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Experimental Approaches to Amber Bead Production in Early Medieval (Fifth- And Sixth-Century AD) England

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Tens of thousands of amber beads have been recovered from furnished early medieval female burials of the later fifth to early seventh centuries AD in southern and eastern Britain (Brugmann, 2004, fig. 64; Huggett, 1988, pp.64-66). Amber reached its peak in the middle of the sixth century, overtaking even glass beads in popularity (Huggett, 1988, p.64; Brugmann, 2004, p.47; Hirst, 1985, p.75). Despite the wealth of evidence for the finished objects, no

archaeological traces of amber-working in southern Britain during the same period have yet been identified, from either excavated settlements or cemeteries.

> “The process of making replicas has also clarified the importance of understanding manufacture when assessing signs of use-wear on excavated early medieval amber beads, since consequences of the former might easily be misinterpreted as the latter.

Introduction

Frequent reworking of broken beads (e.g. Meaney, 1981, p.68, fig. III.b), coupled with evidence for amber-working at contemporary sites in the Netherlands, at Oegstgeest, Utrecht-Leidsche Rijn and Wijnaldum (Langbroek, 2021) and the early eighth-century site of Moynagh Lough in Ireland (Bradley, 1993, p.80), do seem to support the suggestion that beads were made locally, rather than imported as finished objects. Therefore, the beads provide the best evidence for understanding the manufacturing technologies and contexts of production likely to underpin this important early medieval craft. This article presents the results of a series of experimental reproductions to explore the manufacture of different types of early medieval amber beads. It evaluates the implications of these results for our understanding of the economic and social value of amber during this period.

Understanding how and potentially *where* fifth- and sixth-century amber beads were made has broader implications for the early medieval maritime economy. Amber beads are often straightforwardly classified as imports within wider discussions of early medieval North Sea trade. Still, much of the attention is focused on the ultimate provenance of the material and rather less so on the processes by and contexts within which raw amber was transformed into beads (e.g. Harrington and Welch, 2014, p.155; Hines, 1994, pp.15-16). The same kind of amber rich in succinic acid is found across a huge swath of northern Europe, including, importantly, from along the coastlines of eastern England (Beck and Shennan, 1991, pp.17-18; Mainman and Rogers, 2000, p.2501). While the popularity of amber during the sixth century implies at least a partial reliance on the very productive deposits around the Baltic Sea, the contribution of native sources to these flows of material remains uncertain (Hines, 1994, p.16). It may be that local production of amber beads was underpinned by a supply of raw amber, which was supplemented by small-scale exploitation of deposits along Britain's eastern coastlines (Huggett, 1988, p.64). Whether these supplies remained stable over the later fifth to late sixth century is equally not well understood. It is impossible to chemically distinguish true Baltic amber from that present around the broader North Sea zone; it all derives ultimately from the same massive deposits. There is, however, potential for detailed study of the finished objects-the amber beads themselves-to make important contributions to questions of provenance, chronology and trade. A fuller understanding of their likely production contexts will provide an essential foundation for this.

The experiments

The experiments presented here aimed to reproduce seventy-six amber beads from two early medieval burials from a fifth- and sixth-century cemetery at King's Croft Gardens, Cambridge, using the kinds of techniques inferred from close examination of the extant objects and a broader survey of early medieval amber-working as a craft. A typical early medieval inhumation cemetery from eastern England containing a high proportion of furnished burials, King's Croft Gardens produced 351 amber beads from 16 of the 61 burials at the site, all of them the graves of adult women or children buried with other feminine-gendered grave-goods (Haworth, *in prep*.). The two case study graves (8 and 59) were selected because they contain a representative selection of all the different types of amber beads identified at the site, and they belong to different chronological phases. Grave 59 was the richly furnished burial of a young adult woman, aged 18-25. Of the swag of 116 beads worn suspended from a pair of small-long brooches at the shoulders, 67 were amber beads. This was the second-highest number of amber beads from any grave at King's Croft Gardens. The other beads were made from glass (40), translucent rock crystal (8) and stone (1). Grave 8, the burial of a young girl between the ages of eight and eleven, contained only a small collection of nine beads, all of which were amber.

A range of shapes is present among the 76 beads from these two graves (See Figure 1). The classificatory system developed to describe the amber beads is outlined in Table 1. This combines measurements of the beads that characterise their length relative to their maximum diameter, as well as an assessment of their longitudinal and transverse sections. Amber beads can be broadly divided into round, facetted, disc-shaped and convex biconical categories. These show some chronological patterning: bead strings dominated by the smaller, lighter round types are generally earlier in date, while larger facetted amber beads are slightly later (Brugmann, 2012, p.97). As the earlier of the two graves from King's Croft Gardens, grave 59 contains mostly disc-shaped beads (44) in combination with round beads (12), as well as the majority of the convex biconical beads (9) from the cemetery. By contrast, the small collection of beads in grave 8 consists mainly of facetted types (8) and a single disc-shaped bead.

Category	Type	Longitudinal section	Transverse section	Length (after Beck 1928)
Round	Barrel-shaped	Round	Round	short to long
	Flat barrel-shaped	Round	Ovoid or semi-circular	short to long
Facetted	Facetted biconical	Kite-shaped	Square	short to long
	Flat facetted biconical	Kite-shaped	Rectangular	short to long
	Cuboid	Rectangular	Square	standard to long

	Irregular facetted	Irregular	Various	short to long
Disc	Disc-shaped	Cylinder	Various	very short to short
	Short cylinder	Cylinder	Various	short
Convex biconical	Convex biconical	Elongated biconical	Round to ovoid	long

TABLE 1. THE MAIN AMBER BEAD TYPES AS DEFINED BY THEIR SHAPE AND THE RELATIONSHIP BETWEEN THEIR MEASURED LENGTH AND MAXIMUM DIAMETER.

The experimental reproductions are informed by two different strands of evidence. The first is the close, firsthand examination of a sample of 485 amber beads from two Cambridgeshire cemeteries, King's Croft Gardens and Girton College. For several reasons, unequivocal tool marks on the excavated beads are relatively rare. Amber goes through several stages of surface degradation in the burial environment, which can cause surface layers to become unstable and, ultimately, lost (Hutchinson, 1995, pp.2-3). As a soft material, amber also wears easily through abrasion against neighbouring beads, the bead string and underlying textiles, which distorts worked surfaces. It is also possible that, in many cases, the process of finishing the beads has systematically removed physical traces of manufacture (see below).

The second strand of evidence is comparison with other early medieval European amber-working sites, including the evidence from contemporary settlements along the Rhine, especially from Oegstgeest, and the slightly later eighth- to eleventh-century amber workshops at the Viking-Age *emporia*. Numerous northern European proto-urban centres have produced a wealth of archaeological evidence for amber-working, including unworked pieces, waste, part-finished and finished objects, notably York in England, Dublin in Ireland, Dorestad in the Netherlands, and Ribe, Hedeby, Kaupang, Groß Strömkendorf, Åhus and Paviken in Scandinavia (Mainman and Rogers, 2000; Wallace, 2016, pp.291-296; Kars and Wevers, 1983; Botfeldt and Brinch Madsen, 1991; Sindbæk, 2023; Ulbricht, 1990; Gjøstein Resi, 2011; Gerds, 2001; Callmer, 2002; Lundström, 1981, pp.93-95). A wider range of finished products was made at these proto-urban Viking-Age workshops than can be shown to have been in circulation in fifth- and sixth-century England, including finger-rings, pendants and gaming pieces (Coulter, 2015, p.114, fig. 7.4), but the technologies and tools they evidence are comparable, and are therefore surveyed here to better understand the processes of amber bead manufacture.

The seventy-six replica beads were made by the author and by two research assistants. None of the participants had any prior experience of amber-working or other related crafts, and so one aim of the experiments was to understand how easily and intuitively the skill can be acquired. All of the production techniques discussed below were trialled first on small pieces of scrap amber before producing the experimental replicas themselves.

Material sourcing and selection

The first step in the process of making a bead is the selection of a suitable nodule of raw amber. The amber used to produce early medieval beads is almost certainly Baltic amber, deriving from the ancient coniferous forests that covered much of northern Europe during the Eocene (Huggett, 1988, p.64). What few analyses of early medieval beads have been undertaken have generally supported this hypothesis. Fifteen beads in the Liverpool Museum, initially thought to be prehistoric but more likely to be early medieval, were analysed as part of Beck and Shennan's (1991, pp.32-33) major study of British amber objects and all but one proved to be Baltic amber. Viking-Age amber from York and Dorestad analysed by infra-red spectroscopy also proved to be largely derived from Baltic deposits (Mainman and Rogers, 2000, p.2474; Kars and Wevers, 1983). While modern amber is mostly mined, early medieval supplies probably relied on either beachcombing or collecting amber from shallow inshore waters. A diplomatic letter dated to the 520s and ostensibly from the Ostrogothic king Theoderic to the *Haesti* contains a reference to the collection of amber from the Baltic Sea coastlines and its subsequent trade (Cassiodorus, *Variae*, 5:2; transl. Bjornlie, 2019, pp.204-205). However, the letter's author, Cassiodorus, is heavily dependent on very similar descriptions in Tacitus' *Germania* written several centuries earlier (Tacitus, *Germania*, 45; transl. Rives, 2016, pp.95-96).

Characterising the size range of raw amber pieces available to fifth- and sixth-century amber workers is difficult. The dimensions of the finished beads provide an indication of the minimum size of the raw amber available to be utilised. Most of the beads from King's Croft Gardens and Girton are relatively small: 88% measure less than 15 mm in both length and maximum diameter (See Figure 2). Beads weighing more than 1.5 g are unusual, comprising just 4% of the beads from King's Croft Gardens. The shapes of finished beads can be informative: the relative popularity of disc-shaped and short cylindrical beads (corresponding to around 20% of the examined beads), for example, may suggest that flattish slabs of amber were readily available. Examples of very large early medieval amber beads from other early medieval cemeteries, including two from grave 14 at Wheatley in Oxfordshire that measure 40 mm in diameter (Leeds, 1917, p.52, fig. 5), demonstrate that bigger pieces of raw amber could also be obtained, and sometimes bead-makers chose to make the most of this to make an unusually large single bead.

In part, the size of the available amber pieces will be determined by the nature of the supply of the raw material. Certainly, at sites where amber can be collected locally, small pieces dominate the unworked assemblage. This is best illustrated by Viking Age Hedeby, located on the southern part of the Jutland peninsula, where most of the unprocessed amber nodules were small and weighed less than 5g (Ulbricht, 1990, p.68). Any local collection of amber along eastern coastlines of England during the fifth- and sixth-centuries can be expected to have produced mostly smaller pieces, suited to making individual beads, with less frequent discoveries of larger pieces that could be used to make unusually large-and therefore presumably particularly prestigious-beads, or divided up to produce numerous beads. While theoretically a narrower range of sizes might be expected at sites relying primarily on a traded supply of raw amber, the evidence from excavated workshops is equivocal. Extensive sieving of deposits at Oegstgeest produced unworked amber in a range of sizes, from a single nodule measuring 41.6 x 16.5 mm, to fragments less than 5 mm at their maximum diameter (Langbroek, 2021, p.521). Whatever the mechanism by which raw amber arrived at this site, a range of sizes was present within this supply. At York, the raw amber from ninth-century deposits consisted of relatively small pieces, with the largest weighing just 5.18 g (Mainman and Rogers, 2000, p.2509). The same is true at Kaupang in southern Norway: most of the 161 pieces of unworked amber were small, measuring 4-20 mm at their maximum diameter (Gjøstein Resi, 2011, p.110). Some very substantial pieces of unworked amber did circulate around the southern North Sea zone, however. 19th-century excavations at Viking-Age Dorestad produced a huge nodule of raw amber measuring 229 x 152 x 51 mm (Kars and Wevers, 1983, p.66).

