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Excavations at Susiluola Cave

1. Introduction

In 1996, the Geological Survey of Finland began the study of a gravel-filled cleft in a gneiss rock formation resembling granodiorite at the border of Kristiinankaupunki and Karijoki, western Finland. The cleft turned out to be a cave at least several hundred square metres in size and 2.2 m in maximum height. After the discovery of some possible stone artefacts, the work was discontinued. In 1997, the National Board of Antiquities began archaeological excavations in co-operation with the Geological Survey of Finland. In the course of four field seasons, seven stratigraphic layers were revealed in an area of 25 sq. m. The four lower layers turned out to be of Pleistocene date and contained archaeological finds. The aim of this article is to present preliminary results of the research in 1997–2000, including the research history and project organisation, the geology and sedimentology of Susiluola Cave and its surroundings, the TL- and IRSL-dating of the cave deposits, the archaeological material of layers IV and V, the pollen analysis, and the Holocene faunal remains.

The cave is located on the northern slope of Susivuori Hill, 2 km west of Karijoki village in the province of South Ostrobothnia, at 62° 18' 10" N and 21° 40' E (Fig. 1). Its entrance is currently at the elevation of 116.5 m above sea level. The exact size and shape of Susiluola Cave are not known, because it was filled with sediment nearly to the roof. Two other caves were recently discovered west of Susiluola Cave in the same rock formation. Their entrances are still covered by sediment.

The region around Susiluola Cave is today part of the boreal forest vegetation zone; the predominant forest type is submesic heath forest (Alalammi 1988). The mean temperature in the region ranges from –6°C to –7°C in February and from +16°C to +17°C in July. The annual range of monthly mean temperatures is 23–25°C and the annual precipitation 600–650 mm (Alalammi 1987).

The local environment consists of typical Finnish woodland characterised by small patches of variable forest vegetation. South of the cave the forest is more xeric than in the north and is dominated by pine with lingonberry present in the undergrowth. In front of the cave there is a moist zone about 10 m in width with moss, ferns, and deciduous trees, such as rowan, aspen, and some grey alder in addition to equal amounts of pine and birch. The slopes of the hill support some spruce, while juniper, small pine trees and lichen dominate the top of the hill.

2. Background and objectives of the research

The last Ice Age began in the present area of Finland c. 70,000 years ago and ended some 10,000 years ago (Donner 1995, but see Arnold *et al.* 2002). Mammoth bones discovered embedded in till and glaciofluvial sediments in different parts of Finland that have been dated to before the last glacial maximum (Donner 1995: 168; Ukkonen *et al.* 1999) indicate, however, that conditions during interglacials and interstadials have probably been favourable also for man. Nevertheless, archaeologists in Finland found it unlikely that evidence of Palaeolithic human occupation could have survived. The thick masses of ice together with postglacial soil processes were expected to have erased all signs of pre-Holocene human activity, and the Mesolithic occupation finds from c. 10,000 years ago were considered the first indication of human colonisation of Finnish soil (Edgren 1992: 20–39). Because of this, the National Board of Antiquities Department of Archaeology declined the suggestion of archaeological

Fig. 1. The location of Susiluola Cave.

excavations of the potentially Pleistocene sediments of Susiluola Cave advanced from Karijoki early in 1996.

The cave is well known in the area and is associated with a wealth of local tradition. It had sparked the interest of, especially, gravel contractor Kalervo Uusitalo of Karijoki, who thought that evidence of pre-Ice Age occupation might be found in the cave and who initiated and organised the clearing of the sediments from it. In addition to the National Board of Antiquities, he had contacted the Geological Survey of Finland and finally managed to interest it in the undertaking. Consequently, when the clearing was initiated in May 1996, geologists led by Dr. Heikki Hirvas were present. When about 64 m^2 of the cave had been cleared of sediment, local rock enthusiast Mauno Aro found a strange-looking red rock that, judging from morphological features apparently related to reduction, had been intentionally shaped. To the geologists present it did not look like a product of nature, either. The rock was taken to the National Board of Antiquities for investigation. After inspecting the site the National Board of Antiquities declared the cave protected for further research by the Antiquities Act.

Archaeological test excavations were not begun before the following year, however. The results of the test excavation were promising, and a joint research project of the National Board of Antiquities, the Geological Survey of Finland, the University of Helsinki Department of Geology, and the University of Helsinki Dating Laboratory was initiated. So far the field seasons of the project have lasted 3–8 weeks in the summers of 1998–2000. The fieldwork was interrupted in 2000 because of the imminent danger of the roof caving in. The roof structure will be reinforced in 2002, after which decisions concerning continued excavation will be made.

The head archaeologist responsible for the fieldwork and excavation reports is Hans-Peter Schulz, MA, who is also the main author of this paper. The geological and sedimentological investigations have been the responsibility of Heikki Hirvas, Ph.D., and Pekka Huhta, M.Sc., of the Geological Survey of Finland, while the pollen samples from the cave have been analysed by Brita Eriksson, M.Sc., of the Geological Survey of Finland. The IRSL and TL analyses have been carried out by Högne Jungner, Ph.D., of the University of Helsinki Dating Laboratory and the osteological analyses by Pirkko Ukkonen, Ph.D., of the University of Helsinki Department of Geology. Paula Purhonen, Ph.D., director of the National Board of Antiquities Department of Archaeology, has participated in the fieldwork and been responsible for project co-ordination and public relations. In addition, the field team has included Jaana Itäpalo, MA, Tapani Rostedt, BA, and Pirjo Hamari, MA of the National Board of Antiquities and research assistants Pertti Hakala and Markus Torssonen of the Geological Survey of Finland, among others (Fig. 2). This article has been edited for publication and partly translated by Tuija Rankama, Ph.D. Mikko Rautala has redrawn the plans.

The objectives of the multidisciplinary research have been to study the date and character of the sediments and the archaeological site, to survey the position of the artefact assemblage among Palaeolithic technocomplexes, and to reconstruct the palaeoenvironment of the cave contemporary to its occupation.

3. The geology of Susiluola Cave

3.1 The site and its surroundings

South Ostrobothnia, the region where the cave is located, is an area where the Quaternary cover is in many ways exceptional as compared with the rest of Finland. In addition to till deposited by the last glaciation, older till probably deriving from the previous, so-called Saale glaciation has been discovered in South Ostrobothnia. Several sediments deposited during interstadials or interglacials, *i.e.*, ice-free periods between glaciations, have also been detected between the till sediments deposited during the various glacial periods (Niemelä & Tynni 1979; Hirvas & Nenonen 1987;

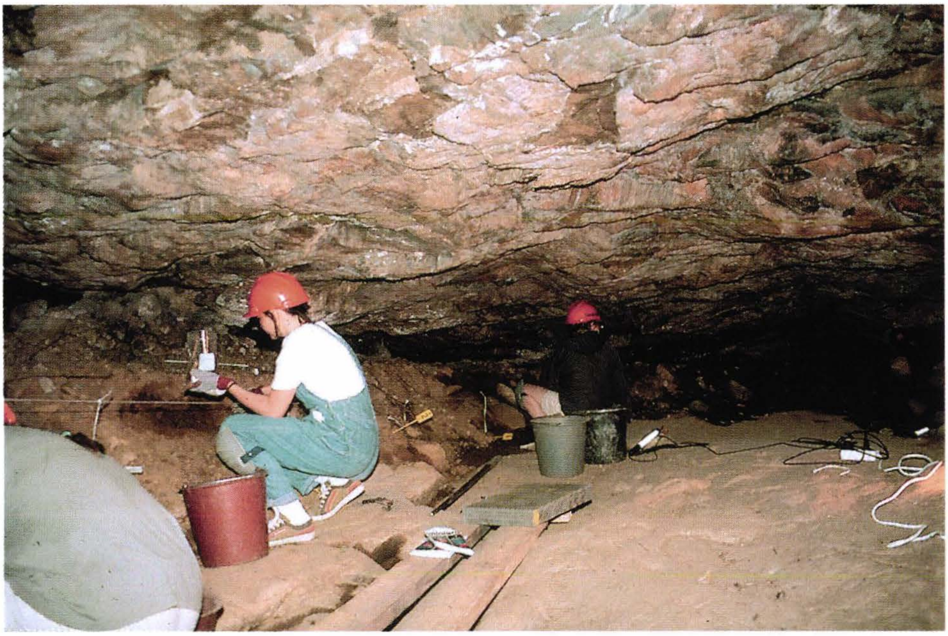

Fig. 2. Work in progress in the cave in 1997. Photograph National Board of Antiquities / H.-P. Schulz.

Gibbard *et al.* 1989; Grönlund 1991; Kujansuu 1992; Kurkinen *et al.* 1993; Nenonen 1995). These deposits consist of a variety of clays, gyttjas, peats, wood fragments, and soils. The thickness of the sediments varies from a few dozen centimetres to a metre.

East of Susivuori Hill a few hundred metres from Susiluola Cave the sediment layers displayed in a gravel pit indicate two separate periods of glaciation (Table 1).

Table 1. Quaternary stratigraphy in a gravel pit next to Susivuori Hill from top to bottom.

Layer	Age
Peat	Postglacial
Sand/gravel (littoral deposit)	Postglacial
Hill clay till	Weichselian Glaciation
Sand (littoral deposit)	Eemian Interglacial
Sand/gravel (esker)	Saale Glaciation (deglaciation phase)
Bedrock	

The esker deposited on top of a crystalline rock formation was probably formed during the deglaciation period of the Saale glaciation in the penultimate Ice Age. The littoral sands on top of it date from 130,000–140,000 years ago (Niemelä & Jungner 1991), while the upper till is a silty till from the period of the Weichselian glaciation. The widespread, dark grey moraine rich in fine particles is in South Ostrobothnia commonly called »hill clay» or »hill clay till» (*e.g.*, Iisalo *et al.* 1974; Niemelä & Tynni 1979; Bouchard *et al.* 1990; Lintinen 1995), because it resembles clay and is found, for example, on tops of hills (Pitkäranta 1996). The abundant fine fraction of

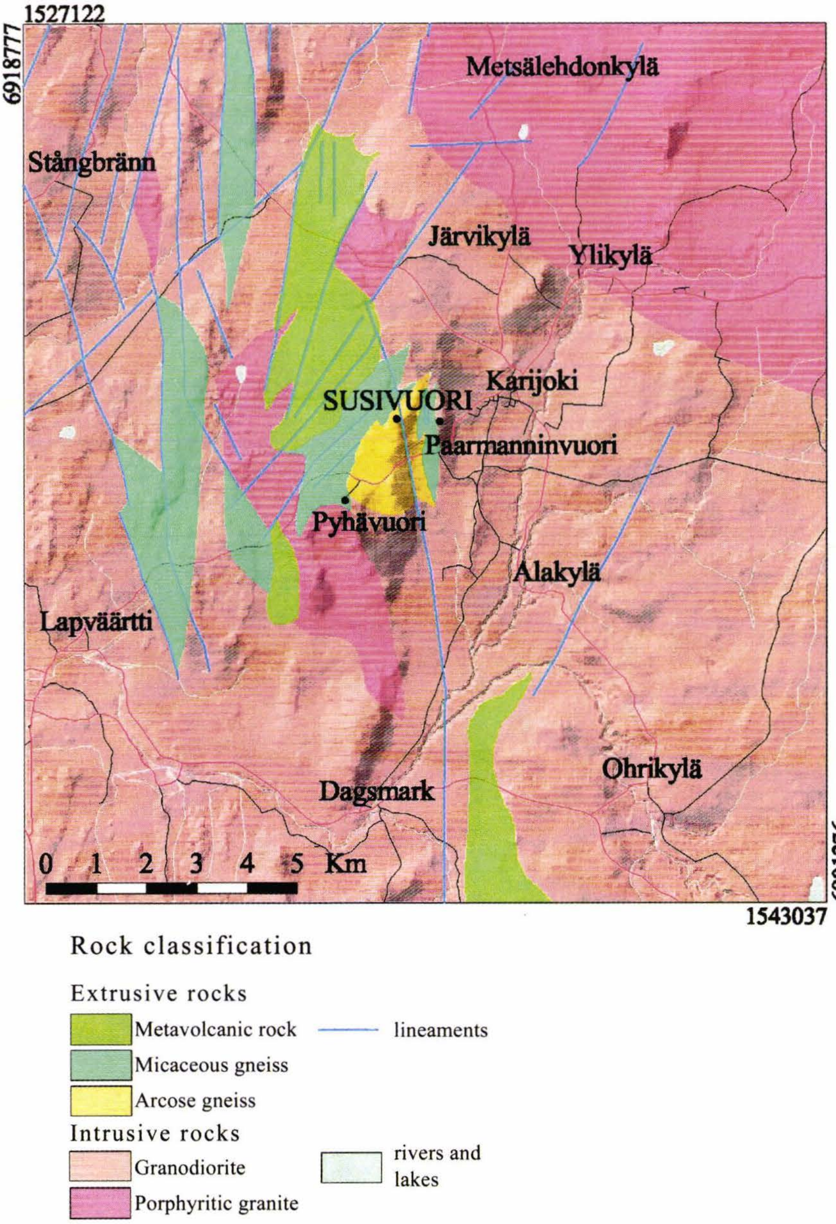

Fig. 3. Rock types in the area surrounding Susivuori Hill. Based on Virkki 2001 and Virransalo 1999.

the till derives from clays and silts deposited on the bottom of the Eemian Sea (Niemelä & Tynni 1979; Pitkäranta 1996).

