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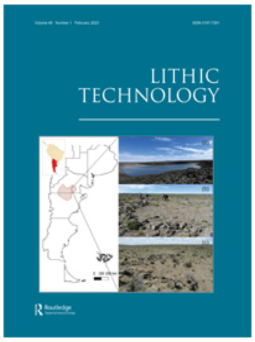

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Recycling Neolithic Axes: An Experiment Re-using Polished Axes as a Flint Source for the Creation of Small Tools

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ABSTRACT
In the western Netherlands Neolithic axes are hardly ever found in a complete state. Flint is scarce in this area and when these axes were exhausted, or when they broke during use, they were often re-used as flake cores. Vlaardingen Culture (3400–2500 BC) sites often yield large quantities of flakes and retouched tools made on polished axe fragments. Using an experimental approach, we tried to better understand the importance of recycling of these objects. For the experiments we reconstructed four so-called Buren axes. The experiments provided insights into the usefulness of broken axes as flake cores. It was also demonstrated that flakes struck from axes generally do not have a remnant of a polished surface, indicating that the importance of broken axes as flake cores has so far been underestimated. Furthermore, it was concluded that micro-debitage can successfully be studied to identify areas where broken axes were flaked.

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Flint; polished axes; Neolithic; experimental archaeology; micro-debitage; recycling

Introduction

Polished flint axes are ubiquitous in the European Middle (4200–2900 BC) to Late Neolithic (2900–2000 BC). Not only do we find complete specimens (see Figure 1), but polished axe fragments also abound, suggesting that these axes, when broken during use, were re-used as a flake core. This practice of recycling broken axes has been observed in the Corded Ware Culture in the Northern Netherlands (Garcia-Diaz, 2017, p. 228), in the Funnel Beaker Culture in Poland (Budziszewski, 2000, pp. 261–262), the Stein group in the Southern Netherlands (Amkreutz et al., 2016, p. 174), the Hazendonk group (Houkes, 2016, p. 168) and Vlaardingen Culture in the Western Netherlands (Amkreutz et al., 2016, p. 174; Van Gijn & Bakker, 2005, p. 295). The Vlaardingen Culture (VL) will serve as a case-study here because the recycling of axes in this period was very common and it is even considered a characteristic trait of this group (Van Gijn, 2010b, p. 82; Van Gijn & Bakker, 2005, p. 295). The current study is part of the NWO-funded project *Putting Life into Late Neolithic Houses, Investigating domestic craft and subsistence activities through experiments and material analysis (NWO AIB.019.020).* One aim of this project is to reconstruct object biographies based on detailed material analysis. The reconstruction ranges from the acquisition of raw materials, the transportation of material, the creation and use of objects to the potential recycling and finally the discarding of objects. This paper will take on a biographical approach, notably focussing on the recycling aspect.

VL sites have been found mostly in wetland contexts in the western and central Netherlands and date between 3400 and 2500 BC. The western Netherlands at this time was characterized by a diverse landscape which mostly consisted of different types of wetland zones (Raemaekers, 2003). Flint was scarce in this area, local flint nodules were generally small in size, consisting of rolled nodules from river deposits. Larger flint objects such as axes and chisels were not produced locally, presumably because of the absence of large flint nodules. These objects were imported in a finished state from the southern Netherlands and Belgium, notably from the Hesbaye area (Bakker, 2006, pp. 248–262). When these axes ceased to be used, probably because they were worn-out or because they broke, they were often re-used as cores to produce flakes and other objects such as scrapers and borers (Glasbergen et al., 1967a, p. 23; 1967b, p. 110; Houkes et al., 2017, pp. 155–172; Van Gijn, 2010b, p. 83). On

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Figure 1. Hekelingen III complete Buren axe (Collection RMO Leiden).

several cores from Den Haag Wateringse Binnentuinen a characteristic end-shock fracture could be observed (see Figure 2) indicating that the axes indeed broke during use before they were re-used as flake cores (Houkes et al., 2017, p. 172). It was estimated that approximately 10–20% of all VL flint objects were made from re-used flint axes and chisels (Van Gijn & Bakker, 2005, p. 295).

