GEOLOGIAN TUTKIMUSKESKUS–GEOLOGISKA FORSKNINGSCENTRALEN
GEOLOGICAL SURVEY OF FINLAND
OPAS–GUIDE 32

IGCP PROJECT 253, TERMINATION OF THE PLEISTOCENE

IUGS UNESCO IGCP

EASTERN FENNOSCANDIAN YOUNGER DRYAS END MORAINES

FIELD CONFERENCE
NORTH KARELIA, FINLAND, AND KARELIAN ASSR

JUNE 26 – JULY 4, 1991
EXCURSION GUIDE

H. RAINIO AND M. SAARNISTO (EDITORS)

GEOLOGICAL SURVEY OF FINLAND
ESPOO 1991

Cover: Karta öfver ändmoräner, åsar och refflor. (Map of endmoraines, eskers and striation). According to: Rosberg, J. E., 1899. Ytbildningar i Karelen med särskild hänsyn till ändmoränerna II. Fennia 14, 7.

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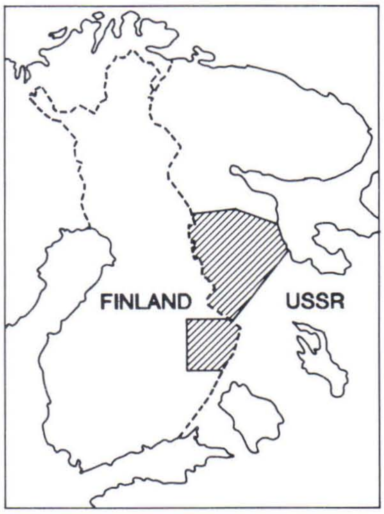
FINLAND
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Preface

The area of the large Younger Dryas ice-marginal formations in Fennoscandia has been very important for Quaternary geological studies. In terms of Quaternary deposits it is a unique entity, an anomaly of deglaciation. As such it is a source of valuable information not only about the genesis of the ice-marginal formations themselves but also about deglaciation as a whole. This is something Nordic geologists realized back in the late 19th century.

This year, 1991, a hundred years have passed since Finnish geographer J.E. Rosberg set out on his first expedition to what was then Russian Karelia. He was sent by the Geographical Society of Finland at the suggestion of J.J. Sederholm, later director of the Geological Survey of Finland, to search for continuations of the Salpausselkäs. Let us, therefore, regard 1991 as a jubilee year for studies on the Younger Dryas ice-marginal formations, particularly since Rosberg returned from his excursion with material of the greatest value.

Our excursion will take us to the problematic area of Finnish North Karelia. We will see ice-marginal formations of the Baltic Ice Lake, the Yoldia Sea, local glacial lakes and the White Sea and also formations deposited on the supra-aquatic area. We will be given important insights into the ice-marginal formations and deglaciation in Soviet Karelia.

Apart from increasing our understanding of the subject the excursion will teach us how difficult it is to draw water-tight conclusions in geology.

The present excursion is a continuation of the first major field conference of IGCP Project 253, "Termination of the Pleistocene", held in May 1990. During the excursion the Younger Dryas zone was followed from Oslo across central Sweden to the Salpausselkä moraines of southwestern Finland. The excursion guide was published by the Geological Survey of Finland.

We shall first follow the Salpausselkä moraines and their counterparts in Finnish Karelia and then cross the border into the Karelian A.S.S.R. This is the first time that many of the sites in Soviet Karelia will have been visited by Western geologists , and also the first time that the site descriptions have been published. This guide's introductory chapter on deglaciation and Younger Dryas end moraines in the Karelian A.S.S.R and the site descriptions were prepared by our Karelian colleagues from Petrozavodsk I. Ekman, A. Lukashov and V. Iljin.

The field conference has been jointly organized by the Geological Survey of Finland and the Institute of Geology, Karelian Branch of the Academy of Sciences of U.S.S.R. Financial support for the conference has been provided by the above institutions, by UNESCO/IGCP and the Academy of Finland.

Harri Kutvonen and Antti Kahra helped with the editorial work of the guide and Kaarina Toikka typed part of the manuscript. Grigorii Sokolev translated the Russian texts and Gillian Häkli the Finnish texts and checked the English of the others. Pirkko Oranne, Mirjam Ajlani, Kirsti Keskisaari, Satu Moberg and Hilkka Saastamoinen drew the maps. We wish to thank all persons and institutions involved.

While in the Soviet Karelia, the excursion will travel through the land where the stories and verses of the Finnish-Karelian national epic "Kalevala" were collected by Elias Lönnrot in the early 19th century. We hope that the cultural heritage of Karelia will add to the stimulus provided by the outstanding geological formations in the region.

Espoo, May 8, 1991

Heikki Rainio Matti Saarnisto

Contents

CHRONOLOGY OF THE SALPAUSSELKÄ END MORAINES IN FINLAND, AND THE FLUCTUATION OF BALTIC ICE LAKE LEVELS

Matti Saarnisto
Geological Survey of Finland

Introduction

The Salpausselkä end moraines provide a vital key for establishment of the history of water level fluctuations in the Baltic basin during Late Weichselian time. Numerous deltas of the Salpausselkäs were deposited up to the fluctuating level of the Baltic Ice Lake and their elevations and spacing form the background for shoreline reconstructions. The dating of the Salpausselkäs and the Baltic Ice Lake levels are mainly based on varve chronology and to a lesser extent on radiocarbon analysis. In the following description, the chronology of the Salpausselkä formations and the Baltic Ice Lake are briefly summarised and the course of water level changes are presented. A short review of the development of the concept concerning the possible Baltic Sea - White Sea connection is also given.

The excursion will visit several Baltic Ice Lake localities in Finnish Karelia and some of the deltas are also listed below.

Varve chronological dating of the Salpausselkäs

According to the old Finnish varve chronology, Salpausselkä I was deposited between 10700-10900 y.a. and Salpausselkä II between 10200-10400 y.a. (Sauramo 1929, Donner 1969,1978); using Sauramo's zero year dated at 8213 B.C. This is the date assigned by Nilsson (1968) to the drainage of the Baltic Ice Lake to the Yoldia Sea (ocean) level. In Finland this means the ice retreat from Salpausselkä II. According to Niemelä's (1971) revision, the ice retreat from Salpausselkä I to Salpausselkä II lasted 240 years longer than Sauramo calculated.

The recently revised Swedish varve chronology (Cato 1987, Strömberg 1990) and its extension into Finland suggest that the Finnish zero year is 480 years older than previously suggested, i.e. dated at 8693 B.C. (10643 y before A.D. 1950) or about 10600 y.a. Accordingly the Salpausselkä moraines are older: Salpausselkä I was formed between 11100 - 11300 and Salpausselkä II 10600- 10800 y.a. The new and old dates are given in Table 1.

Table 1. Dating of major ice-marginal formations in Finland and the corresponding Baltic Ice Lake levels.

Chronostratigraphy (radiocarbon years)	Ice-marginal formations	Baltic Ice Lake level	Varve chronology Sauramo (1929)	Cato (1987) Strömberg (1990)
- 9000 BP				
Preboreal	Central Finland		9650-9800 y.a	10150-10300 y.a
	Pielisjärvi (Jaamankangas)		9900-10000	10400-10500
- 10000				
	Salpausselkä II	B III	10200-10400	10600-10800
Younger Dryas				
	Salpausselkä I	g, B I	10700-10900	11100-11300
- 11000				
Alleröd				
- 11800				

The correlation of the Salpausselkäs with the cold Younger Dryas stadial is supported by evidence of tundra vegetation in pollen diagrams both in and outside the Salpausselkä zone in SE Finland (Hyvärinen 1972). It is also indicated by the occurrence of fossil periglacial features found particularly on emergent delta surfaces of the formations (Aartolahti 1970, Donner 1978). Rapid climatic amelioration took place 10000- 10100 radiocarbon years BP when tundra vegetation was replaced by birch forest. This date may correspond in calendar (varve) years approximately to 10600 y.a. (Zolitschka 1990). The initiation of rapid ice retreat from Salpausselkä II was also the result of climatic warming and, on the basis of the revised varve chronology, it started at 10600 y.a.. These dates therefore appa rently coincide. The study of long varved sequences from large lakes in the Salpausselkä zone and palaeomagnetic measurements from those sediments currently being undertaken at the Geological Survey of Finland will hopefully help the direct dating of the Salpausselkäs.

On the basis of the various Baltic Ice Lake delta levels shown by the Salpausselkäs and their varve dating, Donner (1978,1982) concluded that Salpausselkä I began to form about 350 years earlier in the west than in the east and that the ice margin retreated about 100 years earlier from the western arc of Salpausselkä II than from its eastern arc. Saarnisto (1970) suggested that the ice retreat from the eastern arc of Salpausselkä II was not strictly synchronous. The ice margin had retreated about 10 km inside the formation in the east when it was still at Salpausselkä II in the southern Lake Saimaa area. According to Rainio (this volume), the largest end moraines, the Kalevala (Kuittijärvi) formations in Soviet Karelia, described herein (Ekman, Iljin & Lukasov, this volume) are correlatives of the Finnish Pielisjärvi end moraine. The latter formed about 200-300 years (9900-10000 y.a.) later than Salpausselkä II in Finnish Karelia. These moraines may be synchronous with the Salpausselkä III formation of SW Finland, which is far less well pronounced. It may be that the ice margin responded to climatic changes at somewhat different times in different sectors of the Scandinavian Ice Sheet. This may explain why the largest end moraines in Finland and the Karelian A.S.S.R. are of somewhat different ages, although they all most certainly represent the same climatic event; the Younger Dryas stadial. Firm morphological correlation of the end moraines is, however, a prerequisite for further discussion. The correlation of the Younger Dryas end moraine formations around Fennoscandia is one of the main goals of IGCP 253 Project "Termination of the Pleistocene".

The Baltic Ice Lake levels

The Baltic Ice Lake formed from separate ice-dammed lakes in the Baltic basin about 12000 y.a. in front of the retreating ice margin as it retreated from the coast of Estonia (e.g. Donner and Raukas 1989). The later part of its history, approximately 1000 years, is represented in the delta plains of the Salpausselkä moraines, which formed the northern boundary of the lake.

The level of the Baltic Ice Lake was controlled by the presence or absence of glacial ice in the area north of Mount Billingen in Central Sweden. When the ice covered the Billingen threshold, the level of the Baltic Ice Lake rose and when the threshold became ice-free the level dropped. When the Billingen area was covered by ice, the Baltic Ice Lake drained via Scania and the Danish Straits to the North Sea. The possible connexions and drainage events to the White Sea basin will be discussed below.

The fluctuation of the Baltic Ice Lake levels has been and remains a matter of controversy to some extent. The key question is how many times has the ice retreated and readvanced in the Billingen area. The following simple model proposed by Donner (1969) seems to adequately explain the delta levels of Salpausselkä I and Salpausselkä II in Finland (Fig.1.).

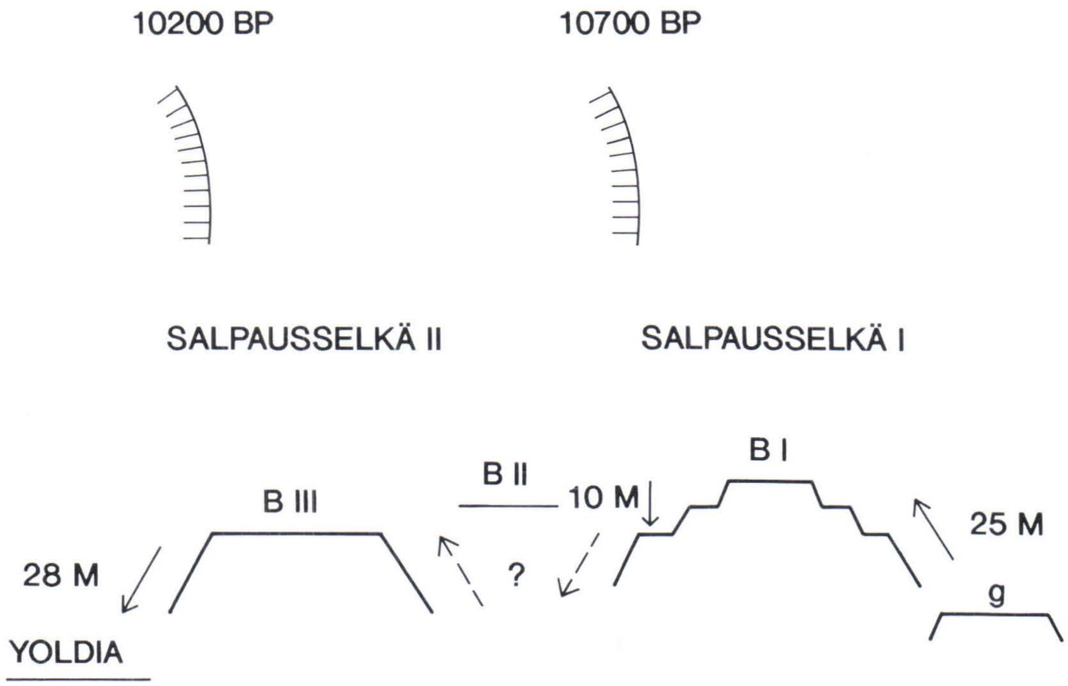

Fig. 1. Fluctuation of the Baltic Ice Lake level during the formation of the Salpausselkä end moraines (modified after Donner 1969, 1982).

Along the western arc of Salpausselkä I low delta levels were deposited at the so-called g level. They formed when the Billingen threshold was open and may even represent eustatic sea level although stratigraphical evidence is lacking. The presence of the g level along the eastern arc of Salpausselkä I is a matter of discussion. Some low-lying plains interpreted as g level deltas may represent later shoreline terraces (Saarnisto 1982). Nevertheless the readvance of the ice caused the Billingen threshold to become blocked and consequently the water level of the Baltic Ice Lake rose about 25 m to the high B I level. This is the highest level of Salpausselkä I within the area of the 'great bend' of the formation west of Lahti and along its eastern arc including Karelia.

The high B II level formed during the ice margin retreat to Salpausselkä II and is representd by local esker deltas in the area between Salpausselkä I and II. The deltas of Salpausselkä II represent the last high water level, the B III level. On the slopes of Salpausselkä I the water level of B III is shown as shoreline terraces 10 m below B I. When the ice margin had retreated some kilometres (0-10 km) inside Salpausselkä II the water level dropped about 28 m to the Yoldia Sea (ocean) level due to the opening of the Billingen threshold. This is indicated by esker deltas.

In eastern Finland, in the area of the Saimaa lake complex, short-lived ice- dammed lakes were formed during drainage of the Baltic Ice Lake (Fig. 6). It is suggested that the delta levels of the Jaamankangas end moraine in Karelia correspond to the levels of these ice-dammed lakes (Saarnisto 1970). Ice-dammed lakes were formed in Karelia also above the Baltic Ice Lake. One of the largest of thesewas the Ilomantsi Ice Lake where the large Selkäkangas delta equivalent to Salpausselkä II was deposited (Hyvärinen 1973, Rainio, this volume).

As a result of differential land uplift, the B deltas of each stage are situated at different elevations (Fig.2). The B I level of Salpausselkä I is the highest at 160 m a.s.l. at Sairakkala, west of Lahti but only 97 m at Tuhkakangas, north of Lake Ladoga. The B III level of Salpausselkä II is highest at 166 m at Evo within the 'great bend' of the formation west of Lake Päijänne and lowest at 104 m at Utula, in SE Finland.

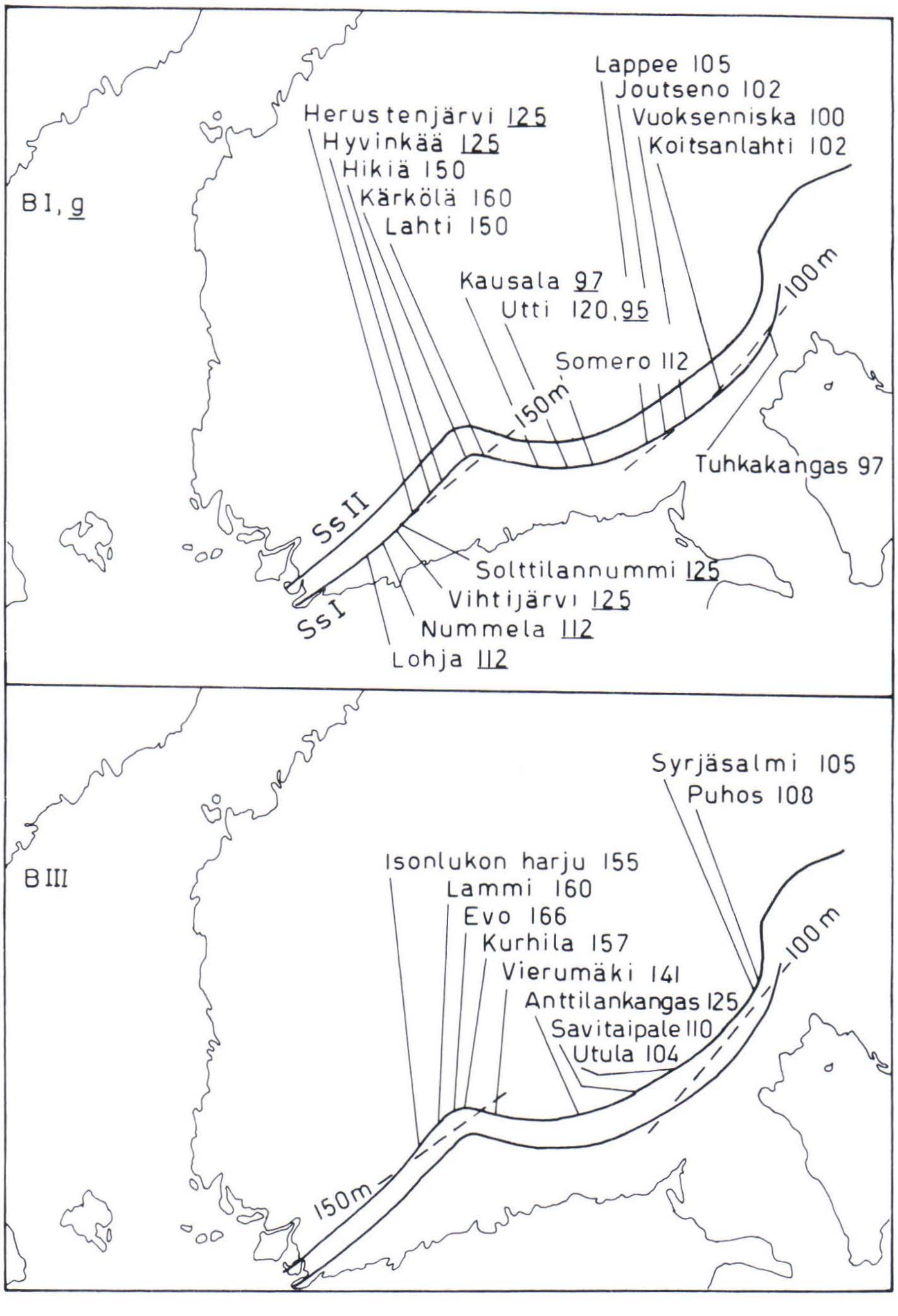

Fig. 2. Elevation of the delta levels g and B I of Salpausselkä I and B III of Salpausselkä II, according to Sauramo (1940) (modified from Alhonen 1979, Fig. 3). Some of the observations along the eastern arc of Salpausselkä I have been omitted.

It has been suggested that the Billingen threshold was also open during the interval between the deposition of Salpausselkäs I and II. Some low delta levels between these moraines seem to support this interpretation (Sauramo 1934, 1958, Synge 1980, Saarnisto 1982). New stratigraphical data from the Billingen area seem to support the idea of two drainages there (Björck and Digerfeldt 1986,1989; Lundqvist 1989, 1990). The recognition of the final drainage event in Finland is clear but the correlation of the first drainage to the low stage(s) is still open to speculation.

During the excursion the high Baltic Ice Lake levels B I, B II and B III and local ice-dammed lake levels will be seen in northern Karelia in the following localities:

List of B-sites and other delta levels in northern Karelia, compiled by H. Rainio

Salpausselkä I, Patsola, Värtsilä: summit plain at 110 m a.s.l. (B I), shoreline terrace at 96-97 m (B III).
Area between Salpausselkä I and II, Kiteenlahti, Kitee: summit plain at 109 m (B II), shoreline terrace at 102-105 m (B III).
Tuupovaara end moraine, Hukkala, Tohmajärvi (between Ss I and Ss II ?): summit plain at 115 m (B II or a little higher ice-dammed lake).
Salpausselkä II, Tervasuo, Kiihtelysvaara: plain at 120-125 m (B III); higher plain at 130 m is supra-aquatic?
Pielisjärvi end moraine, Jaamankangas, Kontiolahti and Liperi: distal part of a plain at 105 m (Yoldia Sea or a little higher ice-dammed lake).
Pielisjärvi end moraine, Kuusoja, Kontiolahti and Eno: distal part of a plain at 100-105 m (Yoldia Sea or a little higher ice-dammed lake).
Pielisjärvi end moraine, Havukka, Eno: marginal plain at 168-170 m (local Havukka ice-dammed lake).
Koitere end moraine, Selkäkangas, Ilomantsi: distal-middle part of a marginal plain at 170-175 m (Ilomantsi Ice Lake).

A possible Baltic Sea - White Sea connection

The possible connection between the lateglacial Baltic Sea and White Sea has been debated from the early days of glacial investigation in eastern Fennoscandia. A good review on the development of ideas is given by Hyvärinen and Eronen (1979), for example, and similarly in several papers by Soviet geologists (e.g. Kvasov et.al. 1970, Biske et.al. 1974). The concept of a Baltic Sea - White Sea connection is closely related to the correlation and dating of end moraines in Finnish and Soviet Karelia.

In the early palaeogeographical maps the lateglacial Baltic Sea (the Yoldia Sea by that time) extended to the White Sea (e.g. Ramsay 1898). This extension of the Baltic was based, in addition to raised beaches, partly on the distribution of relict crustaceans in the area. The presence of the Baltic Ice Lake dammed above the sea level and preceding the Yoldia Sea was first recognised by Munthe (1910). The Baltic Ice Lake finally drained to the sea level when the ice retreated from the Middle Swedish end moraines and north of Salpausselkä II in Finland. On palaeogeographical maps published by Ramsay (1927) and Sauramo (1929, 1934) (Fig. 3) the ice margin during the Baltic Ice Lake and early Yoldia stage is shown continuing from the Salpausselkäs to the endmoraine area in Soviet Karelia. On the maps by Sauramo no connection between the Baltic and White Sea is shown.

The idea of a possible connection was reactivated by Hyyppä (1936) who suggested that the deglaciation of eastern Finland was such an early event that the Baltic Ice Lake extended from North Karelia farther north and drained to White Sea via Kuusamo and Salla in NE Finland (Fig. 4). At the same time the Billingen area in Sweden was also ice free and served as an outlet. Sauramo accepted this concept (e.g.1940,1958). It was based on raised shorelines in eastern Finland which had previously been interpreted as shore levels of local ice-dammed lakes (Tanner 1915).

Pollen stratigraphical studies in eastern Finland seemingly supported the idea of an early deglaciation. The pollen stratigraphy begins with a zone dominated by non-arboreal-pollen before the birch pollen zone. This NAP-pollen zone was first interpreted as representing tundra vegetation and was correlated with the Younger Dryas.

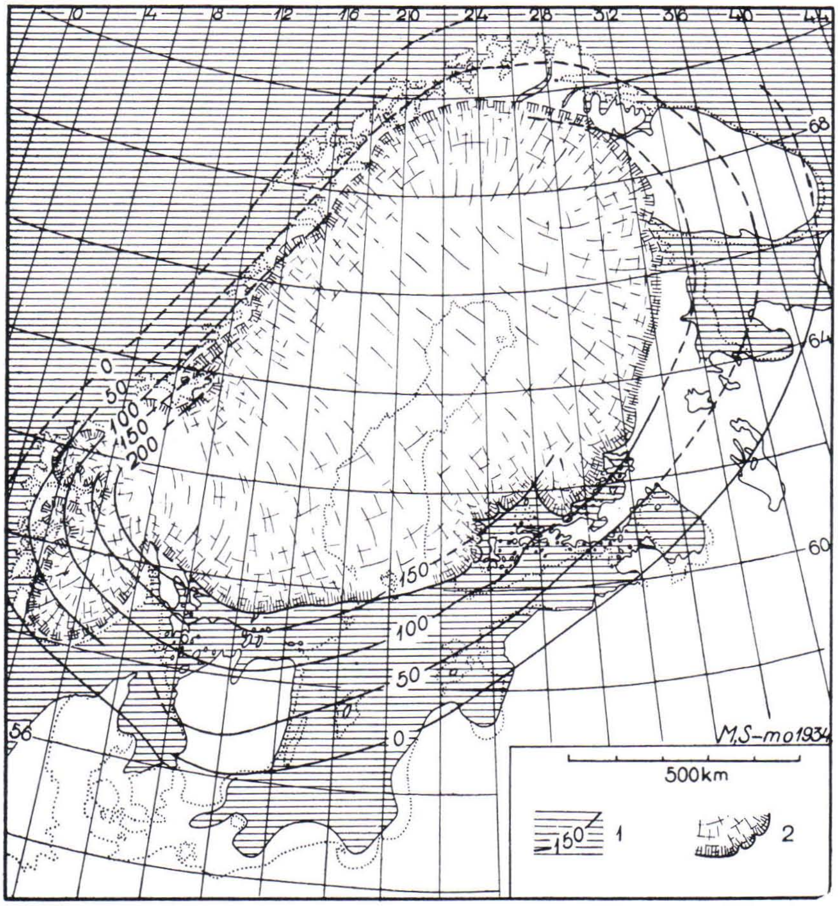

Fig. 3. Palaeogeographical map of the early Holocene Yoldia Sea, according to Sauramo (1934, Fig. 17).

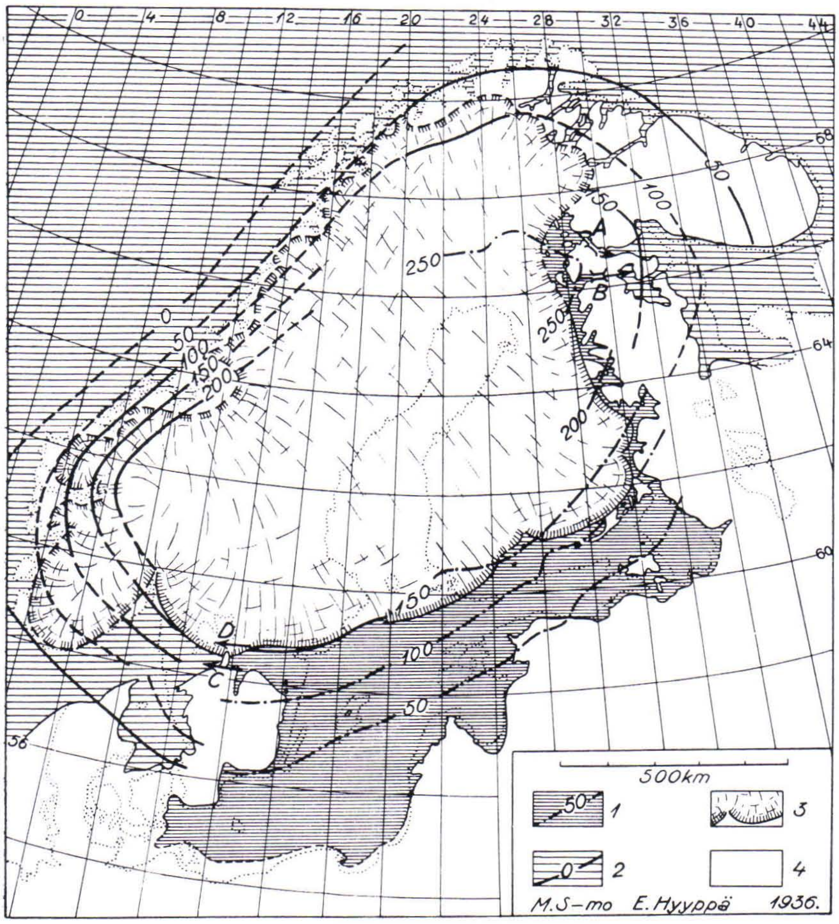

Fig. 4. Palaeogeographical map of the Baltic Ice Lake showing the suggested eastern outlets to White Sea in Salla (A) and Kuusamo (B), NE Finland. From Hyyppä (1936, Fig. 7).

Radiocarbon analyses have shown, however, that the NAP zone merely represents the initial diachronous treeless vegetation that followed deglaciation before the spread of birch (Donner 1951,1978, Hyvärinen 1966,1973). True tundra, indicated by high *Artemisia* pollen frequencies, has only been found in and outside the Salpausselkä zone in SE Finland (Hyvärinen 1972).

The idea of the direct lateglacial sea connection preceding the Baltic Ice Lake gained support during World War II from Finnish geologists who were able to make observations in the threshold area between Lakes Ladoga and Onega as well as north of Lake Onega. The bottommost minerogenic sediments sampled in the threshold areas contained marine diatoms which supported the view that an open sea connection existed at an early stage (Mölder 1944). Hyyppä (1943) named this sea the 'Karelian Ice Sea' and Sauramo (1958) the "Lateglacial Yoldia Sea" (Fig. 5). This sea thus predated the Baltic Ice Lake and was assigned to the Alleröd interstadial or even earlier.

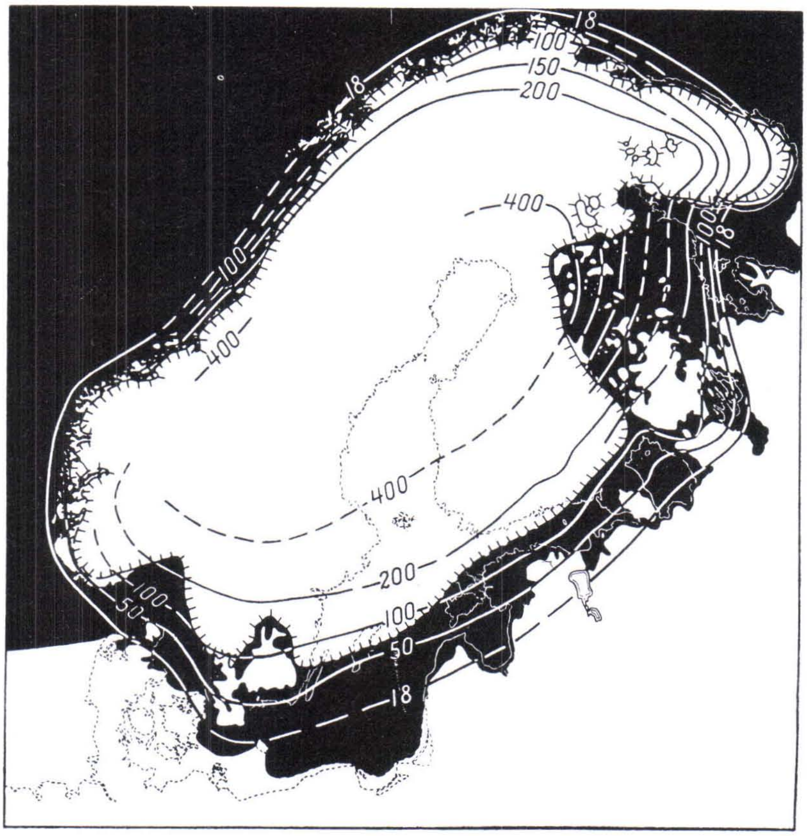

Fig. 5. Palaeogeographical map of the 'Lateglacial Yoldia Sea' before the Baltic Ice Lake showing the extensive submerge of Soviet Karelia and open connection between the Baltic and the White Sea. From Sauramo (1958, Fig. 133).

The concept of the early deglaciation of eastern Finland was abandoned by Hyvärinen (1966, 1973) who showed, on the basis of radiocarbon dates, that the deglaciation of North Karelia north of the Salpausselkäs took place around 9500-10000 BP. Thus the ice margin continued from Finnish Karelia into Soviet Karelia most likely to the moraines mapped by Rosberg (1892). Morphological studies by Rainio (1972, and this volume) also supported this view. This implies that the concept of and extended Baltic Ice Lake to NE Finland was no longer valid and that the Lateglacial Yoldia Sea could not penetrate so far north.

The late deglaciation of Finnish and Soviet Karelia (i.e. early Holocene) in itself is not an argument against a sea connexion between the Baltic and White Seas because the critical threshold areas are situated south of the Younger Dryas moraines. As indicated in the deglaciation map by Ekman and Iljin (this volume), the threshold areas as well as the White Sea basin became ice free during the Alleröd chronozone between 12000 - 11000 BP. Early Soviet authors were in favour of this sea connection (e.g. Markow 1935; Zemljakov 1936) but in later studies a more cautious view has been taken (e.g. Kvasov 1970; Biske et.al.1974). The marine diatoms frequently found in lateglacial sediments between Lakes Ladoga and Onega and north of Lake Onega are most probably reworked last interglacial fossils. These diatoms are almost certainly derived from sediments laid down when marine connection existed between the Baltic and White Seas during high sea levels of the Eemian stage. This connection is well established (e.g. Ramsay 1898, Zemljakov 1936, Grönlund 1991).

The thresholds between the Baltic and White Seas seem to be simply too high unless great irregularities in land uplift are accepted. However, this problem deserves further investigation.

The excursion will travel in the area of Soviet Karelia that was extensively submerged by the waters of the White Sea basin after the ice rereat. The elevated delta levels and raised beaches provide positive evidence of the remarkable shore line displacement.

A shoreline diagram for the Saimaa Lake Complex

Following the deglaciation most of southern Finland was covered by the Baltic basin waters. As a result of land uplift, the area has been continuously emerging and numerous inland lakes became isolated. The shoreline displacement of independent lakes has been controlled by differential land uplift and their threshold elevations. The general course of events in the Finnish lake district has been a shift of outlet channels from north to south towards the area of smaller uplift. Most of the larger lakes first drained towards the north into the Gulf of Bothnia and, as a result of transgression, new outlets opened towards the south.

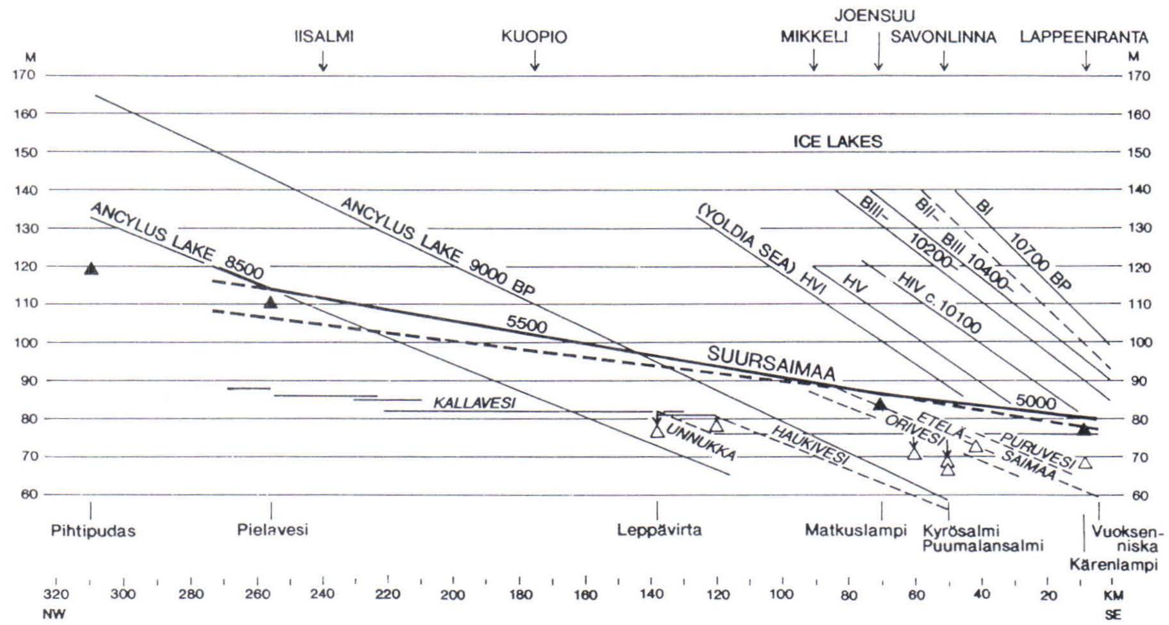

Fig. 6. A shoreline diagram for the Saimaa lake complex showing various shorelines which were determined on the basis of morphological and stratigraphical observations. The dating of the B and H shorelines is based on Sauramo's varve chronology and the dating of the younger shorelines on pollen stratigraphy and radiocarbon dates. Modified from Saarnisto (1970, Fig. 11).

In Fig. 6 a shoreline diagram is presented for the Saimaa lake complex (Saarnisto 1970), which is bordered by the Salpausselkäs to the south and east. The highest and oldest shorelines are the Baltic Ice Lake levels B I, B II and B III. Shorelines H IV, H V and H VI are those of local ice-dammed lakes. All of these shorelines have been determined on the basis of morphological observations. The youngest and lowest shoreline H IV may represent the Yoldia Sea level. The shorelines of the Ancylus lake have been determined purely on stratigraphical grounds. The shoreline dated at 5500-5000 BP is the diachronous upper limit of the transgression of the lake complex formed as a result of differential land uplift. It is a morphologically distinct shore level, dated by radiocarbon analysis from stratigraphical sites.

Acknowledgements

I wish to thank Dr. P.L. Gibbard for checking the English of the manuscript and for his valuable comments.

References

Aartolahti, T., 1970. Fossil ice-wedges, tundra polygons and recent frost cracks in southern Finland. Ann. Acad. Scient. Fennicae A III, 107, 26 pp.

Alhonen, P., 1979. The Quaternary History of the Baltic, Finland. In V. Gudelis & L.-K. Königsson (eds.), The Quaternary History of the Baltic. Acta Univ. Ups. Symp. Univ. Ups. Annum Quingentesimum Celebrantis 1, 101-113.

Biske, G.S., Lak, G.Z. & Ekman, I.M., 1974. On the problem of the Late-glacial White - Baltic Sea connection (in Russian, with English summary). Baltica 5, 105-112.

Björck, S. & Digerfeldt, G., 1986. Late Weichselian - Early Holocene shore displacement west of Mt. Billingen, within the Middle Swedish end-moraine zone. Boreas 15, 1-18.

Björck, S. & Digerfeldt, G., 1989. Lake Mullsjön - a key site for understanding the final stage of the Baltic Ice Lake east of Mt. Billingen. Boreas 18, 209-219.

Donner, J.J., 1951. Pollen-analytical studies of Late-glacial deposits in Finland. Bull. Comm. geol. Finlande 154, 92.

Donner, J.J., 1969. Land/sea level changes in southern Finland during the formation of the Salpausselkä endmoraines. Bull. Geol. Soc. Finland 41, 135-150.

Donner, J., 1978. The dating of the levels of the Baltic Ice Lake and the Salpausselkä moraines in South Finland. Comm. Phys.-Mathem. 48, 11-38.

Donner, J., 1982. Fluctuations in water level of the Baltic Ice Lake. Ann. Acad. Sci. Fenn. A III, 134, 13-26.

Donner, J. & Raukas, A., 1989. On the geological history of the Baltic Ice Lake. Proc. Estonian Acad. Sci. Geol. 38, N 3, 128-137.

Grönlund, T., 1991. The diatom stratigraphy of the Eemian Baltic Sea on the basis of sediment discoveries in Ostrobothnia, Finland. Geol. Surv. Finland, Rep. of Invest. 102, 26 pp.

Hyvärinen, H., 1966. Studies on the late-Quaternary history of Pielis-Karelia, eastern Finland. Soc. Sci. Fennica, Comment. Biol. 29, 4, 72 pp.

Hyvärinen, H., 1972. Flandrian regional pollen assemblage zones in eastern Finland. Comment. Biol. 59, 25.

Hyvärinen, H., 1973. The deglaciation history of eastern Fennoscandia - recent data from Finland. Boreas 2, 85-102.

Hyvärinen, H. & Eronen, M., 1979. The Quaternary History of the Baltic. The Northern Part. In V. Gudelis & L.-K. Königsson (eds.), The Quaternary History of the Baltic. Acta Univ. Ups. Symp. Univ. Ups. Annum Quingentesimum Celebranti 1, 7-27.

Hyyppä, E., 1936. Über die spätquartäre Entwicklung Nord-Finnlands mit Ergänzungen zur Kenntnis des spätglazialen Klimas. Bull. Comm. géol. Finlande 115, 401-465.

Hyyppä, E., 1943. Itämeren historia uusimpien Itä-Karjalassa suoritettujen tutkimusten valossa (Föredragsreferat: Östersjöns historia i ljuset av de nyaste forskningar i Öst-Karelen). Terra 55, 3/4.

Kvasov, D.D., Bakanova, I.P. & Davydova, N.N., 1970. Main questions of the late-glacial history of the east Baltic (in Russian, with English and German summaries). Baltica 4, 65-92.

Lundqvist, J., 1989. Late glacial ice lobes and glacial landforms in Scandinavia. In R.P. Goldthwait & C.L. Matsch (eds.): Genetic Classification of Glacigenic Deposits. A.A. Balkema, Rotterdam, 217-225.

Lundqvist, J., 1990. The Younger Dryas event in Scandinavia. IGCP PROJECT 253. Termination of the Pleistocene. Field conference Norway-Sweden-Finland, May 9-16, 1990. Geological Survey of Finland. Guide 31. (Editors: J. Lundqvist and M. Saarnisto), p. 5-24. Geological Survey of Finland. Espoo 1990.

Markov, K.K., 1935. Yoldievoye morye i problema pozdnelednikovogo Belomorsko-Baltiiskogo proliva II. Izd. Gos. Geogr. Obstch. 67, vip. 1.

Munthe, H., 1910. Studies in the Late-Quaternary history of Southern Sweden. Geol. Fören. Stockholm Förh. 32, 1197-1292.

Niemelä, J., 1971. Die quartäre Stratigraphie von Tonablagerungen und der Rückzug des Inlandeises zwischen Helsinki und Hämeenlinna in Südfinnland. Geol. Surv. Finland Bull. 253, 79 p.

Nilsson, E., 1968. Södra Sveriges senkvartära historia. Geokronologi, issjöar och landhöjning. Kungl. Sven. Vetenskapsakad. Handl. 4:12:1, 117.

Rainio, H., 1972. Ennakkotiedonanto Pohjois-Karjalan itäosan reunamuodostumista (Two end-moraine belts in North Karelia, east of the Salpausselkä end-moraines). Geologi 1972, 50-51.

Ramsay, W., 1898. Über die geologische Entwicklung der Halbinsel Kola in der Quartärzeit. Fennia 16, 1, 151 pp.

Ramsay, W., 1927. Silmäys Suomen syntyyn. Helsinki 20 pp.

Rosberg, J.E., 1892. Ytbildningar i ryska och finska Karelen med särskild hänsyn till de karelska randmoränerna. Fennia 7, 2, 122 pp.

Saarnisto, M., 1970. The Late Weichselian and Flandrian history of the Saimaa lake complex. Soc. Sci. Fennica, Comm. Phys.-Math. 37, 107.

Saarnisto, M., 1982. Ice retreat and the Baltic Ice Lake in the Salpausselkä zone between Lake Päijänne and Lake Saimaa. Ann. Acad. Sci. Fennicae A III, 134, 61-79.

Sauramo, M., 1929. The Quaternary geology of Finland. Bull. Comm. Géol. Finlande 86, 110 p.

Sauramo, M., 1934. Zur spätquartären Geschichte der Ostsee. Bull. Comm. géol. Finlande 104, 28-87.

Sauramo, M., 1940. Suomen luonnon kehitys jääkaudesta nykyaikaan. WSOY, Porvoo, 286 pp.

Sauramo, M., 1958. Die Geschichte der Ostsee. Ann. Acad. Sci. Fennicae A III, 51, 522 pp.

Strömberg, B., 1990. A connection between the clay varve chronologies in Sweden and Finland. Ann. Acad. Sci. Fennicae A III, 154, 32 pp.

Synge, F.H., 1982. A new shoreline chronology for the Salpausselkä. Ann. Acad. Sci. Fennicae A III, 134, 29-58.

Tanner, V., 1915. Studier öfver kvartärsystemet i Fennoskandias nordliga delar III. Om landisens rörelser och afsmältning i Finska Lapland och angränsande trakter. Fennia 36,1, 815 pp.

Zemljakov, B.F., 1936. The Quaternary geology of Karelia (in Russian). Petrozavodsk, 102 pp.

Zolitschka, B., 1990. A 12,800 year sequence of annually laminated lake sediments - a challenge for Quaternary research. INQUA Commission for the Study of the Holocene, Working Group on Laminated Sediments, Workshop at Lammi Biological Station Finland, June 4-6, 1990, Programme and Abstracts, M. Saarnisto & J. Putkonen (editors), Geological Survey of Finland, Espoo, 2 p.

THE YOUNGER DRYAS ICE-MARGINAL FORMATIONS OF SOUTHERN FINLAND

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Introduction

Two chains of large ice-marginal formations, Salpausselkä I (Ss I) and Salpausselkä II (Ss II), run across southern Finland at a distance of about twenty kilometres from each other. They extend as an almost continuous structure for almost 600 km from the coast of southwestern Finland to North Karelia in eastern Finland. In southwestern Finland, about twenty kilometres north of Ss II, there is another ice-marginal formation chain, the 200-km-long Salpausselkä III (Ss III) (Fig. 1).

Three chains of ice-marginal formations, more or less unanimously considered as "extensions" of the Salpausselkäs, are encountered in North Karelia. The two youngest, if not all three, extend to the U.S.S.R.

These structures are part of the ice-marginal formations that deposited at the front of the Scandinavian ice sheet in Younger Dryas time and which encircle the whole of Fennoscandia (Fig. 2)(Hyvärinen, 1975; Donner, 1978, pp. 11-12). As suggested by the varved clay chronology and shoreline displacement data, the segments of the Salpausselkäs are slightly metachronous. According to Donner (1978, p. 11): "The western part of Ss I was formed at 9 250 varve years B.C. The vegetation history and fossil periglacial features suggest that Ss I and Ss II were formed during the Younger Dryas Chronozone, 11 000 - 10 000 conventional radiocarbon years B.P., the oldest part of Ss I possibly earlier."

About 80 - 150 km north of the Salpausselkäs there is yet another formation, the 250-km-long Central Finland ice-marginal formation, which is similar to the

Salpausselkäs in size and structure. According to the varved clay chronology of Sauramo, it deposited at 9 800 - 9 650 B.P. (see Rainio et al., 1986).

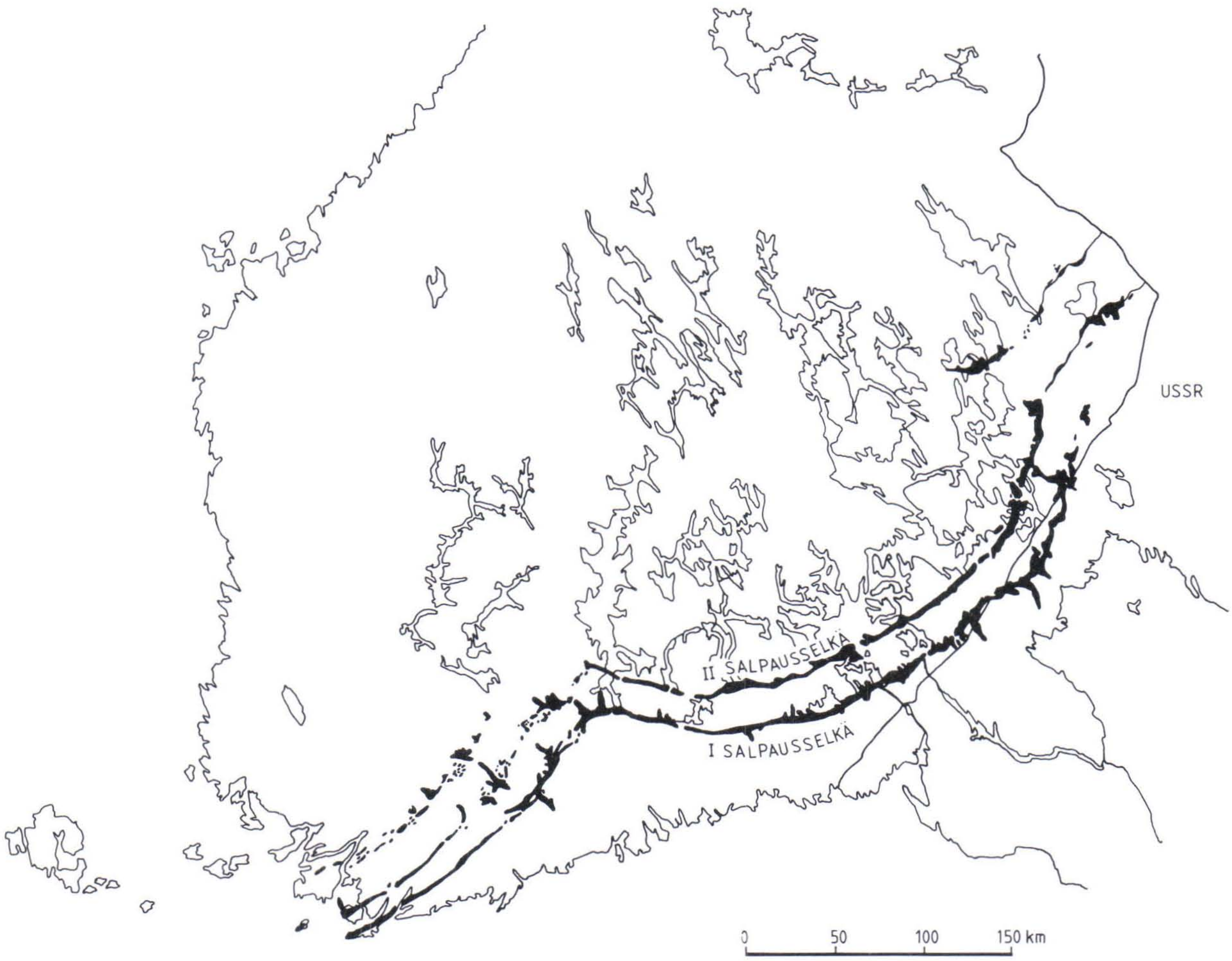

Fig. 1. The Younger Dryas ice-marginal formations of southern Finland.

