Geological Survey of Finland

Bulletin 338

Glacial transport distance distributions of surface boulders in Finland

by Veli-Pekka Salonen

Geologian tutkimuskeskus
Espoo 1986

Geological Survey of Finland, Bulletin 338

GLACIAL TRANSPORT DISTANCE DISTRIBUTIONS OF SURFACE BOULDERS IN FINLAND

by

VELI-PEKKA SALONEN

with 44 figures, 14 tables and one appendix

GEOLOGIAN TUTKIMUSKESKUS
ESPOO 1986

Salonen, V-P. 1986. Glacial transport distance distributions of surface boulders in Finland. *Geological Survey of Finland, Bulletin 338.* 57 pages, 44 figures, 14 tables and one appendix.

The length of glacial transport in Finland was studied by means of the transport distance distributions of surface boulders. A new *Transport distance distribution method* was developed. The results from nine separate study areas representing different glacial geological environments and covering the whole country are presented. The transport distance distribution of surface boulders, which was determined at 111 sample sites, was discussed on the basis of field observations and compared with the results of the *Half-distance method*. The half-distance values were calculated with the aid of 41 observation traverses.

The new method is better than the half-distance method at characterizing the length of glacial transport. The values of the latter method are strongly related to secondary variables, such as the rock type studied, the topography and the width of the provenance rock area. The transport distance distribution method gives more reliable estimates for glacial transport distance than does the half-distance method.

The transport distance parameters for the mean value and its deviation were estimated and found to be associated with the depositional morainic landforms and with the regularities in glacial activity in Finland. The geometric mean of boulder transport was shortest in hummocky moraine areas (0.4—3.0 km), intermediate in cover moraine areas (0.8—10.0 km) and longest in areas of drumlinized landscape (5.0—17.0 km).

The application of the total transport distribution method in ore exploration and in studies of the genesis of till is discussed.

Key words: glacial geology, glacial transport, boulders, moraines, till, stone counting, rocks, provenance, statistical analysis, Quaternary, Finland

Veli-Pekka Salonen
University of Turku, Department of Quaternary Geology
SF-20500 Turku
Finland

ISBN 951-690-237-5
ISSN 0367-522X

Helsinki 1986. Valtion painatuskeskus

To Raili

CONTENTS

INTRODUCTION

General

This study describes the relation between the lithologic composition of the bedrock and the surface boulders in the overlying till in Finland. The provenance of the till material has been a classic question in glacial geological research. The glacial theory was devised 150 years ago on the basis of observations made by tracing erratic boulders in the Alps to their source in bedrock (Agassiz 1840).

The glacial transport of boulders is of importance in understanding the dispersal pattern of the ice sheets. Formulation of the transport distribution of particles has applications in studies of the glacial dynamics of continental ice sheets (Milthers 1909, Hausen 1912, Tanner 1915, Sauramo 1929, Holmes 1952, Repo 1957, Flint 1971, Shetsen 1984, Boulton *et al.* 1985, Donner 1986). Furthermore, the transport distance of till particles is often the main issue in ore prospecting in areas of glaciated terrain (Sauramo 1924, Grip 1953, Kauranne 1958, Hyvärinen *et al.* 1973, Björklund 1976, Hirvas 1977, Kinnunen 1979, Ekdahl 1982, Saarnisto *et al.* 1981, Saltikoff 1984, Salminen and Hartikainen 1985).

Earlier studies

The first attempts to formulate glacial transport by the Pleistocene ice sheets were descriptive. The limits of the Scandinavian Ice Sheet were defined by observing erratic boulders and their dispersal pattern (de Geer 1881, Hausen 1912). Salisbury made observations of the local boulder material in till as early as 1900. Hellaakoski (1930), however, was the first to describe boulder transport numerically. He used stone counts on a traverse running parallel to the ice movement and measured the transport distance of an indicator rock type (rapakivi granite).

Mathematical methods in boulder transport investigations were developed in the early 20th century (G. Lundqvist 1935). The basic research was conducted by Krumbein (1937), who was able to apply the negative exponential function to the distance distribution of glacially derived boulders and to determine the controlling coefficient (a) for the dispersion of glacial boulders in a boulder fan. He found that glaciers appear to disperse debris, reaching a maximum frequency close to their source, followed by an exponential decline in the direction of glacial transport (Shilts 1976). The half-distance value ($x_{1/2}$) corresponds to the point where the frequency of indicator boulders is half its original value at the distal contact. This distance can be calculated from coefficient (a) using the equation:

[1] $x_{1/2} = 0.693{:}a$

The observations by Krumbein (1937) have since been tested in several ways (e.g. Gillberg 1965, Marcussen 1973, Lindén 1975, M. Perttunen 1977). In these experiments it has been shown that the distance of glacial transport is dependent on many variables such as the grain size of the material studied, the type of indicator rocks observed, topographic factors and variations in the components of glacial activity. Recently, Peltoniemi (1985) has pointed out that the length of glacial transport depends primarily on the size of the outcrop that is the provenance for the particles studied.

Dreimanis and Vagners (1971) showed the bimodal size distribution of lithologic components in till. As a matter of fact, the value of the half-distance ($x_{1/2}$) reflects the distance along which the observed particles are comminuted. This value does not give a direct measure for the length of glacial transport. It is a model with a certain relationship to glacial activity. The flow of the ice and the comminution process affect the debris simultaneously, and both factors are reflected in the value of $x_{1/2}$ in a given grain size.

Because of these reservations, measurements of the length of glacial transport are not alone sufficient when describing the glacial dynamics of ice sheets. Nevertheless, Salminen and Hartikainen (1985) were able to find areal systematics in varied glacial action in North Karelia by comparing the results of boulder counts with those of geochemical studies.

Aim of the study

The aim of the study was to ascertain the transport distance of surface boulders in glacial deposits in Finland. It was presumed that determination of the transport distance implies explanation of their distance distribution. The concept *Transport distance distribution* is developed, discussed on the basis of field observations and compared with results of the *Half-distance method.*

The study attempts to explain the variability in the glacial transport distance on the basis of glacial geological variables. The transport distance distributions are described and the parameters (mean value and variability) estimated. The study also seeks to elucidate glacial transport for its relevance to exploration. The results were also used to estimate regularities in glacial activity at the scale of Finland.

METHODOLOGY

Measuring the length of glacial transport

The glacial transport of till particles is associated with the complex interactive system of glacial action of the ice sheets. Factors such as glacial erosion (abrasion and quarrying), incorporation of the debris in the ice, transport and finally deposition and mixing of the till operate at the same time.

The length of boulder transport is the distance between an observed erratic in a glacial deposit and its provenance in bedrock. Two active factors influence this quantity: the flow of the ice and the crushing of the larger fragments during the ice flow. The transport distance of the boulder fraction reflects mainly the last or strongest ice flow because during multistage transport most of the boulder fraction is comminuted to finer fractions (see Mutanen 1971).

The transport distance of surface boulders can be demonstrated in several ways (Fig. 1). All these measures give an estimate of the transport distance of one indicator rock type at a time. In nature, glacial deposits consist of rock material derived from many bedrock

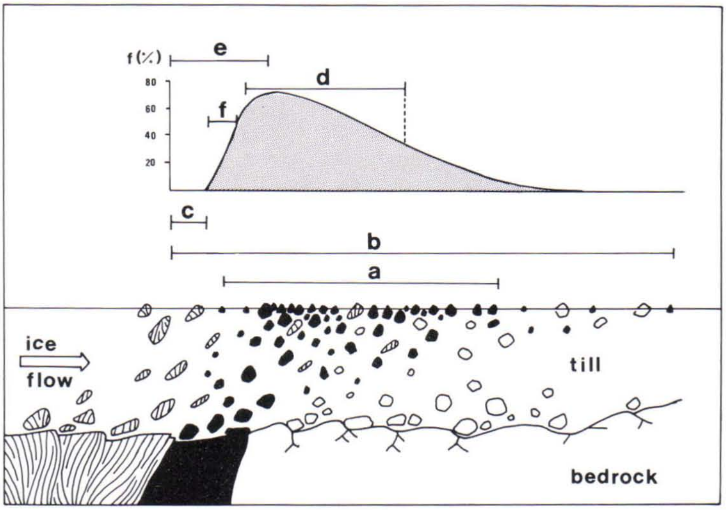


Fig. 1. Different ways to measure the length of glacial transport distance (the indicator rock is black): a = The distance observed from the length of a boulder train. b = The distance between the proximal contact and the location of the farthest travelled particle derived from the same bedrock source. c = The reaching-surface distance. d = The half-distance value (Krumbein 1937). e = The distance between the proximal contact and the maximum frequency of the indicator particles (Salminen 1980). f = The 'renewal distance' (Peltoniemi 1985).

types. Every part of a glacial deposit represents a mixture of bedrock material located upstream with respect to the glacial flow. Hence, the term *Transport distance distribution*, which allows observations to be made of a sample of boulders instead of a single indicator rock type, has been used in this study. In the same way, Eskola (1933) discussed the likely provenance areas for a sample of 961 boulders in Lithuania, and Kivekäs (1946) explained the variation in provenances of moraine boulders.

Matisto (1961) determined lateral limits for each bedrock type upstream with respect to glacial flow. In a more recent technique, it has been possible to present the bedrock lineation of the provenance areas for the boulder sample counted (Salonen 1984).

This kind of formulation of glacial transport is illustrated with a case from Merikarvia (Salonen 1984, Fig. 2). The source area in bedrock is delimited by petrographic determination of a sample of 600 boulders deposited on active ice hummocky moraine (Table 1).

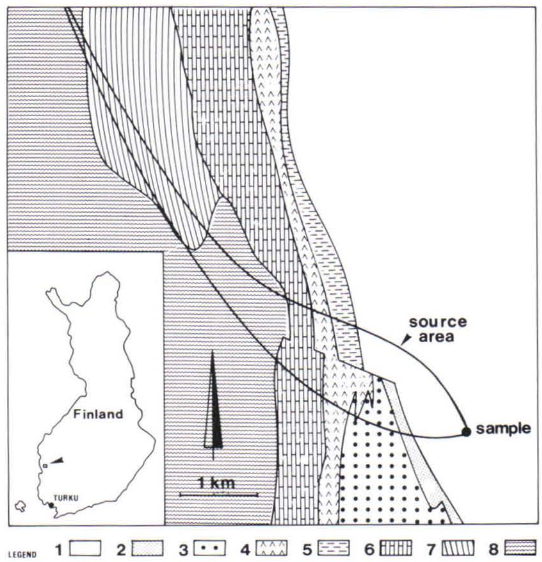


Fig. 2. The lithology of bedrock and the boulder sample site in the Merikarvia area, western Finland (1 = granodiorite, 2 = porphyritic granodiorite, 3 = local granite, 4 = acid volcanic rocks, 5 = biotite-plagioclase gneiss, 6 = quartz-feldspar gneiss, 7 = mica schist, 8 = gneissose granodiorite). The lineation shows the area of the provenance for each boulder in a sample of 600 (Table 1). For detailed description, see Salonen & Kokkola (1981)

Table 1. Determination of source areas for a boulder count from Merikarvia (Salonen & Kokkola 1981, Salonen 1984).

Rock type	F (%)	transport distance km	cumulative percentage
Granodiorite	38.8	0.0— 3.0	38.8
Porphyritite granodiorite	3.0	0.8— 2.0	41.8
Local granite	19.9	1.0— 2.5	61.7
Acid volcanic rocks	4.2	2.2— 5.0	65.9
Quartz-feldspar gneiss	7.5	2.5— 5.0	73.4
Biotite-plagioclase schist	0.8	3.0— 5.0	74.2
Gneissose granodiorite	2.7	3.2—20.0	76.9
Mica schist	10.6	5.0— 8.0	87.5
Basic volcanic rocks	1.7	5.0— 9.0	89.2
Mica gneiss	9.5	6.0—30.0	98.7
Basic intrusive rocks	0.7	>30.0	99.4
Siipyy granite	0.6	>50.0	<100.0

A possible source for each of these boulders was pinpointed on the basis of detailed bedrock mapping, permitting the provenance area for each boulder in the sample to be estimated (Fig. 2). The provenance is understood as the closest locality in the bedrock that could possibly be the source of all (or nearly all) the boulders in the sample count. This area illustrates the glacial transport distance for the total sample. If the sample is a good representative of the population, the provenance area represents the transportation of all the surface boulders in a given glacial geological environment (Salonen & Kokkola 1981, Salonen 1984).

The requirements for using the bedrock lineation method are:

1) Good knowledge of the local bedrock: the source locality of all or nearly all the boulders in the sample has to be exactly definable.

2) Suitability of the bedrock: pronounced lithologic variations perpendicular to the ice flow direction.

3) Abundant surface boulders at the study site.

If the requirements are fulfilled, the data obtained are suitable for further processing.

The distance distribution of surface boulders

Development of the method

The cumulative frequency of boulders versus their distance from the source areas (data in Table 1) can be plotted on cumulative frequency curves (Fig. 3). Surface boulder distribution at this scale approaches lognormality. It has been proposed that the lognormal frequency distribution is appropriate for a number of variates in the geosciences such as grain size and the abundance of trace elements (Griffiths 1967). Variations in particle size in sediments are one of the most valuable and familiar applications (Haldorsen 1981).

Harris (1958) used logarithmic probability paper to identify the depositional environments of sediment samples. Presentation of the total transportation data (Table 1) on the cumulative probability net (cf. Salonen 1984, Aumo

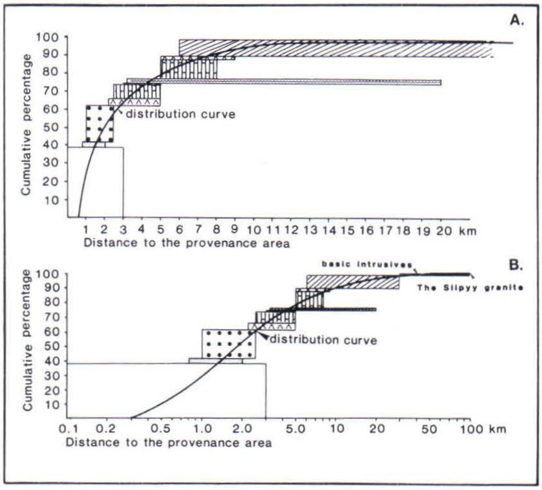


Fig. 3. Cumulative distance distribution curves on (A) linear and (B) semilogarithmic scale. For legend in bedrock areas, see Fig. 2.

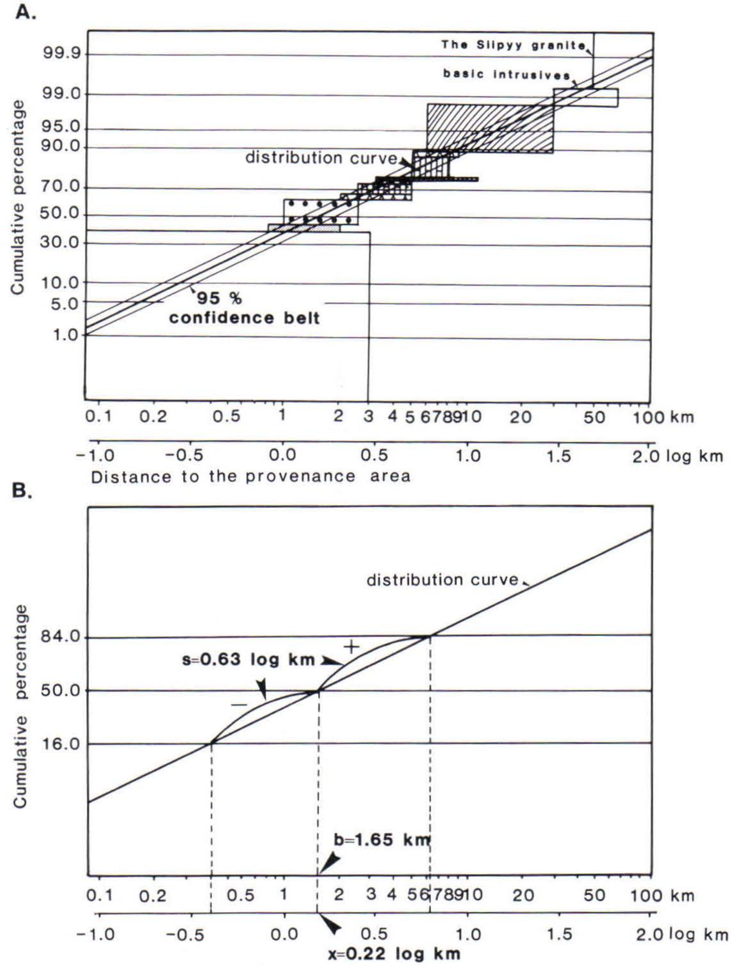


Fig. 4. A) Distance distribution on logarithmic probability paper (based on data in Table 1). B) estimation of statistics, mean, $\bar{x}=0.22$ log km, standard deviation, $s=0.63$ log km and geometric mean, $b=1.65$ km.

& Salonen 1986) permits the statistics of distribution to be calculated (Fig. 4).

On the probability paper, one ordinate is logarithmic, and the other, the probability scale, is arranged so that a cumulative lognormal distribution will plot as a straight line (Sinclair 1983). This line, which is easy to fit visually to the appropriate data, provides direct estimates of the mean value ($\bar{x}$) and standard deviation of the distribution (Fig. 4 B):

[2] $\bar{x} = P_{50}$

[3] $s = (P_{84} - P_{16}):2,$

where P_n is the log value at the n^{th} percentile (Sinclair 1983). The graphical statistics for the data in Table 1 can be estimated from Figure 4 A to be:

$\bar{x} = 0.22$ log km

$s = 0.63$ log km.

