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The site of the discovery of a deposit of beaver dam and lodge sticks, Vimpeli II, in Ostrobothnia, at 63°9'N, 24°3'E, described in the present study, lies in the same stratigraphic position as the Vimpeli I site, i.e. beneath Weichselian till (Aalto, M., Donner, J., Niemelä, J. and Tynni, R., 1983. An eroded interglacial deposit at Vimpeli, South Bothnia, Finland. Geol. Surv. Finland, Bull. 324, 42 p.). The beaver deposit in the Vimpeli II succession is underlain by till interpreted as Saalian. The 33 remains of stick cut by beaver derive mainly from drift peat, although some are also from the underlying fluvial deposit.

Thermoluminescent dating of the sand covering the beaver deposit gives a mean age of 107 000 years. On the basis of its macrofossils and pollen assemblage, the drift peat is of Eemian interglacial age. The age of the organic deposit at Vimpeli I is not known; either it derives from the early Eemian interglacial, before the arrival of spruce in the region, or it was formed during a Weichselian or Saalian interstadial.

Key words: glacial geology, organic residues, till, stratigraphy, Plantae, Castor fiber, pollen diagrams, interglacial environment, Eemian, Vimpeli, Finland.

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INTRODUCTION

In February 1980, Mr. Taito Mustapuro found a dark layer containing remains of sticks and cones (Vimpeli I, appendix 1) beneath a 4 m thick till in the limestone quarry belonging to Partek Oy at Ryytimaa, Vimpeli. The find was considered, with some reservations, to be interglacial (Aalto et al. 1983a). Three years later, at a site almost 200 m east of the former, Mr. Topi Kovanen discovered (Fig. 2) another till-covered organic deposit with abundant wood remains and cones of pine and spruce (Plate I, Figs. 1 and 2, Vimpeli II, appendix 1). Among the wood remains there were more than 30 sticks cut by beaver (Aalto et al. 1983b).

The Geological Survey of Finland considered the finds of such consequence that they rewarded Kovanen and Mustapuro on May, 3, 1984. Never before in the history of the Geological Survey of Finland, which covers a period of over a hundred years, has a financial reward been presented for a find of Quaternary geological importance. The reasons given for the reward were as follows: »The alertness and interest in Nature shown by Kovanen and Mustapuro have contributed to a series of geological discoveries so momentous that we are fully justified in rewarding these men out of the funds of the Geological Survey.» The importance of the beaver find is further accentuated by the fact that it is the first evidence, albeit indirect, of the occurrence of beaver in Finland during an interglacial. The pile of sticks from the beaver dam and lodge at Vimpeli II has been preserved by the National Board of Antiquities and Historical Monuments and placed in the science classroom of Vimpeli senior secondary school.

STRATIGRAPHY

Lithostratigraphy

The description of the first discovery at Ryytimaa introduced a concept of the directions of glacial flow (Aalto et al. 1983a, Fig. 1) which the present authors now consider untenable. A number of new observations have been made on glacial striation, at and around the quarry, and the orientation of the stones in till has been measured from the superimposed till layers at the discovery site and from the test pits excavated in the nearby basal till. The successive flow stages of the

Fig. 1. Two sticks cut by a beaver from the Vimpeli II organic deposit. The thicker stick has a diameter of about 30 mm. The sticks were impregnated with polyethylene glycol to promote conservation (see Fig. 8).

continental ice sheet, their age sequence and the till units related to the stages can be interpreted as follows (see also Hirvas & Niemelä 1986):

The oldest groove direction, about 310°, was encountered on the lee side facet of a polished rock close to the beaver deposit. On the stoss side of the same polished rock, a younger direction trends 290°. In the immediate vicinity, older directions trending 325° and numerous younger ones trending 280°—290° have also been found, all in the same place. The corresponding older flow direction manifests itself in the orientation of the stones in the older, i.e. lower, till bed (appendix 1, Fig. c) and also in the transversal orientation, probably because of the location of the till at the bottom of a fracture zone (appendix 1, Fig. c, cf, Glen et al. 1957). Similarly, the orientation of the stones in the younger till bed coincides with the direction of the striae produced by the youngest flow.

A pothole (Fig. 17) was also discovered in the immediate vicinity of the site of discovery, but slightly higher than it. The pothole will be discussed in greater detail in the context of geological evolution. The stratigraphy, from bottom to top, of the discovery site containing sticks from the beaver dam and lodge is as follows:

— The basement is a fracture in dolomitic bedrock, trending northwest-southeast, with occasional weathered portions (Appendix 1).

— The weathered dolomite is overlain by 1.5—2.2 m of grey, compacted and homogeneous sandy till, the oldest till at the discovery site. This till bed has not been encountered elsewhere in the quarry. It may have survived glacial erosion because it is located in the deepest portion of the

Fig. 2. Ryytimaa quarry, Vimpeli. In the foreground the previously studied site (Vimpeli I), in the background Vimpeli II, i.e. 'beaver dam'. Younger till on the right.

shear. However, the older till has been encountered in test pits about a kilometre southeast of the quarry. Amphibolite (48 %) is predominant in the till, with mica schist accounting for 32 % and basement dolomite for a mere 1 % (d, appendix 1). All the stone counts at the discovery site were done by Fredrik Pipping, who also mapped the bedrock of the area (Pipping 1979).

— The older till is overlain by a 0.70—1.5 m thick sand and gravel layer with very well rounded stones (Fig. 3) interpreted as a fluvial deposit. A corresponding deposit about 200 m further west was earlier interpreted as glaciofluvial (Aalto et al. 1983a), mainly because it was overlain by layered silt. Mica schist (54 %) is the main rock in the fluvial deposit, the abundance of the local dolomite being 7 % (d, appendix 1).

— Resting on the fluvial deposit, and with its basal part grading into it, there is an organic bed less than 20 m long and with a maximum thickness of 0.5 m. The bed contains abundant well-preserved wood remains, cones and other macrofossils (Figs. 4 and 5, Plate I, Figs. 1—3). The deposit is almost or fully *in situ*. The organic bed (drift peat) is disturbed, being folded and partly sunk into the fluvial deposit and between the dolomite boulders; it also shows structures of glacial pressure (Fig. 6). The wood remains include more than 30 sticks cut by beaver (Figs. 1, 7 and 8). It is highly probable that the feature represents a beaver dam and lodge (Aalto et al. 1983b). Most of the sticks and cones are distinctly flattened. A remnant of spruce (*Picea abies*) taken from the deposit was dated at >54 000 years BP (Su-1245). The Quaternary history and ecology of the beaver will be discussed further on.

Fig. 3. Fluvial gravel overlain by the organic deposit. The gravel, which derives from till, contains organic matter including remains of sticks cut by beaver.

Fig. 4. An overall view of the organic deposit with the remains of sticks from the beaver dam and lodge. 1. Fluvial gravel and sand, 2. Organic deposit with stones and boulders, 3. Younger till.

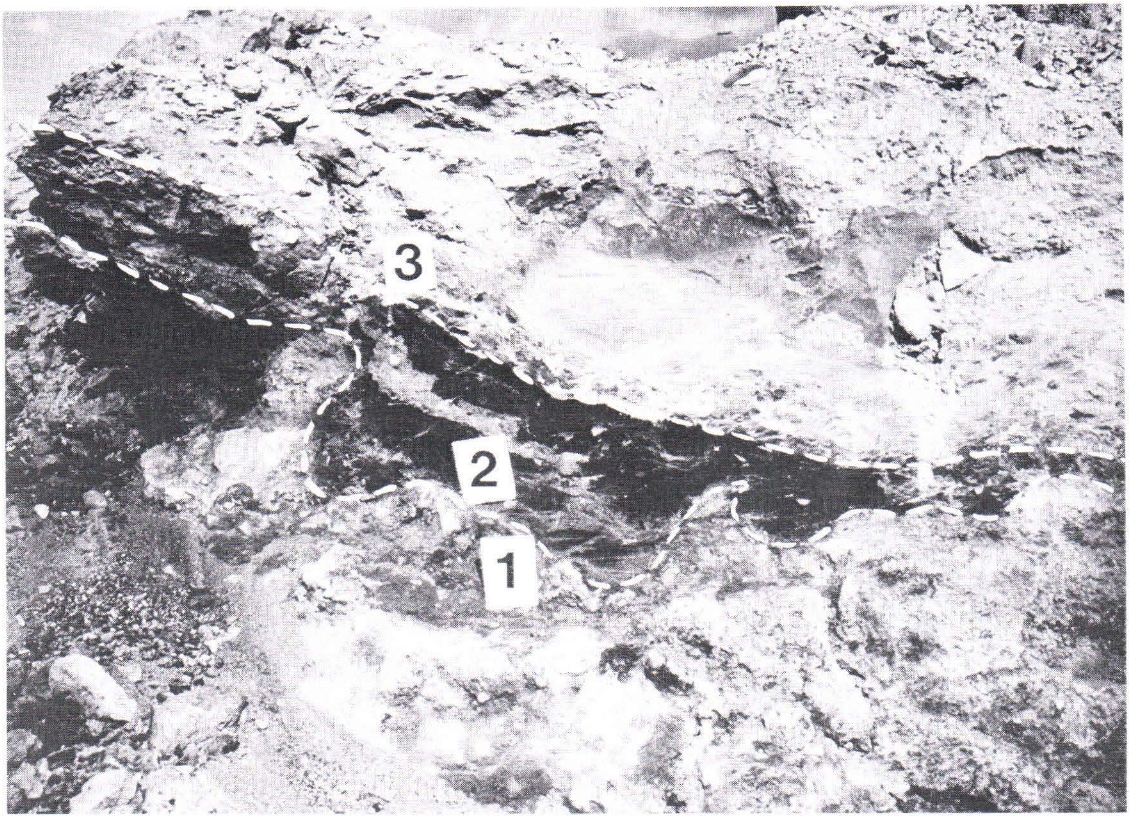

Fig. 5. A detail of the organic deposit (drift peat, 2) sandwiched between till (3) and fluvial gravel (1).

Fig. 6. A peat lens (2) in the fluvial deposit (1). The lens exhibits glaciotectonic structures caused by the pressure of the continental ice: the layers are bent and folded and the tip of the lens forms a flame-like structure.

Fig. 7. Beaver dam sticks. Of the 32 remains of stick cut by beaver, 12 are pine (*Pinus sylvestris*), 12 spruce (*Picea abies*) and 8 juniper (*Juniperus communis*).

Fig. 8. Fragments of sticks cut by beaver. The lowermost are in their natural state. The upper ones were slowly impregnated with polyethylene glycol for 160 days and are thus darker.

— The organic deposit is overlain by a thin bed (maximum 20 cm) of layered silty sand that may be of fluvial or littoral origin (Plate I, Fig. 4). Sand also occurs as thin layers in the organic matter. Several thermoluminescence (TL) ages, ranging from 225 000 to 99 000 years, have been determined on the cover sand and sand layers; although still somewhat tentative, the three most reliable dates methodologically are 99 000, 107 000 and 115 000 years with a mean of 107 000 years (Jungner 1987).

— The thickest member in the succession is the younger till resting on the former. It is thinnest, 0.5—1 m, at the margins of the fracture, (appendix 1) and thickest at the deepest part of the fracture and above the beaver deposit, where it reaches almost 10 m. The till varies in grain size, being partly silty and partly sandy (Fig. e, appendix 1, Figs. 4 and 5). It is homogeneous and brownish grey or grey in colour. Mica schist and amphibolite predominate in the till (31% each), the abundance of the local dolomite being 8% (d, appendix 1).

— In places, the younger till is overlain by a fine-grained waterlaid sediment up to 1 m thick (appendix 1 and Fig. 9) and showing a sharp contact with the underlying till and overlying diamicton. The sediment is predominantly clay but silt in its upper part. It is bluish-grey in colour. The graded-bedded basal part contains 27 varves 5—15 mm thick but the upper part is homogeneous. The downwards thickening basal varves typical of the front of a withdrawing continental ice sheet are lacking. The diatom flora in the clay is scarce and represents late-glacial conditions.

— The succession continues slightly eastwards of the beaver deposit, with the waterlaid sediment being overlain by 1—2 m of till-like diamicton. In grain size it corresponds to till, but there is considerable variation in the grain size distribution (e, appendix 1). The stones in the diamicton, which is probably waterlaid till in origin, do not show a distinct orientation maximum (a, appendix 1). During the retreat of the Weichselian continental ice the water in front of the ice was about 200 m deep.

