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Aivar Kriiska, Esa Hertell & Mikael A. Manninen

ABSTRACT The paper reports the results of technological analyses on flint assemblages found in 1996–2002 in the Pärnu Bay area, Estonia. The assemblages and their find contexts are described and the basic flaking methods and their products are discussed. A special emphasis is given to the bipolar and platform methods, the two basic flaking methods evident in the assemblages. Possible reduction sequences are studied and their relation to a variety of factors is discussed on the basis of artefact size. The study indicates that small raw material size and shape affected core technology. A variety of core reduction methods were used concurrently to achieve the goals and to deal with small nodule size. The study also indicates that the selection of methods was related to the availability of raw material. Finally the large scale patterning observed in the assemblages and its relation to the Holocene hunter-gatherer systems in the research area is discussed. It is suggested that changes in raw material usage were related to organisational changes evident in mobility and settlement patterns.

KEYWORDS
Lithic economy, lithics, raw material procurement, flint, Mesolithic, Neolithic, Pärnu Bay area, Estonia.

Introduction

South-western Estonia has a special place in the history of Stone Age research in the East Baltic and northern Europe in general. Archaeological interest in the Pärnu Bay area (**Fig. 1**) was strong already in the beginning of the twentieth century. In these early years the Pärnu Society for Antiquities collected bone and antler artefacts and other stray finds from the lower reaches of the Pärnu River and from the banks of its tributaries. Academic research in the area started in the 1920s. At this time the prehistory of Pärnu was taken up by Richard Indreko, who carried out short-term archaeological inspections and test excavations near the mouth of Reiu River, one of the major tributaries of Pärnu River (Indreko 1929; 1939). Although excavations were carried out in many places, settlement sites were not found. (**Appendix I.**)

After the Early Mesolithic Pulli site was found in 1967 the Pärnu region became archaeologically widely acknowledged. Extensive archaeological excavations at Pulli in the 1960s and 1970s changed the existing view about the beginning of the Mesolithic in all of the countries east of the Baltic Sea. Many flint artefacts from the Pulli site have been widely published and the typology and technology of the artefacts has also been investigated (Jaanits 1973; 1981; Jaanits & Ilomets 1988; Jaanits & Jaanits 1975; 1978; Jaanits *et al.* 1982).

The questions posed on the Pulli material in the early studies were mainly geared towards culture-historical goals, that is, describing the material and seeking typological parallels for it in order to study its relations to culture groups that had been defined earlier. In northern Europe this kind of an approach has long traditions and

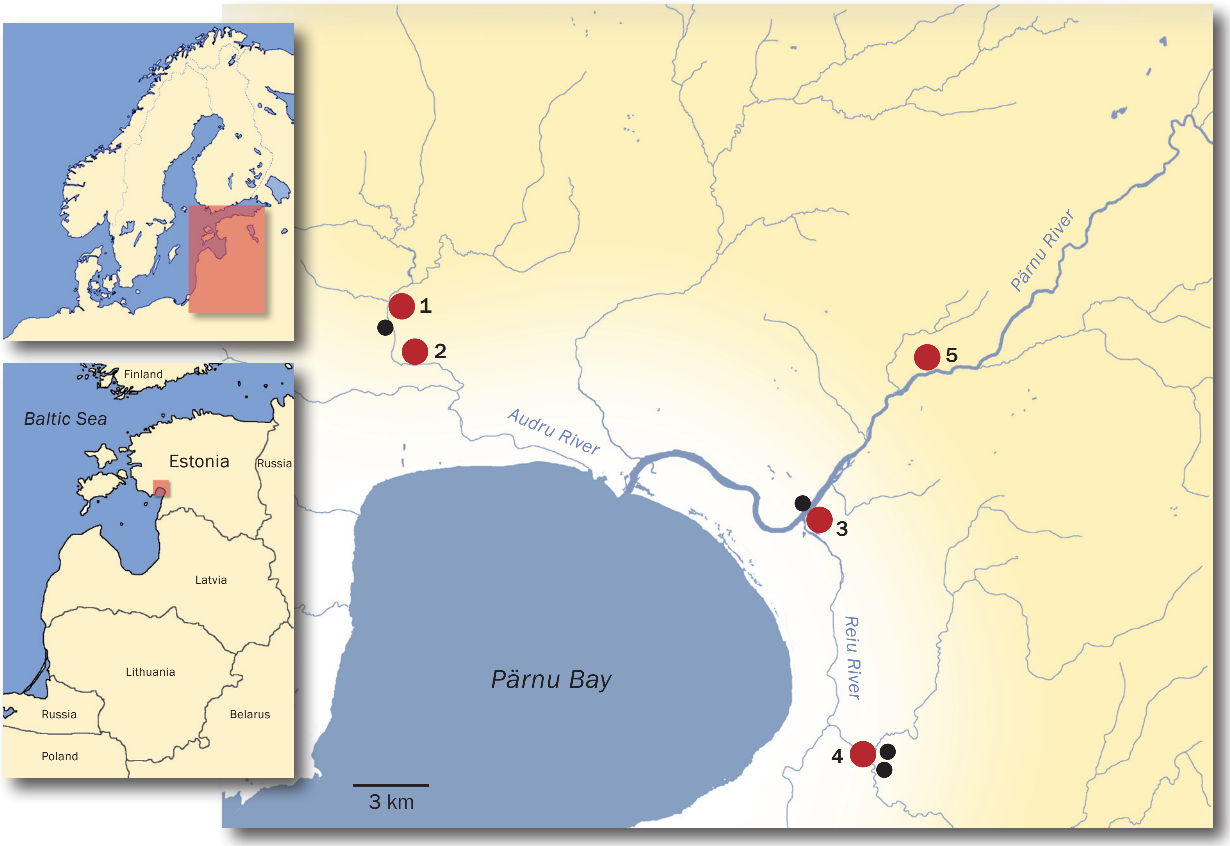

Figure 1. The study area and the sites discussed in the text: **1.** Lemmetsa II; **2.** Lemmetsa I; **3.** the Sindi-Lodja sites (Sindi-Lodja I, II, III and C); **4.** Metsaääre I; **5.** Pulli. Other sites: Malda, Jõekalda, Metsaääre II and III. Map by M. A. Manninen.

is still partly followed today. It is typical that those artefacts that are thought to describe a cultural group and therefore allow the periodisation and comparison of groups, and consequently tracing the origin of cultures, are given priority in publications. Often these are also the most visually impressive artefacts. As a consequence, the products of simple technologies and artefacts of more modest appearance are not usually discussed. Technological approaches that consider the whole of the lithic variation present help overcome some of the shortages of this kind of approaches.

Theoretical approaches that emphasise processes related to stone tool life-cycle, i.e., the study of technological organisation in general and especially raw material economy, have developed significantly during the last decades (e.g., Blades 2000; Carr 1994; Dibble 1995; Fisher & Eriksen 2002; Kuhn 1995; Montet-White & Holen 1991; Nelson 1991). Consequently, in this paper we will concentrate our efforts on the questions how and why lithic assemblages in the Pärnu region came into being and how the variation observed can be linked with the organisational diversity evident in hunter-gatherer socio-cultural systems in the area. Some specific themes were given priority in the analysis. Since all of the assemblages contained artefacts from both bipolar and platform reduction, the question whether these are parts of the same sequence in which a switch to bipolar reduction occurs as the core gets smaller (e.g., Andrefsky 1994a; Callahan 1987; Shott 1989), or two methods used separately for different purposes, was explored. The questions studied also included whether all platform reduction at a site belongs to the same sequence or if several different platform methods were in use, and further, in case several methods were used, what could be the explanation for the use of several core types. Another important theme involved questions related to the origin and nature of the flint raw materials.

Site	Artefact typological date (including pottery)	Radiocarbon date	Shore displacement chronology	Most probable date
Sindi-Lodja I, Mesolithic cultural layer	9000–5500 calBC	7350–6400 calBC	–	7000–6500 calBC
Sindi-Lodja II	9000–5500 calBC	7300–6650 calBC	–	7000–6500 calBC
Find-spot C in Sindi-Lodja	9000–3500 calBC	–	–	Date for none *in situ* material 7000–3500 calBC
Metsaääre I	7000–5500 calBC	–	–	7000–5000 calBC
Sindi-Lodja III	5000–2000 calBC	–	4000–3250 calBC	4000–2000 calBC
Lemmetsa I	4200–1800 calBC	–	3900–3200 calBC	3600–1800 calBC
Lemmetsa II	4200–3500 calBC	–	4150–3600 calBC	4000–3500 calBC

Figure 2. The dating of the sites. See site descriptions for specific radiocarbon dates. Shore displacement dates according to Jussila & Kriiska (2004).

The studied material derives from sites found in the Pärnu region during the years 1996–2002[1] in projects led by Aivar Kriiska. It includes four Mesolithic and three Neolithic flint assemblages from the sites Sindi-Lodja I, II, and III, Metsaääre I and Lemmetsa I and II, and from find-spot C in Sindi-Lodja (**Figs. 1, 2, 3**). The division into Mesolithic and Neolithic sites is based on radiocarbon dates and artefact typology. Flint is the common denominator in these assemblages and the focus of the present study. However, the lithic assemblages contain also ground stone tools and quartz debitage. Quartz forms an important part especially of the Neolithic assemblages, but was excluded from the analyses presented in this paper due to a shortage of time, and therefore the role of quartz is discussed only on a general level.

In the presentation of the analyses we concentrate on the way the artefacts were produced and try to provide readily usable and easily accessible data. The finds have been examined by Kriiska during cataloguing and an additional technological analysis of the flint material was conducted by Esa Hertell and Mikael A. Manninen before the 2003 field season. In eastern Fennoscandia and the Baltic countries proper quantitative metric data allowing the evaluation and study of, e.g., reduction intensity in and between sites in Mesolithic and Neolithic contexts have only recently begun to appear in publications (e.g., Oshibkina 1997; Takala 2004). The lack of this kind of data is a hindrance to studies where comparative data are needed from large areas, for instance in the study of colonisation, mobility, settlement patterns, exchange, and so forth. Since hunter-gatherer land-use systems are composed of multiple sites, the lithic technological organisation, or the whole cultural system, cannot be studied unless we have good comparative data from many sites in a variety of settings. Given the nature of archaeological work and the amount of information needed from large areas, pooled efforts are needed to accumulate the required data. In this paper we provide selected metric data on core and flake dimensions of the assemblages for future research.

The environmental setting

The Pärnu region lies on a geological border zone between Silurian and Devonian sedimentary rocks (e.g., Persits *et al.* 1997), a fact affecting the lithic raw material situation. The Silurian sediments are known to contain small flint pebbles (e.g., Baltrūnas *et al.* 2006:17; Jussila *et al.* 2006:57–58; 2007:157–158; Kriiska & Tvauri 2007:40–41), and flints presumably deriving from these formations are known from the glacial moraines in Estonia and northern Latvia (e.g., Jussila *et al.* 2006:57–58; Zagorska 1992:107, Fig. 5). Besides flint, tool-quality quartz pebbles are also found in Quaternary sediments.

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[1] A total of 10 new sites have been located in these projects. Three sites (Lemmetsa I, Lemmetsa II and Malda) are located on the lower reaches of the Audru River (Kriiska & Saluäär 2000) and other three sites (Metsaääre I, II and III) on the middle reaches of the Reiu River (Kriiska 2001a:28–30). An additional four sites (Jõekalda and Sindi-Lodja I, II, III) lie on the bank of the Pärnu River (Kriiska 2001a:21–28). Many stray finds have also been collected in several places from the sediments of the Pärnu River (Kriiska 2001a; Kriiska *et al.* 2002; Kriiska *et al.* 2003). It is now clear that remains of prehistoric sites have been preserved in a wide territory between the mouth of the Reiu River and the Paikuse village.

Figure 3. The Sindi-Lodja I site at the confluence of the rivers Reiu and Pärnu. Photograph by M. A. Manninen.

The Pärnu Lowland became free of the Scandinavian Glacier at the end of the Weichselian Glaciation, approximately 11,500 calBC.[2] After the retreat of the glacier the area was covered by the Baltic Ice Lake for two thousand years. Since the compensating land upheaval in south-western Estonia after the Ice Age has been relatively small, the waters in the Baltic Sea have several times inundated and again vacated parts of the Pärnu region. During the last 11,600 years there have been three regressive and two transgressive phases. (Andrén *et al.* 1999; Jussila & Kriiska 2004:Table 3; Kriiska & Lõugas 2009:Fig.26.4; Kriiska & Tvauri 2002:19; Raukas *et al.* 1995a:122; Veski *et al.* 2004.)