Interpretation of transport distribution

The arithmetic mean ($\bar{x}$) of a log distribution equals the geometric mean of the original data. The statistical symbol for the geometric mean is (b) and for the standard deviation (S_l). This geometric mean is a more stable statistic, less subject to change with the addition of new data and less affected by high values (Lepeltier 1969).

The fit of the distribution line can be tested by checking it graphically with confidence tables. In Figure 4 A, 95 per cent confidence limits have been plotted for the linear fit. Because the bedrock areas do not totally plot outside the 95 per cent confidence belt, significant curvature is not assumed (see Sinclair 1976).

The curve was fitted manually. This procedure can often become a problem in interpreting the pattern of real data plotted on probability paper (Sinclair 1976). In the present study the lognormality of the transport distribution data could not be tested with the chi-square test because of its diffuse character. Grouping into classes is determined by the geology of the study area; the class intervals are not equal and the classes overlap. Hence it is difficult to designate a single numeric value to each class, as would be essential for numeric testing.

The hypothesis to be tested in the present study is that two statistics, the geometric mean (b) and the coefficient of deviation (s), describe the transport distance distribution of surface boulders. The coefficient of deviation, which is a dispersion index specific for the distribution of rock types in the boulder fraction in a given glacial environment, expresses the degree of homogeneity of this distribution. The geometric mean indicates an average value for the distance of total transport of surface boulders. Similarity in the coefficient of deviation, together with similar average values, may indicate similar transport — depositional origins of the formations studied. The statistics $\bar{x}$ and s are used in this study to estimate the parameters of transport populations. Tests have also been conducted to see if these populations could be used to characterize the variation in glacial transport activity in Finland.

Because the coefficients $\bar{x}$ and s are not dependent on either a single rock type or on the size of the outcrop, it is expected that use of this method will permit the areal variations in glacial transport distance to be presented numerically. The technique allows graphical comparision of the samples.

The half-distance method

The value of half-distance (Fig. 1) is commonly used when measuring the length of glacial transport (see M. Perttunen 1977, Salminen & Hartikainen 1985). The decrease in frequencies was measured on traverses down-glacier from the distal contact of the indicator rock area (Fig. 5). This procedure is often used instead of observing unit areas in boulder trains (cf. Krumbein 1937).

The decrease in frequencies obeys a negative exponential function:

[4] $y = y_o e^{-ax}$

where y = the frequency of indicator boulders at distance x from the distal contact

y_o = frequency x_o

e = 2.7182

a = coefficient of particle distribution

x = distance from the distal contact (km)

The value of (a) can be determined from the following equation (Gillberg 1965):

[5] $$a = \frac{1}{\log e} \cdot \frac{\log y_o - \log y_1}{x_o - x_1}$$

where $y = y_1$, when $x = x_1$. The half-distance value can then be calculated from equation [1].

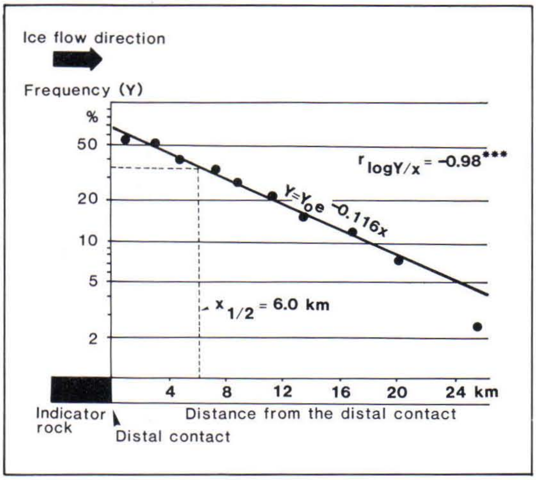


Fig. 5. Determining the half-distance value. Frequencies of indicator boulders in till (y — axis) decrease with the increase in distance from the distal contact (x — axis).

Research methodology of the study

In this study, the length of glacial transport was determined using the half-distance method and the transport distance distribution method. The boulder fraction (diameter >200mm) was studied because the petrographic determinations for this fraction could be conducted in the field. In some half-distance traverses, information on the cobble fraction is included in this study to obtain areal representativity of the data. For the same reason, two half-distance traverses, 40 and 41 (Table 14), outside the study areas are included.

Suitable distinctive rock areas were selected in different parts of the country. Surface boulders were counted on traverses in the direction of glacial flow. The relative frequencies of indicator boulders originating from a distinctive rock provenance were determined for 10 — 30 samples of 100 — 200 boulders and the distribution lines were plotted on a semilogarithmic scale (see M. Perttunen 1977).

The half-distance values were determined in the same way in each of the traverses using equations [1], [4] and [5]. Several more half-distance values were also calculated from data presented earlier (Fig. 6). All this information is listed in Table 14 with additional information on grain size, rock type, outcrop width and reference. To test the fit of the distribution line, the correlation $r_{\log(f)/x}$ is also given.

Transport distance distributions were determined with 111 sample sites representing nine different study areas (Fig. 7). The majority of the sampled areas varied between 1000 and 10 000 m^2, depending on the surface boulder frequency. Suitable counting sites, e.g. the sides of forest ditches, areas ploughed or burned after the cutting of timber and lake shores, were searched in order to restrict the sample as much as possible. The sample size in this study varied from 100 to 1100 boulders, usually being between 150 and 250. The number of groups was mostly 10 — 20, depending on the lithologic variations in the bedrock in the study area.

Statistics $\bar{x}$, s and b were estimated graphically using equations [2] and [3]. The results from the analyses of the total transport distance distributions were compared with other available transport data on the study areas. The results are presented in detail in Appendix.

A morphogenetic analysis of glacial deposits was conducted in connection with the boulder counts. The analysis was based on field ob-

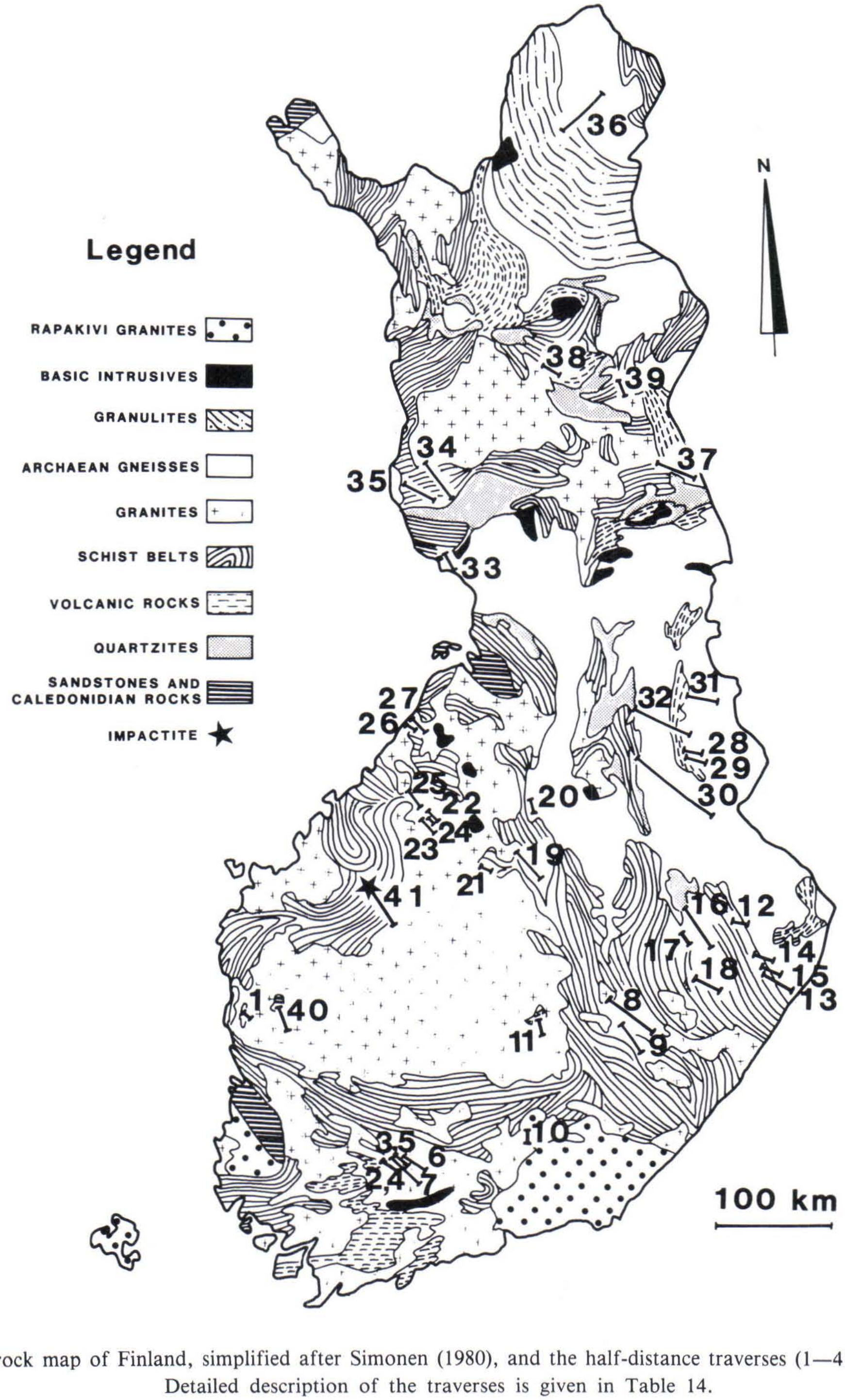


Fig. 6. Bedrock map of Finland, simplified after Simonen (1980), and the half-distance traverses (1—41) of this study Detailed description of the traverses is given in Table 14.

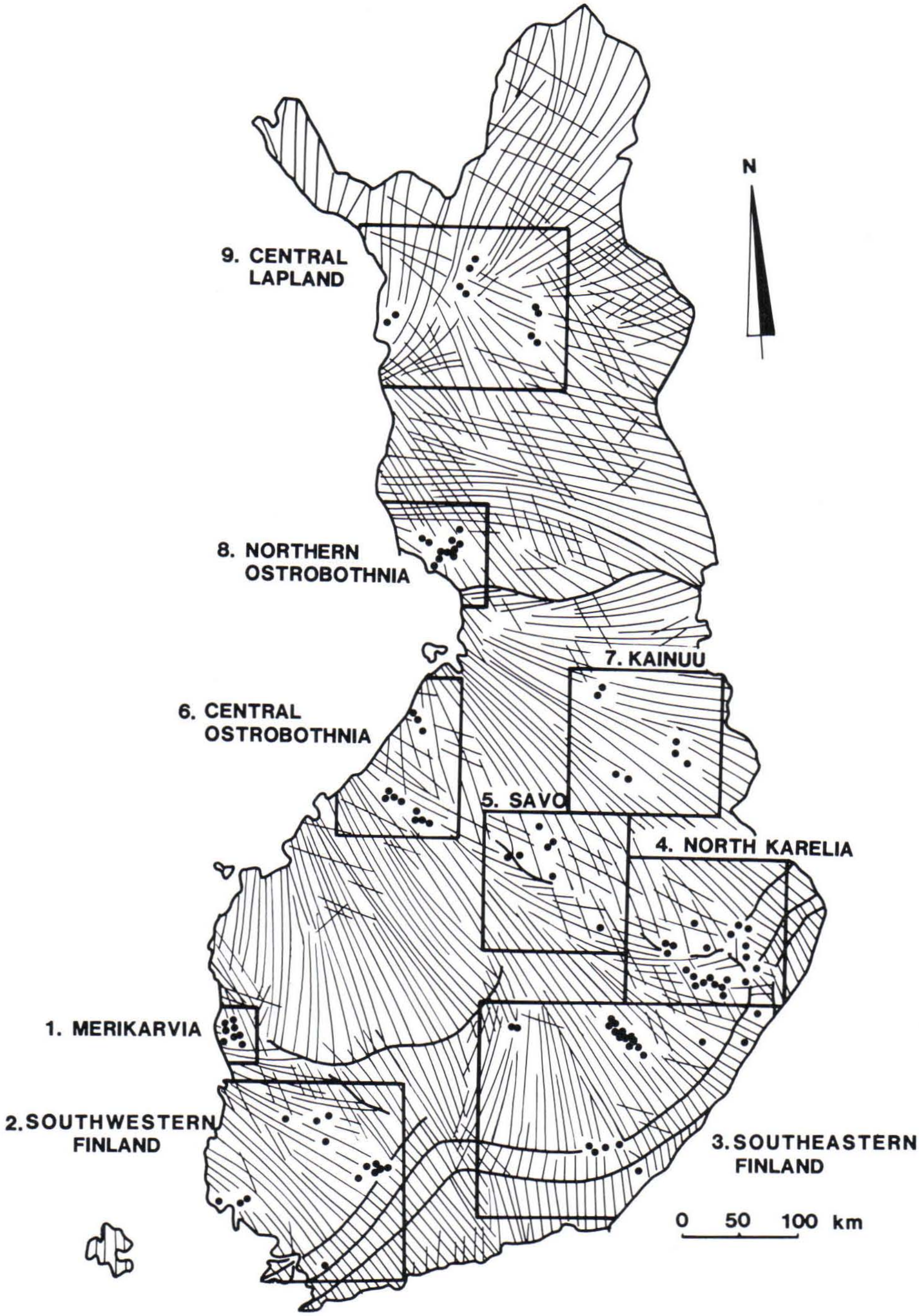


Fig. 7. Location of the nine study areas and sample sites for transport distance distribution analyses (n = 111). The map indicates the general flow directions (light lines) of the Scandinavian ice sheet in Finland (Salonen 1986) and the location of major marginal and interlobate complexes (heavy lines).

servations and general maps of Quaternary geology published by the Geological Survey of Finland (e.g. Kujansuu & Niemelä 1984). Use was made of data from earlier studies published on glacial geology.

The classification of depositional environments at the sample sites is based on the terminology of J. Lundqvist (1969, 1983) and Aario (1977). The following nomenclature was used:

— Cover moraine area. (Glacial drift is commonly less than 3 m thick and the bedrock topography is only slightly modified by the veneer of drift).

— Ground moraine area. (The deposit is thick enough to create its own topographic expression. It may consist of many till beds).

— Hummocky moraines. (The term includes different depositional features. Their genesis is not examined more closely in this study).

— Drumlin assemblage. (Subglacially formed streamlined features include drumlins, flutes, irregular drumlinized ridges and rock drumlins).

— Rogen moraines. (Ribbed moraine ridges transverse to the ice flow).

— De Geer moraines. (Small transverse morainic forms in subaquatic areas).

— Interlobate complex. (Interlobate ridges have ice-contact slopes on both sides).

— Marginal complex. (E.g. Salpausselkä formations).

— Esker

THE STUDY AREAS AND RESULTS

Merikarvia, western Finland

Quaternary deposits

The Merikarvia area (Fig. 7) has a complex glacial geological history (Salonen & Kokkola 1981). An older till unit, deposited as lodgement till by glacier movement from 340°—360°, forms a uniform blanket of cover moraine. This till unit is genetically related to earlier phase of the last Weichselian stadial. In the northern part of the study area (Fig. 8) this unit forms the uppermost layer in the surficial deposits.

In the southern part of the study area, there is a wide field of active ice hummocky moraines (Fig. 8). This bouldery till unit is attributed to the deglaciation phase of the last stadial, in the course of which the direction of ice flow changed and came from the west (Salonen & Kokkola 1981). Between these two till units there are discontinuous layers of glaciofluvial sediments. An esker of interlobate character separates the two subareas from each other.

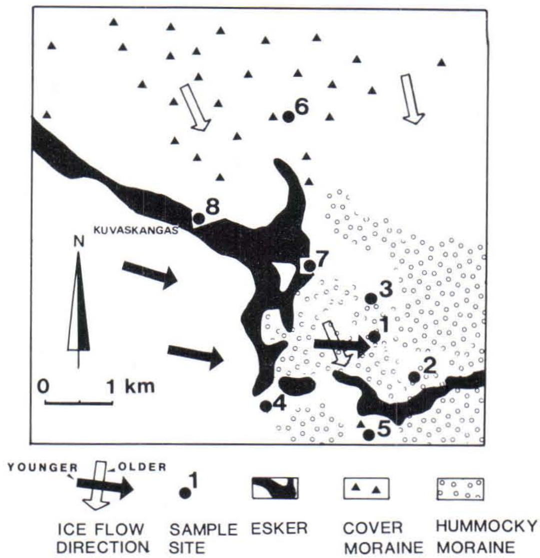


Fig. 8. Quaternary deposits and sample sites 1—8 in the Merikarvia study area. The ice flow directions and moraine forms divide the area into two subareas. The esker of Kuvaskangas is of interlobate character.

Observations

The three different surface boulder populations were sampled by boulder counts from the two till units and the intervening glaciofluvial formation (Fig. 8). The distance distributions were then estimated from the results (Appendix), as indicated in Figure 9. The transport statistics were determined using the distribution curves (Table 2).

