Late Pleistocene Glacigenic Deposits from the Central Part of the Scandinavian Ice Sheet to Younger Dryas End Moraine Zone

Excursion guide and abstracts

INQUA Peribaltic Working Group Meeting and Excursion
Northern Finland, 12-17 June 2011

Edited by

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Rovaniemi 2011

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CONTENT

PROGRAM

Sunday 12th June

12.00 Registration in GTK, Rovaniemi (Lähteentie 2)
15.00 Departure from GTK and drive to Kittilä
18.00 STOP 1. Boulder fields and the test areas on the Levi fell, Kittilä
19.00 Dinner and accommodation in Kittilä (cottages of the Kittilä Lomamökit)

Monday 13th June

08.00 Breakfast and departure from the Kittilä Lomamökit
09.00 STOP 2. Naakenavaara interglacial deposit, Kittilä
09.30 STOP 3. The postglacial fault at Riikonkumpu, Kittilä
10.00 – 13.00 STOP 4. Kittilä Gold Mine, Kittilä; lunch
13.30 STOP 5. The Ounasjoki Ice Lake and the spillway of Seurujärvi, Kittilä
16.00 – 17.30 STOP 6. Siida – The National Museum of the Finnish Sámi, Inari
19.00 Arrival to the Kevo Research Station, Utsjoki; dinner and accommodation

Tuesday 14th June

08.00 Breakfast
09.30 STOP 7. Ala-Jalve – Glaciofluvial deposits in the Tana valley, terraces and an old dwelling site (Finland)
11.00 STOP 8. Bigganjarga tillite – evidence for the Neoproterozoic glaciation (Norway)
14.00 STOP 9. Nyelv – terraces and raised shorelines and field lunch (Norway)
16.30 STOP 10. Tanabru – Younger Dryas end moraine zone (Norway)
17.30 Drive back to the Kevo Research Station
18.00 INQUA Peribaltic Working Group Meeting
19.00 Dinner

Wednesday 15th June

08.00 Breakfast
09.00 – 17.30 Symposium at the Kevo Research Station; oral presentations and posters
- Keynote presentations:
Prof. Volli Kalm, University of Tartu
Prof. Dmitry Subetto, A.Herzen Russian State Pedagogical University
18.00 Sauna
20.00 Symposium dinner

Thursday 16th June

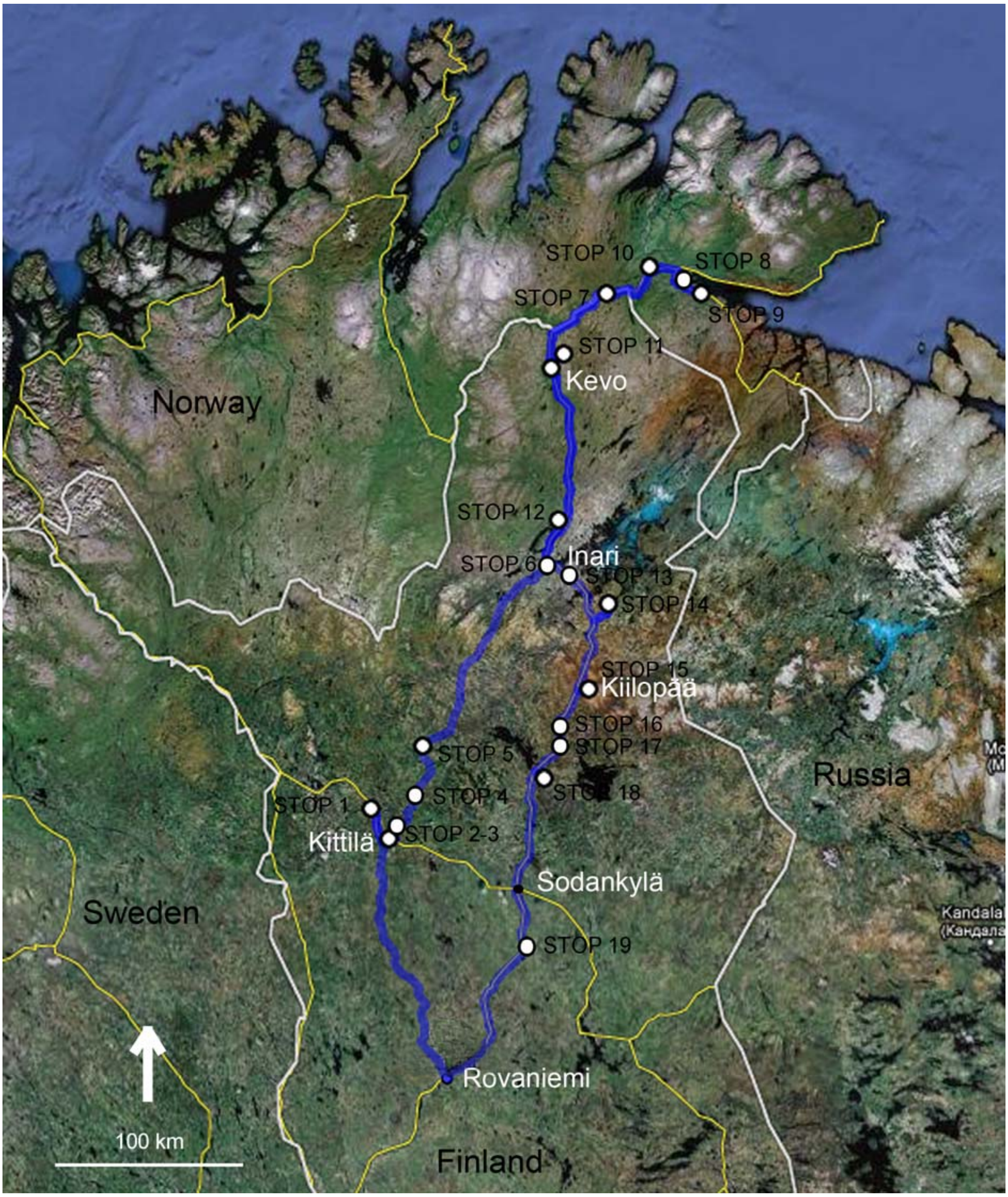
08.00 Breakfast and departure from Kevo
09.00 STOP 11. Palsas at Vaisjeäggi, Kevo
11.00 STOP 12. Drumlins, esker and dunes in Kaamanen - Mutusjärvi area, Inari
12.00 – 13.00 STOP 13. The Cave of the Karhunpesäkivi, the Boulder of Bear's Den, Inari. Field lunch.
14.00 STOP 14. Late Middle Weichselian inter-till deposit in Veskoniemi, Ivalo
16.30 Arrival to Kiilopää, accomodation in the cottages of Kiilopää Fell Centre
17.00 STOP 15. Quaternary geology of the Kiilopää area
Possibility for gold panning on the river near the accommodation.
19.00 Dinner and sauna

Friday 17th June

08.00 Breakfast and departure from Kiilopää
09.00 STOP 16. Placer gold in Lapland - Tankavaara gold museum
11.30 STOP 17. The Quaternary geology in the surroundings of the village Vuotso
12.30 STOP 18. Complex glacial-interglacial stratigraphy in Äältövittikot, Sodankylä. Field lunch.
15.00 STOP 19. The Pyhä-Luosto end moraine field and Torvinen esker in Sodankylä
16.30 Departure to Rovaniemi via airport and railway station.

Front cover photo: An illustration of an ice dammed lake in northern Finland during the last deglaciation (Designed by Mr. Harri Kutvonen)

Back cover photo: Midnight Sun at Pallastunturi, Finnish Lapland (Photo: Peter Johansson)



Excursion route and the locations of the stops and the accommodation places in Kittilä, Kevo and Kiilopää.

Preface

The Peribaltic Working Group is an INQUA (International Union for Quaternary Research) research group. It brings together ice age researchers from countries around the Baltic Sea once a year for over ten years now. The Peribaltic WG is one of the most active working groups and its activities are subordinated to the INQUA Commission on Terrestrial Processes, Deposits and History (TERPRO). The aim of the working group is to enhance the research co-operation between the countries around the Baltic Sea and to create contacts between researchers in different countries.

The 2011 meeting takes place from 12 to 17 June in Finland, at the Kevo Research Station in Utsjoki, which belongs to the Turku University. Researchers from ten different countries comes together to give lectures, discuss and share the latest research results about climate changes during the latest Ice Ages, Saalian and Weichselian, the movement of glaciers, the morphological features they created and the development of the vegetation during several interglacial and -stadial phases. The information is based on new, more accurate age determination methods and a tighter sample network.

The meeting includes a five-day-excursion to northern Finland and northern Norway, with the theme of ‘Late Pleistocene glacigenic deposits from the central part of the Scandinavian Ice Sheet to Younger Dryas End Moraine Zone’. Besides the key stratigraphical points in Central Lapland, the participants will visit different kind of geological localities in northern Fennoscandia, where the glacial dynamics and the circumstances of the glacigenic deposits in the last deglaciation stage are well visible. The Geological Survey of Finland and the University of Oulu’s Institute of Geosciences organize the meeting and excursion. The Finnish National Committee for Quaternary Research and The Peribaltic Group also participated in organising the event.

At the meeting, 37 lectures are given, 15 of which are oral presentations and 22 poster presentations. This publication contains the revised abstracts of the lectures. Prof. Juha Pekka Lunkka, Dr. Peter Johansson and Dr. Pertti Sarala served as the reviewers and the editors of this publication. This volume is available in electronic version: http://www.gtk.fi. The editors express our gratitude to the Geological Survey of Finland (GTK) and the Federation of Finnish Learned Societies for supporting the excursion and this publication.

Peter Johansson, Juha Pekka Lunkka and Pertti Sarala

Rovaniemi 3.6.2011

The glaciation of Northern Finland

Peter Johansson, Juha Pekka Lunkka and Pertti Sarala

Introduction

The Scandinavian Ice Sheet, the centre of which situated in the Scandinavian mountain range, covered Finland and the north-western Russian Plain several times during the Quaternary cold stages. It is not known precisely how many times Finland was covered by ice during the Quaternary. This is because the area is situated close to the glaciation centre and the ice advances eroded and deformed most of previously deposited interglacial and glacial sediments during the cold stages. Therefore it is common that only the pre-Quaternary weathered bedrock surface and the sediments deposited during the last cold stage (Weichselian) rest on the Pre-Cambrian bedrock. Except for some scattered remnants of the Saalian esker ridges (Kujansuu & Eriksson 1995) in the ice-divide zone of northern Finland (Finnish Lapland) and in the major river valleys in the Pohjanmaa area, in western Finland (for location: Fig. 1), there are no distinct geomorphological landforms related to pre-Weichselian glaciations. However, there are a number of sites where Middle and Late Pleistocene organic and glacial sediments have been preserved, particularly in northern Finland and in Pohjanmaa, western Finland (*cf.* Hirvas 1991; Nenonen 1995). These sites provide the basis for the general Quaternary stratigraphy of Finland.

According to the Finnish till stratigraphy, there are six, stratigraphically-significant till beds in Finnish Lapland. The key site for the till stratigraphy is the Rautuvaara area in western Finnish Lapland (Hirvas *et al.* 1977; Hirvas 1991). The three uppermost till beds are thought to represent Weichselian-age tills (Till Beds I – III), two of these (Till Bed I and II) are thought to have been deposited during the Late Weichselian. The so-called Till Bed IV was laid down during the Saalian glaciation. The two lowermost till beds (Till Beds V-VI) that occur beneath the Holsteinian peat horizon may represent Elsterian or pre-Elsterian tills (*cf.* Hirvas & Nenonen 1987; Hirvas 1991).

Middle Pleistocene glaciations

There is only one site, Naakenavaara in western central Lapland where a peat unit, biostratigraphically correlative to the Holsteinian Stage interglacial (Hirvas 1991; Aalto *et al.* 1992) is underlain by the sand and gravel unit and the till unit. According to Hirvas (1991) this till unit was most probably deposited during the Elsterian glaciation. During the Saalian Stage glaciation all of Finland was covered by ice (*e.g.* Svendsen *et al.* 2004) although little is known about the Saalian glacial history. However, there are a number of sites, particularly in Lapland and central western Finland, where till or glaciofluvial deposits underlie Eemian organic sediments (*cf.* Grönlund 1991; Eriksson 1993; Nenonen 1995; Donner 1995).

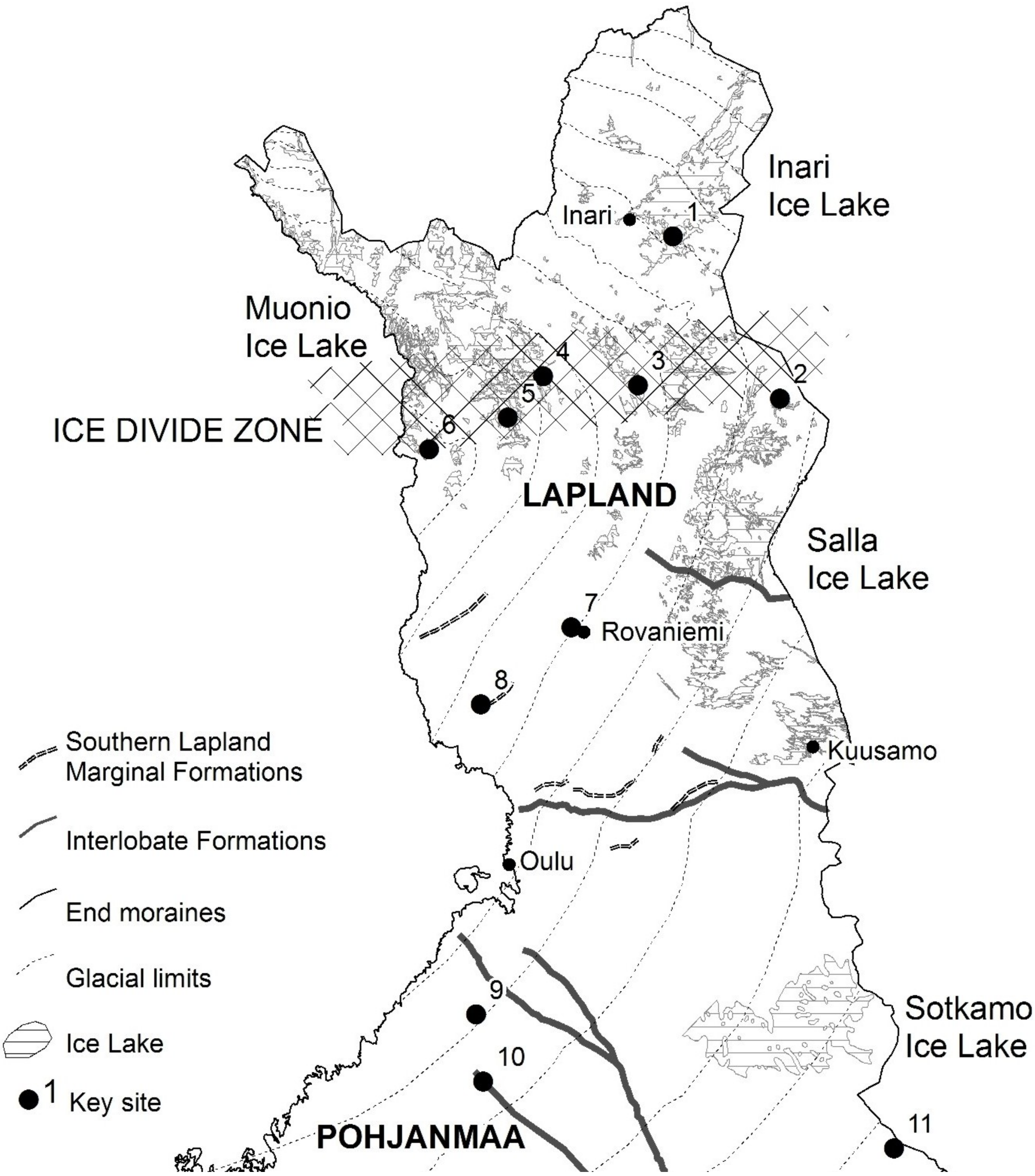


Fig. 1. A deglaciation map of Finland showing the Southern Lapland Marginal Formations and the main Late Weichselian end and interlobate moraines, ice lakes and ice limits. Key sites marked on the map are: 1. Veskoniemi, 2. Sokli, 3. Maaselkä, 4. Tepsankumpu, 5. Naakenavaara, 6. Rautuvaara, 7. Permantokoski, 8. Kauvonkangas, 9. Oulainen, 10. Hitura, 11. Ruunaa.

Observations of the Saalian till bed have been undertaken mainly from the central and southern Lapland (Hirvas 1991; Sutinen 1992; Mäkinen 2005). Saalian till has been preserved in depressions and it is usually highly compacted. Based on till fabrics and striae observations, the ice-flow direction was from the southwest. This indicates that the centre of the glaciation situated in the central Sweden, west to the Gulf of Bothnia.

Late Pleistocene glaciations (*c*. 110 – 11.7 ka)

The stratigraphy of the Early and Middle Weichselian substages is based on the correlation of the interstadial organic deposits, till stratigraphy and till-covered glaciofluvial landforms. These data suggest that southern and northern Finland experienced a rather different glaciation history during the Weichselian. Basically, the main difference between these two areas is that northern Finland was already covered by the Scandinavian Ice Sheet during the Early Weichselian while there is no firm evidence of Early Weichselian ice-cover in the southern part of Finland at this time (Fig. 2). This is probably a result of two separate ice-dome areas in the Scandinavian Mountains that behaved semi-independently in space and time during the Weichselian.

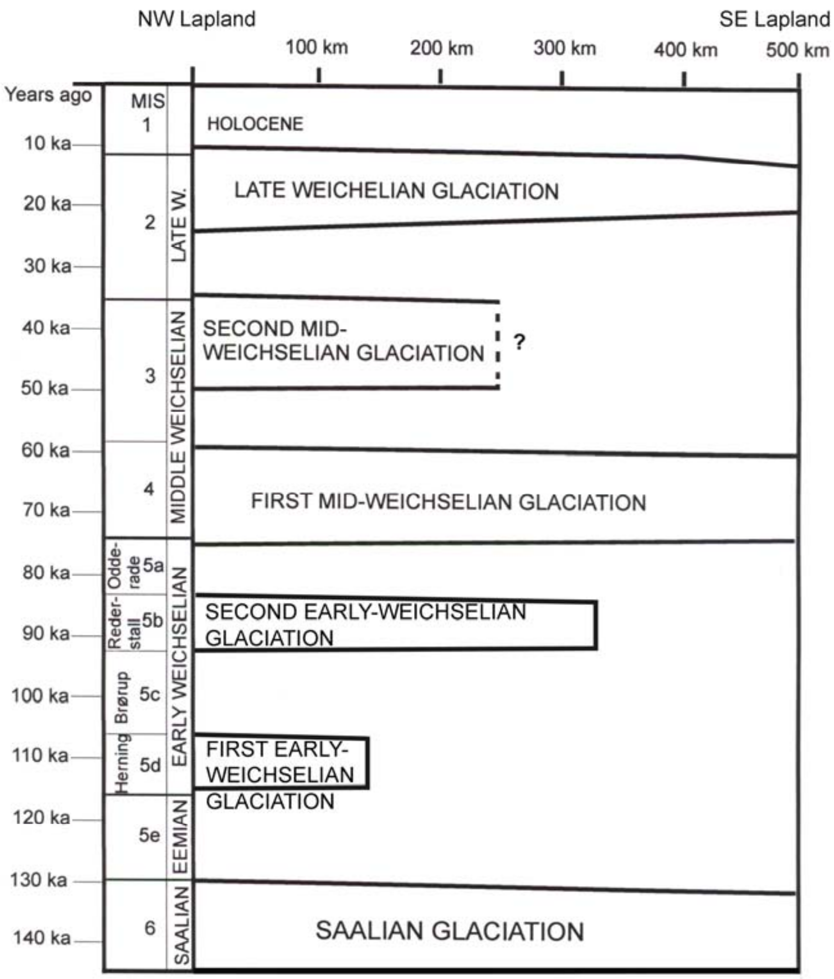


Fig. 2. Time-distance diagram showing the growth and decay of the Scandinavian Ice Sheet during the Middle and Late Pleistocene. A glaciation curve from northwest to southeast across northern Finland.

Early Weichselian Substage (*c*. 110 – 74 ka)

It is generally assumed that after the Eemian Stage interglacial ice began building up in the Scandinavian Mountains and spread into the adjacent areas twice during the Early Weichselian stadials, MIS 5d and MIS 5b. However, during the Early Weichselian interstadials, Brørup, MIS 5c and Odderade, MIS 5a, the ice melted at least once almost completely even in the Scandinavian Mountains (*cf.* Anderson & Mangerud 1990; Saarnisto & Salonen 1995; Donner 1995).

In northern Finland, many stratigraphically important areas and key sites are located in the ice-divide zone in Central Lapland where Pleistocene sediments were preserved as a result of the low ice-velocities and to frozen bed conditions (Hirvas 1991; Kleman *et al.* 1999; Sarala 2005). As mentioned above, six different till units have been discovered in northern Finland and some of these till beds are interbedded with organic layers (*cf.* Korpela 1969; Hirvas *et al.* 1977; Hirvas 1991; Helmens *et al.* 2000, 2007). At Tepsankumpu, Central Lapland, a type locality for the Tepsankumpu Interglacial, a freshwater gyttja unit that occurs stratigraphically between Till Beds IV and III is characterised by a mixed taiga pollen assemblage (*cf.* Saarnisto *et al.* 1999). The Tepsankumpu Interglacial deposits and other gyttja and peat deposits between Till Beds IV and III elsewhere in Central Lapland are correlated with the Eemian Stage (Hirvas 1991; Saarnisto *et al.* 1999). Similarly, a continuous sediment succession from Sokli, in north-eastern Lapland, that consists of three till beds interbedded with lacustrine, fluvial and glaciolacustrine sediments above the Eemian marker horizon clearly indicate that there were at least three separate ice advances across Lapland during the Weichselian Stage (*cf.* Helmens *et al.* 2000, 2007).

Within these Weichselian sediment successions, there are several sites where interstadial units have been discovered between the Weichselian till units. The interstadial unit at Maaselkä, in Central Lapland occurs between Till Beds III and II. In this unit, birch dominates the pollen sequence. The Maaselkä interstadial is considered as the stratotype locality for the Peräpohjola Interstadial, an event that was previously correlated with the Brørup Interstadial (*cf.* Hirvas & Nenonen 1987; Donner *et al.* 1986). However, the results of recent studies in southern and central Lapland suggest that the southern part of Lapland at least was ice-free during the Early Weichselian Stadial, MIS 5d. Likewise, the Peräpohjola interstadial sediments are most probably correlative of either to the Odderade Interstadial, MIS 5a, or to one of the Middle Weichselian interstadials, MIS 3 (*cf.* Mäkinen 2005; Sarala 2005, 2007, 2008).

At Sokli, a silt unit, that contains a tundra-type pollen assemblage, separates the Eemian interglacial and the Brørup interstadial units and both the Odderade and the Middle Weichselian interstadial sediments are underlain by till (Helmens *et al.* 2000). Therefore, it seems that north-eastern Finland was unglaciated until MIS 5b around 90 ka (*cf.* Alexanderson *et al.* 2008). During the MIS 5d, the Scandinavian Ice Sheet margin most probably located in northwestern Finnish Lapland or in northern Sweden (*cf.* Lundqvist 1992).

There are a number of landforms that are related to the ice-flow activity in northern Finland during the Early Weichselian glaciations. Ice-marginal landforms from the Pudasjärvi area, northern Pohjanmaa have been described by Sutinen (1992). These elongate landforms are mostly composed of coarse, glaciofluvial sediment that strikes perpendicular to the Early Weichselian ice-flow direction from NW to NNW. They are buried by Late Weichselian till. On the distal side of the Pudasjärvi End Moraines, the till unit is absent and Eemian deposits lie between the Saalian and Late Weichselian tills. In addition to these Early Weichselian landforms, till-covered, ice-marginal landforms in the Tervola – Ylitornio area (Mäkinen 1985) and till-covered esker sequences (Johansson 1995) in central Lapland might represent the deglaciation phase of the second Weichselian stadial, MIS 5b. Although the Early Weichsleian glacial history in Finland is rather well constrained, it is still poorly known in detail. Particular problems are related to the correlation of different till and interstadial units in northern Finland and to the ice extent during the Early Weichselian stadials.

Middle Weichselian Substage (*c*. 74 - 25 ka)

At the beginning of the Middle Weichselian (*c.* 74–60 ka, MIS 4), the whole of Fennoscandia became covered by the Scandinavian Ice Sheet (*cf*. Saarnisto & Lunkka 2004; Svendsen *et al*. 2004). Litho- and biostratigraphical evidence, supported by ^{14}C- and OSL dates suggest that the major part of Finland was ice free at least once or possibly several times during the latter part of the Middle Weichselian Substage (MIS 3) between *c.* 54–25 ka ago (*cf.* Nenonen 1995; Ukkonen *et al.* 1999; Lunkka *et al.* 2001, 2008; Salonen *et al.* 2008; Helmens *et al.* 2007, 2009).

The extent of the Middle Weichselian ice sheet in northern Finland is still unknown. According to Hirvas (1991), northern Finland remained ice-covered after the Peräpohjola Interstadial, previously correlated with Brørup Interstadial, until deglaciation in the Late Weichselian and Early Holocene. However, at several sites in southern Finnish Lapland silt and sand units between till beds have yielded OSL-ages ranging from 39–69 ka (Mäkinen 2005; Sarala *et al.* 2005; Sarala & Rossi 2006). At one site in Kauvonkangas, southern Finnish Lapland peat and gyttja horizons associated with periglacial palaeosols occurring between two till beds have yielded OSL and ^{14}C ages between 39–27 ka (Mäkinen 2005), clearly indicating a Middle Weichselian (MIS 3) ice-free period. Similarly at Sokli, eastern Lapland, a two metre thick sequence of laminated sediment is thought to have been deposited in a glaciolacustrine environment during MIS 3 at around 40 ka ago (Helmens *et al.* 2000, 2009). The laminated unit contains pollen indicating shrub tundra vegetation. Based on relatively high tree pollen percentages in these sediments, it has also been argued that pine and tree birch were probably growing only a few hundred kilometres south or south-east of Sokli (Bos *et al.* 2009). Recent results have therefore shown that after the Odderade Interstadial the Scandinavian Ice Sheet advanced across northern Finland during MIS 4. Subsequently, eastern and southern Lapland was deglaciated during the MIS 3 before the last glacial ice advance in the Late Weichselian (Fig. 2).

A number of landforms are thought to have been deposited by the Middle Weichselian ice sheet. Sarala (2005) has shown the north-north-west – south to south-east-trending drumlin field and associated stratified sediments above in south-western and western Finnish Lapland were deposited by ice in the early stage of the Middle Weichselian and during its deglaciation. In addition, ice-marginal deposits in southern and central Lapland (*cf.* Sutinen 1992; Mäkinen 1985) were most probably formed during different stages of the Middle Weichselain (MIS 4) ice recession.

At least three cross-cutting esker systems have been identified in north-eastern Finland. Till-covered eskers, with a north-south orientation, were found just south of the Sokli area, in the same region where the 'old northern' till bed (possibly deposited during the MIS 4). This till was deposited by ice that moved southwards (Johansson 1995; Johansson & Kujansuu 1995). Therefore, the till and esker stratigraphy, together with the interstadial sediments of Middle Weichselian age (^{14}C- AMS age 42 ka) found at Sokli, indicate that the area was deglaciated at least once during the Middle Weichselian, prior to the final build-up of ice at the Late Weichselian maximum (Helmens *et al.* 2000).

Late Weichselian Substage (*c*. 25 – 11.7 ka)

The rapid ice-advance of the Scandinavian Ice Sheet across Finland into the NW Russian Plain took place after 25 ka cal BP ago (*cf*. Lunkka *et al.* 2001; Svendsen *et al*. 2004). Based on clast fabric analysis and bedrock striae measurements, the ice-movement direction during this advance phase was from a westerly direction (*cf.* Salonen et al. 2008). Recent results from Veskoniemi, northern Lapland also indicate that the ice did not cover the area until *c.* 22–25 ka ago (Sarala *et al.* 2010). The Scandinavian Ice Sheet reached its maximum extent in the north-west Russian Plain and the Kanin Peninsula between *c.* 18.5–17 ka ago (Lunkka *et al.* 2001; Larsen *et al.* 2006), began retreating and Finland was completely deglaciated by *c.* 10 ka ago (*cf.* Saarnisto & Lunkka 2004).

The Late Weichselian deglaciation (*c.* 11.7 – 10 ka)

The deglaciation of northern Finland is mainly based on the study of glacigenic deposits and glaciofluvial landforms (Tanner 1915; Penttilä 1963; Kujansuu 1967; Aario & Forsström 1978; Johansson 1988, 1995). The retreating ice sheet melted in a supra-aquatic (terrestrial) environment, the results of which created a range of erosional and depositional landforms. Subaquatic conditions existed only in the south-western part of Lapland which was covered by the waters of the Ancylus Lake phase of the Baltic Basin.

The youngest ice flow direction can be used to delineate the retreat of the ice sheet, because this retreat was usually in the opposite direction to that of the last ice flow. The network of subglacial glaciofluvial systems (esker chains) shows the direction of the retreating ice sheet even more accurately. These systems contain depositional landforms, i.e. steep-sided and sharp-crested esker ridges with zones of glaciofluvial erosion between them. The radial pattern of the Late Weichselian subglacial drainage systems reflects the direction of ice-marginal retreat towards the ice divide zone in Central Lapland. In the northern part of Lapland, the ice margin retreated towards the south – south-west and in the southern part of Lapland to the north-west.

Meltwater activity at the boundary of the ice sheet and the exposed terrain produced series of shallow meltwater channels, *i.e.* lateral drainage channels. These channels indicate the surface gradient of the ice sheet and the rate of melting at the end of the deglaciation phase, when the highest mountains emerged from beneath the ice sheet as nunataks. Penttilä (1963), Kujansuu (1967) and Johansson (1995) have used these channels to reconstruct the deglaciation in the mountain areas of Lapland. They found that the surface gradient of ice sheet varied here from 1 to 5 metres per 100 metres and the average ice retreat rate was generally between 130-170 m/year.

In the supra-aquatic area of northern Finland, the ice margin retreated downslope along the main river valleys. As a result the meltwaters were unable to drain but formed ice-dammed lakes in the river valleys at lower altitudes. The lake phases are indicated by the presence of ancient shorelines and outlet channels, coarse outwash and fine-grained glaciolacustrine sediments. The largest of these glacial lakes covered thousands of square kilometres and were located in Salla, eastern Lapland, in Muonio and Ounasjoki valleys, north-western Lapland and in the Inari Basin, northern Lapland (Kujansuu 1967; Johansson 1995; Kujansuu *et al.* 1998). The ice lakes drained from one river valley to another across the water divides creating erosional landforms, such as deep and narrow gorges. Successive extramarginal meltwater systems formed along the retreating ice-front. Some of these features can be followed hundreds of kilometres from the higher terrain in northwestern Lapland to the lower levels in eastern Lapland (Kujansuu 1967; Johansson 1995). Initially meltwater flow was directed northwards over the main water divide. However, as the ice sheet became smaller and retreated south-westwards, the meltwater flow was redirected eastwards and finally south-eastwards along the retreating ice margin towards the Baltic Basin. Collecting all the palaeohydrographic information, for example by mapping the ice dammed lakes and the extra-marginal channels between the ice-dammed lakes, it is possible to reconstruct a reliable picture of successive stages of the ice retreat in the supra-aquatic areas (Johansson 2007).

The Younger Dryas ice-marginal landforms are situated in North Norway only 20 kilometres from the northernmost part of Finnish Lapland (Sollid *et al.* 1973). At that time the ice-divide zone *i.e.* the centre of the ice dome located in Central Lapland, and the active ice flow was towards the north-east and towards the south-east and east. Extensive drumlin fields in Inari, northernmost Lapland and in Kuusamo, south-easternmost Lapland were formed during this flow phase. As the ice sheet began retreating from the Younger Dryas end-moraine zones *c.* 11.6 ka ago (Saarnisto 2000), the highest mountain tops in north-western and northern Lapland were the first to emerge as nunataks from beneath the ice. The main parts of northern and south-eastern Lapland became ice-free *c.* 10,500 years ago (Fig. 3). After ice had reached the ice divide area in Central Lapland *c.* 10.3 ka ago, the ice margin stagnated in several places and the ice melted in situ, partially as separate patches of dead ice. The last remnants of the continental ice sheet melted in western Lapland *c.* 10.0 ka ago (Kujansuu 1967; Saarnisto 2000; Johansson 2007).

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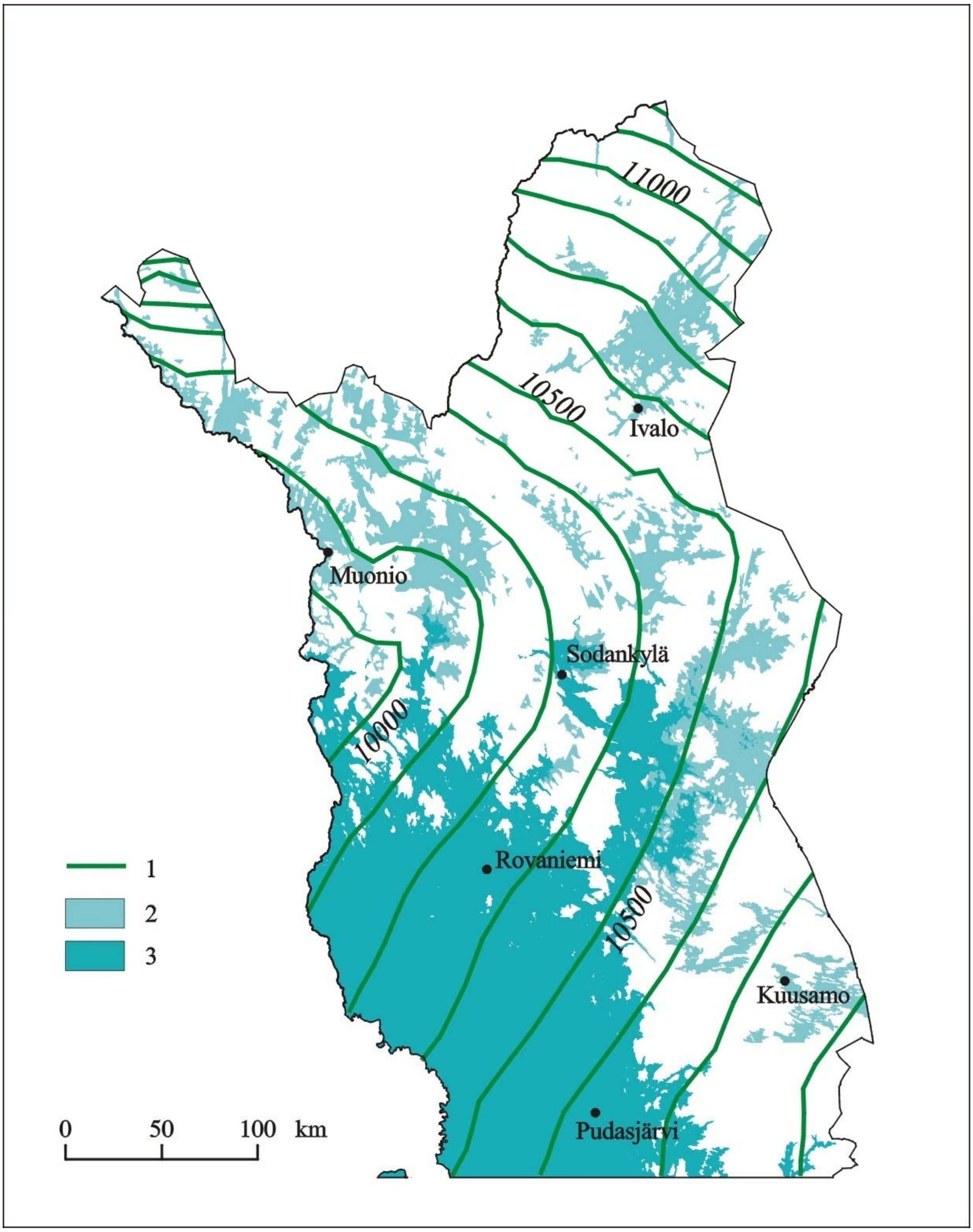

Fig. 3. Recession of the margin of the glacier in northern Finland towards the end of the last deglaciation.1 = position of the ice margin, 2 = areas covered by ice-dammed lakes and 3 = Ancylus Lake (Johansson 2007).

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Fig. 4. Boulder field and scenery towards west on top of the Levi fell. Photo by P. Johansson.

STOP 1: Boulder fields and test areas on the Levi fell

Jouni Pihlaja and Peter Johansson

On the treeless upper parts of the fell slopes (Fig. 4), the climate is harsh and frosty nights are common even in summer. Due to the variations in temperature, surfaces of the rock and boulders alternately expand and shrink. Releasing stresses create fractures, into which rain water and melt water will run. The cycles of freezing and melting widen the fractures, and eventually a lump will fall off the rock or the boulder will fall into jagged pieces. The phenomenon is called frost weathering. At the Levi Fell the top and fell sides demonstrate various phases of weathering. There are smooth, fresh quartzite rock surfaces and slabs that already have outline marks of a future fracture. There are also pieces of rock broken off, but still in their place, and jagged boulder fields – an end product of the weathering (Johansson *et al.* 2006).

GTK was studying with Oy Levi Ski Resort company the properties of the local till, Carex peat and compost material as substrates on the slalom slopes. The project was called POMARA and it was implemented during 2008-2010 (Pihlaja & Kupila 2010). It was partly funded by the European Regional Development Fund program.

The slalom slopes have normally been covered by local Carex peat during the shaping phase of slopes. The problem has been that on the top part of the fell, the peat has "disappeared" because of the frost weathering. Stones have come up under the peat layer, since these areas are naturally covered by block fields.

The research was carried out with three test areas, two of them locating on the top of the fell and one on the hillside. The different soil combinations at this excursion site can be seen in the figure 5. The monitoring studies of the test areas included the measuring of

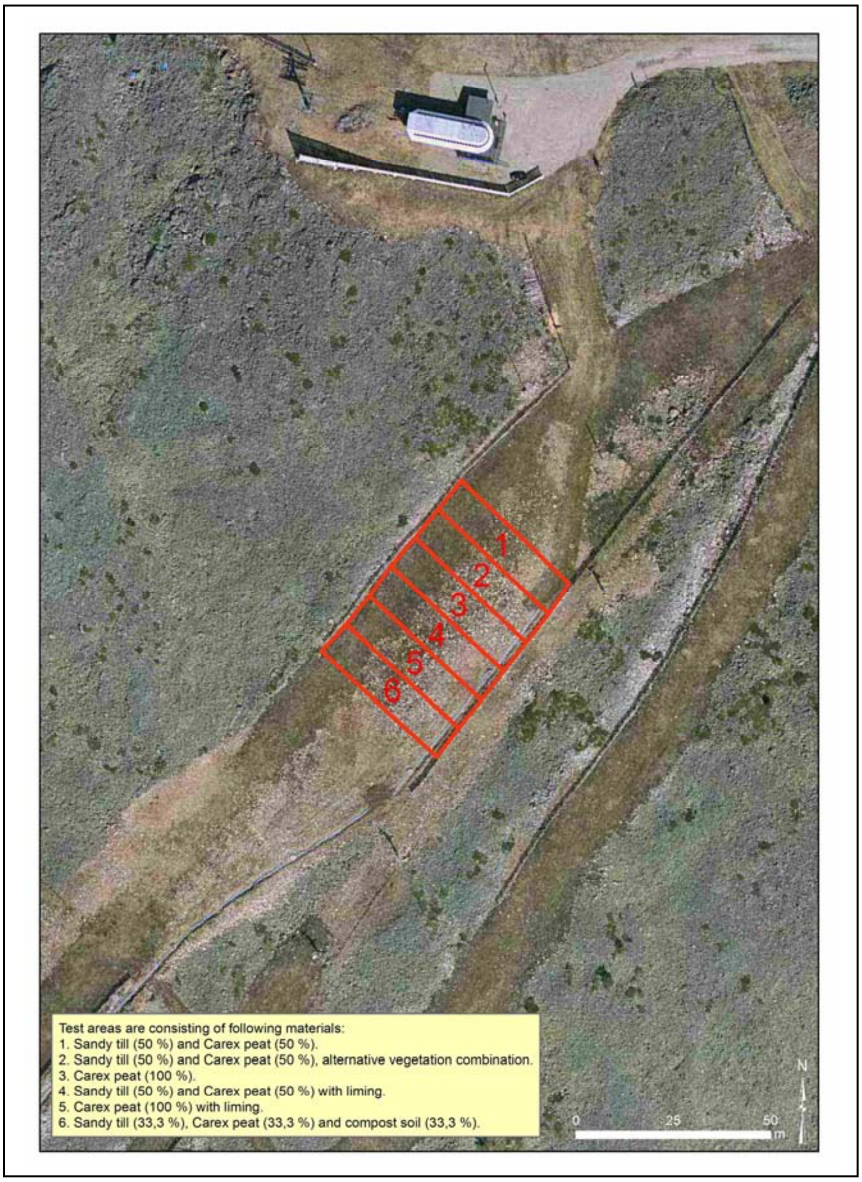

Fig. 5. Test areas near top of the Levi, locating on a block field.

water content and temperature. Results are telling that during summer time water content of Carex peat is remarkably higher than in the combination of Carex peat and sandy till. On the other hand, during spring time the combination of Carex peat and sandy till is thawing earlier than Carex peat (Fig. 6). But when looking the growth of vegetation, the Carex peat area is growing better than the combination of Carex peat and sandy till. In that way Carex peat seems to be better, but in the long run it will be interesting to follow if the combination of Carex peat and sandy till will stand up better against frost weathering than peat itself. And it is not a big surprise that the test area containing compost material from the local water supply and sewerage company is growing well.

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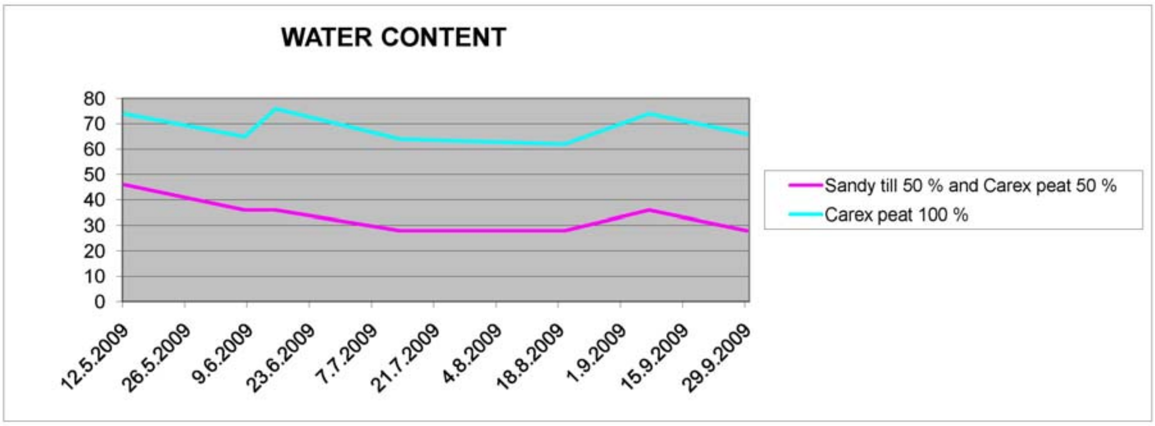

Fig. 6. Water contents during growing season in combination of till and Carex peat and in Carex peat.

STOP 2: Naakenavaara interglacial deposit in Kittilä

Pertti Sarala

The Naakenavaara interglacial deposit in Kittilä (x=7298170, y=3516218), Lapland (Hirvas 1991; Aalto *et al.* 1992), is a 1.5-2-m-thick peat deposit having stratified sediments on upper and lower side of it. The deposit is covered by three till beds and underlined by one till bed (Fig. 7). Hirvas (1991) was presented that the third till bed (above the peat) was probably deposited during the Saalian glacial stage and based on that the peat deposit was correlated with the Holsteinian interglacial. The pollen stratigraphy (with *Aracites johnstrupii*) is clearly indicating interglacial (Eemian or possibly Holsteinian) conditions but the macrofossils suggest the deposit to be of either Holsteinian or Tertiary age (Aalto *et al.* 1992). Saarnisto and Salonen (1995) were interpreted the peat to be correlative with the Holsteinian interglacial (MIS 7), although there is possibility that the sediments may be even older. The pollen and macrofossil contents show that during the deposition of Naakenavaara interglacial sequence, pine, spruce (including *Picea omorika*) and larch forests grew in northern Finland (Ambrosian *et al.* 1998).

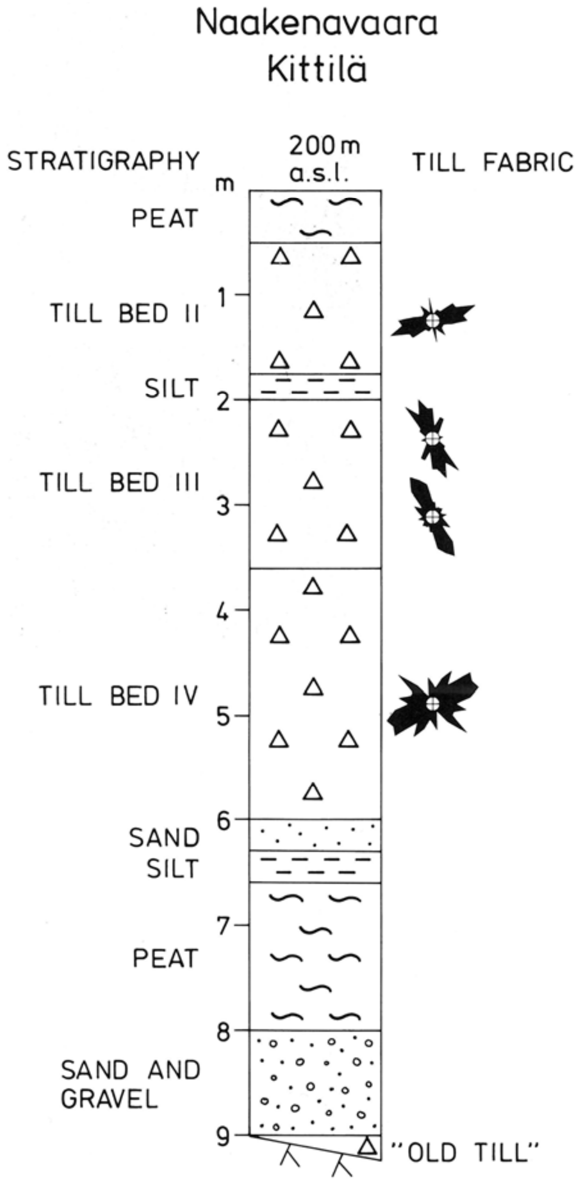

Fig. 7. Stratigraphy log of the Naakenavaara site according to Hirvas (1991). New sampling and subsequent OSL dating give ages 115 +/- 10 ka for the sand under the peat (depth 9.0-9.3 m) and 72 +/- 4 ka (depth 5.8-6.3 m) and 39 +/- 2 ka (depth 5.5-5.8 m) sands above the peat.

Present chronological studies (Fig. 8) based on soil drillings indicate that the stratigraphical succession of the section is representative of deposits from the Saalian age to the last deglaciation. OSL ages for the sand layer under the peat are 115 +/-10 ka and above the peat 72 +/- 4 ka and 39 +/- 2 ka. Based on this data the peat represents in situ Eemian interglacial deposition or indicates redeposition of the older peat layer to the present position.

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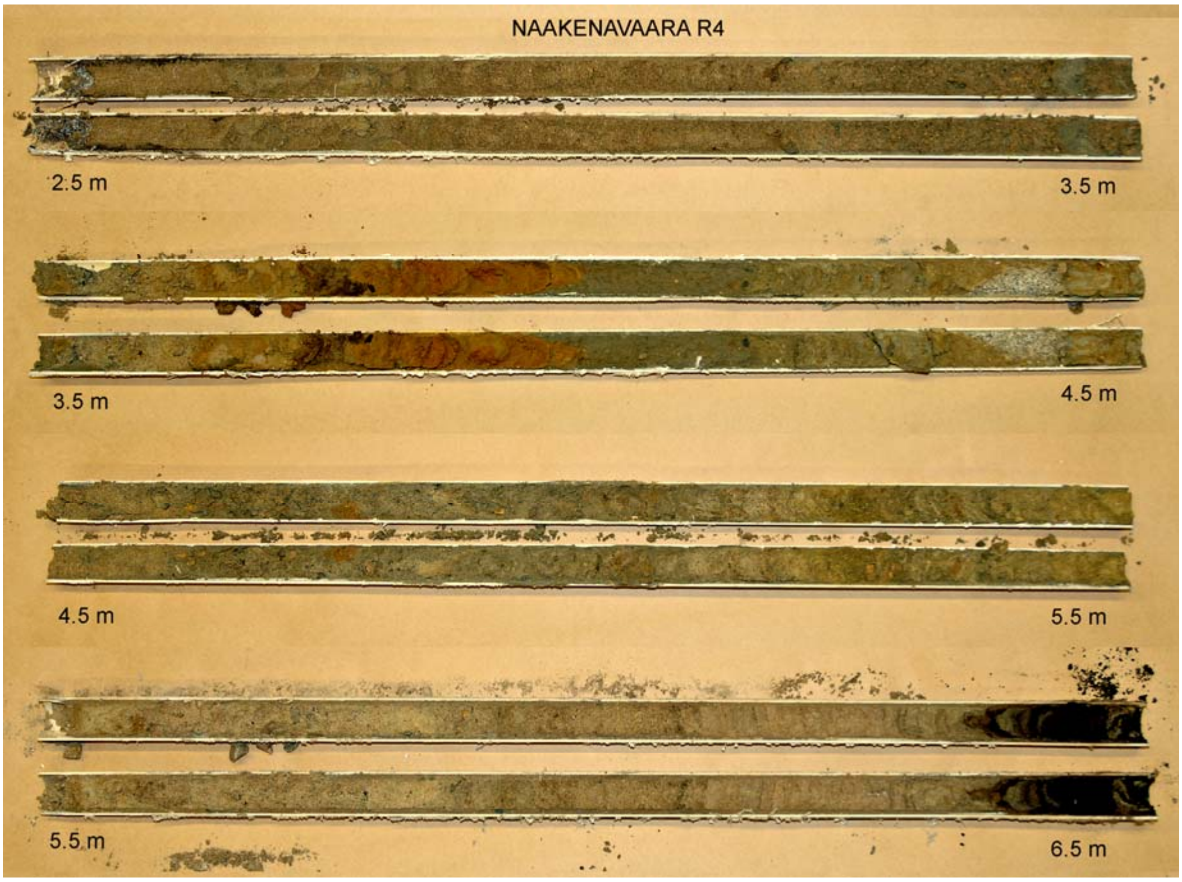

Fig. 8. Drill core R4 (depth 2.5-6.5 m) from the Naakenavaara interglacial site ending to the peat deposit at the depth 6.4 m. Photo by Reijo Lampela.