The sites of the coastal region that were settled during the regressive phases were often flooded during transgressive phases and consequently buried under sediment. Traces of Mesolithic occupation have been found under water- and wind-deposited sediments up to six meters in thickness (Kriiska & Lõugas 2009:168). Due to the isostatic and eustatic changes, the river deltas have been constantly reshaped.

The changes in shore-line in the course of prehistory are of importance for the archaeology of the region. The changing shoreline prevented the continuous use of many coastal sites and consequently the mixing of assemblages from different phases of the Stone Age. The fact that many sites have been covered by sediment has also helped preserve organic material that otherwise would have been destroyed.

After the Ice Age, the emerging sediments were soon covered by undergrowth, bushes and trees (e.g., Raukas 1992). The best opportunities to find lithic materials in this kind of an environment are at the open shorelines and riverbanks, where the vegetation cover is minimal or nonexistent. During prehistory, the changing shoreline washed new areas and rearranged sediments, and consequently provided new opportunities to acquire lithic raw materials from the coastal sediment deposits.

The analytical methods

All artefacts were treated individually in the analyses. Classification was based on the techno-typological attributes of each artefact (see e.g., Andrefsky 1998), besides which the presence of cortex was recorded and basic measurements of length, width and thickness were taken. A theoretical volume for each artefact was also calculated from these measurements (length x width x thickness). The maximum thickness and width were

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[2] Here and henceforth all dates have been calibrated with OxCal 4.1 (Bronk-Ramsey 2009) using the IntCal 09 curve (Reimer et al. 2009). Dates BP ± 1σ, and calBC range at 2σ.

measured at straight angles to the length of the artefact.

Flakes were divided into three main categories according to the mode of detachment: "behind-the-edge" platform flakes, "on-the-edge" bifacial flakes, and bipolar "on anvil" flakes. The length of complete flakes was measured from the point of percussion to the distal tip. Blades were distinguished from flakes on the basis of their length/width ratio. Flakes at least twice as long as their maximum width were considered to be blades. Since there was clear evidence of systematic blade production from prepared cores in the Mesolithic assemblages, an additional distinction was made between prismatic blades with straight margins and straight dorsal ridges and bladeflakes, i.e., artefacts that metrically fall in the blade category but have a somewhat irregular shape and lack straight dorsal ridges.

Objective pieces with distinct scars from flake or blade removals were classified as cores or core fragments. An additional division was made within the core category on the basis of the knapping method used and how the core had been treated. A total of eleven different core types were distinguished using these criteria (**Appendix II**). However, the different types of bipolar cores are treated together in the analyses since it is not clear whether they represent a single opportunistic method or possibly different bipolar methods. The lengths of single platform, opposite platform and bipolar cores were measured in the direction of flake removals. The length of the other cores was considered to be the measure between the two points farthest apart.

All the artefacts not included in the above mentioned categories were classified as debris. This category therefore includes split nodules, blocky pieces brought to the sites that bear no evidence of flake removals, tiny chips and fragments, angular shatter, etc. The length of these artefacts that are neither flakes nor cores was in this analysis considered to be the measure between the two points farthest apart.

A secondary classification was made to distinguish retouched tools from the artefacts that showed no evidence of secondary modification. Since the assemblages were recovered from a variety of contexts (from river banks and beds, ploughed fields, and excavations of undisturbed layers) comparison between the assemblages is complicated. This holds true especially when it comes to tools, since natural retouch is known to develop, for example, by ploughing and when artefacts roll in water (Manninen 2007; Miller 1982; Odell 2003:66–74). When defining tools, care was therefore taken not to confuse naturally retouched pieces with man-made tools. In practice this often meant accepting only the clearest cases as tools and ignoring many pieces with possible wear traces. Nor was any specific typology attempted in the classification of tools and other implements although some conventional categories such as scrapers, burins and bifaces were used (**Appendix II**). Artefacts interpreted as modern strike-a-lights were recorded but not studied further.

The sites and assemblage analyses

Sindi-Lodja I

Stone Age finds have been obtained from four different deposits in Sindi-Lodja I (Kriiska *et al.* 2002:27–32; Kriiska *et al.* 2003). The analysed lithic material[3] derives from a Mesolithic layer dated from soil samples to 7780±100 BP, 7030–6440 calBC (Ta-2826) and 8070±70 BP, 7300–6710 calBC (Ua-17013).

The Sindi-Lodja I lithic assemblage consists of only 18 artefacts. Although too small to be used in more detailed analyses, it is clear that the assemblage includes artefacts from blade production and/or use. For

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[3] At the most investigated area of Sind-Lodja I (test excavation C in Kriiska *et al.* 2003) a 10–20 cm thick layer of humus lies directly under the surface and covers a layer consisting of dark grey sand up to 80 cm in thickness. Structures deriving from a Modern Age building were detected in the sand layer. Both layers contained mostly modern artefacts but to some extent also Stone Age, most probably Neolithic, flint artefacts. This material was not included in the technological analysis (for a discussion of this material see Kriiska *et al.* 2002:27–32; 2003:25–29).

Below the upper cultural layer of Sindi-Lodja I, yellow sediment sands of the Litorina Sea were observed and below these a sloping peat layer (in the excavated area 115 cm in thickness) was revealed. A polished stone adze, some flint flakes, and scrapers were found on top of the peat or in its upper part. These objects were probably lost in the river before the above mentioned stratified sands began to form. The peat has been radiocarbon dated to 7425±100 BP (Ta-2824), which corresponds with a 95.4% probability to 6450–6080 calBC.

Under the peat a 40 cm thick layer of gyttja had been sporadically preserved, the upper part of which contained prehistoric artefacts and animal bones. These artefacts probably sunk to the river/sea bottom near a settlement. A 5–30 cm thick organic layer was observed beneath the gyttja layer. This is the cultural layer of a Mesolithic settlement site. This layer, however, was present in its original position only in a few places. The cultural layer slopes steeply towards the south and, consequently, the elevation of the layer varied strongly over the excavated area. The layer has yielded stone, bone, and antler artefacts (flint and quartz flakes, flint blades, cores and tools, and a grinding stone), as well as animal bones. The artefacts analysed in this study derive from this layer.

example, one exhausted blade core (**Fig. 4**) is present in the assemblage alongside with artefacts from ordinary bipolar and freehand platform flake production. Tools include scrapers and cutting tools. The flint raw-material is mainly of a dark grey colour, but some artefacts of an almost black translucent flint are also present. The analysed artefacts are small. The length of the cores and detached pieces is less than 30 mm for all but one blade (**Appendix III**).

Figure 4. Side view of a narrow-face blade core from Sindi-Lodja I (PäMu 15260/A2553:110). Photograph by A. Kriiska.

Sindi-Lodja II

At the Sindi-Lodja II site the section of a Mesolithic cultural layer can be seen in the steep bank of the Pärnu River almost five metres above the river surface. Although partly collapsed and washed into the river, the layer has still been preserved in an area that is at least 45 metres long and stretching at least 15 metres inland from the river bank (Kriiska *et al.* 2002:27–32). A radiocarbon sample obtained from a piece of wood found in the Mesolithic layer dates the settlement traces to 8035±80 BP, 7190–6680 calBC (Ta-2769).

The flint material found in the Mesolithic cultural layer of Sindi-Lodja II and in the river in front of the site consists mainly of dark grey and black flints. Some lighter grey and brownish flints are also present. The assemblage includes clear evidence of blade production or/and use along with artefacts from flake production (**Fig. 5**). A total of 330 flint artefacts from the site and 170 artefacts found in the river in front of the site were included in the analysis.[4] A fragment of a small pressure flaked typologically Neolithic bifacial point was also found in the river in front of the site, indicating that some younger material may be mixed in the finds collected from the river sediments.

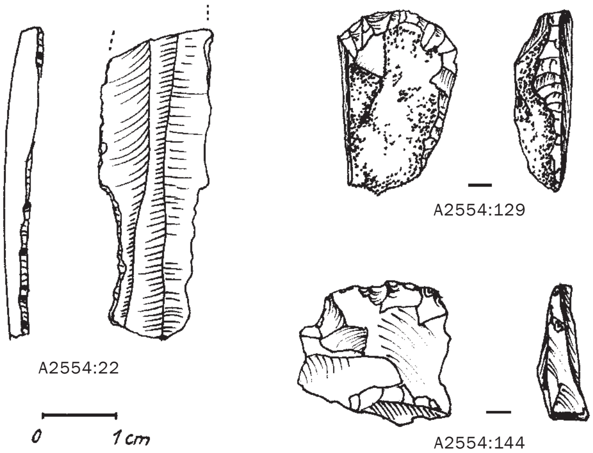

Figure 5. Examples of flint artefacts in the Sindi-Lodja II assemblage (PäMu 15261/A2554). Retouched blade (:22), a scraper on a cortical flake (:129), and a retouched flake (:144). Drawings by Kristel Külljastinen.

Flakes are more common than blades in the Sindi-Lodja II assemblage (**Appendix II**). The flake assemblage itself is dominated by platform flakes over bipolar flakes. The Sindi-Lodja II flake assemblage indicates no clear difference in size between bipolar and platform flakes (**Fig. 6**). Therefore, a sequential change from larger platform cores to smaller bipolar cores does not seem likely. There are at least three things that further support this interpretation. First, the distribution of flake lengths is quite similar in both groups. Although there is a high proportion of small (below 10 mm) platform flakes, this size class probably represents waste from tool manufacture and trimming of cores rather than blanks for tool edges or other implements. Second, the flake volumes (LxWxT) show no clear difference between the bipolar and platform flakes (**Fig. 7**). This is also the case with cortical flakes: there is cortex on 53% of the platform flakes and on 50% of the bipolar flakes.

The cores, however, show a somewhat contradic-

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[4] There are also artefacts from the river sediments in front of the Sindi-Lodja II site in the mixed assemblage discussed individually in Appendix II.

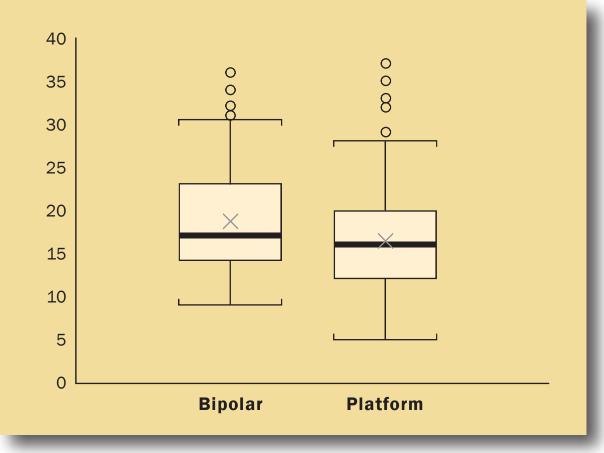

Figure 6. Sindi-Lodja II lengths of bipolar and platform flakes. Vertical axis in millimetres.

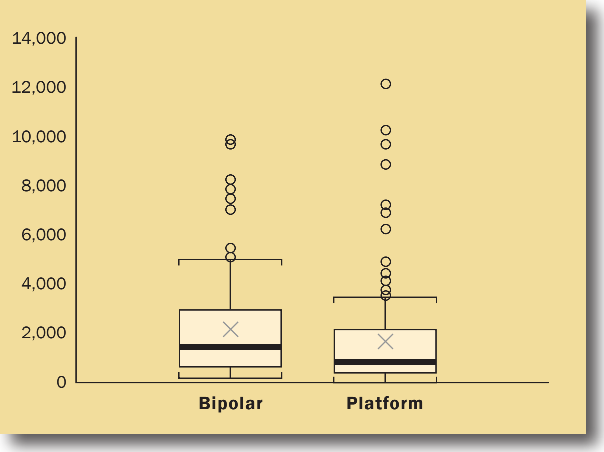

Figure 7. Sindi-Lodja II. Bipolar and platform flake volumes. Vertical axis in cubic millimetres.

tory pattern. The length, i.e., the principal flaking axis, of the cores shows a similar pattern as the flake length data (**Fig. 8**), but the data on core volume suggest that bipolar cores on average were reduced farther than platform cores (**Fig. 9**). The size difference between cores is so small, however, that this evidence must be considered only suggestive. One explanation for the contradiction between the flake and core data could be that larger platform flakes were retouched and consequently modified into several smaller flakes.

The fact that the size range for irregular cores is the largest among platform cores suggests that platform flaking methods may also have succeeded each other to a degree. This seems to be best indicated in the case of single platform cores, which suggests a reduction continuum from producing flakes to producing blades (**Fig 10**).