Note that the surface boulder information can be presented as cumulative frequency curves. In each case the frequencies plot as a straight line, and it was possible to determine coefficients for x̄, s and b. There seem to be systematic variations in the distance distributions of the surface boulders in the study area. In the hummocky moraine area (Fig. 9 A), the values of the geometric means for the distance distributions are lower than in the area of lodgement till (Fig. 9 B). Note also that the distance distributions of cover moraine and esker boulders in the area are close to each other (Figs. 9 B,C).

The hummocky moraine was deposited during the deglaciation and the cover moraine unit during an earlier phase of the same stadial. Sample 4 can be considered to represent the boulder material of both phases, and hence the standard deviation of the sample is high. The mixture is incomplete and as a result two distance distribution populations have developed.

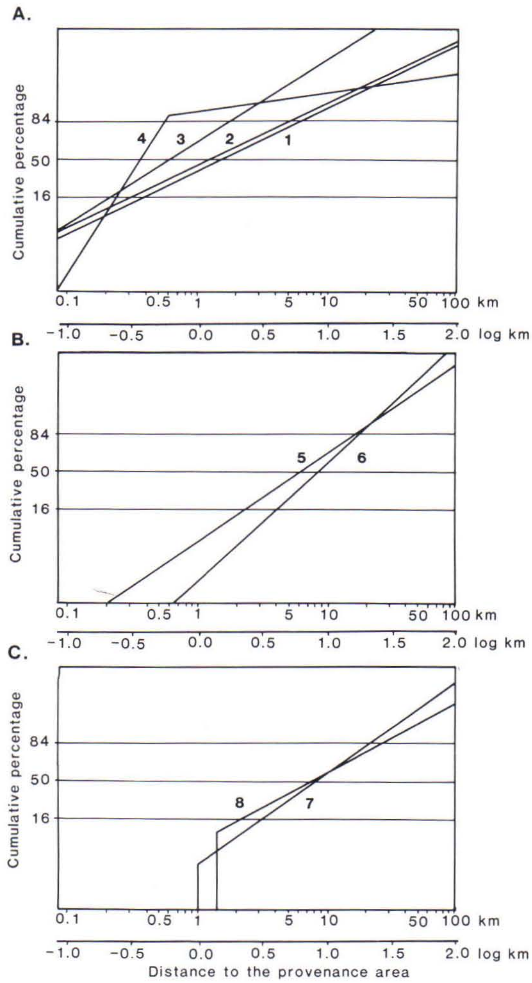


Fig. 9. Transport distance distributions for surface boulders in the Merikarvia study area. A = hummocky moraine, samples 1—4, B = cover moraine, samples 5—6, C = esker, samples 7—8.

Table 2. Statistics for samples 1—8, Merikarvia

Sample site	Mean x̄/log km	Standard deviation s/log km	Geometric mean b/km	Depositional landform at sample site
1	0.22	0.63	1.65	hummocky moraine
2	0.08	0.64	1.20	—,,—
3	—0.14	0.46	0.72	—,,—
4	—0.48	0.20	0.33	—,,—
5	0.78	0.48	6.00	cover moraine
6	0.93	0.33	8.60	—,,—
7	0.92	0.40	8.50	esker
8	0.89	0.60	7.80	—,,—

The straight lines representing the distribution of esker material (Fig. 9 C) do not reach the lowest values in the probability scale. From this curvature in the line it can be estimated that the boulder material in the esker was transported by glaciofluvial activity for about 1.0 to 1.5 km after deposition of the material as a cover moraine.

One half-distance value was determined (traverse 1, Fig. 6). The observation line consisted of 13 boulder counts in an active ice hummocky moraine area. A porphyritic granite acted as the indicator rock area, giving a half-distance value of 0.5 km (Fig. 10, Table 14).

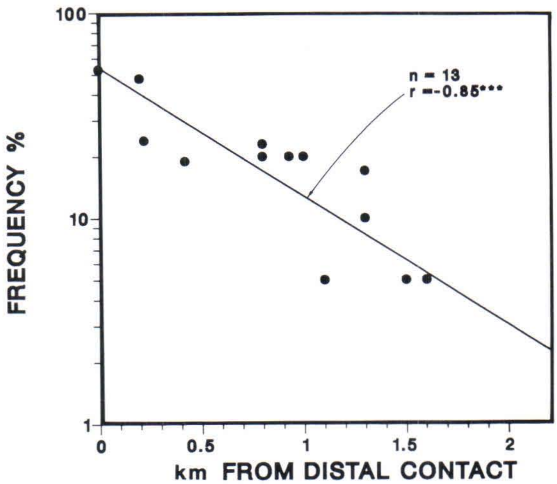


Fig. 10. Determination of half-distance ($x_{1/2}$ = 0.50 km) on traverse 1, Merikarvia, western Finland.

Southwestern Finland

Quaternary deposits

The most conspicuous glacial formations in southwestern Finland (Fig. 11) are the Salpausselkä ridges situated in the southeastern part of the area. The observations sites are located in the proximal area of the formations. The area is mainly sub-aquatic and hence the glacial deposits are often covered with fine-grained sediments. Furthermore, the moraine formations, especially those in the southeast, have been intensely washed. As a result, it was often difficult to find a representative coarse till fraction for boulder investigations in the surficial deposits (e.g. Haavisto *et al.* 1980, Lindroos *et al.* 1983, M. Perttunen *et al.* 1984).

The De Geer moraine ridge is a morphogenetic form typical of this study area (Aartolahti 1972). The ridges, which in places form swarms, have abundant surface boulders. In the northern part of the area the bedrock is mantled by a thin cover moraine. Other common depositional forms are single drumlins and hummocky moraines (Fig. 11).

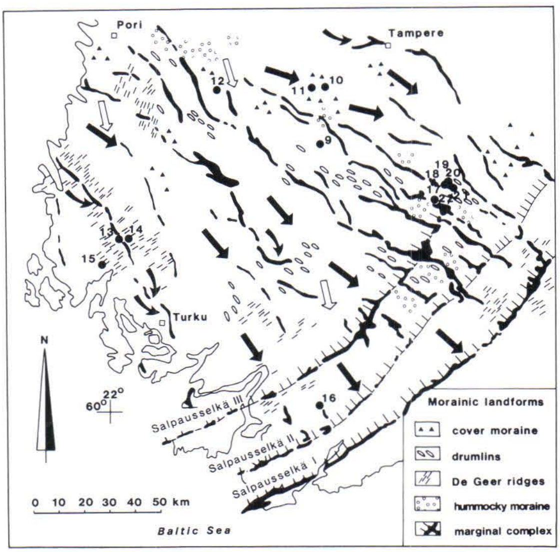


Fig. 11. The study area of southwestern Finland and sample sites 9—22 (for explanations see also Fig. 8). The drumlins and eskers show the general ice flow direction. The main ice flow was towards the arcs of the Salpausselkä marginal complexes. Modified after Kujansuu & Niemelä (1984).

The glacier in the area flowed in a fan-shaped form from 270°—340° towards the arcs of the Salpausselkä ridges. The ice flow was linked with the development of the active Baltic Sea lobe (Punkari 1980). With the exception of some traces of older glacial flow coming from the northwest, markers of an older glacial flow phase are few in the northern part of the area. In general, the stratigraphy of the till is simple, only one till unit deposited by the last ice flow having been encountered.

Sample sites and observations

Sample sites 9—12 are situated in the area of uniform cover moraine near Tampere (Fig. 11). Test pits indicate that this unit is 2—4 m thick. In some places single moraine hummocks also occur.

Sample site 13 consists of esker material, and sample sites 14 and 15 are made up of the surface boulders of De Geer moraines in the immediate vicinity. Sample 16 was taken from the proximal moraine of Salpausselkä II, and samples 17—21 from the zone of Salpausselkä III. Morphological evidence of the Salpausselkä formation has not been found in the latter area, although drilling shows that the till beds are exceptionally thick (5—15 m). Single drumlins occur near the sample sites. Sample 22 was taken from surface boulders near a delta of the Salpausselkä system (Fig. 11).

The results of the boulder counts and their interpretation are given in Appendix. A possible bedrock source was determined for every boulder in the samples according to the bedrock reference listed (Appendix). The transport distance distributions are presented on this basis (Figs. 12 & 13).

Sample 9 (Fig. 12 A) represents a typical distance distribution for surface boulders deposited in the central areas of the Baltic Sea lobe. On the logarithmic probability paper the source areas fit well in the 95 per cent confidence belt, thus permitting the sample statistics for the distance distribution to be determined. Samples 9—12 represent the transport distance distributions for cover and hummocky moraine boulders (Fig. 12 B, Table 3).

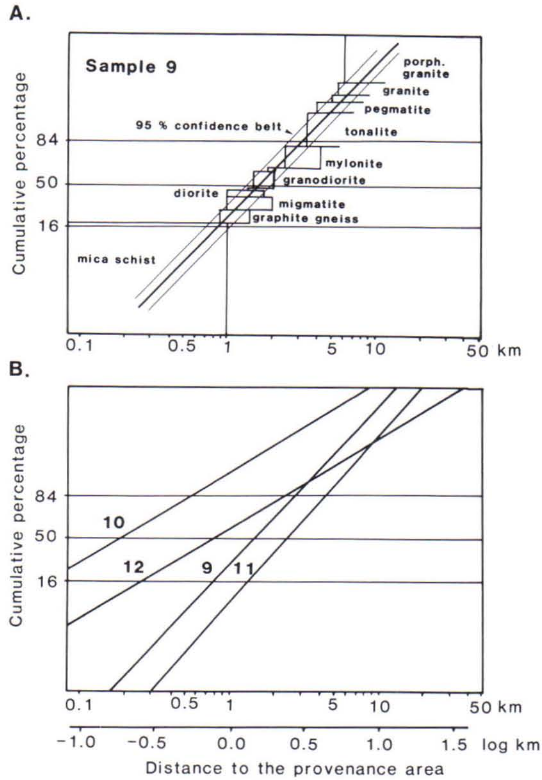


Fig. 12. Distance distribution for surface boulders in A) sample 9 and B) samples 9—12.

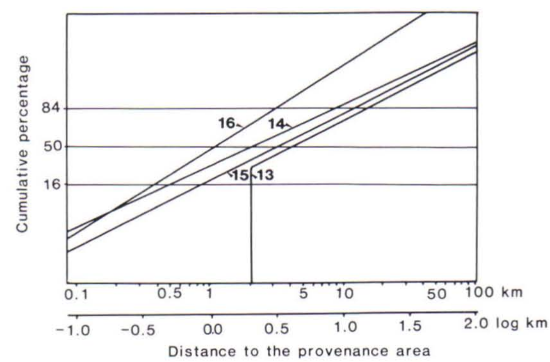


Fig. 13. Distance distribution for surface boulders in samples 13—15 and 16.

Table 3. Statistics for samples 9—22

Sample site	Mean $\bar{x}$/log km	Standard deviation s/log km	Geometric mean b/km	Depositional landform at sample site
9	0.20	0.30	1.60	cover moraine
10	—0.77	0.55	0.17	hummocky moraine
11	0.40	0.25	2.50	cover moraine
12	—0.15	0.55	0.70	hummocky moraine
13	0.60	0.60	4.0	esker
14	0.34	0.72	2.2	De Geer moraine
15	0.54	0.60	3.5	—,,—
16	0.06	0.51	1.15	marginal complex
17	0.32	0.47	2.10	cover moraine
18	0.18	0.53	1.5	—,,—
19	0.28	0.36	1.9	—,,—
20	0.20	0.47	1.6	—,,—
21	—0.15	1.05	0.7	—,,—
22	0.74	1.26	5.5	marginal complex

The transport distance distributions of esker boulders (sample 13) and boulders from a De Geer ridge (samples 14 and 15) resemble each other closely (Fig. 13). However the most local bedrock components, i.e. boulders transported less than one kilometre, are absent from glaciofluvial material. The geometric mean of the transport distance is slightly higher for esker material than for boulders from De Geer moraines, but the deviation in the distribution is similar in all samples.

Figure 13 also shows the transport distance distribution for surface boulders deposited near the proximal side of Salpausselkä II at observation site 16. The values (Table 3) are based on intimate knowledge of variations in bedrock (Appendix).

As pointed out by M. Perttunen (1977), the Hämeenlinna area (Sample sites 17 — 22) is suitable for transport distance measurements. Only one dominant direction of glacial flow with lithologic borders running transverse to it has been observed (Virkkala 1969). The results from boulder counts (Appendix) could thus be interpreted reliably and the variations in transport distributions presented (Fig. 14 A, Table 3).

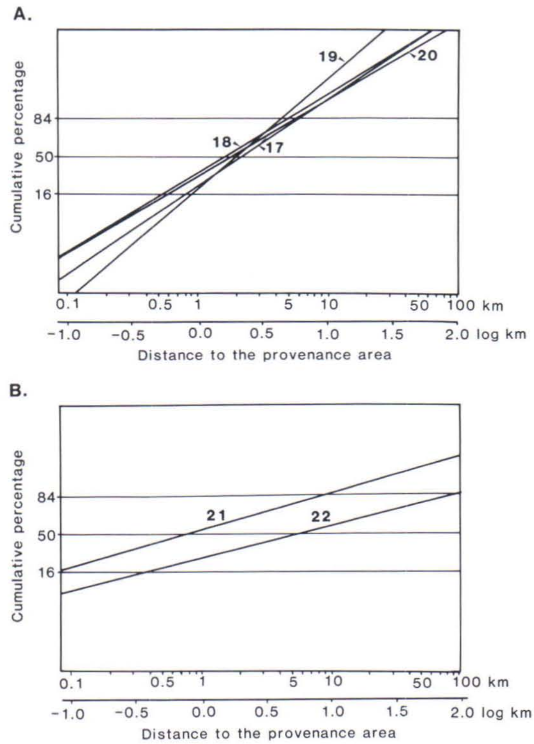


Fig. 14. Distance distribution for surface boulders in A) samples 17—20 and B) samples 21—22.

Sample site 21 is situated on the distal side of a dioritic rock massif, about 5 km wide (Appendix). The boulders originating from schist and volcanic belts behind this massif were under-represented, and as a result the deviation is high (Table 3, Fig. 14 B).

The same phenomenon is observed in the distribution curve for sample 22. The frequencies of the boulder types with their provenance in volcanic belts are too low for the size of the boulder sources. The boulders from areas of igneous rocks are over-represented. The plot on a probability net (Fig. 14 B) gives a high standard deviation for the geometric mean: 1.26 log km (Table 3).

These examples show that the physical characteristics of each provenance rock affect the transport distance distribution. M. Perttunen (1977) has used half-distance analyses to study this effect in the same area. The results of all half-distance determinations from the study area (Fig. 6) are given in Table 14.

Southeastern Finland

Quaternary deposits

The study area (Fig. 15) is part of the active flow zone of the Finnish Lake District ice lobe, the strongest and best developed Late Weichselian ice lobe in Finland (Punkari 1980). Its shape was affected by an oscillation phase, perhaps up to 50 km in length, during the formation of the First Salpausselkä end moraine (Rainio 1985).

During its main active phases, the glacier flowed from 300°—360°, as is indicated by the fan-shaped orientation of the Pieksämäki drumlin field (Glückert 1973). Hummocky moraine terrains are encountered between drumlins especially in the zone of Salpausselkä formations but also in some places in the north. Throughout the study area, till is the most common deposit of overburden. It usually has a simple stratigraphy, only one till bed associated with the genesis of the Salpausselkä ridges having been deposited. Older till units have been described from the southeastern and southwestern parts of the study area (Rainio & Lahermo 1984, Hirvas & Nenonen, in press). The till fabric of these clayey dark tills, is oriented from 300° to 340°.

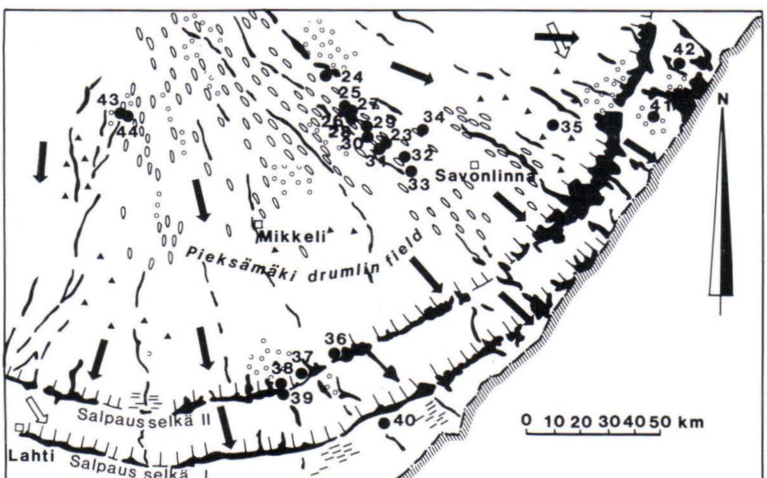


Fig. 15. The study area and sample sites 23—44 in southeastern Finland. For explanations, see Figs. 8 and 11. Modified after Kujansuu & Niemelä 1984.

Sample sites and observations

First, the variability in transport distances in the area of an active ice lobe was measured (samples 23—34), and then the transport distance distribution in the area of a large end moraine complex was determined (samples 36 — 42). Finally, the transport distances between drumlin boulders and boulders on a hummocky ridge close to it were compared (samples 43 & 44, Fig. 15).

The most promising area for studying the transport distance distribution was the Rantasalmi — Joroinen area (Fig. 15), where the isograds of progressive metamorphism (Korsman 1977) run transverse to the direction of glacial flow. This made it possible to use both the petrographic variation found in the boulders and their metamorphic character to help establish their possible provenance areas (see Korsman 1973, 1977, Appendix).