It seems likely that, whether arriving as imports or collected locally, the supply of amber in early medieval England was dominated by small pieces. Many beads were, therefore, made from single nodules of amber, with the size and, in some cases, the shape being dictated by the dimensions of the raw piece. Throughout the experiments discussed here, beads were made from both single amber pebbles and from pieces sectioned off larger nodules.

It is unclear whether colour played any role in the collection and exchange of raw amber. Early medieval amber beads are consistently a dark orange colour, but it is unclear how representative of the original range of hues this is. It is possible to artificially darken the colour of amber by boiling it in animal fat, a process described by Pliny the Elder (*Natural History*, bk. 37, chpt. 12; transl. Eichholz, 1962, p.199), but there is no evidence for this kind of treatment in an early medieval context (Mainman and Rogers, 2000, p.2501). It is also important to note that oxidisation and related surface degradation caused by the burial environment have almost certainly made the beads appear darker and more homogenous than they originally would have been (Hutchinson, 1995, p.4). These colour changes are further affected by the removal of the weathered surfaces of amber during manufacture. At excavated workshop sites that have produced both finished objects and unprocessed nodules, the brownish discolouration is only noted on the former (Ulbricht, 1990, p.70). For these reasons, no attempt was made to colour-match the amber used for the replica beads with the originals. Baltic amber of a variety of colours and translucencies was utilised for the experimental reproductions. This included very pale yellowy amber to dark orangey-brown stones, and from transparent to almost completely opaque examples (See Figure 3). This variability results from inclusions, the presence of bubbles and the degree of oxidisation, rather than any variation in chemical composition (Maish, et al., 2011). Colour banding within a single nodule was common, as were dark inclusions, likely small pyrite crystals.

Sawing

In cases where the amber nodule being utilised is substantially bigger than the intended finished object, it is necessary to divide up larger pieces to make multiple beads, which can be achieved in various ways. At Oegstgeest, percussion marks on amber nodules and numerous flat detached flakes were interpreted as evidence for knapping to break off usable chunks of amber from a larger nodule (Langbroek, 2021, p.286), but this would seem to be more suited to rough shaping of blanks by gradually removing thin surface flakes than sectioning off more significant pieces. At most of the Viking Age amber-working sites, either saws or knives appear to have been the tools used, based on the tool marks on part-finished objects (e.g. Wallace, 2016, p.292; Ulbricht, 1990, p.87).

The present experiments primarily used a jeweller's saw fitted with steel blades to divide larger pieces of amber (See Figure 4). It is possible to cut through amber using a knife, but this has the twin disadvantages of taking more time and producing a V-shaped cut that results in the loss of more material, so the saw is preferred. Sawing amber proved to be a relatively quick process, requiring minimal physical effort. The longest recorded time was around 18 minutes to section off the required piece from a lump of raw amber measuring 23.5 x 17.7 x 8.8 mm, but most of the smaller pieces required much less time to cut to size, typically less than ten minutes. Once the saw has passed through the bulk of the amber, the process can be further sped up by snapping off the remaining stub. Sawing produces a series of horizontal striations on the cut surface of the amber (See Figure 5).

Roughing out

While the sectioning off of usable pieces of material is only necessary when multiple beads were made from a single amber nodule, the next step in the process, roughing out, is required to produce all beads. Roughing out describes the removal of weathered surface layers from the amber nodule, as well as defining the basic bead shape insofar that the perforation can be correctly positioned. Most of the excavated Viking Age amber-workshops have produced discarded bead-blanks, which provide an indication of the degree of pre-drilling roughing out considered appropriate (Mainman and Rogers, 2000, fig. 1219; Ulbricht, 1990, Taf. 5; Sindbæk, 2023, fig. 15.4; Gjøstein Resi, 2011, figs. 6.3.1-6). Some of these unfinished blanks may have been accidentally lost. Still, in other cases it seems likely that during the roughing out process the amber worker had-or at least believed they had-identified an internal flaw likely to lead to the bead splitting and chose to discard the part-worked bead rather than invest further time in it.

Almost all the bead types defined based on the examination of the King's Croft Gardens and Girton beads are worked on all sides. Beads showing little evidence of deliberate working beyond the removal of surface layers and drilling of the perforation are very unusual; only four examples of such perforated nodules could be identified among the 485 examined beads. Retaining the maximum dimensions of the raw amber was not a high priority for bead-makers, which may again indicate something about the regularity of supply. However, some early medieval beads do feature irregular depressions or natural perforations likely to have been features of the original unworked nodule, suggesting that there was judicious use of raw amber pieces of a usable size when possible.

The evidence from the Viking Age workshops has suggested that a knife was the tool consistently used for roughing out (e.g. Ulbricht, 1990, p.86; Mainman and Rogers, 2000, p.2501; Gerds, 2001, p.117). Amber is easily carved with a knife, and with practice, it is possible to both shave away material smoothly or to chip away larger flakes (See Figure 6). A sharp blade is essential; blunt tools proved almost unusable. The knife left a series of linear scratches on the surface of the amber parallel to the path of the blade and, perpendicular to it, elongated ovoid pits (See Figure 7; Mainman and Rogers, 2000, p.2501; Egan and Pritchard, 2002, p.307).

Almost all examined excavated amber beads have very flat perforated faces, including those with relatively narrow diameters, such as the convex biconical beads. True globular forms are rare even among the rounded beads; most beads of this type are barrel-shaped, with rounded sides and flat faces. Experiments showed that these flat faces are an important prerequisite for the next drilling step, in facilitating comfortably holding the bead as still as possible. The roughing-out stage of bead manufacture almost certainly involved the creation of these flat faces, even if they were further refined post-drilling. Rubbing the beads back and forth across coarse sandpaper proved to be the technique most suited to this task and produced the smooth flat surfaces seen on well-preserved disc-shaped beads. A flat piece of sandstone could be used to the same effect. The 12th-century artists' and craftworkers' manual *De Diversis Artibus* (On Various Arts) compiled by the monk Theophilus, recommends the use of hard sandstone, moistened with water, to shape rock crystal, a gemstone with a much higher Mohs score (7) than amber (2.5) (III.95; transl. Hawthorne and Smith, 1963, p.189). In all likelihood, the initial step of roughing out a bead utilised both a knife and a grindstone.

Drilling

Examination of both the early medieval amber beads and the part-worked beads from the Viking Age workshops have shown that the perforations in amber beads were drilled. Spiralling striations produced by drilling are sometimes visible within the perforations of excavated beads, although often this evidence has been lost to thread-wear and surface degradation (See Figure 8). As a soft material, amber can be perforated with a simple handheld drill. Most of the replica beads made during the experiments were drilled using one of five stainless steel drill-bits, measuring 1-3 mm in diameter, fixed in a handheld pin-vice (See Figure 9), but a bow-drill with a 3 mm spoon auger tip was also used to provide a comparison. The same spiralling drill-marks are visible on many replica beads (See Figure 10). Amber can also be perforated by pecking out a hole using an awl or pushing a piece of heated metal through it (e.g. Strafella, et al., 2017; McGloin, 2021, pp.45-46), but the consistently neat and rounded perforations of excavated early medieval beads show neither technique was customarily used. Other experimental studies that have examined all possible methods of perforating amber have found hand-drills to be the most suitable tools (Fiorentini, 2022).

There is a wide variation in the perforation diameters of the amber beads from King's Croft Gardens. However, narrow drills, producing perforations with diameters between 1.6 and 2.3 mm, seem to have been the most used (See Figure 11). Perforation diameter varies according to bead shape. Larger disc-shaped beads have the largest perforation diameters, while those of the longer cylindrical or convex biconical beads tend to be narrower. Whether this variation indicates the production of different shapes by several different amber-workers or whether each amber-worker typically worked with a series of drills of varying diameters was unclear.

As seems to have been the case in the Viking Age amber-workshops, it quickly became clear in the experiments that drilling part-shaped beads is the most efficient process (Mainman and Rogers, 2000, p.2502; Gjøstein Resi, 2011, p.110). There is a risk of beads splitting during drilling, usually because of an internal flaw within the amber, but in some cases simply due to the excess pressure placed on the bead blank. Since shaping the beads is the most time-consuming part of the manufacturing process, drilling at a relatively early stage of bead-making is essential to avoid wasted time. Some part-finished bead blanks from Kaupang and Paviken bear shallow guide-marks for drilling, suggesting that this may have been the final stage of roughing-out (Gjøstein Resi, 2011, p.110; Lundström, 1981, p.93). This further implies that each stage of production involved multiple beads, undoubtedly for efficiency.

Both the handheld drill and the bow drill proved relatively straightforward and intuitive to use. Using a handheld drill, it is possible to simply hold the piece of amber in place on a flat surface with one hand and rotate the drill with the other. Using a bow drill requires either the assistance of a second person or an adhesive or simple clamp to hold the bead blank in place. Blu-Tac proved helpful for this purpose during the present experiments, but the kinds of basic glues made from boiled animal hides or wheatpaste available during the early medieval period would achieve the same result (c.f. the recipes in the later *De Diversis Artibus* I:18, transl. Hawthorne and Smith, 1963, pp.26-27).

Most, although not all, fifth- and sixth-century amber beads were drilled from both sides, as were many of the part-finished beads from the Viking Age amber-workshops (Hutchinson, 1995, p.4; Wallace, 2016, p.292; Gjøstein Resi, 2011, p.110; Botfeldt and Brinch Madsen, 1991, p.101; Mainman and Rogers, 2000, p.2502). Over the course of the experiments, bead blanks were drilled from both one side and both sides; both techniques were successful in perforating the amber. Drilling from both sides introduces the additional challenge of accurately aligning the two perforations to meet in the middle. Often the bead holes join at an angle, although this is only visible in the case of semi-transparent beads. Broken early medieval beads demonstrate that fifth- and sixth-century amber-workers faced the same difficulty, often resulting in a perforation with a characteristic step-shaped profile (See Figure 12). Drilling a bead from both sides is also generally slower, especially if the bead is held in place using a clamp or an adhesive. There are, however, two main advantages to drilling from both sides: firstly, it lowers the risk of splitting by reducing the overall stresses placed on the bead and secondly it produces a much neater pair of perforated faces. Beads drilled from one side only tend to have a ragged exit hole where the drill-bit broke through, and minor loss of material around the edge is common. That early medieval bead-makers appear to have used both techniques perhaps indicates that the economy in terms of time by drilling straight through the blank sometimes outweighed the additional risks of splitting or chipping.

