Hunter-Gatherer Mobility and the Organisation of Core Technology in Mesolithic North-Eastern Europe

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4

Hunter-Gatherer Mobility and the Organisation of Core Technology in Mesolithic North-Eastern Europe

Esa Hertell & Miikka Tallavaara

ABSTRACT **This paper discusses the relationship between forager mobility and Mesolithic core technology in north-eastern Europe. It is suggested that due to its efficiency and the potential to produce a wide diversity of tool blanks, conical blade core reduction was a generalised production strategy suitable for mobile foragers. Other reduction methods used in parallel with conical blade core reduction provided different solutions to tool blank acquisition. An irregular flake core is a less efficient way to turn raw stone into tool blanks. This strategy is expected to have been employed with decreasing mobility, when there was less demand for core efficiency. To test these expectations, we used faunal data from Finland, Estonia and Russia to measure the level of mobility. Regression analyses suggest that the lithic core data and mobility indicators are correlated. This indicates that hunter-gatherers intentionally varied their reduction strategies in relation to the constraints posed by mobility. The conical blade core strategy correlates positively with indicators of high mobility. Irregular flake core reduction was increasingly employed when the duration of site occupation was increasing. During the Mesolithic, there was an increase in the emphasis on irregular flake core reduction and a decrease in conical core reduction. The link between high mobility and the conical core strategy suggests that it was a beneficial strategy during the post-glacial human dispersal to the north. The archaeological record further suggests that hunter-gatherers over large areas in north-eastern Europe made similar decisions and selected to employ similar core reduction strategies.**

KEYWORDS
Mobility, foraging, lithics, core technology, Mesolithic, northern Europe.

Introduction

During the past decades, archaeologists have increasingly began to study variation in lithic technologies and its correlates to explain the organisation of lithic technology (e.g., Andrefsky 1994; Bamforth 1991; Bousman 1993; Carr 1994; Hertell 2006; Kuhn 1995; Neeley 2002; Nelson 1991; Tallavaara 2005; Torrence 1989). This kind of a systemic approach assumes that lithic technology is linked to other areas of culture, as well as to extra-cultural factors. For example, the geology of north-eastern Europe is highly variable, and it can be said that geology and the natural availability of rocks have affected the organisation of lithic technologies more than anything else in this area. In areas where cherts and other good-quality lithic materials were not found, quartz and other local rocks were commonly used. The different raw materials were flaked and treated in different ways, and this resulted in a highly diverse and rich archaeological record in the area. For example, numerous blades and bifaces were made of chert, whereas quartz was flaked mainly through simple platform and bipolar reduction,

Figure 1. Sites discussed in the text. 1) Sujala, 2) Veretye I, 3) Pulli, 4) Butovo, Kultino 3, 5) Ozerki 5, 6) Malaya Lamna 3, 7) Chernaya 1, 8) Spas-Sedcheno 2, 9) Bezvodnoye 10. Data from Koltsov & Zhilin 1999b; Oshibkina 1997; Rankama & Kankaanpää 2007.

and various rocks of igneous origin were pecked and polished. In this paper, we go beyond the effect of the local geology and the different raw material varieties to study the variability in Mesolithic core technology in Estonia, Finland and north-western Russia.

One of the basic premises of research on the organisation of technology is that individuals should organise their technology according to their needs and that technologies are best seen as strategies for solving problems of some form (e.g., Bousman 1993; Kuhn 1995). Mesolithic foragers did not make blades just because they inherited blade technologies from their ancestors, who had made blades throughout their lives. The variability in archaeological assemblages also means that Mesolithic foragers were not tied to one specific production strategy, but, instead, employed a variety of core reduction methods. Because different raw materials, reduction strategies, and tools have variable costs and benefits for the user, different technological solutions have different outcomes. Selecting one strategy over others means gaining something at the cost of something else. For example, choosing to configure a core to make blades means that long, slender tool blanks can be produced, but at the same time, an opportunity to make something else from the same piece of stone is lost.

Research on the organisation of technology has stressed the impact of hunter-gatherer mobility on the technology (Bamforth 1991; Blades 2003; Kelly 1988; Kuhn 1994; Larson & Kornfeld 1997; Parry & Kelly 1987). Instead of collecting lithic raw materials at their sites, mobile individuals need to provision themselves with adequate supplies of tool stone (Kuhn 1995). It is generally acknowledged that mobile foragers cannot carry large supplies of raw material with them, and the technology needs to be adjusted to the constraints of mobile life. In such a situation, different solutions to lithic reduction, i.e., behavioural variants, may have highly different outcomes. When time or energy, or any other factor, is limited, selecting one solution may have far-reaching effects. From a wider evolutionary perspective, optimal technologies ultimately provide fitness benefits to those who invent, adopt, or use them (Bousman 1993; Kuhn 2004; Ugan *et al.* 2003).

Our aim is to test the hypothesis that the variability in the Mesolithic core technology in north-eastern Europe is related to the variability in hunter-gatherer mobility. We present a simple qualitative cost-benefit analysis of Mesolithic core technologies in relation to hunter-gatherer mobility and provisioning strategies. To test the suggested link between core technology and mobility, we analyse the archaeological lithic core and faunal data from Estonia, Finland and Russia (**Fig. 1**). The results of these analyses support the idea that mobility-related factors played a role in the selection of core reduction strategies in the area. This provides an explanation to the variation and frequencies of different core types in the archaeological record.

Variation in Mesolithic blade production strategies

In general, the efficiency of a core (i.e., its use life and number of useful products), and therefore the amount of raw material that must be carried along, depends largely on the configuration, maintenance, and reduction strategy of the core (e.g., Brantingham & Kuhn 2001). Due to the different geometry of blades and flake blanks, blade reduction offers one solution to raw material scarcity by providing more edge per blank volume than flake reduction strategies (see also experimental results by Eren *et al.* 2008:957). The production of blades, therefore, extends core use life and increases the efficiency of raw material consumption. The standardised shape of a blade has potentially very few useless edge parts due to the high regularity. In contrast to flakes, the volume and mass of blades are positioned evenly along the blank, producing further benefits for the optimisation of raw material use (e.g., Bar-Yosef & Kuhn 1999:324). This is not the case, for example, with flakes from irregular cores where the ratio of the flake edge to its mass is smaller.