Fig. 9. A detail of the silt (2) and diamicton (3) resting on the younger till (1). The basal part of the silt shows graded bedding.

— The youngest part of the succession is postglacial fluvial gravel and sand with wood remains and even trunks in its basal portion (Fig. 18). The ^{14}C age of the wood is 3690 ± 70 years BP (Su-1634).

Pollen stratigraphy

The previously studied section (Vimpeli I) of a till-covered organic deposit in the quarry at Ryytimaa, Vimpeli consisted of a 20—100 cm thick layer of compressed drift peat, folded in places and underlain by silt and gravel (Aalto et al. 1983a). The peat contained pine cones and pieces of wood. The pollen diagrams of the three profiles studied showed a Pine zone above a Birch zone. Apart from these two main tree pollen taxa, there were small amounts of pollen of *Corylus*, including *Myrica* and *Picea* and, in addition, occasional grains of *Ulmus, Alnus, Quercus* and *Carpinus* alien to the local vegetation. The change in tree pollen composition, the decrease in values of the pollen of shrubs and herbs and the rise in loss on ignition towards the top showed that the Vimpeli I drift peat represents the lower part of an eroded organic interglacial deposit.

The section exposed in 1983, which is discussed in the present paper (Vimpeli II, appendix 1), lay about 180 m east of the above-mentioned section. The till-covered homogeneous sand, up to 40 cm thick, contained a 10—20 cm thick layer of compressed peat and sand with pieces of wood, some charred, and cones of pine and spruce (Fig. 10). In parts of the section there were some thin, grey silty layers at the contact between till and the underlying sand, with small folds showing as a disturbance in the sediments as a result of the overriding ice that deposited the till (Plate I, Fig. 4). Similarly, some of the pieces of wood were broken and had been displaced as a result of horizontal push. On the whole, however, the thin layers of compressed peat in the sand, which probably deposited in the shallow backwater of a river, were not noticeably disturbed. In one part of the section, a few metres from the site sampled for pollen analysis, a number of pieces of wood had tooth marks showing that they had been gnawed by beavers and that the sediments were deposited close to a beaver dam (Aalto et al. 1983b). The sand was underlain by stony gravel and a lower till, which was not encountered in the section studied earlier (Vimpeli I).

The samples for pollen analysis were taken from the part of the section in which the compressed peat occurred in the basal part of the sand; further west the peat was at the surface of the sand and partly eroded, and still further west it was altogether absent (Fig. 10). Six samples were taken from the 12.5 cm thick peat at 2.5 cm intervals and submitted to analysis. Three hundred tree pollen were then counted in each sample. The tree pollen spectra are dominated by *Pinus, Betula* (up to 10—20 %) and *Picea* (about 10 %). The curves for *Alnus* and *Corylus* attain 3 % and 2 %, respectively. Pollen of the shrubs *Salix* and *Juniperus* was found in only a few samples, whereas the pollen of herbs accounted for 2—8 % of the total pollen sum, excluding that of aquatics, of which there are only a few, random occurrences. A slight change can be detected in the pollen diagram towards the top, as the proportions of *Betula* and herbs increase and those of *Pinus* and *Picea* decrease.

It is obvious from the section, and even more so from the pollen diagram, that the thin layer of compressed peat represents only part of a longer interglacial period. Neither the initial vegetational development nor the development immediately preceding the subsequent glacial stage is shown by the pollen diagram (Fig. 10). The high frequency of *Picea* in the pollen spectra and the absence of pollen of trees such as *Ulmus, Quercus* and *Carpinus* suggest that the sequence formed towards the end of an intergla-

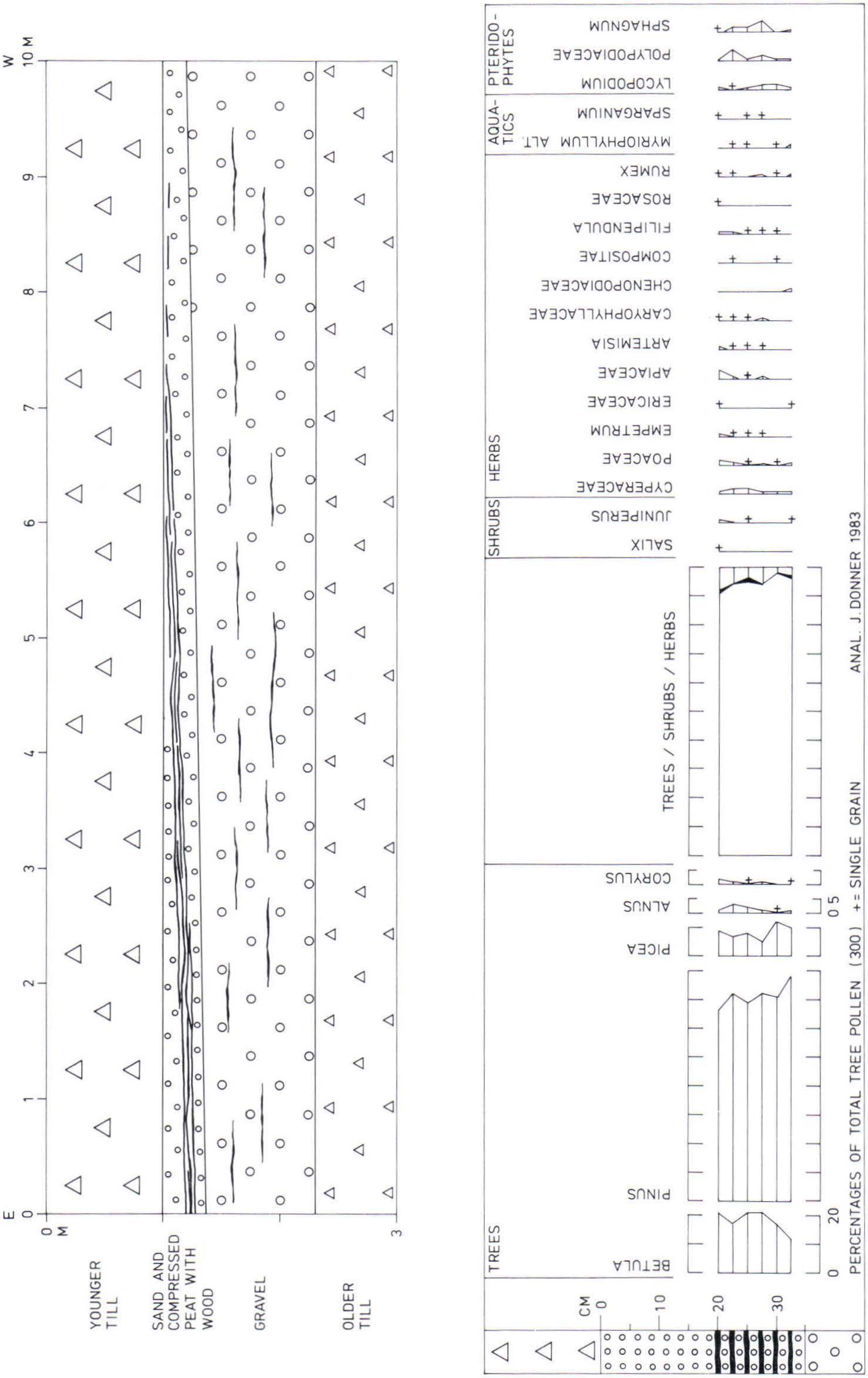

Fig. 10. Pollen diagram of the drift peat in Vimpeli II.

cial stage, after the climatic optimum but before the withdrawal of conifereous trees. Nowhere else have similar pollen spectra been encountered in till-covered organic sediments in Ostrobothnia except at Harrinkangas (Gibbard et al. 1989). They could, however, well represent the upper part of the Evijärvi Interglacial, some parts of which are known from Evijärvi (Eriksson et al. 1980) and Norinkylä (Niemelä and Tynni 1979) and have been correlated with the Eemian (see discussion by Donner 1986 and Donner 1988).

Another sample was analysed from an earlier section of Vimpeli II in which peat rich in spruce cones was folded between boulders. This organic deposit, which rested directly on dolomite, was located about 10 m north of the beaver dam deposit. The older till is absent here. The tree pollen proportions at this site were *Betula* 10 %, *Pinus 65 %* and *Picea* 25 %. Thus, spruce was even more dominant than in the peat section of the pollen diagram. Nevertheless, the two peat deposits probably represent the same section of the interglacial sequence.

The age relationship between the previously studied till-covered organic bed at Vimpeli I (Aalto et al. 1983a) and that described in the present paper is not clear. Taking into account the altitude of the Vimpeli site, it was concluded that the previously studied peat, which on the basis of some macrofossils might be described as interglacial (Aalto et al. 1983a), cannot represent the beginning of the Evijärvi interglacial (= Eemian Interglacial) because at that time the area was still submerged, as shown by other sites. The peat was therefore considered to represent the Weichselian Oulainen Interstadial, correlated with the Brörup (Donner 1983, 1988). If the peat discussed in the present paper, including the remains of a beaver dam, were from the upper part of the Evijärvi interglacial, the Vimpeli site would be the first site in Ostrobothnia where organic deposits of both this interglacial and the subsequent interstadial would have been found together. Unfortunately there is neither direct stratigraphic evidence of this nor conclusive proof of the true age of these peats. They are both beyond the range of radiocarbon dating (Aalto et al. 1983a), as also shown by the date of wood taken from the section studied later, which gave an age of more than 54,000 B.P. (Su-1245). The TL dates obtained from the sand layer (see above) with peat studied here gave a mean age for three samples of 107,000 years, which, according to Jungner (1987), must be considered uncertain.

As mentioned above, an interglacial, probably Eemian, age is likely for the peat of the beaver dam deposit discussed in the present context, but its relationship to the previously described peat cannot yet be established.

Plant macrofossils

Samples and methods

Macrofossils were sampled from a section in Ryytimaa limestone quarry, Vimpeli, in August and September 1983. The samples were taken from open sections exposed for this purpose. Two profiles were sampled and several separate samples were taken. Cones and wood samples were also collected in the field. The data on the samples collected in August 1983, which are close to those of the pollen samples (Fig. 10), are given in Table I. Some species from the profile sampled in October 1983 have been added to the plant list. Sampling points 1—6 of the profile and the separate samples 7—10 close to the former are illustrated in Fig. 11. Sample 4 was one of the three dated by TL, according to which the calculated mean age of the site is 107,000 years B.P. (Jungner 1987).

The lithostratigraphy from top to bottom is as follows;

Depth	(No.)	Profile samples
0—10 cm	(1)	basal till, with large angular blocks
10—12 »	(2)	contact horizon, mixed till and organogenic material
12—15 »	(3)	highly organic dark peat with wood and plant remains, some stratified light fine sand stripes
15—25 cm	(4)	light fine sand band
25—45 »	(5,6)	highly organic dark peat with some sand, and abundant remains of cones and wood

Depth	(No.)	Separate samples:
30—50 cm	(7)	highly organic dark peat with many pieces of wood and cones
12—25 »	(8)	— » — — » —
25—45 »	(9)	— » — — » —
depth not known exactly	(10)	sandy layer, mixed with organogenic material, beneath the above samples

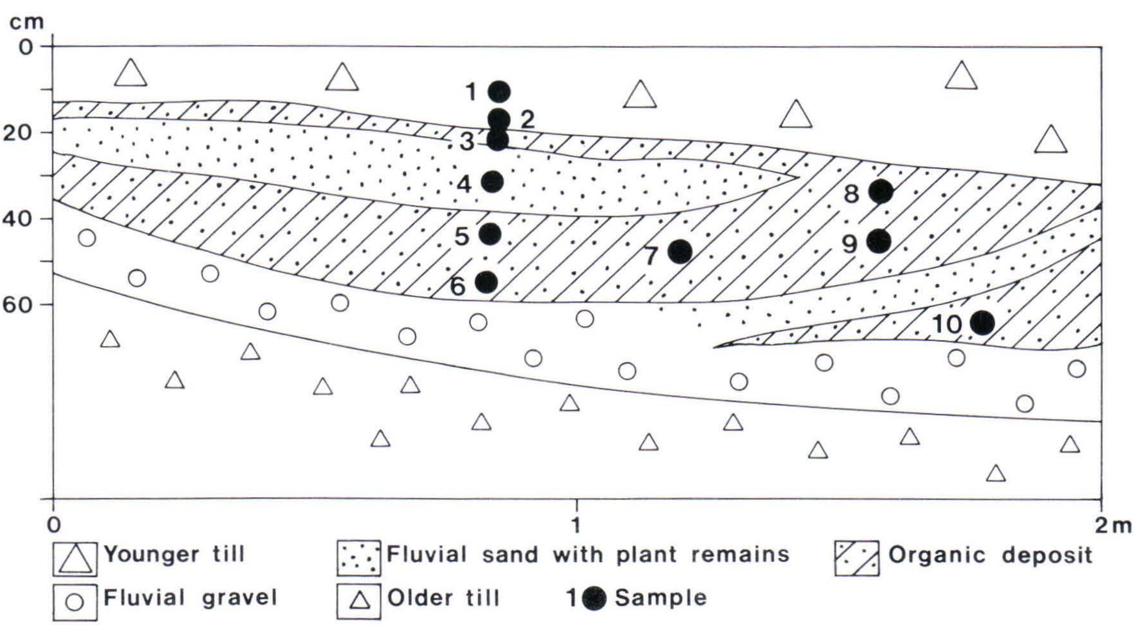

Fig. 11. Section from the Ryytimaa limestone quarry, Vimpeli, in August 1983 showing the macrofossils studied. Nos. 1—10 sampling points.

