distinct from the pitting visible on the experimental pieces and has no rounding present. This piece was thus not used for drilling but rather retouched. The use-wear on the lithic in Figure 8B is very similar to what is seen from the experimental pieces. The entire tip and accompanying laterals are extensively rounded, coarse and have pitting present, and it is thus highly probable that this piece was used as a drill. The third piece (Figure 8C) shows some rounding and pitting on the tip and laterals, but it is not as extensively developed. Taking into consideration the shaping of the tool, when compared to the piece in Figure 8B, some similarities are noted. Both these pieces were made from small, thick flakes and retouched along the laterals, with more focus being directed to the drill's tip and some to a tang (Figure 9). One of the pieces was created with bipolar flaking, and the other appears to have been struck off a core using freehand percussion. However, both pieces have a deliberately shaped tang, likely for hafting into a piece of bone or wood. The tips, when viewed head on, both resemble an almost symmetrical tetrahedron, which is seen for drills from other archaeological studies and was confirmed to be the best shape for drilling by the experiments. The drill in Figure 8C is a Later Stone Age (LSA) tool found within layers dating to around 200BCE from forager occupations prior to Iron Age (IA) farmers entering the region. The drill in Figure 8B is also a LSA tool found within layers after contact with IA farmers from the early first millennium to 750CE.

