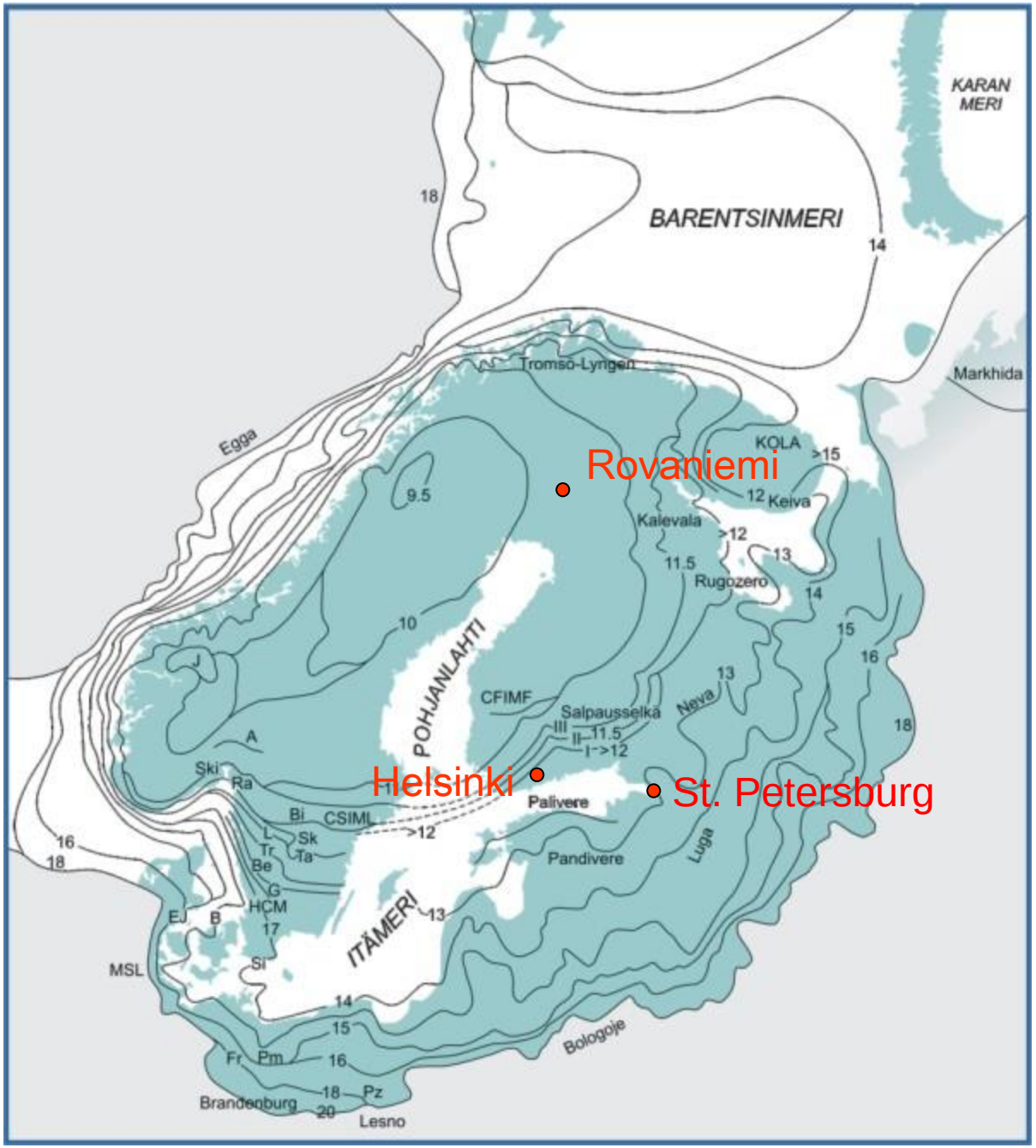
Weichselian glacial history of Finland

Herzen State Pedagogical University, Department of Geography. St. Petersburg 19.-20.02.2019

Peter Johansson


KARAN MERI
BARENTSINMERI
18
14
Tromsö-Lyngen
Markhida
Egga
KOLA
>15
Rovaniemi
12
Keiva
9.5
Kalevala
>12
13
11.5
Rugozero
14
10
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16
POHJANLAHTI
13
CFIMF
Salpausselkä
Neva
III
II
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St. Petersburg
Palivere
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CSIML
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Pz
Brandenburg
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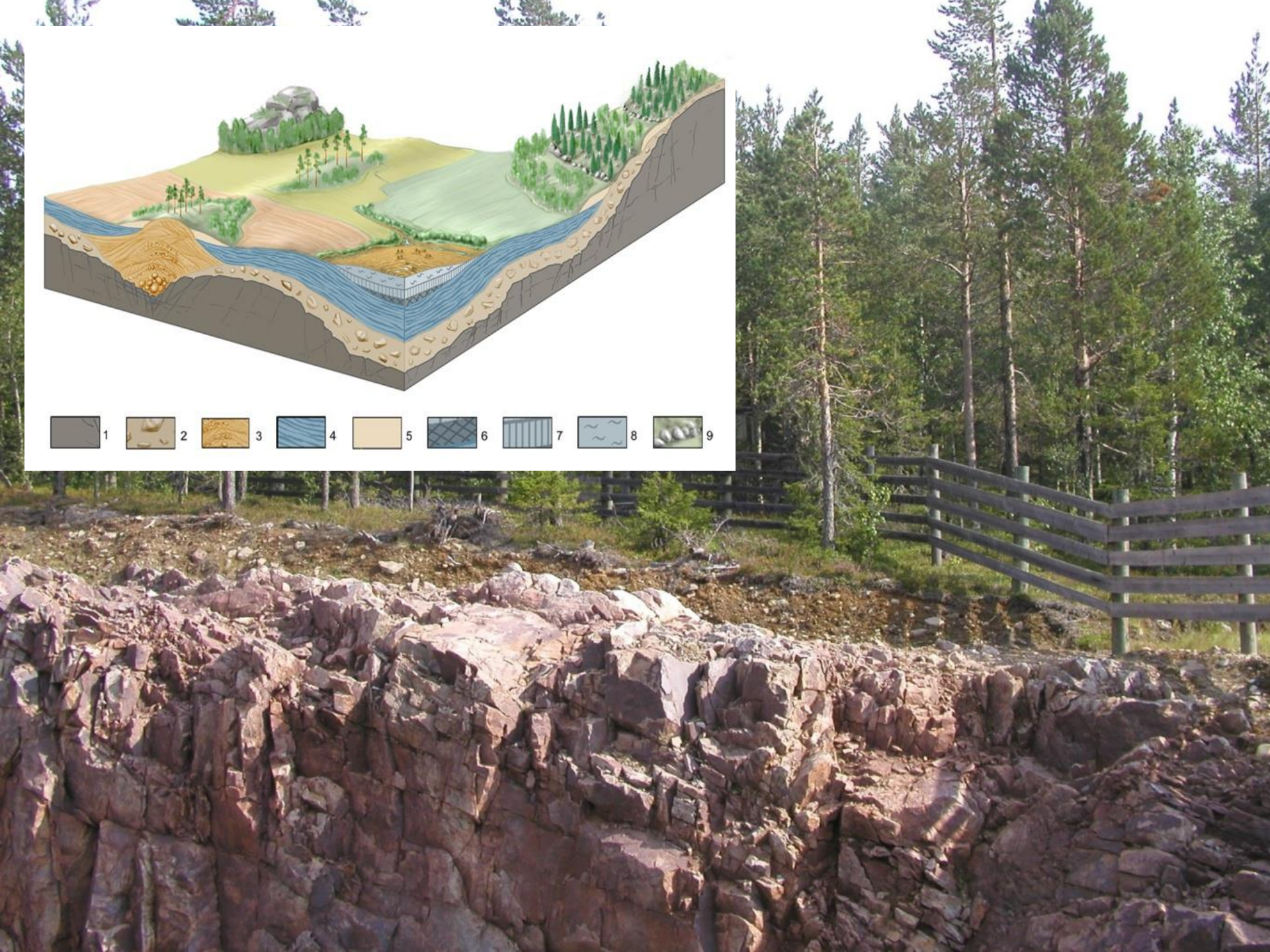
Lesno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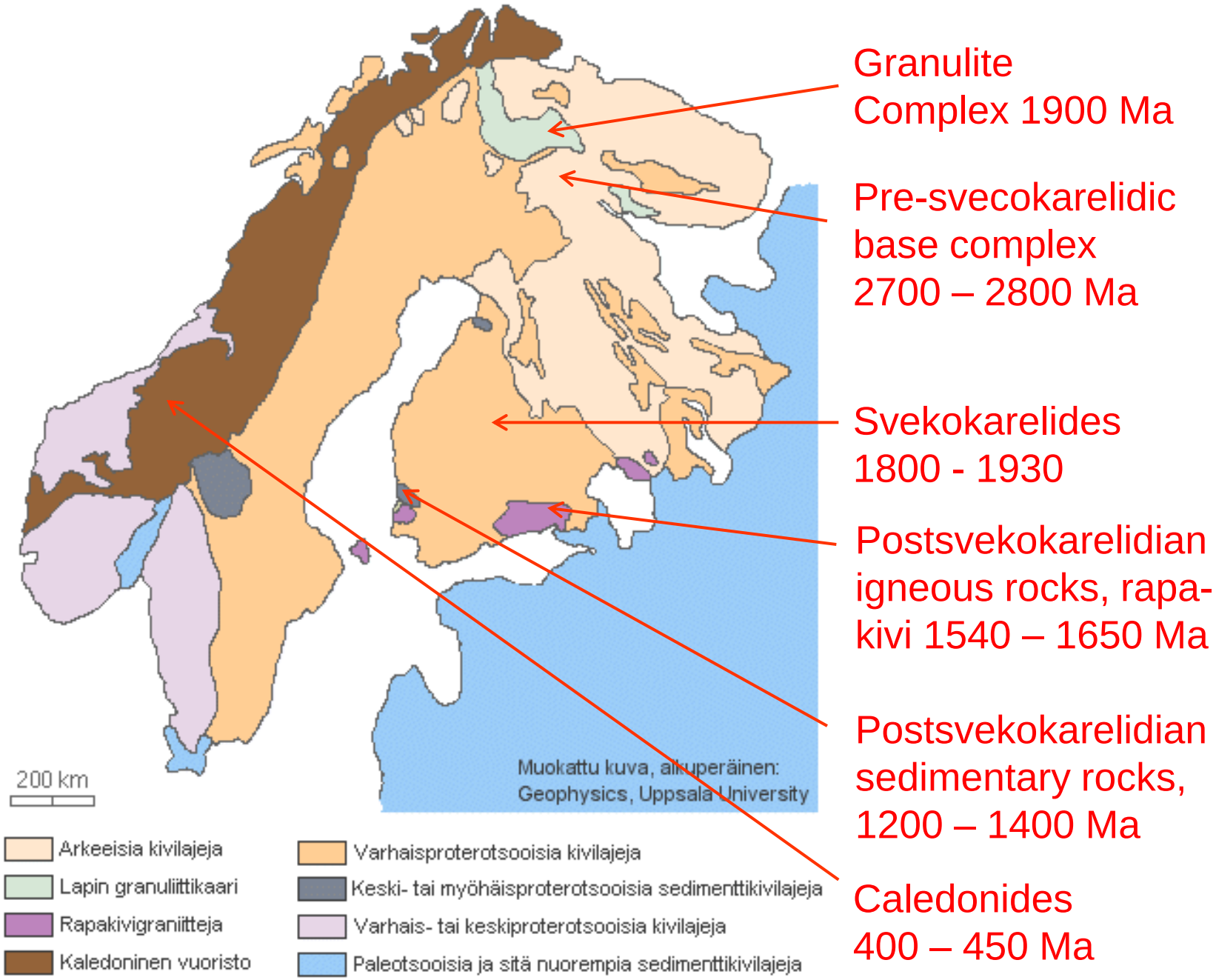
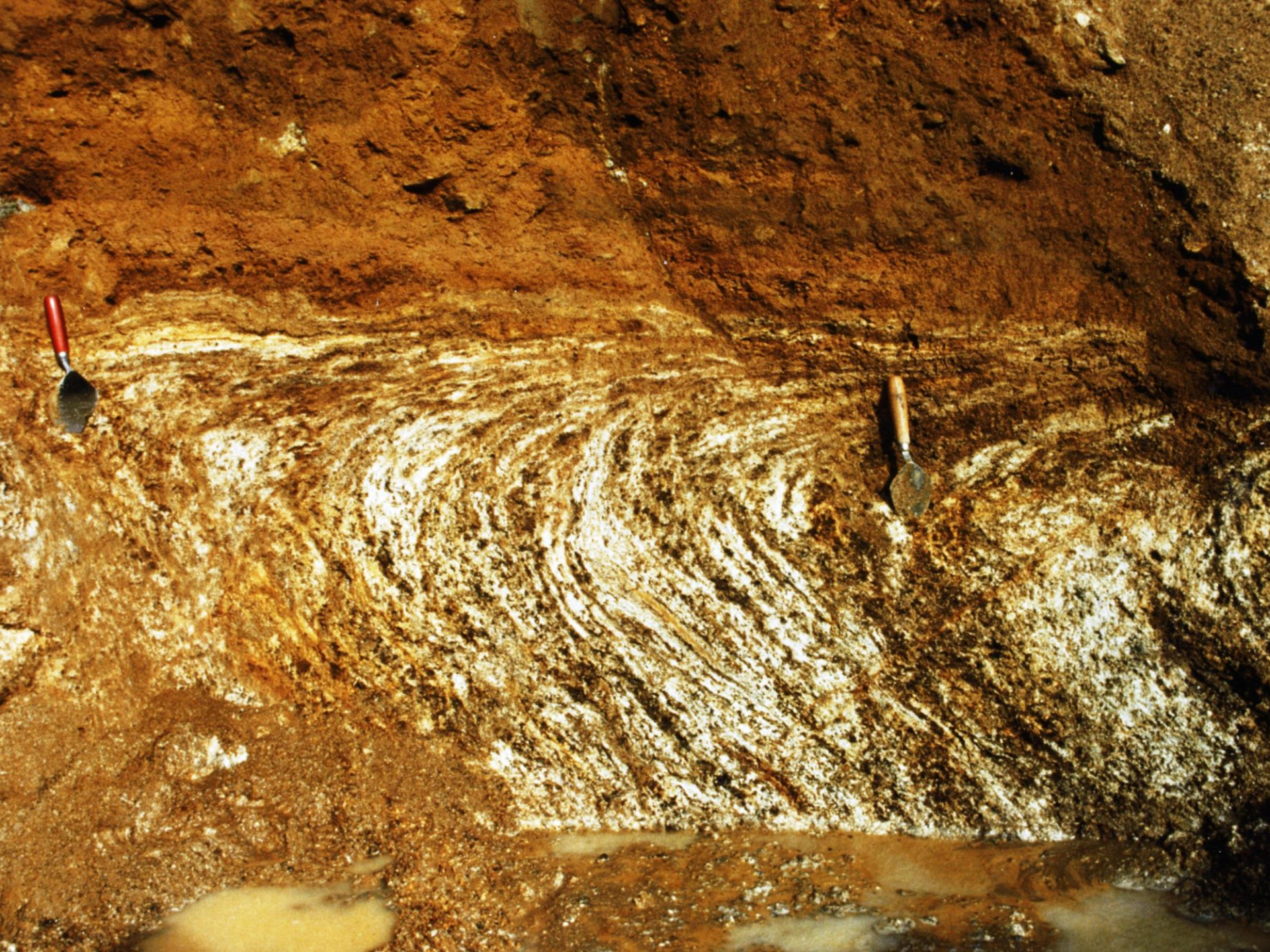
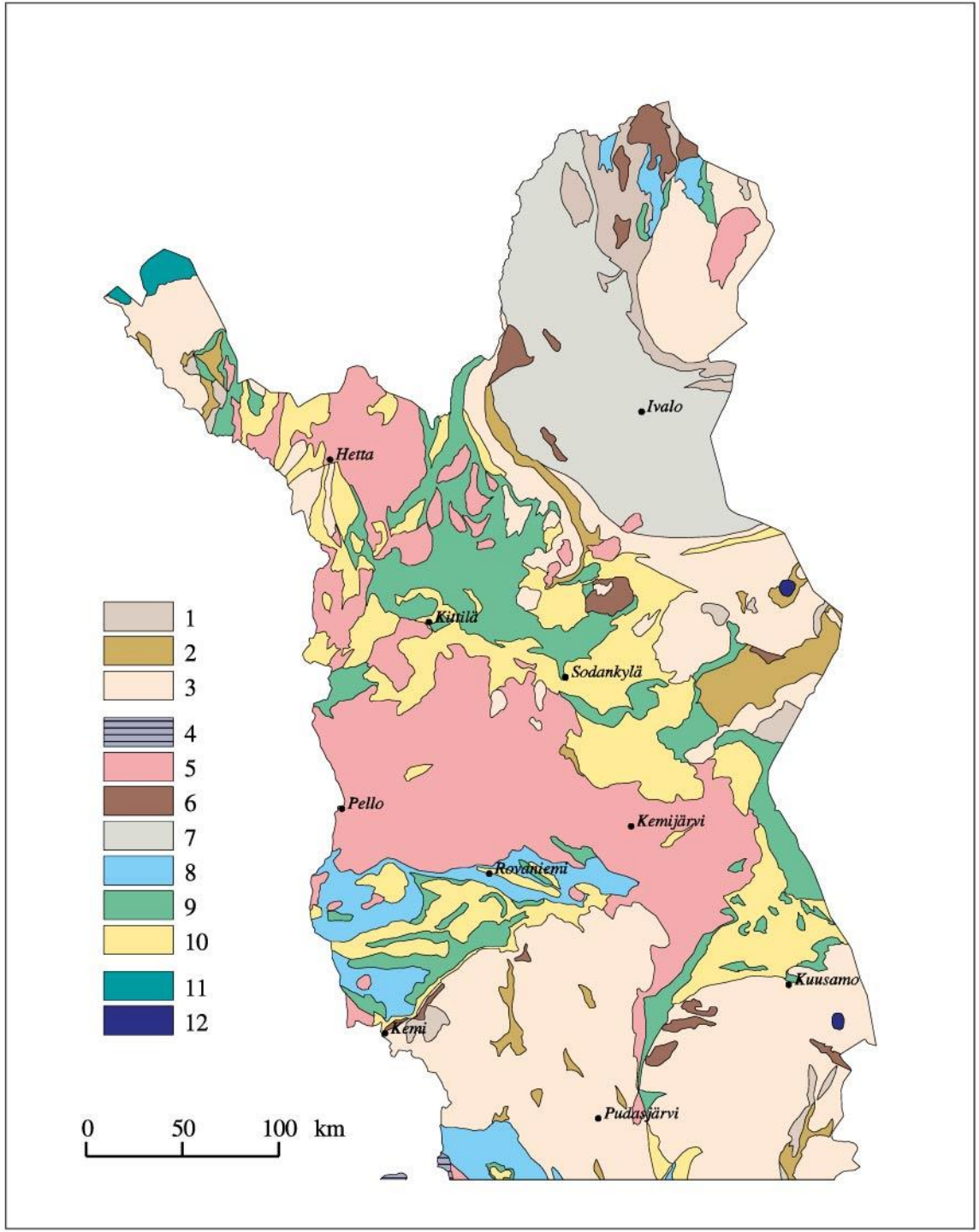

Granulite
Complex 1900 Ma
Pre-svecokarelidic
base complex
2700 – 2800 Ma
Svekokarelides
1800 - 1930
Postsvekokarelidian
igneous rocks, rapa-
kivi 1540 – 1650 Ma
Postsvekokarelidian
sedimentary rocks,
1200 – 1400 Ma
Caledonides
400 – 450 Ma
200 km
Muokattu kuva, alkuperäinen:
Geophysics, Uppsala University
Arkeeisia kivilajeja
Lapin granuliittikaari
Rapakivigraniitteja
Kaledoninen vuoristo
Varhaisproterotsooisia kivilajeja
Keski- tai myöhäisproterotsooisia sedimenttikivilajeja
Varhais- tai keskiproterotsooisia kivilajeja
Paleotsooisia ja sitä nuorempia sedimenttikivilajeja

The zone of weathered bedrock in Finland




ÅKERMAN
ÅKERMAN
H7M^B

Percussion drilling machine with hydraulic piston corer. Sokli investigation area.