Table 1. Plant macrofossil finds of Ryytimaa till-covered organic deposit, Vimpeli, Discovered in August 1983.

Biozone		Picea — Pinus — Oenanthe									
Sediment type		Till	Drift peat mixed with till and sand		Sand	Drift peat					
No. of sample		1	2	3	4	5	6	7	8	9	10
Depth, cm		1—10	10—12	12—15	15—25	25—35	35—45	30—50	12—25	25—45	?
	type of remains										
Aquatic species:											
Chara sp.	o	—	—	—	—	—	—	—	—	1	—
Hippuris vulgaris,	e	—	—	—	—	—	—	—	2	—	—
Isoetes lacustris	m	—	—	—	>100	3	2	4	2	30	—
+ *I. echinospora*	m							28	1	18	—
Myriophyllum verticillatum	s	—	—	—	—	—	2	4	1	4	—
Najas flexilis	s	—	—	—	—	—	—	—	2	—	3
Nuphar lutea	s	—	—	—	—	—	1	1	—	7	1
Oenanthe aquatica	f	1	—	10	2	12	6	65	10	36	1
Potamogeton alpinus	e	—	—	—	—	—	—	—	—	1	1
P. berchtoldii	e	—	—	—	—	—	—	—	—	2	—
P. gramineus	e	—	—	—	—	1	8	11	14	10	—
P. natans	e	—	—	—	—	7	3	11	8	11	—
Ranunculus lingua	e	—	—	—	—	1	—	1	1	—	—
R. sec. Batrachium	e	—	—	—	—	—	—	—	1	1	—
Scirpus lacustris	n	—	1	1	—	5	5	8	7	13	—
Sparganium emersum	e	—	—	—	—	2	2	—	1	—	—
Shore and Marsh plants:											
Alisma plantasgo-aq.	s	—	—	—	—	—	—	3	—	1	—
Carex riparia	n+u	—	—	—	—	10	12	—	—	—	6
C. aquatilis-type	n+u	—	—	—	—	—	1	—	—	—	—
C. canescens	n+u	—	—	—	1	4	—	10	13	12	—
C. rostrata	n	—	—	—	1	4	—	10	13	12	—
C. spp.	n	—	—	—	—	—	—	9	8	3	—
Eleocharis palustris	n	—	—	3	—	4	—	26	10	15	—
Eriophorum vaginatum	n	—	—	—	—	—	1	—	—	—	—
Filipendula ulmaria	s	—	—	—	2	3	4	38	1	14	—
Juncus sp.	s	—	—	—	—	—	—	3	—	—	—
Menyanthes trifoliata	s	—	—	—	—	3	1	8	3	10	2
Potentilla palustris	a	—	—	1	—	2	2	2	1	1	—
Ranunculus repens	a	—	—	—	—	—	—	—	—	1	—
Thalictrum lucidum	a	—	—	—	—	3	4	7	2	11	—
Viola palustris	s	—	—	5	—	7	1	1	3	7	—
Shrubs and dwarf shrubs:											
Andromeda polifolia	s	—	—	—	—	—	—	3	—	—	—
Arctostaphylos uva-ursi	e	—	—	—	—	—	—	—	—	4	—
Chamaedaphne calyculata	e	—	—	—	—	—	—	4	—	—	—
Betula nana	f	—	—	—	—	3	2	18	—	—	—
Empetrum nigrum	e	—	—	—	—	—	—	—	—	1	—
Juniperus communis,	s	—	—	2	1	1	5	8	10	10	—
wood		—	—	—	—	—	1	—	—	—	—
needle		—	—	—	—	—	—	—	1	5	—
Myrica gale	d	—	—	—	—	4	—	25	3	14	—
Rubus idaeus	e	—	—	—	—	—	2	5	8	4	—
Sambucus nigra	e	—	—	—	—	—	—	—	—	1	—
Vaccinium myrtillus	s	—	—	—	—	—	—	—	1	3	—

Table 1. Cont.

Biozone		Picea — Pinus — Oenanthe									
Sediment type		Till	Drift peat mixed with till and sand		Sand	Drift peat					
No. of sample		1	2	3	4	5	6	7	8	9	10
Depth, cm		1—10	10—12	12—15	15—25	25—35	35—45	30—50	12—25	25—45	?
TREES:											
Betula pubescens	f	1	—	1	—	2	—	6	—	1	—
B. sp.	f	—	—	—	—	1	—	8	—	4	—
Picea abies, cones		—	—	—	—	—	1	—	—	1	—
» needles		—	—	—	—	>10	5	15	8	>20	—
» wood		—	—	—	—	1	1	—	—	—	—
»	s	—	—	2	4	—	2	10	2	—	2
Pinus sylvestris	s	—	—	—	—	—	—	2	2	10	—
» cones		—	—	—	—	1	—	—	—	7	1
» needles		3	—	1	—	>10	4	8	5	>20	—
» bark		1	1	+	+	+	+	+	+	+	+
» wood		—	—	—	—	—	2	—	—	—	—
Populus tremula, sh, bs		—	—	—	—	—	—	8	2sh	8	—
Miscellaneous terrestrial habitat:											
Fragaria vesca	s	—	—	—	—	—	2	—	—	—	—
Geum urbanum	s	—	—	—	—	—	—	—	2	—	—
Potentilla anserina	e	—	—	—	—	—	—	—	1	—	—
Rumex acetosella	f	—	—	—	—	—	1	—	—	—	
Selaginella selaginoides	m	—	—	—	—	—	—	3	—	2	—
unidentified seeds		—	—	—	—	—	—	—	4	7	—
Tissue fragments:											
charred wood		6	4	—	—	+ +	—	8	10	>10	—
delicate tissue frgt.		+	+	+ +	+	+ +	+ + +	+ + +	+ +	+ +	+ +
Mosses:											
Bryidae	sh	—	—	4	—	+ +	+ +	5	1		—
Tortuella tortuosa	sh	—	—	2	—	10	18	20	>50	>50	—
Sphagnidae	lv	—	—	2	—	+ +	—	—	—	>10	—

Abbreviations: a = achene, bs = bud scale, d = drupelet, e = endocarp. f = fruit, lv = leaves, m = macrospore, n = nutlet, o = oospores of *Characeae*, s = seed, sh = shoot, u = utricle of *Carex*. Frequencies, when not countable: + some, + + frequent, + + + copious. Nomenclature in accordance with Flora Europaea 1964—1980 (Heywood et *al.*).

In the laboratory 2.5 dl of each profile sample (1—6) and 5—10 dl of the separate samples (7—10) were extracted using the conventional nitric acid method (e.g. Backman 1965). Some reaction was observed in samples containing limestone, but it obviously did not harm the macrofossils. The subfossils were studied, separated under a low-power microscope, labelled and preserved in a mixture of glycerine and alcohol. They are listed in Table 1. The nomenclature is in accordance with Flora Europea (Tutin, Heywood et al. 1964—1980) and the species are classified mainly according to their optimal occurrence in different biotopes.

Results

Sixty plant species were identified from the profiles and separate samples (Table 1). The species from the other profile, and not found in the list, are *Potamogeton perfoliatus* (1 specimen), *Cirsium palustre* (3 specimens) and *Sparganium minimum* (2 specimens). Otherwise the results of the two profiles, which are about 5 m apart from each other, are very similar. There are four plant indicators of a more southerly climate than that of present-day Vimpeli. They include *Thalictrum lucidum* and *Carex riparia*, found also in Vimpeli I at its temperate stage (Aalto et al. 1983a). *Thalictrum lucidum*, a tall waterside herb, is absent from present-day Finnish flora, and the sedge *C. riparia* is a rare, southern species (see maps in Aalto et al. 1983a). These species thus indicate a summer temperature higher than that of today.

Especially noteworthy and common in the present material were the fruits of Fine-leaved water dropwort *(Oenanthe aquatica,* Fig. 12), which is a rare, southern plant in Finland today. This poisonous species of aquatic habitat has been found in river estuaries in Satakunta, western Finland, up to latitude 62°N, some 200 km south of Vimpeli. In northern Europe it is more common south of latitude 60°N in the Baltic area, and in and around the big Swedish lakes Mälaren, Vänern and Vättern, its distribution being concentrated in calcareous and eutrophic areas (Hultén 1971). It is common from western Europe to central Siberia (Hultén & Fries 1986). Godwin (1965) reports it from all known interglacials in Britain, also from transitions of some cold stages and from Postglacial time zone VII onwards. It has not previously been found from the Finnish Quaternary.

An even more southerly species is Elder (*Sambucus nigra*), a tall rich forest shrub not native to Finland. It is common in central Europe but is an alien in northern Europe, where it is a common escaper from cultivation, which is practised up to latitude 63°N in Sweden. In Finland, Elder has only been able to naturalize on the Åland islands, in the southwestern corner of Finland. Its present sub-Atlantic distribution in Europe (Hulten & Fries 1986) may indicate a more oceanic climate in Vimpeli II. There was only one endocarp of a berry of Elder in the finds, and some care must be taken to distinguish it from the other species, *Sambucus racemosa*, another alien but more common in Finland today. However, the author considers the find to be *S. nigra* on the basis of the shape and surface pattern of the endocarp. According to Godwin (1975), it was frequent in the Late Pleistocene, in middle sub-stages of the Hoxnian and Ipswichian interglacials, and from Flandrian zone VII onwards.

Najas flexilis is another plant recorded from Vimpeli II macrofossils that is rare nowadays. It is particularly common in Postglacial sites in Finland (Backman 1948), especially in the Ostrobothnia area. There is also an Eemian interglacial record of the species from Ollala, Haapajärvi (Forsström et al. 1988), about 100 km north of Vimpeli. Elsewhere in Europe the species is frequently found at postglacial and interglacial sites (Backman 1948, Godwin 1975). The postglacial history of *Najas flexilis* indicates climatic and edafic changes and it is considered to be a relic of more favourable circumstances. According to Backman (1948), the most abundant and extensive postglacial distribution of *Najas flexilis* in Finland was in Atlantic time. Though present before and since, it has become increasingly rare, and in present—day Finland, the species occurs only in some scattered localities in five Finnish lakes: Särkijärvi in Liperi; Vesijärvi in Hollola; Simpelejärvi in Parikkala; Kuusanjoki in Kittilä (specimens in Botanical Museum, H); and Kiteenjärvi in Kitee (Meriläinen 1962, Venäläinen 1982).