Susivuori Hill is part of the contact zone between the Central Finnish granitoid complex and the Western Finnish schist area (Korsman *et al.* 1997). The rocks of the contact zone are variable (Virransalo 1999) and the topography of the bedrock sur-

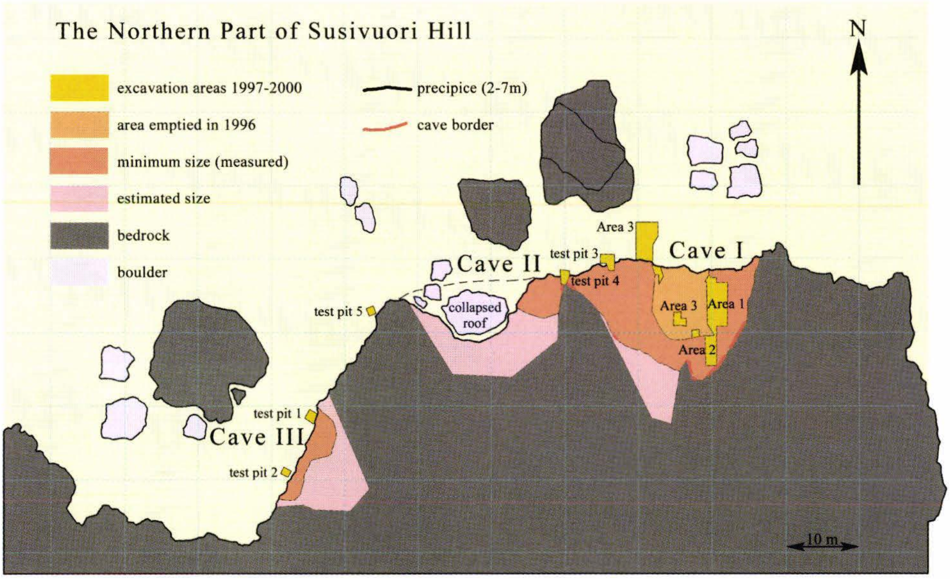

Fig. 4. Plan of the cave area.

face is relatively steep in places (Fig. 3). Thick Quaternary deposits, however, make the surface contours low (Pitkäranta 1996, 1999).

The bedrock of Susivuori Hill consists of micaceous gneiss and arcose gneiss metamorphosed to resemble granodiorite. Due to the large quantity of arcose gneiss, the rock is hard and more brittle than the other rock types in the vicinity. The brittleness has probably caused the abundant formation of jointing in several directions. Susiluola Cave is located in a widening of a large horizontal fracture (Virransalo 1999). The exact size and shape of the cave are not known, because the cavity has been filled with Quaternary sediments almost up to the roof. The horizontal fracture can be followed almost 100 m under the cliff. Three openings have been located in the cleft (Fig. 4).

According to the excavations and ground penetrating radar studies, the biggest cave is triangular in shape, 26 m wide at the mouth, with a maximum depth of c. 30 metres. The maximum height of the cave opening is 1.5 m. In the highest part of the cave a couple of metres in from the mouth the ceiling is 2.2 m above the floor. So far the excavations have reached 16 m into the cave.

The highest parts of Susivuori Hill c. 130 m above the present sea level are exposed rock, but the lower slopes are covered by littoral deposits (Fig. 5). The slopes of Susivuori Hill, as well as the other hills in the region, have been exposed to erosive and depositing wave action during the various shore displacement phases of the Baltic Basin. As a consequence, littoral deposits have been formed almost everywhere at the interface of the till-covered hills and the more even ground (Niemelä 1978). The thickness of the littoral deposits washed from the till ranges from a couple of dozen centimetres to a few metres and the rocks in them are usually very rounded. On the other hand, the gravel and sand formations originally deposited by glacial meltwaters may include littoral deposits more than 10 m thick.

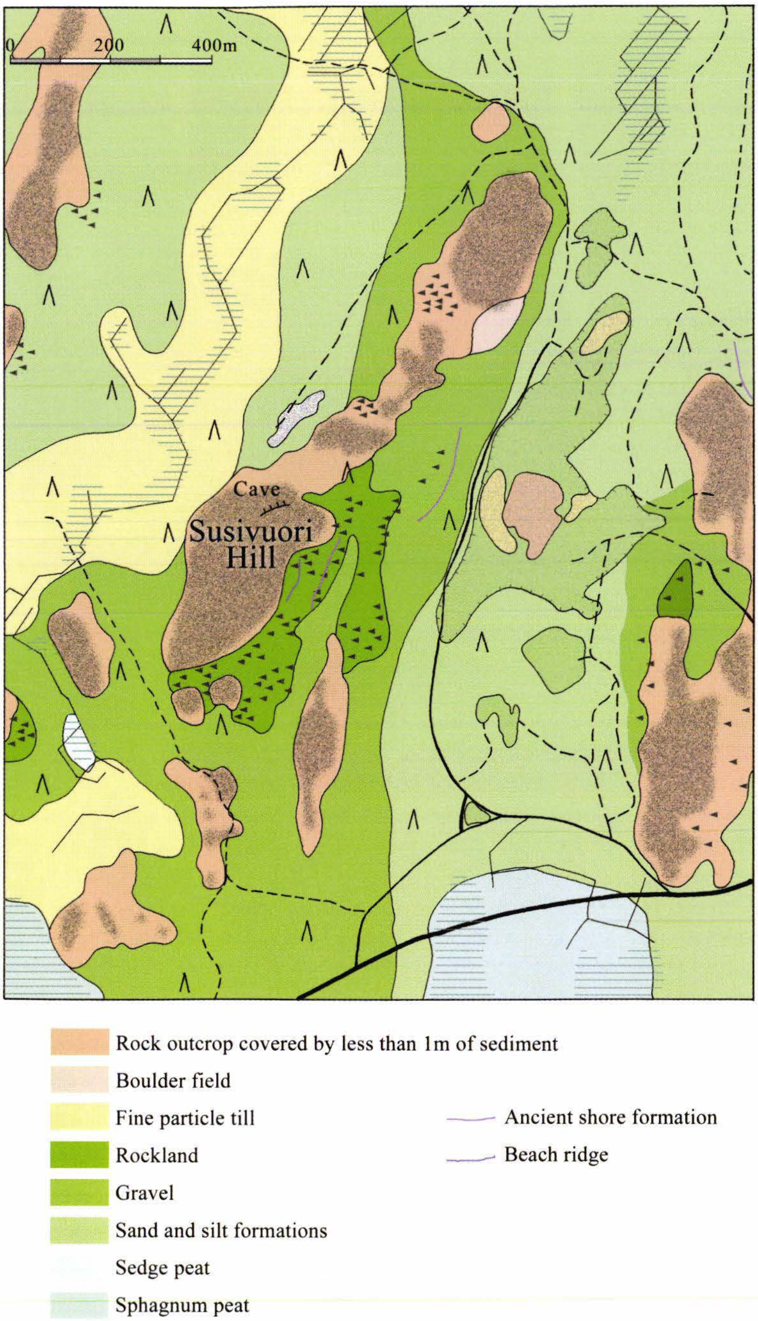

Fig. 5. Quaternary deposits around Susivuori Hill.

3.2 The cave sediments

The sediments in Susiluola Cave can be divided geologically into seven major units on the basis of their characteristics. The stratigraphy and provisional interpretation of the strata from the top of the deposits to the bottom is the following:

Layer I is the top layer and consists of rocks and boulders. Bones of Holocene animals have been discovered in this layer. The layer represents washed littoral sediment from the time the Ancylus Stage shore of the Baltic Basin was at the level of the cave mouth (c. 8,500–8,000 yr BP). The large boulders and rocks may have been pushed into the cave by pack ice.

Layer II can be divided in two parts. The upper part is found near the mouth of the cave and consists of yellowish brown, partly stratified granulate-pebble gravel that also includes large rocks and even boulders. The lower part consists of dark brown cemented pebble gravel without an inner structure. Both parts of Layer II can be interpreted as littoral formations from the Ancylus or older stage. The stream-stratified structure and the sorted character of the gravel indicate wave action, while the presence of boulders particularly towards the mouth of the cave is probably associated with pack ice.

Layer III is a pebbly gravel deposit where the pebble size varies between c. 6 and 26 centimetres. It also includes large rocks. This layer is only found in the southeastern part of the cave. The genesis of this layer is not known at the moment.

Layer IV is a paleosol (ancient soil formation) developed in gravel and sand (of Layer V). According to analyses of clay minerals and Fe-Al extracts it was formed during an interglacial in conditions that were warmer and moister than today (Mahaney *et al.* 2001). The layer consists of two units:

- IV 2 (lower) is the interglacial floor of the cave. In the northeastern part of the cave it forms the surface of a 20–25-cm paleosol that developed at the mouth of the cave. Some 5 m in from the mouth it ends gradually and changes into Layer V. This paleosol is the only layer that has yielded stone artefacts *in situ*. Several burnt stones were found by the edges of the layer.
- IV 1 (upper) consists of soil redeposited by littoral forces. It covers Layer IV 2 and, towards the back of the cave, Layer V. The layer contains a large number of lithic artefacts, which show slight to moderate abrasion by water.

Layer V consists of well-sorted, stratified yellowish granulate pebble gravel and is a littoral deposit. The lithic artefacts from this layer show clear abrasion by water.

Layer VI is also composed of well-sorted light yellow to greyish granulate-pebble gravel. It is a littoral deposit and the lithic artefacts from it show clear abrasion by water. The age of this layer is not known.

Layer VII consists of poorly sorted dark brown granulate gravel that includes sand and silt. The layer contains some lithic artefacts that show clear abrasion by water. The age and morphogenesis of this layer are as yet unknown.

3.3 Discussion

Layers I, IV, V, and VI in Susiluola Cave are clearly littoral deposits, while Layers II and III may have been originally deposited by a glacier and later sorted by littoral processes. The age and morphogenesis of Layer VII are so far unknown. Ice push during glacial periods or later shoreline stages has moved rocks and boulders at least in the vicinity of the cave mouth, resulting in a mixing of the layers.

The geological evidence suggests that Layer V was formed during the deglaciation stage of the Saale Glaciation, while Layer IV (paleosol) was formed in its top part during the Eemian Interglacial. The stratigraphic position and the mode of formation (littoral deposit) of Layer V indicate that it was formed during a period when the sea level had reached the cave mouth because of land upheaval after the Saale Glaciation. The results of the analyses of clay minerals and Fe-Al extracts from Layer IV indicate that the layer was formed under warmer and more humid conditions than today. The analysis results correspond to the results from a paleosol studied at Kärjenkoski, some 20 km south of Susiluola Cave. The Kärjenkoski paleosol was TL-dated to 137,000–144,000 yr BP (Kujansuu *et al.* 1991).

4. Dating the Susiluola Cave sediments

Dating the Susiluola Cave layers is difficult. Apart from some quite recent bone remains in the upper strata, no organic material is available for radiocarbon dating. Luminescence dating of sand samples collected from different points within the cave has been begun. The sand has been transported into the cave partly by wind, but also by water. The area was submerged after the deglaciation and the boulders have been pushed into the cave by ice.

Different preglacial sand deposits in the surrounding region have been dated before (Niemelä & Jungner 1991; Hütt & Jungner 1992; Hütt *et al.* 1993). They date to the early Eemian period.

Samples were collected from different levels inside Susiluola Cave. The sampling points are indicated in Figure 6. In addition, one sample was collected from just outside the cave mouth. So far, only three of the samples (nos. 3, 4, and 7) have been dated.

Feldspar grains were separated from the collected samples and further treated for measurements.

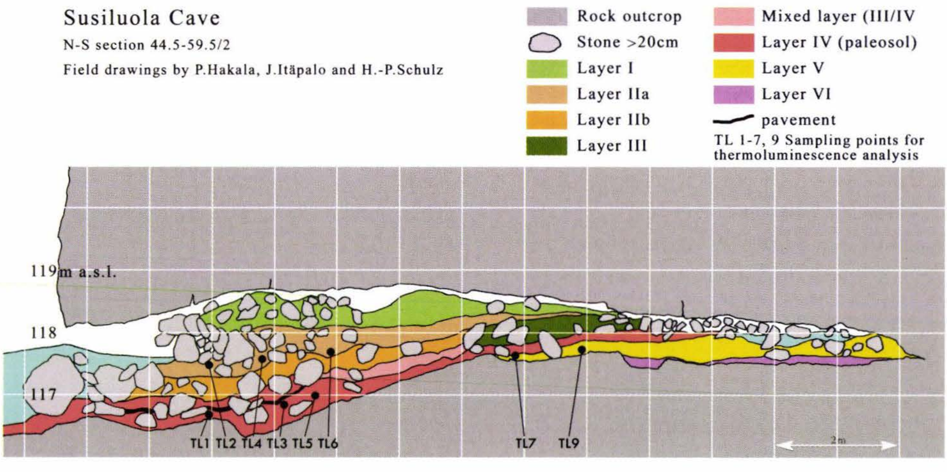

Fig. 6. Section of the cave fill showing the stratigraphic layers and the sampling points for TL/IRSL.

The luminescence measurements were done on a Risoe reader (Bøtter-Jensen & Duller 1992) using both the TL and the IRSL option. The main problem in dating the cave sediments dealt with in this work is poor bleaching of the mineral grains at the time of transport into the cave. The method combining TL and OSL data described by Hütt and Jungner (1992) was therefore also used. The bleaching properties of the mineral were studied using a UV lamp (Jungner 1988) and the data were compared with similar data obtained when sediments from the surrounding area where dated (Niemelä & Jungner 1991).

Luminescence signals were measured after additional doses were given to the natural sample. In addition, regeneration build-up curves were measured after different times of laboratory bleaching. Exponential fitting to the build-up curves was done by using a program developed by Dave Huntley (see Berger & Huntley 1989).

Gamma dose-rates were measured with a scintillation counter at each sampling point and the beta dose-rate was evaluated from beta activity measurements done with a beta counter (Bøtter-Jensen & Mejdahl 1988).

The dating results are presented in Table 2:

Table 2. The results of luminescence dating.

Sample	Layer	IRSL-date (ka)	TL-date (ka)	Dose-rate (mGy/a)	Sample ID
4	IIa	36	114	4.47	TL 446
3	IV	128	148	3.91	TL 445
7	V	87	102	4.18	TL 447

The dates in Table 2 are based on the assumption that the sediment was completely bleached when it was transported into the cave. The dates thus represent maximum ages. The differences between the IRSL and TL dates indicate that bleaching was only partial. Since the IRSL signal bleaches much faster than the TL signal the IRSL dates are closer to the real age for the time of sedimentation. On this basis the age of Layer IIa can be regarded as younger or equal to c. 35 ka. Similarly, the age of Layer V is younger or equal to c. 90 ka. The samples from Layer IV show an apparent age older than Layer V below. This can only be explained through very poor bleaching of this material. The materials in the two layers clearly differ from each other in consistency (see above).