Ivalo
Hetta
Kittilä
Sodankylä
Pello
Kemijärvi
Rovaniemi
Kuusamo
Kemi
Pudasjärvi
1
2
3
4
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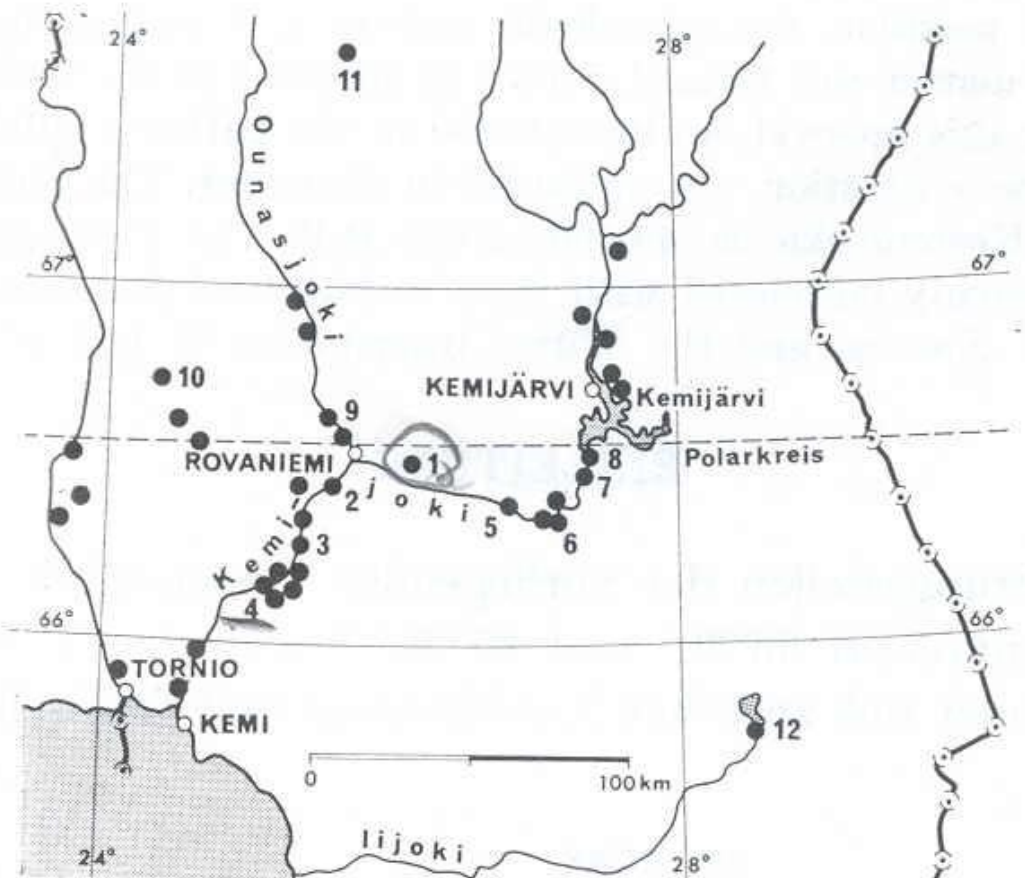
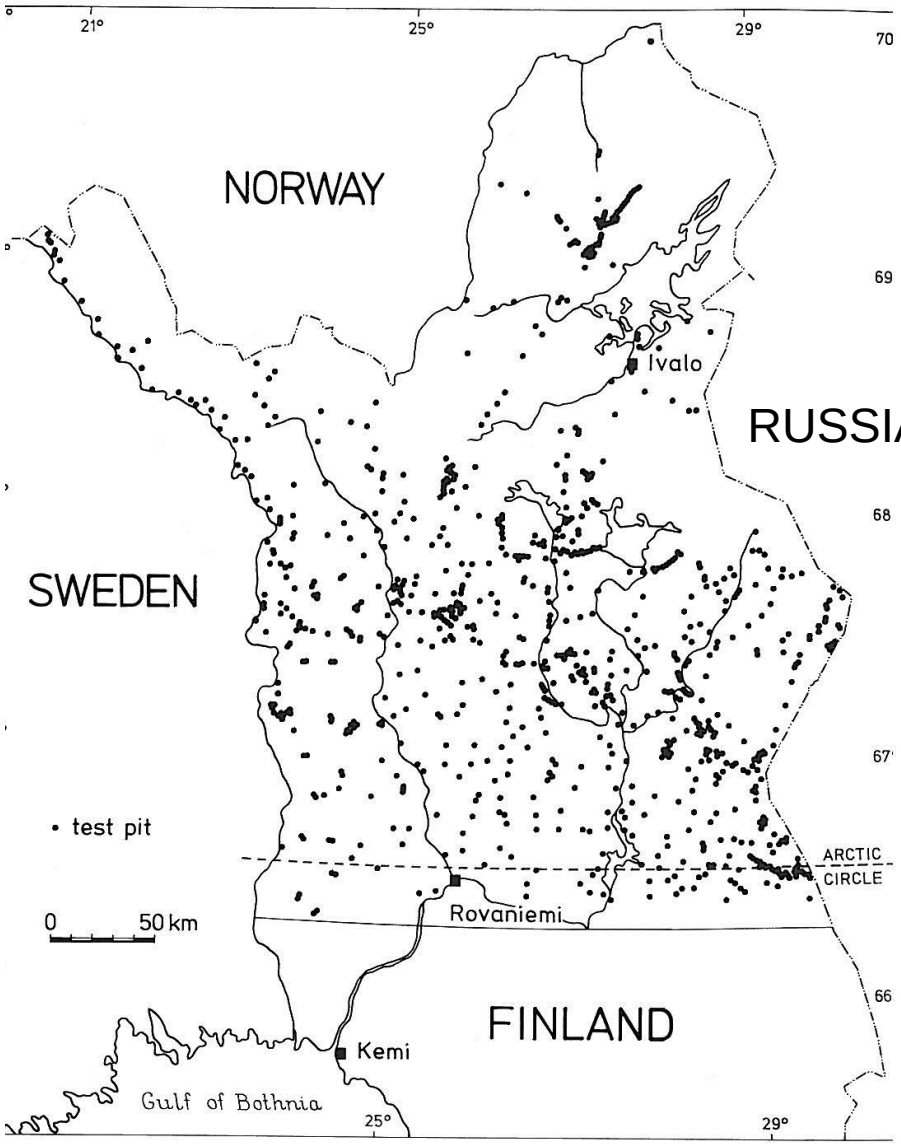
11
12
0
50
100 km

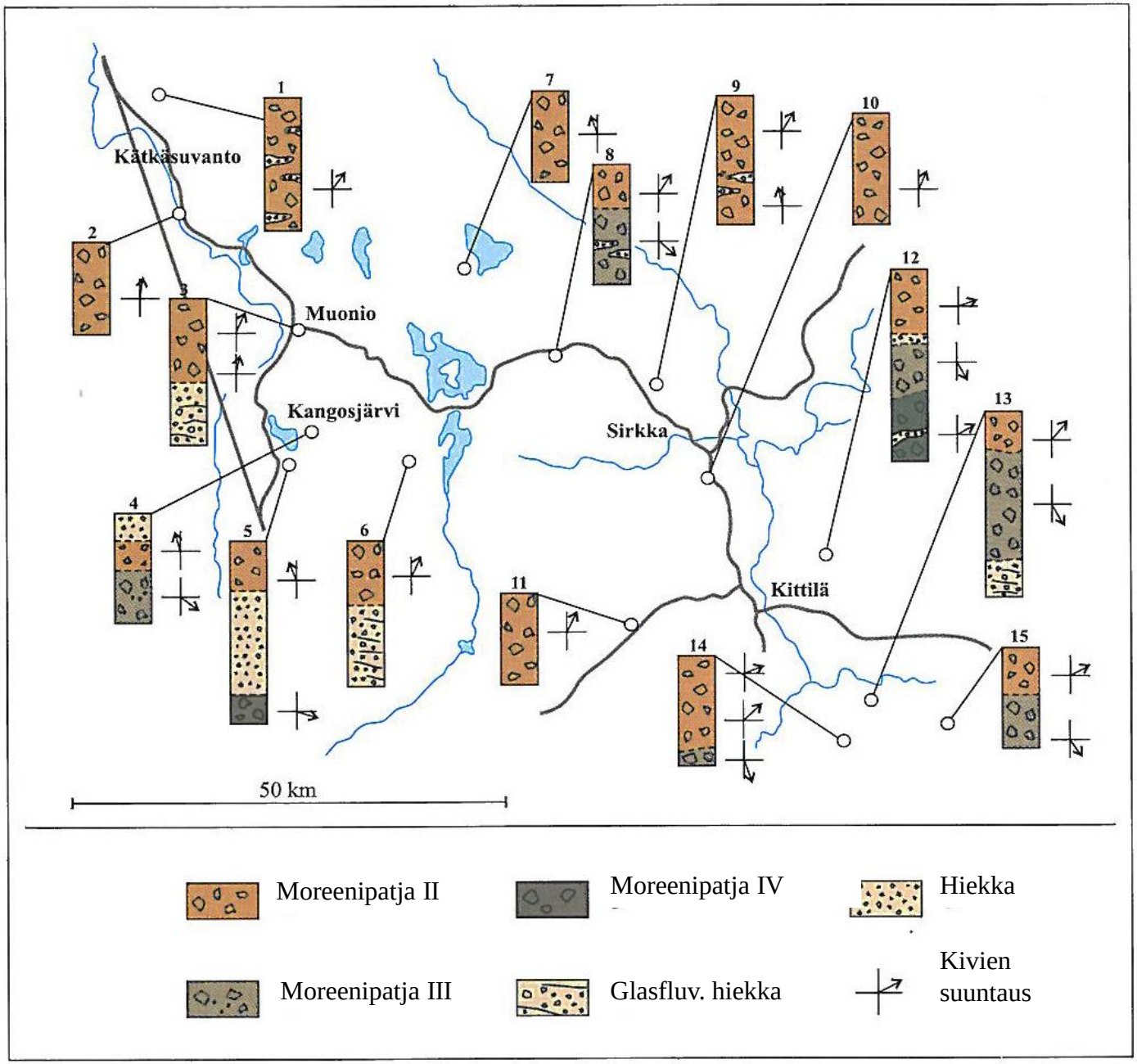


In the Kemijoki River valley there are often more than one till unit commonly found. They are interbedded with sediment and organic layers (K. Korpela 1969). Permantokoski hydroelectric power station (1) was the key area of the till investigations in 1960's.

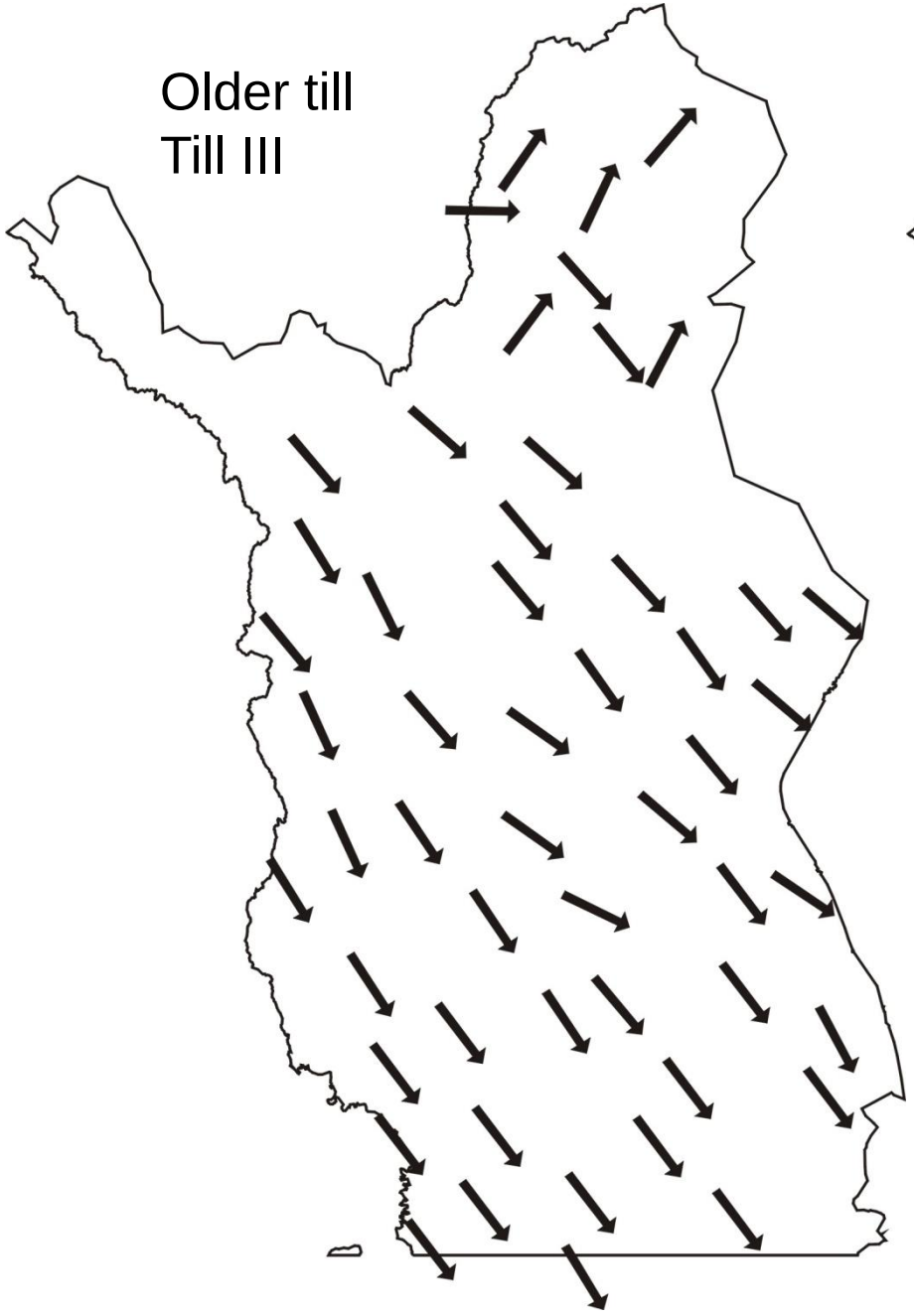


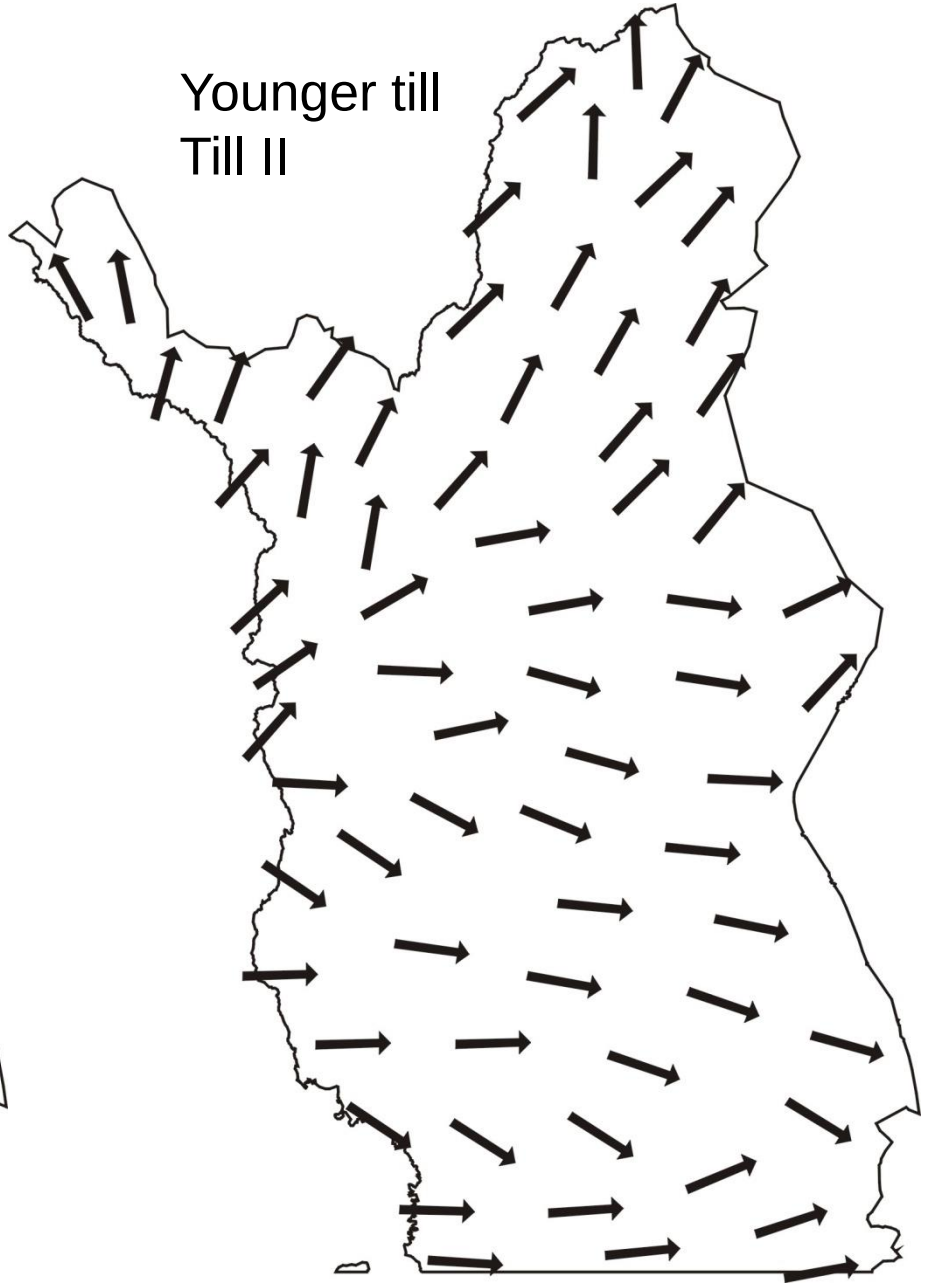
In 1970’ s more than 1300 test pits were made by tractor excavator.

In numerous sites more than two till beds inter-bedded with stratified sediments occur. (Hirvas et al. 1977 and Hirvas 1991)

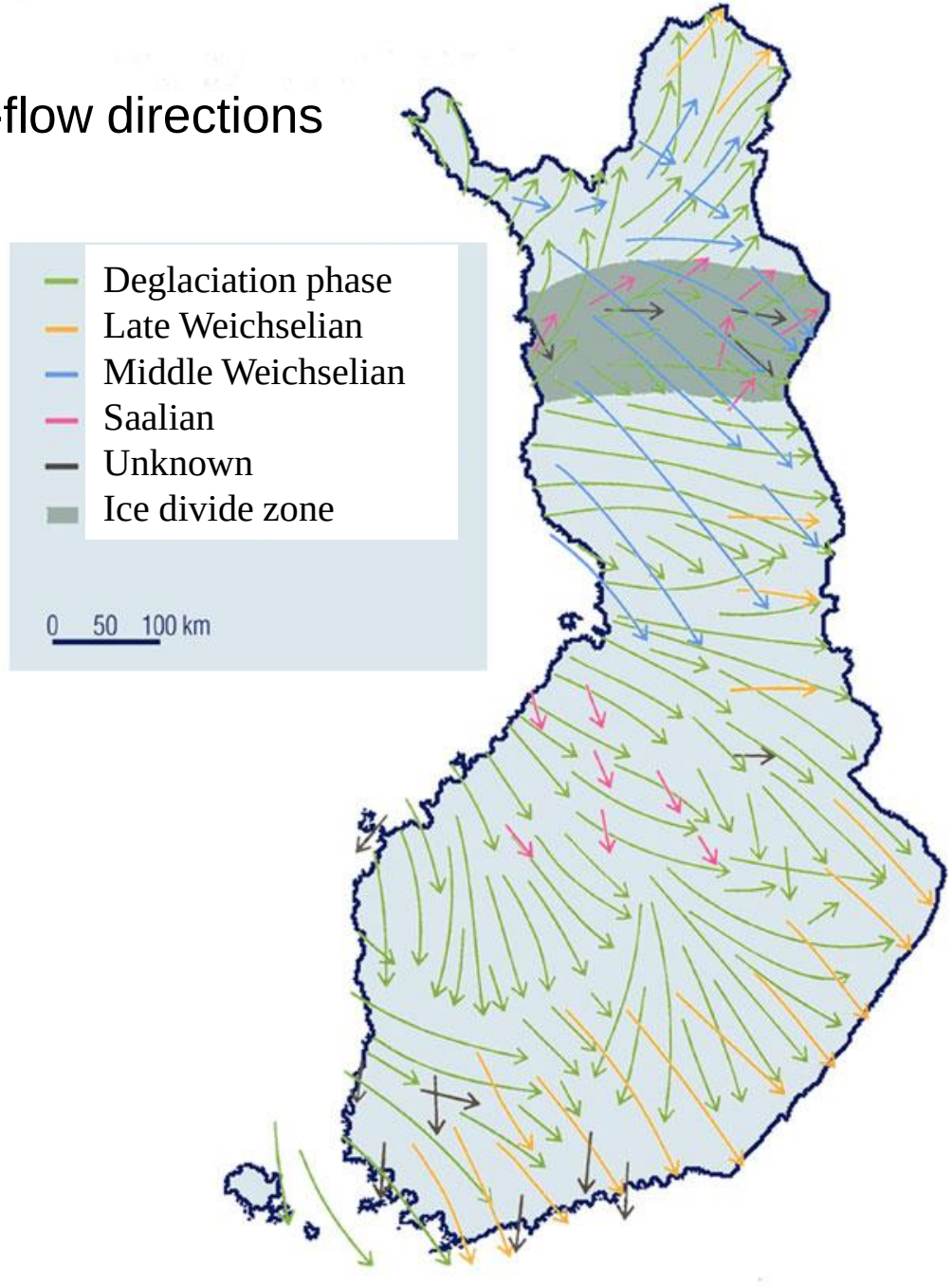


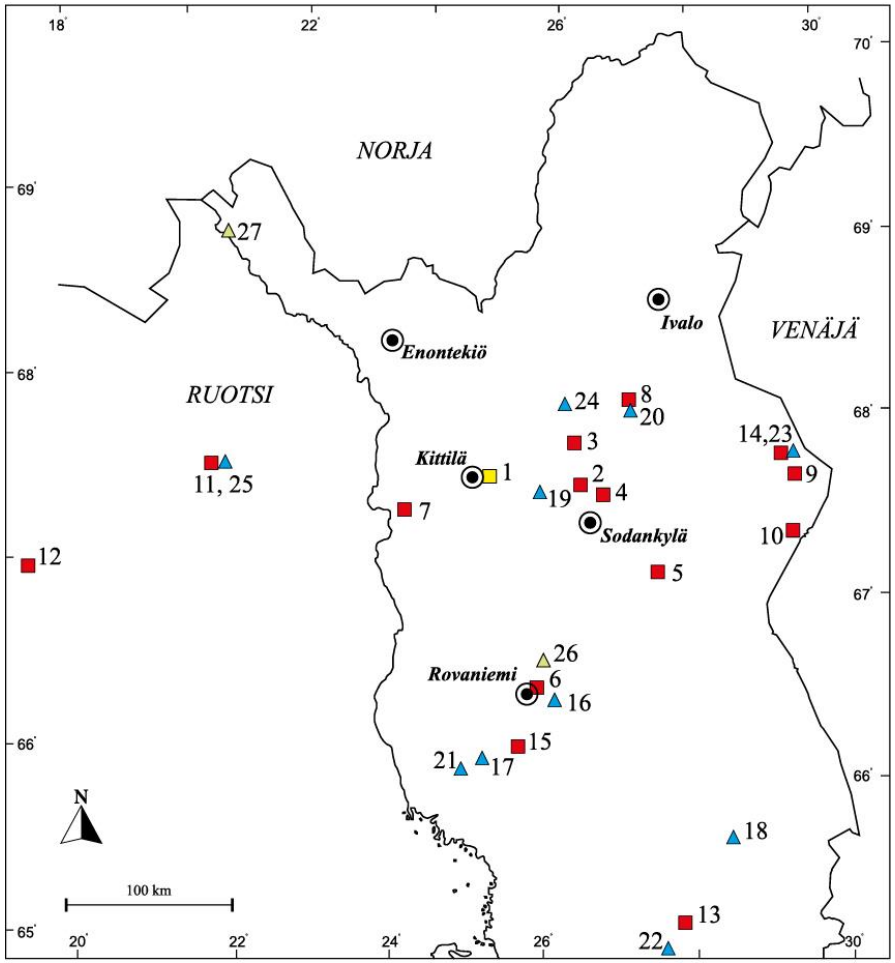
(Johansson & Kujansuu 2005)