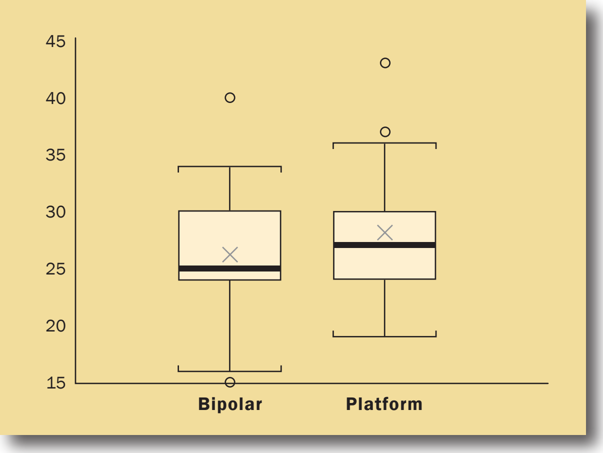

Figure 8. Sindi-Lodja II. Bipolar and platform core lengths. Vertical axis in millimetres.

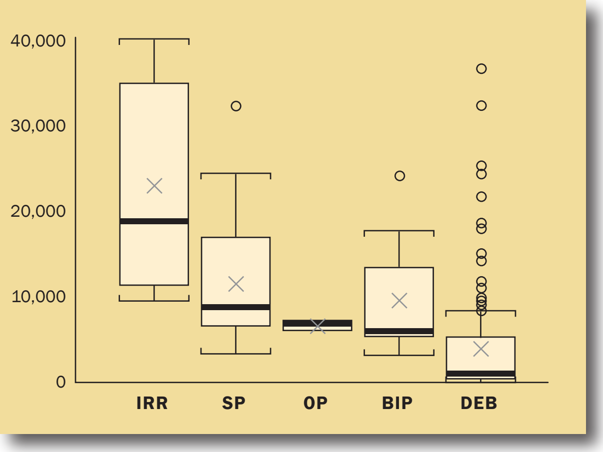

Figure 9. Sindi-Lodja II core volumes: irregular platform cores (IRR), single platform cores (SP), opposite platform cores (OP), bipolar cores (BIP), debris (DEB). Scale in cubic millimetres.

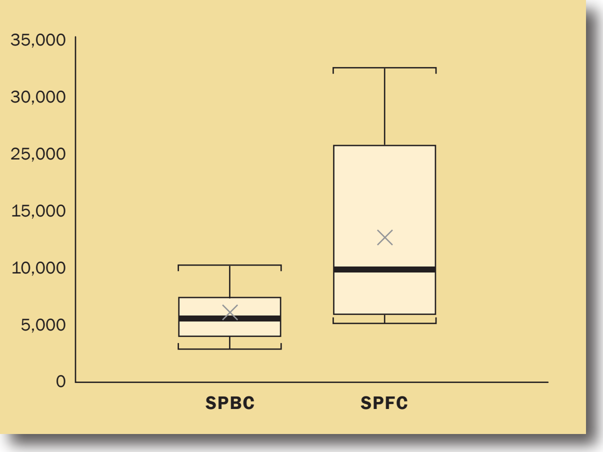

Figure 10. Sindi-Lodja II single platform core volumes: blade cores (SPBC) and flake cores (SPFC). Vertical axis in cubic millimetres.

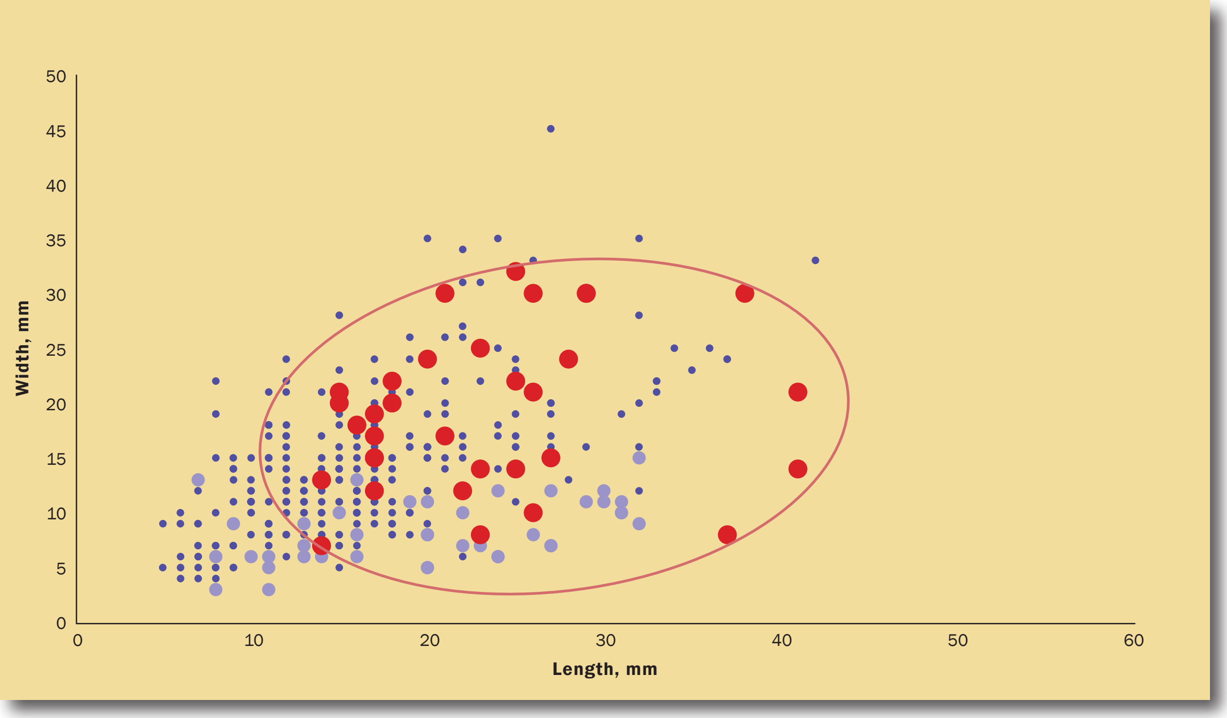

Figure 11. Sindi-Lodja II flakes and flake fragments (blue dots), blades and blade fragments (light blue dots) and tools (red dots).

Single platform cores bearing scars from flake removals alone have a larger size range than cores with scars also from the production of small blades. The fact that the cores for producing blades were often relatively small is also indicated by the blades, bladeflakes and blade fragments that show a median width of eight millimetres (**Appendix IV**). The single platform core size therefore could indicate a continuum from the production of flakes to the production of blades. As the reduction went on and core sizes diminished cores became more regular and began increasingly to exhibit the characteristics of blade cores. This resulted in the pattern presented here (**Fig. 10**). However, this explanation leaves open the question why the larger cores were not used for blade production.

This question can be approached from another direction by asking to what degree knappers actually changed from one platform method to another. There is evidence to suggest that, for example, the irregular and single platform core types represent, at least to a degree, independent types of reduction methods. The size ranges of all major core types have a good deal of overlap and the lower end of the size range for all major core types is rather similar. This indicates that the knappers utilised alternative tactics to deal with diminishing core size and that there was no single static concept of how to proceed with core reduction. Some cores were reduced by flaking from irregularly alternating platforms, others from a single platform, and others yet by bipolar flaking. Even the production of blades can be seen as a tactic for maximising core use-life.

In addition, the different core types produce blanks of different shapes and qualities. For instance, the irregular platform cores produce somewhat irregular flakes, whereas the single platform cores produce more elongated parallel sided flakes and blades. The fact that the size ranges of different core types that produce clearly different kinds of blanks have rather similar lower ends implies that the alternative core types are at least partly related to the need for different kinds of blanks.

The generally small size of cores and detached pieces in the Sindi-Lodja II assemblage is, in part, the result of small raw material size, i.e., small irregular nodules. Another reason most probably is the scarcity of raw material and possibly, as a consequence of this, a tendency to produce also small flakes. As demonstrated earlier (**Fig. 8**), some cores were pushed to a 20 to 15 mm length before being abandoned. This size probably marks the lowest acceptable flake size, but is obviously also a result of flaking small pieces – as the core size gets this small it becomes increasingly difficult to produce flakes even from bipolar cores that are often considered a response to small raw material size (e.g., Andrefsky 1994a; Shott 1989).

The fact that extremely small pieces were used to obtain blanks or edges for tools is supported by the flint debris found at the Sindi-Lodja II site. The debris volumes (LxWxT) demonstrate that only a few pieces equal the largest core volumes (**Fig. 9**). Since even the largest cores had passed the threshold of acceptable minimum size for a core and been rejected at the site, it seems that not many pieces of raw material that had potential for further use were left at the site. This is additional evidence for a scarcity of raw material.

At the same time, the retouched tools in the Sindi-Lodja II assemblage are relatively large when compared with unretouched flakes (**Fig. 11**). This suggests that the largest pieces, i.e., the pieces that had the most future potential for use and the strongest edges, were most commonly and intensively used and retouched. It was at a length of approximately 15–20 mm that the retouched tools were considered to have no more future potential and were discarded.

Find-spot C at Sindi-Lodja

The flint material from find-spot C at Sindi-Lodja includes mainly debitage from flake production, although some blade fragments and an exhausted single-platform blade core are also included. The flint raw material is mainly dark grey. The analysed flint assemblage consists of 77 artefacts. Typologically, most of the flint artefacts are Mesolithic, but some sherds of Typical Comb Ware have also been collected from the river sediments on the present waterfront (Kriiska *et al.* 2002). All of the finds probably represent a site destroyed by the river.

The small size of the Sindi-Lodja C assemblage is a major obstacle in making proper inferences about reduction sequences. Flake sizes show no clear differences between the platform and bipolar flakes. This would suggest that no succession from platform to bipolar reduction took place. In fact the size range of the bipolar flakes is wider than that of the platform flakes (excluding one outlier). However, the percentage of cortical flakes is higher among the platform flakes (90%) than the bipolar flakes (45%). This suggests that flaking may have been initiated with a platform method and that most of the pieces reduced with bipolar reduction had most of the cortex already removed. However, a more accurate measurement of the amount of cortical surface on flakes would be required to test this proposition.

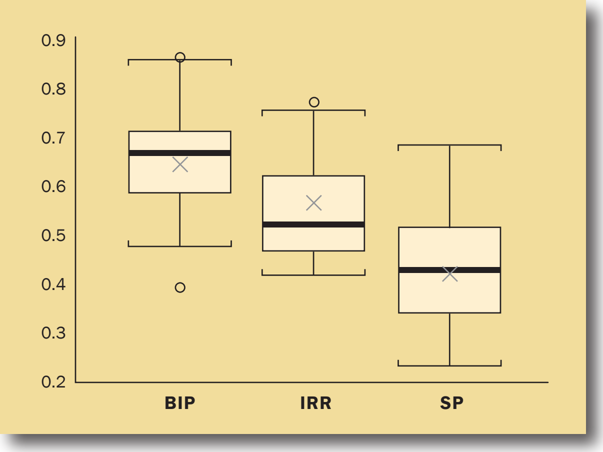

Figure 12. Sindi-Lodja II and Sindi-Lodja C core shape indices (minimum dimension divided by maximum dimension): bipolar (BIP), irregular (IRR), and single platform (SP) cores.

Leaving the issue of possible reduction sequences aside, there is evidence that the occupants of the site employed alternative strategies to deal with the problem of the small raw material pieces. The small size of all of the cores implies that the flaking methods used to reduce small pieces and/or diminishing cores varied. Choosing between alternative methods is likely to have been situational and related to different variables, e.g., the shape of the needed blanks, the shape and size of the core/piece of flint under reduction, and so forth.

This is supported by a comparison of the combined volumes of different core types in Sindi-Lodja II and C assemblages.[5] If the functional properties of the blanks and cores did not matter to the knappers we would expect to see a pattern where the dimensions of different core types are not systematically clustered. The Sindi-Lodja II and find-spot C cores imply that this was not the case.

To calculate a shape index, the minimum dimension of each core (bipolar, single platform, and irregular platform core) from Sindi-Lodja II and find-spot C was divided by its maximum dimension (**Fig. 12**). The core types form clusters although a good deal of overlap exists between different types. Bipolar cores show less variation in their maximum and minimum measurements

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[5] The mixed assemblage from the river in front of Sindi-Lodja II and find-spot C (see Appendix II) is included in the comparison.

than other cores. This means that single platform cores are relatively flatter than, for example, bipolar cores, which in turn are more cube-like. These two groups have relatively little overlap in their shape index range. This is somewhat surprising, given that these two core types actually have a similar unidirectional flaking axis. This implies that, supposing that these two different methods were applied on pieces of flint with a similar shape, the methods were suited for producing different kinds of blanks. Alternatively, the methods might have been applied on pieces that were different to begin with.