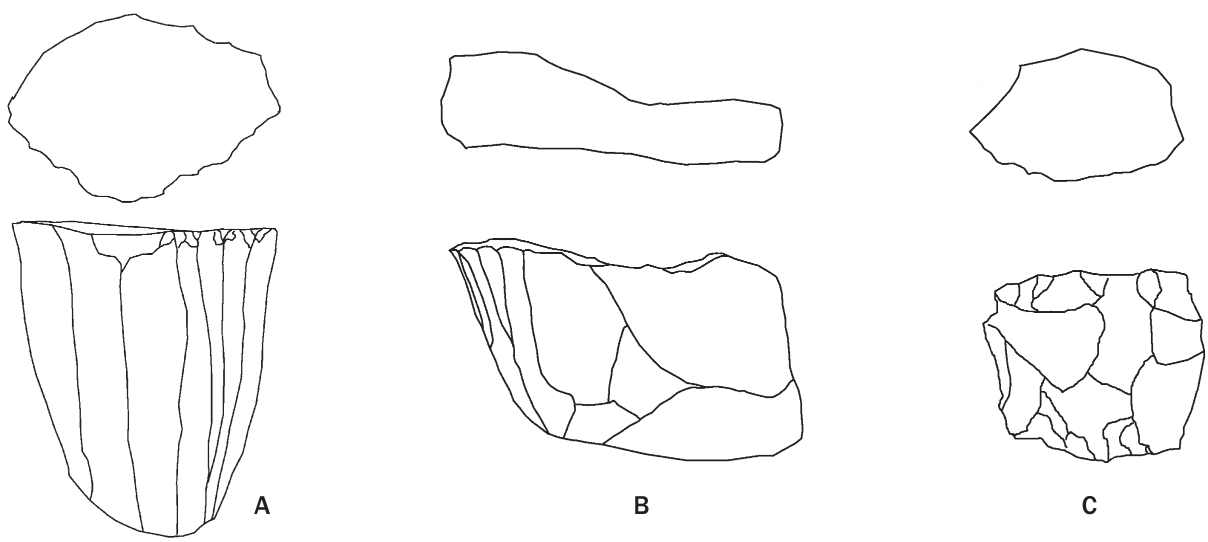

Figure 2. Schematic illustrations of different core types. A) conical core, B) narrow-face core, C) irregular core.
A & B adapted from Oshibkina 1997.

Archaeological data from Mesolithic sites in Finland, the East Baltic countries and north-western Russia suggest that variable strategies were employed in lithic core reduction and in blank production (Kriiska *et al. this volume*; Koltsov & Zhilin 1999a; 1999b; Oshibkina 1983; 1997; Rankama & Kankaanpää 2007). Three major strategies can be recognised in the published data. These are conical blade core, single-face or narrow-face blade core, and irregular core reduction (**Fig. 2**).

To understand the variable costs and benefits of the production strategies, it is helpful to treat them as idealised and somewhat polarised options for producing tool blanks. Some blades were produced from symmetrical conical cores. These cores often exhibit evidence that core maintenance was carried out by continuous shaping, adjustment and trimming of the platform (see Burov 1999a; Koltsov & Zhilin 1999a; 1999b; Rankama & Kankaanpää 2007; 2008). For example, at the Sujala site in northern Finland, where only the conical core strategy is present, platform preparation debitage constitutes 28% of the total lithic weight, whereas blades and exhausted cores amount to 50% and only 6.5%, respectively (Rankama & Kankaanpää 2007:51–52).

During the reduction process, conical core dimensions, and therefore the maximum potential blade width and length, diminish. Judging by the blade lengths, some reduction sequences began with relatively large cores that were probably up to 200 mm in length in the initial stages (Hertell & Manninen 2006:41). The large sizes of the initial stage cores are also supported by the maximum dimensions of the platform rejuvenation flakes, which in Sujala exceed 65 mm (Rankama & Kankaanpää 2007:51). Blade production from large cores reduced the cores, in some cases, to clearly below 100 mm in length. For example, at Sujala, the length of the recovered cores is around 50 to 60 mm. The available data also show that some cores had attained a pencil-like shape (e.g., Burov 1999a; Koltsov & Zhilin 1999b; Oshibkina 1983), implying that these cores were exhausted and that little potential for blade production remained.

Although the conical core reduction process seems to have a high overall symmetry, the strategy clearly was not to maintain a standardised blank size throughout the reduction process. For example, at Sujala, blade width varies widely, ranging from 2 to 43 mm (Rankama & Kankaanpää 2007:53). The large initial size of the blanks and the large size variation imply that a single core can provide tool blanks for a variety of tools of different sizes, e.g., large scrapers, butchering knives, burins and small inserts. Therefore, conical core reduction can be thought of as a generalised blade production strategy in the Mesolithic context of north-eastern Europe. It is a strategy that can provide most of the tool blanks required. It is also a strategy that suits the constraints of mobile life, where large supplies of lithic material or many cores cannot be carried along and where a wide variety of tool blanks need to be extracted from a single core.

Other blade reduction strategies were also employed by north-east European Mesolithic hunter-gatherers. To simplify, varieties of narrow single-face cores stand at the other end of the blade core variation. Oshibkina provides good illustrations of these core types from the area south-east of Lake Onega, but similar blade production strategies were also used in, e.g., Estonia (see Kriiska *et al. this volume*; Oshibkina 1997; 2006:149–151). In this strategy, blade dimensions, i.e., the length, width and thickness, remained relatively standardised during the reduction (e.g., experiments by Callahan 1985; Flenniken 1987). The narrow-face cores are optimised for producing blanks for a restricted set of lithic tools that are typically quite small and can, for example, be used as inserts. In other words, narrow-face core reduction is a specialised blade-production strategy. Instead of producing a large variety of blade blanks, this strategy yields a large number of standardised products. The relatively small size of the bladelets allows stones of variable size to be used as core blanks, and illustrations of archaeological cases seem to indicate that this was, indeed, the case (Kriiska *et al. this volume*; Oshibkina 1997:25).

Amorphous or irregular cores provide an alternative means of obtaining tool blanks. In contrast to systematic blade manufacture, this can be seen as the other end in the continuum of reduction strategies. It can be expected that irregular cores would be increasingly employed when the constraints posed by mobility are relaxed. When raw materials do not need to be carried along but can be collected and stored at the sites, the conical core strategy loses its relative efficiency. No systematic core configuration or continuous core maintenance are required in irregular flaking. Flakes can be detached as the need arises, with little consideration for core efficiency or the need to maintain tool-making potential in the future.

