Title:

Use-wear analysis of Early Mesolithic flake axes from South-eastern Norway.

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Abstract:

The flake axe is one of the most debated stone tools of the Scandinavian Mesolithic. Few analysis have however been carried out in order to investigate the actual function and use of the tool. In this paper we present the results from use-wear analysis of 42 flake axes from nine Early Mesolithic sites (9200-8400 cal. BC) from South-eastern Norway. This study demonstrates that the flake axe was a multi-tool used for several tasks and for working different raw materials. The results from the use-wear analysis are related to morphological variation among the analysed specimens. This suggests that there is no clear cut relation between morphological variation and function.

Highlights:

- New insight into use of Early Mesolithic flake axes from Scandinavia.
- Use-wear analysis proposes several functions for Early Mesolithic flake axes.
- There are no significant differences between morphological variation and use/function.

Key words:

Use-wear; flake axe; Early Mesolithic; South-eastern Norway

USE-WEAR ANALYSIS OF EARLY MESOLITHIC FLAKE AXES FROM SOUTH-EASTERN NORWAY.

1. INTRODUCTION

1.1 Background and aims

The flake axe is one of the most debated stone tools of the Scandinavian Mesolithic. During the last 130 years, the function of the tool has been widely discussed and numerous suggestions to its use and function have been made (table 1). Today, the most agreed-upon hypothesis is that the flake axe primarily was used for butchering and scraping the skin and blubber of sea mammals (e.g. Schmitt, 2013; Bang-Andersen, 2013). In a recent paper, however, Glørstad (2013) suggests that the flake axe was related to the Early Mesolithic groups' marine adaptation and, more specifically, to make log boats. Glørstad's main argument is the close relationship between the distribution of flake axes in Norway and Sweden and the Preboreal coastlines (figure 1). This theory is criticised, as several researchers consider the axes as unfit for woodworking (Bang-Andersen, 2013: 26; Wikell and Petterson, 2013: 40–41; Schmitt et al., 2009).

Even though the use of Mesolithic flake axes has been heavily debated, detailed analyses of the use and functionality of the tool type has been few. Numerous papers discuss what the axes were used for and, maybe even more eagerly, what they not were used for. To our knowledge, only three use-wear analysis of flake axes from the Scandinavian Mesolithic, that can provide insight to the tool's function in greater detail, have been carried out (Juel Jensen, 1988; Thorsberg, 1985; Knutsson 1982).Thus, most of the presented evidence is circumstantial relying on factors such as geographic distribution and analogies to modern and ethnographic tools, or a combination of the two (Schmitt et al. 2009: 14; Fuglestvedt, 2012; Bang-Andersen, 2003: 13).

Within this background we have carried out use-wear analysis of 42 Early Mesolithic flake axes from South-eastern Norway. Here we present results from the use-wear analysis combined with results from technological and morphological investigations including raw material studies. The main aims are to 1) identify use-wear on Early Mesolithic flake axes, 2) analyse what contact material that caused use-wear, 3) investigate if use-wear traces related to different activities could be identified on the same tool, and 4) investigate if different use and function could be related to morphological differences.

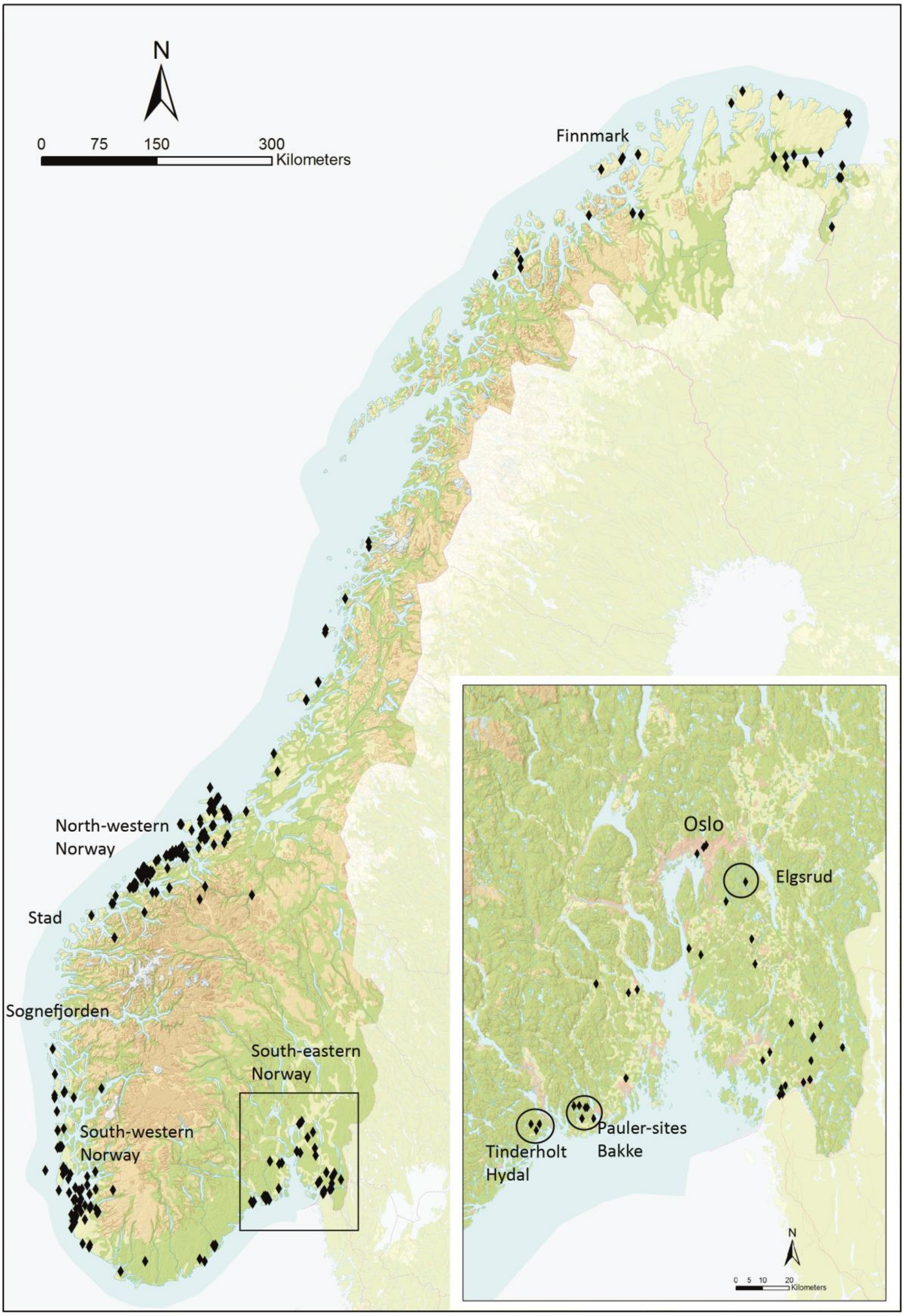

Figure 1: Distribution of flake axes in Norway. The map to the right show distribution of flake axes in South-eastern Norway as well as the location of the analysed sites and place names mentioned in the test. All data retrieved from Unimus.no (6. April 2017). Figure: Steinar Solheim