STOP 3: The postglacial fault at Riikonkumpu

Peter Johansson

The glacio-isostatic rebound of the earth's crust during and after melting of the ice sheet caused large deformations. The rate of emergence temporarily reached a value as high as 15 cm per year in northern Baltic area around 9000 BP (Eronen & Ristaniemi 1992). It has been found that extremely rapid rise of the earth's crust led to many major faults in early post-glacial times in northern Fennoscandia (Fig. 9).

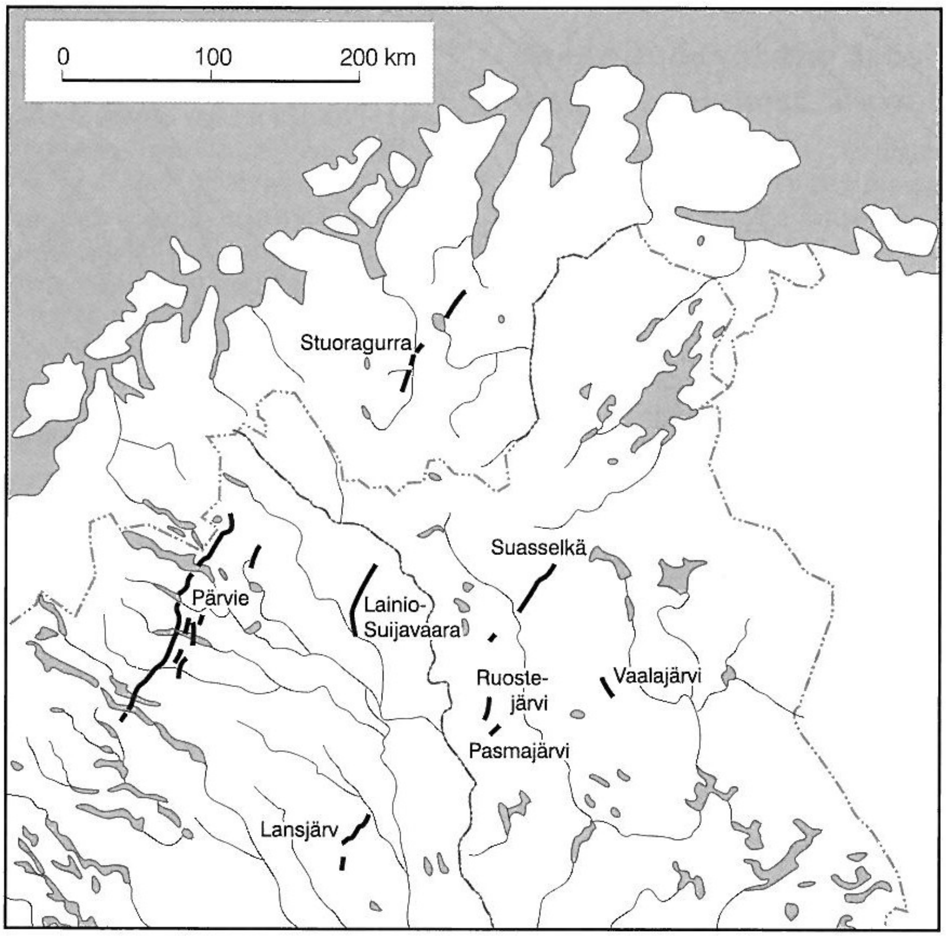

Fig. 9. Location of faults formed in the early Holocene in northern Fennoscandia (Eronen 2005).

The longest of these faults is Pärvie fault in northern Sweden. Its length is 150 km and the fault scarp is 10 m high at the maximum (Lagerbäck 1990). In northern Finland the lengths of the faults vary from 2 to 40 km and fault scarps are 1-8 m high (Kujansuu 1964; Kuivamäki *et al.* 1998). One small fault is located at Riikonkumpu. The height of the scarp is about 1.5-2 m and it can be traced 2-3 km (Fig. 10).

It is concluded that the faulting occurred in the period of deglaciation around 10,000 BP, because the till overlying the bedrock is also faulted. In northern Finland there are also many traces of old landslides in the areas where faults occur, indicating that earthquakes triggered many major landslides on hill slopes (Kujansuu 1972). All the known post-glacial faults are located in old fracture zones and most of them in the direction from SW to NE. It indicates that the crustal movements are directed along the existing weakness zones of the bedrock (Eronen 2005). The dimensions of the faults in northern Fennoscandia indicate that there was rather high seismicity in that area in early post-glacial times, the estimated magnitude being 5.3-7.5 on the Richter scale (Kuivamäki *et al.* 1998). Earthquakes of this magnitude are not experienced in Fennoscandia today.

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Fig. 10. The fault scarp at Riikonkumpu. Photo by P. Johansson.

STOP 4: Kittilä Gold Mine

Pertti Sarala and Nicole L. Patison*

Suurikuusikko deposit and the mine

The orogenic Suurikuusikko gold deposit is within the Palaeoproterozoic Central Lapland greenstone belt, approximately 50 km northeast of the town of Kittilä in Finnish Lapland (Figs. 11 and 12). The host rocks, timing of ore formation relative to regional deformation, metamorphic grade, alteration assemblages present, and structurally controlled nature of the deposit make it analogous to better known deposits in greenstone belts throughout the world (e.g., Yilgarn of Australia, Superior Province of Canada). At Suurikuusikko, the gold is refractory, occurring within arsenopyrite (>70 %) and arsenian pyrite as lattice-bound gold or sub-microscopic inclusions.

* Agnico-Eagle Finland, Kittilä

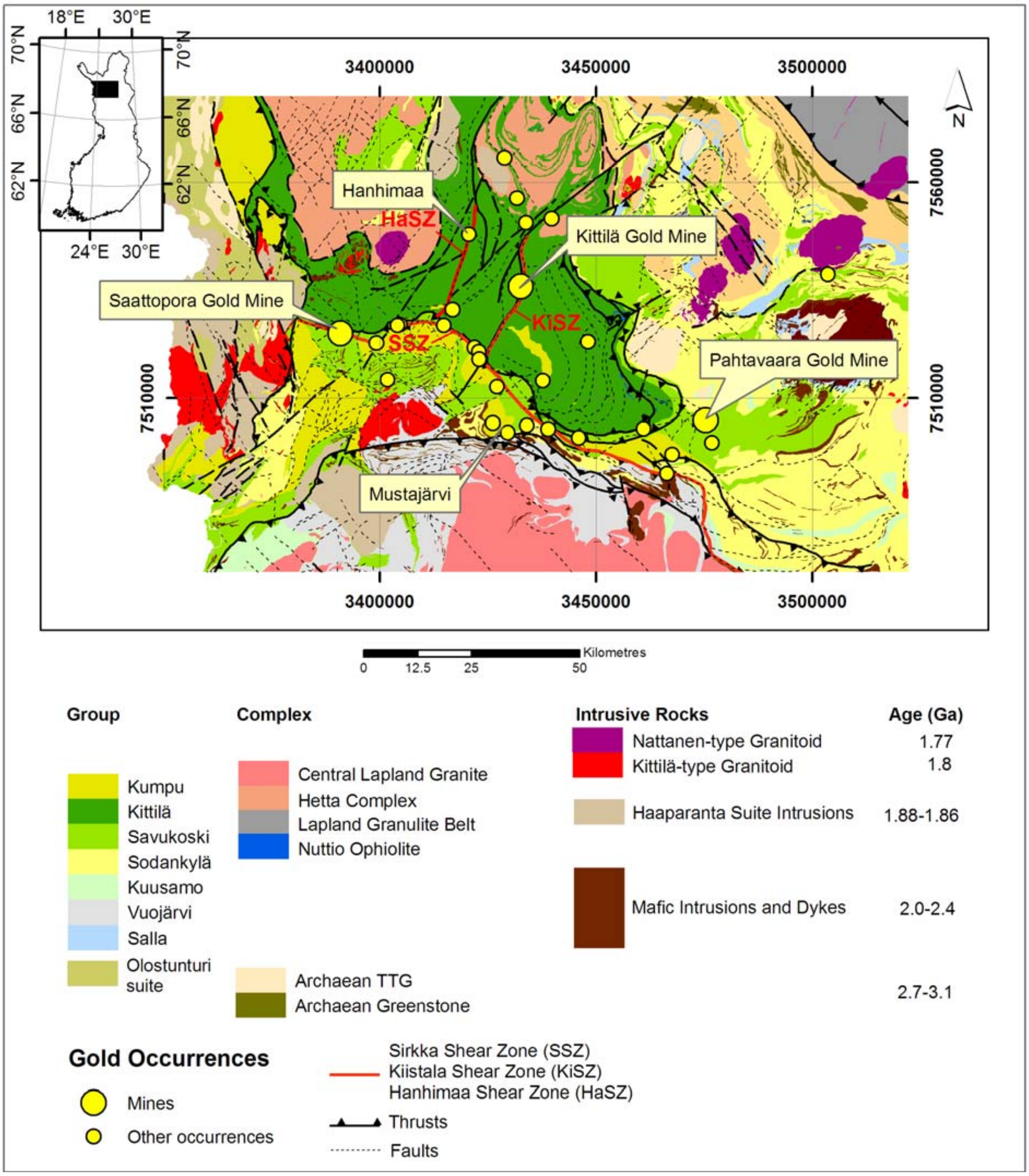


Fig. 11. Formation map of the Central Lapland Greenstone Belt (after Lehtonen *et al.* 1998) showing the location of the gold deposits and occurrences in thea area, with the three largest known deposits named. Composed by Vesa Nykänen.

A mining operation started in 2008 then targeting a gold resource of 16 million tonnes (2.6 million ounces) averaging 5.1 g/t gold (Agnico-Eagle 2007). Until the end of 2010, 2 Mt of ore was mined and more than 6 t of gold produced. The present-proven and probable gold reserves total approximately 4.9 million ounces from 32.7 million tonnes grading 4.6 g/t (Agnico-Eagle 2011). Ore intersections have very even grade distribution due to the ‘disseminated sulphide-like’ nature of the ore (Table 1). The deposit still is open along strike at both ends, and at depth; presently, the deepest ore-grade intersection (6 m @ 9.5 g/t Au) is about 1200 m below the surface (Agnico-Eagle 2011).

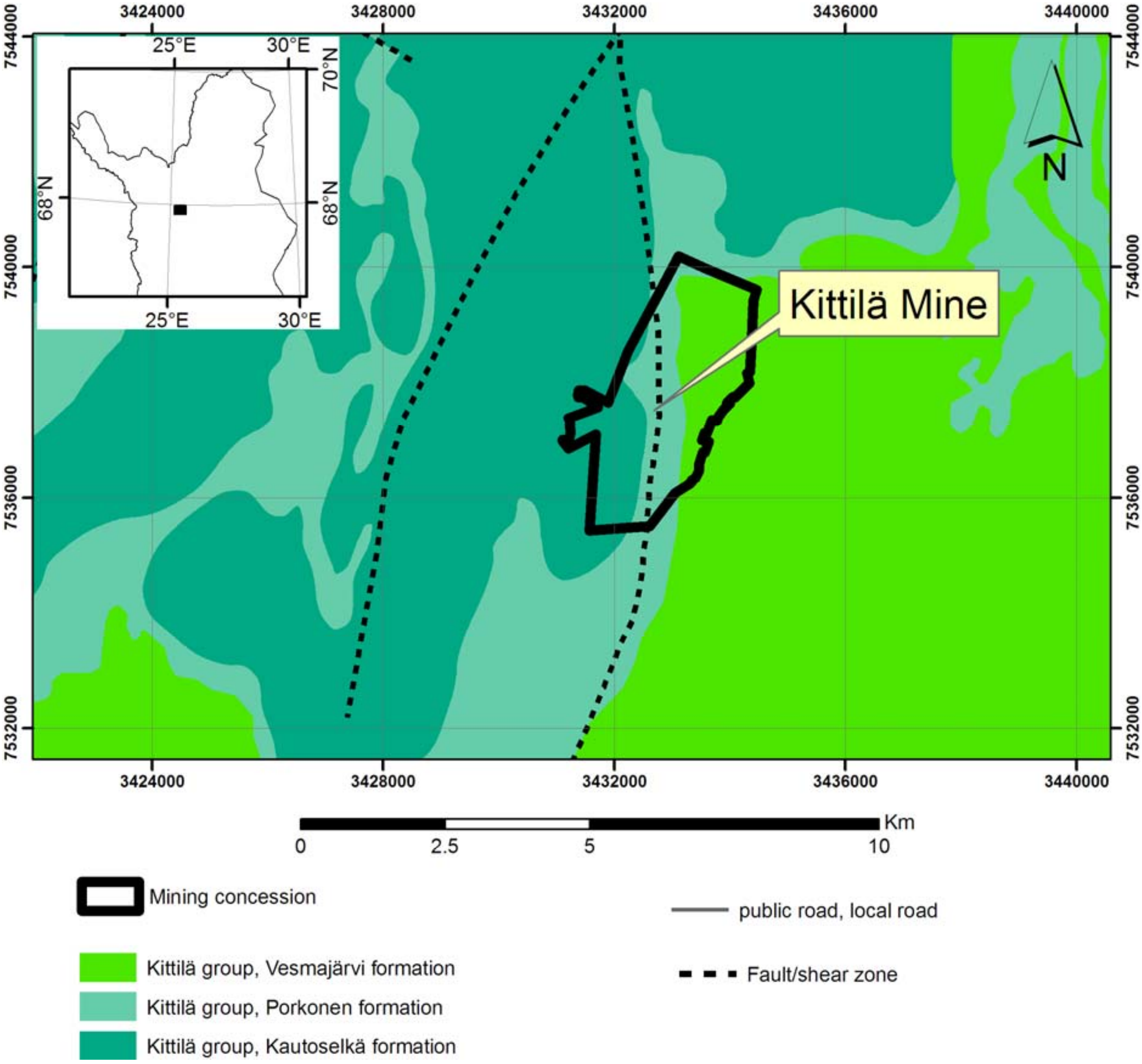


Fig. 12. Geology in the vicinity of the Kittilä Mine and KiSZ. Geological map is derived on the current GTK digital bedrock map database. Composed by Vesa Nykänen.

Exploration history

Visible gold was discovered SSW of Suurikuusikko by the Geological Survey of Finland (GTK) in 1986 (Härkönen & Keinänen 1989). Subsequent ground-geophysical surveys and geochemical sampling lead to the identification of the Kiistala Shear Zone (KiSZ), the deposit's host structure. Suurikuusikko was discovered in 1986 during diamond drilling by GTK. A total of 77 diamond drill holes (9,320 m) were completed by GTK, outlining a resource of 1.5 Mt with an average grade of 5.9 g/t (285,000 ounces of gold) by 1997 (Parkkinen 1997). In April 1998, the deposit was acquired by Riddarhyttan Resources AB and the company's exploration activities increased the resource size to over 2 million ounces of gold (Bartlett 2002). Ore-grade mineralisation was found over a five-kilometre strike length of the KiSZ in similar structural and stratigraphic positions. Mine feasibility studies on Suurikuusikko began in winter 2000. In 2004, Agnico-Eagle Mines Limited acquired a 14 % ownership interest in Riddarhyttan, and in 2005 acquired the remaining Riddarhyttan shares. In June 2006, a decision was made to begin mine development. The Kittilä Mine achieved commercial production in May 2009.

Table 1. Examples of gold intercepts from drill core in the Kittilä Mine.

Zone	Drill hole number	Mineralised section length (m)	Averaged grade of section (g/t Au)
Ketola	02114	6.40	4.20
Ketola	02107	7.00	11.10
Ketola	02107	3.20	7.10
Ketola	02104	10.70	4.00
Etelä	R407	7.00	7.50
Etelä	01802	5.60	8.60
Etelä	02039	8.10	9.50
Main	R473	14.00	10.40
Main	R504	10.80	9.10
Main	00717	14.30	10.60
Main	R478	18.20	5.10
Main	99002	18.20	16.50
Main	R479	26.80	17.30
Main	00730	18.90	9.10
Main	98004	29.60	11.90
Main	00903	46.20	8.90

Geology

Suurikuusikko occurs within greenschist-facies metavolcanic rocks of the ca. 2.0 Ga Kittilä Group (Lehtonen *et al.* 1998). Geochemical heterogeneity among the Kittilä Group rocks has been interpreted to indicate that the Group is a composite of arc terranes and oceanic plateaux amalgamated during oceanic convergence (Hanski & Huhma 2005). Significant variations in metamorphic grade within the Group also suggest that a number of distinct lithological elements could be present within the area currently mapped as Kittilä Group, and seismic surveys across central Lapland indicate a number of distinct crustal blocks (Patison *et al.* 2006). The maximum current thickness of the Kittilä Group is between six and seven kilometres (Luosto *et al.* 1989) in the Kittilä Mine area.

The mineralisation typically occurs in a transitional formation between two thick (several 100 metres) mafic lava sequences (Figs. 13 and 14). The N- to NNE-trending host structure (KiSZ) for the deposit coincides with this contact between western and eastern lava packages. In the area of the 'Main' ore zone, host rocks change from mafic pillow and massive lavas west of the mineralised zones to mafic transitional to intermediate lavas (andesite flows of Powell 2001) and minor pyroclastic material within mineralised zones.

Graphitic sedimentary intercalations containing chert, argillitic material and BIF occur within the mafic volcanic sequence at the eastern margin of mineralised zones, followed further east by mafic lava packages and ultramafic volcanic rocks. The extent of intermediate and felsic rock compositions present at the deposit is not studied. The variation in appearance (and hence the logging and mapping terminology for rock compositions used here) may also alternatively result from progressive alteration of mafic rocks. Most ore is hosted by mafic rocks and those mapped as intermediate or felsic volcanic rocks. Metasedimentary units including BIF typically have low to no gold grade, and the ultramafic rocks are unmineralised.

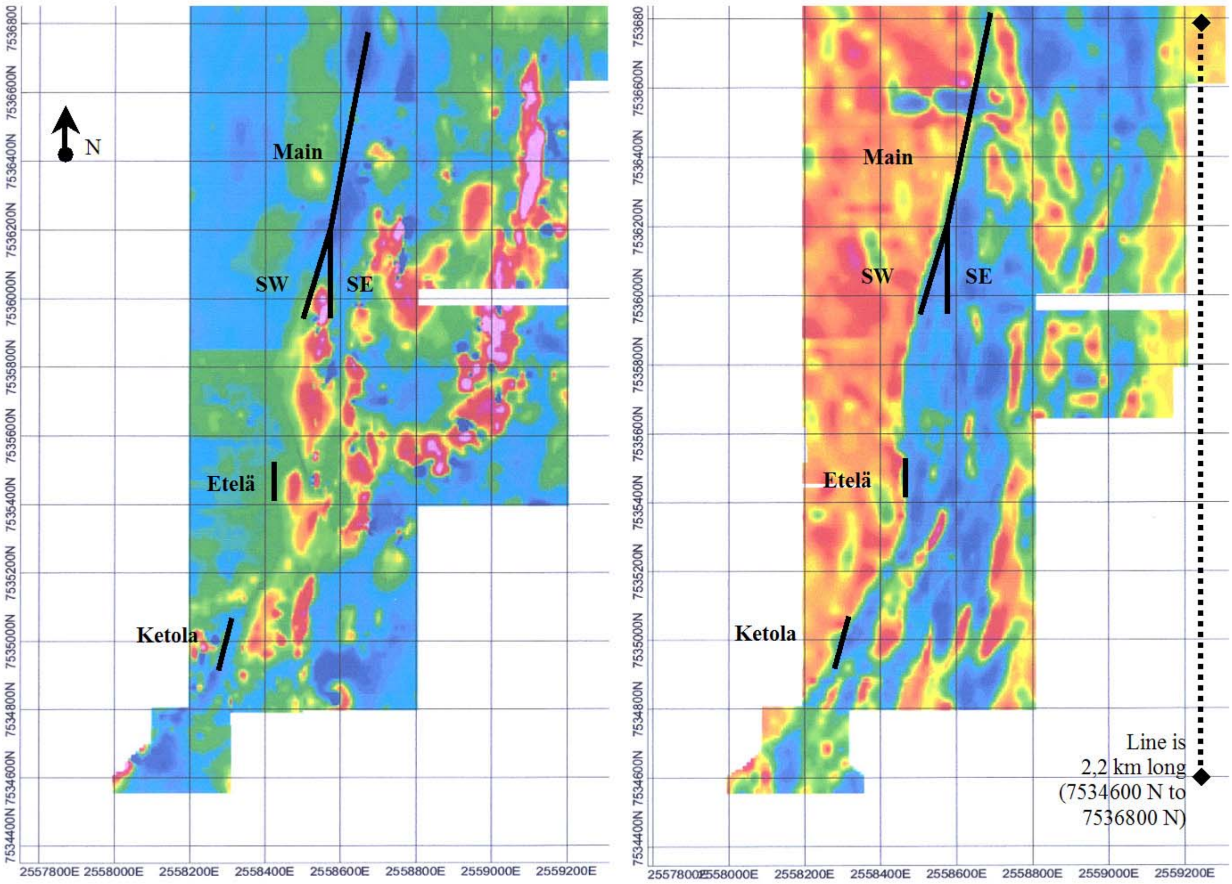


Fig. 13. Total magnetic field (on left) and electromagnetic (slingram out-of-phase, on right) images for the southern part of the Suurikuusikko area, in 200 m grid. The blue colors represents magnetic lows and conductivity highs respectively in Figs. 12a and 12b. Names refer to individual ore zones. Composed by Vesa Nykänen.

Orogenic events relating to CLGB development generated several phases of deformation. The earliest deformation phases preserved (D_1, D_2) involved roughly synchronous N- to NNE- and S- to SW-directed thrusting at the southern and northeastern margins of the CLGB (Ward et al. 1989). Northwest-, N-, and NE-trending D_3 strike-slip shear zones, including the KiSZ hosting the Suurikuusikko deposit, cut early folding and thrusting, but may also reflect reactivation of older structures. Post-D_3 events are limited to brittle, low-displacement faults.

Representative structural data for the deposit are shown in Fig.s 15a to 15d. The Kiistala Shear Zone has a strike length of at least 25 km (Figs. 11 and 12). The dip of this shear zone in the Suurikuusikko area is steeply east to sub-vertical (Figs. 15b and 15c). Known mineralisation occurs within N-trending and less frequently NE-trending (e.g. Ketola ore bodies, Fig. 13) shear zone segments. The KiSZ is a complex structure, recording several phases of movement. Most deformation has occurred by flattening accompanied by some strike-slip movement. Aeromagnetic images of the KiSZ indicate early sinistral strike-slip movement along the zone. Immediately above the widest mineralised zones, late dextral strike-slip movements are recorded on shear planes bounding mineralised zones. It is not yet clear if the mineralisation coincides with a combination of early and late shearing or only to the later dextral shearing event which now delineates the limits of gold mineralisation in most ore zones. An apparent correlation exists between points of more intense shearing within the KiSZ and the amount of gold present in host rocks (Figs. 16a and 16b).

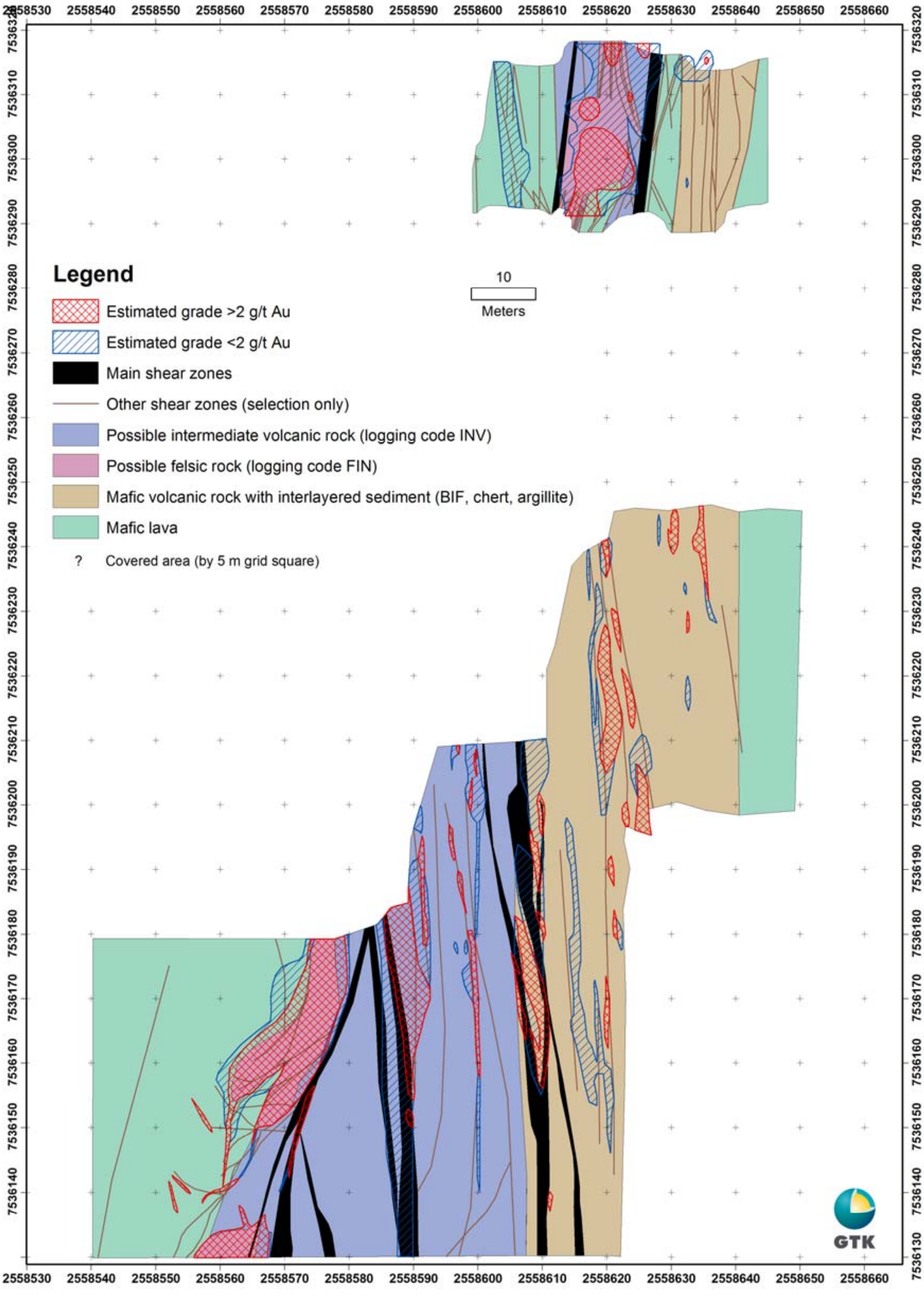


Fig. 14. Pit map from Suurikuusikko showing the main rock types and structures, in 10 m grid (after Patison *et al.* 2006). The grade estimates shown are visual estimates based on arsenopyrite abundance. Exposure of the deposit prior to 2007 was limited to the two pits shown in this figure.

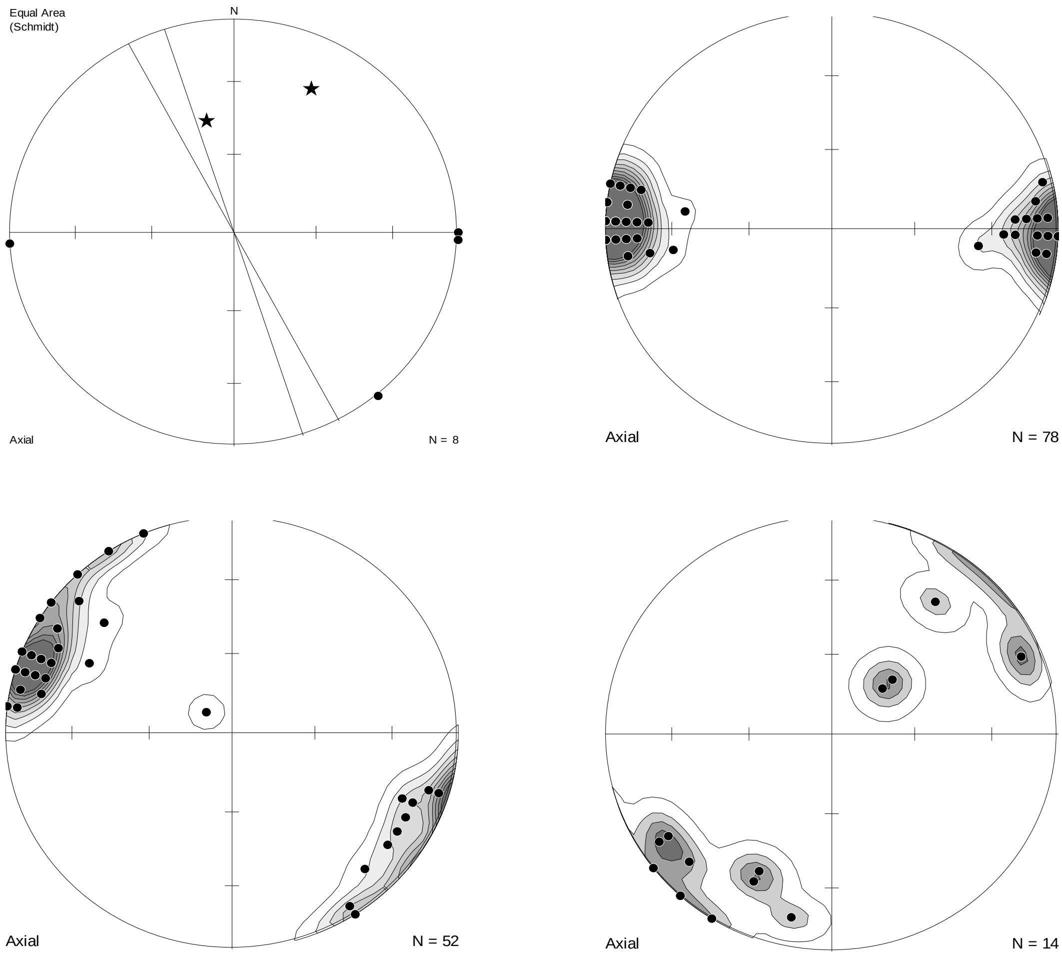
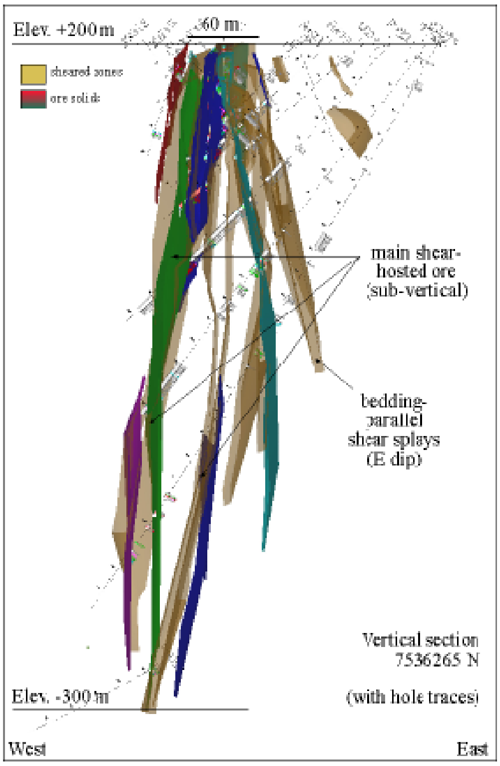


Fig. 15. These stereoplots show the orientations of deformation features observed for Suurikuusikko (ordered from oldest to youngest). Fig. 14a, top left, shows bedding (dots), the trend of the typical regional foliation (lines) formed prior to movements of the KiSZ related to mineralisation, and fold axes measured in the deposit area (stars). Figs. 14b (top right) and 14c (bottom left) show the orientation of the 'graphitic' shear zones (e.g. Fig. 13) associated with the KFZ and ore zones. Fig. 14d (bottom right), shows the common orientation of post-mineralisation faults, although NE- (e.g., Fig. 14a) and E-striking faults and veins are also seen. Plots are lower hemisphere projections on equal area nets; point symbols are poles to planes with frequency contours, stars in Fig. 14a are plunging lines; lines are planes). Plots after Patison *et al.* (2006) and Patison (2001).

The envelopes of ore bodies strike N and have a moderate N plunge. The control on the northerly plunge is not completely resolved: factors to be explored include the role of intersections between multiple shear planes, and of the intersections of depositional surfaces and shear planes. The orientation of regional fold axes (similar to axes in Fig. 15a) may also have a role in determining favourable sites for mineralisation during shearing. Sulphides and host rocks show some evidence for deformation relating to post-mineralisation movements on host shear planes. Post-mineralisation brittle faults crosscut mineralised zones but are not known to cause significant displacement of ore lenses.



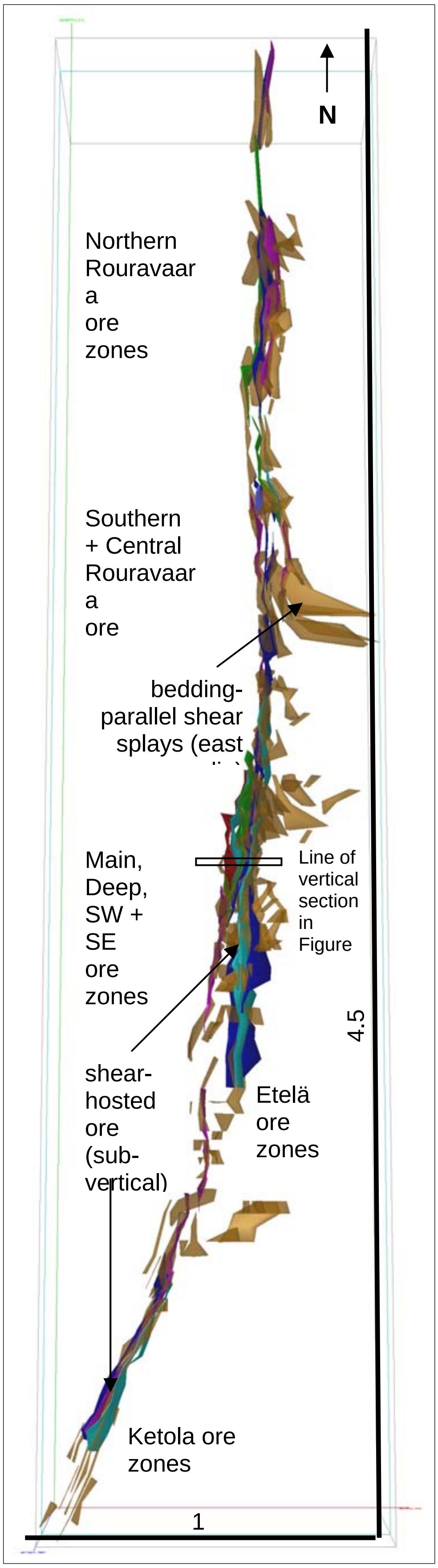


Fig 16. These Figures show 3D solid geology models for the deposit completed in 2004 (Patison 2006b). In both Figures the coloured solids are assay-based ore solids for gold grade (≥ 1 g/t Au). The brown solid is a solid of the host shear zone constructed to show zones were deformation intensity is highest. Fig. 16a (near plan view with slight N plunge) and Fig. 16b (vertical section) show the shear-bound nature of the ore zones. Sheared bedding contacts which are also mineralised (unmineable grades at the time of model creation) are illustrated by the moderately east-dipping solids. Truncation by cross faults is also evident in Fig. 16a.

Alteration in and around the deposit appears typical for deposits of this type. Visually, intense carbonate and albite alteration are associated with gold-rich arsenopyrite and pyrite. Albite occurs as a matrix overprint that typically extends less than two metres into barren rock, and as brecciating micro veinlets. Barren carbonate alteration includes distal calcite veins, and dolomite/ankerite veins and infilling tectonic and/or hydrothermal breccia proximal and within ore zones, respectively. Table 2 presents a summary of progressive alteration of mafic pillow lavas. Absent form this table is amorphous carbon. The abundance of this 'graphitic' carbon correlates with the intense shearing that bounds most mineralised zones. The presence of such carbon suggests extremely reducing fluid conditions during shearing and possibly mineralisation. Gold-bearing sulphides commonly nucleated on shear planes, stylolitic cleavage, and fractures bearing amorphous carbon (Figs. 17a and 17b). Carbon isotope data indicates that this material is sourced from carbon-rich sediments within the host sequence (Patison, unpublished data). Argillite-rich units intercalated with volcaniclastic material have high primary carbon contents, and may have been chemically important for localising gold-rich phases given the association between amorphous carbon and mineralisation. Other alteration and ore mineral phases include rutile and less abundant sericite, tetrahedrite, chalcopyrite, gersdorffite, chalcocite, sphalerite, bornite, chromite, galena, talnakhite, and Fe-hydroxides (the latter produced by weathering) in varying abundances (Chernet *et al.* 2000).

Table 2. Alteration minerals present in progressively altered mafic pillow lava. The data used are modal weight percentages of mineral phases calculated using Mineral Liberation Analysis data collected at GTK. The thickness of line is proportional to the relative volume of each mineral present in the sample. A mafic pillow lava sequence was used for this example to ensure a constant rock type, although pillow lavas do not host significant volumes of ore. The 'felsic' mineralised sample is included for comparison and may, in fact, be the most altered end-member of a mafic rock alteration sequence.

Alteration Zone Rock type Sample	Distal Mafic pillow lava F5-001	Intermediate Mafic pillow lava F5-007	Proximal / Ore Mafic pillow lava 00404 189.90	Ore Mafic pillow lava F5-003	Ore 'Felsic' F5-002
SILICATES					
Actinolite		━━━━			
Epidote		━━━━━━			
Titanite	------------------	---------------		-------------	
Chlorite	━━━	━━━━	------------------	━━━━	
Muscovite			------------------	-------------	------------
Albite		━━━━	━━━	━━━	━━
Microcline		---------------	------------------		------------
Plagioclase	━━━━				
Clinopyroxene (matrix)		=========			
Quartz	------------------	—————————	------------------	-------------	------------
CARBONATES					
Calcite	========	—————————		━━━━━	
Dolomite			━━━━	- - - - - - - -	━━━━━
PHOSPHATES					
Apatite	- - - - - - - - - -	- - - - - - - - -			
OXIDES					
Rutile		---------------	------------------	-------------	------------
SULPHIDES					
Arsenopyrite			==========	========	=======
Pyrite			——————————	————————	=======
Pyrrhotite			------------------	-------------	------------
GOLD GRADE (g/t)	0	0	5.16	3.3	8.71

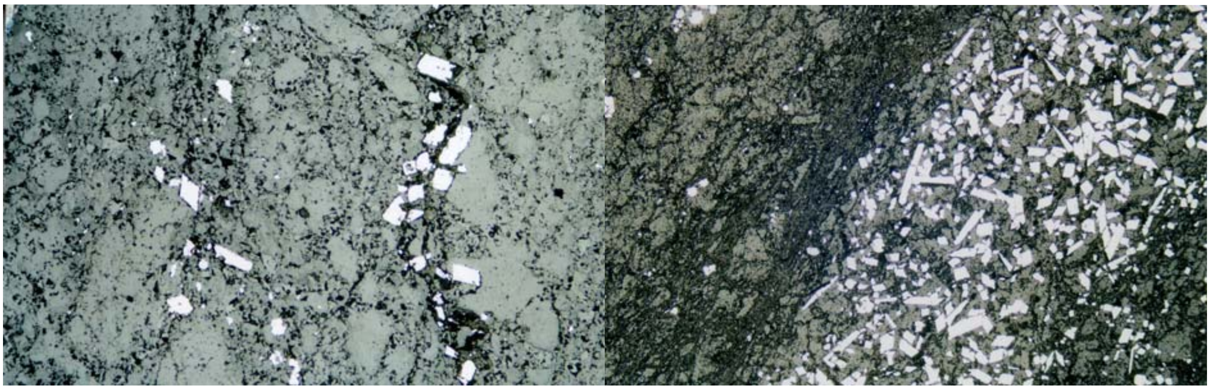


Fig. 17. Back-scattered electron microprobe images of ore samples in mafic host rocks. Fig. 17a, on left, shows nucleation (or recrystallisation) of arsenopyrite in graphitic (black phase) milled zones relating to shearing. Fig. 17b, on rght, shows a fractured competent rock fragment with arsenopyrite associated with fracture infill. A penetrative shear boundary is seen at the edge of this mineralised fragment (center of photograph). Field of view in both figures is 1.5 mm.

The gold-rich sulphides appear to have a late timing within the paragenetic sequence. The majority (71 %) of gold occurs within arsenopyrite, and visible arsenopyrite is a reliable indication of the presence of gold within samples. Remaining gold occurs in arsenian pyrite (22 % of gold), and infrequently as free gold (Kojonen & Johanson 1999). Sub-microscopic gold is found as inclusions or solid-solution lattice substitutions within arsenopyrite and pyrite (Chernet *et al.* 2000). Gold as inclusions is common in pyrite but rare in arsenopyrite (typical grain size from <1 to 100 mm; Kojonen & Johanson 1999). The composition of gold inclusions includes various alloys with Ag and Hg (Chernet *et al.* 2000). Rare stibnite veins and amorphous grains contain extremely high gold grades and overprint the main ore-bearing sulphides.

Acknowledgements

Agnico-Eagle is gratefully acknowledged for the permission to publish the data. The information in this summary reflects the opinions of the author only unless otherwise referenced. The majority of information is based on data collected prior to 2005 (during the exploration phase of the deposit preceding mine development).

Quaternary geology and geochemistry

Surficial geology, till geochemistry and heavy minerals were studied at the Kittilä Mine during 2007-2009. This research was a joint project between the Geological Survey of Finland and Agnico-Eagle Finland. Aims were to clarify the till stratigraphy of the area and study geochemical and heavy mineralogical signature of the glacigenic overburden and reflectance of the three known Au-bearing zones to it in the area of Suurikuusikko open pit (Fig. 18). The methods were conventional geochemistry for till and pre-glacial weathered bedrock surface, using ICP-OES and GFAAS after partial leaching with aqua regia, FAAS with syanide leaching (for Au analysis), mobile XRF, and heavy mineral research. Samples for the Quaternary chronology of stratified inter-till layers and deposits were also taken, and dated by the OSL method in the Nordic Laboratory for Luminescence Dating at Risø DTU, Denmark and in the Dating Laboratory of the University of Helsinki, Finland.

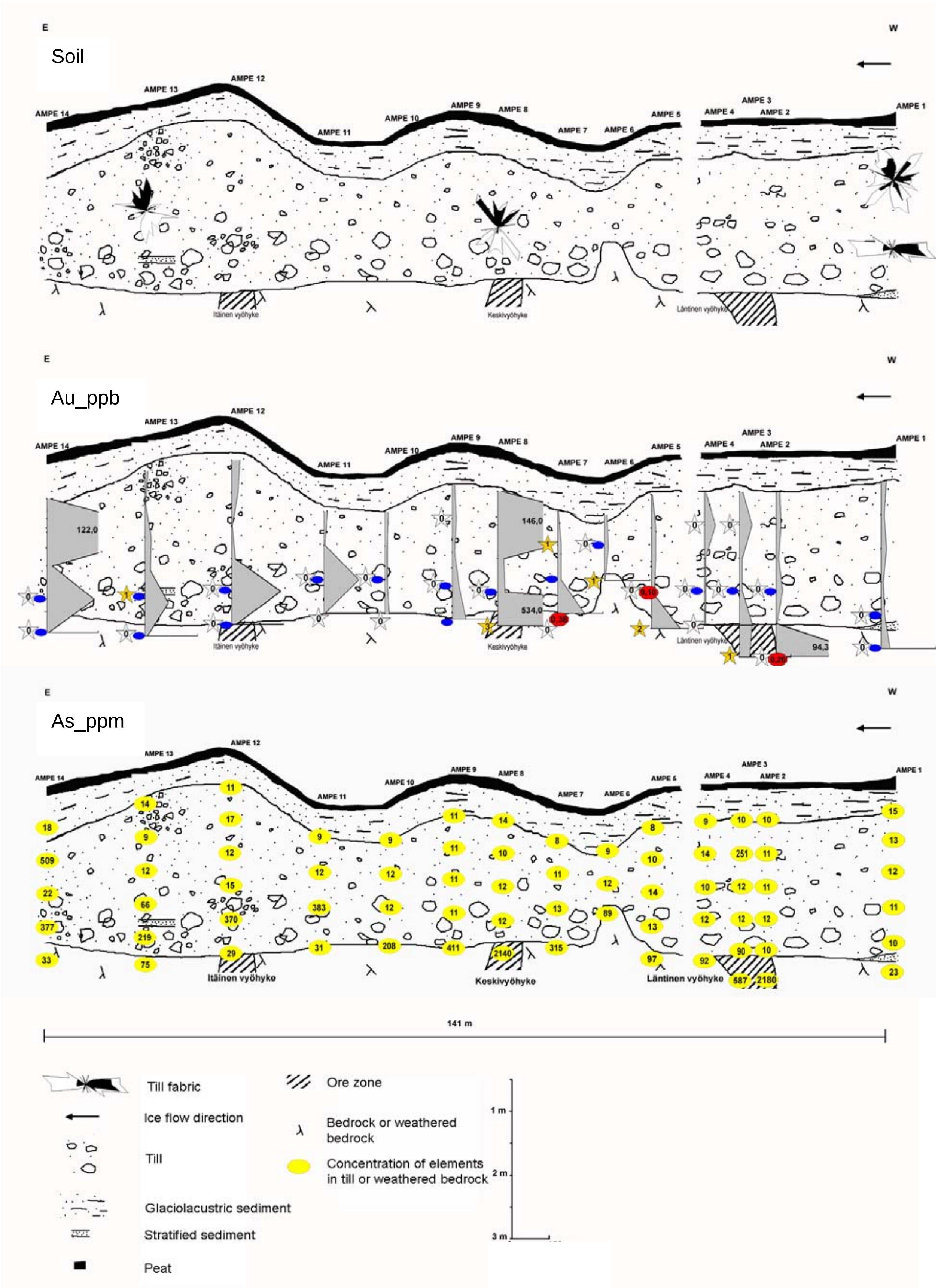


Fig. 18. W-E oriented soil profile over the three known Au ore zone in the southern part of the Suurikuusikko open pit. Au contents in till, weathered bedrock and heavy mineral samples are also presented in the middle. According to Peltoniemi-Taivalkoski & Sarala 2009.

The glacigenic overburden in this area has three till beds representing different glacial phases. The lowest till, which is observed only in places on the distal side of bedrock highs relative to the glacial transport direction, represents the oldest (Early Weichselian) ice advance with an ice flow direction from NW to SE. The uppermost tills represent the latest glaciation phase, having an indication of glacial advance stage in the bottom and a retreat phase on the top of the sequence. Glaciotectonically deformed stratified sediments that were part of a west-east oriented melt-water channel crosscut the till deposits in the middle of the Suurikuusikko open pit area. The sediments were deposited at the end of Early Weichselian, about 73,000-78,000 years ago (Fig. 19).