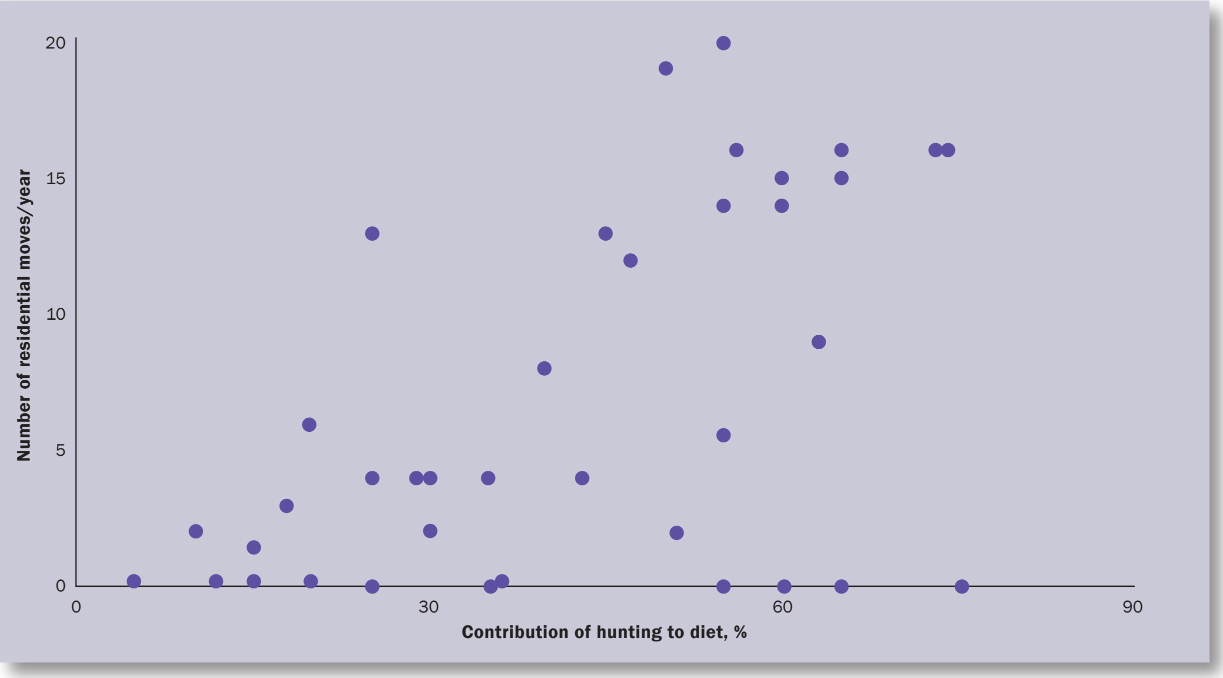

Figure 3. Residential mobility and percentage of hunting products in the diet of ethnographically documented boreal forest hunter-gatherers. Data from Binford 2001.

Methodology

The relationship between foraging and mobility

Both theoretical work and empirical analyses indicate that hunter-gatherer mobility is related to the food resources being used (e.g., Binford 1980; 2001; Kelly 1983; 1995). The theoretical interrelationship between diet and residential mobility is demonstrated in **Figure 3** for ethnographically documented hunter-gatherer groups living in a boreal environment. The groups whose diet was mainly based on foods hunted in terrestrial environments commonly made more than ten residential moves a year. However, much more extreme cases may have existed under different ecological circumstances. Marginal value theorem predicts that when resources are common and resource patches are frequently encountered, patch residence time is shorter and the proportion of consumed resources is smaller than in situations where resource patches are located farther away from each other. Increasing distance between resource patches makes it optimal to stay longer in a patch and consume a larger proportion of the resources (Charnov 1976; Hanski *et al*. 1998).

By targeting large land mammals, hunter-gatherers use only a fraction of the available resources in their environment. Accordingly, foragers targeting these species are typically highly mobile and frequently change their residential sites. For example, Kelly (1995:Table 4-1) estimates that the North American Montagnais, whose main prey was moose, changed their residential sites 50 times a year, i.e., almost once a week. When the duration of site occupation increases, the diet breadth is likely to widen accordingly, due to the pressure on the local resources caused by the hunting (e.g., Kaplan & Hill 1992). The relative amount of hunted large mammals, and their remains at a site then decreases. Increasing the length of a stay at a site results in the accumulation of an increasing amount of lithics and faunal remains on the site. If the growth rate is not the same for both categories, increasing site use leads to changing lithic to bone ratios. In Italy, Kuhn (1995:148-151) found that the relative abundance of animal remains was a suitable indicator of the degree of mobility. Therefore, three variables that employ faunal data to measure mobility can be tentatively suggested: the relative amount of large fauna in diet, faunal richness, and lithic to bone ratios. We studied these variables and their applicability in the present case.

Site	Conical core %	Narrow-face core %	Irregular core %	Other core %	Core total
Pulli	35.1	2.7	51.4	10.8	37
Butovo, excavation 1987	75	12.5	0	12.5	8
Sujala	100	0	0	0	3
Kultino 3	50	10	10	30	20
Malaya Lamna 3	8.9	15.8	71.3	4	101
Chernaya 1, excavation 2	31.3	25	37.5	6.3	16
Veretye I	40.7	15.7	26.9	16.7	324
Chernaya 1, excavation 1	30.8	23.1	38.5	7.7	26
Spas-Sedcheno 2	13.2	26.5	54.5	5.8	189
Oserki 5	19.1	14.9	61.7	4.3	47
Bezvodnoye 10	12.1	12.1	69.4	6.4	157

Figure 4. Core data for the sites. Core fragments excluded. Data from Koltsov & Zhilin 1999b; Oshibkina 1997; Rankama & Kankaanpää 2007.

Osteological and lithic data

To study whether mobility can explain the hunter-gatherer decision to use specific core strategies, we collected osteological and lithic data from published sites in Estonia, Finland and Central Russia (Koltsov & Zhilin 1999b; Oshibkina 1997; Rankama & Kankaanpää 2007; 2008). We used core data to estimate the popularity of the various core reduction strategies, because core data is generally available for the sites. Available debitage data did not allow distinguishing between different blade reduction strategies or separating core trimming flakes from flakes intentionally produced from flake cores. To increase the uniformity between the samples, data were collected only from sites that shared the same basic lithic repertoire and belonged to a single technocomplex. The resulting database that contains both lithic and faunal data consists of five sites: one from Estonia, one from northern Finland and three from Russia. To study the effects of sampling on osteological assemblages, data were also collected from Mesolithic sites where no lithic data were available (Chaix 2003; Koltsov & Zhilin 1999b). The lithic core data and osteological data are presented in **Figures 4** and **5**.

To further study whether the lithic core data show temporal patterning, we collected site-specific lithic core and radiocarbon data from the same area. This dataset contains 11 dated assemblages (**Fig. 4 & 6**). If a site had more than one radiocarbon date, the combined mean date was calculated using the combined function of OxCal 4.1 and was calibrated using the Intcal09 curve. In all of the cases (Chernaya 1, Pulli, Sujala and Veretye I), combining the dates is problematic because the date ranges are statistically too wide. Nevertheless, we used the combined dates as a rough age measure in the regression analyses.

In the original publications, the lithic core data were not presented in a uniform manner from one publication to another. To be able to study the current hypotheses and to make the data comparable between the cases, we regrouped the data published by Oshibkina (1997) and Koltsov & Zhilin (1999b). The different types of conical cores (types 1, 2 and 3) in the original Koltsov & Zhilin

	Pulli	Sujala	Kultino 3	Veretye I	Ozerki 5	Zamostje 2	Okaemovo 5	Nushpoly 11
Mammal IF, total	1011	13	123	2394	757	1595	358	99
Large fauna IF % (elk, reindeer & red deer)	44.4	100.0	78.1	60.9	60.2	35.2	57.5	52.5
Species richness	11	1	8	12	13	10	9	7
Core total	37	3	20	324	47			
Core total / mammal total	0.04	0.23	0.16	0.14	0.06			
Conical core %	35.1	100.0	50.0	40.7	19.1			
Irregular core %	51.4	0.0	10.0	26.9	61.7			
Narrow-face core %	2.7	0.0	10.0	15.7	14.9			

Figure 5. Data on mammal bone (mice excluded) and core types in the studied assemblages. IF = identified fragments. Data from Koltsov & Zhilin 1999b; Lõugas 1997; Oshibkina 1997; Rankama & Kankaanpää 2007.