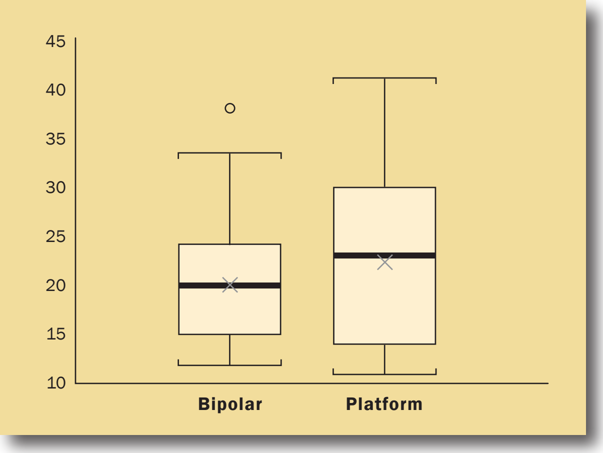

Figure 14. Metsaääre I flake lengths. Vertical axis in millimetres.

Metsaääre I

At the Metsaääre I site finds have been collected from the surface of a field 100 metres in length and 20 metres in width. Since the area has been under intensive cultivation, the cultural layer is in most places mixed by ploughing. Field walking has yielded finds (small flint and quartz artefacts, a stone adze, etc.; Kriiska 2001) that date the site typologically to the Mesolithic.

The Metsaääre I flint assemblage derives mainly from flake production but includes also evidence of blade production and use (**Fig. 13**). The assemblage consists of 151 artefacts. The flint raw material is mainly light yellowish grey, but other light and dark grey and brown flints are also present. Some of the blades were made of the same raw material as most of the flake assemblage. These, together with two bipolar flakes that bear evidence of blade removals on their dorsal sides, constitute clear evidence of on-site blade production. The median width of the blades is 10 mm and, as at Sindi-Lodja II, all are less than 16 mm in width (**Appendix IV**).

The flake assemblage is dominated by bipolar flakes. A comparison of flake sizes (**Fig. 14**) shows that the platform flakes fall slightly more often in the largest size category than the bipolar flakes. This might indicate that bipolar flakes in general were produced from somewhat smaller cores and that bipolar reduction was partly successive to platform reduction in the general operational scheme, but does not exclude an independent use of the methods. A sequence where platform reduction preceded bipolar reduction is supported by the larger number of platform flakes on which cortex is present:

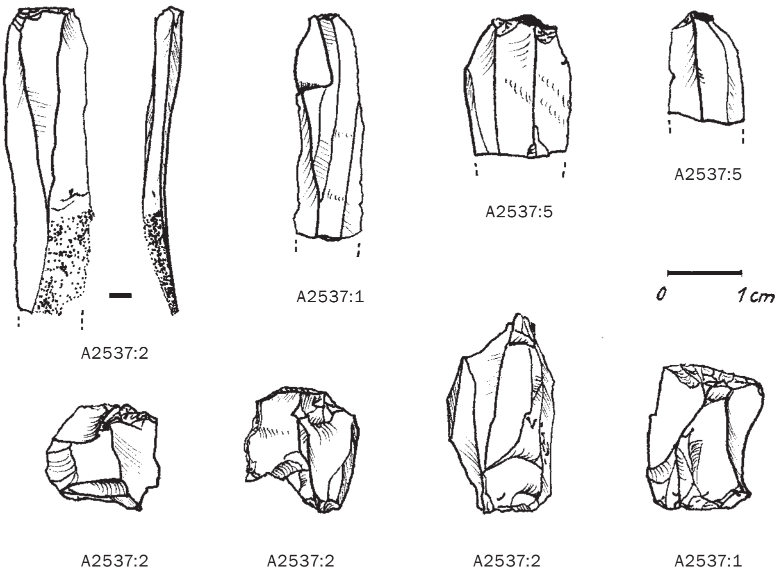

Figure 13. Examples of flint artefacts in the Metsaääre I assemblage (PäMu 15211/A2537). Top row: blades/blade fragments, bottom row: three bipolar cores and a scraper (far right). Drawings by K. Külljastinen.

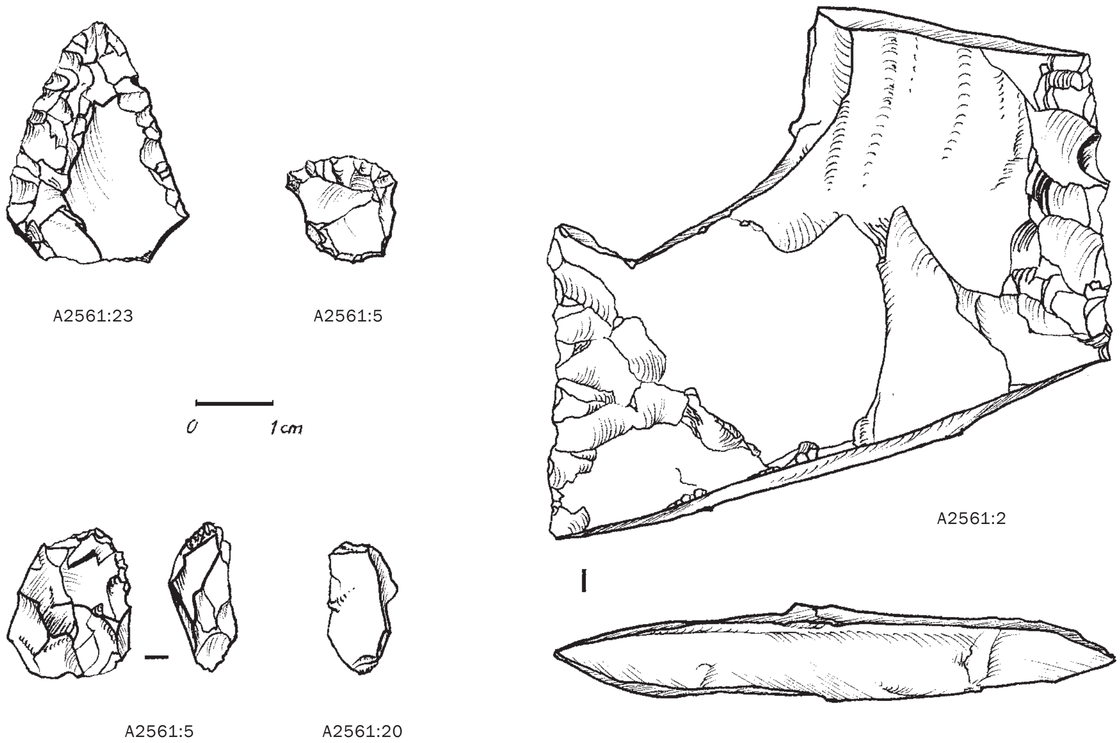

Figure 15. Examples of flint artefacts in the Sindi-Lodja III assemblage (PäMu 15425/A2561). To the left, top row: unifacially worked point (:23), scraper on flake (:5). Bottom row: bipolar core (:5), bipolar flake (:20). To the right: dagger fragment (:2). Drawings by K. Külljastinen.

58%, as opposed to only 38% of the bipolar flakes. The small number of cores precludes drawing further conclusions about possible reduction sequences. However, the core data illustrate again the small size of all of the cores. The maximum dimension is at or below 25 mm. This is in good agreement with the flake size, the cortex data, and with the data from the other studied sites.

Sindi-Lodja III

At the Sindi-Lodja III site, finds have been obtained from the surface, test-pits, and test excavations at the site. The largest find category is pot sherds. Material from the Typical Comb Ware period is the most abundant, but Late Comb Ware, Corded Ware and pottery of the Narva type are also present (Kriiska & Lõugas 2009:170). On the basis of shore-displacement chronology and artefact typology, the main use period of the site can be dated to *c.* 4000–3500 calBC, but there is also evidence of occupation from the 3rd millennium calBC.

The finds collected from the site and from the river in front of the site include flint artefacts, as well as some artefacts made of quartz. In total, the flint assemblage is small, amounting to no more than 48 artefacts (**Fig. 15**). The flint raw material varies from black to yellowish grey, but light grey is the most common colour. Excavations carried out at the site in 2003 and 2004, after the completion of these analyses, yielded several bifacial points typical of the Neolithic, but in the analysed assemblage there is only one, unifacially worked point/cutting tool. In addition, a fragment of a large bifacially worked dagger made of black flint has been recovered from the site. Typo-chronologically the dagger fragment dates to the end of the Scandinavian Neolithic period (*c.* 2000 calBC; for the dating, see Apel 2001).

The small flint assemblage is comprised mainly of bipolar and platform flakes. Bipolar flakes are more common. Intact flakes are small and suggest a small core size. The available bipolar cores support this conclusion. Due to the small size of the assemblage the flake size data shows no clear patterning in flake dimensions and is of little value for the study of the reduction continuum. However, the fact than flake length falls mainly under 30 mm again indicates small core size.

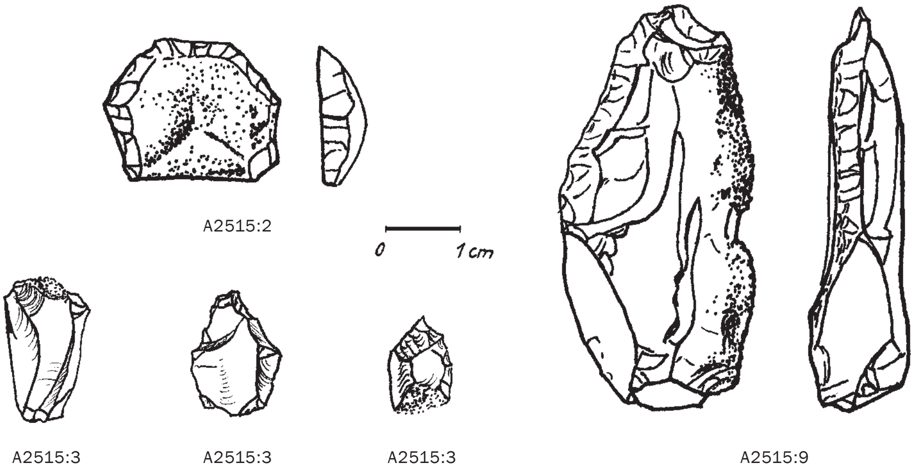

Figure 16. Examples of flint artefacts in the Lemmetsa I assemblage. Top row, left: scraper on cortical flake (:2). Bottom row: bipolar core (:3), bipolar flake (:3), scraper on cortical flake (:3). To the right: scraper on cortical flake (:9). Drawings by K. Külljastinen.

Lemmetsa I

Since 1996, finds have been repeatedly surface collected at the Lemmetsa I site and in 1997 a small test excavation was carried out. The Stone Age cultural layer at the site is almost entirely mixed with a ploughed layer approximately 30 cm in thickness (Kriiska & Saluäär 2000).

Four settlement phases can be distinguished in the finds from Lemmetsa I, two of which can be dated to the Stone Age. Typo-chronologically, most of the pot sherds from the site date to the Late Comb Ware period. It is probable that most of the other artefacts found (small flaked items of flint and quartz, stone processing debris, stone adzes, amber pieces, etc.) also date to the same period. Some artefacts that belong typologically to the Corded Ware Culture, such as pot sherds, a triangular marginally retouched flint point and a battle-axe of Continental type (*Külasema*-type in Estonia), have also been obtained.

The beginning of the water-connected Late Comb Ware period occupation at the mouth of the river can be dated through shore-displacement to *c.* 3850–3200 calBC (Kriiska & Jussila 2004:Table 2), but artefact typology suggests that more intensive occupation took place somewhat later and the site had occupation phases well into the 3rd millennium BC.

A total of 126 flint artefacts from the Lemmetsa I site were included in the analysis. It should be noted, however, that the flint assemblage from the site is considerably smaller (17% of the lithics), than the quartz assemblage. The flint raw-material is variable and includes light grey, reddish orange, brown, beige, white and dark grey flints. The flint artefacts seem in average much smaller than the quartz artefacts. Most of the flint assemblage is very fragmentary and a triangular point made of black flint stands out as exceptional. (**Figs. 16, 17, 18**)

Figure 17. Bifacial margin-retouched triangular flint arrowhead from the Lemmetsa I assemblage (PäMu 14642/A2515:3). Photograph by A. Kriiska.