Author	Interpretation
Sophus Müller (1888)	Cleaver
Knut Kjelmark (1903)	Adze
Otto Rydbeck (1916)	Chopper/axe
Terkel Mathiassen (1937, 1948)	Axe (Knife, scraper)
Jens Troels-Smith (1937)	Woodworking tool, chopper/axe
Åke Fredsjö (1953)	Shellfish knife
Helena Knutsson (1982)	Scraper, knife, wood, raw hide
Helle Juel-Jensen (1988)	Butchering tool
Kalle Thorsberg (1985)	Scraping (hide), wood working
Hans Kindgren (1995)	Scrapers (hide)
Sveinung Bang-Andersen (2003)	Ulus/skin scraper, marine resources
Ingrid Fuglestvedt (2012)	Clubs/hatchets, reindeer
John A. Havstein (2012)	Ulus/skin scraper /butchering tool, marine resources
Lou Schmitt (2013), Schmitt et al. (2009)	Ulus/skin scraper, marine resources
Håkon Glørstad (2013)	Woodworking tool, log boats

Table 1: During the last 130 years researchers have suggested various functions for the flake axe. Some of the most central works are referred to in the table. In the last decade the interpretation of the flake axe as an ulu has gained increasing popularity.

2. MATERIALS AND METHODS

2.1 Definition, chronology and distribution of flake axes

In Norway and Western Sweden the flake axe is dated to the Early Mesolithic period, c. 9400 – 8300 cal. BC, and is considered a chronological marker (Bjerck, 2016; Schmitt, 2015). The tool type is an integrated element of the Early Mesolithic groups' tool kit and is regularly found at sites dated to the period (Bjerck, 2016; Åstveit, 2014; Waraas, 2001).

The flake axe is one of few formal macro tools of the Early Mesolithic in Norway, and several efforts have been made to provide a standardised definition of the tool. Attempts have also been made to divide the tool into subcategories based on differences in shape, symmetry, trimming, edge angles, production concepts etc. These variances have traditionally been linked to chronological differences (Troels-Smith, 1937, 1939; Lidén, 1938; Fredsjö, 1953; Althin, 1954; Brinch Petersen, 1966; Andersson et al., 1975). There is a general agreement that a flake axe is made of a large flake or disc, and that some of the flake or disc's original ventral surface must be part of the axe's working edge. The working edge may be modified and re-sharpened by detaching the worn-out edge with a blow to its side (Andersson et al., 1975: 16; Bjerck, 1983: 17). Flake axes in general display large morphological variation related to differences in tool blank size and form (raw material availability), and also to later modifications of the tool (edge rejuvenation) (Eymundsson et al. 2017).

Despite morphological variation and a pragmatic adaptation to blank size and shape, the flake axe production concept (*schéma opératoire*) is surprisingly stringent. Generally, a flake axe is produced and shaped by applying two techniques: side edge flaking and thinning. The lateral sides of the axe are shaped by removing diagnostic side edge flakes either from the dorsal side or the original ventral surface side, of which the latter is less common. To reduce the thickness, the dorsal side is often modified by the removal of thinning flakes. This production concept usually results in an axe with a trapezoid cross section (figure 2).

Figure 2: A selection of analysed flake axes from Early Mesolithic sites at Pauler, Vestfold County, South-eastern Norway. Photo: Kirsten Helgeland/Museum of Cultural History.

Most flake axes are found at sites in the coastal region (cf. figure 1). They are distributed from Østfold County in southeast, along the southern coast to western Norway, up along the northwestern coast and all the way north to Finnmark (Breivik and Callanan, 2016: 12; Granados, 2011: 68, 75; Bjerck, 1995). North-western Norway, South-western Norway and the Oslo fjord region represents the main concentration areas both in sheer numbers but also regarding number of sites containing flake axes. In some parts of coastal Norway, such as the c. 120 km long stretch from Sognefjorden to Stad, no axes have been found. The lack of axes in this specific area can partially be explained by the rising sea level during the Holocene and that the Early Mesolithic sites are buried under beach sediments (Bjerck, 1986: 105–107; 1994: 46).

2.2 Archaeological data

2.2.1 Axes and sites

A total of 42 axes and edge flakes were chosen for analysis. The flake axes and edge flakes that are included originate from nine excavated sites in South-eastern Norway, dated between 9200 and 8400 cal. BC (table 2). Eight sites are situated in Telemark and Vestfold Counties and one in Oslo.