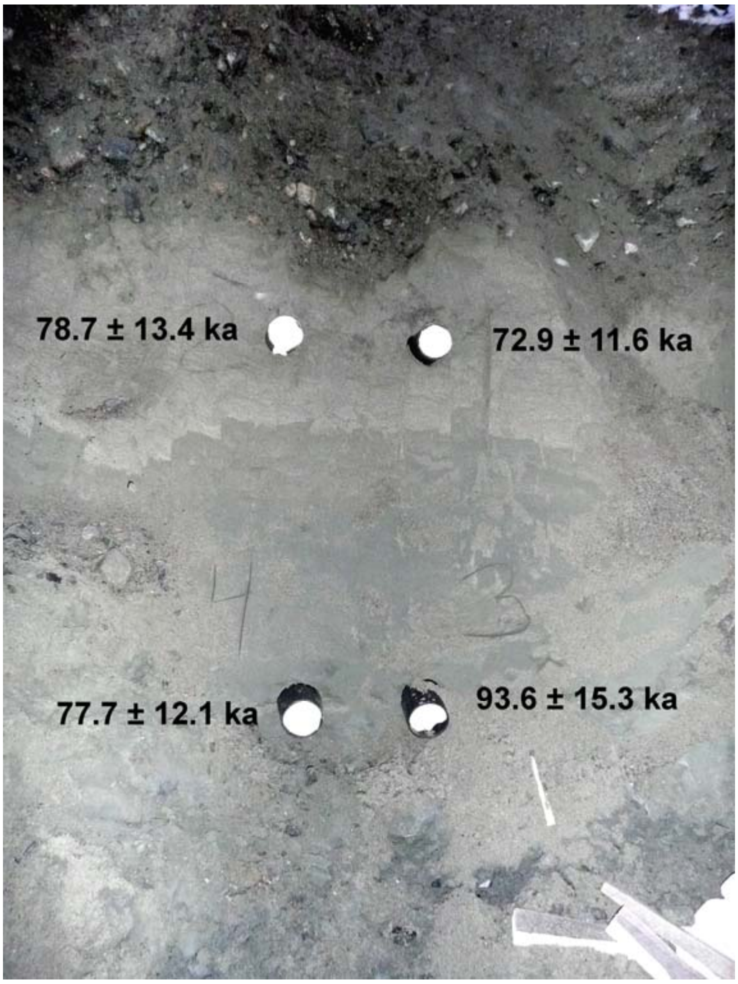


Fig. 19. Till-covered, glaciotectonized sands in the middle of the Suurikuusikko open pit with OSL sampling points and ages. Photo by P. Sarala.

Stratigraphical development since the Early Weichselian is seen in Fig. 20. During the Middle Weichselian there has been an ice free interstadial stage of which the 55 ka old stratified sands are the sign. There are also observations of the ice wedge casts filled with silt and till as a mark of periglacial conditions (Fig. 20). The most suitable time for the formation of them is during the later part of the Middle Weichselian before the Late Weichselian glacial advance of which tills cover the periglacial surface. At the time of the last deglaciation area was under proglacial ice-lake and fine-grained sediments cover underlying sediments in the Suurikuusikko area. Since that little lakes or ponds and peat bogs have been covered the area. The beginning of growth of peat can be dated back to 10,000 cal. years BP based on the antler that was found in the contact of glaciolacustric sediments and peat (Fig. 21).

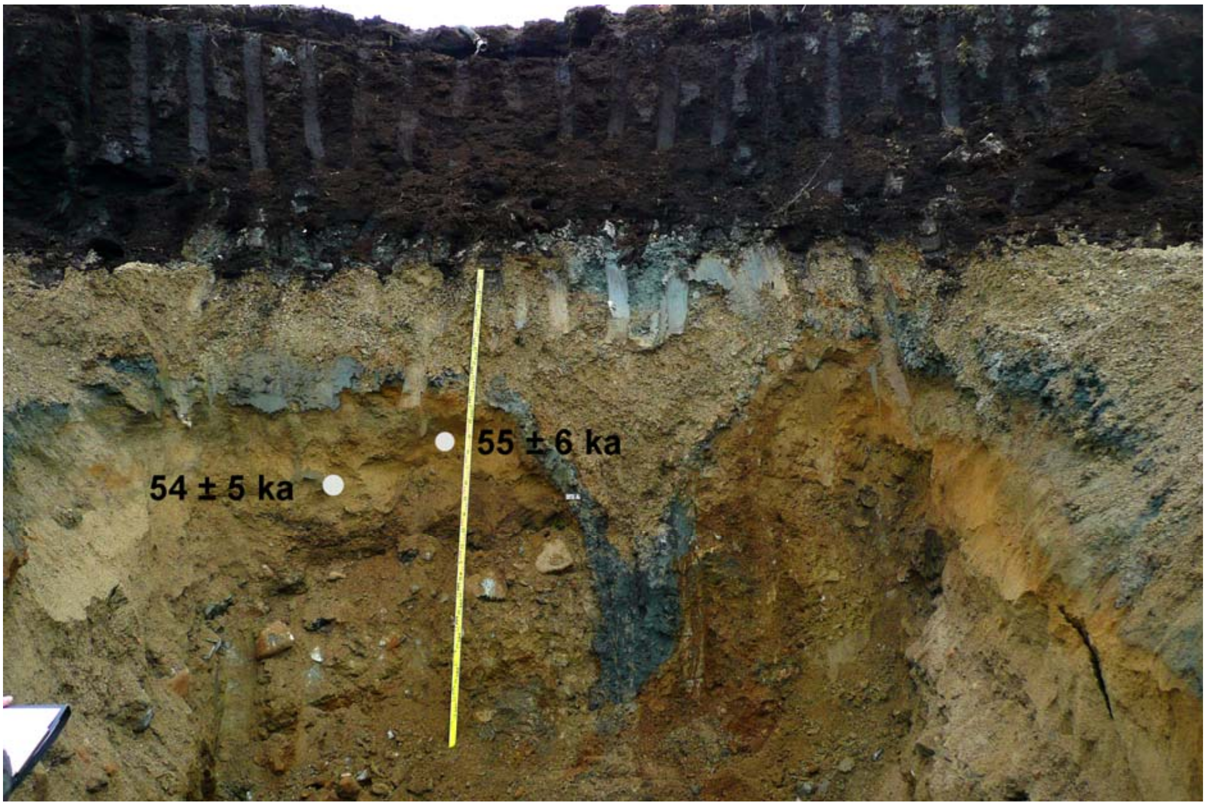


Fig. 20. Ice wedge cast in till in the Rouravaara open pit. Ice wedge is filled by waterlain till and/or glaciolacustrine sediments. OSL sampling points of the glaciofluvial/-lacustrine stratified sands are also marked and the ages dated in separate dating laboratories mentioned in text. Photo by P. Sarala.

Fig. 21. About 10,000 years old antler found from the peat-sediment contact in the Suurikuusikko open pit, Kittilä. Photo by Jyrki Korteniemi.

Based on the till stratigraphy and geochemistry of this area, the transport distance of till debris and pebbles was estimated to be short for the bottommost till bed (Fig. 19). The upper till beds had much longer transportation, and give no clear lithological and chemical indication of the local, underlying bedrock. The most suitable indicator elements in till, besides the gold itself, are As, K, Mn and Sb with the heavy minerals like arsenopyrite and pyrite. Instead, the number of visible (microscopic) gold grains in heavy mineral concentrates both in till and weathered bedrock samples was low reflecting very fine-grained gold particles and/or the occurrence of gold in the lattice of sulfide minerals.

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STOP 5: The Ounasjoki Ice Lake and the spillway of Seurujärvi

Peter Johansson

Central Lapland was favourable area for the formation of ice-dammed lakes for the following reasons: Variations in altitude are considerable over the major part of the area; the main water divide runs across the area, separating the water systems flowing into the Arctic Ocean and the bays of the White Sea from those flowing into the Gulf of Bothnia; and the land surface was inclined towards the margin of the ice sheet that formed the dam (Fig. 22). The suitable conditions are not, however, sufficient proof that large ice lakes really existed in the area. In order to dam melt water, the ice margin had to be intact enough, and the internal pressure of the ice had to exceed the pressure caused by the dammed water. The ice-lake basin could contain abundant ice blocks and icebergs, which had come loose from the margin of the ice. The ice sheet could also be dynamically passive, meaning that the water escaped from the basin along subglacial or submarginal crevasses and fractures. The ice melted down in place, and blocks of dead ice filled the basin. Thus the proportion of free meltwater was small.

The existence and history of the ice lakes in the area were studied using shore marks, spillways and bottom sediments of ice lakes. By reconstruction of morphological conditions it was possible to draw conclusions regarding the size of individual ice-lake basins and their relations to the receding ice margin (Johansson 1995). During the latest deglaciation the Ounasjoki Ice Lake in the western Lapland grew to a fair size. Its spillways of various ages and at various altitudes led northeastwards and eastwards to the Kitinen river valley (Kujansuu 1967).

Spillways are erosional landforms created by strong water streams. Today they are either dry or else the eroding power of the stream flowing on their bottom is in no proportion to their size. On the basis of the shape and dimensions of the spillway, it is possible to get an idea about the strength and duration of the former stream in it. The spillways were normally situating at the contact between the ice margin and the slope.

They were formed as the ice thinned and its margin receded down the slope of the hill. The opening of a new spillway under the margin of the ice sheet, below the preceding ones, led to a successive lowering of the water level in the ice lake. Meltwater erosion was at its most marked when the spillway opened and the level of the ice lake dropped to that of the spillway threshold. From that point onwards the erosion of flowing water weakened, and when a new spillway opened up at a lower level under the ice margin, the former spillway dried out and erosion caused by the water came to an end.

The spillways of Paanosenkuru, threshold level 284 m, Jalkajoki 282 m and Seurujärvi 270 m (Fig. 23) are lying five to ten kilometres apart to the south of the village Pokka (Johansson *et al.* 1996). Their dimensions are remarkable: 7-12 km in length, 200-600 m in width and 20-40 m in depth. Glaciofluvial and till materials deposited in the valley were transported away, and the erosion continued down to the hard bedrock. The washed material was deposited as a delta with several deposition levels in front of the channel. Material in the delta is coarse and poorly sorted in the proximal part and finer and better sorted in the distal part.

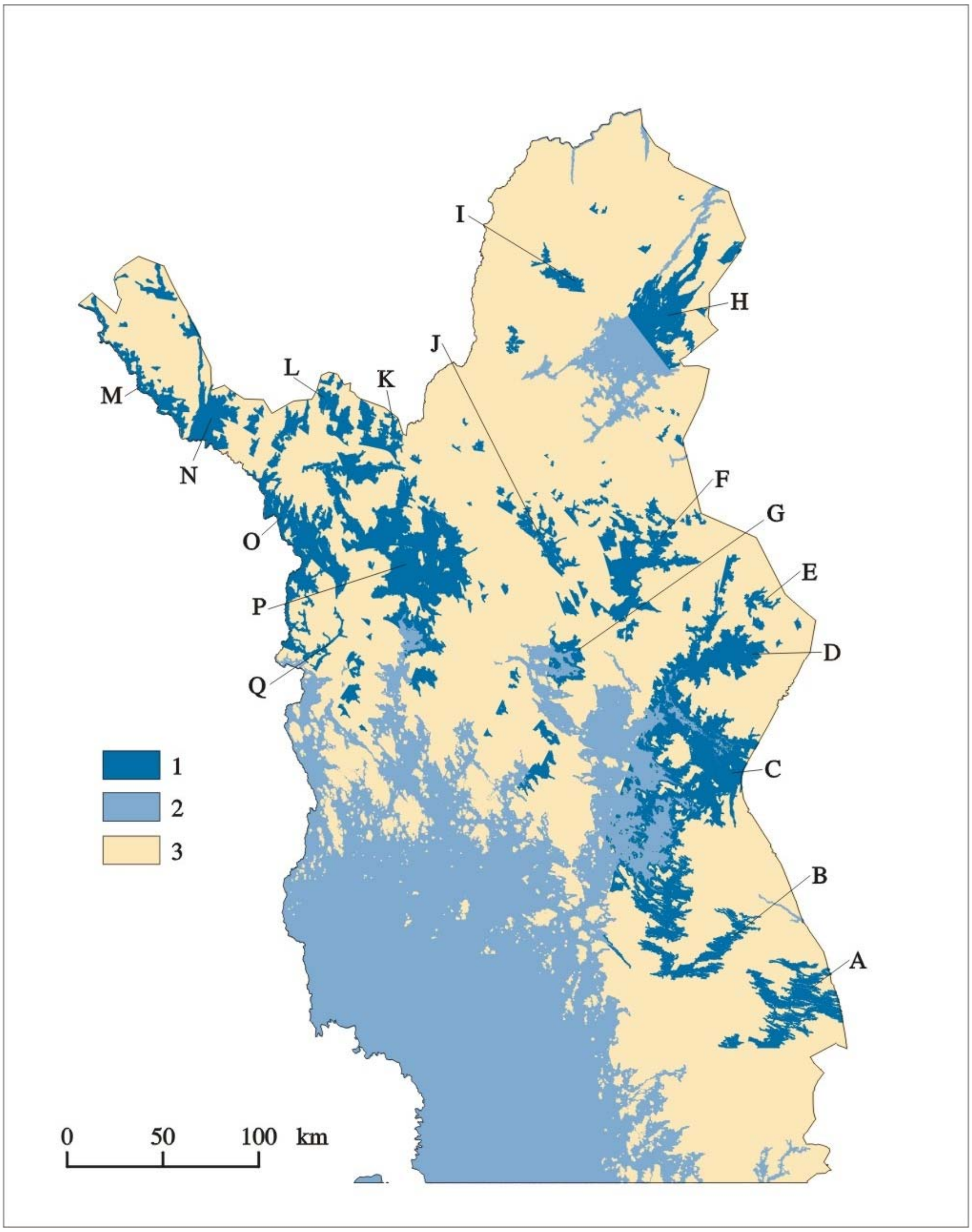

Fig. 22. Ice dammed lakes in northern Finland. 1 = Areas covered by ice dammed lakes, 2 = areas covered by the Baltic Sea or the Arctic Ocean, 3 = supra-aquatic area, P = Ounasjoki Ice Lake. (Johansson & Kujansuu 2005).

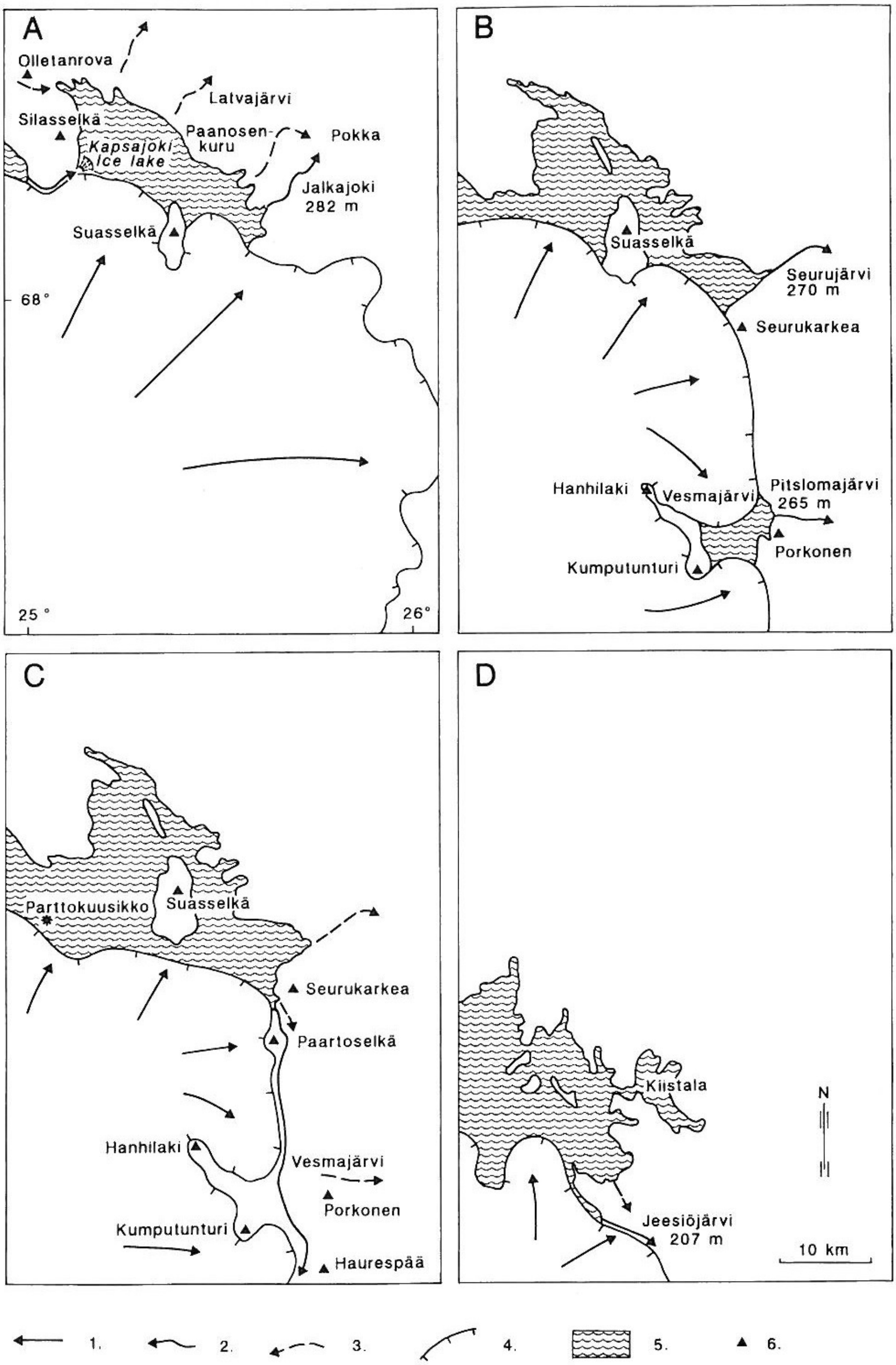

Fig. 22. History of the ice retreat and ice lake stages in the Ounasjoki Valley. 1 = ice flow direction, 2 = spillway in action, 3 = previous spillway, 4 = ice margin, 5 = area covered by ice lake and 6 = hill top. (Johansson *et al.* 1996).

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STOP 6: Siida – The National Museum of the Finnish Sámi

Peter Johansson

The Sámi Museum Siida at Inari is the national museum of the Sámi and a national special museum in Finland. The Sámi Museum stores the spiritual and material culture of the Finnish Sámi in its collections and presents it to the public through its exhibitions and publications. Its main purpose is to support the identity and the cultural self-esteem of the Sámi.

The exhibitions of Siida deal with the history and culture of the Sámi and nature in the northernmost Lapland. The permanent exhibitions are complemented by interesting changing exhibitions. The exhibition services of Siida are jointly provided by the Sámi Museum and Metsähallitus.

The introductory exhibition presents the development of northern nature and culture as a timeline, which is also interlaced with world history. The exhibition also introduces the visitor to the indigenous peoples of the Arctic and the reindeer-herding peoples of Northern Eurasia. Sámi culture and nature are intertwined, and, at Siida's exhibitions, they are introduced to the public as one whole. The exhibitions provide a great amount of scientific information but also visual experiences for the visitor. Beautiful photographs, genuine objects and a rich sound world make a visit to the exhibitions an experience that appeals to many senses. In the main exhibition of Siida, the sections dealing with nature in Northern Lapland and Sámi culture are placed one within the other. The exhibition focuses on survival strategies in the extreme conditions of the north and the demands of the cycle of seasons. The cultural section gives the visitor an idea of the elements that the ethnicity and the present identity of the Sámi are made of. The section on nature describes the cycle of seasons and the phenomena connected with it in Northern Lapland.

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http://www.siida.fi and http://www.luontoon.fi

The Kevo research station

The Kevo research station (Fig. 23) is situated by Lake Kevojärvi, in the commune of Utsjoki, the northernmost municipality in Finnish Lapland. The site (69°45'N, 27°01'E; Grid 774:50, 80 m a.s.l.) lies about 60 km north of the continous pine forest line and belongs to the subarctic or forest tundra zone, a birch subzone of the boreal coniferous forest. The research area as a whole comprises mainly the biological province of Inari Lapland, an area of ca. 20 000 km², including the large Lake Inari.

Precambrian granulite and gneiss are the dominant rocks, but there are some minor areas of basic rocks. The late tertiary upheaval, combined with preglacial erosion, has created steep valleys, with cliffs which provide important ecological niches for many southern and arctic plants. One of the most important valleys of this type is the Kevojoki gorge, lying within the Kevo Nature Reserve, a protected area of some 700 km². The topography is characterized by low mountains with river valleys; the elevation is mostly between 250 and 400 m.

During the last deglaciation glaciofluvial sediments were deposited on the bottom of the precipitous river valleys in the form of kame terraces, esker-like chains and deltas. Periglacial formations include rock cliffs and the talus cones. There are also many results of recent fluvial action, such as undercut bluffs and bars. The wide and strongly eroded areas between the fells contain the streamlined features like drumlins and flutings. There are numerous meltwater drainage channels in the fell region. They can be used as reconstruction of the deglaciation phases of the area. Locally there occur large areas of patterned ground, different types of solifluction lobes and boulder depressions. On the top of fells there are often tor formations.

In the valleys there are mountain birch (*Betula pubescenes* ssp. *czerepanowii*) forest, while areas lying above 300-350 m are low treeless alpine heaths. Draft shrubs and vegetation rich in lichens and mosses are typical. Locally there occur large areas of patterned ground, different types of solifluction lobes and boulder depressions. On the top of the fells there are often tor formations. Around the research station, however, there is an isolated pine forest which follows the Utsjoki and Kevojoki river valleys. In the vicinity of the station the vegetation includes mires, luxuriant woods, riverbanks, cliffs and the meadows which surround some of the Sami farmhouses. The human influence is limited and local. Reindeer herding is the traditional livelihood of the Sami people.

Although Kevo lies only one hundred km south of the Arctic Ocean, the climate is not so maritime as might be expected, due to the influence of the Scandes. The coldest month is January (-16 °C), the warmest July (13 °C); the annual mean is -2 °C. The snow cover lasts on the average until May 20. The polar day begins in mid-May and lasts till the end of July; correspondingly the sun remains below the horizon from late November to mid January. There are great annual variations in phenology. The growth season is approximately 110 days and the thermal sum (+5 °C d.d.) varies between 400 and 900. The soil is mostly very acid, pH 3.5-4.5, and is largely podsolized. There is no permafrost; only in some bogs do the palsas contain small isolated ice lenses.

References:

http://www.kevo.utu.fi

Deglaciation of the northern Fennoscandia and the Barents Sea

Juha Pekka Lunkka

The northernmost Finland and north Norway (Finnmarken) have been glaciated several times during the Quaternary. In addition, there are glacial sediments in the Varanger area that date back to the Neoproterozoic. Although the area has been covered by ice during most of its recent history, there are virtually no Quaternary sediments in the Finnmark area that represent sediments older than the Late Weichselian. The landscape is therefore characterized mainly by barren bedrock and glacial landforms (Fig. 24) that were laid down during the last deglaciation after *ca.* 18 ka ago.

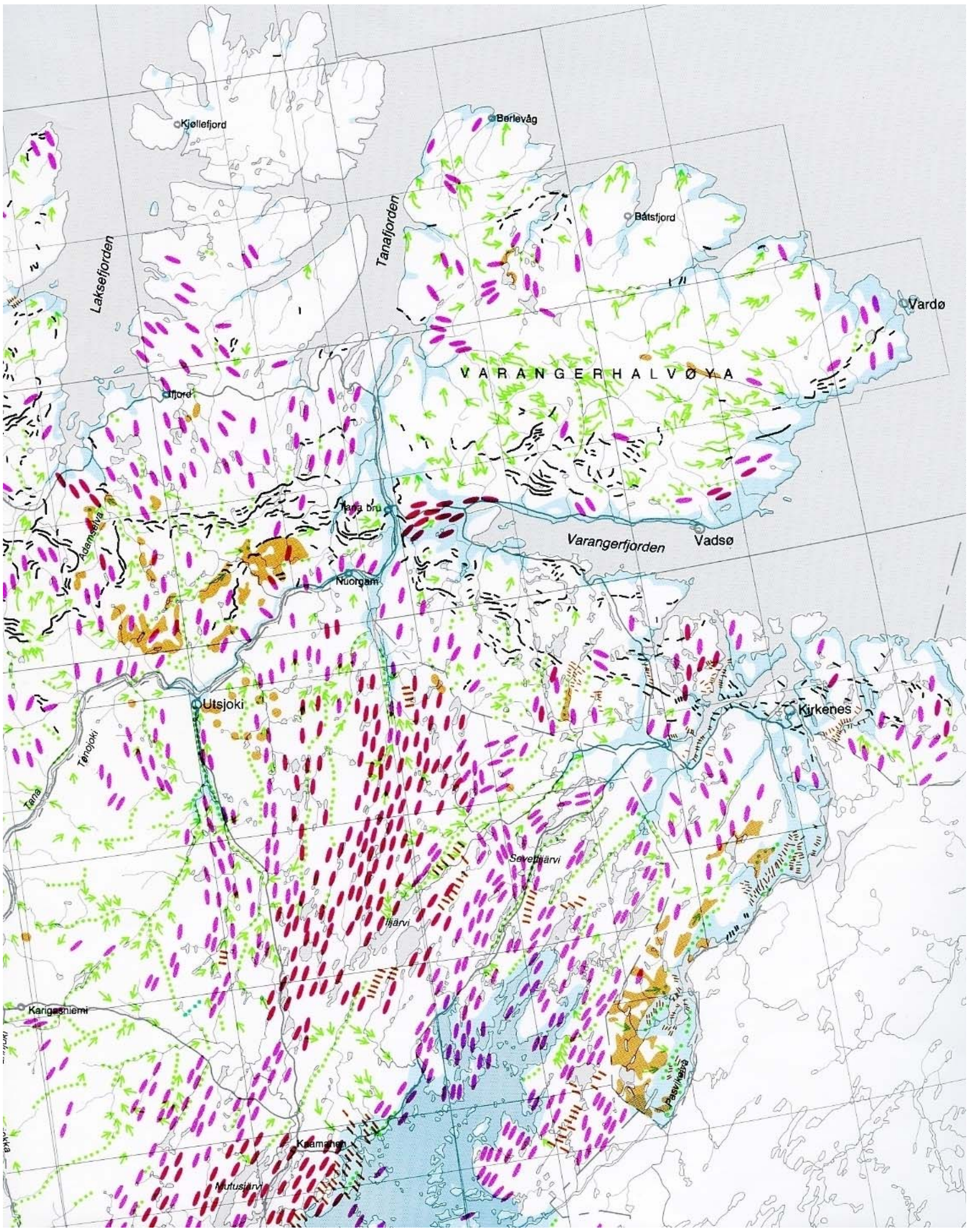

Fig. 24. Quaternary map of northern Finland and Finnmarken showing the main landforms parallel and transverse to the ice flow. Drumlins = red, end moraines = black, green stippled lines = eskers, green arrows = glaciofluvial cahnnel systems (Nordkalott Project 1986).

According to the results of the Nordkalott Project, a suite of ice movement direction indicators (*e.g.* striations) were interpreted to have been formed during the Early Weichselian, when the ice in the Varanger area and Finnmarken was flowing mainly from the south (Fig. 25). The Nordkalott Project also compiled the map of the ice flow patterns for the Middle and Late Weichselian (Fig. 26) in which the ice flow directions deviate slightly from the Early Weichselian ice flow directions.

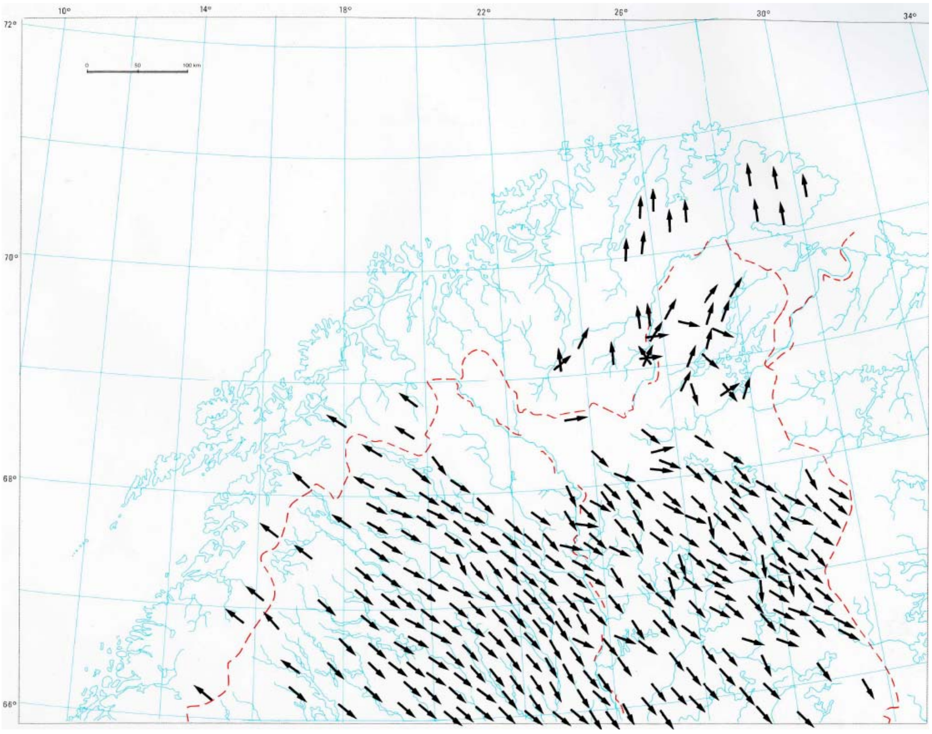

Fig. 25. Ice flow directions in northern Fennoscandia during the Early Weichselian (Nordkalott Project 1986).

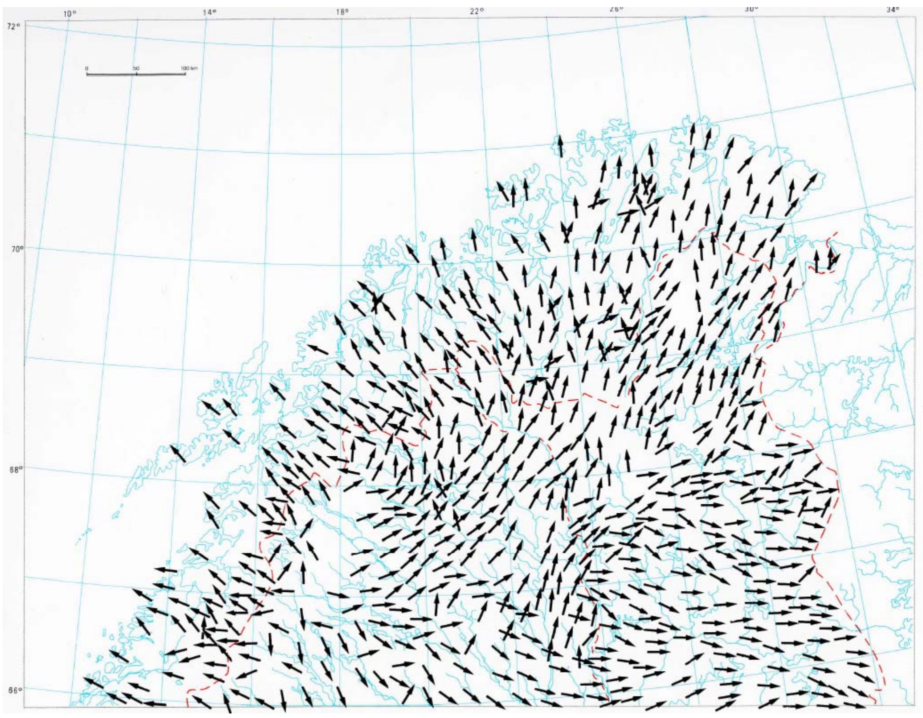

Fig. 26. Ice flow directions in northern Fennoscandia during the Middle and Late Weichselian (Nordkalott Project 1986).

During the last glacial maximum (*ca*. 18–20 ka), the Scandinavian (SIS) and Batrents Ice Sheets (BIS) coalesced at the western edge of the Barents Sea shelf. The SIS was flowing towards the north and northeast while the BIS was flowing towards the west (Svendsen et al. 2004). As both of the ice sheets started to retreat from their maximum position several ice marginal positions can be traced across northern Fennoscandia (Fig. 27). Generations of streamlined forms (flutes, drumlins, striations) can be used to picture the ice flow patterns during the final phases of deglaciation while end moraines and raised shorelines can be used to reconstruct the successive ice marginal positions across the northern part of Fennoscandia (*cf*. Sollid *et al.* 1973).

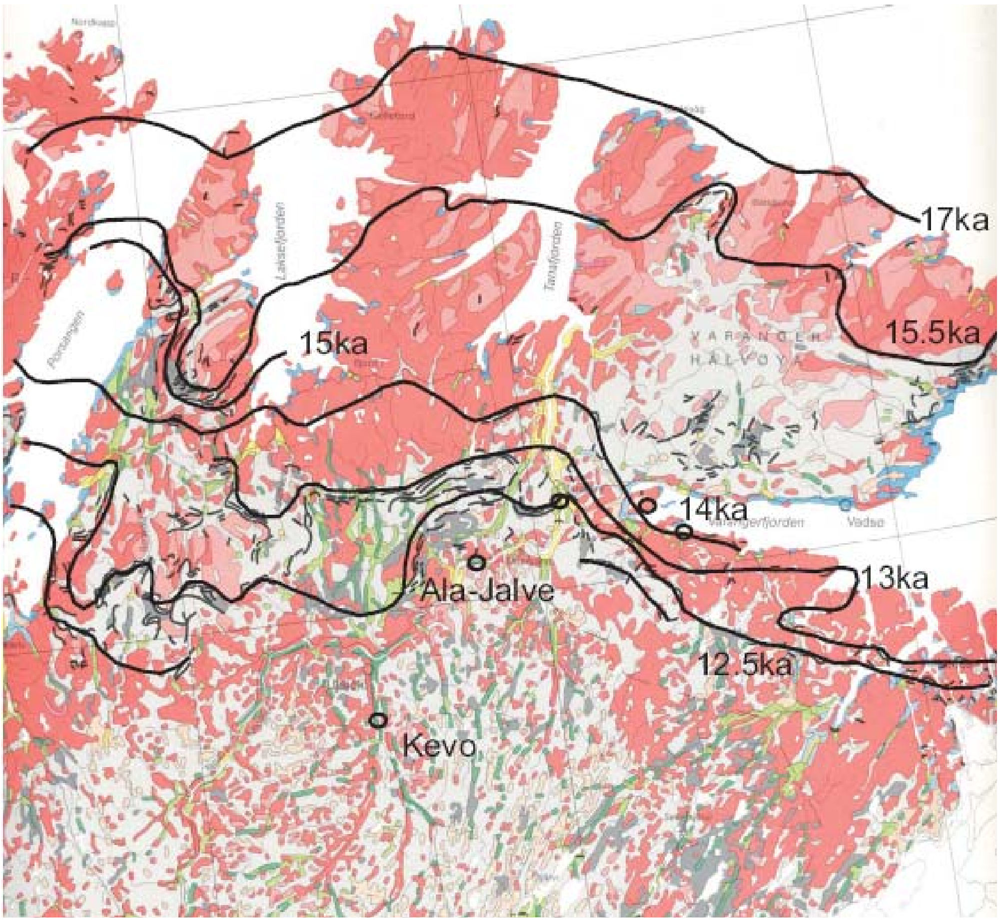

Fig. 27. The main ice marginal positions during the Late Weichselian deglaciation in N Norway. Open dots indicate sites that will be visited during this excursion (modified after Nordkalott Project 1986).

The following ice marginal zones (Fig. 27) and the corresponding substages in northern Norway from north to south have been named and their age have been estimated based on the regional age correlation of dated sediments and associated end moraines and shorelines:

Risvik Substage (*ca*.17–18 ka) representing the most northern ice marginal zone close to the outer coast of Varanger Peninsula with associated shorelines L_{12} and L_{13} (Fig. 28).

Outer Porsanger Substage (*ca*. 15.5 ka). The ice margin at that time is represented by major end moraines at Strømmen and at Vardø with associated shorelines L_6 and L_7 (Fig. 28).

Korsnäs Substage (*ca*. 14.7–15.4 ka). The position of the ice margin related to this substage is uncertain in the Varanger area but the substage is thought to be correlative to increased calving events in the Varangerfjord when the shorelines were close to L_6 (Fig. 28).

Rapparfjord Substage (*ca*. 13.8 ka; Older Dryas-Bølling chronozone). The corresponding ice margin position during this stage is thought to have been at Bransletta, Gandvik and Nyelv on the southern side of Varangerfjord. Shorelines L_3 and L_2 are associated to this substage (Fig. 28).

Gaissa Substage (*ca*.13 ka; Allerød chronozone). During this substage the ice marginal position is marked by the distinct end moraines south of Varangerfjord and west of the Tana Valley. L_2 shorelines are associated to this substage (Fig. 28).

Main Substage (*ca*. 12.4 ka; Younger Dryas chronozone) end moraines are correlative to the Younger Dryas end moraines that run around Fennoscandia, Kola Peninsula and Russian Karelia. Shorelines L_0 and P_{11a} outside and inside the end moraines are correlated to this substage (Fig. 28).

Korselv Substage (11.3–11.5 ka, Preboreal chronozone) during which a minor end moraine formed in the Tana Valley. Shoreline P_{10} is associated to this substage (Fig. 28).

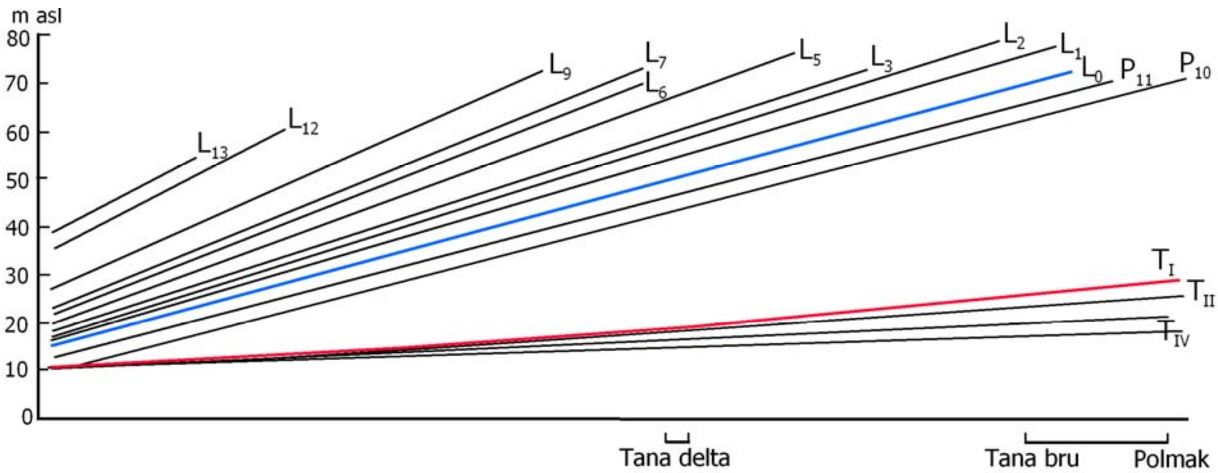

Fig. 28. Equidistant shoreline diagram for the Tana Valley area (modified after Sollid *et al.* 1973). L_0 (blue line) represent the shore line during the Younger Dryas and T_1 (red line) shows the shoreline of the Tapes transgression *c*. 7 ka ago.

During the INQUA Peribaltic Workgroup Excursion 2011 the following sites in northernmost Finland and Teno Valley – Varanger area will be visited.

STOP 7: Ala-Jalve – Glaciofluvial deposits in the Tana valley, terraces and an old dwelling site

Juha Pekka Lunkka

During the last deglaciation subglacial drainage to the Tana Fjord of the Barents Sea took place via subglacial tunnel systems. One of them ran on the western side of the Tana Valley. At this site the Ala-Jalve delta accumulated to the former Preboreal water level P_{10} of the Tana Fjord (see Figs. 28, 29 and 30).

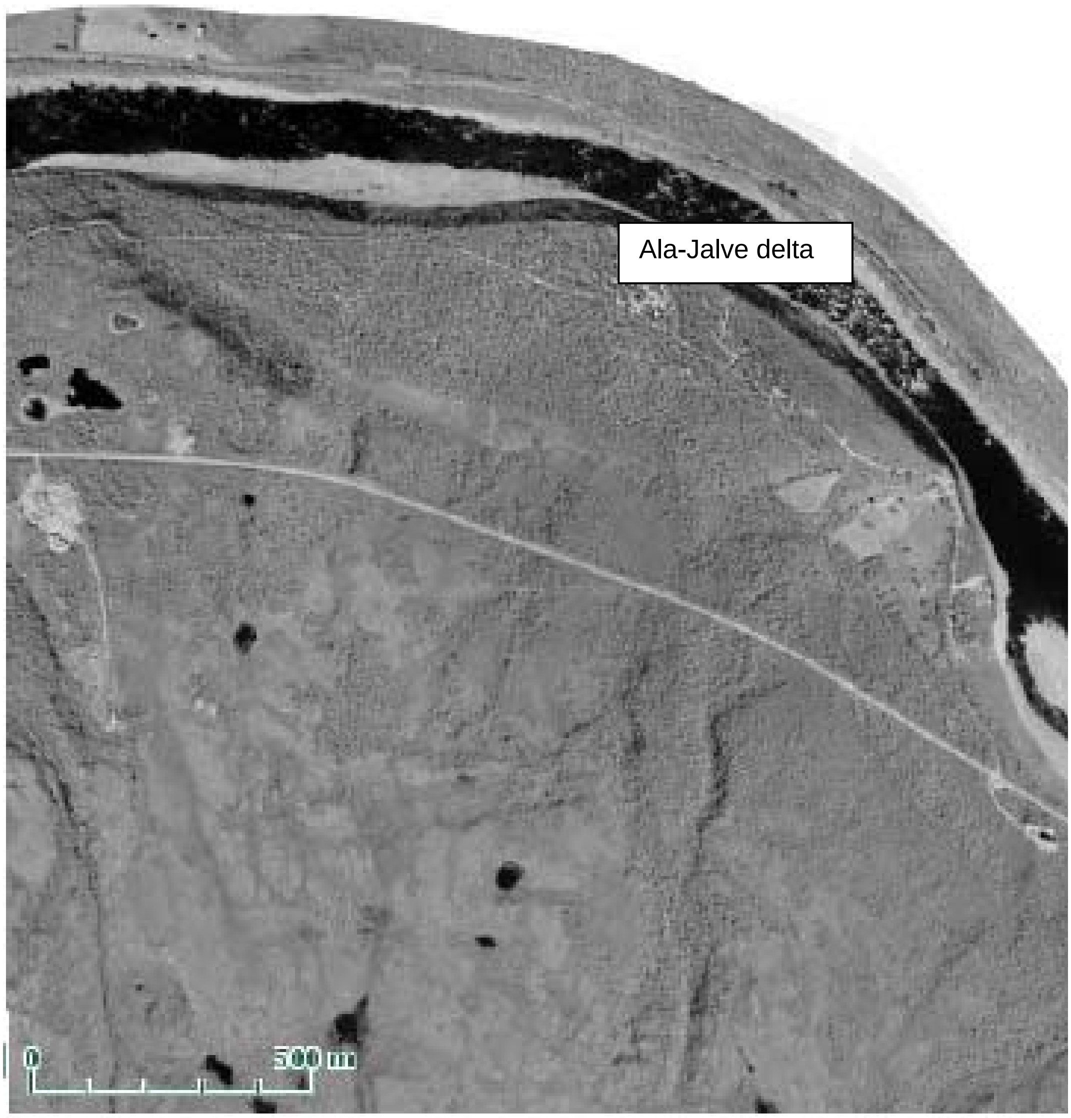

Fig. 29. Air photo of the glaciofluvial Ala-Jalve delta in the Tenojoki Valley.

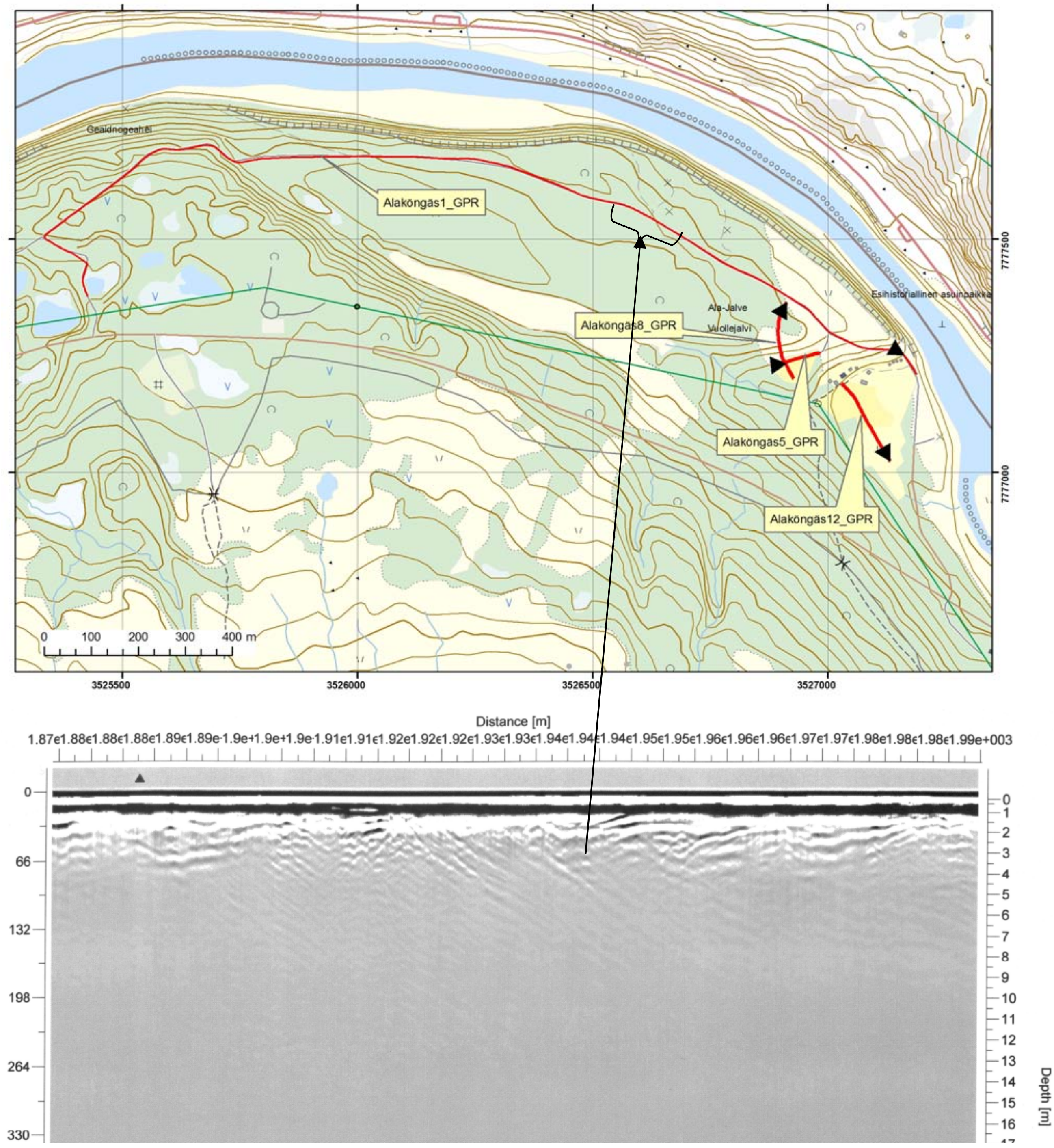

Fig. 30. An example of GPR-profile of the foreset and topset facies of the Ala-Jalve delta.

There are archaeological sites on the terraces of the Ala-Jalve delta (Fig. 31). The oldest signs of human occupation are considered to represent late Mesolithic age (ca. 7,000 calendar yrs ago). The most intensive stage of human occupation in the area was between 4,000-2,500 calendar yrs ago.

Fig. 31. Scenery to the Tenojoki River from the top of glaciofluvial Ala-Jalve delta (eastern part) towards the west. On the top of the delta occur archaeological sites from the late Mesolithic age. Photo by P. Sarala.

STOP 8: Bigganjarga tillite – evidence for the Neoproterozoic glaciation

Juha Pekka Lunkka

Bigganjarga outcrop is protected geological site *ca*. 45 minutes walk from the Karlebotn school along the coast (sampling and hammering of the metasedimentary rocks are not allowed). At this site the contact between Veinesbotn Formation and Smalfjord Formation can be seen. The contact represents a major erosional hiatus in the local stratigraphy (Fig. 32). At this site, shallow marine quartzite-rich sandstone is overlain by grey diamicton. The striations in the sandstone are interpreted as glacial scours and the overlying diamicton as till (*cf*. Edwards 1984).

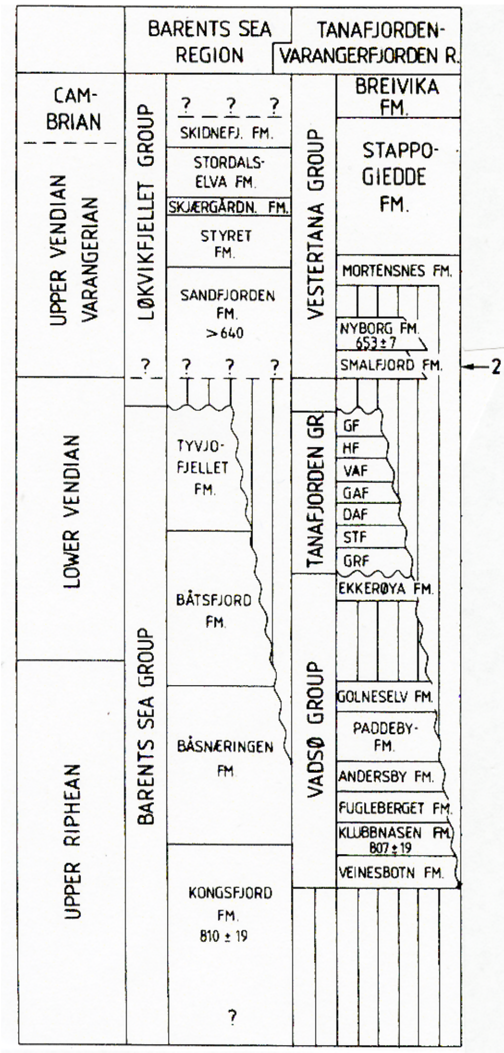

Fig. 32. Stratigraphy of the Tana Fjord area and the Barents Sea region. Number 2 indicates the the diamicton unit.