The limestone effect is shown in the macrofossils by the rather luxuriant species composition as a whole, and particularly by the presence of species such as *Tortella tortuosa* and *Selaginella selaginoides*, which still grow today on the Ryy-

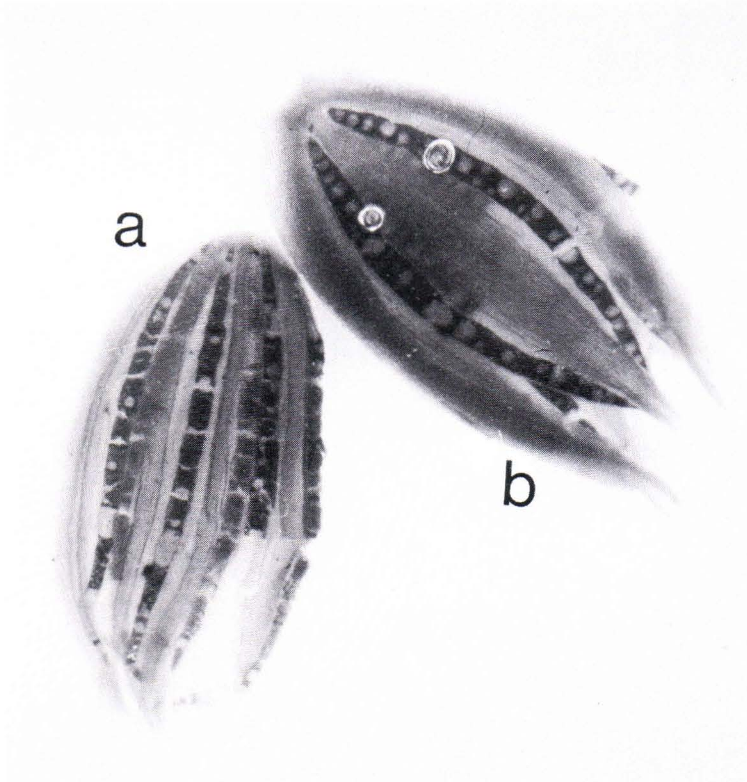

Fig. 12. Two fruits of the subfossil Fine-leaved water dropwort(*Oenanthe aquatica*), showing a very characteristic pattern of secretory ducts (vittae) with gas bubbles. a dorsal side, b ventral side. Photo Mauri Korhonen.

timaa limestone outcrops, and possibly *Chara* sp., too, which often grows in calcareous waters. It is noteworthy that because of the effect of limestone on the vegetation in the Ryytimaa area now, and evidently earlier as well, the vegetation deviates from the typically Finnish one, which grows on mostly acid soils. This might have local effects on pollen assemblage and is clearly seen when the macrofossil composition of Ryytimaa limestone quarry is compared with that of Oulainen, which was laid down in an oligotrophic esker-side lake (Aalto 1982).

The palaeoenvironment of Vimpeli II was similar to that around the Ryytimaa limestone quarry today. The River Poikkijoki runs through the area as evidently its ancestor also did, serving as a good habitat for beaver (see below p. 24).

The running water of both the present and the ancient Poikkijoki shows some pondweed species, especially *Potamogeton gramineus* and *P. alpinus*, both still common in the river today, and also *Ranunculus lingua, Ranunculus subg., Batrachium* and *Oenanthe aquatica*. However, there are indications of plants thriving mainly in stagnant waters, lakes and ponds. Such are the small bottom-plants *Isoëtes lacustris, I. echinospora* and *Najas flexilis*, all of which favour shallow muddy or stony lake bottoms. Because both *Isoëtes* species were particularly numerous in fluvial sandy layers (Fig. 11, sample 4), they may have been sorted into similar spore and sand grain size by the river flow. Also Bulrush (*Scirpus lacustris*), common in fossil finds, and Small pondweed (*Potamogeton berchtoldii*) thrive in stagnant water. The remaining aquatic species (17 in all) grow in both running and stagnant water and include typical, common Finnish water plants such as *Nuphar luteum, Potamogeton natans, P. perfoliatus, Hippuris vulgaris, Myriophyllum verticillatum, Sparganium emersum* and *S. minimum.*

Along the water's edge, the tall sedges *Carex riparia, C. rostrata* and *C. aquatilis* (-type), to name but a few, formed bands mixed with *Alisma plantago-aquatica, Potentilla palustris, Menyanthes trifoliata, Cirsium palustre* and *Filipendula ulmaria.* There are also indications of peaty plant communities, perhaps of pine bog type, with small shrubs such as *Betula nana, Myrica gale, Andromeda polifolia, Chamaedaphne calyculata,* and herbs such as *Eriophorum vaginatum, Menyanthes trifoliata* and *Potentilla palustris.* Some leaves of *Sphagnum* spp. were also found in the sediment, implying the existence of boggy areas. A geolittoral plant association is represented by frequent finds of *Eleocharis plaustris* coll., with *Carex canescens, Juncus sp., Viola palustris, Potentilla anserina* and *Ranunculus repens.*

Rock outcrops with limestone all around the water course were evidently covered by sparse pine forest and juniper bushes (as they still are today). Species such as raspberry (*Rubus idaeus*) and strawberry (*Fragaria vesca*) together with the herbs, *Rumex acetosella, Geum urbanum* and *Selaginella,* may have grown on rock shelves.

The river valley mainly supported dense spruce forest, as shown by the numerous spruce cones (see below under cones) and wood remains in the deposit. Pine forest may have grown in the higher and drier till covered areas. Signs of the rich forest type are the shrubs *Sambucus nigra* and *Vaccinium myrtillus.* A drier forest type with pine is indicated by *Arctostaphylos uva-ursi* and a charred fruit of *Empetrum nigrum* (see under forest fires).

The diatom analysis (made on samples 4 and 6 by Tuulikki Grönlund; oral comm. 1988) also includes indicators of littoral species of lakes and ponds, particularly dominant being *Aulacoseira lirata.* Other species representing this kind of habitat are *Eunotia veneris, E. formica, E. pectinalis* var. *vernalis and* fragments of *Pinnularia* species. True indicators of flowing water are lacking, but their absence does not necessarily preclude the existence of such a habitat.

Forest fires obviously occurred during beaver dam time in Vimpeli II, as charcoal particles were frequently encountered in macrofossil samples. Also some large fragments of charred pine and spruce trunks (Plate I, Fig. 3) were collected in the field. One charred endocarp of *Empetrum nigrum,* a typical dwarf shrub of dry pine forest, was found in sample 9 (Table 1). The plant succession, initiated by forest fires, evidently created favourable local circumstances for a beaver settlement, with deciduous trees and bushes for forage (see under ecology of beaver, pp. 25—27). The plant cover would otherwise have represented only the closed coniferous climax forest type.

Spruce and pine cones in particular were distinct and numerous among the macrofossils at the Vimpeli II site (Figs. 13, 14, Plate I, Figs. 1 and 2). Pine cones were also abundant at the Vimpeli I site (Aalto et *al.* 1983a, pl. Ia), but those of spruce were lacking. Because the spruce cones seemed to be smaller than modern ones,the length and breadth of 100 fossil spruce cones were measured. The average dimensions were 6.72 × 1.95 cm, which are about half those of the *Picea abies ssp. abies* (Lam.) Link. cones reported by Hiitonen (1933), who gives sizes of 10—16 cm × 3—4 cm. The length of the fossil cones is closer to that reported for *Pica abies* ssp. *obovata* (Ledeb.) Domin (5—8 × 3—5 cm. Hämet-Ahti et al. 1984), found in Finnish Lapland and farther east in the USSR.

Recent cones of both subspecies were therefore collected and 30 specimens of randomly selected samples of both were measured. One sample was collected from Finnish Lapland (Kittilä, Naakenavaara 3. 5. 1985, M. Aalto) and the other from southern Finland (Helsinki, Laajasalo, 10. 8. 1988, M. Aalto). The results of the measured lengths are shown in Fig. 15. The fossil cones overlap somewhat with southern subspe-

Fig. 13. Fossil spruce (*Picea abies*) cones from Vimpeli II. Photo Mauri Korhonen.

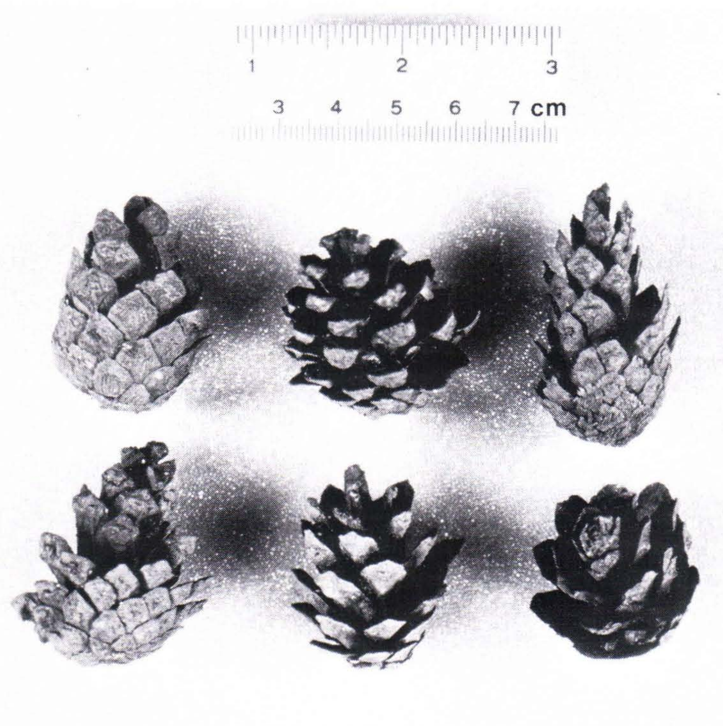

Fig. 14. Fossil pine (*Pinus sylvestris*) cones from Vimpeli II. Photo Mauri Korhonen.

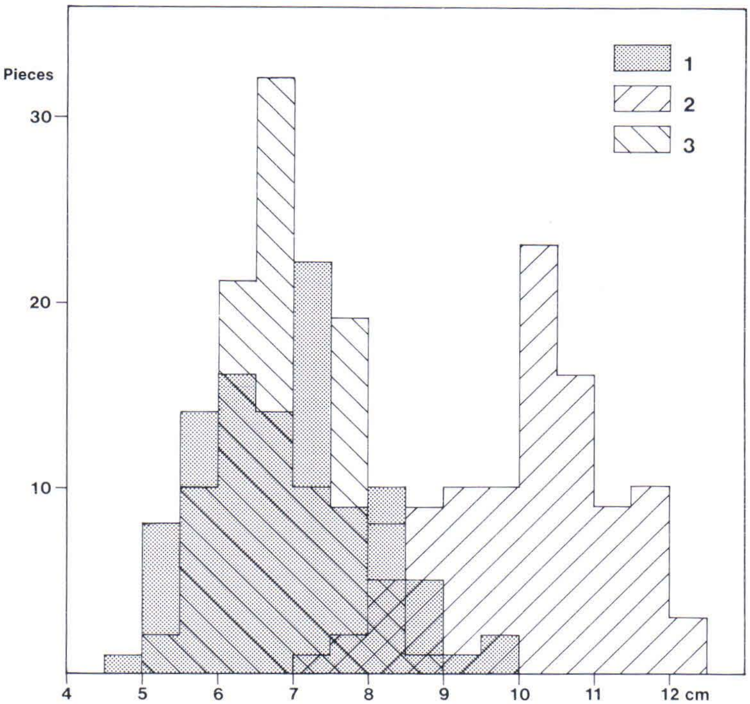

Fig. 15. The length of the fossil spruce cones from Vimpeli II compared with those of two recent taxa (*Pices abies* ssp. *abies* and *P. abies* ssp. *obovata*) encountered in Finland. The cones were measured when wet and the lengths grouped into 0.5 cm classes.
1. Fossil spruce cones (100)
2. Recent *Picea abies* ssp. *abies* (90)
3. Recent *Picea abies* spp. *obovata* (90).

cies, but are almost totally the same as the subspecies of Lapland.

In morphology, however, the fossil cones are close to recent *P. abies* ssp. *abies*, the cone scales being clearly triangular with a pointed and somewhat undulating apex with teeth (Figs. 13, Plate I, Fig. 1). Recent cones measured are closest to *P. abies* var. *acuminata* Beck (Hiitonen 1933, Fig. 54: 1), while the modern northern *P. abies* ssp. *obovata* has rounded, convex scale apexes and, on average, fewer cone scales.