The Salpausselkäs with their "extensions" and the Central Finland ice-marginal formation are composed of two to three big arcuate segments, demonstrating that they were deposited as ice-marginal formations of different glacial lobes (Brenner, 1944; Punkari, 1980). The absence of the middle arc from the third chain of marginal formations is striking evidence of the variation in dynamics of the glacial lobes. Incorporated in the big arcs are smaller arcuate segments.

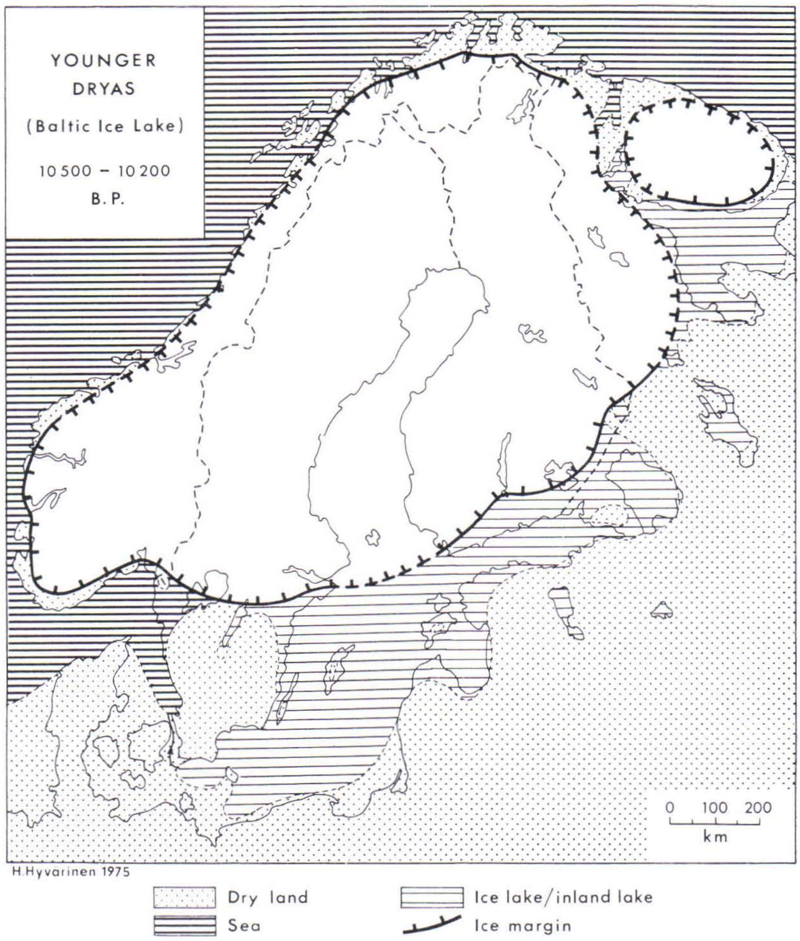

Fig. 2. Extent of the Scandinavian ice sheet and the Baltic Ice Lake at the time of the final drainage at Billingen in the late Younger Dryas. - From Hyvärinen (1975, Fig. 2).

Structure of the ice-marginal formations

The ice-marginal formations of the subaquatic area, including the areas of small glacial lakes, are mainly glaciofluvial. The supra-aquatic end moraines are principally moraine ridges or hummocky moraine zones, which, as a whole, indicate the positions of the front of the continental ice sheet.

In the subaquatic area, the ice-marginal formations are often combinations of glaciofluvial formations and moraine ridges.

The glaciofluvial ice-marginal formations are usually considered as deltas. If they have grown over the water level, the deltas are called sandur deltas (Andersen 1960).

However, these "deltas" exhibit two types that differ clearly from each other. The less common of the two are the distinctly glaciofluvial deltas *sensu stricto* that deposited at the mouth of glacial rivers in their discharge bay. Often associated with eskers, they are thus part of the ice-marginal system. They are triangular in shape, and their proximal and lateral parts are devoid of till.

Most of the glaciofluvial ice-marginal formations in the subaquatic area are of the other type, referred to in this context as marginal terraces. The following overview is based on observations made in the course of regular mapping of Quaternary deposits over 170 km of Ss I between Lahti and Joutseno.

There are stretches where the marginal terraces continue for 10-20 km without any glaciofluvial formations (feeding eskers) joining them on the proximal side. The grain size of the glaciofluvial sediments in the terraces changes regularly only from the proximal to the distal part of the terraces; there is no clear change in the longitudinal direction. The terraces do not exhibit the distinct arcuate distal margin of a delta but may continue more or less the same width for tens of kilometres.

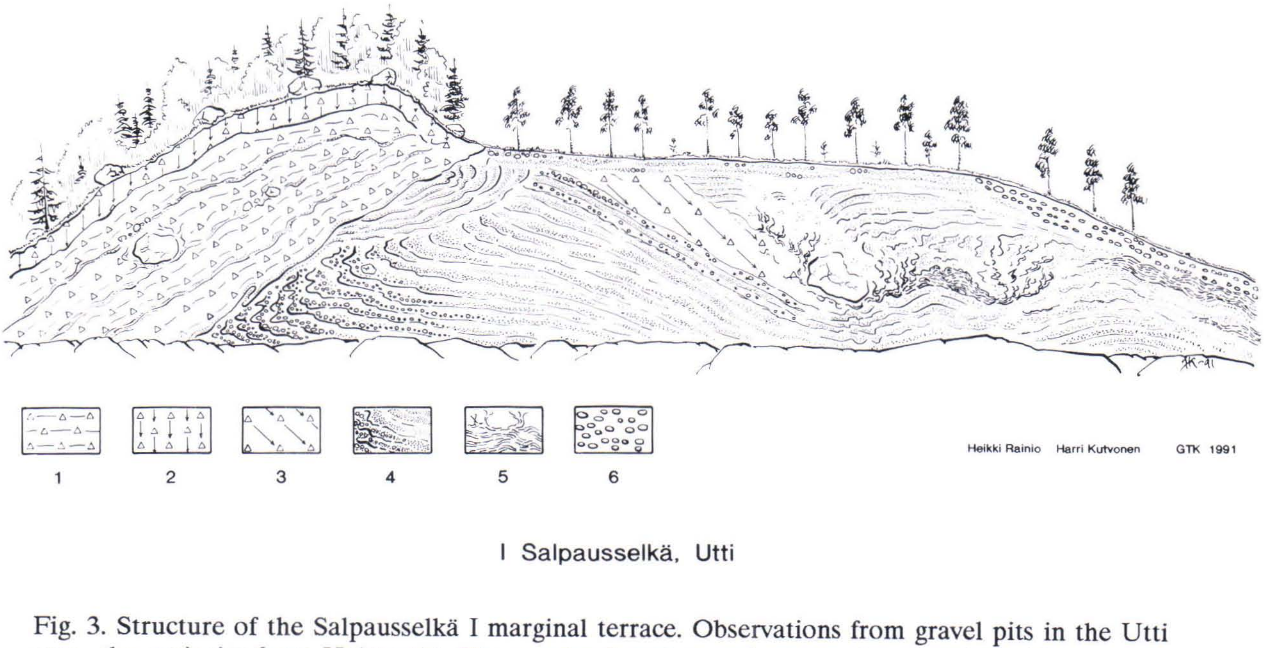

Fig. 3. Structure of the Salpausselkä I marginal terrace. Observations from gravel pits in the Utti area, the majority from Häkämäki. The proximal part contains several concordant till layers. In addition to diamicton, the till is rich in sorted sediments, some of which are glaciofluvial material reworked by the continental ice sheet. The glaciofluvial deposits exhibit deformations caused by ice push or the load due to drift rolled from the ice. 1. Lodgement till; 2. meltout till; 3. flow till; 4. glaciofluvial gravel and sand with deformations; 5. glaciofluvial fine sand; 6. littoral deposits.

The proximal part of the terraces usually includes one or more till layers either one on top of the other or separated by glaciofluvial sand. Between Lahti and Joutseno there are 4-6 superimposed till layers in places, and the till bed that covers the proximal part of the terrace may extend for 200-300 m over the terrace. Morphologically the moraines of the proximal side almost merge with the glaciofluvial portion or show up as a moraine ridge of varying height at the junction of the glaciofluvial platform. In the Finnish literature, they are often interpreted as push moraines. However, sections demonstrate that they are lodgement till or a pile of several lodgement till beds whose distal margin shows up as a ridge on the marginal terrace (Fig. 3).

Marginal terraces of this type predominate in the subaquatic parts of the ice-marginal formations of southern Finland. The amount of till in the proximal parts varies considerably but the structure is the same, indicating that the ice-marginal formations received similar amounts of material along the whole margin of the ice sheet. The ice was flowing all the time the ice-marginal formation was depositing, and local melting and flow were approximately in equilibrium. As shown by the structure of Ss II in North Karelia, the ice may still have been very active right up until the end of deposition of the formation (Fig. 9; site 2).

The deposits in the estuaries of the glacial rivers may be large and thick, but otherwise their structure is different. Therefore, the concept of the glaciofluvial delta needs reconsideration.

The marginal terraces are mainly composed of glaciofluvial sediments. Measured from the proximal to the distal side their width is often from 200 m to 1 km. At their widest the terraces measure 5-6 km. One such is the Taipalsaari terrace of Ss II, Selkäkangas, which was formed in the Ilomantsi Ice Lake, and another is the Jaamankangas terrace of the Pielisjärvi ice-marginal formation.

The base level of erosion controlled the vertical growth of the terraces. As shown by seismic soundings, many terraces, e.g. Selkäkangas and Jaamankangas, have a deposit of glaciofluvial sediments, 70 m thick. The glaciofluvial deposits are commonly 20-30 m thick, whereas the supra-aquatic portions tend to be thin.

The end moraine ridges are from a few metres to a few tens of metres high; at their highest, some parts of Ss II rise as much as 60 m above the glaciofluvial platform. They are from a few metres to a few tens of metres wide, with the maximum width of the Ss II moraine ridges being almost a kilometre (Fig. 10; site 2).

Even in the supra-aquatic area some of the ridges are 30 m high. Several of them may lie side by side yet clearly separated from each other. (Fig. 15; site 7).

The proximal sides of the supra-aquatic and subaquatic ice-marginal formations often show a complicated network of glacial formations up to one kilometre wide (Figs. 1, 22-24; sites 7, 13-15).

Salpausselkä I, recessional or terminal?

The discussion about whether Ss I was recessional or had formed in front of the readvancing continental ice sheet was opened by De Geer (1885). Sederholm (1911) approached the Central Finland ice-marginal formation from the same angle. For many years the view that the formations were recessional was favoured. In recent years, however, additional evidence has been presented showing them to be end moraines formed in front of the readvancing ice sheet and indicating that glaciation in southern Finland and the stratigraphy of the glacigenic deposits are more complicated than had earlier been suspected (e.g. Okko, 1962; Rainio, 1985a; Rainio et al., 1986).

The following facts support the concept of a readvance of the ice:

1. Till-covered glacigenic deposits occur all over Finland. In the south of the country, a considerable proportion of them are concentrated in certain zones. One such zone, 50 - 80 km wide, is on the proximal side of Ss I and another, at least 50 km wide, is on the proximal side of the Central Finland ice-marginal formation. There are sites where clays and glaciofluvial deposits are overlain by till or where there are several superimposed discordant till beds. The chain of glaciofluvial deposits is discontinuous in both ice-marginal formation areas and the eskers do not extend through them. The base level of erosion at the time of formation of the till-covered glaciofluvial deposits was higher than that at the end of deglaciation.

This is very clearly visible in the zone of the Central Finland ice-marginal formation, where the difference in base levels is up to 50 m. The till-covered deposits are often deformed.

2. The striae on either side of the ice-marginal formations differ in direction. Some striae terminate abruptly at the marginal formation.

3. The homogenization of the uppermost till in the Salpausselkä zone is often in its initial stage, making it easy to identify the parent sediments.

Okko (1962) proposed that the period during which the ice sheet retreated from Finland's southern coastal area to somewhere north of Ss I should be called the Heinola deglaciation. The following advance to Ss I should accordingly be referred to as the Salpausselkä readvance. Rainio (1985) suggested that during the Heinola deglaciation the ice sheet receded for at least 80 km on the proximal side of the present Ss I. (cf. Hirvas & Nenonen, 1987, pp. 53, 62; Eronen & Vesajoki, 1988, p. 321)

In the light of the above, Rainio et al. (1986) concluded that the ice sheet receded from Ss I to at least 50 km north of what is now the Central Finland ice-marginal formation without any significant advances interrupting the deglaciation. The ice then readvanced to where the formation now stands. Rainio et al. proposed that the stages be termed the Keuruu deglaciation and the Jyväskylä readvance (Fig. 4). (cf. Hirvas & Nenonen, 1987, pp. 53, 62)

Inferences about the readvance of the ice sheet to Ss I and the Central Finland ice-marginal formation are based primarily on the fact that many glacial features change sharply at these formations. In this context, the zones of the Salpausselkäs and the Central Finland ice-marginal formation refer to the glaciogeologically exceptionally complex proximal areas of these formations.

It has also been argued that the concentration of till-covered sediments in certain zones need not necessarily be due to one single advance. In Sweden, Persson (1983) and Lundqvist (1987) have attributed similar stratigraphies to a series of halts in the receding ice front (Lundqvist, 1990, p. 20).

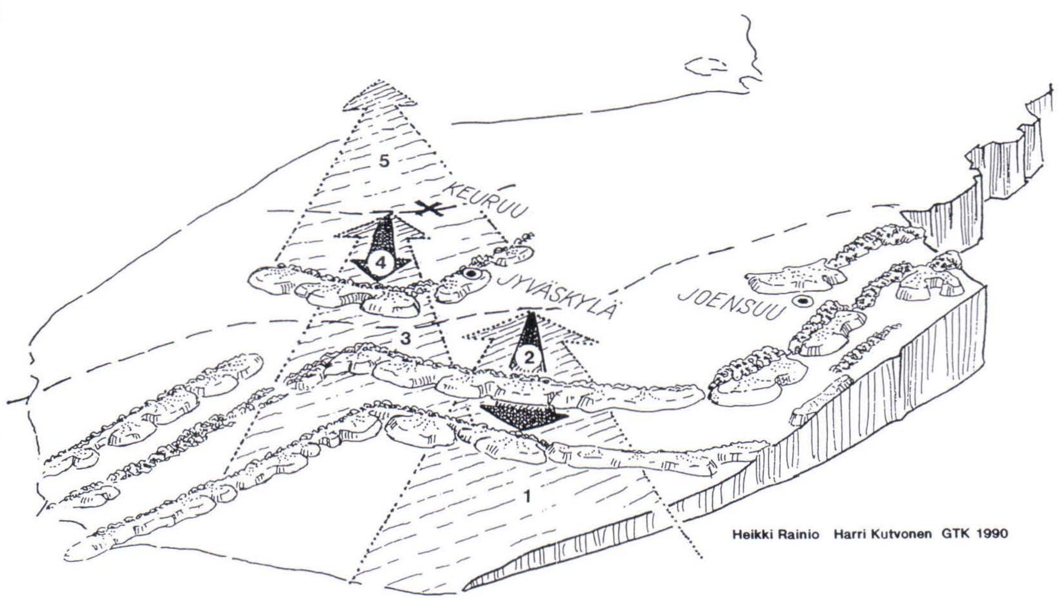

Fig. 4. The large ice-marginal formations in southern Finland and the wide late-glacial oscillations of the ice sheet. 1. The Heinola deglaciation; 2. the Salpausselkä readvance; 3. the Keuruu deglaciation; 4. the Jyväskylä readvance. (Rainio, 1990)

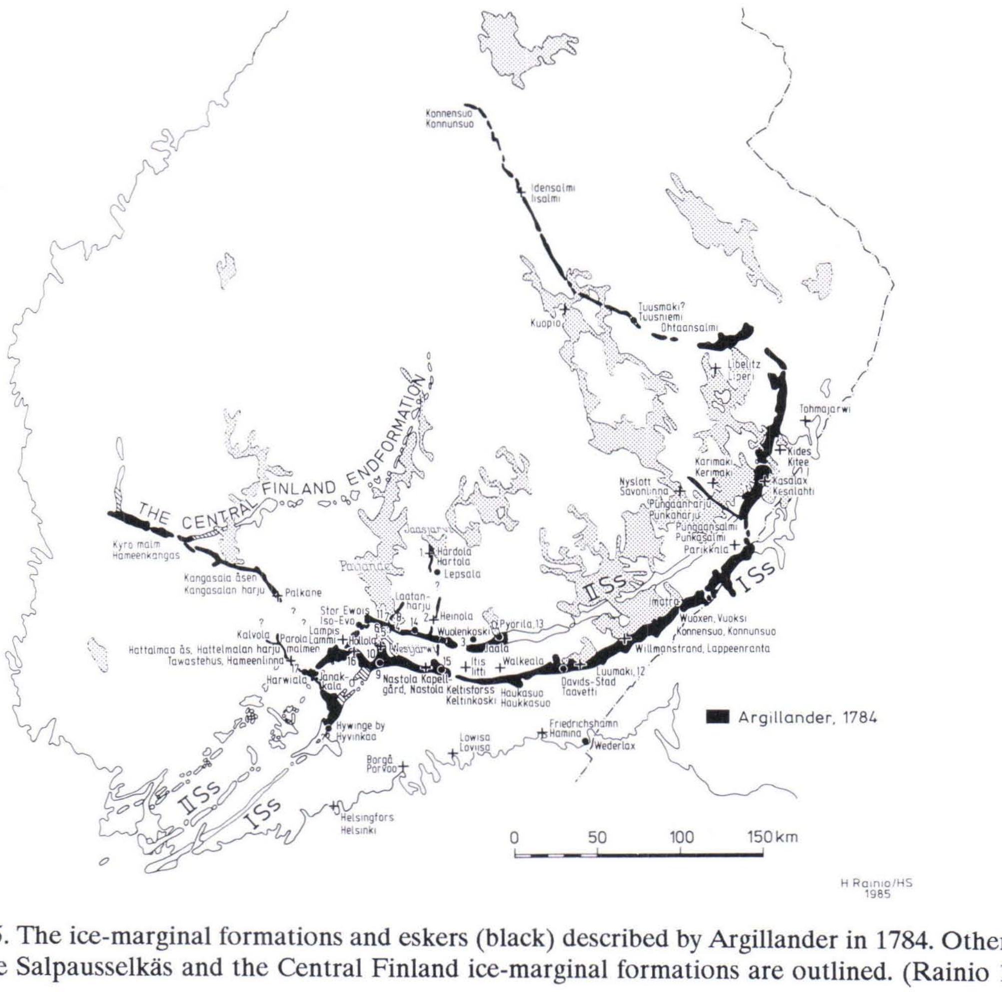

Fig. 5. The ice-marginal formations and eskers (black) described by Argillander in 1784. Other parts of the Salpausselkäs and the Central Finland ice-marginal formations are outlined. (Rainio 1985c)

A series of brief halts do not, however, explain the sharp change in striation, the difference in the base levels of the glaciofluvial sediments and the break in the network of glacial rivers. The eskers continue across the marginal terraces of Ss II and Pielisjärvi end moraine, which were formed during long-lasting stillstands, but not across Ss I and the Central Finland ice-marginal formation. The subtill varved clays can also be most easily attributed to readvancing ice.

Studies on the Salpausselkäs

Long before the Salpausselkäs became a subject of geological study they would appear to have aroused people's interest as formations of an exceptional nature. This is demonstrated, for instance, by the fact that the uppermost Viipuri road seems to have followed Salpausselkäs I and II in the 15th and 16th centuries (Wallin 1893, pp. 59 - 91).

Geographical descriptions started to include the Salpausselkäs among the eskers in the late 18th century. In his description of the parish of Lohja in 1766, Heinricius showed that the network of the western parts of Salpausselkäs I and II and the associated eskers were known all the way to southern Ostrobothnia (Rainio, 1985c).

Writing in 1784 in the Åbo Tidningar newspaper about Tuneld's Geography of Sweden published in 1773, Abraham Argillander elaborated on Tuneld's brief reference to an esker. His full description of the esker network in southern Finland includes long stretches of the two Salpausselkäs (Fig. 5) (Rainio, 1985c).

The information given by Argillander and Heinricius reveals that the course of the Salpausselkäs between Joensuu and Tammisaari had already been well established by the end of the 18th century, considering the facilities of the time. A more detailed description was to wait for almost a century.
In the early 19th century, the formation of soil - eskers and the Salpausselkäs included - was explained in terms of the diluvial theories (Rainio & Kukkonen, 1985). The first attempt to assign the Salpausselkäs to their proper position in geology was made by Wilhelm Boehtlingk in 1839.

Nils Gustav Nordenskiöld applied the new glacial theory to Salpausselkä I while studying the Saimaa canal cutting in 1846. He thought that the Salpausselkä "would be a huge ice-marginal moraine provided that the theory of Agassiz holds". However, according to Nordenskiöld, the degree of sorting of the sediments in the section demonstrated that this could not be the case. Unfortunately his ideas, which he expressed in a letter to J.J. Berzelius, remained unknown for about twenty years (Arppe, 1867, p. 34).

The first comprehensive description of the extensive ice-marginal formation of the Salpausselkäs was published by Anders Thoreld in 1863. He described a great cutting formed when the waters of Höytiäinen discharged through the large glaciofluvial delta of Jaamankangas in 1859. He considered Jaamankangas as part of an extensive esker network, but was unable to decide whether or not the ice age had anything to do with it (Thoreld, 1863; Rainio & Kukkonen, 1985, p. 74 and Fig. 10).

The term Salpausselkä, which was introduced in the late 1850s, referred to the outermost chain of ice-marginal formations, i.e. Salpausselkä I (Ramsay, 1921).

Systematic studies on the Salpausselkäs started in the 1870s, by which time they could be based on sound principles, as the ice age theory had been accepted as a research tool. It was realized how important it was for Finnish geological studies as a whole that the geology of these ice-marginal formations be established (Sederholm, 1889, p. 29 and 40 - 41). By the end of the century basic information about their course had been obtained that is still valid today.

F.J. Wiik dealt with the Salpausselkäs in numerous papers (1871, 1874, 1875, 1876, 1879), discussing several basic issues related to the Salpausselkäs. Initially (1871), in accordance with the earlier concepts, he considered the Salpausselkäs as beach ridges. Three years later, after studying the striae, he distinguished Salpausselkä I from other eskers and advanced the notion, rejected by Nordenskiöld 30 years earlier, that both Salpausselkä I (Wiik 1874, p. 290) and its northern parallel ridge (Ss II) were ice-marginal moraines (op. cit. p. 293 and Wiik, 1875, p. 234). He stated that Salpausselkä I extended from Lahti to the Joensuu area (Wiik, 1874, p. 291), and, soon afterwards (1875, p. 233), that the Salpausselkä extended from Hankoniemi to Joensuu. In his doctoral thesis, Wiik declared that Salpausselkä I was a distinct ice-marginal moraine both in external and internal structure and in relation to the striation (Wiik, 1876, p. 89). Wiik's other principal theses were that the front of the ice had retreated to Salpausselkä I from its earlier, more extensive position (1874, p. 293 and 1876, p. 89), that Salpausselkä I marked the maximum level of the Diluvial Sea or the Late-glacial Sea (1874, p. 293 and 1876, pp. 95 - 96) and that, calculated from the land uplift, no more than 25000 years had passed since that time (1874, p. 293).

Around the same time, Solitander (1875) and Jernström (1876) were collecting more detailed material from the Salpausselkä to support the broad general delineation of Wiik.

Information about the course, shape and structure of the Salpausselkä and its parallel ridge accumulated rapidly with the start of geological mapping in Finland in 1876.

In 1885, the Swede De Geer concluded that the ice-marginal moraines in the Vänern and Vättern areas of central Sweden and the Ra moraines in Norway were contemporaneous with the Salpausselkä and its parallel ridge, Salpausselkä II (De Geer, 1884 - 1885, pp. 436, 438). According to him, they all mark the position of the front of the readvanced continental glacier (pp. 443, 456). Between them, however, there had been the Baltic Ice Stream, which had flowed along the basin of the Baltic Sea far to the south. Consequently, the ice front could not have extended over the Baltic Sea (pp. 442 - 443). He also postulated that the ice front could not have passed Maanselkä, the water divide on the eastern border of Finland, but that the margin of the continental ice sheet in Finland had trended northwards from the Joensuu area (op. cit. pp. 438, 457 and Plate 13).

In 1889, Sederholm proposed that the Salpausselkä and its parallel ridges mark synchronous positions of the ice front during the retreat of the ice and that in southwestern Finland there are three of these positions. Unlike De Geer, he thought it very likely that the ice-marginal formations continued on the other side of the eastern border. He also rejected De Geer's idea that the Baltic Ice Stream had been contemporaneous with the formation of the ice-marginal moraines of the Salpausselkäs or Vänern (Sederholm, 1889 and Appendix 1).

In 1890, Ramsay studied the course of the eastern parts of the Salpausselkäs and their continuations, the ice-marginal formations of Koitere and Pielisjärvi. He pointed out that as the course of the big ice-marginal formations in Norway, Sweden and Finland had now been established, it was time to continue the studies in the Russian Karelia. (Ramsay, 1891)(Appendix 1)

Financed by the Geographical Society of Finland, Rosberg followed up Sederholm's ideas and began to study the continuation of the ice-marginal formations in Russian Karelia in 1891. He elaborated on the findings of Ramsay concerning the Koitere and Pielisjärvi segments, and in 1895 set off on a new expedition to Russian Karelia (Rosberg, 1892, 1899)(Appendix 1 and the cover).

At the same time the staff of the Geological Commission, the forerunner of the Geological Survey of Finland, were mapping the course of the ice-marginal formations in North Karelia (Frosterus & Wilkman, 1915).

Thus, by the end of the last century, Finnish researchers had largely established the course of the ice-marginal formations, in Russian Karelia, too, mainly by interpreting landforms, i.e. by means of geomorphology. Initially, the Koitere ice-marginal formation was considered contemporaneous with Salpausselkä I (Ramsay, 1891; Rosberg, 1892, 1899). Before long, however, all the leading scholars had come to the conclusion that the Koitere ice-marginal formation was contemporaneous with Salpausselkä II and that the Pielisjärvi ice-marginal formation was younger than them (Sederholm, 1899; Frosterus & Wilkman, 1915; Ramsay, 1921) and evidently Rosberg, too (Suomenmaa VIII, 1927, pp. 228, 326). Only Leiviskä (1920) maintained that the eskers extending from Kiihtelysvaara towards Jaamankangas were extensions of Salpausselkä II.

Contact with Karelia was severed when Finland became independent, and the USSR was established. From the 1920s Finnish efforts concentrated on shoreline displacement studies and the application of the results under the supervision of Sauramo and Hyyppä. The position of the ice front in North Karelia at the time of the deposition of the Salpausselkäs was re-interpreted. The ice-marginal formations in easternmost Finland and Soviet Karelia were overlooked, because they were incompatible with the interpreted shore line displacements; they were not referred to in the literature or mentioned at university lectures.

Hyyppä (1936, p. 437, app. 7) was the first to suggest that the Baltic Ice Lake (B II) had extended via eastern Finland to Kuusamo. Thus, at the time the Salpausselkäs were formed the ice front would have trended to N from North Karelia.

His ideas were backed up by the conclusions reached by Sauramo (1937, pp. 17 - 22) and Kilpi (1937, pp. 111 - 113) from studies of shoreline displacements in North Karelia and Kainuu. Sauramo (1937, p. 9) summarized the old and new concepts by stating that: " ...der Erste Salpausselkä setzt sich also nicht, wie man es bisher angenommen hat, in NE nach Ostkarelen und dem Seesjärvi zu, sondern direct nach N, nach dem See Pielisjärvi" (in contrast to what has been considered thus far, Salpausselkä I does not trend to NE towards East Karelia and Lake Seesjärvi but directly northwards towards Lake Pielinen). Further "at the time of the Baltic Ice Lake, the ice had disappeared from the east of the Pielinen basin and during the Yoldia stage from almost the whole basin. Hence, it was possible that already during the Salpausselkä stage the Baltic Sea extended from the south between the eastern water divide and the ice sheet as far as Maanselkä" (op. cit. pp. 17 - 18).

In the following decades Sauramo and Hyyppä refined their concepts, unfortunately to the point at which their only interest lies in their contribution to the history of research. As a consequence, the ice-marginal formations in easternmost Finland and in Soviet Karelia were largely ignored until the 1960s, when a fresh look was taken at the concepts of shoreline displacement (Hyvärinen 1966 a, b), and studies on the course of the ice-marginal formations were reopened using a geomorphological approach (Rainio, 1972). Pollen and radiocarbon evidence was used to demonstrate precence of organic deposits of Younger Dryas age in the southern foreland of North Karelian end moraines (Selkäkangas) whereas at sites farther north the pollen record opens with Early Holocene assemblages; hence the end moraines could be biostratigraphically correlated with the Younger Dryas (Hyvärinen 1971a, 1972, 1973).

In the early 1970s, the Geological Survey of Finland and the geologists of Soviet Karelia joined forces in studying the deglaciation of the Salpausselkä stages (Lukashov et al., 1981). As a result, the work of Rosberg on Russian Karelia became topical once more (see Hyvärinen 1973).

Several interpretations have been advanced during the last two decades of the deglaciation of North Karelia. According to them, the results of the studies conducted in the 19th century were in fact more or less correct. New studies are briefly reviewed in the context of the description of North Karelia.

The Salpausselkäs and associated ice-marginal formations in North Karelia

Broadly speaking, the southwestern ice-marginal formations in North Karelia were deposited in the subaquatic area covered by the Baltic Ice Lake and the Yoldia Sea, and the northeastern formations either in the supra-aquatic region or in local aquatic basins. This is shown by the structure, material composition and size of the formations, and the levels of the deltas and plateaus and the history of Quaternary geological research in Finland.

Partly for reasons related to the history of research, there is no clear agreement on the concept of the Salpausselkäs. The chain of ice-marginal formations called Salpausselkä I is usually considered to terminate in the east with the marginal terrace at Patsola, a village in the Värtsilä parish (e.g. Ramsay, 1921). However, there is less unanimity as to where Salpausselkä II "terminates" in the east, although it is generally thought to extend at least as far as the Kiihtelysvaara area.

The prevailing trend of the ice front as indicated by the marginal terraces at the northeastern end of Salpausselkä I is by and large NNE. The terrain becomes supra-aquatic immediately ENE of the Patsola marginal terrace, which is where the search for any continuations of the ice-marginal formations should be concentrated. Indeed, between Patsola and Möhkö, Ilomantsi, there is a zone, a few kilometres wide and trending NNE, of small marginal moraines, marginal terraces formed in glacial lakes, areas of NNE-trending hummocky moraines and expanded eskers. Rainio (1978) has suggested that this group of glacial formations might mark the position of the ice front at the time of the formation of Salpausselkä I. Some small marginal moraines in the USSR (Frosterus & Wilkman, 1915) and the large Himola esker delta may be of the same age. Approximately the same position of the ice front has been proposed by Kurimo (1982), Lyytikäinen (1982) and Punkari (1982, 1984).

The Tuupovaara end moraine, which is about 50 km long, extends from north of Patsola towards N (Rainio, 1983, 1985b). The Koitere end moraine chain extends from the Kiihtelysvaara area to the Soviet border, and the Pielisjärvi end moraine chain from Jaamankangas to the Soviet border (Rainio, 1985b) (Fig. 6).

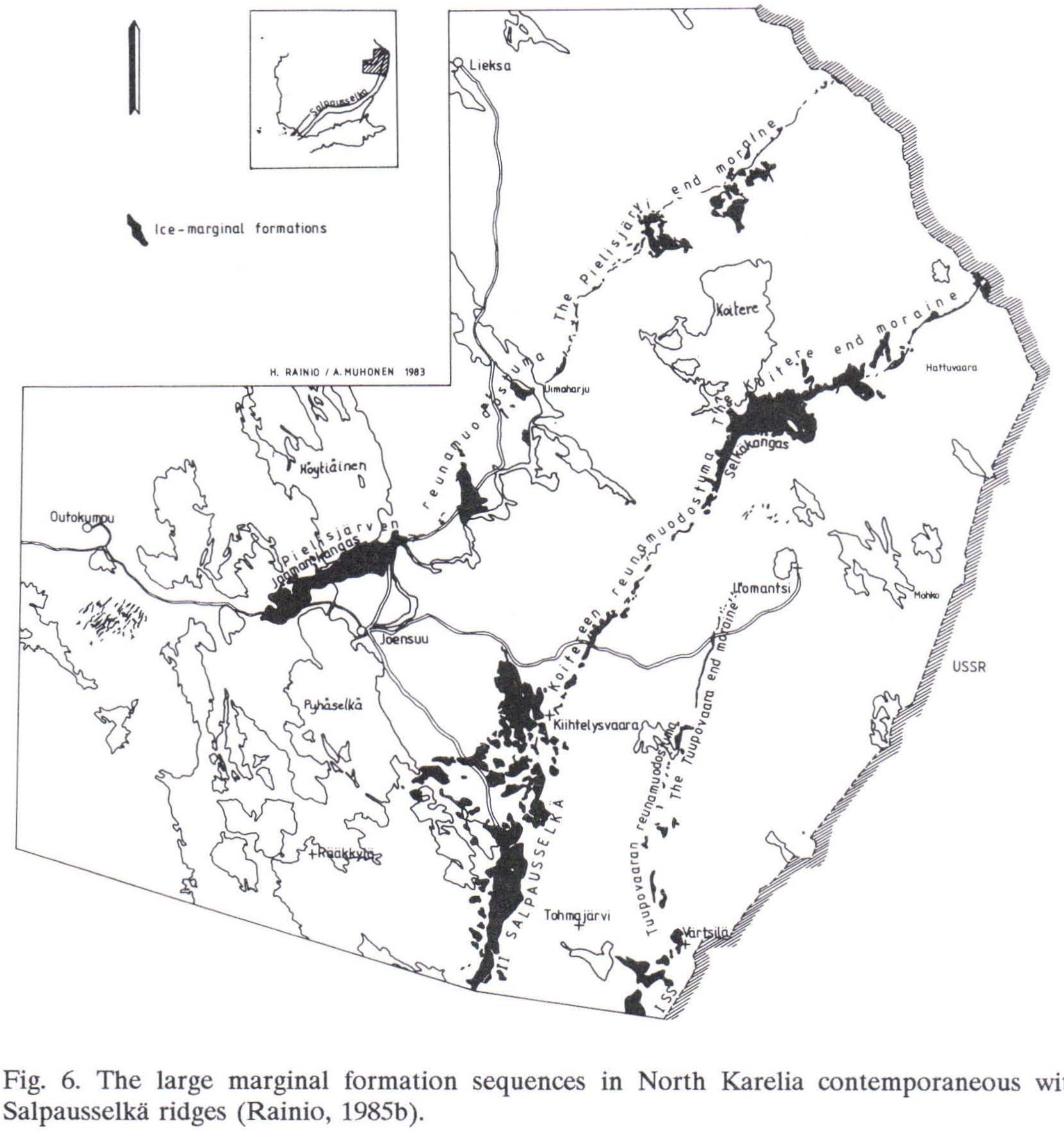

Fig. 6. The large marginal formation sequences in North Karelia contemporaneous with the Salpausselkä ridges (Rainio, 1985b).

The question of the continuation of the Salpausselkäs in North Karelia or the location of the ice front at the time of their formation has still not been satisfactorily answered. The relation of the Salpausselkäs to the Tuupovaara, Koitere and Pielisjärvi chains has been explained in various ways, but general agreement has not been reached. Emphasizing the independence of the glacial lobes, geologists now think that the ice-marginal formations of different lobes may not even be contemporaneous. However, the meaning of contemporaneous has not been defined, even though other parts of the Salpausselkäs have been interpreted as metachronous for decades (e.g. Saarnisto 1970; Donner 1978). This problem, too, has a bearing on the concept of the Salpausselkäs.

Rainio (1972, 1978, 1983, 1985b) has based his interpretation on the mutual position of the ice-marginal formations, shoreline displacement, and analyses of the esker network. According to him, the Tuupovaara end moraine is distinctly older than Salpausselkä II, but slightly younger than Salpausselkä I. The Koitere end moraine appears to be of approximately the same age as Salpausselkä II. The heights of the plateaus of the Pielisjärvi ice-marginal formations, which were deposited in the Baltic Sea, demonstrate that they did not form until the Baltic Ice Lake had sunk to, or almost to, the Yoldia level (cf. Saarnisto 1970). The formations should evidently be contemporaneous with Salpausselkä III in southwestern Finland.

In the 1980s in particular, researchers emphasized that during deglaciation, the Scandinavian ice sheet was divided into several lobes, each with its own mass balance and dynamics. "For this reason, the end moraines of different ice lobes situated opposite to each other in boundary zones of the ice lobes are not necessarily of the same age" (Punkari 1980). The Finnish Lake District ice lobe, which flowed approximately from the west, and the North Karelian ice lobe, which flowed from N-NNE, were the main ice lobes in North Karelia during deglaciation (Punkari 1980).

The action of these ice lobes has been studied by Hirvas (1980), Punkari (1982, 1984, 1985), Lyytikäinen & Kontturi (1980), Lyytikäinen (1982), Kurimo (1982), Forström (1984), Kujansuu & Nenonen (1987) and Eronen & Vesajoki (1988). In their deglaciation models, the ice-marginal formations in North Karelia are not rigidly tied to each other in age. However, it is generally accepted that the Younger

Dryas ice-marginal formations extend from North Karelia to Soviet Karelia in much the same way as was proposed at the turn of the century.

Soviet geologists Ekman, Iljin and Lukashov have studied the ice-marginal formations in Soviet Karelia, without, however, finding a formation corresponding to Salpausselkä I in that region. The Koitere and Pielinen ice-marginal formations, however, clearly continue into Soviet Karelia. On the basis of this finding and some radiocarbon dates they consider the Rukajärvi zone, which is directly connected to the Koitere chain, to be the counterpart of Salpausselkä I, and the Kalevala ice-marginal formation, which is associated with the Pielisjärvi chain, to be the counterpart of Salpausselkä II (cf. p. 79).

Salpausselkäs I and II, with their "extensions", and the Pielisjärvi end moraine occur in North Karelia as a zone about 70 km wide (Fig. 6). As elsewhere in Finland, this zone is characterized by the occurrence of numerous small glaciofluvial and other ice-marginal formations, hummocky moraine stretches, and till-covered older glacial deposits. In this zone, the glacigenic deposits are much more diverse than elsewhere, even, for example, on the immediate distal side of Salpausselkä I.

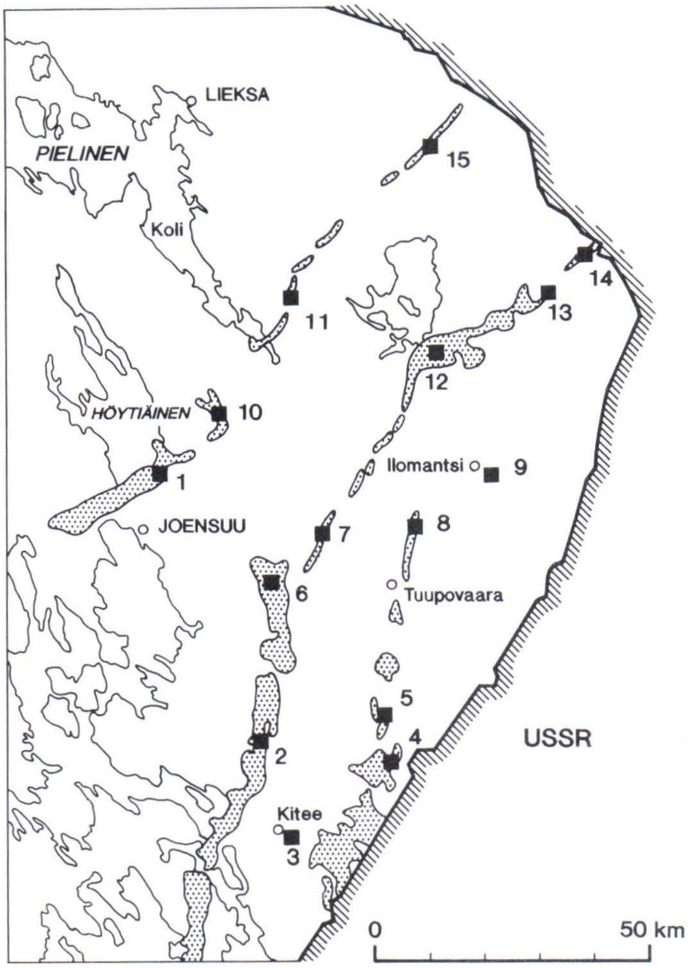

Fig. 7. Sites visited by IGCP-253 excursion in North Karelia
1. The Pielisjärvi end moraine; Jaamankangas, Kontiolahti and Liperi. A marginal terrace and an esker passing through it, the Höytiäinen transgression shore.
2. Salpausselkä II; Miilu, Tohmajärvi. A big marginal moraine ridge.
3. The area between the Salpausselkäs; Kiteenlahti, Kitee. The Kiteenlahti esker delta, stages of the Baltic Ice Lake.
4. Salpausselkä I; Patsola, Värtsilä. The easternmost marginal terrace of Salpausselkä I.
5. The Tuupovaara end moraine; Kankaankylä-Hukkala. A marginal moraine section and marginal plateau.
6. The Tervasuo interlobate complex, Kiihtelysvaara.
7. The Koitere end moraine; Mäkräsärkkä, Eno. A supra-aquatic marginal moraine ridge with its back complex.
8. The Tuupovaara end moraine; Pitkäkorpi, Tuupovaara. A supra-aquatic marginal moraine ridge.
9. Kuuksenvaara, Ilomantsi. Loess and cover sand.
10. The Pielisjärvi end moraine; the Kuusoja valley train, Eno and Kontiolahti.
11. The Pielisjärvi end moraine; the Havukka ice-marginal formation and glacial lake, Eno.
12. The Koitere end moraine; the Selkäkangas marginal terrace and Ilomantsi Ice Lake.
13. The Koitere end moraine; the Hattujärvi ice-marginal formation, Ilomantsi.
14. The Koitere end moraine; Koivusuo-Kaitasärkkä, Ilomantsi. A supra-aquatic marginal moraine and the marginal terrace of a glacial lake.
15. The Pielisjärvi end moraine; Lusikka-aho, Lieksa. A supra-aquatic moraine ridge.

Site descriptions

Site 1

The Pielisjärvi end moraine; Jaamankangas, Kontiolahti and Liperi.

The section of the canal dug across Jaamankangas was studied even before the glacial theory was accepted in Finland. The name Jaamankangas was introduced into the geological literature by Pjotr Kropotkin, a Russian who is better known as an anarchist in the 1870s. By the name he meant the sandy heaths (kangas = sandy heath with pines) which constitute a distinct marginal terrace at the southern end of Lake Höytiäinen. Later the name was extended to include the interlobate esker complex that runs westwards from the marginal terrace. However, owing to the genetically diverse geological features of Jaamankangas, the term has caused some confusion.

Some researchers have regarded Jaamankangas as contemporaneous with Salpausselkä II (e.g. Repo 1957). Most, however, have considered it contemporaneous with Salpausselkä III, in southwestern Finland.

The eastern part of Jaamankangas, which is clearly a marginal terrace, is 3-4 km wide, with a steep, till-covered proximal flank, including an unmistakable end moraine ridge. Jaamankangas and it's extension in the northeast is called the Pielisjärvi end moraine. The plateau, which is furrowed by a network of meltwater channels, slopes gently in the distal direction. According to seismic soundings, the glaciofluvial deposits may be up to 70 m thick. Three eskers starting at the Tervasuo complex of Salpausselkä II extend to the marginal plateau. Their course is marked by rows of kettle holes, demonstrating that the eskers and the ice-marginal formation were formed in the same deglaciation process.

The elevation and channels of the distal portion of the plateau indicate that the base level of erosion was at about 105 m at the end of the period during which the ice-marginal formation deposited. It refers to either the level of the Yoldia Sea or a slightly higher elevation (Saarnisto 1970), but is distinctly below the level of the Baltic Ice Lake. Lehmonharju, a ridge which runs across Jaamankangas (Fig. 8), seems to have formed when the base level of erosion was at 120-125 m, probably during the existence of a glacial lake that developed after the drainage of the Baltic Ice Lake.

At first, Lake Höytiäinen, which is located north of Jaamankangas, drained to the west from its central part. Owing to differential land uplift, however, water spilled over the southern end of the lake and flooded the proximal slope of Jaamankangas. In the 1850s work started on constructing a canal across Jaamankangas. In 1859 the water forced its way past the structures of the canal and carved a deep and wide channel in the readily eroded sediments of Jaamankangas. The transgression shore of Höytiäinen is visible on the proximal slope of Jaamankangas as a shore terrace with ice-pushed boulders.

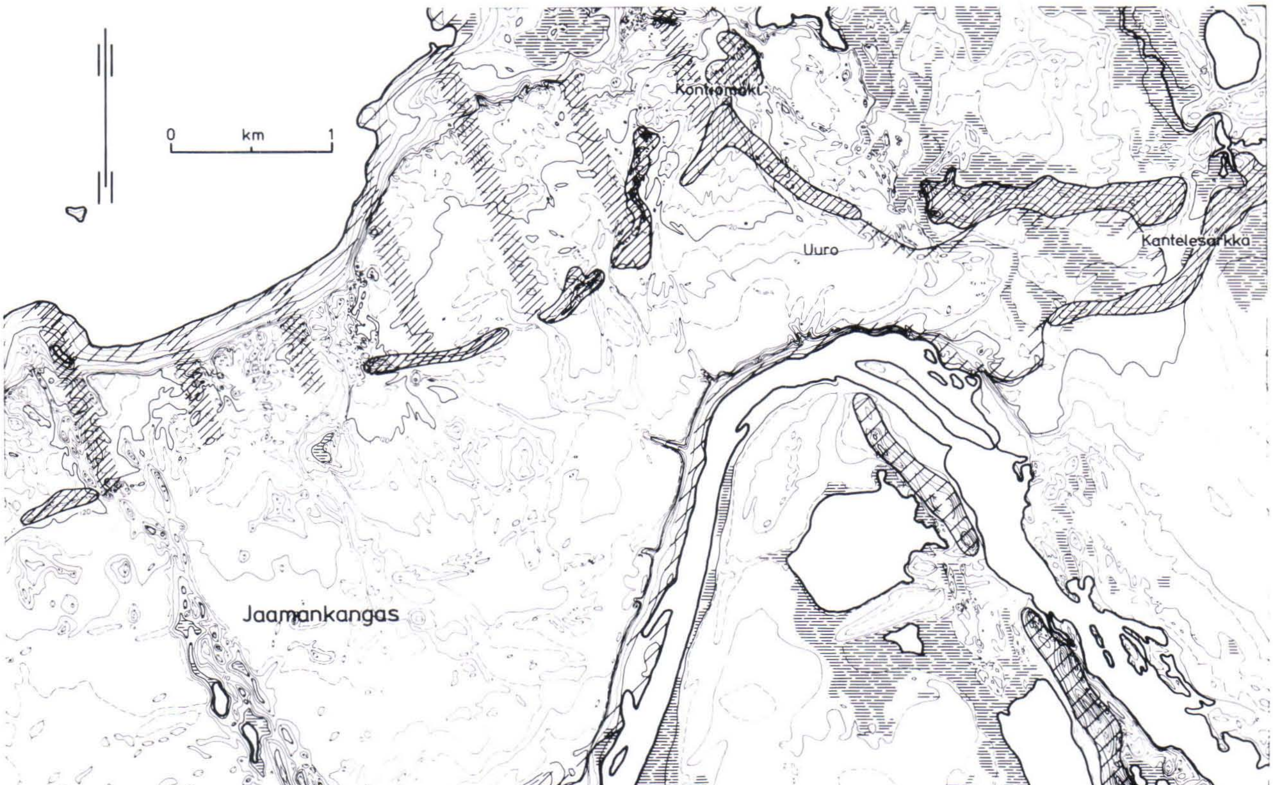

Fig. 8. The Pielisjärvi end moraine, Jaamankangas, Kontiolahti and Liperi. The course of Lehmonharju ridge bordered by a row of kettle holes across the ice-marginal formation is clearly visible. In places the till cover of the proximal part is a kilometre wide. Here and there the marginal moraine ridge shows up as a distinct arc. At Kontiomäki the seam of the local ice lobes was located at the esker running from the southeast in the picture. The marginal moraine makes a turn of over 90° there. Dense diagonal shading = moraine ridges and hummocks; less dense diagonal shading = glaciofluvial deposits.

Site 2

Salpausselkä II; Miilu, Tohmajärvi. Over a distance of at least 100 km, the easternmost part of Salpausselkä II is often composed of a wide glaciofluvial portion and a proximal, supra-aquatic marginal moraine ridge, 20-50 m high and 0.5-1 km wide. Further west the marginal moraine ridges tend to be lower. The moraine ridges of Salpausselkä I are smaller than these. It is therefore feasible that glaciofluvial processes were dominant at the time Salpausselkä I was formed. During the formation of Salpausselkä II the ice sheet was more active, accumulating till into supra-aquatic ridges too big for the meltwaters to erode. The difference in glacial activity may also be the reason why the distinctly ice-marginal formations are lacking in the supra-aquatic area to the east of Salpausselkä I, while the moraine ridges contemporaneous with Salpausselkä II are big and continuous.

The big marginal moraine ridges exhibit a very chaotic pattern of kettle holes, hummocks and ridges on the map. The aerial pictures in particular show that the kettle holes and ridges are arranged roughly parallel to the general trend of the ridge, suggesting that the structure of the marginal moraine is similar to that shown in the picture 9.