#	Site	Cal. BC	Type	Lenght axe	Width axe	Thickness axe	Lenght edge	Shape edge, profile	Shape edge, front	Flint type
1	**Pauler 1**	**9200-8900**	**Flake axe**	**67,9**	**69,5**	**17,1**	**69,3**	**Asymetrical**	**Straight**	**Coarse**
2	**Pauler 1**	**9200-8900**	**Flake axe**	**67,6**	**63,6**	**21,4**	**58,5**	**Symetrical-asymetrical**	**Convex**	**Medium**
3	Pauler 1	9200-8900	Flake axe	72,9	45,6	24,1	42,8	Asymetrical, w. concave edge	Irregular	Coarse
4	Pauler 1	9200-8900	Edge corner						-	
5	**Pauler 1**	**9200-8900**	**Flake axe**	**46,0**	**42,7**	**17,6**	**39,3**	**Asymetrical**	**Protruding mid part**	**Medium-fine**
6	**Pauler 1**	**9200-8900**	**Flake axe**	**45,0**	**29,7**	**10,8**	**29,3**	**Symetrical-asymetrical**	**Convex**	**Fine**
7	**Pauler 1**	**9200-8900**	**Edge flake**	**12,2**	**32,6**	**4,3**	**31,8**	**Asymetrical**	**Weak convex**	**Medium**
8	**Pauler 1**	**9200-8900**	**Edge flake**	**22,5**	**44,0**	**5,0**	**41,9**	**Asymetrical?**	**Straight/weak convex**	**Medium**
9	Pauler 1	9200-8900	Edge flake	13,1	45,7	6,9	41,1	Asymetrical	Convex	Medium
10	Pauler 2	9150-8850	Flake axe	52,3	37,5	19,9	29,9	Asymetrical	Weak convex	Fine
11	Pauler 3	9000-8700	Flake axe	53,9	51,4	17,5	47,5	Asymetrical	Olique	Medium
12	**Pauler 3**	**9000-8700**	**Flake axe**	**49,3**	**32,4**	**14,7**	**29,4**	**Symetrical-asymetrical**	**Weak convex**	**Fine**
13	Pauler 3	9000-8700	Flake axe	42,3	32,4	15,1	20,5	Asymetrical	Weak convex	Fine
14	Pauler 3	9000-8700	Flake axe	55,4	36,9	15,5	33,2	Symetrical	Weak convex	Medium
15	**Pauler 3**	**9000-8700**	**Flake axe**	**48,0**	**39,1**	**16,2**	**36,5**	**Asymetrical**	**Oblique convex**	**Medium**
16	**Pauler 3**	**9000-8700**	**Flake axe**	**45,6**	**40,4**	**13,6**	**39,3**	**Asymetrical**	**Straight, rounded corners**	**Medium**
17	**Pauler 3**	**9000-8700**	**Flake axe**	**49,4**	**51,2**	**14,0**	**51,9**	**Asymetrical**	**Weak convex**	**Fine**
18	Pauler 3	9000-8700	Flake chisel	61,9	25,3	18,5	25,3	Asymetrical	Rounded V-shape	fine
19	Pauler 3	9000-8700	Flake chisel	43,2	24,1	11,4	19,7	Asymetrical, w. concave edge	Straight	Fine

20	Pauler 3	9000-8700	Flake chisel	43,5	24,3	14,2	17,0	Asymetrical	Straight/weak angular	Fine
21	**Pauler 4**	**8950-8650**	**Flake axe**	**50,4**	**45,6**	**17,8**	**45,6**	**Asymetrical**	**Weakly rippled**	**Fine**
22	Pauler 4	8950-8650	Flake axe	58,4	42,1	24,3	40,5	Asymetrical	S-shape	Fine
23	Pauler 4	8950-8650	Flake axe	42,9	37,5	17,8	34,8	Asymetrical	Straight	Fine
24	Pauler 4	8950-8650	Flake axe	57,5	49,5	18,6	37,5	Asymetrical	Weak convex	Medium
25	Pauler 4	8950-8650	Fragment						-	Medium
26	Pauler 4	8950-8650	edge flake						-	Medium
27	Pauler 4	8950-8650	Flake axe	58,3	44,7	20,8	43,8	Asymetrical	Weak convex	Medium
28	Pauler 4	8950-8650	Flake axe	54,3	39,8	16,6	37,6	Asymetrical	Convex	Medium
29	**Pauler 6**	**8850-8550**	**Flake chisel**	**81,0**	**30,2**	**16,1**	**10,8**	**Asymetrical**	**Narrow convex**	**Medium**
30	Bakke	8850-8550	Flake axe	51,9	28,8	16,4	21,7	Concave edge	Weak concave	Medium
31	Bakke	8850-8550	Flake axe	53,2	29,1	21,2	19,3	Asymetrical	Straight	Medium
32	Bakke	8850-8550	Flake axe	40,2	24,8	11,8	17,3	Asymetrical	Straight- weak concave	Medium
33	**Bakke**	**8850-8550**	**Flake axe**	**48,8**	**33,1**	**16,2**	**27,7**	**Asymetrical**	**Straight, weak S-shape**	**Fine**
34	Bakke	8850-8550	Flake axe	44,6	30,0	15,3	29,4	Asymetrical	Straight	Medium
35	**Bakke**	**8850-8550**	**Flake axe/chisel**	**54,5**	**29,2**	**14,2**	**12,9**	**Asymetrical**	**Straight, uneven, two-edged?**	**Coarse**
36	**Bakke**	**8850-8550**	**Flake axe/chisel**	**47,0**	**24,5**	**13,7**	**11,9**	**Asymetrical**	**Straight, uneven, two-edged?**	**Fine**
37	Bakke	8850-8550	Flake axe/chisel	52,9	23,4	11,3	12,3	Asymetrical	Straight, uneven, two-edged?	Fine
38	**Bakke**	**8850-8550**	**Flake axe/chisel**	**79,7**	**36,1**	**25,0**	**21,4**	**Asymetrical**	**Straight, uneven, two-edged?**	**Medium**
39	Elgsrud	8950-8700	Edge flake	29,7	46,8	10,2	44,1	asymetrical, w. concave edge	Straight, weak S-shape, asymetric?	Medium
40	**Tinderholt 1**	**8600-8300**	**Flake axe**	**51,6**	**44,5**	**19,3**	**39,7**	**Asymetrical**	**Weak convex**	**Fine-medium**
41	**Tinderholt 1**	**8600-8300**	**Flake axe**							
42	**Hydal 4**	**8400-8200**	**Flake axe**	**58,6**	**45,9**	**15,0**	**31,6**	**Asymetrical**	**Straight**	**Medium**

Table 2: The axes that were chosen for analysis. Specimens in bold have use-wear traces. All measurements are given in mm. Figure: Steinar Solheim

2.2.2 Technology, morphology, raw materials

Some researchers have suggested that the flake axes display morphological changes over time, with more extensive flaking and thinning as well as the introduction of so-called flake chisels at sites younger than 9000 cal. BC. Also, the length of the flake axe's working edge appears to decrease towards the end of the Early Mesolithic (Nyland and Amundsen, 2012: 152, 157; Jaksland and Fossum, 2014). This trend has also been noticed on axes from the latest part of the Early Mesolithic in southern Scandinavia (Johansson, 1998: 114). The differences in working edge length could indicate functional differences between axes dated to the beginning of Early Mesolithic and axes from the latter part of the period (Jaksland and Fossum, 2014).

The axes analysed in this study are found at sites dated within an 800-year time span, covering large parts of the Early Mesolithic period. The morphology of the analysed axes varies, but is in accordance with the above-mentioned definition of a flake axe. The majority of the axes are made of larger flakes, which vary in length and in thickness. Eight axes have an unmodified original ventral surface, and the lateral sides are shaped from the ventral side. The lateral sides of the remaining axes were shaped from the dorsal side. The majority of axes are thinned by flaking, but the extent of flaking varies. Some display a more extensive thinning and may resemble core axes. This applies especially to the narrow-edged axes, termed flake chisels. Most of these axes are from sites dated to the latter part of the Early Mesolithic, and are in line with the chronological tendencies as described above. Evidently, the tool blank size and shape have guided the shaping of the axes, and this shows the flexibility of the flake axe production concept. Even though it appears to be chronological differences with regard to the extent of thinning, the production concept is rather persistent. We interpret the noted morphological differences as related to raw material availability but this should be further explored by analysing a larger data set.