It has also been suggested that drilling beads from both sides was necessary to avoid excess heat from the drill cracking or otherwise warping the amber (Mainman and Rogers, 2000, p.2502). Although drilling often produced a pleasant piney fragrance, the rate at which the handheld drill and bow drill could be operated was never sufficient for the heat generated to be an issue.

To quantify both the success rate of drilling and the time required for the process, a series of 141 drilling experiments was undertaken. These included both unworked slabs of raw amber and the replica bead blanks. The colour of the raw amber, depth of material through which the drill passed, time taken and the outcome of the experiment were all recorded. The replica beads were primarily perforated using the handheld drill, because it was possible to switch out the drill-bit to correspond as closely as possible to the measured diameter of the original bead. The unworked amber chips were drilled using both the handheld drill and the bow drill.

The overall success rate of the drilling experiments was 82.3%. However, the likelihood of successfully perforating a piece of amber increased markedly as the user became more familiar with the tools and the material at hand. The success rate of the initial 27 experiments using flat unworked amber chips was 59.3%. Generally, the handheld drill proved slightly easier to use and less susceptible to failure than the bow drill. The success rate of the former was 85.4% compared to just 61.1% for the latter. However, because the replica beads were made almost exclusively using the handheld drill, it is possible that the success rate of the bow drill would have improved similarly had it continued to be used with the same regularity. It was not possible, however, to completely avoid breakages and even towards the end of the experiments, when participants had become accustomed to the tools, beads still split during drilling.

As might be expected, there was a correlation between the time needed to drill a piece of amber and the thickness of the material itself; thicker pieces required more drilling time than thin slabs. However, the correlation between the two is not particularly strong (See Figure 13). Other factors played a role, including the shape of the bead blank and the affordances of the amber itself. It was also noted that the drilling time even for thicker pieces reduced as the skill level and confidence of the drill operator increased. Most of the pieces of amber perforated during the course of the experiments, ranging between 1.4 and 15.1 mm thick, required between four and 16 minutes of drilling time. Similarly, Fiorentini (2022) recorded a time of ten minutes to drill a piece of amber 5 mm thick. The size of the drill-bits used did not make a noticeable difference to the effort or time required to perforate the amber.

Drilling the convex biconical beads, even in their roughed-out form, proved to be the most challenging of all the replicated shapes, because the length of the bead through which the drill bit passed is proportionally much larger than the maximum diameter. The delicate, tapering shape of these beads could, without exception, only be formed after drilling cylindrical bead-blanks, as the faces of the bead were otherwise too small to accurately drill. Even so, often there was some chipping around the perforations caused by the drill, which can be seen when the bead is viewed from the side.

Pieces of amber broke during drilling for various reasons. Some very thin slabs of unworked amber between 2.5 and 3.8 mm shattered shortly after drilling commenced, usually within a minute, because the pressure exerted by the drill was too much. None of the early medieval amber beads from King's Croft Gardens or Girton are so thin, and presumably any chips of this size would have been customarily discarded as waste by early medieval bead makers. In the case of thicker pieces of amber, drilling too close to the edge of the bead could cause it to split. In most cases, however, part-drilled beads split along pre-existing flaws within the amber matrix. With practice, it becomes possible to intuit when and indeed where amber is likely to split as faults become visible during the process of roughing out the bead shape. Noticeably off-centre perforations in excavated beads could plausibly represent attempts by bead makers to avoid internal cracks or flaws in the bead that were thought less likely to withstand drilling.

It has been suggested that opaque ambers would be more susceptible to splitting during drilling because internal flaws are less likely to be visible in the body of the bead blank (Mainman and Rogers, 2000, p.2501). In recognition of this, the colour and transparency of the amber were recorded during the drilling experiments. Pale and opaque ambers (sometimes called bone amber) did not shatter or split at a noticeably higher rate than the darker or more transparent orangey ambers. Since the colour does not seem to markedly affect the working properties of amber, any preferential selection of amber of a particular hue or transparency by early medieval amber-workers is likely to have been primarily an aesthetic choice. The only exception to this was poor-quality amber containing lots of dark inclusions, which did prove difficult to successfully drill; this would almost certainly have been avoided, perhaps even at the point of collection.

Split beads or halves of perforated beads have also been recovered among amber-working debris at most of the Viking Age workshops, as well as in medieval London (Mainman and

Rogers, 2000, fig. 1219; Gjøstein Resi, 2011, figs. 6.3.16-19; Mead, 1977, p.212). These have often been cited as evidence that beads 'often' split and thus that drilling beads was a particularly difficult or risky operation (e.g. Mead, 1977, p.212; Wallace, 2016, p.292; Gjøstein Resi, 2011, p.110). Of course, this somewhat overlooks the fact that finished objects are necessarily vastly underrepresented in archaeological assemblages of amber-working byproducts. Using the present experiments as a proxy, perhaps fewer than one in five beads split during drilling; for experienced amber-workers the rate of failure was likely even lower.

Shaping

After drilling, the beads required additional shaping to produce smooth finished surfaces. Again, this was achieved using a combination of a knife and sandpaper, but for fine shaping, grinding proved more effective than carving, even if it was the more time-consuming process (See Figure 14). Abrasion of the beads against sandpaper produced irregular multi-directional surface striations (See Figure 15). As already noted, flat surfaces, such as the perforated faces of disc-shaped beads and the sides of facetted bead types, evidence the use of a grindstone during bead production. Importantly, grinding requires less skill and care than carving, with the result that the easiest shapes to replicate for an inexperienced amber-worker are the larger disc-shaped beads. Although they are often the largest beads in terms of dimensions, they take less time overall than some of the more complex rounded or facetted shapes. Beads with flat sides, such as the cuboid beads, are similarly relatively straightforward to produce. Beads with a biconical longitudinal section are made by first producing a cuboid bead of the desired dimensions and then abrading away the sides of the beads perpendicular to the perforated faces.

Beads with a rounded surface pose greater challenges and require much more time to shape than those with flat faces. When the final shape is produced by grinding, the result, especially prior to polishing, is a bead with multiple tiny facets all over the surface (See Figure 16). The most challenging shape of all to produce at the convex biconical beads. These begin as long cylindrical bead blanks, which are then shaped by tapering down the sides of the bead towards the perforation. This can be achieved by rubbing the bead across a flat piece of sandpaper, but it proved easier to abrade away the surfaces by folding the sandpaper around the bead. Feasibly early medieval amber-workers may also have utilised a piece of leather or cloth coated with a suitable abrasive to shape, as well as polish, the beads.

The ease of shaping the beads also depends partly on the size of the raw amber piece being worked. Larger pieces are much easier to hold steady for carving or grinding than smaller pieces. Possibly very small beads would have been clamped in place, affixed to a stable surface or threaded onto a rigid tool to facilitate shaping. The latter proved useful in creating the tapering shape of convex biconical beads. The issue of holding very small beads comfortably in the hand meant that, paradoxically, they often took a longer time to shape than the larger beads.

There is no convincing evidence for the use of a lathe in the shaping of the early medieval amber beads, although it was occasionally used in some Viking Age contexts (*contra* Harrington and Welch, 2014, p.157; on the use of a lathe in Viking Age amber workshops, see Wallace, 2016, p.292; Gerds, 2001, p.117; Ulbricht, 1990, p.73). Some of the common shapes are incompatible with turning, including the disc-shaped and facetted beads. Even the beads with a rounded transverse section, such as the barrel-shaped or convex biconical types, very rarely show the kind of perfectly symmetrical profile indicative of lathe-turning. Indeed, the present experiments have demonstrated that all the shapes present among the early medieval beads can be replicated using a limited selection of handheld tools.

Polishing

Polishing was almost certainly the step that removed many of the visible traces of manufacture from the beads. This is especially evident in the Viking Age amber workshops, where tool-marks are a much more commonly identified feature of the part-finished objects than the finished pieces (Ulbricht, 1990, p.83). Semi-finished beads produced during the experiments were often covered in surface striations from both the knife and the sandpaper, but comparable manufacturing evidence is almost never visible on the excavated beads. One of the aims of the experimental reproductions was to understand how far these manufacturing traces could be removed through polishing.

It is not clear what abrasives were used by early medieval bead-makers for the purposes of polishing beads. In *De Diversis Artibus* Theophilus recommended the use of ground-up tile mixed with saliva as a suitable abrasive for polishing gemstones, firstly against a sheet of lead plate and secondly against a piece of goatskin (III.95; transl. Hawthorne and Smith, 1963, p.189). Pumice, sea sand, crushed chalk, powdered charcoal, bone ash and shave-grass (*Equisetum*) are also materials suggested to have been used as abrasives in bone-, antler- and wood-working during the early medieval period (MacGregor, 1985, p.58). The same deposits in Anglo-Scandinavian York that produced evidence for amber- and jet-working contained significant quantities of chalk cores. The conical shape of many of these cores suggested that they were used in polishing both jet and amber, both of which were worked at the site, either directly or by removing powder for use as an abrasive (Mainman and Rogers, 2000, p.2159).

Two polishing agents were tested in the present experiments: lumps of natural chalk and the small chips, drill filings and amber dust produced during the shaping of the beads. In the case of the chalk the amber beads were first rubbed firmly across the surface of a substantial piece of chalk (See Figure 17). It was possible to create the same kind of conical chalk cores as recovered from York in this way. This produced a great deal of fine chalk powder, which could then be mixed with a suitable lubricant and applied as a polish using scraps of coarse linen cloth. The amber waste was used in the same way (See Figure 18). Rapeseed oil was utilised as a lubricant, but animal fats or saliva would have had the same effect. The chalk proved to be more effective than the amber filings at removing manufacturing marks from the amber beads. After 15 minutes of polishing using chalk, the shallower surface marks had begun to disappear, whereas the same traces remained visible after amber dust was used for the same amount of time.

At least 25 minutes of polishing time using solid chalk and powder in combination was required to remove surface striations to the extent that they were no longer visible to the naked eye (See Figure 19). Particularly deep striations resulting from the shaping of the bead are still evident under a microscope, and it was difficult to fully polish away all manufacturing traces. As noted, tool marks are relatively rarely identified on extant early medieval beads, although it is not clear how systematically these were removed during the finishing of the objects, since this manufacturing evidence could also be lost to wear and degradation of the surfaces in the burial environment. One additional benefit of polishing is the improvement in the appearance of the beads. Both the beads polished using chalk and those using waste flakes and dust showed increased transparency and, in the case of the thicker beads, a deepening of the colour towards a deep reddish orange.

