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FRACTURED SILTSTONES IN SUSIVUORI ESKER CLOSE TO SUSILUOLA CAVE, KARIJOKI, FINLAND

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INTRODUCTION

The majority (36 %) of the 325 fractured pebbles and cobbles excavated from the Susiluola Cave (Fig. 1), which are interpreted as artifacts (Schulz 2002; Schulz et al. 2002), consists of siltstone. Likewise, the pebble described by Professor Joakim Donner in this issue, consists of siltstone. Schulz et al. (2002: 23) state, that these siltstones are not local, and therefore 'the material must have been brought into the Susiluola cave'. This would suggest early human action.

Sedimentary rocks, however, are known to occur as erratics in Pleistocene sediments in Ostrobothnia (Salonen 1986; Salonen 1991). Their known bedrock source is under the Bothnia sea (Kohonen & Rämö 2005). The distance of glacial transport to the Susiluola area is 40–50 km at minimum. These sedimentary rocks, sandstones and siltstones, are mostly Mesoproterozoic in age (about 1500–1300 Ma) but younger Neoproterozoic siltstones and sandstones may be present, too (cf. Winterhalter 2000; Kohonen & Rämö 2005).

In this note the siltstone fragments collected in sediments outside, but near Susiluola Cave, are described. The terminology is mostly geological and some morphological terms may have a different meaning in archaeological context.

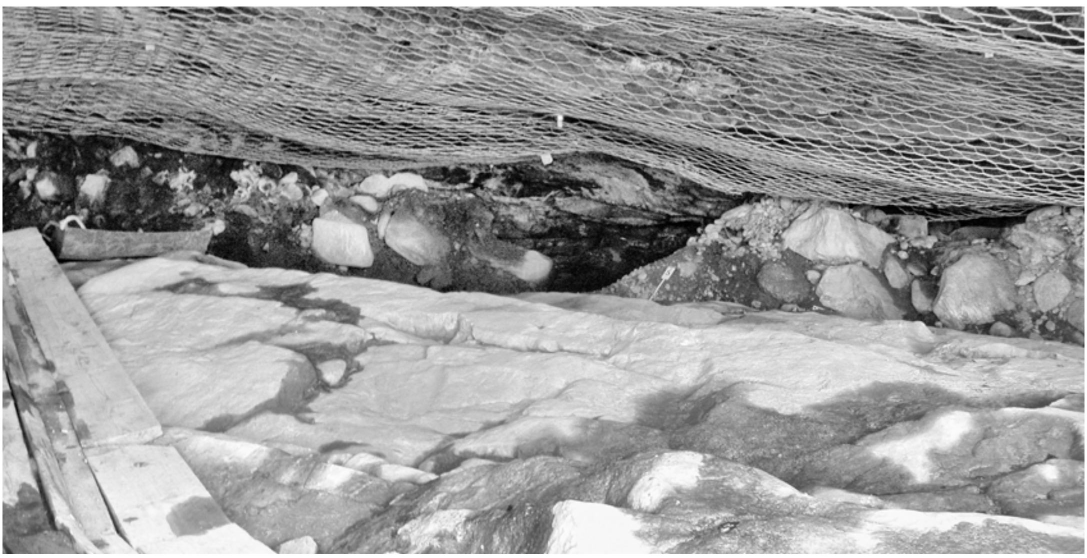

Fig. 1. Interior of the Susiluola Cave showing its bedrock floor cleaned from its sediment cover. The back wall shows the clast-supported texture of the boulder belt layer and its fractured boulders. Photographed through the barrier fence in April 2007. Photo: Kari A. Kinnunen.