As an example, sample 23 (Fig. 16 A) demonstrates the suitability of the bedrock in determining the distance distribution of surface boulders. The plot fits well in the 95 per cent confidence belt, and the statistics can be estimated graphically (Table 4).

The geometric mean for the transport distance of sample 23 is 8.5 km. Table 4 also gives

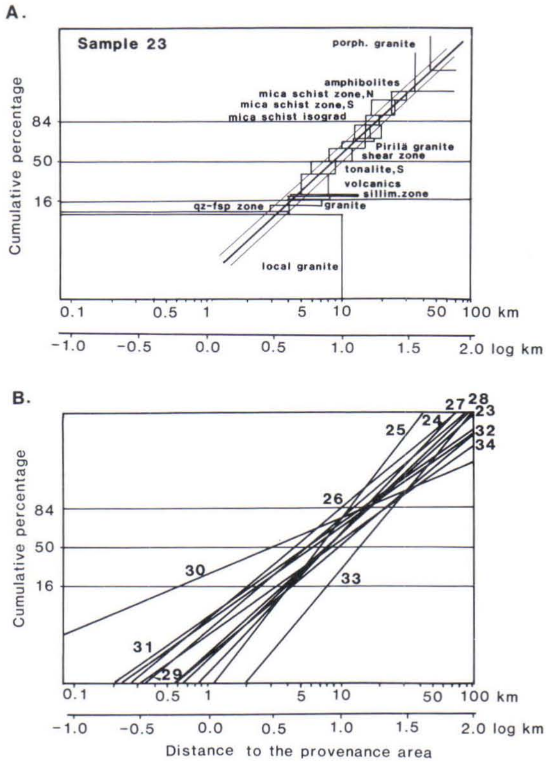


Fig. 16. Distance distribution for surface boulders in A) sample 23 and B) samples 23—34.

Table 4. Statistics for samples 23—35

Sample site	Mean x̄/log km	Standard deviation s/log km	Geometric mean b/km	Depositional landform at sample site
23	0.93	0.32	8.5	drumlin assemblage
24	0.67	0.38	4.7	cover moraine
25	0.85	0.23	7.0	drumlin assemblage
26	0.78	0.40	6.0	—,,—
27	0.93	0.29	8.5	—,,—
28	0.92	0.33	8.4	—,,—
29	0.78	0.35	6.0	—,,—
30	0.46	0.74	2.9	hummocky moraine
31	0.78	0.41	6.0	drumlin assemblage
32	1.00	0.39	10.0	—,,—
33	1.18	0.28	15.0	—,,—
34	0.95	0.42	9.0	—,,—
35	0.93	0.35	8.5	cover moraine

the statistics for samples 23—34. They form a uniform group with 0.38 as the grand mean for standard deviation and 7.3 km for the geometric mean. These samples exhibit a notably longer transport distance than those in the previous examples. The values may indicate the transport distance distribution for the area of a large drumlin field.

Sample site 30 differs from the others. The distribution curve has a higher standard deviation and a lower value for the geometric mean than the other samples. At this site the local granite (the Pirilä granite, Appendix) makes the terrain hilly, and the till cover is thin. There are no drumlins as at the other sample sites but some, mainly disintegration, hummocks are found. The distribution curve (Fig. 16 B) resembles those for the Hämeenlinna region (samples 21 and 22, Fig. 14 B), which are in a similar position in relation to lithologic variations: the schists are behind the igneous rocks transverse to the ice flow.

Comparision of the transport distance distributions of the drumlin field by area (Figs. 15, 16) reveals that in the northern part of the study area the boulders are of more local origin (e.g. sample 24, b = 4.7 km) than in the southern part (e.g. sample 33, b = 15.0 km). This feature is also demonstrated by half-distance traverses 8 and 9 (Fig. 6). The granite boulders originating from the Pieksämäki stock (Vorma 1971) have a half-distance value of 3.8 km (Fig. 17, Table 14), and the curve fits the negative exponential function [4] well (r = 0.907***). The counting sites that are farthest from the distal contact deviate for most of the curve, possible because the half-distance traverse extends from a hummocky moraine area to a drumlin field (Fig. 15). Over this distance the value for $x_{1/2}$ increases. Likewise, measurement of the half-distance value in the drumlin area (traverse 9, Fig. 17, Table 14) gives a longer half-distance (5.6 km).

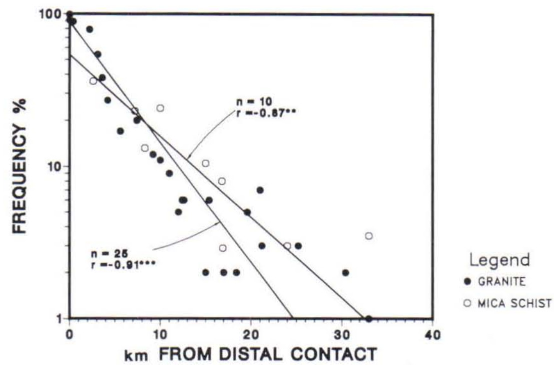


Fig. 17. Half-distance determinations for traverses 8 (porphyry granite) and 9 (mica schist). Traverse 8 in an active-ice hummocky moraine area gives a shorter value for $x_{1/2}$ (3.85 km) than traverse 9 (5.33 km) extending to a drumlin field.

Samples 36—39 were chosen to describe the transport distance distribution of surface boulders to the proximal surroundings of the Salpausselkä I formation (Figs. 15, 18, Table 5).

Table 5. Statistics for samples 36—44

Sample site	Mean x̄/log km	Standard deviation s/log km	Geometric mean b/km	Depositional landform at sample site
36	0.48	0.57	3.0	marginal complex
37	0.95	0.33	9.0	—,,—
38	0.72	0.35	5.2	—,,—
39	0.70	0.39	5.0	—,,—
40	0.50	0.35	3.2	ground moraine
41	0.02	0.34	1.05	—,,—
42	0.40	1.00	2.5	—,,—
43	0.23	0.83	1.7	hummocky moraine
44	0.88	0.87	7.5	drumlin assemblage

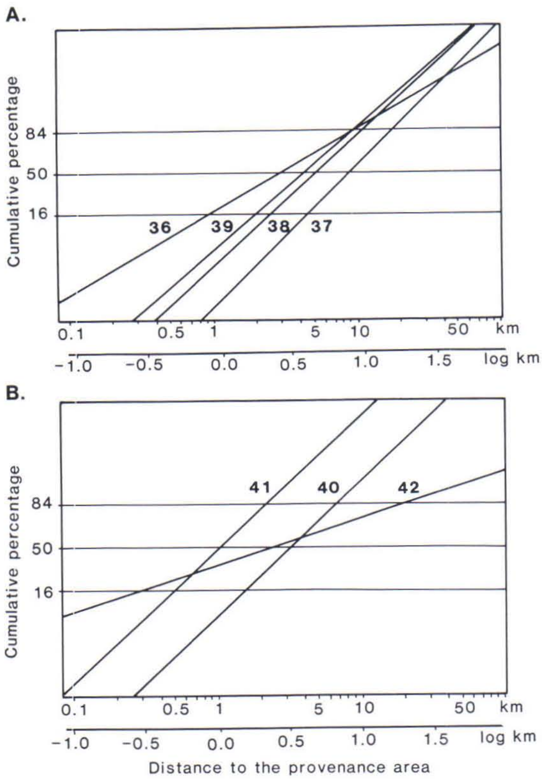


Fig. 18. Distance distributions for surface boulders in A) samples 36—39 and B) samples 40—42.

For comparison, a half-distance observation line (traverse 10, Fig. 7) based on data of Johansson (1980) is presented (Table 14). It gives a value of $x_{1/2} = 4.0$ km for indicator boulders originating from the Rapakivi granite stock of Ahvenisto.

Sample site 40 represents the distance distribution for surface boulders in the distal part of Salpausselkä II. Samples 41 and 42 give estimates for the length of glacial transport in

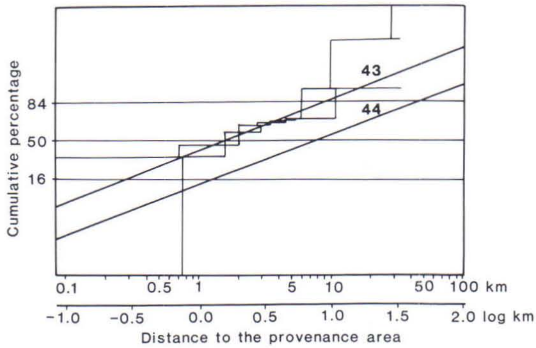


Fig. 19. Distance distribution for surface boulders in samples 43 (hummocky moraine) and 44 (drumlin).

the area between these ridges (Fig. 18 B, Table 5).

The results suggest a relatively short transport distance. Worth noticing is the high value of the standard deviation at sample site 42. This may be due to the existence in the area (Fig. 15) of moraine units deposited by several glacial flows (Salminen 1980, Hirvas and Nenonen, in press).

Sample sites 43 and 44 were chosen for comparison of the surface boulder distribution of different glacial geological formations. According to the measurement (Fig. 19, Table 5), the geometric mean of the transport of the boulders of drumlin material is nearly six kilometres longer than that of the boulders of hummocky moraine. The sample sites are situated about 300 m apart.

Near sample sites 43 and 44, the half-distance value was calculated from material of Johansson (1980) (Fig. 6, Table 14). The value $x_{1/2}$ = 2.1 km is the transport distance for volcanic cobbles 60—200 mm in diameter.

North Karelia

Quaternary deposits

North Karelia is an area of complex glacial transport mechanism (Fig. 20) that has been described earlier in a variety of contexts. The Quaternary glacial history of the area has been treated by Repo (1957) and Rainio (1983). The various stages of glacial transport and the associated deposition of till have been discussed in detail by Aurola (1955), Repo (1957), Nenonen (1984) and recently by Salminen and Hartikainen (1985) and by Aumo and Salonen (1986). The stratigraphy of till in North Karelia has been discussed exhaustively by Hirvas (1980), Salminen (1980) and Hirvas and Nenonen (in press).

Cover moraine is the most common depositional unit in the study area. Together with large glaciofluvial systems it forms the huge Salpausselkä ridges and interlobate formations (Fig. 20), the most prominent of which are the Salpausselkä II and Jaamankangas end moraines. They developed between two oscillating ice lobes, namely, the Finnish Lake District ice lobe and the North Karelian ice lobe (Punkari 1980).

Indications of the older glacial flow from the north-northwest abound in the study area. However, the most significant glacial movements are associated with the formation of large marginal complexes. During the first Salpausselkä stage the ice readvanced from the west-northwest (Rainio 1985). Later, during the deglaciation, the direction of glacial transport turned towards the interlobate system between the two ice lobes (Repo 1957, Salminen & Hartikainen 1985). In many places the flow and oscillation of active lobes during the deglaciation phase destroyed the striae and other traces of the older movement.

Deglaciation began in the southeastern corner of the study area. According to Rainio (1985), the whole area was ice free during what

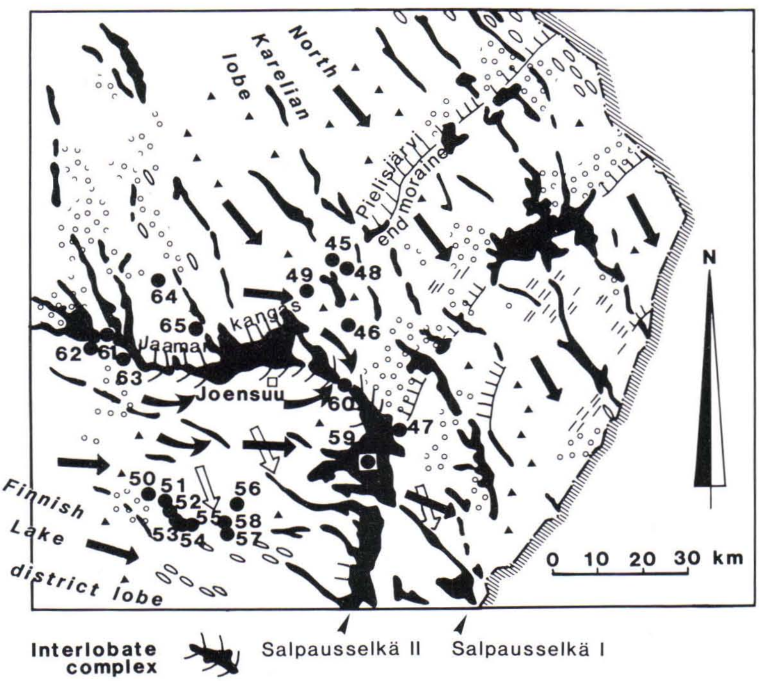


Fig. 20. The study area in North Karelia and sample sites 45—65. The directions of glacial transport vary markedly on either side of the marginal and interlobate complexes. For explanations, see Figs. 8 and 11. Modified after Kujansuu & Niemelä 1984.

is known as the Heinola deglaciation (M. Okko 1962). Afterwards, the ice readvanced from the west-northwest for a distance of about 50 km, thus giving rise to the main arc of Salpausselkä I.

The ice flow dynamics were then divided between two lobes, with flow regimes oriented in different directions. Salpausselkä II was formed during the marginal stage of the Finnish Lake District lobe, and the Selkäkangas, Pielisjärvi and Jaamankangas end moraines developed in the marginal positions of the North Karelian ice lobe (cf. Repo 1957, Punkari 1980, Salminen 1980, Lyytikäinen 1982, Rainio 1983, Salminen and Hartikainen 1985). An intelobate system operated between those lobes, especially in the area west of the Jaamankangas marginal formation (Fig. 20).

As a rule, the till stratigraphy comprises only one till bed, which can be correlated with the two ice lobes mentioned earlier. In some places, in the southwestern part of the study area in particular, a lower till unit has been found underlying the upper lobe till unit (cf. Hirvas and Nenonen, in press).

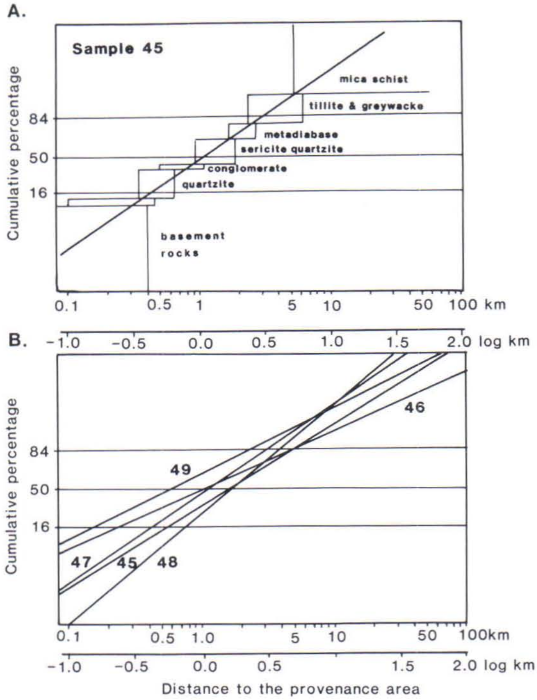


Fig. 21. Distance distribution for surface boulders in A) sample 45 and B) samples 45—49.

Sample sites and observations

The transport distance distribution was observed at sample sites 45 — 49 in the area outside the strongest ice flow activity during the deglaciation. In this area, the till cover is thin and, having no topography of its own, it follows the relief of the bedrock surface.

Sampling sites 50—60 form a line along which the variability in transport distances in the terminal area of an active ice lobe can be observed (Fig. 20). Sample sites 61—65 represent the area of an interlobate complex. Two different flow regimes operated during the deglaciation, and the flow directions of the two adjacent ice lobes differ from each other.

The sampling with boulder counts was planned so that the lithologic variability of the Karelian schist belt could be utilized when determining the provenance areas (Appendix). The procedure is demonstrated in the total transport analysis for sample site 45 (Fig. 21 A).

Rock types have characteristic variations in habit and are, therefore, easy to classify. They occur in bedrock as suitably wide (0.1—2.0 km) belts transverse to the direction of the most prominent glacial flow. The distributions for samples 45—49 are given in Figure 21 B and Table 6.

The distributions (Fig. 21) give an impression of a transport distance that is shorter than in similar glacial geological positions in the southern part of the Salpausselkä ridges (sites 36—39, Fig. 18). In North Karelia the distributions form a uniform group, allowing the

Table 6. Statistics for samples 45—49

Sample site	Mean $\bar{x}$/log km	Standard deviation s/log km	Geometric mean b/km	Depositional landform at sample site
45	0.04	0.44	1.1	cover moraine
46	0.04	0.74	1.1	—,,—
47	0.15	0.53	1.4	—,,—
48	0.23	0.38	1.7	—,,—
49	—0.19	0.63	0.65	—,,—

Table 7. Statistics for samples 50—60

Sample site	Mean $\bar{x}$/log km	Standard deviation s/log km	Geometric mean b/km	Depositional landform at sample site
50	0.48	0.47	3.0	cover moraine
51	0.72	0.80	5.3	—,,—
52	0.79	0.39	6.2	—,,—
53	1.04	0.31	11.0	—,,—
54	1.11	0.26	13.0	—,,—
55	0.93	0.30	8.5	drumlin assemblage
56	0.91	0.39	8.2	cover moraine
57	1.18	0.35	15.0	ground moraine
58	1.43	0.25	27.0	—,,—
59	1.57	0.27	37.0	marginal complex
60	1.36	0.41	23.0	—,,—

determination of parameters for glacial transport in the contact zone of Prekarelian basement gneiss and Karelian schists (Fig. 6). No elongated moraine forms have been found in this area. It is obvious that the glacier did not flow as fast or as uniformly as in the area of the active ice lobe farther south (Fig. 18).