Production waste

Making amber beads results in a range of production waste. Amber dust and tiny crumbs are produced during all stages of manufacture, including sawing, carving, grinding and drilling. Drilling also produced larger amber shavings. Small, detached flakes of amber were also frequently lost from surfaces during sawing, drilling and carving. The present experiments also produced numerous small pieces of amber, too small to be usable, left over from dividing larger nodules into suitably sized pieces for replicating individual beads. Often these pieces had a single worked face, with clear saw or knife marks visible (See Figure 20). It is likely that an early medieval bead-maker would not produce these kinds of worked waste pieces at the same frequency as the current experiments, on the assumption that the size of the finished beads will be more directly related to the size of the raw nodules in most cases. Nevertheless, small, minimally worked waste fragments of amber are present at almost all of the identified Viking-Age workshop sites (Ulbricht, 1990, p.75; Gjøstein Resi, 2011, p.110; Mainman and Rogers, 2000, p.2504; Wallace, 2016, p.291; Botfeldt and Brinch Madsen, 1991, p.103). The other substantial category of working waste was failed beads, most of which split during drilling (See Figure 21). The size of most of the replicated beads meant that, once a bead split, the two halves were each too small to be worked into another bead. Again, a comparison with the Viking-Age amber workshops would suggest that these failed beads would typically be simply discarded as waste (Sindbæk, 2023, fig. 15.4; Gjøstein Resi, 2011, p.110; Botfeldt and Brinch Madsen, 1991, p.101).

Much of the working waste produced during amber bead manufacture is extremely small, often only a few millimetres in diameter. Unless sieved using a very fine mesh, much of the evidence for amber-working would not be recovered during excavations (Langbroek, 2021, p.287). Some by-products of production, notably the amber dust and the very smallest filings and chips, would be archaeologically invisible. As noted, these 'waste' materials can be reused as a polishing medium by mixing with a suitable lubricant. It would also be possible to pulverise any small pieces of waste amber for the same purpose, but whether this was ever done is unclear.

Discussion

The toolkit required to produce amber beads is relatively minimal, consisting of a knife, a drill and suitable abrasives, and possibly also a saw in a small number of cases. Knives were undoubtedly ubiquitous in early medieval settlements (Knox, 2016, pp.252-253) and simple abrasives could be readily sourced, but the drill and saw would have been more specialised tools. Interestingly, there are considerable overlaps here with the tools used for other early medieval craft activity, in particular bone- and antler-working. Bone, antler and horn were used extensively in the fifth- to seventh-centuries to produce a range of utilitarian objects, including combs, pins and spindle whorls (MacGregor, 1985). Saws were particularly important in the primary processing of bone and antler, while a comb-maker would have possessed the kind of small drills needed construct and decorate composite bone objects (Riddler, et al., 2023, p.80; MacGregor, 1985, pp.59-60). Several processes-sawing, drilling and polishing-are common to both crafts. If anything, bone- and antler-working requires a greater degree of physical strength and skill than amber-working, because the material is harder and therefore more difficult to work (Ulbricht, 1990, pp.103-104).

Speculation about cross-craft interactions between bone- and amber-working in both the Viking Age and in other contexts is not uncommon (Gerds, 2001, pp.118-121; Coulter, 2015, p.115; Wallace, 2016, p.292; on the interactions of Classical period amber- and ivory-workers see Causey, 2011, pp.111-114). The evidence for the overlap of the two crafts in Viking Age urban contexts is mixed. At some sites, including Ribe, Hedeby, Åhus and Dublin, differences in the spatial distribution of amber- and bone-working waste indicate that these were separate crafts (Sindbæk, 2023, p.321; Ulbricht, 1990, p.102; Coulter, 2015, p.116). By contrast, at Groß Strömkendorf, Wolin and Kołobrzeg, there was such a correspondence in the stratigraphic contexts evidencing comb-making and amber-working that it could be suggested that the two crafts were practised simultaneously, perhaps by the same artisans (Gerds, 2001, p.118). Since early Anglo-Saxon amber working is unlikely to have been undertaken at a comparable scale as in the Viking Age, in the latter case responding to a market demand, a connection between amber- and bone-working is perhaps more plausible than not in the former. Certainly, the occasional perforation of small pieces of bone, animal teeth and claws, and fossils to serve as beads in the same fifth- and sixth-century bead-strings would lend some support to this suggestion (e.g. Meaney, 1981, pp.45-47, 115-117; MacGregor, 1985, p.101). Other kinds of cross-craft interactions were suggested by the evidence from mid- to late-tenth-century York, where amber-work seems to have been practiced alongside ferrous and non-ferrous metalworking (Mainman and Rogers, 2000, p.2514).

A single craftworker working alone can produce an amber bead. Many of the replica beads produced over the course of these experiments were made this way. Only the use of a bow-drill to perforate the beads requires a second pair of hands, and this can be easily overcome using a simple clamp or weak adhesive. The replica beads were primarily made individually, following each of the production stages in sequence, in order to fully record and document the processes. This is almost certainly not reflective of early medieval practice: as seems to have occurred at the Viking-Age workshops, small groups of amber beads were probably produced together in batches (roughing out all bead blanks before moving onto drilling). This may have implications for contextually-linked assemblages of beads, looking, for example, at the variation in perforation diameters of the beads.

The skills required to produce amber beads can be acquired quickly and intuitively, without the need for instruction. Some of the steps in the production, such as drilling and shaping, become quicker and produce better results when the maker has a degree of familiarity with the material, but not to the degree that the craft can be considered a speciality. Some processes, especially polishing the finished beads, require very little skill at all, and are the kind of time-consuming and repetitive tasks that could plausibly have been given to apprentices. Based on the evidence from Hedeby, where amber was locally available to be collected with relative ease and where there was almost no spatial patterning in the distribution of the material across the site, Ulbricht (1990, p.103) suggested amber-carving was a craft routinely undertaken by everyone, and thus entirely non-specialised. In other contexts, it is likely that only certain individuals worked amber, not because of the level of skill required, but because the supply of inherently valuable raw material was reliant on networks of trade and exchange. This seems to have been the case at both Dublin, Dorestad and possibly also Kaupang, where the distribution of amber-working debris suggests a craft centred on discrete organised workshops (Wallace, 2016, p.294; Kars and Wevers, 1983, p.66; Gjøstein Resi, 2011, p.117). On the basis of analogy, amber-working in early medieval England probably therefore did fall into the remit of specialised craft-workers, and that these individuals likely also worked, perhaps even primarily, in other media.

Conclusions

Almost all the raw amber pieces used in these experiments required considerable reworking, removing a good deal of surface material. Even when rounded amber pebbles were used to make barrel-shaped beads, inevitably some working was required to even out the shape and produce the flattened perforated faces that are a feature of almost all beads. The same judicious use of nodules of a favourable shape for transformation into beads was noted at Hedeby (Ulbricht, 1990, p.71). Given that barrel-shaped beads are among the most common form among the examined early medieval beads, accounting for 53% of the King's Croft

Gardens and Girton beads, it seems unlikely that the supply of rounded amber pebbles was sufficient for all beads of this type to have been produced in this way, and indeed, the experiments proved that the shape can be created through a combination of carving and grinding. All other shapes (convex biconical, facetted and disc-shaped beads) required deliberate shaping through abrasion of the surfaces. Very irregular perforated nodules are quite unusual among the excavated beads; instead, most belong to one of a relatively restricted number of basic forms. Producing the desired shape seems to have taken precedence over retaining the maximum amount of material in most cases. Based on the present experiments, it seems unlikely that wastage was a major concern for early-medieval amber workers. This, in turn, implies that there was a relatively regular and reliable supply of amber, of the kind that would be supported by a combination of traded amber supplemented by exploitation of locally available material. The chronology of amber beads is currently only understood in broad terms, but the longer barrel-shaped and facetted beads, which require more intensive working of raw nodules than the shorter disc-shaped beads, do seem to belong to a sixth-century peak in the popularity of amber (Brugmann, 2012). Perhaps the introduction of particular bead shapes can be connected to subtle shifts in the relative availability of the material? Further research should also explore whether the declining popularity of amber into the seventh century was connected to a shrinking supply network, and if so, how the production and circulation of amber beads changed with this (c.f. Haworth, 2021, p.121).

The process of making replicas has also clarified the importance of understanding manufacture when assessing signs of use-wear on excavated early medieval amber beads, since consequences of the former might easily be misinterpreted as the latter. Loss of material around only one perforation can result from drilling a bead from one side, rather than uneven thread-wear, for example. In this case, other features, such as a wedge-shaped longitudinal profile, would be needed to confirm wear resulting from repeated use. Convex biconical beads are especially susceptible to chipping around the perforation, because the drill necessarily passes through a narrow diameter of amber. Where the loss of material affects opposite sides of the bead, this is incontrovertibly drilling-related damage, rather than wear, since the direction of thread-wear would have been the same at each face. Also important to recognise is that there is likely a great deal of interaction between manufacturing traces and wear-related distortion of the bead's original shape; elongation of perforations, for example, might begin as minor chipping during drilling and become exacerbated through use. More research is required to understand exactly how different wear-patterns develop, how this is affected by the overall size and weight of the affected beads and how long this process takes. A robust understanding of manufacture is an essential foundation in further exploring patterns of use-wear and object curation.

It is also possible to comment on the different shapes of amber beads identified among early medieval collections, which require different levels of time and skill to produce and have a different visual impact when strung (See Figure 22). Disc-shaped beads are comparatively easy to produce, especially when making use of naturally flat slabs of raw amber. The fact that the largest surfaces are the flat sides means that they can be shaped relatively quickly with little skill, almost certainly by rubbing the beads across an abrasive. Although disc-shaped beads are some of the largest and heaviest replicated beads, their visual impact when strung is less than that of other types, because of their short longitudinal profile. Notably, the transverse section is difficult to determine when strung, which might explain why early medieval disc-shaped beads come in a wide variety of shapes, from neat, rounded examples to irregular trapezoidal forms. Other than rounding off the shape, producing disc-shaped beads of a specified transverse section does not seem to have been considered important. Conversely, the observed difficulty in producing the long convex biconical beads is rewarded by their visual impact when worn. As the perforation passes through the maximum dimension of the bead, the biconical shape is visible when strung. This relatively unusual bead type was probably particularly prestigious. That convex biconical beads appear to be associated with the more richly furnished female burials, including grave 59 at King's Croft Gardens, is therefore unsurprising. This provides an important note of caution in attempting to use the dimensions or weight of individual beads or collections of beads as a straightforward proxy for wealth or value (e.g. Malim and Hines, 1998, p.211; c.f. Harrington and Welch, 2014, p.157).

Finally, the question of value can also be examined as it relates to both time and labour. Although amber working did not require an extensive toolkit or a fixed workshop location, each bead takes a not insignificant amount of time to produce (*contra* Gerds, 2001, p.118). Especially when the tendency for a small number of beads to fail during drilling is considered, a small collection of beads, such as the nine placed in the grave of the young girl in burial 8 at King's Croft Gardens, almost certainly represents several hours' work for an individual amber-worker. Necklaces comprising huge swags of amber beads, like the 280 beads in grave 71 at Long Wittenham (Oxon.) or the 250 beads in grave 143 at Sleaford (Lincs.) (Huggett, 1988, p.66), therefore represent a considerable investment in terms of labour, in addition to the inherent value of the amber as a material. This speaks to the agency of the wearers of this material to acquire the finished objects, tapping into complex networks of exchange that stretch around the broader North Sea zone.