As a species, the recent *P. abies* is morphologically very heterogeneous and many forms of it have been reported. This heterogeneity may be due partly to its geological history and partly to the diversity of overwintering centres and migration routes it favoured during glaciation times throughout the Quaternary. In the Eemian Interglacial, the Siberian spruce, sometimes considered as the species *P. obovata* Ledeb., sometimes as a subspecies of *P. abies* (L.) Karsten, occupied a much wider area in Europe. Its fossil cones have been found from several Polish Eemian sites (Srodon 1967, map 4 and Plate I). Also the range of *P. abies* ssp.*abies* once reached much farther west than nowadays, especially during some Late Quaternary interstadials. Intermediate leaf forms and cones of the two taxa have been found in England, from the Chelford Interstadial (Holyoak 1983), which has been correlated with the Brørup Interstadial (Simpson & West 1958). However, the Chelford cones were larger than typical *P. abies* ssp. *abies* cones and had more rounded scales (Holyoak 1983, Fig. 1), whereas the cones of the Vimpeli II site were morphologically closer to the modern southern Finnish subspecies *abies*, but considerably smaller, resembling the Lappish subsp. *obovata*. Evidently introgression has occurred between disjuncted populations throughout the Quaternary, resulting in the herogeneity of *Picea abies* in Europe today.

Observations of fossil cones smaller than those of the modern Sitka spruce (*P. sitchensis* (Bong.)

Carr.) have been made from Late Quaternary time in Western Canada (Warner & Chmielewski 1987), where the difference is assumed to be due to introgression between *P. sitchensis* and *P. glauca* during their migration to British Columbia after the last glaciation.

Discussion

The deposit was laid down by a small river, evidently an ancestor of the present River Poikkijoki. It was dammed by beavers and had pools or small lakes upstream. The organic sequence of Vimpeli II studied for plant macrofossils does not show any clear vegetational succession or climatic trend. The differences between samples 1—10 and their species composition is mainly due to changes in sediment and sedimentation rate. It is very likely that the sequence covers a rather short period, an episodic happening that included a beaver settlement.

The flora of Vimpeli II was very similar to that of present-day Vimpeli, in the Ryytimaa area. If in a natural state, they would both be covered by closed coniferous forests dominated by spruce and pine. However, because some of the indicator plants have a more southerly distribution, e.g. *Oenanthe aquatica, Thalictrum lucidum, Carex riparia* and *Sambucus nigra*, the climate is presumed to have been somewhat warmer than it is today and the summer temperatures thus a little higher. This suggests an interglacial rather than an interstadial character for the site.

Present-day Vimpeli, Vimpeli I (Aalto et al. 1983a) and Vimpeli II have 33 species of the total of 63 fossil species recorded in common. Present-day flora has 43 species in common with Vimpeli II and 36 with Vimpeli I.

Vimpeli I and Vimpeli II both have *Thalictrum lucidum* and *Carex riparia* as indicator species, implying a higher summer temperature than that prevailing in the Vimpeli area today. Also *Myrica gale* was present at both fossil sites but is absent today (for discussion, see Aalto et al. 1983a). Finds specific to Vimpeli II are the three indicator plants, two of more southerly distribution *Oenanthe aquatica, Sambucus nigra*) and one relic *(Najas flexilis)*. Plants specific to Vimpeli I are the five indicator species, four of a colder period (*Phyllodoce coerulea, Dryas octopetala, Arctostaphylos alpina, Loiseleuria procumbens)* and one of a warmer period (*Lycopus)*. Another difference between the two sites, which are 180 m apart, is the clear trend in Vimpeli I from cold, open birch tundra during the sedimentation of silt to closed, more temperate pine-dominated forest with some spruce at the top of the peat and in basal till.

In the interglacial cycle (Iversen 1958, Andersen 1969), the Vimpeli II site could be most easily allocated to the telocratic phase, i.e. the post-temperate period of forest development. The dominance of *Picea* excludes the pre-optimum stages of an interglacial. The sparse representation of deciduous trees, typical of the closed climax forests of the climatic optimum, excludes the mesocratic interpretation. Similarly, the lack of species indicating a cold climate and open vegetation is not consistent with cooler periods of the cycle.

Macrofossils alone do not solve the question of the interglacial during which Vimpeli II deposited, as no classical marker fossils such as *Brasenia, Dulichium* and *Azollas*, to name but a few, were recorded. However, the flora and vegetation of Vimpeli today and Vimpeli II are very similar, more so than those of Vimpeli I. This, together with geological evidence (the location between two separate till units of different glaciations) and pollen evidence, points to the youngest, or Eemian, interglacial.

The position of Vimpeli I in the Quaternary and its relationship to Vimpeli II is somewhat problematic. It very likely marks the beginning of an ice-free interval with both a colder and a warmer period. The similarity in flora and the fact that some of the indicator species are shared suggest a close connection between Vimpeli I and Vimpeli II. This might be either the beginning of the same interglacial (Eemian), a Late Saalian or an Early Weichselian stage. The fourth possibility is that the silt (cold period) and the drift peat (warmer one) are from different periods, separated by a hiatus. However, the first possibility (Eemian) does not seem very likely. The main profile of the section (App. 1) demonstrates that the quarry site was deeply submerged at the beginning of postglacial time, and evidently also at the beginning of the Eemian interglacial, as was pointed out by Donner (1983, 1988). Evidently the general patterns of uplift were rather similar after the two last major glaciations, the Saale and Weichsel (Forsström et al. 1988). Assessment of the likelihood of the three other possibilities from macrofossil information is beyond the scope of the present study.

THE BEAVER

Dam deposit

The remains of trunks and branches cut by beaver were found between two till beds (Figs. 1, 7, 8, 16, Plate I, Figs. 1 and 2). From the type of sediment and the stratigraphy, the main body of the site was interpreted as a fluvial deposit. However, the macrofossils and diatoms show that there were also basins, ponds or lakes of standing water upstream (see macrofossils, p. 16—17). The thickness of the deposit varied from 10 cm to 100 cm, the exposed length being over 100 m (Fig. 4). The organic material and the wood remains were deposited in lenses within inorganic material (sand and gravel, Plate I, Figs. 1 and 2), partly embedded in it. Evidently more organic sediment with many plant remains, cones and wood was laid down during periods of less intense flow, perhaps trapped by beaver dams; sand and gravel bands with fewer plant remains were deposited during periods of flood or more rapid flow. Of special interest were the many macrospores of *Isoëtes* species found in the sand layers. Their concentration might result from the similarity in spore and sand grain size due to sorting by water. In the field, the wood remains with beaver tooth marks were found 20 m upstream from the sampling site, the exposed width being 4—5 m. It is evident that components were mixed when the glacier passed over the site, possibly cutting part of the deposit off.

The »Beaver dam deposit» was first discussed by Aalto et al. (1983b), who suggested that the wood remains (conifers only) represent a beaver dam and lodge materials rather than forage. Macroscopic remains of conifers are particularly numerous and constitute significant fossils at Vimpeli II and also at Vimpeli I (see Aalto et al. 1983a, pl. I). Analyses of 33 sticks with tooth marks proved that they were all coniferous wood: 13 were spruce (*Picea abies* (L.) Karst.), 12 pine (*Pinus sylvestris L.*) and 8 juniper (*Juniperus communis* L.). The size of the numerous remains of small trunks and branches, including the gnawed ones, varied, the length being 50 cm at the most and the average thickness from 2—5 cm to 20 cm (Figs. 1, 7 and 8). There were also field observations of two very decayed larger trunks. The largest gnawn trunk with tooth marks is 36 cm × 4,5 cm.

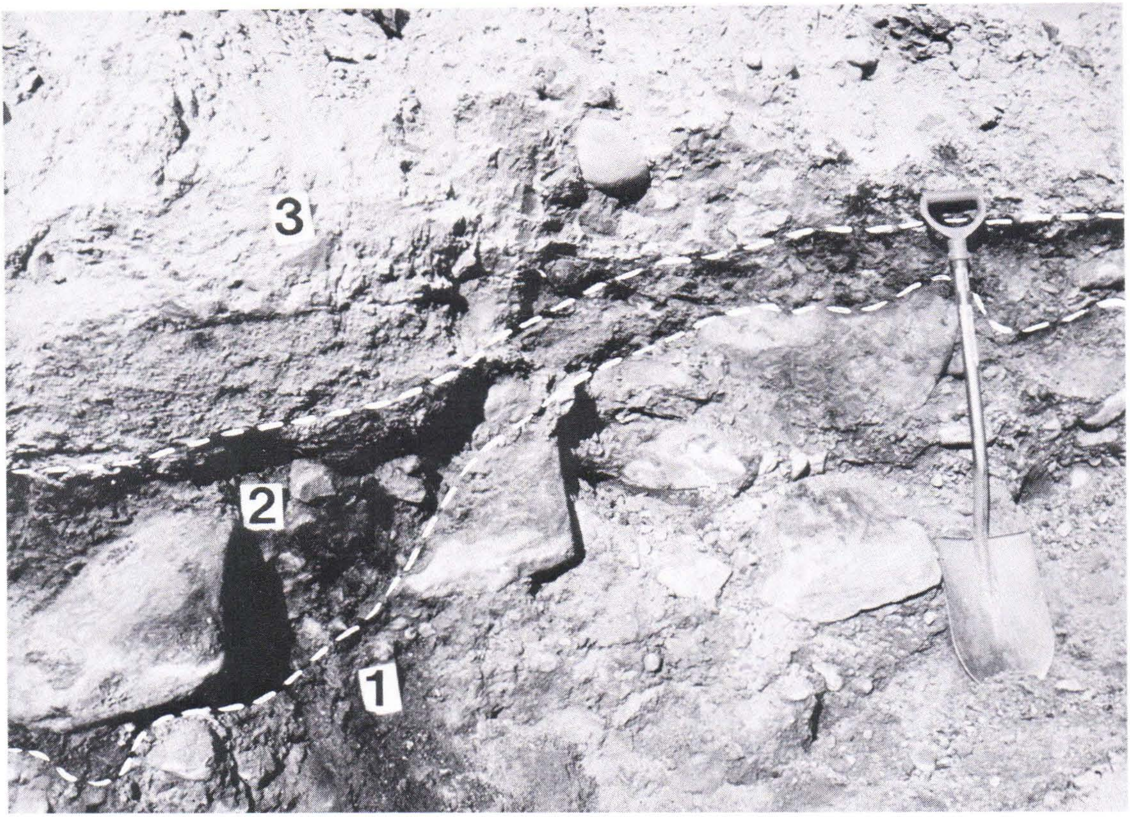

Fig. 16. A detail of the organic deposit. For 1—3 see Fig. 4.

Ecology of the beaver

Observations of both the European (*C. fiber* L.) and the Canadian (*C. canadensis* Kuhl.) beaver show that they prefer deciduous trees as food, the bark of aspen (*Populus*), birch (*Betula)* and willow (*Salix)* species in particular (Hall 1960, Lahti 1966, 1972, 1987, Simonsen 1966, 1973, Ostgård 1977, 1987, Nummi 1983). In contrast to the finds in the Vimpeli beaver deposit, they make less use of coniferous trees. However, in his studies on the Canadian beaver, Chabreck (1956) reports two pines (*Pinus taeda* and *P. glabra*) that are preferred to deciduous tree species. In his Canadian beaver studies, Hall (1960) found some use of Lodgepole Pine (*Pinus contorta*) and White Fir (*Abies concolor*). He also mentions that almost every woody plant was cut to some extent. It seems that there may be marked differences in the selection of tree species between beaver populations, and the selection may often (but not always) correlate with the availability of tree species. Lahti (1972) reports damage caused to pines by some beaver individuals, when they developed a taste for the bast (»pettu» in Finnish) of growing trees. It is also possible that deciduous tree remains have decayed, leaving a one-sided representation of coniferous trees in the deposit. Differences between the methods of zoological studies and those used here may also cause discrepancies in the results.

On the other hand, as shown by the pollen diagram (Fig. 10) and the list of macrofossils (Table 1), the frequencies and counts of deciduous trees and bushes are rather low. Pollen of birch (*Betula*) accounts for 20 % at the most, and the proportions of macroscopic remains are low compared with those of conifers — spruce (*Picea*, 10 %) and pine (*Pinus*, up to 70 %). Spruce and pine cones (see p. 18) as well as seed, needle and wood finds are numerous. Many remains of juniper (seeds, needles, wood) indicate the frequent presence of bush around the water basin.

In the list of macrofossils, among species suitable for beaver forage (marked with 1 to 4 asterisks according to Simonsen 1973, Ostgård 1977) there are some finds of budscales of aspen (+ + + +), especially favoured by beaver as winter food (e.g. Lahti 1972, Hall 1960). Birch (*Betula pubescens*, + + + + and *B. nana* + +) nutlets and scales show the presence of the species, although it was not found in wood determinations. According to Scandinavian observations (Lahti 1966, Simonsen 1973), birch is the tree most extensively used as beaver forage evidently because of its common availability. Also willow (+ + +, a pollen record) is favoured by beaver and is a much used source of food because of its good ability to be renewed (e.g. Semyonof 1951, Hall 1960). In his studies on beaver forage in Evo National Park, Lahti (1966) found Gray alder (*Alnus incana* + + +) to be the species most frequently cut. *Alnus* exhibits a continuous pollen curve up to 3 % in the pollen diagram, but there are no macrofossil finds. All the trees listed above are harvested most heavily in autumn and often stored near the lodges as big floats for winter food (Lahti 1966, 1972).