Different flint types have been used for axe production, and the types are divided into subgroups based on the flint's grain size: Fine (translucent), fine (matte), medium, and coarse. Fine-grained translucent flint and medium-grained flint are most common and make up 38 % and 44 %, respectively. Few axes are made of coarse flint (13 %) and matte fine-grained flint (6 %). The variation in raw material composition applies to the earliest Early Mesolithic sites as well as to sites from the latter part of the period (table 2). Many axes have eroded cortex on the dorsal side, indicating that the blanks were detached from (small) beach nodules.

The working edge is the most essential part of the tool, and establishing a functional edge appears to be more significant than where it was placed on the original blank. Most axes have an unsymmetrical working edge (88 %), and the edge is strait (42 %) or convex (36 %). The angle measurements of the working edge have a largest and a smallest value, and the difference between these two values varies. This suggests that the axes were not produced in order to establish and maintain a uniform working edge. The working edge length varies between 10.8 to 69.3 mm, and variation is apparent within axe assemblages from the different sites. Flake chisels are identified at three sites. These have a particular narrow edge, and the edge length is often less than the actual width of the tool's body.

2.3 Use-wear analysis

Helena Knutsson conducted the use-wear analysis. All microscopic analysis for the present study was carried out with a Nikon Epiphot incident light microscope, using mainly magnifications of 50× and 400×. The wear features were documented using a microscope camera (Nikon Ds-U2) and related software (NIS-Elements D 3.0). This allows for a sequence of digital photographs taken at different heights to be combined into one extended focus micrograph. When multiple use-wear traces were identified a stereomicroscope of type Nikon SMZ 800 Nikon with 10x and 69x enlargement was used.

All axes passed through standard cleaning routines. The specimens were first kept in weak (1–3%) HCl-solution for 24 hours. Furthermore, they were rinsed with tap water and put into an ultrasonic bath in distilled water for 2 minutes. The purpose of the acid treatment and ultrasonic bath is to remove microscopic particles of sediment that have adhered to the tool surface while buried in the soil. Next the artefacts were kept in weak NaOH-solution for 5 minutes in order to remove grease and other traces of handling that usually cover the artefact surfaces. This phase was completed with a 2 minutes' ultrasonic bath. The specimens were air-dried after cleaning. If needed, handling grease was removed from the axes with acetone or ultrasonic bath during the analysis.

Use-wear analysis is the study of damages and traces that are (microscopically) visible on a tool and which are developed when the tool is used. The characteristics of the traces vary depending on the contact material that is worked and the direction in which the tool is used (Vaughan, 1985). The interpretation of use-wear on prehistoric tools rests on different parameters built on documented damages and use-wear traces from experiments with replicated tools. The experimental work carried out by Kjel Knutsson (1988) has demonstrated that wear visible on tool edges is the result of use and that the characteristics of the different microscopic traces vary systematically according to use situations (Knutsson et al., 2015: 518). Combinations of use-wear features seem to be related to how the tool was used, but more importantly the different characteristics of the contact materials and the material created between the tool surface and the contact material (Knutsson et al., 2015: 518–519; cf. Knutsson, 1988). Here we have considered and documented the direction, location and distribution of damages on the axes' edge, butt and sides. The morphology of the damages and their depth at the edges, indicate the angle the tool was held against the worked surface, the work direction and the resistance of the contact material (Knutsson et al., 2015: Knutsson, 1988).

The analysis was carried out in order to investigate 1) if use-wear could be identified on Early Mesolithic flake axes, 2) what contact material caused use-wear, and 3) whether use-wear on the same tool can be related to one or several activities and contact materials.

3. RESULTS AND INTERPRETATION

3.1 Use-wear

Of the 42 analysed flake axes, 13 of the chosen specimens could not be analysed due to damages to the edge and the lack of use-wear. 10 specimens are either considered to be unused or that visible use-wear is caused by post depositional factor. A total of 19 specimens have use-wear traces that is interpreted as caused by use in prehistory and these axes display variation in use direction and working of different contact materials.

3.1.1 Direction of use and function

The direction of the use-wear indicates in what direction the tools were used. The direction of use is easier to document and interpret than what type of contact material that caused use-wear on a tool. The use-wear is, in most cases, a general alteration of the tool surface, or distinct striations in the tool surface.

The dominant direction of tool use and/or tool movement is measured as the angle related to the working edge and divided into three categories: 1) parallel to the edge (0–30°); 2) diagonal to the edge (45–60°); and 3) transverse to the edge (80–100°). The three categories correspond to following use: 1) cutting and sawing; 2) scraping, whittling, and chopping; 3) planing and use as adze. The placing of the use-wear on the edge is also significant for the interpretation of the use-wear, and use-wear on one side and/or both sides of the edge counts for differences in use.

The direction of use as defined by angle also affects the interpretation of function. We have used modern tool names as analogy to describe function. Tools with linear damages transverse to the edge are interpreted as adzes or planers. Adzes are identified by a combination of macroscopic and microscopic damages that are more intensive on one side of the edge and continuing onto the axe body. Planers have use-wear traces primarily on one side, most visible close the edge. Scrapers have use-wear traces around the edge, often more intensively on one side and usually away from the axe body. Axes have use-wear traces on both sides of the edge and onto the axe body. The damages are often seen behind the edge.

Re-sharpening of flake axes is often identified, and was made with a blow from one side of the edge, normally removing the whole working edge. The angle of the edge changed and use-wear traces are thus removed. This might, in some cases, explain to lack of use-wear traces on the analysed tools.

If one expected that the flake axe was a specialised tool, a rather homogenous picture of use-wear should emerge from the analyses. This is not the case, and a total of 41 different use-wear traces are documented on 19 different axes, implying that several axes have had different functions. The majority (71 %) of the recorded use-wear is one sided, while 29 % is two sided (table 3). Most one sided wear is interpreted as caused by planing (41 %) or scraping (17 %). Among the two sided wear, sawing (10 %) is most frequent, while one axe have indications of being used for chopping, i.e. as an actual axe (2 %).