Experimental drill use-wear

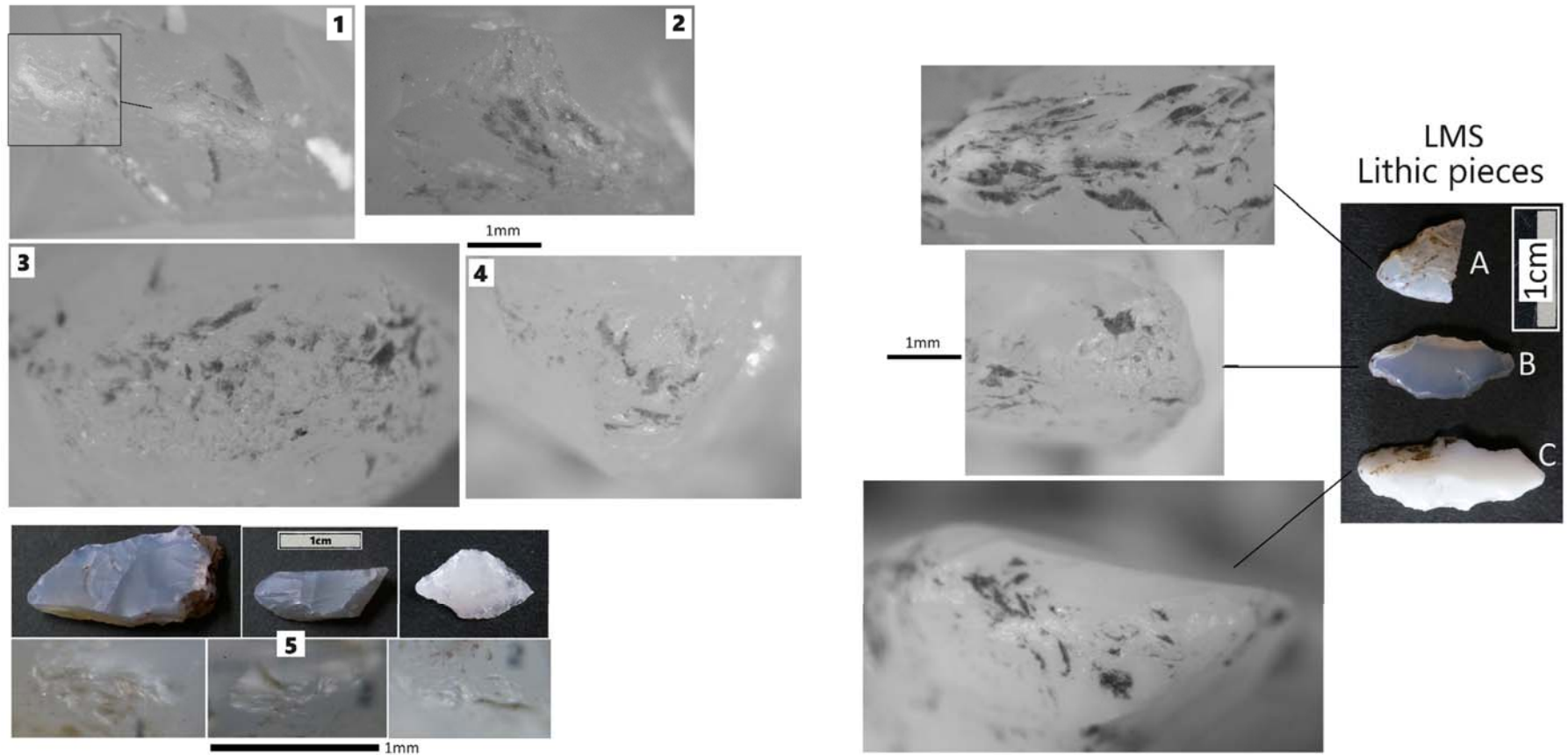


Figure 8: Use-wear on drill tips showing rounding and pitting. 1: Drill tip and lateral edge after drilling one bead. 2: Drill tip showing breakage from rotational torque. 3 and 4: Drills with extensive use showing rounding of surface on the tip and laterals, as well as pitting. 5: Tips of the drills showing pitting centred into the midline when used with a bow drill (more downward pressure applied than rolling between the hands as 1-4 above). A: A retouched piece showing no pitting on the midline but flakes removals towards the sides (not a drill). B and C: LMS drills showing rounding and pitting development on the tip and lateral edges.

The maximum diameter of the apertures of complete beads from LMS were obtained to compare with the dimensions of the drills. The average maximum aperture diameter of the beads was 2.61 mm ranging from 1.51 - 4.48mm. OES pieces are roughly 2mm thick, thus measuring the diameter of the drill at around 1.5mm from the tip (the drill usually stops about 0.5mm short of perforating the shell) should give an estimation of drill diameter relative to that of perforations in OES. The drill diameters were 2.86 and 3.45 respectively, which places them in the range of OES diameters.

In addition, complete beads found from the same layers as the drills were used to compare to the drill tips under a dino-lite microscope with magnification of 66X. Figure 10 shows the relative dimensions of the drill tip and those of beads made during the same time-period. The bottom drill tip fits perfectly to the contours of the cone in the bead (as observed through the dino-lite from multiple angles), which likely indicates that this drill was used to drill that bead. However, this would have to be confirmed with micro-CT or 3D scans of the surfaces ([Yang et al. 2016](#)), which is not in the scope of this project, but can be explored in future studies when more drill pieces are isolated.

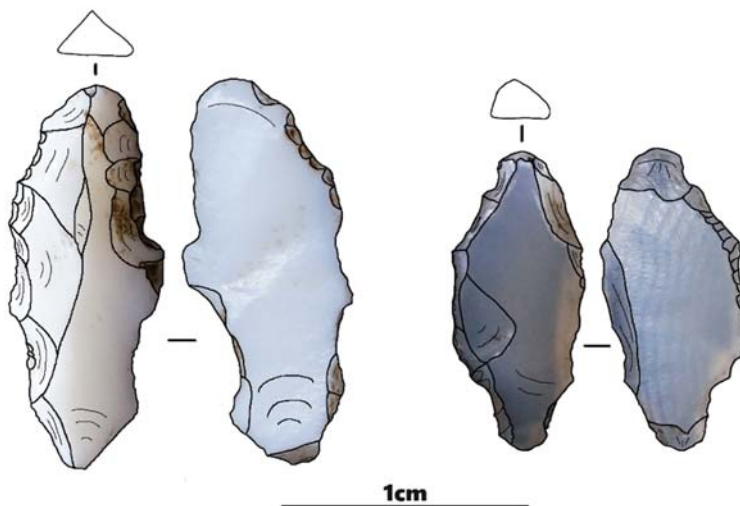


Figure 9: LMS drills.