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Country United Kingdom

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Gallery Image

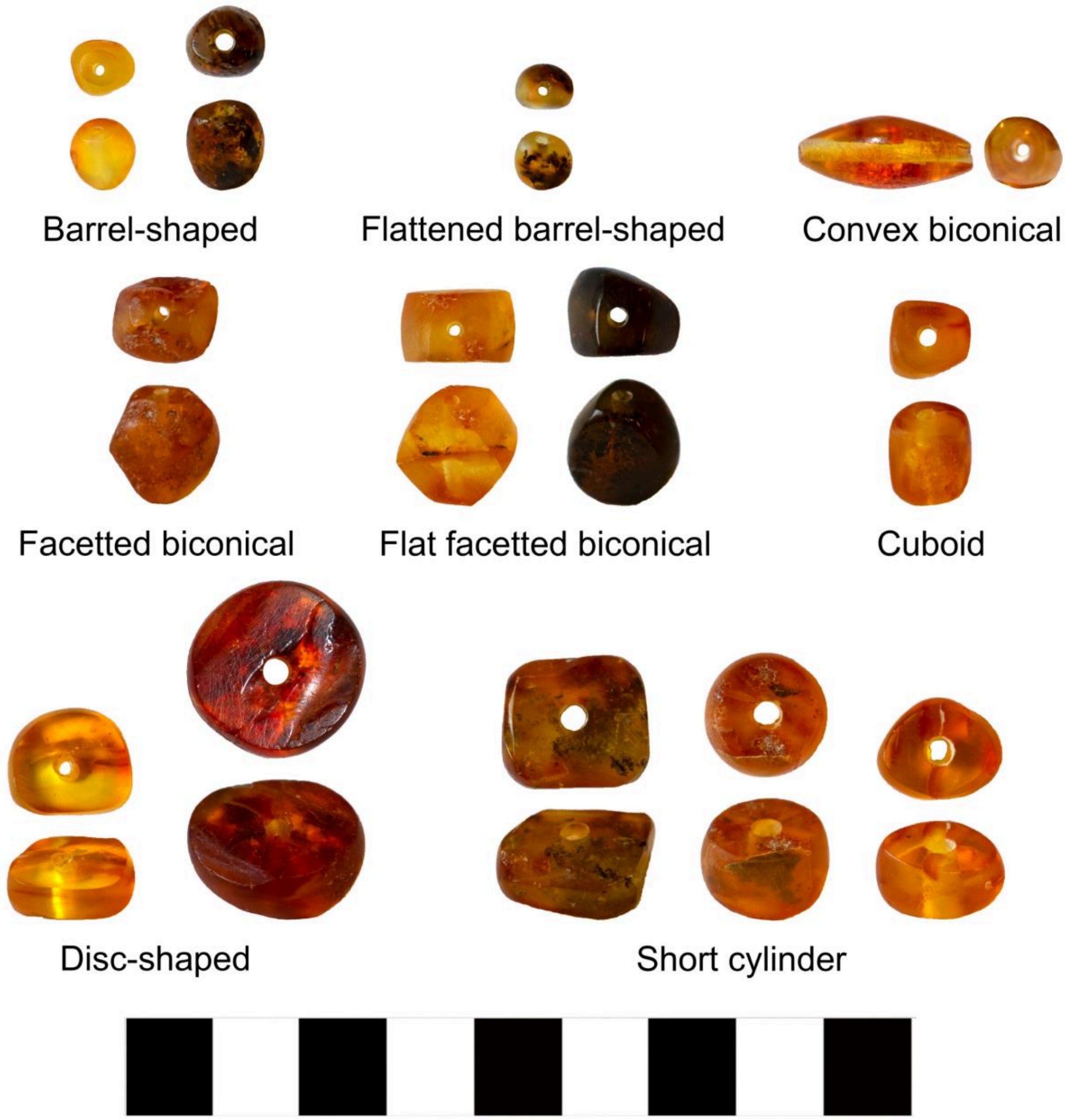

FIG 1. THE VARIOUS AMBER BEAD SHAPES IDENTIFIED AT KING'S CROFT GARDENS AND GIRTON, ILLUSTRATED BY REPLICA BEADS PRODUCED DURING THE PRESENT EXPERIMENTS. PHOTO BY KATIE HAWORTH.

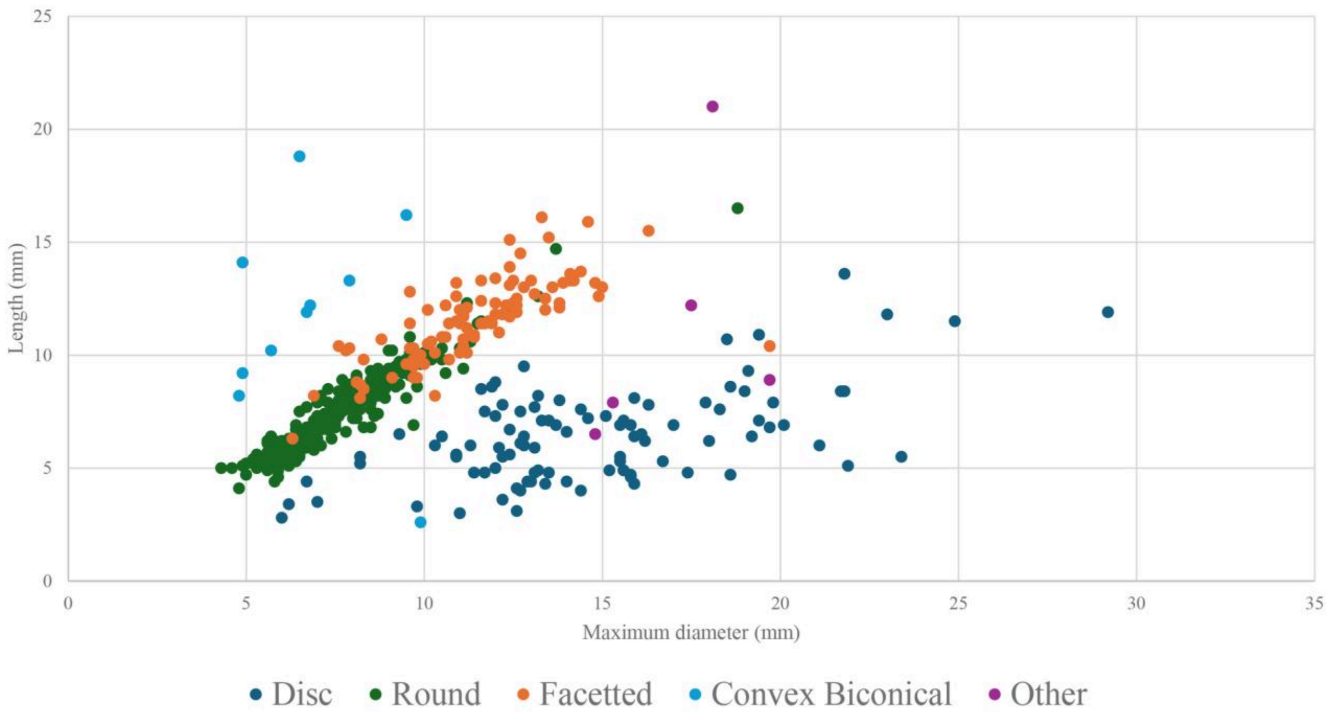

FIG 2. THE SIZE RANGE OF AMBER BEADS FROM KING'S CROFT GARDENS AND GIRTON, ACCORDING TO BEAD TYPE. GRAPH BY KATIE HAWORTH.

FIG 3. VARIATION IN COLOUR AND TRANSPARENCY OF BALTIC AMBER NODULES. PHOTO BY KATIE HAWORTH.

FIG 4. SAWING AMBER USING A JEWELLER'S SAW. PHOTO BY KATIE HAWORTH.

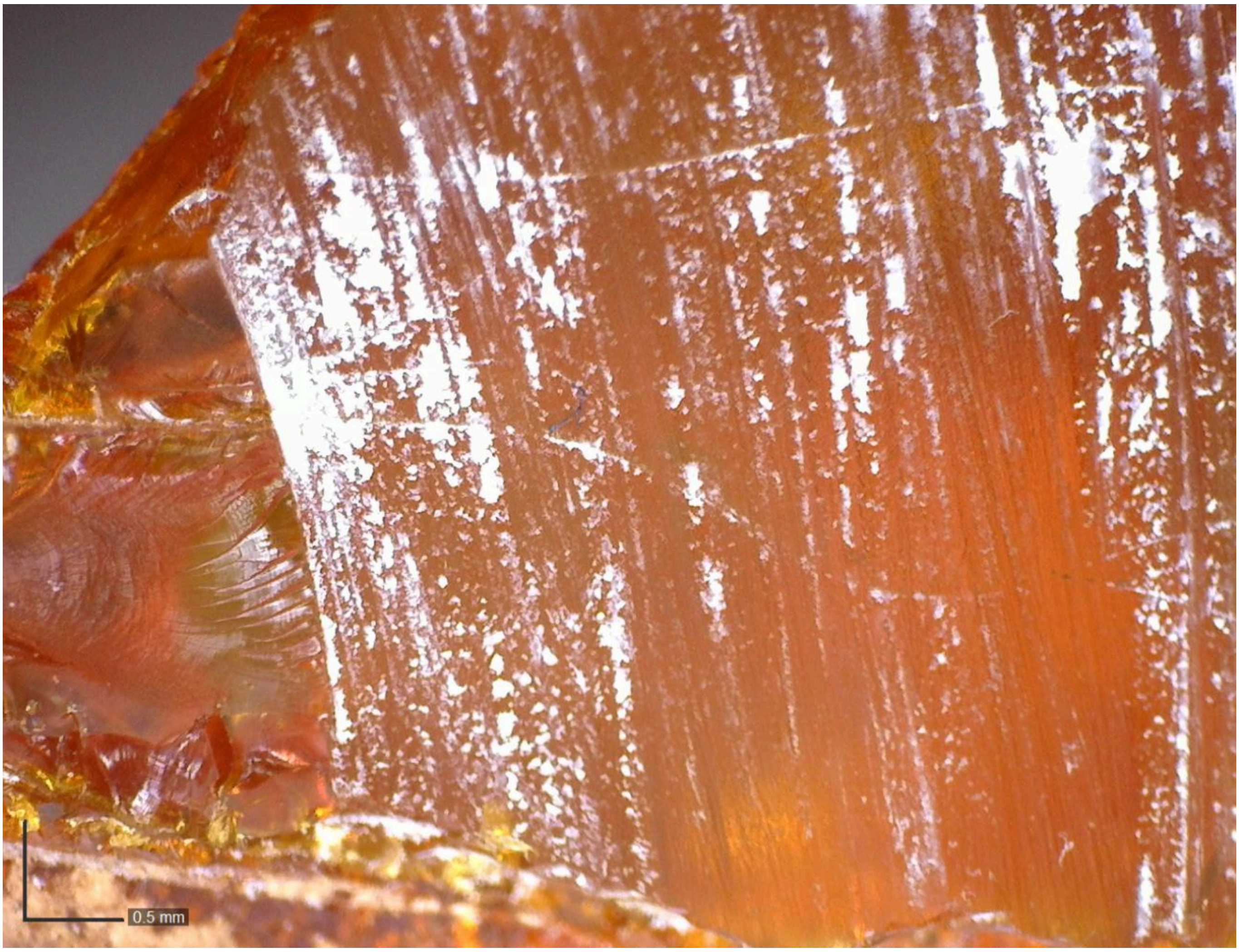

FIG 5. LINEAR PARALLEL SCRATCHES RESULTING FROM SAWING A PIECE OF UNWORKED AMBER. AT THE LEFT SIDE IS THE PLACE WHERE THE AMBER WAS SNAPPED OFF, SHOWING THE CHARACTERISTIC SURFACE FRACTURES. PHOTO BY KATIE HAWORTH.