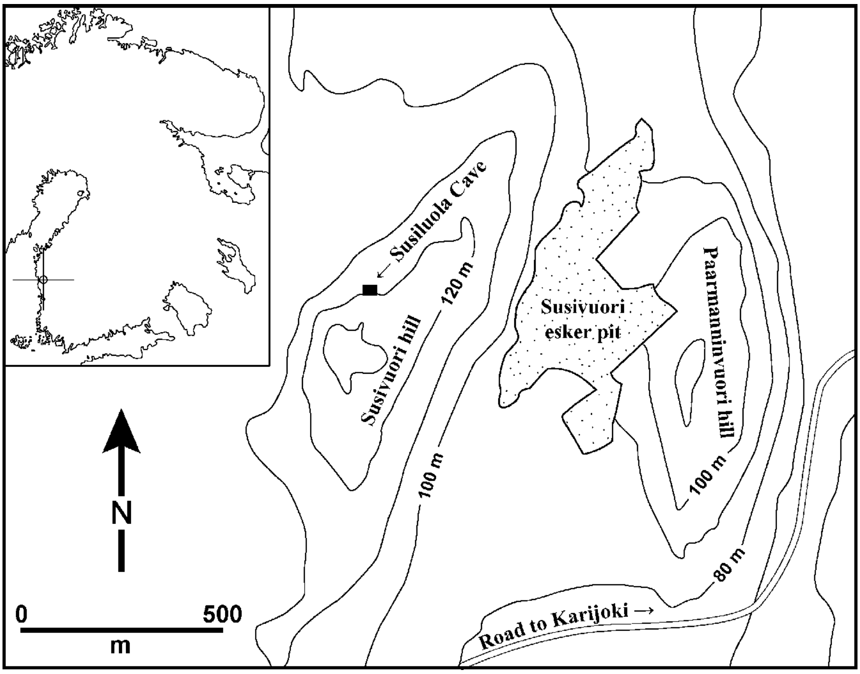

Fig. 2. The Susivuori esker formation lies between the bedrock ridges of Susivuori and Paarmanninvuori. The siltstone clasts were collected from the esker pit of the Susivuori formation.

SILTSTONES IN SUSIVUORI ESKER

The Susivuori esker formation is 3 km long and 0.5–1 km wide and is located in a natural depression between two bedrock ridges: Susivuori and Paarmanninvuori (Fig. 2). Basal till covers the esker (Niemelä & Tynni 1979). The esker formation has been dated by thermoluminescence method to 115–159 ka, corresponding to pre-Eemian age (Niemelä & Jungner 1991). This is in the same age range as the maximum IRSL-date for the layer rich with fractured pebbles in the Susiluola Cave: 128 ka (Huhta 2007).

Fig. 3. Siltstone pebbles and cobbles from the Susivuori esker formation. Clast size is from 2 to 10 cm. Natural fracture scars cut the moderately rounded surfaces. The planar surfaces represent old jointing planes in the bedrock that controlled the shape and size of the siltstone fragments formed. Photo: Kari A. Kinnunen.

Stone counts were carried out in the Susivuori esker pit about 0.5 km east from the Susivuori hill and its Susiluola Cave. About 100 clasts were identified. Results were: gneiss 50 %, granitoids 30 %, sandstone 11 %, schists and quartzite 6 %, siltstone 1 % and vein quartz 1 %. About 50 % of all the pebbles and boulders (90 % of the siltstones) were fractured. For this study 11 naturally fractured siltstone fragments (2–10 cm) were selected (Fig. 3).

PETROGRAPHY

The siltstone is grayish red (Munsell colour 10 R 4/2) and stratified. It is composed of detrital feldspars (mostly K-feldspar), quartz and micas, and of reddish fine-grained matrix. The grain size mode of detritals is at 10 microns and their range 3–60 microns. No microfossils were observed in the matrix material. Petrographically, under the polarizing microscope, the rock type is a feldspathic siltstone, silicate-siltstone. It is significant, that diagenetic silica is lacking from the matrix. The X-ray diffraction (XRD) patterns reveal quartz, albite, microcline and hematite. Clay minerals were not observed.

The high proportion of feldspar mineral indicates that the material is composed of Mesoproterozoic (Jotnian) sedimentary rock (cf. Simonen & Kouvo 1955). In the Susivuori esker some boulders of Jotnian-type arkosic sandstone included siltstone interbeds (Fig. 9). This, too, classifies the siltstones most probably as Jotnian.

MORPHOLOGY

In general, the shape of rock clasts is a combination of overall form, roundness and surface textures (Barret 1980; Gale & Hoare 1991). Shape and size reflect inherited planes of weakness, along which the rock fragment was loosened from the bedrock and along which it was subsequently broken. Sedimentary processes (rivers, glacier, wind, ground water etc.) smooth particles and lead to different degrees of roundness. Mechanical abrading processes include breaking, fracturing and grinding. Chemical weathering smooths the mechanically formed structures and shows correlation to the relative age of surface.

The shape of sedimentary particles can be reported with numerical parameters (Barret 1980). The Susivuori siltstones were firstly examined with the Power's roundness scale, which gives a measure of the intensity of abrasion (see Barret 1980). The Power's scale was selected so that the results could be compared to the ones published from Susiluola Cave by Schulz et al. (2002: 20–1), which they apparently used (see Schulz et al. 2002, Table 5).

In Power's scale the siltstones are mostly angular and subangular (Table 1). Some later fracture scars are only slightly abraded. The results are similar in both locations although the Susivuori esker material shows more angular siltstone clasts compared to the Susiluola Cave. Littoral processes (see Huhta 2007), that abraded material in the Susiluola Cave, may explain this difference.

Fig. 4. Natural fracture scar on siltstone clast showing step termination and radial fissures. Susivuori esker. Picture width 50 mm. Photo: Kari A. Kinnunen.