Boulder counts 50—60 represent the transport distribution samples for surface boulders deposited by the active flow of the Finnish Lake District ice lobe (Fig. 20). The distributions based on provenance estimations in Appendix are presented in Figure 22 A and Table 7.

The development in the transport distance distribution is shown with a sinuous arrow (Fig. 20), which connects the sample sites so that they form a line from the central area of the Finnish Lake District ice lobe to the margin of the Salpausselkä II formation. Note that the value for the transport distance increases along this line (Fig. 22 A). The geometric mean grows from 3.0 km (sample 50) to 37 km at sample site 59. At the same time the value of standard deviation decreases from 0.5 (sample 50) to 0.25 log km (sample 58).

Observation samples 61—65 were collected from the area of the interlobate complex (Fig. 20). Glaciofluvial deposits are common in the area, and it was not easy to find boulder-rich till on the surface of the overburden. The results (Fig. 22 B, Table 8) for all the samples reflect similar depositional conditions. The standard deviation tends to be high and sample

Table 8. Statistics for sample distributions 61—65

Sample site	Mean x̄/log km	Standard deviation s/log km	Geometric mean b/km	Depositional landform at sample site
61	0.34	0.50	2.2	interlobate complex
62	0.11	0.63	1.3	—,,—
63	0.78	0.38	6.0	—,,—
64	0.82	0.57	6.6	—,,—
65	—	—	1.9	cover moraine

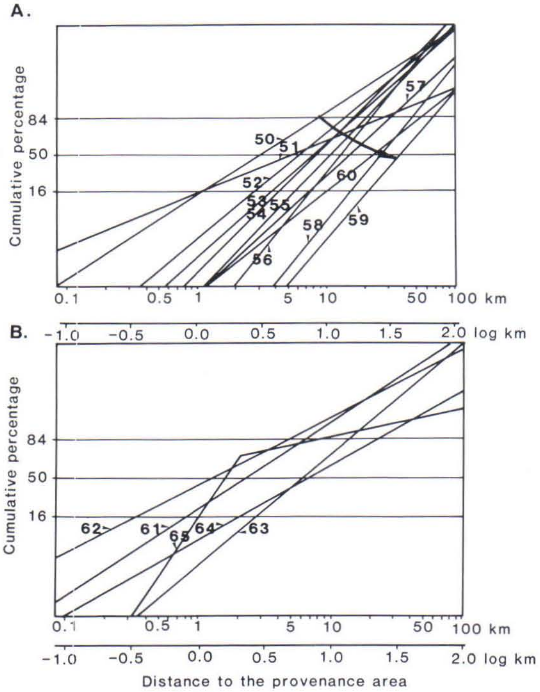


Fig. 22. A) Distance distribution for surface boulders in samples 50—60. The arrow connecting the sample sites forms a line from the cover moraine area through the area of active lobate ice flow to the marginal complex of Salpausselkä II (see Fig. 20). B) Distance distribution for surface boulders in the interlobate zone, samples 61—65.

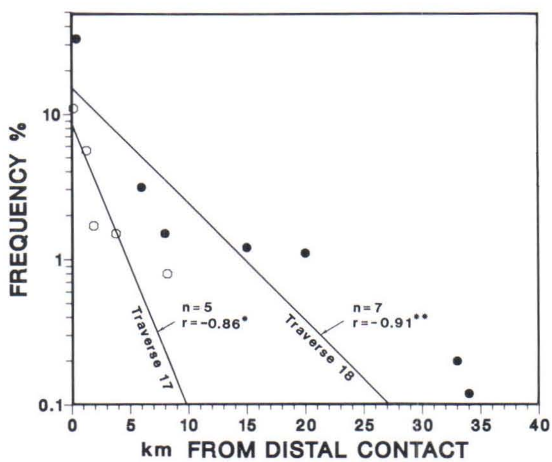


Fig. 23. Half-distance values in two traverses for boulders originating from the Outokumpu belt. The transport distance is longer in the area of the active ice lobe (traverse 18) than in the surroundings of the interlobate complex (traverse 17).

65 seems to consist of two sub-populations, possibly because of the existence of a solid and extensive area of basement granites and gneisses close to the sampling point (Appendix). Behind this, forming the population of longer-travelled boulder material, is the bedrock area of mica schists and volcanic rocks. This kind of lithologic effect was also noted at sample sites 21, 22 and 30.

Three half-distance traverses were established in the study area. Four more values of $x_{1/2}$ could be calculated using the data presented in the literature (Fig. 6, Table 14).

The Kalevan mica schist belt in North Karelia is about 60 km wide (Fig. 6). Boulder count traverse 12, which extends from its distal contact in the direction of glacial flow, gives a half-distance of 1.2 km. The data of Rainio (1983) from the same bedrock contact give 2.3 km and those of Salminen (1980) 1.4 km for the half-distance. The fourth value $x_{1/2} = 0.77$ km of Salminen and Hartikainen (1985) from the same contact supports the observations that short glacial transport prevailed in the area.

Two half-distance values for the surface boulder fraction were measured from the traverses extending from the distal contact of the Outokumpu Assemblage in the direction of glacial flow (traverses 17 and 18, Fig. 6, Table 14). The belt of rocks of the Outokumpu zone (quartzites, serpentinites and tremolite skarn rocks) is of approximately the same width at the beginning of both traverses (Fig. 23). The value for the half-distance is 1.5 km in the area of the interlobate complex (traverse 17) but as much as 4.2 km in the area of the active ice lobe (traverse 18).

In the north of the study area one half-distance value could be calculated from the data of Repo (1957). The transport distance for quartzitic boulders in the active area of the North Karelian ice lobe is 13.4 km (Fig. 6, Table 14).

Savo

Quaternary deposits

The Quaternary geology of the study area in Savo has been described by Brander (1934). He was the first to come upon indications of three glacial blocks that had probably been affected by topographic features. Two of them have since been named the Finnish Lake District ice lobe and the North Karelian ice lobe. The interlobate complex of Pielavesi is situated between the two ice lobes (Fig. 24) (Punkari 1980, Ekdahl 1982).

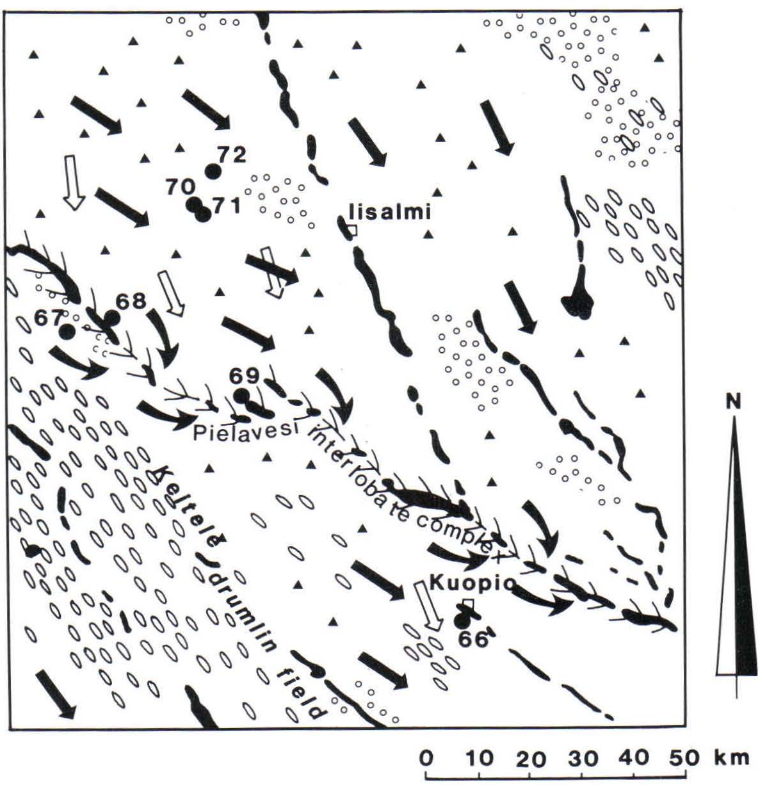


Fig. 24. The study area in Savo, sample sites 66—72. Two different glacial geological subareas can be distinguished in relation to the Pielavesi interlobate complex. For explanations, see Figs. 8 and 11. Modified after Kujansuu & Niemelä 1984.

In the central areas of the ice lobes the ice flowed from a constant direction during the last active phases of the Weichselian glaciation. This caused intensive drumlinization in the area (Fig. 24). The Keitele drumlin field in the south has over 3000 drumlin formations (Glückert 1973).

Between the active zone of the ice lobes the till occurs as cover moraine. Striae and till fabric observations indicate that the ice flowed in various directions in this area (Sauramo 1926, Brander 1934, Ekdahl 1982). The till is approximately 3—5 m thick (Ekdahl 1982).

All the observed ice flow directions in the area are associated with the development of the Weichselian ice flow configuration after the formation of the Salpausselkä ridges. The striae systems in the area of the town of Kuopio may be still older (Fig. 24). If they are, they may have developed during the growth phase of the last Weichselian glaciation and can thus be correlated with the deposition of 'dark till' (Rainio & Lahermo 1984). A similar stratigraphy of till has been described from the Pielavesi area (Ekdahl 1982).

Sample sites and observations

The purpose of the observations was to investigate the transport distance distributions on both sides of the Pielavesi interlobate complex. Boulder counts were carried out at seven sample sites in the study area (Fig. 24). The most reliable results were obtained in the area where only one direction of glacial flow dominated and where rock contacts run transverse to the last glacial movement. In one example from the Kuopio region (Fig. 25 A, Appendix) the geometric mean has a typical value of (b = 1.6 km) for the cover moraine.

Sample sites 67 and 68 are situated on opposite sides of the interlobate formation (Fig. 24). Sample 67 represents boulder-rich hummocky moraine material, whereas sample 68 was collected from surface boulders from an undulating ground moraine. The distributions (Fig. 25 B, Table 9) differ from each other. The geometric mean of the transport distance is smaller but the standard deviation is greater in hummocky moraine than in the ground moraine. The same phenomenon was observed in the Merikarvia area with samples from different sides of the interlobate formation (Figs. 8 & 9).

At Sarvimäki, on the proximal side of the Pielavesi end formation, there are traces of several ice flow directions. The distribution curve for sample site 69 (Fig. 26 A) is based on provenance areas in the 290° to 350° sector (Appendix). The 95 per cent confidence belt covers the variability of the plot well and as a result the statistics can be estimated (Table 9).

This is not the case for the whole study area. For example, the transport parameters of a boulder sample from ten km north of sample

Table 9. Statistics for samples 66—72

Sample site	Mean $\bar{x}$/log km	Standard deviation s/log km	Geometric mean b/km	Depositional landform at sample site
66	0.20	0.58	1.6	cover moraine
67	0.45	0.74	2.8	hummocky moraine
68	0.78	0.52	6.0	ground moraine
69	0.81	0.36	6.5	interlobate complex
70	0.49	0.45	3.1	cover moraine
71	0.44	0.46	2.5	—,,—
72	0.56—0.76	0.54	3.5—5.7	ground moraine

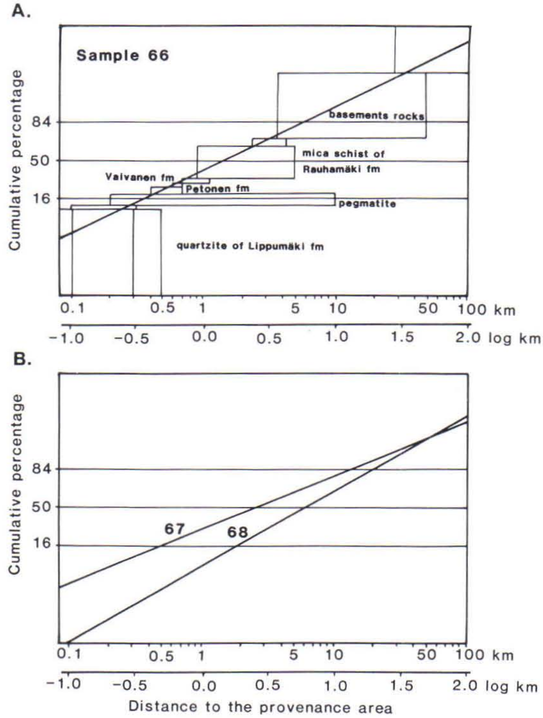


Fig. 25. Distance distribution for surface boulders in A) sample 66 and B) samples 67 and 68.

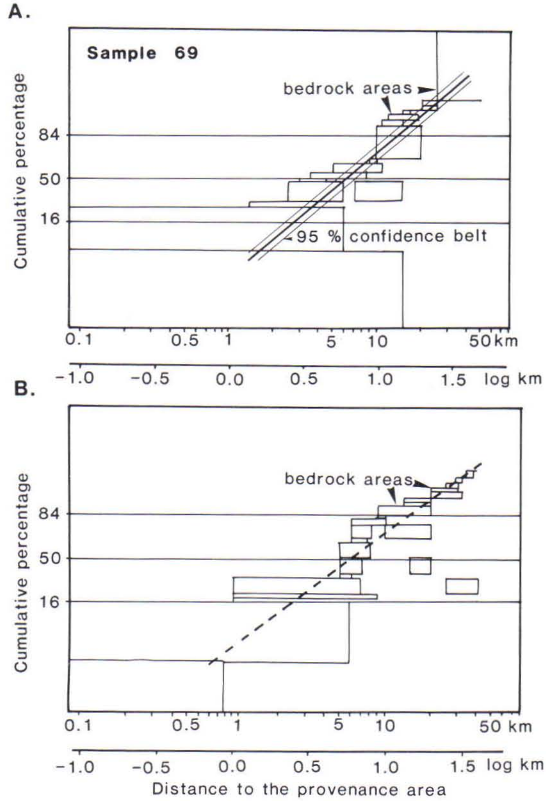


Fig. 26 A) Distance distribution for surface boulders in sample 69. B) Two separate ice flow directions have disturbed the natural trend in the distribution, and the transport statistics cannot be estimated.

site 69 (Fig. 26 B) cannot be estimated, probably because there were several ice flows from different directions, and they cannot be separated from each other.

The results from the boulder counts in sample sites 70—72 are presented as distribution curves (Fig. 27) based on data given in Appendix. Sample 72 consists of five different boulder counts conducted close to each other. The results (Table 9) represents the transport conditions in the intermediate stagnant zone between two active ice lobes.

Three half-distance traverses (19—21, Fig. 6) were analysed from the study area. The results are presented in Table 14. The values of $x_{1/2}$ are relatively low (1.06—3.1 km), indicating short glacial transport.

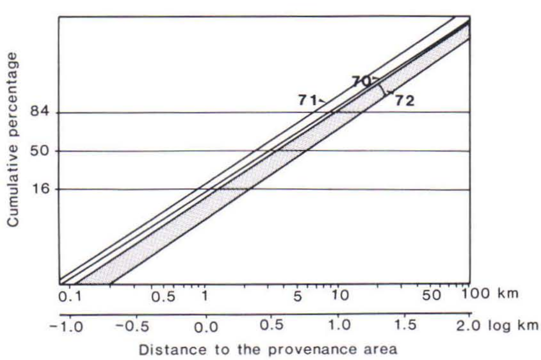


Fig. 27. Transport distance distributions for samples 70—72.

Central Ostrobothnia

Quaternary deposits

The general Quaternary geology of the study area has been described by V. Okko (1949) and Punkari (1982). The southwesternmost part of the area (Fig. 28) is characterized by ribbed moraines. They are short ridges transverse to the ice flow, which form belts parallel to the regional direction of the ice flow. Much of the terrain within the belts of ribbed moraine is heavily covered with boulders. In many places the belts pass laterally into a drumlinized till plain. Ribbed moraine of this kind has been reported from near the central parts of the Laurentide Ice Sheet (Shilts 1977); it also resembles the Rogen moraine described from Sweden (J. Lundqvist 1969).

The terrain in the northern part of the study area (Fig. 28) is even more rocky, and formations such as drumlins and flutings, which are associated with the active ice flow, are lacking here. Most of the morainic formations consist of disintegration hummocky moraines without any orientation.