A sample collected just outside the cave was dated to 2500 yr BP, which is in agreement with the geological history. This result also shows that luminescence dating of the sediments in the area can give reliable young dates.

5. The archaeology of the cave

5.1 General character of the deposits

The deposits of the cave either derive from littoral processes or have been secondarily influenced by them. The stratum surfaces are not quite horizontal but slope down towards the mouth of the cave. Because of this no part of the cave displays the complete stratigraphic sequence of seven layers (see Fig. 6). The bottom layers (VII–V) are only found at the back of the cave, 5–12 m from the entrance; Layer VII is present only in a shallow pit in the southwestern part of the cave. Layer IV stretches

8–9 m in from the cave mouth. In the front part it lies on top of bedrock, while at the back it covers Layer V. Layer III was detected only in the southeastern part of the cave. Layer II covers Layers IV and III in an area between 1.5 and 8 m from the entrance. Big boulders pushed into the cave by ice form its outer border. An interesting point is the ENE–WSW alignment of the boulder belt, which differs from the ancient coastline (E–W) in front of the cave.

Two fossil soil formations detected in the cave indicate longer terrestrial periods that affected the cave sediments. The interglacial paleosol of Layer IV 2 was formed in the gravel of the littoral deposit designated as Layer V. Its thickness at the cave mouth is 25–30 centimetres, but it thins down towards the back of the cave and tapers out c. 6 m from the entrance. The surface of Layer IV 2 was the floor of the cave for a long period (see also Chapter 5.1.2). During this time the maximum height of the cave was 1.8 m in the north-east near the entrance and about 1.6 m in the south-west. Elsewhere, the open space ranged from 1.4 m near the cave mouth to 0.5 m at the back.

The deposition of Layer II decreased the open space between the floor and the ceiling to 0.2–0.5 metres. The cave was filled nearly completely, apart from an area of several square metres near the western edge of the entrance. A soil formation in Layer II derives from a longer terrestrial period after the deposition of the layer some 36,000 years ago (see TL-IRSL date in Chapter 4). It was detected only in an area 1–3 m in from the mouth of the cave; closer to the mouth it was destroyed by a Holocene soil formation. The soil type is A/Es-Bv-C with a thickness of about 60 centimetres, which could indicate a cool dry climate at the time of its formation (B. Mahaney, pers. comm.).

Disturbances in or between deposits have mainly been effected by tree roots and burrowing badgers. Big tree roots had grown through the paleosols of Layers II and IV and up to five metres into the cave. In the front part of the cave four badger burrows were detected in the sediments, causing disturbance in Layer I and the upper part of Layer II. Towards the back of the cave two badger burrows caused disturbance in the sediments of Layers IV–VI in squares 46–49/19–20 and 48–50/15–16.

5.1.1 Stratigraphy and archaeological units

Four of the seven geological layers contain archaeological finds (see also Schulz 2002). They are grouped into three units:

Table 3. The archaeological units.

Archaeological Unit	Description	Number of finds	Geological layer	Isotope stage
	Sterile	–	I	1
I (Layer U 2)	Short-time occupation outside the cave	18		1
	Sterile	(12)	II	3
	Sterile	(3)	III	?
II (Layer IV–V)	Several occupations; Layer IV1 is secondary;		IV	5 (5e)
	Layer IV2 is a palaeosol with few structures	748		
	in situ, the material is partly redeposited;		V	5 (5e)
	Layer V is completely secondary			
III (Layer VI–VII)	Several occupations, Layer VI is		VI	?
	completely secondary;	112		
	Layer VII may be the remains of an older			
	palaeosol		VII	?

The few finds from Layers II and III derive from an implication-zone at the back of the cave, where sediments from Layers II–IV have been mixed. The finds originate most probably from Layer IV, because in all other parts of the cave Layers II–III are sterile. The archaeological material of Layer IV and Layer V is partly mixed (see Chapter 5.3), and was therefore analysed as one unit. As indicated by the TL and IRSL dates, the occupations of Layers IV and V both date from Isotope Stage 5. According to the geological evidence the occupations are most probably associated with the Eemian (OIS 5e). The difference in age between the occupations is unclear. The genesis and age of Layers VI and VII are still unknown. Only 2 sq.m of Layer VII have been excavated (yielding 24 artefacts); as of now there is too little information about Layer VII to determine it as a separate archaeological unit.

5.1.2 The pavement in Layer IV 2

In the northeastern part of the cave (squares 54–57/19–22) the surface of Layer IV 2 displays a pavement (Fig. 7). The excavation has so far uncovered an area of 5 square

Fig. 7. The pavement in Layer IV 2. Photograph National Board of Antiquities / H.-P. Schulz.

metres, where all the surface stones are aligned horizontally forming a flat surface. The only disturbances in this level plane are oval depressions secondarily produced by big boulders deposited later on top of the layer. The pavement marks an interglacial floor of the cave. It is the only archaeological *in situ* horizon that contains lithic artefacts; several burnt stones were found at its borders. The pavement is covered by Layer IV 1, which is part of the same paleosol as Layer IV 2, but has been redeposited in a probably littoral environment.

5.1.3 Traces of fire

Layers IV–VII contain no structures in clear context that would indicate the presence of hearths in the cave. The only traces of fire are scattered burnt stones in Layer IV 2 at the border of the pavement and in Layer V at the back of the cave. These stones were clearly in a secondary position. Magnetic susceptibility measurements by J.-P. Lunkka (then) of the University of Helsinki Department of Geology showed a number of strong anomalies in the fine sediment near the burnt stones, which indicates campfires during the occupations of Layers IV and V. In the south-eastern part of the cave in squares 50–51/15–16 the roof forms a vault created by splintering rock fragments. This could be the consequence of repeated fires here. Preliminary studies of the vault indicate the presence of charcoal particles covered by a layer of silicate oxide. The age of these traces of fire is still unknown. A correlation with the higher charcoal particle contents in the same squares in Layer V is uncertain.

Near the western edge of the cave entrance 1–2 m inside the cave a bigger lens of charcoal was found beyond big boulders, when the locals started clearing the cave in 1996. When archaeologists arrived in 1997, nearly all traces of the hearth had been destroyed. Stratigraphically the charcoal lens belongs to the period between the genesis of Layer II and the boulder belt, which derives either from the glaciation in the beginning of OIS 2 or from the littoral period during the Ancylus Lake stage. The hearth could be contemporary with the soil formation in Layer II (36 ka). No artefacts were found either in Layer II or in the remains of the hearth on top of it.

A pit hearth was discovered outside the cave on the top of littoral sediment derived from the Ancylus Lake stage. It was dated to 2500 yr BP and some quartzite flakes were found with it.

5.2 The raw materials

The lithic raw materials of the cave (Layers IV–VII) consist of at least six rock types (Table 4) of quite different »quality». The rock is partly of local origin; partly its origin is unknown. In Finland, quartz and quartzite have been commonly used during the Mesolithic and Neolithic periods. In addition, smaller amounts of (basic) volcanic rock and fine-grained quartzite have been employed. These raw materials have been studied archaeologically. Red siltstone and Jotnian sandstone, however, have never (or extremely seldom) been used as raw material for chipped stone implements during the Holocene. The fracturing qualities of these materials are not yet well known; the descriptions below are based on a few series of experimental reduction in 1998–1999.

Table 4. Lithic raw materials from Layers IV–VII.

		N	%	Weight	%
Fine-grained quartzite		10	1.2	120 g	2.4
Red siltstone		321	35.9	678 g	13.7
Volcanic rock		8	0.9	6 g	0.1
Quartzite	Red quartzite	133	14.9	1348 g	27.2
	Greyish quartzite	15	1.7	442 g	8.9
Quartz	Vein quartz	134	15.0	366 g	7.4
	Pebble quartz	8	0.9	171 g	3.4
Sandstone	Jotnian sandstone	257	28.8	1577 g	31.8
	Red sandstone	5	0.6	86 g	1.7
Others		2	0.2	168 g	3.4
Σ		893		4962 g	

• Fine-grained quartzite
Yellow-brown to reddish brown and grey variations. Contains grains of quartz and feldspar (50–200 μm) and, as a very fine fraction (< 20 μm), quartz, feldspar, muscovite and chlorite (SEM + EDS-analysis by the Geological Survey of Finland). The fracturing quality is moderate; the surfaces show features clearly.
Origin: Unknown, not local.

• Red siltstone
Dark red fine-grained silt- (or clay-) stone, which is geologically part of the Jotnian sandstone formation. It occurs as thin layers or lenses within the sandstone bedrock and contains quartz grains < 50 μm, hematite-pigments and very fine grained material. The fracturing quality is moderate, surface features are not always clear (flat bulbs, seldom ripples, coarse surface).
Origin: Unknown. The Jotnian sandstone bedrock area lies at the bottom of the Gulf of Bothnia and in the Pori region south of Karijoki. The sandstone appears mainly as boulders and pebbles in glacial and postglacial sediments in southwestern Finland. Pebbles of red siltstone are rather rare, very few pebbles have been observed in the till-covered sediments close to Susiluola Cave.

• Volcanic rock
Dark grey to black variations. Volcanic rock is the group name for a number of rock types; the black flakes from Susiluola could be amphibolite (not analysed). The fracturing quality is moderate.
Origin: Local (?). Appears as pebbles in the cave sediment (mainly intermediate volcanic rock; amphibolite and basic volcanic rock are missing). Volcanic rock was unimportant as a raw material, only eight small flakes have been found.

• Quartzite
Red and dark grey to light grey variations, partly coarse grained (> 1 mm). The fracturing quality is poor. Only strong direct percussion produces bulbs; usually there are no recognisable morphological features related to reduction.
Origin: Local. Appears as pebbles in the cave sediment and on the slopes of the hill.

• Quartz
White to colourless variations, appears as pebble quartz and vein quartz. The fracturing quality of pebble quartz is comparable to that of quartzite. Vein quartz has always

been a problem for archaeological research, because it behaves »chaotically». The fissures and cleavages in a vein quartz block prevent systematic reduction; on the other hand a block can be split by the »anvil-technique» in a short time to a large number of irregular flakes with uneven, sharp edges (Schulz 1990). Vein quartz is at the same time a poor quality raw material from a technical/typological point of view and a »good» raw material from a logistical one. The problem for research is that the flakes seldom bear recognisable morphological features related to reduction and are not often retouched.
Origin: Local. Appears as quartz veins in the bedrock of Susivuori Hill and pebbles on the hill slopes; few pebbles in the cave sediment.

• Sandstone
Different red variations (grouped as Jotnian sandstone and red sandstone). The fracturing quality of the red sandstone is quite poor. Only strong percussion produces bulbs; recognisable morphological features related to reduction are rare. The Jotnian sandstone is more fine-grained; some of the flakes show flat bulbs.
Origin: Local. Appears as pebbles in the cave sediment and on the slopes of the hill.

Fine-grained quartzite (core)	Red silt stone (core)	Quartzite, (core)	Quartzite (coarse var.)	Jotnian sandstone	Red sandstone	Vein quartz

Fig. 8. Examples of the different lithic raw materials.

5.2.1 The condition of the material

The lithic material shows abrasion of different degrees (see Fig. 9) produced in a coastal environment. In addition, a few pieces with wind abrasion were discovered in Layer IV. Six categories of abrasion are distinguished:

0 sharp edges, no abrasion (only material from Layer U2 outside the cave)
1 edges slightly rounded, surface features still clear
2 edges rounded, slight abrasion on surfaces
3 edges strongly rounded, partly destroyed, clear abrasion on surfaces
4 edges destroyed, no surface features left
5 completely rounded (not included in the catalogue)

Table 5. The degree of abrasion of the different rock types.

Rock type / degree of abrasion	0	1	2	3	4
Fine-grained quartzite	–	(25%)	(50%)	(12%)	(12%)
Red siltstone	–	8%	47%	27%	17%
Quartzite	–	4%	63%	27%	6%
Sandstone	–	6%	60%	24%	9%
Quartz	–	19%	51%	30%	–

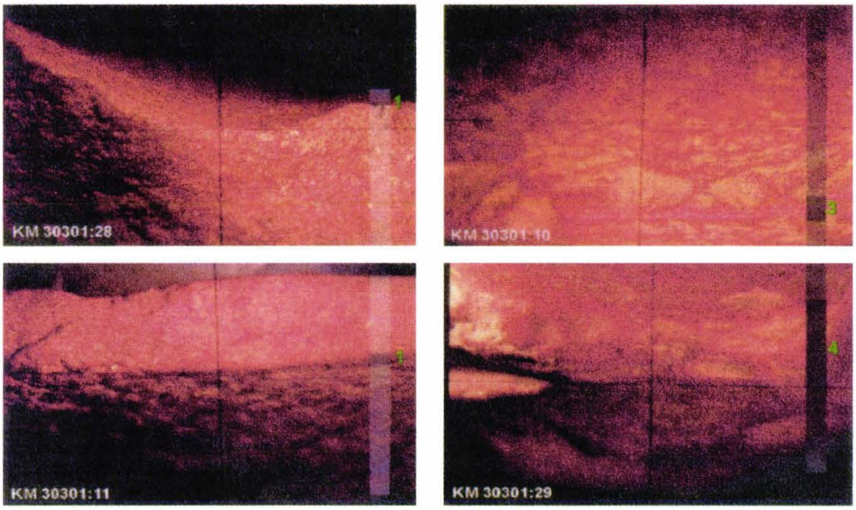

Fig. 9. Different degrees of abrasion (1–4) on red siltstone flakes.

No significant differences appear to exist between the different rock types in the degree of abrasion. More pieces with sharp edges occur in the quartz material. This may be a consequence of the physical fracturing qualities of vein quartz.