Table 1. The percentages of abrasion grades of the siltstones.

	Susivuori	Susiluola
0	--	--
1	36%	8%
2	46%	47%
3	9%	27%
4	9%	17%
5	--	--
6	--	--

Grades are given in Power's grades, from 0 = non-abraded to 6 = totally abraded.

Table 2. The elongation of the clasts.

	Susivuori	Susiluola
Mean	69	61
Range	32–94	44–79
S.D.	17	10

S.D. = standard deviation

Elongation of the clasts (intermediate axis x 100/long axis) gives a simple parameter to compare patterns of rock breakage. The elongation was compared between the siltstones in Susivuori esker material and in Susiluola Cave (the latter measured from photos digitized from Plates 1 and 3 in Schulz 2002). Results show a high similarity of elongation and breakage patterns in both locations (see table 2).

About 90 % of the siltstone pebbles and cobbles show conchoidal fracture scars. These scars are rough, comparatively little abraded and moderately chemically resorped (see Fig. 3). They were common especially on the largest pebbles. One pebble showed 11 fracture scars on its moderately rounded surface. It is likely that the siltstones may have been broken in several episodes connected with glacial and glaciofluvial transport and littoral environments including storm bursts. It is significant, that in the Susivuori formation the fractures are ground and resorped to varying degrees. This shows their relative age differences and at least three mechanical breakage/rounding cycles could be inferred. The surface markings typical of fracture scars (ripple marks, radial fissures etc.) were obscure at best or not present. Similar observations have been presented from the Susiluola cave (cf. Schulz et al. 2002).

The morphology of the natural fractures showed features that differed from the scars produced in experimental knapping. The natural fractures had step (or hinge) terminations (Fig. 4). But the flake scars, that were experimentally knapped using hard hammer technique common in Paleolithic period, showed feather termination (Fig. 5). Step termination seen on natural fracture scars could by duplicated by a firm push against the edge. This produced small step terminations resembling the natural fractures seen on the siltstone pebbles.

There were also other features that differed in naturally and experimentally fractured siltstones. The edge damage consisted of truncated fracture scars in natural breakage. This feature is typically not seen in genuine artifacts (cf. Hahn 1993: 45–72). Likewise the breakage angles of the fracture scars stayed commonly near 90 degrees compared to 70–80 degrees, which is typical in man-made scars (see Hahn 1993). The angles were measured from digital photos using ImageJ image analysis software.

Weaknesses related to jointing and stratification guided the fracturing of Susivuori siltstones and consequently influenced their overall shape and size in sedimentary processes. The symmetry classes of the siltstone fragments were classified mainly as varihedroids according to the Holme's scheme (see Fig. 5 in Kaitanen & Ström 1978). It should be noted, that the natural breakage patterns are different in siltstones compared to sandstones of the Susivuori esker (compare Fig. 3 to 6 and 7). This may well explain the incompatible '*Chaine operatoire*' patterns (see Schulz 2002) between these different rock types in the Susiluola Cave sediments as well.

Fig. 5. Experimental flaking scar on siltstone. Termination of the scar is of feather type. Faint ripple marks and very faint radial striae can be seen on the fracture plane. Susivuori esker. Picture width 50 mm. Photo: Kari A. Kinnunen.

CUTTING QUALITY

Mohs' hardness value was determined from the siltstone flakes that were knapped experimentally. In Paleolithic technology stone tools were used to cut meat and plants (reeds and grasses) and to scrape wood (Ambrose 2001). The hardness of the edge should rise above 5 for a useful tool, although the Mohs' hardness value of wood material only is in the range 2–2.5. The high quality lithic materials such as flint, chert and quartz (Hahn 1993; Andrefsky 1998) all have Mohs' values from 6 to 7. The Susivuori siltstone showed extreme softness in experiments. It could not cut wood properly. Its Mohs' value dropped after the first strokes from about 6 down to about 2, which is the same hardness as in human nails. Therefore, it is difficult to consider it as an appropriate material for stone tools.

The edges produced in experimental flaking were studied under a polarizing microscope. The edge itself is composed of a few silt-grade quartz grains and of a very fine-grained matrix material (Fig. 8). When carving on wood or bone, the quartz grains are easily loosened, and after that the soft matrix material forms the outermost part of the edge.

Silicified harder types of siltstones have been used as lithic raw materials for example in East Finnmark, Norway. However, the Susivuori siltstone does not contain any silicified matrix material. Consequently, the Susivuori siltstone, although it is easily fractured, is considered to be of too low quality to be suitable for manufacturing of stone scrapers.