Although the importance of polished flint axes for the production of flakes and small tools in the Vlaardingen Culture has been recognized since the 1960s (Glasbergen et al., 1967a, p. 23; 1967b, p. 110), the quantitative aspects behind the use of these axes as cores have so far been poorly understood. It is not known whether a single axe can produce a handful of potentially useful flakes, or if it can be reduced to dozens of useful flakes and blanks for other tools. Furthermore, it is unclear if flakes produced from these axes are always recognizable by the presence of a polished surface. It is possible that some flakes produced from axes did not have remnants of a polished surface, in which case a larger percentage of the archaeological flint assemblages were actually produced from axes (Houkes et al., 2017, p. 171).

To explore the use of broken polished axes as cores from such a quantitative perspective, we conducted several experiments re-using replicated (broken) axes as a flake core. Furthermore, we aimed to better understand the visibility of axe fragments in the archaeological record by studying the presence and absence of polished surfaces on the axe fragments from the experiments. An unexplored aspect in this respect is the study of micro-debitage (see also: Chan et al., 2020). If polished surfaces can be recognized on micro-debitage this provides new research potential for the study of this artifact category.

Object Biographies

This study is conducted from the perspective of object biographies (Fontijn, 2002, p. 23; Kopytoff, 1986, pp. 64–67; Van Gijn, 2010a). Gosden and Marshall make a distinction between “specific” and “generalized” biographies (Gosden & Marshall, 1999, pp. 171–172). An example of the latter might be a guitar which is built, then being played after which it eventually ends up being destroyed. This life trajectory generally holds true for guitars. A specific biography might be that of a guitar used by a famous musician, this guitar is also built and played but it might eventually end up in a museum collection as a cherished treasure (Fontijn, 2002, p. 26). The biographies of these axes can be divided into a generalized part and a specific part. All axes are produced, distributed and then used in a similar manner. Nevertheless, after the axes break they are re-used in many different ways, creating a plurality of specific biographies. In their “lifetime”