Drill: Square:J42B Spit:27 Layer VDB2
Bead: Square: I42B spit: 27 Layer VBD2



Drill: Square:J42B Spit:24 Layer VDB1+
Bead: Square: I42C-D Spit: 24 Layer: VDB1+



Figure 10: LMS drills and beads from the same layers showing perfect fit.

Discussion and conclusions

The experimental testing of different materials and shapes that can be used to make drills showed that, before the implementation of iron into forager toolkits, stone was the best source for consistently making effective drills for OES bead manufacture. In addition, the experiments indicated that the shape of a stone drill is most important. Having a sturdy and somewhat symmetrical tip with angular edges made drills durable and effective for perforating multiple OES pieces before needing to be retouched or discarded.

The results reflect findings in the available literature, such as [Nguyen and Clarkson \(2013\)](#), who describe the production of drills in Vietnam where flake blanks selected for drills were of

a standardised shape and size. They also determined that at least three different core reduction strategies were used for flake production, being freehand percussion, bipolar reduction, and pressure flaking. The two drills from LMS shelter exhibit two different flaking strategies, but a similar standardised shape and size for the flakes that were used for the drills. However, this is a small sample size and further finds from the site would help to gain more insight into the drill technology at LMS. [Nguyen and Clarkson \(2013\)](#) also showed that the lateral edges of these flake blanks were shaped to produce a tetrahedral or pyramidal tip with a symmetrical cross section (reflected also by [Gwinnett and Gorelick 1998](#); [Coşkunsu 2008](#); [Wright *et al.* 2008](#); [Shoda *et al.* 2013](#)). Though, there is no mention of any modifications to the base of the tools, whereas LMS drills appear to have deliberate shaping of the base into a tang. The presence of the tang suggests that these drills were hafted, which would make sense since drills that are between 1 and 2 cm in size would be too small to use with just one's hands effectively. Use-wear for hafting was not evaluated but is certainly something that can be studied later once more lithics are identified from the assemblage that might be drills, alongside evaluating the cups in the beads themselves ([Werner and Miller 2018](#)). Many of these lithics might currently be classified as miscellaneous retouched pieces, points, segments, or scrapers, due to the steep retouch on the laterals. This study highlights the importance of revisiting older assemblages when equipped with new information as time continues, as this can bring to light technology overlooked initially.

Most of the literature describing OES bead technology often mentions that not much is known about the drilling technology used to make these beads or that no such technology was present. This may simply be a case of lithics from those assemblages not being identified as drills but placed into other categories. This is a particular problem with micro-lithic technology, which can often overlap in form and function and needs close inspection to determine function. It also raises the importance of experimental studies and associated use-wear that can be obtained, as it helps archaeologists more accurately identify and classify technology. This study provides use-wear on CCS lithic drills used to perforate OES, as well as, potentially provides a formal tool typology for forager drill tools that can be used by future researchers to identify such lithics, which can be sorted and later studied. We suggest these pieces be classified as microlithic drills.

The use-wear of the experimental drills was able to help isolate drills that were used at LMS. However, it is not certain if these drills were used on OES or other materials such as stone,

bone, or wood. No stone or bone tools and fragments excavated from LMS exhibit any perforations or holes indicative of drilling, which potentially rules out these categories. Nonetheless, organic materials rarely preserve in archaeological contexts so drilling activities on organic materials cannot be ruled out without further experimentation. Given the abundance of OES beads at LMS throughout its sequence, as well as, finding these drills in deposits alongside them it is likely that they were used for OES bead making. In addition, the dimensions of the two drills evaluated correlate with those of the bead cup dimensions quite well as is seen in Figure 10. Further studies and revisiting lithic pieces in other squares, as well as other archaeological sites to isolate more drills would be able to give a clearer picture in the future. Something that was also not tested in this study was the use of abrasives alongside various material to see if that would have an impact on the hole making process, which is also something to consider for future experimentation.

In conclusion, the use of experimentation and use-wear was able to help identify drills at LMS that were potentially used for the creation of OES beads. This study provides data that can be used by other researchers to identify similar technology that may have been overlooked in the past and by extension broaden our understanding of the complexity of forager technology and behaviours.

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