Table 6. The degree of abrasion on the lithic material in each layer

Layers /degree of abrasion	0	1	2	3	4
Layer IV	–	15%	62%	19%	4%
Layer V	–	4%	52%	33%	10%
Layer VI	–	6%	51%	34%	9%
Layer VII	–	–	40%	40%	20%

The degree of abrasion is astonishingly similar in Layers IV–VI. Each layer has probably been exposed to similar processes in a coastal environment. The lithic material from the pavement of Layer IV near the mouth of the cave (squares 54–56/19–21) and from the two excavated squares (54–55/20) of the block under the pavement (Layer IV 2) was clearly better preserved than the material from Layers IV 1, V, VI and VII. That is why Layer IV in Table 5 shows a higher amount of abrasion of degrees 1–2. Flakes with sharp edges (degree 0) were found only in the younger (Holocene) Layer U 2 outside the cave. Some kind of erosion must also have affected the lithic material of Layer IV 2, which had not been disturbed by the coastal environment.

5.2.2 The question of »artefacts» produced by natural forces

The analysis of the lithic material is complicated by the fact that the sediment layers of the cave that consist of different types of gravel contain a large amount of pebbles, partly of the same rock types that have been used as raw material. Naturally cracked rocks that appear to show evidence of deliberate reduction are known from many

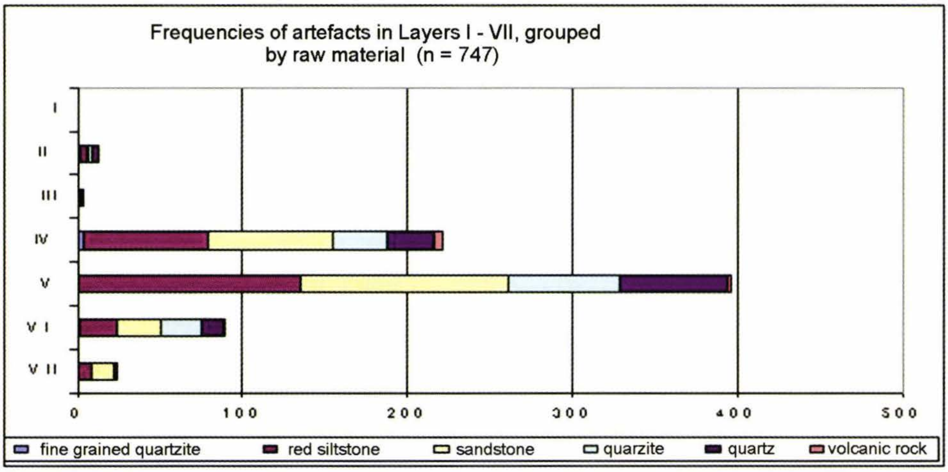

Fig. 10. Frequencies of artefacts in Layers I–VII grouped by raw material.

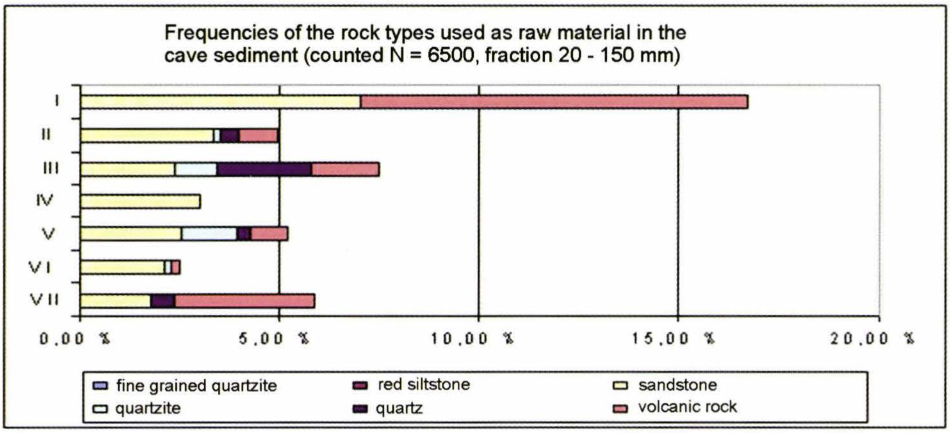

Fig. 11. Frequencies of the rock types used as raw material in the cave sediment.

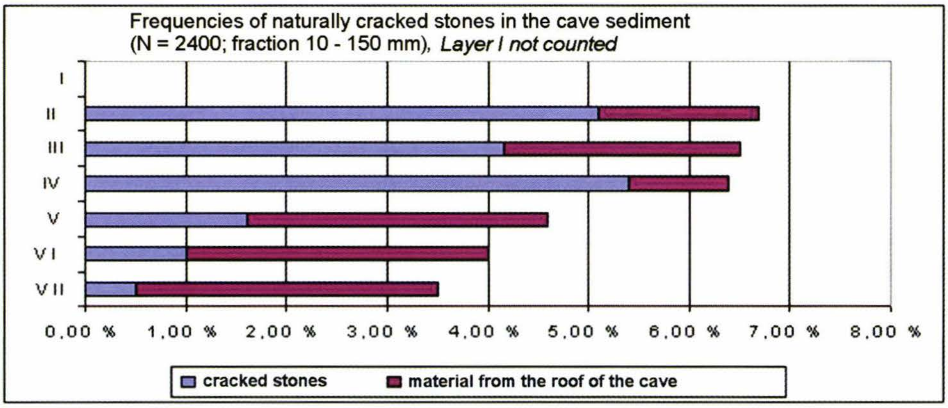

Fig. 12. Frequencies of naturally cracked stones in the cave sediment.

contexts (Bosinski et al. 1980; Clark 1958; Peacock 1991). In the case of Susiluola Cave, we can exclude »tephrofacts.» (Gaudzinski 1996), since there has been no volcanic activity in Finland after the Precambrian. However, we have to consider cracking by frost and by sediment movement, as well as abrasion and cracking caused by glaciofluvial processes and also the coastal environment. During the Quaternary glaciations, the cave was covered by the Fennoscandian Ice Sheet and was exposed to glaciofluvial processes. After the deglaciation, due to isostatic recovery the mouth of the cave was for a short period at the same level as the sea. During this period, water and pack ice pushing in during the winter affected the cave sediments.

Rock type frequencies and the amount of fractured stones were calculated for each layer (except for Layer I). For the analyses, 25% of the excavated sediment (a quarter of each square) was separated, and bigger pebbles (5–15 centimetres) were collected from about 50% of the excavated area. The comparisons of the frequencies of rock types with moderate physical fracturing qualities in the cave sediment with the frequencies of the defined artefact material in each layer (Figs. 10 and 11), as well as the comparison of the frequencies of fractured stones per layer (the complete material) with those of the artefacts (Figs. 10 and 12) show very clear differences:

- the artefacts appear in Layers IV–VII and concentrate clearly in Layers IV and V (the few pieces from Layers II and III derive from the implication zone at the back of the cave);
- in the cave sediment, sandstone, quartzite and quartz appear in nearly the same frequencies in Layers II–III and V, Layer IV contains only sandstone, while Layer I contains a clearly larger amount of sandstone and volcanic rock;
- volcanic rock is common in all layers except Layer IV, whereas the artefact material contains only 0.9% volcanic rock;
- the most commonly used artefact raw material, red siltstone (35.9%), is absent from the cave sediment;
- the amount of fractured stones in the cave sediment rises clearly from Layer VII to Layer II. Not including the material from the roof of the cave, the frequencies are 0.5–1.5% in Layers VII–V and 4.2–5.4% in Layers IV–II.

If natural processes had formed all or a major part of the lithic material classified as artefacts, the frequencies shown in Figures 10–12 should be at least similar. This is not the case; quite the contrary, they differ distinctly from each other.

Since the red siltstone and the fine-grained quartzite are not local, the material must have been brought into the cave. Morphological features related to reduction are quite often unclear in quartz, quartzite, and sandstone; especially among the smaller flakes the distinction between naturally fractured and artificial surfaces is problematic. For those flakes, the following selection criteria have been used:

- platform remnant (primary) + clear features on the ventral surface
- platform remnant (negative) + ventral surface features or at least one clear dorsal negative
- unclear or missing platform remnant + bipolar splintering (prox./dist.) or at least one surface with clear morphological features related to reduction.

5.3 The lithic industry of Layers IV and V

Layer V covers the bottom of the cave in its eastern part; at the back part, where older layers are present beneath, it fills the cave nearly to the ceiling. The layer is completely secondary: it was deposited in the cave during a coastal period. At this time, the whole cave was partly under water and was nearly completely »washed out», apart from Layers VI and VII, which were preserved at the back of the cave. Stream processes filled parts of the cave with gravel originating from sediments in the vicinity of the cave. Long distance transport can be ruled out: during the shore periods Susivuori-Hill was a small island many kilometres from the mainland. The archaeological finds of Layer V are remains of human activity near the cave.

Layer IV consists of two geological units: the undisturbed (*in situ*) Layer IV 2, preserved in a depression of the cave floor near its mouth (about 6 sq.m uncovered so far) and the secondary Layer IV 1, which was pushed into the cave during a coastal period after the human occupation. IV 1 and IV 2 are probably part of the same paleosol-formation; Layer IV 1 must represent the remains of a soil formed originally in front of the cave. Consequently, the artefacts as well as the burnt stones in Layer IV 1 originate in activities outside the cave.

Layer IV 2 is a paleosol developed in the gravel of Layer V. Due to this, Layer IV contains lithic material from the older occupation(s) of Layer V. Although this older material has been exposed to stronger abrasion, an exact differentiation is not possible. Because of this, the lithic material of both layers has been grouped together as one archaeological unit. The analysis also includes 4 modified pieces, 4 cores, and 49 flakes from Layers IV and V, which were removed from the cave in 1996, when the Geological Survey of Finland was emptying it before its protection as an archaeological site.

The lithic material of this unit derives from at least two occupations, but we have to take into account the possibility of several occupations for each of the layers. Because most of the artefacts have been moved from their original context by several natural processes, the lithic material is not representative of one or several of the occupations. Nor can it be treated as a statistical random sample, because the location as well as the amount and character of the activities that produced this material are unknown. The present excavation results allow presenting some technological and typological characteristics of the lithic industry of the Susiluola site.

5.3.1 Material of moderate fracturing qualities: red siltstone, fine grained quartzite, and volcanic rock

The analysis is based mainly on red siltstone (N = 325); fine-grained quartzite is represented by 3 cores and 7 small flakes and volcanic rock by 8 small flakes:

Table 7. Lithic material: red siltstone, fine-grained quartzite and volcanic rock

Flakes < 15 mm	256
Flakes >15 mm	61
Cores	7
Others/waste	2
Modified flakes	14
Modified cores	2
Modified pebbles	1
Σ	343

5.3.1.1 The tools

Only 4.3% of the lithic artefacts show secondary modification by retouch, percussion, or use. To exclude »retouch» caused by sediment movement or edge forming by abrasion only regular series of retouch/percussion were taken into account. Two of the cores have splintered edges, which have probably resulted from use as hammer stones. One cracked pebble (or thick flake?) was formed by percussion and bears a denticulate edge. All retouched flakes have primary (cortical) dorsal surface; the butt is either primary or negative. Edge modification is always simple margin retouch. A typological classification of the Susiluola Cave assemblage is problematic, because the physical fracturing qualities of the raw material are different from those of high quality flint. Nevertheless, four morphological types can be distinguished: (simple convex) side scrapers (Plate I: 1, 2), denticulates (Plate I: 4), notches (Plate I: 3) and retouched flakes. Some flakes show bipolar splintering of the proximal and/or distal end.

Table 8. Tools: red siltstone, fine-grained quartzite

Side scrapers	2
Denticulates	4
Notched tools	4
Retouched flakes	4
Coarse tool (pebble)	1
Hammer stones (cores)	2

5.3.1.2 The lithic production (Fig. 13)

The red siltstone was probably brought into the cave as small pebbles (< 10 centimetres, possibly mainly oval, with flat sides). They were cracked near one end and some of the primary flakes were modified (⇒ denticulates, ⇒ notches). The reduction continued with flaking in the direction of the long axis; some of the lateral flakes (with negative platform remnant and primary dorsal surface) were used for the production of side scrapers. Because of the abrasion and the insufficiency of the material, refitting has not yet been possible. A series of flakes (Plate I: 9–16) and three cores (Plate III: 1–3) indicate a special reduction technique:

The flakes have parallel sides and
- 2 parallel dorsal negatives (same flaking direction)

or – 1–2 (parallel) dorsal negatives and cortex remains

or – 1 dorsal negative (same flaking direction) and lateral negatives (transverse flaking direction).

The butts are negative or (seldom) dihedral, faceted butts are absent.

The cores are polyhedral with 2–3 platforms; they have series of parallel negatives along two axes crossing each other. A part of the core surface (within the smaller angle between the axes) is cortical.