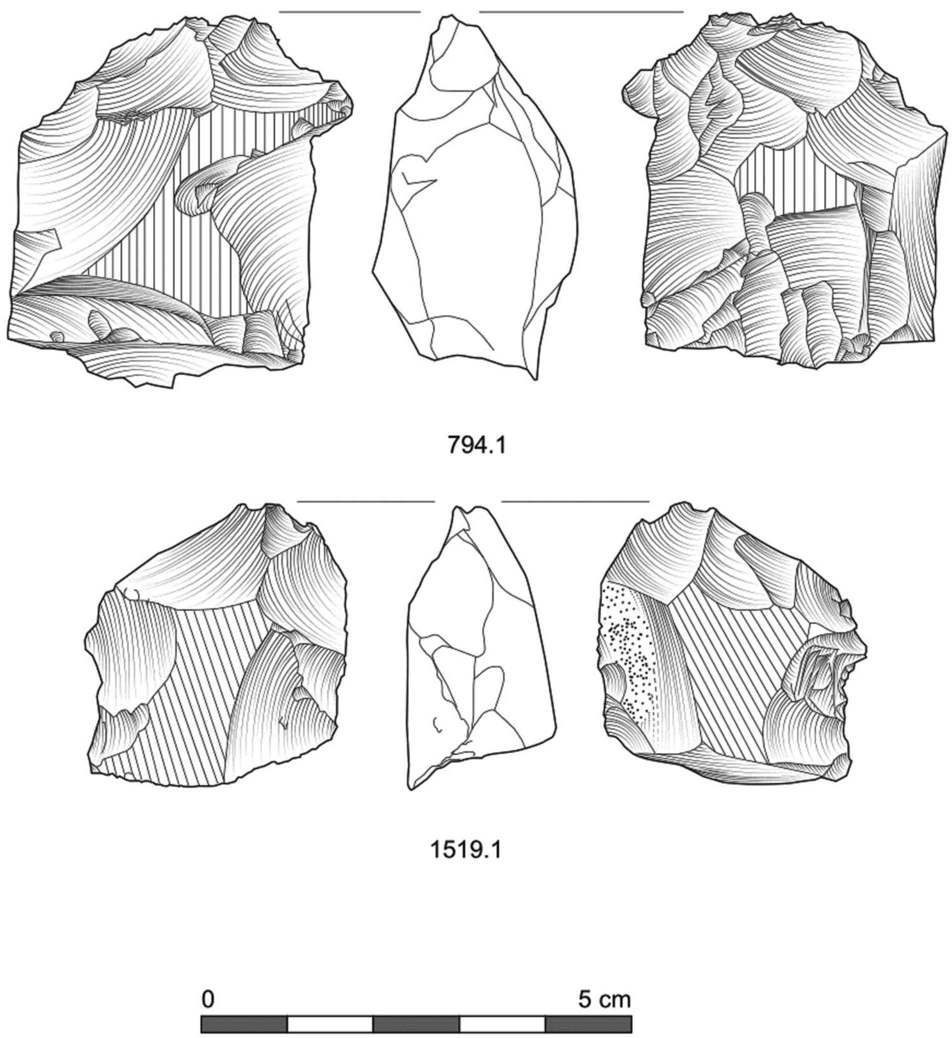

Figure 2. Flake cores from Den Haag Wateringse Binnentuinen, cores produced from axes with characteristic end-shock fracture, the result of breakage during use (Drawing by Marjolein Laan in: Houkes et al., 2017, p. 172).

these objects have multiple births, multiple use-phases and multiple phases in which they fall in disuse, before finally being discarded. Anthropology and archaeology often emphasize the dichotomy between parts and wholes (Chapman & Gaydarska, 2006, p. 15; Hillman & Mazzio, 1997, p. xiv). Polished axe fragments seem to defy a simple dichotomy. The parts become new wholes while they are still recognizable as parts of an axe. The biographies of these objects are shaped by complex interactions with different actors and objects. Their biography is shaped both by intentional actions and accidents. Our experiments seek to highlight how these parts become new wholes.

Experimental Set-Up

The experiments were set-up as an "analogue model experiment", as the aim of our experiments was to make predictions based on empirically documented situations, in this case experiments (Diez-Martin et al., 2021, p. 187; Eren & Andrews, 2013, pp. 173–174; Eren et al., 2016, pp. 105–118). In our study, the presence and absence of polished surfaces on the flint axe fragments was used to make predictions about invisible aspects of the archaeological record. In the archaeological assemblages we are only able to conclude that flint fragments originated from flint axes if these polished surfaces are present. In our experimental assemblages, however, we know for all fragments that these originate from flint axes. Hence, this assemblage is used as an analog to make predictions about the underrepresentation of flint axe fragments in the archaeological assemblages.

For these experiments, three polished Buren axes were replicated specially by Diederik Pomstra (an experienced flintknapper). A fourth replicated axe had been broken during the manufacturing of a dugout (Van Gijn, 2021). The three axes were flaked by hand

Table 1. Dimensions of the experimental axes.

Axe number	Length (cm)	Max width (cm)	Max thickness (cm)	Weight (g)
1	16.9	6.5	2.8	342
2	18.1	5.9	2.7	327
3	17.8	6.6	2.8	434
4	20.8	6.8	3.2	848

and then ground mechanically. We chose to grind them mechanically as that would save a lot of time. The grinding was only needed to allow for the identification of the presence of a polished surface, and this would not be affected by mechanical grinding. The fourth axe was initially intended as reference material for micro-wear analysis, therefore it was finished on a fine sandstone to resemble archaeologically observed grinding traces. The dimensions of the reconstructed axes were similar to those known from the archaeological record based on the overview presented by Bakker (2006). We chose to use axes which were comparable to the smaller axes of this type as we assumed that frequent resharpening or reshaping would have taken place before the axes were discarded and re-used (see Table 1).

Axes number 2 and number 3 were broken before the experiment. They were broken intentionally in halves, thereby simulating an end-shock fracture (see Figure 3). These kinds of transverse fractures occur when an axe breaks due to impact force during use (Andrefsky Jr, 1998). Two axe cores from Den Haag Wateringse Binnentuinen seem to have been broken in this manner before they were re-used as a core (Houkes et al., 2017, p. 172). The third axe was kept whole before we began the reduction sequence. The fourth axe was later added to the experiment. This axe was used in an experiment where we replicated a dugout, but during use the cutting edge broke off (Van Gijn, 2021). We decided to then use these axe fragments for this experiment as well as this most closely represents the past scenario of a flint axe which broke during use, after which it would be repurposed as a flake core.