STOP 9: Nyelv – terraces and raised shorelines

Juha Pekka Lunkka

The coastal areas of the Varanger Peninsula are famous for its terraces and raised shore lines. One of the good examples of rather complicated terrace and shoreline successions can be seen in the mouth of the River Nyelv (Fig. 33).

The terraces and shorelines at Nyelv have been described in Corner and Raymond (2008) as follows:

“The terraces and raised shorelines at Nyelv comprise, in chronological order, the following main elements:

Marine limit. A washing at 99 m, on rock surfaces near the proximal end of the Nyelv terraces, represents mean sea-level at 97 m immediately following deglaciation. This is higher than the marine limit according to Sollid *et al.* (1973), who identified it as a beach ridge at 91 m (L_3).

High delta. An upper, ice-contact, glaciofluvial, deltaic terrace slopes from 97 to 85 m. The terrace has a distinct proximal slope, and contains kettles and braided channels above 89 m, and beach ridges on a wave-washed surface between 89 and 85 m (Fig. 34). It is bordered distally by a 3-5 m high, river-erosion scarp to the E and a shore-erosion scarp to the W. The delta formed at the front of the 'Nydal ice lobe', which corresponds with the Main N Haukdal moraine/Gandvik readvance which, in turn is correlated with the Repparfjord substage on the basis of distal (91 m ≈ L_3) and proximal (98 m ≈ L_2) shorelines (Sollid *et al.* 1973). Rose and Synge (1979) interpreted the landform assemblage as indicating a transgression (with channel submergence) from 85 to at least 87 m, followed by a gradual regression (with beach building) and then a rapid regression to below 80 m (Fig. 33).

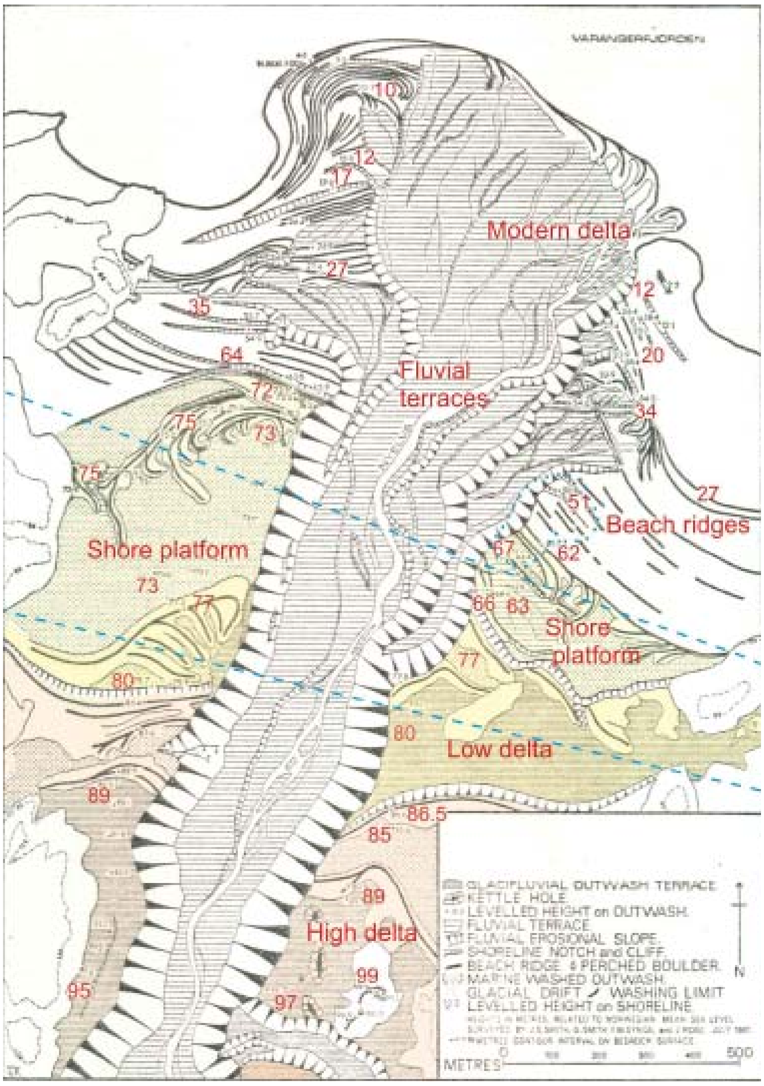

Fig. 33. Map of Nyelv delta and terrace levels (copied from Corner and Ellertsen (2008), original figure Sollid *et al.* (1973)).

Low delta. A lower, glaciofluvial deltaic terrace slopes from 80 to 77 m. It contains meltwater channels that are sealed distally by beach ridges at 78 m. A shore platform is well developed in association with an erosion notch at 80 m, especially to the W. The low delta formed during the Hauksjøen readvance, corresponding to the Gaissa substage. The erosion platform is interpreted as having formed during a minor transgression at around 79 m a.s.l., although low sediment supply may conceivably have contributed.

Delta-front shore platform. Erosion platforms containing numerous recurved beach ridges are cut in the front of the low delta at c. 73-74 m in the W, and c. 63-64 m in the E. They are interpreted as representing minor transgressions belonging to the 'Main Line Sequence' (Younger Dryas) and 65 m Sequence (Preboreal), respectivelty (Fig. 33). This differs from Sollid *et al.* (1973), who correlated these levels with Preboreal P_{11} and P_8-P_9 shorelines, respectively.

Delta-front slope with postglacial shorelines. Prominent shorelines on the steep delta slope include beach ridges at 34 and 27 m a.s.l. The latter is the pumice-bearing Tapes (T_I) shoreline. Distinct shore notches occur at 17 m to the W, and 12 m a.s.l. on both sides of the river.

Delta foreset beds exposed in sand pit. A large pit, currently being excavated on the delta slope in the E side of the river, reveals moderately steeply dipping beds of sand and gravel."

Fig. 34. Terraces of the high delta in Nyelv. Photo P. Sarala.

STOP 10: Tanabru – Younger Dryas end moraine zone

Juha Pekka Lunkka

An end moraine belt which is thought to have been deposited during the Younger Dryas chronozone is located in the Tana bro area (Fig. 35). The Tana River Valley cuts through the end moraine zone south of Tana bro town.

Fig. 35. End moraine running west-east, south of Tana bro town on the western side of the Tana River. photo taken from the south towards the north. Photo by J.P. Lunkka.

The stop locality is on the eastern side of the Tana River *c*. 1 km south of Tana bridge where ice front delta and post glacial terraces can be seen (Fig. 36). After Corner and Raymond (2008) and Sollid *et al.* (1973) the delta and higher terraces have been formed during the so-called Main and Korselv substages correlative to the Younger Dryas and Preboreal age (*ca*. 12.5–11.5 cal. yrs BP). The sea levels at that time varied between *c*. 66 and 77 metres above the sea level corresponding to L_1 and P_{10} shorelines.

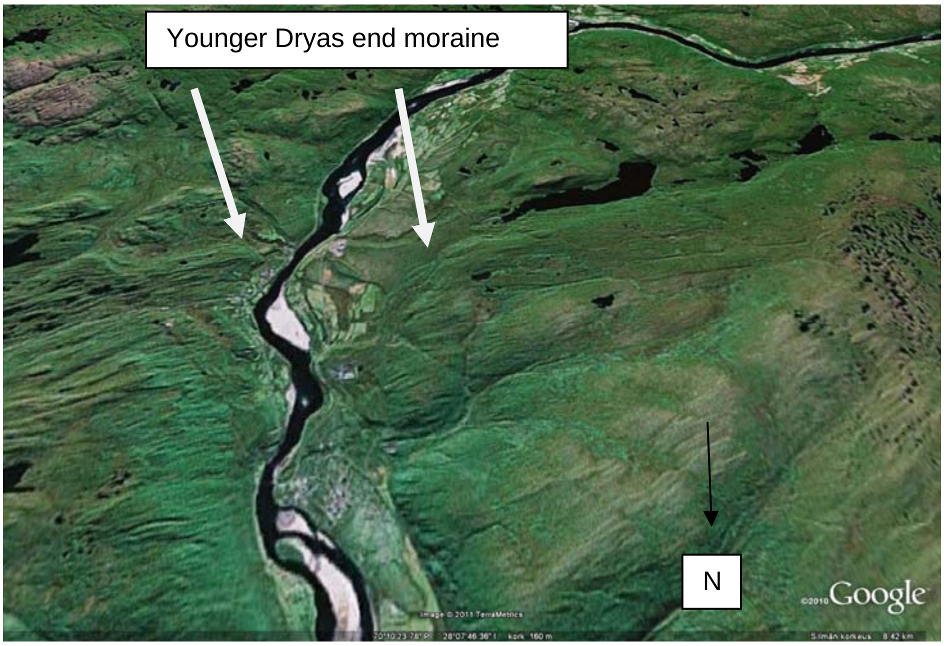

Fig. 36. The Younger Dryas end moraine and an ice contact delta in the Tana bro area.

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STOP 11: Palsas at Vaisjeäggi

Peter Johansson

Palsas are permafrost-cored mounds rising above the mire surface in the zone of discontinuous permafrost (Seppälä 2006). They contain perennially frozen peat with segregated ice and small ice crystals. The frozen core is surrounded by unfrozen peat and mineral soil underneath. Palsas can be classified according to their morphology: dome-shaped, elongated string-form, longitudinal ridge-form, and extensive plateau palsas as well as palsa complexes with many basins, hollows and ponds of thermokarst origin. The diameters of palsas range from a few metres to several tens of metres and their height from less than 0.5 m up to 7 m in Finland. The surface peat on an old palsa is produced mainly by Bryales mosses, lichens and Ericales schrubs. It can be also old moss peat eroded by wind. Below the dry surface, peat is the original mire peat formed of *Sphagnum*, *Carex* and *Eriophorum* remains (Seppälä 2006). When the cores of palsas have thawed completely, thermokarst hollows may form closed ponds that indicate the former distribution of palsas that were once much larger than today (Luoto and Seppälä 2003). The recent trend has been for palsas to thaw, rather than for new palsas to be formed (Seppälä 2005a).

Palsas mainly occur in northernmost Finland between 180 and 390 metres a.s.l. (Seppälä 2005a). Palsas are found in valleys where the insulating peat layers are thick enough (50-70 cm) to preserve the frozen core from thawing but the snow cover is thin enough to let cold penetrate deep into the peat layers. The southern limit of the palsa region in Finnish Lapland, 68^{o} 30', coincides with the -1^{o}C mean annual air temperature isotherm and has an annual precipitation below 400 mm (Fig. 37). Less than half of precipitation is snow, received during 8 winter months when the air temperature is below zero.

Palsas form on mires in places where wind thins the snow cover, so that frost can penetrate deeply into the peat already in early winter (Fig. 38). This causes initial upheaval of the surface, and during subsequent winters the hump has a greater tendency to become snow-free and the thickness of the frozen layer increases. This has been tested in the field by clearing the mire surface of snow several times during the winter (Seppälä 1995). An insulating peat layer is important for preserving the frozen core during the summer. The peat should be dry during the summer, thus having a very low thermal conductivity, and wet in autumn, when the freezing starts, giving a much higher thermal conductivity. This allows the cold to penetrate so deep into the peat layers that they do not thaw during the summer (Seppälä 2006).

When the palsa grows in height, its peat surface cracks. Pieces slide down the slopes. As a consequence the palsa loses its insulation layer, the frozen core melts, and the palsa collapses. The end point of the syclic development of a palsa is a rounded open pond or group of thermokarst ponds on the mire. According to radiocarbon datings most palsas are less than 1,000 years old (Seppälä 2005b). By means of plant macrofossil analyses, physico-chemical analyses and AMS-radiocarbon dating of peat deposits Oksanen (2006) concluded that the first permafrost aggradation on a palsa mire in North Finland took place *c.* 2,460 years B.P.

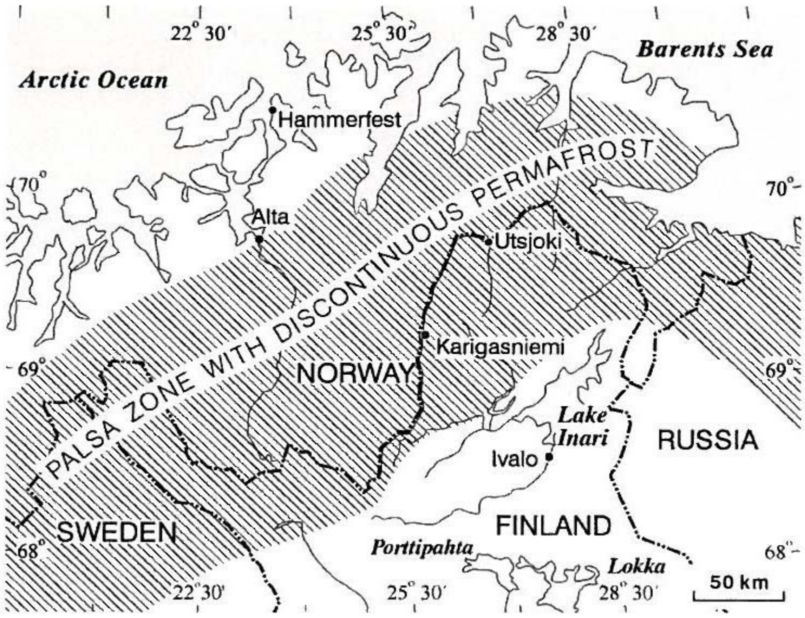

Fig. 37. Distribution of palsas and zone of discontinuous permafrost on northern Fennoscandia (Seppälä 1988).

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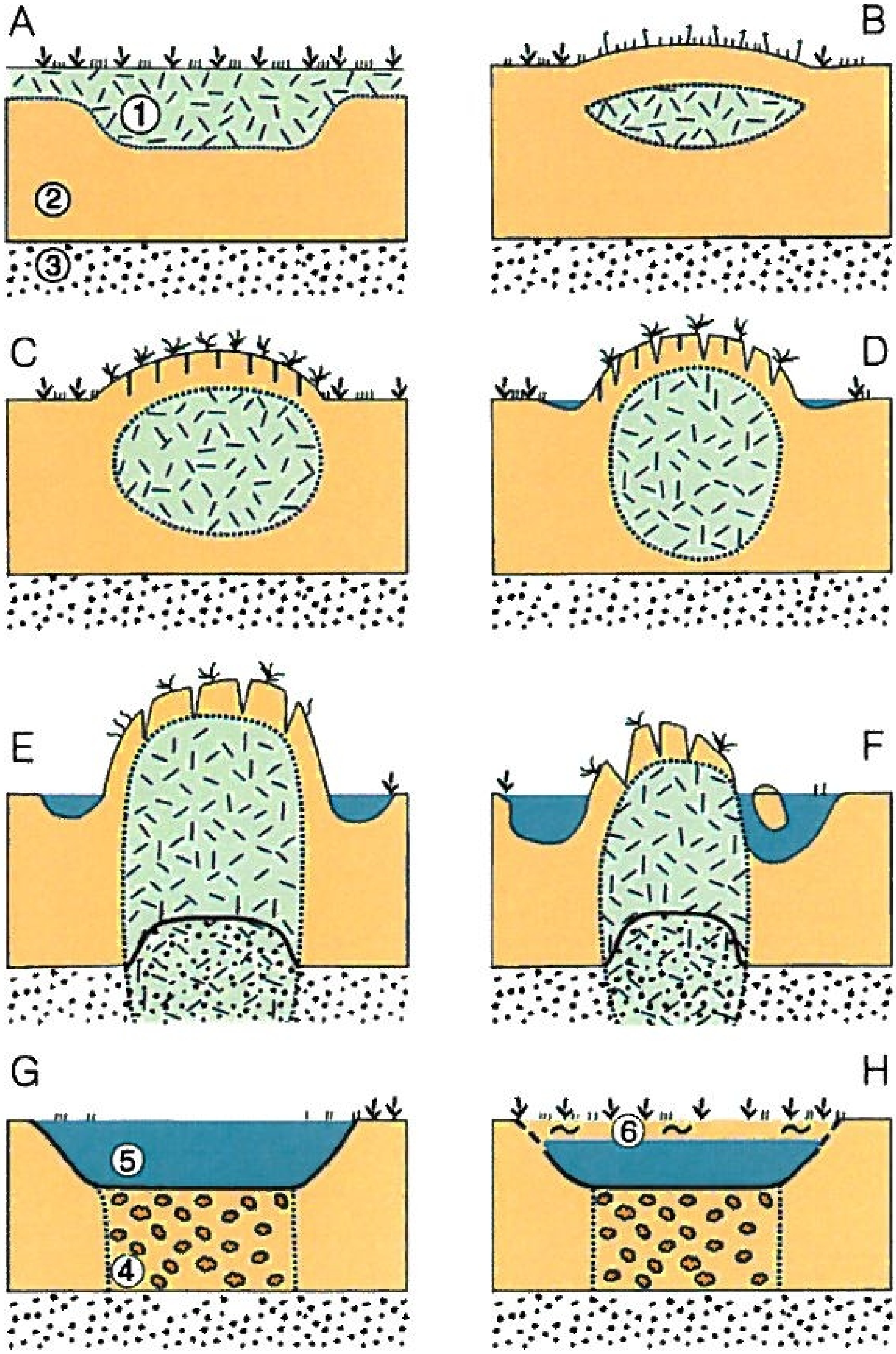

Fig. 38. A general model of the formation of the frozen core (1) of a palsa in a mire (2) with a silty till substratum (3). A = the beginning of the thaw season, B = the end of the first thaw season, C = embryo palsa, D = young palsa, E = mature palsa, F = old collapsing palsa, G = fully thawed palsa giving a circular pond (5) on the mire and H = new peat (6) is growing on the pond and the cycle of palsa development recommences from the beginning (Seppälä 2006).

STOP 12: Drumlins, esker and dunes in Kaamanen - Mutusjärvi area

Peter Johansson and Pertti Sarala

The Inari Lake basin is a typical area of a high rate of the continental ice sheet. The glacier eroded its base by grinding the bedrock surface and tearing out big fragments up to tens of cubic metres in size. The basal till and hummocks of ablation moraine are strewn with numerous boulders and stones, which is a striking feature around the village Inari.

The streamlined moraine forms are typical in the Kaamanen area (Fig. 39). The active ice flow during the Younger Dryas stade was characterized by the formation of drumlins and flutings. The drumlins vary in length from 150 to 2,000 m, in width from 30 to 450 and in height from 2 to 60 m. The width-length ratio is 1:2 – 1:20. The highest flutings are almost 1 km long, 10-35 m wide and 1-4 m high (Ström 1980). At its smallest, fluting consist of some metres long till tails beginning from the distal side of the boulder. Most common types of drumlins are the lee-side forms with a core of bedrock, varying widely in size. The smallest drumlins are normally without a core of bedrock. In drumlins the till material is in most cases well sorted, better sorted than in flutings (Ström 1980). The streamlined moraine forms are formed during the deglaciation phase. The drumlins indicate a predominantly north to northeastwards direction of ice flow from the initial phase of the deglaciation. To the north of Kaamanen the direction of flutings deviates from that of drumlins almost 30^{o}, which indicates younger ice flow direction from the final phase of the deglaciation (Kujansuu 1992).

The steep-sided esker of Kaamanen is deposited on the bottom of the subglacial glaciofluvial conduit (Fig. 39). The debris transported by the meltwater was washed and sorted into different grain sizes according to speed of the water flow. The Kaamanen esker is over ten meter high and it runs from SSW to NNE (Fig. 40). It reflects the meltwater tunnel running to NNE towards the ice margin. Near the esker there are Aeolian deposits and some small dune ridges.

In northern Finland there is limited aeolian activity on fine sediments, mainly deflation of old, stable periglacial sand dunes, eskers and the edges of glaciofluvial deltas that are exposed to strong winds. Dunes and drift of aeolian sand are composed of material deriving from sorted sediments of glaciofluvial and fluvial origin. Dune material is well-sorted fine sand (Ø 0.2 – 0.6 mm). It occurs as single dunes, like at Mutusniemi or large dune fields e.g. south of the lake Iijärvi and on the both sides of the esker Tuuruharju.

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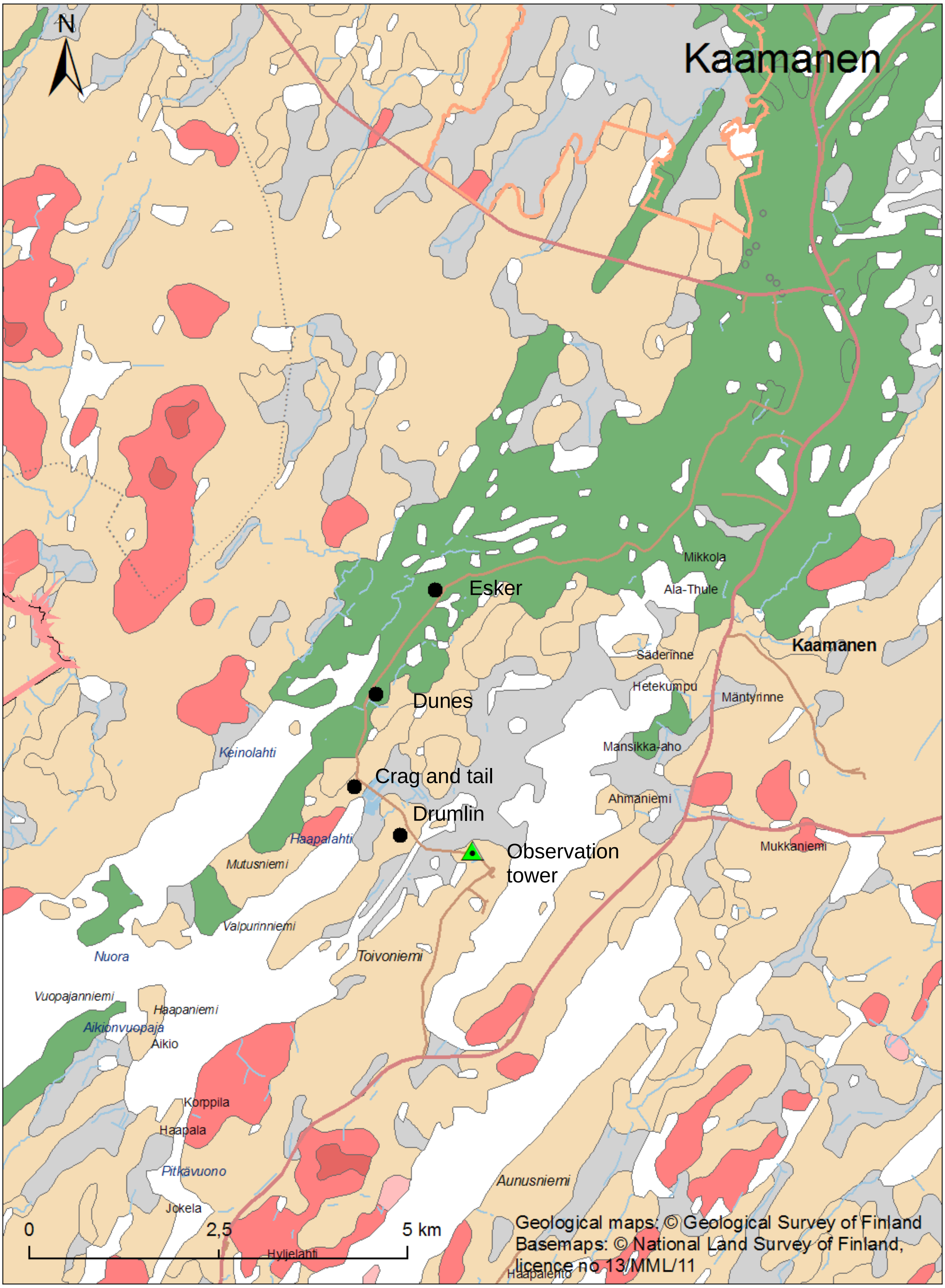

Fig. 39. Geological map of the Kaamanen area. Green = esker, light brown = till, red = bedrock, grey = peat and white = lakes and rivers.

Fig. 40. Cross section of the esker ridge in Kaamanen. Photo by P. Sarala.

STOP 13: The Cave of the Karhunpesäkivi, the Boulder of Bear's Den

Peter Johansson

The Cave of the Karhunpesäkivi is situating near the lake of Myössäjärvi in Inari. The cave is inside a garnet- cordierite-gneiss -boulder, which dimensions are 6 x 6 x 4 metres. The mouth of the cave is under the block. You have to creep under the edge of the rock if you like to visit the cave.

The cave is about 5 m long, 1.5 m wide and 1-2 m high. It is formed through tafoni-weathering *in situ* mainly by disintegration caused by differences in temperature between the inner rock and the surfaces of the cavities (Fig. 41). The cavities have thus developed from an initial pit or score on the bottom side of the boulder. The weathering now proceeds along the comb-like cavities (Uusinoka & Eronen 1979). Tanner (1935) considered the cave as a result of cavitation erosion made by flowing water, because cavities resembled the holes of the stones in river rapids.

After the explanation of Laitakari (1938) the tafoni-weathering has happened in the post-glacial time, after the glacier had transported and left the boulder on the slope. Same kind of traces of the tafoni features have been found on the other erratic boulders around Karhunpesäkivi, too. Uusinoka (1976) prefer pre-glacial weathering, when the boulder was still as a part of bedrock and the climate was warmer and more suitable for tafoni-weathering.

Fig. 41. A view inside the cave of the Karhunpesäkivi. Photo by P. Johansson.

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STOP 14: Late Middle Weichselian inter-till deposit in Veskoniemi, Ivalo

Pertti Sarala, Niko Putkinen and Jouni Pihlaja

Over the last ten years, the age of stratified inter-till layers has been the subject of intense investigations both in Finland and in other areas influenced by the Scandinavian Ice Sheet (SIS). The purpose of the research is to find further evidence for the debate on the extent and timing of these intestadial/interglacial stratified deposits. One of the inter-till stratified sediment deposits was found from the Veskoniemi area, northern Finland.

Veskoniemi situates on the southern side of Lake Inarijärvi, near the Ivalo village (Fig. 42). The site is situated about 125-150 m a.s.l., and consists of glaciogenic hummocky terrain that shifts into larger bedrock-core moraine hummocks eastwards. During the earlier stratigraphical studies done by Hirvas *et al*. (1977, 1991) inter-till stratified sediments were found, but no instrumental age estimations were done. Through stratigraphical correlation and till fabric analyses, the age of deposits has been estimated to be older than the Late Weichselian.

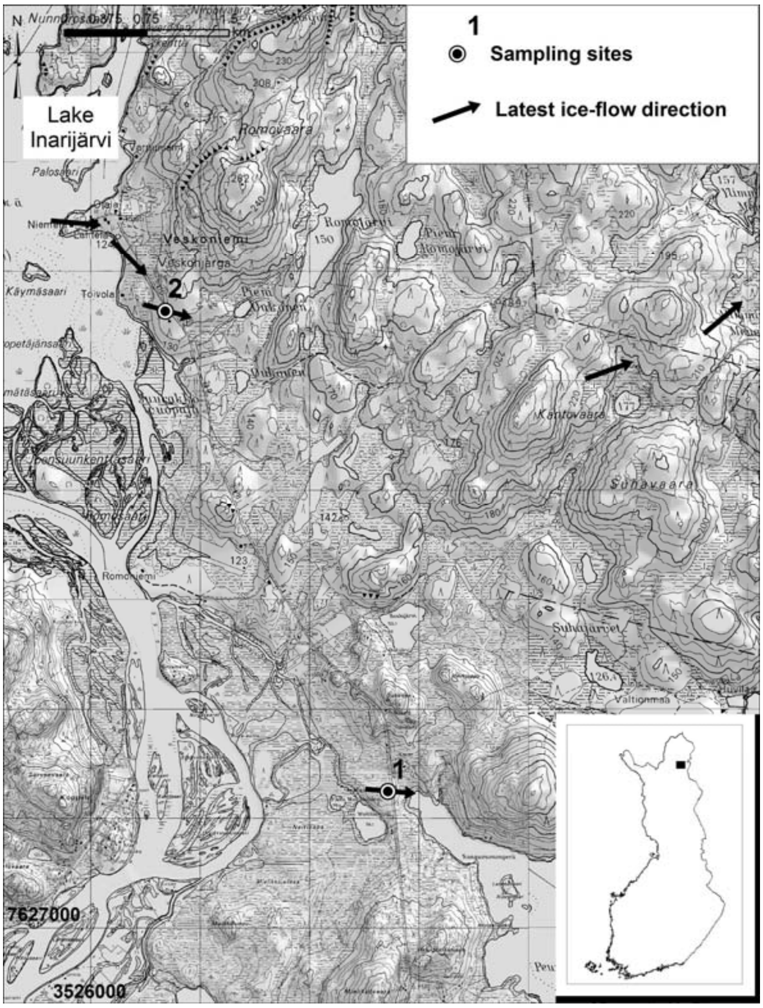

Fig. 42. Location of the Veskoniemi area and the visiting site (number 1).

New stratigraphical studies together with OSL dating of stratified, till-covered sands, the stratigraphy were carried out in the area in 2007-2010 (Sarala *et al*. 2010). Sands were deformed (convolution structures) under periglacial conditions and later glaciotectonized during the Late Weichselian glacial advance phase. OSL ages range between 21.0 ± 1.5 and 22.4 ± 1.6 ka for laminated sands at the depth of 2.8 m, and 46 ± 3 and 39 ± 3 ka for sands at a depth of 2.2 m (Fig. 43).

Based on the age difference between the two levels, the sand deposit is taken to represent an ice free period at the end of the Middle Weichselian interstadial. These dating results indicate that this ice free period may have lasted up to the beginning of the Late Weichselian, about 22-25 ka ago, in northern Finland. The sands are covered with Late Weichselian tills, which help to give us confidence in the reliability of the OSL ages.

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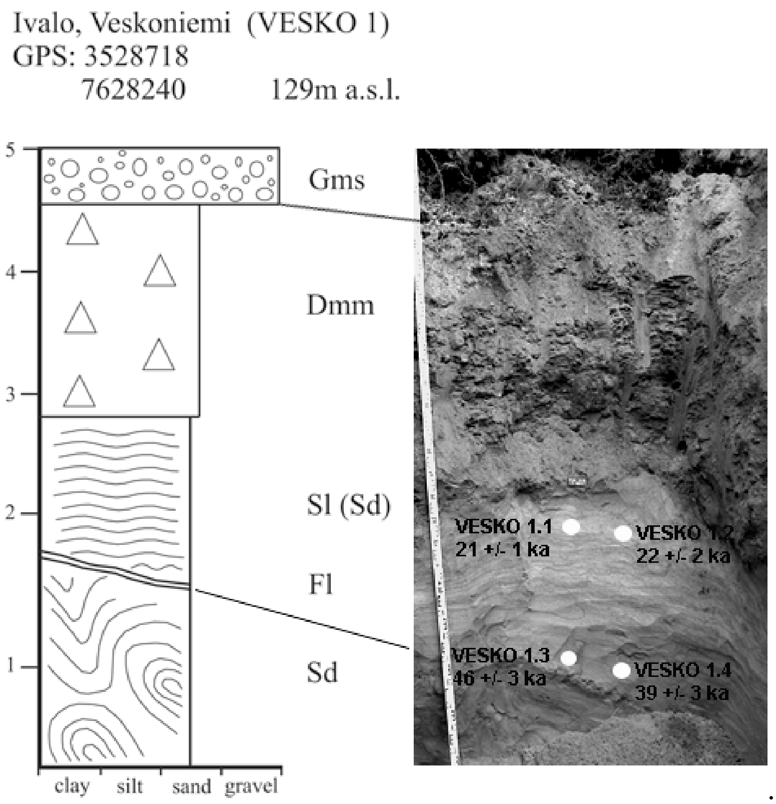

Fig. 43. Stratigraphy log of the test pit VESKO 1 and the OSL ages of stratified sans. After Sarala *et al.* 2010.

STOP 15: Quaternary geology of the Kiilopää area

Peter Johansson

Urho Kekkonen National Park is the second largest protected area in Finland. The heart of the park consists of the continuous Saariselkä – Raututunturit fell area. It is an easily traversable mountain area, shaped by the last Ice Age. It consists tens of gently undulating, treeless fell tops rising over 400 meters and typified by rounded mountain tops, gorges, boulder fields and heaths. The bedrock is Precambrian granulite, a garnet rich gneiss, which was formed around 1,900 million years ago. The present-day fells were formed by block movements during the Tertiary period, around 30 – 50 million years ago. The uplift gave rise to pronounced erosion, which lowered the fells and smoothed over the originally sharp and angular forms of the landscape. The blocks' fracture lines formed present river valleys. During the Quaternary the erosion was minor, except some deep meltwater channels. The boulder fields have formed from the rock which has slowly weathered after the deglaciation. In the south-west part of the National Park there is typical forest wilderness with isolated fells, extensive open aapa mires, pine forests and thickly-mossed spruce forests.

Reideer husbandry, hunting and fishing have long traditions in the region. They have left their mark in the form of hole traps, reindeer fences and herders' huts. Reindeer husbandry is to this day the main source of livelihood in the region, although tourism is growing up in the tourist centres. Around them there are marked trails, which make it easy for even the inexperienced backpacker to move around. Alternatively it is possible to go on long and demanding hikes in the park's wilderness areas.

The esker of the Kiilopää

The fell of Kiilopää (456 m) belongs to the fell group of Raututunturit. On the northern slope of the fell there is a small esker ridge climbing over the fell range. It is a typical small subglacial esker formed in the meltwater conduit at the base of the retreating glacier. The esker ridge leads into the meltwater gorge and further to the Luulammet valley, where there are again larger glaciofluvial hillocks and ridges. Both depositional and erosional landforms belong to the same subglacial meltwater system.

The Kiilopää ice lake

During the deglaciation stage of the last glaciation the ice flow direction was from southwest. About 10 500 years ago the ice margin was in the Kiilopää area. There was dammed an ice lake in the Kiilo-oja river valley between the slope of the fell and the ice margin. It discharged its waters over the fell range towards northeast. The spillways were formed on the lowest points between the felltops. At these points the meltwater eroded deep gorges (overflow channels) into the bedrock. There are three closely grouped proglacial gorges north of Kiilopää, the southernmost of which was originally subglacial. The other gorges functioned one after the other as outlet channels of the Kiilopää Ice Lake (Fig. 44).

The southernmost gorge (S) formed at a location where subglacial meltwater erosion had taken place earlier. Although the route of the subglacial meltwaters did not always coincide with the lowest points in the terrain, the existing eroded point on the water divide could well be the lowermost route offered to the meltwaters. As the ice sheet melted, the ice lake started to form at the mouth of a subglacial meltwater conduit. The formation of the lake was favoured by strong melting of the ice and by a large volume of meltwater coming from the conduit. Ice lakes that received a subglacial stream also had the most impressive proglacial spillways. The part played by the subglacial meltwater erosion was certainly more significant than that of the proglacial one, because this gorge served as the spillway of the Kiilopää Ice Lake for only a short time before the next spillway opened, situated on a lower level than the first one.

The overflow channels cross ridges that form water divides and are frequently situated at the lowest point of a ridge between two tops. They generally start at the crest of the divide and terminate in the middle of a descending slope, because the lower part of the slope was still covered by ice. Although the meltwater channels are clearly eroded by running water, the formation of a overflow channel was also favoured by existing fractures and crush zones in the underlying bedrock.

Lateral meltwater channels

The groups of laterally formed meltwater channels are very typical in the Kiilopää area. They were formed in spring by meltwater from the ice sheet, which eroded a channel on the slope of the fell along the ice margin. When the ice became thinner in summer its surface sank a few metres. Next spring a new channel was formed below the preceeding one. Thus a series of parallel channels were formed one below the other. The channels are usually few meters deep and the distance between them varies between 20 and 50 meters. The best developed lateral drainage channels are on the slopes of the fell Teräväkivenpää. By the aid of them we can get more information about the gradient of the ice sheet. They also reflect the annual recession of the ice sheet. In the Kiilopää area it varied 130-170 metres a year.

Near the fell of Teräväkivenpää we can see a small delta on the slope of a hill. It was deposited as a result of a meltwater discharge on the water level of a local ice lake. Because the deposition occured very soon, the delta consists of poorly sorted gravel and sand. Penttilä (1963) has described more detailed this delta in his work.

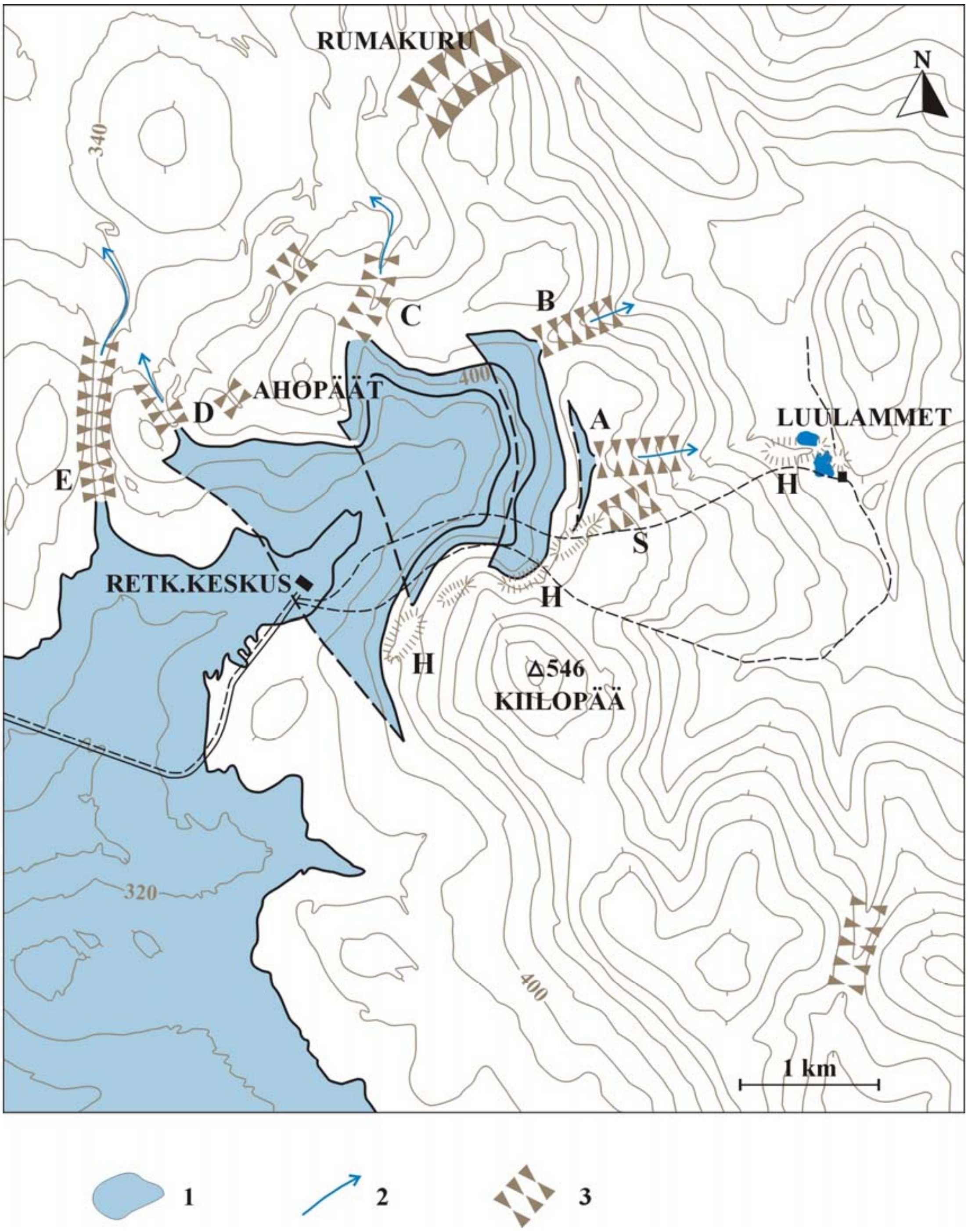

Fig. 44. Kiilopää Ice Lake. The various stages of the ice lake with related spillways (A-E) and the subglacial gorge (S) related to the formation of the Kiilopää Esker (H). 1 = ice lake stage, 2 = spillway with altitude, 3 = gorge and Retk.keskus = Kiilopää Fell Centre.

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STOP 16: Placer gold in Lapland - Tankavaara gold museum

Pertti Sarala and Peter Johansson

Tankavaara, Ivalonjoki and Lemmenjoki are the most famous placer gold areas in Finnish Lapland. Tankavaara gold field was found in the year 1936. An old Lapp Sauva-Aslak Peltovuoma, from the nearby village Purnunmukka, saw this place in a dream. Cripled as he was, neighbours helped him to the site at the foot of Tankavaara, near he source of Lauttaoja creek. They really found a rich deposit which was easy to work by simple methods.After few years Werner Thiede, a German architect, claimed this field in the name of his Finnish friend in an attempt to estabilish a large-scale gold mine. In 1939, just before the Winter War, Thiede was expelled from the country. Max Peronius continued working in Tankavaara after the war. In 1946 he was killed in an explosion while dismantling war-time landmines left behind by the retrieting German soldiers. The work was contiuned by his stepsons Jouko and Tauno Virtanen until 1953.In year 1950 Tauno found biggest gold nugget (183 gr) in the area. This happening was one of those which aroused GSF:s interest to the area and Lapland.

Today in Gold Village of Tankavaara one can visit in Gold prospector museum or in large Golden World exhibition. In Tankavaara it is also possible to try gold panning or even taste Laplands Gold in liquid form. See more http://www.tankavaara.fi.

STOP 17: The Quaternary geology in the surroundings of the village Vuotso

Peter Johansson, Keijo Nenonen and Pertti Sarala

The Vuotso area is a part of the ice-divide zone, which was situating in the Central Lapland. It constituted the centre of the ice flow during a number of the more recent glaciations and it is characterized by weak glacial erosion and deposition. The centre of ice flow during the last glaciation was located about 20-60 km to the south of the Vuotso area, so that an ice divide was formed along the line Kittilä-Koitelainen-Lokka-Korvatunturi. From there the ice sheet spread out towards its margins in a fan-like manner. During the latest deglaciation the ice flow direction was from SW to NE at Vuotso.

The weakness of the glacial action is also reflected by the common occurence of weathered bedrock, glaciofluvial landforms dating from before the last glaciation and tor-formations on the Pyhä-Nattaset Fell and the Riestovaara Fell. The occurrence of old Quaternary deposits, and especially the concentration of sorted and organogenic intercalations found between them, provides probably the most reliable proof of the weakness of glacial erosion and deposition in the ice-divide zone.

Interglacial Larch subfossils at Vuotso

In 1979, a larch (*Larix*) trunk about 8 metre long and 40 cm thick was found during the excavation of the Vuotso canal. The canal connects two large water reservoir in central Lapland, Lokka and Porttipahta. The trunk lay in the sand layer at a depth of 4.5 metres. The stratigraphy was as follows: the top consists of 0,5 metres thick postglacial peat layer. It is underline by an one metre thick sand layer and two metres thick till layer. The trunk is rather well preserved and it comprises from 145 to 250 annual rings. The pollen composition in the organogenic layer just below the trunk is Pinus dominant (87 %) while the amount of the other pollen are as follows: *Betula* 6 %, *Picea* 5 %, *Alnus* 2 %. About 20 cm below the trunk the pollen content is as follows: *Pinus* 49 %, *Betula* 24 %, *Picea* 20 %, *Alnus* 4 %, *Corylus* 2 %, and some C*arpinus*, *Larix*, *Abies* and spores of *Osmunda*. It indicates that the larch trunk grew during the interglacial period. *Larix* pollen has also been found in the interglacial deposits at Tepsankumpu, Härkätunturi, Sokli and Paloseljänoja in central Lapland. Correlating the stratigraphies and the pollen compositions it is assumed that they originate from the Eemian interglacial period. According to radiocarbon dating the age is more than 49 200 years (Su-826) (Mäkinen 1982).

Weathered bedrock

Pre-glacial weathered bedrock surface has been preserved beneath glacial deposits in many areas in northern Finland. The mechanically fractured and chemically altered rock known in Finnish as 'rapakallio'. Remnants of weathered bedrock up to tens of meters thick are frequently found in topographic depressions at the ice divide zone of Central Lapland (*cf*. Hirvas 1991), being mostly covered by a Late Weichselian till unit, 1-3 m in thickness According to Hyyppä (1983) it has not been possible to determine exactly when the weathering occurred, but pronounced weathering is known to have taken place as early as during the Palaeozoic and Mesozoic eras, while the climate was also favourable for weathering during the Tertiary, approximately 25-50 million years ago. According to Sarapää (1996) the weathering started about 1,200-1,000 Ma ago (much earlier than the ca. 100 Ma suggested by Hirvas & Tynni (1976) Söderman (1985) Saarnisto & Tamminen (1987) and propably developed episodically.

The fact that weathered rock is common in the gently undulating areas south of Saariselkä. At the Vuotso airfield the weathered bedrock in situ between basal till and fresh bedrock is seen (Fig. 45). The boundary between the weathered bedrock and the fresh bedrock is alternating and in the fracture zones weathering extends to tens of metres. The fresh bedrock is quartz-feldspar gneiss or gneissose granite. Its mineral content is quartz, potash feldspar and plagioclase with minor amounts of biotite and hornblende. The consistency of the weathered rock, which may be clayey or sandy, depends mainly on the degree of alteration and on the rock type. In the weathered bedrock the clay minerals mostly only a few per cent of the matrix, consist mainly of hydromica (illite) and kaolinite. The increase of aluminium and the decrease of silicon dioxide are the clearest proofs of kaolinisation (Hyyppä 1983).

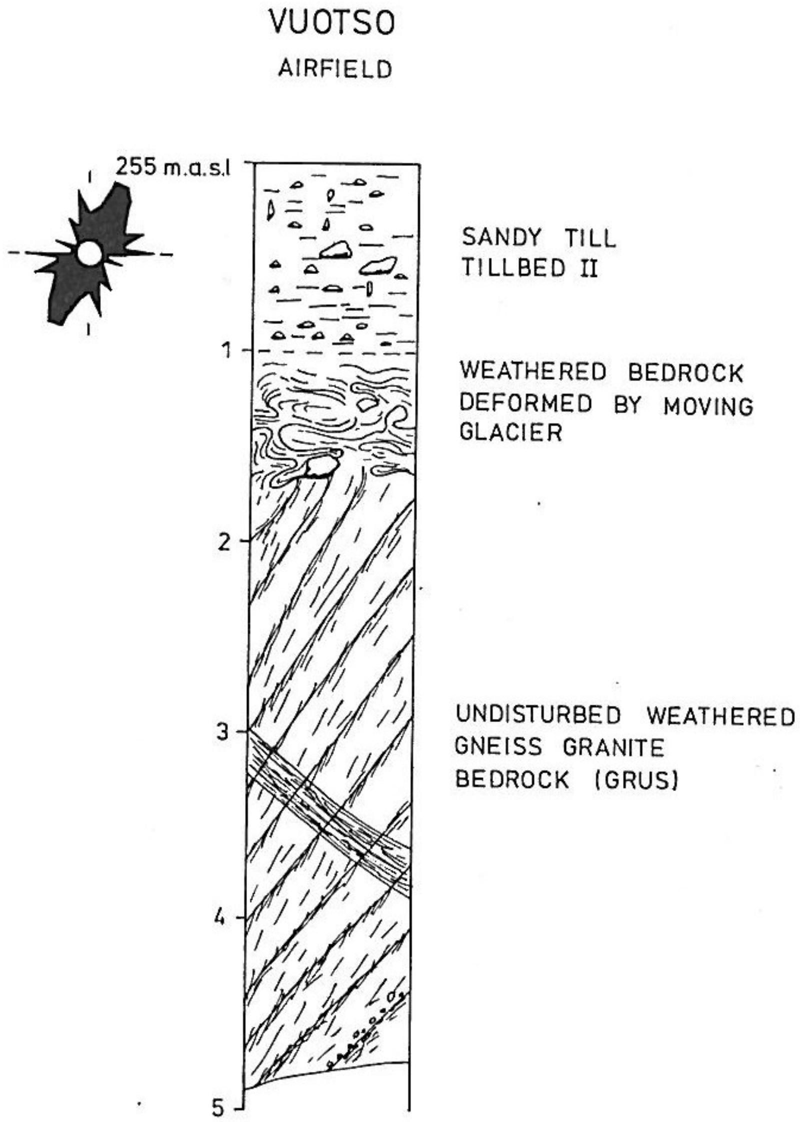

Fig. 45. Till-covered pre-glacial weathered bedrock surface near the Vuotso airfield.

Trace elements such as Cu, Ni, Co, Zn and Mb have been enriched in the fine fraction of the weathering crust and the concentrations can be many times higher than in the underlying fresh bedrock. This is why the weathered material mixed in till causes problems in till geochemistry and can lead to the situation that in places, large amounts of secondary enriched weathered material in till may not necessarily be related in any way to ore deposits (Sarala *et al.* 2007).