Besides the bark of trees, beavers also use herbs and dwarf shrubs in varying amounts as their seasonal summer food. In his study of Norwegian beaver populations, Simonsen (1973) found 16 non-arboreal plant species that were used to a varying extent, six of which are also common in the list of subfossils (Table1). Of these, rootstocks of Yellow water-lily (*Nuphar luteum* + + + +) and Quill-wort (*Isoëtes lacustris* + + +), frequent also in Vimpeli finds, constituted an important food. The others were Bullrush (*Scirpus lacustris* + +) and rootstocks of Broad-leaved pondweed (*Potamogeton natans* +) and rootstocks of Marsh cinquefoil *Potentilla palustris* +) all also common here but of little value as forage. There are observations of forage use of almost every species of dwarf shrub listed among the macrofossils. Bog myrtle (*Myrica gale* + +), Raspberry (*Rubus idaeus* + +) and Bilberry (*Vaccinium myrtillus* + +) grew in the vicinity and may have served as food (Simons 1973). Other plants not quoted in the literature, but present in Vimpeli II, such as pondweeds, especially *P. gramineus, Sparganium* species and *Najas flexilis*, may also have been a potential source of forage. An interesting question that has not yet been answered is the role of Fine-leaved water dropwort *(Oenanthe aquatica* Fig. 12), which is said to be poisonous to both humans and animals. The plant tastes and smells bad (Hegi 1918) and in the Nordic countries at least some species (*O. fistulosa*) of this commonly poisonous genus have been used to drive away small rodents, voles and mice (Lagerberg 1939). The great abundance of the species among the fossils (Table 1) may be due to its rejection by the beavers.

The macrofossil assemblage indicates a flora and a vegetation similar to those in the vicinity of the Ryytimaa limestone quarry today. The effect of limestone on the plant cover is very local, apparent only where the rock is exposed or covered by thin layers of peat. Extensive areas north, northwest and west of the quarry are flat and covered with thick layers of peat of a rather oligotrophic aapa-mire complex type (Ruuhijärvi 1960). Around the quarry, the rocks are covered with pine and especially juniper bushes. The Poikkijoki, a small river that originally ran through the quarry and is now dammed to make a detour round it, is bordered by dense spruce forest, as are usually the till-covered areas to the east and southeast, in the direction of glacier flow (see Aalto et al. 1983, Figs. 1, 2).

The flora with its rarities such as Lady's slipper (*Cypripedium calceolus*) was described by Backman at the beginning of the century (1909). The most striking difference between past and present floras in the vicinity of the Ryytimaa quarry at Vimpeli is due to the impact of man, which has created a disturbed, bushy look with many willow species, and birch and alder stands in different successional stages. Numerous rich forest bushes such as *Ribes, Rosa, Prunus padus* and *Viburnum opulus* are indicators of a better habitat today. The only representative among the macrofossils is Elder (*Sambucus nigra*), a species that is considered a rare alien in modern Finnish flora. Østgård (1987) also mentions Elder in his list of beaver forages. The limestone effect is indicated by a moss species (*Tortella tortuosa*) and a small Pteridophyte (*Selaginella selaginoides)*, both found as fossils and on and around recent rock outcrops in the Ryytimaa area. All in all the macrofossil assemblage has a rather demanding habitat requirement. During the beaver episode of Vimpeli II, there were successional stages of forest as a result of forest fires, which may have encouraged beaver to settle in the Ryytimaa area: the large pieces of charred wood found in the sediment are an indication of forest fires (Suomen Kuvalehti 1984/4, Fig. p. 41 and Plate I, Fig. 3).

History of the beaver

The European beaver became extinct in Finland during the last century, but the stock has been restored both in Finland and elsewhere in northern Europe by animals transplanted from Norway and Canada (Lahti 1987, Lavsund 1987, Østgård 1987, Danilov & Kan'shiev 1983, Danilov & Petrozavodsk 1987).

According to Lavrov (1983), the ancestor of the Genus *Castor* originated in Europe and developed during the Pliocene, when animals penetrated to North America, and the European and American populations grew separated. Of the two closely related species, the Canadian race (*Castor canadensis* Kuhl) is more advanced than the more primitive European one (*Castor fiber* L.).

The trees and branches gnawed by beaver were found close to each other within a small area and were obviously *in situ* or had moved only a short distance downstream. They provide documentation of beaver habitation in the area during the last Eemian interglacial, evidently during the telocratic phase, or later part of the interglacial cycle (Iversen 1958, see discussion p. 23). This concept is corroborated by the dominance of conifers in the macrofossils, the presence of plant species with a more southerly distribution than that of today in the Vimpeli area and the absence of species indicating a colder climate. There are no earlier interglacial records of beaver from Finland. From Denmark, trees gnawed by beaver have been found from deposits interpreted as interglacial (Degerböl 1982, Hansen 1965), from Tuesbol (Hartz 1909) and Emmelv (Nordmann 1924). Because the sites were not covered by the Weichselian glacier it is also possible that they originate from a Weichselian interstadial.

The European beaver is an old rodent species, remnants of which have been found from Villafrancian mammal faunas since the Early Quaternary (Scheuder 1928, Nilsson 1976, Caloi & Colombo 1978). It is typical of the beaver that it survived unchanged throughout the Quaternary at a time when many animal species became extinct. Besides the big mammals, beaver and hippopotamos (*Hippopotamus amphibius)*, other survivors of the Villafrancian fauna are the smaller Badger (*Meles thorali)*, Forest vole (*Clethrionymus glareolus*), Forest mouse (*Apodemus flavicollis* group) and Dwarf shrew (*Sorex minutus*) (Kurten 1968). Side by side with the European beaver lived another member of the beaver family (*Trogontherium*), remains of which have been found from the same strata. The most famous site of this kind is Tegelen, in the Netherlands, where abundant fossils of *Trogontherium*, but fewer of *Castor*, have been found in clay (Schreuder 1928, May 1978). Because beaver fossils from the Quaternary are found elsewhere in Europe, too, the animal evidently lived in Finland during other interglacials as well.

Abundant finds of beaver, both bone fossils and gnawing marks in wood, dating from postglacial time have been made in Finland and other northern European countries. In the mid-1970s, 25 subfossil finds of beaver were recorded (Forsten & Lahti 1976, Kurten 1988). The oldest are the find from Suomusjärvi, southern Finland, from the period of the Suomusjärvi Culture of the Mesolithic Stone Age, and the 6,500—7,000 year old skull of a beaver from Vihanti (Forsten & Lahti 1976). In postglacial vegetation zonation, these finds represent the Atlantic time. There are numerous records of beaver bone fragments from archaeological sites, from refuseheaps and so on, such as those listed by Siiriäinen (1980, p. 36). They are indications of Stone and Bronze Age man's activity in beaver hunting.

There are also numerous late-glacial and postglacial subfossil records of beaver from Sweden, the oldest of which may date from Alleröd time (Liljegren 1975). Many finds of postglacial beaver sites have also been made from Denmark; there, too, the oldest has been dated to Alleröd time (Nordman 1915, Jessen & Nordman 1915, Iversen 1973). Some of the younger finds are connected with the dwelling places of man.

GEOLOGICAL DEVELOPMENT

The Quaternary succession at the Ryytimaa quarry in Vimpeli represents an unusually long period of geological evolution and provides fascinating indirect evidence of beaver activity at the site during the Eemian interglacial, as demonstrated by the above pollen and macrofossil data.

Older till

Assuming that the peat sandwiched between till dates from the Eemian interglacial, the succession begins with Saalian glaciation till. The ice sheet that deposited the till flowed from 310°—325°, i.e. from the northwest. This demonstrates that during the previous glaciation the ice flowed from about the same direction as during the latest, i.e. Weichselian, glaciation. However, it does not give direct proof of the maximum extent of the Saalian glaciation; rather it indicates the flow direction of an ice lobe during the Saalian deglaciation.

Northwest of the Ryytimaa quarry there is a drumlin field covering 60×30 km^2 in which the longitudinal axes of the drumlins are oriented parallel to the oldest flow direction of ice. The authors believe that the drumlins have survived, albeit slightly deformed, erosion by the Weichselian glaciation. As stated in the description of the stratigraphy, older till has been encountered in test pits west of the quarry in a flat basal till area, suggesting that the till may occur in the area fairly abundantly as the lowermost till. The mean thickness of this bed, interpreted as Saalian till, in the Ryytimaa area has not been established. However, on the basis of drilling undertaken in Norinkylä, Teuva, its thickness varies between 6 and 15 m (Hirvas and Niemelä 1986).

Eemian interglacial

If we combine the findings of the present study with earlier data from Vimpeli I (Aalto et al. 1983a), we get the following picture of the last interglacial:

The coarse fluvial deposit, 0.5—1.5 m thick, overlying the Saalian till shows that the hydrography of the area was fairly similar to what it is now. At present, the river Poikkijoki flows on the upper Weichselian till; during the Eemian interglacial the topography of the basement differed in that the bed of the river flowing at the observation site was at an elevation 2—9 m lower than the bed of the present river. East of the 'beaver deposit' there was a small waterfall, as demonstrated by the pothole in dolomite found at the site (Fig. 17). The backwater of this interglacial river probably constituted the beaver habitat. The evolution of the climate in the Eemian interglacial cannot be fully reconstructed as the succession at each studied site represents only part of the total vegetation succession (Aalto et al. 1983a).

It was concluded previously that the organic deposit of Vimpeli I represents the cold, partly late-glacial, stage of the early Eemian interglacial (Aalto et al. 1983a), although the younger Peräpohjola interstadial has also been proposed (Donner 1983). If the succession is complete, then the members representing the warm climatic stage have been largely eroded away. Even so, the macrofossils in the upper portion of the succession indicate a more favourable climate in terms of temperature than that prevailing today (Aalto et al. 1983a, p. 30). There is no spruce among the macrofossils of the Vimpeli I organic deposit. However, since its abundance in the pollen flora is 8 %, it must have grown in the area. The spruce needles encountered in the basal part of the Weichselian till covering the organic deposit (Aalto et al. 1983a, p. 31) indicate that the ice sheet that deposited the till advanced over the area when spruce had already become prevalent.

The Vimpeli II 'beaver deposit' represents a warm stage of the Eemian interglacial as shown by both the macrofossils and the pollen flora. Growing conditions were somewhat better than those provided by the present-day climate, as demonstrated by the macrofossil remains of plants such as *Oenanthe aquatica, Thalictrum lucidum* and *Carex riparia*, which today have a more southerly distribution.

^{14}C determinations of the wood remains from the organic deposit give only the minimum age; the true age of the Eemian interglacial is about 120 000 years.

The lodge and dam sticks cut by beaver demonstrate that the species lived in a backwater of the river at the site. Since, moreover, beaver is known to be a pioneering species, and to have spread to Finland, too, during the late-glacial stage of the last glaciation (Lahti & Lappalainen 1972), the occurrence of beaver in itself is no proof of interglacial conditions, whereas the presence of macrofossils and microfossils in the 'beaver deposit' is.

The sand covering the 'beaver deposit' may have deposited in a backwater of the river, where it was laid down either by flowing water or as a littoral deposit. The TL ages of sand (p. 8), averaging 107 000 years, fit well with a stage succeeding the Eemian interglacial, particularly since the sand covers a deposit with vegetation indicating the thermal maximum.