The analysis shows variation in working movement with planing, scraping and sawing as the main types of movement. The single trace of chopping indicates that this was not the flake axes' primary function. In sum, the direction of use indicates that the flake axe was used in a variety of ways.

Site		One sided damages				Two sided damages					
Category	Unused	3	2	2	3	2	1	1	1		
Movement	Unused	Planing	Scraping	Whittling	Planing	Chopping	Sawing	Cutting	Grooving	Shafting	Sum
Suggested tool		Plane	Scraper	Whittle	Adze	Axe	Saw	Knife	Burin		
Pauler 1	1	6	2	2	2				1	1	15
Pauler 2	1										1
Pauler 3	5	3	2			1	2				13
Pauler 4	2	1					1	1			5
Pauler 6		1	1							1	3
Bakke	1	3	2				1	1		2	10
Elgsrud	1										1
Tinderholt 1		2		1							3
Hydal 4		1									1
Sum	11	17	7	3	2	1	4	2	1	4	52

Table 3: The different directions of documented use-wear and suggested function and tool. See chapter 3.1.1 in main text for categories. Figure: Steinar Solheim

3.1.2 Contact material

The interpretation of contact material is here based primarily on comparisons with use-wear traces on replicated tools (cf. Knutsson, 1982). The experimental procedures have, however, a disadvantage of not being similar to the prehistoric use. This problem has been addressed, and the assumed uses of tools have been broken down to single experimental procedures, in order to be able to classify different traces and keep reliable comparative samples (Knutsson, 1988). For several reasons the identification of worked materials has been a problematic issue in traceology. The method is criticised for not being sufficiently precise to interpret the contact material (see discussion in Taipale, 2012; Stevens et al., 2010: 2671; Odell, 2003: 138). Traces from working different raw materials can be hard to identify, and different factors and processes affects traces of use-wear on the tools. Blind tests focusing on definition and interpretation of use-wear on experimental tools have however been carried out with good results (e.g. Bamforth et al., 1990; Bamforth, 1988; cf. Evans; 2014).

Postdepositional alteration of the use-wear is also an important factor. These issues have previously been addressed (see Taipale's (2012) summary of the field; further Stevens et al., 2010; Burroni et al., 2002; Levi-Sala, 1996; Plisson and Mauger, 1988; Knutsson, 1988). Quantitative discrimination of use-wear traces have also been subject of method development (e.g. Stevens et al., 2010; Gonzales-Urquijo and Ibánez-Estevéz, 2002; Derndarsky and Ocklind, 2001; Knutsson et al., 1988) as well as the effect of the raw material type on the development of use-wear (e.g. Lerner et al., 2007).

Based on experimental works with quartz Knutsson (1988) and Knutsson et al. (2015) have, with reference to research in material science and the concept of tribology, shown how different contact materials cause different use-wear features. The tribology in documentation and interpretation provides possibility to explain and predict different types of wear features related to the contact material and physical circumstances during contact, thus, not just describing their effects. We now know that use-wear is the result of both mechanical and chemical processes. Even though experiments with replicated tools may differ from actual prehistoric use, it is a valid method for testing different variables (Rots and Plisson, 2014: 154; Van Gijn, 2014: 168).

#	**Site**	**Direction 1**	**Material 1**	**Direction 2**	**Material 2**	**Direction 3**	**Material 3**	**Hafting**	**Material 1**	**Material 2**
1	Pauler 1	Plane	Wood	Whittle	Wood	Adze	Wood			
2	Pauler 1	Plane	Antler/bone	Plane	Antler					
5	Pauler 1	Plane	Wood	Whittle	Wood	Adze	Wood			
6	Pauler 1	Burin	Antler/bone	Plane	Wood					
7	Pauler 1	Scraper	Hide							
8	Pauler 1	Plane	Antler/bone	Scraper	Meat					
9	Pauler 1	0								
10	Pauler 2	0								
11	Pauler 3	0								
12	Pauler 3	Saw	Wood	Saw	Antler?					
14	Pauler 3	0								
15	Pauler 3	Plane	Wood	Scraper	Wood					
16	Pauler 3	Plane	?	Scraper	?					
17	Pauler 3	Plane	Antler/bone	Axe	Antler/bone					
18	Pauler 3	0								
19	Pauler 3	0								
20	Pauler 3	0								
21	Pauler 4	Plane	Wood	Saw	Wood	Knife	Plant			
27	Pauler 4	0								
28	Pauler 4	0								
29	Pauler 6	Plane	Wood	Scraper	Wood			Shaft	Wood	Antler/bone
33	Bakke	Plane	Wood	Scraper	Wood			Shaft	Wood	Antler/bone
34	Bakke	0								
35	Bakke	Knife	Wood	Saw	Wood					
36	Bakke	Plane	Wood	Scraper	Wood			Shaft	Wood	Hide

38	Bakke	Plane	Hard							
39	Elgsrud	0								
40	Tinderholt 1	Plane	Wood	Whittle	Wood					
41	Tinderholt 1	Plane	Wood							
42	Hydal 4	Plane	Wood							

Table 4: Summary of use-wear directions and contact materials identified on the axes. Figure: Steinar Solheim

The results from the use-wear analysis show that the flake axes were used to work several different raw materials (table 4, table 5). A total of 37 different use-wear traces related to different contact material were documented. For several specimens we have identified different use-wear as well as working directions, which underlines the variation in the tool's functionality. The most common contact material is wood (67 %), most likely both dry and fresh wood. Some use-wear can be interpreted as resulting from working either wood or hide, of which woodworking is the most likely due to placing on the edge, work intensity and linear striations (figure 3). We have also been able to document the use of flake axes for working antler or bone (14 %) as well as plants. Use-wear polish on surfaces indicates the use of flake axes for working soft, animal products such as meat, tendons and raw and worked hide (figure 4).