Diederik Pomstra flaked these axes into larger usable flakes which could be used as a blank for the production of smaller objects and flakes with a straight cross-section >2 cm as these are known to have been used as tools in the Vlaardingen Culture (Van Gijn, 1990, pp. 128, 139).[1] We chose to use a hard hammer for the reduction because hard hammer percussion is the most frequently applied technique in this period group (Van Gijn, 2010b, p. 83). For the first three axes, we directed the reduction sequence mostly towards the production of blanks for scrapers and borers, which could be fairly small. For the fourth axe we decided to gear the reduction sequence more towards the production of larger flakes, with the aim of also creating a few suitable blanks for larger tools such as strike-a-lights. Because of this, the fourth axe, even though it was twice as heavy, did not yield twice as many flakes.

Figure 3. Breaking one of the axes to simulate an end-shock fracture, dividing the axe into two halves to be used as flake cores (photograph: Yuri van Koeveringe).

Documentation

After the experiments all flakes and micro-debitage were collected. The flakes which had a length of >1 cm were individually recorded in a Microsoft Access database. The database recorded the dimensions and weight of the flakes. It was noted if a polished surface was still present on the flakes. The database also recorded whether the flakes had a straight cross-section >2 cm and whether the flakes were suitable as blanks for the creation of different types of objects.

To classify blanks for scrapers the data from the recent excavation of Den Haag Wateringse Binnentuinen was used to estimate the average dimensions of these objects. The 619 scrapers found on this site have an average length and width of 2 cm and a thickness of 0.7 cm (Houkes et al., 2017, p. 180). To be suitable as a blank for a scraper the experimentally obtained flakes needed to have these dimensions and the longest side needed to be 2.5 cm, to allow for the edge to be retouched properly. For a round scraper (with 75% or more of the scraper edge being retouched), we added 0.5 cm to the expected dimensions to allow for the edge to be retouched. To be suitable as a round scraper blank the following dimensions were required: length 3 cm, width 2.5 cm, thickness 0.7 cm.

For the borers, the expected dimensions are based on the borers from Den Haag Steynhof (Houkes, 2021). These have an average length of 2 cm and their widths vary between 0.5 and 4 cm. The publication did not mention an average width and the median would have been larger than the average length. Therefore, a width equal to the length was chosen as the expected width for borers. The average thickness of these borers was 0.9 mm. These borers needed to be retouched from two sides, so 1 cm is added to the expected length to allow for the retouch.

For strike-a-lights the average dimensions are based on the strike-a-lights from the excavation of Den Haag Steynhof, which have an average length of 3.3 cm a width of 2.7 cm and a thickness of 1.5 cm (Houkes, 2021). Here 0.5 cm is added to the length and 1 cm is added to the width to allow for retouching to take place.

Micro-Debitage

Studies on micro-debitage have so far focussed on their potential for the identification of knapping and activity areas (Chan et al., 2020; Clark, 1986, p. 31; Hodder & Cessford, 2004). These studies focus on the technological aspects or micro-wear traces on flint micro-debitage. For Neolithic assemblages we would like to propose another prospective research potential: the identification of polished surfaces. In the VL assemblages polished surfaces only appear on imported axes and chisels. The presence of a polished surface on a flake thus indicates that it was originally part of either of these objects. This holds true regardless of the size of the flake, even for micro-debitage flakes. If a polished surface is present on archaeological micro-debitage this necessarily implies that these axes and chisels were reworked on-site. This will therefore provide direct evidence for the recycling of axes or chisels to make flakes and smaller objects on-site.

To gain further insight into the (in)visibility of axe fragments in archaeological assemblages we therefore decided to study the micro-debitage from the first three experiments. We divided the micro-debitage into three categories: 10–4, 4–1 and <1 mm. The smallest fraction was not studied. During our analyses we used stereo- and metallographic microscopes to look for grinding traces on some of the smaller facets on the micro-debitage, especially for those flakes where the polished surface could not clearly be distinguished with the naked eye. It should be noted that these polished surfaces would usually not have been recognized in archaeological excavations, as microscopes are (unfortunately) often not employed when studying lithic assemblages for basic reporting. Furthermore, micro-debitage is often not collected in most excavations.