These cores as well as some of the flakes indicate a reduction starting with parallel flaking from one platform, rotating the core and using the negative surface as a new platform (without preparation), removing the second series of flakes, rotating the core again, and continuing the reduction in the same way. This reduction technique can be compared to those of some well-investigated assemblages of Isotope Stage 5e (Sitlivy 1996; Moncel 1998; Bourguignon 1998; see next chapter). However, the technique

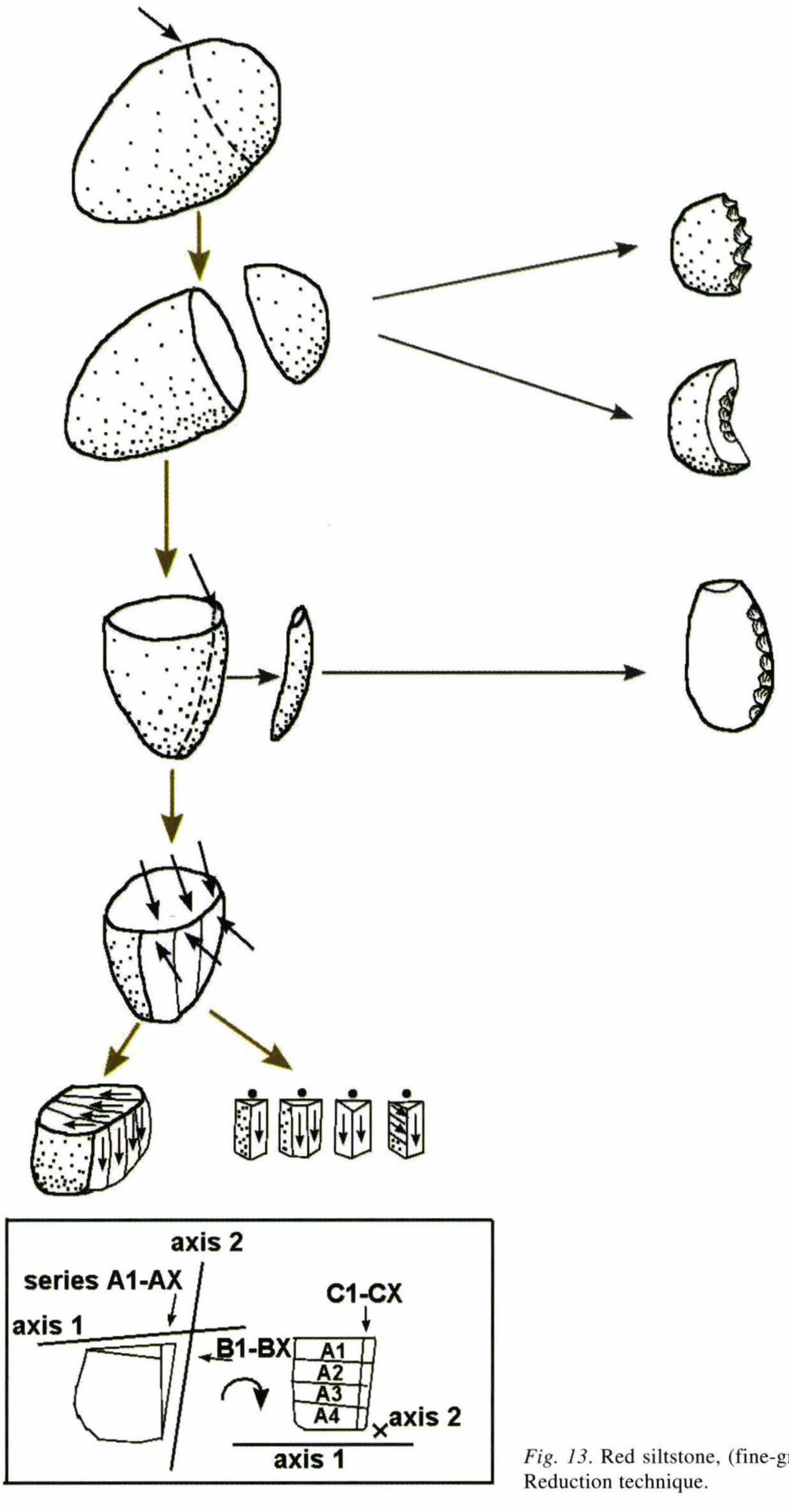

Fig. 13. Red siltstone, (fine-grained quartzite): Reduction technique.

cannot be confirmed by core refitting; at the moment, we are only able to say, »That is what it looks like.» Some of the flakes with parallel sides could originate from a different reduction technique (Levallois flake?, Plate III: 1, 2); but this remains speculation. There are no other indications and red siltstone as a raw material is probably too low quality for the Levallois technique.

5.3.2 Material of poor fracturing qualities: quartzite, sandstone, and quartz

The analysis includes middle-grained greyish quartzite (n = 15), coarse-grained red quartzite (n = 133), red sandstone (n = 5), Jotnian sandstone (n = 257), and pebble quartz (n = 8). The investigation of the vein quartz material (n = 134) has not yet been finished and the reduction technique will not be presented in this context.

Table 9. Lithic material A: quartzite, sandstone, pebble quartz; B: vein quartz

A	N	B	N
Flakes < 15 mm	311	Splinters/waste < 15 mm	86
Flakes >15 mm	83	Flakes/waste >15 mm	35
Cores	11		–
Splintered pieces	2	Splintered pieces	3
Others	4	Others	2
Modified flakes	3	Modified flakes/waste	8
Modified pebbles	5		–
Σ	419	Σ	134

5.3.2.1 The tools

Five pebbles are modified by percussion (Plate II: 1–2); only three of the flakes (0.7%) are modified by retouch (*cf.* 6% of the vein quartz flakes or waste). The pebbles selected for modification are flat and more or less oval and include one ventifact (»Dreikanter»; Plate II: 2). The same technique was used in all cases: strong direct strikes from one side, either a centripetal series covering about a third of the periphery or a series of a few strikes on one edge. The question naturally arises, whether these artefacts are cores or tools. Since they were found in a clear stratigraphic context with evidence of different reduction techniques on the same raw materials, we consider the pieces coarse pebble tools (»choppers»).

The few modified flakes are rather large, with mainly cortical dorsal surface and large (negative) butts (Plate II: 3–4). The striking angle and the bulb indicate strong direct percussion. Unfortunately the pieces have suffered from strong abrasion and the surface features are not clear. Because of edge damage the retouches are not completely preserved, which complicates the morphological classification. Although the retouched edges are somewhat irregular, the pieces have been classified as side scrapers on the basis of the other morphological features.

5.3.2.2 The lithic production (Fig. 14)

The raw materials are local: they appear in frequencies of 1.5–3% in the cave sediment (Layers IV and V). Three different production chains can be distinguished:

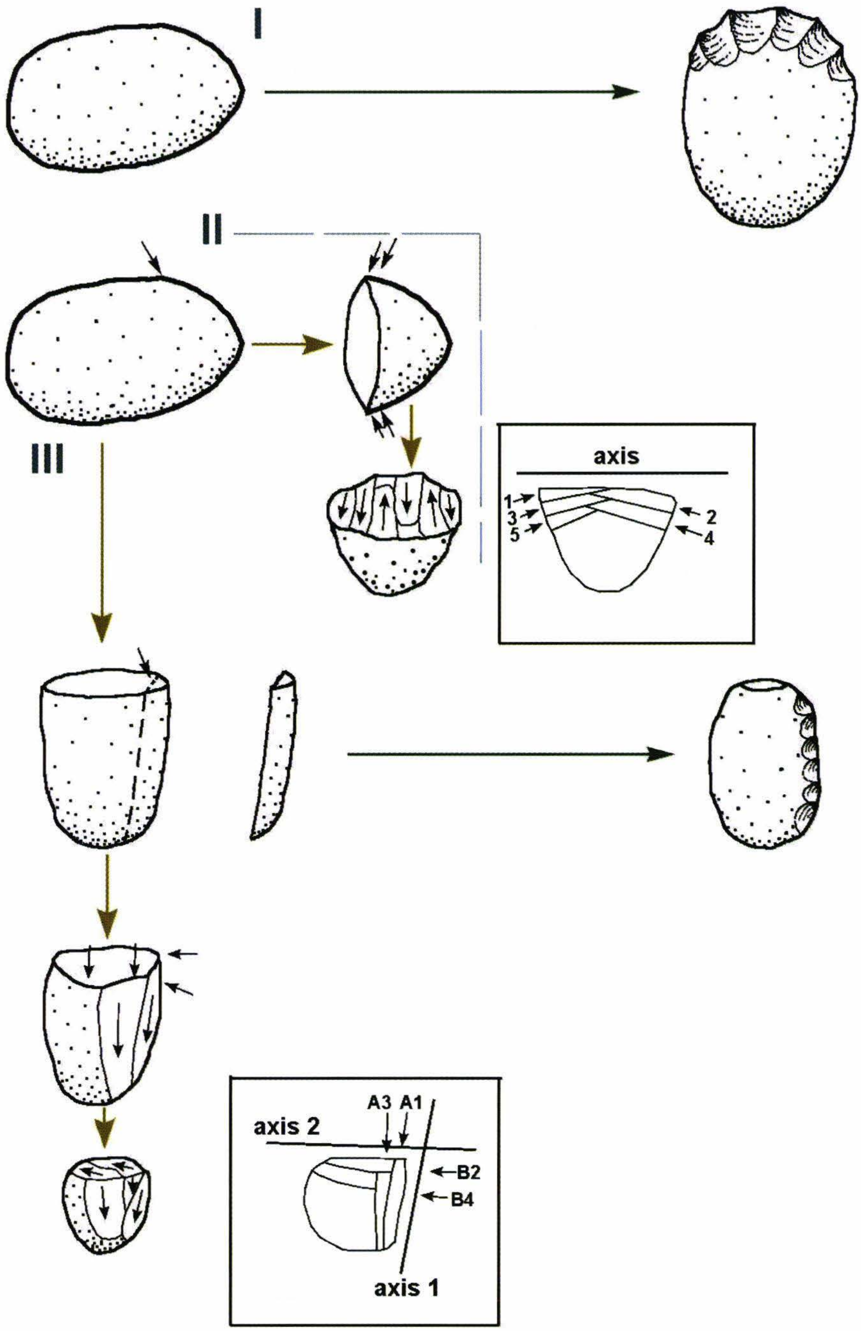

Fig. 14. Quartzite, sandstone, (pebble-quartz): Reduction technique.

- I Direct modification of the pebble by flaking from one side (coarse quartzite, sandstone)
- II Cracking the pebble, using the half with acute angles between the platform and the cortical surfaces as a core, and starting reduction by alternate flaking on one axis (parallel to the platform). The technique produces flakes with cortical butts, negative dorsal surfaces and partly lateral cortical surfaces. The cores display 40–60% of cortical surface and have one side (sometimes flat, often prismatic) with alternating negatives (quartzite, sandstone, pebble quartz; Plate III: 4, 7, 8, 10).
- III Cracking the pebble; the reduction continued with flaking in the direction of the long axis. The lateral flakes (with negative platform remnant and primary dorsal surface) were in some cases used for the production of side scrapers. The next step is unclear. Up to now, there is no evidence of core preparation in the assemblage. The core remnants (Plate III: 6, 9) indicate alternate flaking along two axes crossing each other. 35% of the flakes have cortical butts (including flakes from Production Chain II) and 65% have negative butts. Dihedral and faceted butts are absent (middle-grained quartzite, pebble quartz).

Table 10. The operation chains of the different raw materials of Layers IV–V.

Rock type	Provenance	Preparation	Production	Use
Red siltstone	unknown, not local	absent	*reduction: parallel flaking on 2 crossing axes, rotation of the core*	denticulates and notches (primary flakes)
Fine-grained quartzite		?	polyhedral cores, flakes with parallel dorsal negatives; negative/dihedral butts	side scrapers flakes?
Medium-grained quartzite	cave, local	?	*Reduction: alternate flaking on 2 crossing axes*	side scrapers
Pebble quartz		absent	Cores with two planes, flakes with cortical or negative dorsal surface and negative butt	flakes?
Coarse-grained quartzite Sandstone Pebble quartz	cave, local	absent	*»nucleus-chopper» reduction*	»choppers»
			reduction: alternate flaking on one axis cores with one (prismatic) reduction surface, flakes with cortical butt	flakes?
Vein quartz	cave, local	absent	*Reduction by anvil technique* Bipolar cores, splintered pieces *(to be presented later)*	flakes

6. The pollen record

6.1 Methods and material

A total of fifty samples from squares 56/20, 55/21, 54/21, 53/20, 51/15, 50/15, 50/16, 48/18, and 46/20 were analysed to determine their pollen content. Three times the usual amount of sample material, c. 3 cubic centimetres, was employed for the pollen

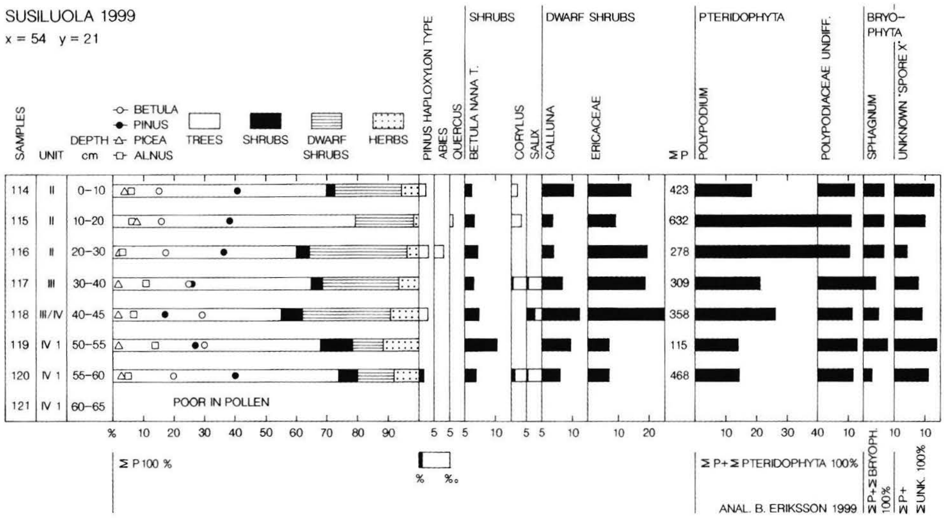

Fig. 15. Simplified pollen diagram (selected taxa) of the sample series from square 54/21 (D) in Susiluola Cave.

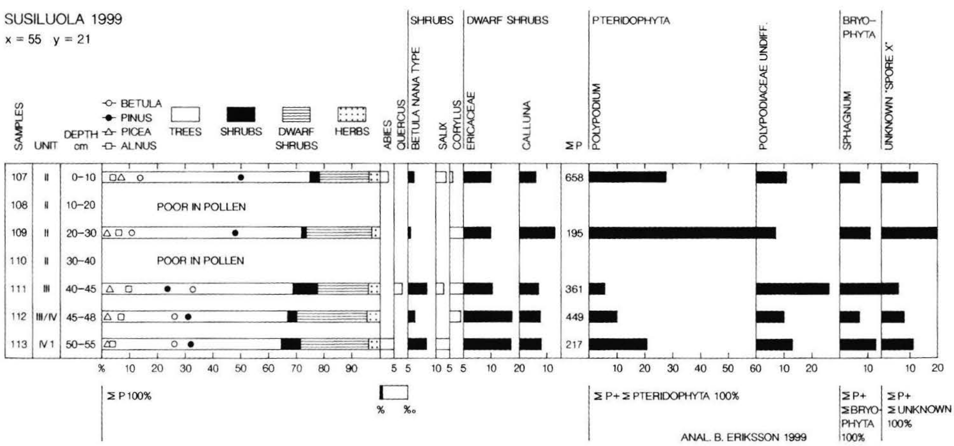

Fig. 16. Simplified pollen diagram (selected taxa) of the sample series from square 55/21 (B) in Susiluola Cave.

analysis. The coarsest mineral fraction was removed by decanting in hydrochloric acid, after which the samples were treated with the conventional HCL-HF-KOH method. The material was mounted in glycerine and, whenever possible, 300–500 land pollen grains per sample were counted. The sums ($\sum P$ includes trees, shrubs, dwarf shrubs, and herbs excluding aquatic taxa) from which the percentages of the pollen and spore types were calculated are presented in diagrams (Figs. 15–17).