Older till
Till III


Younger till
Till II

Ice-flow directions





Holstein interglasiaali, interglacial

Eem interglasiaali, interglacial

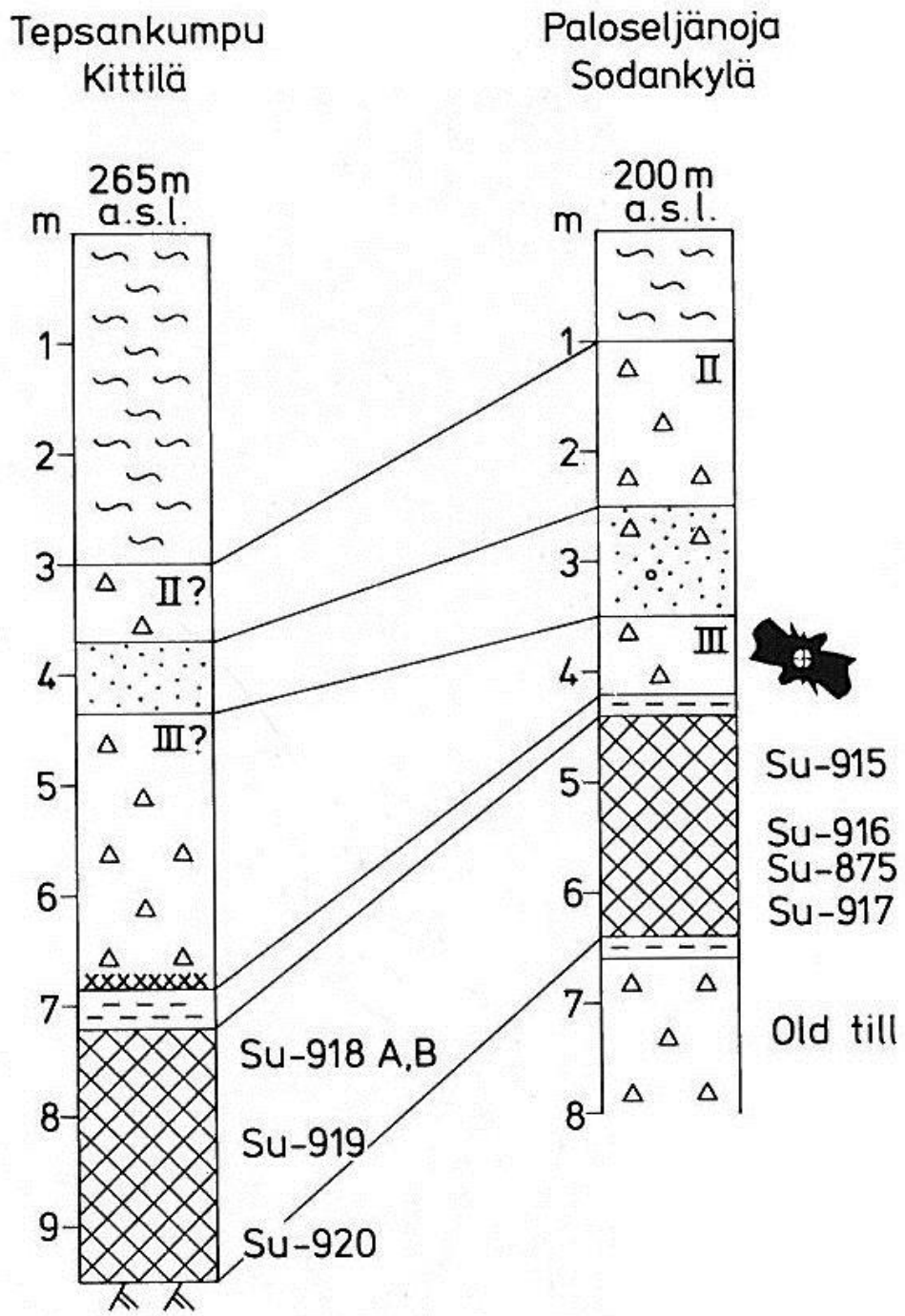
Interstadiaalikerrostumat, interstadial deposits

Holoseenikohteet, Holocene localities

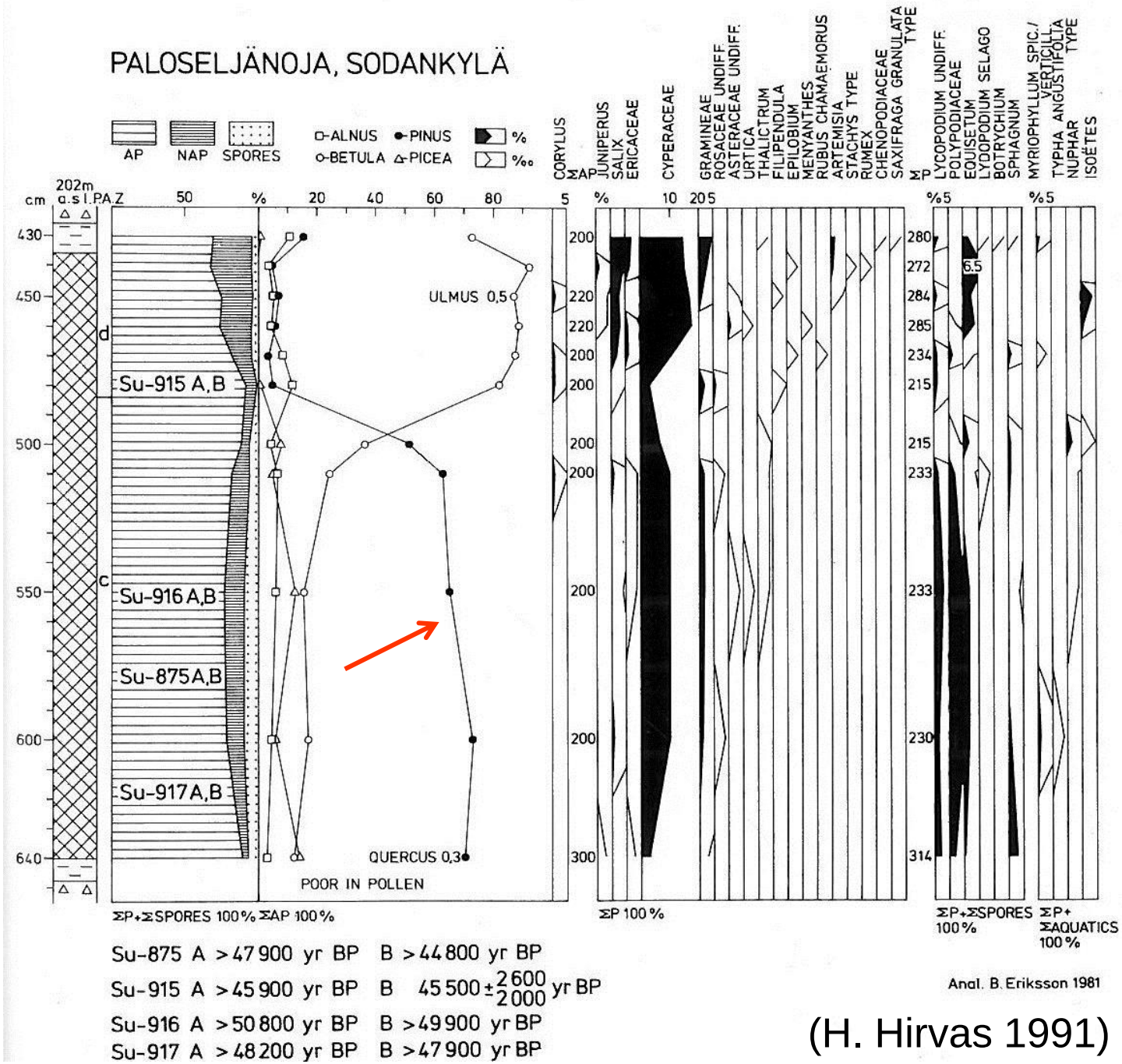
More than 100 observations of subtill organic deposits have been made in Northern Finland.

Fifty deposits have been studied:

39 = interglacial,
10 = interstadial
and one both.

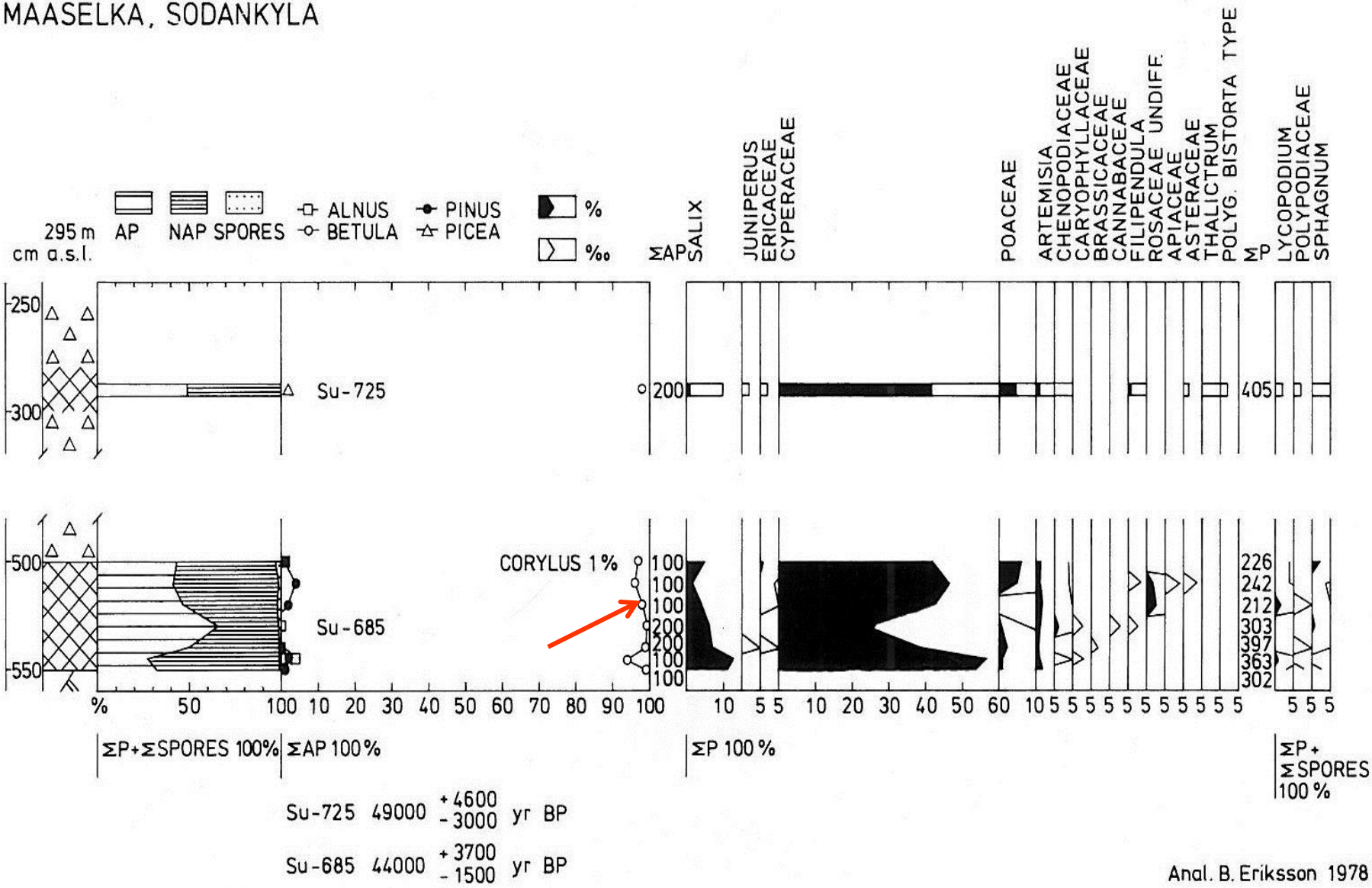


In the picture stratigraphic positions of the interglacial deposits and correlation of the general till stratigraphy of northern Finland.
(H. Hirvas 1991)



(H. Hirvas 1991)