Results: Polished Surface

The four experiments yielded a total of 466 axe fragments larger than 1 cm, 276 (59%) of which lacked the polished surface. These flakes could thus no longer be recognized as having been part of a polished axe. This confirms our suspicion that axe fragments are likely to be heavily underrepresented in the archaeological record. The presence of flakes without a polished surface was consistent amongst the four experiments, although the percentages of flakes with a polished surface differ per experiment (see Table 2). It is clear that when the reduction sequence is geared towards the production of larger flakes, as was the case with

Table 2. Percentages of flakes with a polished surface still present.

Axe number	Flakes with polished surface (*n*)	Flakes without polished surface (*n*)	Percentage with polished surface
1	31	83	27.2
2	35	53	39.8
3	49	69	41.5
4	75	71	51.4

Table 3. Polished surface on micro-debitage of the experiment per axe (after: Crombeen, 2021, pp. 7–8).

Axe number	Fraction	Flakes with polished surface	Flakes without polished surface	Percentage with polished surface
1	10–4 mm	20	58	26%
	4–1 mm	175	489	26%
2	10–4 mm	8	16	33%
	4–1 mm	119	540	18%
3	10–4 mm	11	56	16%
	4–1 mm	164	711	19%
Total	10–4 mm	39	130	23%
Total	4–1 mm	458	1740	21%
Total	**10–1 mm**	**497**	**1870**	**21%**

the fourth axe, a larger percentage of flakes will display a visible polished surface. The underrepresentation of axe fragments thus seems to increase with higher fragmentation rates.

Polished Surface on Micro-Debitage

Axe number four was only added later to the experiments after we completed the study of the micro-debitage. Therefore, the study of micro-debitage from the experiments was based only on the first three axes. It is clear that recognizable axe fragments are very underrepresented in the micro-debitage (see Table 3 and Figure 4).

Of the 10–4 mm fraction 23% of the flakes had a polished surface, while for the 4–1 mm fraction this amounted to only 21%. On average 21% of all the micro-debitage flakes still had a remnant of a polished surface. This means that generally micro-debitage flakes will no longer be recognizable as having been part of a polished axe. Nevertheless, in all three experiments we were able to identify the polished surface of the axes, even in the small fractions of the micro debitage. This indicates that when micro-debitage is properly collected from a closed archaeological context, it can be used to identify areas where axes and chisels were reworked into smaller tools (Crombeen, 2021).

Furthermore, the study of polished surfaces on micro-debitage flakes can be used to aid archaeological prospections. The prospection of Stone Age sites frequently takes place via coring campaigns. Sites are often only discovered by the presence of small flakes which are discovered after sieving. It is advisable to look for a polished surface on these flakes as this might give an indication of the date for these sites. The discovery of a polished