The relative pollen frequency varied strongly. Samples with a very coarse grain structure were completely sterile. In most of the samples the pollen frequency was fairly low, although fern spores could still be plentiful. In Layer IV the pollen frequency was usually low/moderate. At the back of the cave (squares 48–50) in Layers

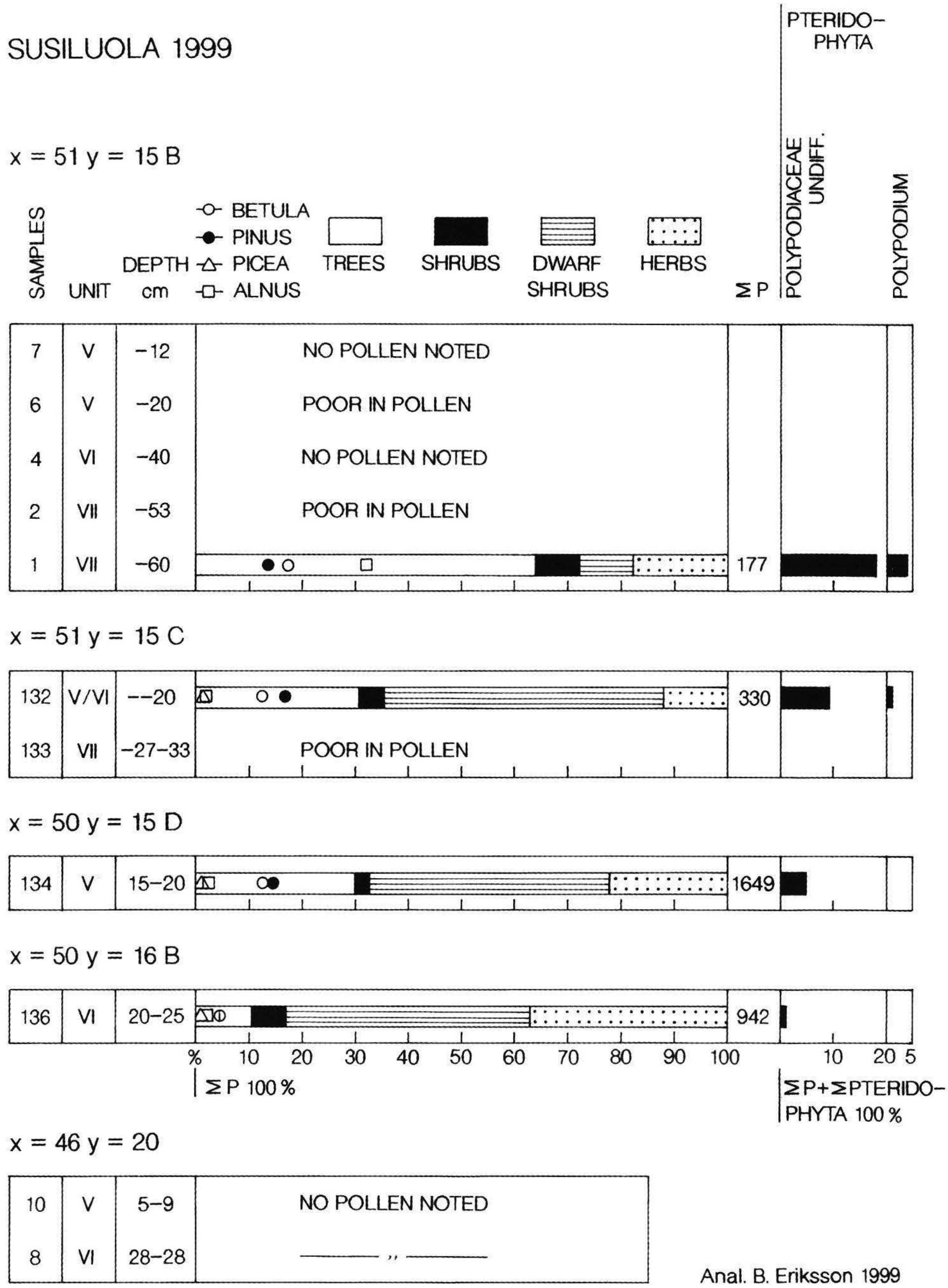

Fig. 17. Percentages of total pollen (∑P = 100%) and ferns (∑P + ∑Pteridophyta = 100%) in squares 51/15 (B ja C), 50/15 D, 50/16 B, and 46/20 in Susiluola Cave.

V and VI the pollen frequency was substantial, considering the grain structure of the sample material. Square 46/20, which was the farthest inside the cave of the squares studied, did not contain any organic material in Layers V and VI. The samples contained large amounts of fungal spores and hyphae, as well as carbonised cell tissue; charcoal was fairly plentiful particularly in square 50/15, Layer V and in the front part of the cave in square 56/20, Layer IV1/IV2, which was otherwise poor in pollen and spores.

The pollen grains were well preserved apart from the Ericaceae pollen and the *Polypodium* spores, part of which were corroded. Most samples contained a large amount, up to 26% ($\sum$P + $\sum$Unknown = 100%) of spores that are as of now unidentified (spore X), as well as of a type of unidentified microfossil.

6.2 The pollen assemblages

The pollen flora of the cave is fairly identical from sample to sample, but the proportions of the pollen groups vary strongly. The diagrams of some of the sample series taken in 1999 (squares 55, 54, 51, 50, and 46) are presented in Figures 15–17. The pollen spectra from the cave fill have provisionally been arranged in three pollen assemblages (Su 1–3) and correlated with the different layers of the cave deposits. The pollen assemblages, however, are not unequivocally associated with particular layers; one pollen assemblage may in different squares be found in different layers.

Su–1. Six samples were analysed from Layer VII (squares 50/15D and 51/15B). In three samples from the bottom part of the layer the pollen spectra were dominated by arboreal pollen, one was very poor in pollen, and two samples from the top part of the layer contained the same dwarf shrub and herb species as pollen assemblage Su–2. The latter species have probably been mixed into Layer VII at a later stage through water action. The arboreal pollen flora is dominated by *Betula*, but *Alnus* is also abundant (as much as over 30%) and even *Corylus* reaches several percent, with a maximum of 6%. *Picea* and *Ulmus* pollen grains are found sporadically. In contrast to the other cave layers, the proportion of grasses is as high as over 10% in the bottommost samples. Ferns (Polypodiaceae undiff. and *Polypodium*) reach a maximum of c. 20%.

Su–2. The pollen spectra are dominated by dwarf shrubs and herbs; their combined share of the total pollen varies between 64.2% and 87.7%, while the herbs reach 11.2–38.7%. The distribution area of this pollen assemblage is centred at the back of the cave in squares 48/18, 49/19, 50/15–16, and 51/15B (Layers VI–IV and II). The same dwarf shrub and herb species are present in most of the cave samples in smaller proportions, dwarf shrubs (*Calluna* and other ericaceous pollen) being the most common. The arboreal pollen includes, in addition to *Pinus*, *Betula*, and *Alnus*, a small amount of *Picea*. Grains of *Corylus* pollen are found occasionally. The ferns present consist mostly of Polypodiaceae spores and their share reaches a maximum of 9%. Aquatic plants are represented by just one pollen grain of the *Sparganium* type.

The most abundant herb species are *Melampyrum*, *Filipendula*, *Trifolium* spp., Apiaceae, and *Epilobium*. In addition, the taxa *Campanula*, *Centaurea cyanus*, and *Helianthemum* are represented in the species list that consists almost exclusively of insect pollinated plants. The proportion of *Artemisia* does not reach above 1% in any of the samples from the cave deposits, and the pollen value of Poaceae is 3.5% at its highest (with the exception of Su–1). As of today the total of identified herb taxa is 44.

Su–3. In Layers IV–II (squares 55–54/21 and 53/20) the pollen spectra are dominated by trees, with *Pinus* reaching in most cases the highest values. In addition to *Betula*, *Alnus* and *Picea* are present, with the maximum values of 21.1% and 3.1%, respectively. Dwarf shrubs reach as much as over 40%, while the share of herbs amounts to a good 10% at its highest. The herb species are the same as in the previous pollen assemblage (Su–2). The small shrub portion consists mostly of *Betula nana* type pollen. The maximum values of fern spores in Layer II reach 70%, while the unidentified spore reaches 14.2%.

6.3 Discussion and conclusions

The taphonomy of fossil pollen and spore assemblages in cave sediments is often very complicated and difficult to interpret (*cf.*, Coles *et al.* 1989). Pollen and spores make their way into caves with wind, water, animals, and people. Most of the airborne pollen derives from the vegetation at the cave mouth and the local vegetation zone, the rest primarily from the regional vegetation zone. The vegetation at the cave mouth acts as a filter for the airborne pollen, which leads to under-representation of the regional vegetation. Pollen analyses of cave deposits often show large amounts of fern spores; even today the cave mouth area often carries a plentiful fern vegetation. The sporangia usually open during the night and the spores are then transported onto the cave floor with the cold air current.

Before the present study, the sedimentary pollen of only two caves in Finland had been studied (Salonen & Kejonen 1991). In both caves the pollen assemblages reflected the Holocene vegetation development. According to the authors, pollen analysis can in exceptional cases be used to estimate the age of cave deposits, but a study of the sedimentary record is essential as a complementary factor. The pollen concentration was found to wane quickly from the top of the deposits downward, as well as towards the back of the cave, where the pollen rain is small and selective. The over-representation of the vegetation at the cave mouth may complicate comparisons with the known vegetation development.

In Susiluola Cave the pollen values of *Alnus* and *Corylus* in the pollen spectra of Layer VII (Su–1) reflect a temperate substage of an interglacial. The completely dwarf shrub and herb dominated pollen assemblage (Su–2) found at its most abundant in Layers V and VI has been transported into the cave by insects or other animals (including man) and has probably been deposited *in situ* at the back of the cave. The herb pollen indicates the presence of meadows of varying dampness among the local vegetation. Heather and other ericaceous dwarf shrubs as well as *Melampyrum* have probably been present in the vicinity of the cave the same way as they are today. Grass pollen and immature pollen are absent, contrary to the sediments of, for example, Geissenklösterle (Wille 1978) and Ramesch (Hille & Rabeder 1986) Caves, where the pollen has been interpreted as having found its way into the cave mostly with animal remains.

After the Weichselian and the retreat of the continental ice, Susivuori Hill was within the sphere of the Ancylus Lake stage of the Baltic Sea. As the isostatic uplift proceeded, the littoral processes of the Ancylus Lake reached the cave. At this stage some of the pollen content of the older sediments was probably washed into Layers III and II, forming the mixed, tree dominated pollen flora (Su–3) in Layers IV–II. Pollen of the contemporaneous vegetation was also transported into the cave. The

Armeria pollen, as well as some of aquatic plants, possibly even most of the fern spores, probably derive from the Ancylus Lake shore stage. The *Picea* values indicate that at least part of the pollen content of Layers IV–II derives from a pre-Weichselian interglacial. After the later part of the Eemian Interglacial (Eriksson 1993; Donner 1995), spruce has only been present on the Finnish west coast during the Holocene, becoming abundant in the area c. 3500 yr BP (Aartolahti 1966; Berglund *et al.* 1996). It is unlikely that such amounts of spruce pollen could have found their way in the cave filling with wind or seep water during the Holocene. The amount of Holocene pollen in the cave sediments seems to be modest as a whole: *Juniperus* pollen, for example, was only occasionally found in the samples, although juniper bushes are common on Susivuori Hill today.

Table 11. Tentative correlation of the lithostratigraphic units of the cave fill with the pollen assemblages. The most significant characteristics of the pollen assemblages are expressed as percentages of total pollen (∑P).

UNIT		POLLEN ASSEMBLAGES
II		AP-DOMINATED
III	**Su–3**	*Pinus* 17–52, *Betula* 14–39, *Alnus* 2–14,
IV	(mixed)	*Picea* 1–8, Ericaceae 11–42
V		NAP-DOMINATED
VI	**Su–2**	Ericales 44–81, herbs 11–39
		(*Melampyrum* 1–16, *Filipendula* 3–12)
		± AP-DOMINATED
VII	**Su–1**	*Alnus* 7–32, *Betula* 12–26, *Pinus* 10–13,
		Corylus 0.6–6, *Picea* < 1

7. Faunal studies

The history of the Finnish vertebrate fauna after the last glacial periods is still poorly known in spite of the intensified research of the past decade (Ukkonen 1993, 2001, 2002; Rankama & Ukkonen 2001). The main problem of faunal history studies in Finland is the scarcity of subfossil stray finds (Kurtén 1988), which is due to the poor preservation of bones in the acid soil. Fortunately the Holocene history of Finnish vertebrates can also be studied with the help of animal remains from archaeological sites, where bones have been preserved due to intensive heating (Ukkonen 1993, 1997, 2002; Rankama & Ukkonen 2001).

The faunal situation prior to the last glacial maximum ca. 18,000 yr BP is even less known. The mammoth bones found in different parts of Finland date from this period (Ukkonen & al.1999), and so does the reindeer antler from Tornio (Siivonen 1975). The oldest known indication of mammalian presence is the beaver dam deposit from Vimpeli, Western Finland, which is dated to 107,000 years ago (Aalto & al. 1989), that is, to the last interglacial period.

The excavation of Susiluola Cave offered a unique opportunity to look for animal remains more than 100,000 years in age. The circumstances in a cave are favourable for bone preservation because of the relative stability of the temperature and the minimal physical disturbance of the sediments. The main goal of the zoological studies at Susiluola Cave was to find new fossils or subfossils in order to reconstruct past environments.