A wide diversity of ice flow directions has been reported. Many of them cross each other, especially on the shores of the recent Gulf of

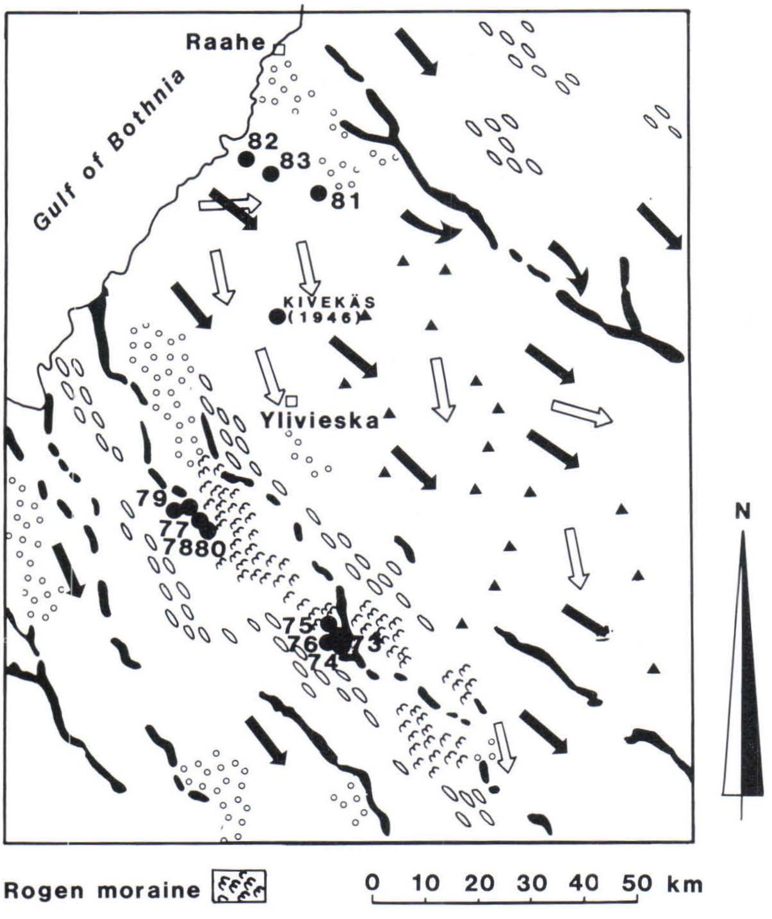


Fig. 28. The study area in Central Ostrobothnia, sample sites 73—83. For explanations, see Figs. 8 and 11. Modified after Kujansuu & Niemelä 1984.

Bothnia. Helaakoski (1940) discussed their significance in his study of the glacial history of the Weichselian ice sheet. It is evident that some of the directions of glacial flow are connected with the final phases of the glaciation, but others may be considerably older, as is evidenced by sorted and organic sediments encountered beneath the till (Niemelä 1979, Niemelä & Tynni 1979, Forsström 1982, Hirvas and Nenonen, in press).

Sample sites and observations

The observations made at sample sites 73—76 have been compiled in Figure 29 A and Table 10. The delineator for transport distance distributions bears evidence of relatively short transport distance. Two different subpopulations can be distinguished on the basis of the distributions at sample sites 75 and 76. The statistics were determined only for the greater, that is, the local, sub-population. They indicate a short transport distance for surface boulders deposited with Rogen moraines.

Another sample set (77—80) from nearby (Fig. 29 B, Table 10) shows a similar trend. The gentle slope of the transport distance

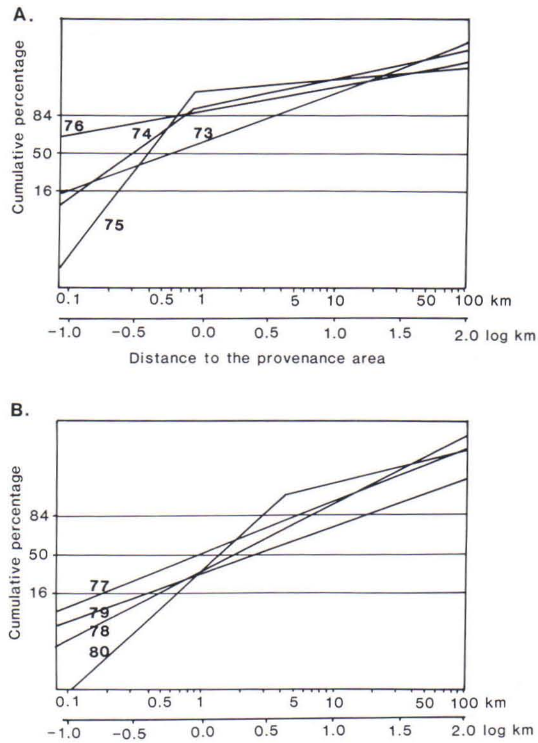


Fig. 29. Distance distributions for surface boulders in A) samples 73—76 and B) samples 77—80.

Table 10. Statistics for samples 73—83

Sample site	Mean x̄/log km	Standard deviation s/log km	Geometric mean b/km	Depositional landform at sample site
73	—0.26	0.74	0.55	Rogen moraine
74	—0.52	0.41	0.30	—,,—
75	—0.40	0.24	0.40	—,,—
76	—2.52	1.19	0.003	—,,—
77	0.00	0.78	1.00	hummocky moraine
78	0.28	0.58	1.9	—,,—
79	0.43	0.90	2.7	—,,—
80	0.15	0.37	1.4	—,,—
81	0.78	0.47	6.0	ground moraine
82	0.41	0.65	2.6	cover moraine
83	0.82	0.57	6.6	—,,—
Kivekäs (1946)	1.32	0.42	21.0	ground moraine

distributions may be the result of mixing of two sub-populations. For sample site 80 these populations appear as their own curves in the graph. The statistics were determined for the local transport population, which can presumably be attributed to the last quarrying erosion phase of the glacier. Incorporation of the material into the ice was still effective, but the flow of the ice was already weak and thus the transport distance was insignificant.

The transport distance distributions obtained in the coastal area of Central Ostrobothnia (Fig. 28) are presented in Figure 30. The statistics for their delineators (Table 10) resemble those of others in the area. Long-distance transport has also been obtained in this area. The material collected by Kivekäs (1946, p. 21) was re-treated with the method used in the present study. The data of Kivekäs show that the long-distance boulder material predominates at the sample site. Hence all the other samples (Table 10, Appendix) contain a mixture of two different boulder transport phases.

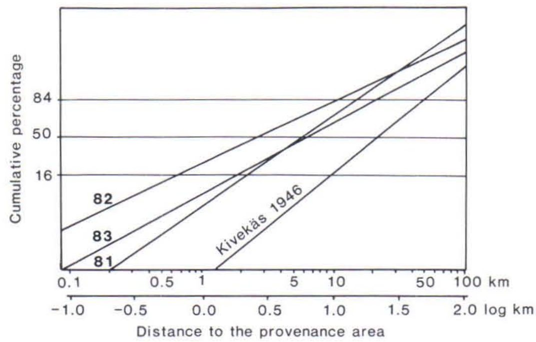


Fig. 30. Distance distributions for surface boulders in samples 81—83, and for the data of Kivekäs (1946, p. 21).

The half-distances were measured from six traverses (22—27, Fig. 6). Several types of distinctive indicator rocks were used and the observation lines were located in different glacial geological environments. The results (Table 14) show conspicuously short transport distance values, i.e. $x_{1/2}$ varies between 0.2 and 1.4 km.

Kainuu

Quaternary deposits

The composition of glacial deposits and the morphology of the Kainuu region (Fig. 31) have been described by Saarnisto and Peltoniemi (1984). The bedrock in the area is covered with till that is normally only a few metres thick. Elongated drumlins have formed in places, the most prominent field being in the environment of the lake Ontojärvi. In the Kuhmo area there are several small swarms that together form a larger drumlin area, called the Kuhmo drumlin field (Glückert 1976). The striations and the trend of the streamlined ridges indicate that the general direction of the last ice movement in the area was from 290°—300°.

The glacial geology for the northern part of the study area has been described by Aario and Forsström (1979). The most common depositional form of till is cover moraine. In the north there is the wide Suomussalmi train of morainic hummocks. Trains of hummocks parallel to nearby eskers are found here and there throughout the study area (Saarnisto & Peltoniemi 1984).

The markers of glacial flow are in general in a fan-shaped orientation sector from 270° to 320° (Fig. 31). The main glacial dynamic agent in the area was the North Karelian ice lobe (Punkari 1980). However, marked variations in the directions of glacial flow have been described from the northern part of the study area in particular (Aario & Forsström 1979,

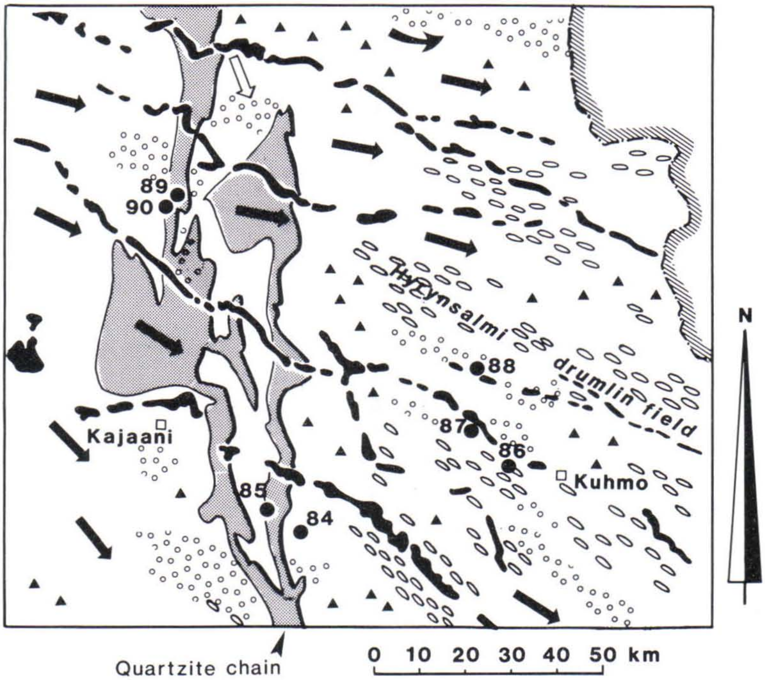


Fig. 31. The study area in Kainuu, sample sites 84—90. The drumlins and striae indicate the direction of glacial movement. The quartzitic highs have disturbed the general ice movement and in places led to deposition of hummocky moraines. For explanations, see Figs. 8 and 11. Modified after Simonen (1980) and Kujansuu & Niemelä (1984).

Saarnisto & Peltoniemi 1984). The age difference between the flow phases is not great (Saarnisto & Peltoniemi 1984).

Most of the bedrock in the area consists of rocks of the Archaean basement gneiss complex. In the middle lies a narrow greenstone belt, with quartzite belts of Kainuu schists forming a chain of higher ground (Fig. 31). This has a sufficiently marked relief to have influenced the location of ice lobes and their flow patterns during the deglaciation. It is also worth noting that the hummocky moraines often deposited on the proximal sides of these quartzitic highs (see Kujansuu and Niemelä 1984).

Sample sites and observations

Sample sites 84 and 85 are situated on the slope of the quartzitic hill of Vuokattivaara (Fig. 31). The characteristic variations in the bedrock (Havola 1981, Appendix) provide a good basis for determining the transport distance distributions (Fig. 32 A, Table 11).

Table 11. Statistics for samples 84—90

Sample site	Mean $\bar{x}$/log km	Standard deviation s/log km	Geometric mean b/km	Depositional landform at sample site
84	0.85	0.38	7.0	ground moraine
85	0.85	0.58	7.0	—,,—
86	1.08	0.38	12.0	drumlin assemblage
87	0.54	0.42	3.5	hummocky moraine
88	0.89	0.50	7.8	—,,—
89	0.85	0.75	7.0	ground moraine
90	1.15	1.15	14.0	—,,—

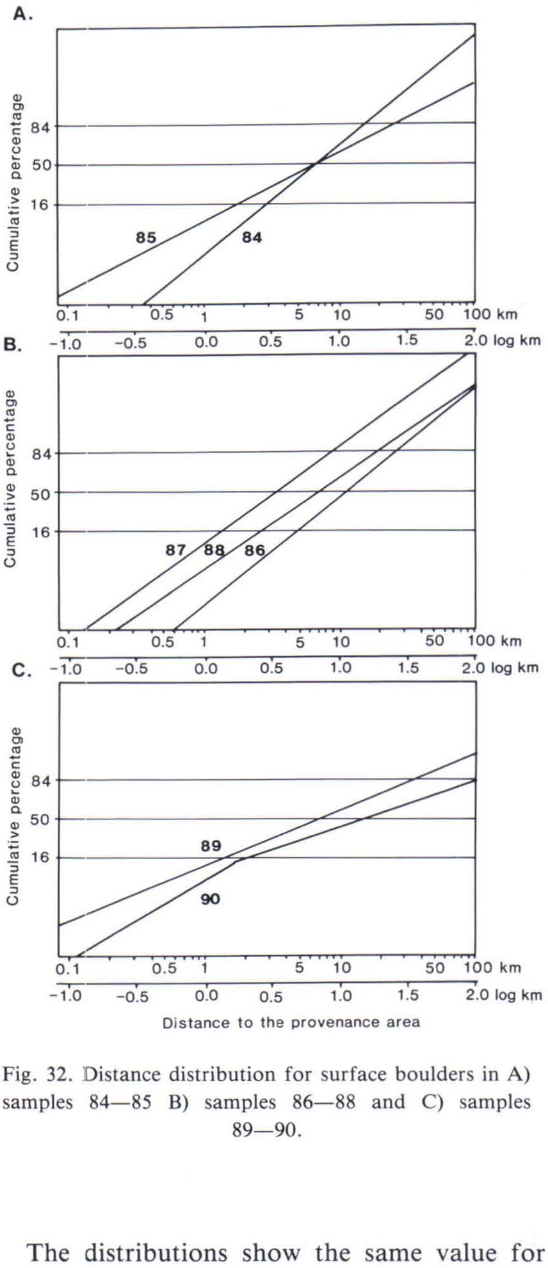


Fig. 32. Distance distribution for surface boulders in A) samples 84—85 B) samples 86—88 and C) samples 89—90.

The distributions show the same value for the geometric mean, but the values of the standard deviation differ from each other. The boulder material at sample site 85, which is located on the proximal side of the hill, contains a higher proportion of far-travelled material than does sample 84 from the distal part of Vuokattivaara (Fig. 31, 32 A).

A half-distance value of 29.0 km was calculated for the Vuokatti area from Virkkala's (1949) observations of quartzitic pebbles originating from the Kainuu quartzite zone (Fig. 6, traverse 30). This is the highest half-distance value calculated in the present study (Table 14).

Boulder counts 86—88 (Fig. 32 B) are presented as distribution lines giving the transport distance statistics for surface boulders in the Kuhmo area. The results (Table 11) show that sample site 86 has the longest transport distance. The boulders of this sample were deposited with a small drumlin swarm. Samples 87 and 88 represent hummocky moraine material deposited near an esker area (Fig. 31).

The transport distances of till clasts in this area have been discussed by Peltoniemi (1985). According to him, the half-distance value for the rocks of the 5-km-wide Kuhmo greenstone belt varies between 2 and 16 km, depending on the model used in the estimation. From equation [4], the value was calculated to be 5.8 km (Table 14); the correlation is poor (-.44), however.

Data presented by Saarnisto and Taipale (1984, Fig. 2) provide another possibility for estimating the half-distance, by using equation [4]. A value of 6.6 km for the boulder fraction was obtained with a good correlation (r = -.995***) for the fit of the distribution curve (Table 14). The half-distance value based on data on quartzitic cobbles originating from the hill of Moisionvaara (traverse 31, Fig. 6) (Virkkala 1960) is slightly higher ($x_{1/2}$ = 9.4 km) (Table 14). This observation traverse extends to the Suomussalmi drumlin field (Fig. 31).

Samples 89 and 90 were collected from surface boulders of the cover moraine deposited on the proximal side of the hill area (Fig. 31). The transport distance distribution curves (Fig. 32 C) show that the boulders have been transported a long distance. The value of standard deviation is also high (Table 11).

Evidently the high Paljakkavaara has collected englacial debris and thus lengthened the transport distance of the surface boulders.

The long transport distance in the area is also demonstrated by half-distance traverse 32 (Fig. 6), where the half-distance value has been found to be 15.6 km for quartzitic cobbles. The original data are from Virkkala (1949).

Northern Ostrobothnia

Quaternary deposits

The northernmost coastal area of the Gulf of Bothnia (Fig. 33) is the site of activity of the last remnants of the Weichselian ice in Finland. During its final stage the glacier flow weakened and as a result many signs of earlier depositional units are encountered in the area. One of the Peräpohjola interstadial sites of Korpela (1969) is located in this same area.

The uppermost till bed was deposited by the last glacier flow from ca. 280°. Underlying it in many places there is a till unit deposited by a glacier flowing from 340° (Mäkinen 1979). These till beds are correlated with the stratigraphic units, till bed II (upper) and till bed III (lower), presented by Hirvas *et al.* (1977) and by Hirvas and Nenonen (in press).

The main direction of glacial flow in the area is the older one, which varies between 340° and 360° (Fig. 33). A small drumlin field is associated with the active phase of this stade, and most of the esker systems are due to the deglaciation of this earlier active stade of the Weichselian (see Mäkinen 1979, Mäkinen & Maunu 1984).