(1999b) classification were combined, as were the three types of single-face cores (4, 5 and 8), and three types of irregular cores (6, 9 and 10). Type 1 is a pencil-shaped core and types 2–3 are conical or sub-conical cores. Types 4 and 8 are single- and double-platform end-face or single-face cores, and type 5 is a single-platform keel-shaped core. Types 6, 9 and 10 are irregular or amorphous cores with varying numbers of platforms. The original classification of Veretye I material contains two kinds of flake cores (discoidal and irregular), as well as conical blade cores (conical and conical-like; Oshibkina 1997). These were combined to form two groups: conical blade cores and irregular flake cores. Bipolar cores are not separated in the original data. In general, bipolar debitage is illustrated in Russian literature, but these pieces are often classified as burins (Kriiska *et al. this volume*).

For the sake of the analyses, we suggest that the discarded cores, at least to a degree, represent separate reduction strategies and not simply a continuum of cores that were discarded at different stages of reduction. However, the shape of cores can go through major changes during reduction. Because of this, the numbers of certain types of cores present in an assemblage may not be directly related to the frequency of the application of a particular core reduction strategy. This, together with the lumping of the core types, may cause additional noise in the data and complicate pattern recognition.

Taphonomic processes have affected faunal collections at the sites, complicating attempts to understand resource and site use. First, the Sujala bone assemblage differs from the others, as it consists of burnt bone fragments only. Second, it is acknowledged that there is variation in bone preservation depending on their size and density (e.g., Bartram & Marean 1999; Binford & Bertram 1977; Lyman 1984). **Figure 7** shows that at Pulli and at Veretye I, for which MNI counts have been published, the count of identified bones per individual is higher for larger species than for smaller species. This is in contrast to the expectation that a relatively higher amount of small mammal bones per individual will be brought to the residential sites, since species of different sizes are butchered and transported under different behavioural regimes. We suggest that the preservation of the bones of different species has been biased in favour of large mammals at these sites. The variable preservation of bones can be expected to cause additional noise in the data.

Site	Laboratory code	^{14}C age	STD	Median age calBC
Pulli	Ua-13352	9095	90	8324
Pulli	Ua-13351	9385	105	8672
Pulli	Ua-13353	9145	115	8393
Pulli	TA-176	9575	115	8969
Pulli	TA-175	9300	75	8541
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Pulli	TA-245	9600	120	8987
Pulli	TA-284	9285	120	8532
Pulli	Hel-2206A	9620	120	9001
Pulli	Hel-2206B	9290	120	8539
Pulli, combined				**8614**
Butovo, exc. 1987	GIN-5441	9310	110	**8560**
Sujala	Hela-1102	9265	65	8492
Sujala	Hela-1441	9140	60	8367
Sujala	Hela-1103	8940	80	8091
Sujala	Hela-1104	8930	85	8079
Sujala	Hela-1442	9240	60	8460
Sujala, combined				**8319**
Kultino 3	Tln-1406	8850	200	**7978**
Malaya Lamna 3	*	8800	90	**7904**
Chernaya 1, exc. 2	GIN-3551	8730	300	**7875**
Veretye I	GIN-4031	9050	80	8265
Veretye I	GIN-4869.Mg-P	8790	100	7893
Veretye I	LE-1472	8750	70	7807
Veretye I	GIN-2452.U	8560	120	7614
Veretye I	GIN-4030	8520	80	7560
Veretye I	GIN-2452.D	8520	130	7566
Veretye I, combined				**7755**
Chernaya 1, exc. 1	GIN-3891	8720	200	7852
Chernaya 1, exc. 1	GIN-3894	8630	40	7636
Chernaya 1, exc. 1	GIN-3893	8190	120	7213
exc. 1, combined				**7594**
Spas-Sedcheno 2	GIN-5440	8540	120	**7586**
Oserki 5	GIN-6659	7410	90	**6286**
Bezvodnoye 10	GIN-5442	6920	380	**5848**

Figure 6. Dates for the sites with core data. *Laboratory code not published. Data from Koltsov & Zhilin 1999b; Oshibkina 1997; Rankama & Kankaanpää 2007; Veski *et al.* 2005.

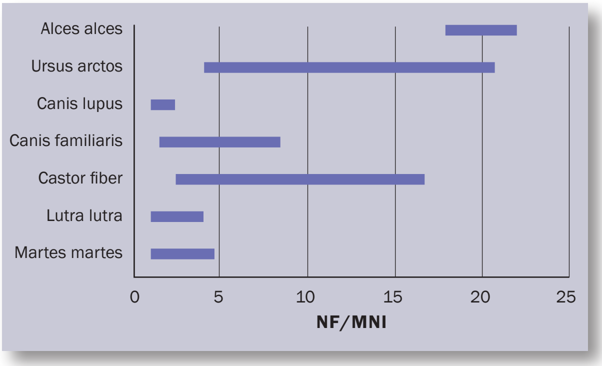

Figure 7. The number of bone fragments / minimum number of individuals at Pulli and Veretye I. The species are in decreasing size order from the left to the right. Only species that are present at both sites are included. Data from Lõugas 1997; Oshibkina 1997.

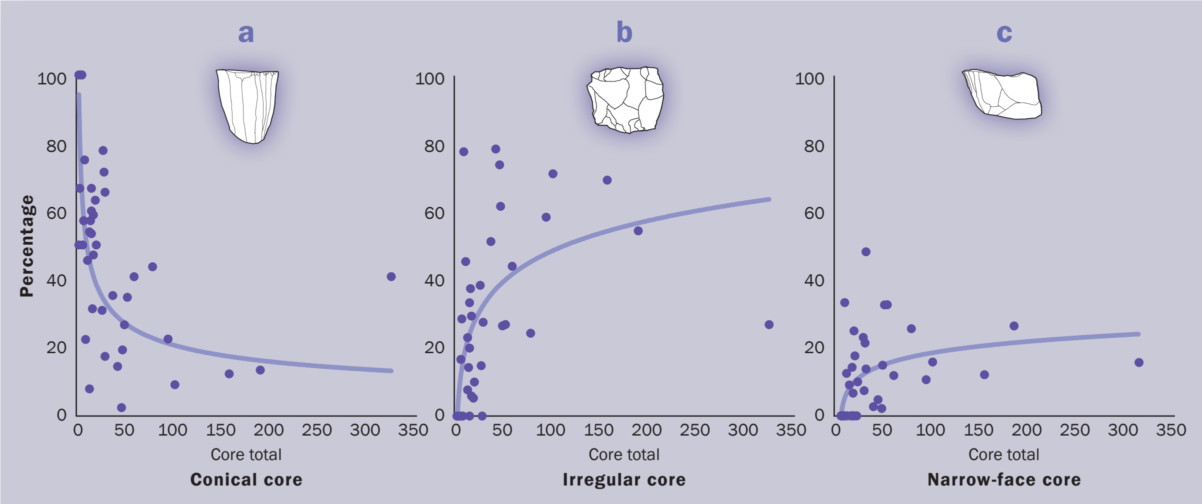

Figure 8:abc. Core assemblage sizes plotted against the percentages of conical, irregular and narrow-face cores. Data from Koltsov & Zhilin 1999b, Oshibkina 1997, Rankama & Kankaanpää 2007.

Study of the variation

Assemblage size and composition

Growing sample size may increase diversity and, therefore, have an effect on the proportions of different categories (animal species, core types) in an assemblage. Due to this, patterns observed in the archaeological data are not necessarily the result of past behavioural variability, but may be related to sample size. In the present cases, there is little information about the representativity of the archaeological assemblages, lithic or osteological. The Sujala site (find cluster 2) is the only one which we know has been excavated completely (Rankama & Kankaanpää 2007). Other sites need to be treated as samples.