Site	Lenght	Width	Thickness	Shape
Lemmetsa I	25*	18	3	Triangular
Lemmetsa II	72	34	9	Leaf-shaped
Lemmetsa II	52	23	5	Leaf-shaped
Lemmetsa II	41	18	6	Leaf-shaped

Figure 18. The sizes and shapes of bifacially flaked flint points in the Lemmetsa I and II assemblages. * Tip missing

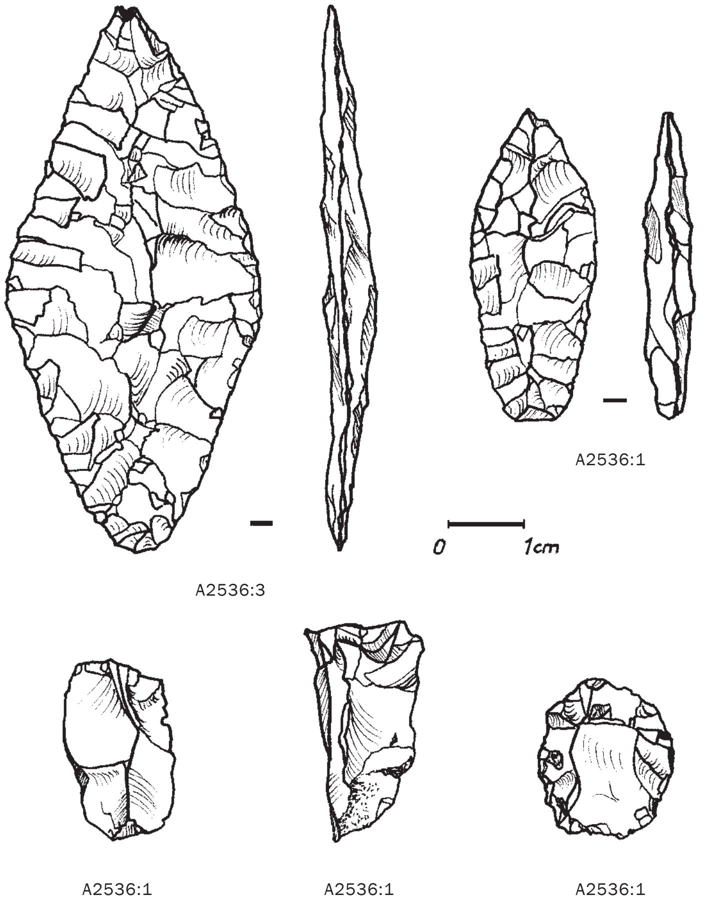

Figure 19. Examples of flint artefacts in the Lemmetsa II assemblage (PäMu 15210/A2536). Top row: bifacial points. Bottom row, from left: bipolar core, platform core, scraper on flake. Drawings by K. Külljastinen.

Small bipolar flakes dominate the flint flake assemblage. Intact platform flakes are too few for making meaningful comparisons of flake dimensions. The length of the bipolar flakes ranges between 12 and 28 mm. Although slightly higher, the core length is in agreement with the flake data. All of this implies small core, as well as raw material, size – an interpretation supported by the presence of cortex on 65% of the flakes, as well as by two flint nodules with a maximum dimension below 25 mm collected at the site.

Lemmetsa II

Since 1998, recurrent survey trips to the Lemmetsa II site have resulted in a collection of surface finds (pot sherds, small artefacts of flint and quartz, stone adzes, etc.). Due to long-term cultivation in the recent past, the Stone Age cultural layers have been seriously disturbed and mixed by ploughing (Kriiska & Saluäär 2000).

The Lemmetsa II finds date typologically, and by shore displacement, to the Typical and Late Comb Ware periods. Typical Comb Ware dominates clearly among the pot sherds. There are also traces of Iron Age and later activity at the site. Shore-displacement chronology dates the sea-connected Typical Comb Ware settlement to *c.* 4160–3600 calBC (Jussila & Kriiska 2004:Table 2) but the site has most likely also been occupied later, at the time of the forming of the Audru River.

The analysed Lemmetsa II flint material consists of 275 artefacts. Flint slightly outnumbers quartz in the total lithic assemblage (54% and 46%, respectively). There are many different flint raw materials in the assemblage, including a variety of greys (i.a., a translucent grey), brown, reddish, and black flints. Several bifacial points stand out among the artefacts (**Figs. 18, 19**). There are 3 leaf-shaped points, 1 biface rough-out and a burnt tip of a bifacial point.

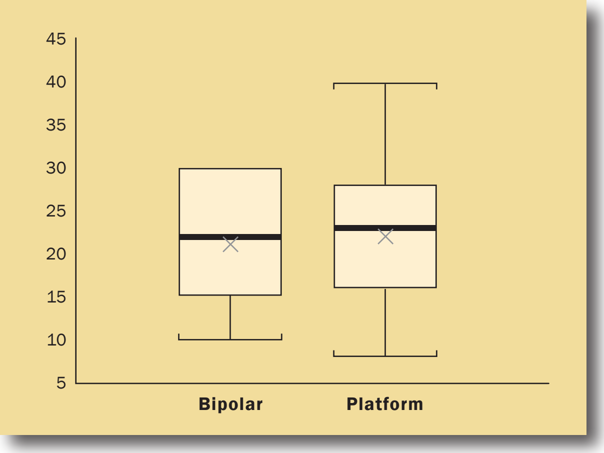

Figure 20. Lemmetsa II flake lengths. Scale in millimetres.

The main component in the flint assemblage is, nevertheless, material from simple flake production. However, finds include also ten diagnostic flakes and flake fragments that derive from bifacial production. The selection and possible trade of large disc-shaped biface thinning flakes for use as blanks has been suggested by Jan Apel (2001:216–229) to have taken place in the Late Neolithic in eastern central Sweden. However, the small size of the Lemmetsa II flakes suggests that they represent local reduction rather than flakes imported for further use as biface blanks. The largest three of these artefacts are further retouched into flake tools.

Intact platform flakes are more numerous than bipolar flakes. The flakes show little variation in length, although some platform flakes are exceptionally large (**Fig. 20**). The proportions of cortical flakes agree with general flake length. A slightly larger number of platform flakes than bipolar ones bear cortex: 58% and 50% respectively. This suggests that the two methods are not successive reduction stages, although platform reduction may have been, on occasion, preferred on larger pieces of raw material. The core size data seems to support this conclusion to a degree, since rejected platform cores are larger than bipolar cores.

Relatively large flakes and fragments were modified for retouched tools in the assemblage (**Fig. 21**), which is not surprising, given the generally small size of the artefacts. The bifacial points are among the largest tools and only the very largest flake tools equal the size of the smallest bifacial points.

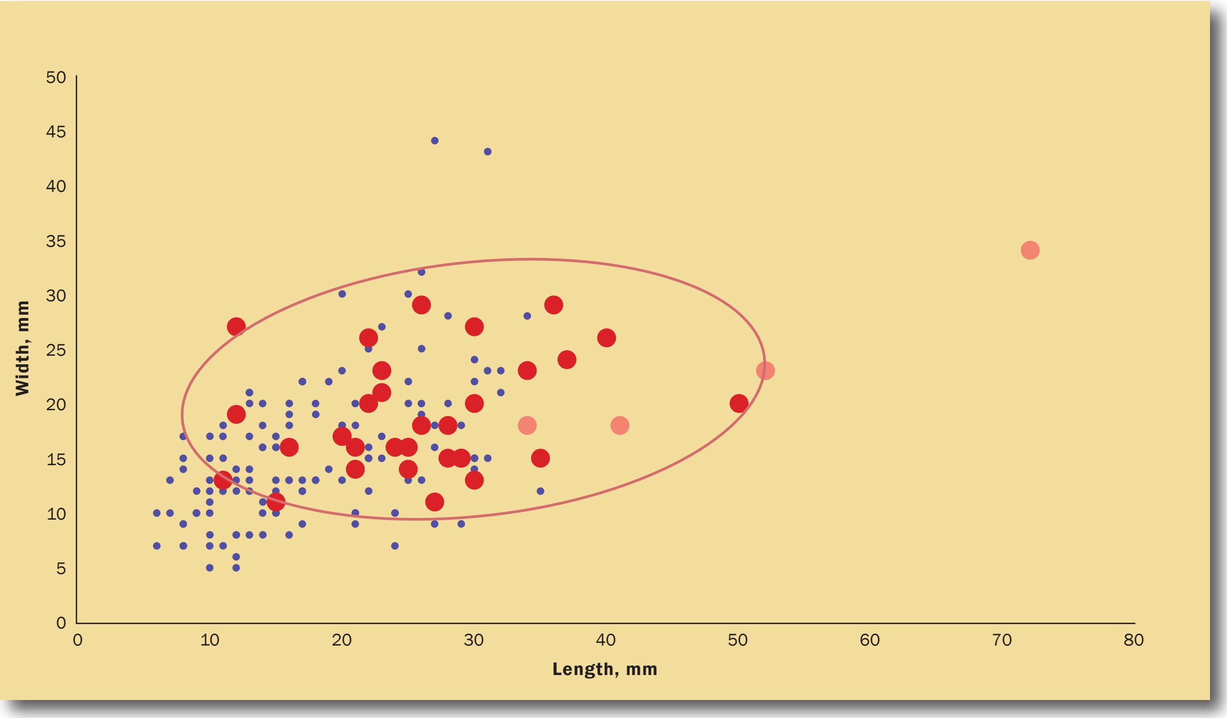

Figure 21. Lemmetsa II. Flakes and flake fragments (blue dots), bifaces (pink dots), tools (red dots).

Summarising and expanding on the results

Raw materials

Flints of many different colours and textures are present in the studied assemblages (besides opaque greys, browns, and yellows of different shades, also some translucent black and grey varieties). This material can be roughly divided into local and imported flints. The division is by no means clear-cut and no geo-chemical sourcing or other provenience analyses have been carried out on the material. However, something can be said about probable sources of raw material on the basis of visual comparison between the assemblages and samples from known outcrops. It appears that flint has been imported to the Pärnu area both during the Mesolithic and the Neolithic.

The Mesolithic finds from the Sindi-Lodja sites include some blades and tools of brownish black translucent flint of high quality, most probably deriving from outcrops of Cretaceous flint-bearing formations that are known to exist, for instance, in Lithuania, Poland, Belarus, and southern Scandinavia (e.g., Baltrūnas *et al*. 2006; Herforth & Albers 1999:Abb.1; Sulgostowska 2002:9). The same kind of flint is prevalent in the Early Mesolithic Pulli assemblage, and is present also in several other Mesolithic assemblages in Estonia and adjacent areas (Jaanits 1989:32; Jussila *et al*. 2007:157; Kriiska & Tvauri 2007:42). However, the low quality and the large cortex percentage of the rest of the black and dark grey flint from Sindi-Lodja suggests that it was not, at least not exclusively, acquired from the large outcrops of Cretaceous flint several hundreds of kilometres away, where good quality raw material is abundant, but rather from some, possibly nowadays unknown, glacial moraine sources closer to the Sindi-Lodja sites.

The triangular point from Lemmetsa I and the bifacial dagger fragment from Sindi-Lodja III have also been made of the black translucent high quality flint. These artefacts, however, were probably imported to the sites ready-made, since no corresponding debitage has been found. The main part of the Neolithic import consists of multicoloured flints that derive most probably from the Carboniferous formation ranging from the Moscow area to the White Sea. Carboniferous flint from Central Russia was imported to the East Baltic region during the Mesolithic and Neolithic (Galibin & Timofeev 1993; Jussila *et al*. 2007:157–158; Kriiska & Tvauri 2007:42) and is also the main flint type in the analysed Neolithic flint assemblages in Finland (Costopoulos 2003; Kinnunen *et al*. 1985; Manninen *et al*. 2003; Matiskainen *et al*. 1989). It has even been found in Comb Ware contexts in northern Sweden (Halén1996).

The Neolithic flint import in Estonia appears analogous to the Neolithic flint import in Finland, and is presumably associated with the manufacture of Typical Comb Ware period bifacial points (Manninen *et al*. 2003). It is precisely the bifacial points that are most clearly made of imported flint also in the Neolithic Pärnu assemblages. The points differ in colour and texture from the majority of the flint assemblages, and it is evident that the raw material pieces used in their manufacture were much larger than the nodules typical for the local Silurian flint.[6] This notion is further validated by evidence suggesting that the bifacial points were manufactured from large flake blanks, which means that they derive originally from even larger pieces of raw material. Although flake scars from pressure flaking usually cover the whole surface of the Typical Comb Ware period bifacial points, sometimes the original flake blank can still be seen.

Most of the flint artefacts in the studied Pärnu assemblages originate from small, mainly grey, brown, and yellowish pebbles and nodules that are most likely of local origin. In all of the analysed assemblages, cortex is present in 38–64% of the artefacts, which is a clear indication that the original nodules were small. As a point of comparison, in the Raikuu Martinniemi 3 assemblage in Kerimäki, south-eastern Finland, which only includes imported flint, the amount of artefacts containing cortex is as low as 6% (Hertell & Manninen *analysis on file*). However, the distribution of Silurian flint by glacial processes in Estonia could mean that this kind of flint may also have been acquired over considerable distances. The presence of chalk covered blocky pieces in some of the studied assemblages suggests that brownish Silurian flint was also quarried for raw material. Since there are no accessible chalk formations in the Pärnu region, this flint must derive from elsewhere, possibly from Central Estonia. This also makes it likely that some of the small flint nodules could also have been imported to the Pärnu Bay area from other parts

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[6] The split nodules in the assemblages have a diameter of less than 5 cm, a size typical for the Silurian flints from quaternary deposits in Estonia.

of Estonia. Whether this was the case is a question that must be left open at this stage.