FIG 6. CARVING AMBER USING A WHITTLING KNIFE. PHOTO BY KATIE HAWORTH.

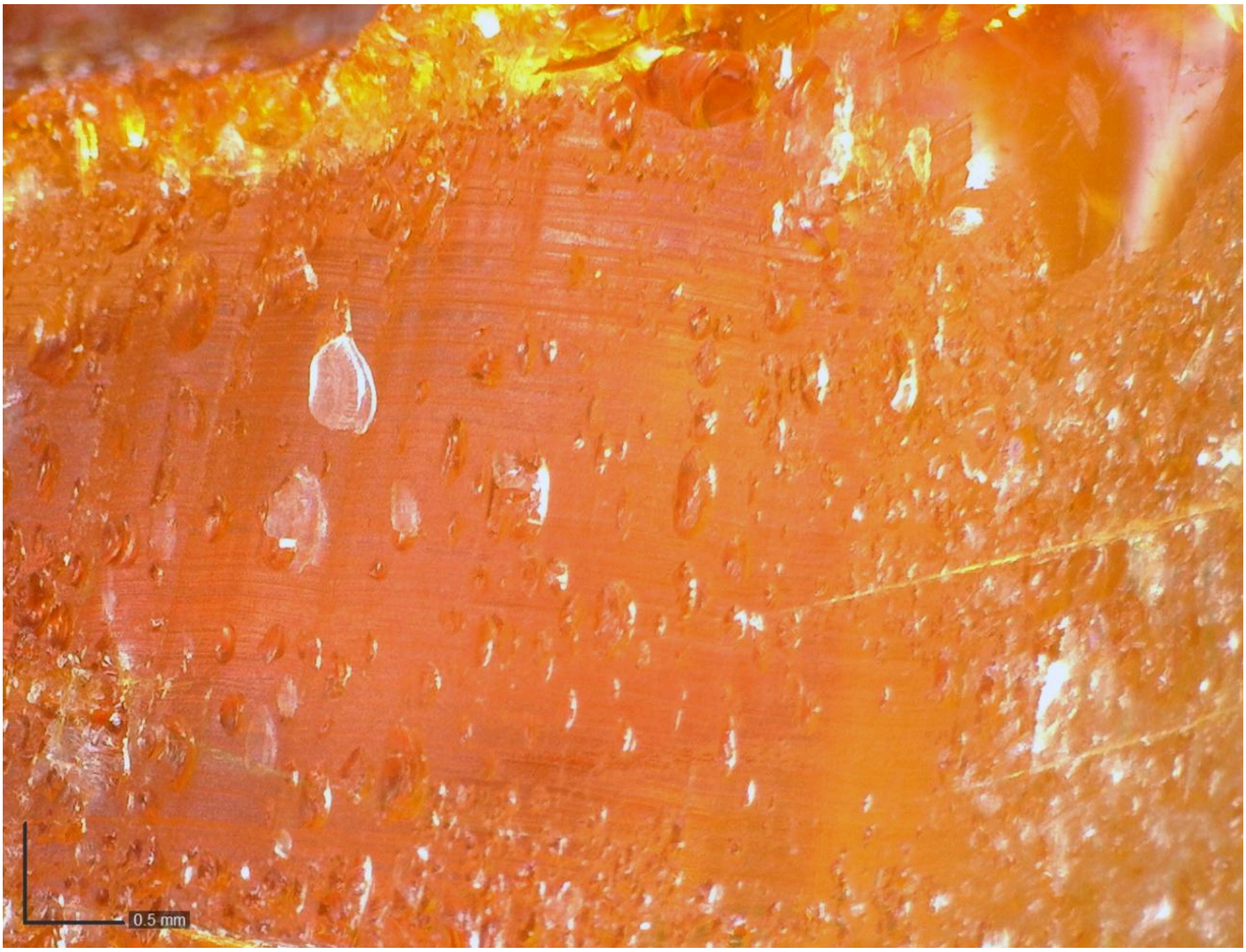

FIG 7. SHALLOW PARALLEL SURFACE SCRATCHES PRODUCED BY CARVING AMBER WITH A SHARP KNIFE. NOTE ALSO THE NUMEROUS OVOID PITS PERPENDICULAR TO THE DIRECTION OF CARVING. PHOTO BY KATIE HAWORTH.

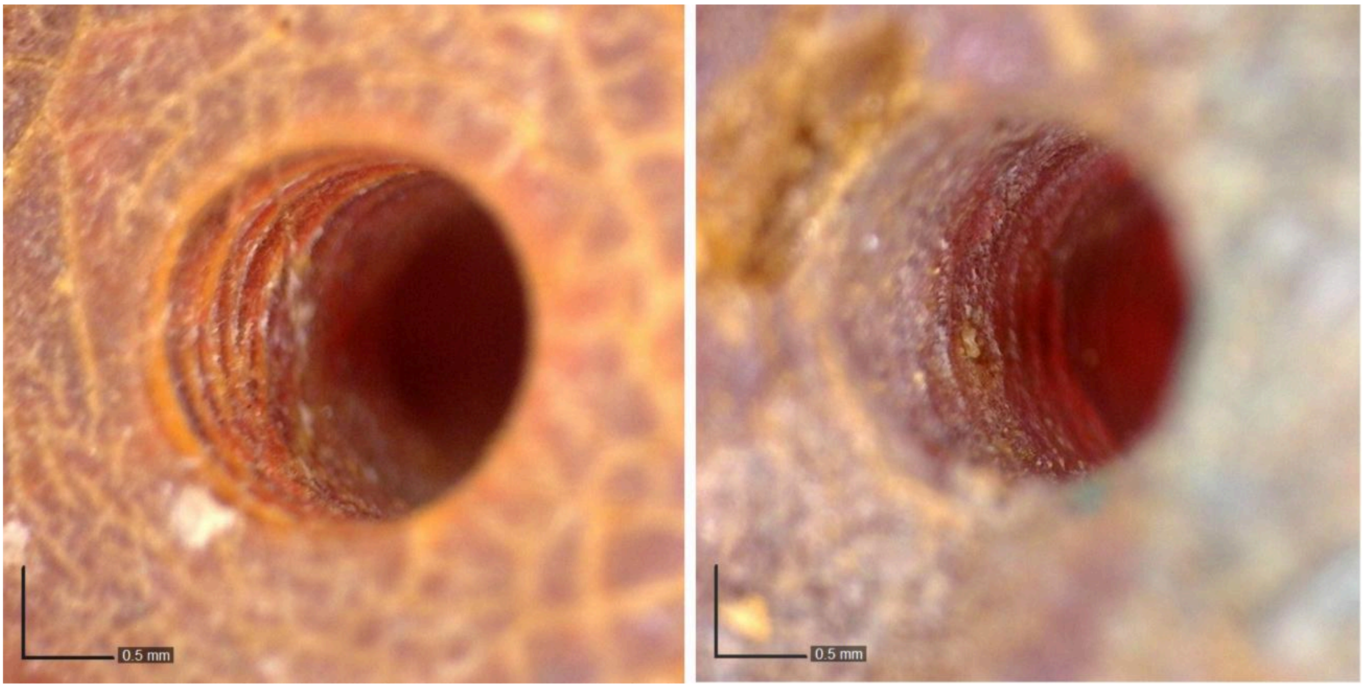

FIG 8. DRILLING STRIATIONS VISIBLE WITHIN THE PERFORATIONS OF TWO AMBER BEADS FROM KING'S CROFT GARDENS; (LEFT) A FLATTENED BARREL-SHAPED BEAD FROM GRAVE 22 AND (RIGHT) A SHORT CYLINDRICAL BEAD FROM GRAVE 29. PHOTO BY KATIE HAWORTH.