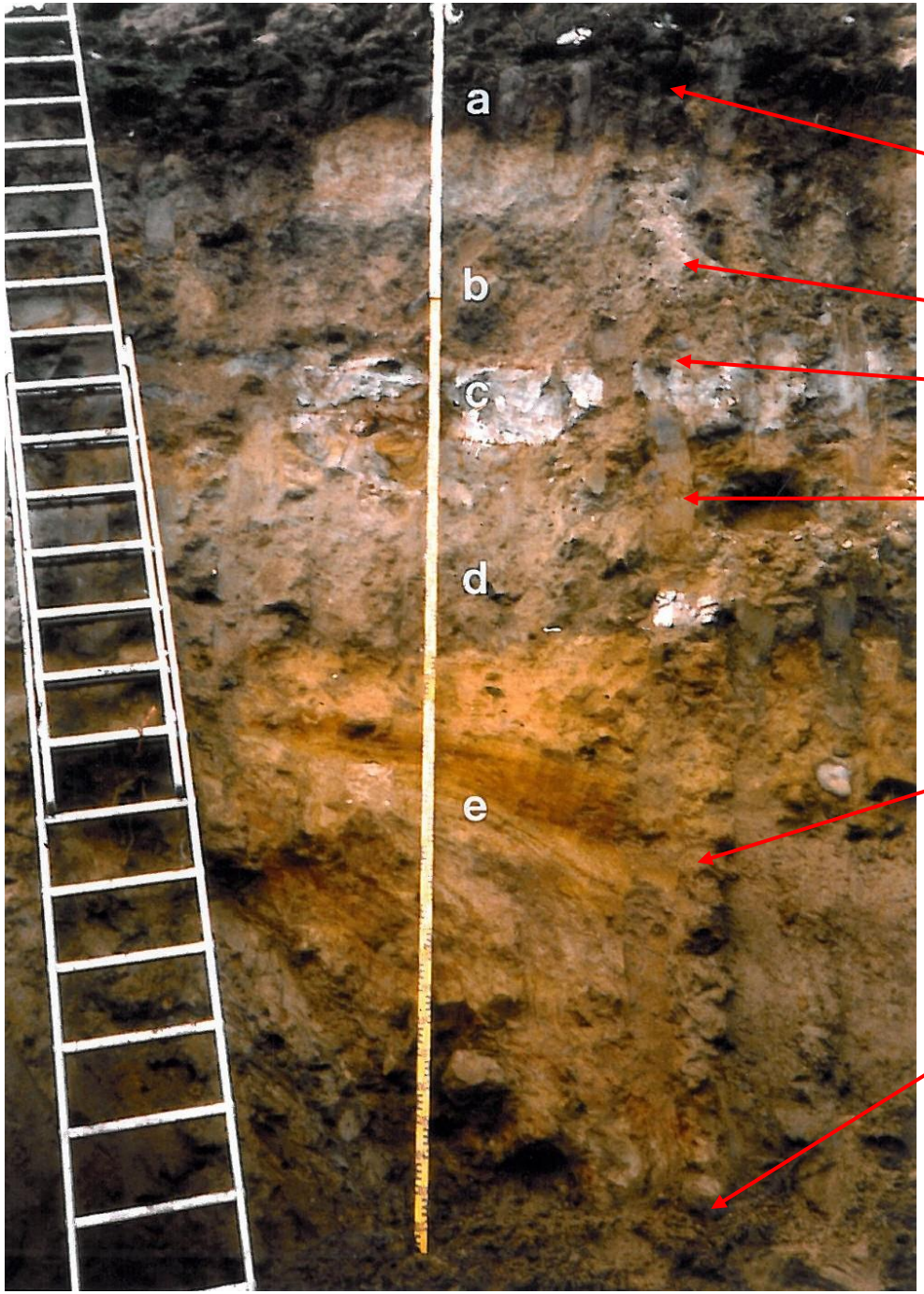
MAASELKÄ, SODANKYLÄ

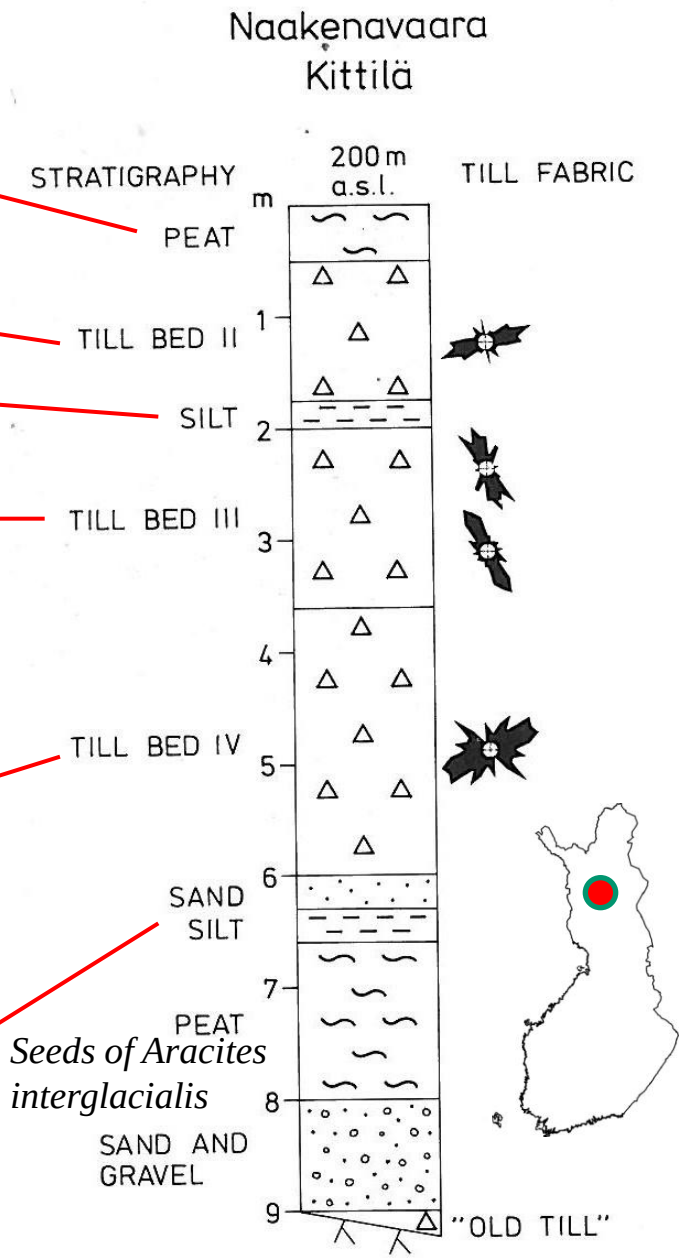


Su-725 49000 $^{+4600}_{-3000}$ yr BP

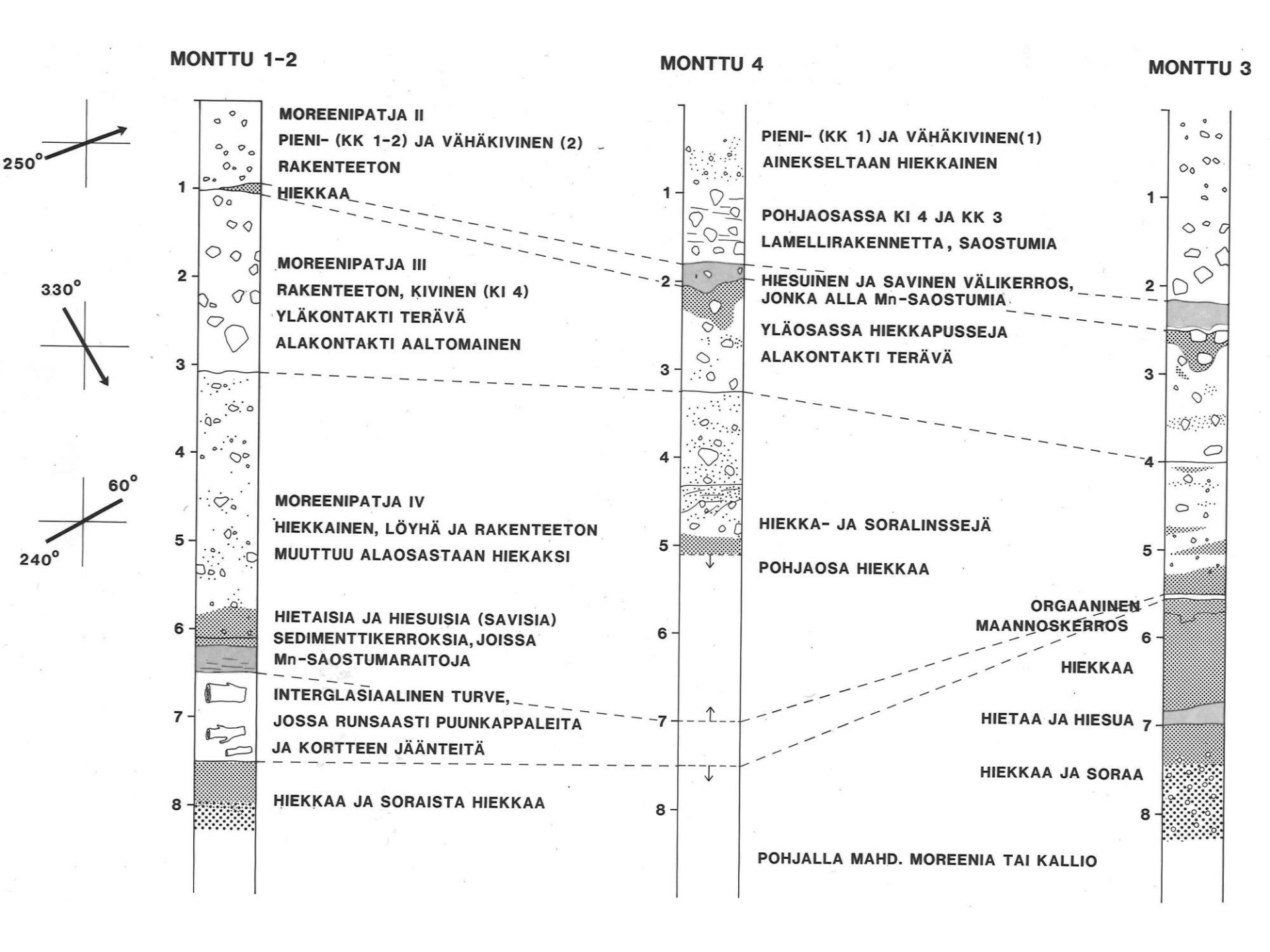
Su-685 44000 $^{+3700}_{-1500}$ yr BP

Anal. B. Eriksson 1978

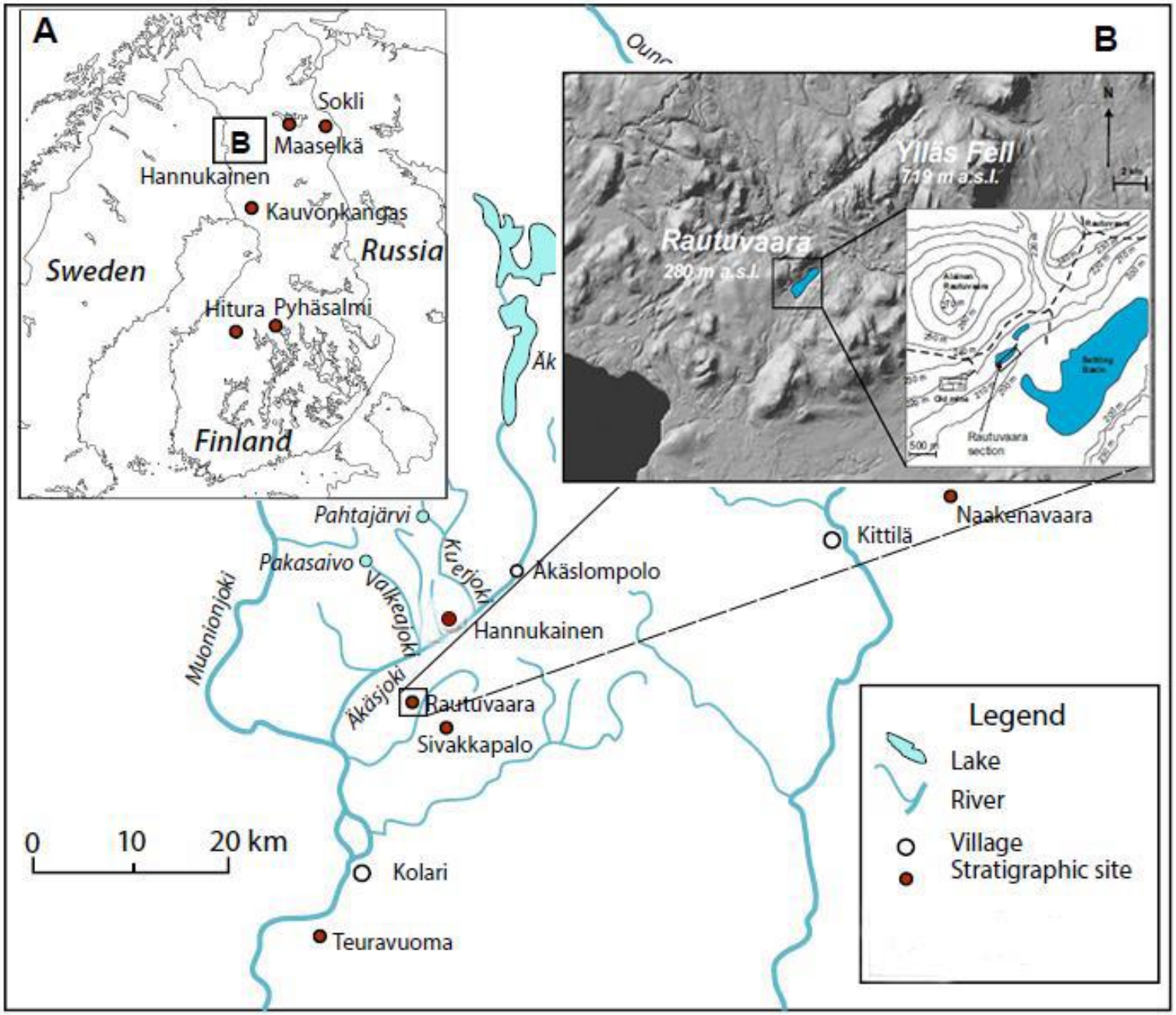


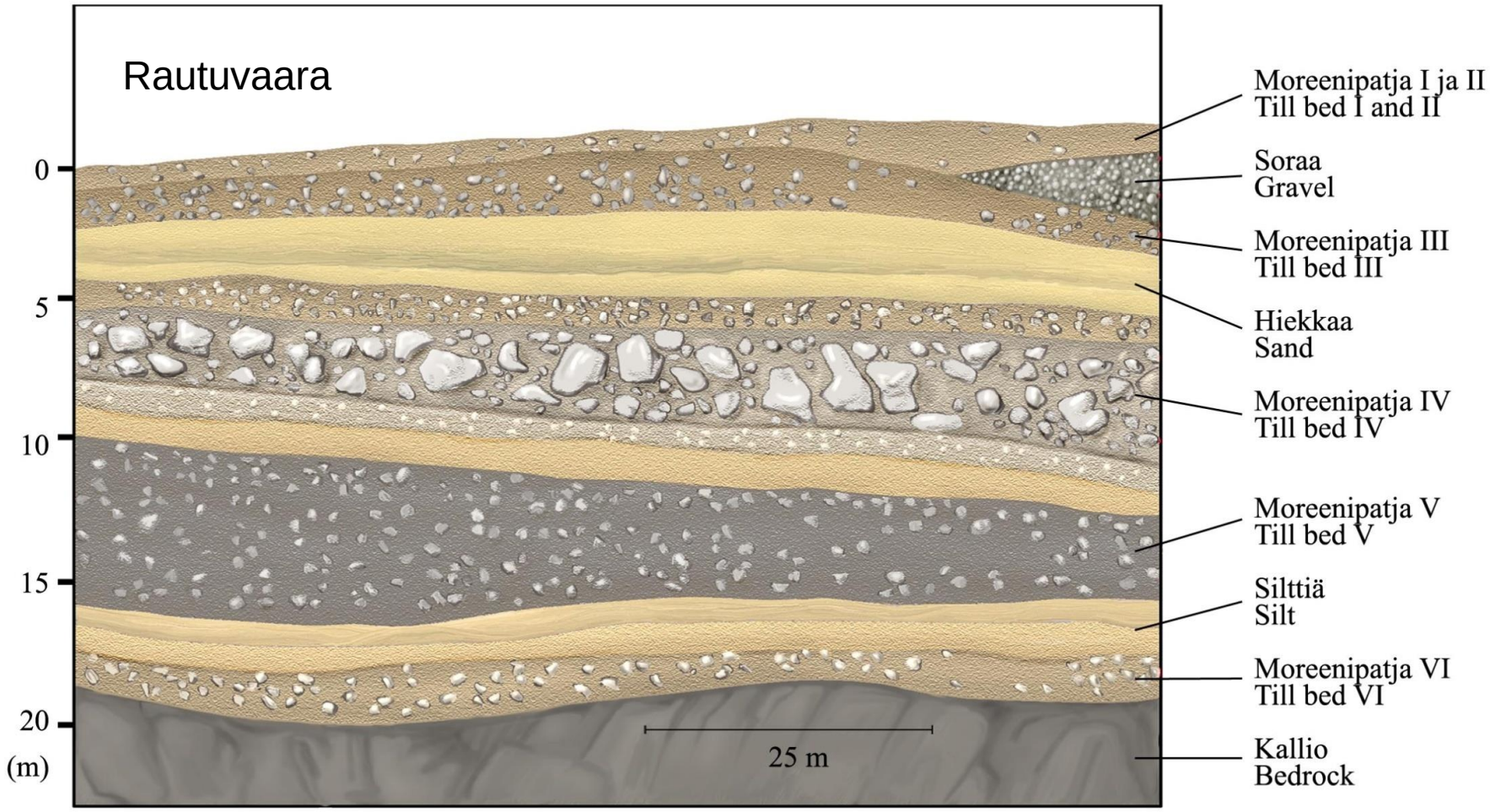


(Aalto, Eriksson and Hirvas 1992)

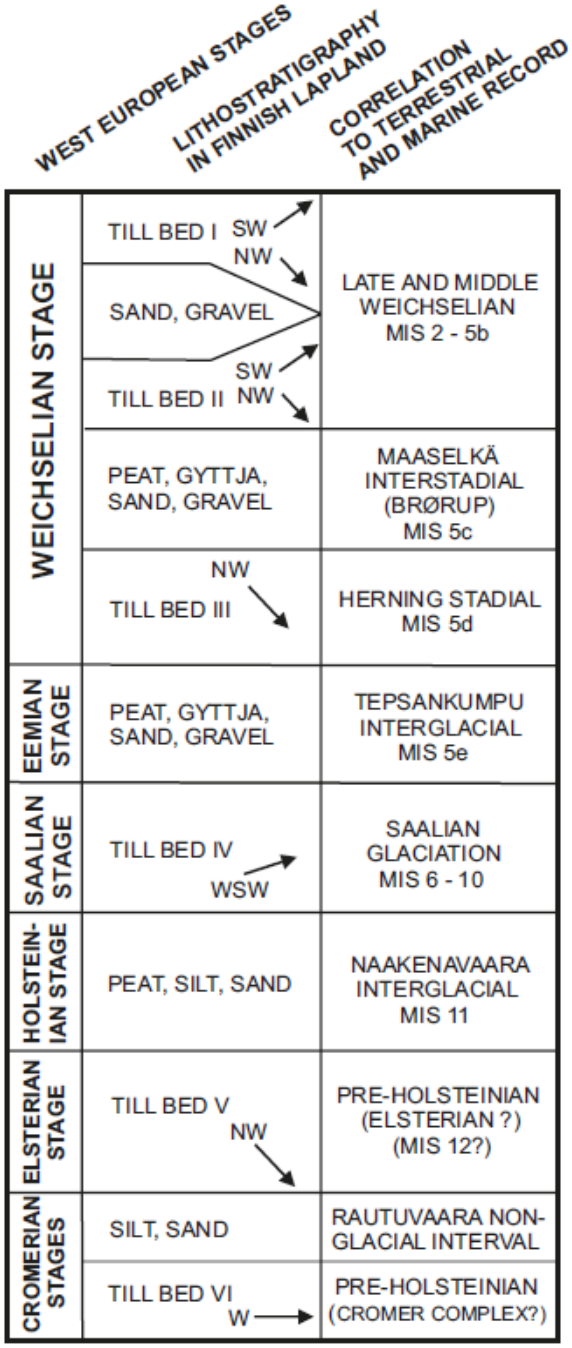

MONTTU 1-2
MONTTU 4
MONTTU 3
250°
330°
60°
240°
1
2
3
4
5
6
7
8
MOREENIPATJA II
PIENI- (KK 1-2) JA VÄHÄKIVINEN (2)
RAKENTEETON
HIEKKAA
MOREENIPATJA III
RAKENTEETON, KIVINEN (KI 4)
YLÄKONTAKTI TERÄVÄ
ALAKONTAKTI AALTOMAINEN
MOREENIPATJA IV
HIEKKAINEN, LÖYHÄ JA RAKENTEETON
MUUTTUU ALAOSASTAAN HIEKAKSI
HIETAISIA JA HIESUISIA (SAVISIA)
SEDIMENTTIKERROKSIA, JOISSA
Mn-SAOSTUMARAITOJA
INTERGLASIAALINEN TURVE,
JOSSA RUNSAASTI PUUNKAPPALEITA
JA KORTTEEN JÄÄNTEITÄ
HIEKKAA JA SORAISTA HIEKKAA
PIENI- (KK 1) JA VÄHÄKIVINEN(1)
AINEKSELTAAN HIEKKAINEN
POHJAOSASSA KI 4 JA KK 3
LAMELLIRAKENNETTA, SAOSTUMIA
HIESUINEN JA SAVINEN VÄLIKERROS,
JONKA ALLA Mn-SAOSTUMIA
YLÄOSASSA HIEKKAPUSSEJA
ALAKONTAKTI TERÄVÄ
HIEKKA- JA SORALINSSEJÄ
POHJAOSA HIEKKAA
POHJALLA MAHD. MOREENIA TAI KALLIO
ORGAANINEN
MAANNOSKERROS
HIEKKAA
HIETAA JA HIESUA
HIEKKAA JA SORAA

The Rautuvaara section in western Lapland has been considered as a type section for the northern Fennoscandian Middle and Late Pleistocene.


A
B
Sokli
Maaselkä
Hannukainen
Kauvonkangas
Sweden
Russia
Finland
Hitura
Pyhäsalmi
Yllas Fell
719 m a.s.l.
Rautuvaara
280 m a.s.l.
Rautuvaara section
Äk
Pahtajärvi
Pakasaivo
Valkeajoki
Kuerjoki
Äkäslompolo
Muonionjoki
Hannukainen
Äkäsjoki
Rautuvaara
Sivakkapalo
Kittilä
Naakenavaara
0 10 20 km
Kolari
Teuravuoma
Legend
Lake
River
Village
Stratigraphic site



The open pit was studied for the first time during the 1970's, when the section was 25 m thick.
Several till units and statified inter-till layers were interpreted to represent five separate glasiations.



The stratigraphy of Finnish Lapland and its suggested correlation to the NW European Pleistocene stages after Hirvas (1991).

The correlation of the NW European Pleistocene stages to the Marine Isotope Stages (MIS) is also indicated.

Weichselian glaciation

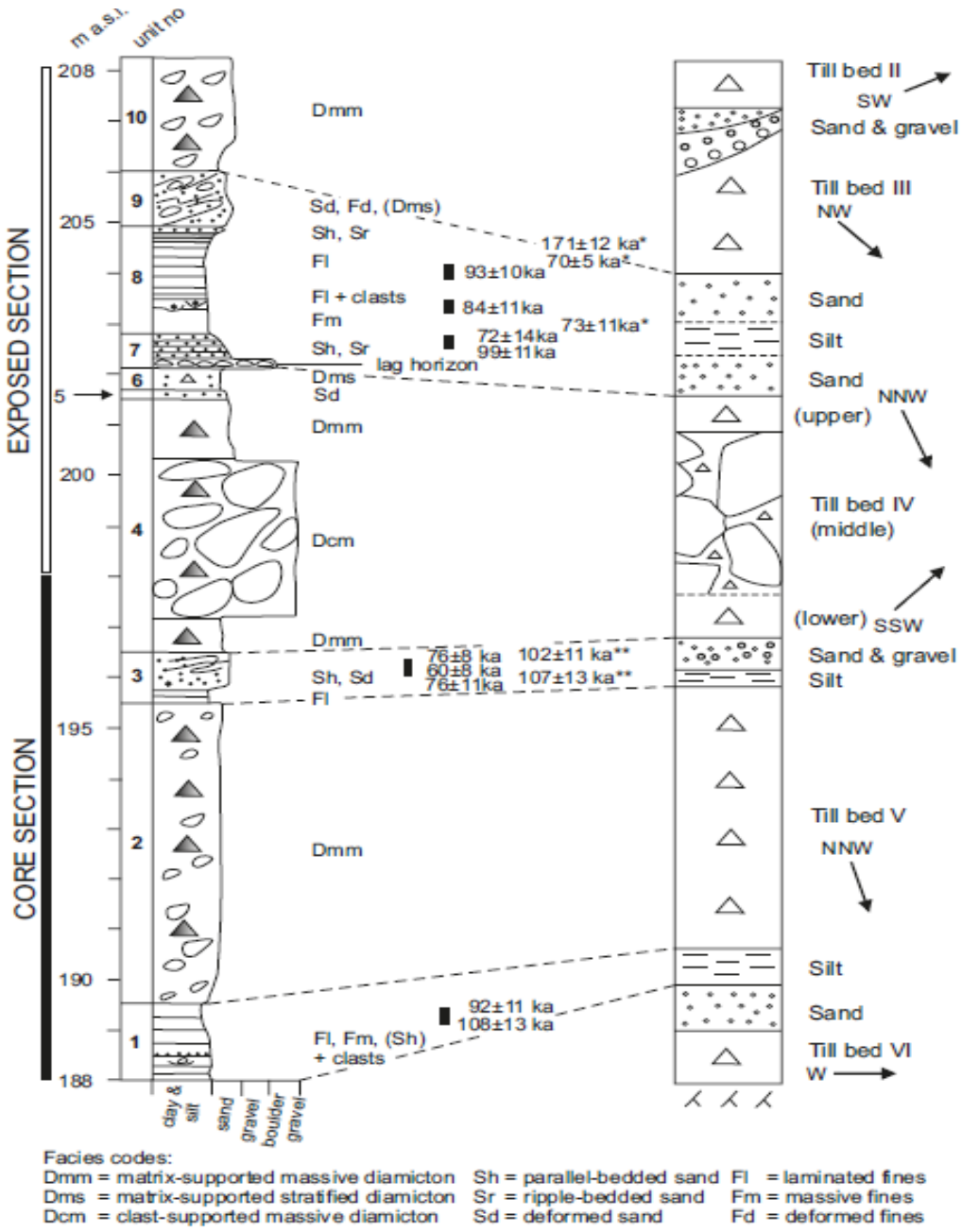
Saalian glaciation

Pre-Saalian glaciation

On the upper part of the Rautuvaara section new chronostartigraphical studies were carried out in the 2010's (Lunkka et al. 2015).

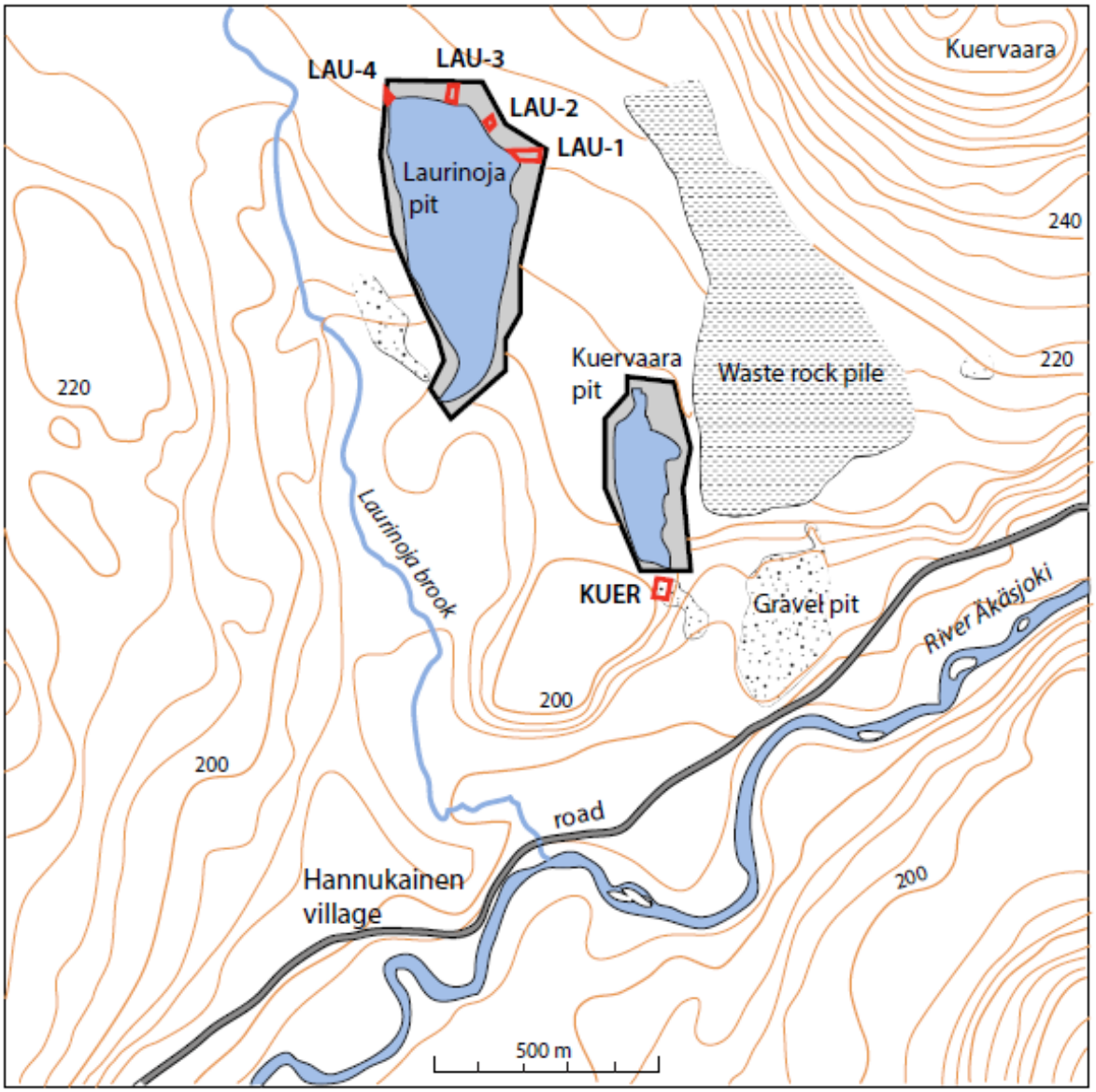
- Sedimentological studies.
- Till fabric analyses
- Sand-rich inter-till layers were dated using OSL method.

Lunkka et al. 2015



Hirvas 1991

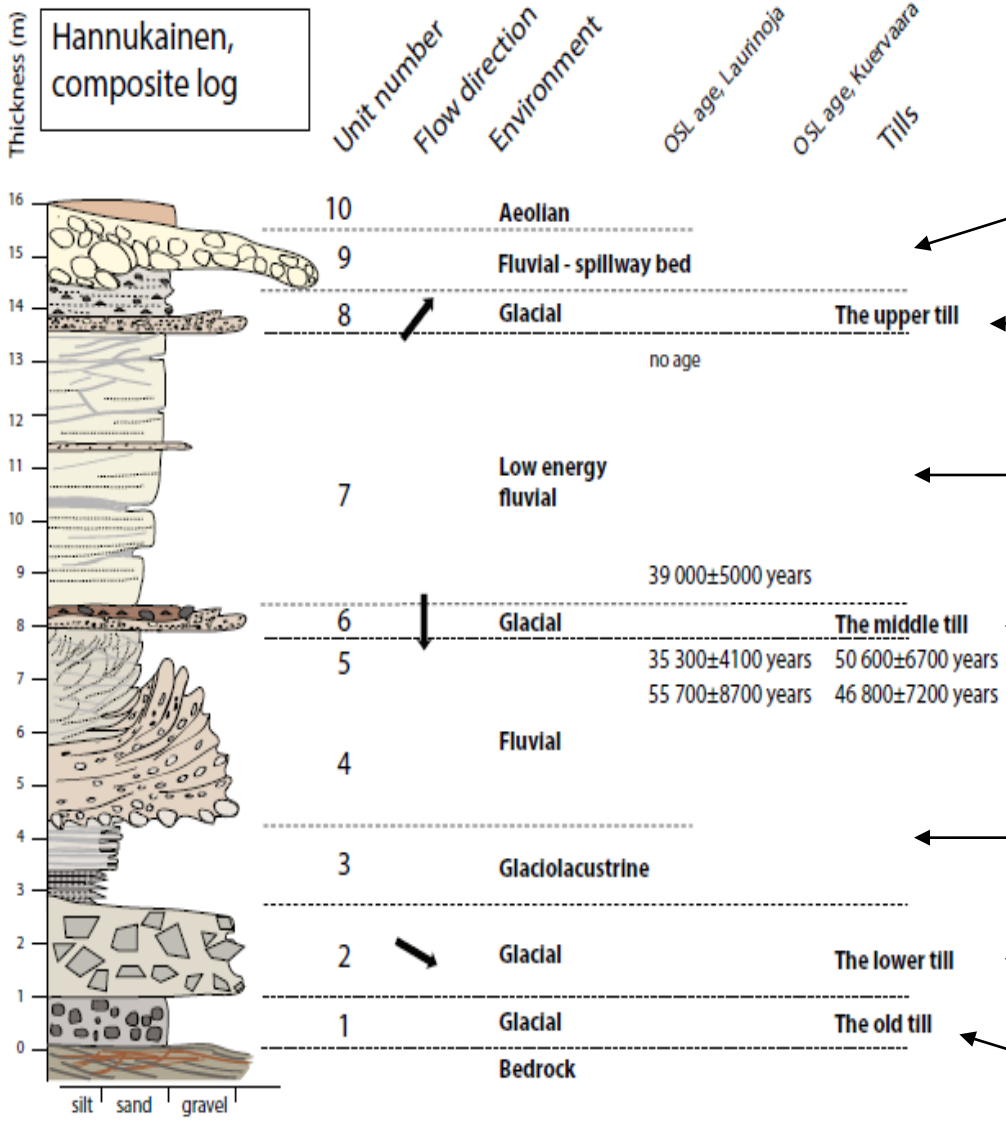
- New studies confirmed the earlier observations of five till beds
- The whole sediment succession was deposited during the Weichselian Stage
- The SIS advanced Lapland at least once during the Early Weichselian (MIS 5 b?)
- Twice during the Middle Weichselian (MIS 4 and 3)
- Once during the Late Weichselian (MIS 2) substages
- There were two ice-free intervals in Lapland during the Middle Weichselian



At Hannukainen Mine open pit, ten kilometres north from Rautuvaara sedimentological investications were carried out (Salonen et al. 2014).