Markers of younger, westerly ice flow are common in the northern part of the study area (Fig. 33). In some places this last phase of glacial flow involved quarrying. Much debris has been eroded from the bedrock and deposited as a boulder-rich till. For example, the

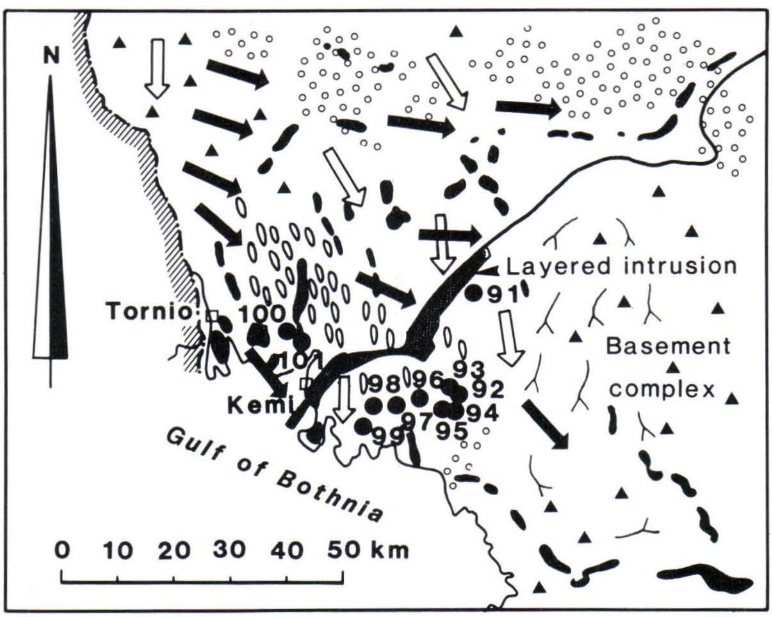


Fig. 33. The study area in northern Ostrobothnia, samples 91—101. The bedrock contact of Karelian schists and Archaean rocks controls the youngest ice flow direction. For explanations, see Figs 8 and 11. Modified after Simonen (1980) and Kujansuu & Niemelä (1984).

wide hummocky moraine field at Tervola was formed during this stage.

There is also a lithologic boundary in the bedrock in the transition zone between these two different glacial geological provinces (Fig. 33). The contact of the Prekarelian basement and Karelian schists runs through the study area (V. Perttunen 1984), and between these two main units there is a basic layered intrusion. The intrusion and quartzites of Karelian schists form a hilly terrain with a relative elevation of 60—80 m.

Sample sites and observations

The purpose of sampling in this area was to collect material for study of the glacial transport of the boulder fraction in an area of several ice flows. Sampling sites 91—99 represent the cover moraine area, where the markers of earlier glacial flow are most common. The moraine is thinner and it has no topography of its own.

Sample sites 100 and 101 are situated in a drumlin assemblage deposited by the earlier glacial flow. The drumlins exhibit north-south orientation (Fig. 33), and in places they grade into the submorainic glaciofluvial formations. Presumably these drumlins are, at least in part, reworked older esker forms.

The bedrock units in the study area show a transverse trend in relation to the direction of glacial flow (V. Perttunen 1984). This simplifies interpretion of the data (Appendix) and means that statistics for transport distance are easy to obtain. As an example, sample 91 (Fig. 34 A) gives 2.7 km for the geometric mean of transport distance. The bedrock units located upstream in relation to the glacial flow plot in the expected proportions on the graph.

Note that the curve of the transport distance distribution does not have the correct proportions of bedrock types. Quartzites are overrepresented and the proportion of mica schists in smaller than expected.

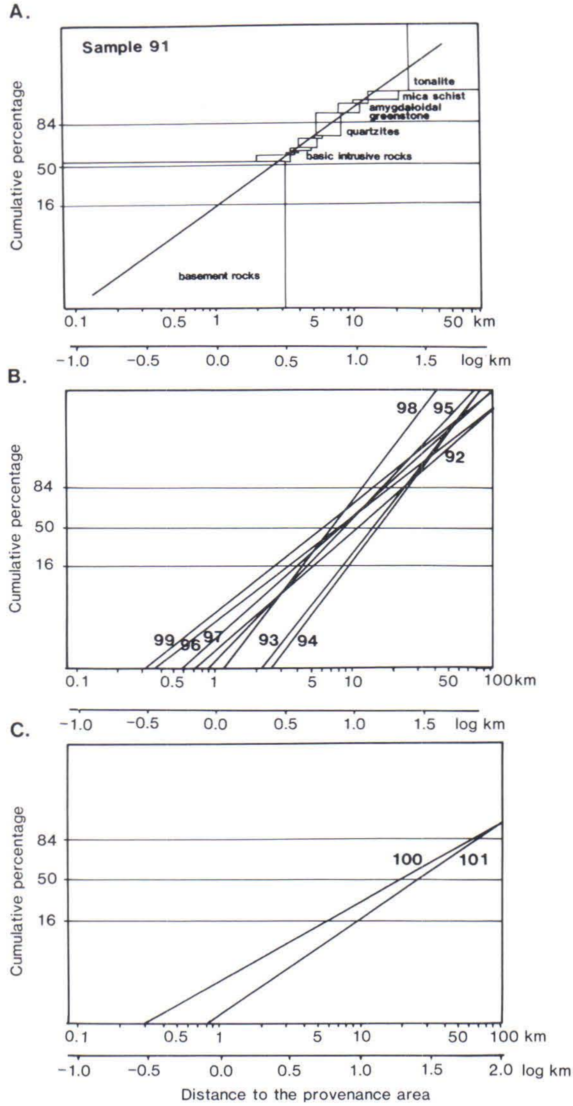


Fig. 34. Distance distributions for surface boulders in A) sample 91 B) samples 92—99 and C) samples 100—101.

Sample site 91 was located in an area of thin (0.5—1.0 m) cover moraine. It is possible that a large proportion of boulders in the sample derives from weathered bedrock material. Thus the transport distance is shorter than at the other sites in the area (Fig. 34 B, Table 12).

All the curves form a uniform group, in-

Table 12. Transport statistics for samples 91—101

Sample site	Mean x̄/log km	Standard deviation s/log km	Geometric mean b/km	Depositional landform at sample site
91	0.43	0.40	2.7	cover moraine
92	1.03	0.34	10.8	—,,—
93	1.15	0.24	14.0	—,,—
94	1.18	0.21	15.0	—,,—
95	0.93	0.27	8.5	—,,—
96	0.90	0.37	8.0	—,,—
97	0.91	0.32	8.1	—,,—
98	0.85	0.24	7.0	—,,—
99	0.78	0.39	6.0	—,,—
100	1.30	0.53	20.0	drumlin assemblage
101	1.40	0.44	25.0	—,,—

dicating long transport distance for the surface boulders. The value of the geometric mean varies between 6.0 and 15.0 km.

In the area of the drumlin field (Figs. 33, 34 C) the transport distance seems to be even longer (Table 12), and the statistical values are among the highest in this study. However, the values of deviation are lower than those of samples 89 and 90 in the Kainuu area (Fig. 32 C).

A half-distance value of 3.6 km was determined for the boulders with the layered intrusion as their provenance (Traverse 33, Fig. 6). This result is not reliable, however, since the correlation $r_{\log f/x}$ is only 0.60° (Table 14).

From the data presented by V. Okko (1941) it was possible to calculate two half-distance values (traverses 34 & 35, Fig. 6). The results (Table 14) give a measure for the transport distance of the cobble fraction (diameter 5—10 cm). The values are greater than in the previous case, 8.8 and 13.8 km, respectively.

Central Lapland

Quaternary deposits

The study area of Central Lapland has the roughest topography of the observation areas discussed here. The bedrock has such an influence on the relief that most of the major morphological features of the region are due to the bedrock topography (Kujansuu 1967).

The main part of the study area is a peneplan, approximately 200—300 m above sea level. The bedrock in the area consists of Archaean greenstones and associated schists. The fell area surrounding it clearly represents an erosion remnant towering above the less resistant greenstone areas (Fig. 35). In this area the relative differences in elevation exceed 200 m.

In the west of the study area till occurs as a moderately thin cover. The till blanket is thinnest on the summits of the fells, where it varies from 0 to 1.5 m in thickness, and thickest in the broad valleys and flat terrains, where it varies from 2 to 7 m in thickness (Kujansuu 1967).

In the east of the study area the overburden is thicker, and surficial deposits 20—30m thick are common. Usually, however, this unmoulded till cover is between 3 and 11 m thick (Pulkkinen 1983).

Till constitutes the most common deposi-

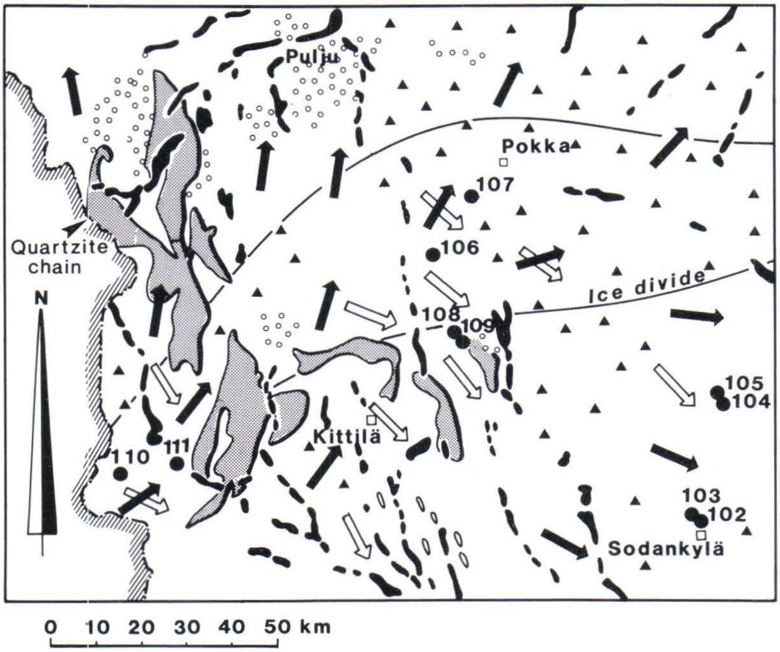


Fig. 35. The study area in Central Lapland, samples 102—111. The quartzites (stippled) form the fell chain of Western Lapland. The ice divide zone runs through the area. For explanations, see Figs 8 and 11. Modified after Simonen (1980) and Kujansuu & Niemelä (1984).

tional unit. Its complicated stratigraphy is well known. In Central Lapland, owing to the presence of the ice divide, i.e. the central area of glaciation, the erosional effects of the repeated glaciations have been extremely weak, as is evidenced by the abundance of weathered Pre-Quaternary bedrock over extensive areas and the numerous interstadial and interglacial organic deposits (Hirvas *et al.* 1977, Hirvas and Nenonen, in press).

Two till beds, till bed II, which can be reliably correlated with the bed that overlies the interstadial deposits described by Korpela (1969), and till bed III, which occurs immediately below these deposits, are very common in Lapland (Hirvas and Nenonen, in press); Both have affected on glacial transport. The main trends of transport have been described by Tanner (1915) and Kujansuu (1967).

According to Mäkinen & Maunu (1984), the bulk of the esker chain in the area formed during the last Weichselian glacial events. However, the glaciofluvial formations in the west are attributed to melting of the ice during the first Weichsel stade.

As a rule no elongated moraines associated with active flow of the glacier have formed. Some single drumlins occur in the south, and fluted moraine surfaces are fairly common, especially in the west of the study area (Kujansuu 1967).

Hummocky moraines are the dominant landforms in the northwestern part of the study area (Fig. 35), and in the village of Pulju this moraine is present as a special squeezed-up type (Kujansuu 1967).

Sample sites and observations

Observation site 102 was used to describe the transport distance in the area of veneer of cover moraine; samples 103—105 were used in the area of thick ground moraine. These units were deposited by two different glacial flows moving in almost the same direction (Fig. 35). Sample sites 106 and 107 are located in the central area of the main ice divide, where the

Table 13. Statistics for samples 102—111

Sample site	Mean x̄/log km	Standard deviation s/log km	Geometric mean b/km	Depositional landform at sample site
102	—0.07	0.87	0.85	cover moraine
103	0.60	1.13	4.0	ground moraine
104	0.85	0.74	7.0	—,,—
105	0.78	0.70	6.0	—,,—
106	1.15	1.37	14.0	—,,—
107	0.20	1.03	1.6	—,,—
108	0.90	0.53	8.0	—,,—
109	0.60	0.56	4.0	cover moraine
110	0.11	0.64	1.3	ground moraine
111	0.18	0.48	1.5	cover moraine

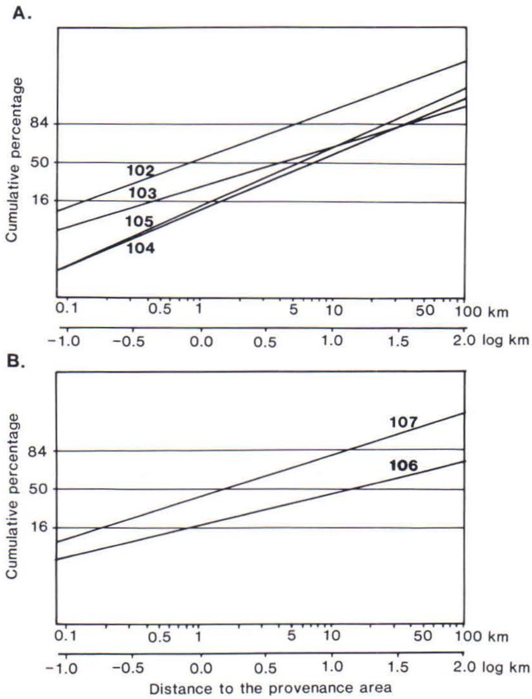


Fig. 36. Distance distributions for surface boulders in A) samples 102—105 and B) samples 106 and 107.

erosional effects of repeated glaciations were weak and the deposits of ground moraine are often thick. The directions of the two ice flows differ radically from each other.

Sample sites 108 and 109 describe the transport distribution of the surface boulders in an area where the till was deposited by an earlier glacial flow (III) from the northwest. Sample sites 110 and 111 are situated in the area of the last southwestern ice flow (till bed II); thick till sequences with a complex stratigraphy have been described from this area (Hirvas *et al.* 1977).

The total transport distributions for samples 102 — 105 are presented in Fig. 36 A. The geometric mean of transport distribution varies (b = 0.85—7.0 km, Table 13), showing a high deviation.

The standard deviation of the geometric mean for the total transport distribution of surface boulders is even greater in areas where till beds of many ice flows are common. For example, sample 106 (Fig. 36 B) shows that in surface boulder material a minor proportion (5%) originates from the local bedrock. On the other hand, 25% of the sample material has its provenance at a distance of 80 km or more (Table 13, Appendix). Sample 107 indicates the same fact, but the material is more local in origin.

The value of the geometric mean increases along with an increase in the activity of glacial flow. At the same time, the value of the standard deviation tends to decrease. This is evident if samples 108 and 109 (Fig. 37 A) are compared with samples in the previous exam-

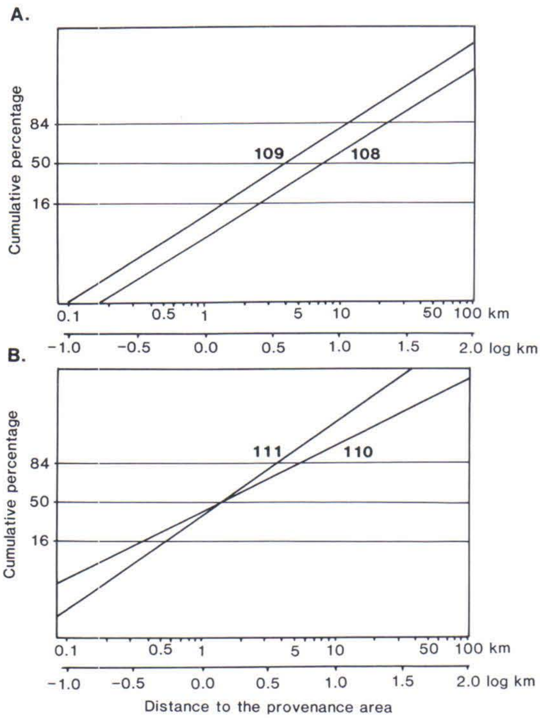


Fig. 37. Distance distributions for surface boulders in A) samples 108 and 109 and B) samples 110 and 111.

ple (Fig. 36 B). Samples 108 and 109 give the transport statistics for an area of active ice (Table 13) in an area similar to northern Ostrobothnia (cf. Table 12).

Samples 110 and 111 represent the transport distance distribution for surface boulders deposited during the last active phases of Weichselian glaciation (Fig. 37 B). The distributions give statistics for transport distance that resemble those for the samples from the Hämeenlinna area (Table 3).

For comparison, boulder count material reported by Hirvas *et al.* (1977) was also used. The data were treated with formulas [4] and [5], and the results from the traverses (Fig. 6) are presented in Table 14. Boulder count traverse 36 describes the dispersion due to the ice flow that deposited till bed II. Traverse 37 shows the half-distance for boulder material in the area of the Kuusamo drumlin field originating from the extensive granite of Central Lapland. Traverses 38 and 39 show the half-distances in an area of weak glacial erosion in Central Lapland.

DISCUSSION OF RESULTS

Half-distance values

The following discussion will examine the variability observed in the length of glacial transport and the factors affecting it. The results from the half-distance traverses used in this study (Fig. 6) are compiled in Table 14.

The lowest value for the half-distance was measured from traverse 24, where the 200-m-wide quartz porphyritic dyke has produced boulders already showing the half-distance at 0.2 km in the direction of glacial flow. The longest half-distance value for the boulder fraction in this study was obtained from the data by Virkkala (1949, Fig. 15), the value $x_{1/2}$ = 29.0 km being calculated for quartzitic boulders from traverse 30 (Fig. 6).

The arithmetic mean ($\bar{x}$) for the half-distances is 5.01 km. The median (M) for the same parameter is 3.6 km (Fig. 41 A). The standard deviation of the half-distance values is 5.6 km.