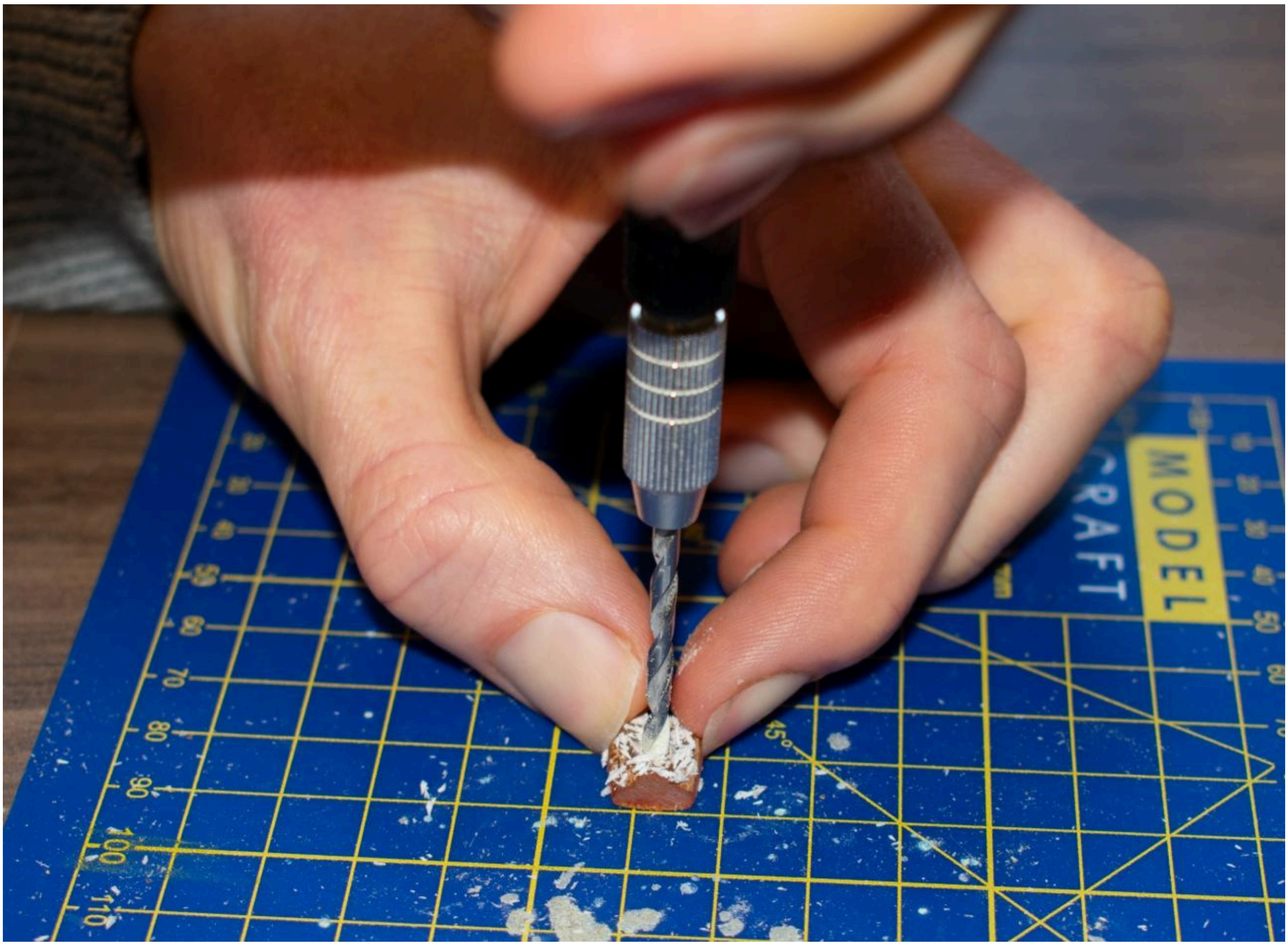

FIG 9. DRILLING AN AMBER BEAD-BLANK USING A HANDHELD DRILL FITTED WITH A 3 MM STAINLESS STEEL BIT. PHOTO BY KATIE HAWORTH.

FIG 10. STRIATIONS WITHIN THE PERFORATION OF A FAILED REPLICA BEAD RESULTING FROM DRILLING USING A HANDHELD DRILL WITH A 2 MM BIT. PHOTO BY KATIE HAWORTH.

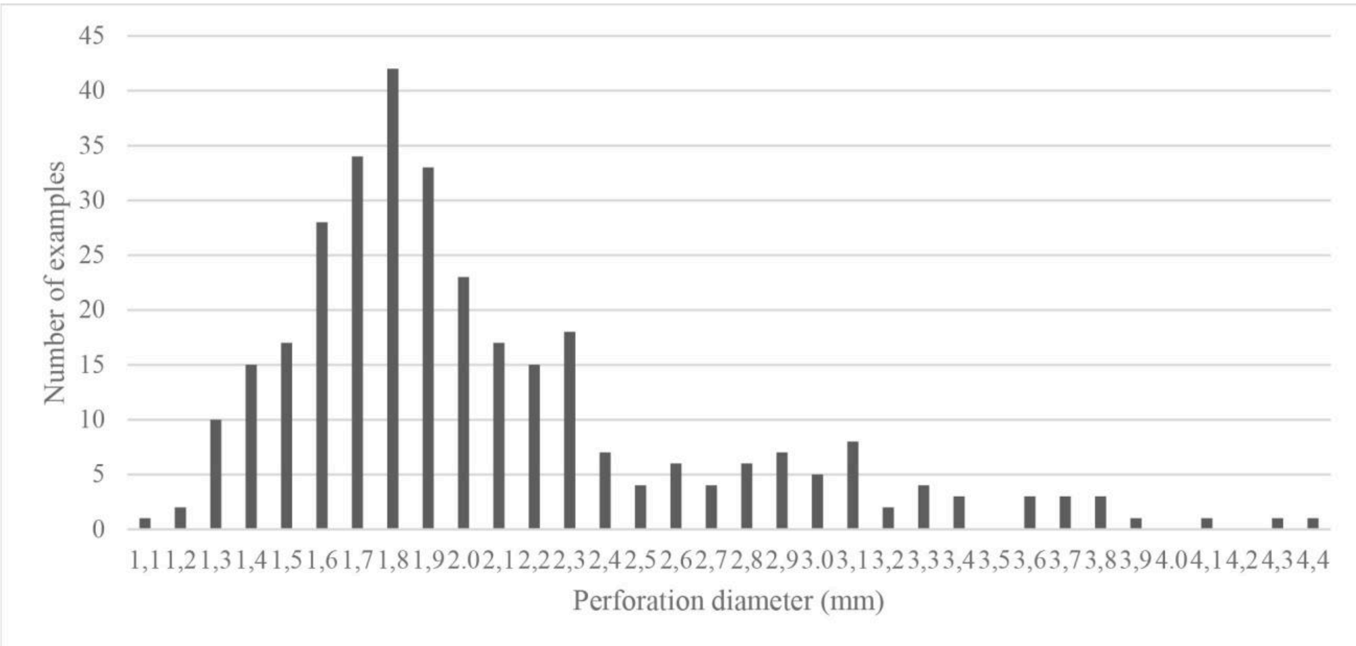

FIG 11. MEASURED PERFORATION DIAMETERS OF 324 AMBER BEADS FROM THE KING'S CROFT GARDENS CEMETERY. GRAPH BY KATIE HAWORTH.

FIG 12. BROKEN AMBER BEADS FROM KING'S CROFT GARDENS EVIDENCING DRILLING FROM BOTH SIDES; (LEFT) APPROXIMATELY HALF OF A BARREL-SHAPED BEAD FROM GRAVE 7 AND (RIGHT) AN INCOMPLETE CONVEX BICONICAL BEAD FROM GRAVE 59. PHOTO BY KATIE HAWORTH.

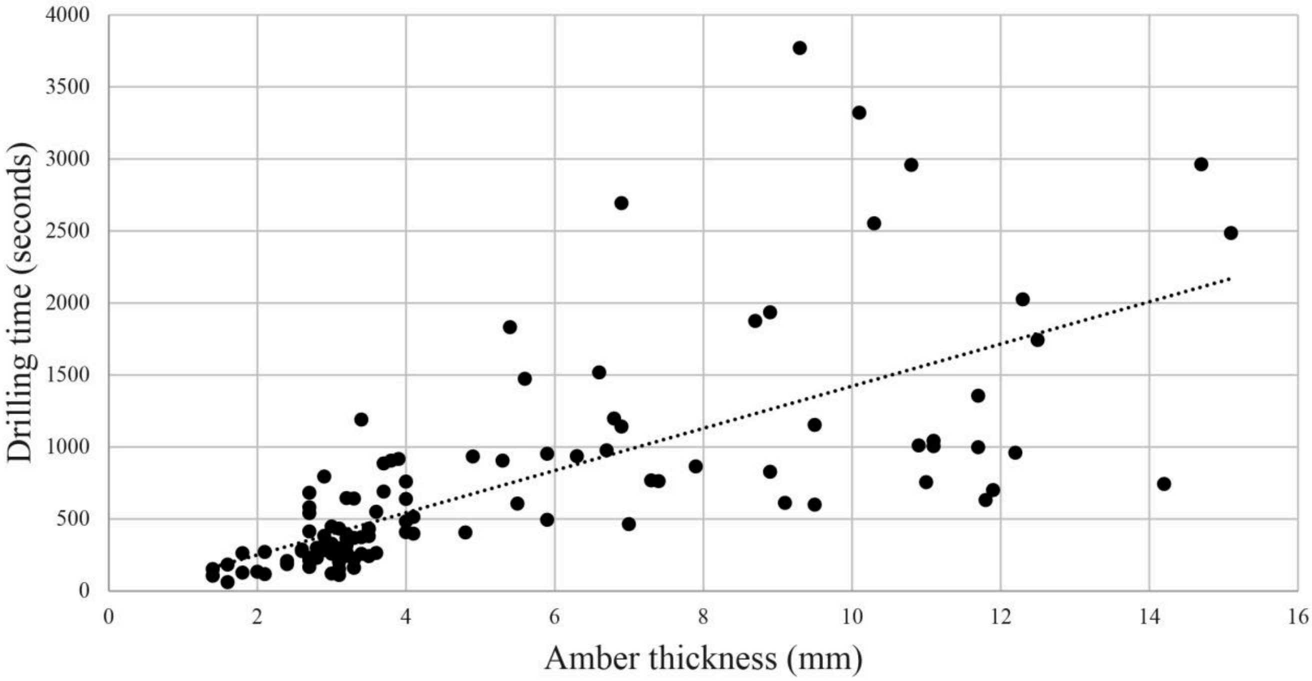

FIG 13. DRILLING TIME IN SECONDS COMPARED TO THE THICKNESS OF THE AMBER IN MILLIMETRES, BASED ON 116 SUCCESSFUL DRILLING EXPERIMENTS USING BOTH FLAT SLABS OF RAW AMBER AND PART-FINISHED BEAD BLANKS. GRAPH BY KATIE HAWORTH.

FIG 14. SHAPING A PERFORATED ROUGHED OUT BEAD USING COARSE SANDPAPER. PHOTO BY KATIE HAWORTH.

FIG 15. MULTI-DIRECTIONAL SURFACE MARKS PRODUCED USING A FINE ABRASIVE TO SHAPE AMBER BEADS, IN THIS CASE FINE-GRIT SANDPAPER. THE REPLICA BEAD IS A SHORT CYLINDER WITH A ROUNDED TRANSVERSE SECTION, PHOTOGRAPHED PRIOR TO POLISHING. PHOTO BY KATIE HAWORTH.