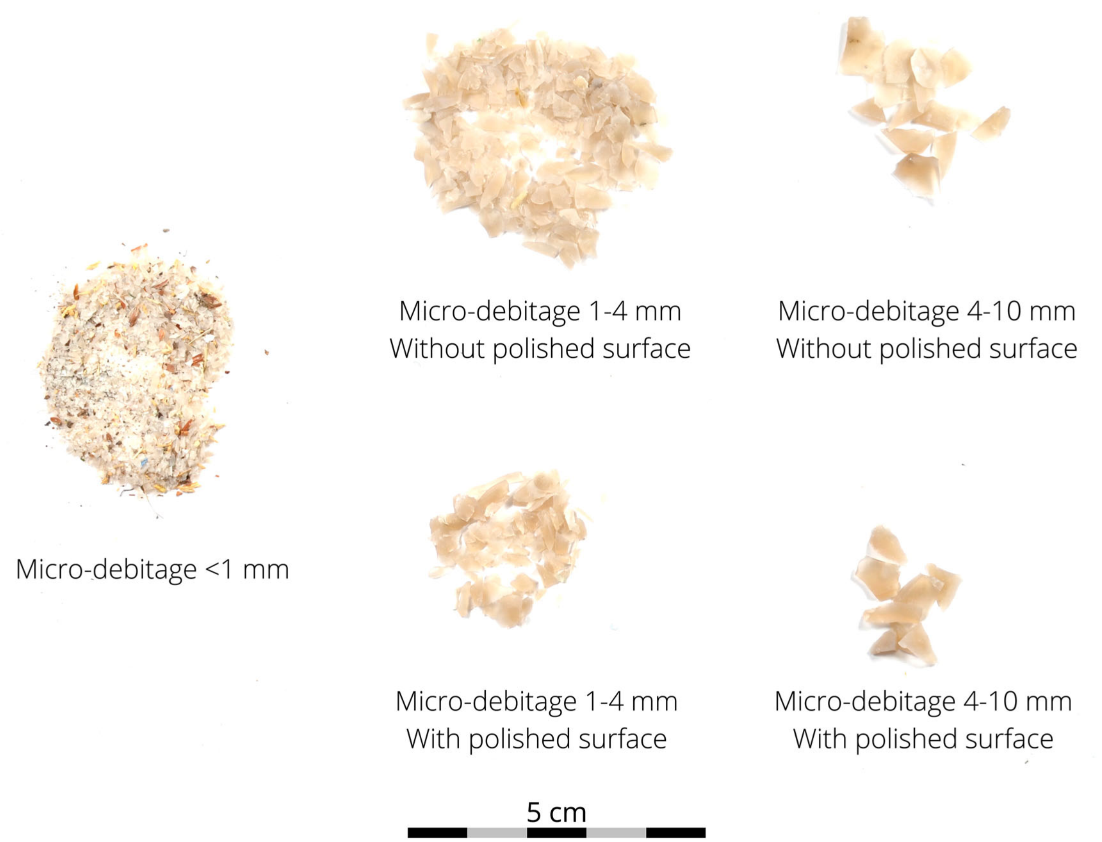

Figure 4. Micro-debitage of axe 2, different fractions with and without remnants of a polished surface (photograph: Lasse van den Dikkenberg).

Table 4. Quantification of the suitability of flakes of the experiment per axe.

Axe number	Amount of flakes	Suitable flakes	Flakes with straight edges >2 cm	Blanks for scrapers	Blanks for borers	Blank for Strike-a-light
1	114	33	25	23	23	1
2	88	24	13	15	13	0
3	118	46	35	29	24	0
4	146	41	34	27	26	4

surface can be used as an argument to date sites in the Middle to Late Neolithic, even when other dating evidence might be absent.

Useful Flakes

The four axe experiments yielded between 24 and 46 suitable flakes per axe (see Table 4). These flakes were either suitable because they had a straight cross-section >2 cm and/or because they could potentially serve as a blank for the production of tools such as scrapers, borers or strike-a-lights. It can be seen from the results that the reduction sequence of the fourth axe was geared towards the production of larger flakes in order to also create some blanks for potential strike-a-lights.

Fourteen of the potentially useful flakes did not have a polished surface. These flakes, which could have been used as tools, were no longer recognizable as axe fragments. Seven of these flakes were suitable as blanks for scrapers or borers.

Discussion

Broken and worn-out axes provided a valuable source of flint. Even in a broken state, these axes could still produce between 24 and 46 suitable flakes. This also warrants caution, if a site yields 20 or 30 large axe fragments these can all come from a single broken axe. Fragmented axes were clearly recognized as a potential source of flint in the past. The re-use of these axes does not seem to be incidental but rather structural. Many hundreds of axe fragments have been found on VL sites, while only a few complete axes are known.

The experiments provided insights into the visibility of axe fragments in the archaeological record. It became clear that polished axe fragments are not always recognizable as such. On average 59% of the fragments (>10 mm) were no longer recognizable as such, as they lacked the characteristic grinding traces. This has implications for our interpretations of archaeological assemblages. We can use this percentage to make an estimate of the number of missed axe fragments. In Table 5 a list of VL sites is presented with the percentages of polished axe fragments and an estimated percentage of the amount of axe fragments, based on our experimental results. We thus assume that the amount of recognizable polished axe fragments in the assemblages only represents 41% of the total amount present at these sites.