Therefore, we first studied the proportion of conical, irregular and narrow-face cores in relation to the size of the core assemblages in Sujala, Veretye I and several sites in central Russia and the East Baltic (Koltsov and Zhilin 1999b:Table 1; Oshibkina 1997:Table 5; Rankama & Kankaanpää 2007). **Figure 8:c** shows that the number of narrow-face cores varies little with assemblage size. **Figures 8:a** and **8:b** further show that for small assemblages the conical core percentage is higher than the irregular core percentage, while the opposite is true for large assemblages. Small assemblages show a higher number of conical cores, while large assemblages show a higher number of irregular cores (**Fig. 9**). This pattern is not likely to be the result of sampling.

As a whole, irregular cores (n=680) are more common than conical cores (n=532) in the studied assemblages (Koltsov & Zhilin 1999b:Table 1, Oshibkina 1997:table 5; Rankama & Kankaanpää 2007). Therefore, if the composition of individual assemblages were purely the result of sample size, small assemblages should show high frequencies of irregular cores. Increasing sample size should decrease the proportion of irregular cores, but this is not the case. If conical cores were more common in the original core population instead of irregular cores, the average conical core percentage should be higher than the irregular core percentage both in small and large core samples, but again this is not the case. We suggest that different core reduction strategies were systematically employed in different circumstances, as discussed above. This explains the variation in site assemblages, their size and composition. Most notably the conical and irregular core patterns are mirror images of each other. This is consistent with the hypothesis that these core strategies were employed at the opposite ends of the mobility continuum. It is also supported by the Sujala site. As the site is excavated completely, the small core assemblage and small core diversity in the Sujala assemblage is not related to sampling, but is the direct result of past behaviour. Notably, the Sujala core assemblage composition parallels other small assemblages. These contain only conical cores (**Figure 8:a**).

Figure 10:a shows that increasing sample size increases richness in Mesolithic bone assemblages in

Estonia, Finland, and Russia until the threshold of *c.* 700 specimens is reached. In the present data set there are three sites that have more than 700 bone specimens: Ozerki 5, Pulli and Veretye I. **Figure 10:b** shows that the size of the bone assemblage and the size of the lithic core assemblage have a strong positive correlation. This is problematic, since the measures of lithic and faunal data (e.g., richness, percentages) will co-vary due to the sample size effect. These things suggest that in the present case the mammalian species richness is not a good proxy for measuring mobility. **Figure 10:c** further shows that assemblage size also largely explains the variation in the large mammal (European elk, reindeer and red deer) percentage. As a consequence, this measure is not without problems, either. However, there is reason to suspect that the large mammal percentage is not only an artefact of sample size. For the larger set of osteological data (**Figure 5**), bone assemblage size still explains almost 90% of the variation in richness but only 61% of the variation in large mammal percentage. This suggests that other factors than sample size have had an effect on the large mammal percentages. To have an additional measure, we further studied assemblage formation and the applicability of the lithic to bone ratio as an indicator of site use and mobility.

Sampling a standard lithic core and bone population should produce a relatively stable core to bone ratio pattern for the subpopulations. **Figure 5** shows that this is not case in the present context, and that the lithic core to bone ratio varies markedly. To a degree, the differences in the ratio may be related to the preservation of faunal remains at the sites, but these processes cannot be controlled properly beyond what has been discussed above. However, the Veretye I case suggests that preservation alone does not explain the variation in core to bone ratios. Despite the exceptionally good preservation of the organic material (osseous and wooden tools, birch bark containers, etc.), the Veretye I site has a high core to bone ratio when compared with Pulli and Ozerki 5. The relative amount of bones at Pulli, for example, is almost

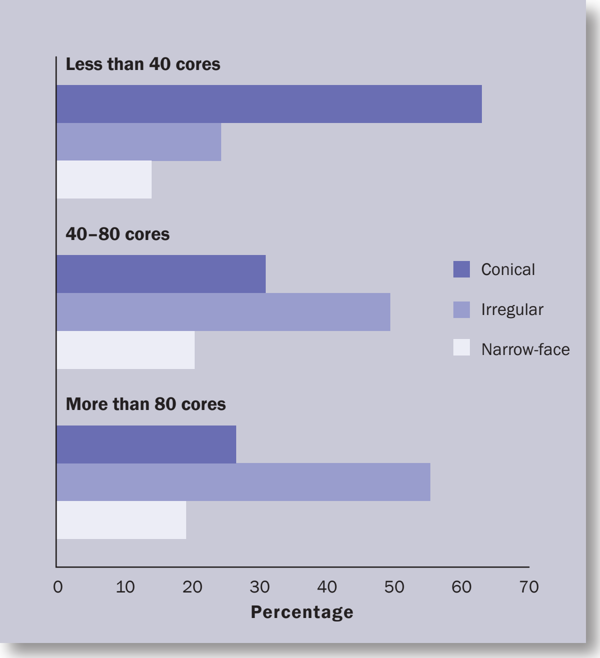

Figure 9. Conical, irregular and narrow-face core percentages in small, medium and large core assemblages (less than 40 cores, 40 to 80 cores, and more than 80 cores).

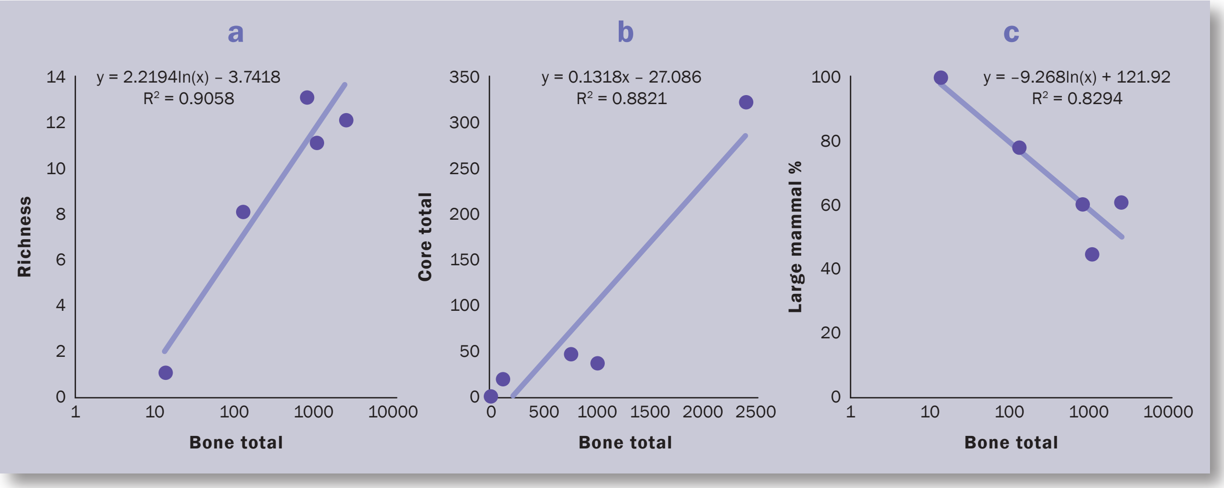

Figure 10:a. Mammal bone totals and species richness at the sites. **10:b.** Mammal bone totals and core totals at the sites. **10:c.** Bone totals and large mammal percentages.

four times higher than at Veretye I. This is in contradiction with the animal bone data that suggest that the Veretye I bone assemblage is better preserved than the Pulli assemblage: at Veretye I, almost all animal species are represented by more preserved bones per individual (**Fig. 7**). Therefore, we suggest that past behaviour explains at least part of the lithic core to bone ratio variation at these sites, and that this proxy can be used as an indicator of site use and mobility.