Tor-formations

The tor-like forms at the top of the Pyhä-Nattanen and Riestovaara Fells are more than five metres high and look like works of an artist, although they were sculpted by nature. These tors probably consist of the most durable parts of the granite bedrock, where the weathering has been slower than in the surroundings. The tors were formed before the last glaciation, since the post-glacial erosion has not been rapid enough for them to form. The glacial erosion has been slight and the tors have been preserved in shape under the ice sheet. They have stayed intact, while the broken rock around them has been transported away.

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STOP 18: Complex glacial-interglacial stratigraphy in Äältövittikot, Sodankylä

Niko Putkinen, Jouni Pihlaja and Pertti Sarala

The Äältövittikot sequence (x=7539028, y=3496224 z=257 m) in northern Sodankylä (Fig. 46) was initially discovered during the ore exploration project carried by GTK in 1975 (Hirvas 1995). In the site there occurs 100 m long and 30 m wide quarry that has been used for investigating the detailed stratigraphy (Fig. 47). Several sections were also made around the quarry using a tractor excavator. The inter-till stratified sediments were typically found under the 2-3 m thick till cover.

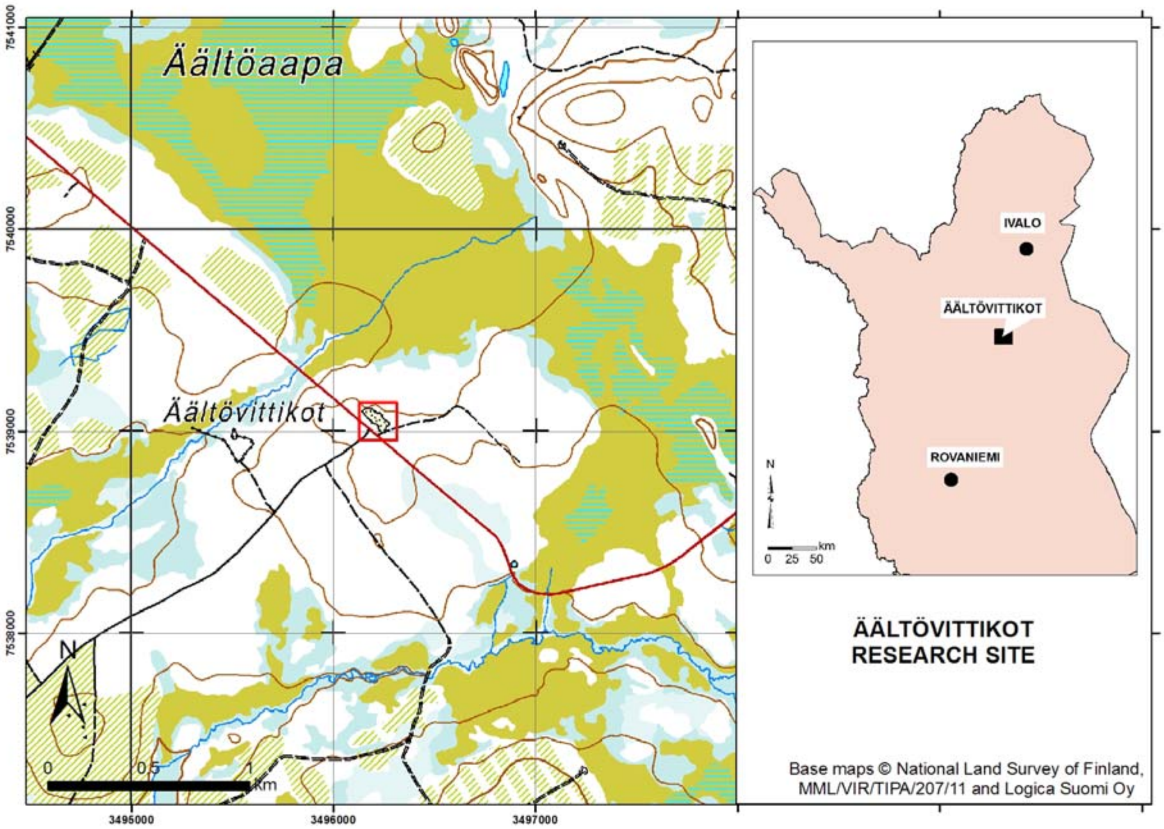

Fig. 46. Location of the Äältovittikot research site.

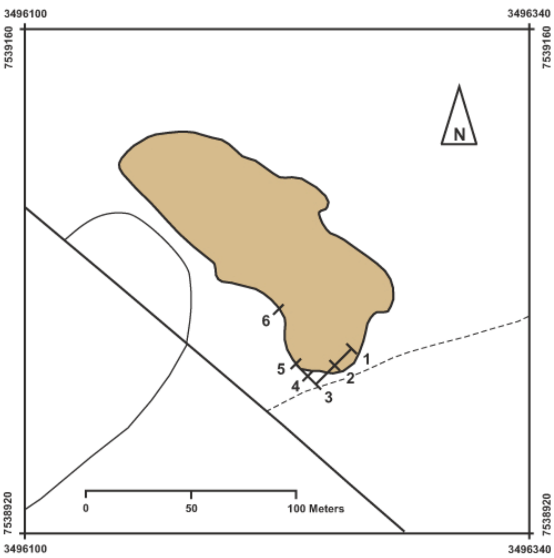

Fig. 47. Detailed map of the excavated sections.

The quarry was subsequently investigated in detail during 2007-2009. The excavated sections were 3-8 m deep. Topography around the quarry slightly slopes towards 310º i.e. direction of sections 4, 5, 6. The lithostratigraphy of the sites is shown in Fig. 48.

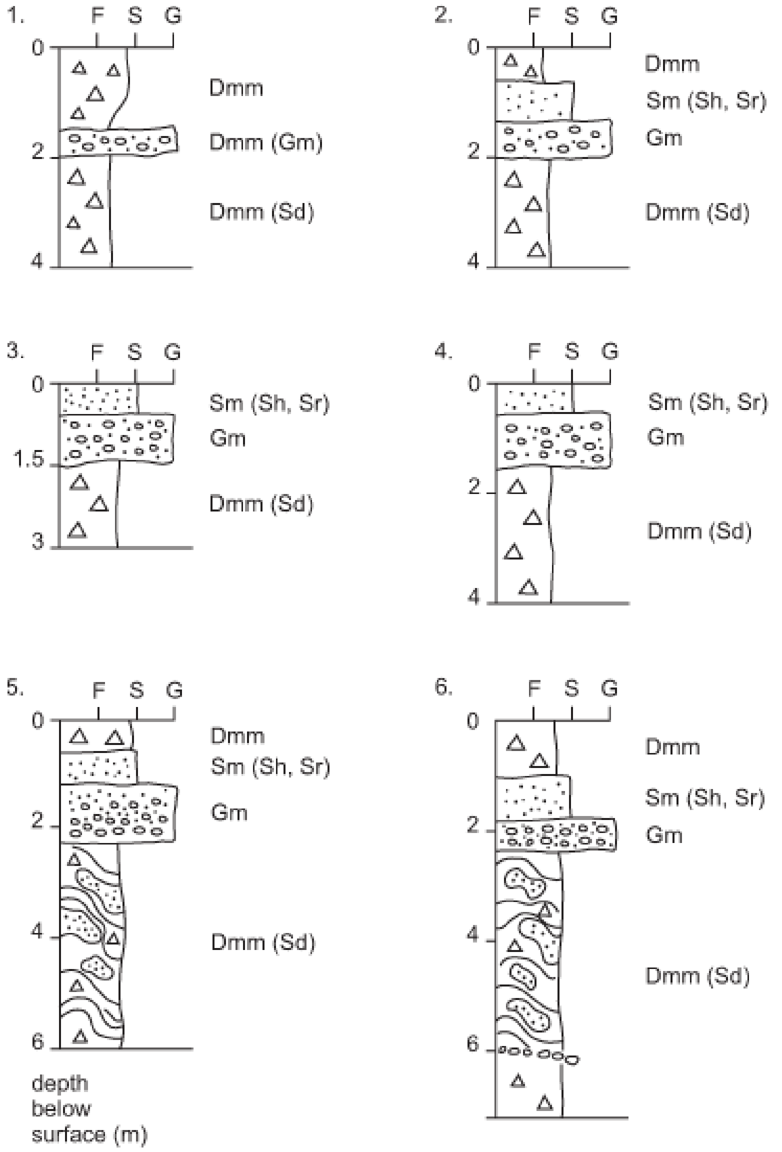

Fig. 348. Stratigraphy of the Äältovittikot section in northern Sodankylä.

The lowermost unit in the quarry is slightly deformed, mainly laminated fine sand. However, ripple marks and cross bedding are also observed (Fig. 49). The age of the sands is based on the OSL dating (252±17k calendar years) (See section 6 in Fig. 48).

The laminated sand is overlain by grey, stone-poor, coarse silt-rich matrix supported till that has two sub units. The lower one is a typical grey till that passes into a layer that includes sand and inclusions of the local pre-glacial weathered bedrock, and stones surrounded by grey till. The inclusions are common in the sections 4, 5 and 6 (Fig. 348). Original lamination and ripples are slightly deformed inside the sand inclusions. Two OSL dates of these sand gave 258±14k and 251±18k calendar years ages representing the Early or Middle Saalian deposition. According to the fabric analyses, grey till was deposited by the ice that entered the Äältövittikot area from west – northwest.

The grey till is overlain by poorly sorted and weakly layered gravel that has a sharp contact between grey till (Fig. 48). Normal grading and clay - sand matrix also varies in places. Gravel seems to grade to a brown till in the sections 1 and 2. Towards the northwest, on the quarry area, the sandy/gravelly layer becomes thicker. Elsewhere the gravel grades into the clay-rich sand that occurs below the brown till. The sand is rippled and horizontally laminated. Two OSL dates gave 305±21k and 190±18.6k calendar years ages for the sands.

The uppermost unit in the quarry is a loose, silt-rich, brown till. According to the fabric analyses, brown till was deposited by the ice that entered the Äältövittikot area from northwest.

Fig. 49. Stratified inter-till sands in section 6.

The Äältövittikot stratified sediments existing as an inter-till layers represents old and relatively shallow fresh water depositional environment during the early and/or middle stages of the Saalian cold period. Deformation stuctures of the sections indicate that this unit is disturbed and mixed with till above.

STOP 19: The Pyhä-Luosto end moraine field and the Torvinen esker in Sodankylä

Pertti Sarala

The end moraine morphology of the Pyhä-Luosto area includes small and narrow till ridges that occur in a restricted area and are formed of unique formations (Sarala *et al.* 2009). An interval of the ridges is some tens of metres, and the chain of ridges is several kilometres in length (Fig. 50). The ridges are composed of two till units, of which the lower one represents basal till deposited during the western advance phase of glacier. The upper till was deposited as an ablation till during the retreat phase of the ice margin. Between the till units occur interlayers distinguished by shear and thrust structures, and sandy or gravelly layers and lenses with variable size from 10 cm to 1.5 m. This unit has formed during short oscillating movements of the ice margin during deglaciation. After formation of the ridges and retreatment of the ice-margin periglacial conditions has prevailed in the area, and of that the ice wedge and convolution structures occur in the upper till.

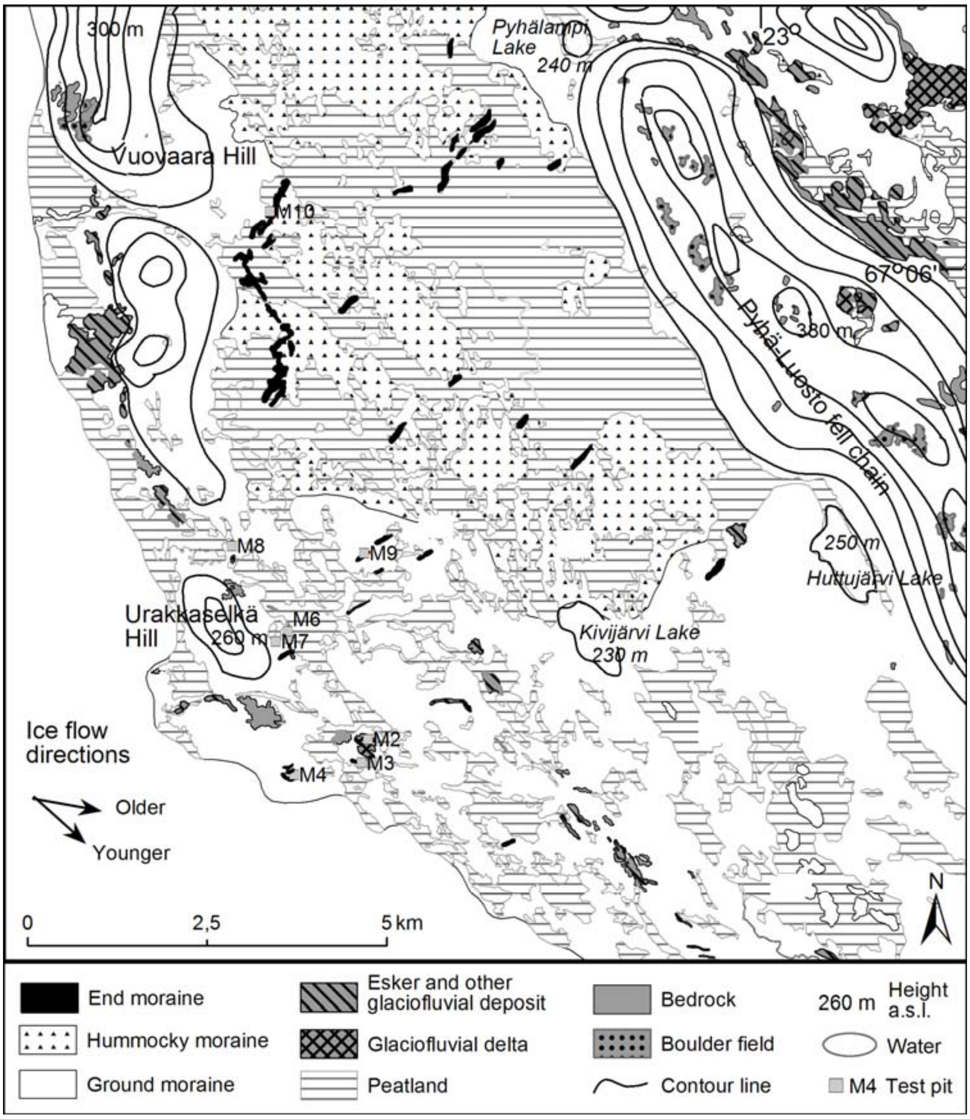

Fig. 50. Minor end moraine ridges in Pyhä-Luosto area. After Sarala et al. 2009.

The esker in Torvinen, which is a part of longer esker chain of Riipi-Torvinen-Vuostimo is sharp crested, sandy and/or gravelly deposit having clear sedimentological and stratigraphical indication of different water pressure and stream conditions during the subglacial deposition (Fig. 51). However, any signs of deformation or glaciotectonization that might indicate glacial crossing have not been found from the sections. One OSL age from the sand on the topmost part (depth 2.2 m) of the esker gives an age 146 +/- 15 ka (dated in 2007 in Risø laboratory, in Denmark). Based on the observations, it is hard to say if the deposit is an age of the Early Weichselian as supposed earlier. It is highly probable that the esker is representing the Late Weichselian deglaciation phase including redeposition of the older stratified sand and gravels to the meltwater channel, with followed cover of young ablation till during the last deglaciation.

Fig. 51. Till-covered esker in Torvinen. Photo by P. Sarala.

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INQUA Peribaltic Working Group Symposium
Kevo Research Station, 14 June 2011

Oral and poster presentations

Abstracts

Symposium program, 14 June 2011

Oral presentations

09.00 – 09.20 Suominen, Otso, Station Manager: Presentation of the Kevo Research Station

09.20 – 09.50 Keynote presentation: Kalm, Volli: Late Weichselian Glaciation on East European Platform: Ice-flow Pattern Compared with Geothermal Heat Flow Density and Bedrock Water Properties (Kalm, V. and Gorlach, A.)

09.50 – 10.10 Bregman, Enno: Implications of past glaciation on today's landscape-functioning in the province of Drenthe, the Netherlands (Bregman, E.P.H., Magri, F., Hof, J., Dijk, E., Klootwijk, A., van Vulpen, M., Brilleman, G., Siemonsma, M. and Cohen, K.M.)

Pause

10.30 – 10.50 Semenova, Liudmila: Quaternary history and stratigraphy of the White Sea region (Semenova, L., Rybalko, A., Zhuravlev, V., Kolka, V. Korsakova, O. and Molodkov, A.)

10.50 – 11.10 Putkinen, Niko: Deglaciation chronology of Younger Dryas end moraines in Kalevala region, NW Russia (Putkinen, N., Lunkka, J-P., Ojala, A.E.K. and Kosonen, E.)

11.10 – 11.30 Lamsters, Kristaps: Glacial landforms of the Madliena Tilted Plain, Central Latvian Lowland

11.30 – 11.50 Garankina, Ekaterina: Cryogenic structuring of superficial moraine sediments in low mountains of Kola Peninsula, Northwestern Russia

Lunch

13.00 – 13.30 Keynote presentation: Subetto, Dmitry: Paleolimnological investigations on Solovki Islands, the White Sea (Subetto, D., Kuznetsov, D., Ludikova, A., Sapelko, T., Shevchenko, V. and Subetto, G.)

13.30 – 13.50 Czubla, Piotr: Geological processes record in the vertical and horizontal changeability of the Weichselian tills profiles in northern Poland – a concept of the research project and preliminary results (Woźniak, P.P. and Czubla, P.)

13.50 – 14.10 Lasberg, Katrin: Onset of Late Weichselian Glaciation on the western part of Russian Plain (Lasberg, K. and Kalm, V.)

14.10 – 14.30 Bitinas, Albertas: The Last (Nemunas, Weichselian) Glacial in the Western Lithuania (Bitinas, A., Damušytė, A., Grigienė, A., Molodkov, A., Šeirienė, V. and Šliauteris, A.)

Poster presentations and coffee

15.30 – 15.50 Dzieduszynska, Danuta: The Younger Dryas subfossil forest (Central Poland) (Dzieduszyńska, D. and Petera-Zganiacz, J.)

15.50 – 16.10 Kuznetsov, Vladislav: The ^{230}Th/U and ^{14}C dating of buried peat layer from the North-Western Russia and its stratigraphic significance (Tolokonka Site case study) (Kuznetsov, V., Maksimov, F., Zaretskaya, N., Subetto, D., Shebotinov, V., Zherebtsov, I., Levchenko, S., Kuznetsov, D., Larsen, E., Lyså, A. and Jensen, M.)

16.10 – 16.30 Sohar, Kadri: Late-glacial and Holocene development of lacustrine environment inferred from the ostracod record in Estonia

16.30 – 16.50 Börner, Andreas: First results of detailed geological mapping at pipeline trench "OPAL" in Mecklenburg-Western Pomerania (NE-Germany)

16.50 – 17.10 Hang, Tiit: Varve chronology and proglacial sedimentary environment in Pärnu area western Estonia. (Hang, T., Ojala, A., Kohv, M. and Tuvikene, T.)

17.10 – 17.30 Discussion and Closing

19.00 Conference dinner

Posters

Alexanderson, H.: New dates from the Riipiharju interstadial site, northernmost Sweden

Andreicheva, L. and Andreichev, V.: K-Ar isotopic dating of basal tills

Baltrūnas, V. , Karmaza, B. , Katinas, V. , Kazakauskas, V. , Kisielienė, D. , Šeirienė,V. and Zinkutė, R.: Palaeoenvironmental changes and cyclicity during the main Quaternary warm periods in Lithuania

Česnulevičius, A., Švedas, K., Pukelytė, V. and Kulbickas, D.: Post-glacial relief evolution of South-East Lithuania glaciolacustrine basins and moraine uplands

Dausknas, M., Zelčs, V. and Nartišs, M.: Kame terraces of the interlobate insular uplands: the case study in the Vidzeme Upland, Latvia

Druzhinina, O.: Palaeogeographic Researches in Southeast Baltic: Results of 2009-2011 (based on materials from the Kaliningrad Region)

Helmens, K.F. and Johansson, P.: Environmental conditions and climate at Sokli (northern Finland) during early MIS 3 (~ 50 ka): Revising earlier concepts on glacial and vegetation dynamics and climate in northern Fennoscandia during the Middle Weichselian

Kalinska, E.: Geological situation and sedimententary characteristic of coversands distributed on the Błonie glaciolacustrine basin (Central Poland) – preliminary results

Karmaziene, D.: Quaternary Geology and Geomorphology of the North Lithuanian Ice marginal ridge and surrounding plains

Karpukhina, N. and Tatarnikov, O.: The complex facies of the morpholitosystem dead ice

Kolka, V., Korsakova, O., Shelekhova, T., Lavrova, N., Tolstobrov, D., Alekseeva, A. and Steshenko, Ye.: Isolation basin stratigraphy and Holocene relative sea-level change at the Kuzema village, Karelia, NW Russia

Kosonen, E. and Ojala, A.E.K.: Paleosecular variation and deglaciation events in Eastern Finland during the Late Glacial time

Krotova-Putintseva, A.Y. and Verbitskiy, V.R.: Preglacial, glacial and postglacial landforms of NW Russia

Kuznetsov D.D., Subetto D.A., Ludikova A.V. and Sapelko T.V.: Small lakes sediments: what can they tell us about Lake Ladoga level changes?

Ludikova, A.: New sediment sections in the easternmost part of the Gulf of Finland – a contribution to the studies of the post-glacial history of the Baltic Sea

Marchenko-Vagapova, T.I.: Palynological characteristics of the Middle Valdai (Leningradian) deposits in the Komi Republic, north-western Russia

Markots, A. and Zelčs, V.: Internal structure and palaeogeographical conditions of plateau-like hills formation in interlobate isometric uplands of Latvia

Nartišs, M. and Zelčs, V.: A succession of Lateglacial ice-dammed lakes in north Vidzeme, Latvia

Novikova, N.: Formation of the Late Weichselian (Valdai) glacial relief and deposits in the mountains of the Kola Peninsula (based on lithology analysis)

Pihlaja, J. and Kupila, J.: An example of applied Quaternary geology project: Testing of different soil combinations as substrates in slalom slopes and golf courses

Pukelytė, V.: Palaeogeographical development of geomorphological districts in South Lithuania

Saarse, L.: Timing of deglaciation in Northe Estonia

Sarala, P., Väliranta, M. and Eskola, T.: Climatic conditions during the deposition of the Middle Weichselian inter-till deposit in Petäjäselkä, northern Finland.

New dates from the Riipiharju interstadial site, northernmost Sweden

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A kettle hole at Riipiharju in northernmost Sweden (Fig. 1) contains so far the most complete Weichselian stratigraphy in northern Sweden and it forms an important part of the basis for reconstruction of the glacial history of northern Fennoscandia. The stratigraphic record, which is more than 18 m thick and dominated by sandy deposits, contains three horizons that have been interpreted to represent the Holocene interglacial and two Weichselian interstadials (Lagerbäck & Robertsson 1988). Pollen analyses show that the interstadial sediments were deposited in tundra and birch woodland environments (Lagerbäck & Robertsson 1988; Hättestrand & Robertsson 2010).

Several attempts at absolute dating of the Riipiharju record by radiocarbon and luminescence dating have been made, but the results are largely inconclusive. Most radiocarbon dates have been infinite, the luminescence ages were considered unreliable and the chronology has therefore mainly been based on biostratigraphical correlations to other sites of known age. The two interstadials (Tärendö I and Tärendö II) have been placed in the Early Weichselian and correlated to the North European interstadials Brørup (103-95 ka) and Odderade (85-74 ka), respectively (Lagerbäck & Robertsson 1988), see Fig. 2 (Alt. A1).

This chronology has recently been challenged by Hättestrand (2008) and Hättestrand & Robertsson (2010) based on new palynological investigations of the stratigraphy from Riipiharju. They suggest an alternative chronology (Fig. 2:A2), where the two interstadials instead represent Odderade (85-74 ka) and a Mid-Weichselian interstadial (59-24 ka).

To test this new hypothesis we retrieved a new, 13 m long core from the Riipiharju kettle hole to re-date the deposits. Sandy beds were sampled for luminescence dating, including optically stimulated luminescence (OSL) dating of medium sand-sized quartz grains and infrared stimulated luminescence (IRSL) dating of fine- and medium sand-sized feldspar grains. Macrofossils (moss remains) and organic-rich sediments (gyttja) have been sampled for AMS radiocarbon dating.

Analyses are currently ongoing but preliminary results from luminescence dating suggest that the upper interstadial (Tärendö II) is younger than 70 ka, which supports the alternative hypothesis of Hättestrand (2008). If true, this indicates a largely ice-free Fennoscandia during the Mid-Weichselian, which is in line with recent results from other sites in Sweden and Finland (Helmens *et al.* 2007; Ukkonen *et al.* 2007; Lunkka *et al.* 2008; Alexanderson *et al.* 2010; Helmens & Engels 2010; Sarala *et al.* 2010; Wohlfarth *et al.* in press).

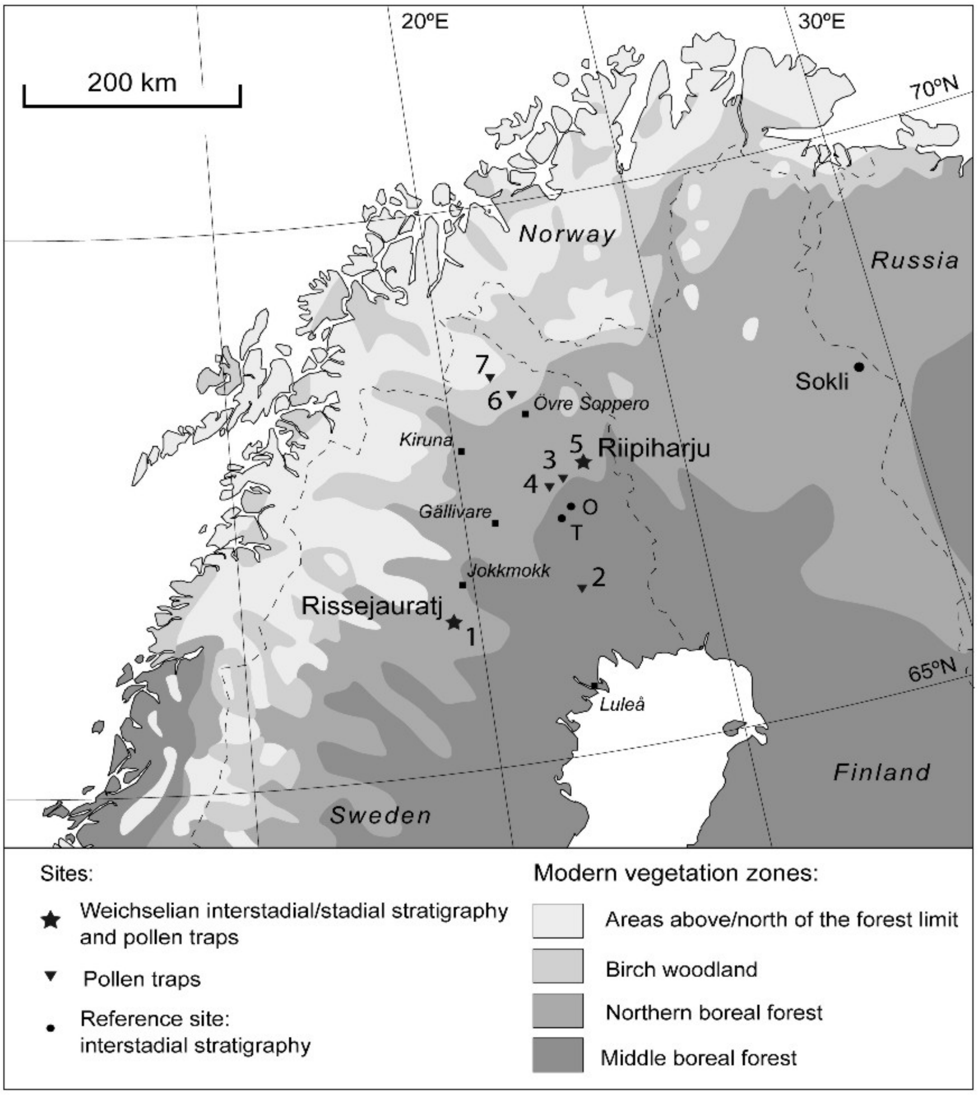

Fig. 1. Location of Riipiharju in northernmost Sweden, close to the boundary to Finland (from Hättestrand 2008).

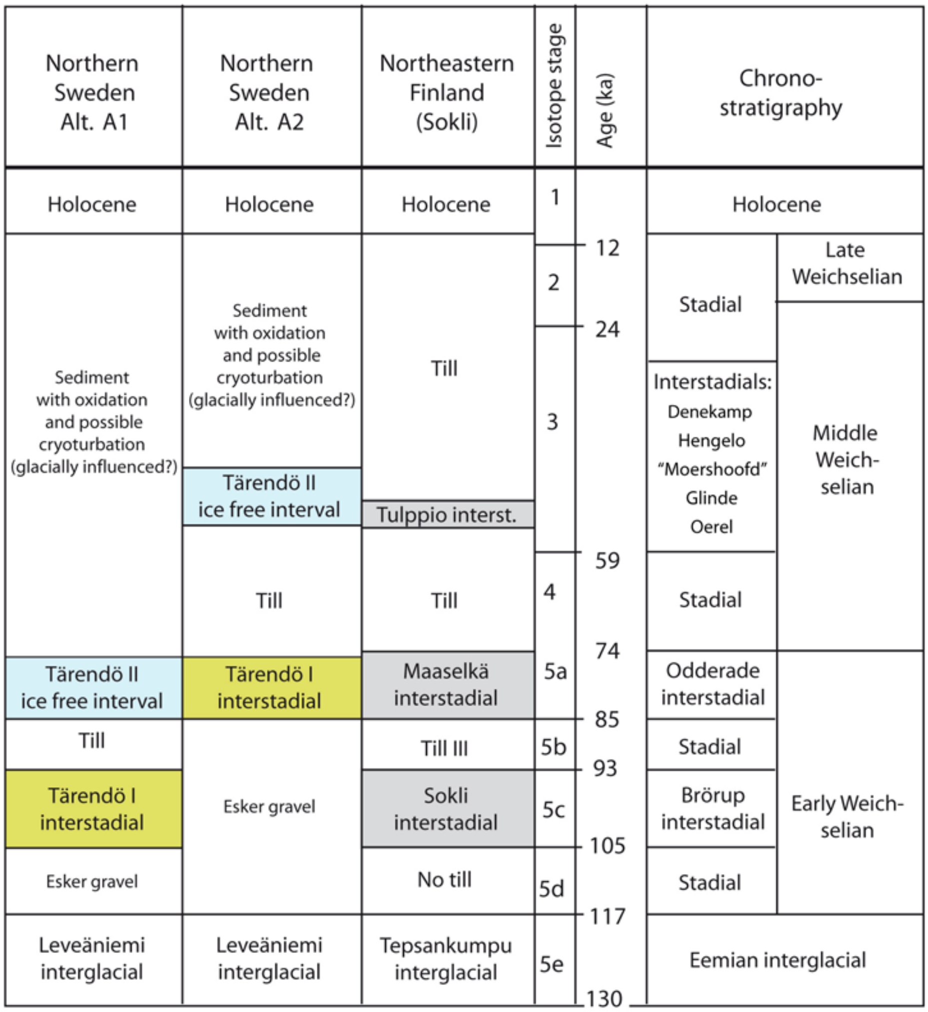

Fig. 2. Alternative correlations between the Tärendö I and Tärendö II interstadials and the stratigraphy of northern Finland and the North European Weichselian stratigraphy (from Hättestrand 2008).

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K-Ar isotopic dating of basal tills

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The problem of correlation of the Pleistocene deposits and paleogeographical events connected with them is extremely topical. For the first time an attempt has been made to stratify sections by means of K-Ar isotopic dating data of the terrigenous material of tills in the Timano-Pechoro-Vychegodsky region. The essence of this method is that the smallest particles of terrigenous minerals keep the isotope Ar-K ratio similar to initial rocks. The isotopic data of rock flower of the basal tills and the absolute dates of the boulders contained in the tills allow to determine the till horizons of different age and to correlate them in distant sections.

Accumulation of the till material of different age is connected with different glacial source provinces, which are composed of bedrocks of contrasting isotopic age. The age of crystalline rocks from Fennoscandia is considerably older than 1000 million years, and the age of magmatic and metamorphic rocks of Ural-Novaya Zemlya region is not older than 500 million years. The primary material was diluted with the material of transit areas when the glacier was moving. Therefore "age marks" of the tills rock flower essentially differ from the isotopic age of the source provinces rocks. However, the general tendency is that "age marks" of the terrigenous material corresponds with the age of the initial rocks remains: absolute dates of the rock flower from the tills of northwest origin is characterized by older isotopic dates, in comparison with tills, composed by the glacier moved from Ural-Novaya Zemlya. It should be noted that the “age marks” do not show the age of till sedimentation, but show the age of the rocks – deliverers of clastic material.

Isotopic K–Ar data obtained for till rock flower and boulders from different areas of northeastern Europe are presented in a table 1.

The terrigenous material of the Lower Pleistocene Pomusov (Oka) till (Q_I^6pm), drilled in the middle Pechora River Valley, has an "age mark" of 815 million years. The rock flower of the Middle Pleistocene Pechora (Dneprovian) till (Q_{II}^2pc) has an “age marks” of 352-448 million years. This fact testifies the connection between this till and the Ural-Novaya Zemlya region. The age of a granite boulder (250 million years) from this till horizon proves this conclusion. The age of rock flower from the Vychegda (Moscovian) tills (Q_{II}^4vc) of the Middle Pleistocene is 498-660 million years and thus testifies its forming by terrigenous material from Fennoscandia. This material diluted with material of younger rocks along the way of the glacier. This conclusion is confirmed by the dates of granite and gneisses boulders (1345-2015 million years) and by the reconstructed direction of glacial streams. The rock flower of the Valdai Polyarnyi (Ostashkovo) till (Q_{III}^4p) from the sections in the north of Bol’shezemelskaya Tundra has “age marks” of 288-378 million years. The orientations of rock fragments in the Polyarnyi till are directed from northwest (azimuth 310-320º). It is possible that contamination of the Fennoscandinavian material (distal) by the transit material from Timan ridge and also by the local underlying deposits has occurred in this case.

The obtained data show the availability of the method for lithostratigraphic and paleogeographic purposes. Dating of boulders is more perspective because in this case the isotopic dates unambiguously indicate the source region of the terrigenous material of till.

Table 1. Isotopic data on clastic material of tills.

Sample	Material	Horizon	K, %	$^{40}Ar_{rad}$, ng/g	Age ± 2σ, Ma
Middle reaches of Laya River, sections 15, 27					
15/76	rock flower	Q_{II}^{2}pč	1.81	56.55	402 ± 18
15/85	rock flower	Q_{II}^{2}pč	1.79	50.80	369 ± 17
27/170	rock flower	Q_{II}^{2}pč	1.68	45.33	352 ± 16
27/443	rock flower	Q_{II}^{2}pč	1.79	54.96	396 ± 17
27/440	rock flower	Q_{II}^{4}vč	1.78	73.26	513 ± 25
27/173	rock flower	Q_{III}^{4}p	1.60	40.78	335 ± 15
27/174	rock flower	Q_{III}^{4}p	1.94	42.02	288 ± 12
Middle reaches of Sercheyu River. sections 107. 112. 115					
107/286	rock flower	Q_{II}^{2}vč	1.93	83.16	534 ± 25
107/1	granite-gneiss	Q_{II}^{4}vč	3.06	640.00	1775 ± 40
107/269	rock flower	Q_{III}^{4}p	2.14	55.58	341 ± 16
112/323	rock flower	Q_{III}^{4}p	2.06	60.05	378 ± 17
115/408	rock flower	Q_{III}^{4}p	2.06	45.00	291 ± 12
Adz'va River. section 425					
425/1	granite	Q_{II}^{4}pč	3.81	69.20	245 ± 10
Middle reaches of Pechora River. Kipievo. borehole 105					
105/600	rock flower	Q_{I}^{6}pm	2.08	148.05	815 ± 30
105/598	rock flower	Q_{II}^{2}pč	1.88	66.20	448 ± 20
105/593	rock flower	Q_{II}^{4}vč	1.79	71.10	498 ± 22
River Vychegda. Bolshaya Sluda. section 202					
202/486	rock flower	Q_{II}^{2}pč	1.62	44.40	357 ± 16
202/475	rock flower	Q_{II}^{4}vč	1.88	87.60	571 ± 26
4a/202	diorite	Q_{II}^{4}vč	0.88	207.40	1910 ± 75
30/202	diorite	Q_{II}^{4}vč	0.91	161.95	1595 ± 65
13/202	gneiss	Q_{II}^{4}vč	2.72	515.20	1665 ± 50
17/202	plagiogneiss	Q_{II}^{4}vč	0.92	236.10	2015 ± 80
River Vychegda. Gavrilovka. section 203					
203/506	rock flower	Q_{II}^{2}pč	1.55	55.10	451 ± 20
203/516	rock flower	Q_{II}^{4}vč	1.82	91.45	610 ± 27
203/526	rock flower	Q_{II}^{4}vč	1.97	108.50	660 ± 28
5/203	granite	Q_{II}^{4}vč	4.60	891.50	1685 ± 40
20/203	schist	Q_{II}^{4}vč	1.67	302.15	1625 ± 55
21/203	diorite	Q_{II}^{4}vč	0.77	106.30	1345 ± 60
River Vychegda. Ust'-Pozheg. section 205					
205/534	rock flower	Q_{II}^{2}pč	1.61	44.55	361 ± 16
205/538	rock flower	Q_{II}^{2}pč	1.95	66.50	435 ± 19
River Vychegda. Ryabovo. section 207					
207/2	rock flower	Q_{II}^{2}pč	1.56	49.96	411 ± 18
207/1	rock flower	Q_{II}^{4}vč	1.65	72.00	540 ± 27

The constants used were: $\lambda_e = 0.581 \times 10^{-10}$ yr^{-1}; $\lambda_\beta = 4.962 \times 10^{-10}$ yr^{-1};
$^{40}K/K = 0.01167$ at. %.

Palaeoenvironmental changes and cyclicity during the main Quaternary warm periods in Lithuania

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The new project "Palaeoenvironmental changes and cyclicity during the main Quaternary warm periods in Lithuania" was initiated in order to provide a detail analysis of the Quaternary warm periods (interglacials) palaeoenvironmental variations in local and global scale for better understanding of the factors determining species migration, invasion and adaptation. Research is supported by Research Council of Lithuania (No LEK–10008).

Complex proxies such as geochemical, isotope (^{14}C, ^{210}Pb, IR-OSL), palaeomagnetic and magnetic susceptibility, palaeobotanical, ichnological and granulometrical studies were carried out and enabled to distinguish the main biogeochemical and other indicators of palaeoenvironmental changes. Those investigations will serve as a methodological and informational background for the further research, devoted to the analysis and modeling of the dynamics and cyclicity of the identified Quaternary palaeoenvironmental changes in long-range perspective.

Investigations were carried out on Daumantai prepleistocen, Vindžiūnai (Bavelian), Turgeliai (Voigstedt), Butėnai (Holstein), Snaigupėlė (Karlich) and Merkinė (Eem) interglacial sediments exposed in outcrops and boreholes. Current studies elucidate important questions of the paleoenvironment development during the Quaternary warm periods - described the features of the cyclicity of the Quaternary interglacials in time finding out and using the most informative biogeochemical and other indicators; established the peculiarities of the vegetation development and their causing main natural factors. Data obtained are summarized in statistical, graphical and cartographical models and allows describing the differences of interglacial environmental changes and their cyclicity.

New substantial results of palaeomagnetic studies carried out on Daumantai outcrops were obtained. 26 hand oriented samples were taken in plastic boxes from Lower Pleistocene black clay Fig. 1. Natural remnant magnetization (NRM) was measured by means of a JR-6 spinner magnetometer while magnetic susceptibility during thermal demagnetization was monitored with a KLY-2 bridge. The rock specimens were AF demagnetized with a Molspin demagnetizer. During investigations on Daumantai-3 outcrop Brunhes/Matuyama and most probably Jaramillo time periods were detected.

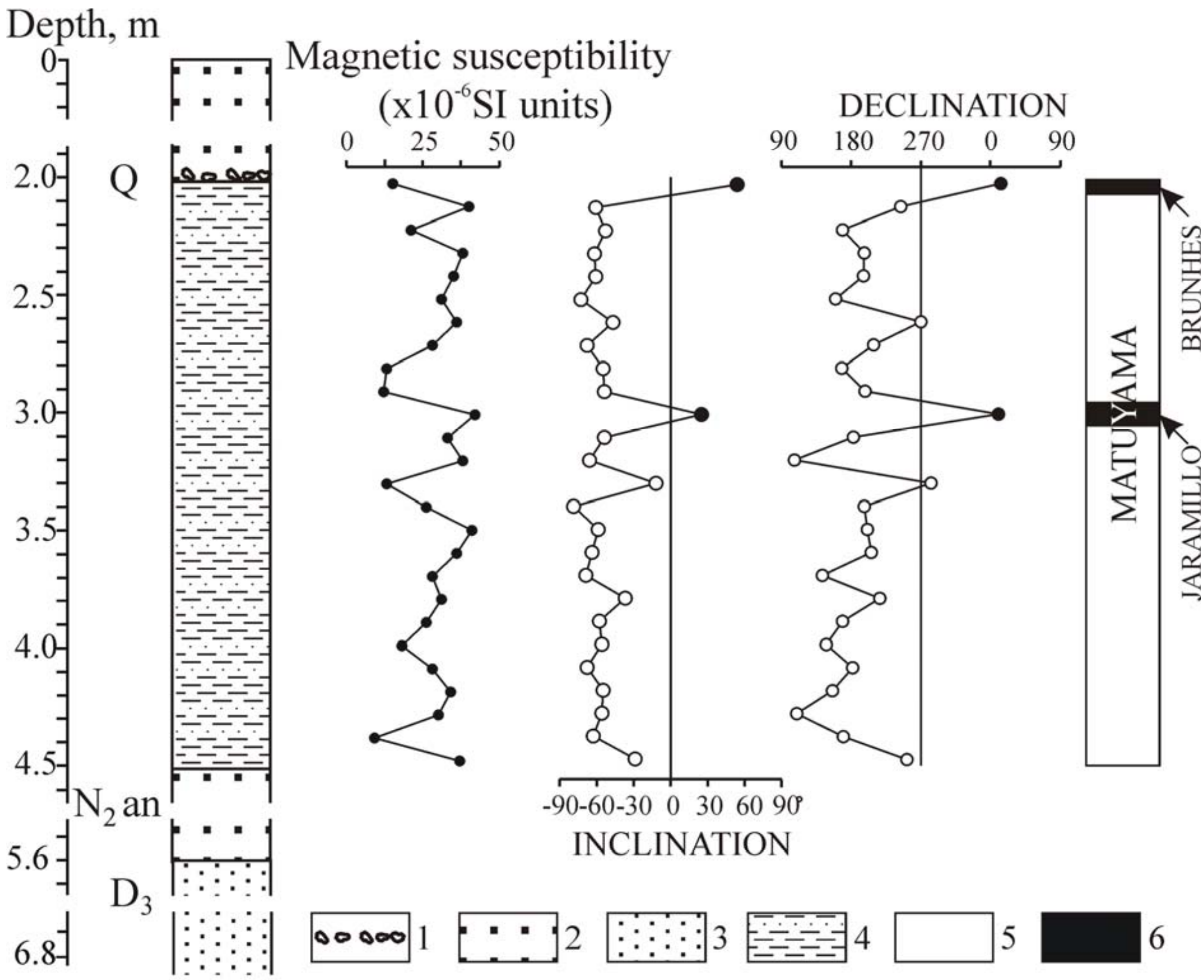

Fig. 1. Daumantai-3 outcrops paleomagnetic data: 1 – boulders, cobbles, 2 – coarse sand, 3 – various grained sand, 4 – succession of clay and sandy silt, 5 – reverse magnetic polarity, 6 – normal magnetic polarity.

The Last (Nemunas, Weichselian) Glacial in the Western Lithuania

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In the international stratigraphic schemes the Last (Weichselian) Glacial corresponds with the marine oxygen isotope stages from MIS 5d until MIS 2 (Litt, Gibbard 2008). For a long time the glaciation in the territory of Lithuania was associated just with the second marine oxygen isotope stage (MIS 2), i.e. a period when the Scandinavian Ice Sheet (SIS) covered the biggest part of Lithuania. Meanwhile, the time span of MIS 5d – MIS 3 was interpreted as a non-glacial period and the climate conditions were considered as an alteration of krio- and thermo-stages. This standpoint is reflected in the resent stratigraphic schemes and palaeoenvironmental reconstructions of Lithuania (Satkūnas *et al.* 2007, 2009). The results of geological investigations of the last decade carried out in the Klaipeda Strait and the adjacent areas show that the absolute majority of the infra-red optically stimulated luminescence (IR-OSL) ages of the investigated inter-till sediments laying beneath the bottom of the Klaipėda Strait were formed 113.2 ± 7.3 – 76.5 ± 4.9 kyr BP, i.e. fell within the age range of MIS 5d-5a (Early Weichselian). The composition of diatoms and the remnants of mollusc fauna indicated that these sediments were formed in a freshwater basin, but the sampled inter-till sediments are occurring not *in situ*: they are lying as blocks (rafts) within the till bed formed during the Weichselian (Nemunas) Glacial. The latter, most probably, can be associated with the ice movement during MIS 4. Thus, the results of the mentioned investigations have led to the assumption that the Western Lithuania was covered by continental ice sheet during MIS 4 (Molodkov *et al.* 2010; Bitinas *et al.* 2011). This assumption is in a good correlation with the standpoint of some researchers stating that during MIS 4 the glacier occupied a significant part of the Baltic Sea depression (Svendsen *et al.* 2004). The recent researches in the Šventoji (northern part of the Lithuanian coastal area) confirmed this approach. One till stratum between two inter-till layers has been discovered in the uppermost part of the Pleistocene thickness. According to the results of IR-OSL dating, the age of the lower inter-till layer varies from 113.1±8.5 to 83.6±6.7 kyr BP, the uppermost layer – from 48.8±6.2 to 43.7±4.0 kyr BP. According to these data, the mentioned inter-till sediments could be formed during MIS 5d-5a and MIS 3 correspondingly. These both layers are not rich in diatoms, but findings of such species as *Hyalodiscus scoticus* (Kutz.) Grun., *Rhabdonema arcuatum* (Lyngb. In Horn.) Kutz., *Rhabdonema minutum* Kutz., *Cocconeis scutellum* Ehr., *Actinocyclus octonarius* Ehr. maintain that they could be formed in marine conditions. Thus, the 2.3-5.5 meters-thick till stratum between the mentioned two inter-till layers could be formed only during cold period of Middle Weichselian, i.e. during MIS 4 about 75-64 kyr BP (Bouwen *at al.*, 1986). The discovered new till stratum could be correlative with Świecie stadial in Poland (Marks, 1998) and Talsi stage in Latvia (Zelčs & Markots, 2004). Some corresponding corrections should be done in the Quaternary stratigraphy scheme of Lithuania according to the new data discovered on the Baltic Sea coastal area.

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First results of detailed geological mapping at pipeline trench "OPAL" in Mecklenburg-Western Pomerania (NE-Germany)

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In 2009-2010 the 105 km natural gas OPAL-pipeline trench (Ostsee-Pipeline-Anbindungs-Leitung) crossed the eastern districts of Mecklenburg-Western Pomerania (M-V) general in N-S orientation (cf. Börner 2010, Fig. 1). The main Weichselian glaciation in M-V is subdivided in three phases (W1-3) with three subdivided till-layers and a few subordinated substages (cf. Bremer 2000; Rühberg *et al*. 1995). After ice retreat of Pomeranian phase (W2) the third Weichselian ice advance of Mecklenburgian phase (W3) moved over NE-Germany. The 1-5 m thick W3-till has a very sandy lithology with less clay and silt. In higher till plains in positions above groundwater level were detected up to 3,5 m deep weathering profiles of decalcified sandy tills ("Geschiebelehm") with dominating yellow/brownish colours. The weathering oxidation followed by leaching of carbonates is characterized by colour change and is connected with pedogenetic processes of brunification. In gravel samples of such weathered W3-till the calcareous clasts (4-10 mm) like Cretaceous marls (MK) and Paleozoic limestones (PK) shows clearly marked signs of weathering (cracks). This upper till contains increasing contents of rotten magmatic boulders.

For lithostratigraphical classification the Geological Survey M-V realized a detailed sampling campaign in distances between 500-1 000 m in average. At the end of field campaign a total of 135 OPAL-samples with till clasts were separated. For classification of first 45 samples Börner & Müller (2011) used a marginal modified pebble-counting method 4-10 mm (based on standard TGL 25 232, 1980). The small gravel analysis of uppermost till (W3) has clear detectable "East-baltic" clast association. The W3-till includes high prevalences of PK in comparision to Nordic cristallines (NK) and in some samples dolomites (D) from East-Baltic region (cf. Rühberg *et al*. 1995). The second type of till gravel composition included conspicuous contents of local pepples like MK and flints (F). The high abundance of MK and F is a significant attribute of tills, which in NE-Germany are locally distributed in tills of different glaciations. Due to this multistratigraphical appearence the contents of MK and F for lithostratigraphical classification has only local but no supraregional importance. Underneath the upper till in some places a lower till was detected. Sometimes this lower till shows boulder pavement at the top and clear features of glaciotectonics like shear planes, folds and angular orientated joints of local pressure direction.