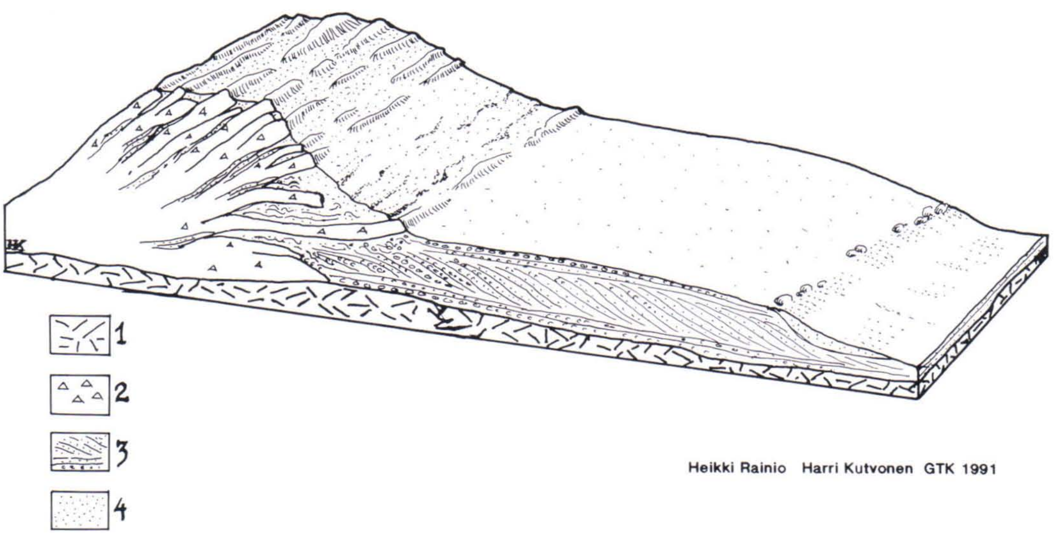

Fig. 9. Structure of Salpausselkä II. This structure predominates in North Karelia in formations deposited in the Baltic Ice Lake. The proximal moraine ridge is several tens of metres high and 500-800 m wide over long stretches. It was formed when the ice sheet piled numerous till layers on top of each other (cf. Fig. 3). The diamicton of till got abundant sorted material from the melting ice front. The ice sheet was still very active just before the ice front started to retreat.
1. Bedrock; 2. till; 3. glaciofluvial sand and gravel; 4. littoral deposits.

Site 3

The Kiteenlahti delta, Kitee. Between Salpausselkäs I and II there are short ice-marginal moraines, terraces and deltas. Over large areas they are in approximately the same zone, i.e. at a more or less equal distance from Salpausselkä I. In all likelihood, they indicate a brief stillstand of the ice front. The terraces and deltas often grew to the level of the Baltic Ice Lake, which is about five metres lower than B I and is referred to as B II. On the slopes of the terraces and deltas there is frequently a shore terrace another five metres or so lower down. This represents the last stage, B III, of the Baltic Ice Lake.

The Kiteenlahti formation is a spearhead-shaped glaciofluvial delta that deposited in the fractured front of the ice. After the ice had disappeared the delta divided into several parts. The surface of the delta is at 109 m a.s.l. and thus represents the B II level. The slopes of the delta have a shore terrace contemporaneous with B III. Its elevation varies, depending on how the littoral forces acted on it. In the part of the delta shown in the picture 12, B III is at 102-105 m a.s.l.

Site 4

Salpausselkä I; the Patsola marginal terrace, Värtsilä. The Patsola marginal terrace is the last "official" part of Salpausselkä I. The elevation of the distal part of the plateau, 110 m, represents B I. At an elevation of 96-97 m on the distal slope there is a shore terrace of B III. The proximal part of the plateau has the usual till cover but no moraine ridge. As shown by well data, there are till beds at greater depths, too. The terrain immediately east of the terrace is supra-aquatic. The Tuupovaara ice-marginal formation begins at Pykälävaara, about four kilometres north of Patsola. The plateau there, albeit poorly developed, is at 103 m a.s.l and the shore terrace on its slope at 93 m. This supports to some extent the idea that the Tuupovaara ice-marginal formation is slightly younger than Salpausselkä I. (Fig. 13)

Site 5

The Tuupovaara end moraine; Kankaankylä and Hukkala, Tohmajärvi. The Kankaankylä ridge is a six-kilometre-long segment of the Tuupovaara end moraine. It varies in width from 100 to 400 metres and in height from a few metres to 25 metres. Judging by the data from the gravel pits, it is mainly composed of glaciofluvial material, which, on the proximal side, is covered with a thin layer of till. After a break of a couple of kilometres, there is the terrace plain of Hukkala, which is about two kilometres long and 600-800 metres wide, lying at 115 m a.s.l.

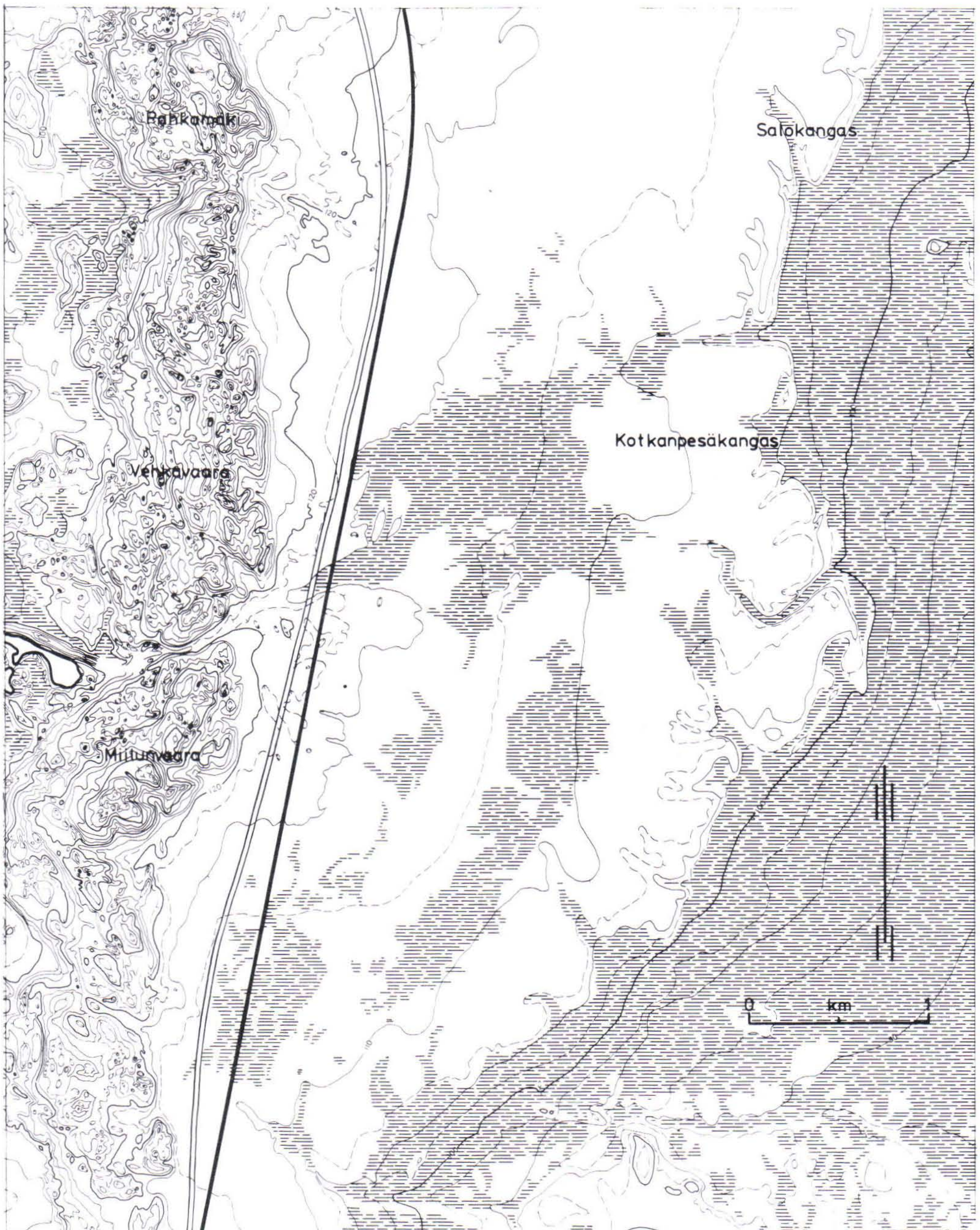

Fig. 10. Salpausselkä II, Miilu, Tohmajärvi. The elevation of the glaciofluvial plateau is 107-125 m, of which at least the portion exceeding 115 m is supra-aquatic. The proximal moraine ridge, Miiluvaara, Vehkavaara and Pahkamäki rise up to 170 m, i.e. 50-60 m over the base level of erosion. The terrain of the proximal side of ice-marginal formation is at 80-100 m a.s.l.

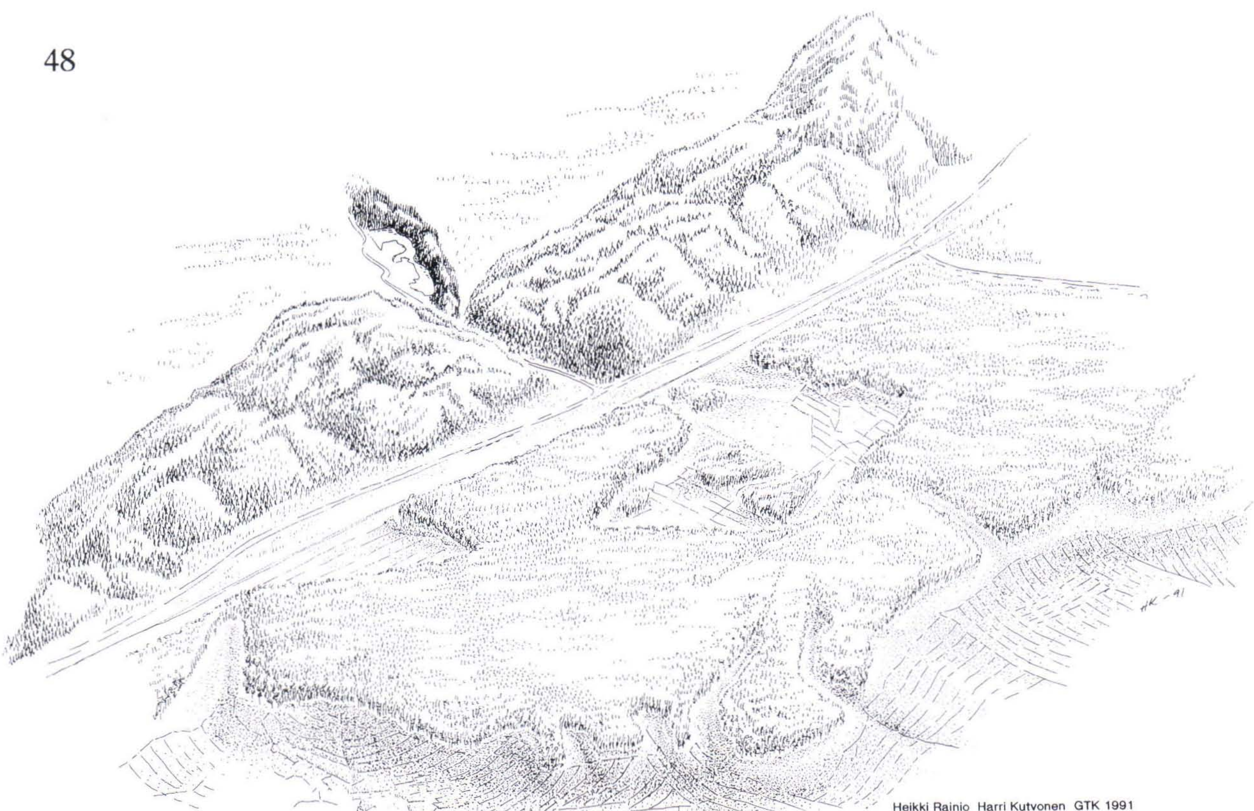

Fig. 11. Salpausselkä II at Miilu, Tohmajärvi. In the foreground there is a glaciofluvial plateau that developed on the level of the Baltic Ice Lake or of a small glacial lake a few metres higher up. In the background, a marginal moraine ridge less than one kilometre wide is cut by the channel of a glacial river that discharged into the glacial lake. On the proximal side, there is an esker at the site of the glacial river (cf. Figs. 9, 10).

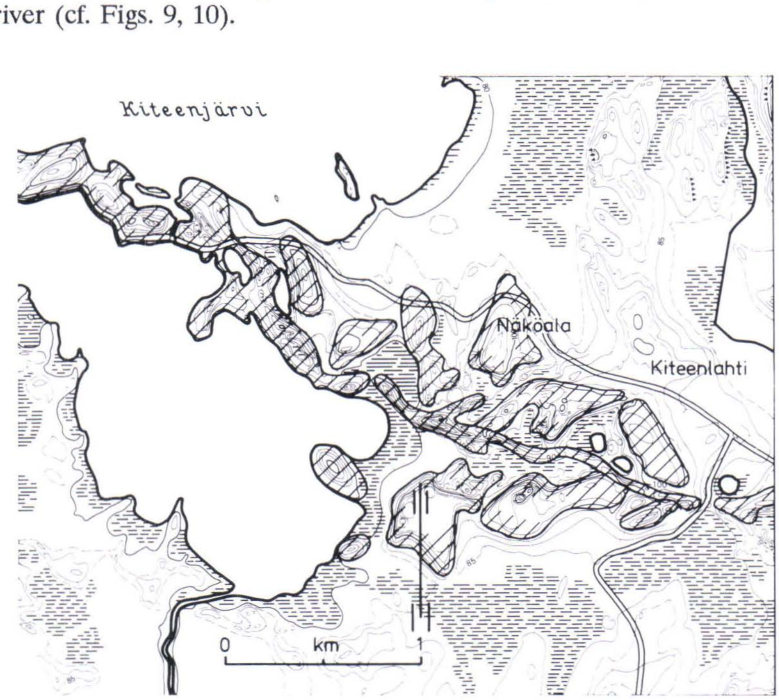

Fig. 12. Kiteenlahti delta, Kitee. A delta formed on the B II plane in the front of fractured ice on both sides of an esker trending approximately east-west. Once the ice melted, the delta disintegrated into several parts. The esker itself did not grow to the base level of erosion. Diagonal shading = glaciofluvial deposits.

Fig. 13. The easternmost part of Salpausselkä I, the Patsola marginal terrace. The Tuupovaara end moraine begins at Pykälävaara, four kilometres north of Patsola. Dense diagonal shading = moraine ridges and hummocks; less dense diagonal shading = glaciofluvial deposits.

Site 6

The Tervasuo ice-marginal formation complex; Kiihtelysvaara

On the SW-NW side of the parish center of Kiihtelysvaara, there is an area marked by the occurrence of glaciofluvial plains, till ridges and mounds, kettle holes and dry meltwater channels. Clearing up this complex has proved laborious. Thus it has been unanimously agreed that Salpausselkä II extends east at least this far; but as to where it "continues" from there, opinions differ a great deal.

This complex of glacial formations developed in a interlobate zone between the Finnish Lake District Lobe and the North Karelian Lobe of the continental ice sheet, which to some extent accounts for the diverse character of the formations.

The region is roughly divided into two parts. To the east is an area of glaciofluvial marginal terraces and to the west, an area of hummocky moraines and end moraines. The eastern part is composed of numerous marginal terraces that have formed consecutively and the borders of which are indicated by rows of elongated kettle holes. In this area the North Karelian Lobe receded at its western margin toward the NNW. The Finnish Lake District Lobe would appear to have been active last. It transported thick layers of till from the west, partly on top of the marginal terraces.

The elevation of the glaciofluvial plateaus is 120-125 meters above sea level, corresponding to the level of the Baltic Ice Lake (B III) in this region. Dry meltwater channels occur, especially on the surface of the Palokangas plain. The plateaus are intersected by numerous steep slopes, indicating the erosive action of ancient meltwater streams. They originated at a time when the base level of erosion had changed on account of land uplift.

A considerable portion of the till formations on the western side are supra-aquatic. Sampling drilling at Tukholmanvaara, which rises to an elevation of over 160 meters, showed that it was composed of alternating strata of sorted and unsorted material. After the retreat of the margin of the ice sheet, there was at first in the Pielisjoki valley a glacial lake, the waters of which flowed between the Tervasuo complex and the Heinävaara rocky ridge into the Jänisjoki river system. The drainage channel of the ice-dammed lake can be traced in the glaciofluvial deposits on the southwest side on Heinävaara. (Rainio 1990)(Fig. 14)

Fig. 14. The Tervasuo ice-marginal formation complex. The area of glaciofluvial deposits in the middle and on the right-hand side of the picture comprises a continuous succession of regularly younging marginal terraces. Separated from each other by dry or water-filled kettle holes they were formed in front of the North Karelia ice lobe, when the front was gradually moving northwestwards. In the east of the area there are banks and terraces carved by meltwaters and waters flowing from the Pielisjoki glacial lake. The left-hand part, i.e. the western part of the picture, is dominated by the till deposits of the Finnish Lake District ice lobe. Coring at Tukholmanvaara has shown that the total thickness of the alternating nonsorted and sorted sediments is about 50 m. Dense diagonal shading = moraine ridges and hummocks; less dense diagonal shading = glaciofluvial deposits.

Site 7

The Koitere end moraine; the Mäkräsärkkä end moraine, Eno. At this point the ice-marginal formations run across a supra-aquatic area. North of the Joensuu - Ilomantsi road the formation complex is over a kilometre wide and consists of a network of hummocky moraines and both longitudinal and transverse moraine ridges. In the distal part there is usually a continuous end moraine ridge. The most striking formation is Mäkräsärkkä, which rises very steeply 25-30 metres from the distal side. Seismic sounding indicates that it is composed of partly sorted till up to 30 m thick. Like most supra-aquatic areas, the distal side of Mäkräsärkkä is without outwash deposits. (Fig. 15)

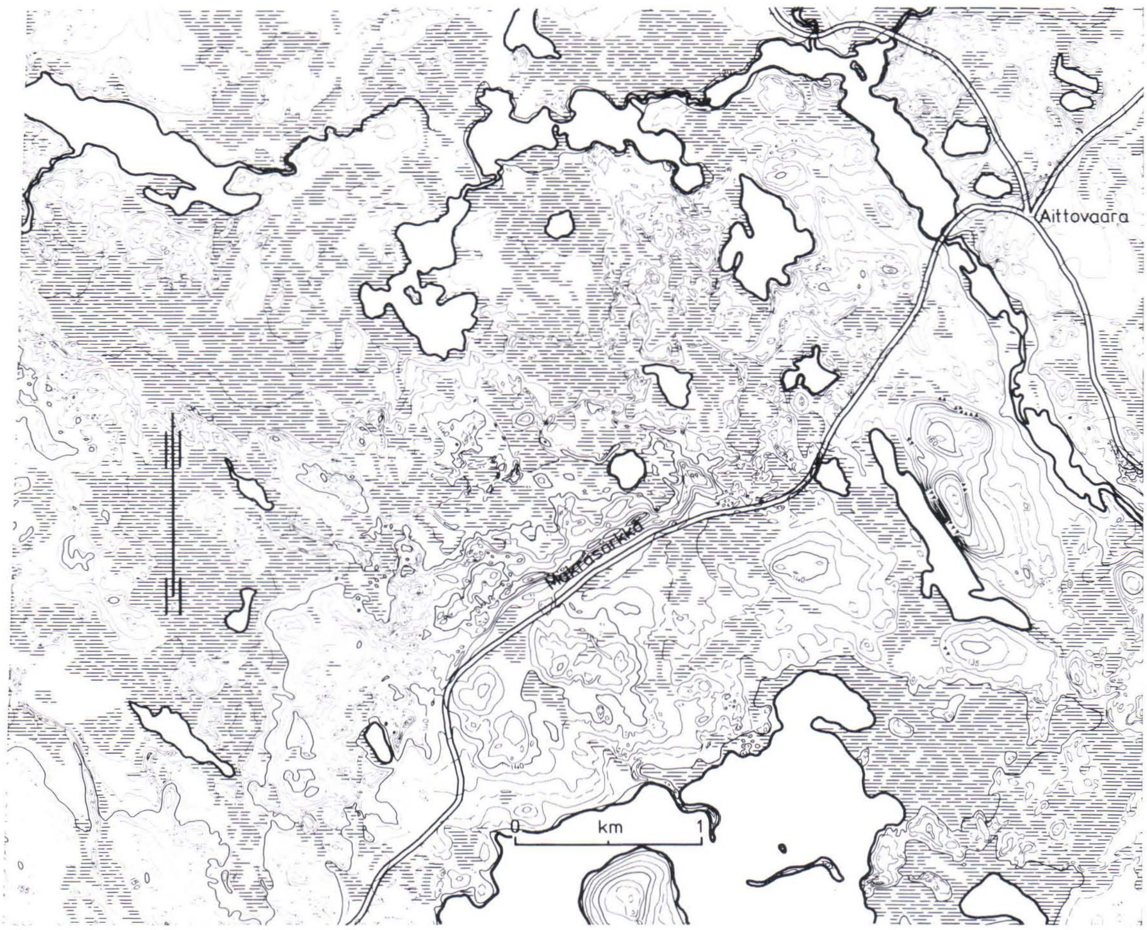

Fig. 15. The Koitere end moraine, Mäkräsärkkä end moraine, Eno. Mäkräsärkkä is a supra-aquatic moraine ridge. The gently sloping lodgement till terrain on the distal side passes into a capricious network of glaciofluvial and moraine ridges on the proximal side of the moraine ridge. The activity of the ice sheet mainly produced moraines. There is no outwash field on the distal side of the ice-marginal formation.

Site 8

The Tuupovaara end moraine; Pitkäkorpi, Tuupovaara

The Tuupovaara ice-marginal formation is at this point 100-300 meters broad and at most 25-30 meters high, and it consists of 1-2 parallel till ridges. To judge by the evidence provided by highway and railroad cuttings, the material is unsorted. (Rainio 1990)(Fig. 16)

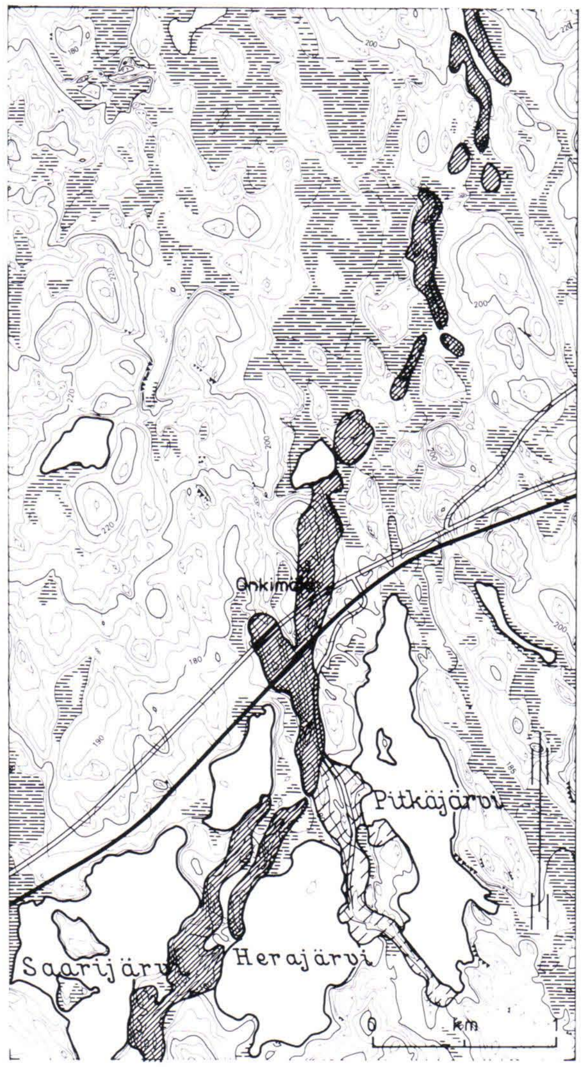

Fig. 16. The Tuupovaara end moraine, Pitkäkorpi, Tuupovaara. Dense diagonal shading = moraine ridges and hummocks; less dense diagonal shading = glaciofluvial deposits.

Site 9

The south side cover sand and loess of Salpausselkä II; Kuuksenvaara, Ilomantsi

In the distal area of Salpausselkä II, in the southern Finland, there occurs a zone where loess and cover sand are often found, especially in the supra-aquatic portions. The width of this zone varies from some tens of kilometers in North Karelia to a few kilometers in the Kymi and Häme districts. This layer is often more than half a meter thick, but the thickness rarely exceeds one meter. The cover sand consists mainly of fine sand fractions and the loess generally of coarse silt, with 15-35 per cent of the fine silt fraction and 3-8 per cent of the clay fraction. This cover sand was likely deposited when the continental ice sheet had receded to the Salpausselkä II zone, probably at the time when the Baltic Sea and the Ilomantsi Ice Lake sank to a lower level and vast areas were exposed to wind action. The source area for most of the material probably was the vast outwash plains of Salpausselkä II. (Rainio 1990)(cf. Rainio 1982 a,b)

Site 10

The Pielisjärvi end moraine; Kuusoja valley train, Eno and Kontiolahti

The region between Jaamankangas and Uimaharju lies both absolutely and relatively at one of the highest elevations in the southern Finland. Between rocky ridges rising to heights of 200-250 meters, there run valleys overlain by glaciogenic deposits located at an elevation of slightly over 100 m.

In this region, there is no uniform ice-marginal formation. The sequence of formations consists of short supra-aquatic till ridges and associated glaciofluvial valley trains or small marginal terraces (Figs. 17-19).

The elevations of the valley trains vary from a hundred meters in the distal portions to 110 m in the proximal portions or 120 m in the Kuusoja valley. The dry meltwater channels of the proximal parts, together with the base level of erosion in the distal parts indicate, that at the end of the deposition of the valley trains, the surface of the water was 100-105 m above sea level. That again indicates that the valley trains were deposited in the Yoldia Sea or slightly above it and at the same time as Jaamankangas.

The Kuusoja valley is some eight km long and 2-4 km broad, being a NNW-trending fracture valley. On the west side, the rocky ridges are intersected by the couple of kilometers broad Salmilammenoja valley, the level of the bottom of which is roughly the same as that of the main valley, or the 105-120 m.

The valley is filled with glaciofluvial deposits. On their surface are meltwater channels, which become shallower in the down-valley direction. They continue clearly defined below the 110 m level. At the mouth of the Salmilammenoja valley is a marginal plateau that has risen to the 115 m level. On top of the plateau rests an end moraine.

Kujansuu & Nenonen (1987) have studied the stratigraphy of the moraine in, for instance, the vicinity of Kuusoja. They found that on the proximal side of the ice-marginal formation there are two moraines, of which the younger deposited by the ice flowing approximately from the west. (Rainio 1990)

Fig. 17. The Pielisjärvi end moraine, Kuusoja valley train, Eno and Kontiolahti. Meltwater channels and late-glacial and post-glacial erosional terraces are clearly shown by the contours. Kuokkasenkangas exhibits channels on at least two levels, now left hanging because the late-glacial erosion plane moved down due to uplift. The deep channel between Kuokkasenkangas and Palokangas was carved during late-glacial time. The contours show a marginal ridge on Palokangas terrace.

KUUSOJA, ENO

Fig. 18. The Pielisjärvi ice-marginal formation at Kuusoja, Eno. The palaeogeographic situation at the final stage of glaciation. The last direction of the continental ice sheet flow was almost from the west. The Yoldia Sea or the glacial lake at a slightly higher elevation filled the valley up to the level of about 105 m. In the upper part of the valley the glaciofluvial deposits grew until they were above the water level.

Site 11

The Pielisjärvi end moraine; Havukka ice marginal formation and ice-lake, Eno

The margin of the continental ice sheet ran in this region across supra-aquatic hills and the NW-SE fracture in the bedrock between Lakes Koitere and Pielinen. The highest point in this fracture is at an elevation of 168 meters less than five kilometers on the distal side of the Pielisjärvi end moraine quite near by the Uimaharju--Kivilahti road. A fragmented esker occurs at the fracture. (Figs. 20-21).

At the marginal formation, the esker expands into a marginal terrace or delta, the surface of which lies at an elevation of 168-170 meters, that is, at the same level as the watershed threshold of the fracture. The breadth of the delta is 200-400 meters in the longitudinal direction of the valley and 700 meters in the transverse direction.

The till ridge of the ice-marginal formation running across the hills is broken at the point of the esker, but it continues after a short distance in the proximal part of delta, rising to a height of some ten meters.

At the time of genesis of the Pielisjärvi end moraine there was an Ice Lake in the fracture, the surface of which was at an elevation of about 170 meters in relation to the present sea level. The Lake was about five kilometers long and 0.2-2 km broad. The ice lake was some 65 meters higher than the level of the Yoldia Sea, which extended to the valley of Pielisjoki, 12 km away. The lake discharged its waters over the proximal side of the hills right after the ice sheet receded from the Pielisjärvi end moraine. (Rainio 1990)

Fig. 19. The Pielisjärvi end moraine, Kuusoja valley train, Eno and Kontiolahti. Meltwater channels on the valley train. Some of the big erosional channels are late-glacial, probably caused by the outburst of the glacial lake. Some are postglacial, produced by riverine erosion.

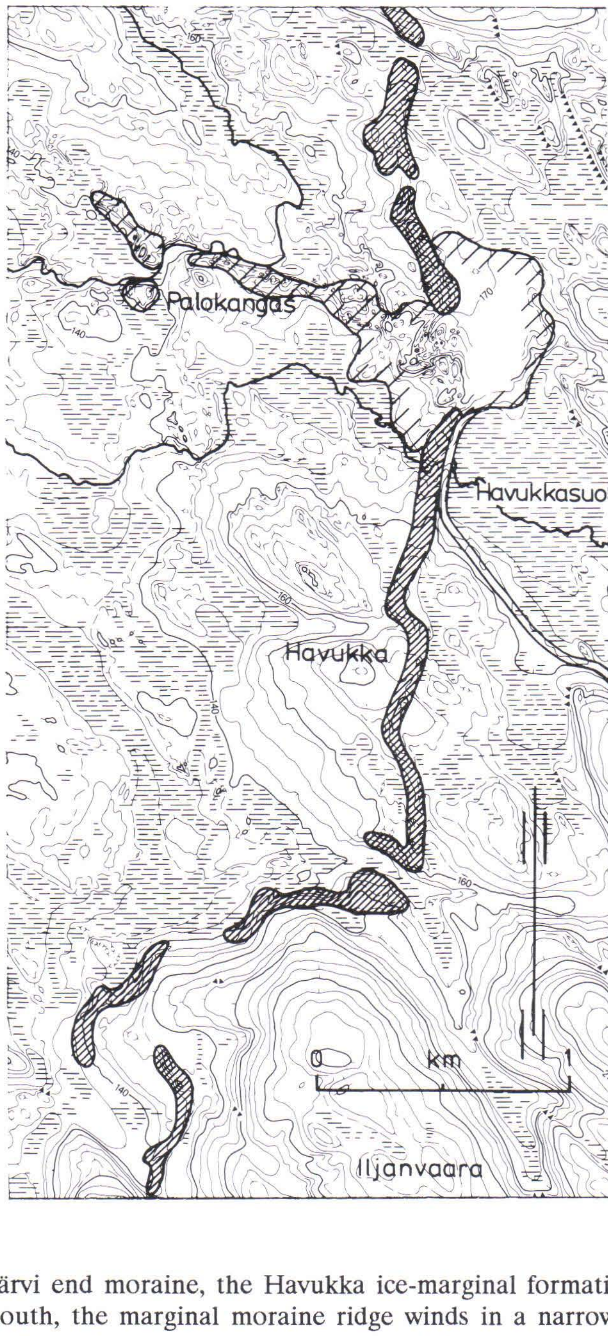

Fig. 20. The Pielisjärvi end moraine, the Havukka ice-marginal formation and glacial lake, Eno. Coming from the south, the marginal moraine ridge winds in a narrow belt along the proximal slopes of fells. Havukka mire now occupies what used to be the glacial lake. At this site the marginal formation widens into a combined marginal terrace/glaciofluvial delta. The moraine ridges in the proximal part of the terrace are over ten metres high in places. The feeding esker runs from the marginal formation towards Palokangas. Dense diagonal shading = moraine ridges and hummocks; less dense diagonal shading = glaciofluvial deposits.

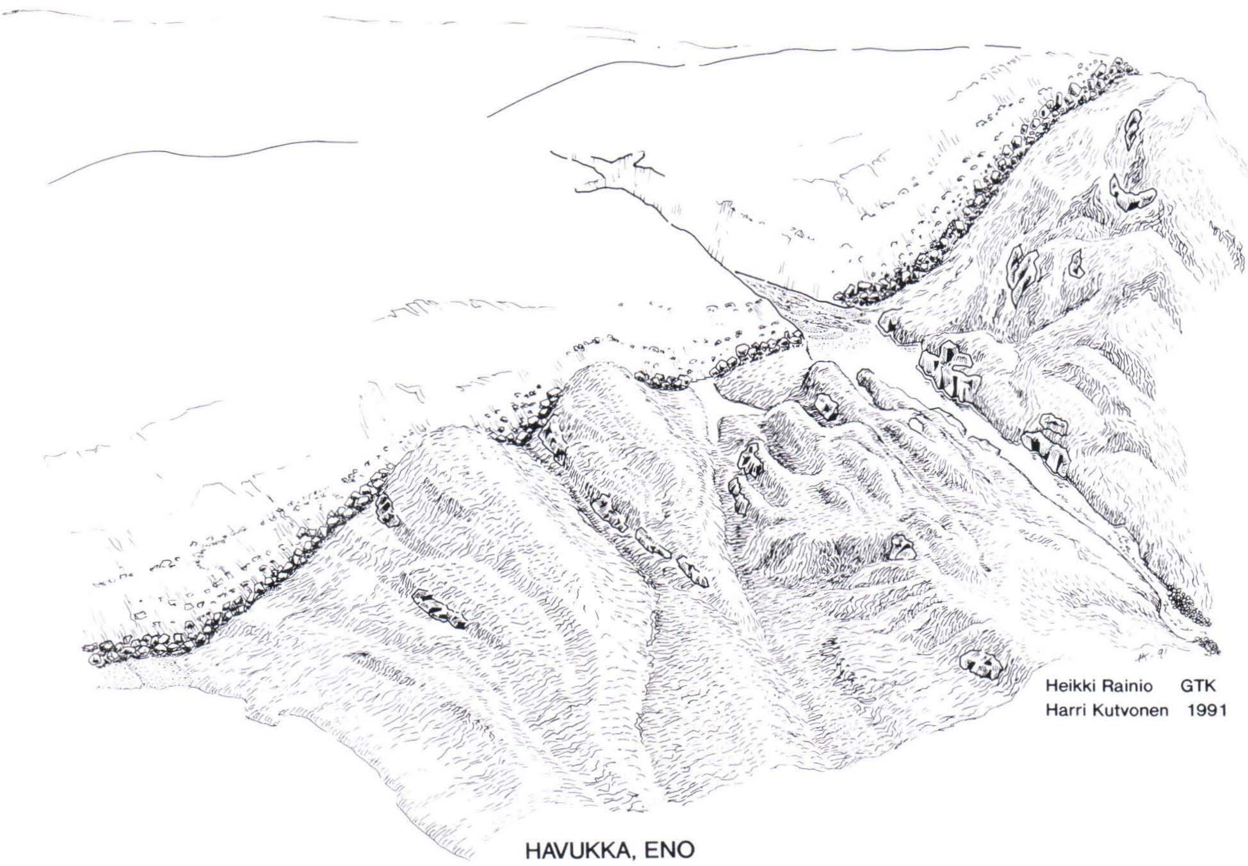

Fig. 21. The Havukka Ice Lake during the genesis of the Pielisjärvi end moraine. Yoldia Sea to the left reached the Pielisjoki valley.

Site 12 The Koitere end moraine; Selkäkangas, Ilomantsi

The name Selkäkangas was introduced by Frosterus & Wilkman (1915). By it they meant the chain of ice-marginal formations that begins at Lylykoski, in the area of Koitajoki, and terminates about 30 km north of Valkeasuo mire, where it almost disappears.

From north of Lylykoski the formation continues as an almost kilometre-wide structure comprising as many as five parallel ridges. After a couple of kilometres it begins to grade into glaciofluvial deposits, widening at the same time. At the village of Huhus, its course turns from NNE almost directly east. After a bend, the marginal plateau expands into the formation, 5-6 km wide, called Palokangas. At the bend, there had been a zone of weakness, a crevasse, in the ice sheet, as shown by the multibranched glaciofluvial ridges associated with the ice-marginal formation.

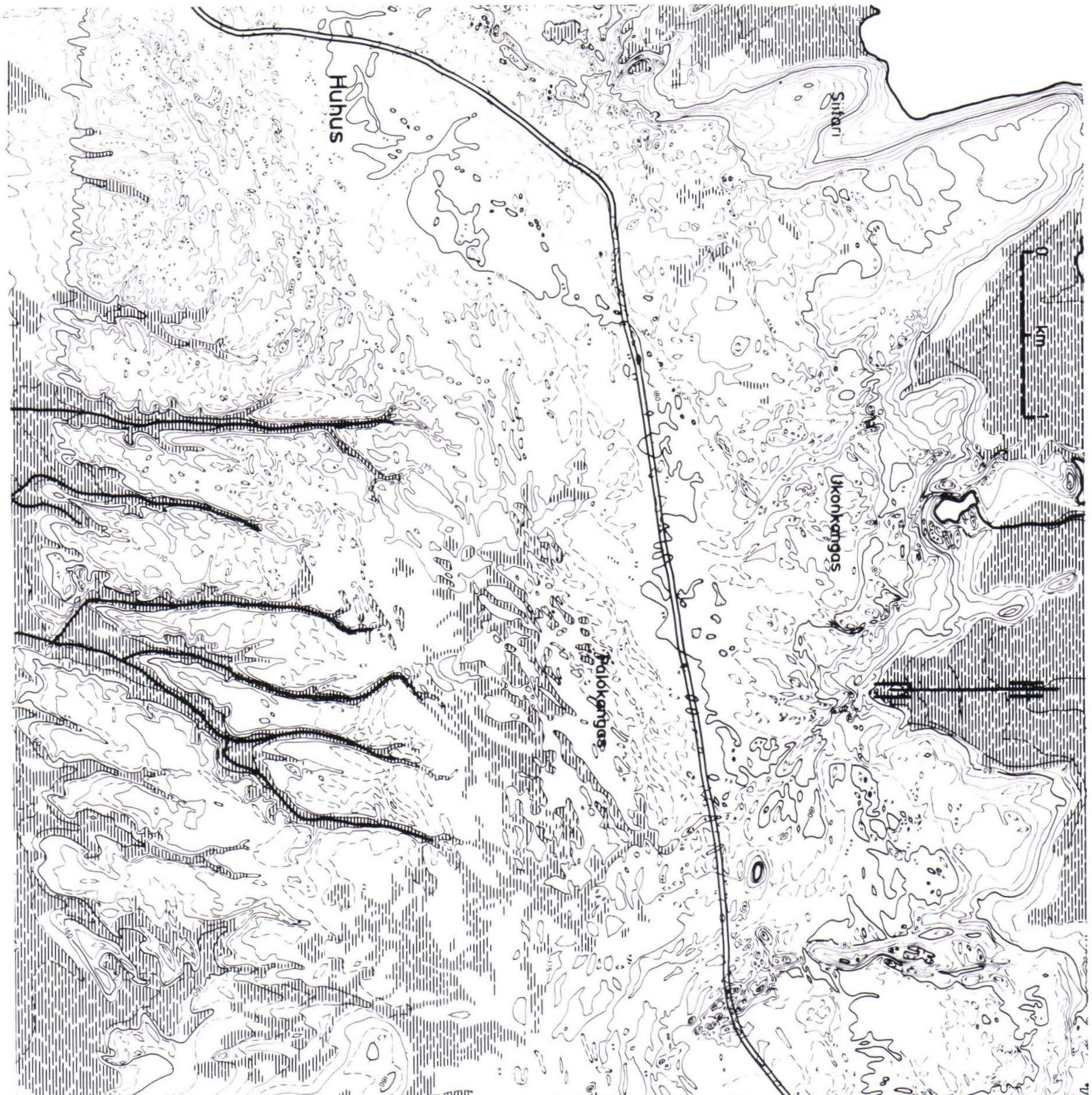

Fig. 22. Part of Selkäkangas. Here it exhibits the distinct structure of a marginal terrace. A 2-km-long sounding profile measured southwards from Ukonkangas shows that the glaciofluvial deposits are 60-80 m thick. The row of kettle holes from the centre of the figure to the right marks the place where the large Ilomantsi esker crosses the ice-marginal formation. Postglacial spring erosion has carved deep ravines in the fine-grained distal sediments.

The proximal portion of Palokangas is covered with a thin till mantle, which in places extends for more than a kilometre from the proximal margin. Data collected from wells demonstrate that till beds also occur at greater depths between glaciofluvial layers. The distal margin of Palokangas is at 165-170 m a.s.l.

The glaciofluvial plateaus of Selkäkangas, which are at considerably higher elevations than the plateaus of formations deposited in the Baltic Ice Lake in the Joensuu region, led Sauramo (1958) to conclude that they represent a marine stage much older than the Baltic Ice Lake. Hyvärinen (1971) suggested that at the time the margin of the continental ice sheet was at Selkäkangas, the wide Ilomantsi Ice Lake (Fig. 22) was located in front of it. This concept is now widely accepted .

Site 13

The Koitere end moraine; Hattujärvi ice-marginal formation, Ilomantsi

On the eastern side of Selkäkangas, the Koitere ice-marginal formation runs a couple of kilometers wide. On the south side of Hattujärvi, it turns sharply north-northeastwards. The width of the main ridge is a couple of hundred meters. On top in the distal portion, there occurs a distinct separate moraine ridge 5-10 meters high. On the eastern side of Hattujärvi, the ridge breaks at the point where the esker from the direction of Hattujärvi joins, and there a small outwash plain occurs as part of the ice-marginal formation. At that point, the channels run down to the 177-meter level and disappear in a mire.

In back of the main ridge of the Hattujärvi marginal formation there occur till ridges and hummocks in a zone a couple of kilometers broad. The ridges are both longitudinal and transverse. They indicate that the margin of the ice sheet had been very fragmentary at its final stage, when till moved into fissures, either by flowing or under pressure. Pits dug for testing purposes indicate that the material of the main ridge itself is till. (Rainio 1990)(Figs. 23, 24)

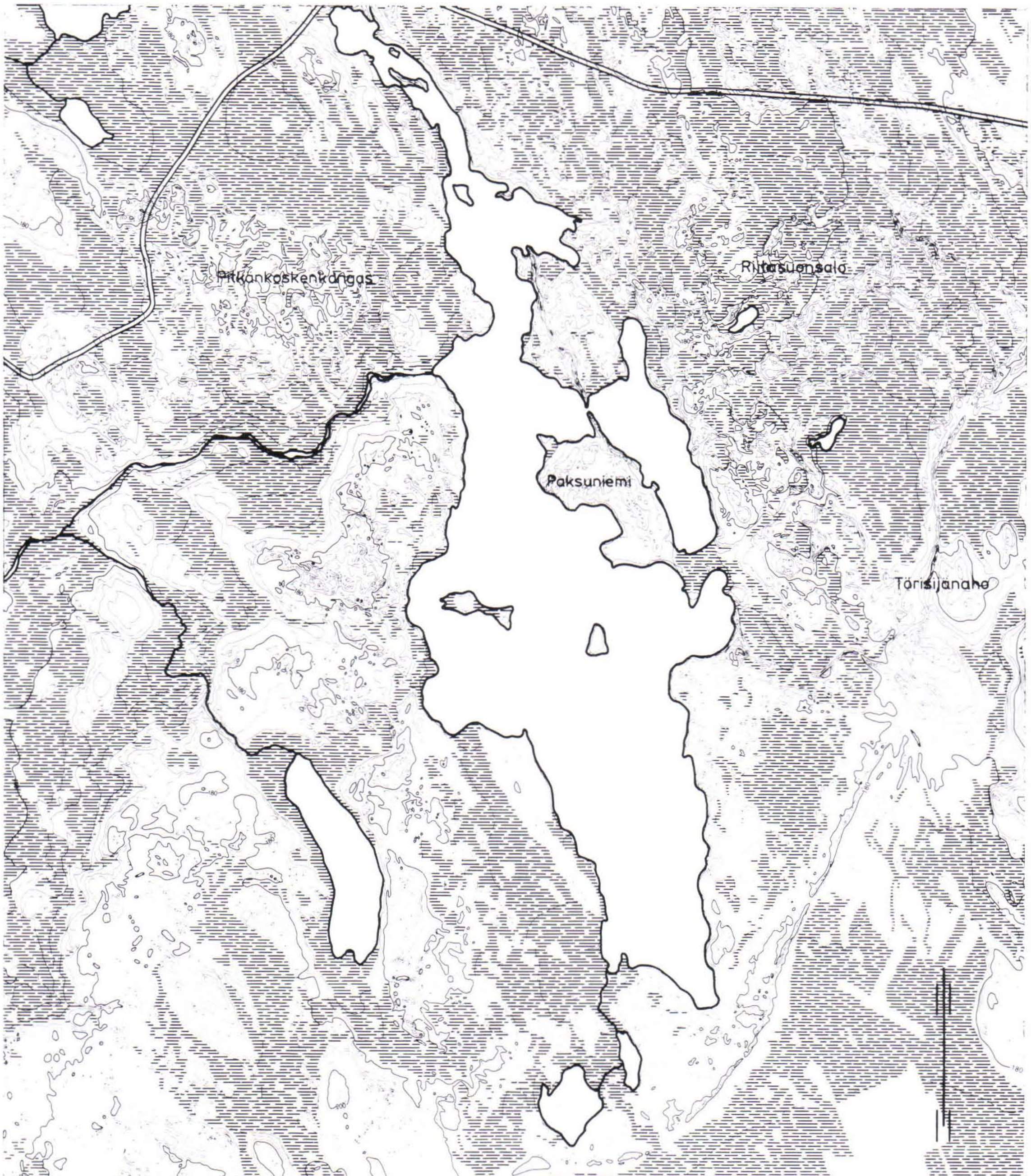

Fig. 23. The Koitere end moraine, Hattujärvi ice-marginal formation, Ilomantsi. The Koitere marginal formation, which trends almost east-west, turns to NNE here and, slightly to the northeast of the area shown in the picture, back east again. A kilometre south of Törisevänaho there is a break in the marginal moraine at the esker coming from Paksuniemi. The network of channels in the outwash field is clearly shown by the contours. The irregular contours in the proximal part are due to moraine hummocks and ridges in which the till layer may be as much as 10-20 m thick.

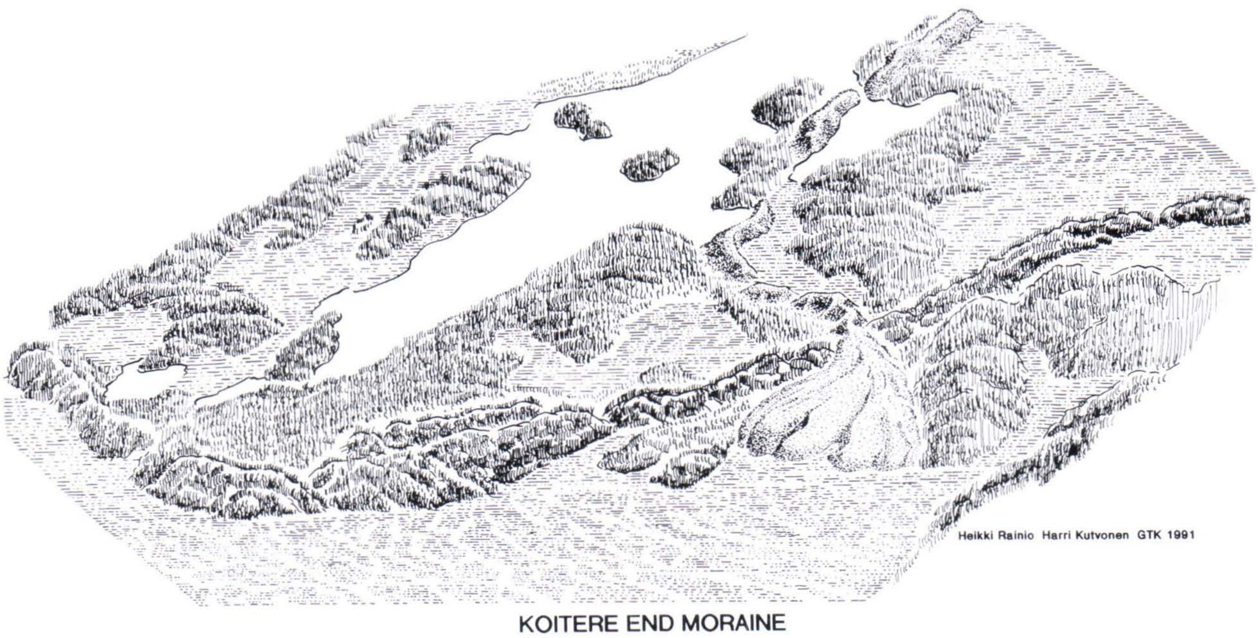

Fig. 24. The Hattujärvi end moraine. Ramsay followed the Koitere end moraine up to this place in 1890. "Der Lauf der grossen Randmoränen, welche die spätere Ausbreitung der Landeisdecke im Nordeuropa bezeichnen, ist somit in Norwegen, Schweden und Finnland verfolgt worden. ... Ein weiteres Aufsuchen der mit Salpauselkä zusammenhängenden Randmoränen in Russland wäre von sehr grossem Intresse,..." (Ramsay, 1891, s. 8).

Site 14

The Koitere end moraine, Koivusuo-Kaitasärkkä end moraine, Ilomantsi. For its last ten kilometres in Finnish territory the ice-marginal formation runs as a narrow ridge, 5-10 m high. In places it forks into two parallel ridges. In the background there is a zone, 1-2 km wide, composed of a network of ridges, hummocks and kettle holes. The material is mainly till.