Hannukainen open pit

Ten different sedimentary units were identified with a variety of depositional environments



Sand layer with well-developed podsolic soil horizons

Diamiction, erosional contact and deformed gravels

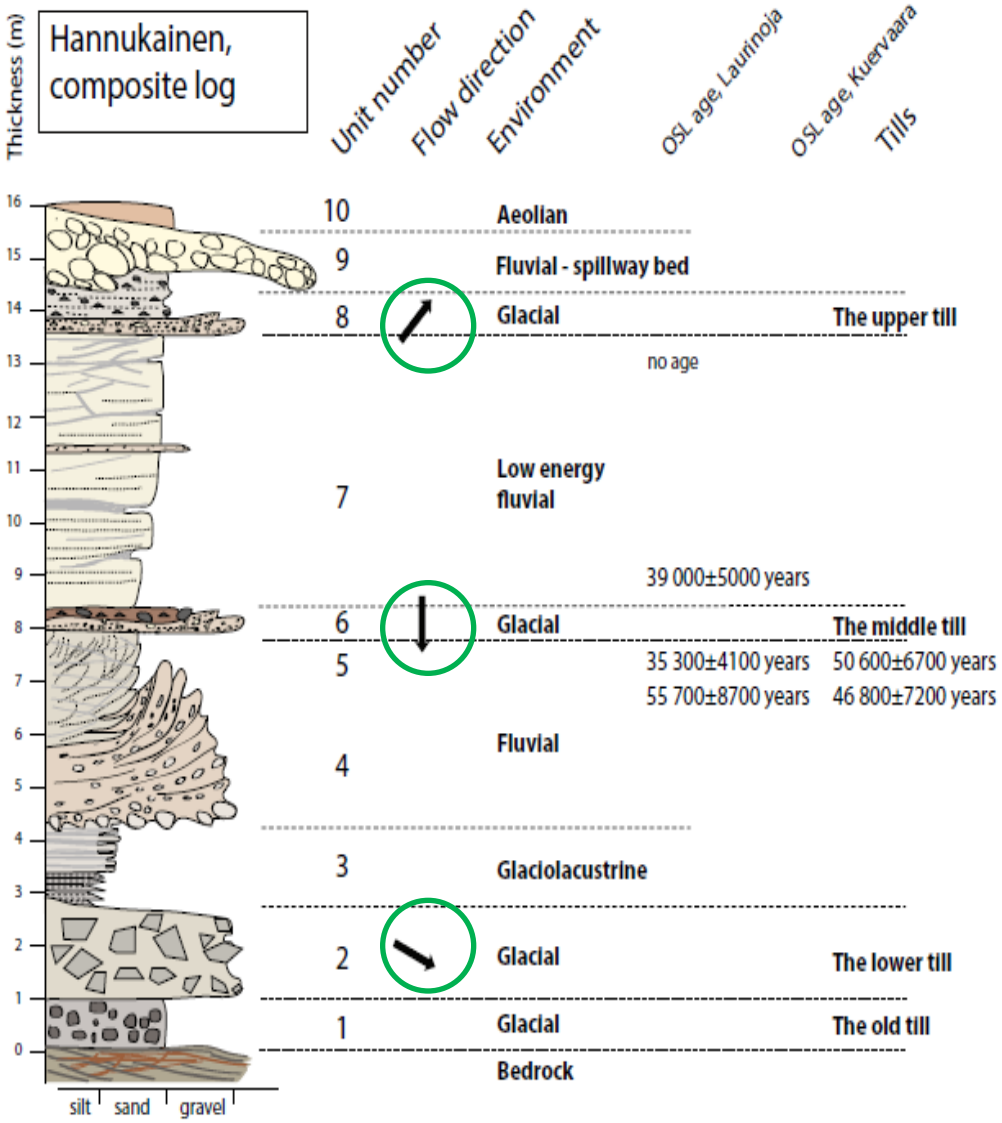
Horizontally bedded sands with ripple laminations and deformation structures

Gravel-rich diamiction

Stratified sediments from lami-nated silts coarsening upwards

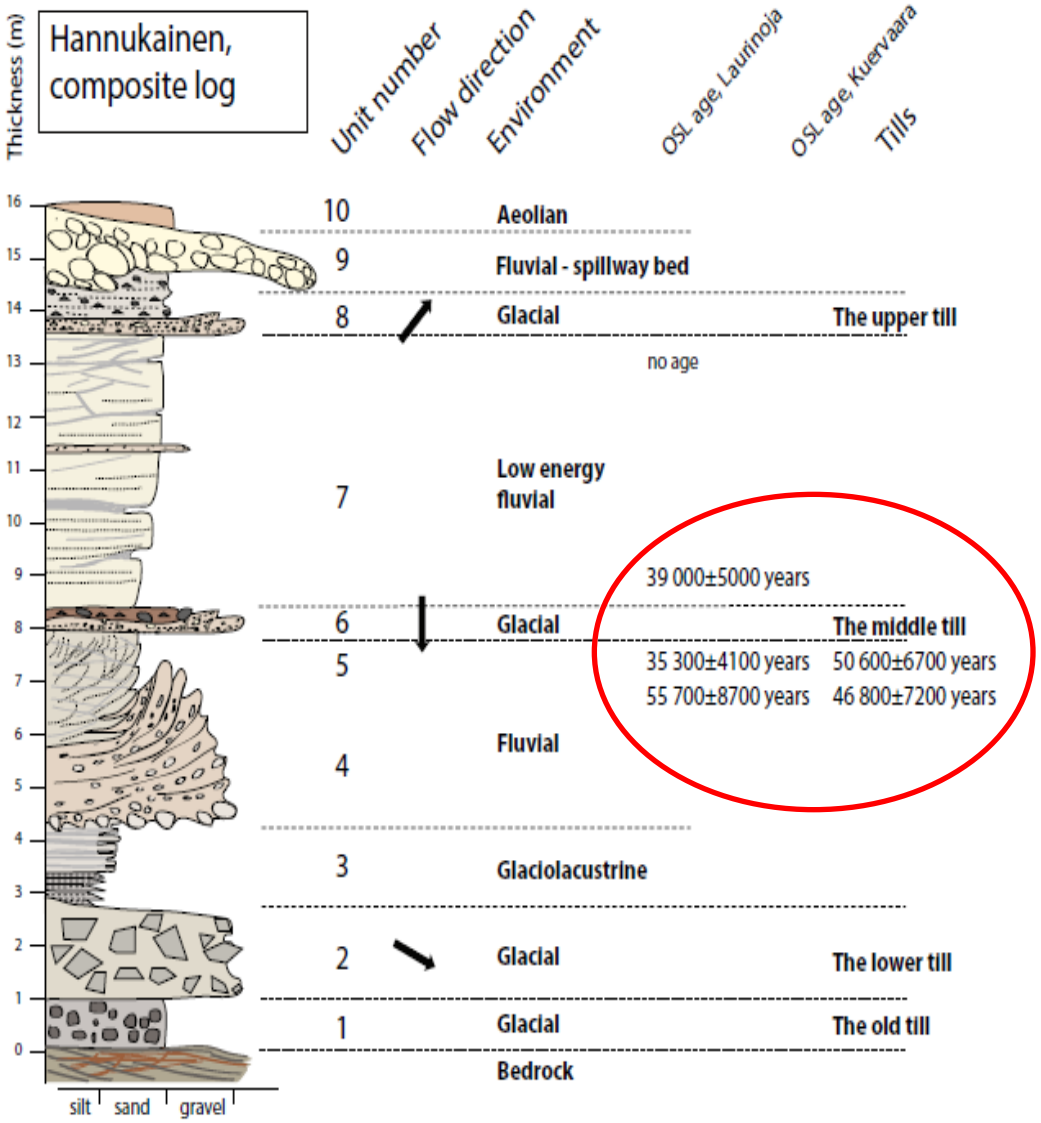
Unweathered till unit

Till unit with weathered rock material



Sedimetary units 2 – 10 are interpreted to be Mid or Late Weichselian age. The age of the lowermost till unit (1) is unknown.

Three different ice flow directions have been found.

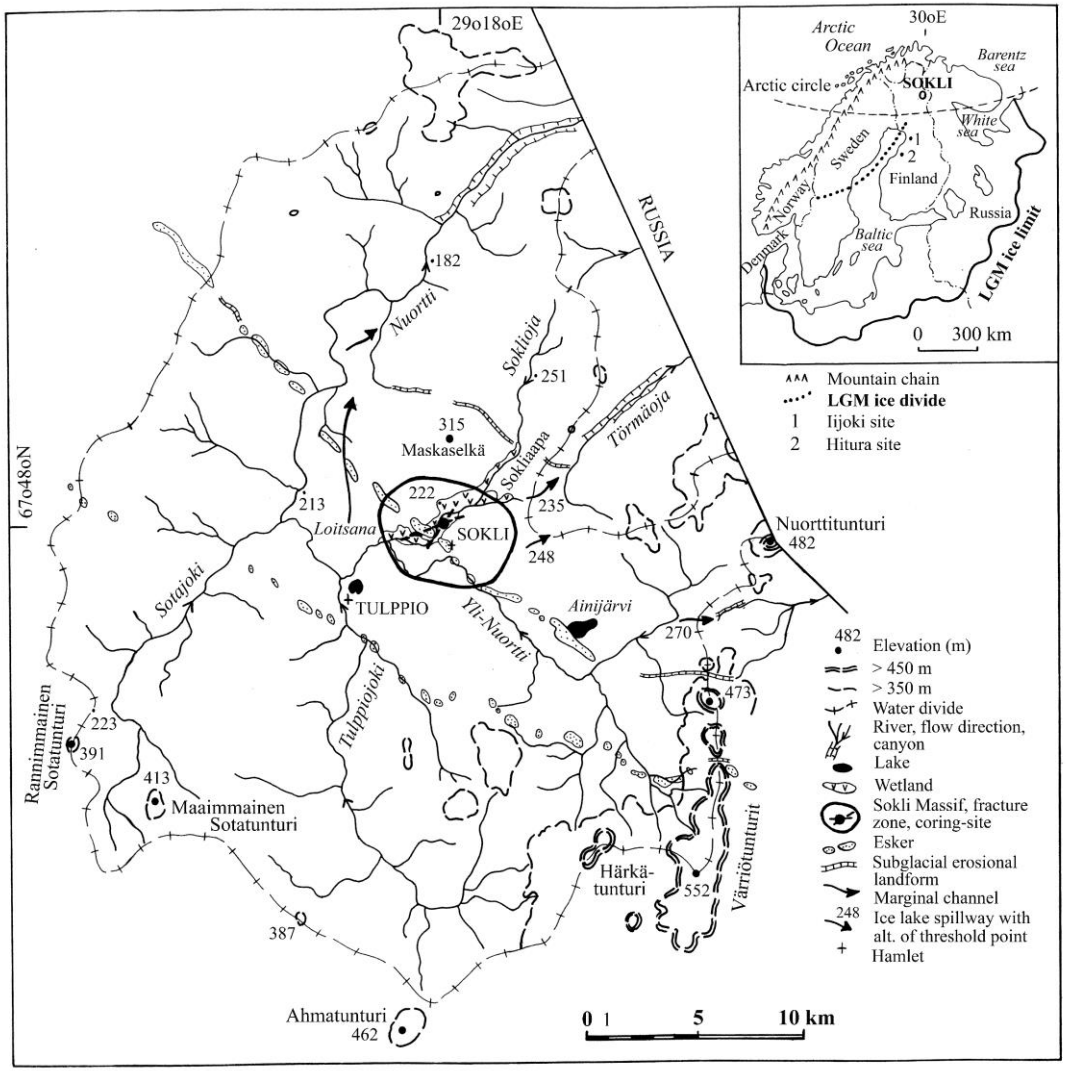


Sedimetary units 2 – 10 are interpreted to be Mid or Late Weichselian age. The age of the lowermost till unit (1) is unknown.

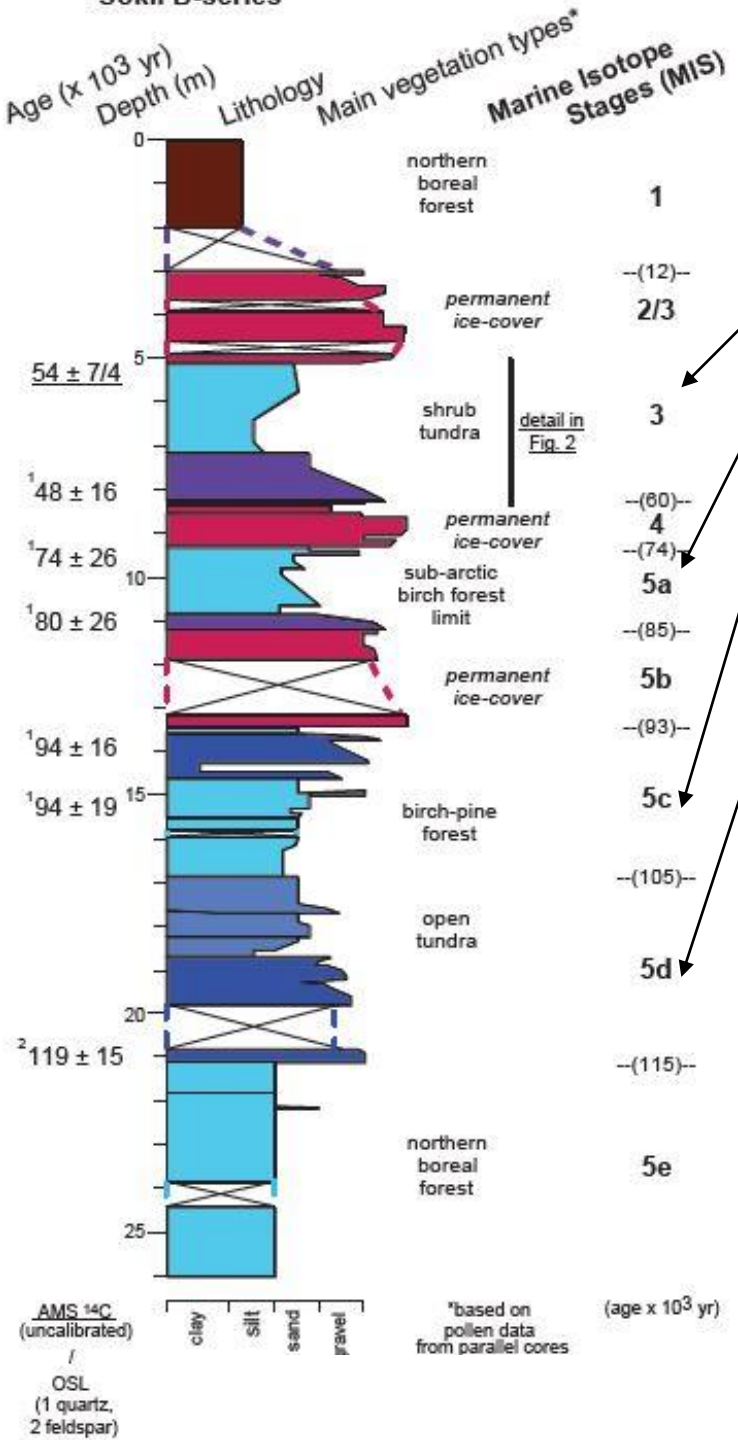
Three different ice flow directions have been found.

OSL dates from the lower and the upper interstadial sediments suggest two ice-free intervals for MIS 3 age (56 – 35 ka).

Precision of the dates is too poor to determine the exact age and duration of the interstadials.



A multiple till sequence with interbedded, microfossil rich, finegrained sediments are described analyzed from the boreholes at Sokli, northeastern Finland (Helmens, Räsänen, Johansson, Jungner and Korjonen 2000).

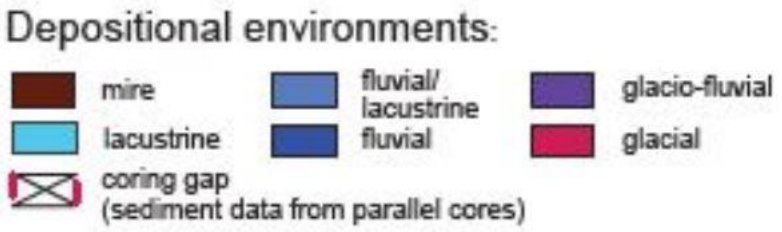


Sokli

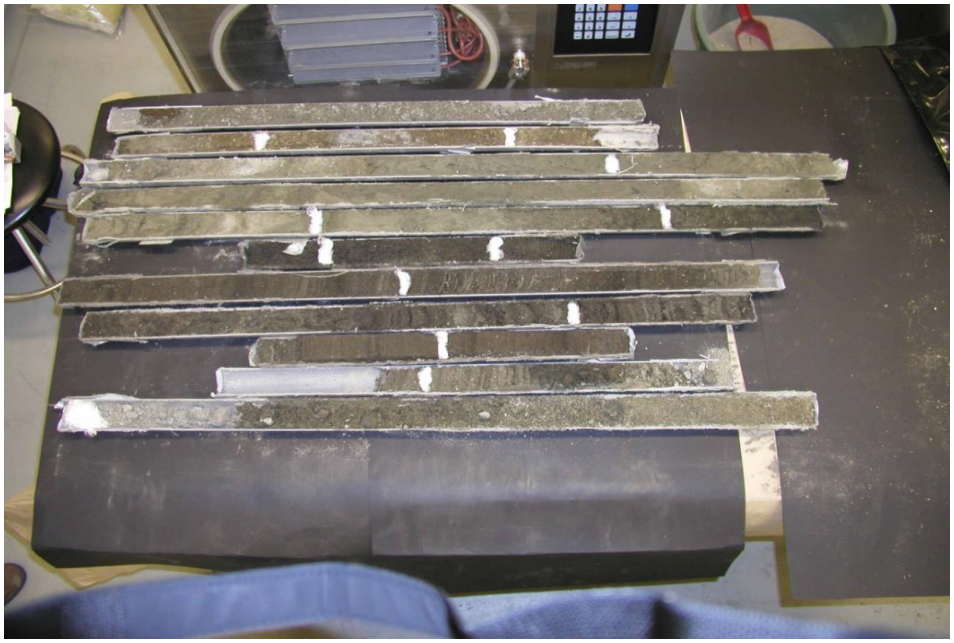
The Middle Weichselian (MIS 3 and 4), the Odderade (MIS 5 a) and the Brørup interstadial (MIS 5 c) units are overlain by till.

At Sokli, a silt unit (5 d), that contains a tundra-type pollen assemblage, separates the Eemian interglacial and the Brørup interstadial units

(K. Helmens, M. Räsänen, P. Johansson, H. Jungner & K. Korjonen 2000)



- North-eastern Finland was unglaciated until Rederstall Stadial (MIS 5 b) around 90 ka.
- Early Weichselian interstadials, *i.e.* the Brørup (MIS 5c) and Odderade interstadials (MIS 5 a), were ice-free intervals.
- During the Herning Stadial (MIS 5d), the Scandinavian Ice Sheet margin most probably located in the mountains of northwestern Finnish Lapland and in northern Sweden.

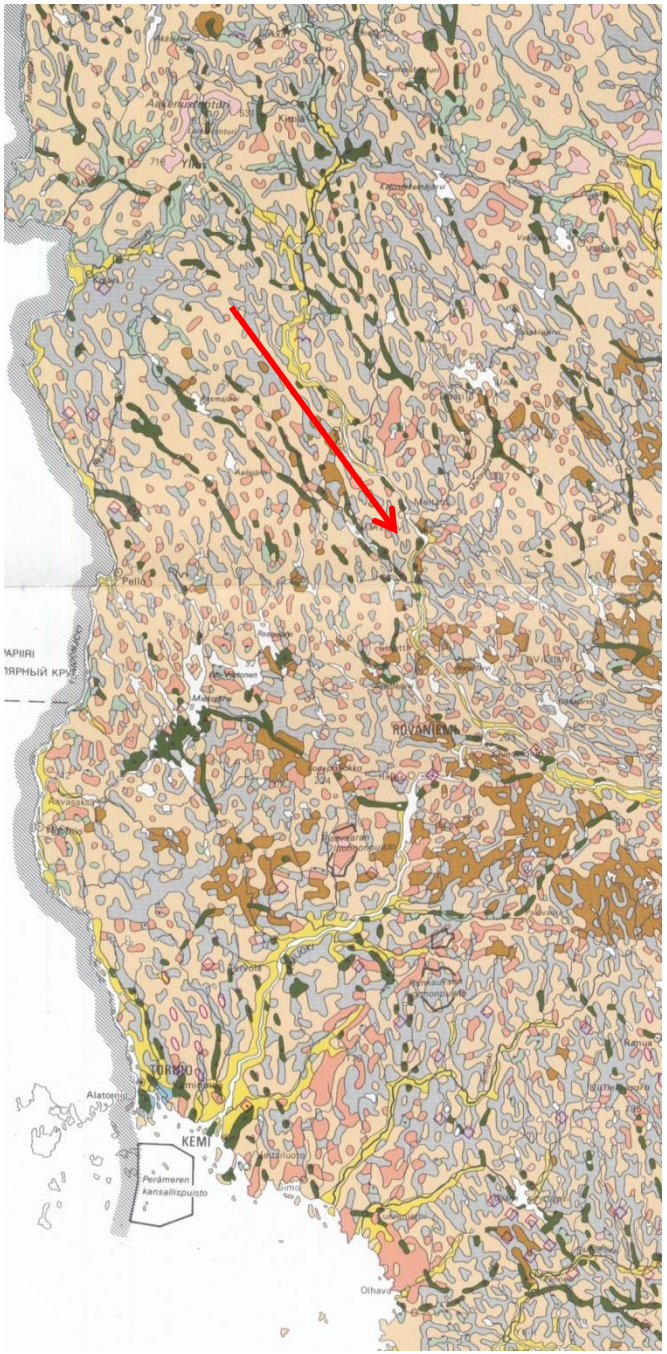


After the Odderade interstadial, the Scandinavian ice sheet (SIS) advanced across northern Finland during MIS 4 (~ 74 ka ago).