After deglaciation of youngest Weichselian ice sheet (Mecklenburgian Phase, qW3) the lower region between Pasewalk and Ueckermünde was a part of a large meltwater drainage system in combination with local ice-dammed lake basins ("Haffstausee-Becken" in terms of Keilhack 1899). In southwestern part of the "Haffstausee" basin numerous periglacial structures like meso-scale frost cracks up to large-scale frost wedge casts were observed. Furthermore we detected soft sediment deformation structures like "dropsoils" and "ball and pillow" structures in fine grained glaciolacustrine silts, organic silts and glaciofluvial sands. These multi-scale graviturbations mainly caused by gravity-dominated load structures in periglacial conditions.

In "Haffstausee" basin first sedimentation of shallow rheophilous mires began in with dercreasing of permafrost in late glacial period too. The palynological analysis of the first four samples from 2-4 cm thin buried peatlayer (fossil humic gleysoil) shows a clear dominance of Pine pollen (*Pinus sp.,* 84-95%). During peat accumulation (Allerød interstadial, Strahl 2011) predominated an open landscape (weald) with grasses of sedge family (*Cyperaceae*), heather (*Calluna sp.)* or rosebay willow-herb (*Epilobium sp.*). In this fossil soil layer were observed several “dropsoils” structures in ranges between 2-10 cm. Due to the palynological classification of fossil gleysoil this small-scale deformation structures caused by load processes of active layer during periglacial period of Younger Dryas stadial.

The Geological survey of M-V thanks WINGAS company for permission of geological mapping acivities at pipeline trench and for good cooperation.

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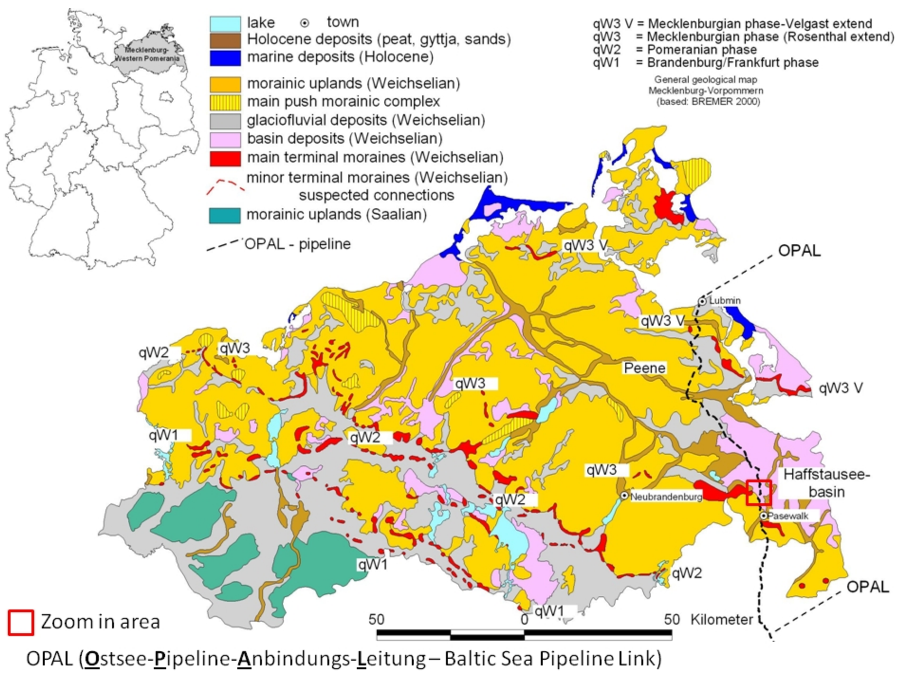

Fig. 1. Simplified map of Quaternary deposits in Mecklenburg-Western Pomerania with OPAL pipeline trench.

Implications of past glaciation on today's landscape-functioning in the province of Drenthe, the Netherlands

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The glaciation history of the North Netherlands has influenced its landscape functioning till today. Therefore, in its various aspects, it is considered important information for nature- and landscape management planning and sustainable exploitation of groundwater and soil-energy, particularly at Province governmental level (100x100 sq.km.). Examples from Drenthe underline this. Drenthe has brook valleys in a glacial-inherited landscape, sculptured in the Saalian Drenthe substage (within MIS 6), in complex interaction with the overridden Quaternary substrate, with deep Elsterian subglacial channels, overlying active domes of Zechstein salt. Clusters of halophyte plants in modern brooks reveal the local surfacing of deep groundwater (GW) flow. A 2008-pilot-study tried to relate eco-geohydrological to paleoglaciological questions, integrating both fields.

GW monitoring data and subsurface mapping were combined in a regional model (NEBG/FEFLOW interface; Imod 2.3.5./MIPWA) calibrated to the field measurements. Surficial drainage and GW flow maps were compared with deep subsurface data. Correlations exist with tectonic blocks and saltdome crests, indicating postglacial activity, but importantly also syn-glacial activity. This includes faults *below* the Zechstein salt, hinting that part of the salt may be anhydrite "hard-rock", rather than "plastic" halite. This notion is of importance for the process of glacio-isostasy into peripheral crustal movements during glaciations too. Another strong conclusion is that thermohaline processes drive deep groundwater flows, today but also when the area was last under ice. The effect is strongest in the subarea with Elsterian buried subglacial channels. Nested semi-isolated hydrological systems exist at fixed points with specific groundwater characteristics (bicarbonate rich water; higher Pw and T). This approach and its insights are relevant for GW resource- and nature protection in ice-marginal Europe (NL, N-GER, DK, Poland, Baltic).

Post-glacial relief evolution of South-East Lithuania glaciolacustrine basins and moraine uplands

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The emergence of periglacial lakes in Lithuania was conditioned by Baltic stage recessions and oscillations of the degrading Nemunas glacial. Slow retreat of the glacier edge affected the evolution and drainage of the basins. Determination of the drainage levels and analysis of glaciolacustrine sediment sections showed their relationships with recession phases of melting glacier. The most intensive development of glaciolacustrine basins took place during the Frankfurt phase and Baltic stage deglaciations.

For determining the arrangement of the shores of the former glaciolacustrine basins and distribution of terraces, large-scale topographic maps and aerophotographs were used. Relief forms were investigated by the cartographic, descriptive and granulometric analysis of sediments (Šeirienė *et al.* 2008, Švedas *et al.* 2009). It enabled to define relief evolution in the South-East Lithuania glaciolacustrine basins zone by permafrost, erosion, aeolian, fluvial and organogenic formations (Stančikaitė *et al.* 2002). Two different shoreline type zones are determined in investigation area: upper eastern and lower western. In eastern part dominated periglacial erosion, which embody by gullies, ravines, valleys of ice meltwater. In western part predominated gullies and ravines, which joined in complicated network thermokarst holes and kettles (Fig. 1).

In South-East Lithuania glaciolacustrine basins area were distinguished six types of relief form complexes: glacial, nival, glaciofluvial, glaciokarst, glaciofluvial–thermokarst, erosion and suffusion (Table 1).

Late epigenetic processes (plane outwash, solifluction, slides, erosion, coastal abrasion) substantially changed the initial relief forms. Under their influence the relief became polygenetic. During the post-glacial epoch, sculptural hilly–ridges and hills (Medininkai and Baltija Uplands) were formed, which show more complicated and epigenetically transformed glacial relief complexes. Degrees of epigenetic transformation are more intense in eastern part and shoreline of South-East Lithuania glaciolacustrine basins area. It was determined by steady long-term subsidence of glaciolacustrine water level. In western part subsidence or water level are more complicated: small glaciolacustrine basin subsidence in short-time, more steady shoreline was formed only by later stage of basin.

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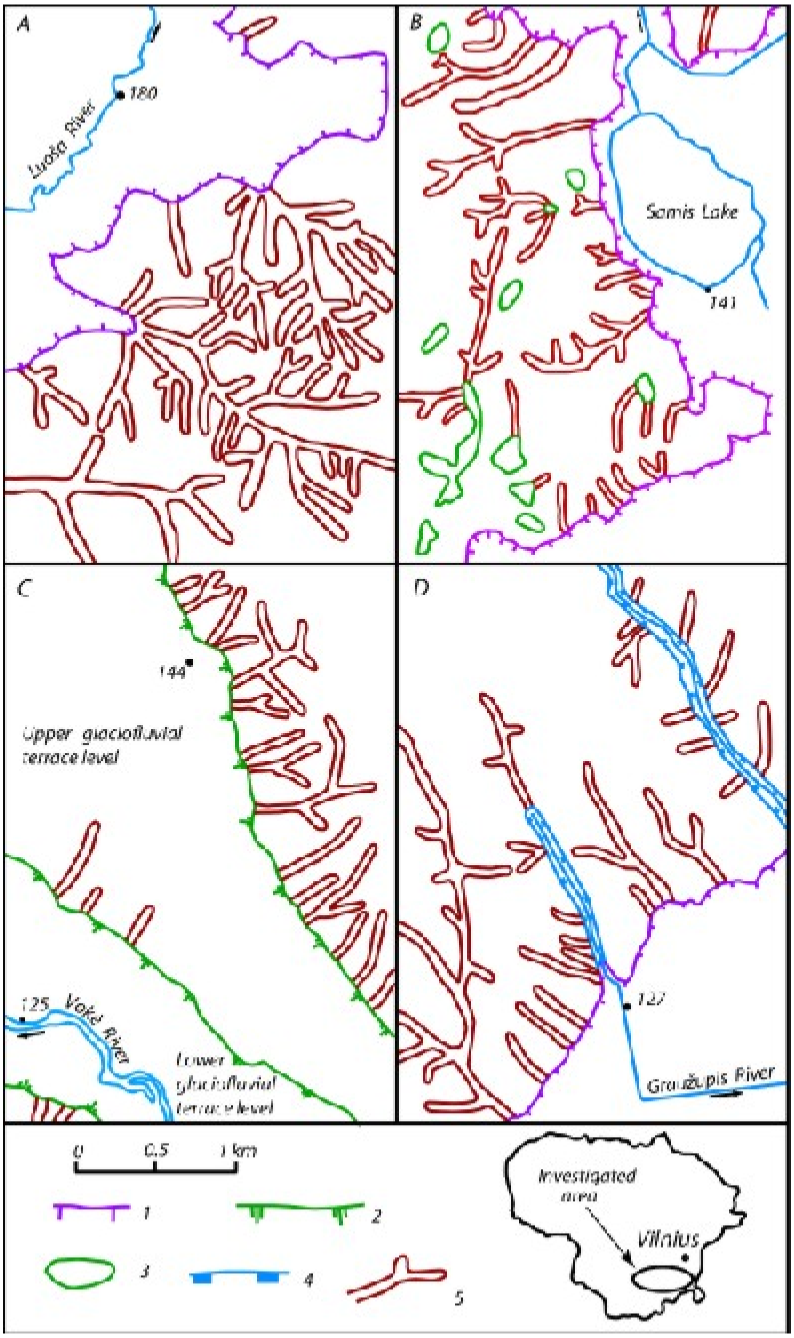

Fig. 1. Epigenetic transformation of relief in investigation areas: A – eastern shoreline of Luoša glaciolacustrine basin, B – western shoreline of Samis small glaciolacustrine basin, C – eastern and western shoreline of Vokė glaciofluvial stream, D – western shoreline of Rūdininkai–Valkininkai glaciolacustrine basin; 1 – glaciolacustrine shorelines, 2 – glaciofluvial stream shorelines, 3 – thermokarst kettles and holes, 4 – fluvial valleys of glaciolacustrine tributaries, 5 – gullies and ravines.

Table 1. Classification of epigenetic relief forms in South–East Lithuania glaciolacustrine basin shoreline zones.

Processes	Forms
Glacigenic	Inter-ridge depression, inter-hill depression
Nival	Nival holes and kettles
Glaciofluvial	Distal valleys of meltwater, lateral valleys of meltwater, break-channel of ice meltwater, valleys of glaciolacustrine tributaries
Glaciofluvial - thermokarst	Subglacial valleys (rines), thermokarst holes
Erosion	Dry periglacial valleys, transgressive corrosion valleys, regression corrosion valleys (dells), gullies, ravines
Suffusion	Suffusion circuses
Aeolian	Dunes, ridges, sandy waves
Organogenic	Boggy flat planes

Kame terraces of the interlobate insular uplands: the case study in the Vidzeme Upland, Latvia

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The interlobate insular uplands (otepeas according to terminology used by Karukäpp 2004) occupy significant part of the territory of Eastern Latvia. These uplands are normally circular or slightly elongated without any preferred orientation, and with bedrock core. Bedrock is covered by up to 200 m thick cover of the Pleistocene sediments, accumulated mostly during the Weichselian glaciation. The ice marginal formations of the peripheral zone almost entirely surround the hypsometrically highest central part, where various types of hummocky moraines prevail (Āboltiņš 1998). The Vidzeme upland can be regarded as a typical pattern of the interlobate insular uplands. In the territory of this upland kame terraces are widespread across both zones, and occur in different hypsometric positions.

In order to reveal morphological diversity, internal structure and time transgressive development of the kame terraces field study sites were located in different parts of the upland. In gravel pits samples were collected for determination of the OSL age and granulometric composition of glacioaquatic sediments. In outcrops the internal structure was examined, and the bedding elements, macrofabric, displacement planes and minor fold limbs were measured. As a result two morphological types of kame terraces can be recognized in the study area.

The segment-type kame terraces stretch for a distance up to some hundred meters along the slopes of the largest composite glaciostructural and plateau-like hills of the central zone. These terraces are 75-125 m wide and up to 15 m high. Each terrace is morphologically expressed as a simple step-like elongated strip with a relatively smooth surface that widens downglacier.

The linear kame terraces are located in lower hypsometric positions. In the central zone of the Vidzeme upland the flights of these type terraces occur on walls of tunnel valleys, indicating periodic reduction of the glacier surface during terrace formation. For example, the kame terrace along Bānūži-Lode tunnel valley is almost 5 km long and 700 m wide. This kame terrace has four levels striking as staircases along the tunnel valley. Headwards of older and upper three levels record erosion by proglacial meltwater. Lower level of the kame terrace passes into kettled surface topography at the distal edge.

In the peripheral zone of the upland the linear type kame terraces are the most expressive because have been produced by large size meltwater streams between an ice lateral margin and an upland hillside. Here at elevations from 120 to 180 m a.s.l. up to 8-9 terraced levels occur along SE slope of the Vidzeme Upland. A total length of this terrace is almost 30 km, and a width varies from 2.5 km to 6 km. Four older and upper terrace-like levels have been generated by proglacial meltwater erosion. These levels represent beds of lateral drainage valleys mantled by boulder pavements that formed as a result by washing out fines from till. OSL age of the thinly laminated sand underlying the pavement suggest sedimentation in a basin between 19.6 and 26.8 ka (Raukas *et al.* 2010). In a downstream direction mentioned above levels of the laterally drained channels are associated with glaciofluvial outwash delta and fans. Kettle topography occurs only in front of terminal moraines, particularly in SW corner of the Vidzeme Upland. The lower 4-5 levels show signs of ice marginal fluvial deposition and can be identified as typical lateral kame terraces. OSL age of the sands collected in the lower level of the kame terrace yielded 16.9 ka.

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Palaeogeographic Researches in Southeast Baltic: Results of 2009-2011 (based on materials from the Kaliningrad Region)

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The project 'The Evolution of the Baltic Sea and the Stages of the Earliest Human Settlement in the Southeast Baltic' initiated by I.Kant Baltic Federal University in 2009 looks at fundamental problems related to the Late Glacial and Post Glacial evolution of the Baltic Sea, and its impact on prehistoric migrations of populations in the southeast Baltic.

The methods of radiocarbon dating, combined with palaeoenvironmental and palaeolimnological studies, make it possible to correlate the early stages of human settlement with the evolution of the Baltic Sea and internal waterways in the southeast Baltic.

The project's main objectives include:

1. An assessment of the impact of environmental change on prehistoric settlements in the southeast Baltic.
2. New data on Stone Age archaeology and palaeogeography, and climate and landscape changes on the border of the Late Glacial and Holocene.

Within the framework of the research, there are two main parts of investigations. In the first preliminary stage, existing data on palaeogeography were summarised, and several conclusions about features of the Late Glacial environment were made. The correlation of palaeogeographic maps and a retrospective analysis permits to define territories with the most convenient natural characteristics, and therefore which were settled by ancient people first. This approach allows to make a prognosis, and to divide areas which offer the most hope for field archaeological prospecting.

The second part of the project includes field research, which consists of archaeological prospecting, the investigation of key archaeological sites within palaeogeographic methods, and the investigation of objects of the palaeohydrological net. The main methods of palaeogeographic investigation are coring and sampling of bog and lake deposits, with the subsequent high-resolution radiocarbon dating, pollen and diatom analyses.

In 2009 - 2011, the internal eastern areas of the Kaliningrad region (the valley of the River Sheshupe, the Vishtynetskaya highland) have beeing investigated.

Intermediate results of the palaeogeographic research are as follow.

The Late Glacial landscape conditions within the limits of the River Sheshupe valley underwent numerous changes (Druzhinina 2011). The general picture of change in the environment looks as follows: landscapes of open tundra (*Artemisia, Cyperaceae Selaginella, Chenopodiaceae*) in the Early Dryas take the shape of park tundra with a light pine-birch forest and a high role of *Artemisia and Cyperaceae and Juniperus* in the Böling; in the Middle Dryas, grassy communities (*Chenopodiaceae, Ericaceae*) with *Alnaster fruticosus and Salix* gave way to pine-birch woods with *Juniperus* and *Salix* in the Alleröd; at last, finishing the Late Glacial, the cold snap in the Late Dryas led to the regeneration of landscapes of tundra and forest-tundra, with the domination of grasses (*Artemisia, Chenopodiaceae, Brassicaceae*) and dwarf forms of birch and willow, and also juniper.

During the archaeological prospecting between 2006 and 2009, the surface of the partly preserved second and third 'high' terraces of the river Sheshupe was surveyed. On the left bank of the river, several sites preliminarily dated to the Late Palaeolithic period were uncovered (Druzhinina 2008). The arrangement of the Ryadino 5, one of these sites, is characterised by the greatest height (12 m) above the water level in comparison with other objects in the group. In the relief, the site occupies a flat platform on the edge of a terrace. In 2010 palaeoecological research of the site had begun. Samples on the palynological analysis were selected. The geochemical analysis of 82 samples of a soil was carried out; the preliminary results which give the chance to establish presence of various functional zones within the excavated part of the site were received. Unexpected results were obtained in the investigation of the stratigraphy of this site. The geological structures breaking natural "normal" stratigraphy of the cut were found out. Originally they were treated as “household holes”, however archaeological researches haven't confirmed this conclusion. More detailed studying of the fixed structures gives the grounds to put forward the version of “palaeoseismodislocations”. The further complex researches of the site Ryadino are required.

Archaeological work in the River Sheshupe valley was supplemented by a set of palaeogeographic research aimed at reconstructing the evolution of the Holocene environment. As an object of study, in 2009 the peatbog Velykoje (54º 57'06 "N, 22º 20'28" E, 34 m above sea-level) was chosen. The cut of the peatbog is represented by layers characterising changes in the environment throughout the last 7,500 years. The earliest dating, 7520±70 cal. years (LU-6261), was received from a depth of 6.6 to 6.5 metres from the present surface of the peatbog. Botanical, diatom and palynological analyses, together with radiocarbon dating, allow to track the history of the development of the reservoir and the evolution of the vegetation from the beginning of the Atlantic period (Arslanov *et al. 2010*). In 2011 palaeolimnological researches of group of small lakes of the Vishtynetskaya highland which will allow to detail environmental changes on a boundary Pleistocene – Holocene are planned.

As the further results of the project, we expect to obtain a model of demographic processes that occurred in the area of the southeast Baltic during the Late Glacial and Early Holocene against environmental changes.

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The Younger Dryas subfossil forest (Central Poland)

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The subfossil forest has been found in central Poland, within the middle section of the Warta River valley, close to the Koźmin village. In the light of the results achieved so far, the forest existed in the turn of the Allerød and Younger Dryas period. The investigated site was located about 800 km from the Younger Dryas ice-sheet southern margin (Fig. 1A).

The well preserved forest remnants, with clearly visible annual tree rings, occur in a peat unit (0,5-0,3 m thick) and the bottom of overbank sandy-silty series (2-3 m thick) of an anabranching river type 2 (Nanson & Knighton, 1996; Turkowska *et al.*, 2004; Forysiak, 2005). These Late Weichselian lower terrace deposits are underlain by the Upper Plenivistulian braided river sands.

The tree stand, according to preliminary assessment, was dominated by a pine forest with birch and probably alder and juniper. The stumps are found *in situ* but mostly as a series of collapsed trunks as well as individual branches and roots. The length of the trunks reaches up to a few metres. Their diameters are locally significantly over 0.2 m. As their diameters equal or exceed the peat thickness, it is difficult to state the real position of the trunks in relation to the base or top of the peat. In some localities a significant assemblage of trunks was documented, where they were found lying one on the other even in three levels which causes the increasing of a peat and trunk horizon (Fig. 1B). Additionally, the trunks are somewhat flattened, by pressure of an overlying material. The examples of *in situ* stumps, suggesting an existence of the forest synchronically with the peatbog formation, have been found too (Fig. 1C). For some collapsed trunks there is no evidence that they were relocated because of (1) the lack of any mineral interlayers pointing to fluvial interruptions, (2) preserved bark on the trees, (3) cases of interlocking roots. Some of the trees may have been washed away and buried in the sediment by overbank flow.

Timeframe for a peat unit formation and a subfossil forest existence have been determined using conventional radiometric method. The results cover a wide range between 11 850±80 ^{14}C BP /13 874–13 454 cal BP (95.4 %) and 10 200±430 ^{14}C BP / 12 941–10 660 cal BP (95.4 %), but only the oldest date exceeds the Younger Dryas lower boundary. In general registered palaeobotanical signal (Petera, 2002; Turkowska *et al.*, 2004; Forysiak 2005; Dzieduszyńska *et al.*, 2011) is in agreement with the radiocarbon datings, and points to increasing severe climatic conditions.

From the geological, palynological and chronological arguments being known so far it is possible to assume that rapid and deep Younger Dryas cooling led to destruction of the forest as a response of probable permafrost reactivation under the peat bog, uplift of the ground water table and intensification of fluvial activity.

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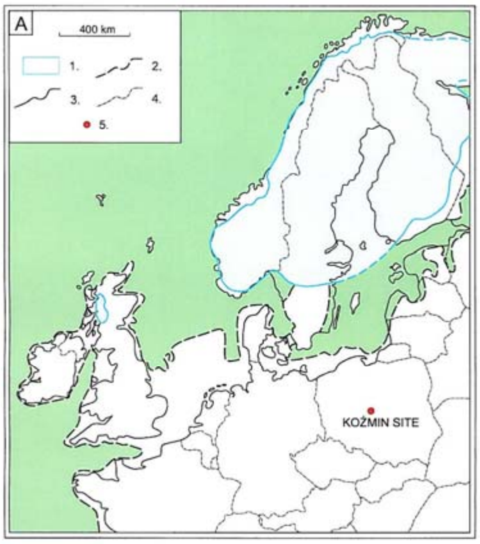

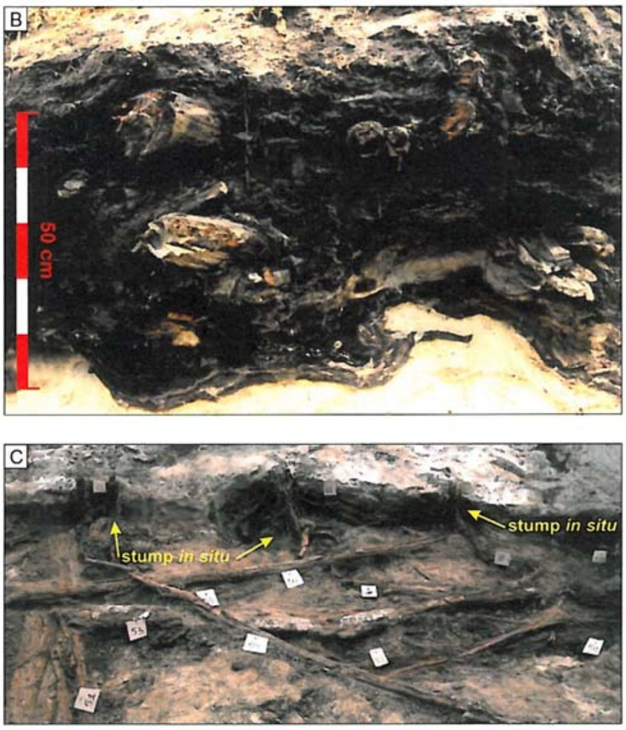

Fig. 1.
A. The Younger Dryas ice-sheet extent (after Forsström & Punkari 1997) and location of the investigated site
1 – ice-sheet; 2 – outline of the Younger Dryas land;
3 – present land; 4 – borders; 5 – location of the investigated site
B. Assemblage of the tree trunks in the peat unit
C. Forest remnants in the excavation

Cryogenic structuring of superficial moraine sediments in low mountains of Kola Peninsula, Northwestern Russia

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The Kola Peninsula located close to the Scandinavian center of ice, was a region of a significant glacial activity in the Pleistocene. Due to combination of lowland and mountainous relief there can be found moraines deposited by ice sheets, valley and cirque glaciers and also their collisions. After last deglaciation superficial moraine sediments tend to be reworked by different geomorphic agents. In subarctic climate conditions of low mountains cryogenic processes begin to act one of the main roles in alteration and structuring of these sediments.

The Khibins and the Lovozeskie tundras are low mountains elevated around 0.9-1 km above the sea-level and located in the central part of the Kola Peninsula. These massifs represent small round alkaline intrusions into the frame of gneiss-granitoid rocks. The massifs are greatly tectonically dissected, reworked by glaciers and water erosion due to their relatively low resistance to the surface environmental conditions and partially covered by a complex diamicton layers (Regionalnaya cryolitologiya 1989). Large troughs cross the massifs and a lot of smaller glacial valleys with cirques in their heads erode central parts of the mountains. These depressions usually carry certain amounts of alpine moraine sediments, thickness of which depends not only on the primary deposition rates, but also on the intensity of erosion in the particular places. These sediments consist generally of badly sorted coarse debris of local alkaline material (nepheline syenites). The low marginal zones of the mountainous massifs (outward slopes and valleys opened to the adjacent plains) are usually buried with continental moraines of the last glaciation. These mixed sediments (both rounded and coarse debris of derived rocks and local material) are found up to 600-700 m height in mountain valleys, but their occurrence hardly depends on the exposition of the valleys and the direction of the ice flow during the continental glaciations. Some erratic boulders are recorded on the tops of the mountains (on widely spread plateaus higher than 1 km) corresponding the influence of older and thicker glaciations.

Detailed fieldworks were provided in this region during last five years (2006-2010) and thorough analysis of literary materials (Baranov 1958; Gladcin 1936; Washburn 1969) allow determining some particular features in distribution, development and variety of types of cryogenic structuring of widely spread moraine sediments. Lots of excavation works have been done during this period which can help to understand also the specifics of inner structure of cryogenic micro relief and to reveal some concealed patterns of its growth. Furthermore a station for measuring the modern rates of sediment movements on the slopes was installed.

Impact of cryogenic processes on the ground surface in subarctic mountains declines with the lowering of its elevation. Therefore cryogenic microforms are common only for two geomorphic situations: 1) cirque's floors and bottoms of mountain valleys in their upper parts covered with alpine moraines and 2) upper parts of mountainous slopes covered with continental moraines. In other geomorphic positions cryogenic structuring of superficial moraines also can occur, but they are much less typical for the studied territory and are not considered in this paper. It has to be said that in the first case abundance and variety of types of cryogenic micro relief are far greater. It is caused by the various local geomorphic conditions those occur due to modern erosion activity and differential draining of the territory. In the second case drainage of the sediments is usually much more even and depends mostly on the inclination of the slope.

One of the main factors in the intensity of cryogenic structuring of the sediments is a fine-grained content. Alpine moraines in the studied field area usually include small amount of fines so the most accurate cryogenic forms originate in the local accumulation zones (like small shallow depressions or ephemeral lakes in the river valleys' bottoms). These conditions in addition to the high level of moisture of the sediments lead to the appearance of well-sorted medium size (from 0.4 to 1.5 m in diameter) high-centered polygons and circles (with small boulders to pebbles in the ridges and silts to loams in the centers). With the increase of inclination (on the slopes of the depressions) these rounded cells of micro relief transform to a linear ones (Mudrov 2007), so the ridges oriented across the slope come apart and disappear, while the ridges spread along the slope remain as a parallel stripes of fine and coarse grained material. In the vertical profile material is also sorted into prominent cells (0.2-0.6 m depth) and turns to the unsorted mass lower than 0.7 m from the surface.

The surface of moraine ridges often also demonstrates signs of cryogenic structuring. But better drainage of the sediments and lower fine-grained content explain much less evident cryogenic micro relief. In these terms small flat forms with diameter less than 0.5 m appear. Their centers consist of gravel and small pebbles with a little amount of sand or sandy loam and ridges include also pebbles and sparsely boulders. Lateral sorting of material is much worse and in depth structuring never reaches 0.1 m. Sometimes the mixed composition of the material acts is the point of the visual evidence of these microforms. Derived (and much better rounded) material tends to gather in the ridges of microforms, while the coarser local material remains in their centers.

It is important to mention, that if the upper margin of cryogenic structuring of moraine sediments defines by the height of distribution of the glacial deposits, then the lower margin of cryostructuring is controlled by the appearance of vegetation with the declining of height and softening of the climate conditions.

Thereby these two different types of the cryogenic structuring of moraine sediments are only two extreme cases, whereas in natural environment we can observe a great variety of forms which combine the signs of both types and have got other particular features. So we have to point that the character of the cryogenic micro relief is controlled mainly by local conditions like regime of moistening, extent of vegetation, local amplitudes within the scope of microforms, inclination of the slopes and etc. It has to be considered during the studies focused on moraine explorations because of highly uneven processing of these sediments by cryogenic agents.

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Varve chronology and proglacial sedimentary environment in Pärnu area western Estonia

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The decay of Weichselian ice from Estonian territory between 14.7 – 12.7 ka yrs BP (Kalm 2006) was followed by extensive proglacial bodies of water, which developed in accordance to the receding ice margin and opening of new drainage roots. This is reflected in a wide distribution of varved clays with their characteristic summer (silty) and winter (clayey) layers which are interpreted to reflect seasonal variations in sedimentation environment in proglacial lake. Potential of these sediments as a chronological tool and high resolution proxy for the reconstruction of sedimentary environment has been widely used in Scandinavia. This tool has been less exploited in eastern Baltic area. Currently a local varve chronology and varve thickness changes are analysed across the Pandivere-Neva (13.5-13.3 ka yrs BP) belt of ice-recessional formations in western Estonia.

The study area includes the shallow water Pärnu Bay and adjoining coastal lowland. Pandivere-Neva belt of ice-recessional formations is crossing the area and is represented by push end-moraines and glaciofluvial deltas (Karukäpp & Raukas 1997). The hummocky upper surface of the Late Weichselian bluish-grey loamy till is covered by glaciolacustrine varved clay or silt with average thickness ca 10 m. Varved clays in western Estonia have been deposited in the Baltic Ice Lake and are characterised by very distinct lamination and easily distinguishable seasonal layers. Varves are usually thick and clayey with silty microlayers in some intervals. In limited area at the distal slope of the Pandivere-Neva formations (in NW part of the Pärnu Bay and in the City of Pärnu) a massive silty clay unit (0.40-10 m in thickness) with dispersed sand grains and few dropstones has been described within the varved clay complex which according to varve correlation is synchronous with the interval of 20 silty varves in more distal part of the basin (Fig. 1).

A new varve chronology comprising 570 consecutive varve years was constructed from the 33 cores. All investigated sequences display a normal varve series with decreasing varve thickness upwards. No drastic or very rapid changes in total varve thickness which could be attributed to the ice readvance (Raukas *et al.* 2004) during the Pandivere-Neva Stade were reported. According to the varve correlation two groups of varve graphs could be distinguished: those representing sequences from the distal side and those representing sequences from the proximal side of the Pandivere-Neva ice marginal formations (Fig. 1). Accumulation of varved clays started ca 100 yrs earlier at the distal part. Massive clay unit with corresponding 20 silty varves in some sequences precedes the beginning of varve formation at the proximal part of the basin and is interpreted as an ice-drift material during the ca 20 yrs stagnation of glacier margin at the Pandivere-Neva line. Ice proximal conditions on both sides of the recessional formations (within 30 km distance) ceased simultaneously within ca 20 yrs reflected in the decrease of the total varve thickness accompanied with the beginning of winter layer dominance within a single varve. Periodic varve thickness variations in the proximal part of the chronology are driven by the thickness of summer layer while winter layer thickness remains rather stable through the whole chronology (Fig. 1). It is why the varve thickness changes are attributed to the proximity of the ice-terminus rather than to palaeoclimatic signal. Length of the chronology certainly underestimates the duration of proglacial conditions as all the varve series have erosional discontinuity at the upper contact with overlying sands pointing to the post-sedimentary erosion.

Magnetostratigraphic study of the three clay sections demonstrates weak but useful NRM magnetization. NRM results differ between the core sections due to poor orientation of a sampler during the coring and only relative changes in magnetization can be derived. Strong eastern shift in declination is correlated with similar data from regional declination curves between 13.9-13.3 ka BP. This correlation places the stagnation of ice margin at Pandivere-Neva line to ca 13.9-13.7 ka BP being thus ca 600 yrs earlier than proposed from NE Estonia and Lake Ladoga in NW Russia (Saarnisto & Saarinen 2001; Hang 2003) and questions the time synchronous formation of Pandivere-Neva ice recessional landforms in Estonia.

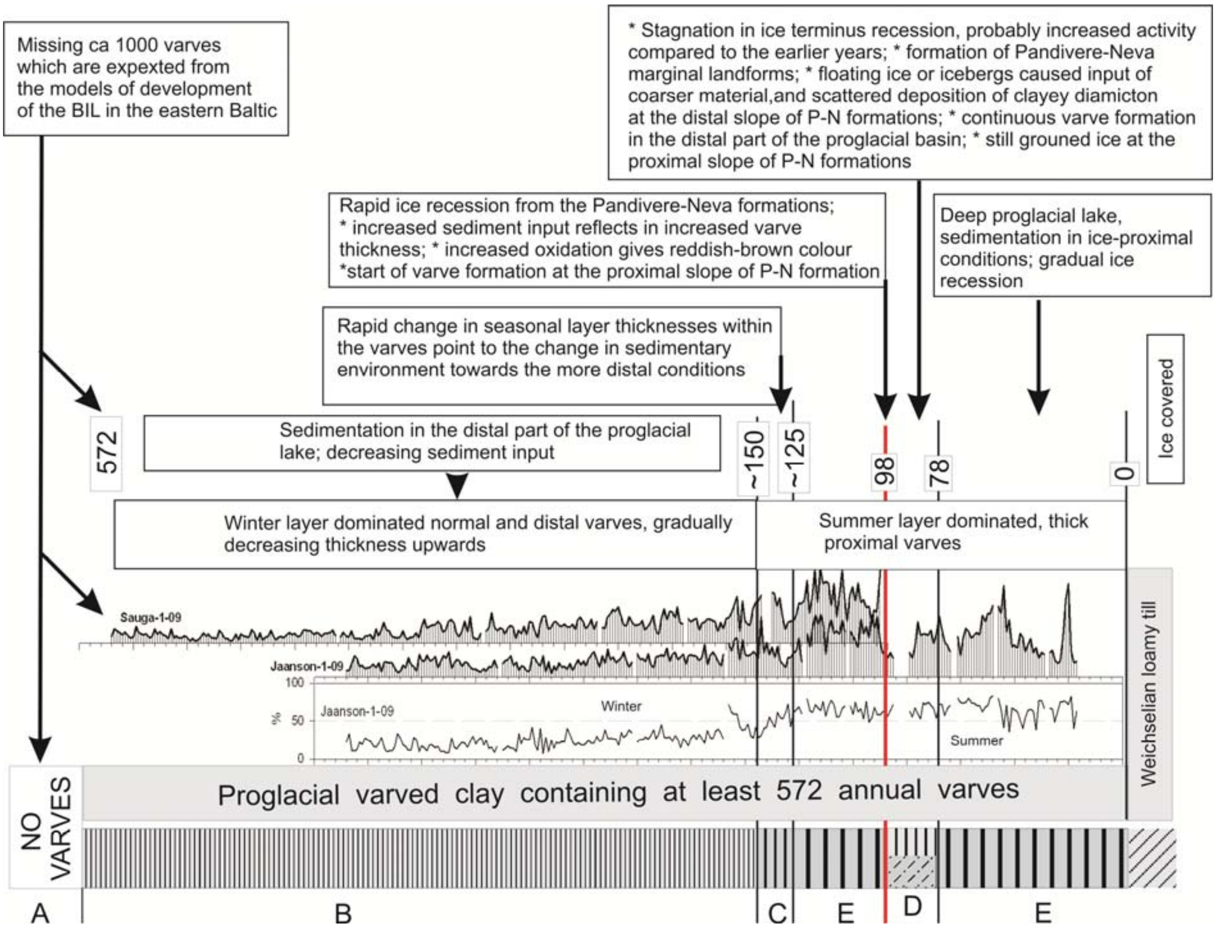

Fig. 1. Principle scheme displaying varve thickness changes and the changes in relation of seasonal layer thickness within the varves together with the interpretation of proglacial sedimentary environment in Pärnu area, western Estonia.

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Environmental conditions and climate at Sokli (northern Finland) during early MIS 3 (~ 50 ka): Revising earlier concepts on glacial and vegetation dynamics and climate in northern Fennoscandia during the Middle Weichselian

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Long sediment records that register environmental changes in formerly glaciated regions such as Fennoscandia in the period preceding the Last Glacial Maximum (LGM) at ~ 20 kyr are rare. The environmental history of Fennoscandia during the Weichselian has been mostly reconstructed based on long-distance correlation of often poorly-dated stratigraphic fragmentary evidence.

A for Fennoscandia unusually long and continuous sediment sequence covering the last ~130 ka has been recovered at Sokli in northern Finland. The sediment sequence consists of tills and glacio-fluvial beds interlayered with fossil-rich lacustrine and fluvial sediments. The Sokli sediments have been protected from glacial erosion due to their sheltered position in a depression formed in deeply weathered rocks of a carbonate-rich magma intrusion (Ilvonen 1973) and to sustained cold-based sub-glacial conditions during the LGM (e.g. Kleman *et al*. 1997). The sediment sequence has been dated by AMS ^{14}C and OSL dating which is in agreement with stratigraphic dating based on correlation with the deep-sea record (Helmens *et al*. 2000, 2007a; Alexanderson *et al*. 2008).

The lacustrine and fluvial sediment intercalations in the Sokli sequence are being subjected to detailed study. Comprehensive environmental reconstructions are made based on high-resolution, multi-proxy analysis including lithological characteristics; organic content (LOI); plant microfossils (pollen, spores, algal and fungal remains); macrofossils of plants (e.g. seeds) and of aquatic animals (e.g. statoblasts of Bryozoa); chironomids (i.e. aquatic insects); and diatoms and other siliceous microfossils (e.g. phytolits). Additionally, geomorphic evidence and analysis of Digital Elevation Model (DEM) data are employed in the environmental reconstruction. Climate parameters (e.g. mean July temperatures) are reconstructed quantitatively by applying transfer functions to the pollen, chironomid and diatom records and by the use of plant indicator species.

We here present an overview of the results obtained on a two meter thick laminated, lacustrine clay-silt sequence of early MIS 3 age. Results have been surprising in various aspects, seriously challenging earlier concepts on environmental and climate conditions during early MIS 3 in the near-central area of the Fennoscandia glaciations. Traditionally, the area is thought to have been ice covered throughout MIS 4-2 from ~ 70 kyr to the deglaciation at 10 kyr ago (e.g Donner 1995). The Sokli study shows not only ice-free conditions but also warming to present-day summer temperatures during the Tulppio Interstadial at ~50 ka.

The siliceous microfossil record registers sudden changes in lake level and extent and together with lithology and a low LOI indicate that major part of the Tulppio Interstadial lacustrine sediments were most probably deposited in a glacial lake (Helmens *et al*. 2009). The

DEM combined with morphological evidence is able to reconstruct the proxy-inferred glacial lake evolution and places the coring-site in a sheltered lake embayment. This explains a limited influence of the ice sheet at the coring-site, resulting in a proxy record that in detail registers the biotic environment around the coring-site and reconstructs the regional climate. Throughout the deposition of the Tulppio sediments, the reconstructed terrestrial ecosystem on the deglaciated land is low-arctic shrub tundra very similar in composition to modern tundra in the continental sector of northern Fennoscandia (Bos *et al*. 2009). The distributional ranges of pine and tree birch were probably only few hundred kilometres south or south-east of Sokli. Stands of tree birch were probably present in the Sokli area in favourable spots. This is concordant with the sparse evidence for the presence of boreal tree taxa during MIS 3 in the Baltic countries and further east in Europe but contradicts with the commonly inferred treeless tundra or grass-dominated steppe conditions in central Europe. Mean July air temperatures in the magnitude of present-day values are reconstructed by the chironomid and diatom records as well as by fossils from aquatic plants and Bryzoa (Helmens *et al.* 2007b, 2009; Engels *et al*. 2008). Comparison with recently published, well-dated sediment sequences in eastern (at Ruunaa: Lunkka *et al*. 2008) and western Finland (Hitura: Salonen *et al*., 2008) suggest ice-free and warm conditions in major part of eastern Fennoscandia at ~ 50 kyr (Helmens & Engels 2010).

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Geological situation and sedimententary characteristic of coversands distributed on the Błonie glaciolacustrine basin (Central Poland) – preliminary results

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The Błonie glaciolacustrine basin, known also as the eastern part of the Łowicz-Błonie Plateau (Kondracki 2000), is located in Central Poland, between Warsaw and Sochaczew (Fig. 1). The total lenght of the Błonie basin reaches about 60 km while width: 20 to 30 km. The unit is surrounded by the elevated area of the Rawa morainic plateau from the south and the lower area of the Warsaw Basin from the north. It is continued as the Iłów glaciolacustrine basin (or western part of the Łowicz-Błonie Plain) to the west and as the Warsaw Plain in the east. The Błonie and Iłów glaciolacustrine basins are divided by the Bzura river valley (Fig. 1).

The Błonie glaciolacustrine level is a monotonous horizon located between 82.5-100 m a.s.l. It is built of glaciolacustrine deposits in its northern part and Warthanian (Saalian) morainic tills in the southern part. Glaciolacustrine clays were accumulated in the Warsaw Ice-Dammed Lake, which existed during two glacial episodes in the Warsaw Basin at least: Warthanian (Saalian) and Vistulian (Weichselian) Glaciations. Cover sands lie above both glaciolacustrine and morianic deposits forming the highest points of the eastern part of the Błonie glaciolacustrine basin.

So far, coversands have not been conducted accurately. Only Karaszewski (1972) pointed at their distribution and correlated them with the youngest loess level in the South Polish Uplands. The range of cover sands were also investigated during geological mapping of Błonie sheet (Szumański & Kwapisz 2006). Some textural features of cover sands in Chodaków area were analyzed in details (Kalińska 2008).

The field works including excavation and collecting samples were investigated in the Plecewice area near the Bzura river (Fig. 1), the most north-western part of Błonie glaciolacustrine basin. The following laboratory works were made: grain size analysis with Folk and Ward (1952) indicators, analysis of light minerals of the sand fraction (0.5-0.8 mm) and roundness and frosting analysis of quartz grains of two fraction (0.5-0.8 and 0.8-1.0 mm). The latter is also known as a Cailleux analysis (1942) modified by Mycielska-Dowgiałło and Woronko, 1998 where 6 groups of quartz grains are distinguished: NU – non-abraded grains, EL – well-rounded shiny “beach-like” grains, EM/EL – partially rounded, shiny grains, RM – well-rounded matt grains, EM/RM – partially rounded matt grains and C – cracked grains.

Medium- and fine-grained sands occur in the cover sands forms. The medium diameter (Mz) varies within 1.12-1.9 φ. The finest deposits are noted in the lowest part of profiles (e.g. 1.4-1.9 m) near the border with the glaciolacustrine clays (varved deposits). Sorting of sands is moderate within 0.63-0.8. Deposits are positively skewed in almost all cases. The cumulative curves are characterized by the well-distinguished parts responsible of suspension, traction and saltation transport. Parts representing of traction are more steeply than saltation parts which might indicated on better sorting of the coarser fractions. The Cailleux analysis of 0.5-0.8 mm fraction points on enrichment in partially rounded frosted grains (EM/RM) which varies within 59.5-83.3%. The share of well-rounded frosted grains (RM) changes within 10-21 %. The highest content of well-rounded grains is noted in parts of profiles with the lowest content of partially rounded one (e.g. 1.0 m). The fraction 0.8-1.0 mm is characterized by the higher content of well-rounded frosted grains as a rule. Analyses of light minerals indicate on quartz prevalence in samples from all profiles: 77-90%.

The texture features point on some variability in the development of cover sands characterized by the high and the higher aeolisation. According the studies the accumulation of cover sands took place in extreme dry climate condition with some warmer episodes after the drainage of the ice-dammed lake and the drying up of the area during the Vistulian Glaciation in Poland. Future dating of cover sands would enable to reconstruct the duration of dry climate conditions and their detailed description.

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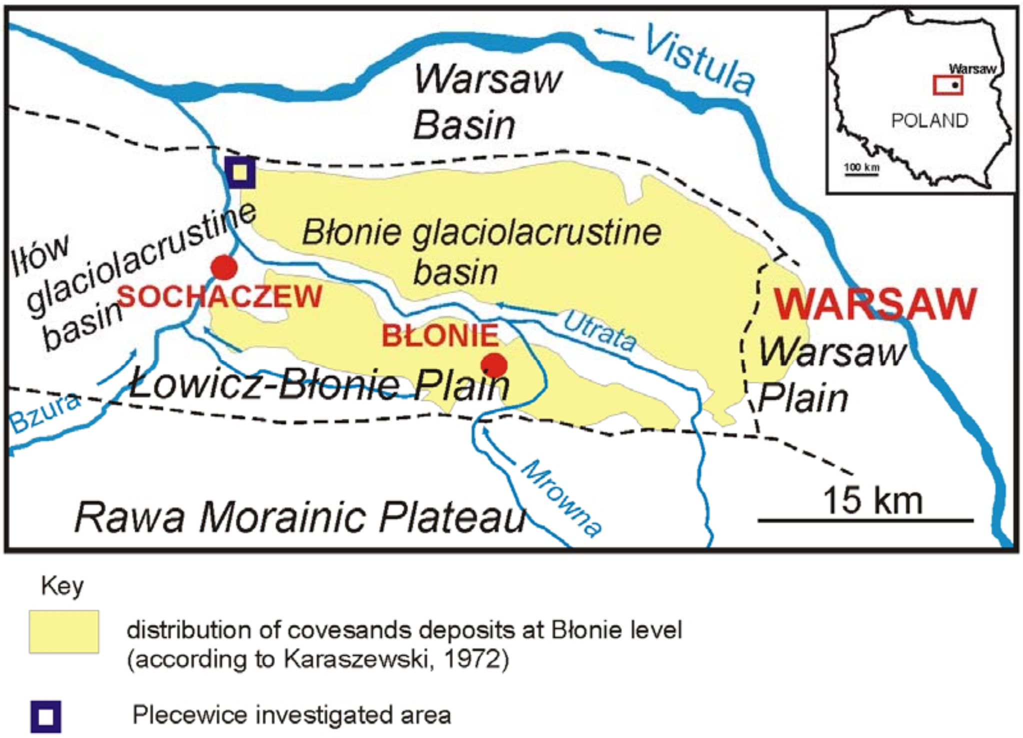

Late Weichselian Glaciation on East European Platform: Ice-flow Pattern Compared with Geothermal Heat Flow Density and Bedrock Water Properties

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In this study we correlate Late Weichselian ice-flow pattern with geothermal heat flow density (HFD) distribution, and with bedrock/sediment hydraulic conductivity (HC) in the area of Late Weichselian Glaciation on East European Platform.

Non-uniform geothermal heat flux beneath an ice sheet influences its basal T° and thus, together with the heat generated by friction at the base of the ice, the production of subglacial meltwater (Winsborrow *et al*. 2010). High T° and basal meltwater lubricates the base of a glacier and facilitates its flow. Näslund *et al*. (2005) calculated that an average HFD within the LGM of Scandinavian ice sheet is 49 mW/m^2. Southeast of the Baltic Sea, within the Late Weichselian glaciation area, the HFD varies from <30 mW/m^2 to 80-90 mW/m^2 (Hurter & Haenel 2002). There are two regions, Izora Heights south of St. Petersburg, and Lower Nemunas Lowland in Western Lithuania (Fig. 1), where the HFD is 1,5-2x higher (>70 mW/m^2) than in most of the area (30-50 mW/m^2). High HFD in the Lower Nemunas Lowland region conforms to the area where the Neman ice-stream operated during the Late Weichselian Glaciation. In the region of Izora Heights a convergent pattern of ice flow is seen in Digital Elevation Model (DEM) and satellite images. This may indicate an ice flow towards the high HFD area where the ice mass was reduced due to higher than average basal melting. Alternatively, the convergent orientation of subglacial bedforms on Izora Heights may also refer to two different episodes of ice flow, one originated from Ladoga-Ilmen ice stream and another from the direction of the Gulf of Finland.