On the Soviet border there is a marginal terrace whose plateau is at 181 m a.s.l. It was probably deposited in a glacial lake a few metres higher than the Ilomantsi Ice Lake.(cf. Vesajoki et al., 1986)(Fig. 25)

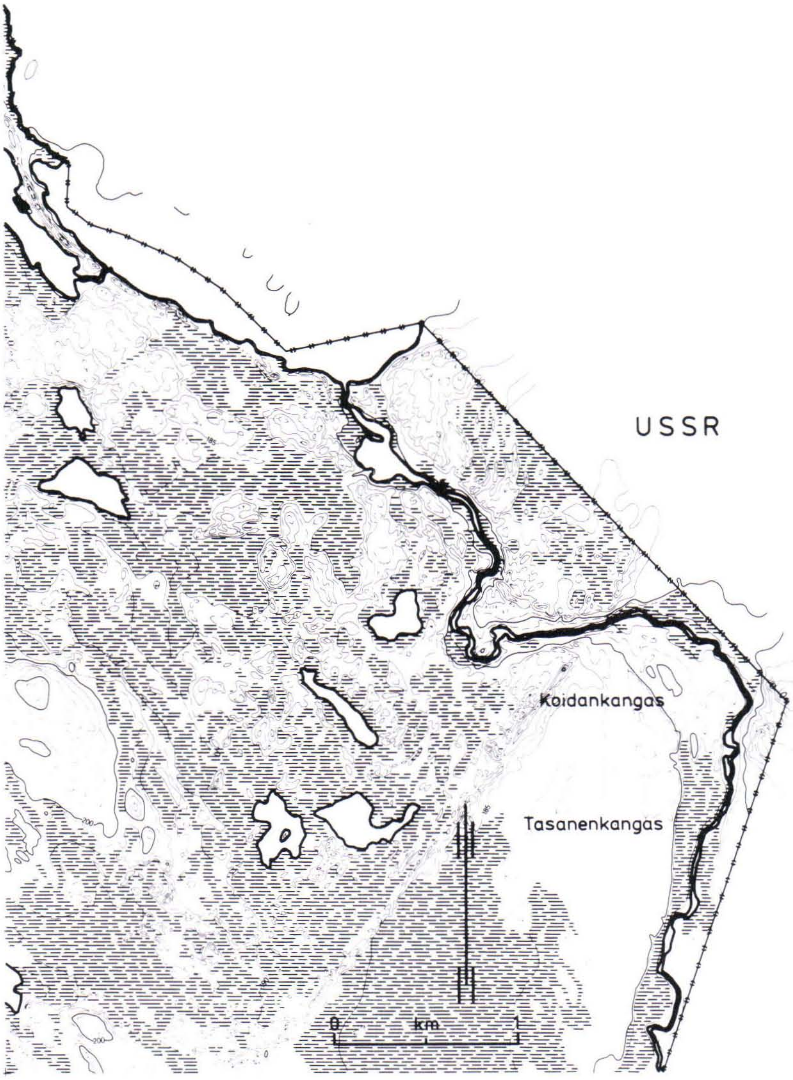

Fig. 25. The Koitere end moraine, Koivusuo-Kaitasärkkä, Ilomantsi. A supra-aquatic marginal moraine and the shore terrace of a glacial lake. On the other side of the border the end moraine assume the name of Rukajärvi end moraine (Ekman & Iljin, this volume).

Site 15

The Pielisjärvi end moraine, Lusikka-aho end moraine, Lieksa. The ice-marginal ridge is supra-aquatic, 5-15 m high and forks in places into two parallel ridges. In the background there are ridges and hummocks in a zone half a kilometre wide, belonging to the same structure. As elsewhere in the Pielisjärvi ice-marginal formation, the back complex is not as wide or distinct as that in the Koitere ice-marginal formation. (Fig. 26)

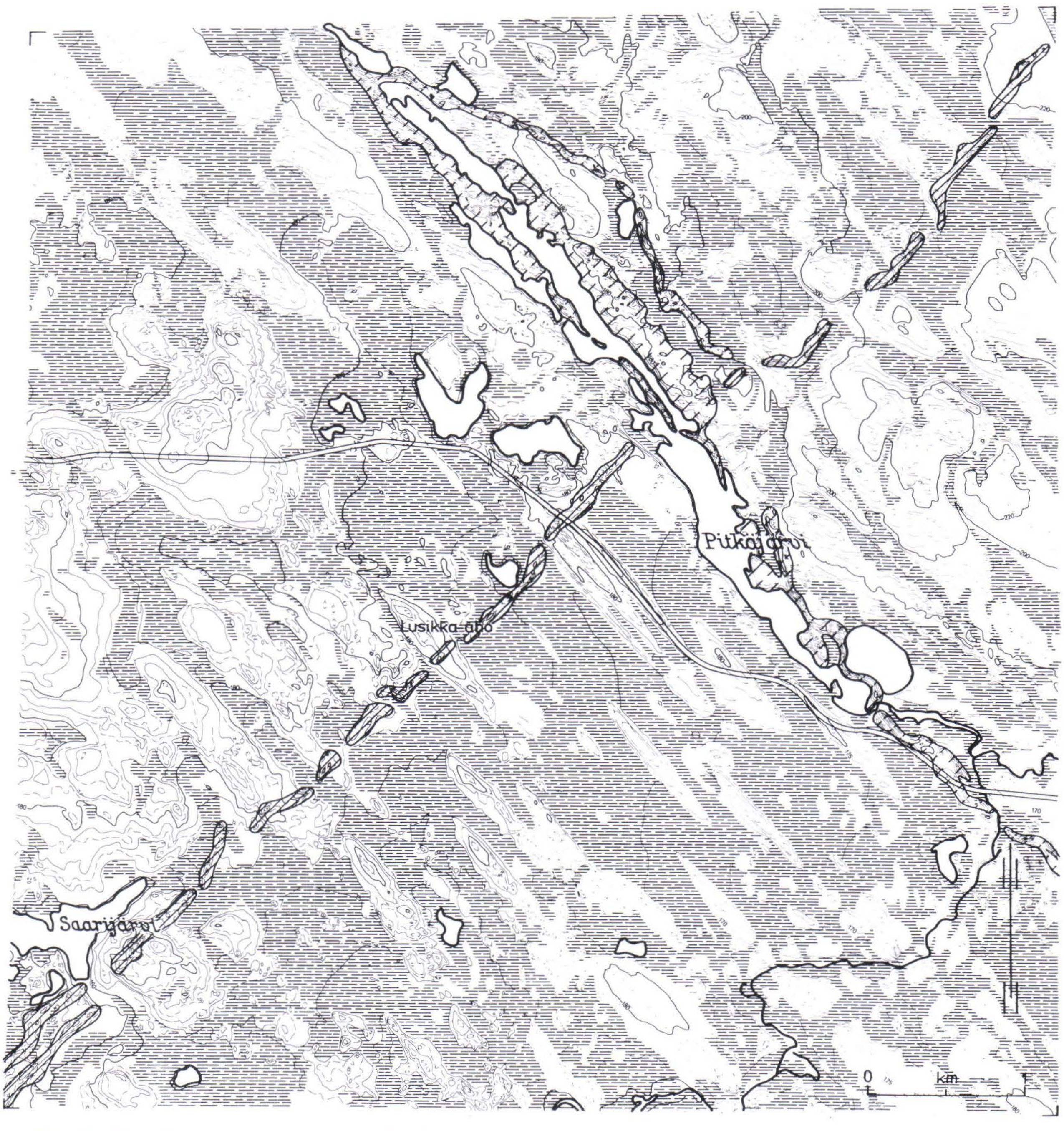

Fig. 26. The Pielisjärvi end moraine, Lusikka-aho, Lieksa. A supra-aquatic marginal moraine. Dense diagonal shading = moraine ridges and hummocks; less dense diagonal shading = glaciofluvial deposits.

References

Andersen, B.E., 1960. Sørlandet i sen- og postglacial tid. Norges Geol. Unders. 210, 1-142.

Arppe, A.E., 1867. Minnestal öfver Nils Gustaf Nordenskiöld. Acta soc. sci. fenn. 8. 35 pp.

Boehtlingk, W., 1839. Ein Blick auf die Diluvial and Alluvial Gebilde im südlichen Finnland. Bull. sci. l'Acad. Imp. des sci. de St.-Petersb. V:18-19, 273-294.

Brenner, T., 1944. Finlands åsars vittnesbörd om ytgestaltningen hos landisen. Fennia 68, 4, 1-39.

Donner, J.J., 1978. The dating of the levels of the Baltic Ice Lake and the Salpausselkä moraines in South Finland. Soc. Scient. Fennica, Comment. Phys.-Math. 48, 11-38.

Eronen, M. & Vesajoki, H., 1988. Deglaciation pattern indicated by the ice-margin formations in Northern Karelia, eastern Finland. Boreas 17, 317-327.

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

Frosterus, B. & Wilkman, W.W., 1915. Geologisk öfversiktskarta öfver Finland. Sektionen D 3 Joensuu. Beskrifning till jordartskartan. Resumé en francais. Geologiska kommissionen. 1-161.

De Geer, G., 1884-1885. Om den skandinaviska landisens andra utbredning. Geologiska Föreningens i Stockholm Förhandlingar, 7, 436-466.

Hirvas, H., 1980. Moreenistratigrafiasta ja sen merkityksestä malminetsinnässä. Geologi 32, 3, 33-37.

Hirvas, H. & Nenonen, K., 1987. The till stratigraphy in Finland. Geological Survey of Finland, Special Paper 3, 49-64.

Hyvärinen, H., 1966a. Studies on the late-Quaternary history of Pielis-Karelia, eastern Finland. Societas Scientiarum Fennica, Commentationes Biologicae 29, 4, 72 pp.

Hyvärinen, H., 1966b. A shoreline diagram for the easternmost section of the Salpausselkä. Societas Scientiarum Fennica, Commentationes Physico-Mathematicae 33, 4, 7 pp.

Hyvärinen, H., 1971a. Two Late Weichselian stratigraphical sites from the eastern foreland of the Salpausselkäs in Finland. Societas Scientiarum Fennica, Commentationes Biologicae 40, 1-12.

Hyvärinen, H., 1971b. Ilomantsi Ice Lake: a contribution to the Late Weichselian history of eastern Finland. Societas Scientiarum Fennica, Commentationes Biologicae 41, 171-178.

Hyvärinen, H., 1972. Flandrian regional pollen assemblage zones in eastern Finland. Societas Scientiarum Fennica, Commentationes Biologicae 59, 25 pp.

Hyvärinen, H., 1973. The deglaciation history of eastern Fennoscandia - recent data from Finland. Boreas 2, 85-102.

Hyvärinen, H., 1975. Myöhäisjääkauden Fennoskandia - käsityksiä ennen ja nyt. Summary: Lateglacial palaeogeography of Fennoscandia. Terra 87, 3, 155-166.

Hyyppä, E., 1936. Über die spätquartäre Entwicklung Nord-Finnlands mit Ergänzungen zur Kenntnis des spätglazialen Klimas. Bull. Comm. géol. Finlande 115, 401-465.

Jernström, A., 1876. Om Qvartärbildningarna längs Åbo - Tavastehus - Tammerfors jernvägslinie. Bidr. till känn. af Finlands natur och folk 20.

Kilpi, S., 1937. Das Sotkamo-Gebiet in spätglazialer Zeit. Bull. Comm. géol. Finlande 117, 1-118.

Kujansuu, R. & Nenonen, K., 1987. Till stratigraphy and iceflow directions in North Karelia. Geological Survey of Finland, Special Paper 1, 59-65.

Kurimo, H., 1982. Ice-lobe formation and function during the deglaciation in Finland and adjacent Soviet Karelia. Boreas 11, 59-78.

Leiviskä, I., 1920. Der Salpausselkä. Fennia 41, 3, 1-388.

Lukashov, A., Iljin, V. & Ekman, I., 1981. Marginal glacial formations of the Salpausselkä stage in Soviet Karelia. Glacial deposits and glacial history in eastern Fennoscandia, Academy of Sciences of the USSR, 128-139. Apatity.

Lundqvist, J., 1990. The Younger Dryas event in Scandinavia. IGCP PROJECT 253. Termination of the Pleistocene. Field conference Norway-Sweden-Finland, May 9-16, 1990. Geological Survey of Finland. Guide 31. (Editors: J. Lundqvist and Matti Saarnisto), pp. 5-24. Geological Survey of Finland. Espoo 1990.

Lyytikäinen, A., 1982. Pohjois-Karjalan harjumaiseman kehitys, käyttö ja suojelu. Summary: The development, use and conservation of the esker landscape in North Karelia, eastern Finland. The Nation-Wide Esker Investigation, Rep. 14. Joensuu. 149 p.

Lyytikäinen, A. & Kontturi, O., 1980. Pohjois-Karjalan harjuluonto. Summary: Esker Landscape of North Karelia, Eastern Finland. The Nation-Wide Esker Investigation, Rep. 13. Joensuu. 112 p.

Okko, M., 1962. On the development of the Firs Salpausselkä, west of Lahti. Bull. comm. géol. Finlande 202, 1-162.

Punkari, M., 1980. The ice lobes of the Scandinavian ice sheet during the deglaciation in Finland. Boreas 9, 307-310.

Punkari, M., 1982. Glacial geomorphology and dynamics in the eastern parts of the Baltic Shield interpreted using Landsat imagery. The Photogrammetric Journal of Finland 9, 77-93.

Punkari, M., 1984. The relations between glacial dynamics and tills in the eastern part of the Baltic Shield. Striae 20, 49-54.

Punkari, M., 1985. Glacial geomorphology and dynamics in Soviet Karelia interpreted by means of satellite imagery. Fennia 163, 113-153.

Rainio, H., 1972. Ennakkotiedonanto Pohjois-Karjalan itäosan reunamuodostumista. Geologi 24, 50-51.

Rainio, H., 1978. Exkursionslokaliteterna i Nordkarelen, 1-24. In: Norqua-exkursionen i södra och mellersta Finland 22-25.5. 1978. Guide. Geological Survey of Finland. Espoo. Unpublished report P 13.7.004.

Rainio, H., 1982a. Lössiä Etelä-Suomessa Toisen Salpausselän distaalipuolella. Summary: Loess in Southern Finland in the distal area of the Second Salpausselkä. Geologi 34, 7, 134-136.

Rainio, H., 1982b. Pohjois-Karjalassa ovat Suomen laajimmat pölyhietamaat eli lössit. Pohjois-Karjalan luonto 12, s. 32-34.

Rainio, H., 1983. The Tuupovaara end moraine in North Karelia, Eastern Finland - and ice-marginal formation of the same age as the Salpausselkä ridges. Bulletin of the Geological Society of Finland 55, 67-76.

Rainio, H., 1985a. Första Salpausselkä utgör randzonen för en landis som avancerat på nytt. Summary: The First Salpausselkä is a marginal formation of the outermost margin of a readvanced ice sheet. Geologi 37, 4-5, 70-77.

Rainio, H., 1985b. Pohjois-Karjalan Salpausselkien aikaiset reunamuodostumajaksot tarvitsevat nimet. Summary: Names needed for North Karelian marginal formations contemporaneous with the Salpausselkä ridges. Geologi 37, 3, 48-50.

Rainio, H., 1985c. Abraham Argillanders roll i den finländska naturforskningens historia. Nordenskiöld-samfundets tidskrift 45, 12-21.

Rainio, H., 1990. The ice-marginal formations of Southern Finland and associated zones. MID-NORDEN PROJECT, subproject Quaternary geology. Guide for the excursion to Central Finland 3-7.9.1990 (edited by Kalevi Mäkinen), p. 9-23, 29-41, 48-58. Geological Survey of Finland. Rovaniemi 1990.

Rainio, H., Kejonen, A., Kielosto, S., Lahermo, P., 1986. Avancerade inlandsisen på nytt också till Mellanfinska randformationen? Summary: Is the Central Finland ice-marginal formation terminal? Geologi 38, 4-5, 95-109.

Rainio, H. & Kukkonen, M., 1985. Before the Glaciofluvium. - In Glaciofluvium (L.-K. Köningsson, ed.). Striae, Vol. 22, p. 9-15. Uppsala.

Ramsay, W., 1891. Über den Salpausselkä im östlichen Finland. Fennia 4, 2, 1-8.

Ramsay, W., 1921. Salpausselkä såsom geografisk benämning. En historik och förslag till nomenklatur. Referat: Salpausselkä als geographische Benennung. Historik und Vorschlag einer Nomenklatur. Fennia 42, 9, 1-11.

Repo, R., 1957. Untersuchungen über die Bewegungen des Inland-eises in Nordkarelien. Geol. Surv. Finland, Bull. 179, 1-178.

Rosberg, J.E., 1892. Ytbildningar i ryska och finska Karelen med särskild hänsyn till de karelska randmoränerna. Fennia 7, 2, 122 p.

Rosberg, J.E., 1899. Ytbildningar i Karelen med särskild hänsyn till ändmoränerna. II. Fennia 14, 7, 71 p.

Saarnisto, M., 1970. The Late Weichselian and Flandrian history of the Saimaa lake complex. Soc. Sci. Fennica, Comm. Phys.-Math. 37, 107 p.

Sauramo, M., 1937. Das System der spätglazialen Strandlinien in südlichen Finnland. Soc. scient. Fennica. Comm. Phys.-Math. 9, 10, 1-23.

Sauramo, M., 1958. Die Geschichte der Ostsee. Ann. Acad. Sci. Fennicae. Ser. A III, 51, 1-522.

Sederholm, J.J., 1889. Om istidens bildningar i det inre af Finland. Auszug: Über die Bildungen der Eiszeit im inneren Finnland. Fennia 1, 7, 1-50.

Sederholm, J.J., 1899. Les dépots quaternaires. Atlas de Finlande 1899. Karte N:o 4. S. 1-28. Fennia 17. 1899 und Bull. comm. géol. Finl. 10.

Sederholm, J.J., 1911. Mouvement des glaces dans la Fennoskandia. Atlas de Finlande 1910. Nature, carte n:o 5, 6a. Fennoskandia IV, 62-71. Also Fennia 30, 1.

Solitander, C.P., 1875. Några geologiska iakttagelser vid en vandring längs Hyvinge - Hangö jernvägsanläggning. Bidr. till känn. af Finlands natur och folk 24.

Suomenmaa VIII, 1927. Maantieteellis-taloudellinen ja historiallinen tietokirja. Toim. J.E. Rosberg, K. Hildén ja K. Grotenfelt. WSOY. Porvoo. 436 p.

Thoreld, A.F., 1863. Bidrag till kännedomen om sandåsbildningen i Finland. Bidr. till kännedom af Finl. Nat. och Folk 8, 41-81.

Wallin, V., 1893. Suomen maantiet v. 1808 saakka. Valaistu kolmella kartalla. Auszug: Die Geschichte der finländischen Landstrassen während der Schwedenzeit (bis zum Jahre 1808). Mit drei Karten. Fennia 8, 1, 1-141.

Vesajoki, H., Eronen, M. & Zetterberg, P., 1986. Monivaiheinen Ilomantsin jääjärvi. Summary: The various phases of development of the Ilomantsi Ice Lake, eastern Finland. Geologi 38, 4-5, 111-115.

Wiik, F.J., 1871. Några iaktagelser beträffande södra Finlands qvartära formation. Acta societ. scient. fennicae 9, 1, 349-352.

Wiik, F.J., 1874. Om östra Finlands primitiva formationer. Bihang. Om östra Finlands posttertiära bildningar. S. 285-295. Bidrag till kännedom af Finlands natur och folk. 21. s. 231-295. I Profilentafel.

Wiik, F.J., 1875. Öfverblick af södra Finlands geologi. Geol. fören. i Stockholm förh. 2, 189-196 und 228-236.

Wiik, F.J., 1876. Öfversigt af Finlands geologiska förhållanden. Dissert. Helsingfors (Helsinki) S. 1-104.

Wiik, F.J., 1879. Geologiska iaktagelser under en resa i östra Finland, mellan Joensuu och Lahtis sommaren 1878. Bidrag till kännedom af Finlands natur och folk., 35, 1-20.

DEGLACIATION, THE YOUNGER DRYAS END MORAINES AND THEIR CORRELATION IN THE KARELIAN A.S.S.R AND ADJACENT AREAS

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Introduction

The Karelian Autonomous Soviet Socialist Republic, hereinafter referred to as Karelia, occupies the NW part of the East European Plain. Geographically, Karelia is located at latitudes 60°41' - 66°39' N and longitudes 29°40' - 37°55' E. It extends for 672 km from north to south and for 324 km from west to east and occupies an area of 173 300 square kilometres and borders Finland in the west. The climate is temperate continental, partly marine with a relatively long mild winter and a short cool summer. Average temperatures vary from +14° to +16°C in July and from -9° to -13°C in February.

Karelia is located in both the northern and mid - taiga subzones. The boundary between the subzones is marked by the line Lexozero - Medvezhyegorsk - Lake Vyg. Pine is the predominant tree in the north and spruce in the south. Birch, aspen, alder and other deciduous trees are less common. Forests occupy about 87 % of the surface area. Karelia has more than 60 000 lakes covering a total area of ca. 16 000 km^2. Mires and marshy land account for ca. 30 % of the territory.

Geomorphology

Old plains of subaerial denudation locally indicated by weathering crusts are widespread in Karelia. However, because of the intense erosion, these crusts are far less common in Karelia than on the Kola Peninsula or in Finland. Thrust movements resulted in the deformation of old plains of subaerial denudation and the altitude dependent differentiation of their segments. Tectonic movement gave rise to the major morphostructures which are the basis of Karelia's present topography. The old structural elements of the crystalline basement, rejuvenated by recent movement, were responsible for the distribution and orientation of both the positive and negative forms of the denudation-tectonic and structural-denudation topography and the fluviolacustrine network. The above morphostructures had a considerable effect on the distribution of various genetic types and the thickness of Quaternary deposits (Lukashov & Ekman, 1972).

Continental glaciations were another factor which substantially affected the present geomorphology of Karelia (Fig. 1). Young glacial morphosculpture, unaffected by erosion and related to the last (Late Valdai/Weichselian) glaciation, is widespread in Karelia (Fig. 2).

The main feature of Karelia's glacial morphosculpture is its radial-concentric structure, comprising two concentric belts of ice marginal glacial and glaciolacustrine and glaciomarine deposits[1)].

One is located in both southern and eastern Karelia and consists of two zones of marginal deposits, e.g. end moraine ridges, push-depositional units, frontal aprons and glaciofluvial deltas connected with ice-divide (interlobate) accumulative and bedrock highlands. This belt corresponds to the Sämozero-Karelian (Neva - Luga) stage of continental ice deglaciation.

The other belt of marginal glacial deposits, which consists mainly of moraine ridges and frontal glaciofluvial deltas, is located in both western and northern Karelia. The belt is divided into two marginal zones corresponding to the Rukajärvi and Kalevala (Kuittijärvi) stages (Salpausselkä I and II stages in Finland). The marginal zones indicate the stationary position of the front of the last continental ice sheet in the course of deglaciation.

The radial system of glacial morphostructure has two components: extensive glacial depressions, seen topographically as drumlinized morainic plains, and long linear ice-divide zones (Fig. 2). The latter consist of bedrock and accumulative interlobate

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[1)] A third belt of marginal deposits, known as the Krestets - Vepsian belt, has locally been traced in southern Karelia.

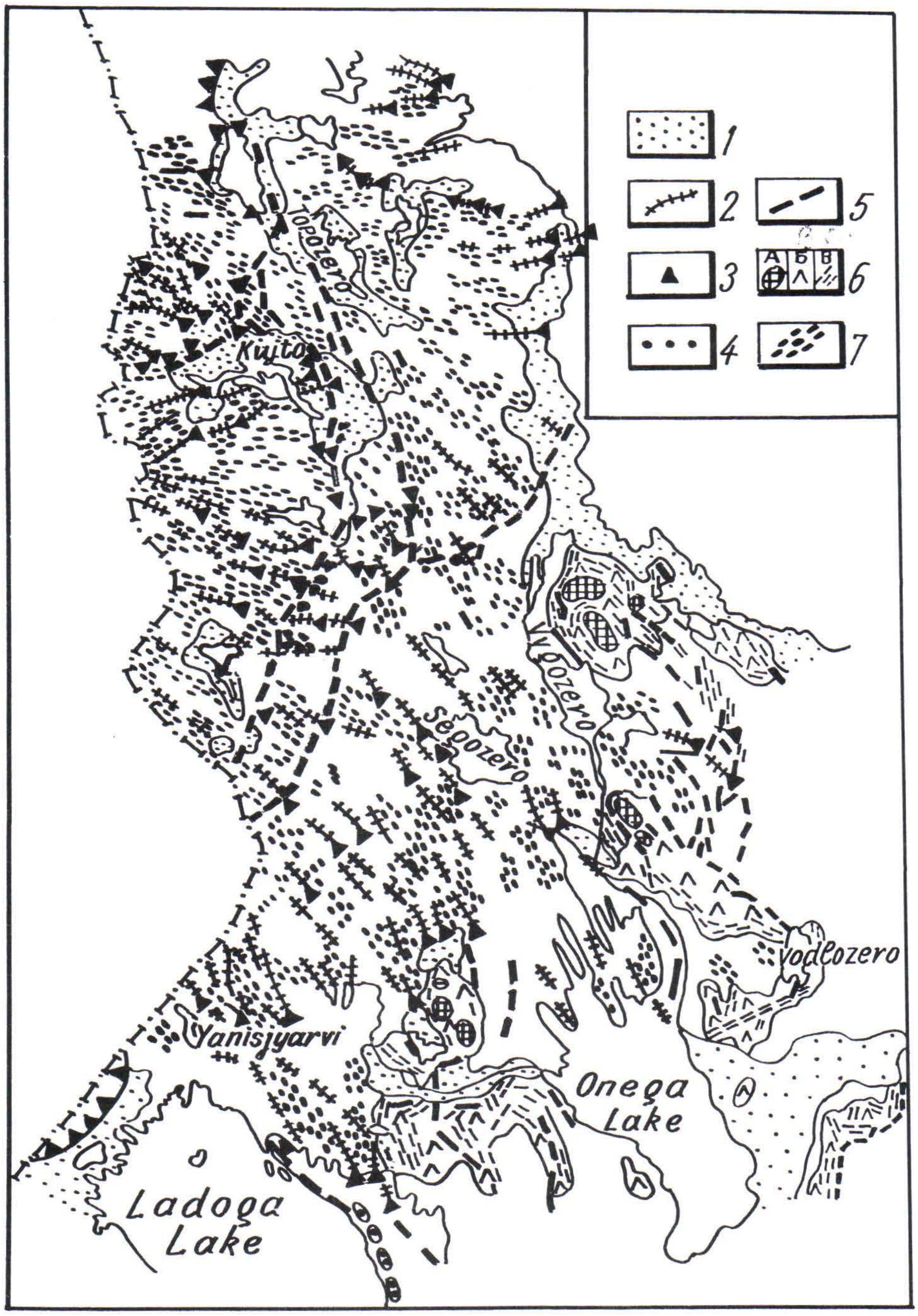

Fig. 1. Geomorphological scheme of Soviet Karelia. Glacial relief. After I. Ekman et al. (1981, Fig. 1):

(1) Glaciolacustrine and glacial - marine plains. (2) Eskers. (3) Marginal and esker deltas. (4) Outwash plains. (5) Ice-divide and frontal marginal ridges. (6) Glacial relief of big ice-divide elevations: (a) hilly moraine, (b) hilly-circular relief, (c) linear-ridge marginal relief. (7) Drumlins.

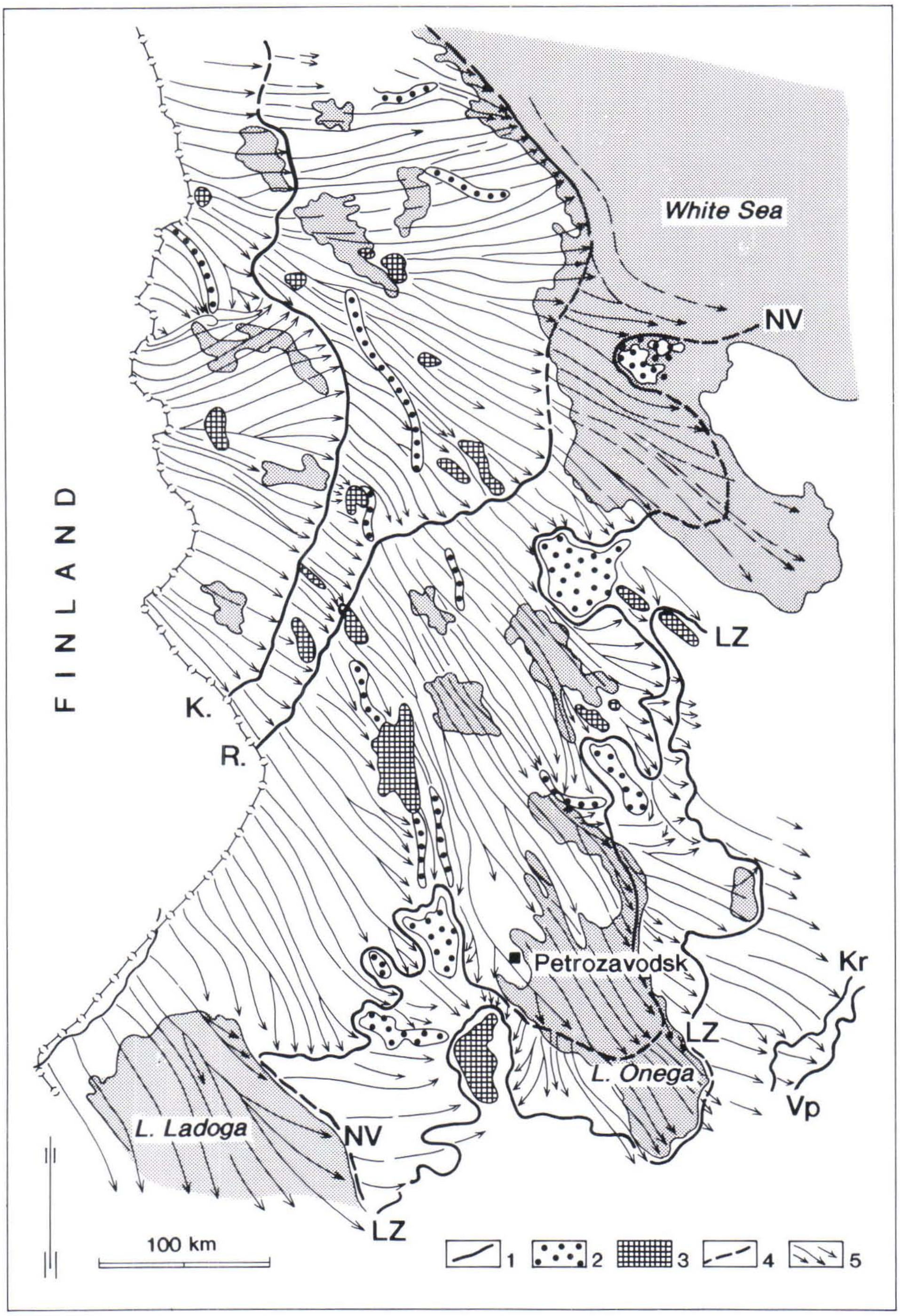

Fig. 2. Palaeoglacial scheme for the deglaciation of the last (Visla, Ostashkovo, Valdai) glaciation in Soviet Karelia. Glaciation stage 17.0-19.3 Ka B.P. After I. Ekman (1987, Fig. 20):
(1) Boundaries of the glaciation stages: Vp- Vepsian, Kr- Krestets, Lg- Luga (Karelian), Nv- Neva (Sämozero=Säämäjärvi), Rk- Rugozero (Rukajärvi)(= Ss I), Kl- Kalevala (= Ss II). (2) Ice movement directions. (3) Ice-divide accumulative elevations (a) and radial (closed) ridges or zones (b). (4) Ice-divide bedrock uplands and ridges and smaller elevations of the crystalline basement which affected the direction of ice movement. (5) First-order ice-divides (between Finland and Karelian ice flows): (a) proved sites, (b) inferred sites. (6) Second-, third- and lower-order ice-divides: (a) proved sites, (b) inferred sites. (7) Extensive open cracks separating vast dead ice fields. The cracks were predominantly filled with sorted sand-boulder material, till being less common.

highland and relatively narrow radial (median) systems. These systems are composed of depositional marginal ridges, esker-like forms and other types of glaciofluvial deposit. Glacial depressions and ice-divide zones reflect the tongue - lobate structure of the last ice sheet. The glacial depressions are confined to structure-dependent depressions in the crystalline basement, whereas the radial ice-divide zones are restricted to uplifted areas. Other important features in Karelia's topography are the accumulative and abrasive-accumulative marine, glaciolacustrine and lake plains confined to the basins of contemporary big lakes and the White Sea.

The glacial accumulation complexes of Karelia are characterized by a variety of glacial dislocations. They are studied in an efford to establish the conditions and mechanism of till sheet formation, to reveal the internal structure of continental ice sheets and to determine the direction of ice movement.

Palaeomagnetic and radiocarbon dating of marginal glacial zones

Karelia has a few zones of marginal deposits formed during the following deglaciation stages the last (Visla - Late Valdai - Ostashkovo) ice sheet: the Vepsian, Krestets, Luga - Karelian, Neva - Sämozero (Säämäjärvi), Rugozero (Rukajärvi) = Salpausselkä I, and Kalevala[2)] (Kuittijärvi) = Salpausselkä II stages. In southern Karelia, where the Baltic crystalline shield is adjacent to the Palaeozoic sedimentary rocks of the Russian Plain, there is a wide arcuate depression which includes the Onega and Ladoga lake basins and, to the west, the basin of the Gulf of Finland. Large glacial lakes such as Vodla, Onega and Ladoga - Baltic in which varved clay (VC) deposited, developed in this depression at the front of the retreating ice. The accumulation of VC covered the entire time between glacial retreat from the Vepsian - Krestets marginal belt (ca. 16 000 B.P.) and retreat from the Salpausselkä II

[2)] The name "Kalevala" proposed for this stadial zone is borrowed from the Karelian - Finnish epic "Kalevala". The folk runes of this literary masterpiece were collected by Elias Lönnrot (1802 - 1884), a Finnish folklorist and linguist. The runes were recited by Karelians who had lived for centuries in the Kuito lake area, and were then revised and combined by Lönnrot (first edition in 1835, second complete edition in 1849). The name "Kalevala" was coined for a country inhabited by Kalevalians. The same area is now called Kalevala (former name Uhtua). Karelia's largest fragment of Younger Dryas marginal deposits, which is geomorphologically the most complex, is located in the area. In our opinion, it could be a target of international studies and field trips.

marginal ridge (ca. 10 200 B.P.) when the level of the Baltic ice lake finally dropped. It has thus been established that deglaciation took about 6 000 years in southern Karelia (Ekman, et. al., 1987 a, b).

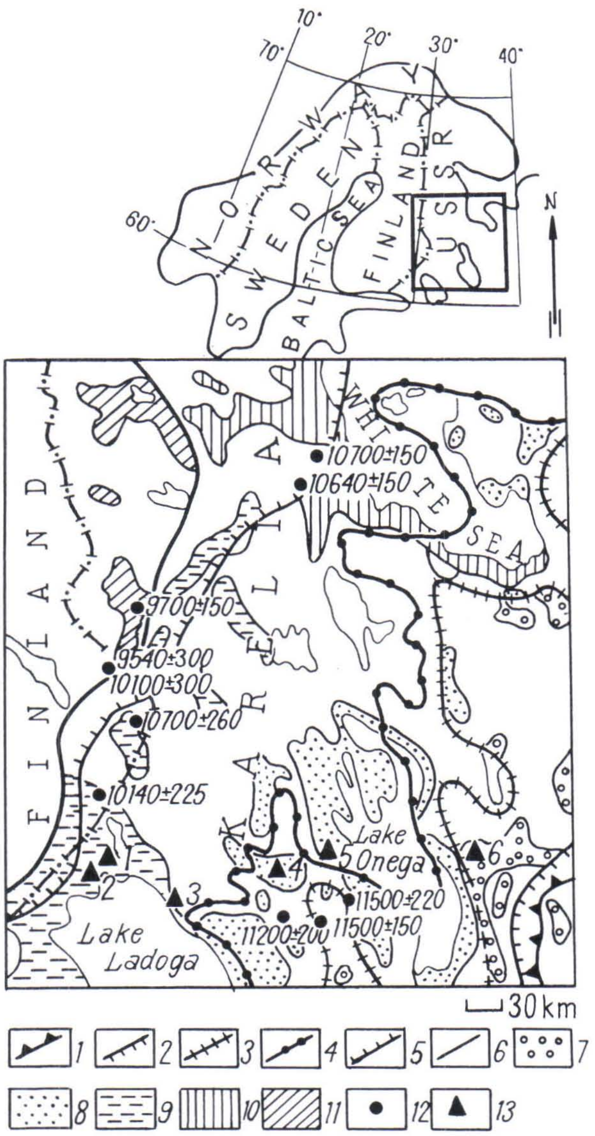

Fig. 3. Distribution of exposed varved clays relative to the deglaciation stage boundaries of the last (Late Valdai, Visla) glaciation in SE Fennoscandia. From I. Ekman et al. (1987 a, Fig. 1), V.G. Bakhmutov and G.F. Zagniy (1990, Fig. 1). (1-6) Boundaries of glaciation stages: (1) Vepsian. (2) Krestets. (3) Luga - Karelian. (4) Neva - Sämozero (Säämäjärvi). (5) Salpausselkä I = Rugozero (Rukajärvi). (6) Salpausselkä II= Kalevala. (7-10) Varved clays from ice-dammed lakes: (7) Krestets - Luga time. (8) Oldest Dryas - Oldest Alleröd. (9) Alleröd - Younger Dryas. (10) Preboreal time. (11) Clays from Portland Sea, a brackish-water basin (Alleröd-Preboreal time). (12) ^{14}C datings from the basal layers of lake bottom sediments with organic matter. (13) Sections at varved clays studied palaeomagnetically. Note: The ^{14}C datings published by H. Hyvärinen (1971, 1973, etc.) for SE Finland were used in mapping. 1. Sortavala. 2. Haapasalmi. 3. Uuksu. 4. Kindasovo. 5. Petrozavodsk. 6. Pudozh.

Oriented varved clay samples were taken for palaeomagnetic measurements from reference sections in deglaciation zones of different ages (Fig. 3). The sections were also investigated varve chronologically, and series of samples were taken for palynological studies.

Curves for changes in the components of secular variations in the Earth's magnetic field, declination (D°) and inclination (I°), were used to compile a composite magnetostratigraphic scheme for varved clays based on data on six reference sections. Local stratigraphic units were used in the scheme, which is tied to a time scale (Fig. 4). The time of glacial retreat from the Salpausselkä II marginal ridge (10 200 B.P.) is taken as an age datum point. The above scheme is partly based on varve chronological and palynological data. The results of ^{14}C dating of organic matter from the lower portion of bottom sediments sampled in lakes located in deglaciation zones differing in age have been taken into account (Fig. 3). For instance, datings of organic matter from sediments in small lakes of the Onega - Ladoga isthmus indicate that the end moraine ridges preceded the Alleröd Interstadial. More precise radiocarbon dates have been obtained for glacial retreat from the marginal zone during the Rukajärvi stage on the SW shore of the White Sea (Fig. 3). The dates of 10 640 ± 150 and 10 700 ± 150 years obteined for the basal layers of two small lakes lying in glacial depressions near the distal slopes of end moraine ridges are compatible with the time of glacial retreat from the Salpausselkä I marginal ridge, at ca. 10 800 B.P. in southern Finland. (Termination of the Pleistocene. Field conference, 1990, pp. 16 - 18). The lakes of the southeastern White Sea area are about 30 km apart. A pollen diagram of bottom sediments with radiocarbon data on Lake Alinlampi is given in Fig. 23 (Locality 14a. Shuezero = Suikujärvi). Dates obtained from bottom sediments sampled from the lakes of the Kalevala marginal zone enable us to correlate them, with a certain degree of probability, with the Salpausselkä II marginal ridge, southern Finland. However, Karelian geomorphological and stratigraphic data cannot be used to correlate this continuous and impressive marginal zone with the discontinuous moraine ridges known as Salpausselkä III, which are common only in SW Finland.

Nonetheless, some Finnish geologists think that such a correlation is possible. The Kalevala[3] frontal zone of marginal moraines extends northeastwards from the Jaamankangas delta north of Joensuu, Finland, via Uimaharju to Lake Suomunjärvi, where it crosses the frontier and continues in the Soviet territory to Lendery (Lentiera) station. Then it turns gradually northwards and continues for hundreds of kilometres through the western part of northern Karelia and the southwestern part of the Murmansk district. Marginal moraine ridges have been traced from the Karelian border via Alakurtti as far as the village of Yena and even slightly northwards. End moraine ridges gradually disappear as geomorphological units near the steep slopes of the mountains which form a major water divide on the Kola Peninsula.

The extensions of the marginal zones formed at both the Kalevala and Rukajärvi stages in SE Finland have been investigated, after a long break, by Finnish geologists including R. Repo (1957), H. Rainio (1972, 1978, 1983, 1985) and H. Hyvärinen (1971, 1973). H. Rainio proposed a new nomenclature. He called the segment of the first zone Koitere end moraine and correlated it in age with the Salpausselkä II marginal ridge. He gave the name Pielisjärvi to the extension of the second zone, which, according to him, postdates Salpausselkä II. Thus it can probably be correlated with the Salpausselkä III deposits in SW Finland mentioned earlier. All the above age estimates and correlations, which are largely based on geomorphological studies, are only tentative. It is therefore clear that Finnish geologists are not unanimous as to the pattern and sequence of ice margin deglaciation in the two big adjacent lobes. The above event, which gave rise to marginal moraines, is also responsible for the difficulty of correlating them. Comprehensive studies based on geomorphology, magnetostratigraphy and varves and, possibly, palynological analysis are needed the age problems are to be resolved. Studies in deglaciation zones of different ages should be directed at complete varved clay sequences (up to moraines) deposited in the Baltic Ice Lake and local lakes such as Ilomantsi Ice Lake (H. Hyvärinen, 1971). These studies would, at least, provide an opportunity for correlating the majority (or even all) of the marginal zones in SE Finland using a composite magnetostratigraphic scheme based on reference varved clay sections. This, in our opinion, is indispensable for successful implementation of the research

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[3] Finnish geographer J.R. Rosberg (1892, 1899) made a major contribution to the distinguishing the Karelian marginal zones. Until the 1960 - 1970s the results of his studies had been either forgotten or neglected.

programme seeking to correlate Younger Dryas marginal zones in Finland and Soviet Karelia outlined as part of IGCP Project 253.

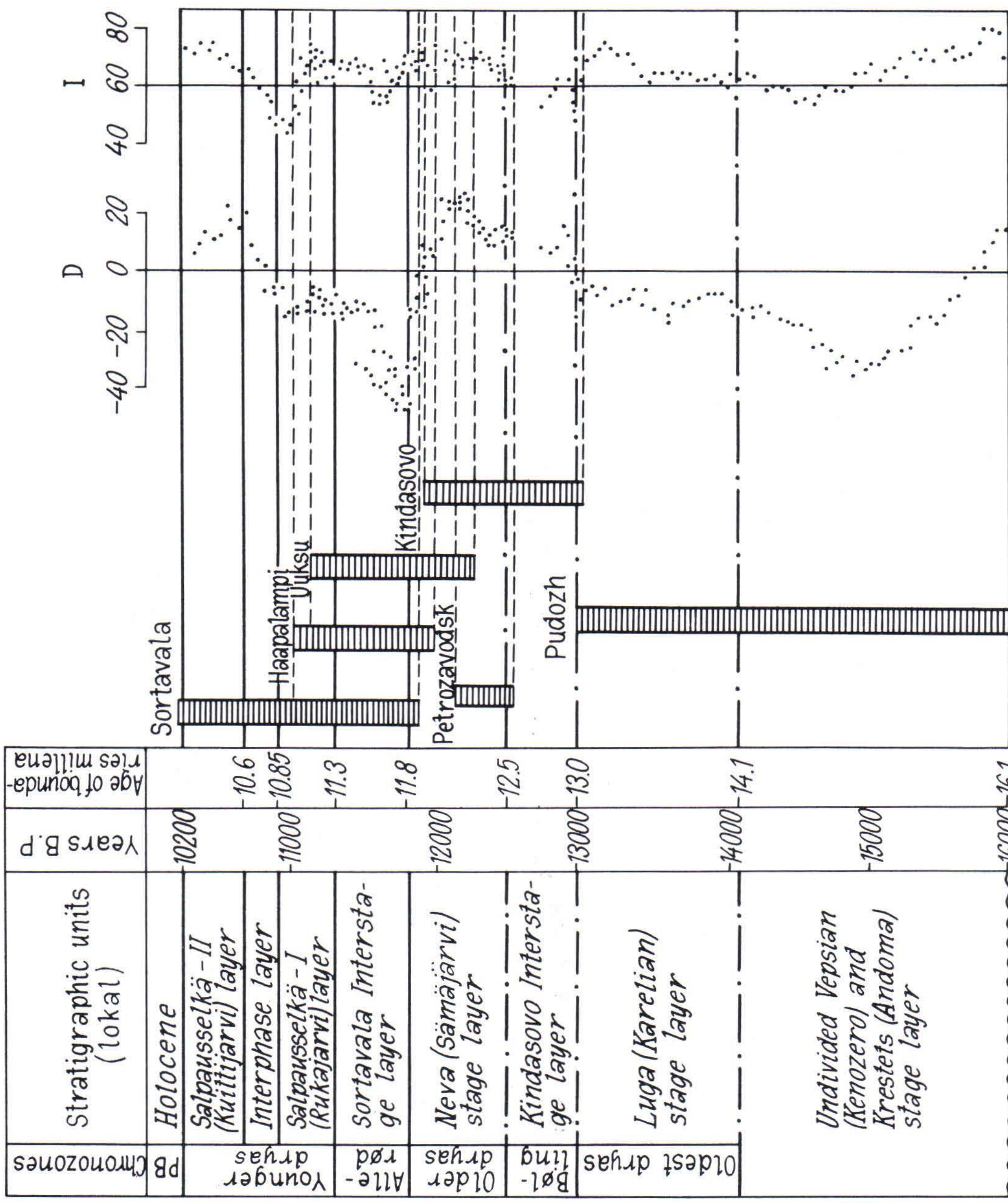

Fig. 4. Composite chrono- and magnetostratigraphic scheme for upper Valdai-Visla varved clays, Soviet Karelia. Angular components of secular variations in the Earth's magnetic field: (1) D° - declination, (2) I° - inclination.

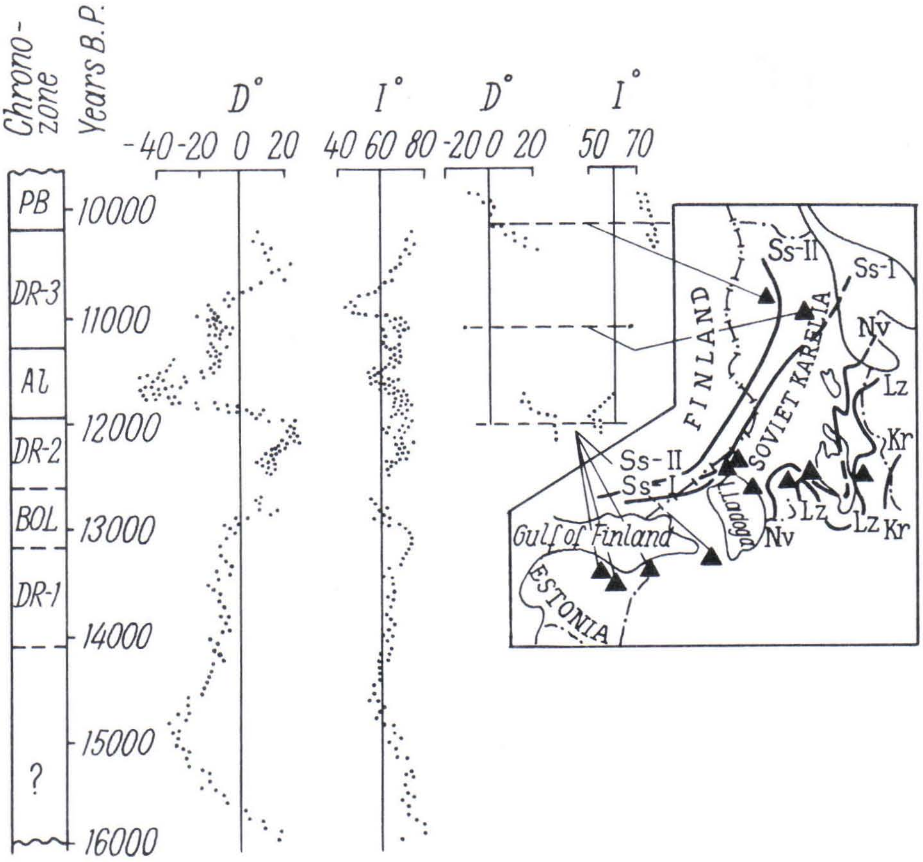

Fig. 5. Correlation of varved clays in Soviet Karelia, the Leningrad district and Estonia based on palaeomagnetic data. See explanations to symbols in Fig. 4.

The chrono- and magnetostratigraphic scheme for reference sections in southern Soviet Karelia (Fig. 4) could probably be adopted in Finland. Comparison of the above standard scheme with the results of palaeomagnetic studies conducted in northern Karelia, the Leningrad district and Estonia (Fig. 5) shows that the palaeomagnetic method is highly appropriate for both remote and close correlation of Late Pleistocene varved clays. Note that the distance between the extreme points of the study area was more than 700 km.