Increasing the length of a stay at a site means that a growing amount of lithics and faunal remains are brought to the site. As demonstrated above, faunal remains accumulate at a site much faster than lithic cores. The relative amount of bones at a site is expected to be the result of the strategies of bringing prey into the site. As explained above, in high mobility situations, foragers use only a fraction of the available resources in a patch, and a small amount of animal foods is brought to the site. In low mobility situations a diversity of animal species are hunted and brought back to the site. If this is the case, then the core to bone ratio can be expected to be patterned along the gradient of mobility and to correlate with the core reduction strategies. In other words, those assemblages that, as a result of low mobility, include a high relative number of bones should include a high number of irregular cores, while assemblages with a low relative number of bones should include a high number of conical cores.

To summarise, we suggest two variables that employ faunal data to measure mobility. The percentage of large land mammals is expected to be high in assemblages formed under a high mobility regime. This method is problematic due to the variation in osteological sample size and the unequal preservation favouring the bones of large animals. The core to bone ratio is not related to sampling, but is sensitive to bone preservation and identification. In this sense, we consider Sujala to be the most problematic assemblage, as burnt bone assemblages typically show low numbers of identified specimens when compared with unburnt assemblages. Due to the small bone assemblage, even a small change in the identified fragments results in a major change in core to bone ratio. Therefore, we studied the core to bone ratios and the core type percentages with and without Sujala.

Fauna and core reduction strategy – large mammals

If the conical blade core reduction strategy results from the need for a generalised core reduction strategy especially suitable for a mobile way of life, then there should be a positive correlation between the proportion of conical cores and indicators of high mobility. **Figure 11:a** shows that there is a positive correlation between the percentage of large land mammals and the frequency of conical cores in the assemblages. The proportion of large mammal bones explains *c.* 76% of the variation in conical core assemblages. **Figure 11:b** shows that the correlation between the large mammal percentage and irregular cores is negative. **Figure 11:c** shows that the large mammal percentage explains narrow-face core technology poorly.

Fauna and core reduction strategy – lithic to bone ratio

If irregular cores were employed in low mobility situations, when a relatively large amount of bones accumulated at the sites, then the high proportion of this core type should correlate with low core to bone ratios. **Figure 12:b** shows the negative correlation between core to bone ratios and irregular core percentages. The core to bone ratio explains *c.* 91% of the variation in irregular core percentages at the sites (*c.* 87% if Sujala is excluded). This is consistent with the mobility hypothesis, and with the previous finding that the large lithic assemblages have more irregular cores, as discussed above.

If the conical core strategy results from the need for a generalised core reduction policy especially suitable for a mobile lifestyle, then there should be a positive correlation between the proportion of conical cores and indicators of high mobility. **Figure 12:a** shows that there is a positive correlation between core to bone ratio and the percentage of conical cores. The core to bone ratio explains *c.* 78% of the variation in conical core proportions in the assemblages (*c.* 57% if Sujala is excluded).

Figure 12:c shows that the core to bone ratio does not correlate with narrow-face cores. Therefore, it seems that the use of narrow-face cores is not related to mobility. These cores seem to have been employed in variable contexts.

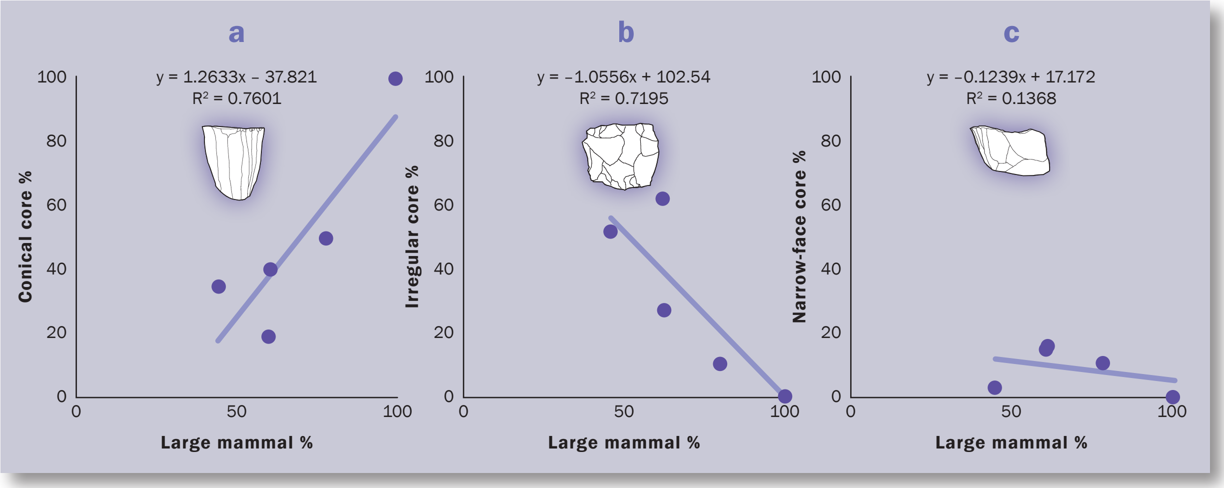

Figure 11:abc. The proportions of large mammals plotted against core type percentages.

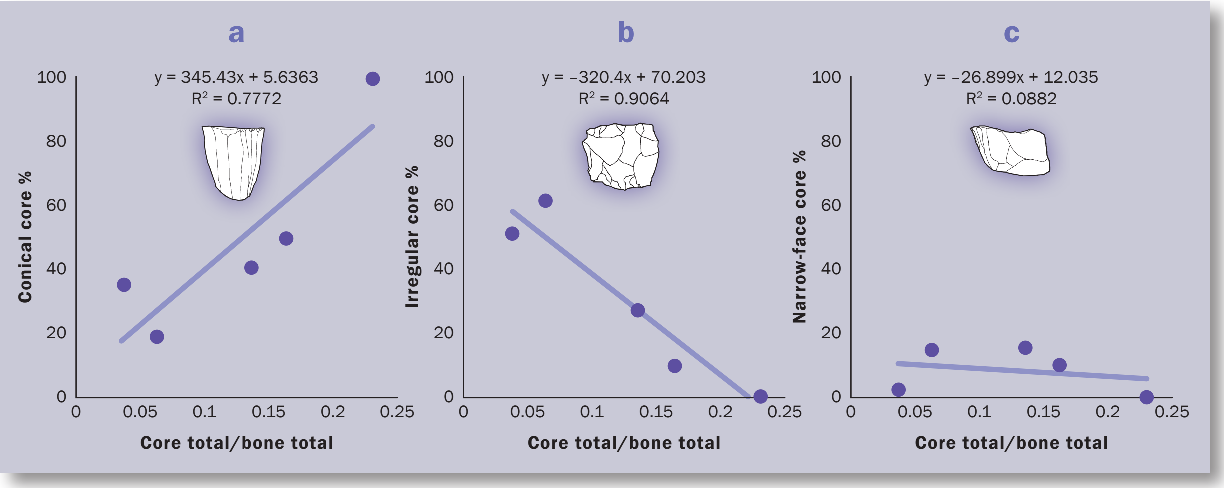

Figure 12:abc. Core to bone ratios plotted against core percentages at the studied sites.