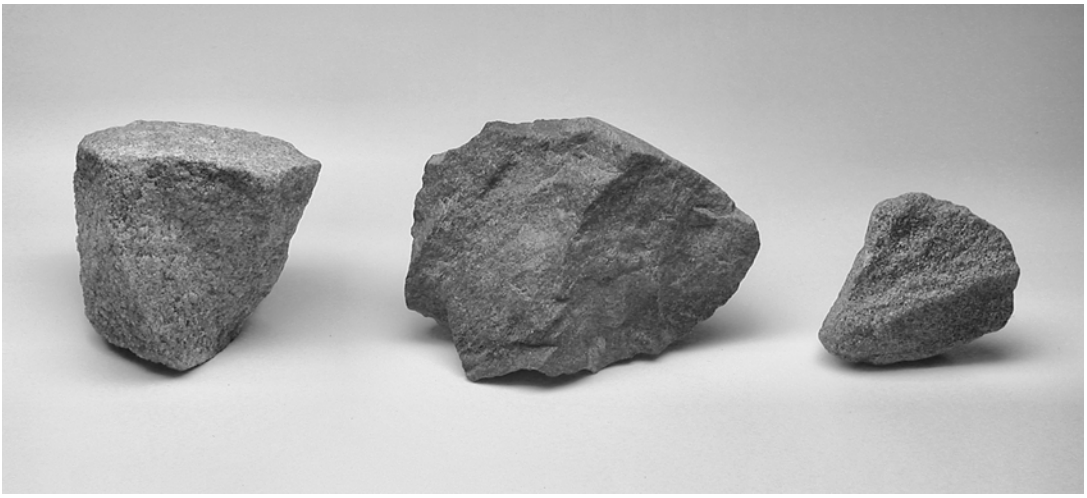

Fig. 6. Naturally fractured, fresh looking, originally rounded, sandstone pebbles are common as geofacts in the 'hill clay till' covering the Susivuori esker pit. Diameters from 22 mm to 38 mm. Photo: Kari A. Kinnunen.

DISCUSSION

1. Siltstones are shown to occur naturally in the Susivuori esker near the Susiluola cave. Therefore, the siltstones found inside the Susiluola cave may also be interpreted as naturally transported clasts.

2. The experimental chipping of the Susivuori siltstones showed, that the rapid loosening of quartz grains from the soft matrix material renders the edge too soft to cut wood or bone. Likewise the termination of natural fractures showed features that differed from the scars produced in experimental knapping.

Fig. 7. Some of the sandtone pebbles from Susivuori esker show geofact morphology. This sample was found by Satu Hietala. Photo: Kari A. Kinnunen.

3. It appears that the original jointing patterns, stratification etc. of different rock types (siltstone, sandstone, quartzite and vein quartz) lead to differences in their later natural fracturing patterns. This may explain the otherwise incompatible '*Chaine operatoire*' patterns (Schulz 2002) between siltstone and sandstone observed in the stones interpreted as artifacts in the Susiluola Cave sediments.

4. The high proportion of naturally fractured pebbles and cobbles (90 %) in the Susivuori area, especially in its hill clay till, suggests that the till-covered eskers underwent high stresses during the glacier flow. In cave classification the Susiluola cave is a typical fracture cave (Kejonen et al. 1990; Kejonen 2007). It is suggested, that the cave was to some extent open during subglacial plucking processes (cf. Evans et al. 1998). If so, the glacitectonic shearing may have caused fracturing of clasts now inside the cave (cf. Evans et al. 2006).

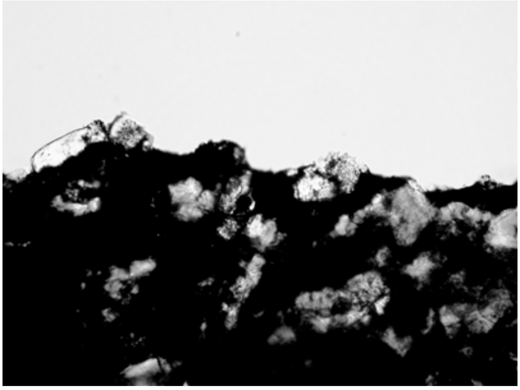

Fig. 8. Experimental cutting edge knapped from a siltstone clast found in the Susivuori esker formation. Quartz silt grains (grey) are easily loosened from the soft matrix material (dark). This process dulls the edge quickly and makes it unsuitable for wood or bone working. Picture width 0.55 mm. Photomicrograph taken in transmitted light with circular polarization. Photo: Kari A. Kinnunen.

Fig. 9. Jotnian-type sandstone boulder with darker siltstone interlayers in the Susivuori esker pit. The length of the compass is 11 cm. Photo: Kari A. Kinnunen.

ACKNOWLEDGMENTS

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