Both varve chronological and palaeomagnetic methods have been used in northern Karelia (Fig. 5) to study varved clays and silts in the Kalevala and Shomba (Sompa) areas, located both inside and outside the push-end ridges which formed at the Kalevala stage (= Salpausselkä II). The varved sediments on the right bank of the River Uhtua, near Kalevala, deposited in a glacial lake 10 300 - 9 800 B.P., i.e. in Younger Dryas - early Holocene (the first third of Preboreal) time. The curves for changes in the angular components of secular variations (SV) in the Earth's magnetic field, declination (D°) and inclination (I°), obtained for this sequence can well be correlated with those of the standard scheme (Figs. 4 and 5). Also, they add a Preboreal section to the scheme. There is no doubt as to the age of the Kalevala marginal strata, which can obviously be correlated with the Salpausselkä II marginal ridge.

The palaeomagnetic method has been used in the Shomba (Sompa) area to investigate a thin clay deposit with only 40 varves. In Fig. 5, the palaeomagnetic measurements made on this clay are shown as one averaged declination (D°) and inclination (I°). The clay varves can thus be dated at ca. 11 000 B.P. Unaffected by abrasion, this clay could well have been deposited at an earlier deglaciation stage associated with the retreat of the ice margin from the Rukajärvi stage marginal ridges.

Stratigraphic and chronological data indicate that the Rukajärvi and Kalevala marginal zones can be geological correlated with the Salpausselkä I and II frontal ridges, respectively. The age correlation scheme proposed by the Finnish geologist R. Repo (1957) is quite acceptable in this respect.

There are many reasons for the difficulty of correlating the above strata. First of all, they were formed by the action of two active ice lobes located in different radial sections and frontal slopes of the Scandinavian Ice Sheet. The lobes differed markedly in both activity and direction of movement. The suture zones between the lobes are indicated by ice-divide ridges composed predominantly of sorted sands and gravels, the lower portions being deformed. The thickest ridge, deposited during the Salpausselkä II - Kalevala stage, extends NW for about 300 km from the western end of the Jaamankangas via the Tuusniemi - Kuopio - Iisalmi areas. The Finnish Lake District lobe was more active during the Salpausselkä II stage. This lobe was characterized by a strongly divergent ice flow pattern which impeded ice movement, shifted the Karelian ice flow eastwards and truncated the frontal and closed ice-divide ridges formed at the Salpausselkä I stage.

The ice could not, of course, have retreated simultaneously in different lobes because the ice margin was mainly on land at both the Rukajärvi and Kalevala stages. The position of the ice margin is largely indicated by end moraine ridges

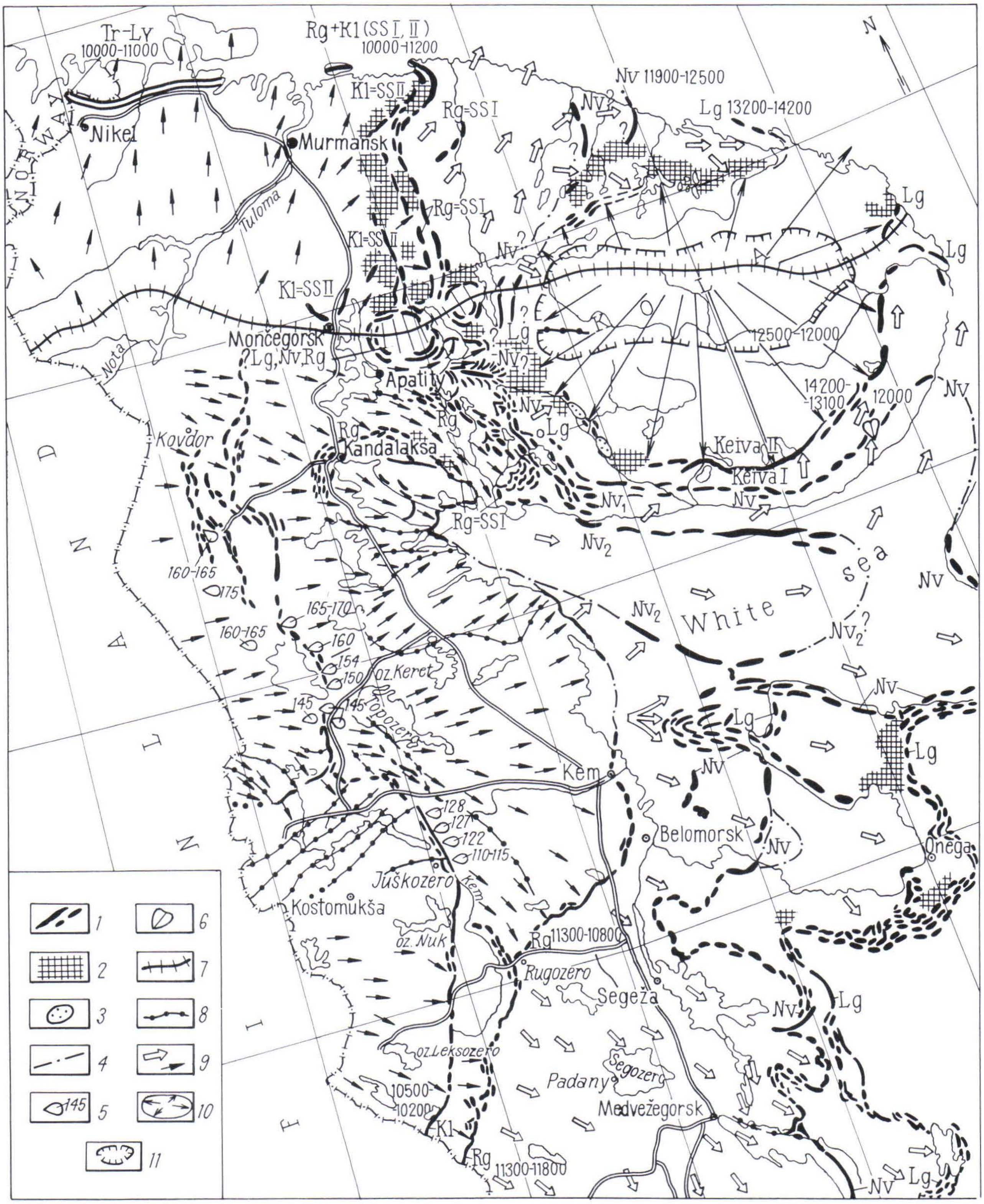

Fig. 6 A & B. Correlation scheme. Oldest to Younger Dryas end moraine ridge zones in Eastern Fennoscandia: Soviet Karelia, the Murmansk region and the White Sea basin. (1) Frontal marginal ridges: predominantly morainic ridges, depositional types being less common. (2) Hilly moraine. (3) Glaciofluvial deltas and outwash plains. (4) Inferred location of marginal ridges: beneath younger sediments on the sea bottom, etc. (5) Kalevala-stage marginal deltas with absolute surface marks indicating the highest level of the White Sea basin (ca. 10,200 - 10,000 B.P.). (6) Marginal delta in the Keiva-I (Marine Keiva) zone at the mouth of the River Ust - Pyalitsa with palaeomagnetic dating of varved clay deposit. (7) The major ice-divide of the Scandinavian Ice Sheet. (8) Part of some lower-order ice-divides. (9) Major ice flow directions. (10-11) Independent Ponoy Ice Sheet:

(10) Slightly active during the Luga stage ca. 14.1 - 13.0 Ka B.P., (11) passive during the Neva stage ca. 12.5 - 11.9 Ka B.P. Note: With the exception of, for example, the southern Kola Peninsula, the Keiva I marginal zone is very seldom composed of glaciofluvial ridges, deltas or hilly moraines etc. extending for a long distance. Glacial dislocations occurring as hills and including plastic marine clays formed during the Eemian interglacial have been encountered.

and outwash plains, as glacial meltwater flowed distally along the channels of postglacial discharge. The Salpausselkä I and II marginal ridges developed at a time when the ice margin was in contact with the Baltic Ice Lake, as shown by the levels of numerous marginal deltas in glaciofluvial ridges. The above conditions favoured rapid ice melting. Generally, deglaciation began earlier and was more vigorous. Note also the position of the Karelian Lobe, on the eastern flank of the Younger Dryas continental glacier, where the surface of the crystalline basement had already undergone substantial uplift. Its absolute altitude generally varies from 160 to 300 m and locally from 300 to 400 m (West Karelian upland). The climate was obviously much colder and less humid (continental) than in southern and southeastern Finland, where the Baltic Ice Lake was located. Such environmental conditions also retarded deglaciation in western Soviet Karelia.

Karelian geologists believe that the Tuupovaara end moraine, which formed offshore above the g-level of the Baltic Ice Lake, is the extension of the Salpausselkä I marginal ridge. It is linked to Rugozero (Rukajärvi)-stage end moraines.

Correlation of end moraine zones in Soviet Karelia and the Murmansk district

A correlation scheme for marginal ridges in eastern Fennoscandia is shown in Fig. 6. The correlation and dating of individual segments of the marginal zones over a vast land area and on the White Sea bottom are not unequivocal. For instance, geologists are not unanimous as to the depositional conditions and age of the Keiva I (Marine Keiva) and Keiva II marginal ridges, which extend for 250 - 300 m along the Tersky White Sea coast (Fig. 6). These marginal zones in the eastern Kola Peninsula have been studied by many Soviet geologists and geographers (e.g. Vvedensky, 1934; Grigoryev, 1934; Richter, 1936; Lavrova, 1960; Armand, 1960, 1964; Apukhtin, et al. 1965; Strelkov, 1976; Yevzerov, 1990).

Many workers refer to the inactive Ponoy Ice Sheet, which existed independently in the central Kola Peninsula. Its distribution, the relationship between the Scandinavian and Ponoy Ice Sheets at different evolutionary stages and the position of the Keiva I and II marginal ridges relative to them are still subjects of debate.

Special attention should be paid to some controversial points when seeking to correlate marginal zones of different ages in Karelia and the Kola Peninsula. Our correlation problems could, of course, be resolved by determining the age of the Keiva I and II ridges. In this connection, the results of recent studies of varved clay in the zone between these marginal ridges are reported.

Lavrova (1960) regarded the Keiva I and II ridges as marginal strata of the independent ice sheet which occupied the Kola Peninsula. According to her, the ridges developed after rapid melting of the Scandinavian Ice Sheet, which occupied the White Sea basin. Both Vvedensky (1934) and Lavrova referred to Tersky Keiva as the morphological and age analogues of the Salpausselkä I and II marginal ridges.

Grigoryev (1934), Richter (1936) and Armand (1960, 1965) understood Keiva ridges predominantly as closed (ice-divide) marginal strata deposited in the suture zone between the ice margins of the White Sea lobe of the Scandinavian Ice Sheet and the Ponoy Ice Sheet. Armand had no precise data on the age of these marginal zones.

In the early 1960s, the findings of a national survey of Quaternary deposits conducted in the NW Soviet Union were compiled under the supervision of N.I. Apukhtin and I.I. Krasnov and published as a monograph (1967) and as "A map of Quaternary deposits" (1967). It has been found that the Karelian (Luga) and Neva-stage marginal zones in eastern Karelia and the northwestern Arkhangelsk district can well be correlated with the Keiva I (Marine) and Keiva II marginal ridges. Their boundaries intersect the White Sea Strait (Fig. 6). Tersky Keiva I and II are referred to as marginal ridges of the active Scandinavian Ice Sheet, which occupied the White Sea basin and shores (Apukhtin & Ekman, 1967; Apukhtin and Yakovleva, 1967). The marginal ridges deposited during these glaciation stages largely contributed to the evolution of the relief of the islands of the Solovetsky Archipelago. The above authors denied the existence of an independent ice sheet in the centre of the Kola Peninsula in Karelian - Neva times because there is no till sheet in the region, whereas both eluvial and eluvial-colluvial deposits are widespread. Their opinion was supported by the fact that marine sediments of the Eemian transgression in the middle River Ponoy are not overlain by till. A large tract extending from the centre of the Kola Peninsula to its eastern end was hardly affected by continental glaciers and was thus thought to have been entirely devoid of ice sheet in Late Pleistocene time. Only relatively narrow ice flows of the Scandinavian

Sheet spread eastwards along the Barents Sea and White Sea coasts of the Kola Peninsula. This ice flow pattern was probably affected by the local ice flow centre in Zaimandra and the more westerly mountain tundra, the ice-divide of the Khibiny and Lovozero Mountains and some other pre-Quaternary rocks on the Kola Peninsula.

Thus, the first publications correlating Tersky Keiva I and II with Neva and Karelian (Luga) marginal zones on the southern White Sea coast were those edited by Apukhtin and Krasnov (1967 a, b).

An important contribution to the study of marginal deposits in the Murmansk area was made by S.A. Strelkov (1976). According to him, the Tersky Keiva marginal ridges are genetically more complex than the well studied Salpausselkä I and II marginal ridges in southern Finland. He agree that the ridge systems had much in common and that locally they were similar in origin. From paleogeographic reconstructions Strelkov inferred that the Tersky Keiva ridges could be somewhat older than the Salpausselkä marginal ridges. He recognized the existence of the autonomous, practically immobile, Ponoy Ice Sheet and assumed that its margin had been in contact with the active White Sea ice flow only in the southeastern part of the Keiva II ridge, between the River Strelna and the lower River Ponoy. Both western and central Keiva II developed in the suture zone between the ice margins of the White Sea lobe and those of the less active flow which moved from the Khibiny Mountains southeastwards. According to Strelkov, the ice-divide between the latter and the ice margin of the Ponoy Ice Sheet ran along the line Panskie Tundry - the left bank of the River Strelna. In the southeast, the ice-divide terminates where the northeastern branch of the Keiva II, which takes the form of en echelon ridges, turns south of its western extension (Fig. 6). We think that the position of the ice-divide, which stretches for more than 200 km, is fairly arbitrary because it is not indicated by aggradational interlobate deposits composed of either till or glaciofluvial strata. Loose eluvial and eluvial-colluvial deposits are common in the area. It is hard to contend therefore, that an aggradational ice-divide ridge, quite apparent morphologically, did not form at the boundary between two ice flows, even though they were not active enough.

According to Strelkov (1976, pp. 88, 95), the nepheline syenite boulders found in the middle section of the Keiva II ridge between the rivers Varzuga and Strelna are indicative of ice flowing from the Khibiny Mountains towards the lower River Strelna. The fact that clasts of the above rocks are included in this marginal deposit is probably due to the activity of the autonomous Ponoy Ice Sheet, which redeposited the remains of Early to Middle Pleistocene tills. Ice flows from more intense old Scandinavian glaciations were far more common on the Kola Peninsula than were young Late Pleistocene glaciers.

V.Y. Yevzerov (1990), who works on the Kola Peninsula, shares Strelkov's (1976) view on the formation of the Terskie Keivy marginal ridges and the development of both the Scandinavian ice flows and the Ponoy Ice Sheet in the region. Yevzerov joined Ukrainian geophysicists V.G. Bakhmutov and G.F. Zagnyi for a comprehensive study of varved clays in the Ust-Pyalitsa river valley. Varvechronological observations have shown the clay sequence to consist of some 400 varves. According to Bakhmutov, palaeomagnetic measurements indicate that the curves for changes in the secular variation components of EMF, declination (D°) and inclination (I°), can be perfectly correlated with those for the reference chronomagnetostratigraphic scheme for varved clays of southern Karelia (Fig. 4). Clays were deposited in the River Ust - Pyalitsa in late Older Dryas to early Alleröd times. A warmer climate during the Alleröd is also indicated by pollen data (Yevzerov, 1990). It should be noted that varved clay strata were deposited on the distal side of the marginal delta (Fig. 6) which is part of the Keiva I (Marine) zoned system. Consequently, the latter was formed at the Neva stage (12 400 - 11 900 B.P.). In that case the Keiva II marginal ridge, which lay further north, could only have developed at the Karelian (Luga) stage and has an age of 14 000 - 13 000 years. Like N.N. Armand (1965), we consider Keiva II to be an interlobate marginal ridge which mainly developed in the suture zone of the White Sea ice flow and the Ponoy Ice Sheet.

The Keiva I and II ridges extend as far as the Lake Vyalozero - Munozero area, where the marginal relief strikes NW. Extensive moraine ridges are observed. Linearly-oriented ridge and hilly-ridge marginal relief is common over a large area. Circular and hilly-circular relief was formed in depressions between the marginal zones. The depressions are often waterlogged, probably owing to the penetration of relatively small ice tongues.

The relief described is observed over a vast area from Lake Vyalozeo northwestwards via Lake Ingozero and the Polysarian lake group to Mount Umba south of Lake Umbozero. This geomorphologically complex area of glacial relief is about 100 km long and up to 50 - 60 km wide. As a rule, the absolute altitude is no more than 250 - 300 m, which is 100 - 180 m higher than the adjacent drumlin plain.

The above area of large-scale ice and water-ice accretion is often characterized by a rugged surface and its topography seems to be largely related to glacial dislocations. The area can be regarded as ice-divide upland with marginal zones formed at different glaciation stages, like those in Soviet Karelia (Lukashov & Ekman, 1980; Iljin & Ekman, 1982). The above assumption is supported by the stepped relief and the presence of big wedge-shaped ice-divide scarps separating concave end moraine arcs. The arcs indicate the position of small tongues on the western slope of the Umba-Vyalozero upland. The base of some of the ice-divide scarps is composed of crystalline rocks. Apparently, the marginal ridges formed at different deglaciation stages join the slopes of Mount Umba.

Three to four levels of glacial relief are distinguished in the Umba - Vyalozero ice-divide upland: 1. Upper level. Surface of primary terrains 250 - 300 m, probably up to 350 m, above sea level. Developed in the course of maximum ice advance. Outcrops of crystalline rocks can probably be found locally. 2. Upper middle level: ca. 200 m above sea level. Kame-circular relief is common. Possibly formed at the Karelian (Luga) stage. 3. Lower middle level. Absolute surface altitude ca. 150 m. Kame-circular relief is characteristic. Possibly formed at the Neva stage. 4. Lower level. 100 - 120 m above sea level. Drumlin moraine plain, locally ridge-circular relief. Formed at the Rugozero (Ss I) stage.

The relief levels are separated by end moraine ridges, marginal slopes and kame-ridge zones formed during the various stages of the last glaciation.

Special geomorphological and geological studies are required to enable us to elucidate the structure and depositional environment of the Umba-Vyalozero ice-divide upland and to distinguish the marginal terrains of diffirent ages.

Attention should be given to the NW-trending marginal zone branching off Keiva II in the River Varzuga area (Fig. 6). The branch extends almost to the Varzuga river valley and the River Pana, the Varzuga's right-hand tributary. South of Lake Umbozero, the branch merges with the Luga-stage ridges, which are part of the marginal complex in the Umba-Vyalozero ice-divide upland. The zone is poorly defined morphologically and seems to indicate the maximum westerly distribution of the Ponoy Ice Sheet (Fig. 6). The flows of the Scandinavian Ice Sheet may well have reached this boundary in Luga time. At the initial phase of the Luga stage, ice probably flowed through the Ingozero lake basin and the Plysarian lake area, where a large depression hosted an extensive glacier tongue within the ice-divide upland. Initially, the glacier tongue probably advanced as far as the River Pana and then flowed southeastwards in contact with the margin of the Ponoy Ice Sheet.

Southeast of the southern shore of Lake Umbozero, the Luga- and Neva-stage marginal zones turn northeast and extend via Lake Seijavr as far as the upper right hand tributaries of the River Vostochnaya Litsa and Lake Yenozero (Fig. 6). It is not always possible to trace the boundaries of these glaciation stages over the entire distance because an aerial survey has not been conducted and the ground studies are not detailed enough. Further investigations should, therefore, be undertaken in the area stretching for tens of kilometres east and southeast of Lovozero tundra. Recommended targets of study are the evolutionary patterns of both the Ponoy and Scandinavian Ice Sheet, and their relations and contact sites.

The Luga-stage marginal strata extend eastwards from Lake Yenozero to the lower River Iokanga, where they cross the river valley and probably continue on the Barents Sea bottom in the Cape Svyatoi Nos area (Fig. 6). The marginal zone is located about 30 - 40 km from the seashore. This, together with its morphological aspect, indicates that the Scandinavian Ice Sheet, the northern margin of which reached the littoral shelf, was not active. In the south, the flow was in contact with the passive Ponoy Sheet margin.

Neva-stage marginal moraines can be traced northeastwards from the upper River Pina and Lake Pinozero to the Barents Sea coast. They deposited on the sea bottom east of the Vostochnaya Litsa river mouth.

The active ice margin was located on the littoral Barents Sea shelf in the course of both the Luga- and Neva-stage deglaciation of the Late Valdai ice sheet (Matishov, 1973, 1980). Marginal ridges developed on the above Murmansk littoral shelf covered by continental ice. According to M.A. Spiridonov and A.E. Rybalko, marginal strata deposited during different stages of the last glaciation are located in the centre of the White Sea basin and in the Kandalaksha, Onega and Dvina bays (Fig. 6). Most of them correlate well with their age counterparts deposited on the seashore. It is more difficult to estimate the age and depositional environment of the glacier tongue which moved southeastwards from the Kandalaksha Bay along the central White Sea depression almost as far as Gorlo Strait. In the north, the ice flow boundaries are clearly indicated by the lateral ridges that extend from the mouth of the River Olonitsa along the Tersky shore of the Kola Peninsula. Northwest-striking lateral moraines have been traced north of the Solovetsky Archipelago, where the White Sea shelf grades into a central deep-water depression. On the northernmost Onega Peninsula the sea bottom ridges turn eastwards and extend towards the Winter coast of the White Sea. The frontal border of the glacier tongue shows no discernible forms of marginal relief.

According to Yevzerov (1990), the outlet glaciers confined to depressions became active again and deposited the above lateral ridges in Younger Dryas time. He believes that the ridges developed at the Salpausselkä II stage. The glacier tongue was rapidly destroyed by the waters of the sea which occupied the bulk of the White Sea basin in Younger Dryas time.

We think that the lateral moraine ridges surrounding the central White Sea depression were formed by a glacier tongue advancing rapidly along the Kandalaksha Bay depression towards the deep (290 - 300 m) part of the sea. This was the second phase of glacier advance in Late Neva time. Such a development in the palaeoglaciological setting of this part of the White Sea basin was very local, being mainly due to the unique conditions under which the continental ice moved and accumulated at the head of Kandalaksha Bay and its extension on land.

Why were there two phases of continental ice flow in the White Sea basin in Neva time?

The ice sheet, which was still fairly thick, advanced largely during the first half of Neva time, by when its margin had reached its maximum extent (Fig. 6). The effect of crystalline basement relief was not so great as it was later, although many fells (e.g. Khibiny, Lovozero, Zaimandra) in the Kola Peninsula occurred as nunataks.

Note that ice sheets and especially their peripheries (500 - 100 m) decreased in thickness during both the Luga (Karelian) and Neva stages of glaciation in Karelia and in the Kola Peninsula. They became "warm" and could, therefore, move rapidly. According to Strelkov (1976 a), the above ice sheets developed at the second stage (phase) of deglaciation in the Kola Peninsula. Their lateral moraines and terraces, which developed on the upstream fell slopes, formed at two levels at an altitude of 700 - 500 m above sea level. They occupy a much lower hypsometric position on the leeside hillslopes. Strelkov (1976 a, b) has observed variations in the absolute altitude of lateral moraines and terraces on the slopes of the Khibiny and Lovozero fells. According to him, the surface of the peripheral part of the ice sheet is inclined to the east at 0.5 - 1° on average (15 m per km) and the ice thickness near the margin did not exceed 80 - 100 m. In his opinion the above data indicate that the periphery of the ice sheet was relatively thin at some stages.

The second phase of accelerated ice movement from the Kandalaksha graben to the deep White Sea depression took place in late Neva time when stagnation had ceased and the first-phase ice sheet was dead. Ice destruction was destroyed most rapidly in the White Sea basin, where it was affected by the water of the marine-glacial reservoir. The cessation of stagnation near Gorlo Strait seems to coincide with the beginning of the second half of Neva time.

The Kandalaksha graben and adjacent depressions were then a province of relatively poor accumulation of thin peripheral ice-sheet tongues that were not free to move. The tongues affected each other, thereby deviating from the initial directions. Such conditions favoured intense glacial dislocation processes such as the formation of thick units composed of ice layers from different tongues as a result of over-thrusting, the formation of compressive folds from till-bearing ice and pure ice, and the development of ice hummocks[4]. Ice deposited in this manner in the Kandalaksha graben, local bodies of ice were formed and the total "warm" ice thickness increased in the province. After reaching its critical volume, the ice flowed rapidly to the central deep-water depression of the White Sea basin, where it formed big lateral moraine bars (Spiridonov, 1985). We believe that the formation of these unusually thick moraine relief units may well be related to the squeezing-

[4] These types of glacial structure have been observed in moraine relief near Kandalaksha, Konda Bay and in other areas adjacent to the Kandalaksha graben. Many of them are referred to as Rugozero -stage moraines.

out of the silt-pelites and sands deposited on the slope of the depression. The till, which rests on the bar surface, seems to be mainly of the ablation type. Till clasts could have been transported by ice lenses and icebergs to the depositional area from either the upper part or the surface of the ice sheet. The absence of frontal end ridges indicates the markedly decreased thickness of the distal portion of the ice and the slow rate at which it spread out. This near-passive dynamic state of the peripheral ice-flow zone was not conducive to the deposition of prominent end moraine strata on the White Sea bottom.

The melting and complete destruction of this last local Older Dryas ice flow, which extended as far as the White Sea basin, had ceased by the climatic amelioration of early Alleröd time. The rapid destruction of the ice was promoted by the relatively free access of seawater to the basin through elevated bottom sites in Gorlo Strait. As a result, the water level of the reservoir rose and continental ice remains came to the surface. From mid-Alleröd time onwards, a glacial-moraine brackish-water regime was established over almost the whole White Sea basin, with a more fresh-water setting in Onega Bay.

It is easier to correlate the Younger Dryas marginal zones in Eastern Fennoscandia than the segments of the contemporary end moraine ridges that deposited at some earlier stages of deglaciation. Few direct data from radiocarbon dating, varve chronology and palaeomagnetic methods are available to help us to date the age of the Oldest to Older Dryas marginal zones. On the other hand, the above methods have yielded interesting results for study of the Younger Dryas marginal strata (Figs. 3, 4, 5, 6). It is difficult to correlate the marginal zones when their segments are separated by large bodies of water or by poorly studied areas, as is the case in the Kola Peninsula.

In both Luga (Karelian) and Neva time, the ice sheet spread out mainly as large lobes and tongues that occupied the biggest depressions at the basement of the link zone between the Baltic Shield and the Paleozoic sedimentary cover of the Russian Plate (Figs. 2, 6). The biggest tongues formed during the above glaciation stages spread over depressions in the White Sea and lakes Onega and Ladoga. The deglaciation shows a "tongue" pattern.

Younger Dryas deglaciation is externally characterized by the frontal planation of the ice sheet margin. Continuous marginal zones in Karelia can be reliably correlated for hundreds of kilometres using a geomorphological method for tracing end moraines backed up by aerial and satellite survey.

The Rugozero (= Salpausselkä I)-stage marginal ridges northeast of Kem extend northwards via the shallow White Sea shelf to the eastern shore of Oleny Island (Fig. 6)[5]. In this area, the position of the ice margin is indicated by a marginal delta whose proximal slope is attached to a feeding esker. The low, intensely eroded ridges found on the island, represent marginal relief forms, as indicated by their position relative to the delta.

Near the Karelian shore of Kandalaksha Bay the ice margin closely followed the present White Sea shoreline northwestwards as far as the northern end of Veliky Island, where the bay narrows markedly. The position of the ice margin can be reconstructed by studying the marginal delta located in the area. Note that all the deltas are linked to either feeding esker systems or glaciofluvial ice-divide ridges. However, the ridges do not extend distally beyond the esker boundaries.

The end moraine formed by the ice flow, which moved southeastwards along the Kandalaksha graben, extends from the northern end of Veliky Island across the narrow portion of the Kandalaksha Bay bottom to the mouth of Porjä Bay. The above data were obtained by A.E. Rybalko and M.A. Spiridonov, who also report a marginal moraine intersecting the mouth of Porjä Bay. With some reservations the ice margin can be traced eastwards as far as the Pilsky Bor marginal delta located near the end of the big glaciofluvial ice-divide Vilasselga delta. The position of the marginal zone is further indicated by the Kologuba Bor delta and, beyond the River Umba, by frontal push ridges and hilly terrains that stretch northeastwards as a wide strip. This end moraine relief was formed by a tongue of the active Kanozero glacier. In the east, the tongue boundaries are indicated by the marginal ridges that stretch continuously northwestwards from the head of the Vyala River for about 70 km to the area west of Lake Nizhneye Kapustnoye. These ridges are

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[5] Continental ice flow directions in Younger Dryas time are indicated by thin arrows.

part of the Umba - Vyalozero ice-divide upland relief and constitute the youngest external marginal strata in this biggest accumulative form of relief.

The western boundary of the Kanozero glacier tongue is indicated by the position of the Vilasselga ice-divide ridge which extends northwestwards from the southeastern shore of Lake Kolvitskoye and then farther along the bottom of the lake and the eastern shore of Lake Glubokoye to the southern slope of Kososelga fell. Ridge-hummocky moraine marginal relief is seen on both the eastern and northern slopes of the fell and also on the northern slope and at the piedmont of the Iolga fell in the west (absolute altitude up to 785 m). Individual marginal ridges have been found further west on the lower parts of the northern slopes of Kandalaksha fells (absolute altitude up to 650 m) and on the southern slope of Mount Bolshaya Plyosovaya (absolute altitude 588 m), where hummocky moraine marginal relief is observed.

The NE-trending moraine zone located to the north and west of the head of Kandalaksha Bay is of great interest. It occupies topographic lows between extensive uplands and fells. The zone stretches for some 35 km, its average width being about 10 km, with a maximum of up to 18 - 20 km in the area south of Kanda Bay. The biggest ridges located in the distal part of the zone are 10 - 20 km long. The nothern end of one that has been reported from the western boundary of Kandalaksha is located in the Niva river valley south of Lake Plesozero (Lavrova, 1960). Slightly bent in plan to the southeast, the ridge is cut by the valleys of two rivers, the Lupche Savvina and the Virma. It seems to extend eastwards as a marginal ridge on the southern slope of Mount Bolshaya Plyosovaya. There is similar ridge in the southern Kandalaksha marginal zone, west of the White Sea station. As stated above, the structure of the strata that make up the ridges is clearly indicative of their glacial dislocation genesis.

Note that another transverse marginal ridge is probably located in the narrow middle part of the Kandalaksha graben. This ridge extends from Mount Pentelskaya on the eastern shore to the end of the big peninsula on the western shore in the Lesogorsk area. Three successive marginal zones were thus formed by ice flow within the Kandalaksha graben in Rugozero (Salpausselkä I) time. This was undoubtedly due to retarded ice flow resulting from ice movement followed by ice deposition in the upper part of the Kandalaksha graben. The evolution of the palaeoglaciological setting in the area was partly due to the complex topographic pattern of the crystalline basement of both the graben and the surrounding uplands and fells.

Individual end moraine ridges have been encountered at fairly high altitudes on the slopes of the Kandalaksha fell. Their formation in Younger Dryas time is, therefore, somewhat obsorve uncertain and they may have formed during earlier evolutionary stages of the ice sheet.

Marginal strata are most common in valleys between fells and in topographic lows between fells terranes, e.g. Kandalaksha and Kolvitsa. They have been reported earlier by other workers (e.g. Lavrova, 1960; Strelkov, 1976), and we have distinguished them by deciphering aerial photographs. Ridges abraded by the sea have also been found on the northern shore of Kolvitsa Bay and at the base of the western slope of the Kolvitsa fell. Marginal moraines occur in the valley of the southern Kandalaksha fells along which the River Luvenga flows. There they occur together with dead ice units such as ring forms of relief and small dome-shaped moraine hills and kames. In a wide low between the Kandalaksha and Kolvitsa fells, in the Kolvitsa river valley, at the base of the northern valley slope there occurs a well-defined EW-striking marginal ridge which extend to the Kolvitsa depression. There it turns southeastwards and can be traced along the western shore of Lake Kolvitskoye as far as the area south of the lake, were it joins the western part of the Vilasselga ice-divide ridge.

The above data on the occurrence of marginal ridges in the Luvenga and Kolvitsa intermontane valleys and in the Kolvitsa lake basin indicate that the ice moved along the valleys to the Kolvitsa depression and from there southwards as far as the line: Kolvitsa Bay mouth - upper Pilsk Bay. This inactive ice movement could have occurred in the first phase of palaeoglaciological setting in the Kandalaksha graben. Of utmost importance for glacier advance towards the Kolvitsa depression was the accumulation of ice in the upper part of Kandalaksha Bay. In the second phase of ice movement in the graben, ice was supplied to the Kolvista depression on a limited scale. Continental ice could hardly have spread beyond the depression at this time.

Thus, the Vilasselga ice-divide glaciofluvial ridge, which developed in the contact zone between the active Kanozero and the inactive Kolvitsa glacier tongues, is arbitrarily drawn between the Porya river valley and the eastern slopes of the Kolvitsa fell.

Analysis of the palaeogeographic setting in the Kandalaksha and Kolvitsa fell areas in early Younger Dryas time shows that these fells were then as extensive high nunataks towering over the ice surface.

In Younger Dryas time a big local centre of continental ice outflow was located in the western Murmansk district, in a large topographic low encompassing Lake Girvas, the upper Nota (Nuorttijoki) and Javar river basins and adjacent fells, including those in eastern Finnish Lapland. At the Rugozero stage (Salpausselkä I) a thick ice flow spread southeastwards along the wide valley between the Zaimandra mountains and fells in the southwestern Murmansk district towards the Ekastrovskaya Imandra lake basin and the Kana and Umba river basins. Glacier tongues branched from this flow southeastwards to the Kandalaksha graben and the Umba area. Evidence of the movement of the marginal ridges formed by the Kandalaksha and Kanozero tongues was presented earlier.

The northern portion of the South Imandra flow on the eastern shore of Ekastrovskaya Imandra was detached from the Kanozero tongue and spread actively as an independent glacier tongue as far as the southern slope of Lovozero fell. An ice-divide ridge developed between these independent structural elements of the ice sheet. The ridge extends to the Lake Nizhneye Kapustnoye area, where it joins the Umba - Vyalozero ice-divide upland.

The small scarps of the Lovozero glacier tongue jutted out to the Lake Umbozero basin and towards Lake Lovozero. Small tongues also moved along the lows in the Umba - Vyalozero ice-divide upland. The Lovozero tongue gave rise to marginal strata in all the above localities, including the southern slope of Khibiny fells.

Discontinuous marginal ridge zones related to continental glaciation have also been reported from both the western and northern slopes of the Khibiny mountains at altitudes much lower than 500 m above sea level (Strelkov, 1976 a, b). They may well indicate the position of the ice margin in early Younger Dryas time.

Two isolated subparallel marginal ridge zones composed of till and glaciofluvial material extend northwards from the northern end of Lake Umbozero. Towards the sea, the external zone deviates sharply to the east and then turns northwestwards. In the Teribersky Cape area, the marginal ridge plunges towards the Barents Sea shelf area.

A segment of a marginal zone of unknown age has been found west on Kildin Island in the west. Farther west, inland marginal ridges have been reported from the Zapadnaya Litsa Bay on the Barents Sea shore (Fig. 6). Two end moraine ridges extend westwards from this area as far as the Soviet-Norwegian border. Here they are in contact with the Tromsö - Lyngen end moraine (age 10 000 - 11 000 years) in Norway. The more southerly of the two adjacent marginal ridges are in the Zapadnaya Litsa Bay - Norwegian - Soviet border area can be related to ice movement in late Younger Dryas time.

As already noted, the Kalevala - stage marginal zone can be traced continuously to the southern slopes of the fells that make up a major ice-divide in the eastern Murmansk district.

Note that on the western slopes of the fells in the southwestern Murmansk district, a single marginal zone branches off as a few subparallel subzones that converge again in the Yoja village area (Fig. 6). This is related to the evolutionary characteristics of ice sheets in mountain areas.

North of the major ice-divide, marginal ridges have been reported from the Monchegorsk area. They extend as a marginal-ridge and hummocky-moraine zone to the north of the Khibiny Mountains towards the Barents Sea shore in the Tersk Bay area, where they approach to the marginal zone formed in early Younger Dryas time.

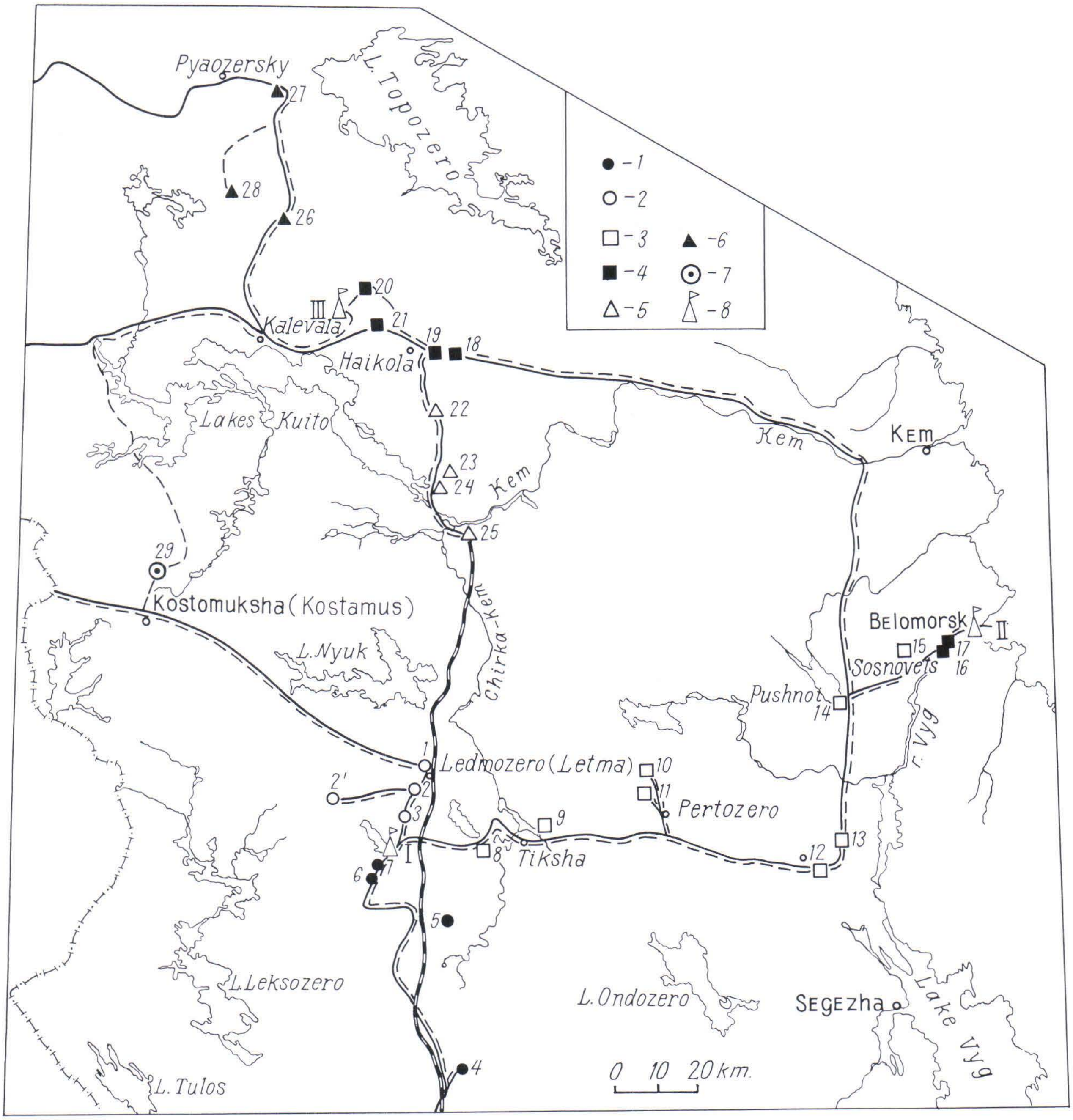

Fig. 7. Field trip itinerary in Soviet Karelia: (1) 28 June: Stops 1-3: Length of itinerary 120 km. (2) 29 June: 4-7. 200 km. (3) 30 June: 8-17. 220 km. (4) 1 July: 18-21. 250 km. (5) 2 July: 22-25: 180 km. (6) 3 July: 26-28. 210 km. (7) 4 July: 29. 170 km. (8) Overnight: I - field camp, Lake Tikshozero (Tiiksijärvi); II - hotel, Belomorsk, III - field camp, Lake Stafella.

Field trip itinerary in the Karelian A.S.S.R.

June 28. 1991 Vartius - Kostamuksa (Kostamus) - Ledmozero (Lietma) (the Kalevala end moraine; moraine ridges, sandur, dislocations) - Lake Kovdozero (Koutjärvi) (end moraines) - Lake Tikshozero (Tiiksjärvi) field camp

June 29. 1991 Tikshozero - Peninga (Pieninkä) (the Rukajärvi end moraine) - Urakkajärvi (esker, end moraine) - Karniz (Karnisjärvi) (the Kalevala end moraine; feeding esker, outwash plain) - Tikshozero

June 30. 1991 Tikshozero - Kolongozero (Kuollunkijärvi) (deformations caused by ice push) - Mergubskoye (Meru) (interlobate formation associated with the Rukajärvi end moraine; abrupt bend in the course of the end moraine) - Pertozero (Pirttijärvi) - Khizozero (Hiisjärvi) (end moraine) - Idel (Ieljärvi) (esker delta) - Murmansk-Petrozavodsk highway - Parandovo (esker) - Shueozero (Suikujärvi) (big Rugozero -stage marginal ridge) - Sosnavitsa (end moraine complex) - lower course of the river Vyg (Uikujoki) (rock carvings) - Belomorsk, hotel

July 1. 1991 Belomorsk - Kem river - Kepa (the Kalevala end moraines; dunes, marginal ridges and deltas) - Päivä (glacial erosion, dislocations, outwash) - Lake Stafella field camp

July 2. 1991 Lake Stafella - Shonga (Shonanniemi) (usually big end moraine ridge) - Päiväjärvi (end moraine complex) - Yuskozero (Jyskyjärvi) (end moraine complex; old Karelian village) - Lake Stafella

July 3. 1991 Lake Stafella - Regozero (Röhö) (drumlin field) - Tungozero (Tunkujärvi) (the Kalevala end moraine; interlobate complex; big end moraine) - Urakkajärvi (end moraine ridges; sandurdelta; kame topogrophy) - Lake Stafella, farewell party

July 4. 1991 Lake Stafella - Kostomuksa (openpit iron mine) - Vartius, Finland - Kajaani

I. Ekman, V. Iljin & A. Lukashov

Field trip itinerary
Localities to be visited

Most of the field excursions (Fig. 7) scheduled for IGCP Project 253 will be made in northern Karelia from 28 June to 4 July 1991 the aim being to show the most characteristic localities in two Younger Dryas marginal glacial zones. Some geological localities in central Karelia will also be visited. The excursion will cover six administrative districts of Soviet Karelia: Muezersky, Segezha, Belomorsk, Kem, Kalevala and Louhi and visit two cities: Belomorsk and Kostomuksha.

The place names of the marginal zones located in the above territory refer to the names of the corresponding evolutionary stages of the last ice sheet. The marginal zone which developed in the early Younger Dryas is called the Rugozero (Rukajärvi) zone. Participants will see some segments with a total length of 180 km extending from the elevated supra-aquatic province to the area affected by the transgression of the marine-glacial body of water on the White Sea coast. In terms of age, we correlate this zone of marginal strata with the Salpausselkä I marginal ridge in southern Finland.

The second zone of marginal deposits developed during the late stage of the Younger Dryas. This glaciation stage is referred to as the Kalevala stage. This marginal zone can be traced continuously for 270 km. At some of the sites to be visited the glacier margin was on land; at others it was in contact with proglacial bodies of water. Many spectacular geomorphological sites in marginal zones and a few good sections illustrating their internal structure and the composition of sediments will be shown. We correlate the Kalevala-stage marginal zone with the Salpausselkä II ridge in southern Finland.

In the Lake Bolshozero area, typical Lower Proterozoic tillites will be shown. In the rocky Vyg river valley near Belomorsk, the participants will see ancient rock carvings made by the people who lived in the area 3 - 4 thousand years ago. The petroglyphs of both Zalavruga and Besovy Sledki are known all over the world. An openpit mine in the Kostomuksha area, with an annual production of 26 million tons of iron ore, will be visited. Time permitting, we shall visit other natural monuments, historical and ethnographic museums and other places of interest.

Nights will be spent under canvas in two field camps (Fig. 7). Thus participants will have a memorable opportunity to experience the Karelian wilderness. The night of 30 June will be spent in a hotel in the town of Belomorsk.

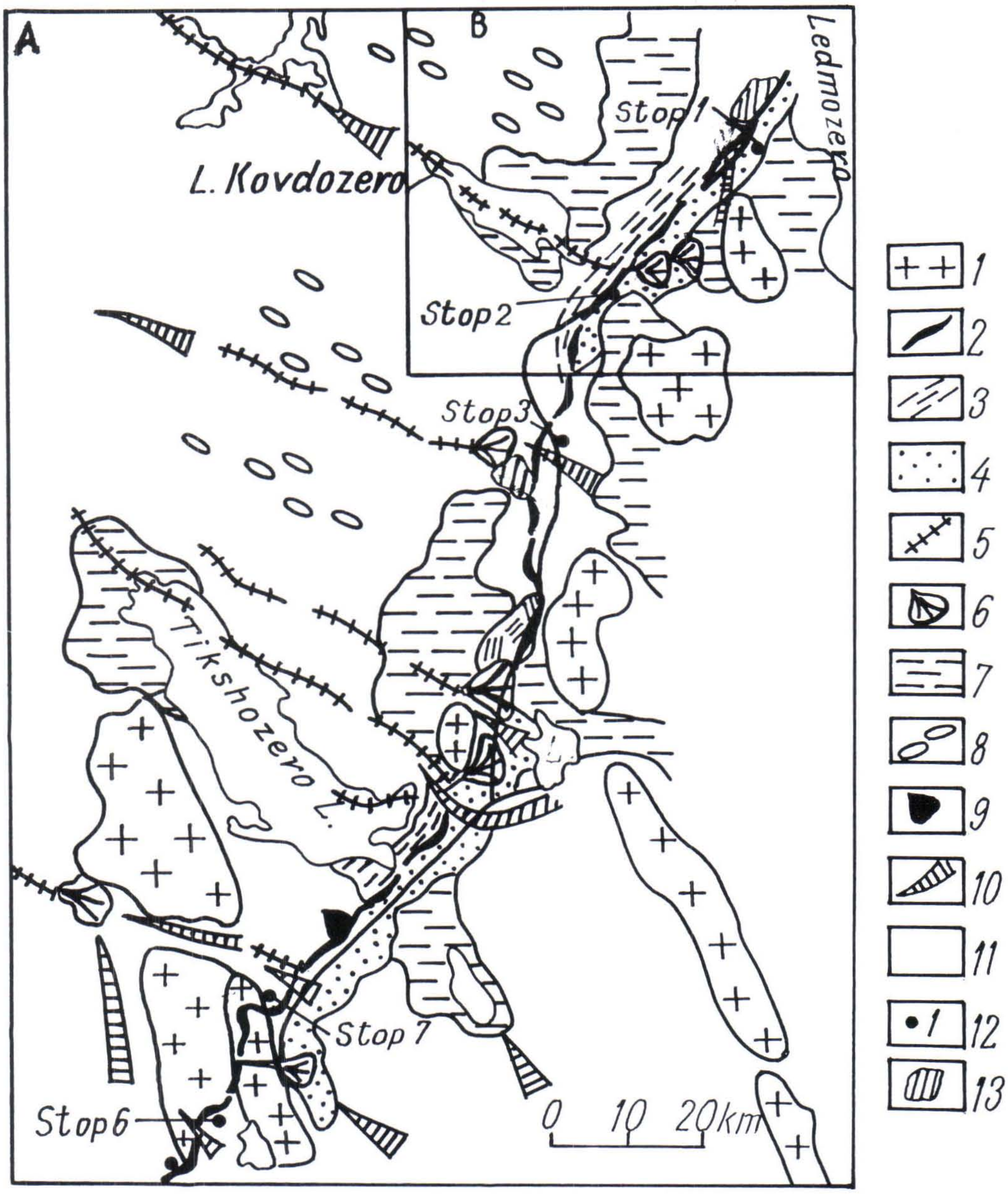

Fig 8. Stops 1-3; 6-7. Kalevala-stage marginal strata, Ledmozero (Lietma) - Lake Tikshozero (Tiiksjärvi) area. (1) Crystalline rocks. (2) Marginal-moraine ridges. (3) Oriented ridge moraine relief. (4) Outwash plains. (5) Eskers. (6) Glaciofluvial fans. (7) Glaciolacustrine plain. (8) Drumlins. (9) Ice-divide terrain. (10) Meltwater channels. (11) Till. (12) Stop and its number. (13) Ledmozero area.

We hope that all the excursions will be both interesting and useful, that you will enjoy the outdoor life, keep fit and well, and make many new discoveries in Quaternary geology.

The first ice marginal strata to be seen stretch for 35 km in the Kalevala zone (Fig. 8) between Ledmozero (Lietma) railway station and Lake Tikshozero (Tiiksijärvi). This marginal zone extends northwards for about 400 km from the Soviet-Finnish border via western Karelia to the Murmansk region (Figs. 1, 2, 6). Its extension in SE Finland is referred to as the Pielisjärvi end moraine zone (Rainio, 1972, 1978, 1983, 1985).