Comparison between Sujala and Veretye I

The above results, i.e. the behavioural link between core assemblage size and composition on the one hand, and core data and faunal evidence on the other, suggest that the Mesolithic hunter-gatherers intentionally varied their core reduction strategies in relation to site use and mobility patterns. When the Mesolithic hunter-gatherer mobility level was high and there was a need to employ an easily transportable and versatile core technology, the technology was adapted accordingly by investing in a conical blade core strategy. If this is true, then archaeological data other than lithics and bones should also be patterned accordingly. Two sites, Sujala and Veretye I, provide data for testing the hypothesis further. For the other sites we lack similar data.

The Sujala site in northern Finland supports the hypothesis that high mobility and investment on conical core reduction strategy are related to each other. The evidence for the site use activities and housing is in good agreement with the lithic core (low diversity, investment in conical cores) and faunal data (low diversity, investment in large land mammals). The small site area with little evidence for structural remains and the patterning of finds around a hearth indicating easily transportable housing (Kankaanpää & Rankama *this volume*; Rankama & Kankaanpää 2007) all imply that the site was used for a relatively short time and that the mobility level of these hunter-gatherers was relatively high.

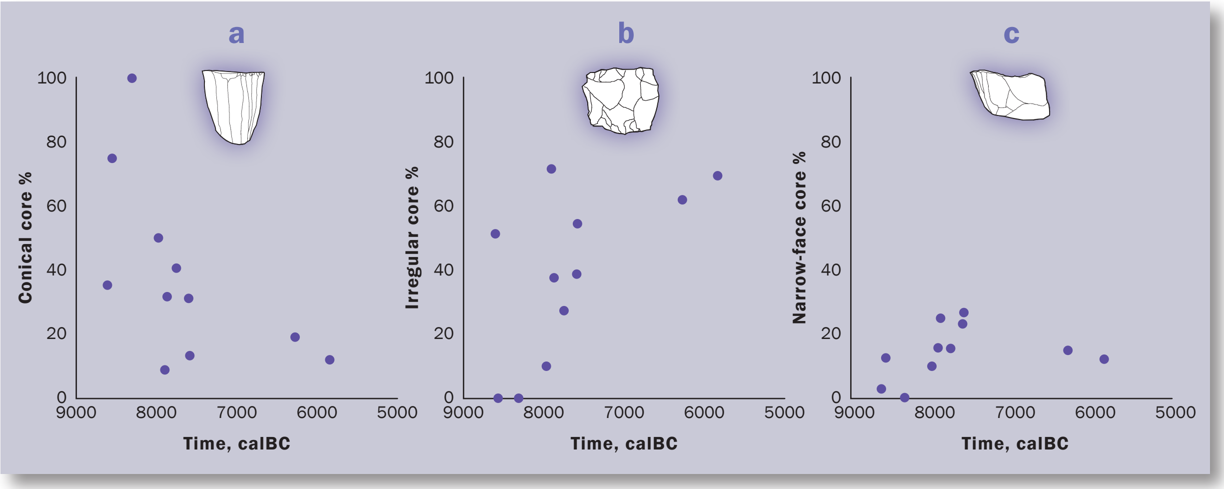

Figure 13:abc. Time and conical core percentages. Time and irregular core percentage. Time and narrow-face core percentages.

The archaeological data from Veretye I lend support to the association between decreasing mobility and decreasing reliance on conical core technology. Among other things, the Veretye I excavations revealed preserved wooden house structures that suggest a relatively low level of mobility when compared with Sujala. At Veretye I, lithic raw material and cores were also stored at the site in birch bark containers, most probably in anticipation of future use (Oshibkina 1989). Caching of lithic raw material at the site suggests that the emphasis was on provisioning sites, rather than individuals, a further indication of relatively low mobility (Kuhn 1995).

As a whole, it seems that as residential mobility decreased, the conical core reduction strategy was given less emphasis, suggesting that conical core reduction was either a relatively costly strategy to invest in or that the other reduction strategies had advantages that the conical core strategy could not offer. In such settings the use of conical cores was still profitable during hunting trips and other logistical activities, but it was less advantageous to employ that strategy alone.

Temporal patterning and core reduction strategy

Elsewhere, we have argued that Early Mesolithic hunter-gatherers in north-eastern Europe in general had larger home ranges and were more mobile than their successors (Hertell & Tallavaara *this volume*). This is mirrored in the osteological collections, which show a decreasing proportion of European elk through the Mesolithic.

If the Early Mesolithic hunter-gatherers in north-eastern Europe were more mobile than their successors, we would expect to see evidence of temporal changes in their lithic technology. In other words, the conical core percentage should decrease through time, while the irregular core proportion should increase. **Figure 13:a** shows that the use of the conical core reduction strategy decreased through time, although the correlation is rather modest. The narrow-face core shows no proper trend when the whole Mesolithic is considered, but there is a clear rising trend between 8600 and 7600 calBC (**Fig. 13:c**). After this period, the combined proportions of the two blade reduction strategies markedly diminished. The percentage of irregular cores shows an inverse pattern as compared with the conical cores (**Fig. 13:b**). This is mirrored in the central Russian Mesolithic Butovo complex sites, for which Koltsov and Zhilin demonstrated that the frequency of flakes increased from the middle boreal period onwards towards the end of the Mesolithic (Koltsov & Zhilin 1999b:135). Beyond the general pattern, the conical and irregular cores also show marked variation in core frequency in the Early Mesolithic. The figures may also indicate that frequency shifts grew less common through time (**Figs. 13:a, b**).

Discussion

The results show that lithic core assemblage size and composition are systematically related in Mesolithic north-eastern Europe. Small site assemblages have a high proportion of conical cores, and large assemblages have a high proportion of irregular cores. Site use intensity and core to bone ratios also correlate with the lithic core assemblage composition. These indicate that these hunter-gatherers intentionally varied their core technologies. We suggest that the hunter-gatherers employed different core reduction strategies as a response to the constraints that mobile life placed on technologies. Furthermore, the variation in intra-site data, housing, and lithic provisioning strategies at Sujala and Veretye I agrees well with the lithic core and faunal data. Thus, increasing mobility, decreasing occupation length, the provisioning of individuals, the increasing use of conical core reduction, and assemblage size are all related to each other. There is also a correlation between conical and irregular core technology and the proportion of large land mammals in the refuse fauna, although the effects of sampling complicate the interpretation of these patterns. Interestingly, narrow-face cores have little correlation with assemblage size or faunal indicators at the studied sites, but show a clear temporal trend.