Weichselian glaciation

The till of the Weichselian glaciation is fairly thick, at the site of the 'beaver discovery' almost 10 m (Fig. 18). It is evident, however, that it is distinctly thicker at the depression in bedrock

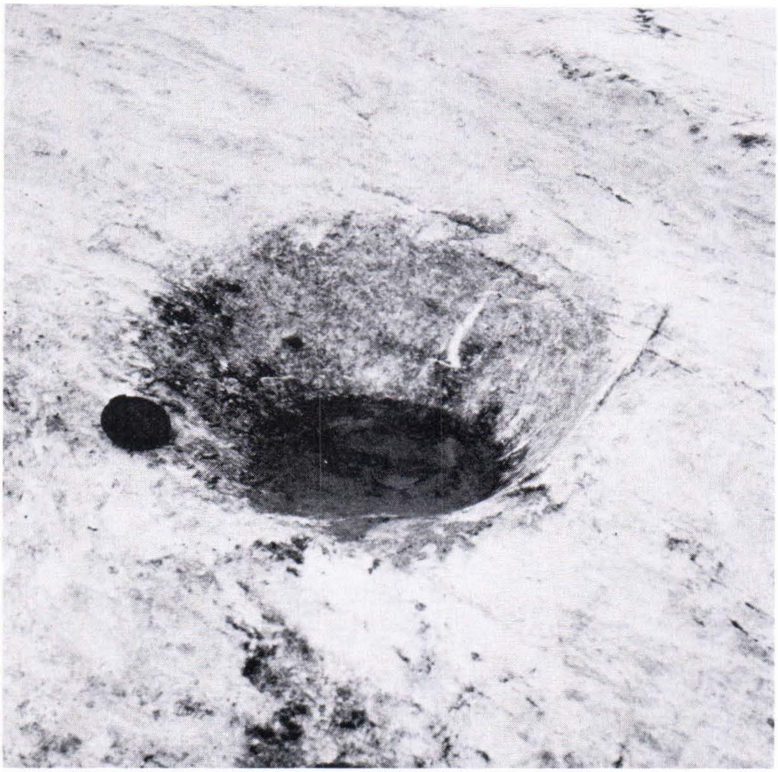

Fig. 17. A small pothole in the basement dolomite at the discovery site. It was probably formed in the waterfall of a brook during the Eemian interglacial. The beaver dam was found immediately below the waterfall. Scale 6 cm. Photo Lauri Sahala.

caused by the fracture than it is in the area in general. For example, in the drill holes in Norinkylä, Teuva, the Weichselian till is a mere 3—4 m thick (Hirvas & Niemelä 1986), which is consistent with test pit observations about the thickness of the Weichselian till.

The data on striation and the orientation of the stones in the Weichselian till are compatible and demonstrate that the ice sheet that deposited the Weichselian till flowed from 280°—290°, i.e. from a distinctly more westerly direction than the Saalian ice sheet. The concept that the drumlin field northwest of the Vimpeli site formed during the Saalian glaciation is corroborated by the drumlin morphology. Thus, the field contains drumlins trending 320° that have an asymmetric, deformed shape and often a more gentle western slope, or then two or three adjacent drumlins have grown almost together as a result of the western flow. Ridges of the pre-crag and crag - and - tail type also developed in some Saalian drumlins during the Weichselian glaciation.

The younger Weichselian flow also manifests itself in 280°—290° trending pre-crag and tail forms in the drumlins. The fact that the old drumlins survived the younger ice flow fairly well is in harmony with the numerous observations from southern and central Ostrobothnia showing that the Weichselian ice sheet caused little glacial erosion in the area (Kurkinen & Niemelä 1979, Niemelä & Tynni 1979, Hirvas & Niemelä 1986). At the two Ryytimaa sites there is a Weichselian till that obviously did not deposit until after the Jämtland/Peräpohjola interstadial. So far no observations have been made on an early-Weichselian till deposited before the Peräpohjola interstadial in the immediate vicinity either.

Fig. 18. An overall view east of the beaver deposit. Uppermost there is postglacial flood-plain sand with stick remains (F), diamicton (D), late-glacial silt (S) and the younger till (Y). Mr. Topi Kovanen, the discoverer of the beaver deposit, is on the left.

Therefore, it can be concluded that not only in this area but throughout southern and central Finland there is only one Weichselian till (Donner 1986, p. 5, Nenonen 1986, Hirvas & Nenonen 1987).

Weichselian deglaciation

Late-glacial graded-bedded silt deposited on the Weichselian till at both Vimpeli sites after the withdrawal of the ice (Fig. 18). At the 'beaver site' the silt contains 27 varves. Since the thickness of the varves in silt varies only slightly, i.e. a pattern with thick basal varves overlain by rapidly upwards thinning varves, which is typical of the front of withdrawing continental ice, is lacking, it can be assumed that the withdrawal of the ice either came to a standstill or that a short withdrawal was succeeded by an oscillation. The fact that silt became structurally complex and homogeneous and that the diamicton deposited on the silt is suggestive of an oscillation. Since the varved silt is completely undeformed it is obvious that the continental ice sheet did not readvance over the silt. Consequently, the diamicton was formed either from the till under the margin of the ice or it was transported by icebergs. The diamicton exhibits the same coarseness as the basal till. The grain size varies more than in basal till in general (Fig. e, appendix 1), the stones are not distincly oriented (Fig. a, appendix 1) and the diamicton can, therefore, be interpreted as waterlaid till.

Postglacial time

The sand layer in the post-glacial succession was deposited by the Poikkijoki, which nowadays flows in a new bed that was opened to make a detour of the quarry. The tree trunks and other organic remains buried in the basal part of the river sand (Fig. 18) are geologically young, being no more than about 3 700 years old.

CONCLUSIONS

The correlation of interglacial, mainly Eemian, deposits in Finland is a subject that has aroused lively debate in recent years (Niemelä & Tynni 1979, Eriksson, Grönlund & Kujansuu 1980, Donner 1983, 1986,1988, Forsström 1984, Nenonen 1986, Hirvas & Nenonen 1987, Forsström, Aalto, Eronen & Grönlund 1989). If Vimpeli II represents the Eemian interglacial and if the shore displacement model for the late Eemian sea deduced from the Ollala succession in Haapavesi (Forsström, Aalto, Eronen & Grönlund 1989) is correct, then Vimpeli I (Aalto et al. 1983a) cannot be from the Eemian interglacial. But then again, our knowledge about the oldest shore displacements during the marine stage succeeding the Saalian glaciation is still very fragmentary.

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REFERENCES

Aalto, M., 1982. Macrofossil plant analysis from Oulainen, Vuojalankangas site. Acta Univ. Oul. A 136, Geol. 4, 119— 123.

Aalto, M., Donner, J., Niemelä, J. & Tynni, R., 1983a. An eroded interglacial deposit at Vimpeli, South Bothnia, Finland. Geol. Surv. Finland, Bull. 324, 42 p.

Aalto, M., Donner, J., Hirvas, H. & Niemelä, J., 1983b. Tikuista asiaa — majavan jyrsimiä pesä- ja patopuita moreenin alla Vimpelissä. English summary: Till-covered branches and small tree trunks gnawn by beaver found in Vimpeli. Geologi 35 (9—10), 137—139.

Andersen, S.T., 1969. Interglacial vegetation and soil development. Dansk Geol. Fören. Meddel. 19, 90—102.

Backman, A.L., 1909. Floran i Lappajärvi jämte omnejd. Acta Soc. pro Fauna et Flora Fennica 32 (3), 1—138.

—, **1948.** Najas flexilis in Europa während der Quartärzeit. Acta Botanica Fennica 43, 1—44.

—, **1965.** Växtpaleontologiska studier på Åland. Acta Soc. pro Fauna et Flora Fennica 77 (4), 1—43.

Caloi, L. & Palombo, M., 1978. Amfibi, rettili e mammaferi di Torre del Pagliaggetto (Torre in Pietra, Roma). Quaternaria XX, 315—348.

Chabreck, R., 1958. Beaver forest relationships in St. Tammy Parish. Louisiana. Journ. Wildlife Managem. 22, 179—183.

Danilow, P.I., 1987. The Canadian and European beavers in Soviet Karelia. Nordisk Bäverseminar, rapport 1/87, 17—19.

Danilov, P.I. & Kan'shiev, V. Ya., 1983. The state of populations and ecological characteristics of European (*Castor fiber* L.) and Canadian (*Castor canadensis* Kuhl.) beavers in northwestern USSR. Acta Zoologica Fennica 174, 95—97.

Degerbøl, M., 1928. Mindre bidrag till Danmarks forhistoriske Dyreverden I. Et fragment af Baever (*Castor fiber* L.) fra Bronzealderen. Videnskabel, Meddel. Dansk naturhist. Foren. København 86. 75—81.

Donner, J., 1983. The identification of Eemian interglacial and Weichselian interstadial deposits in Finland. Ann. Acad. Sci. Fennicae A III, 136, 38 p.

Donner, J., 1986. Introduction to the Quaternary of Finland *In* Haavisto-Hyvärinen, M. (ed.): Excursion Guide, excursion no. C 2 Quaternary geology, southern Finland. Geol. Surv. finland, Guide 15, 5—13.

Donner, J., 1988. The Eemian site of Norinkylä compared with other interglacial and interstadial sites in Ostrobothnia, western Finland. Ann. Acad. Sci. Fennicae A. III. 149, 131 p.

Eriksson, B., Grönlund, T., & Kujansuu, R., 1980. Interglasiaalikerrostuma Evijärvellä, Pohjanmaalla (Summary: An interglacial deposit at Evijärvi in the Pohjanmaa region, Finland). Geologi 32: 6, 65—71.

Forsström, L., 1982. The Oulainen Interglacial in Ostrobothnia, western Finland. Act Univ. Ouluensis A 136, Geologica 4, 116 p.

Forsström, L., 1984. Eemian and Weichselian correlation problems in Finland. Boreas, Vol. 13, 301—318.

Forsström, L., Aalto, M., Eronen, M. & Grönlund, T., 1988. Stratigraphic evidence for Eemian crustal movements and relative sea-level changes in eastern Fennoscandia. Palaeogeogr., Palaeoclimatol., Palaeoecol., 68, 317—335. Elsevier Science Publishers B.V., Amsterdam.

Forstén, A., 1972. The refuse fauna of the Mesolithic Suomusjärvi period in Finland. Finskt. Museum 1972, 74—84.

Forstén, Ann & Lahti, S., 1976. Postglacial occurrence of the beaver (*Castor fiber* L.) in Finland. Boreas, Vol. 5, 155—161.

Gibbard, P., Forman, S., Salomaa, R., Alhonen, P., Jungner, H., Peglar, S., Suksi, J. & Vuorinen, A., 1989. Late Pleistocene stratigraphy at Harrinkangas, Kauhajoki, Western Finland. Ann. Acad. Sci. Fennicae A. III. 150, 36 p.

Glen, J.W., Donner, J.J. & West, R.G., 1957. On the mechanism by which stones in till become oriented. Am. J. Sci. Vol. 255, 194—205.

Godwin, H., 1975. The history of the British Flora, 2nd ed., University Press, Cambridge. 541 p.

Hall, J.G., 1960. Willow and Aspen in the ecology of beaver on Sagehen Creek, California. Ecology 41 (3). 484—494.

Hansen, S., 1965. The Quaternary of Denmark *in:*The Quaternary Vol. 1, pp. 1—90, ed. K. Rankama. Intersciece. New York.

Hartz, W., 1909. Bidrag til Danmarks tertiaere og diluviale Flora. Danm. Geol. Uneers. II Raekke, 20, 1—192.

Hegi, G., 1918. Illustrierte Flora von Mittel-Europa. VI, 1. 544 p. J.F. Lehmanns Verlag. München.

Hiitonen, I., 1933. Suomen Kasvio. 771 p. Oy Otava. Helsinki.

Hirvas, H. & Niemelä, J., 1986. Ryytimaa, Vimpeli. *In* Haavisto-Hyvärinen, M. (ed.): Excursion Guide, excursion no. C 2 Quaternary geology, southern Finland. Geol. Surv. Finland, Guide 15, 47—50.

Hirvas, H. & Niemelä, J., 1986. Norrinkylä, Teuva. *In* Haavisto-Hyvärinen, M. (ed.): Excursion Guide, excursion no. C 2 Quaternary geology, southern Finland. Geol. Surv. Finland, Guide 15, 55—57.

Hirvas, H. & Nenonen, K., 1987. The till stratigraphy of Finland. *In* Kujansuu, R. & Saarnisto, M. (eds.): INQUA Till symposium, Finland 1985. geological Survey of Finland, Special Paper 3, 49—63.

Holyoak, D.T., 1983. The identity and origins of *Picea abies* (L.) Karsten from the Chelford Interstadial (Late Pleistocene) of England. The New Phytologist 95, 153— 157.

Hultén, E., 1971. Atlas of the distribution of vascular plants in North Western Europe. 2nd ed. ab Kartografiska Institutet. Stockholm, 531 p.