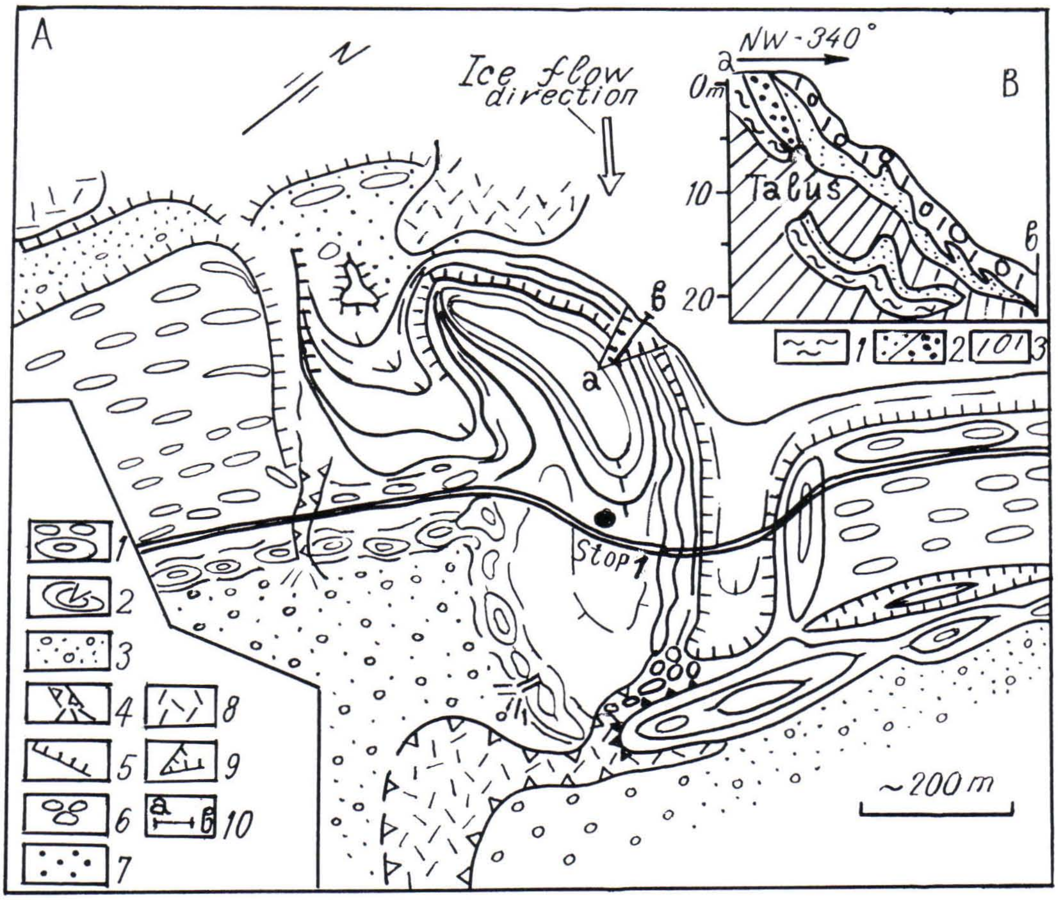

Fig. 9. Stop 1. Domal glacial dislocation in the Kalevala-stage end moraine ridge zone near Ledmozero (Lietma) railway station. A. (1) Morainic ridges. (2) Glacial dislocation. (3) Outwash plain. (4) Meltwater channels. (5) Steep slopes and scarps. (6) Clusters of boulders. (7) Surface of sand terraces. (8) Swamp. (9) Open pit. (10) Position of section.
B. Section through the strata making up glacial dislocation: (1) Silt. (2) Fine to medium-grained sand. (3) Till.

The frontal deposits in the above portion of the Kalevala marginal zone (Fig. 8) are represented by moraine ridges, linearly oriented low-ridge relief and small ice-divide moraine terranes, often triangular in plan (the sharp angle points upstream). There are also dome-shaped hummocks whose long axes are oriented transverse to the strike of the moraines (Fig. 9). Such forms develop in shift zones, where the segments of end moraines are displaced laterally relative to each other.

Radial eskers join to the proximal side of the end moraine zones (Fig. 8). Glaciofluvial fans, deltas and glacial meltwater channels are observed on the esker extension on the external side of the moraine ridges. Relatively narrow strips of outwash plain are often seen on the distal side of the frontal ridges. The lowest portions of the near-frontal subzone are occupied by glaciolacustrine plains. These are locally in contact with meltwater channels with deltas at their mouth (Fig. 10 A).

1. Ledmozero (Lietma). Fig. 9. A dome-shaped glacial dislocation at the southeastern boundary of Ledmozero (Lietma). It developed in the shift zone of two segments of an end moraine zone. The amplitude of their distal shift relative to each other was more than 200 m. A glacial dislocation elongated-oval in shape and slightly convex to the north, was formed in the rupture zone. The hummock is narrower at its western end, where the slopes are steep. Its southwestern end is wider and the slopes are more gentle. The top of the hummock is fairly smooth. Its relative height is 20 - 23 m. The glacial dislocation shows a scaly overthrust internal structure (Fig. 9 B). Its constituent sand and silt layers are folded and dip steeply. The hummock slopes are covered by a thin till bed with a lamellar structure.

The internal structure of a moraine ridge in both longitudinal and transverse sections has been studied at the extension of a dome-shaped glacial dislocation to the north. Two till beds have been found in transverse section (Fig. 10, C-1). Intense deformation with lamellar (schistose) texture has been revealed in the lower bed. The till beds are separated by two coarse to fine sand horizons.

In longitudinal section it can been seen (Fig. 9, C-2), that both the till and coarse sands are compressed into a system of transverse folds and are cut by injective bodies composed of fine sands.

2. Lake Kovdozero. The relationship between glaciofluvial complexes and marginal moraine ridges is of interest. A winding esker ridge with characteristic sigmoid curvatures stretches the length of the lake. At the southeastern end of the lake the esker ridge terminates at two fans. At this site, the marginal moraines have shifted along strike relative to each other (Fig. 10 A, B).

Two till beds with coarse sand and silt intercalations have been found in the longitudinal section of the marginal ridge (Fig. 10, C-3). The layers are compressed into recumbent folds with their axes transverse to the trend of the ridge. An explanation has been sought for the occurrence of transverse folds in the moraines.

Aerial photographs have shown that, in the centre of the locality, the segments of the marginal zone have shifted relative to each other by 180 - 200 m. There were two lateral shifts, one of them along the axial part of Lake Kovdozero. Esker ridges with characteristic sigmoid curvatures displacement and identical in shape to dynamic cracks occur in the shift zone. The second shift is expressed topographically as a rill of discharge along which the marginal ridge was displaced.

The marginal ridges and oriented drumlins between the shifts form gentle curvatures. It can be assumed from a comparison of the curvatures and by analysing sections through the marginal ridges that they indicate the position of transverse folds (Fig. 10 B).

Transverse folded structures could arise from the displacement of marginal zone segments along shift lines accompanied by additional compression along the marginal belt.

3. Unosvaara. A frontal ridge up to 5 - 6 m high and 15 - 20 m wide. On the proximal side, it is adjacent to a small ice-divide with well-defined scaly-overthrust structure. Beds occur as slightly bent subparallel ridges 1 - 2 m high.

In this area it is possible to trace the representative rock boulders transported from the Lower Proterozoic Lake Bolshozero sequence to their source 18 -20 km northwest (280 - 290°) of the site visited. Granite, diabase and polymictic conglomerates, often referred to as tillites, occur amongst boulders along the road. Thin-laminated shales, similar to varved clays, are also encountered.

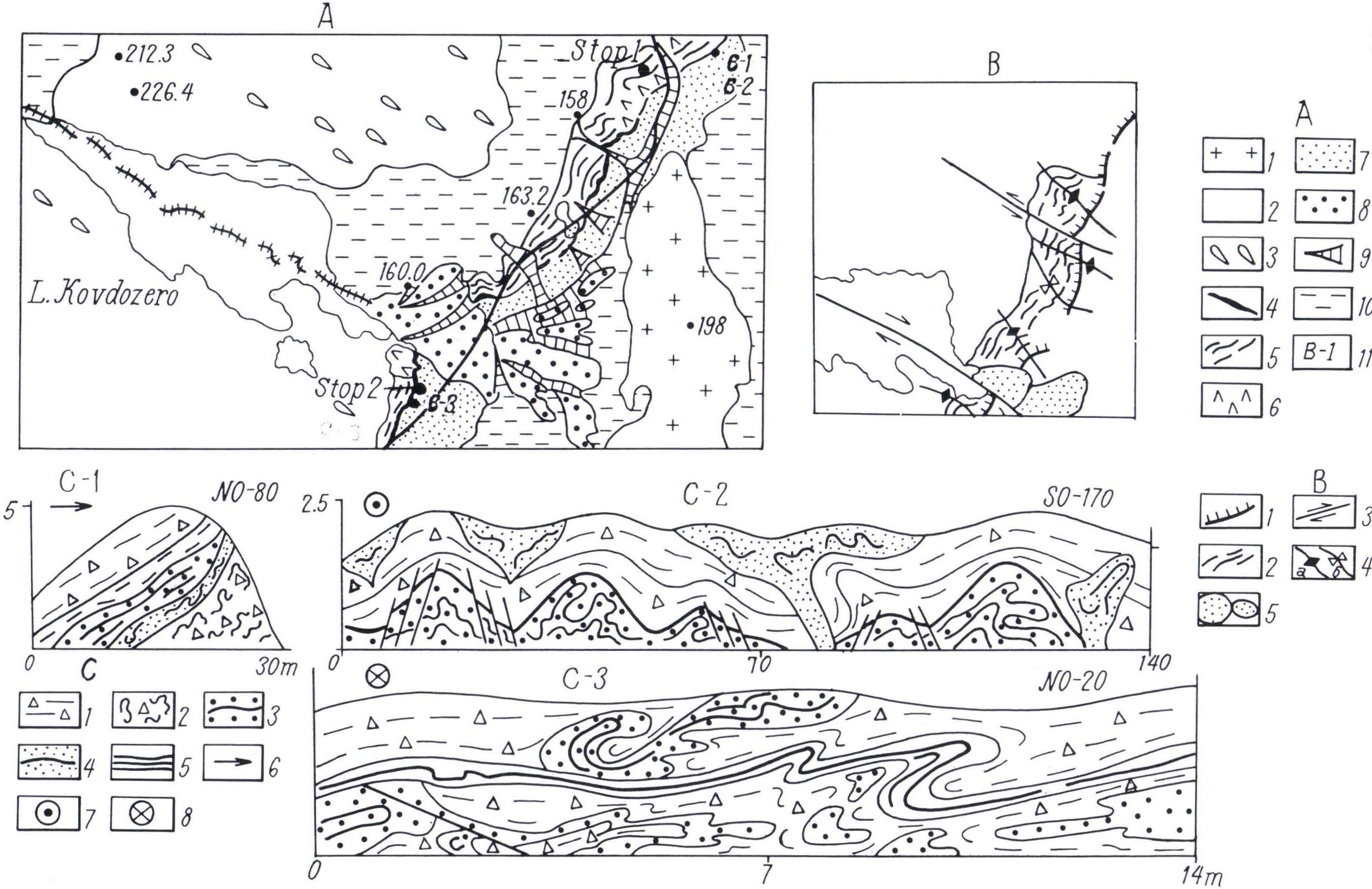
A
212.3
226.4
Stop1
B-1
B-2
158
163.2
160.0
L. Kovdozero
198
Stop2
B-3
B
A
1
2
3
4
5
6
7
8
9
10
B-1
11
C-1
NO-80
5
0
30m
C-2
2.5
SO-170
0
70
140
B
1
2
3
4
5
C
1
2
3
4
5
6
7
8
C-3
NO-20
0
7
14m

Fig. 10. Stops 1-2. (A) Kalevala marginal strata in the Ledmozero (Lietma) - Lake Kovdozero (Koutjärvi) area. (B) Glaciostructural scheme of the locality. (C_1, C_2, C_3) Section through end-moraine ridges. (1) Crystalline rocks. (2) Till. (3) Drumlins. (4) End moraine ridges. (5) Oriented ridge-moraine relief. (6) Hilly morainic relief. (7) Outwash plains. (8) Glaciofluvial fan. (9) Meltwater channels. (10) Glaciofluvial plain. (11) Location of sections.

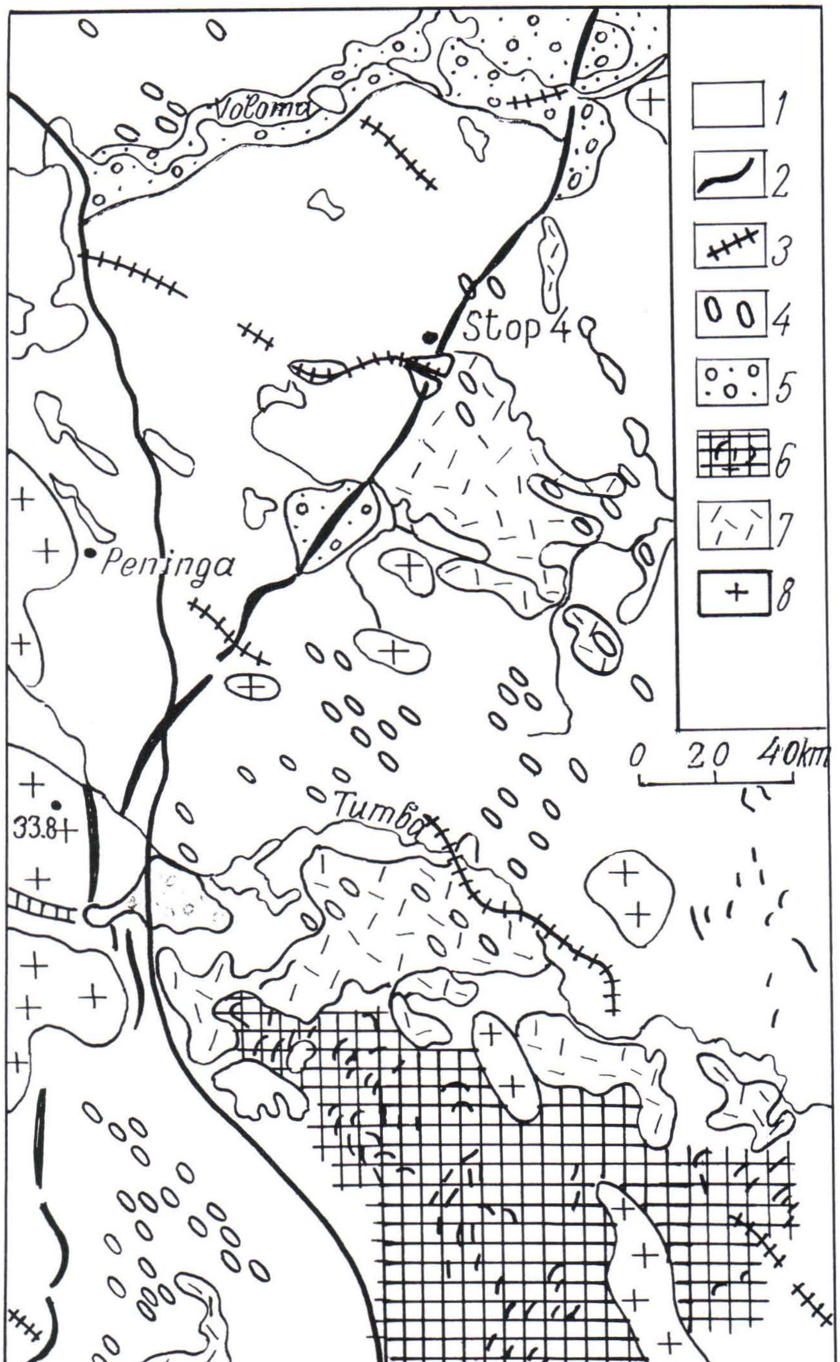

Fig. 11. Stop 4. Rugozero-stage marginal strata in the River Tumba - River Voloma area. (1) Till. (2) End moraine ridges. (3) Eskers. (4) Drumlins (5) Glaciofluvial deltas, fans and outwash plains. (6) Hilly-ridge and hilly-morainic relief. (7) Swamp. (8) Crystalline rocks.

Time permitting, the participants will visit the Lake Bolshozero area to admire old tillite and varved shale outcrops. The round-trip to Lake Bolshozero is about 40 km.

The second day of the excursion will include a visit to the most remote and interesting parts of the Rugozero- and Kalevala-stage marginal zones south of Lake Tikshozero (Tiiksjärvi). The morning will be set aside for a geomorphologically complex locality that lies approximately in the middle of the Rugozero end moraine zone between the Voloma and Tumba river valleys (Fig. 11). In the southern part of the zone, the marginal ridges lie on the slopes of the West Karelian upland, with an altitude of 340 - 380 to 400 - 410 m above sea level. The upland is dominated by quartzites.

The rugged topography of the upland impeded the advancing ice. Some small ice tongues moved farther along the lows, whereas other ice margin portions ceased moving alltogether. As a result, the marginal ridges were shifted relative to each other by 3 km (Fig. 11). The ridges are 2.5 - 4 km long and 6 - 10 m high. Note that the till debris making up the marginal ridges is composed entirely of quartzites.

On the eastern slope of the West Karelian upland the end moraines show a N-S orientation. North of the River Tumba, the marginal zone strikes NE (Fig. 11). An end moraine ridge up to 8 - 12 m in high extends for about 25 km in this area. It is locally pushed over the drumlins formed during the Sämozero (Neva) glaciation stage. One of the most characteristic and accessible localities in this zone will be visited.

4. Peninga (Pieninkä). The stop is 8 km northeast of the village of Peninga. A segment of the Rugozero (Rukajärvi)-stage marginal zone, which extends for 400 - 500 m, will be visited (Fig. 12). The end moraines differ morphologically and are divided by meltwater channels into individual segments. In the southern part of the locality, the moraine occurs as a well-defined steep ridge up to 7 - 8 m in high, whereas in the central part there is only a north-trending chain of low gently-sloping ridges 1.5 - 2 m in high. The end moraine, which is largely eroded by meltwater, is locally buried under glaciofluvial sediments. A big crystalline outcrop, broken into a few closely spaced segments, has also been found.

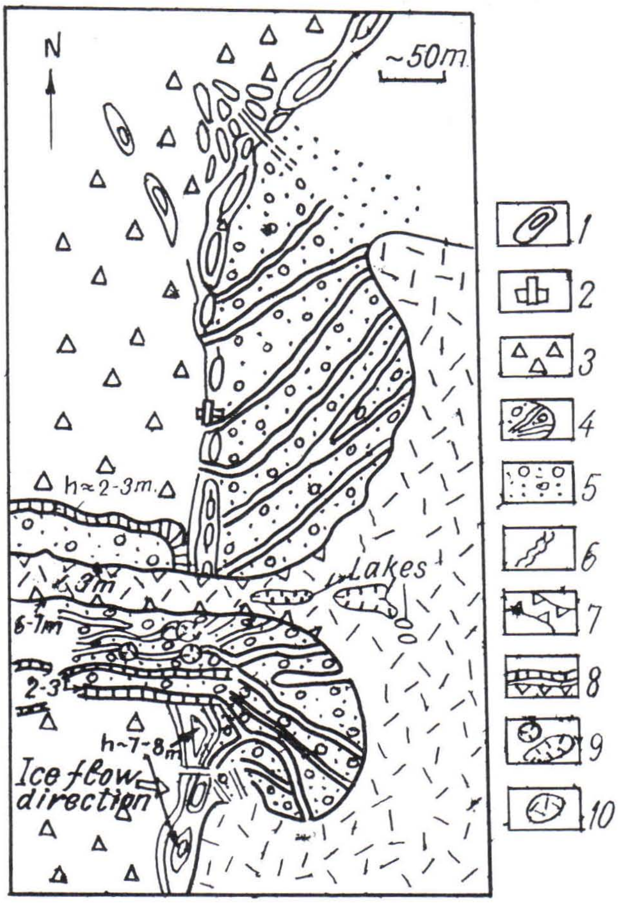

Fig. 12. Stop 4. Rugozero (Rukajärvi)-stage marginal strata NW of Peninga (Pieninkä) station. (1) End moraine ridges. (2) Crystalline rock outcrop. (3) Till. (4) Outwash plain. (5) Glaciofluvial deposits (sand, gravel and pebble). (6) Early meltwater channel. (7) Late meltwater channel. (8) Slopes of meltwater channel. (9) Whirlpool depressions. (10) Swamp.

The distal slope of the end moraine is adjacent to a relatively narrow strip of outwash plain consisting of several glaciofluvial fans of different age. Each has its own systems of meltwater channels. Thus, when one system stopped functioning, a new system was formed and so forth (Fig. 12). At least 4 - 5 generations of accumulative-erosional systems can be distinguished in the runoff valley - glaciofluvial fan chain. Some morphological elements (bottom, erosion scarps, terraces and whirlpool depressions) that occur at different altitudes can be used to distinguish between the meltwater channels of different age. The central channel, which cuts the whole end moraine ridge, is spatially related to the runoff valley and esker in the Lake Ladvajärvi area in the west (Fig. 11).

5. Urakkajärvi. Stop 5 is 7 km east of the district centre, Muezersky, which lies south of Hill Urakkajärvi (257.4 m above sea level). The esker observed here stretches along the base of the western slope of a big ridge composed of Jatulian quartzites, and is replaced by a thick glaciofluvial fan in the low portion of the ridge (Fig. 13). The delta surface is cut by deep meltwater channels, tunnel-shaped in their upper parts.

Note the moraine ridges, on the quartzite ridge slope.

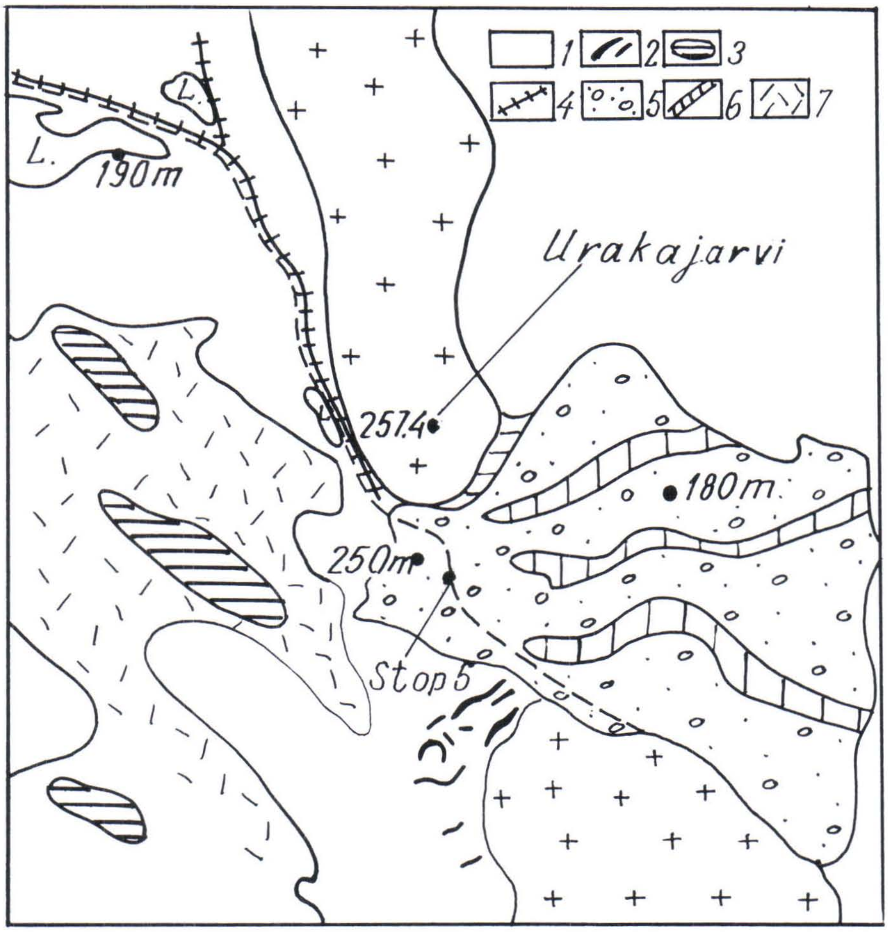

Fig. 13. Stop 5. Esker ridge crossing an elevation composed of crystalline rocks, east of Muyezerski (Muujärvi) settlement. (1) Till. (2) End moraine ridges. (3) Drumlins. (4) Eskers. (5) Glaciofluvial delta. (6) Meltwater channels. (7) Swamp.

6. Karniz (Karnisjärvi). The site is 500 m northwest of the northern end of Lake Karniz (Figs. 8, 14). The 7-8 m high end moraine ridge formed at the Kalevala stage in Younger Dryas time. An esker ridge attached to the proximal side and an outwash plain delta will be seen. The structure of the glaciofluvial sequence and the layering can be examined on the walls of an open pit. Meltwater channels are visible locally.

The marginal ridge, traceable for 2 km, runs upslope northwards to the top of a steep elevation.

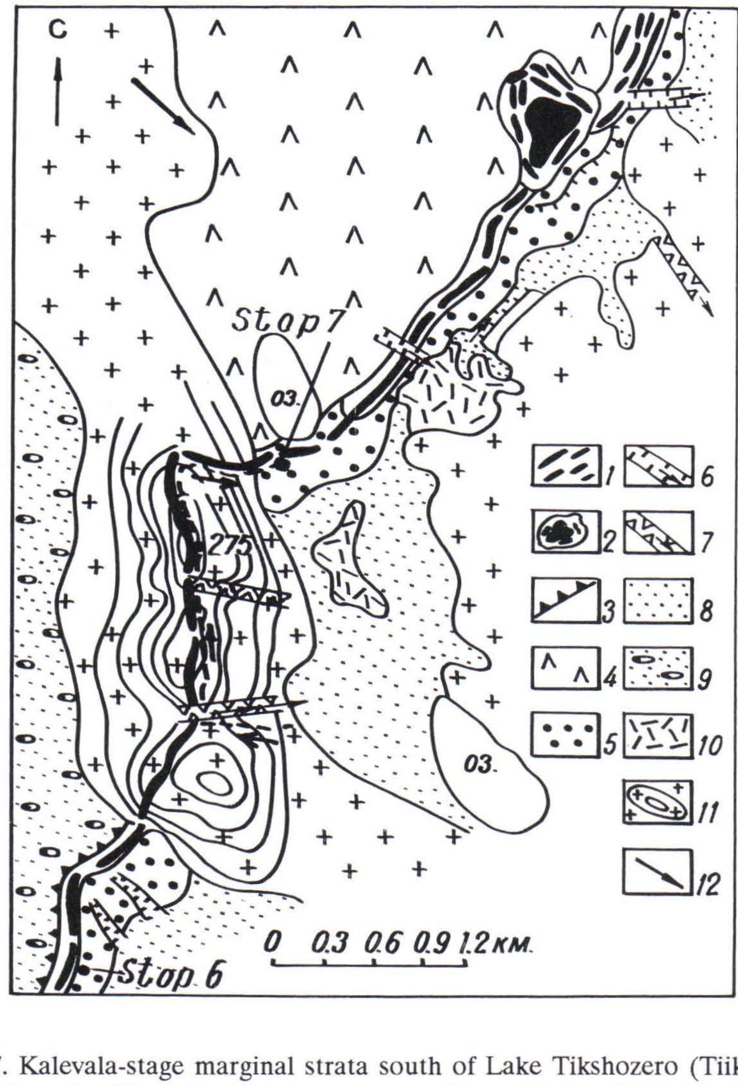

Fig. 14. Stops 6-7. Kalevala-stage marginal strata south of Lake Tikshozero (Tiiksjärvi). (1) End moraine ridges and bands of linearly elongated moraine ridges. (2) Ice-divide terrains. (3) Marginal scarp. (4) Ridge-hilly relief. (5) Glaciofluvial deltas, fans and outwash plains. (6) Meltwater channels. (7) Meltwater channels confined to tectonic fractures. (8) Glaciolacustrine plains. (9) Morainic plain. (10) Swamp. (11) Basement scarps (horizons 15 m apart). (12) Ice movement direction.

7. Tikshozero (Tiiksjärvi). Stop 7 is 3.5 km north of Stop 6 (Figs. 8, 14). For a distance of 2.5 km participants will walk along an end moraine crest to the top of an elevation composed of Lower Proterozoic quartzites. The ridge base is 170 m above sea level near the lake at the beginning of the walk and about 270 m on the summit of the elevation. In two places the end moraine is cut by meltwater channels confined to tectonic structures which striking approximately E-W. Sand-pebble fans occur at the mouths of the channels near the foot of the elevation.

8. Kolongozero (Punsajärvi). The ice-divide terrain south of Lake Kolongozero (Fig. 17) is characterized by a two-level surface structure with rugged ridge topography on both levels. The upper level is represented by two steep scarps located in the distal part of the ice-divide. They are 30 - 40 m higher than the surrounding plain and are almost isometric in plan view. Their surface is rough due to the presence of subparallel moraine ridges trending approximately eastwards and then turning to the north. These steep scarps, which occur as big hummocks, are primary. They are normally formed during the first phase of ice-divide development when the thin peripheral portion of the ice margin is divided into two independent flows (tongues) (Figs. 15, 16). Such glacial relief is often formed near the scarps and slopes of Quaternary rocks.

The primary scarps are surrounded by lower-level ridge relief. They reflect a second evolutionary phase, i.e. the enlargement of the ice-divide terrain. This indicates that two ice flows moved away from each other. The lower-level ridge relief is characterized by the repeated curvature of moraine ridges and hummocks (triangular in plan view) separated by hollows. The tapered proximal upstream portion of the ice-divide is worth noting. It is here that moraine ridges of two directions converge.

It can be assumed from comparing the above characteristics with other topographically similar localities of known internal structure that these ridges reflect overthrust-folded structures (Fig. 17 B). The internal structure of the upper-level ridges is seen in a small open pit on the eastern slope of the terrain.

9. Mergubskoye. Stop 9 is north of Lake Mergubskoye (Figs. 15, 18) at the site of a Rugozero-stage marginal ridge, 6 - 7 m high and 50 - 60 m wide. Hummocky-ridge moraine relief is common on the proximal side of the ridge. Low domes and ridge-ring forms of relief are encountered in small areas. Outside the moraine area

there is an outwash plain which grades distally into a paludified glaciolacustrine plain.

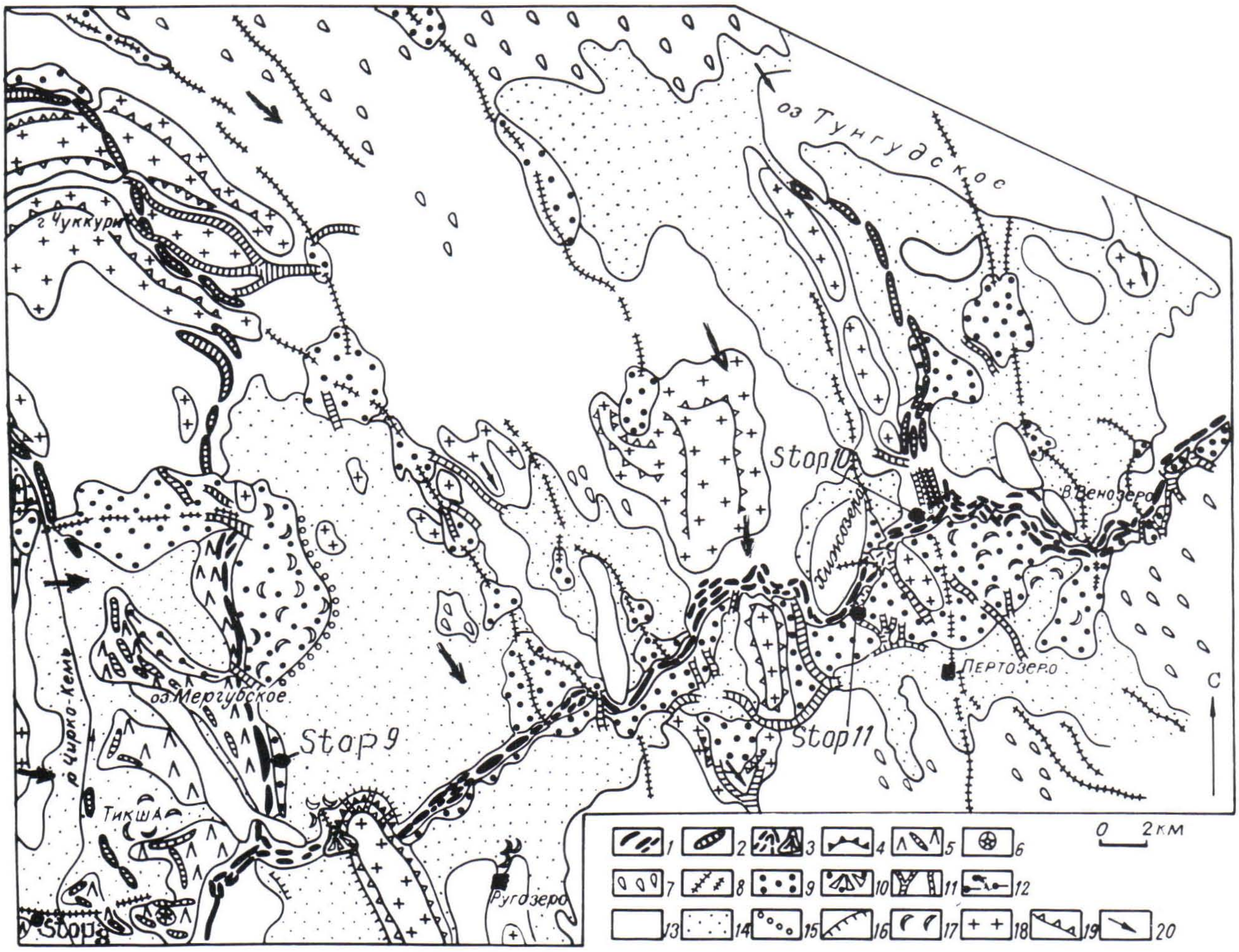

Fig. 15. Geomorphology of marginal and ice-divide zones and adjacent strata in the Rugozero - Tunguda (Rukajärvi-Tunguajärvi) area. (1) End moraine ridges. (2) Depositional ridges. (3) Minor marginal deltas. (4) Ice contact slopes. (5) Ridge-hilly moraine relief. (6) Large domal morainic hills. (7) Drumlins. (8) Eskers. (9) Thick glaciofluvial strata: deltas, outwash plains etc. (10) Large glaciofluvial deltas. (11) Meltwater channels. (12) Kame terrace. (13) Morainic plain. (14) Glaciolacustrine plain. (15) Shore ramparts. (16) Terrace cliff of a local glacial lake. (17) Dune ridges. (18) Large scarps of the crystalline basement which affected the distribution of accumulative (marginal) relief. (19) Steep slopes and cliff in the crystalline basement relief. (20) Glacial scars.

This marginal ridge seems to have been in contact with the margin of a thin ice body moving slowly eastwards. It moved towards the lateral part of a fairly active ice tongue advancing from northwest to southeast (Fig. 15). Ice movement generated an impressive marginal zone in the Rugozero - Khizhozero (Rukajärvi -

Hiisjärvi) area[6]. The lateral portions of the Rugozero tongue are restricted by prominent ice-divide glaciofluvial ridges.

The next two stops will be on the Rugozero-stage marginal strata formed by the Rugozero tongue east of Lake Khizhozero near the ice-divide zone and on the southeastern shore of the lake. These sites lie to the north of Pertozero.

10. Pertozero (Perttijärvi). The bus will stop near the place, where big marginal depositional ridges join to an ice-divide glaciofluvial ridge (Figs. 15, 19). The ridge is surrounded on both sides by deep meltwater channels. Glaciofluvial strata largely overlie moraines, partly levelling and burying them. Outside the marginal ridge there is an unusually large outwash plain which gives way to a glaciolacustrine plain. At a short distance to the east and west of the ice-divide ridge the marginal zone is represented by moraines.

11. Khizhozero (Hiisjärvi). Southeastern lakeshore. An end moraine, 8 - 12 m high, stretches along the shore (Figs. 15, 19). It is adjacent to an outwash plain. The meltwater channels observed on the inclined surface of the outwash plain are cut by transverse hollows in its distal, gently sloping portion. The water in the hollows flowed to the east. Large irregular glaciokarst lows have been found locally in the proximal part of the outwash plain, near the marginal ridges.

12. Idel (Ieljärvi). Kochkoma - Reboly (Repola) highway south of Lake Idel. The esker which extends southwards to this area from the western end of Lake Idel gives way to a glaciofluvial delta near the highway (Fig. 20). A cross-section through the delta, about 600 m wide, can be seen. The open pit wall is 10 - 12 m high. Grey loamy sandy till overlain by sand and silt has been found locally at the delta base. The till shows the unidirectional inclined-diagonal layering characteristic of deltas. It is characteristic of this part of the esker that the cross-section shows abundant boulders, gravel-pebble material and coarse sand buried under deltaic sediments.

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[6] Rugozero (Rukajärvi), one of the oldest settlements in Karelia, was first referred to in the 12th century in the Novgorod record. By the 16th century, Rugozero had grown into a big village on Lake Rukajärvi and was inhabited by Karelians (Fig. 15). The name Rugozero was borrowed for an early glaciation stage in Younger Dryas time and for the ice tongue which produced marginal ridges in the Rugozero - Khizhozero area.

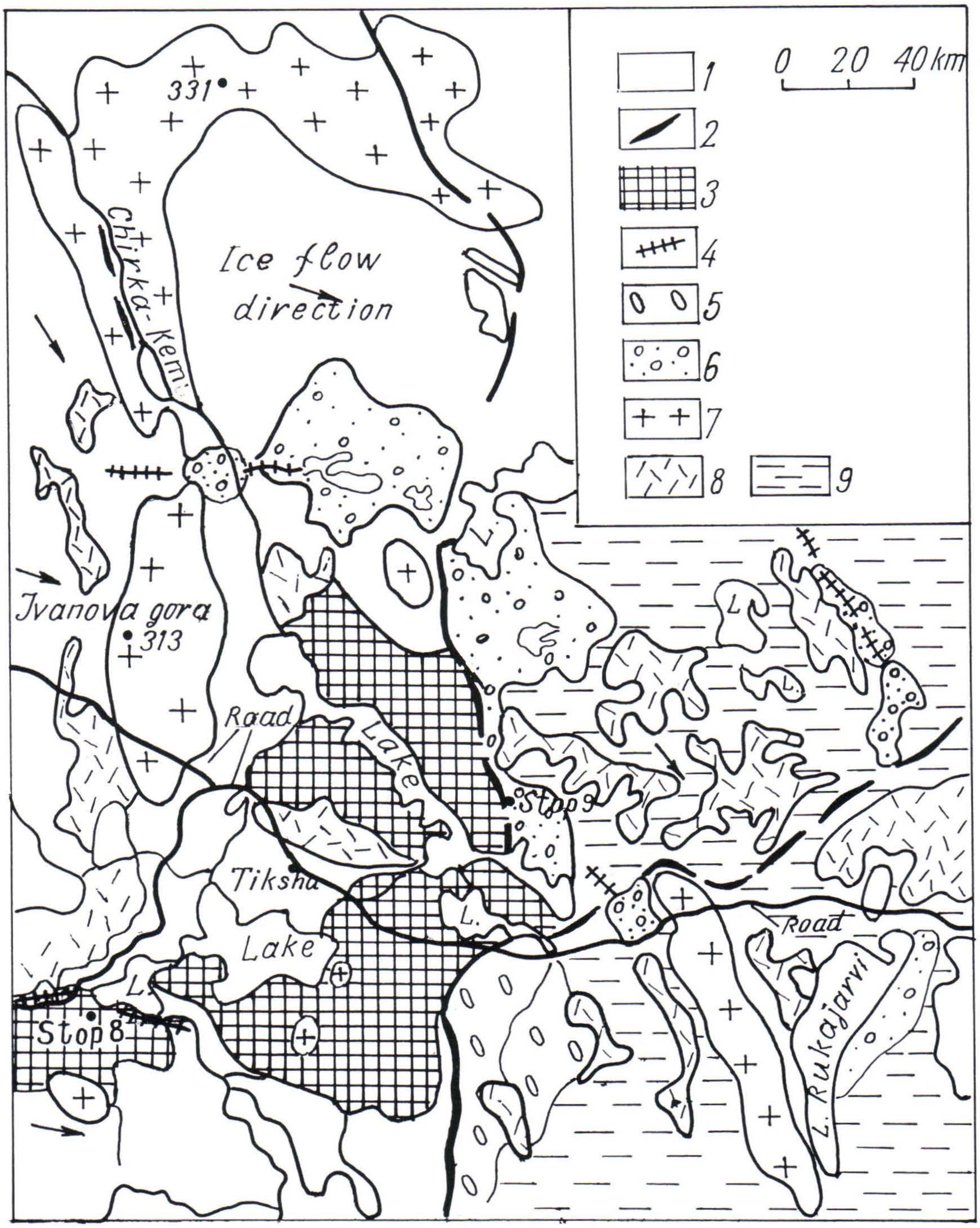

Fig. 16. End moraine ridges combined with big scaly-folded terrains. Tiksha (Tiiksi) - Rugozero (Rukajärvi) area. (1) Till. (2) End moraine ridges. (3) Hilly and hilly ridge morainic relief. (4) Eskers. (5) Drumlins. (6) Glaciofluvial deltas. (7) Crystalline rocks. (8) Mire. (9) Glaciolacustrine plain.

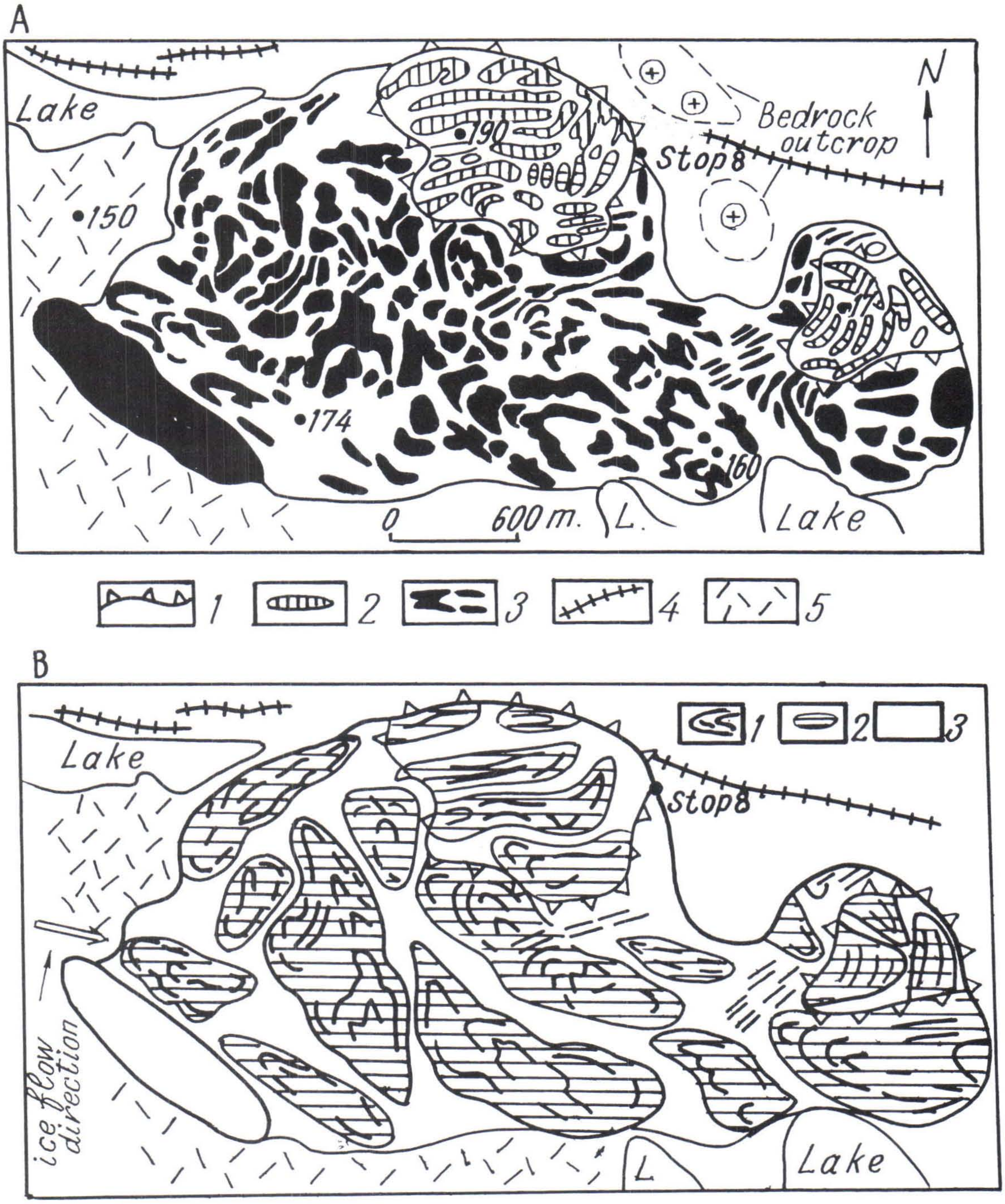

Fig. 17(A). Structure of the scaly folded morainic terrain south of Lake Kolongozero (Punsajärvi). (1) Cliff separating upper and lower relief stages. (2) Upper stage ridges. (3) Lower stage ridges. (4) Eskers. (5) Mire. (B) Glaciostructural scheme of scaly-folded morainic terrain. (1) Ridge (fold, scale) axes. (2) Synclines. (3) Anticlines.

The delta surface lies at an altitude of about 130 m above sea level and is thus 15 - 18 m higher than the surroundings. The surface of the preserved proximal portion of the delta is rough because of the presence of glaciokarst basins and meltwater channels. The location of the delta seems to indicate a short-term existence of a small local glacial lake in the area.

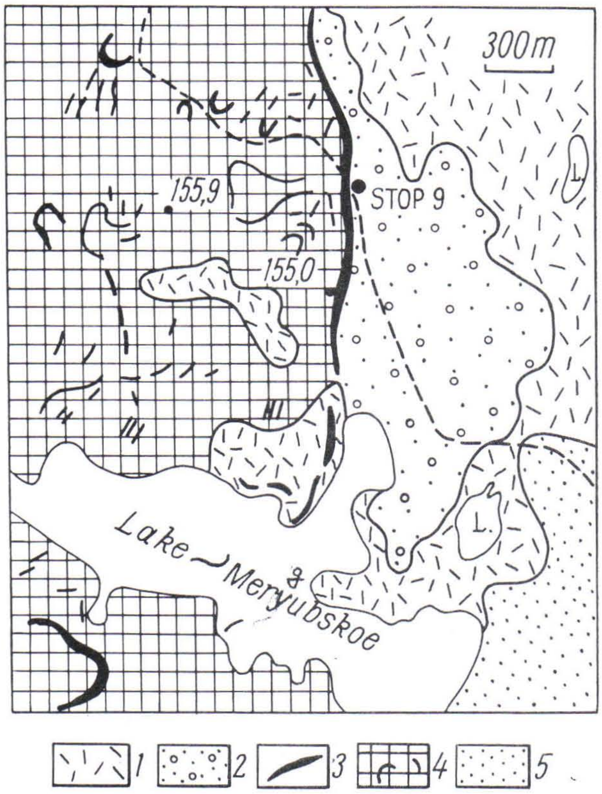

Fig. 18. Marginal frontal and interlobate zones, Lake Merguba area. (1) Mire. (2) Outwash plains. (3) End moraine ridges. (4) Hilly and hilly-ridge morainic relief. (5) Glaciolacustrine plain.

13. Parandovo. Stop 13 is 3 500 m north of the intersection of the Kochkoma - Reboly and Leningrad - Murmansk highways. There used to be an esker trending NW at 315° at this site, but it was completely destroyed when its constituents were used for building the Leningrad - Murmansk highway. Upper Archaean rocks such as diabases, gabbro-diabases, various tuffs, amphibolites and pyrite-pyrrhotite ore bodies have been found in the basement. The ore zones lie conformably with host rocks and occur as lenses 50 - 500 m long and 5 - 8 m thick. This sedimentary-volcanogenic sequence forms a zone 1-2 km wide in the granite and granite gneiss field. The whole sequence is compressed into NW-striking folds and is cut by tectonic fractures running in the same direction.

The esker deposited in a zone of tectonic disturbances, as reflected in the present day topography. Pillow lavas, tuffs and other rocks polished by flowing water crop out at the exposed base of the former esker. No glacial striae have been found.

The Rugozero (Rukajärvi)-stage marginal zone (Fig. 15), already visited at two localities north of Pertozero (Perttijärvi), extends northeast as far as the southern shore of Lake Shuezero (Suikujärvi). A long segment of the zone is shown in Fig 21. Ridge-circular and ridge-crescentic form relief, sometimes with low dome-shaped hummocks, is common inside the end moraine ridges of the area. Our studies suggest that such forms are diapirs (Iljin and Ekman, 1982) that developed when the glacier tongue was waning in this part of the zone.

14. Shuezero (Suikujärvi). Stop 14 is 1.5 km south of Lake Shuezero (Figs. 21, 22, 23), at the site of a big Rugozero-stage marginal ridge. In the north, it is in contact with the esker system responsible for the formation of a large glaciofluvial fan. The marginal ridge is overlain by abundant sorted coarse sediments. Two basal till horizons showing lamellar (foliated) structure have been found in one of the walls of a sand-gravel pit (Fig. 22 A). The structure is deformed in the lower till horizon. The till is underlain by boulder-bearing gravel layers, sand and silt lenses. All the rocks are compressed into ridge-like anticlines and gentle, flattened synclines. The anticline crests are faulted.

Meltwater channels extending distally for many kilometres divide the entire marginal zone south of Lake Shuezero into separate ridges.

Pollen analyses were made of bottom sediments from Lake Alinlampi, and a diagram with three radiocarbon datings was prepared (Fig. 23)[7]. The lake is located 1.5 km east of Stop 14 (Fig. 21), inside the end moraine ridge. The lake basin lies in the glacial depression of a small ice margin festoon. The southeastern lake-shore is formed by the proximal slope of the end moraine. The water surface is 105 m above sea level. Analysis of the lower part of the pollen diagram with its

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[7] Pollen-and-spore analysis: A.M. Kolkanen, Institute of Geology, Karelian Research Center; determination of the botanical composition of plant remains: A.A. Belova, Institute of Biology, Karelian Research Center; radiocarbon dating was supervised by A.A. Liiva, (index: "TA"), Institute of Zoology and Botany, Tartu, Estonian Academy of Science.

one radiocarbon date (10 640 ± 150 years) is essential for estimating the age of the marginal ridge on the southern shore of Lake Shuezero (Suikujärvi). In a lithological column, this portion of the diagram is occupied by mineral sediments such as sands and grey silts with clast grains of variable size.