Site	Wood		Antler/Bone		Hard material		Plants		Hide		Meat		Undefined		Sum
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	
Pauler 1	8	22	3	8					1	3	1	3			13
Pauler 2															0
Pauler 3	3	8	2	6									3	8	8
Pauler 4	2	6					1	3							3
Pauler 6	2	6													2
Bakke	6	17			1	3									7
Elgsrud															0
Tinderholt 1	2	6													2
Hydal 4	1	3													1
Total	24	67	5	14	1	3	1	3	1	3	1	3	3	8	36

Table 5: Overview of types of contact material in the data set. Figure: Steinar Solheim

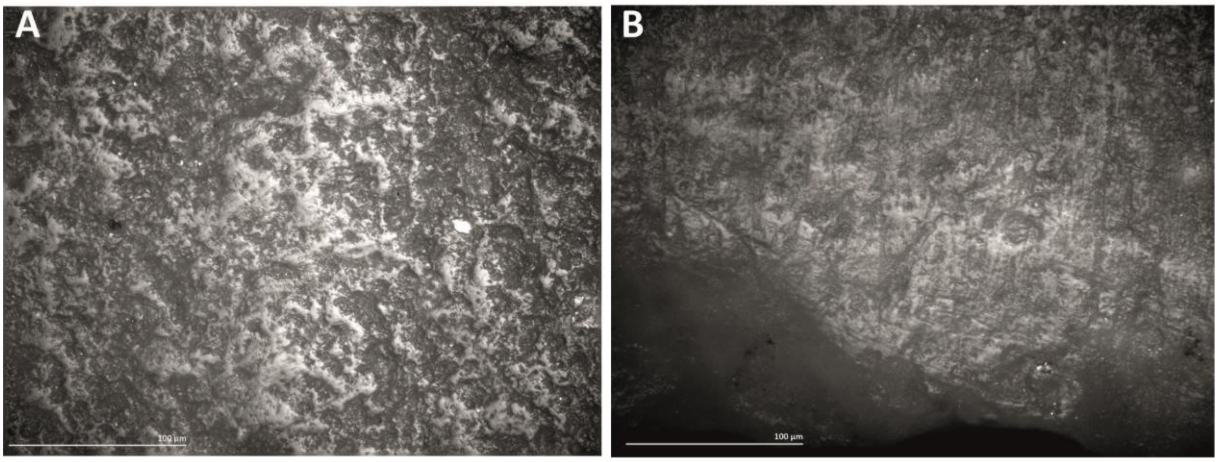

Figure 3: A: Microscope photo of axe # 5 from Pauler 1 showing use-wear from planning of wood. B: Microscope photo of axe # 33 from Bakke showing contact with wood or hide/leather. This illustrates some of the difficulties with distinguishing different contact material. Photo: Helena Knutsson.

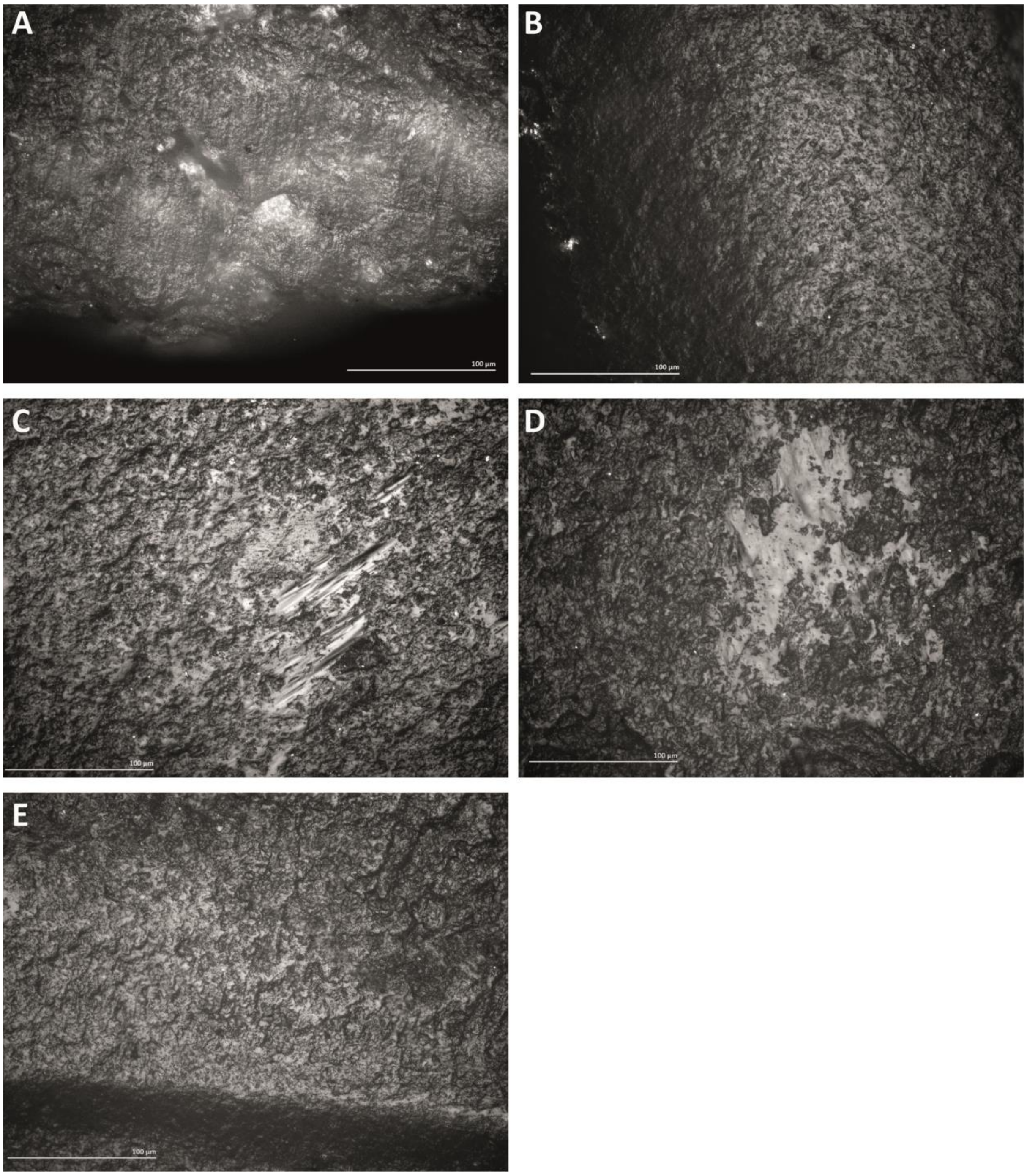

Figure 4: A selection of axes with different use-wear. a) Scraping of dry hide (axe # 7, Pauler 1); b) Raw hide/wet hide (axe #36, Bakke); c) Antler (axe #12, Pauler 3); d) Antler (axe # 17, Pauler 3); e) Intensive contact with fresh wood or plant material (axe # 21, Pauler 4). Photo: Helena Knutsson.

3.1.3 Technology and morphology

The analysed axes vary in size and shape, and there is no clear connection between tool form and function. Neither is there any significant relation between the attributes of the axes working edge (angle, form and length) and type of use (figure 5).