Eastern and southern Lapland was deglaciated (several times?) during the MIS 3 (56 – 35 ka ago).

2-m-thick sequence of laminated sediment is thought to have been deposited in a glaciolacustrine environment during MIS 3 at around 40 ka ago.
The laminated unit contains pollen indicating shrub tundra vegetation.
Based on relatively high tree pollen percentages in these sediments,
pine and tree birch were probably growing a few 100 km south of Sokli.

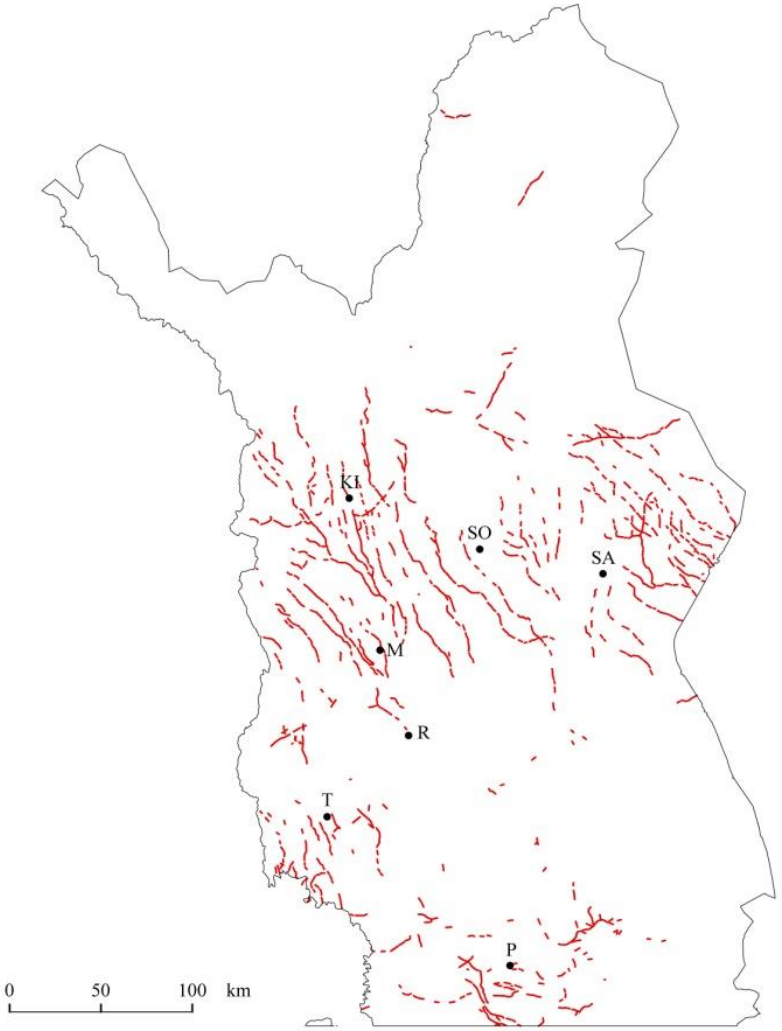
Till-covered esker at Meltaus, Rovaniemi



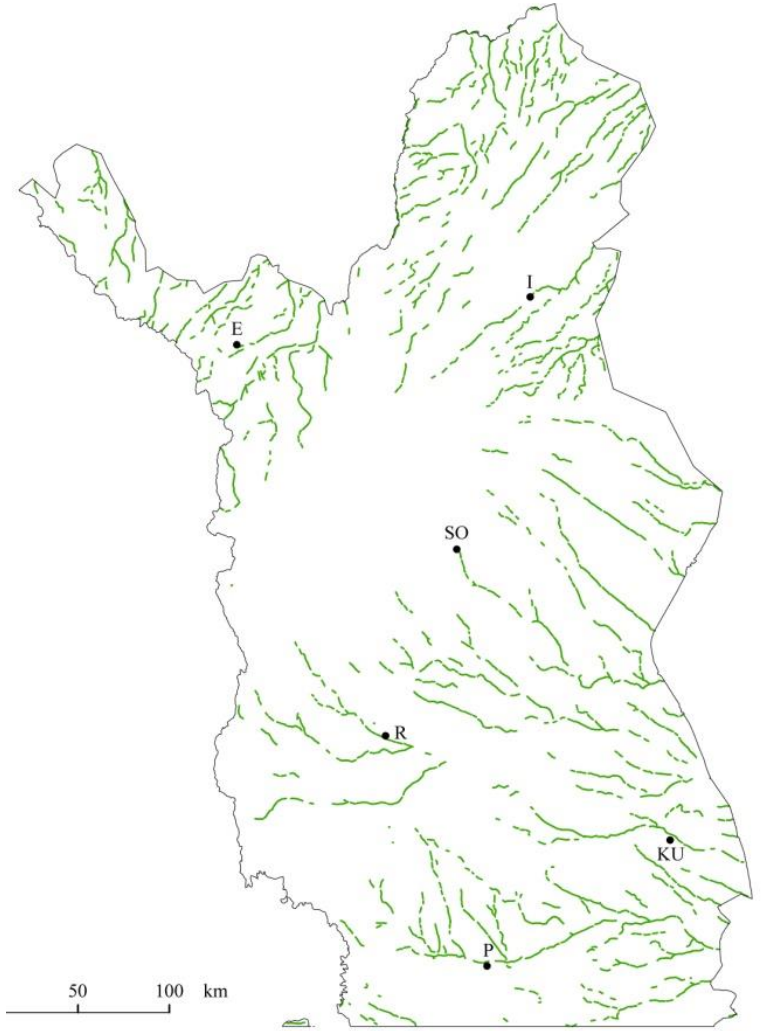
The north-north-west – south to south-east-trending drumlin field and associated stratified sediments above in south-western Finnish Lapland were deposited by ice during the Middle Weichselian and its deglaciation.

In addition, ice-marginal deposits were most probably formed during different stages of the Middle Weichselian ice recession.

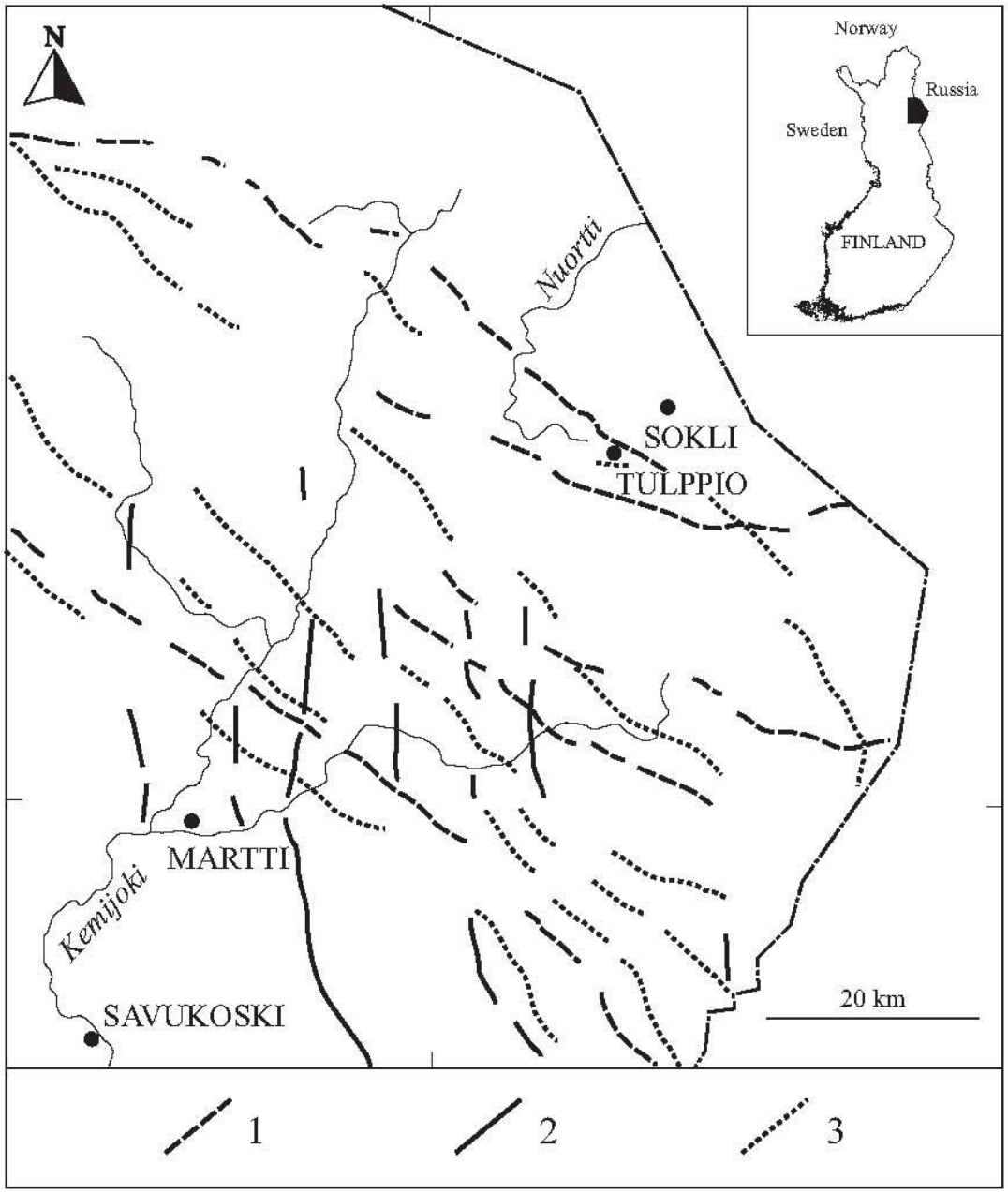
Old till-covered eskers



Young eskers
without till cover



(Johansson & Kujansuu 2005)



At least three cross-cutting esker systems have been mapped in north-eastern Finland.

1 = Saalian or Early Weichselian esker

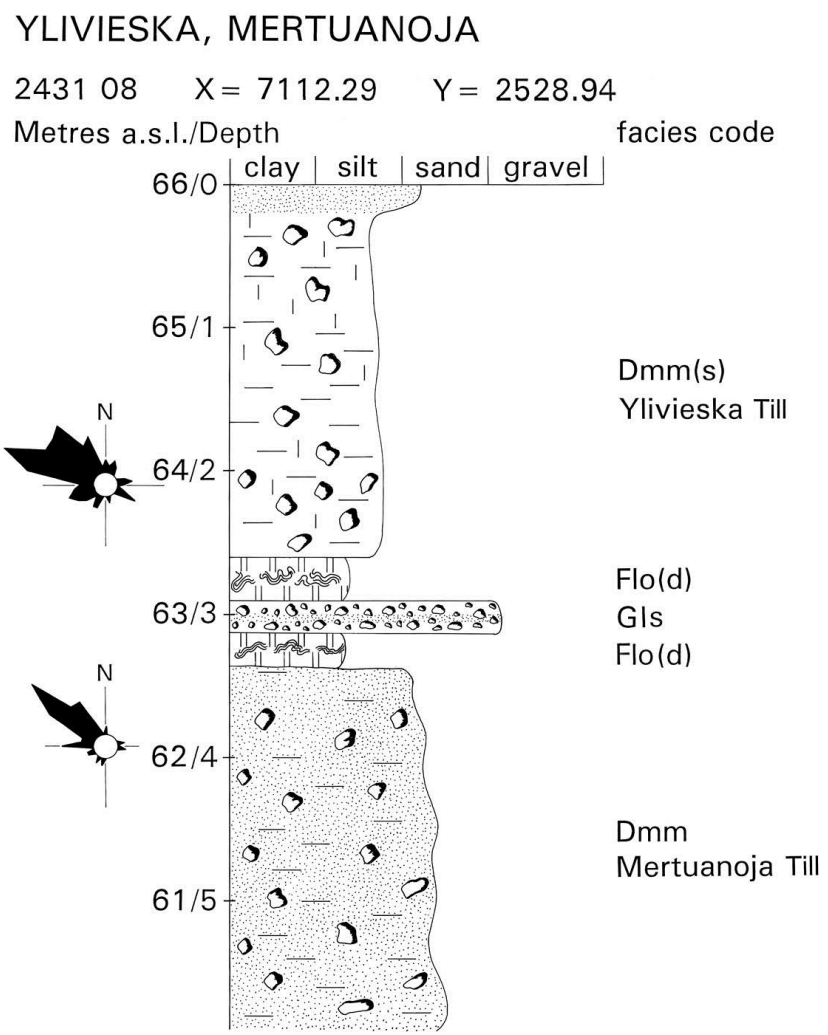
2 = Mid-Weichselian Esker

3 = Late Weichselian esker

(Johansson and Kujansuu 1995)

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.

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.



K. Nenonen, 1995

In Pohjanmaa, central western Finland, two till beds are found overlying organic sediments that were deposited in the Eemian interglacial Stage or Early Weichselian stadials. The ice flowed from north-west.

The Scandinavian ice sheet (SIS) advanced into southern Finland and beyond during MIS 4, some 74–60 ka ago and Southern Finland was covered by ice during the early Middle Weichselian (MIS 4).

The ice flowed from the north-north-west across the southern part of Finland. The time and the duration of the ice cover over southern Finland is not yet precisely known.

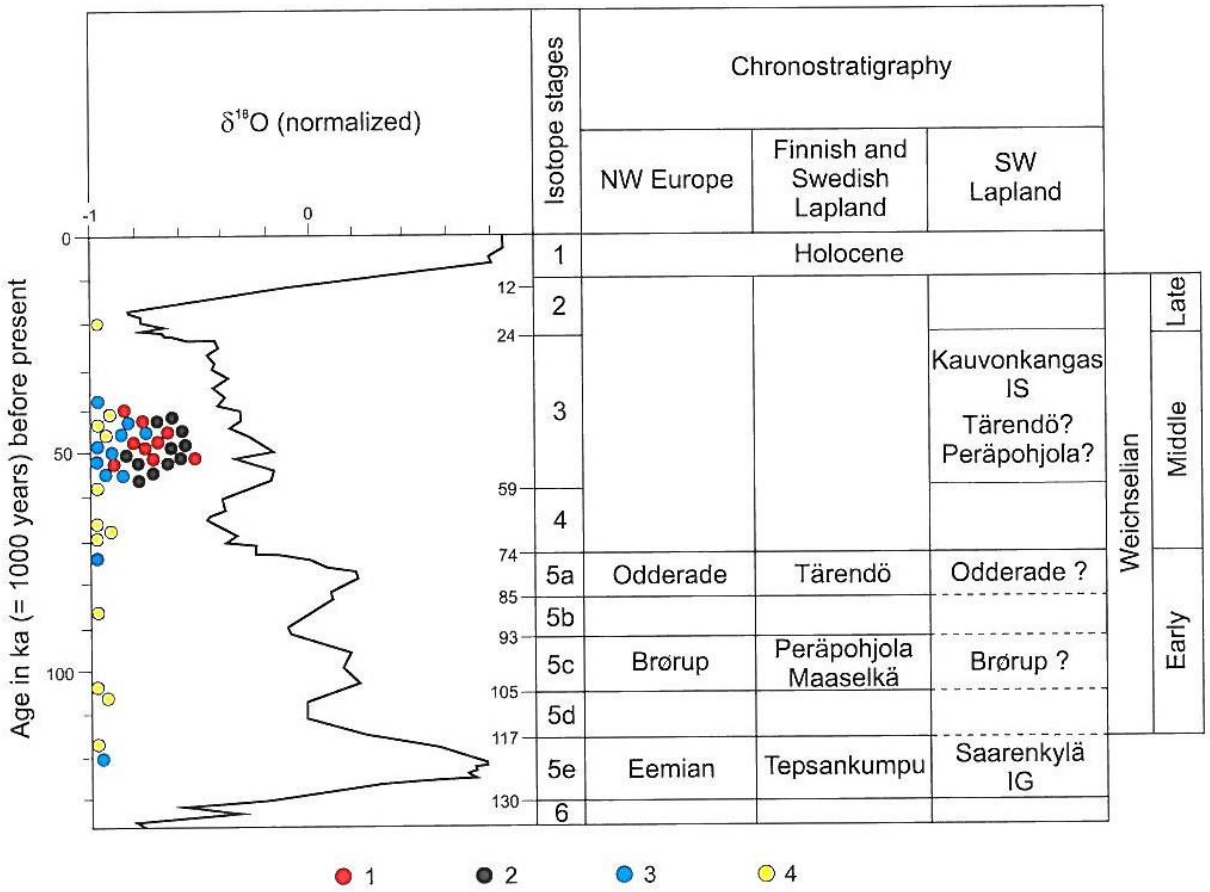
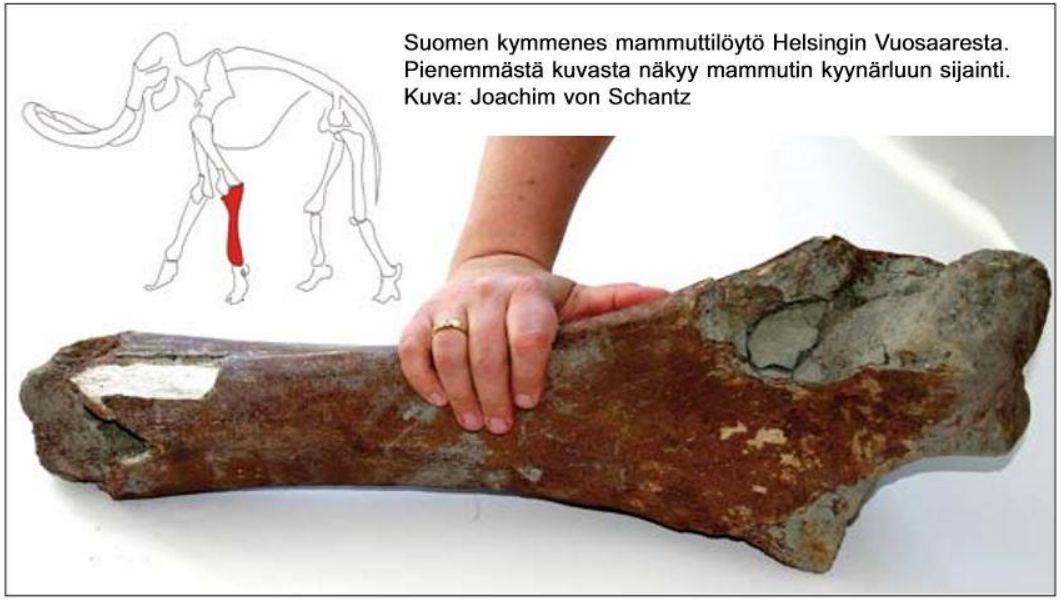


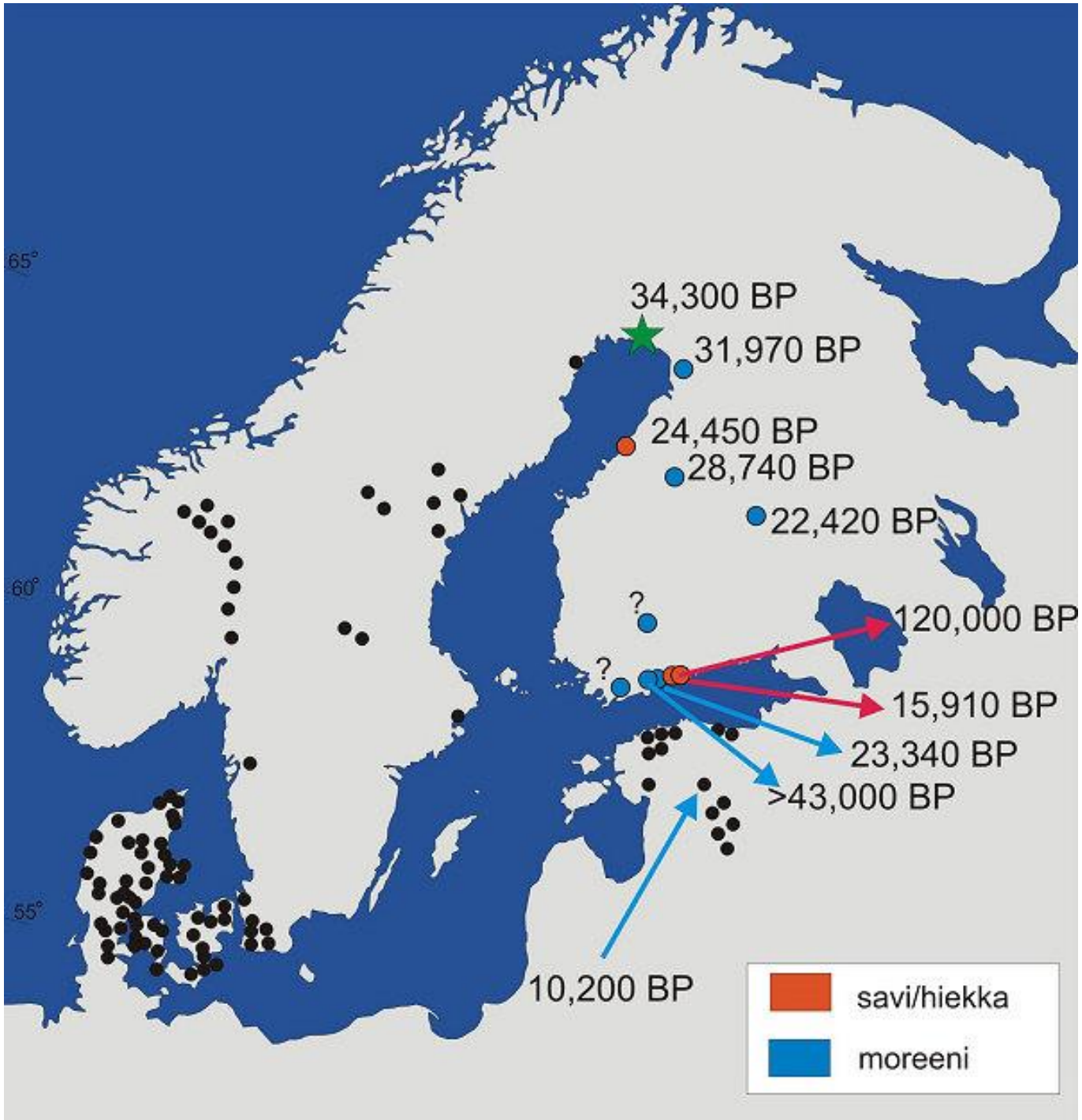
Fig. 3. Ages obtained through ^{14}C, TL and OSL dating from SW Lapland compared with the deep sea isotope curve (Martinson et al. 1987). Symbols 1 = finite ^{14}C age, 2 = infinite ^{14}C age, 3 = TL age and 4 = OSL age. Chronostratigraphy in Finnish and Swedish Lapland after Hirvas (1991) and Lagerbäck & Robertsson (1988).