Besides the change in the geological source for imported flint, another marked change takes place in raw material procurement practices during the Stone Age in the Pärnu region. Quartz is practically absent in the Mesolithic assemblages, but is a common raw material during the Neolithic. For example, the Lemmetsa I and II lithic assemblages contain 83% and 46% of quartz, respectively – strikingly high figures when compared with the Mesolithic assemblages. This change, as well as the different flint raw materials used in the research area, is important when considering the flint technology also in relation to other topics, such as mobility and trade.

Tools, blank production, and core technology

The presence of bifacially flaked points of different sizes and shapes in the Neolithic assemblages is in line with the general picture from other parts of Estonia (e.g., Kriiska & Tvauri 2002:64) where bifacial points are also mainly found in Typical Comb Ware, and later, contexts.

In Estonia, triangular (or heart-shaped) points of the kind included in the Lemmetsa I assemblage belong typo-chronologically to the Corded Ware Culture. These points seem to represent a different tradition than the leaf shaped bifacial points. This tradition originated in Neolithic Central Europe and entered Estonia mainly from the south (Kriiska & Saluäär 2000:25–26). In Finland, heart-shaped flint points have been reported only from one mixed Typical Comb Ware/Corded Ware context (Luoto 1987:12–15).

Technologically, the triangular/heart-shaped points in Estonia differ from the leaf-shaped (Comb Ware) bifacial flint points in the way the blank has been worked. In the Comb Ware period points flake scars usually cover the whole surface of the point and only occasionally small areas of the original flake blank surface can be seen, as in the case of one of the Lemmetsa II points. The triangular Corded Ware Culture points have usually been retouched only around the margins, leaving the centre of the original flake blank untouched (see figures in Kriiska & Saluäär 2000:Fig. 8 and Kriiska & Tvauri 2002:77).

In general, the Mesolithic and Neolithic secondary production was mainly aimed at making small tools like scrapers and knives on flakes.[7] The main difference in tool categories between the time periods is the presence of bifaces in the Neolithic assemblages. In the Lemmetsa II assemblage there are also ten diagnostic flakes deriving from bifacial reduction and a biface rough-out indicating that it was not only ready-made bifacial points that entered the Pärnu area in the Neolithic but also a new technology.

The production of flakes from different kinds of cores is the backbone of both the Mesolithic and the Neolithic flint technology. This can be further illustrated by arranging the assemblages in two temporal groups (**Fig. 22, Appendix V**). The debitage size distribution is virtually identical in both groups and no diachronic change can be seen. Despite the source critical problems, such as the partly mixed nature of some of the assemblages, the emerging picture is not in disagreement with the impression gained from any of the assemblages from chronologically more or less closed contexts. Therefore, this pattern is likely to be the result of the prevailing use of raw material pieces of a similar size throughout the Mesolithic and the Neolithic.

No definite conclusion can be reached on the question whether the knapping sequences involved a switch from platform reduction to bipolar reduction. It seems that the ways to deal with diminishing core size were variable and therefore there seems to be no direct sequential linkage between platform reduction and bipolar reduction. Both reduction methods were parts of the same technological system, and bipolar reduction was sometimes used on exhausted platform cores.

The Mesolithic and Neolithic core reduction strategies, however, were partly different. Both the Mesolithic and Neolithic assemblages contain parallel-sided flakes, i.e., blades and blade-flakes, but no convincing evidence of systematic blade production at the Neolithic sites was observed. The fact that prismatic blade – and, to a degree, also bladeflake – production in the Pärnu area was a distinctly Mesolithic technological feature is best illustrated by the absence of blade cores in the Neolithic assemblages, especially the single platform cores suitable for producing parallel-sided flakes and blades.

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[7] In the Mesolithic assemblages, ten blades/blade fragments are retouched. However, many blades are also snapped, which may sometimes represent intentional truncation. There is no evidence of the microburin technique at these sites. This is typical for many of the East Baltic Mesolithic sites, i.e., Kunda sites north of the Janislawice culture (cf. Ostrauskas 2000:172–175). However, in the Early Mesolithic Pulli assemblage there are also microburins (A. Kriiska personal observation). Single microburins in quartz have been reported also in Finland (cf., Schulz 1990; 1996).

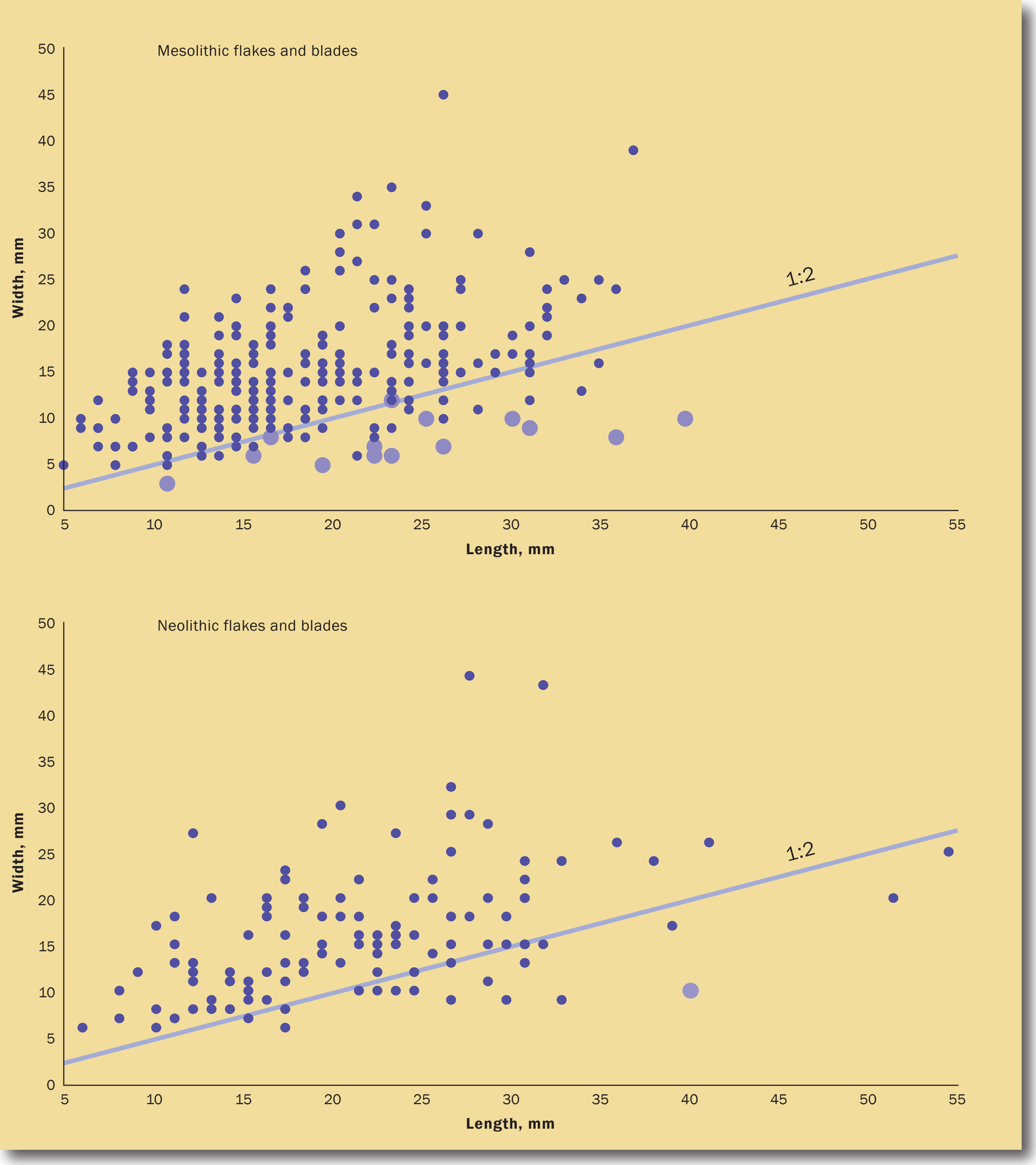

Figure 22. The dimensions of flakes, bladeflakes and blades (light blue) in the combined Mesolithic and Neolithic assemblages.

A variety of methods were employed for making blades and parallel-sided flakes during the Mesolithic. More than one centimetre wide, elaborate, and 'classic' prismatic blades, possibly produced from conical cores, are present in the Sindi-Lodja I, II and Metsaääre I assemblages. It is also clear that other smaller, and often less elaborate, blades were produced from smaller cores that were not treated in a similar fashion as the conical cores. Only a narrow core face was used for producing small, somewhat irregular, blades, making these pieces burin-like or sometimes handle core-like in shape.

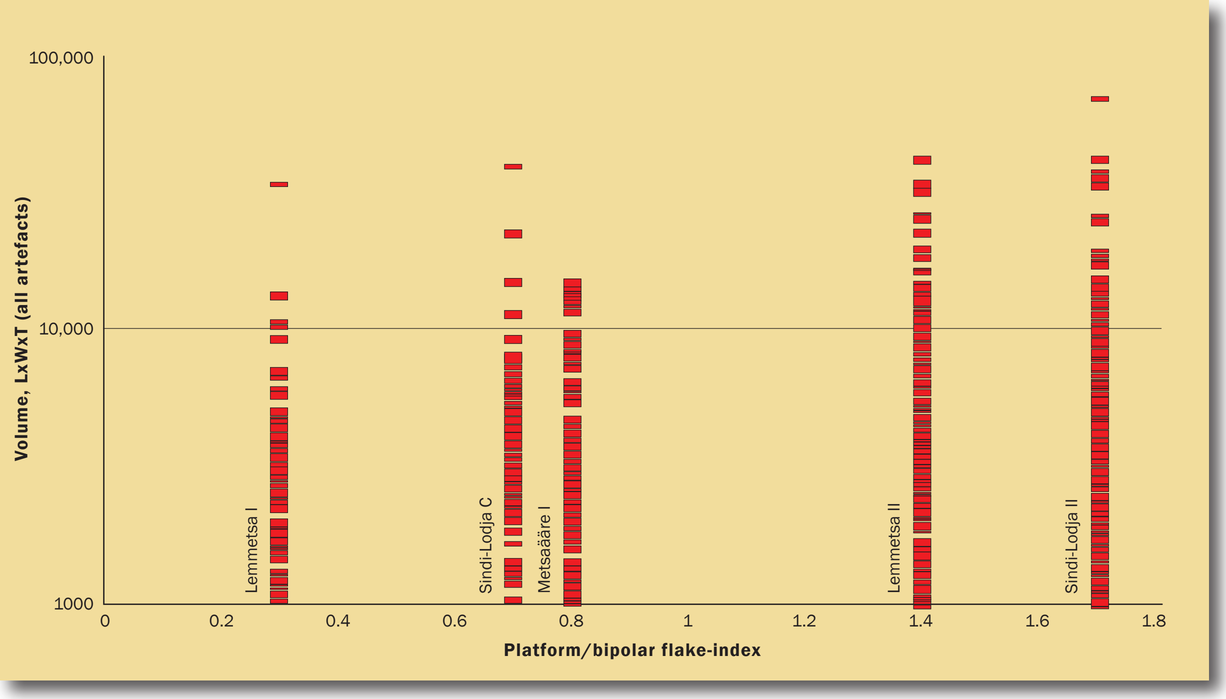

Figure 23. The platform/bipolar index in relation to artefact volume.

Moving beyond the question of parallel-sided flakes, the variability in core reduction methods is best demonstrated when comparing all the blank production methods in the Pärnu assemblages. As discussed above, the archaeological evidence implies that the decision to use a given method depended on the situation at the Sindi-Lodja II and C sites. The major core types produced different kinds of blanks and the different kinds of reduction methods were applied on pieces of different shapes and dimensions – these facts probably affected the selection of a method in each particular case. This pattern is obvious at least in the Mesolithic assemblages. Since platform cores are absent from the Neolithic assemblages, a similar comparison is not possible.