Based on working edge shape and length, the analysed axes form two groups: flake axes and flake-chisels. Jaksland and Fossum (2014) suggest that the differences in working edge length imply functional differences between the two groups. However, results from the use-wear analysis indicate no distinct functional differences between the flake axes and the narrow-edged flake-chisels analysed in this study. Similar, experiments carried out by H. Knutsson in 1982 showed that the tools are useful for many different tasks, and that the function seems to relate to the symmetry of the axe working edge rather than its length.

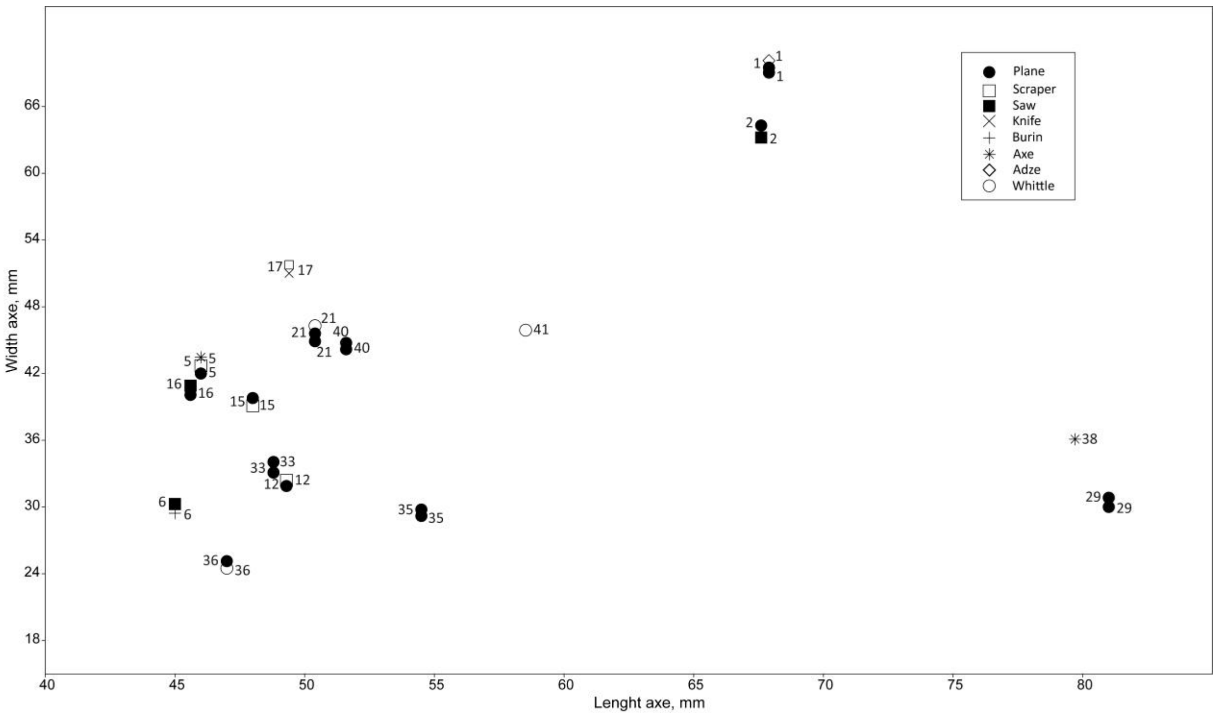

Figure 5: The plot show all different use directions identified on the analysed axes compared to the size of the axes (length, width). Different sized axes have been used for the same tasks and there is no clear pattern that indicates a connection between size and function. The numbers in the figure corresponds to the numbering of axes in figure 2. Figure: Steinar Solheim

3.1.4 Raw materials

As grain size makes up an important part of the properties of flint, one might expect a preference for certain types of flint, but this is not the case for the analysed axes. Rather, the results of the use-wear analysis clearly indicate that contact material and wear directions are not raw material-dependent. Axes made of coarse flint were used in the same manner and on the same type of contact material as axes produced from fine-grained translucent flint.

3.1.5 Hafting

Very little is known about how flake axes were hafted (Juel Jensen 1988: 178). Hafting was not a main concern of this study, yet some observations are worth commenting on. The large morphological variation is already emphasised, but the combined measurements of axe width and thickness can potentially provide us with some clues on how they were hafted. Morphological variation between axes from the same sites suggests that a) all axes had individual shafts, b) the shaft was flexible, or c) just some axes were hafted. Only three of the analysed axes bear evidence of hafting, and the results are not uniform or conclusive. Some of the use-wear located on the lateral sides of the axe may have been caused by using the axe as a scraper.

In a study of flake axes from Early Mesolithic sites in North-western Norway, John A. Havstein (2012) identified significant morphological similarities between three axes from the same site. The axes had almost identical butts suggesting that they were adjusted to fit the same shaft (Havstein, 2012: 79-80). In order to explore this further, the application of morphometric analysis, in combination with use-wear studies, might have potential to shed further light on this topic.

4. DISCUSSION

4.1 Earlier research and interpretation

Recently, Ingrid Fuglestvedt (2014: 117–118) stated that the flake axe's function has been, and still is, an open question. There are only a few clues to what they were used for, and most hypothesis concerning its function and use cannot be supported by solid evidence. A wide range of functions and potential usage has been suggested. Of importance are the three published use-wear analysis of flake axes from Swedish Mesolithic sites (Juel Jensen, 1988; Thorsberg, 1985; Knutsson, 1982). The majority of the analysed axes in Knutsson's (1982: 90) and Thorsberg's (1985: 22) analysis have use-wear traces from scraping of hide and woodworking. The majority of Juel Jensen's (1988: 175) analysed axes have use-wear traces from butchering. Although these works are important for interpreting use and function, these interpretations cannot be directly applied on Early Mesolithic flake axes from South-eastern Norway. The axes analysed by Knutsson and Juel Jensen all belong to Late Mesolithic assemblages from Scania, Southern Sweden. Hence, the chronological and geographical distance, as well as the different environmental setting, to the Early Mesolithic of South-eastern Norway is evident. Only Thorsberg's axes are from an Early Mesolithic site, more precisely from Lake Hornbogasjön, Sweden. The analyses only consist of three specimens with use-wear, and the low number of studied axes makes it problematic to infer a general interpretation of the use and functionality of flake axes.