The compensated percentages probably give a more realistic assessment of the importance of broken axes for the production of flakes and small tools. For some sites, like Leidschendam-Prinsenhof and Voorschoten-De Donk, the polished axe fragments still only represent a small part of the assemblage. Why this may be the case is a question that is currently difficult to answer and in need of further exploration. Nevertheless, it is evident that on several sites broken axes were not just incidentally re-used. In Hekelingen III, Voorschoten Boschgeest, Den Haag Wateringse Binnentuinen and Den Haag Steynhof more than 20% of the flint is likely to have originated from broken axes. This seems to indicate that the import of these axes was not only essential because they were required for woodworking activities. Even after breakage, these axes continued to play an important role in the VL technological system. The people in these wetlands depended on the import of

Table 5. Compensated percentages of polished axe fragments in Vlaardingen Culture sites (Devriendt, 2013, p. 114, 121; Glasbergen et al., 1967a, p. 23; Van Hoof, 2009, pp. 81–85; Houkes, 2021, p. 142, 166; Houkes & Verbaas, 2014, p. 257; Houkes et al., 2017, p. 175, 200; Van Beek, 1990, pp. 78–208; Van Veen, 1989, pp. 25–26; Verhart, 1983; 1992, p. 80).

Site	Total amount of flint objects	Percentage of recognizable axe fragments	Compensated percentage of axe fragments, based on the experiments
Hekelingen III	1023	17.9%	43.7%
Voorschoten Boschgest	258	12.8%	31.2%
Den Haag Wateringse Binnentuinen	3384	9.6%	23.4%
Den Haag Steynhof	2335	8.4%	20.5%
Hellevoetsluis Ossenhoek	2823	7.6%	18.5%
Vlaardingen Arij Koplaan	6732	6.0%	14.6%
Veldhoven Habraken	694	4.9%	12.0%
Haamstede Brabers	590	4.7%	11.5%
Leidschendam-Prinsenhof	1773	2.9%	7.1%
Voorschoten-De Donk	1881	2.4%	5.9%
Voorburg Hadriani	1748	1.8%	4.4%

these polished axes because they did not produce these themselves and because they constitute highly effective woodworking tools. Although it is clear that people became dependent on the import of flint axes, it is unclear why this dependency arose. Our experiments have shown that heavy woodworking could also be done with antler and bone axes and adzes (Van Gijn & Pomstra, 2013). Moreover, although flint was not available locally, certain flint types such as Meuse eggs and terrace flint could be obtained from sources that were located much closer than the flint mines in Hesbaye. Therefore, the import of these axes also seems to have had a cultural significance, likely to have played a part in the social network linking the coastal inhabitants with the hinterland.

Conclusion

Polished axe fragments are most probably underrepresented in the archaeological record of the late Neolithic Vlaardingen sites mentioned above. Our experiments indicated that approximately 59% of the polished axe fragments, obtained through the reduction of broken polished axes, will not be recognizable as such. It should be noted that these percentages vary depending on the reduction sequence. If reduction is geared towards the production of larger tools a larger percentage of flakes will be recognizable. It would be interesting to expand these experiments with different reduction sequences to also assess the differences in micro-debitage resulting from different procedures. This is important to bear in mind when interpreting assemblages from the Vlaardingen Culture. It should also serve as a warning for the interpretation of other Neolithic contexts which contain polished axe fragments. For the Vlaardingen Culture the imported flint axes were not only important because they were highly efficient tools, but they also constituted a source of good quality flint. Their "second life" may not have occurred intentionally, breaking an axe most likely was not, but was certainly part of the VL technological repertoire. The axes were frequently re-used after breakage. A single axe could create a large quantity of blanks for the production of retouched and unretouched tools. The biographies of these axes did not end when they broke, but instead, they entered a new life phase after breakage. Both in an unbroken and in a broken state these axes were important objects for the Vlaardingen Culture people.

Note

1. Van Gijn applied the selection criteria that flakes should have a straight cross-section >2 cm during her micro-wear study of the flint from Hekelingen III. Here it was successfully demonstrated that these flakes were frequently used in this period, which is why we applied this criterium here as well (Van Gijn, 1990).

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