It must be borne in mind that the decision to use one or the other of the general knapping schemes – platform or bipolar – was not only related to the above-mentioned circumstances but also to raw material availability at the sites. Intuitively, it makes sense that as the raw material for stone tools is, or becomes, scarce, this is compensated for by increasing reliance on methods that conserve material and/or methods that allow the utilisation of increasingly small pieces. Since the bipolar method is well suited for the reduction of small pieces, we should expect to see increasing reliance on the bipolar method as the tool stone material grows scarce. For example, Goodyear (1993) found that the presence of bipolar cores correlated negatively with the measures of raw material abundance at the Paleo-Indian sites in north-eastern United States, and Andrefsky (1994b) found that the percentage of bipolar cores was higher for rare non-local lithic materials than for local raw materials in north-eastern Washington, United States.

Comparing the proportions of diagnostic platform vs. bipolar flakes by dividing the amount of platform flakes by the amount of bipolar flakes in an assemblage, i.e., the platform/bipolar (P/B) index, gives support to this expectation. Since the P/B index shows the proportions of the two flake types in an assemblage, the higher the index, the greater the proportion of platform flakes. As a consequence, the P/B index is expected to show decreasing values in a situation of decreasing availability of flint.

This hypothesis finds some support in the analysed assemblages when we use the artefact volumes of each site as a proxy for the availability of tool stone material at the site. In the diagram in **Figure 23**, the artefact volumes in each of the larger assemblages are contrasted to the P/B index.[8] Excluding the outliers, it appears that *the larger* the

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[8] The Sindi-Lodja I, III, and Sind Lodja II+C assemblages were excluded because of their small size (see **Appendix II**).

proportion of platform flakes, i.e., the higher the index, *the larger* pieces were left at the site. In other words, the greater the proportion of bipolar flakes in an assemblage the less relatively large pieces are included in it.

This implies that the choice between the platform and bipolar methods was related to the availability of raw material for stone tools. When relatively large pieces were scarce, bipolar reduction was used more often than when raw material and large pieces were more easily available. It seems evident that the increasing use of bipolar reduction is related to the availability of raw material for stone tools and is therefore situational. However, the artefact volumes also correlate to some degree with assemblage size and therefore the effect of assemblage size to the P/B-index should be studied further when the research material allows it.

If the high P/B index values are related to the better availability of raw material it would be reasonable to expect that a similar correlation between raw material availability and tool use should also exist. As the raw material for stone tools becomes scarce the availability of flakes suitable for use also decreases. In such a situation we should expect to see increasing tool curation, in this case an increasing rate of retouch on flake edges, executed in order to increase their use-life. This should be apparent as high tool percentages when contrasted to blades and/or flakes.

When contrasting the tool percentages (**Appendix II**) with the P/B indices, a trend is revealed for all cases except Lemmetsa II (**Fig. 24**). For the four cases, the P/B index explains 86% of the variation in tool percentages. Lemmetsa II clearly deviates from the pattern, but the reason for this is not obvious. As noted above, the source critical problems related to the varying recovery contexts and field work methods make comparison between the assemblages problematic. These factors probably affect, to a degree, both the P/B index and the tool ratio, and although both of these seem to match the expectations to some extent, the bias deriving from the different fieldwork methods and find contexts is difficult to avoid. Nevertheless, the figure suggests an emerging pattern in keeping with the expectation, which may become stronger in the future with more assemblages under comparison.

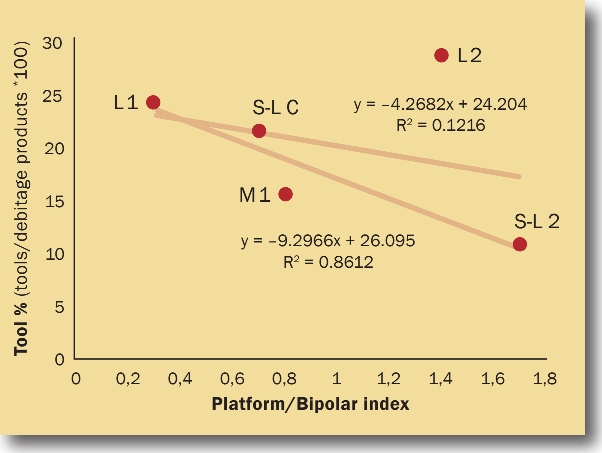

Figure 24. Comparison of the platform/bipolar index and tool percentage (tools/debitage) for Lemmetsa I (L1), Sindi-Lodja C (S-L C), Metsaääre I (M1), Lemmetsa II (L2), and Sindi-Lodja II (S-L2).

In order to understand the raw material economy better, core volumes can be compared between assemblages. It is reasonable to expect that in a situation where raw material for stone tools is scarce, cores are utilised more effectively than in a situation where raw material is easily available. This means that we should see a pattern in which small core size correlates with poor availability of flint. This kind of correlation at sites where other raw materials than flint were also used – quartz in the Pärnu area – would indicate, in addition, that flint was favoured over them.

To study this, the amount of flint in the total lithic assemblage, i.e., the availability of flint in relation to its need can be taken as a proxy measure. If quartz was used to compensate for the inadequate flint supply in the Neolithic, we would expect to see a pattern where flint cores were utilised more economically in Neolithic contexts. If quartz was not used to compensate for the lack of flint, then there should be no difference in core size between the Mesolithic and the Neolithic.

By arranging the assemblages into two temporal groups, Mesolithic and Neolithic, a pattern that is consistent with the prediction of economical flint use emerges (**Fig. 25**). At the Neolithic sites the bipolar cores are smaller. This pattern, however, does not seem to be consistent with the P/B index/artefact volume comparison discussed earlier that showed no temporal patterning. Instead, it showed that the high P/B index was related to the presence of large pieces of flint in an assemblage. On the other hand, the fact that bipolar cores are smaller at Neolithic sites is in agreement with the high relative flint tool ratios in the Neolithic (**Appendix II**).

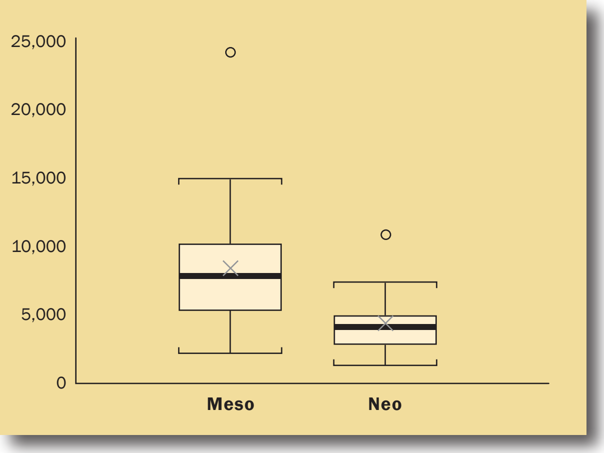

Figure 25. The volumes of Mesolithic and Neolithic bipolar cores. Scale in cubic millimetres.

It is clear that many of the issues and explanations discussed here are complex. One obvious reason for this is that sites are not equal in their settings and contents, and therefore a site assemblage is not a constant that is only related to the availability of raw material in the surrounding area. As the tactics for provisioning places and individuals differ, assemblages differ accordingly (Henry 1995; Kuhn 1995). However, it is likely that with increasing data these issues can be studied further in the future.

When it comes to tools and other implements, as already noted, it is common that the largest blanks were retouched. This is also in good agreement with general economical predictions on raw material use. The largest pieces had the most future potential for use and consequently they were the pieces that were carried along, used, sharpened, and re-sharpened. Therefore these pieces in general exhibit clear retouch, a feature that is probably generated on many of the tools through a process of repeated use and sharpening.

Discussion

The variation in blank production methods observed in the Pärnu Bay area is not without counterparts in neighbouring regions. One can easily see this by looking into blade producing methods – the most common interest area among researchers working with lithics in the neighbouring countries.

The flexibility in blade production is well documented at Mesolithic sites in the Peri-Baltic region. For example, at Veretye I in north-western Russia, different kinds of "handle core"-types for the production of small blades are found in addition to the more elaborate conical blade cores (e.g., Oshibkina 1997:43, 153) and an equally high variation in core treatment practices seems to be present also at sites in central Russia (e.g., Koltsov & Zhilin 1999; Lozovski 1999:Figs. 1,2). The illustrations published by Oshibkina (e.g., 1997:Fig. 25) imply that it is not uncommon at Veretye I that core thickness, i.e., core face width, in some "handle" cores is less than 20 mm. These examples illustrate the small size of some of the blades that were produced at these sites.

In connection with these small blades, a note on the burin-like cores in the Mesolithic Pärnu assemblages is required. It is not always clear, whether these are burins or cores for producing small blades, but we suggest a core function. The same kind of 'burin-like' small blade production could be suggested also for assemblages from other Mesolithic sites in the surrounding areas. However, these kinds of artefacts are usually interpreted as burins (see e.g., Sorokin 2002).

In this connection, it is also worth discussing the wedge-like pieces, i.e., bipolar cores. In the Pärnu Bay area, the use of the bipolar method to produce flakes seems to be associated with the general nature and size of the raw material pieces.[9] However, as the analyses suggest, this alone does not explain the whole spectrum of bipolar reduction. It seems that the bipolar method was a salient part of the Mesolithic and Neolithic lithic technologies in north-eastern Europe although its use varied in relation to the general access to and availability of raw material.

One of the important features of the Pärnu assemblages is the change in the lithic procurement tactics that takes place in the course of the Stone Age. The Mesolithic assemblages consist mainly of flint, whereas the Neolithic sites also contain a large quantity of quartz. The large scale change that can be seen in the Pärnu Bay area brings forth a question that goes into the very basics of all archaeological inquiry, i.e., how to explain cultural change.

A similar change in raw material use has also been observed in other parts of coastal Estonia. For example, on the coastal islands the use of quartz increases in the Late Mesolithic. On the Saaremaa, Hiiumaa and Ruhnu Islands Late Mesolithic and Neolithic lithic assemblages consist of 41,2–98,1% quartz (Kriiska 2002:36). It is clear

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[9] For a similar situation in Gotland, see Rundkvist *et al.* 2004:18.

that there was no clear-cut change, no single event, after which foragers in the area began to utilise quartz. The decisions of how to select and procure lithic raw materials were related to a number of variables in settings that were undergoing gradual change throughout the Stone Age.

A scenario that explains the increasing reliance on quartz can be presented. In the Pärnu Bay area much of the data suggests that flint was not abundant at the studied sites at any time. The abundance of flint, however, is not a constant but a relative factor that depends on the amount of resources and consumers. Consequently, much of the change can be explained by understanding the way foragers position themselves in the landscape and in relation to other, non-lithic, resources. These decisions are mirrored in the lithic raw material selection and use and, therefore, in the archaeological assemblages.

From the Late Mesolithic onwards the foraging strategies changed from a reliance on terrestrial resources to a more aquatic resource use in the coastal area. The associated change in the way people positioned themselves in relation to the resources is seen, e.g., in the colonisation of the large islands, Saaremaa and Hiiumaa (Kriiska 2001b). The colonisation of the islands implies a marked reorganisation of the mobility strategies and the associated settlement pattern. With the increasing use of marine resources it is likely that the amount of residential mobility decreased, which in turn meant longer periods of continuous occupation at a single site. This relaxed also the constraints on tool kit size and weight. Although quartz is generally easily available around sites, it has higher transportation costs than flint (Tallavaara *et al.* 2010). Therefore, it is reasonable to expect a reorganisation of lithic selection and use strategies with decreasing residential mobility, as the benefit from high quality raw material is smaller than for mobile groups.

Further, the large land areas utilised in hunting land mammals facilitate the detection and procurement of relatively scarce flint resources from large territories. With the change to a more marine diet the diminishing terrestrial range reduces the amount of available places from which lithic raw materials can be procured.

In the Pärnu Bay area, most of the flint raw material seems to have been collected from sedimentary deposits that have a patchy distribution. As a consequence, no single specific location for collecting lithic raw materials probably existed. Rather, the raw materials were collected from the open shorelines in an opportunistic way. The increase in the length of occupation at the sites combined with the long use history of many sources led to the gradual depletion of the surrounding lithic sources.

Since it appears that in the Pärnu Bay area the available flint was already quite effectively exploited in the course of the Mesolithic, a large-scale intensification of flint use with the increasing length of occupation of the sites was not a viable option. This meant that other lithic resources were required to compensate for the poor availability of flint. As a consequence, the use of quartz began to grow. This scenario is readily testable in other areas around the Baltic Sea and in the Peri-Baltic regions. It is within this general scenario that we can incorporate in the research other important factors, such as risk management, which must have had an effect on the technological organisation of the groups in question.

Raw material use is also known to be related to cultural preferences that show no clear association with economic behaviour. For instance, preferences of certain lithic raw materials related to spiritual beliefs have been reported (e.g., Taçon 1991). There is, however, no contradiction between these kinds of choices and the lithic economical scenario presented here. The scenario should be taken as a benchmark to which other cultural choices beyond economical behaviour are compared – when assemblages do not fit into this scenario a different, cultural, explanation must be sought.