The most common hypothesis in recent years is that flake axes were used as knives or scrapers for butchering sea mammals, and procurement and processing of skin and blubber (e.g. Schmitt, 2013: 121; Bang-Andersen, 2013: 82; Wikell and Peterson 2013: 100; Havstein, 2012: 93; Schmitt et al., 2009: 13–14). This hypothesis is based on the close association between the distribution of axes and the prehistoric coastlines and coastal areas. The much-used analogy to the Inuit *ulus* relies mostly on the combination of geographical distribution and morphological similarities, particularly that the central axis of both tools is perpendicular to a horizontal cutting edge (Schmitt 2013: 121). Based on analogy to the younger Late Mesolithic Nøstvet adzes as well as the association with coastal areas, Glørstad suggest the possibility that the flake axe was a woodworking tool used to carve out log boats (Glørstad, 2013; 2011; cf. Fuglestvedt, 2014: 118). Our results cannot be taken as evidence for the proposed connection between flake axes and log boats, but they certainly show that the tool has, amongst other things, been used a woodworking tool.

4.2 Function, use and available raw materials, flora and fauna

The environmental and climatic setting in which the axes where used might have caused constraints in raw material and resource availability, and in relation to the identified use-wear it is therefore relevant to look into what resources that was available.

The Scandinavia Ice Sheet retreated from the region c. 10 600 – 10 000 cal. BC (Sørensen et al., 2014:173). During the Preboreal severe climatic changes took place and the climate gradually developed from a cold to a milder climate. The sites where the flake axes were found are among the oldest known in the region, and are dated between c. 9200-8400 cal. BC. During this period previously unsettled and inhospitable landscapes became available, and a new flora and fauna was established. The vegetation and fauna can, at least, during the early Preboreal be characterised as being in a “pioneer condition”.

No organic remains are retrieved from Early Mesolithic contexts in South-eastern Norway. The few and geographically closest finds that can inform us about what humans hunted in the Preboreal reveals that both terrestrial and lacustrine resources were exploited (Ahlström and Sjögren, 2009; Kindgren, 1995). The available palynological and faunal data does not contradict the use-wear traces identified on the flake axes.

Sørensen et al. (2014) have recently carried out pollen analytical investigations in the Pauler-region (cf. figure 1). The earliest vegetation is characterised by low bushes, such as dwarf birch (*Betula nana*), juniper (*Juniperus*), and sea-buckthorn (*Hippophaë rhamnoides*). A variation of different herbs, plants and grasses are also identified at an early date. Birch is the earliest tree type that is recorded in the pollen assemblages (c. 9300–9000 cal. BC), followed by aspen (*Popolus*) (c. 9000–8500 cal. BC) and soon pine (*Pinus*), hazel (*Corylus*) and elm (*Ulmus*) (8400–8000 cal. BC). During the Early Mesolithic when the different archaeological sites were settled, an increasing wood cover is documented in the region. Small tree species as well as the larger ones might very well have been used as raw materials. From historical and modern times it is well known that for instance juniper has been used for a variety of different purposes, such as building material, rope, fishing implements and tool shafts (Høeg, 1996).

Little is known about the vertebrate fauna in Norway during the Preboreal period. The fauna is mainly known through finds of animal remains in natural deposits (e.g. Johansen and Undås, 1992). The earliest fauna comprised most likely of sea mammals and sea birds as well as different fish species (Jonsson, 2014: 162–165). The earliest C14-dated find of terrestrial mammals is a reindeer antler (*Rangifer tarandus*), found in Egersund, Rogaland, dated to 10 440-9760 cal. BC (10 255±80 BP, T-8821). The Moose (*Alces alces*) was one of the first large mammal species to migrate into Norway after the deglaciation, of which the earliest is C14-dated to 8450-8240 cal. BC (9100±50 BP, Poz-22238) (Grøndahl et al., 2010: 9–11). The antler is similar to Late Glacial and Early Holocene moose antlers found in Denmark and Scania, and the find demonstrates that moose had arrived in South-eastern Norway in the late Preboreal period. This also indicates that large terrestrial mammals colonised Norway as soon as the natural conditions made it possible (Grøndahl et al., 2010: 12).

The palynological evidence demonstrates that various tree species were available in the region, and this supports the identification of use-wear resulted from working of wood. The natural deposits of animal remains indicate a varied fauna, also including large, marine and terrestrial mammals. The observation of wood and bone/antler as the dominant contact material is thus highly likely based on the environmental background and documented available resources.

5. CONCLUSION

In this paper we have presented the results from a use-wear analysis of 42 flake axes. 13 specimens could not be analysed due to damages to the edge and the lack of use-wear. 10 specimens are considered as unused or that use-wear is either caused by or camouflaged by post depositional factors. A total of 19 specimens have use-wear traces that are interpreted as related to prehistoric activity. Identification of different work directions and contact materials clearly indicate that the flake axes were utilised for a variety of tasks. Further, use-wear traces from different tasks and contact materials are identified on one and the same specimen. Among the work directions planing and scraping is most common.

We have identified a total of 37 different use-wear traces caused by at least five different contact materials. Wood is dominating, followed by antler/bone. Previous interpretations have largely rejected that the flake axe was a woodworking tool and rather emphasised its potential function as an *ulu* or skin scraper. In that respect it is highly interesting that our results show that the dominant worked material is wood. This clearly demonstrates the importance of use-wear analysis in order to interpret tool function.

Our results show that the flake axe was a multi-tool (cf. Havstein 2012: 93; Juel Jensen 1988: 178; Knutsson 1982: 90). This fits well with the context of which the analysed axes belonged to, namely the colonisation of coastal South-eastern Norway during the Preboreal period and the following centuries of settling this landscape. In that regard we argue that Early Mesolithic lithic technology and tools display a functional flexibility within a rather rigid technological tradition, and hence demonstrating the need for flexible toolkit (Breivik, 2016; Åstveit, 2014; Callanan, 2007; Waraas, 2001). This is also observed in the analysed data with regards to morphology, raw materials and use/function.

Most hypothesis concerning the Preboreal flake axes' function and use lack substantial and direct evidence (cf. Fuglestvedt, 2014: 118; Åstveit, 2014b: 131). Rather than expecting one "correct" answer our aim was to investigate whether previously suggested interpretations of the Early Mesolithic flake axe based on, what we consider to be circumstantial evidence, could stand up to scrutiny. For that matter, information on whether tools were used on hard or soft contact material would probably have sufficed (Stevens et al., 2010: 2671-2672).

We acknowledge that use-wear analysis is interpretive archaeology (Van Gijn 2014: 168). However, we also believe that it is important to gather information from different methodologies in order to interpret the function of a prehistoric tool. With this in mind, and even though the data included in the present analysis is limited considering time span, number of known axes and geographical distribution, the results clearly provide a more solid foundation for discussing the functionality of flake axes from Early Mesolithic Scandinavia.

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