Meltwater beneath ice streams promotes fast flow by saturating sediments that permits their deformation and sliding of ice, and/or decouples ice from the bed if the water pressure is sufficient. Hydraulic conductivity (HC) of sediments/rocks at the base of a glacier determines how much of meltwater may evacuate by groundwater flow. HC of the bedrock was important in the regions where the pre-Late Weichselian sediment layer between the glacier and bedrock was thin. HC of karst-affected Ordovician and Silurian limestone decreases rapidly as the depth increases and is between 10^{-4}–10^{-5} m/s in the upper 100 m thick layer. HC of Devonian sandstones is equally high – $5*10^{-5}$ m/s (Jõeleht & Kukkonen 1996). Dense net of subglacial valleys, incised into the bedrock in the outcrop area of Palaeozoic limestone in Estonia and St. Petersburg region of Russia refers to high water pressure at the glacier base, regardless of good HC of the bedrock. HC of glacial sediments varies from $6*10^{-8}$ m/s (clayey till) and $1.2*10^{-4}$ m/s (sand). In the regions where the Late-Weichselian glaciers advanced on thick (>25 m?) layer of older, predominantly glacial sediments, the HC of sediments, not bedrock, influenced the abundance and pressure of meltwater at the glacier bed.

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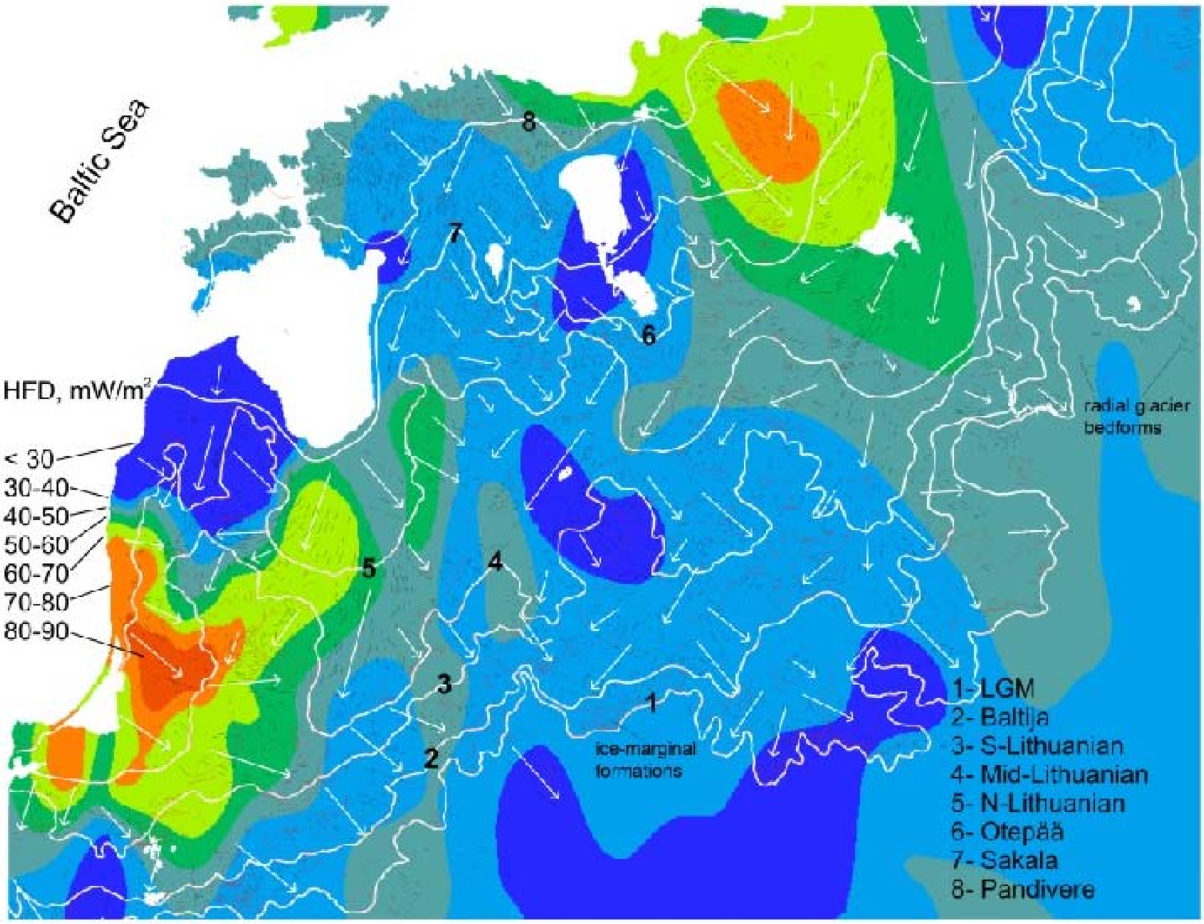

Fig. 1. Late Weichselian ice-flow pattern and ice marginal zones southeast of the Baltic Sea in the background of heat flow density map.

Quaternary Geology and Geomorphology of the North Lithuanian Ice marginal ridge and surrounding plains

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The aim of the present paper is to report new information on structural peculiarities and geomorphology of the North Lithuanian ice marginal moraine ridge. Lately this object was an object of researches for many investigators. According to some of authors, starting from the Linkuva ridge, the SIS decay began in the Baltic Sea basin, as well as in the Northern Vidzeme, Middle Gauja and all of the Central Latvian Lowlands. According to Āboltiņš *et al*. (1972) the Linkuva phase is the earliest lobate deglaciation phase. The North Lithuanian ice marginal ridge is clearly marked by the push moraine arc in the Central Latvian Lowland also Doss (1910), Āboltiņš (1970) and is correlating with the Haanja phase (Raukas *et al*. 1995) of Estonia.

The North Lithuanian region has been known as a zone of dominant glacial erosion where the Quaternary sediment cover is relatively thin and has a specific structure. A previous research has shown that the character of glacial erosion and glacial material transportation are reflected in the structure of Pleistocene deposits, particularly in tills Fig. 1.

The Pleistocene sediments in the central part of North Lithuania are overlying the Upper Devonian dolomite, marl, limestone, clay, and gypsum layers.

The thickness of the Quaternary deposits is 10-12 meters on the average but varies from 1.0 to 39.0 meters: the thinnest Quaternary is characteristic for river's valleys, whereas the thickest one is related with the highest altitudes of the present relief or with rare palaeoincisions of the sub-Quaternary surface. Pleistocene strata deposits on an investigated site is subdivised on three till complexes in some places separated by inter-till sediments.

The relative height of the end moraine reaches up to 23.6 m. It was discovered that physical and mechanical properties of till of the North Lithuanian ice marginal moraine, which composes the major part of the Linkuva ridge, are different from the Middle-Lithuanian marginal till as well as from North and Middle Lithuanian basal tills. The Linkuva marginal till looks like a clay because contain a great amount of fine (clayey) particles. Moreover, the input of gravel is negligible, less than 2%.

Glaciolacustrine kame terrace is 22 km long and 0.5-1.0 km wide and located on the distal slope of the North Lithuanian ice marginal moraine ridge (Bitinas *et al*. 2004). Its surface is slightly inclined southward and reaches up to 65-70 m in absolute height. The northern edge of the terrace is bound by the marginal ridge, which rises more than 80 m above sea level. The surface of the kame terrace is 10-15 m above the glaciolacustrine plain of ice-dammed lake that is located to the south of the terrace. Ravines intersect the slope of the kame terrace. The solifluction debris is developed in the eastern part of terrace foot.

Ice-dammed glaciolacustrine basin was formed to the south from the North Lithuanian marginal ridge, after glaciolacustrine kame terrace was formed. The absolute altitudes of the surface of the glaciolacustrine plain are 45-55 m. It has been established that the maximal thickness of reddish-brown clay reaches up to 13.9 m there (an average thickness is 4.5 m). Glaciolacustrine sediments overlay the till of the Middle Lithuanian phasial of the Nemunas Glaciation Baltija stadial. The contact of glaciolacustrine sediments with the basal till is distinct. Correlation between the thickness of glaciolacustrine sediments and till roof is significant negative (–0.82).

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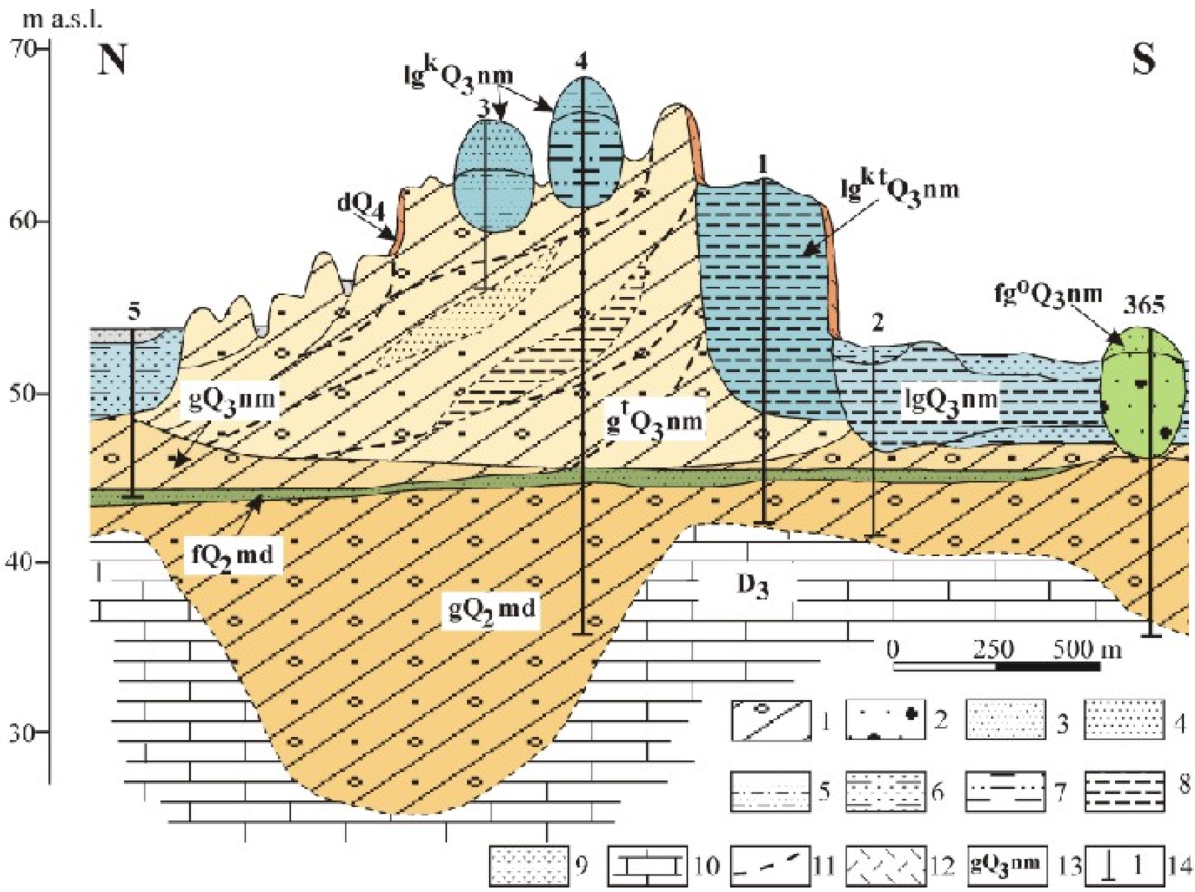

Fig. 1. Structure of Quaternary strata of North Lithuanian ice marginal ridge Linkuva:
1 – till, 2 – sand with gravel, 3 – various grained sand, 4 – fine sand, 5 – silty sand, 6 – sandy silt, 7 – sandy silty clay, 8 – clay, 9 – peat, 10 – dolomite (D_3), 11 – shear lines, 12 – deluvial deposits, 13 – genetic and stratigraphic index of deposits (gQ_2md – Medininkai (Warthian) till, fQ_2md – Medininkai glaciofluvial, gQ_3nm – Nemunas (Upper Weichselian) basal till, g^tQ_3nm – Nemunas deformation till, $lg^{kt}Q_3nm$ – Nemunas glaciolacustrine kame terrace, lg^kQ_3nm – Nemunas glaciolacustrine kame, f^oQ_3nm – Nemunas glaciofluvial esker, lgQ_3nm – Nemunas glaciolacustrine, dQ_4 – deluvial deposits), 14 – borehole and its number.

The complex facies of the morpholitosystem dead ice

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The section of dead ice should be regarded as an open degraded glaciofluvial morpholitosystem. This system is formed in the warming periglacial environment. That morphology is composed of glacial ice, debris material enclosed in glacial ice, and melt water. Evolutionary degradation cycle of such morpholitosystem includes irreversible stages of alternation from its inception until the termination of its operation. Exogenic processes modify the external shape of this system. Due to an increase of the solar energy income the quantity of melt out debris increases. The volume of its accumulation grows within the space, and in the periphery of morpholitosystem, the grow tendency of the amount of melt water involved in moving, sorting, and sedimentation of the debris. At the same time, the volume of ice component which forms a carcass of dead ice morpholitosystem decreases. The nature of litomorphogenesis and, consequently, the formation of relatively specific to each stage of morpholitosystem dead ice facies complex degradation determines by several factors: the difference in ratios between the mass of debris; the amount of melt water, creating a certain type of environment to move it to the sites of accumulation; and the volume of glacier ice, in particular glaciostructure thickness which transports and accumulates debris. Thus, the dead ice facies complex formation is the result of several effects: interaction of landscape features and climatic conditions, ensemble between acting exogenic processes and geological and structural features of the dead ice thickness. Possible types of this interaction can provide within the dead ice facies complex the ablation, fluvioglacial and limnoglacial accumulation. Dead ice facies in accordance with the place of formation are divided into supraglacial, englacia and subglacial (marginal) types. Subglacial facies are sediments that had been made beyond dead ice morpholitosystem and set aside near its borders (Tatarnikov 2002, 2008).

Ablation till was formed during the melting of ice. Its accumulation is controlled by surface ablation followed by gravity–solifluction processes. In the margin of ice the basal till material is raised to the surface by planes of internal cleavages and thrusts and is involved in ablation moraine formation. Inside ablation moraine facies of dead or passive ice two subfacies are proposed to allocate: 1) the melt-out till subfacies 2) solifluction subfacies and mud- and stones flow deposits or flow till.

Dead ice fluvioglacial and limnoglacial facies are derivatives of ablation, internal and basal tills. They are represented by sand, gravel and pebble sediments impure the boulder materials and underlie as lenses, stringers and packs. Fluvioglacial facies are formed by meltwater streams activity under different hydrodynamic conditions. These streams have circulated on the supraglacial valley network and interlinked systems of cavities and channels runoff which was developed in the interior of dead ice. They are characterized by layered structure typical for deposits formed by water flows. Limnoglacial facies are accumulated in reservoirs on the dead ice surface area, inside of its column and on the periphery of it. Substantially they are represented by well-sorted fine-grained sands, silts and clays, which are characterized by horizontal layering. Second sedimentary subsiding type texture is peculiar to the dead ice fluvioglacial and limnoglacial facies related to its sedimentary rocks morphological clearance after ice melting in the enclosing rocks. These textures are detected as discontinuities, flexure-shaped bends and folds, which are localized at the periphery or at the bedside of sedimentary rocks. Sediment bodies from fluvioglacial and limnoglacial facies are expressed as linear and isometric inversion landforms or imposed in the form of sheets on the main moraine landforms at sites of the dead ice.

Analysis of the diversity and quality characteristics of sediments which form the facies of dead ice and a variety of morphological forms of sedimentary bodies allowed to propose a classification provided in Table 1.

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Table 1. Complex facies of dead ice and morphological forms of its sedimentary bodies

Genetic group of deposits	Genetic type of deposits	Genetic species of deposits	Main complex of sediments	Main textural peculiarities of sediments	Morfological forms of sedimentary bodies
Ablation moraines	1.Supraglacial 2.Englacial 3.Marginal	a)subaeral surfice melt out deposits b) subaeral solifluction deposits c) subaeral mud-and- stones flow deposits d)subaquatic deposits	Clays, loams, sandy loams, sands with gravel, pebbeles and boulders	Uncertenly, interrupted layering, dotted line layering, fluidal layering	Hills and ridges (till crevasse-fillings ridges, ring ridges, ice-contact ridges, prairie mounds)
Fluvioglacial deposits	1.Supraglacial 2.Englacial 3.Subglacial 4.Marginal	Water derivates of debris material ablation and bazal moraine	Sandy-gravely-pebbely sediments with boulders	Oblique, oblique –crossed and crossed layering, waved layering, diagonal layering, secondary subside defofmations	Hills and ridges, plateauxes, terraces (fluvioglacial kames, eskers, fluvioglacial deltas, fluvioglacial terraces and plateauxes)
Limnoglacial deposits	1.Supraglacial 2.Englacial 3.Subglacial 4.Marginal	Water derivates of debris material ablation and bazal moraine	Sands, alevrites, clays	Horizontal layering, varved and similar varved layering, secondary subsided deformations	Hills, rarely ridges, plateauxes, terraces, (zvonces, limnoglacial kames, limnoglacial eskers)

Isolation basin stratigraphy and Holocene relative sea-level change at the Kuzema village, Karelia, NW Russia

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The periglacial lake - marine and marine – lacustrine transition (isolation contact) in sediment cores from eight lake basins situated 9.5 – 72 m a.s.l. in Kuzema River area, south coast of White Sea, was identified based on lithological, diatom and spore-pollen analysis, radiocarbon dating, and used to construct a relative sea-level (RSL) curve for the Holocene.

Cores were collected from lake basins lying along 14 km-long transect situated west of Kuzema village Karelia, NW Russia. The lakes occupy glacially eroded rock basins in the area of undulating, relatively low relief. Glacial deposits and glaciofluvial sediments occur locally in the depression. Bedrock comprises Archaean igneous and metamorphic rocks, mostly granite and gneiss. The investigated lakes range in size from 100 m to 1.5 km (0.01-1.0 km^2). Lake depths are 1-4 m. Thresholds consist of glacigenic sediments usually covered by a layer of peat.

The investigated area is located 10-15 km behind the Younger Dryas (Rugozero (Salpausselka I) Stage – 11.3-10.8 C^{14} ka B.P.) end moraine (Ekman & Iljin 1993).

The shorelines are not conspicuous in this area and no attempt was made to determine their elevation. The high marine limit have been determined in Chupa area situated 100 km to north of Kuzema approximately at 100 m a.s.l.

Five genetic facies units are identified in lake bottom sediments of White Sea depression primarily based on lithological character which reflect, in turn, major differences in depositional environment: I - periglacial lake (non-laminated clay, varve clay), II - transitional (mixed silt and sand with plant detritus), III - marine (mud silt, sand, shell fragments), IV - transitional (laminated gyttja and silt), V - lacustrine (gyttja, plant detritus).

The stratigraphic successions identified in the investigated lakes are shown in table.

Lithostratigraphic investigations of raised lake basin sediment successions suggest a complicated history for basins development in Kuzema area during the Late Weichselian and Holocene.

Two sediment successions (lakes 7 and 8 in table) contain the varve clay unit (facies I) which deposited in periglacial lake during the Allerød. Then in this successions are registered the missing of facies II-III units. Results from the depressions of lakes 7 and 8 were blocked by the dead ice during long time (Allerød –Younger Dryas).

Of the eight investigated lake basins, three contain a III-IV-V (marine – transition – lacustrine) facies succession indicative of a single isolation event, three contain an abrupt III-V succession indicating a rapid or unconformable marine-lacustrine transition.

The reconstructed relative sea-level curve for Kuzema shows a rapid rate of relative sea-level fall between 10,000 and 8,500 years BP (from 72 to 39 m a.s.l.), moderate rate of relative sea level fall (<0.5 cm $year^{-1}$) between 8,500 and 5,700 years BP, abrupt fall of relative sea level between 25 and 18.7 m a.s.l., and moderate rate of relative sea level fall (<0.5 cm $year^{-1}$) after 5,500 years BP.

It is supposed that the abrupt fall of relative sea level between 25 and 18.7 m a.s.l was caused by the tectonic forces of the reactivated Kandalaksha graben. The disturbance of the sediments in successions of lakes 2 and 3 could be an evidence of this.

Table 1. Stratigraphy of recovered cores.

Lake N	Threshold elevatio	Core stratig-raphy (Facies units)	Comments		
			Lithological succession	Diatom assemblage	Isolation contact
1	9,5	III-IV-V	Normal regressive, occurrence of plant detritus in III-IV	Normal transition	Lover part of IV
2	18.7	III-IV-V	Normal regressive,	Normal transition	Base of IV
3	25,3	III-V	Disturbance at base of V	Normal transition	Lover part of V
4	39	III-IV-V	Disturbance at base of IV-V	Fluctuating in IV	Upper part of IV
5	44.7	III-V	Disturbance at base of V	Normal transition	Lover part of V
6	53	III-V	Sharp	Abnormal occurrence of freshwater diatoms in III	Lover part of V
7	66.9	I-IV-V	Possible hiatus between I-IV. Normal regressive IV-V.	Fluctuating in IV	Base of IV
8	72	I-IV-V	Possible hiatus between I-IV. Normal regressive IV-V.	Normal transition	Lover part of V

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Paleosecular variation and deglaciation events in Eastern Finland during the Late Glacial time

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The dating of the deglaciation events in the Southern Finland end moraine zones have hitherto been based on 1) Finnish and Swedish floating varve chronologies Sauramo (1923), De Geer (1912) and their correlation Strömberg (1990), 2) ice-margin formations and Baltic Ice Lake sea-level changes (Donner 1969, 1995), 3) biostratigraphy and radiocarbon analyses Hyvärinen (1973), 4) ^{10}Be dating Rinterknecht *et al.* (2004) and 4) paleomagnetic dating Saarnisto & Saarinen (2001). During the cold Younger Dryas chorozone (12,910-11,640 BP) Alley *et al.* (1993) and the following long ice sheet stagnations two parallel end moraine ridges formed in Southern Finland Fig. 1. The end moraine ridges, Salpausselkä I (SS I) and Salpausselkä II (SS II), continue from Eastern Finland to Russian Karelian. These Russian Karelian end moraines, Rugozera and Kalevala, have been formed by a separate ice stream (Fig. 1). The ice lobes activity differed in many ways causing the plausible diachronous ice-marginal formation. For many decades, Eastern Finland deglaciation pattern has been debated due to its complexity. In this study we aim to determine the Late Glacial events in Eastern Finland by dating the formation of 8 lakes located in the SS I, the Rugozero end moraine and the interlobate area (Fig. 1). The lakes were selected to represent different positions of the retreating ice lobes. The main objectives of this research were: 1) to investigate the deglaciation history with paleomagnetic correlation of the 8 lake sediment sequences and 2) to encompass the palaeosecular variation in Finland 10,000-12,000 years ago. The changes in Earth´s magnetic field have been preserved in the lake sediments and the carrier of the natural remanent magnetization (NRM) is stable and strong. The palaeosecular dating is based on visual correlation to varve-based Lake Nautajärvi master-curve (0-9,550 BP) Ojala & Saarinen (2002). The radiocarbon dating was used to the lower sediment parts exceeding the correlative master-curve. Based on the dating of the lake basin isolations the Salpausselkä end moraines are diachronous with the Russian Karelian end moraines.

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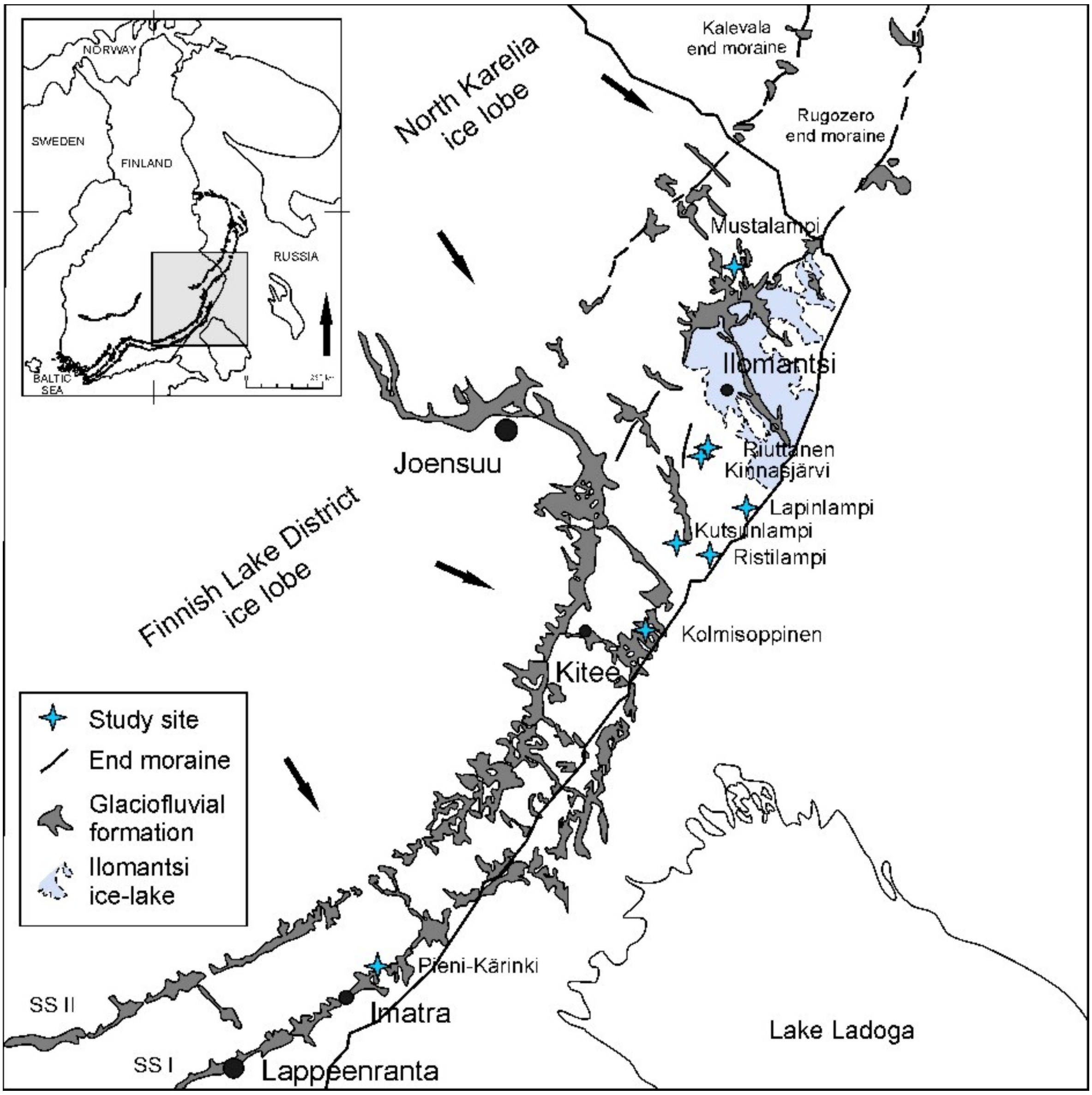

Fig. 1. End moraines (SS I=Salpausselkä I, SS II=Salpausselkä II), glaciofluvial formations and study sites. Sub-aquatic areas of the Ilomantsi ice-lake during the Late Glacial time.

Preglacial, glacial and postglacial landforms of NW Russia

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Geomorphological investigations were carried out in the frame of the State geological map compilation at 1:1,000 000 scale (third generation) for O-35 – Pskov, O-36 – Saint-Petersburg sheets. The research area is located in NW Russia and includes the northern part of the Baltic Lowland, the Valdai Hills and the southern part of the Gulf of Finland.

Investigations are based on the aerial photo and satellite image interpretation, field studies, analysis of geological and geophysical data.

Modern relief is presented by Middle-, Upper Pleistocene-Holocene plains of fluvial, lacustrine, marine and biogeneous accumulation, and hilly and ridge landforms of glacial and glaciofluvial genesis formed during Moskovskoe (Varta), Early and Late Valdaian (Weichselian) glaciations. Denudation plateaus were formed at places with thin Quternary cover. In process of research schemes of geomorphologic districts, glaciations, and glacial lakes have been created.

The geomorphologic appearance of study area was highly affected by the sub-Quaternary surface's structure, which predetermined ice flow directions, forming of ice marginal zones and interlobate uplands, and orographic pattern of observed relief.

In period of Neogene - Eopleistocene tectonic activity of the East European Plain and the Fennoscandian Crystalline Shield, triggered by the Alpine tectogenesis, remarkable regression of the World ocean took place. Investigations of the sea level changes in geological past show that ocean regressions, as a rule, coincided with orogenic periods. According to existing data, in Pliocene base level was 200 m lower than modern (Klige, 1980; Grigelis, 1991). That is why the sub-Quaternary surface is dissected by deep valleys (-106 m a.s.l. Saint-Petersburg, -130 m a.s.l. Ljubitino, <-55 the Ilmen lake depression and etc.) with V-shaped cross-sections.

In NW Europe main discharge of the paleoriver network went through the Baltic sea depression (Malahovskiy & Fedorov, 1984). Using geological and geophysical data, it has been possible to reconstruct paleoriver network, which had two general flow directions. The first one was related to main valley, stretched along western side of the Valdai Hills. That valley is characterized by deepest marks (-130 a.s.l. – borehole near Liubitino). Probably, at the beginning of tectonic activity, it was a base of the drainage system with outlet to the North (around present Ladoga lake) and then into the paleoriver system of the Baltic sea bottom.

Further tectonic movements could lead to uplift of the Beglovskiy swell, which is located to the east of the Ilmen lake. As a result, at the end of Pliocene – in Pleistocene the paleoriver network got outlet to the west – via paleovalley of the Shelon river (Verbitskiy *et al.* 2007) and further via the Gulf of Riga depression into the paleoriver system of the Baltic sea bottom.

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The ^{230}Th/U and ^{14}C dating of buried peat layer from the North-Western Russia and its stratigraphic significance (Tolokonka Site case study)

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The ^{230}Th/U radioisotope dating method has started to be applied in the beginning of 1980's (Vogel & Kronfeld 1980; Heijnis 1992). It allows dating of Neopleistocene Interglacial (interstadial) buried organic-rich deposits with the age up to 300-350 kyr whereas possibilities of ^{14}C method are limited to ~ 50 kyr. Buried peat and gyttja is rather complicated object for the ^{230}Th/U dating. Until now, the strict approach to practical use of this method is not possible and the ^{230}Th/U dating of these deposits did not become widely applied method. Therefore, it is very important to estimate the reliability of ^{230}Th/U dates applying simultaneously a complex of dating methods: e.g. ^{14}C and ^{230}Th/U dating of organic sediments with ages less than 50 kyr and OSL dating of the overlying and underlying sediment layers. Similar investigations were already carried out for lignite deposits located in Austria and Switzerland (Geyh & Schluchter, 1998).

The object of our geochronological study was the buried peat layer from the Tolokonka section (N 61^{0}46,25', E 45^{0}26') located on the right bank of the North Dvina River about 100 km down stream from Kotlas City. A river bank is orientated NW-SE, height up to 25-30 m above the river water level. Stratigraphy of the studied section is presented in Fig. 1.

The main objectives of our study were:

- A cross-dating of the buried peat by both ^{230}Th/U and ^{14}C methods and OSL dating of the overlying and underlying layers.
- Comparison of both ^{230}Th/U and ^{14}C ages (and with OSL dates) obtained for checking whether reliable ^{230}Th/U dates can be determined from buried peats.
- Estimation of chronostratigraphic position of the dated organic layer.

The ^{14}C dates determined from the bottom and the top of peat layer are 37.8±0.6 kyr and 33.27±0.35 kyr corresponding calibrated ages 42.5±0.6 kyr and 38.5±0.4 kyr respectively.

Two ^{230}Th/U dates 39.1+/-7.6/6.6 kyr and 42.5+/-2.8/2.7 kyr were calculated according to the new version of isochron approximation. This approximation is based on agreement of isochron-corrected ^{230}Th/U ages obtained for the same duplicate samples, which had been analyzed by the "leachate alone" (L/L) and "total sample dissolution" (TSD) techniques (Kuznetsov & Maksimov, 2003; Maksimov et al. 2006).

The OSL dates determined from the overlying layer are 12-16 kyr and from the underlying layer are 73±10 kyr and 78±10 kyr.

The results of ^{14}C and ^{230}Th/U are in a good agreement. It is seen on the summary diagram of the Tolokonka section (Fig. 1) that all the dates (OSL, ^{230}Th/U-, ^{14}C) fit to the stratigraphic sequence.

The both ^{230}Th/U and ^{14}C dates testify that time of peat formation took place during Tyrybeyan warm period of Valdai (Weichselian, Würm) glacial age which correlates to the MIS-3.

The data obtained confirms the possibility of applying the new version of the ^{230}Th/U dating of buried organic-rich sediments with age up to 300-350 kyr and create perspectives to solve disputable questions of chronostratigraphy of Middle and Upper Neopleistocene.

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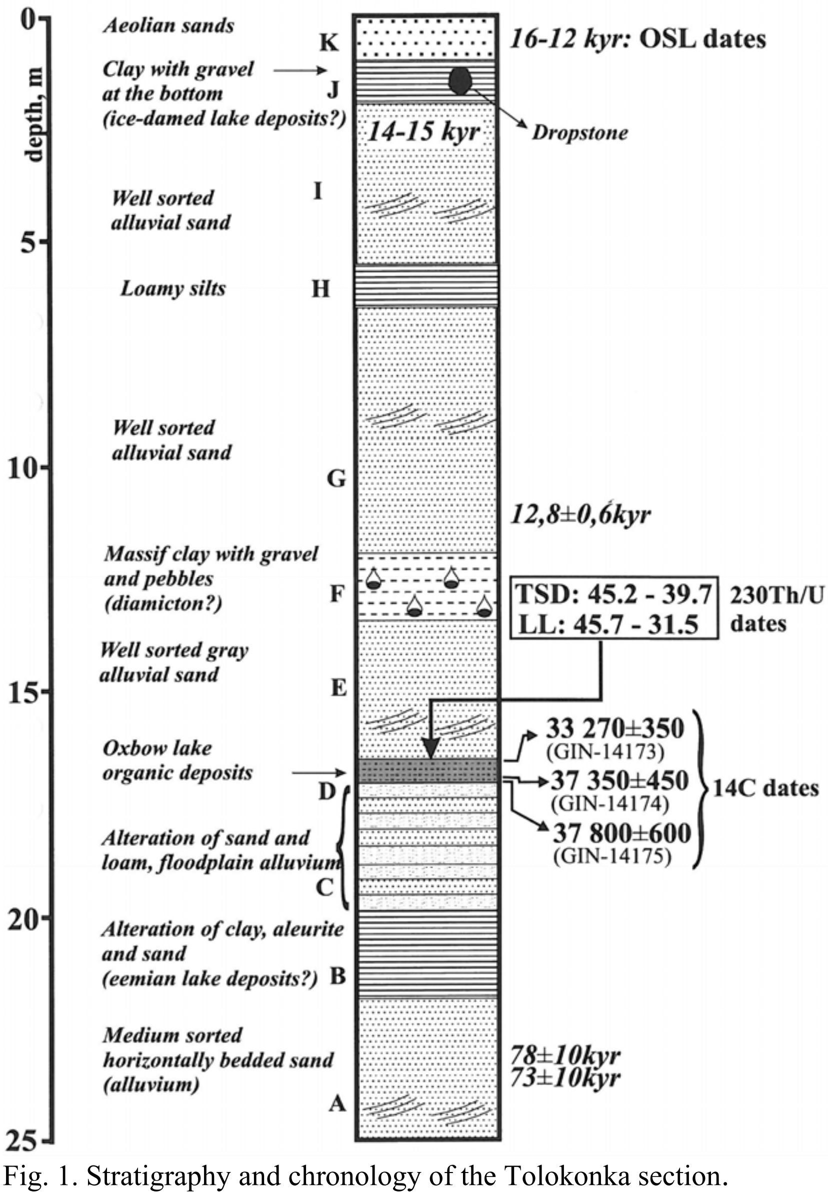

Fig. 1. Stratigraphy and chronology of the Tolokonka section.

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Glacial landforms of the Madliena Tilted Plain, Central Latvian Lowland

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This research focuses on the morphology, spatial distribution and some aspects of the internal composition of the glacial landforms of the NE part of the Central Latvian Lowland, known as the Madliena Tilted Plain.

The elevation data for identification and digitization of the glacial topographic features were derived from the topographical maps of scale 1: 25,000 by using ArcView software. There were mapped 1353 glacial landforms such as drumlins, terminal moraines, recessional moraines, lateral shear moraines, eskers and some others. The landform mapping resulted in the data being stored in GIS layers as 'shapefiles': the layers containing landforms expressed by their bounding break of slope as GIS polygons and conforming to the LKS92/Latvia TM projection.

Most of the mapped landforms are of glaciotectonic origin. Their formation is contributed by lateral ice compression along western slope of the Vidzeme Upland and by uneven permeability of bedrock and Pleistocene strata. That cause level variations of pore water what has resulted in spotty bed deformation and basal decoupling. The field observations of sand pits prove that the Late Weichselian Riga (Zemgale) ice lobe flow emerged from a combination and fluctuation in time of subglacial bed deformation and basal sliding, by mechanism mentioned by Rattas & Piotrowski (2003).

The thickness of glacial sediments in the Madliena Tilted Plain varies from 5 m to 60 m, on average it is 20 m. The Pleistocene deposits are composed mainly of the Late Weichselian till with interlayers of glacioaquatic sediments.

The greatest part of the Madliena Tilted Plain is occupied by drumlins, what forms the Madliena drumlin field composed of about 900 drumlins covering an area of 1248 km^2. The length of the field is 70 km, whereas the width increases from 5 km in Nup to 33 km towards S and decreases to 18 km at the distal end. Most attention in this study was paid to the morphology of the drumlins.

The drumlin field is bordered by the Vidzeme Upland along its eastern side, while the western side is transgressively covered by the Linkuva end moraine (Āboltiņš 1970) of the Linkuva or North Lithuanian reactivation phase. The northern and southern boundaries of the drumlin field are marked by the Gauja and Daugava River valleys.

The Madliena drumlin field is situated on an uneven slope of bedrock. The bedrock surface declines from 85 m to 30 m above sea level towards the southwest. The bedrock of the research area is a variety of Upper Devonian sandstone and dolomite. Bedrock influence on drumlin distribution, spatial arrangement and morphology is not established.

Drumlins are widely distributed in the whole Latvia and they are originated as a result of multiphase glaciotectonic deformation, how it is revealed by Zelčs (1993) and Zelčs & Dreimanis (1997), as well as drumlins of the Madliena drumlin field are complex glaciotectonic formations. Theyare originated during Middle Lithuanian (local term – Gulbene) deglaciation phase of the Late Weichselian glaciation by the reactivation of the Riga ice lobe. Most drumlins are cored by glacioteconically dislocated Pleistocenedeposits, that mainlyconsist of sand or gravel; the flanks are covered by deformation till.

A geographic information system (ArcView) was used to collect a range of parameters on drumlins. Shape parameters of each drumlin were compiled into an attribute table included the length and width, which were measured from the GIS polygons and elongation ratio (length/width).Elongation ratio was calculated by GIS from these parameters.

A mean length of drumlins is found to be 810 m,a mean width is 320 m. A mean elongation ratio is 2.62, varying between 1 and 11.4. Most drumlins are between 200 and 1500 m in a length; between 100 and 600 m in a width; and between 1.5 and 5 times as long as it is wide. The most frequent length is 400 m, width is 200 and elongation ratio is 2.5. The longest drumlin is 5.76 km long, and the widest is 2.04 km wide. These measurements are not normally distributed around the mean value; all have a strong positive skew and are markedly peaked.

The internal composition of drumlins was studied in the Brenceni sand pit. There were done directional measurements of planar structural elements on the strata compositing the drumlin. The internal composition was tested also by drilling and radiolocation by ground-penetrating radar. The highest part of drumlin is the stoss side; it is mainly composed of fine sand with interlayers of till. This material is squeezed out of glacier bed. The flanks of drumlin are made by thrusts of sand and till. The ice pressure was oriented from inter-drumlin depression during formation of the drumlin core and flanks.

The landforms situated in the western part of the Madliena Tilted Plain are recognized as recessional moraines which formed during the subsequent ice retreat from the Linkuva push moraine. Recessional moraines are few hundreds to 5 km long and by tens up to one thousand meters wide.A few hundreds of meters wide landforms are predominant. The distance between recessional moraines also are a few hundreds of meters. It is assumed that the rate of ice retreat was up to a few hundreds of meters in a year.

There were obtained 3 samples for OSL dating in Brenceni, Zadzene and Silgali sand pits during field works. In all cases OSL samples were collected from well sorted fine grained sand layers. All of the samples were processed at the University of Helsinki Dating Laboratory.

To specify the direction of ice flow in research area, 55 measurements of glacial striae in Turkalne dolomite pit were done. The resulting azimuth indicates on ice flow direction of NW to SE, conforming with general trend of the orientation of drumlins.

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Onset of Late Weichselian Glaciation on the western part of Russian Plain

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Based on our dating database a possible timing of the onset and development of Late Weichselian Glaciation on the western part of Russian Plain is suggested. Chronological data on lower limiting ages of the glaciation were sorted into two parallel, northwest–southeast oriented zones, A and B (Fig. 1). In our scenario we used OSL and calibrated ^{14}C ages of sediments which are between the following two main time-horizons: 1) beginning of the Marine Isotope Stage 3.3 at ca. 35 cal kyr BP (Lambeck *et al.* 2010), when the western part of Russian Plain was ice-free, and 2) age of the LGM for Scandinavian Ice Sheet (SIS) in the study area, which varies from 22.3 to 19.2 cal kyr BP (Rinterknecht *et al.* 2007). Two parallel time-distance diagrams were built in the direction of general ice advance from northwest (Fig. 1). The diagrams are based on 56 OSL and 94 calibrated ^{14}C ages. From the available chronological data next general conclusion can be derived:

1. Last SIS reached western shores of current Eastern Baltics (e.g. Ulmale site in Western Latvia) not before 26 kyr;
2. Last SIS advanced to northern shores of Gulf of Finland not before 21 kyr;
3. Calculated average linear advance rate of the ice from the mentioned sites (Western Latvia, Gulf of Finland) to respective LGM positions ranges from 103 to 433 m/yr.

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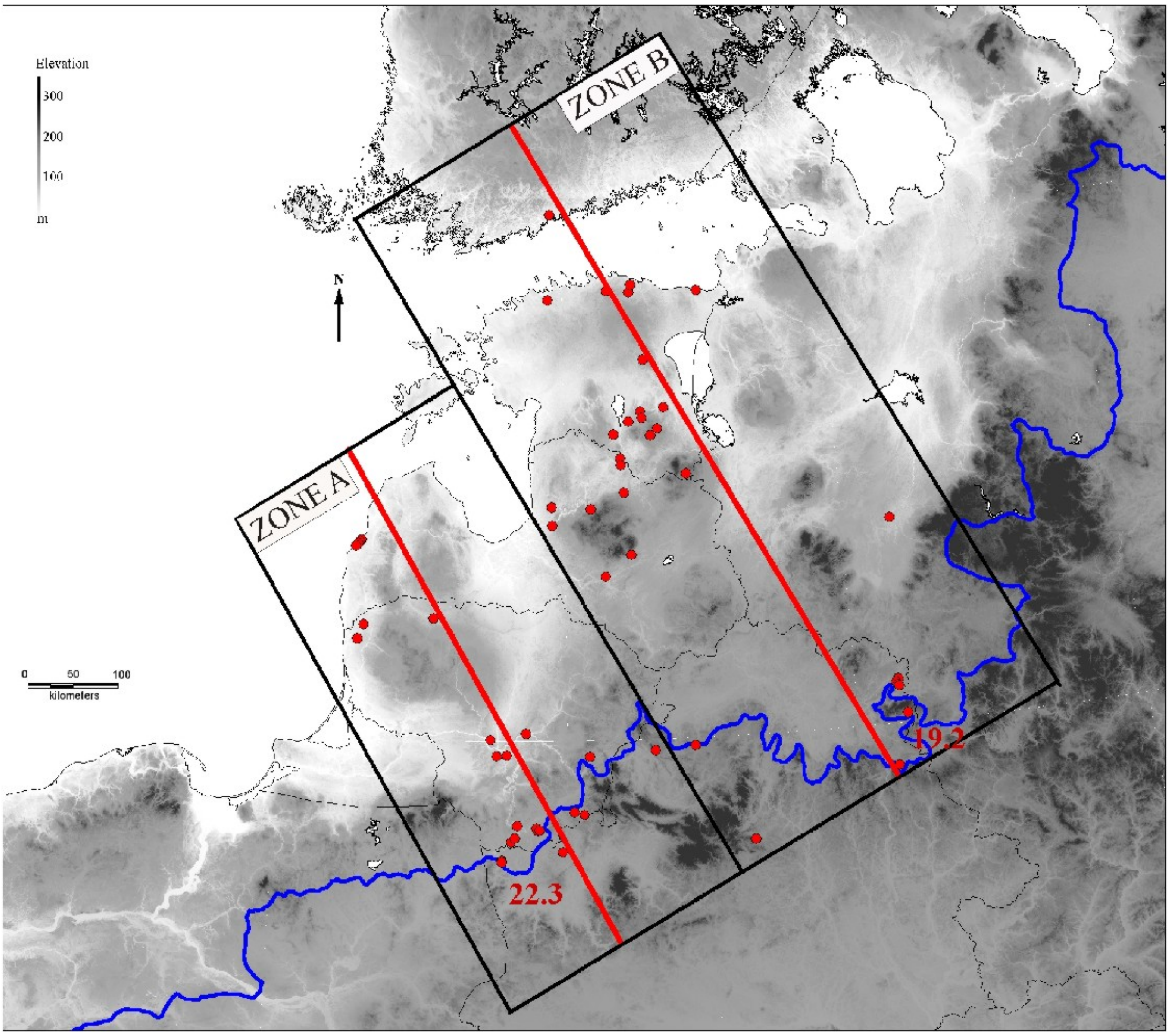

Fig. 1 Study area with zones A and B. Red lines denote orientation of time-distance diagrams that illustrate the onset of Late Weichselian glaciation. Blue line marks LGM position with suggested ages of attaining it by SIS. Red dots indicate location of dated sections, used in this study.

New sediment sections in the easternmost part of the Gulf of Finland – a contribution to the studies of the post-glacial history of the Baltic Sea

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About 100 years have passed since the pioneer studies of the ancient shorelines of the eastern part of the Gulf of Finland were performed by G. De Geer (1894) and J. Ailio (1915). During this period, a number of works has been carried out in the region aimed at reconstructing the history of the Baltic palaeo-basins. Along the Russian part of the southern coast of the Gulf of Finland, in particular, thorough geological and geomorphological investigations of the 1920s enabled to trace the shorelines of the Baltic Ice Lake and the Littorina Sea, above 30 m and at 10 m a.s.l (above sea level), respectively (synthesised in Markov, 1931). In turn, Yoldia Sea sediments were only found below the present sea level due to the lowstand of the Ocean in the Early Holocene and minor isostatic uplift of the area, while the Ancylus Lake shorelines are often discrete and can be easily confused with the Littorina ones (Apukhtin & Sammet 1967). Recent studies of lacustrine sediments in the Luga Lowland revealed two phases of the Littorina transgression, the highest one having reached at least 10 m (Sandgren *et al.* 2004). On the contrary, only single transgression was suggested by K. Markov (1931; boreholes, outcrops), H. Kessel & J.-M. Punning (1976; outcrops) and lately by A. Miettinen (2002; lake sediments).

The present study is focused on lithostratigraphies and preliminary results of the diatom analysis of 3 new terrestrial sections located at different elevations in the Luga-Narva Lowland, and the following tasks are hoped to be further fulfilled: 1) find a signal of the second wave of the Littorina transgression, 2) confirm the highest transgression level of the Littorina Sea, and 3) try to distinguished between the Ancylus and Littorina shorelines.

Palynological characteristics of the Middle Valdai (Leningradian) deposits in the Komi Republic, north-western Russia

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The palynological study of the Middle Valdai (Leningradian) deposits, located in Komi Republic, shows the following vegetation changes through time:

After the deglaciation of the Lower Valdai (Podporogjskii) glacier vegetation was composed of birch, tundra and bog vegetation assemblages. The bush and grass associations were developed (phase Bz_I). The complex reflects a cold climate.

The subsequent warming resulted in increasing of trees. The pollen of birch *Betula* sect. *Albae* had the greatest value, its values reached 65 % in the north of the studied territory. The amount of coniferous species *Pinus sylvestris* and *Picea* sp. were considerable, the presentage of the firs increased north-eastwards. Sparse occurrence of *Tilia, Ulmus, Corylus* was in the pollen spectra of southern sections. This indicates that the wood groups were widely distributed (phase Bz_{II}).

The climate deterioration resulted in predominance of birches, especially *Betula* sect. *Nanae* (to 30 %). The firs and pine-trees pollen content decreases gradually and in the north of territory they are rare. Among grasses the wormwood content increases. Wood groupings are not dominating and birch-formed light forests changed them. Bog-tundra formations and xerophytic communities (phase Bz_{III}) were widely distributed.

Further warming promoted distribution of tree species, first of all *Betula* sect. *Albae*. The increase in participation of coniferous breeds is noted. The pollen of broad-leaved *Tilia, Ulmus, Corylus* was rare. The structure of grassy plants in the south of territory is homogeneous. The pollen of mesophilic herbage prevailed. However, elements of xerophytic periglacial flora increased northwards. Thus at this time wood groupings seemed to be widely developed (phase Bz_{IV}).