Conclusion

In this paper we have studied lithic raw material procurement and the reduction of flint at Stone Age sites in the Pärnu Bay area, Estonia. We have provided quantitative metric data on assemblage characteristics. We hope that these data can be used as comparative material in studies concerning lithic technology, not only in the Pärnu region, but also in the surrounding areas.

The analyses of seven Mesolithic and Neolithic flint assemblages show a rather uniform technological character. With the exception of the Mesolithic blades and Neolithic bifaces, the general character of the primary production in flint shows little or no evidence of change over several millennia. All assemblages are flake-dominated and produced by simple platform and bipolar methods.

The flint technology at all sites seems to have been dominated by strategies that made use of small flakes and cores. This phenomenon is related to the dimensions, quality, and availability of raw materials. The cores demonstrate that despite the small size of raw material pieces, different reduction methods were employed. This can be explained by a need for different types of blanks, but also as a response to the different shapes of the cores.

An analysis of the use of different lithic raw materials in the assemblages was not included in this study. However, it seems evident that the observed changes in the use of flint and quartz, i.e., in the lithic technological organisation, were related to other socio-cultural factors. The archaeological record suggests a major reorganisation of hunter-gatherer foraging strategies, including mobility, settlement patterns, and associated demography, during the study period. Much work needs to be done to make proper and reliable inferences about these issues.

However, we believe that the study of lithic technology, using different and sometimes diverging approaches, will become a central field in future studies concerning this region. As a consequence, the changes seen in the lithic procurement tactics, the use of different raw materials, the choices between reduction methods, and so forth, in essence, the whole technological organisation, will gradually become understandable. In this way the study of technological organisation becomes meaningful to the study of the cultural system as a whole. We believe that the theoretical orientation used in this paper, if more widely accepted, will help in gaining a better understanding of the past cultural systems in this area.

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Appendix I. The history of Stone Age research in the lower reaches of the Pärnu River 1/2

In the beginning of the twentieth century, when Estonian archaeology was still relatively young, *Altertumforschende Gesellschaft zu Pernau* (the Pärnu Society for Antiquities) came to the fore and for a while had a leading role in Stone Age research in the whole of Estonia. The society, founded in 1896, was not unique. Associations of a similar kind were common in Europe at the time. The originality of the Pärnu society was in its markedly intensive interest in archaeology and especially in Stone Age research (Põltsam 1997; Kriiska 1997).

The main reason for this interest was the large amount of stray finds gathered from the lower reaches of the Pärnu River and from the banks of its tributaries. The first Stone Age artefacts were collected in 1901 at the mouth of the Reiu River by veterinary surgeon and future active amateur archaeologist Eduard Glück, a member of the *Altertumforschende Gesellschaft zu Pernau* (Glück 1906, 272). A couple of years later Friedrich Rambach, a manufacturer interested in archaeology, started another large collection of Stone Age artefacts from the same area (Indreko 1932:283).

The artefacts collected by these Baltogermans formed the basis of the large collection of more than a thousand artefacts – mostly of bone and antler – from the lower reaches of the Pärnu River. Most of the finds were catalogued and published in the publications of the society (see Kriiska 1997). Archaeological excavations were carried out in 1905 near the main find-spot at the mouth of the Reiu River, but they did not provide the hoped-for results (Frank 1906).

The collections were later augmented by brewery owner Eduard Bliebernicht, also a member of the *Altertumforschende Gesellschaft zu Pernau*. His efforts in collecting and preserving Stone Age finds gathered during gravel digging in the Pärnu River were especially important. Bliebernicht also published an article (Bliebernicht 1924) on the prehistoric finds from the lower reaches of the Pärnu River, but his work ended with the beginning of the Second World War. In addition, August Laury and Johan Pajo were also instrumental in gathering artefacts from the lower reaches of the Pärnu River (Indreko 1932).

Antler artefact collected from the Pärnu River. Collections of the Pärnu Museum (PäMu 6 / A 2092). Length 36.2 cm. Photograph by M. A. Manninen.

Appendix I. The history of Stone Age research in the lower reaches of the Pärnu River 2/2

Academic research in the area began in the 1920s. At this time, the prehistory of Pärnu county, including the traces of settlement from the mouth of the Reiu River, was taken up by Richard Indreko, who was one of the first generation of Estonian professional archaeologists. He catalogued Rambach's collection (Indreko 1926) and later the Stone Age artefacts gathered from the lower reaches of the Pärnu River by veterinary Johan Pajo (Indreko 1932). Indreko also carried out short-term archaeological inspections and test excavations near the mouth of the Reiu River (1929; 1939). Although excavations were carried out in many places, settlement sites were not discovered.

After the war, Stone Age research on the lower reaches of the Pärnu River came to a standstill: only stray finds were occasionally added to the collections. Indreko had moved to Sweden, Blibernicht to Germany, and in general the focus of archaeological research was directed to other parts of Estonia. The discovery of the Preboreal Pulli settlement site in 1967 was then impetus for a new period of intensive research. In 1968–1973 and 1975–1976 an area of more than 1100 m² was investigated at the site in archaeological excavations led by Lembit Jaanits (Jaanits & Jaanits 1975; Jaanits & Jaanits 1978).

This work changed drastically the existing conception about the beginning of the Mesolithic in all of the Baltic countries. Many flint artefacts from the Pulli site have been widely published and the typology and, partly, the technology of the flint artefacts has been investigated (Jaanits 1973; 1981; Jaanits & Jaanits 1975; 1978; Jaanits *et al.* 1982; Jaanits & Ilomets 1988).

After a few survey trips (1969 by Lembit Jaanits and 1974 by Kaarel Jaanits) to the banks of the Pärnu River, research was activated again at the end of 1990s under the leadeship of Aivar Kriiska (e.g., Kriiska 2001; Kriiska & Saluäär 2000; Kriiska *et al.* 2002; Kriiska *et al.* 2003). The attention that was previously concentrated mainly on the lower reaches of the Pärnu River, was partly turned on the shores of the rivers Audru and Reiu, where traces of Stone Age settlements have been detected during the last decades.

Appendix II. Artefact inventory

Artefact inventory of analysed assemblages

	Mesolithic					Neolithic		
	Sindi-Lodja I	Sindi-Lodja II	Sindi-Lodja C	S-L II + S-L C	Metsaääre I	Sindi-Lodja III	Lemmetsa I	Lemmetsa II
All artefacts, total	18	500	77	26	151	48	126	275
Blank production								
Cores, total*	3	35	7	8	6	3	7	20
Blade cores, single platform	1	7	1					
Flake core, single platform		7		2	1			
Flake cores, opposite platform		2						
Flake cores, irregular		6	5	2				3
Flake cores, discoidal		1						
Flake cores, single removal		1			1			1
Flake cores, bipolar pillow shaped		4		2	3	3	5	9
Flake cores, bipolar with platform	2	3	1	2	1		1	2
Flake cores, bipolar multidirectional		3						
Flake cores, mixed bipolar & irregular platform		1						
Bifacial points and fragments							1	5
Flakes and blades, total**	12	330	56	13	110	33	79	184
Blades & fragments	4	39	5		15		1	0
Flakes & fragments***	8	291	51	13	95	33	78	184
Debris	3	134	14	5	35	12	41	71
Diagnostic flakes								
Total****	5	213	34	11	70	19	33	106
Platform	3	135	14	8	30	6	7	56
Bipolar	2	78	20	3	40	13	26	40
Bifacial								10
Tools								
Total*****	6	36	12	5	17	3	19	52
Scrapers, scraper fragments	3	13	3	4	6		8	8
Denticulates		1						
Burins					3			
Retouched blades and blade fragments	2	7	1		1			
Retouched pieces******	1	15	8	1	7	2	10	39
Bifacial points and fragments							1	5
Unifacial point/cutting tool						1		
Strike-a-lights							7	16
Indices								
Blades & fragments / Flakes & fragments	0.5	0.1	0.1	0	0.2	0	0	0
Platform / Bipolar flakes	1.5	1.7	0.7	2.7	0.8	0.5	0.3	1.4
Tools / Flakes and blades	0.5	0.1	0.2	0.4	0.2	0.1	0.2	0.3

* Core fragments included, ** Tools included, *** Bladeflakes included, **** Diagnostic fragments included, ***** Tool fragments included, ****** Retouched and/or used flakes, fragments, cores, and debris.

Appendix III. Individual core dimensions

Core dimensions*	Sindi-Lodja I	Sindi-Lodja II	Sindi-Lodja C	S-L II & S-L C	Metsaääre I	Sindi-Lodja III	Lemmetsa I	Lemmetsa II
Length (millimetres)								
Blade cores, single platform	23	37 21 24 37 21 28	32					
Flake cores, single platform		43 30 21 30 29 36 35		42	21			
Flake cores, opposite platform		22 27						
Flake cores, irregular		27 27 24 30 24 27	38 21 21 21	22 20				20 48 36
Flake cores, discoidal		19						
Flake cores, bipolar pillow shaped		30 19			25 13 25	20 15	20 20 32	30 28 24 23 23 18
Flake cores, bipolar with platform	22 27	24 28 15	18	24 15	16		39	27
Flake cores, bipolar multidirectional		25 40 32						
Flake cores,mixed bipolar & irregular platform		18						
Width (millimetres)								
Blade cores, single platform	21	13 23 13 20 11 9	10					
Flake cores, single platform		37 18 22 33 23 37 12		23	24			
Flake cores, opposite platform		18 20						
Flake cores, irregular		30 16 36 27 46 25	36 22 20 13	21 16				18 34 26
Flake cores, discoidal		13						
Flake cores, single removal					22			32
Flake cores, bipolar pillow shaped		22 21			23 15 17	15 14	21 11 24	16 18 15 18 17 15
Flake cores, bipolar with platform	17 28	16 19 19	18	24 12	15		13	15
Flake cores, bipolar multidirectional		22 27 19						
Flake cores,mixed bipolar & irregular platform		18						
Thickness (millimetres)								
Blade cores, single platform	15	18 7 21 16 20 15	19					
Flake cores, single platform		20 11 15 17 10 18 27		10	17			
Flake cores, opposite platform		17 11						
Flake cores, irregular		23 7 40 14 36 14	16 16 13 19	10 10				18 20 12
Flake cores, discoidal		12						
Flake cores, single removal					19			16
Flake cores, bipolar pillow shaped		20 14			22 – 10	9 6	12 9 14	9 8 9 11 10 9
Flake cores, bipolar with platform	14 11	14 11 11	21	14 12	10		14	12
Flake cores, bipolar multidirectional		18 22 23						
Flake cores,mixed bipolar & irregular platform		24						

* Fragments not included

Appendix IV. Blade widths

Blade width	3mm	4mm	5mm	6mm	7mm	8mm	9mm	10mm	11mm	12mm	13mm	14mm	15mm	16mm	17mm	18mm	Total	Median	Mean
Sindi-Lodja I					1	1		1		1		1				1	6	10	11.5
Sindi-Lodja II	2		2	8	6	5	3	5	4	4	2	1	1				43	8	8.2
Find-spot C						2			2				1				5	11	10.6
Metsaääre I		1	1	1	2		3	5	1		1	2	1				18	10	9.6
Lemmetsa I								1									1	10	10
Total	2	1	3	9	9	8	6	12	7	5	3	4	3			1	73	9	9.1

Appendix V. Flake dimensions

Flake dimensions[*]	Flake length, mm		Flake width, mm		Flake thickness, mm		Flake volume (LxWxT)	
Mesolithic	Bipolar, n=130	Platform, n=152	Bipolar, n=130	Platform, n=152	Bipolar, n= 130	Platform, n=152	Bipolar, n= 130	Platform, n=152
Minimum value	8	5	6	5	2	1	182	25
25th percentile	14.25	12	11	11	4	3	690	498
Median value	18.5	16.5	14.5	14	6	5	1434	1035
75th percentile	23.75	22	18	17	8	6	3009	2389.5
Maximum value	38	128	39	52	13	26	14820	66560
Neolithic	Bipolar, n=44	Platform, n=32	Bipolar, n=44	Platform, n=32	Bipolar, n=44	Platform, n=32	Bipolar, n=44	Platform, n=32
Minimum value	10	6	6	6	1	1	112	36
25th percentile	15.75	13.5	11	14.5	3	3	595.5	561
Median value	20.5	20	13.5	18	5	5	1435	1953
75th percentile	25.25	25.25	17	24.25	7	7.25	2438.75	3862.5
Maximum value	38	32	26	44	12	19	8640	25327

[*] Fragments not included