Hultén, E. & Fries, M., 1986. Atlas of North European vascular plants, North of the tropic of Cancer. I—III. Koelts Scientific Books, D-6240 Königstein.

Hämet-Ahti, L., Suominen, J., Ulvinen, T., Uotila, P. & Vuokko, S. (eds.), 1986. Retkeilykasvio 3rd ed., 544 p. Suomen Luonnonsuojelun Tuki. Helsinki.

Iversen, J., 1958. The bearing of glacial and interglacial epochs on the formation and extinction of plant taxa.*In* O. Hedberg (ed.), Systematics to-day. Acta Univ. Upsalaensis, 210—215.

Iversen, J., 1973. The Development of Denmarks Nature since the Last Glacial. Danmarks Geol. Undersøgelse, V. Raekke. Nr. 7 — C. 128 p.

Jessen, A. & Nordmann, V., 1915. Ferskvandslagene verd NørreLyngby. Danmarks Geol. Undersøgelse, I Raekke. Nr. 29.

Jungner, H., 1987. Thermoluminescense dating of sediments from Oulainen and Vimpeli, Ostrobothnia, Finland. Boreas, Vol. 16, 231—235.

Kurkinen, I. & Niemelä, J., 1979. Rapaumahavainto Kauhajoella. English summary: Weathered bedrock in Kauhajoki. Geologi 31, 5, 79—81.

Kurtén, B., 1968. Pleistocene Mammals of Europe. 317 p. London.

Kurtén, B., 1988. Fossil and subfossil mammals in Finland. — Memoranda Soc. Fauna Flora Fennica 64, 35—39.

Lagerberg, T., 1939. Vilda växter i Norden III. 3rd ed. Oenanthe, 1214—1218. Stockholm.

Lahti, S., 1966. Majavan ravinnonvalinnasta ja ravinnon käytöstä. Suomen Riista 18, 7—19. English summary: On the food habits of the beaver (Castor spp.) in Northern Finland.

—, 1972. Majava. *In* L. Siivonen. Suomen nisäkkäät, 285—308. Keuruu. 474 p.

—, 1987. Bäverns tidligare og nuvarande utbredning i Finland. Nordisk Bäverseminar. Rapport Nr. 1/87, 13—16.

Lappalainen, E. & Lahti, S., 1972. Postglacial evidence of the occurrence of the Beaver *(Castor fiber* L.) in eastern Finland. ann. Zool. Fennici 9, 139—140.

Lavrov L.S., 1983. Evolutionory development of thegenus *Castor* and taxonomy of the contemporary beavers of Eurasia. Acta Zool. Fennica 174, 87—90.

Lavsund, S., 1987. Bäverns utbredning i Sverige 1986. Nordisk Beverseminar. Rapport Nr. 1/87, 9—12.

Liljegren, R., 1975. Subfossila vertebratfynd från Skåne. Univ. Lund. Dept. Quaternary Geology Report 8, 1—187.

May, H., 1978. Untersuchung von Gebissen der pleistozänen Biberarten Trogontherium und Castor und ihre Stratigraphische Einordnung. Schr. Naturw. Schlesw.-Holst., Bd 48, 35—39.

Meriläinen, J., 1962. Muutamia vesikasvilöytöjä Itä-Suomesta. Luonnon Tutkija 66: 163.

Nenonen, K., 1986. Orgaanisen aineksen merkitys moreenistratigrafiassa. English summary: The significance of organic material in till stratigraphy. Geologi 38 (2), 41—44.

Niemelä, J. & Tynni, R., 1979. Interglacial and interstadial sediments in the Pohjanmaa region, Finland. Geological Survey of Finland. Bulletin 302. 48 p.

Nilsson, T., 1983. The Pleistocene: Geology and Life in the Quaternary Ice Age. Reidel Publishing Co., Dordrecht, 651 p.

Nordmann, V., 1915. On remains of Reindeer and Beaver from the commencement of the Postglacial forest period in Denmark. Danmarks Geol. Undersøgelse, II Raekke. Nr. 28, 24 p.

—, 1928. Iagttagelser over nogle af Baeveren, Castor fiber, gnavade Grene, og: Tillföjelse tille samme. Vidensk. Medd. Dansk naturh. Foren. Bd 78, 74—81.

Nummi, P., 1983. Majavan vaikutuksesta vesilintuihin. Pro gradu, Helsingin yliopisto, Eläintieteen laitos. (Unpublished).

Pipping, F., 1979. Prequaternary rocks. Sheet 2313 Alajärvi. Geological Map of Finland, 1 : 100 000.

Ruuhijärvi, R., 1960. Über die regionale Einteilung der Nordfinnischen Moore. Annales Bot. Soc. »Vanamo», 31 (1), 1—360.

Schreuder, A., 1929. Conodontes (Trogontherium) and Castor from the Teglian Clay compared with the Castoridae from other localities. Arch. Mus. Teyler, ser. 3, vol. 6, 99—320.

Semyonoff, B.T., 1951. The river beaver in Archangel province. Translation of Russian Game Reports, Vol. 1, 5—46. *In* Canad. Wildl. Serv. 1957. Ottawa.

Siiriäinen, A., 1980. On the cultural ecology of the Finnish Stone Age. Suomen Museo 87, 5—40.

Simonsen, T.A., 1966. Beverens naeringsplanter. Kristiansand Museum. Årbok 1966, 18—36. Kristiansand.

—, 1973. Beverens naeringsokologi i Vest-Agder. Medd. Stat. Viltunders. 2. serie, 39, 1—61. English summary: Feeding ecology of the beaver (*Castor fiber* L.). Papers of The Norwegian State Game Research Institute.

Simpson, I.M. & West, R.G., 1958. On the loess stratigraphy and palaeobotany of a late-Pleistocene organic deposit at Chelford, Cheshire. The New Phytologist 57, 239—250.

Srodon, A., 1967. The common spruce in the Quaternary of Poland. Acta Palaeobotanica 8 (2), 1—59.

Tutin, T.G., Heywood, V.H. et al. (Eds.), 1964—1980. Flora Europaea I—V. University Press, Cambridge.

Venäläinen, J., 1982. Notkea näkinruoho (*Najas flexilis),* löydetty Parikkalan Simpelejärvestä. Mem. Soc. Fauna Flora Fennica 60.

Virkki, J. & Rissanen, Y., 1984. 120 000 tuhatta vuotta vanhat majavan hampaanjäljet. Suomen Kuvalehti 1984 (4), 38—41.

Warner, B.G. & Chmielewski, J.G., 1987. Biometric analysis of modern and Late Pleistocene cones of *Picea* from Western Canada. New Phytologist 107, 449—457.

Østgård, J., 1977. Beveren i Søndre Vestfold. Bestandsutvikling og økologi. Hovedfagsoppgave, NLH.

—, 1987. Beverens ernaering med spesiell vek på treefelling. Baevernebroblematikk. Nordisk Beverseminar. Rapport. Nr. 1/87, 42—47.

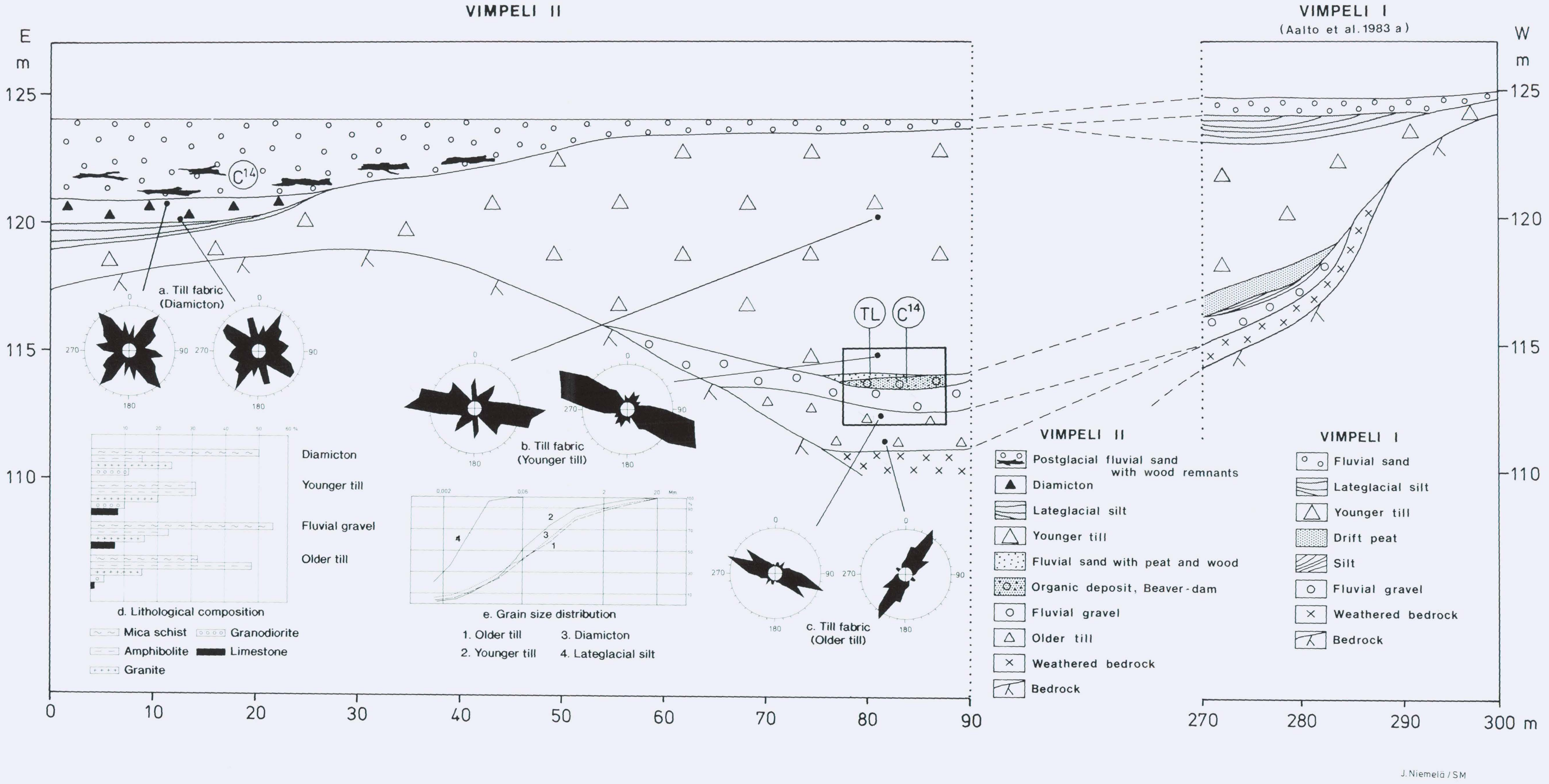
PLATE

Fig. 1. Two spruce (*Picea abies*) cones, a pine (*Pinus sylvestris*) cone and a stick remnant in a sandy organic deposit. Scale 5 cm.

Fig. 2. Flattened cones and pieces of sticks in the organic deposit. See also Fig. 1, the stick remnant on the right. Scale 5 cm.

Fig. 3. A charred stick from the 'beaver deposit'.

Fig. 4. A detail of partly silty fluvial sand. Uppermost there is till, in the middle sand and lowermost the organic deposit. There are faults in the fluvial sand caused by glacial pressure.
Scale 5 cm.



VIMPELI II
VIMPELI I
(Aalto et al. 1983 a)
E
m
W
m
125
120
115
110
C14
TL
C14
a. Till fabric
(Diamicton)
b. Till fabric
(Younger till)
c. Till fabric
(Older till)
Diamicton
Younger till
Fluvial gravel
Older till
d. Lithological composition
Mica schist
Granodiorite
Amphibolite
Limestone
Granite
e. Grain size distribution
1. Older till
2. Younger till
3. Diamicton
4. Lateglacial silt
0
10
20
30
40
50
60
70
80
90
270
280
290
300 m
VIMPELI II
Postglacial fluvial sand with wood remnants
Diamicton
Lateglacial silt
Younger till
Fluvial sand with peat and wood
Organic deposit, Beaver-dam
Fluvial gravel
Older till
Weathered bedrock
Bedrock
VIMPELI I
Fluvial sand
Lateglacial silt
Younger till
Drift peat
Silt
Fluvial gravel
Weathered bedrock
Bedrock
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