During the prospecting of the cave in 1996 and the excavations in 1997–1998 a quantity of bones of mammals, birds, fish, and amphibians were found in the cave, both over (Table 12) and under (Table 13) the sediment bed. However, none of these finds could be reliably associated with the oldest sediment layers. Burrowing animals, especially the badger, have disturbed some parts of the layers leading to a situation where bones — and even pollen — now reside in a »wrong» layer. Stratigraphic problems have also been caused for instance, by hibernating frogs. Small bones found within the sediment were found to be only about 220 years old.

Table 12. Animal bones found in Susiluola Cave. Upper layer. Bones from the eagle-owl nest (1997) and sediments with badger burrows (1998) are excluded.

Species	1996	1997	1998
Small and medium-sized prey species:			
Felis sp. (cat)	x	–	x
Castor fiber (beaver)	–	x	x
Ondatra zibethica (muskrat)	–	x	x
Lepus sp. (hare)	x	x	x
Tetrao urogallus (capercaillie)	–	x	x
Tetrao tetrix (black grouse)	–	x	x
Anas platyrhynchos (mallard)	–	–	x
Esox lucius (pike)	–	x	x
Large prey species:			
Phocidae (seals)	–	x*	x
Sus scrofa (boar)	–	x	–
Ovis/Capra (sheep/goat)	x	x	x
Alces alces (European elk)	–	x	x
Rangifer tarandus (wild reindeer)	x	x	–
Species living in the cave:			
Canis lupus (wolf)	x	–	–
Canis sp. (wolf/dog)	–	–	x
Meles meles (badger)	x	x	–
Canidae cf. *Vulpes* (red fox?)	–	–	x

* 14Cdating: 2505 ± 75 BP (Hela-230)

Table 13. Animal bones found in Susiluola Cave. Bottom layer. Bones from the eagle-owl nest (1997) and sediments with badger burrows (1998) are excluded.

Species	1996	1997	1998
Large and medium-sized prey species:			
Felis sp. (cat)	x	–	–
Lutra lutra (otter)	–	x	–
Arvicola terrestris (water vole)	x	–	–
Lepus sp. (hare)	x	x	x
Tetrao urogallus (capercaillie)	x	–	–
Tetrao tetrix (black grouse)	–	x	–
Parus sp. (tit)	–	–	x
Amphibia (amphibians)	x	–	x*
Large prey species:			
Rangifer tarandus (wild reindeer)	x**	–	–
Species living in the cave:			
Canis lupus (wolf)	–	x	–

* 14C-dating: 220 ± 65 BP (Hela-272), ** 14dating: 1030 ± 65 BP (Hela-229)

8. Discussion

The Susiluola cave site is in many respects interesting as well as problematic. It is the first archaeological site within the area of the Fennoscandian Ice Sheet that has provided evidence of human activity in northern Fennoscandia before the last glaciation. Most of the lithic material derives from a clear stratigraphic context, from Layers IV and V that could be dated by several methods.

Layers I, IV, V, and VI in Susiluola Cave are clearly littoral deposits, while Layers II and III may have been originally deposited by a glacier and later sorted by littoral processes. The age and morphogenesis of Layer VII are so far unknown. The geological evidence suggests that Layer V was formed during the deglaciation stage of the Saale Glaciation, while Layer IV (paleosol) was formed in its top part during the Eemian Interglacial. The stratigraphic position of Layer V and the fact that it is a littoral deposit indicate that it was formed during a period when the sea level had reached the cave mouth during the process of land upheaval after the Saale Glaciation. The results of the analyses of clay minerals and Fe-Al extracts from Layer IV indicate that the layer was formed under warmer and more humid conditions than today. The analysis results correspond to the results from a paleosol studied at Kärjenkoski, some 20 km south of Susiluola Cave. The Kärjenkoski paleosol was TL-dated to 137,000–144,000 yr BP (Kujansuu *et al.* 1991).

The luminescence dating of Layer IV gave the dates 128 ka (IRSL) and 148 ka (TL), the latter representing the maximum age. For Layer V the results showed clearly younger ages: 87 ka (IRSL) and 102 ka (TL). According to this result Layer V should be slightly younger than 90 ka, which, however, is in contradiction with the geological and pedomorphological results.

Employing cave palynology in archaeological investigations involves serious taphonomical and methodological problems (*e.g.*, Coles *et al.* 1989; Carrión *et al.* 1999; Navarro Camancho *et al.* 2000). Nevertheless, some palaeoreconstructions of pollen records from caves inhabited by man in continental Europe have been done. These indicate a number of cold and warm stages (*e.g.*, Bastin *et al.* 1986; Schneider 1986; Carrión *et al.* 1998, 1999). In Susiluola Cave the correlation of the pollen and lithostratigraphy is not very clear (Table 11). The arboreal pollen assemblage (Su–1) in Layer VII reflects interglacial conditions. The abundant dwarf shrub and herb pollen (Su–2) in Layers VI and V may have been transported into the cave with animals/people. The pollen in assemblage Su–3 (Layers IV–II) is mixed. The tree pollen is presumed to be derived mainly from some interglacial predating the Weichselian glaciation; a Holocene date is considered unlikely.

Considering all the results, the date range of the uppermost layers that contain archaeological finds (Layers IV and V) spans from the Eemian to the Early Weichselian (OIS 5; c. 132–74 ka). Because a sea transgression affected Layer V and the soil formation of Layer IV is interpreted as interglacial, the most probable date for these layers is the Eemian Interglacial (OIS 5e; c. 132–120 ka). It is of great importance for the dating of the occupation in Susiluola Cave that the artefacts of Layer V show clear abrasion produced in a coastal environment. This proves their contemporaneity with Layer V.

The interpretation of the site is complicated by several factors. It is chronologically and geographically »isolated»: previously, the first known traces of human occupation in Finland dated from the Early Holocene and the nearest Central and East European sites dated to Isotope Stage 5e are at a distance of more than 1,000 kilometres. Most of the evidence of the occupations on Susivuori Hill has been destroyed by the subsequent glacial and littoral phases; only the cave itself, functioning as a sediment trap, has preserved Pleistocene deposits and the archaeological material embedded in them. Several (glaciofluvial or littoral) processes have, however, partly disturbed even these deposits and the lithic material has suffered from abrasion. Because of the acidity of the bedrock and the gravel layers, no Pleistocene faunal material has been preserved. At this time, the excavation results only allow presenting some technological and typological features of the lithic industry of the interglacial Layers IV and V.

A noticeable characteristic of the lithic material of Layers IV–V in Susiluola Cave is the coexistence of different operation chains with, especially, differing reduction techniques (*cf.* Boeda *et al.* 1990). The »Clacton» technique appears on sandstone, quartz and quartzite: »nucleus-chopper» reduction, alternating flaking on one axis, alternating flaking on two crossing axes, and series of flakes that show typical signs of pebble core reduction (Chabay & Sitlivy 1993; Sitlivy 1996). Technological parallels for these reduction techniques are found, for example, in the quartz and quartzite material from the Eemian levels of Predmosti II (Moncel & Svoboda 1998) and the quartzite material of the Eemian level 5 of Scladina Cave (Bonjean 1998; Moncel 1998; Otte 1998). On the other hand, a more developed technique has been employed for the reduction of the raw materials with better physical fracturing qualities, fine-grained quartzite and red siltstone: parallel flaking on axes crossing each other, rotating the core. This technique is associated with the Middle Palaeolithic (Boëda *et al.* 1990; Chabay & Sitlivy 1993); during Isotope Stage 5e it has parallels in the lithic material of Scladina Cave (Sclayn, Belgium; Otte & Bonjean 1998; Bourguignon 1998; Moncel 1998).

The few cores and flakes from Susiluola Cave do not provide enough evidence for an exact typological classification, but the indicated reduction technique can be regarded as Mousterian. The quartzite and siltstone flake tools (side scrapers, notches, and denticulates) also fit in this frame. Nevertheless, assignment into a precise assemblage type (Rolland 1999; Moyer & Rolland 2001) is not possible. Since these different reduction techniques derive from the same stratigraphic context, they obviously do not represent technological or typological traditions, but are linked to the occurrence, cobble size, and fracturing qualities of the lithic raw material. The very hard medium-coarse grained quartzite can be flaked only by very strong direct strikes; the »Clacton»-technique is necessary for its reduction. Red siltstone and fine-grained quartzite allow the use of more developed core reduction techniques, but the small size of the red siltstone pebbles had a clear effect on the lithic production. The absence of high quality flint from the Susiluola Cave raw material inventory might be the reason why there is no clear indication of the Levallois technique. Nevertheless, the other indicators allow placing the lithic assemblage from Layers IV– V in Susiluola Cave in the early (Eemian) Mousterian technocomplex.

The discovery of the Susiluola site gives new perspectives on the behaviour of Neanderthal populations especially because of its high latitude and its probable dating to the Eemian. It was not, however, completely unexpected. The geographic span of the Eurasian Neanderthals covers a belt extending from Western Europe (Portugal, Spain, France, and Southern England) to Southern Siberia, crossing Central and Southern Europe. Its southern border runs from Gibraltar across the Mediterranean to the Levant and the Middle East. The northern border of the find locations follows astonishingly well the border of the maximum of the late Weichselian glaciation. This indicates that a number of the northernmost Neanderthal sites were probably destroyed by the last glaciation, and that we actually do not know how far north the Neanderthals spread. According to Rolland's model of the development of Middle Palaeolithic settlement, land use, and subsistence, occupation of mid-latitude habitats can be observed already during cold stadials of the Saale glaciation (OIS 6; Rolland 1990:358 ff.; Rolland 1999, Rolland 2001). During the Eemian settlement systems changed and the territories of population groups grew at the same time as mobility increased. In addition, occupation spread to more high latitude and steppe habitats as well as to alpine habitats to an altitude of over 2000 metres. Considering this background, the occupation of Susiluola Cave and its date are not too far outside the frame of the present research concerning the Middle Palaeolithic.

Acknowledgements

The author of the chapter on dating wishes to express his thanks to Kari Korjonen and Kari O. Eskola for laboratory measurements.

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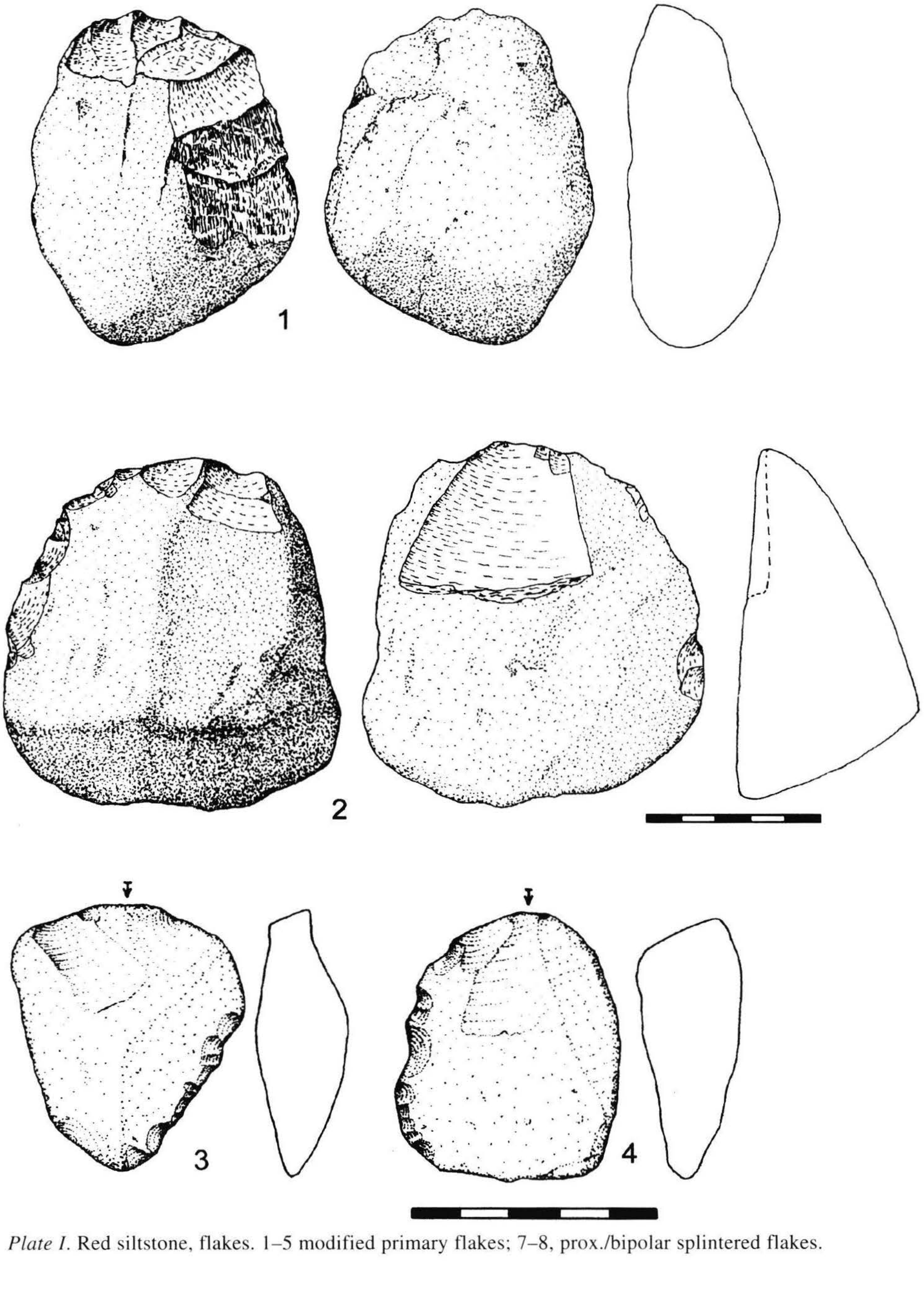

Plate I. Red siltstone, flakes. 1–5 modified primary flakes; 7–8, prox./bipolar splintered flakes.