During the next deterioration of climate the tree species decreased in the south of the territory. The presentage of trees strongly decreased in the north. They were either absent, or observed in insignificant quantities. The species of genera *Betulaceae* prevailed among trees and the coniferous species were rare. The presentage of pine gradually increased in the southern areas. Small birch-pine and fir-tree communities were basic components in vegetatition in the south of the region. The tundra-components dominated in the north (phase Bz_V).

The subsequent warming resulted in the domination of wood forms of birches, the increase of coniferous species, especially in the southern pollen spectra. The cereals and wormwood prevailed in the composition of grassy plants. Thus, the various wood groupings: birch, birch-fir-tree, birch-pine were the basic components of the vegetation in the south of the territory and birch, pine and fir-tree light forests in the north (phase Bz_{VI}).

The advantage of the Upper Valdai (Ostaschkovskii) glacier from the north caused a rapid cooling. The tree pollen percentage strongly decreased or was absolutely absent. The pollen of under wood birches dominated among the latter. The grains with undeveloped air bags or considerable number of air bags were noted among the pine pollen with normally developed forms. There are almost no xerophytic forms (ice-holes, *Chenopodiaceae*); cereals are dominating; the percentage and variety of mesophilic herbage pollen decreased. The birch light forests and various under wood groupings were the basic components of the vegetation cover. The hygrophilic grassy associations were considerably developed, that is close to forest-tundra and tundra zone (phase Bz_{VII}).

Thus, received palynological material of northern and southern areas of the studied territory indicated the existence of general law in the change of phases of vegetation. The vegetation in warming periods reflected rather cold climate and characteristic distribution of rare boreal taiga wood formations with groupings of southern under wood tundra.

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Internal structure and palaeogeographical conditions of plateau-like hills formation in interlobate isometric uplands of Latvia

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Plateau-like hills belong to the most prominent continental ice formations in the areas covered by Pleistocene ice sheets. These landforms are particularly common for the insular isometric uplands. The plateau-like hills usually form the hypsometrically highest areas of these uplands.

The results of the internal composition are obtained from field investigations. These investigations are aimed to find out information helping in reconstruction of the formation conditions of the plateau-like hills. The examination of the internal structure of the base of plateau-like hills was mainly based on boreholes data. The topmost part of the base, bedding contacts between baseforming deposits and capping beds of glaciolacustrine sediments were studied in details in clay and gravel pits.

In general the base of the plateau-like hills is built-up by glaciotectonic structure. This glaciotectonic moulding forms up to two thirds of the relative height of hills. The main landforming-structures of individual hills are asymmetric folds that incline to the direction of the ice flow or complex of imbricate thrusts, or rafted megablocks of glacial strata with thrust planes dipping upglacier. The subsequent imbricate scales on the upglacier slopes of asymmetric landforming folds can also be detected. The uneven surface of the glaciotectonic base is mantled by glaciolacustrine sediments. The thickness of clayey and silty sediments, in some places with lense-like sand and gravel inclusions, varies in wide range – from some tens centimeters up to 28.5 m. Thickness of coarser grained, suposedly deposited by meltwater streams, deposit increases, but glaciolacustrine sediment cover is thinning out down slope.

On the basis of internal structure the plateau-like hills can be certainly defined as glacial landforms of complex genesis and composition, as it is previosly note by Āboltiņš & Markots (1995), Bitinas (1994) and Markots (2010). Their formation was started at the initial stages of the insular deglaciation (according to the terminology used by Āboltiņš 1975) of the last Fennoscandian Ice Sheet when shrinkage of the glacier ice started in the inner parts of the interlobate isometric uplands as lessening of the ice thickness and appearance of the stagnant ice marking the transition from the glacier bed deformation to formation of the subglacial and supraglacial meltwater lakes.

The spatial arrangement of the plateau-like hills, the morphological asymmetry and composition of the glaciostructures point at least to two phenomena connected with the genesis of the plateau-like hills. First of all, the asymmetric glaciotectonic folds composing the glaciotectonic base which planes are directed perpendicularly to the ice flow direction have been formed under the condition of the unilateral compressive ice flow. Secondly, the formation of the recessional type imbricate scale complexes that comprise the glacier bed sediments and locate on the downglacier flanks of the glaciotectonic folds suggest the gradual calming down of ice mass activity.

The results obtained leave open the possibility of the sediment deposition in supraglacial basins within the border of the stagnant ice fields. They rather suggest the model of the meltwater clayey and silty sediments accumulation in the subglacial meltwater escape zones. Such subglacial meltwater discharge zones could be related to the fault surface of the imbricate scale and megablock structures produced in the migrating transitional zone between active and passive ice. Here, due to the development of subglacial pot-holes and subsequent formation of the crevasses in front of glaciotectonic obstacles in a glacier bed, and because of the different gradients of the hydrostatic and hydrodynamic pressure, the subglacial meltwaters flew away transporting also the eroded material to glacier surface. The meltwater erosinal activity and solar radiation enhanced widening of the crevasses and the appearance of much broader irrigated areas in the marginal zones of ice lobes and ice tongues.

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A succession of Lateglacial ice-dammed lakes in north Vidzeme, Latvia

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Development of the Late Weichselian ice-dammed lakes in north Vidzeme started during retreat of Middle Gauja glacier lobe from the Gulbene phase maximum extent line. Sediments of ice-dammed lake with water levels of 130 m and 120-122 m are present only along the southern margin of the Middle Gauja ice lobe. As the ice margin retreated to NNW, lake level was gradually falling approximately to 117 m, 110 m and 89-91 m. Since the lakes were quite shallow, the most information about their spatial distribution and development comes from sedimentary records or is derived from various morphological indicators, particularly delta levels. There is no evidence of the existence of large ice-dammed lakes with similar water levels in the area NW of the Aumeisteri Interlobate Heights at the margin of the Burtnieks glacier lobe during the Linkuva (North Lithuania) deglaciation phase.

During deglaciation that followed the North Lithuanian reactivation of the Burtnieks glacier lobe, a succession of ice-dammed lakes formed to the northwest of the Vidzeme Upland. The main evidence for this lake succession consists of abandoned shorelines at altitudes of 75 m, 70 m and 65 m, 60 m and 52 m above sea level. The altitudes of these shorelines correspond with altitudes of terraces of the outflows and deltas of the inflowing rivers. As indirect information for reconstruction of water levels of ice-dammed lakes has been used geomorphological correlation of eroded surfaces of various glacial landforms referencing on modern topography and location of glaciolacustrine sediments. Experimental simulations of the proglacial meltwater basins and related drainage levels based on GIS with removing of isostatically deformed palaeowater planes from the modern DTM reveal need of substantial revision of the previous interpretation of the proglacial drainage system development and correlation of the shorelines of ice-dammed lakes.

It was considered that the isolated ice-dammed lakes at 85-90 m were formed along the northern, southern and eastern margin of glacier ice of the downwasting Burtnieks lobe. The lowest ice-dammed lake was drained by the Gauja spillway valley.

Formation of the Late Weichselian (Valdai) glacial relief and deposits in the mountains of the Kola Peninsula (based on lithology analysis)

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The Kola Peninsula has repeatedly been affected by major glaciations during the Quaternary. As a consequence of considerable thickness of the Quaternary ice sheets, the area underwent an intense exaration. This led to the fact that each subsequent glaciation erased the traces of previous one. Therefore, the most examined sections of Quaternary deposits cover only Late Pleistocene and Holocene.

Traces of the last (Late Valdai) glaciations are better conserved in the relief and sediments. That allows to create detailed paleogeographic reconstructions for this time. Despite of the good geomorphological and geological scrutiny of the peninsula, there are still many controversial issues concerning the selection stages of the last glaciation, relations of Ice Sheet and mountain glaciers, conditions of its existence and degradation, formation of Quaternary deposits.

The main aim of this research is to identify the structural features and distribution of glacial relief and friable sediments for the purpose of reconstruction their formation conditions. This investigation was based on materials collected during the field studies on the Kola Peninsula in 2009-2010. Research methods included geomorphological study of glacial landforms and lithology analysis. Published sources were also used. The main method of the research was a lithology analysis of glacial deposits, which included a fractional particle size analysis on Baturin scale, petrographic analysis of the clastic material and study of texture features. Study of lithological features of glacial sediments can receive valuable information about ice sheets spatial distribution, the nature of the clastic material transport and its sediment conditions used for specification conditions of relief formation and friable deposits in Late Pleistocene - Holocene.

The research area included Khibiny and Lovozero Tundras and the surrounding plains, located in central part of the Kola Peninsula. Key areas are located in the southern and southeastern parts of Khibiny Mountains and Prihibinskaya plain and the western Lovozero Mountains.

Khibiny and Lovozero Tundras rise over the surrounding plain by 1000-1100 m. The main feature of relief is plateau-like shape peaks, divided by valleys and cirques into several separate massifs. More or less continuous cover of glacial deposits is observed up to a height of 550-600 m and 700 m above sea level (Armand 1964). Below this border ice formation covers all sloping areas and create their accumulative relief. End moraines, side moraines, moraine hills, eskers and kames, fluvioglacial deltas, proglacial terraces, coastal lakes and trees, etc are referred to accumulative relief (Romanenko *et al*. 2004).

Main features of relief in this area were formed primarily in the pre-glacial times. Glacial activity appeared in smoothing of mountainous relief and sediment accumulation in large valleys, on the exterior slopes and surrounding plains. Traces of the earliest – Middle Pleistocene – glaciers are found only in deep depressions of bedrock relief (Yevzerov, Nicolaeva 2010). The last glaciation is divided into two stages. During the first stage ice sheet had a maximum thickness and overlapped the top of plateau-like massif. Erratic boulders on the plateau and moraine at the bottom of some Quaternary deposits sections are the traces of that stage. During the second stage ice sheet reached the middle part of the slope. At the same time, as well as afterwards, in large valleys there were mountain-valley glaciations (Armand 1964). As a result, after the degradation of last glaciation in this area glacial relief was formed by unconsolidated sediments.

The complex of friable glacial deposits is represented by moraine and melt water (fluvioglacial and limnoglacial) genetic types. Thickness of the Quaternary deposits ranges from zero to hundreds of meters. At the bottom and on the slopes of mountain valleys unsorted moraines of two types are found: mountain and cover glaciation, composing a variety of hilly ridges and ridge relief complexes. Melted water flows were of primary importance in shaping relief. They formed complexes of fluvioglacial deposits as on the exterior slopes of the massif as on piedmont plains and interior valleys.

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An example of applied Quaternary geology project: Testing of different soil combinations as substrates in slalom slopes and golf courses

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The Geological Survey of Finland (GTK) was, with some partners, carrying out a cooperative project, POMARA, in the Levi tourist centre in northern Finland during 2008-2010. The purpose of this applied geology project was to determine which soil combinations work best over the long term as substrates on slalom slopes and golf course areas in a cold climate environment. The monitoring studies of the test areas on the slalom slopes and golf courses included the measuring of water content and temperature and also some measurements of deflection.

In the slalom slopes the most important task was to compare test areas covered by:

1. Carex peat
2. Combination of sandy till and Carex peat

Results are telling that during summer time water content of Carex peat is remarkably higher than in the combination of Carex peat and sandy till. On the other hand, during spring time the combination of Carex peat and sandy till is thawing earlier than Carex peat. But when looking the growth of vegetation, the Carex peat area is growing better than the combination of Carex peat and sandy till. In that way Carex peat seems to be better, but in the long run it will be interesting to follow if the combination of Carex peat and sandy till will stand up better against frost weathering than peat itself.

In the golf course areas the main task was to compare test areas consisting of:

1. Fine sand and Sphagnum peat
2. Fine sand and Carex peat

During the growing season the water content in test areas consisting of fine sand and Carex peat was a little bit higher than in fine sand and Sphagnum peat. In temperatures no clear differences between the testing areas were detected. Growing of the green was good in both combinations. In the combination of fine sand and Carex peat the flexibility of green was higher.

GTK's partners in the project were Oy Levi Ski Resort, Levi Golf & Country Club Oy, the local water supply and sewerage company, the Municipality of Kittila and Tampere University of Technology. The project was partly funded by the European Regional Development Fund program. Follow-up research will continue afterwards.

Palaeogeographical development of geomorphological districts in South Lithuania

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Many publications have been dedicated to Late Pleistocene palaeogeography in South Lithuania. Environment conditions during the Late Pleistocene and Holocene were summarize in the scientific programme"Stone Age in South Lithuania'' (Baltrūnas 2001). The purpose of it was investigation of the settling of people and their living conditions in South Lithuania, relation of the inhabiting of this territory with the global and regional glacial epoch and post-glacial natural phenomena.

South Lithuanian surface is rather heterogeneous in its age, origin, and composition and associated with the different palaeogeographical history of a few glaciations and post-glacial geological processes. The glacigenic formations of penultimate glaciation (Medininkai, Saalian) are spread in the southeastern part of investigation area. They represent the most ancient sediments in Lithuania, which have endured long-lasting periglacial conditions (cryogenesis, solifluction, glaciokarst, erosion, deflation, bogging up, etc.). The recurring permafrost and cryogenic structures in the ground were an important phenomenon. Ice wedges and veins, pseudomorphoses, involutions and other cryogenic structures formed in permafrost – affected ground (Švedas 2001). The glacigenic formations of the Last (Nemunas, Weichselian) Glaciation are widely spread and found in the middle and northwestern part of South Lithuania. The northwestern part – the impact of glacigenic sedimentation of the Grūda (Brandenburg) and Baltic (Pomeranian) stages of the Last (Nemunas, Weichselian) Glaciation (Baltrūnas 2001; Baltrūnas *et al*. 2007). The middle part of South Lithuania - the Southeastern sandy Plain – extending from southwest to northeast – was formed by very intensive melt water erosional and accumulative (glaciofluvial and glaciolacustrine) and, later, intensive aeolian and bog formation processes. It endured intensive interstadial erosion and accumulation, glacier exaration and sedimentation, accumulation in glaciofluvial sandurs and cascade glaciolacustrine basins. At the end of late glaciation – repeated glaciofluvial (alluvial) erosion and accumulation, which left a great number of terraces over flood plains of Middle Nemunas and Lower Merkys (Švedas *et al*, 2004).

The Early Holocene was marked by the last intensive relief forming processes – glaciokarst and aeolian. The glaciokarst processes lasted in Lithuania for a long time and transformed the morphological features of South Lithuania river valleys. The buried ice finally melted only in Boreal.

The dynamics of the spread of Pleistocene glaciers was very important not only for development of Lithuania relief, but for settlement of people too. The Stone Age camps have been found on periglacial lakes, upper fluvioglacial terraces, outwash plains, breakthrough valleys connecting lakes, middle fluvioglacial terraces, lower and first terraces, floodplain terraces in river valleys (Baltrūnas (ed.), 2001).

Taking into consideration the differences of relief age, origin and composition the following six geomorphological districts are distinguished in South Lithuania: Medininkai (Ašmena) Upland, Eišiškės (Lyda) Plateau, Southeastern (Dainava) Plain, South Lithuanian Upland, and Middle Nemunas Plateau (Basalykas 1965, 1987; Lietuvos TSR atlasas 1981). Each of these regions is subdivided into microdistricts, which unite genetically and morphologically comparable lithological and geomorphological complexes of the same age. Sixty nine microdistricts, differing pin geomorphological and geological specific features and human economic activity, were distinguished (Pukelytė 2001).

Now Nature Research Centre of Lithuania is working on a new project of the National programme "The effect of anthropogenic factors on the development of invasive species in the context of the palaeoecosystem history throughout the Holocene (2010-2012)".

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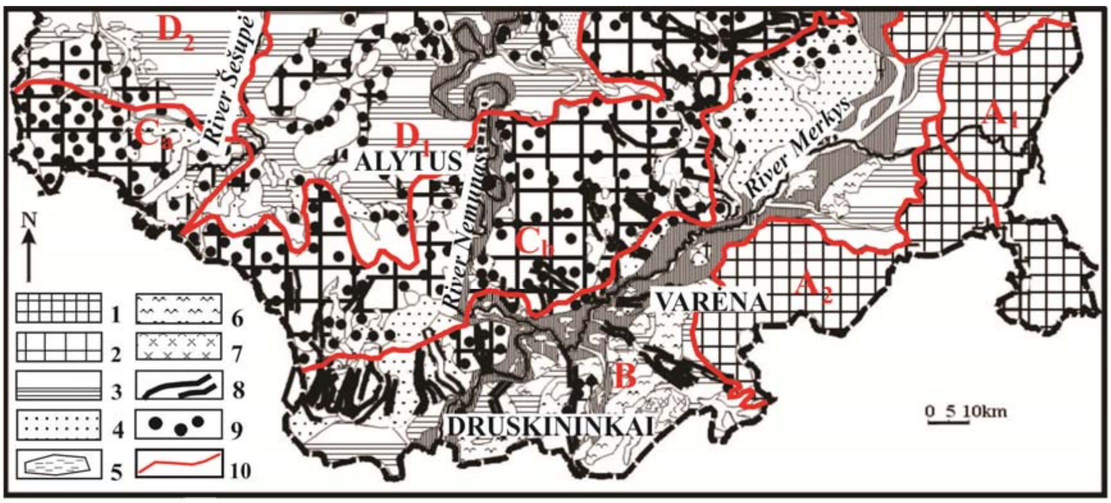

Fig. 1. Palaeogeographical situation of Boreal in South Lithuania: 1 – hilly relief marginal deposits of next-to-last (Medininkai, Saalian) glaciation formed cryogenic and solifluction processes; 2 – hilly relief marginal deposits of Last (Nemunas, Weichselian) Glaciation; 3 – glaciolacustrine plain; 4 - sandur (glaciofluvial) plain; 5 - lake; 6 – formed aeolian relief; 7 – moor plain; 8 – renewing tunnel valleys; 9 – glaciokarst phenomenon; 10 – geomorphological districts: A – uplands of last but one glaciation: A_1 – Ašmena Upland, A_2 - Lyda Plateau; B – plains of last glaciation: Southeast (Dainava) Plain; C –marginal till hills of last glaciation: South Lithuanian Upland (C_a – Sūduva Upland, C_b – Dzūkija Upland); D – Baltic lowlands: D_1 – the Middle Nemunas Plateau, D_2 – the Lower Nemunas Plain.

Deglaciation chronology of Younger Dryas end moraines in Kalevala region, NW Russia

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Three lake basins were cored in the Kalevala area, northwestern Russia in order to determine the Weichselian deglaciation history of the eastern flank of the Scandinavian Ice Sheet and to date the Kalevala and Pääjärvi end moraines adjacent to these basins. Two of the lake basins, Ala-Kuittijärvi and Keski-Kuittijärvi are situated on the proximal side of the Kalevala end moraine while the third lake basin, Tuoppajärvi, is located on the distal side of the Pääjärvi end moraine e.g. Putkinen & Lunkka (2008). One site from each lake basin was chosen for sedimentological and chronological study. The chronology based on palaeomagnetic measurements and counting of varved clays and the results are compared to the Finnish palaeomagnetic master curve.

The results indicate that the deglaciation sediments in the Ala- and Keski Kuittijärvi lakes were deposited mainly by extra-marginal rivers, while those in Tuoppajärvi were deposited in an ice-contact setting. After the glacial melt water input ceased, typical large-lake gyttja clay/clay gyttja sediment accumulated in all three basins. The palaeomagnetic record obtained from the Ala-Kuittijärvi sediment sequence extends back to 10,800 cal. BP, while that of Keski-Kuittijärvi and Tuoppajärvi back to 9,800 cal. BP. The palaeomagnetic record, together with 450 counted varves in Ala-Kuittijärvi, indicates that the basin was deglaciated at 11,250 cal. BP and the Kalevala end moraine was formed between 11,400 – 11,300 cal. BP while the Pääjärvi end moraine, west of Tuoppajärvi was formed at 11,000 cal. BP. It is shown that the Kalevala and Pääjärvi end moraines are not time equivalents of the Younger Dryas-age Salpausselkä I and II moraines in southern Finland. It is suggested that Kalevala end moraine was formed at the same time as the Pielinen end moraine and possibly the Salpausselkä III i.e. 11,400 – 11,300 cal. BP.

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Timing of deglaciation in North Estonia

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Deglaciation pattern of the Scandinavian Ice Sheet is well reconstructed in Estonia. Five ice marginal zones (Haanja, Otepää, Sakala, Pandivere and Palivere) have been distinguished and their age determined (Kalm 2006). The aim of the current study was to highlight the age of ice recession in North Estonia on the base of newly obtained AMS dates from four sites. As marginal zones composed of minerogenic sediments, lack of datable by radiocarbon techniques material, proglacial lake sediments were dated. Due to scarcity of terrestrial plant macrofossils preserved in the Late Glacial sediments, the number of AMS ^{14}C dates is still scanty and prevents to work out more precise chronostratigraphy and ice recession chronology in Estonia. Recently the Late Glacial chronostratigraphy has been set up for Haljala (Saarse *et al*. 2009), Udriku (Amon & Saarse 2010), Prossa and Tõdva sequences (Fig. 1).

Among mentioned sites, Prossa in the Saadjärv Drumlin Field deglaciated first. According to Rosentau *et al*. (2007) Saadjärv Drumlin Field between the Otepää and Pandivere ice marginal zones started to deglaciate 14,000–13,800 cal yr BP. AMS dates from Prossa confirm that varved clay and laminated silt deposited earlier, before 14,300–14,200 cal yr BP. This age is in good accord with that suggested to the Otepää stage (14,700–14,500 cal yr BP; Kalm 2006).

The age of the Pandivere ice marginal zone has been adjusted relying on the AMS ^{14}C dates from Haljala and Udriku sites (Saarse *et al*. 2009; Amon & Saarse 2010). Results from both sites support the idea that ice retreated from the northern slope of the Pandivere Upland not later than 13,800 cal yr BP or 300–500 years earlier than previously suggested. Taking into consideration distance between Prossa and Udriku and start of sedimentation, ice recession rate was ca 150 m yr^{-1}, in case if retreat was more or less frontal and continuous.

The chronology of the Palivere ice marginal zone has remained a matter of speculation for a long time, because different dating methods yielded variable results. At first, it was proposed that the Palivere ice advance commenced about 11,200 ^{14}C BP and was correlated with the Vimmerby advance in Sweden (Serebryanny & Raukas 1966), contrast to Swedish researchers who correlated Palivere with the Levene Moraines (Berglund 1979). Vimmerby age was lately adjusted using terrestrial cosmogenic nuclide (^{10}Be) method and dated to 14,000 yr (Johnsen *et al*. 2009). ^{10}Be technique, utilized also in Estonia, yielded results from 5,200 to 15,200 years with a mean of 13,600±1,200 for the Palivere zone (Rinterknecht *et al*. 2006). Dating of glaciofluvial deposits by OSL method also showed different ages (Raukas & Stankowski 2005). Lately Raukas (2009) supposed that Palivere ice marginal belt was formed about 11,500 ^{14}C BP and Estonia became free of ice cover in the second half of the Allerød. Kalm (2006) suggested that the Palivere zone was formed later, about 12,700–12,800 cal yr BP and according to varve chronology about 11,800 (Hang & Sandgren 1996). Three terrestrial macroremain samples from the Tõdva site within the Palivere marginal zone were submitted for the AMS ^{14}C determinations. The age of the *Dryas octopetala* leaves (11,310±130 ^{14}C BP; 13,190 cal yr BP) from the lowermost sample evidences glaciolacustine sediment deposition in the Allerød chronozone. Two additional samples from the higher level showed Holocene age.

Assessing rightness of the basal AMS date we relayed on the age of the Pandivere zone and varve counts from the Vigala section (Hang & Sandgren 1996). Considering that age of the

Pandivere zone is 13,800 cal yr BP and ice retreated from the Pandivere to the Palivere zone within at least 476 varve years (Hang & Sandgren 1996) Palivere ice marginal zone could have been formed about 13,300 cal yr BP. Difference between dated and calculated age is ca 110 years and could be resulted from delay of sedimentation in the proglacial lake. Further AMS dates of the Late Glacial deposits are needed to shed light to this problem. At moment we can speculate that known so far "Younger Dryas" ice advance in Estonia occurred already during the Allerød chronozone. This is in good accord with the latest estimations from Finland, according to which ice margin reached to the southern coast of Finland about 13,000 cal yr BP (Lunkka *et al*. 2004).

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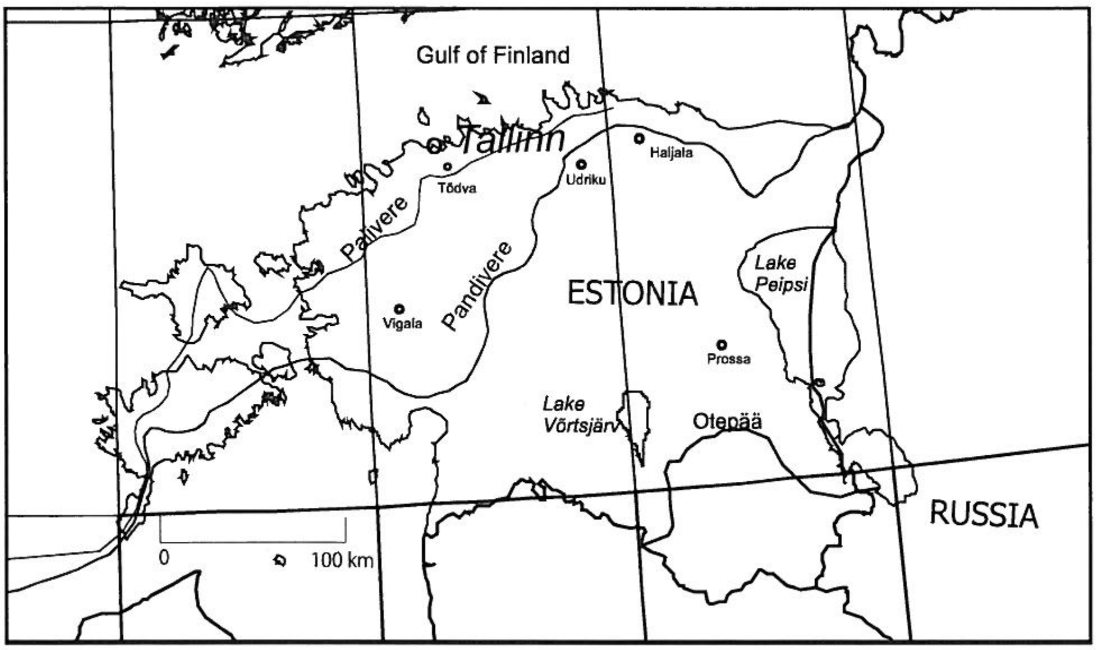

Fig. 1. Position of ice marginal zones and location of sites mentioned in text.

Climatic conditions during the deposition of the Middle Weichselian inter-till deposit in Petäjäselkä, northern Finland

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Petäjäselkä interstadial deposit was found in Kittilä, northern Finland in 2005. Inter-till deposit exists under the present mire in the depth of about 4.5-6 m. It was first time described by Sarala & Eskola (2010) and based on the pollen composition the peat was proved to be Pinus-Betula dominated. The C-14 age of the peat was 35,300 ± 600 BP. Stratigraphically the peatlayer lies between sand layers dated by the OSL method to 72.6 ± 21.3 ka and 58.1 ± 17.0 ka, respectively, below the peatlayer, and to 31.8 ± 5.6 ka above the peatlayer.

Plant macrofossil study was carried out in order to study local environment and climate conditions during the deposition. For the plant macrofossil analyses two consecutive 5-cm thick peat layers were studied. The sample size was ca. 100 cm^3. The peat samples were sieved under running water using a 140 µm mesh. The residuals were examined under a stereomicroscope.

Both samples were highly humified and contained plenty of wood and Cyperaceae sl. remains. Bryophytes were encountered infrequently. The dominant bryophyte species belonged to *Warnstorfia exannulata* group. Bryophyte species and *Selaginella selaginoides* indicate a nutrient rich mire environment. High amount of wood remains and fungi sclerotia suggests that dry habitats were abundant. However, evidence of local wet habitat was also found: small remains of *Nuphar* seed. These finds together with presence of tree-type birch indicate that the minimum July temperature was at least 10-12 °C.

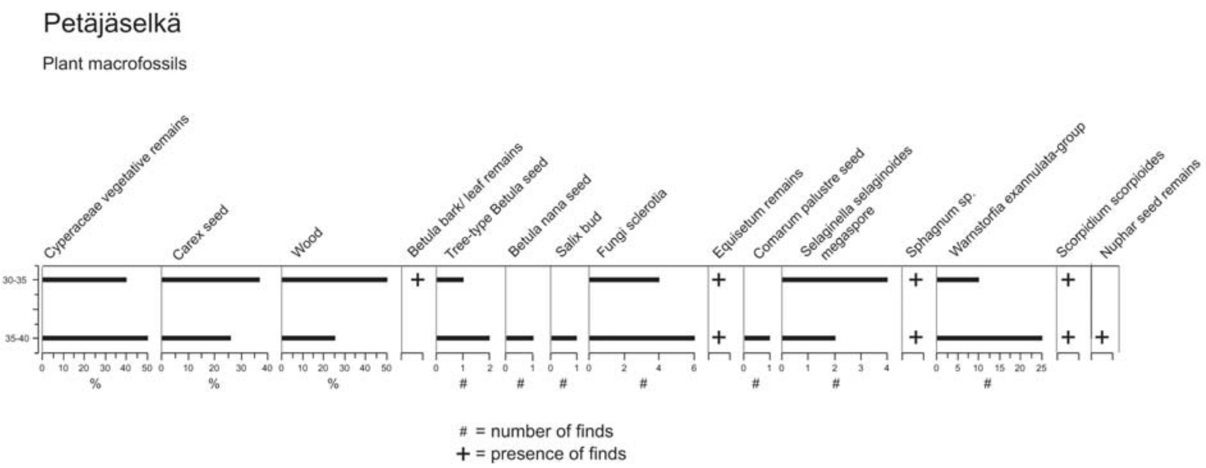

Fig. 1. Composition of plant macrofossils in the inter-till peat deposit in Petäjäselkä. Macro fossil analyses by Minna Väliranta.

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Quaternary history and stratigraphy of the White Sea region

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White Sea region embraces the White Sea Basin and the adjacent land within the White Sea drainage area. Quaternary deposits covers the region. Their thickness is irregular and ranges in the shelf and on land from 330 m in the depressions of Belomorsko-Kuloiskoie Plateae to over 200 m on the White Sea floor. The regional Quaternary stratigraphical sheme was made on the basis of the data received from investigations of the main sections on the White Sea coastal areas using lithological, palaeoenvironmental and geochronological methods. 21 reference sections on land were studied using unified method including lithology, texture, granulometric, petrological, diatoms, spore-pollen, foraminifera, mollusks analyses and IR-OSL-, ESR-, C^{14} - dating. In addition, the data from the State Maps of 1:1,000 000 and 1:2,00 000 scales, and the archives of Kola Science Centre RAS and "Sevmorgeo" are taken into account. Russia-Norwegian field work in the Russian North during last ten years (Demidov *et al.* 2006; Grøsfjeld *et al.* 2006; Kjær *et al.* 2006 and other), and seismic investigations within the White Sea shelf carried out by MAGE have been accounted. The A Quaternary Map of the White Sea region in the scale of 1: 1,000 000 was produced as the result.

The sedimentological sequences of the White Sea coastal areas are composed by heterogeneous Middle – Late Pleistocene and Holocene deposits. More ancient units are Middle Pleistocene marine sediments of the Likhvinskii Horizon (MIS 9) first chronologically dated in Varzuga section on the Kola Peninsula, and lacustrine and alluvial sediments of the Gorkinskii Horizon (MIS 7) in the Kovdor sections on the Kola region and from Kyma section on the Mezen River area. An Okskii Horizon (MIS 12) has been discriminated in the sections observed in the Vashki-Mezen interstream area. Regional stratigraphy scheme includes the Moskowskii (MIS 6), Mikulinskii (MIS 5), Podporozhskii (MIS 4), Leningradskii (MIS 3) Ostashkovskii, (MIS 2) and Holocene Horizons.

The Quaternary stratigraphy for White Sea shelf is based on the seismic complexes which has been correlated with the lithostratigraphical units – glacial Moskowskii Horizon (MIS 6), marine Mikulinnskii (MIS 5) Horizon, glacial Ostashkovskii Horizon (MIS 2), undivided Early-Late Pleistocene and Late Pleistocene-Holocene marine-declivity sediments, Late Pleistocene glacio-marine and glaciolacustrine sediments, Holocene wave, fluvio and nepheloid sediments.

During the Pleistocene, the White Sea region was repeatedly covered by glacial ice and the glacial sediments of the Vologda, Moscow and Podporozhje glaciers have been deposited. During the warming periods, such as the Likhvinan (MIS 9-11), the Mikulian (MIS 5e), a considerable part of the area was flooded by sea, and coastal lowland and depressions turned to the shallow sea and gulfs. In the Gorcinian (MIS 7) and the Leningradian (MIS 3) the sedimentation occurred in cold-water basins. The detailed history of White Sea region can be identified from the Ostashkovian (MIS 2) sediments. Cold based glacier occupied the Ponoy River area and the Kuloi Plateae during the first stage of glaciation. There were local mountain glaciers, too. The Scandinavian Ice Sheet expanded from the west and covered Kola Peninsula, the White Sea depression and Kuloi Plateae. The Novozemelskii Ice Sheet expanding from N-E reached the Pyoza River and the Kola Peninsula along the Throat of White Sea. The Novozemelskii Ice Sheet was overlapped by the thicker Scandinavian Ice Sheet before the maximum of the latter at longitude 45 east. The Mezen' and Pyoza Rivers were dammed by ice and a huge lake was formed at that time. After the maximum oscillation of Scandinavian Ice Sheet from the Cheshskaia Guba (Pechorskoe Sea) had took place and end moraine complex formed on the Kanin Peninsula. Scandinavian Ice Sheet retreated during several stages that were reflected in several end moraine complexes in the White Sea depression. The last stage of deglaciation finished in the beginning of the Holocene. Marine environment in White Sea replaced periglacial one at the Allerød that caused the lateglacial marine transgression nearly 11,500 C^{14} years B.P. The transgression lasted during the Late Younger Dryas - early beginning of Holocene. From the Preboreal (aprx. 9100 C^{14} years B.P.) the distinct irregular marine regression developed in White Sea depression which included the stable sea level position or even short transgression in the White Sea. The latter correlates with the Tapes transgression which lasted 500 years. The sea-level oscillation promoted the mosaic-like distribution of the Holocene heterogeneous sediments.

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Late-glacial and Holocene development of lacustrine environment inferred from the ostracod record in Estonia

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Records on fossil (pollen, diatoms, macro plant remains, etc.) data are available for palaeoecological research into lacustrine environments. Information derived from ostracod subfossils is widely used in the reconstruction of late-glacial and Holocene environmental conditions in Europe. Ostracod subfossil records and biostratigraphy are applied in palaeoenvironmental history (e.g. temperature, trophic level, water level) for the post-glacial period in Estonia.

Five dated tufa sequences from small Estonian lakes revealed similar distribution patterns of indicator ostracod species. *C. lacustris, C. candida* and *T. estonica* dominate in late-glacial silts, indicating cold and oligotrophic deep-water lakes. This refers to increasing humidity and low temperatures, recorded over the northern mainland (e.g. Seppä *et al*. 2009).

Described assemblage was soon replaced by species preferring warm and eutrophic conditions in shallow lakes. Appearance of *M. cordata* in the ostracod assemblage indicates increased temperature and lowering water level since the late late-glacial until the Holocene climate optimum (time interval between ca. 12.8 and 7.5 ^{14}C cal kyr BP). The prevalence of *M. cordata* and a gradual increase of its abundance in sediments are due to the water level lowering and increase in temperature and trophic status in the lakes. The periods of the lowest lake levels and dry climate culminated in the middle of the Holocene (Seppä *et al*. 2009; Heikkilä *et al*. 2010).

Appearance of *P. rostrata* in the Late-Holocene sequence of tufa is suggesting increasing water level and high groundwater discharge in northern Estonia, which is in agreement with the decrease in temperature, recorded since ca. 4.5 cal ^{14}C kyr BP in northern Europe (Seppä *et al*. 2005; Antonsson & Seppä 2007).

Birks *et al*. (2000) suggested that, next to the temperature variations, conditions of catchment areas of small lakes have likely been equally important in facilitating environmental changes during the Holocene. Changes in ostracod assemblages were in principle similar in studies sections; however, the environmental history was non-contemporaneous in different water bodies. This proves that regional climatic changes are not the only factor influencing lake biota and evolution. Environmental impact of local catchment's features (biological productivity, vegetation cover, water level fluctuations, groundwater inflow, and local temperature) appears in the background of regional climatic conditions.

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Paleolimnological investigations on Solovki Islands, the White Sea

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The results of the palaeolimnological investigations in the White Sea area are presented with the accent on the large palaeobasins level changes in the region (Subetto 2010). The study sites are small lakes of the Solovki Archipelago located at different altitude. Five lakes (Lesnoye, 3 m a.s.l., Svyatoe, 8 m a.s.l., Bol.Korzino, 17 m a.s.l., Nikolskoye, 14 m a.s.l., Bol.Zelenoye, 32 m a.s.l., Mal.Zelenoe, 35 m a.s.l.) on the Solovki Island have been cored during several field campaign to obtain sedimentary records of the sea-level changes of the White Sea during the Holocene (Fig. 1). The sediments corresponding to the large freshwater proglacial basin formed at the White Sea depression after the glacier retreat. Marine conditions established in the basin when the connection between the White Sea and the ocean appeared. Sediments of this basin were found in the lakes of the Solovki Archipelago. The sea level lowering resulted from the glacial uplift of the area brought about an isolation of the study lakes. Stratigraphy of the bottom sediments of the small lakes at the Solovetsky Island revealed a gradual process of their isolation depending on their elevation. The area located above 30 m a.s.l. became isolated before 10,000 cal. yr BP while the lowlands at 3 m a.s.l. remained under the sea conditions till 1,300 cal. yr BP. The generalized stratigraphy of the lakes' sediments includes three main units reflecting the common pattern of their evolution from marine bays through transitional stage to isolated freshwater bodies.

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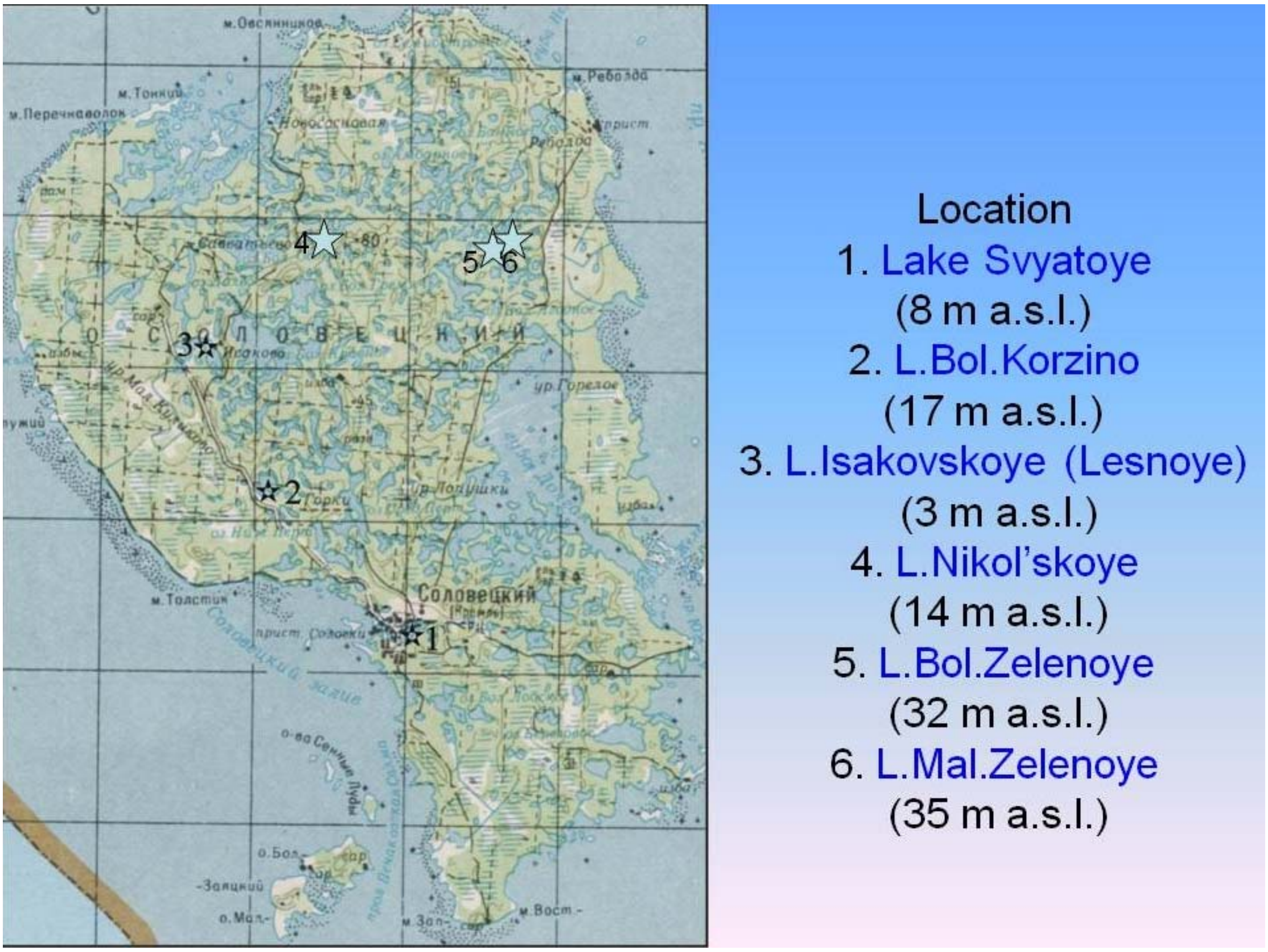

Fig. 1. Location of the cored lakes in the Solovki Island.

Geological processes record in the vertical and horizontal changeability of the Weichselian tills profiles in northern Poland – a concept of the research project and preliminary results

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The aim of the project is to reconstruct the geological processes which led to the formation of the Late Weichselian till profiles in selected key exposures in northern Poland. The research works are scheduled to be performed in a transect along the longitudinal axis of the area engulfed during the Pomeranian phase of the last glacial period by the Vistula lob: from the neighbourhood of the Puck Gulf in the north, through the eastern edge of the Kashubian Lakeland in the vicinity of Gdańsk, and then along the Vistula Valley towards the vicinity of Gniew and Nowe in the south. On the basis of the results of analyses in 13 key exposures, horizontal (approximately longitudinal) differentiation of the LGM tills will be determined along the designated transect.

The location of the considered quarter in relation to the ice-sheet extent during the successive phases of the Late Weichselian made that the LGM (Last Glacial Maximum) is represented in a substantial part of this area (especially in the north) only by one till bed. Discrete till beds, representing the individual Late Weichselian phases can be found only in the southern part of the transect. Thus one can seek here for the ice-sheet advance recordings not only in the form of separate till beds (characterizing different advances during the Late Weichselian) but also in the form of a sequence, which constitutes recording of the glacial accumulation processes within one particular till bed and covering a much wider span than one phase. To do this, it is necessary to examine variation of the glacial deposit sequences (facial differentiation and petrographic composition) in the selected sites. Determination of such sequences will enable one to correlate later individual till beds in the southern part of the research area with relevant part of the till bed profile in the north. Recognition of the location where tills deposited during the subsequent phases merge into one horizon would also allow one to reveal the extent of the ice-sheet regression preceding its advance in the next phase. The problem is still open and it is worth of interest.

The project is continuation of several years of previous works, during which a vertical variation has been observed in petrographic composition of one of the till beds, not related to the sediments weathering (Woźniak *et al.* 2009). Examination of such variation together with its changeability within a transect is possible by analysis of samples taken with high vertical resolution. After an exposure mapping combined with facies analysis, samples are taken for petrographic investigation of the fine-gravel fraction (following the methodology recommended by Polish Geological Institute, e.g. Lisicki 2003). Next, subhorizons are identified, characterized by diverse petrographic composition. Finally, petrographic analysis of the fraction >20mm is performed in the differentiated till subhorizons, by means of the indicator erratics method. In addition, measurements are taken of the directional elements orientation: in particular the orientation of a-axes of elongated pebbles and the striae on the top surfaces of stones. In the indicator erratics examinations the Lüttig (1958) technique is employed, which was modified by Smed (1993) and Czubla (2001). Taking into account in the study the sub- and intermorainic sediments, will allow one to identify events between the periods of glacial deposition and will provide the most reliable possible stratigraphic findings. Those results will be additionally supported by luminescence dating. Introductory thermoluminescence studies will help to select sediments for the optically stimulated luminescence (OSL) dating. Next, the results of all the analyses and luminescence dating will be correlated with the data from other sites, especially the ones situated down-south, reported by other authors (e.g. Wysota *et al.* 2009).

A methodological approach utilized in the project, i.e. a sequence of parameters that describe the petrographic composition in a vertical profile is considered instead of relevant average values taken for the entire profile, is a trial of finding new solutions to old problems. As it was described, among others, by Ehlers (1996), changes of the ice-sheet dynamics or paths of glacial transport occuring during one particular advance result in variations of the petrographic composition which complicate litostratigraphic correlations. The results of the works, which have been already completed by the authors of this report, indicate that the vertical changeability in the petrographic composition within a single till bed can be considerable. And the observed variations can be even bigger than those corresponding to two different till beds. In case of the fine-gravel fraction (5-10 mm) this fact manifests in changes of the petrographic coefficients. While in case of the coarse fraction (> 20 mm) the proportions are altered between indicator erratics originating from different Fennoscandia provinces. Moreover, the location of the so called TGZ (German, das Theoretisches Geschiebezentrum, Lüttig 1958) is shifted. Changes in the petrographic composition can be accompanied in some cases also by variations of directional properties.

It should be also emphasized that a vertical changeability of the till unit, noticeable macroscopically in an exposure, is not necessarily related to long-distance changes (like ice-sheet advance and regression) and is not subject to simple rules of the vertical facies sequence within a till bed. It is often a consequence of quite complex process (see e.g. Munro–Stasiuk 2000,; Piotrowski *et al.* 2006; Wysota 2007) and the macroscopic vertical diversity of a till bed does not have to be explicitly reflected in its petrographic diversity. One of the few examples of tills correlation based on a vertical sequence of petrographic composition (and also on clasts orientation) can be found in the work of Lagerlund *et al.* (1995). Similar approach to the problem is proposed by the authors of this project.

The expected results should allow one to create profiles changeability model of the tills within the Central European Lowland which in the Pleistocene, despite changes in the ice-sheet extent, generally remained under ice-sheet cover. Besides, they may help to explain the genesis of the petrographic composition changeability of tills not only in eastern Pomerania, but also in other regions of northern Poland. In addition, they should provide new information and data vital for determination of the extent of the ice-sheet regression which preceded its successive advances during the Late Weichselian in the considered part of Pomerania.

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I think it is lousy to be a stone

They are sitting on their places without moving themselves anywhere

Right you are, glaciations come so seldom

ERRATUM – Missing abstract in the printed version

Small lakes sediments: what can they tell us about Lake Ladoga level changes?

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One of the good-working methods for the reconstruction of the large basins levels changes is the study of the sediments of the small lakes. These small lakes situated at different elevations and now isolated were (or could have been) the part of the large basins in the past. Studying their sediments provides independent information about the configuration of the large basins, time of their existence in these borders and so on. Comparing this information with the data obtained from the traditional geological and geomorphological investigations we have more reliable base for the palaeogeographical interpretations than if we would use only the latter.

The dimensions and time of existence of the Ladoga transgression were investigated by many researchers (e.g. Ailio (1915), Markov et al. (1934), Koshechkin and Ekman (1993) Saarnisto and Grönlund (1996) and many others). During the last decade we worked on the small lakes situated near the present shore of Lake Ladoga at the different elevations. These lakes must have been influenced by the waters of Lake Ladoga during its transgression in the Subboreal. In the sediments of the small lakes in the northern parts of Lake Ladoga we found unambiguous records of Ladoga waters penetrations and subsequent isolation. As an example, Lake Uzlovoe (11 m a.s.l.) sediments consist of the three basic units – 1) silts attributed to the time, when this lake was a part (a bay) of Lake Ladoga; 2) transitional unit; 3) organic gyttja, sediments of the small isolated lake, appeared after Lake Ladoga level dropped.

On the contrary, no clear lithological signals (that could be an evidence of the large lake level change) have been found in the sediments of the lakes situated in southern parts of Lake Ladoga. The sediments of Lake Volojarvi (16 m a.s.l.) consist of the peaty gyttja up to 2 meters thick, overlying the sands, clayey sands and underlying dark brown homogeneous organic gyttja. The accumulation of the peaty gyttja started about 6000-6600 cal. yr. BP. No diatom assemblages typical for Lake Ladoga were recorded in the section. The age of the bottom part of detritus gyttja (Lake Rybeszskoe (14 m a.s.l.)) is about 7000-7300 cal. yr. BP. Since that time organic sedimentation prevailed in the lake.

So the preliminary results suggest that the transgression level might have been lower than it was previously thought. Possibly in the southern shores the Ladoga waters did not flood the area above 13-16 m a.s.l. and the main influence of the Ladoga transgression on the small lakes only resulted in the changing hydrological conditions such as reduced drainage, extensive macrophyte growth and so on. Anyway before the final conclusions the complete analytical studies should be performed and only the preliminary results are to be presented so far.

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