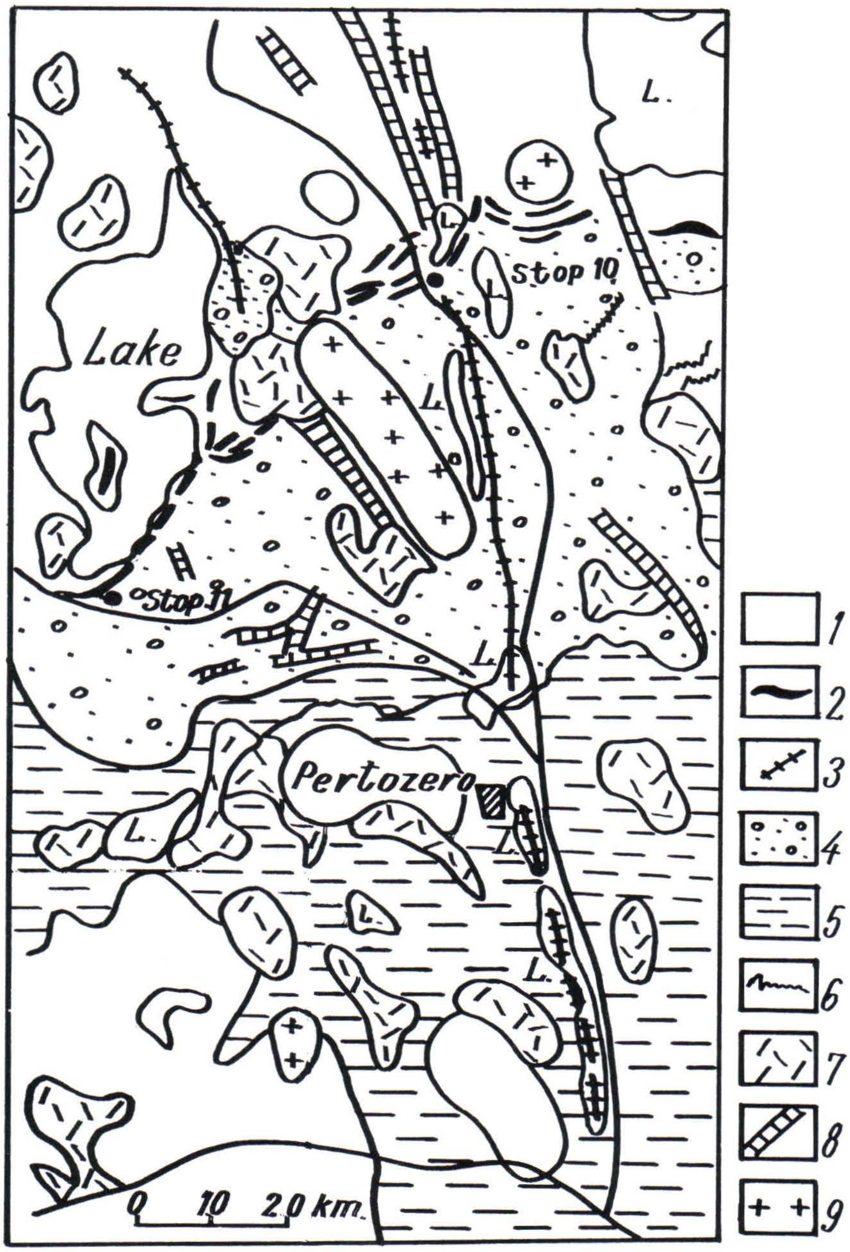

Fig. 19. Rugozero (Rukajärvi) marginal strata, Pertozero (Perttijärvi) area. (1) Till. (2) End moraine ridges. (3) Eskers. (4) Glaciofluvial plain. (5) Glaciolacustrine plain. (6) Dunes. (7) Mire. (8) Meltwater channels. (9) Crystalline rocks.

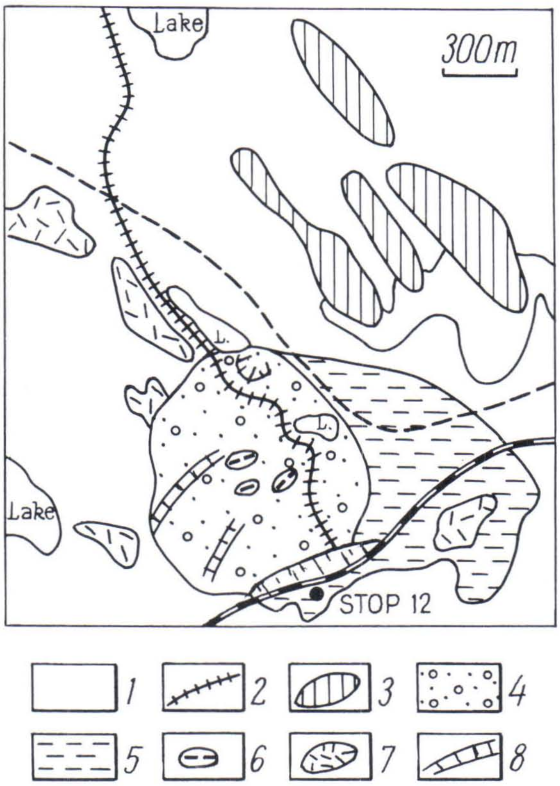

Fig. 20. Esker ridge partially buried under glaciofluvial delta south of Lake Idel (Ieljärvi). (1) Till. (2) Esker. (3) Drumlins. (4) Glaciolacustrine plain. (6) Kettle holes. (7) Mire. (8) Meltwater channels.

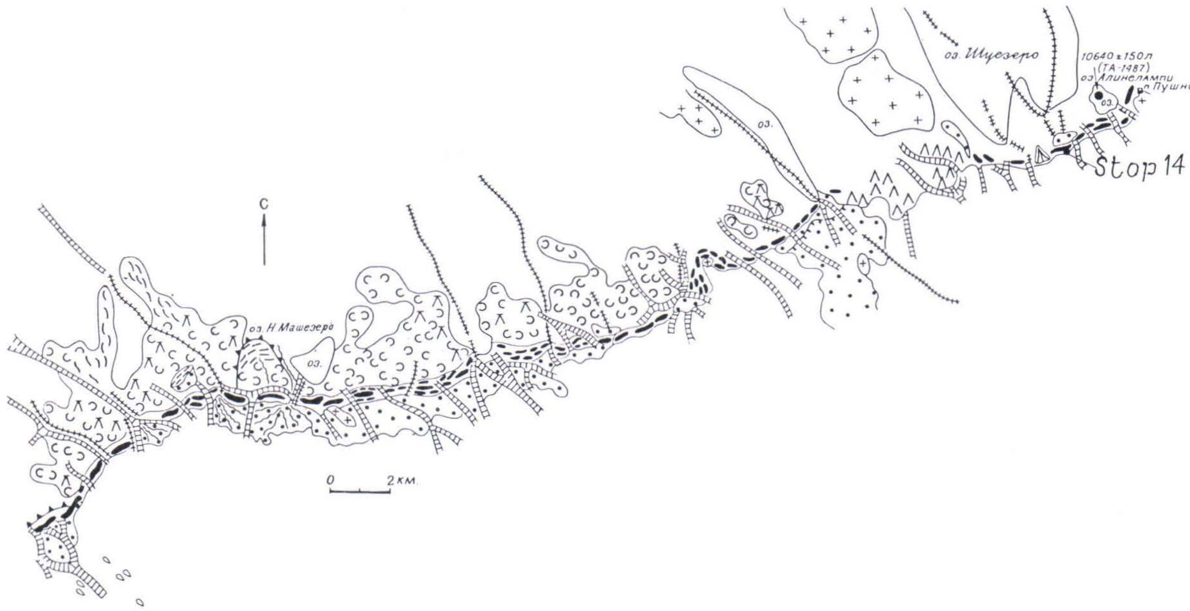

Fig. 21. Rugozero (Rukajärvi)-stage marginal strata, Lake Nizhneye Mashezero (Ala-Maasjärvi) - Lake Shuyezero (Suikujärvi) area. For explanation to symbols, see Fig. 23.

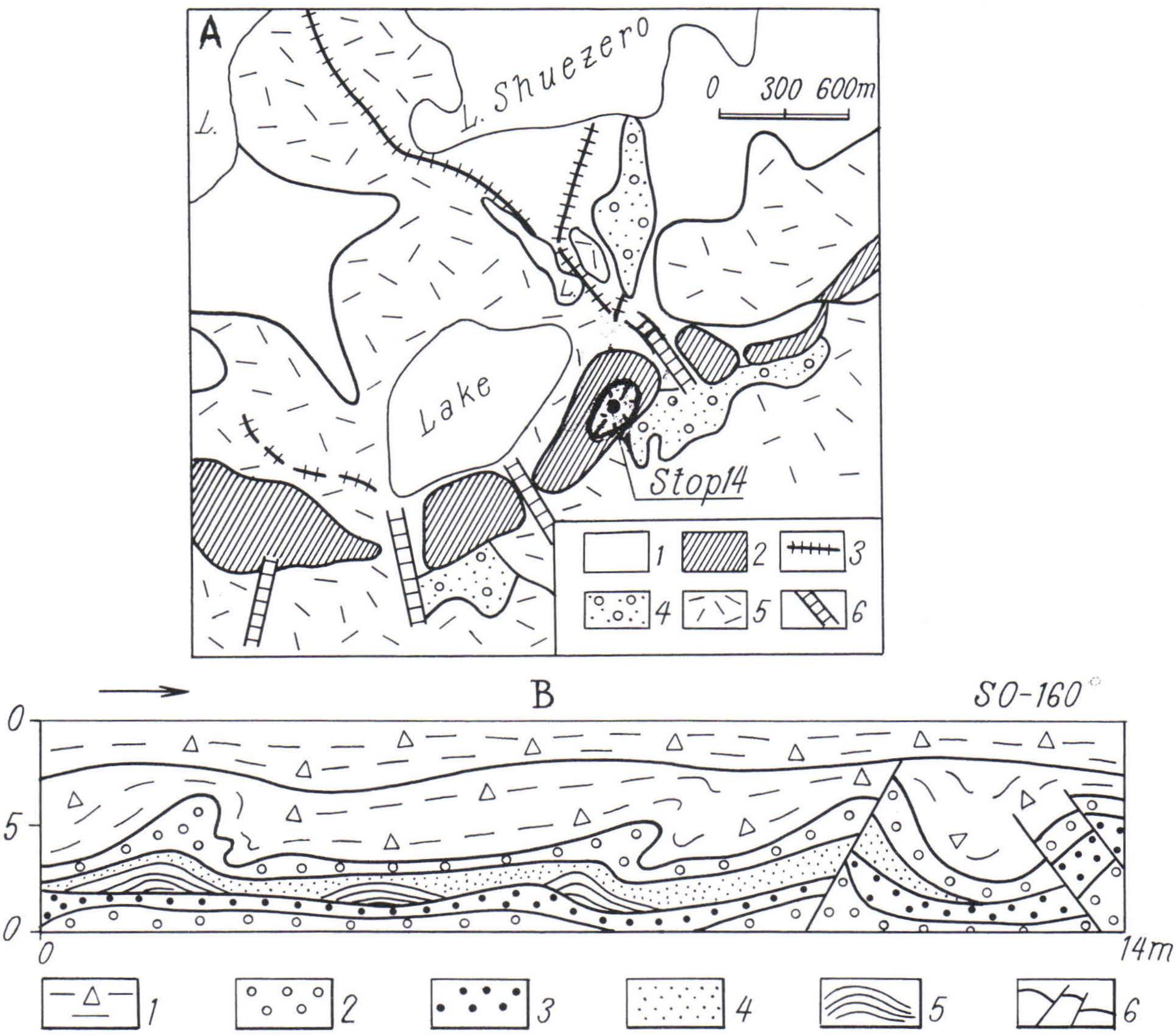

Fig. 22. Stop 14. (A). Structure of Rugozero (Rukajärvi)-stage marginal strata south of Lake Shuyezero (Suikujärvi). (1) Till. (2) End moraine ridges. (3) Eskers. (4) Glaciofluvial deltas and outwash plains. (5) Bog. (6) Meltwater channels.

(B) Cross-section through a marginal ridge. (1) Till. (2) Gravel. (3) Coarse sand. (4) Fine sand. (5) Silt. (6) Ruptures.

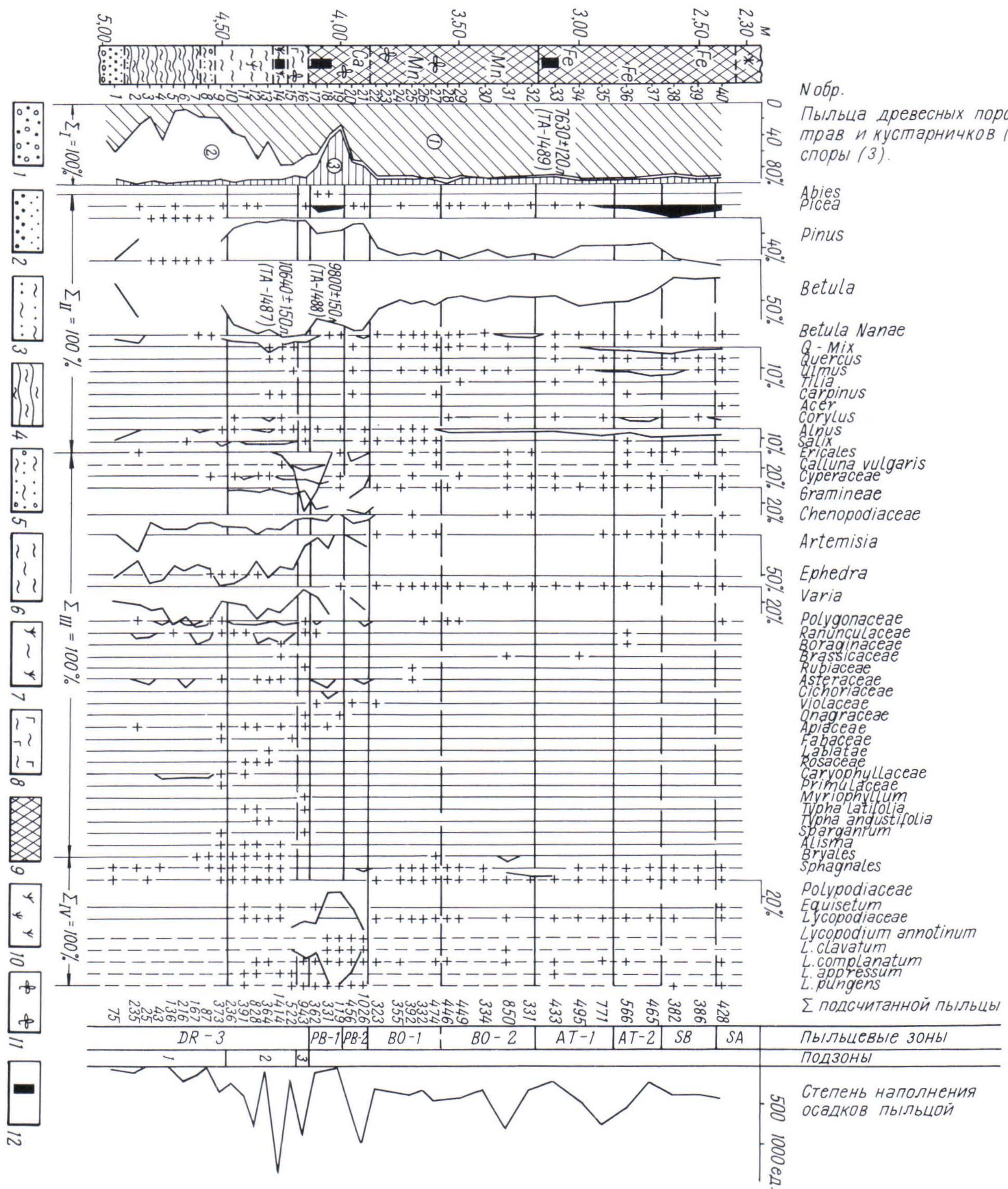

Fig. 23. Pollen and spore diagram for bottom sediments from Lake Alinlampi, south of Lake Shuezero (Suikujärvi), near the proximal slope of the end moraine (see Figs. 21 and 24). (1) Coarse sand and gravel. (2) Fine to medium sand. (3) Coarse silt grading into silty sand. (4) Light-grey fine silt. (5) Fine silty sand with pebble. (6) Light-grey silt. (7) Plant remains with silt intercalation. (8) Grey silt with humus. (9) Sapropels (symbols on column indicate: Ca - calcareous, Mn - manganous, Fe - ferrous). (10-11) Plant remains: (10) Bryales. (11) Predominance of grassy plants. (12) Samples for ^{14}C dating.

The lower part of the mineral unit (5.0 - 4.55 m interval) is mainly composed of light-grey silts with varve-like layering. These are underlain by coarse sand and gravel and overlain by fine silty sand with fine gravel inclusions. The pollen is dominated by *Artemisia* and *Chenopodiaceae*, species indicative of Arctic tundra conditions and a cold dry climate. The margin of the retreating ice sheet seems to have been close to the area. These thin-laminated silts were deposited in the local marginal ridge-dammed glacial lake which occupied the Shuezero lake basin. The level of the lake dropped when ice was removed from the runoff threshold at the northern end of the Shuezero basin and water discharged along the present Shuya river valley. Excess water had earlier discharged southwards along hollows cutting the marginal ridge.

Our calculations have shown that the glacial lake existed for no more than 100 - 120 years. Varve-like silts were deposited at the end of an early cold phase in Younger Dryas time. As indicated by the pollen diagram, the overlying nonlamellar silts (4.55 - 4.20 m) were formed under warmer climatic conditions. Birch forests consisting largely of *Betula nana* and *Salix* spread over the area. Grasses are dominated by *Artemisia* and *Chenopodiaceae*, although *Gramineae*, *Polygonaceae* and *Ranunculaceae* are fairly common, too. This evolutionary pattern of vegetation suggests that the territory was occupied by birch forest tundra.

Plant macroremains, which increase in abundance upwards, have been found in the silt of this horizon. Silt enriched in well-preserved plant remains makes up the upper portion of the middle mineral sedimentary unit. *Drepanocladus* (dominant species) and *Calliergon* were only revealed after the plant remains had been submitted to botanical study. One sample taken from the mosses was dated to 10 640 ± 150 (TA - 1 487) years by a radiocarbon method.

The lake, in which grey silts and mosses were deposited, was characterized by a regime common for northern bodies of water. Preliminary assessment suggests that deposition of this silt horizon could not have lasted longer than 150 - 200 years. Such a time span is roughly consistent with the interphase warming of climate that took place in mid - Younger Dryas time.

If we consider all the estimates for Younger Dryas depositional processes and radiocarbon datings, it can be argued that the ice margin retreated from the end moraine zone on the southern shore of Lake Shuezero 10 850 - 10 900 years ago.

The thin silt layer (4.25 - 4.15 m) developed in the late Younger Dryas, when the climate was colder and the Kalevala-stage ice sheet was moving. This is reflected above all in the total pollen and spore composition and in the increased proportion of grassy plants.

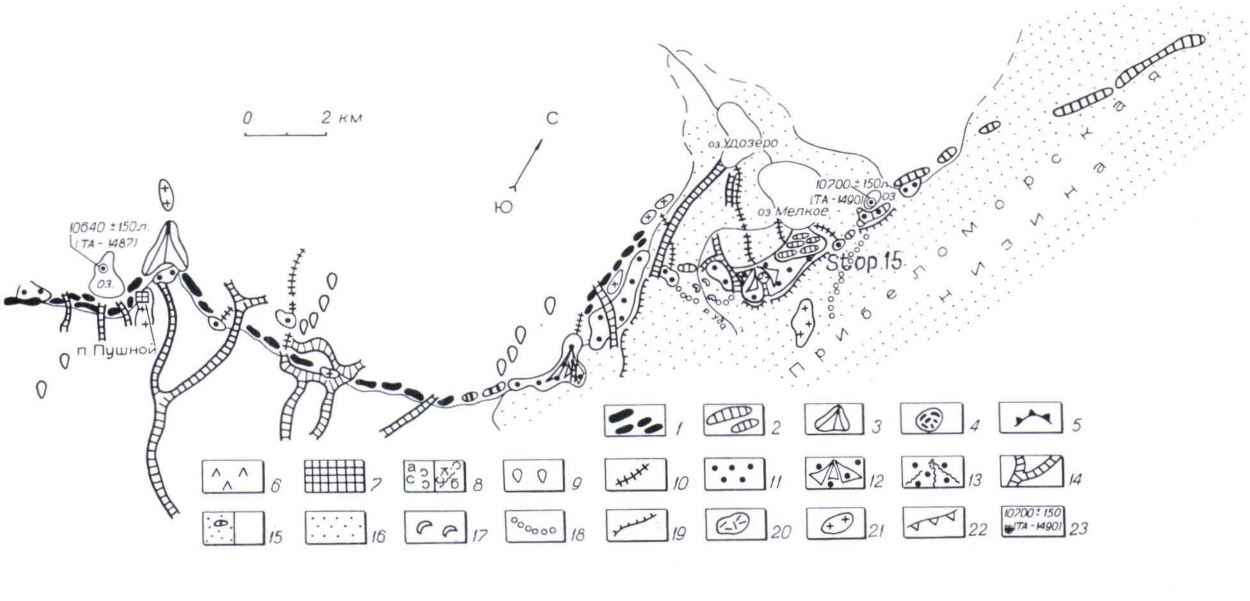

Fig. 24. Rugozero (Rukajärvi)-stage marginal strata, Lake Shuyezero (Suikujärvi) - Lake Udozero area, SW White Sea region. Late glacial White Sea basin evolution area. (1) End moraine ridges and bands of linearly oriented ridge relief. (2) Depositional marginal ridges. (3) Ice-divide terrains. (4) Scaly-folded morainic terrains. (5) Marginal scarps. (6) Hilly-morainic marginal relief. (7) Hilly moraine and kames. (8) Ridge-circular relief: a - dominated by circular and crescent-shaped ridges (circular diapirs); b - together with flattened kames, domal diapirs and small esker ridges. (9) Drumlins. (10) Eskers. (11) Outwash plains, glaciofluvial fans and deltas. (12) Glaciofluvial deltas of eskers, runoff delta mouths and meltwater channels. (13) Well-defined glaciofluvial fans. (14) Meltwater channel. (15) Morainic plains. (16) Glaciolacustrine and glaciomarine plains. (17) Dunes. (18) Bars. (19) Abrasion cusps. (20) Mire. (21) Basement scarps. (22) Cusps in crystalline basement. (23) ^{14}C datings of organic matter from the basal layers of bottom sediments in small lakes.

15. Melkoye. Stop 15 is 8 km (340°) northwest of Sosnovets (Sosnavitsa) in the Lake Melkoye area. A Kalevala-stage marginal zone extends from Lake Shuezero (Suikujärvi) to this area (Fig. 24). End moraine ridges, with their upper portions composed of glaciofluvial material, are observed. The position of the ridges, which are 15 - 20 m high, reflects the lamellar structure of the marginal zone. Eskers join to the proximal side of the marginal ridges, whereas glaciofluvial deltas lie outside. The delta surface, which is at 70 - 75 m above sea level, reflects the level of the marine-glacial reservoir in the White Sea basin.

A sample taken from an organic layer of bottom sediments in a small lake 1 km east of Lake Melkoye (Fig. 24) was dated by a radiocarbon method. The date obtained is 10 700 ± 150 (TA - 1 490) years. The lake lies near the proximal slope of the marginal ridge.

16 - 17. Rock carvings (petroglyphs) of the White Sea region[8]. Hundreds of isolated figures and dozens of scenes were carved on the gently sloping walls of granite islets at the mouth of the River Vyg (Uikujoki), 6 - 7 km from where it enters the White Sea. The carvings are now regarded as the finest example of primaeval rock art in the European North. They illustrate the life of ancient people, their awareness, cultural level, perception of the environment and spiritual requirements. It is one of the largest and most impressive collections of rock carvings in Northern Europe. Their topography is unique. Silhouettes carved with a rock chisel are predominant. The pictures include men, anthropomorphous beings, boats, forest and sea animals, bows, arrows, harpoons and skis. Fishing, hunting and battle scenes are abundant. The pictures succeed each other in time and so the evolution of rock art can be traced. The human image gradually gains prominence, and the number of impressive narrative carvings increases. Comparison with rock carvings in Besovy Sledki, Yerpin Pudas and Staraya and Novaya Zalavruga reveals the great progress made by those who contributed to this rock record kept some 5 - 4 millenia ago, from the late Atlantic to the Subboreal period. Variations in sea level, changes in both climate and vegetation etc. affected the economic and spiritual life of the people who settled on the lower River Vyg.

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[8] Described by Dr. Y.A. Savvateyev (1970, 1977, 1984, 1990). His monograph deals with monuments of ancient rock art.


Таблица 22
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Fig. 25. Besovy Sledki. Figs. 25-30, photo Y.A. Savvateyev.

Fig. 26. Besovy Sledki. Detail of central portion (See Fig. 25).

The area was the centre of an unusual sanctuary where important rites were performed by the primeval communities in the hope of well-being and prosperity.

16. Besovy Sledki. (Fig. 25, 26). The group includes more than 400 figures dominated by forest and sea animals such as reindeer, elk and white whale. Birds, boats and human figures are common. The carvings, although abundant, seem to be without any order and differ in both size and orientation. Compositions are very few. The figures are not contemporaneous, each "layer" representing a certain time span. The Demon with his huge phallus was carved at the final stage of this creative work.

17. Zalavruga (Figs. 27 -29). The group consists of some 1500 figures testifying to a new stage in the evolution of rock art in the White Sea region. Narrative scenes, each with many figures, are characteristic. White whale, seal and whale hunting scenes are common. The people hunting for forest animals and birds carry bows and arrows. Skiing hunters are carved for the first time. Although partly based on fantasy and imagination, the scenes look fairly realistic. They do not merely show life, but reflect the human perception of the world with a mythological bias.

18. Kepa I[9]. Dunes occupy an area of no more than 200 km^2. They are composed of aeolian sand transported from glaciofluvial and glaciomarine strata. They also cover large areas to the west, in the near-frontal strip of Kalevala-stage marginal ridges. Aeolian hummocks and crescentic forms and less common linear ridges have been distinguished. The dune vegetation cover is disturbed by economic activities nowadays and as a result, the sand is transported by wind, as observed in the village of Kepa.

19. Kepa II. Stop 19 is 5 km west of the village of Kepa. The glaciofluvial delta is located to the east of the Kalevala-stage marginal ridges (Fig. 31). Sandy and sandy-gravel members with current bedding, have been revealed in a pit. Their visible thickness is some 10 m. The diagrams show the structure of the glaciofluvial sequence. The delta surface (130 m above sea level) corresponds to the highest level of the postglacial brackish water body which existed in the area.

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[9] Site description 18 and 19 prepared by I. Demidov.

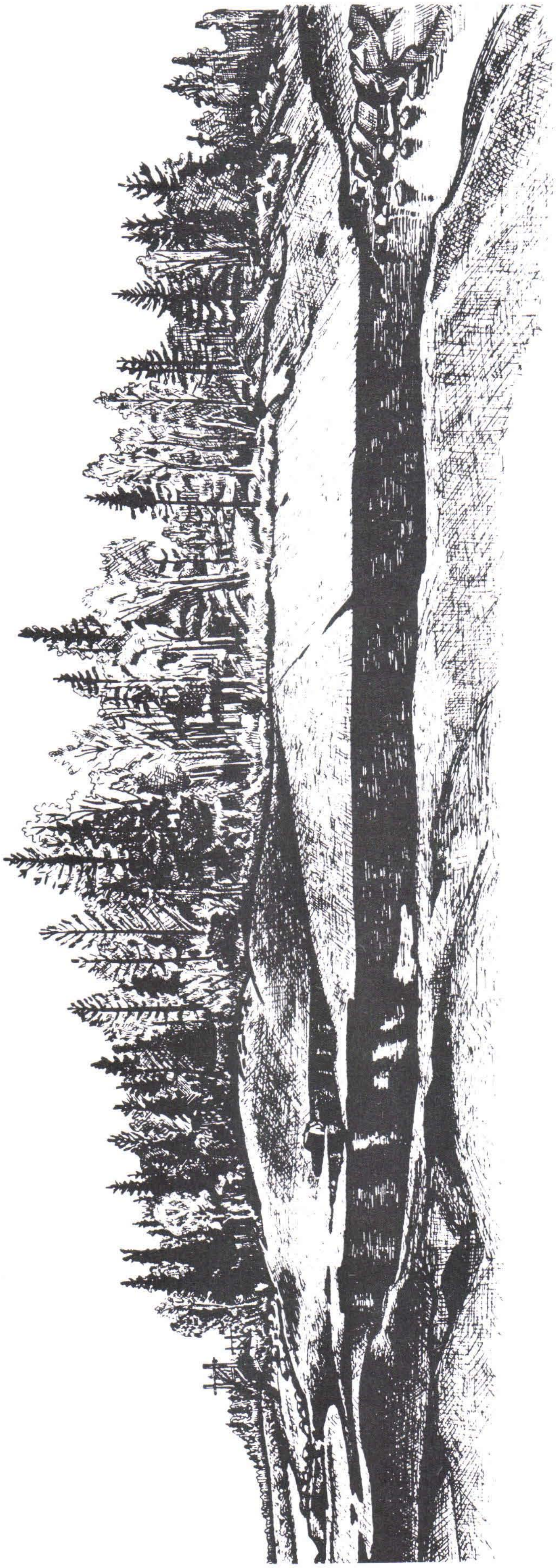


Fig. 27. General view of Zalavruga before excavation.

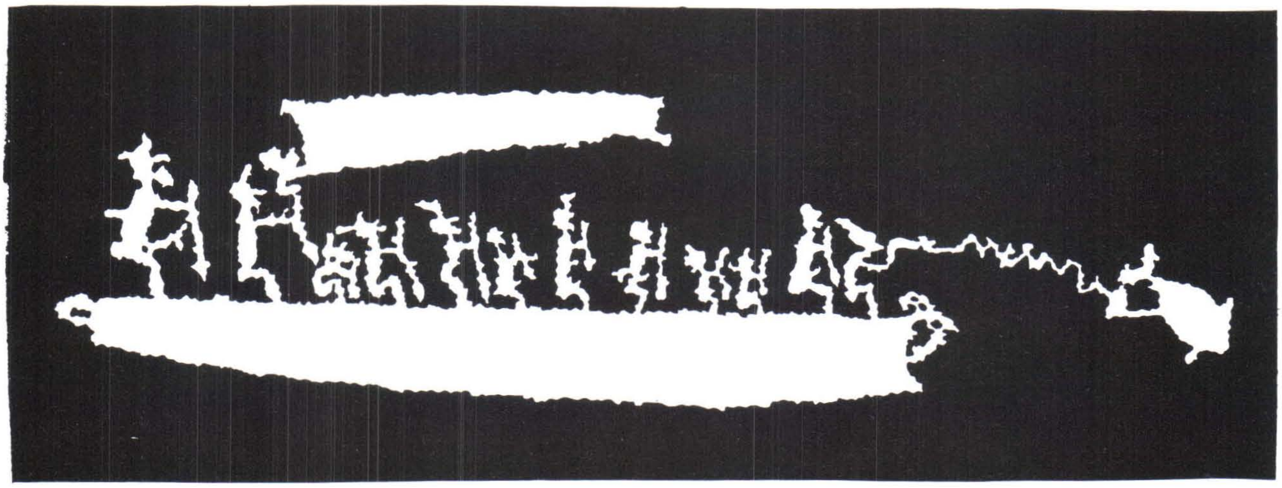


Fig. 28. Fishing scene. Novaya Zalavruga; Group IY.

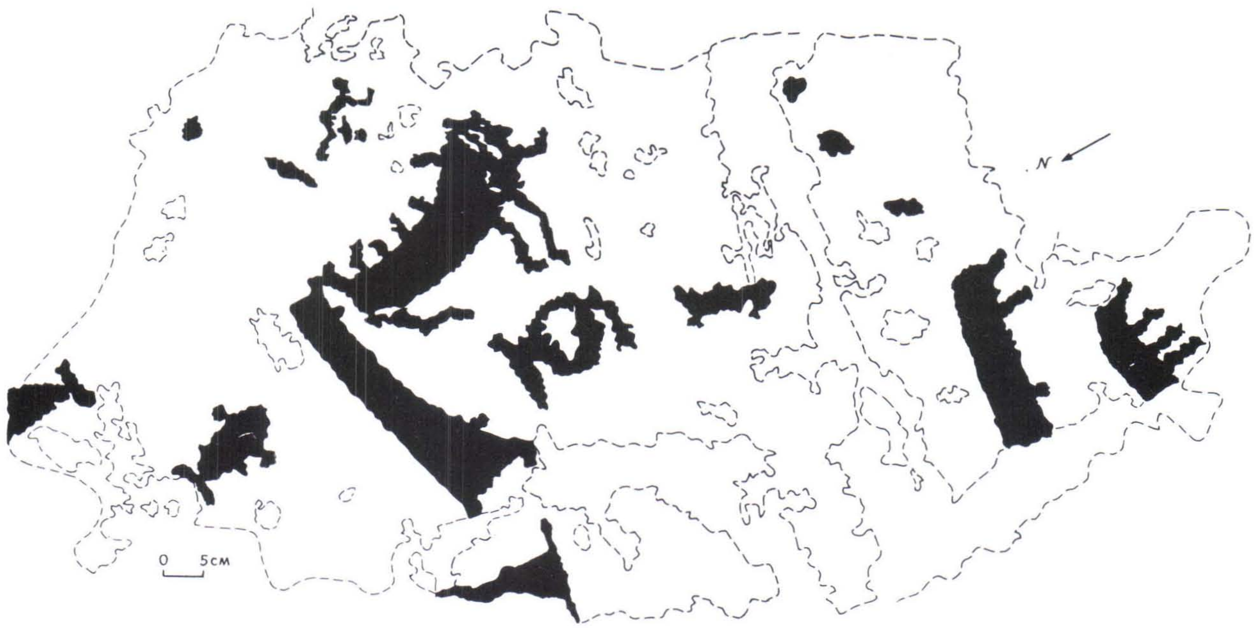


Fig. 29. Boats and other figures. Novaya Zalavruga, Group XYI.

Fig. 30. Chasing a white whale with a harpoon and other carvings. Novaya Zalavruga, Group XXI.

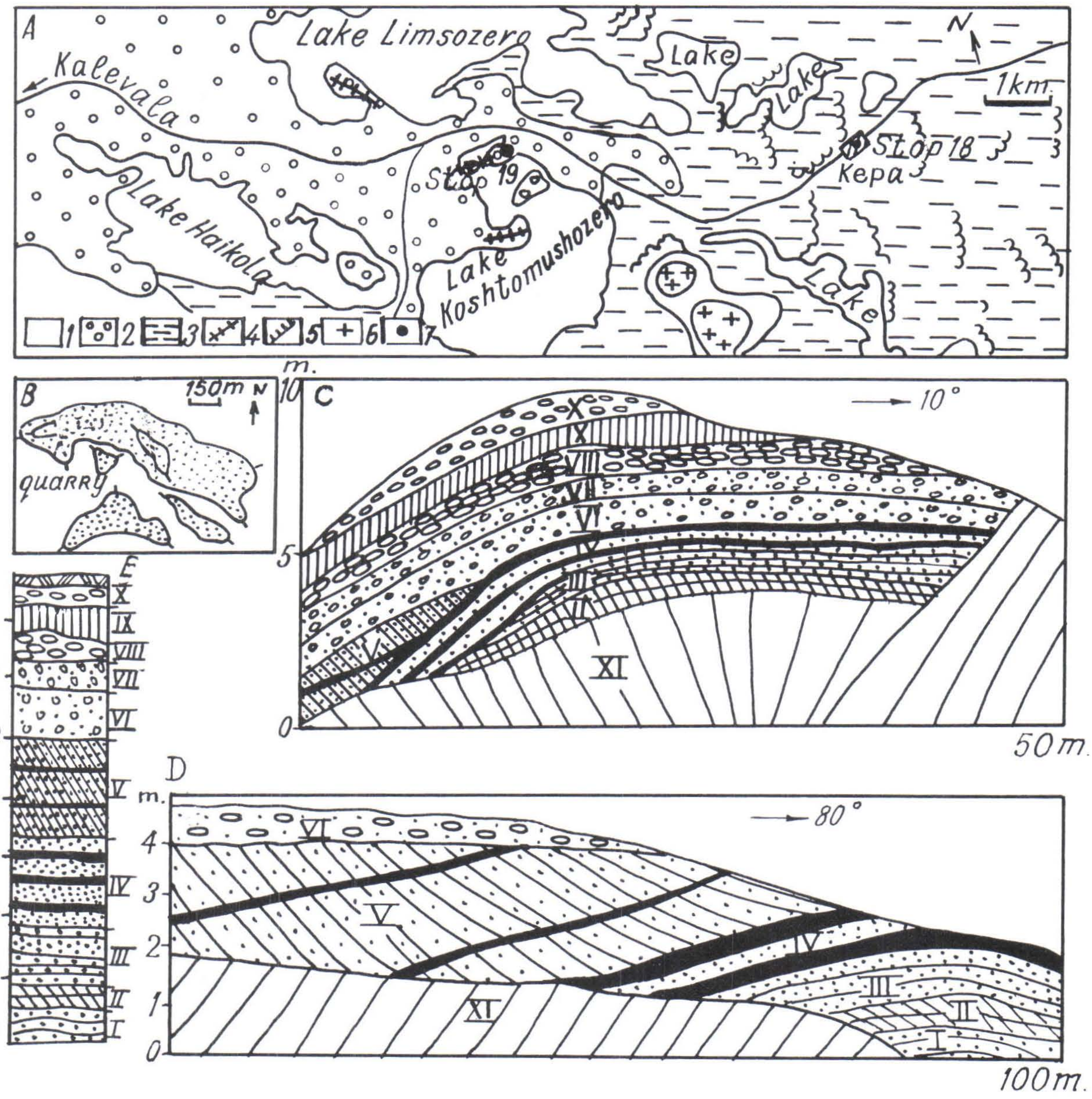


Fig. 31. Glaciofluvial delta, Kepa area.
(A) Geomorphologival structure of the Kepa - Lake Haikola area. (1) Till. (2) Glaciofluvial plain. (3) Glaciolacustrine plain. (4) Eskers. (5) Dunes. (6) Crystalline rocks. (7) Location of section (Stop 19).
(B) Plan of delta. (C.D) Section through delta. Lithology: 1 - horizontally layered medium sand, II - current-bedded medium sand, III - subhorizontal medium sand, IY - silty and fine sand, Y - current-bedded medium sand with gravel and pebble intercalated with silt, YI - nonlayered gravel-pebble strata, YII - current-bedded gravel-pebble strata, YIII - cobble round-stone, IX - loessal loamy sand with columnar jointing, X - gravel and pebble, XI - talus.

20. Päivä-I. Stop 20 is 4 km north of Lake Päivä, on the upper River Luashtanga. Diabase porphyrites are exposed over an area of 220 x 300 m^2 and lie 3 - 5 m higher than the surrounding plain (Fig. 32). The exposed surface is smooth and locally well-polished. The polished diabase porphyrite surfaces exhibit well-defined glacial striae. A Kalevala-stage moraine ridge stretches northwestwards near the southwestern slope of the outcrop. Outcropping porphyrite blocks, which have disturbed the polished surfaces and shifted glacial striae, have been found in the eastern part of the outcrop (Fig. 32 A- instrumental plan of site; Fig. 32 B- Block-diagram of site). This apparently tectonic feature, which can be regarded as a certain type of glacial dislocation, resulted from the pressure exerted by ice on the rock scarp and the squeezing-out of porphyrite blocks along foliation zones.

Similar outcrops occur elsewhere in the area. However, they are far from the marginal ridge zone, and no disturbances have been found on their surfaces.

20-I. Päivä-II. Stop 20-I is 2.2 km north of Lake Päivä. The structurally complex scaly-overthrust terrain lying 25 -30 m above the surroundings consists of ridges separated by lows. It is a composite glaciotectonic unit, as indicated by the morphology, conformable curvatures and unconformable contacts of the ridges.

21. Päivä-III. Stop 21 lies east of Lake Päivä, near the Kem - Kalevala highway. The marginal unit to be examined developed in the lateral part of the ice flow and seems to be an outwash plain (Fig. 32). Because the proximal slope, which extends for tens of metres, is unusually steep and high it can be defined as marginal. An esker with a widened delta-like end joins to the slope at an acute angle. A chain of kettle holes stretches almost continuously parallel to the marginal slope. The kettle holes are often elongated (length 0.7 - 0.8 km) and very deep (8 - 12 m or more). Meltwater channels are observed on the surface of the outwash plain. At the end of its distal portion there is a steeper portion of the slope shown in Fig. 32. Marginal ridges could have been buried under thick glaciofluvial strata.

The strip of Kalevala-stage marginal zone between lakes Haikola and Päiväjärvi is an impressive and interesting area (Fig. 33). Both Yushkozero (Jyskyjärvi) station and the old Karelian village of Yushkozero, remarkable for their northern wooden architecture, will be visited. On the drive south from Lake Haikola through this marginal zone, participants will see end moraine ridges for tens of kilometres on their right.

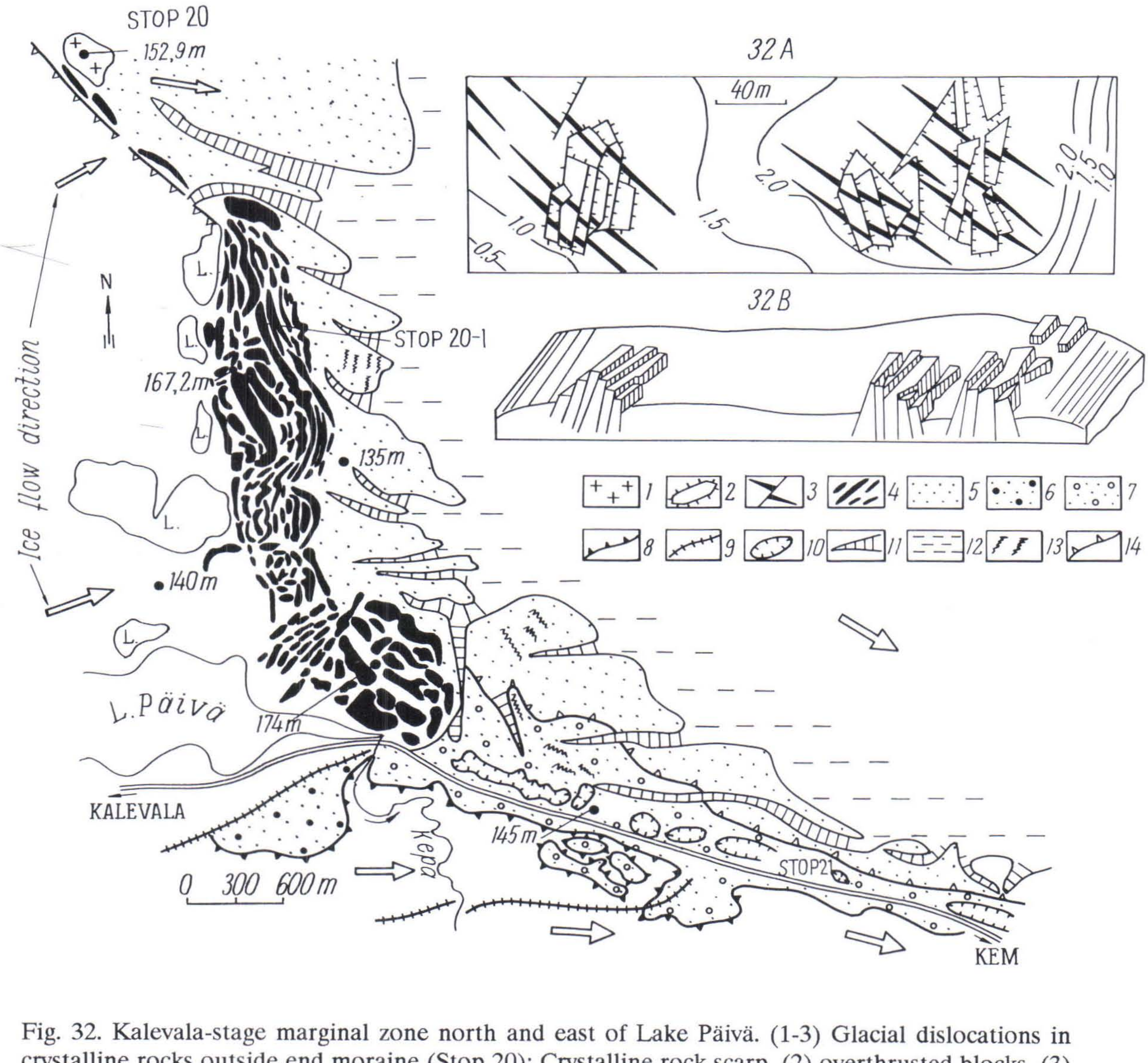


Fig. 32. Kalevala-stage marginal zone north and east of Lake Päivä. (1-3) Glacial dislocations in crystalline rocks outside end moraine (Stop 20): Crystalline rock scarp. (2) overthrusted blocks. (3) glacial striae. (20 A) Plan of glacial dislocations. (20 B) Block diagram. (4) Marginal ridge relief of scaly - thrust origin. (5) Lower-level outwash plain. (6) Glaciofluvial fan. (7) Late upper-level outwash plain. (8) Cusp-slope of ice contact. (9) Eskers. (10) Kettle hole. (11) Meltwater channel. (12) Glaciolacustrine plain. (13) Ridge dunes. (14) Slope separating outwash plains of different levels.

22. Shonga (Shonanniemi). Stop 22 is south of the former village of Shonga. Thick NW-trending marginal strata were deposited here at 173.8 m above sea level (relative altitude about 70 m). This unusually big ridge-shaped unit consists of a series of subparallel ridges that reflect the scaly overthrust structure of the marginal zone.

A glaciofluvial delta is observed outside the marginal moraine at an altitude of the former village. It lies at 127 m above sea level, an altitude that indicates the upper level of the glacial-marine body which existed in the area in Younger Dryas time. A long esker joins the proximal side of the marginal zone. An extensive area to the east is occupied by an intensely paludified plain partly composed of argillaceous sediments from a big periglacial reservoir connected with the slightly brackish White Sea basin.

23 - 24. Päiväjärvi. Composite Kalevala-stage marginal strata occur either as moraine ridges (Stop 23) or as big composite accumulative terrains well-defined in the Päiväjärvi area (Stop 23 a).

A few accumulative terrains separated by glaciolacustrine plains and meltwater channels occur in the area. They are subdivided morphologically into two groups:

The first group (Stops 23, 23 a) forms a strip in the marginal zone and lies 22 - 41 m above the surrounding plains. The terrains are characterized by composite ridge and ridge-hummocky relief with numerous kettle holes. The complex topographic pattern is due to undulating ridges. The outlines of the multiple curvatures in the neighbouring ridges resemble those of folded structures, this suggesting that the above terrains represent composite lamellar-folded glaciotectonic strata.

In the east, the marginal zone is adjacent to a glaciofluvial delta which is seen as a 250 to 400-meter-wide strip. The absolute altitude of the delta surface is 122.7 m. The distal slope of the delta is cut by the abrasion cliff of the periglacial reservoir. The cliff is 17.5 m high, with 2 to 3-metre-high bars located at the cliff edge. A heavily paludified glacial-marine plain composed mainly of silt and varved clay lies east of the abrasion cusp. Bars forming a series of subparallel ridges protrude from the thin peat cover in the inland part of the plain near the abrasion cliff base.

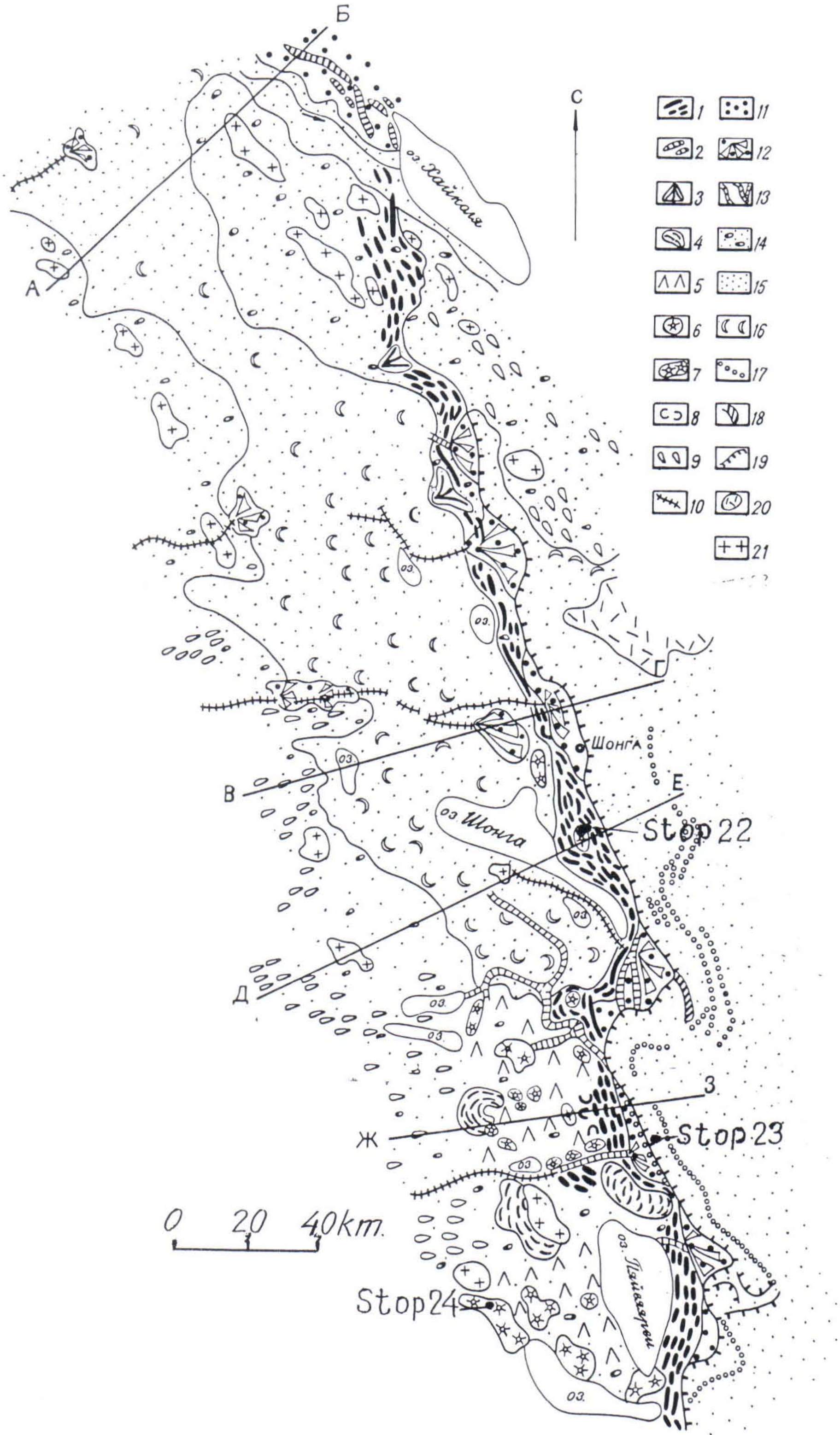


Fig. 33. Kalevala-stage marginal deposits, Lake Haikola - Shonga (Shonanniemi) - Lake Päiväjärvi area.