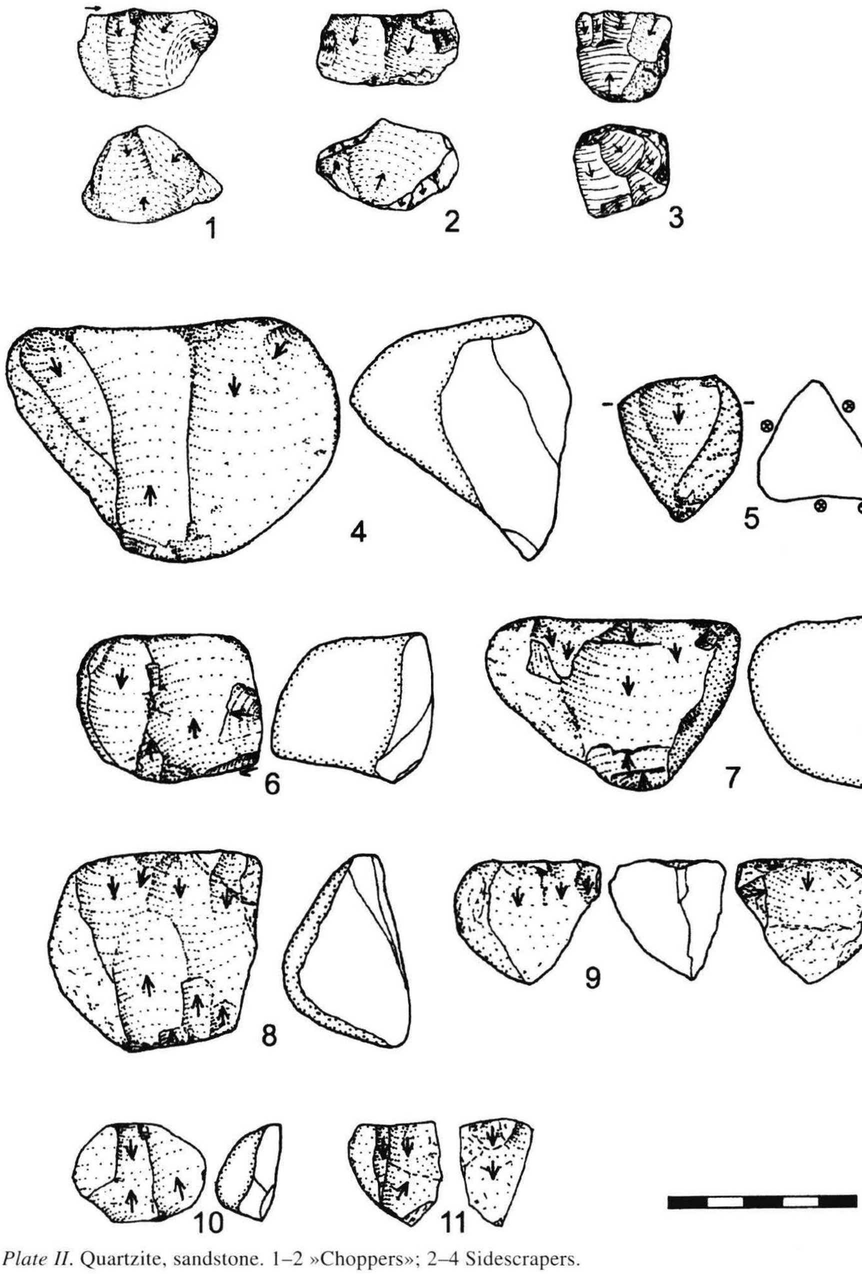

Plate II. Quartzite, sandstone. 1–2 »Choppers»; 2–4 Sidescrapers.

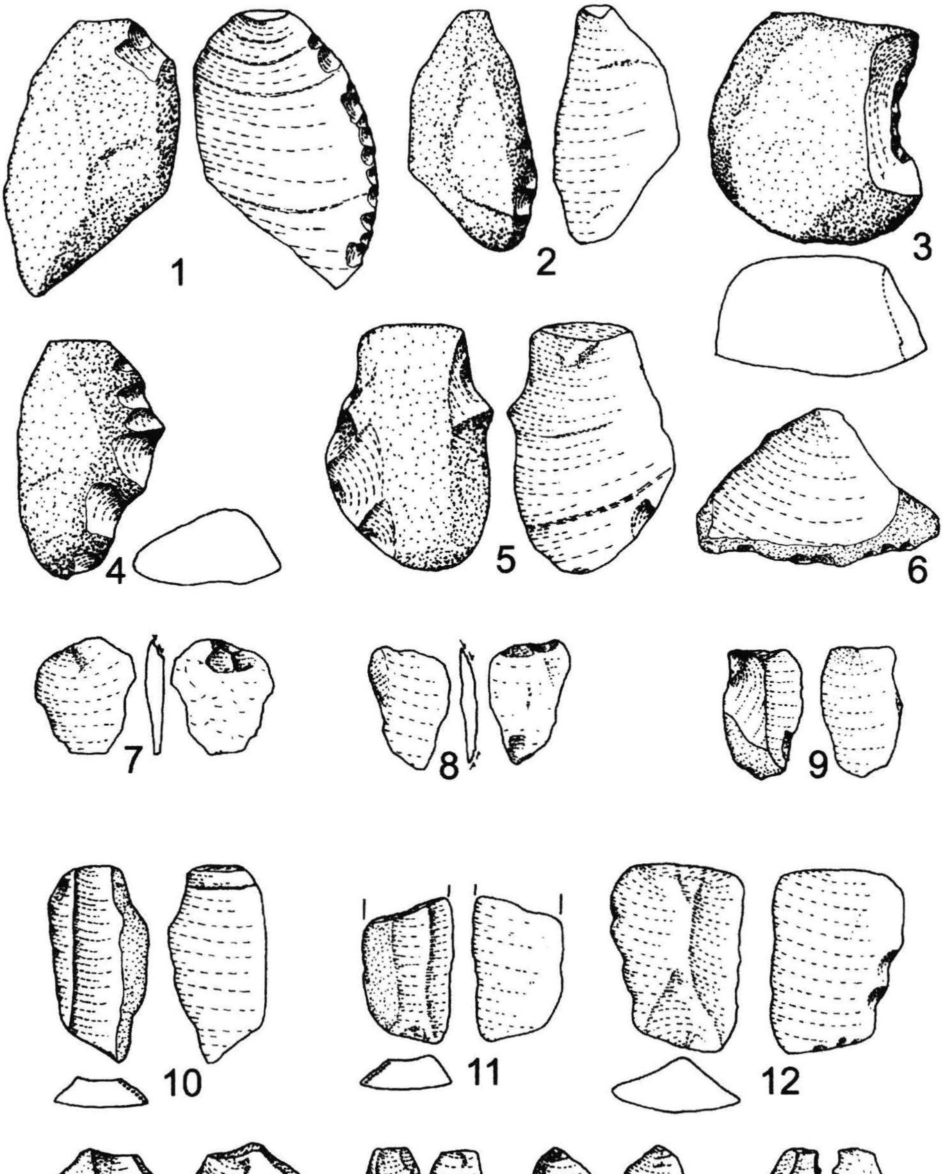

Plate III. Cores: 1–2 red siltstone; 3 fine-grained quartzite; 4, 6 quartzite; 5, 7, 10 sandstone; 9, 11 pebble quartz.

TIIVISTELMÄ

Susiluola

Susiluola sijaitsee Kristiinankaupungin ja Karijoen rajalla Susivuoren pohjoisrinteessä. Vuonna 1996 käynnistettiin luolan tyhjentäminen sorasta ja Geologian tutkimuskeskuksen edustajat saapuivat paikalle tekemään tutkimuksia. Koska työn yhteydessä löydettiin muutamia mahdollisia kiviesineitä, se keskeytettiin ja kohde rauhoitettiin muinaismuistolain perusteella. Arkeologisia kaivauksia on suoritettu paikalla vuosina 1997–2000 Museoviraston, Geologian tutkimuskeskuksen, Helsingin yliopiston geologian laitoksen ja Ajoituslaboratorion yhteistyönä. Neljä luolan alinta kerrosta on osoittautunut jääkautta vanhemmiksi ja ne sisältävät myös arkeologisia esinelöytöjä. Artikkelin tarkoituksena on esitellä luolan alustavat tutkimustulokset.

Susiluola ei ole varsinainen luola, vaan kysymyksessä on granodioriittikallioon muodostunut vaakarako, joka on täyttynyt paikoin kattoaan myöten maa-aineksella. Luolan suuaukko on 116,5 metrin korkeudella nykyisestä merenpinnasta ja sen suurin korkeus on 2,2 m. Luolan täyte koostuu seitsemästä kerroksesta, joista kerrokset I, IV, V ja VI ovat selviä rantamuodostumia. Kerrokset II ja III saattavat olla alunperin jään luolaan työntämiä ja niiden lajittuminen on voinut tapahtua myöhempien rantaprosessien vaikutuksesta. Kerroksen VII ikä ja synty on vielä epäselvä.

Geologinen aineisto viittaa siihen, että kerros V on syntynyt Saale-jääkauden sulamisvaiheessa, kun taas kerroksen IV yläosa (paleosoli) on muodostunut Eem-interglasiaalin aikana. Kerroksesta IV tehdyt savimineraalianalyysit ja sen rauta- ja alumiinipitoisuudet viittaavat siihen, että kerros olisi muodostunut nykyistä lämpimämmissä ja kosteammissa olosuhteissa. Kerroksen IV luminesenssiajoitus antoi tulokset 128 ka (IRSL) ja 148 ka (TL) viimeksi mainitun edustaessa maksimi-ikää. Kerroksen V ajoitustulokset osoittautuivat selvästi nuoremmiksi: 87 ka (IRSL) ja 102 ka (TL). Sen perusteella kerros V olisi hieman nuorempi kuin 90 ka, mikä ei kuitenkaan ole sopusoinnussa geologisten ja pedomorfologisten tutkimustulosten kanssa.

Luolista tehtyjen siitepölyanalyysien yhdistäminen arkeologisiin tutkimustuloksiin on aiheuttanut huomattavia tafonomisia ja metodologisia ongelmia. Myöskään Susiluolasta tehtyjen siitepölyanalyysien tulokset eivät korreloi kovinkaan hyvin litostratigrafian kanssa. Puupölyjen koostumus (Su–2) kerroksessa VII heijastaa interglasiaalin aikaisia olosuhteita. Varpukasvien ja ruohovartisten kasvien siitepölyt (Su–2) kerroksissa VI ja V ovat mahdollisesti joutuneet luolaan eläinten tai ihmisten mukana. Näytteen Su–3 (kerrokset IV–II) siitepölyt ovat sekoittuneet. Puupölyjen voi olettaa olevan pääasiallisesti peräisin joltain Veiksel-jääkautta edeltävältä interglasiaalilta ja niiden ajoittuminen holoseenin aikaisiksi onkin hyvin epätodennäköistä.

Tutkimustulosten perusteella aikahaarukka ylimpien löytöjä sisältävien kerrosten (kerrokset IV ja V) kohdalla ulottuu Eemistä varhaiseen Veikseliin (OIS 5; noin 132–74 ka). Koska merenpinnan transgressio on vaikuttanut kerrokseen V ja kerroksen IV maannos on tulkittu interglasiaaliseksi, todennäköinen ajoitus näille kerroksille on Eem-interglasiaali (OIS 5e; noin 132–120 ka). Suuri merkitys on kerroksesta V peräisin olevissa esinelöydöissä todetuilla selvillä, rantaolosuhteissa syntyneillä abraasiojäljillä.

Luonteenomaista Susiluolan kerroksista IV–V saadulle kiviaineistolle on siinä samanaikaisesti esiintyvät erilaiset valmistustekniikat. »Clacton»-tekniikkaa on käytetty hiekkakivessä, kvartsissa ja kvartsiitissa. Toisaalta työstöominaisuuksiltaan paremmissa kivilajeissa kuten hienorakeisessa kvartsiitissa ja punaisessa silttikivessä esiintyy keskipaleoliittikumille tyypillisiä valmistustekniikoita.

Susiluolan muutamat ytimet ja säleet eivät tarjoa riittävästi aineistoa tarkkaan typologiseen luokitteluun, mutta niissä ilmenevää iskentätekniikkaa voidaan pitää Moustérienille ominaisena. Myös kvartsiitista ja silttikivestä valmistetut, säleestä muotoillut esineet sopivat sen puitteisiin. Kiviesineitä ei ole kuitenkaan mahdollista sijoittaa määrättyihin esinetyyppeihin. Korkealuokkaisen piimateriaalin puuttuminen voi olla syynä siihen, ettei esineistössä ilmene Levallois-tekniikan piirteitä. Silti esineistön muut ominaisuudet antavat mahdollisuuden liittää kerrosten IV–V kiviesineet Moustérien-teknokompleksin piiriin.

Susiluola on tutkimuskohteena mielenkiintoinen, mutta samalla monessa suhteessa ongelmallinen. Kysymyksessä on tähän mennessä ainoa paikka Fennoskandiassa, jossa mannerjään peittämältä alueelta on todettu ihmistoiminnan jälkiä viimeistä jäätiköitymistä edeltävältä ajanjaksolta. Lähimmät samanaikaisen asutuksen merkit tunnetaan yli 1000 km:n etäisyydeltä Susiluolasta, mikä tekee siitä ilmiönä kronologisesti ja maantieteellisesti »eristetyn». Aineiston tulkintaa vaikeuttaa myös se, että Susivuorella tapahtuneen paleoliittisen toiminnan jäännöksiä on säilynyt ainoastaan vähäisessä määrin itse luolan pohjalla olevassa sedimentissä.

Susiluolan löytyminen antaa kuitenkin uusia mahdollisuuksia tutkia Neanderthalin ihmisen käyttäytymistä. Tähän mennessä tunnettujen Neanderthal-löytöpaikkojen pohjoisraja seuraa hämmästyttävän hyvin Veiksel-jäätiköitymisen reunaa, jolloin voidaan olettaa pohjoisimpien niistä tuhoutuneen viimeisen jäätiköitymisen seurauksena.