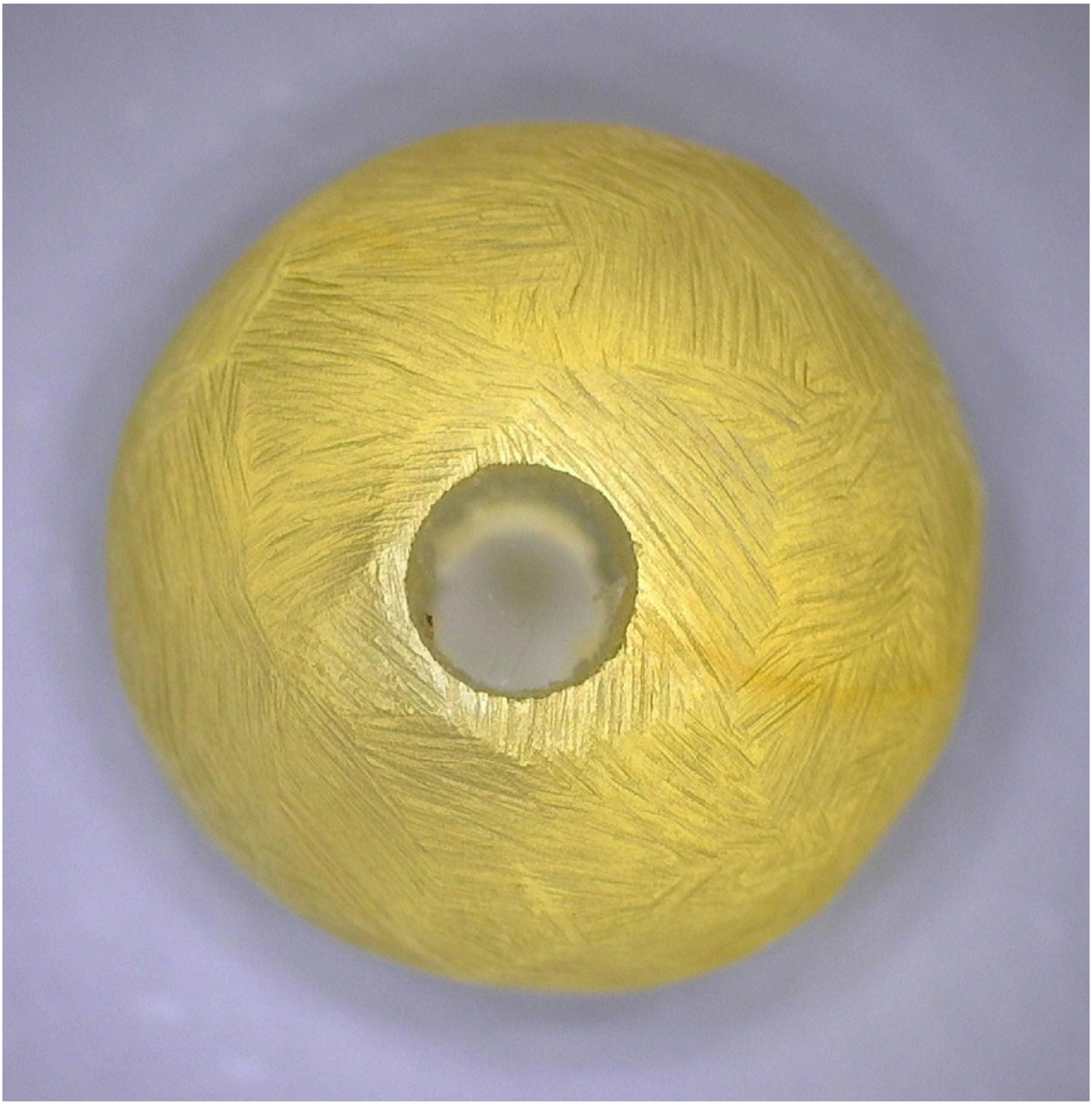

FIG 16. TINY SURFACE FACETS ON A BARREL-SHAPED BEAD. PHOTOGRAPHED PRIOR TO POLISHING. MAXIMUM DIAMETER OF BEAD: 8.9 MM. PHOTO BY EMILIA SAMBOREK.

FIG 17. POLISHING AN AMBER BEAD AGAINST A PIECE OF CHALK. NOTE THE CHALK DUST PRODUCED AND THE CONICAL SHAPE OF THE CHALK CORE. PHOTO BY KATIE HAWORTH.

FIG 18. POLISHING A FINISHED AMBER BEAD USING A MIXTURE OF GROUND CHALK AND RAPESEED OIL AND A SCRAP OF LINEN CLOTH. PHOTO BY KATIE HAWORTH.

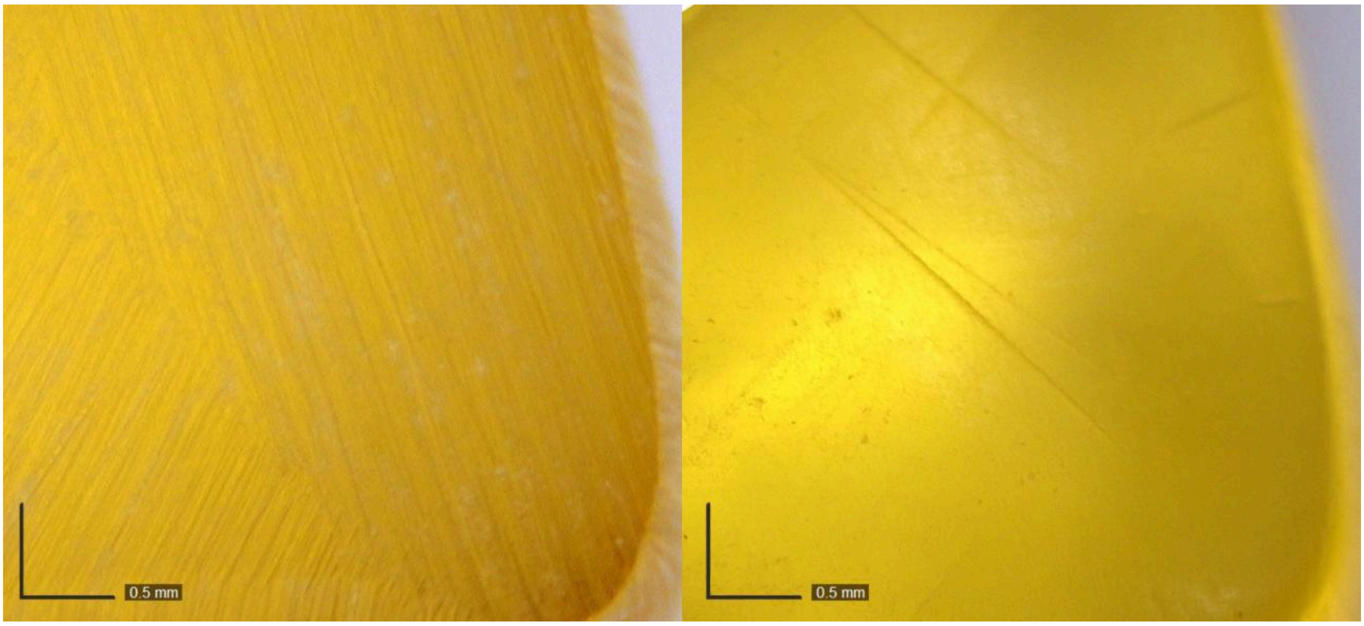

FIG 19. LEFT) SURFACE OF A SHORT CYLINDER BEAD PRIOR TO POLISHING, SHOWING LINEAR STRIATIONS RESULTING FROM SHAPING WITH SANDPAPER. RIGHT) SAME AREA OF THE BEAD AFTER 20 MINUTES OF POLISHING USING A PIECE OF NATURAL CHALK AND 5 MINUTES OF POLISHING USING A MIXTURE OF GROUND CHALK AND RAPESEED OIL ON A PIECE OF COARSE LINEN. SOME DEEPER SURFACE SCRATCHES STILL REMAIN, BUT THE MAJORITY OF MANUFACTURE-RELATED MARKS HAVE BEEN POLISHED AWAY. PHOTO BY KATIE HAWORTH.

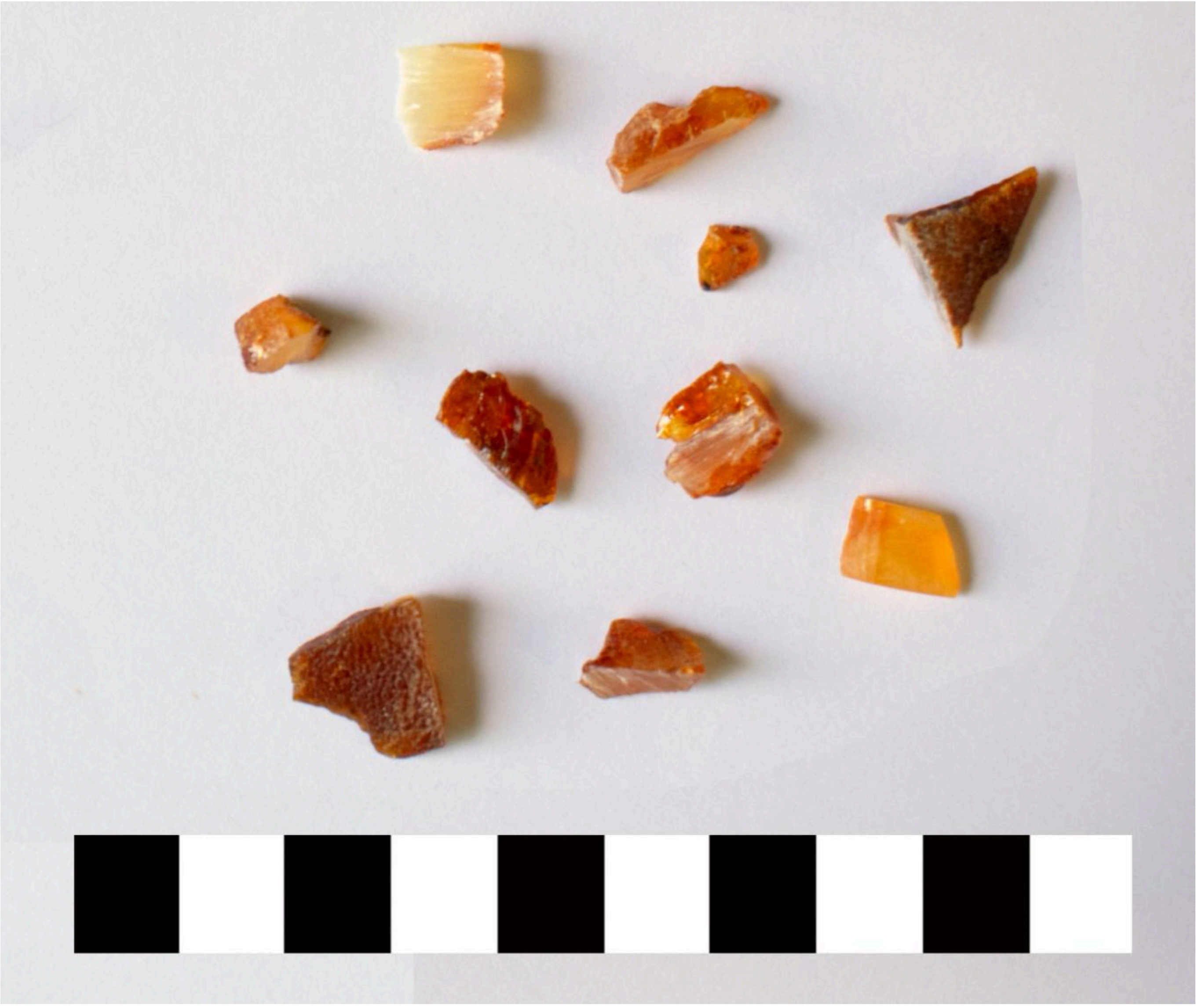

FIG 20. MINIMALLY-WORKED WASTE FRAGMENTS PRODUCED DURING THE COURSE OF EXPERIMENTAL BEAD-MAKING. PHOTO BY KATIE HAWORTH.

FIG 21. EXAMPLES OF BEADS THAT SPLIT DURING DRILLING. PHOTO BY KATIE HAWORTH.

FIG 22. REPLICA AMBER BEAD STRINGS FROM GRAVES 8 AND 59 AT KING'S CROFT GARDENS, STRUNG ON UNDYED HEMP YARN 0.6 MM IN DIAMETER. THE STRINGING ARRANGEMENT IS BY WEIGHT, WITH THE HEAVIEST BEADS AT THE CENTRE. PHOTO BY KATIE HAWORTH.