At 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.

In Finland eleven mammoth fossils have been found.

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 54 – 25 ka ago.

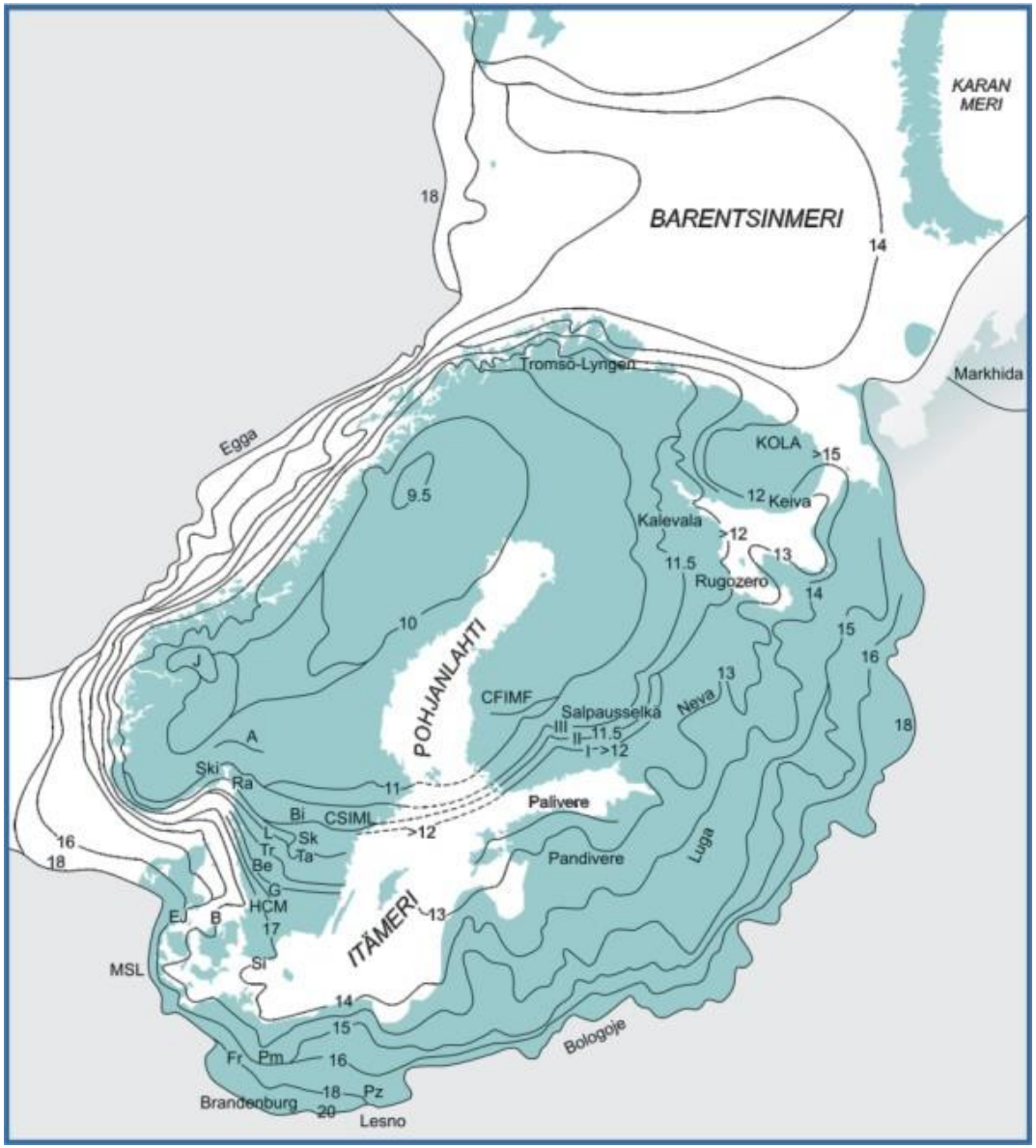



65°
60°
55°
34,300 BP
31,970 BP
24,450 BP
28,740 BP
22,420 BP
?
?
120,000 BP
15,910 BP
23,340 BP
>43,000 BP
10,200 BP
savi/hiekka
moreeni

The rapid ice-advance of the Scandinavian Ice Sheet across southern and central Finland into the NW Russian Plain took place after 25 ka cal BP ago.

Based on fabric analysis and striae measurements, the ice-movement direction during this advance phase was from a westerly direction.

The Scandinavian Ice Sheet reached its maximum extent in the north-west Russian Plain and the Kanin Peninsula 18.5 – 17 ka ago.



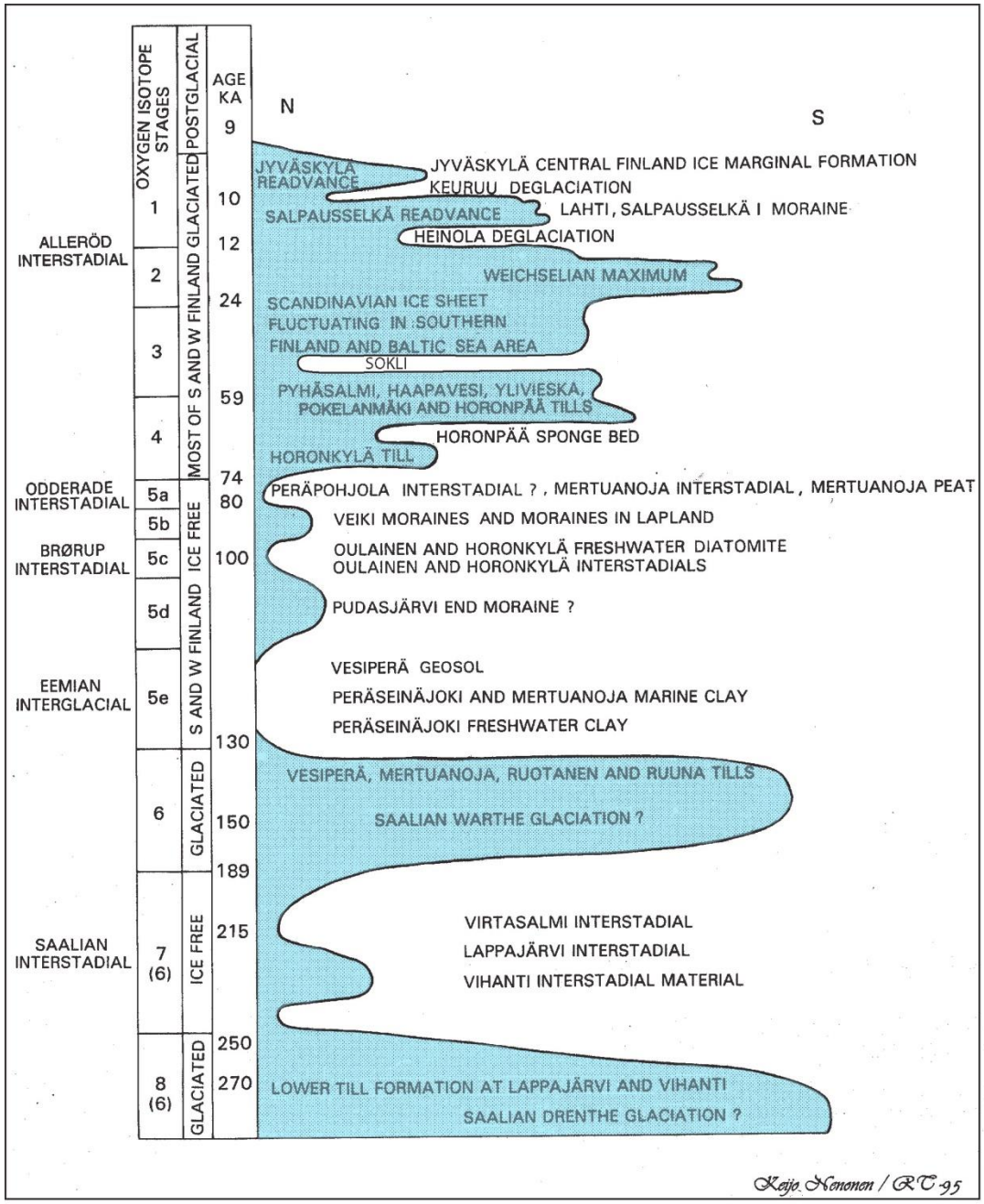


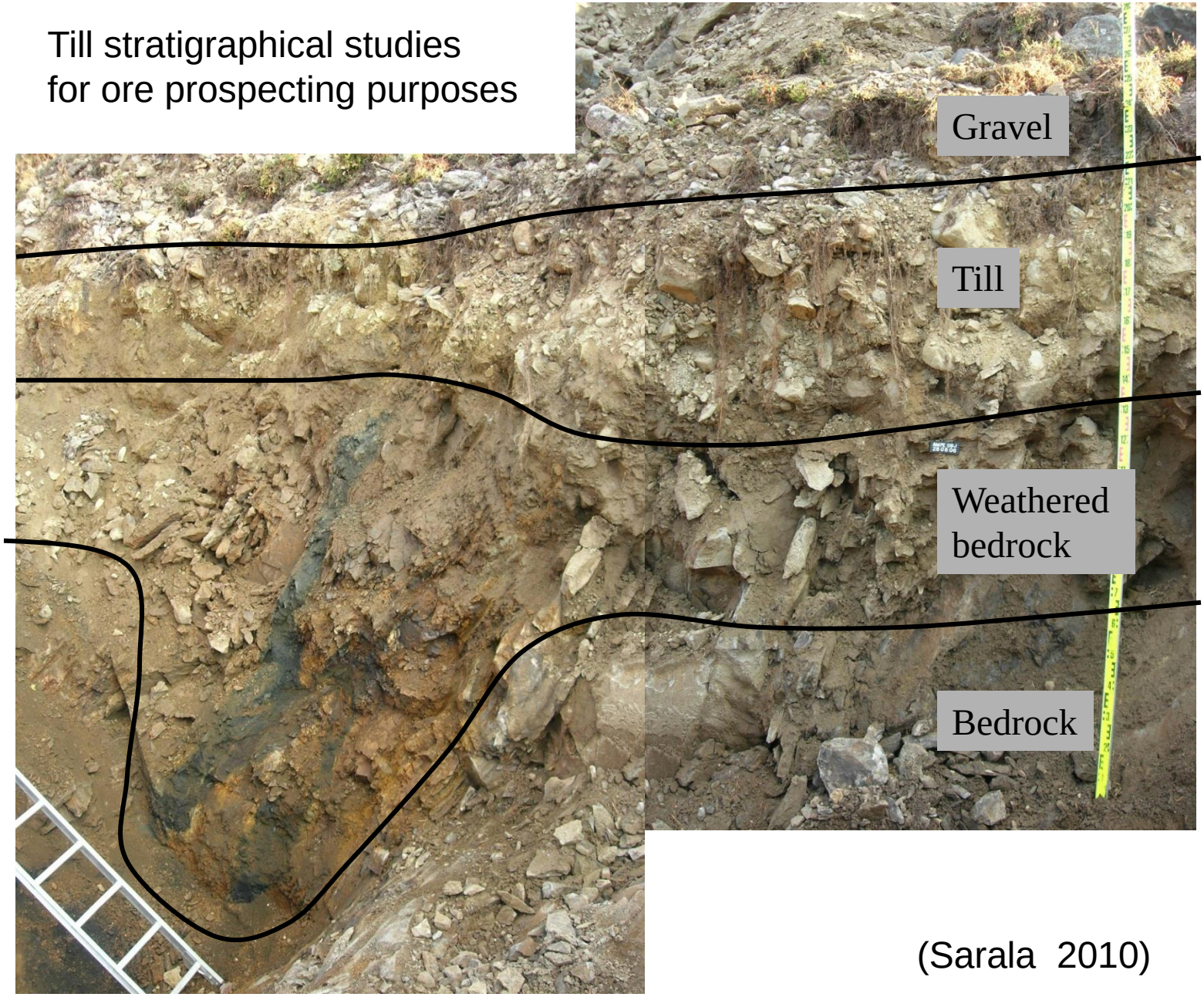
Fig. 3.2.1

TD-diagram for Saale og Wichselistidene og korrelasjoner av avsetninger og hendelser i Sør- og Vest-Finland. Ved Sokli i Nord-Finland (markert med pil) er det nylig beskrevet en interstadial som faller inn i isotopstadium 3 (Helmens mfl. 2000). Modifisert etter Nenonen 1995 (Bargel 2003).

Quaternary geological methods for ore prospecting purposes in glaciated terrains:

- Mapping of ore boulders and boulder trains, probability sector
- Till geochemistry and the study of heavy minerals
- Glacial landforms and their orientation in relation to the ice flow
- Physical properties of surficial deposits (stucture, content, colour and density)
- Till fabric and striations

Till stratigraphical studies
for ore prospecting purposes

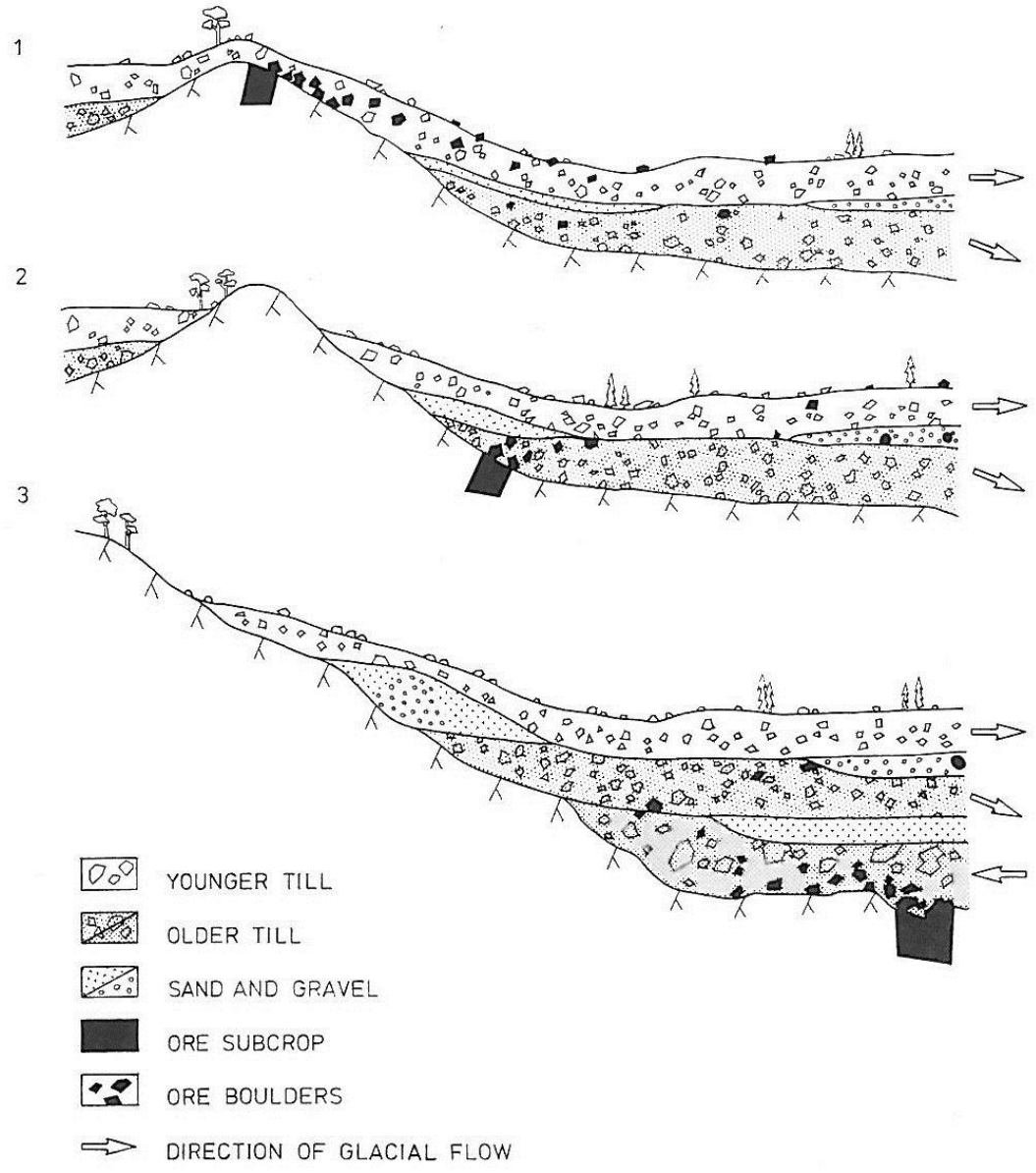


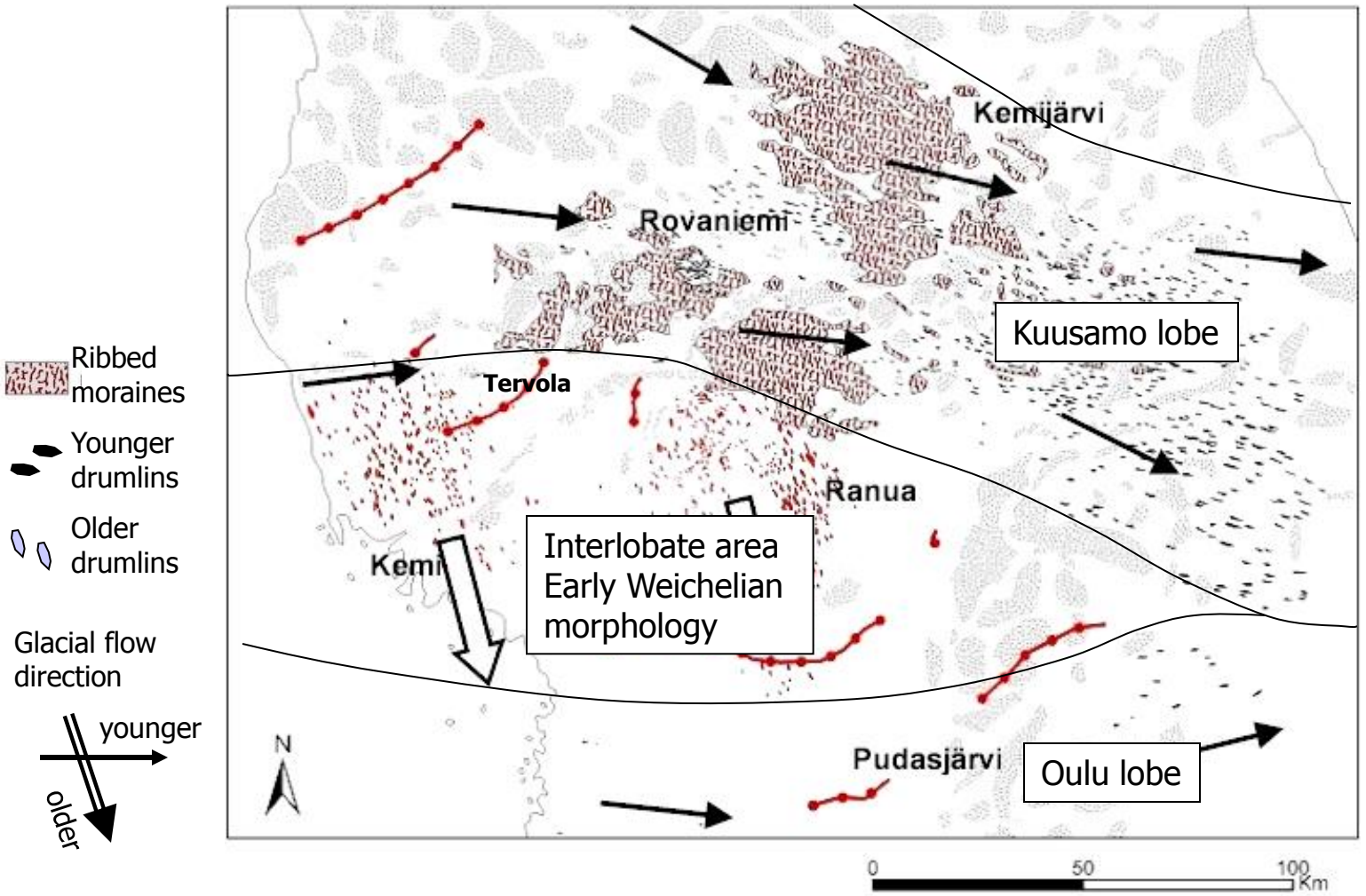
(Sarala 2010)

For ore prospecting purposes it is necessary to know the ice flow direction and the transportation of till material.