(1) End moraine ridges. (2) Depositional marginal ridges. (3) Ice-divide terranes. (4) Scaly-folded morainic terranes. (5) Hilly-morainic relief. (6) Domal hills (domal diapirs). (7) Morainic terrains with domal hills. (8) Ridge-circular relief. (9) Drumlins. (10) Eskers. (11) Outwash plains. (12) Glaciofluvial deltas. (13) Meltwater channels. (14) Morainic plains. (15) Glaciolacustrine and glacial-marine plains. (16) Dunes. (17) Bars. (18) Accumulative spits of land. (19) Abrasion cliff. (20) Mire. (21) Crystalline rock scarps.

The second group consists of terrains at a certain distance from the marginal zone (Stop 24). They constitute large hummocky units lying 36 - 65 m above the surrounding plains. Big hummocks and ridges with convex monolithic slopes locally disturbed by glacial meltwater channels and landslides rest on a common base within the above terrains.

25. Yushkozero (Jyskyjärvi). Yushkozero station area. An end moraine ridge extends along the western boundary of the village (Fig. 35). It is 5 - 6 m high and about 40 - 50 m wide. The ridge is composed of grey schistose till with magnetite quartzite clasts in its gravel-pebble fraction. The clasts have been transported from the Kostomuksha iron deposit 80 km away. Hummocky-ridge moraine relief is observed over a large area to the south. It is one of the biggest ice-divide deposits in the Kalevala marginal zone. An esker trending NE at 75° stretches northwestwards from Yushkozero. The end portion of the esker is a marginal delta. In this part of the marginal zone the delta surface lies at 110 - 115 m above sea level.

South of the glaciofluvial delta, the marginal deltas are adjacent to an outwash plain, its sandy-gravel sediments showing a composite type of current bedding (Fig. 35 B). East of Yushkozero station, there is an esker trending SE at 130° that it is partly buried under Kalevala-stage glaciofluvial sediments. This radial esker stretches southeastwards for tens of kilometres. Rugozero-stage ice flows moved in the same direction, whereas Kalevala-stage ice advanced toward Yushkozero station.

26. Regozero (Röhö). The name is shared by a former village and a lake. South of Regozero, the road crosses the drumlin plain of the Päozero - Engozero drumlin field. We will examine it over a distance of 20 km. The drumlins are ellipsoidal-elongated to fusiform. They occur both individually and as shields, with adjacent drumlins forming isolated groups. These forms of relief are 0.8 - 2.5 km long, 500 - 600 m wide and 10 - 12 high.

27. Tungozero (Tunkujärvi). The area is remarkable for both the size and composite geomorphological structure of the Younger Dryas marginal zones (Fig. 36). Note that the relative altitude of some of the macroforms of marginal relief is 80 - 90 m in this area. Such tremendous glacial landforms seem to be uncommon in Fennoscandia.

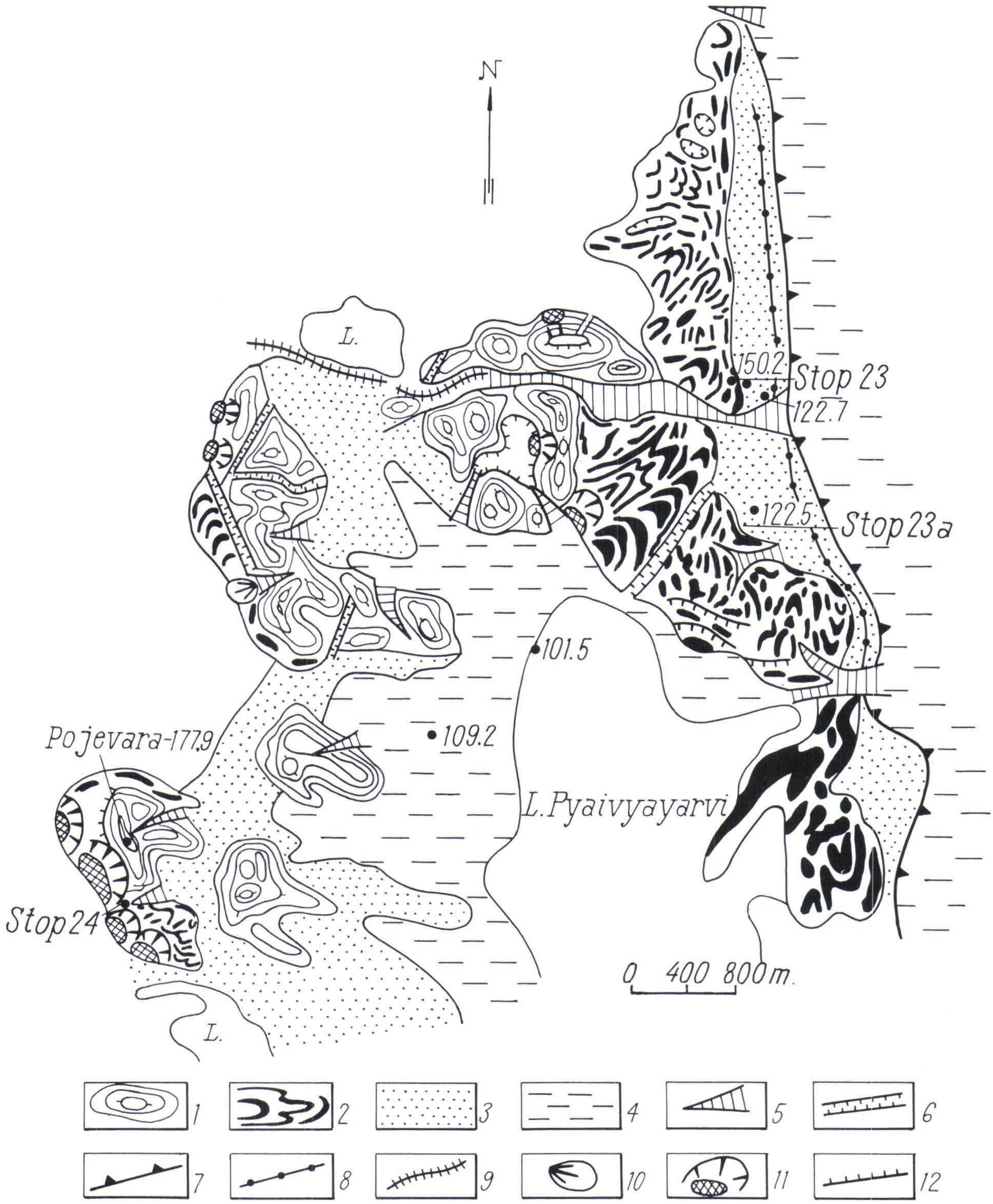


Fig. 34. Kalevala marginal strata, Lake Päiväjärvi area.
(1) Big hills and clusters of hills. (2) Scaly-folded terranes. (3) Outwash plains. (4) Glaciolacustrine and glacial-marine plain. (5) Meltwater channels. (6) Rectilinear cracks. (7) Abrasion cusp. (8) Bars. (9) Eskers. (10) Fans at the mouth of meltwater channels. (11) Landslides. (12) Steep slopes and cliffs.

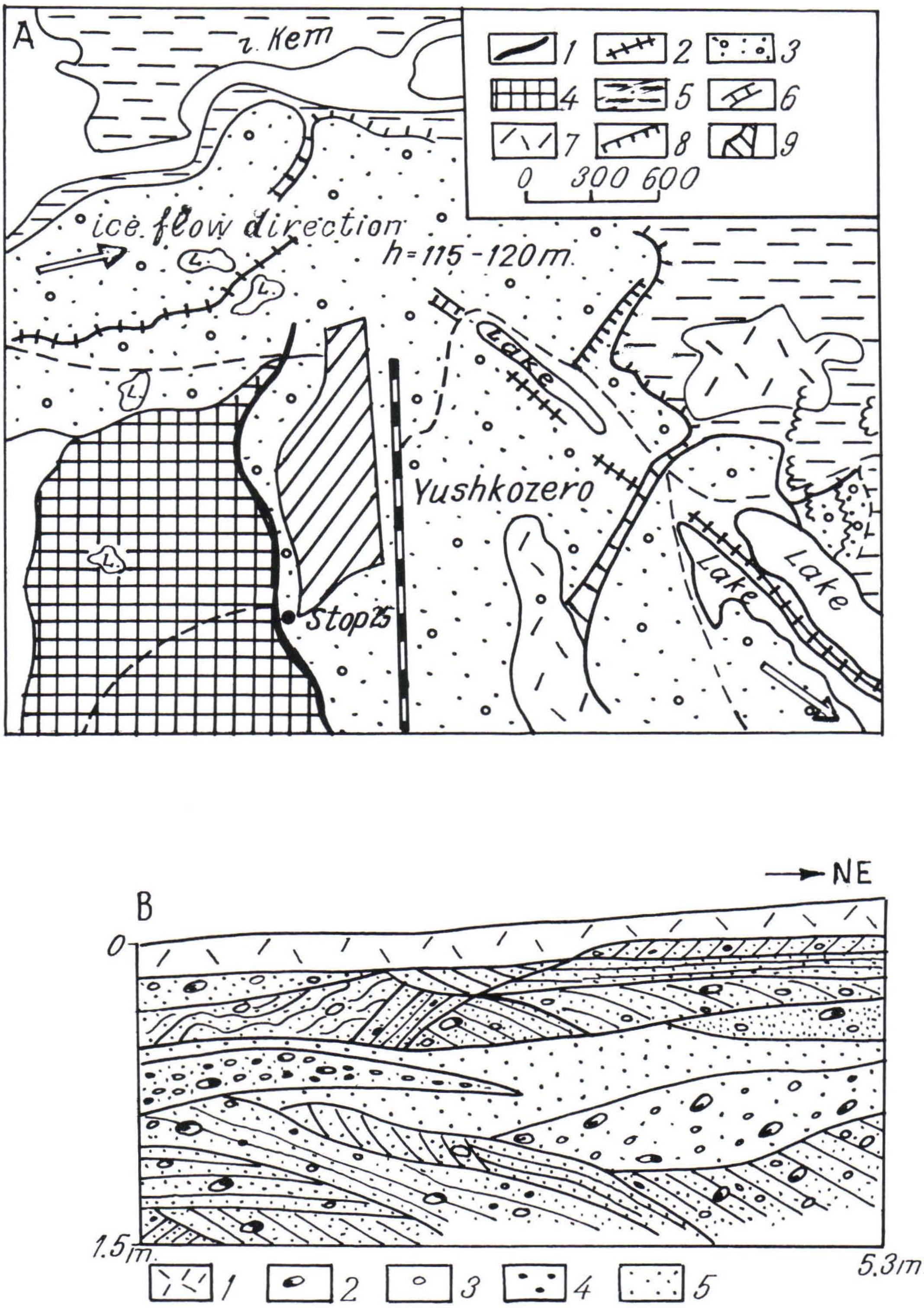


Fig. 35. (A) Kalevala-stage marginal strata near Yushkozero railway station.
(1) End moraine ridges. (2) Eskers. (3) Glaciofluvial deltas and outwash plains. (4) Hilly-ridge morainic relief. (5) Glacial-marine plain. (6) Meltwater channels. (7) Terrace cliffs. (9) Yushkozero area. (B) Section through outwash plains: (1) Mire. (2) Boulders. (3) Pebble. (4) Gravel. (5) Sand.

The internal structure of the units making up the marginal zone and the whole complex could hardly be more diverse. It is not easy to interpret the environment and deposition sequence of such a highly composite marginal landform at the final evolutionary stage of the ice sheet in late Pleistocene time, when the ice was very thin (50 - 60 m) at the periphery of the continental glacier. Further investigations is required. The difficulty of resolving the problems is compounded by a lack of deep open sections in the area, which would provide insight into structure and composition of individual landforms.

Two zones of diffirent age can be distinguished within this big belt of marginal strata. The first zone developed along the entire ice front in the course of major glacier advance. The zone extends from SW to NE to the southern shore of Lake Tungozero and then turns north along the eastern shore. The zone is not related morphologically to the marginal relief observed to the west.

Five segments differing in morphology, in orientation and size of landforms and in their functional role and position relative to the ice margin are distinguished in the above zone.

Thus, the big bar-like terrain with a rugged surface south of Lake Käppelä is clearly a frontal marginal push sequence. This is also indicated by the subparallel position of the winding ridges observed on its surface. These are generally oriented along the long axis of the bar-like terrain, which lies at a relative altitude of 60 - 70 m. This pattern is indicative of their overthrust-folded internal structure of the landforms.

Two big accumulative units, one on the southern shore of Lake Tungozero and the other north of the lake, represent former ice-divides. However, they differ markedly in both the pattern and structure of landforms. On the southern shore of Lake Tungozero there occurs a big WNW-trending terrain with a rugged surface. The winding moraine ridges observed on the surface are also oriented along the trend of the terrain. There is no doubt as to the glaciotectonic genesis of this ice-divide unit. Its maximum altitude is 87 m above the water level of Lake Tungozero.

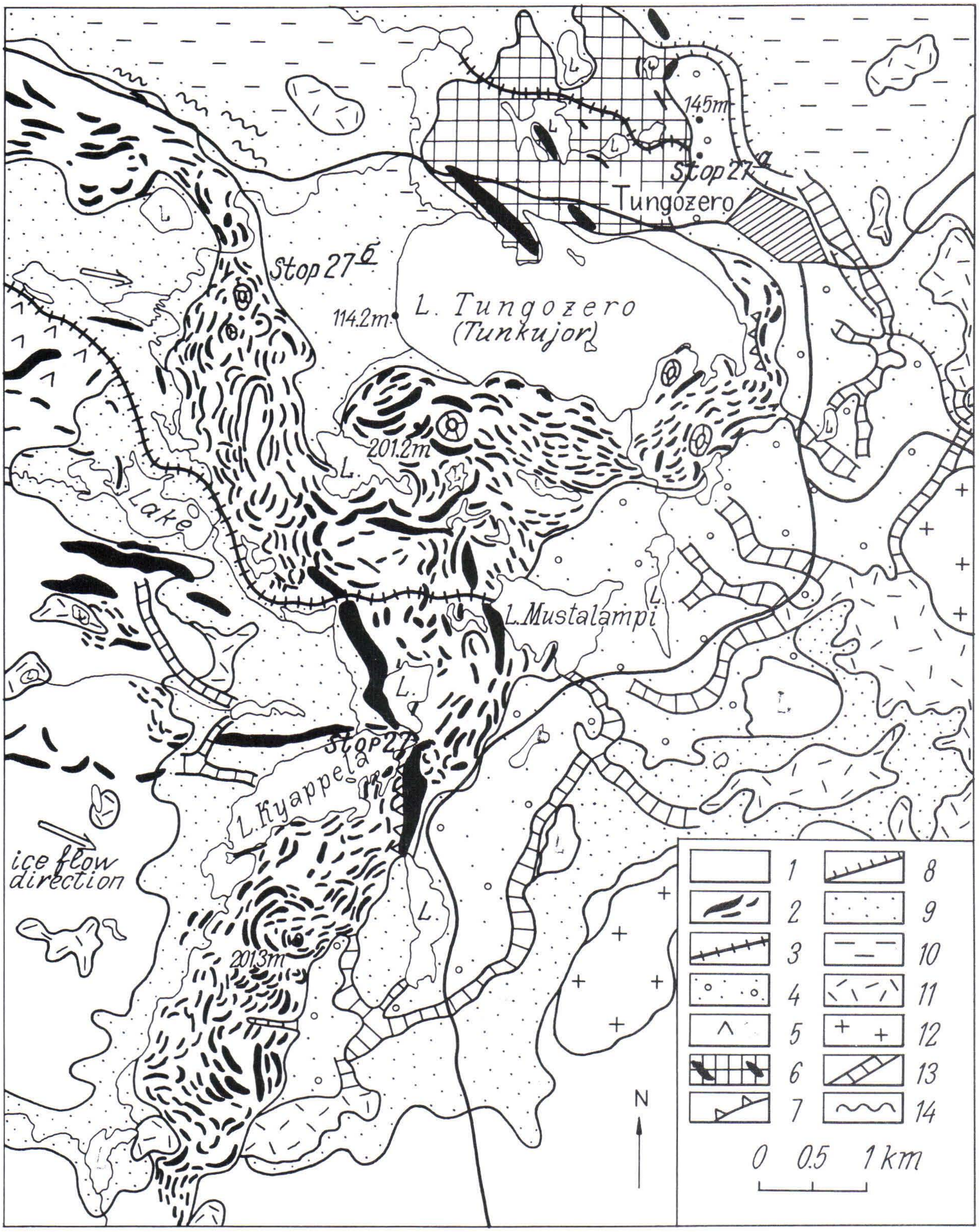


Fig. 36. Kalevala-stage marginal terrain, Lake Tungozero (Tunkujärvi) area.
(1) Basal till. (2) Ridge system indicative of complex marginal zone structure. (3) Eskers. (4) Marginal deltas. (5) Hilly relief and individual domal hills (diapirs?). (6) Ridge hilly marginal relief. (7) Slope of glacier contact. (8) Abrasion cusps. (9) Portland Sea sandy coastal plain. (10) Clay and loam. (11) Bog. (12) Exposed crystalline rocks. (13) Meltwater channels. (14) Dune ridges.

North of Lake Tungozero, the ice-divide is mainly represented by hummocky relief and individual ridges. The ice-divide unit joins a marginal delta (Stop 27 a) whose surface is at 145 m above sea level. The delta surface indicates the highest level of the late glacial brackish-water reservoir which existed in the White Sea basin at the time.

An active small glacier tongue moved along the Tungozero lake basin giving rise to rather impressive end moraine ridges that are now largely buried under glaciofluvial strata on the eastern lakeshore.

A series of parallel marginal ridges was formed in a similar environment west of Lake Mustalampi. Interestingly, the frontal ridges are also partly buried under glaciofluvial strata.

One more big bar-like terrain with a rugged surface occurs west of Lake Tungozero (Stop 27 b). Its relative altitude is 75 - 80 m above the surrounding plains. It is the morphological counterpart of the bar-like terrain south of Lake Käppälä. The ridges that occur here are bent and closed, suggesting that the terrain is one of the biggest glaciotectonic sequences in the Younger Dryas marginal zones of Soviet Karelia.

These marginal strata were formed by later local over-thrust of the narrow ice flow which occupied the deep Ponchi (Pontselenjoki) river valley. The flanks of the moving ice flow extended to lateral ridges (Fig. 36).

28. Urakkajärvi. Stop 28 is NE of Lake Ohtajärvi in the Lake Urakkajärvi area (Fig. 37). Kalevala-stage end moraines stretching for 6 km are common. The ridges are 5 - 8 m high and 40 - 60 m wide. The end moraine crests lie at 205 - 206 m above sea level. Its surface is locally cut by shallow meltwater channels, a wide strip of outwash plain is attached to the marginal ridges. Deep channels cutting the marginal ridge have also been reported from the southern part of the locality.
Hummocky-ridge moraine relief and individual ice-divide hummocky terrains occur inside the push ridge. The distal portion of the end moraine ridge is exposed in an openpit mine. The cross-section shows the following relations: three till horizons are interlayered with fine to coarse sand. The deposits are overthrust, and the till and sand horizons are compressed into distally overturned near-fault folds.

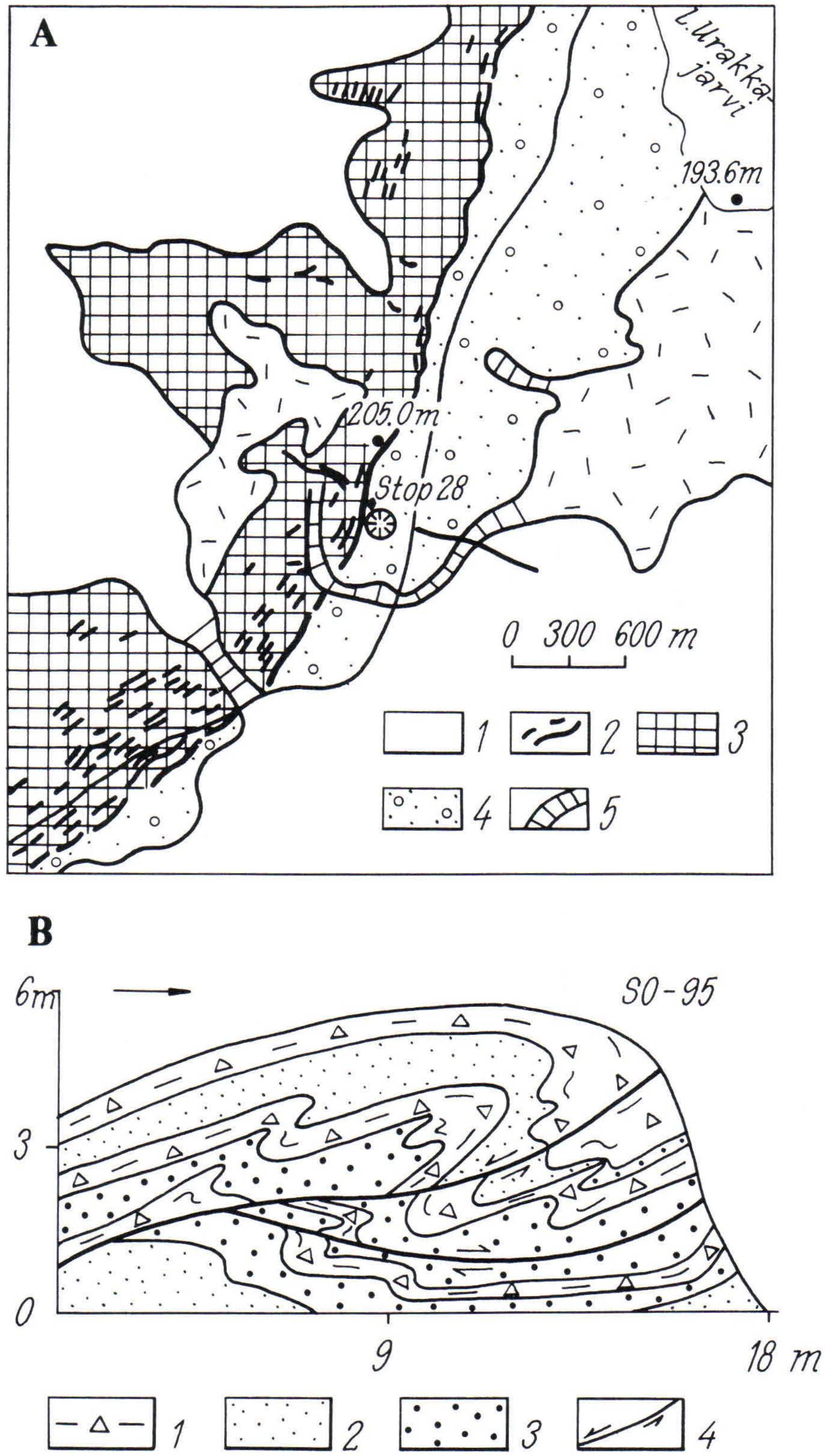


Fig. 37. Kalevala-stage marginal strata NE of Lake Ohtanjärvi.
(1) Till. (2) End moraine ridges. (3) Hilly and hilly-ridge morainic relief. (4) Outwash plains. (5) Meltwater channel.

29. Kostomuksha (Kostamus). Observation site of the central openpit mine for the Kostomuksha concentration plant. Upper Archaean metamorphic, partly intensely migmatized strata composed of volcanogenic, volcano-sedimentary and sedimentary rocks cut by granites are common.

The ore bodies are composed of iron formation admixed with biotite, grűnerite and riebeckite. The average iron content of the ore exceeds 30 %. A cutting tabular body composed of hälleflinta, a rock of rhyolite-dacite composition, can be seen in the open pit.

Crystalline rocks are overlain by a till bed 2 - 4 metres thick. The total thickness of Quaternary deposits within the ore field is 21 - 23 m. In Karelia, a till stratum is often subdivided into 3 - 4 beds 0.5 to 1.0 m thick separated by either a layer of silt 1 - 3 cm thick or a layer of sand 10 - 20 cm thick with markedly dislocated layering. The bed contacts dip at 10 - 15° towards the ice movement.

In Kostomuksha the beds are in contact with each other (Fig. 38). Thus, they are actually flattened lenses with a thickness to length ratio of 1:50 - 1:100. The microshifts observed at the contacts between the lenses suggest that the till-bearing ice lenses were sliding relative to each other.

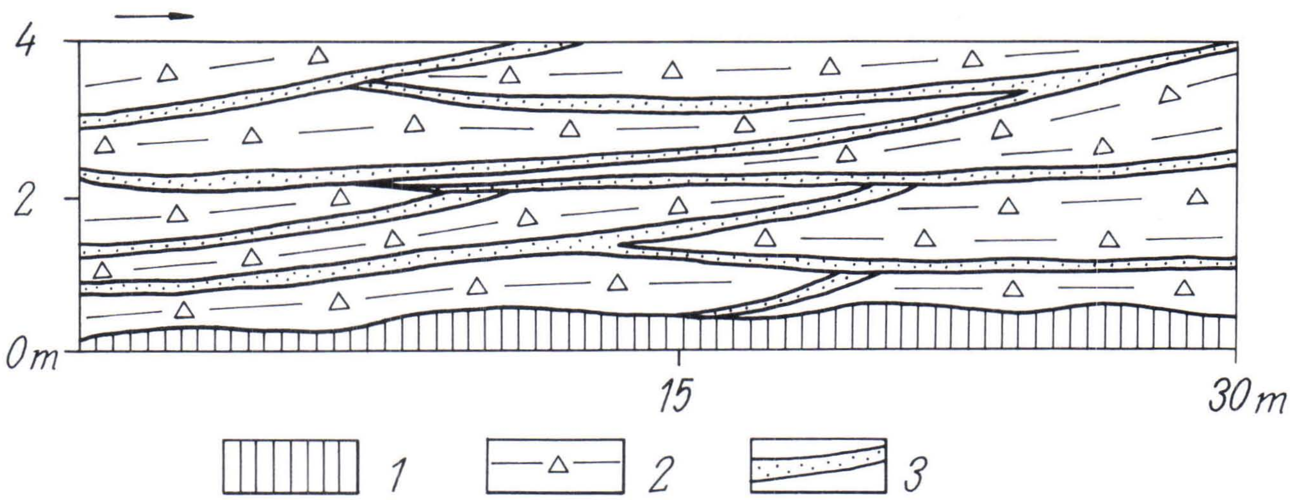


Fig. 38. Structure of morainic cover in the Kostomuksha openpit mine.
(1) Crystalline rocks. (2) Till. (3) Sand interlayers.

References
Литература

Апухтин, Н.И., Экман, И.М. & Яковлева, С.В., 1965. Новые доказательства существования позднеледникового Беломорско-Балтийского морского пролива на Онежско-Ладожском перешейке. Baltica 2.

Апухтин, Н.И. & Экман И.М., 1967. Стратиграфия: Мурманская область, Карелия, запад Архангельской, северо-запад Вологодской и север Ленинградской области. Геология четвертичных отложений Северо-Запада Европейской части СССР. Ленинград, Недра, 48-110.

Апухтин, Н.И. & Краснов И.И.,1967. Корреляция опорных стратиграфических разрезов и сводная стратиграфическая схема четвертичных отложений Северо-Запада Европейской части СССР. Геология четвертичных отложений Северо-Запада Европейской части СССР. Ленинград, Недра, 295-318.

Апухтин, Н.И., Яковлева С.В. & Экман И.М., 1967. Четвертичные отложения Северо-Запада Русской равнины. Материалы по четвертичной геологии и геоморфологии СССР. Москва, Недра, 6.

Арманд, Н.Н., 1960. О последнем оледенении на Северо-Востоке Кольского полуострова. Вопросы геоморфологии и геологии осадочного покрова Кольского полуострова, 1, Апатиты, 136-150.

Арманд, Н.Н., 1964. Грядово-кольцевой рельеф морены. Рельеф и геологическое строение осадочного покрова Кольского полуострова. Москва-Ленинград, 68-71.

Арманд Н.Н., 1965. Краевые образования малоактивного ледникового щита и зона его сочленения со Скандинавским покровом. Краевые образования материкового оледенения. Вильнюс, 45-50.

Bakhmutov, V.G. & Zagniy, G.F., 1990. Secular variation of the geomagnetic field: data from the varved clays of Soviet Karelia. Physics of Earth and Planetary Interiors, 63, 121-134.

Экман, И.М., 1987. Стратиграфия. Четвертичная система. Геология Карелии. Ленинград, Наука, 79-93.

Ekman, I.M., Ilyin, V.A. & Lukashov, A.D., 1981. Degradation of the late ice sheet on the territory of the Karelian ASSR. Acad. Sci. USSR, Glacial Deposits and Glacial History in Eastern Fennoscandia. Apatity, 103-117.

Экман, И.М., Загний, Г.Ф. & Бахмутов, В.Г., 1987. Палеомагнитная стратификация осадочных толщ позднего плейстоцена юговосточной части Балтийского щита. Новые данные по геохронологии четвертичного периода. Москва, Наука, 218-224.

Ekman, I.M., Bakhmutov, V.G. & Zagniy, G.F., 1987. Stratification and correlation of varved clays in term of the fine palaeostructures of the earth's magnetic field. Методы исследования озерных отложений в палеоэкологических и палеоклиматических аспектах. Труды Международного симпозиума, 1986. Вильнюс, 47-60.

Евзеров, В.Я.,1990. Дегляциация северо-восточной части Балтийского щита. Тезисы УП Всесоюзного совещания. Четвертичный период: методы исследования, стратиграфия и экология. Таллин.

Григорьев, А.А., 1934. Геоморфология Кольского полуострова по новейшим исследованиям. Доклады советских делегатов на Международном Географическом конгрессе в Варшаве. Москва, 10 с.

Hyvärinen, H., 1971. Ilomantsi Ice Lake: a contribution to the Late Weichselian history of eastern Finland. Comment. Phys-Math. 41. Helsinki. 171-178.

Hyvärinen, H., 1973. The deglaciation history of eastern Fennoscandia - recent data of Finland. Boreas 2, 85-102.

Ильин, В.А. & Экман И.М., 1982. К вопросу о размещения, морфологии и генезиса холмисто-кольцевидного комплекса рельефа (на примере Волозерской ледораздельной возвышенности). Природа и хозяйство Севера, 10. Мурманск, 3-11.

Карта четвертичных отложений Северо-Запада Европейской части СССР, масштаба 1:2500000. Всесоюзный аэрогеологический трест Министерства геологии СССР. Москва, 1967. Н.И Апухтин и И.И Краснов (редакторы).

Лаврова, М.А., 1960. Четвертичная геология Кольского полуострова. Москва-Ленинград, 233 с.

Лукашов, А.Д. & Экман, И.М., 1972. Влияние рельефа фундамента на формирование четвертичного покрова Карелии. Региональные исследования ледниковых образований. Материалы IV Всесоюзного совещания по изучению краевых образований материкового оледенения. Рига, 257-272.

Лукашов, А.Д. & Экман, И.М., 1980. Деградация последнего оледенения и некоторые особенности маргинальной и островной ледниковой аккумуляции в Карелии. Природа и хозяйство Севера, 7. Мурманск 8-20.

Матишов, Г.Г., 1973. Основные черты геолого-геоморфологического строения подводной окраины материков Северо-Запада Атлантики и Норвежско-Гренландского бассейна. Проблемы изучения и освоения природных ресурсов Севера. Апатиты, 5-14.

Матишов, Г.Г., 1980. Основные геоморфологические аспекты проблемы оледенения дна Баренцева моря. Природа и хозяйство Севера, 7. Мурманск, 31-37.

Rainio, H., 1972. Ennakkotiedonanto Pohjois-Karjalan itäosan reunamuodostumista. Geologi 4, 50-51.

Rainio, H., 1978. Exkursionslokaliteterna i Nordkarelen, 1-24. In: Norqua-exkursionen i södra osh mellersta Finland 22-25.5. 1978. Guide. Geological Survey of Finland. Espoo. Unpublished report P. 13.7.004.

Rainio, H., 1983. The Tuupovaara end moraine in North Karelia, Eastern Finland - in ice-marginal formation of the same age as the Salpausselkä ridges. Bull. Geol. Soc. Finland 55, 67-76.

Rainio, H., 1985. Pohjois-Karjalan Salpausselkien aikaiset reunamuodostumajaksot tarvitsevat nimet. Geologi 37, 48-50.

Repo, R., 1957. Untersuchungen über die Bewegungen des Inlandeises in Nordkarelien. Bull. Commiss. Geol. Finland, 179, 1-178.

Рихтер, Г.Д., 1936. Результаты геоморфологической рекогносцировки в бассейне рек Варзуги и Поноя. Труды Института физической географии АН СССР 19, 49-120.

Rosberg, I.E., 1892. Ytbildningar i ryska och finska Karelen med särskild hänsyn till de karelska ändmoränerna. Fennia 7 (2), Helsinki, 122 p.

Rosberg, I.E., 1899. Ytbildningar i Karelen med särskild hänsyn till ändmoränerna. Fennia 14 (7). Helsinki, 71 p.

Стрелков, С.А., 1976. История формирования рельефа и рыхлых отложений северо-восточной части Балтийского щита. Ленинград.

Strelkov, S.A., 1976. On peculiarities of marginal glacial formation appeared in the presence of waves of ice quickened spreading.The V-th All-Union Conference on marginal formation. Kiev, 51 p.

Спиридонов, М.А., 1985. Позднеплейстоценово-голоценовое осадконакопление и рельефообразование в гляциально-шельфовых областях на примере внутриконтинентальных акваторий. Гляциальные шельфы. Ленинград.

Termination of the pleistocene, 1990. Field conference Norway-Sweden-Finland, May 9-16, 1990. J. Lundqvist and M. Saarnisto (editors).

Введенский, Л.В., 1934. Рельеф южной части Кольского полуострова. Известия Географического общества СССР, LXVI (6). 844-863.

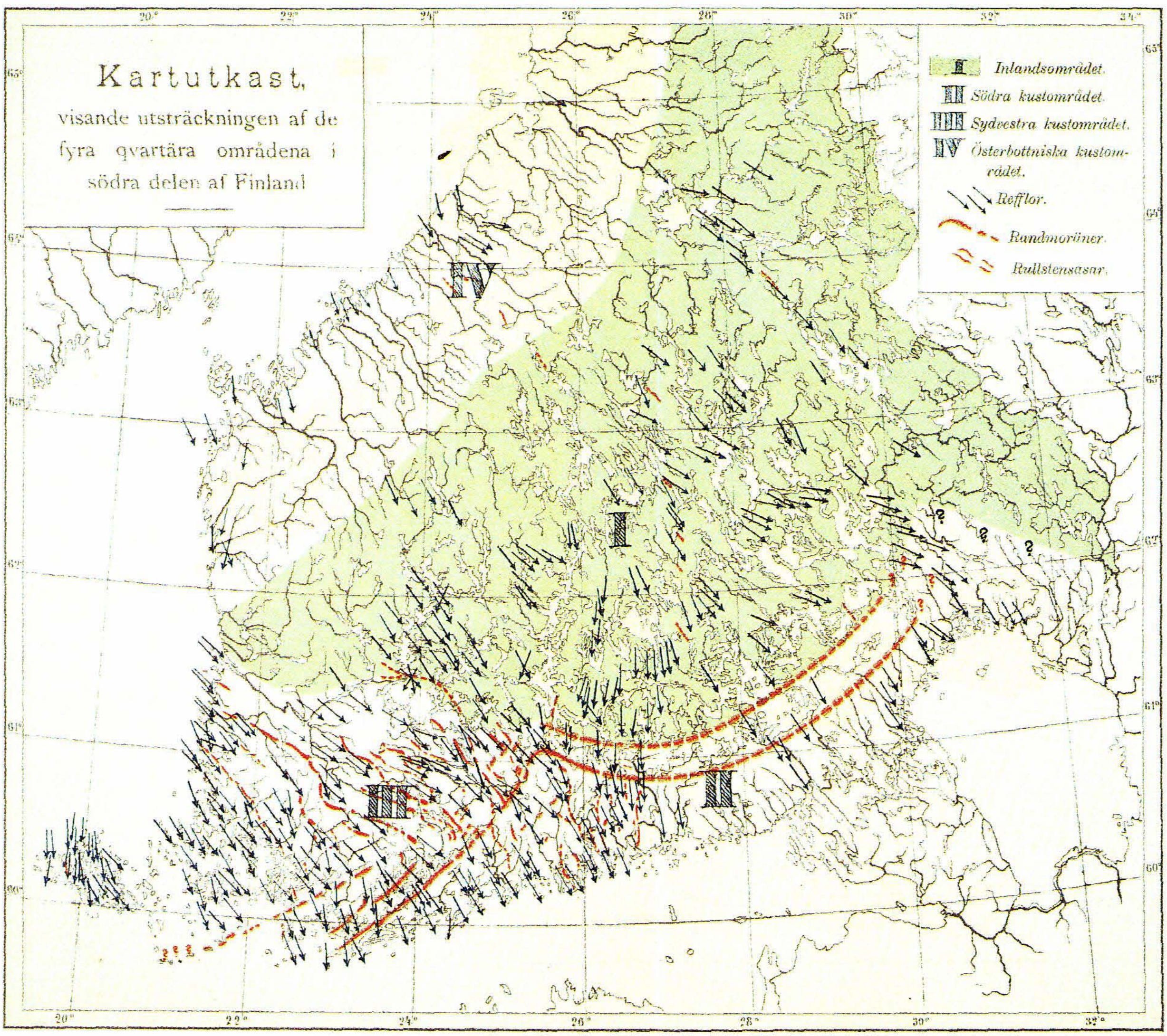
APPENDIX 1. Four science historical maps of the Younger Dryas end moraines in Eastern Fennoskandia.

The question of the "continuation" of the Salpausselkä ridges in Finnish North Karelia and Russian Karelia was eagerly investigated at the end of the last century. These maps show that reliable results were obtained rapidly in spite of the lack of base maps and the shortage of roads.

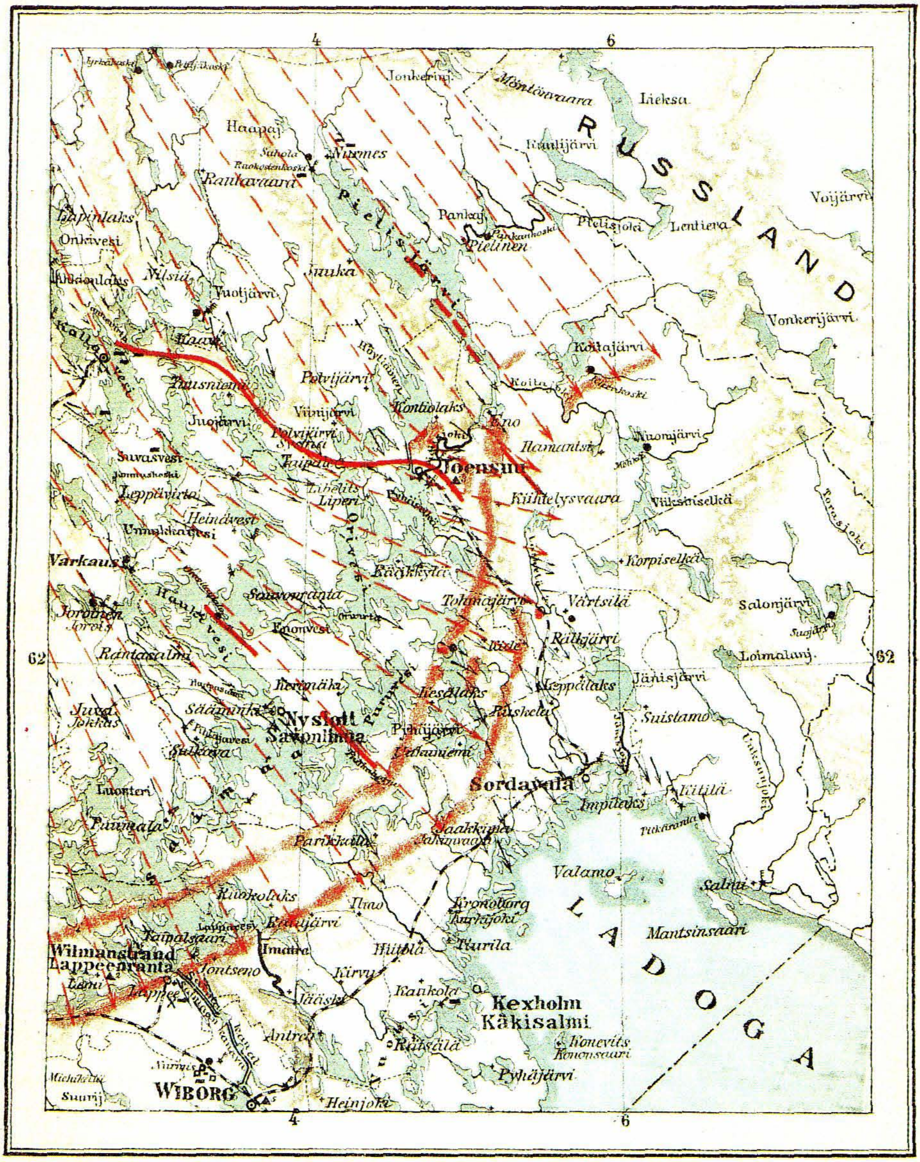
1. Sederholm 1889; 2. Ramsay 1891; 3. – 4. Rosberg 1892.

1

FENNIA I. No 7. Sederholm, Om Istidens bildningar i det inre af Finland. Tafl. N:o 2. KARTAN N:o 2.



DIE RANDMORÄNEN IM ÖSTLICHEN FINNLAND.



Schrammen

Randmoränen

Gerölle-åsar

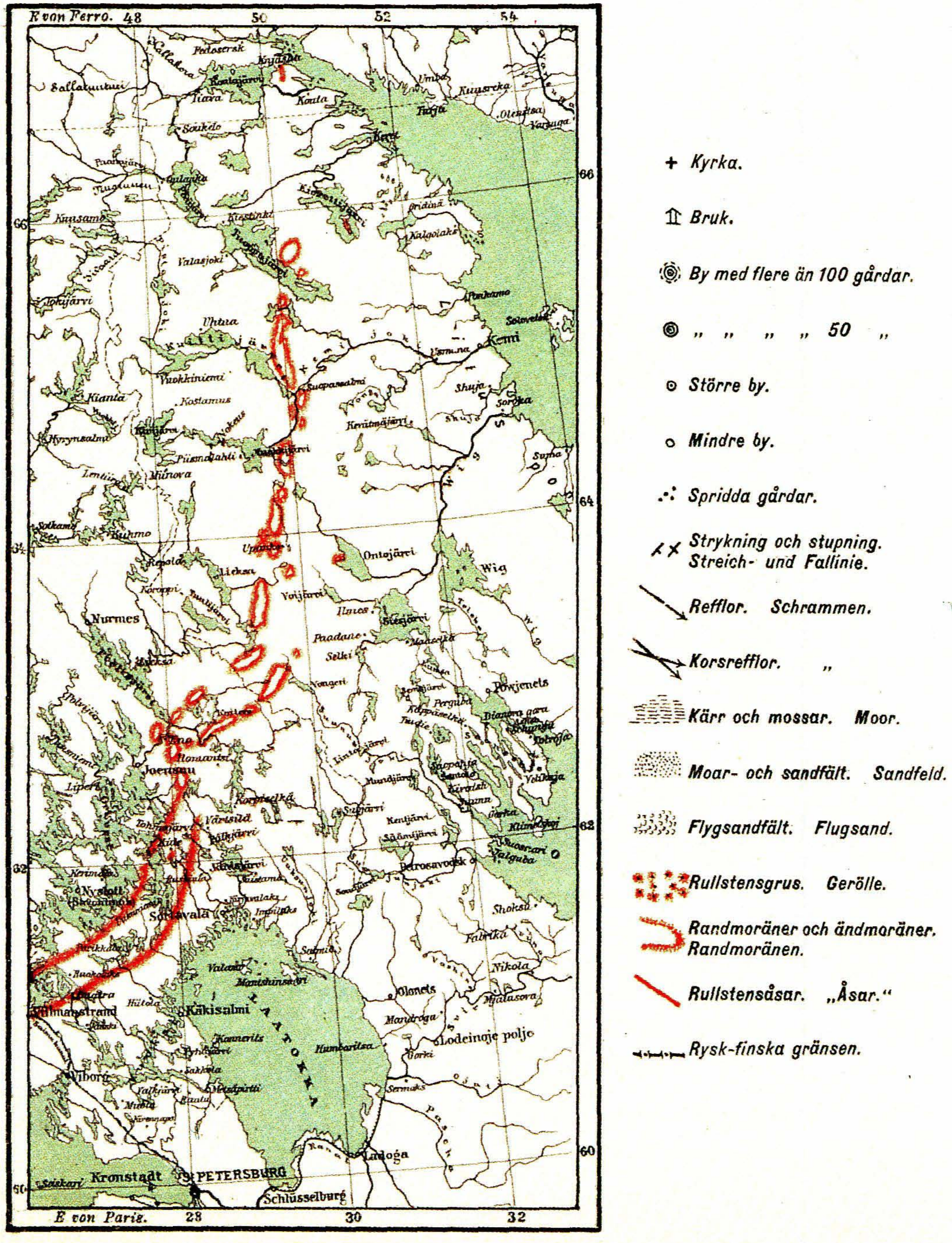
Die Bewegungsrichtung des Eises zur Zeit der Bildung vom Salpausselkä.

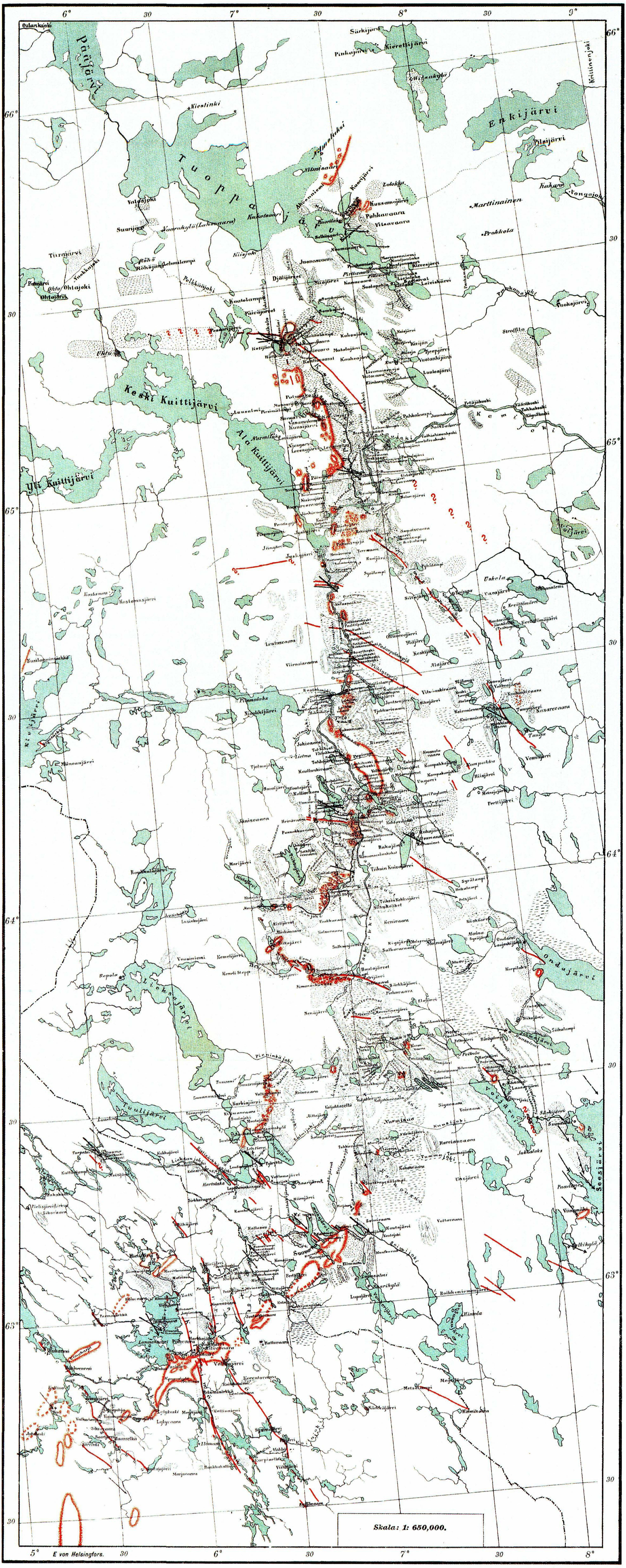
Höhen und Landrücken (u. a. Salpausselkä) nach älteren Karten.

FENNIA 7. N:o 2.

Karelska Randmoränerna

Resekarta af J. E. ROSBERG.





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