The conical core reduction strategy employed in Mesolithic north-eastern Europe was a core technology suitable for ensuring tool stone availability and minimising weight and raw material consumption, while at the same time providing blanks for different needs from a single core. In this sense, the technology parallels the New World Late Pleistocene Clovis and Folsom bifacial core and tool technologies, which have been linked with the constraints posed by high-mobility regimes (Kelly 1988; Kelly & Todd 1988).

We suspect that the conical blade reduction strategy may have had a selective advantage over other reduction strategies, and that this was especially significant in the Early Mesolithic context. According to Koltsov and Zhilin, blade production in the central Russian Mesolithic Butovo complex was the most elaborate during its second stage, i.e., the Late Preboreal–Early Boreal, (Koltsov & Zhilin 1999b:135). This period corresponds to the time of the post-glacial human expansion northwards (e.g., into Finland) and may imply a link between high mobility, lithic technological organisation, and the colonisation of uninhabited lands. In a similar fashion, the increasing reliance on narrow-face blade cores after 8600 calBC coincides with the time period during which the colonisation reached the northern parts of Finland. This suggests that core technologies were related to forager niche and habitat selection. Filling up the available habitats in northern Europe gradually made it optimal to increase diet breadth and restricted the options for high mobility. This suggests a gradual relaxation of the need to maintain an efficient multi-purpose conical core technology. The other side of the coin, i.e., the growing popularity of the irregular core reduction strategy through the Mesolithic, parallels the large-scale pattern in North America, where the emphasis on informal core strategies was demonstrated to grow with diminishing mobility (Parry & Kelly 1987).

Hunter-gatherer mobility strategies can change markedly even during a single year, for example from one season to another. The emphasis on different core reduction strategies can therefore vary widely in a short time. In the winter, frozen ground and snow cover pose problems for raw material procurement. This implies that the core technology of mobile foragers, who cannot provision sites or collect raw material freely from snow-covered ground, tends towards raw material conservation and efficient core technology. The availability of transportation technology, however, is expected to diminish the constraints that mobility places on technologies (Binford 1990; Shott 1986:32). Transportation technology makes it possible to have extra tool stone on hand in times of need and therefore decreases the effect of mobility. In north-eastern Europe, osteological data show that Early Mesolithic hunter-gatherers mainly targeted terrestrial species, and that aquatic resources were of less importance (e.g., Koltsov & Zhilin 1999b; Lõugas 1997; Ukkonen 2001). The use of terrestrial resources implies a constant need to traverse dry land areas. Sledge runners preserved in bogs are known from the Early Mesolithic onwards and imply that sledges were used for transportation in the winter time (Aario 1934; 1935; Seger 1988:21; 1990:16). Dog bones further suggest that these animals may have been used as beasts of burden (Oshibkina 1997; Seger 1988:23; Schulz 1996:25; Ukkonen 2001). Summing up, we suggest that the north-east European Mesolithic, and especially the Early Mesolithic, archaeology makes an interesting case for future research on hunter-gatherer mobility and the organisation of technology. In this high-latitude area, the constraints that high mobility and winter conditions place on core technology act against transportation technology and its alleviating effect. These vectors, pulling in different directions, suggest a system that is not stable but is instead liable to change radically even with a small change in the underlying parameters. We suspect that this may explain the high variability observed in the core frequencies (seen in **Figures 13:abc**) in the Early Mesolithic.

In north-eastern Europe, the importance of aquatic resources increased during and after the Mesolithic (e.g., Kriiska 2001; Ukkonen 2001). This suggests that the transportation technology was simultaneously reorganised and that watercraft became increasingly important in hunter-gatherer adaptations at this time. As an increasing use of aquatic resources typically suggests diminishing residential mobility (Binford 2001, Kelly 1995), the increasing use of water transportation technology and reduced mobility parallel each other and act together to relax the constraints that mobility places on technologies. We further suggest that the use of advanced watercraft levelled any difference in the transportation costs between seasons. As a consequence, the variation of core frequencies is smaller in the Late Mesolithic, and, especially, in the Sub-Neolithic assemblages, in comparison with the Early Mesolithic assemblages. This kind of a trend may be seen in **Figures 13:a & b**, which show a high degree of variation in the percentages for the Early Mesolithic and lower variation in the Late Mesolithic, although data for the Late Mesolithic are currently scarce. Furthermore, coastal and inland areas show different changes in the foraging strategies (Koltsov & Zhilin 1999b; Lõugas 1997; Oshibkina 1997; Ukkonen 2001), which suggests that the core reduction strategies had different evolutionary trajectories from area to area. Hunter-gatherers allocating time to aquatic foraging had less constraints on core technology than inland hunters with a larger proportion of terrestrial resources in their diet. Therefore, we predict that inland foragers in the area were more efficient in their use of raw material. When tool stone availability is considered, this analysis also suggests that there was a change in the constraining factors with time. The importance of the availability of natural raw material and its effect on technological organisation is expected to grow in contrast to the constraints caused by mobility and the need to provision individuals. These predictions can be tested in future analyses.

The systematic production of symmetrical blades from conical blade cores requires more personal practice and skill than the detachment of flakes from irregular cores. Our results imply that the relatively higher investment in learning conical core blade production, possibly in childhood, was compensated for later in life by efficient core technology. Those who had technologies that allowed frequent camp moves for locating and consuming high-return-rate food patches had a selective advantage over others. Conical core technology provided one such advantage. We therefore suspect that when the symmetrical conical core reduction strategy came into use, it was adopted quickly by many hunter-gatherers in the area. This is supported by the archaeological distribution of conical core technology, which implies a convergent evolution among many hunter-gatherer groups. Similar core reduction strategies are found over a large area, from Central Russia to the Barents Sea and from the Baltic Sea to the Ural Mountains and beyond (e.g., Burov 1999b; Koltsov 1989; Koltsov & Zhilin 1999b; Kosinskaya 1997; Rankama & Kankaanpää 2008). The vast size of the area suggests that many groups adopted the technology. Our analyses imply that the adoption was due to the selective advantage of the technology. Inside this area, core reduction strategies may therefore have little value for archaeologists for analysing and distinguishing ethnic groups in time or space, but they can be fruitful from a systems perspective, as illustrated above. In other areas, such as North America and western Europe, different trajectories in cultural evolution caused selection to operate on a different set of behavioural variants in the Late Pleistocene and Early Holocene context.

Conclusion

Our results show that north-east European Mesolithic core technology is a fruitful subject for the study of technological organisation. The analyses suggest that core technologies are correlated with assemblage size and the faunal record. This implies a systemic link between different areas of hunter-gatherer life, in this case foraging, mobility and core technology. The symmetrical conical blade core reduction strategy was a technology adjusted to the constraints of mobile life. Irregular flake core and narrow-face blade core strategies were employed in different settings and were practised when there was less need to maximise the number and diversity of blanks from a single core.

For future research, it can be summarised that we expect the conical core technology, exemplified at Sujala, to be correlated with indicators of high residential mobility in the studied area in north-eastern Europe. Additionally, a diversification of blade and other core technologies can be expected when residential mobility decreases and the need for a multi-purpose conical core strategy diminishes. We have further suggested that the frequency shifts in the application of a core strategy diminish with time. If the conical core strategy was selectively advantageous in colonisation settings, we also expect to see a high frequency of symmetrical conical core technology correlated with dispersal towards the north. As new sites and new data become available, these suggestions can be tested further.

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