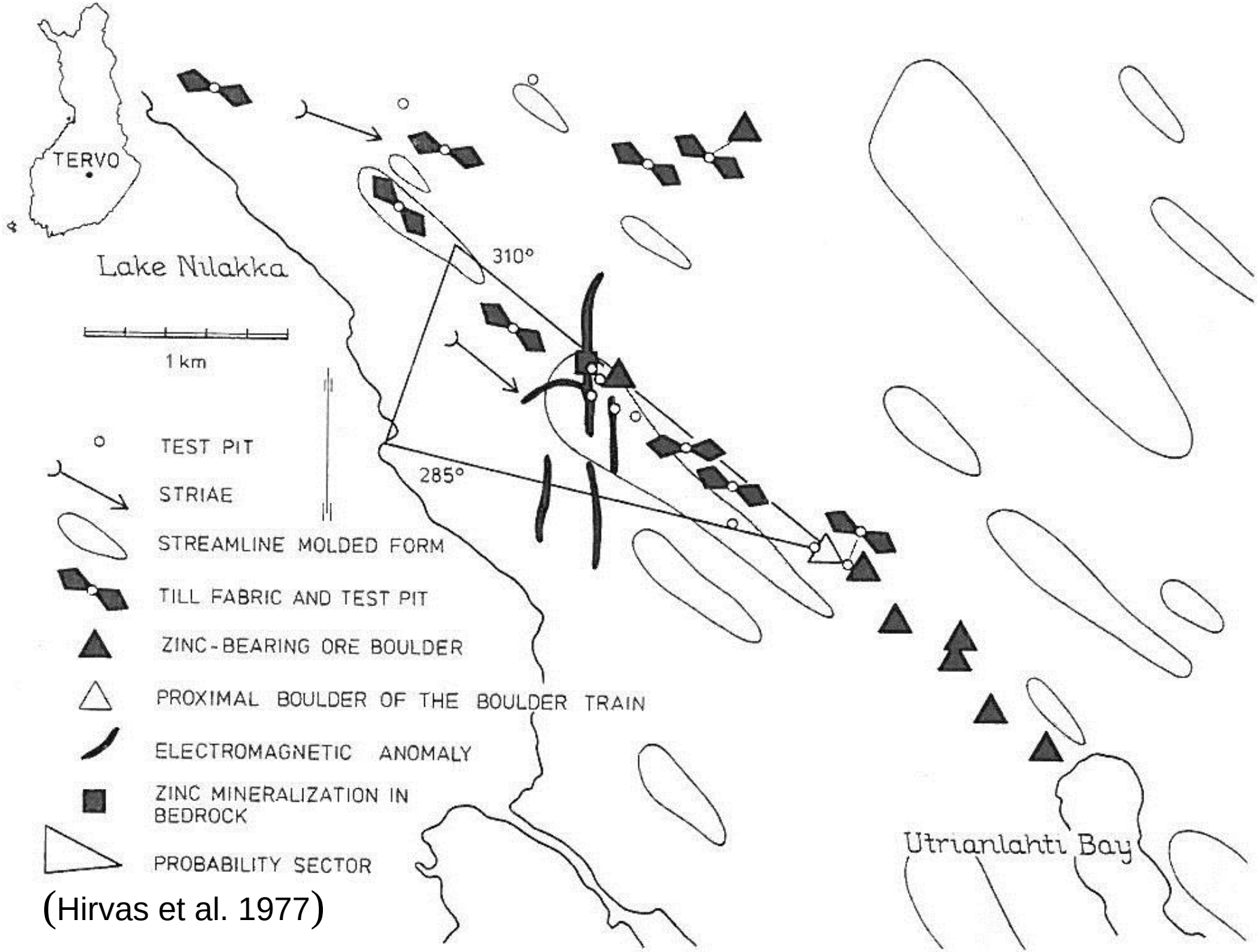
- Glacial dynamics
- Glacial history and ice flow directions during different phases
- Quaternary stratigraphy and different Quaternary deposits

(Hirvas 1991, Sarala 2010)

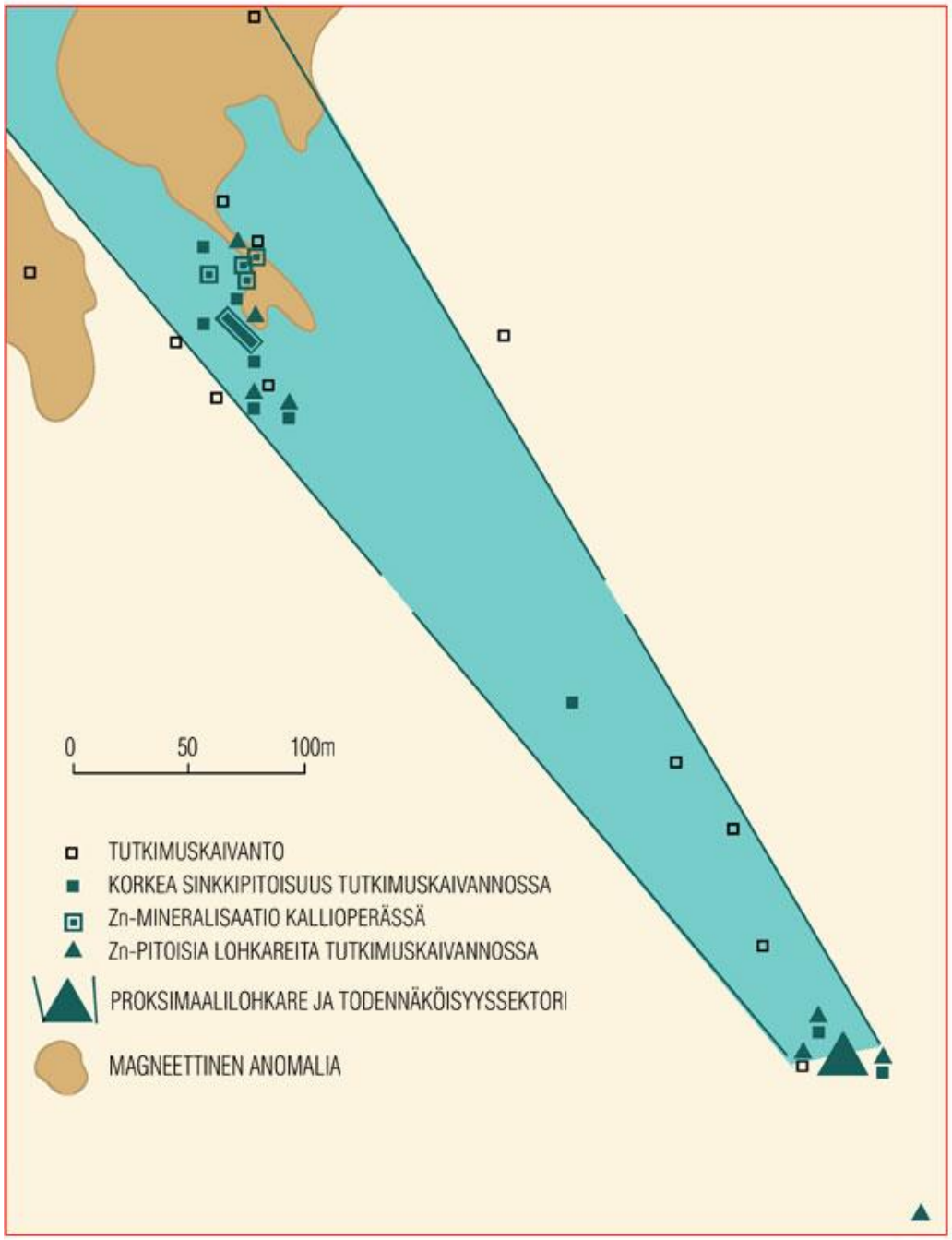


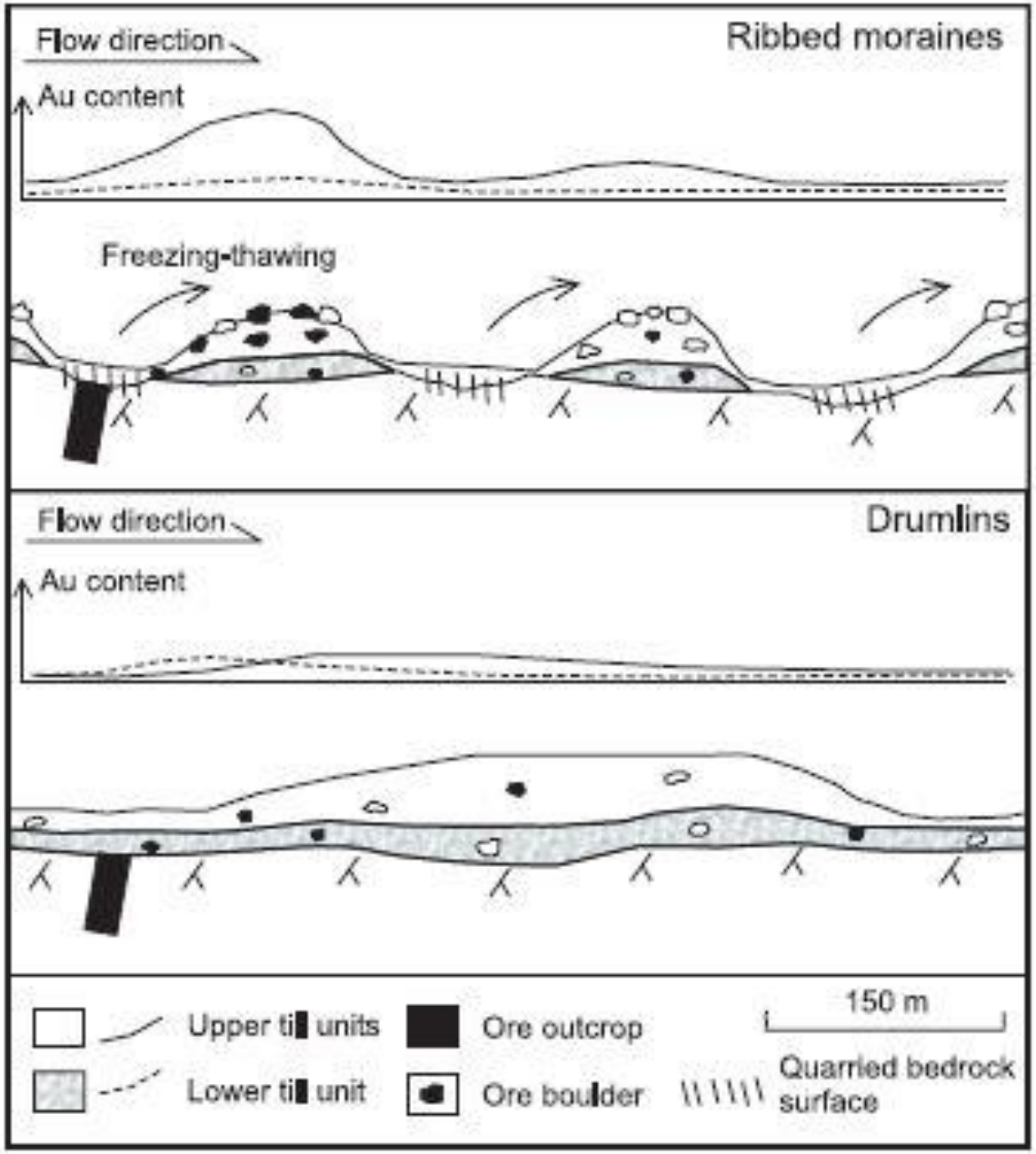

Ribbed moraines
Younger drumlins
Older drumlins
Glacial flow direction
younger
older
Kemijärvi
Rovaniemi
Kuusamo lobe
Tervola
Ranua
Kemi
Interlobate area
Early Weichelian
morphology
N
Pudasjärvi
Oulu lobe
0
50
100
Km

(Sarala 2007)

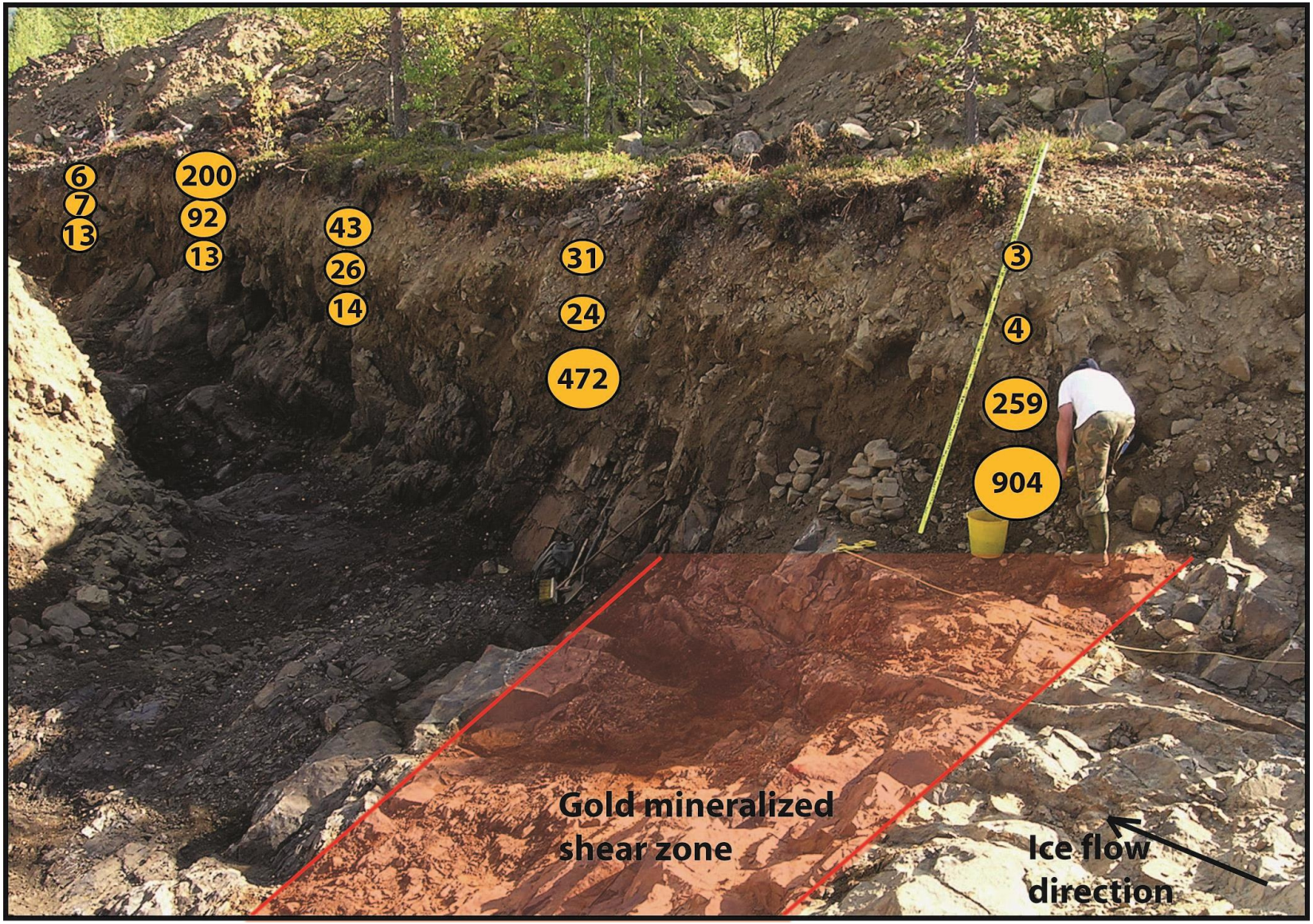


(Hirvas et al. 1977)


0
50
100m
TUTKIMUSKAIVANTO
KORKEA SINKKIPITOISUUS TUTKIMUSKAIVANNOSSA
Zn-MINERALISAATIO KALLIOPERÄSSÄ
Zn-PITOISIA LOHKAREITA TUTKIMUSKAIVANNOSSA
PROKSIMAALILOHKARE JA TODENNÄKÖISYYSSEKTORI
MAGNEETTINEN ANOMALIA



(P. Sarala & J. Nenonen, 2005)



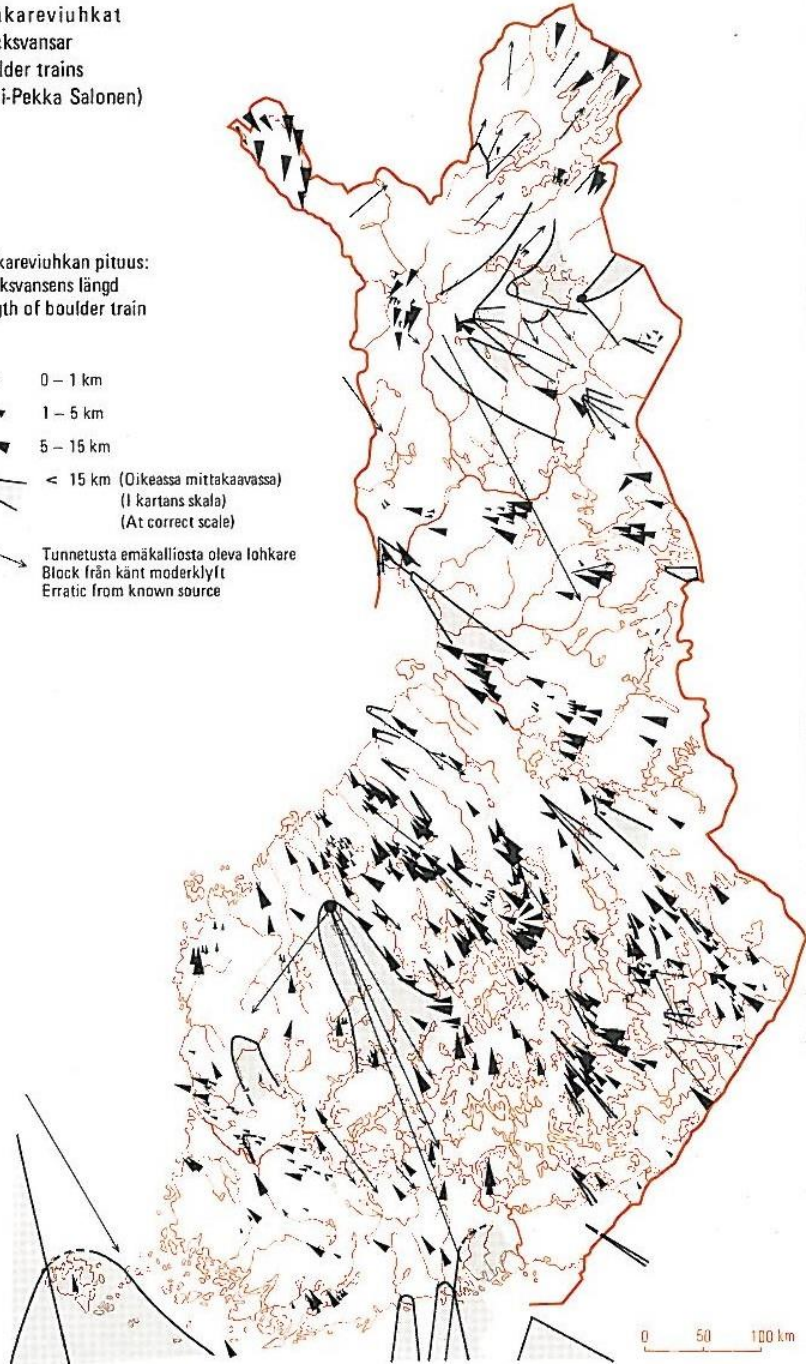
Glacial transportation and (92) gold content in till (ppb, < 0,06 mm at Petäjäselkä, Finnish Lapland (Sarala and Ojala 2008)

Lohkareviuhkat
Blocksvansar
Boulder trains
(Veli-Pekka Salonen)

Lohkareviuhkan pituus:
Blocksvansens längd
Length of boulder train

0 – 1 km
1 – 5 km
5 – 15 km
< 15 km (Oikeassa mittakaavassa)
(I kartans skala)
(At correct scale)

Tunnetusta emäkalliosta oleva lohkare
Block från känt moderklyft
Erratic from known source



Mannerjään yleisimmät virtaussuunnat eri vaiheissa
Isströmmarnas allmännaste riktningar i de olika skedena
The predominant flow directions of the continental ice during the various glacial stages

Salpausselkävaiheen aikainen ja sitä nuorempi virtaus
Isrörelserna under Salpausselkäskedet och därefter
The flow during and after the Salpausselkä stage

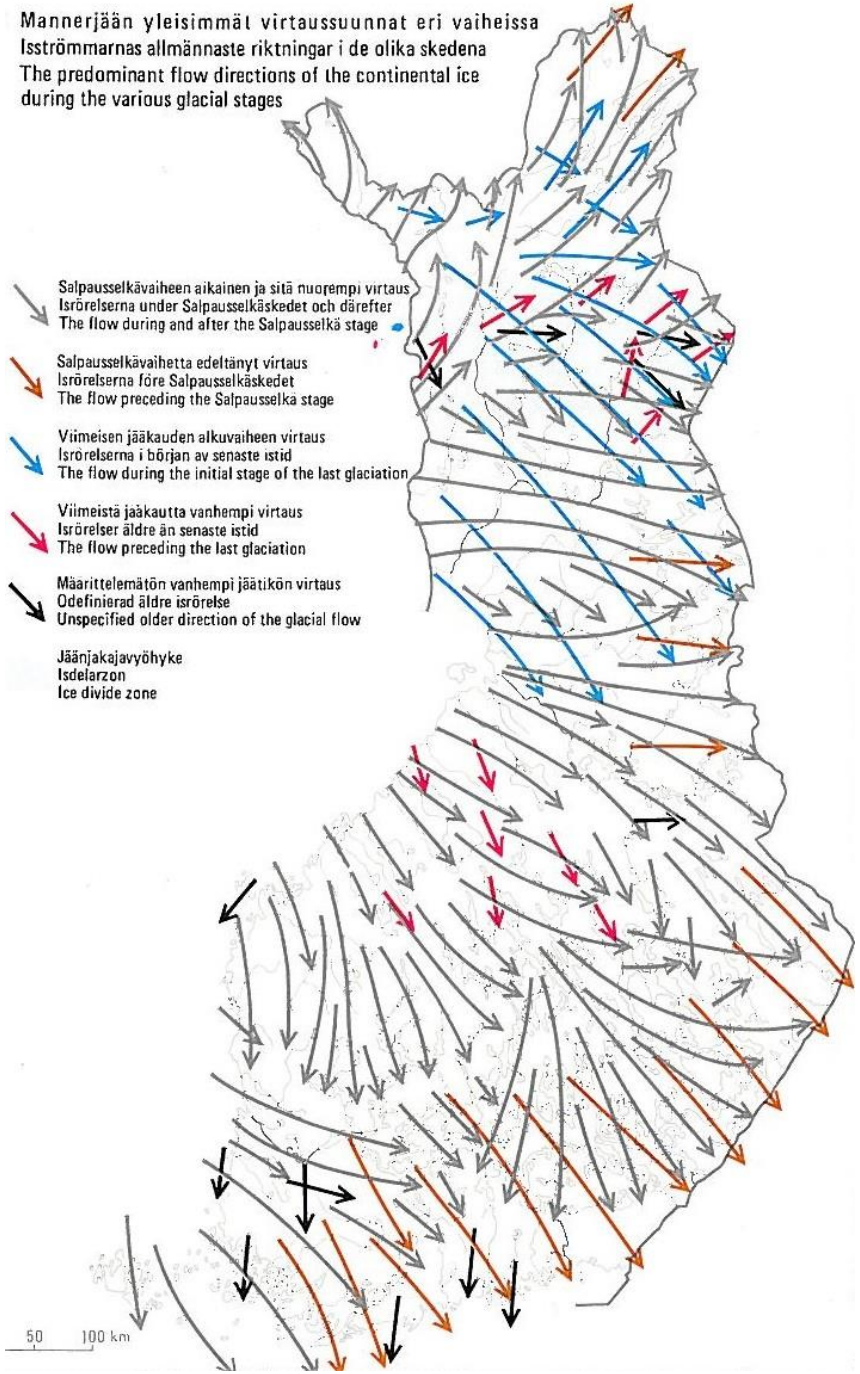
Salpausselkävaihetta edeltänyt virtaus
Isrörelserna före Salpausselkäskedet
The flow preceding the Salpausselka stage

Viimeisen jääkauden alkuvaiheen virtaus
Isrörelserna i början av senaste istid
The flow during the initial stage of the last glaciation

Viimeistä jääkautta vanhempi virtaus
Isrörelser äldre än senaste istid
The flow preceding the last glaciation

Määrittelemätön vanhempi jäätikön virtaus
Odefinierad äldre isrörelse
Unspecified older direction of the glacial flow

Jäänjakajavyöhyke
Isdelarzon
Ice divide zone



Thank you Спасибо