Gillberg (1965) has proposed that the standard value (a) of the distance distribution of till lies between 0.055 and 0.065. This means a half-distance value of about 10.6 — 12.6 km. However, the results presented here show that the natural variation is great and that the half-distance cannot be assigned a constant value.

Peltoniemi (1985) has postulated that the size of the provenance outcrop is the main factor affecting the value of the half-distance. Hence the negative exponential function [4] would not be capable of describing the transport distance of till material, with the possible exception of the largest boulder fraction. The data presented here (Table 14) permit discussion of this issue.

There is no clear linear correlation (r = 0.30) between the length of the cross-section (parallel to ice flow) and the percentage of boulders at the distal contact originating from the outcrop (Fig. 38). As Peltoniemi (1985) points out, the model he presents does not explain the dispersion of the boulder fraction.

The relation between the rock type and the half-distance value (cf. M. Perttunen 1977) is evident in the data presented in Table 14 (Fig. 39). A certain grouping is seen in the plot, the rock types forming their own zones. For example, the quartzites have the highest half-distance values, irrespective of the size of the provenance outcrop, whereas the mica schists have the lowest values.

Kauranne (1970) used laboratory tests to study the abrasion and impact strength of different rock types. He was able to demonstrate that the most brittle rocks are limestone, pegmatite, quartzite and rapakivi. According to Swedish impact tests, the impact-resistant rocks are phyllite, leptite, diabase, greenstone and amphibolite. The impact-resistant rocks tend to have the shortest half-distances in relation to the width of the outcrop (Fig. 39). On the other hand, the most brittle rocks, quartzites and granites, have the highest values of $x_{1/2}$. Hence glacial erosion (crushing and quarrying) has a more marked effect on half-

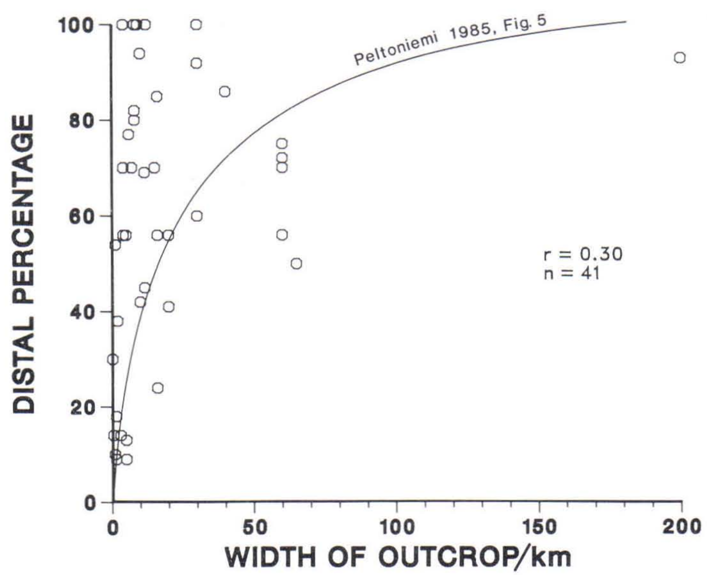


Fig. 38. Plot of the distal percentage (y — axis) versus the cross-section of the outcrop (x — axis) compared with the curve given by Peltoniemi (1985).

Table 14. The half-distance determinations

No. of traverse	Rock type	Outcrop width/km	Size (mm) of particles	n	$-r_{log}$ f/x	-a	$x_{1/2}$ /km	Distal percentage	Depositional landform	Reference
1	porph. granite	1.3	>200	14	0.85***	1.40	0.50	54	hummocky mor.	present study
2	granitoid	9.0	20-200	8	0.97***	0.34	2.70	100	cover moraine	M. Perttunen 1977
3	granitoid	8.0	20-200	7	0.96***	0.36	2.20	80	—,,—	—,,—
4	volcanics	6.0	20-200	10	0.94***	0.13	5.70	77	—,,—	—,,—
5	volcanics	11.5	20-200	8	0.87**	0.23	3.20	69	—,,—	—,,—
6	mica schist	4.0	20-100	11	0.72**	0.44	1.60	70	—,,—	Virkkala 1969
7	tuffites	8.0	20-100	17	0.76**	0.44	1.60	100	—,,—	—,,—
8	porph. granite	10.0	>200	25	0.91***	0.18	3.85	94	hummocky mor.	present study
9	mica schist	20.0	>200	9	0.87**	0.13	5.33	56	drumlin ass.	—,,—
10	rapakivi	16.0	60-200	13	0.92***	0.17	4.07	85	cover moraine	Johansson 1980
11	volcanics	4.0	60-200	5	0.54	0.37	1.90	56	drumlin ass.	—,,—
12	mica schist	60.0	>200	13	0.96***	0.59	1.20	56	cover moraine	present study
13	mica schist	60.0	20-200	22	0.78***	0.29	2.40	75	marginal comp	Rainio 1983
14	mica schist	60.0	20-200	8	0.99***	0.49	1.40	70	cover moraine	Salminen 1980
15	mica schist	60.0	60-200	8	0.98***	0.91	0.76	72	marginal comptex	Salminen & Hartikainen 1985
16	quartzite	15.0	30-100	17	0.90***	0.05	13.4	70	cover moraine	Repo 1957
17	Outokumpu-zone	1.5	>200	5	0.86*	0.47	1.50	9	interlobate c	present study
18	Outokumpu-zone	0.5	>200	6	0.91**	0.17	4.20	14	cover moraine	—,,—
19	porph. granite	30.0	>200	15	0.95***	0.23	3.10	100	interlobate c	—,,—
20	pyrox. granite	3.0	>200	12	0.97***	0.32	2.10	14	cover moraine	—,,—
21	greywacke	1.0	>200	14	0.62*	0.65	1.06	10	—,,—	—,,—
22	monzonite	8.0	>200	15	0.90***	0.62	1.10	82	hummocky mor.	—,,—
23	volcanics	10.0	>200	12	0.89***	1.61	0.43	42	—,,—	—,,—
24	quartz porphyry	0.2	>200	10	0.88***	3.45	0.20	30	—,,—	—,,—
25	granitoid	12.0	>200	14	0.63*	1.10	0.63	100	Rogen moraine	—,,—

26	gabbro	1.5	>200	4	0.99***	1.45	0.50	18	cover moraine	—,,—
27	greywacke	5.0	>200	6	0.84*	0.50	1.40	9	—,,—	—,,—
28	volcanics	5.0	>200	5	0.44	0.12	5.80	56	drumlin ass.	Peltoniemi 1985
29	volcanics	5.0	>200	4	0.99***	0.11	6.60	13	—,,—	Saarnisto & Taipale 1984
30	quartzite	20.0	20-200	12	0.89***	0.02	29.0	41	cover moraine	Virkkala 1949
31	quartzite	2.0	20-100	10	0.96***	0.08	9.4	38	drumlin ass.	Virkkala 1960
32	quartzite	30.0	20-100	7	0.93**	0.05	15.6	60	cover moraine	Virkkala 1949
33	gabbro	4.0	>200	6	0.60	0.19	3.6	100	drumlin ass.	present study
34	granite	40.0	20-200	14	0.84***	0.05	13.8	86	hummocky mor.	V. Okko 1941
35	gneiss	30.0	20-200	13	0.61	0.08	8.8	92	cover moraine	—,,—
36	granulite	65.0	>60	71	0.95***	0.05	12.0	50	drumlin ass.	Hirvas *et al.* 1977
37	granite	200	>60	43	0.78***	0.07	9.8	93	—,,—	—,,—
38	porph. granite	7.0	>60	10	0.91***	0.12	6.0	70	ground mor.	—,,—
39	gabbro	4.0	20-60	36	0.70***	0.21	3.4	56	—,,—	—,,—
40	sandstone	11.6	>200	20	0.79***	0.14	5.0	45	cover moraine	Simonen & Kouvo 1955
41	impactite	16.0	20-200	13	0.76**	0.08	8.6	24	drumlin ass.	Mölder 1948

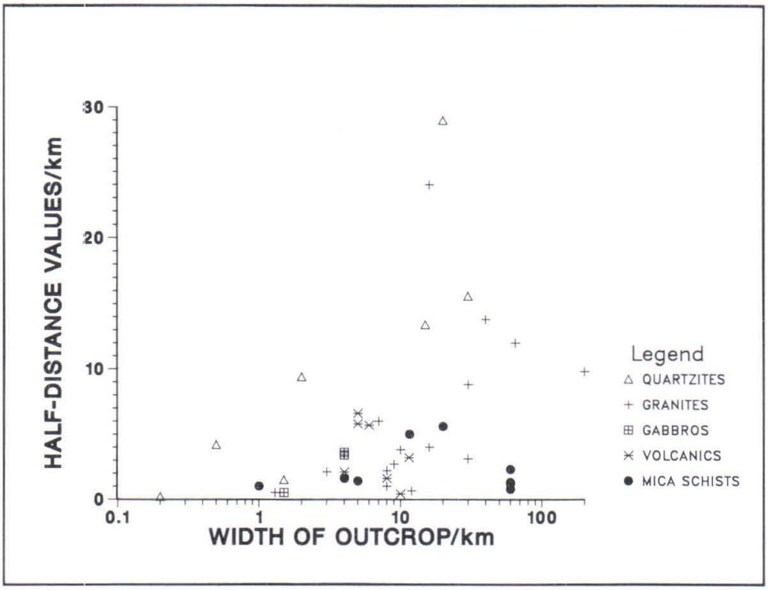


Fig. 39. Different rock-types in the half-distance/cross-section of the outcrop system. The most brittle rocks, quartzites and granites have the highest half-distance values despite the size of the provenance outcrop.

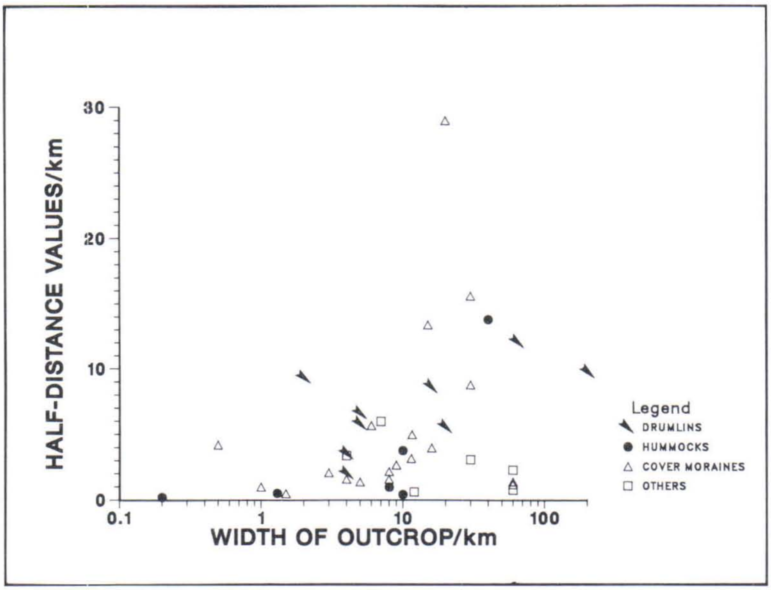


Fig. 40. Plot of glaciomorphic deposit types in the half-distance/cross-section of the outcrop system. The groups ovelap because the observation traverses often cross different glaciomorphic landscapes.

distance values than does the glacial comminution process during transport.

It was found in the present study that the size of the outcrop is not so important factor in explaining the half-distance value as is the rock type. The third possible factor is the glacial geological environment during the deposition of the boulders. Its effect can be assessed by comparing the relation between the size of the outcrop and the half-distance value in different depositional glacial landforms (Fig. 40).

The half-distance traverses that extend to drumlin landscapes form a cluster of their own on the plot (Fig. 40). In drumlin areas, the boulder fraction often shows a relatively high half-distance value, which is not directly related to the size of the provenance outcrop. There is possibly a limit, a maximum value for half-distance, which is approximately 15.0 km in drumlin assemblage. It is evident that, during drumlinization, the comminution process causes the boulder fraction to decrease whereas the transport distance indicated by $x_{1/2}$ increases.

The half-distance traverses in hummocky moraine areas also form a uniform group (Fig. 40). Here the values of $x_{1/2}$ show a short transport distance. It can be concluded that, in areas of hummocky moraines, three factors were decisive, namely, erosion of the strong quarrying type, weakened flow of the ice and marginal deposition. As a result, hummocky moraine areas contain exceptionally large amounts of local surface boulders (cf. Minell 1979).

The half-distance method gives results with a certain relation to the variations in glacial activity, as was concluded by Salminen and Hartikainen (1985). However, the reasons for areal variability in the half-distance values are often difficult to establish. There are several additional factors (type of bedrock, topography, thickness of glacial deposits and grain size) that affect the half-distance value (cf. Gillberg 1965). This variability is the reason why the half-distance values obtained from traverses in cover moraine areas vary within such a wide range (Fig. 40).

Transport distance distribution curves

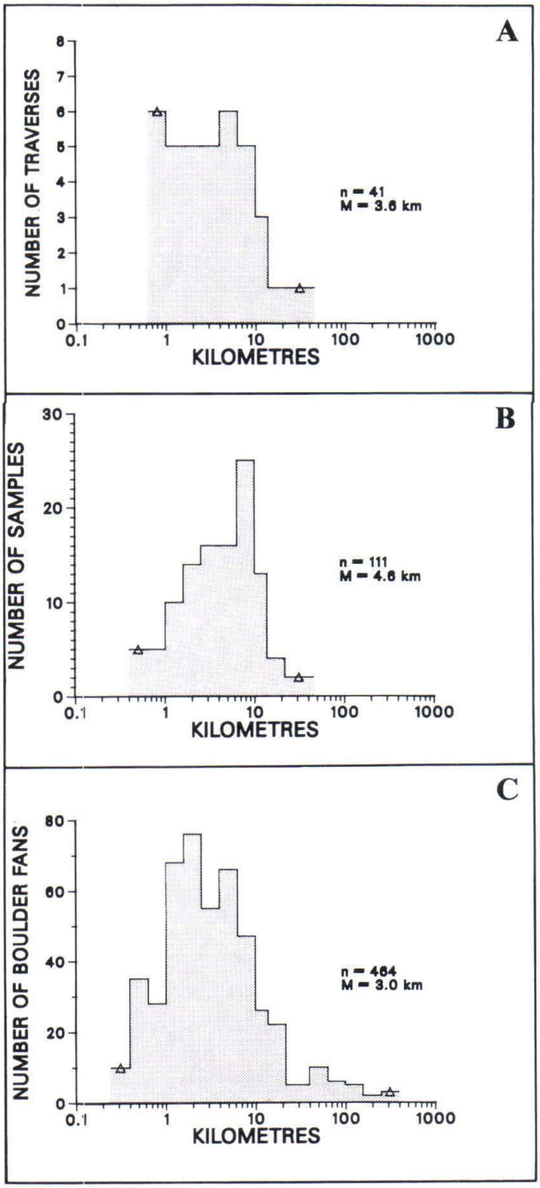
The median value for the geometric means of the transport distance distributions is 4.6 km (Fig. 41 B); it varies between 0.001 and 37 km. The shortest observed transport distribution is associated with the active ice hummocky moraine at sample site 10 ($b = 0.001$ km). The highest value for the geometric mean, 37 km, was measured from the distribution of boulder material from the Salpausselkä II marginal complex (sample site 59).

The median length for the 464 boulder fans measured in Finland (Salonen 1986) is 3.0 km (Fig. 41 C). These three values of the length of glacial transport are so close to each other that they probably reflect the same phenomenon, namely, active boulder transport by a continental glacier.

The half-distance values are controlled by many unexpected variables that interact with each other, as was concluded in the preceding discussion. It can be a tedious task separating the variables and distinguishing their effects from those of glacial activity. In some places the variations in half-distance values could be attributed to differences in the glacial depositional environment. For example, traverses 7 and 8 (Fig. 17) gave two different lengths for the half-distance, the traverse in the drumlin area having a greater half-distance than that in hummocky moraine terrain.

Peltoniemi (1985) concludes that the concept of half-distance should be abandoned in favour of the distance required by a given rock type to increase its proportion in till from 0% to 50% (see Fig. 1). This 'renewal distance' is 15 km in the Kuhmo area. This value should be comparable with the geometric mean of total transport distribution, but the latter term is preferable statistically.

The length distribution of indicator fans and geometric means are nearly log-normal in form (Fig. 41). In contrast, the distribution curve of



half-distance values does not show a maximum. The geometric mean for the transport distance distributions usually varies between 1.0 and 13.0 km. The value is comparable to the length distribution of boulder fans.

Total transport measurements show that, in some places, the shape of the distribution curve is due to local conditions. For example, at sample sites 21, 22 and 30, local differences in the physical properties of the rock types increased the value of the standard deviation. At sample site 68, this variation resulted in formation of two distribution populations. In a third example, the low value of the transport distance at sample site 91 can be attributed to the lowest thickness of the surficial deposits.

Nevertheless, these secondary features are of minor importance. It can therefore be hypothesized that transport distance distributions are closely related to the main variable, namely glacial depositional assemblages.

Fig. 41. Length distribution of A) half-distance values, B) geometric means of transport distance distributions, and C) boulder trains. Class widths are 0.2 log km.

Variations in boulder transport in Finland

Depositional environments

Close analysis reveals regularities in the variability in observed boulder transport distance distribution (Fig. 42). The median of geometric means is 4.6 km and the median of standard deviation is 0.45 log km. These average values hold in areas of cover or ground moraines. Figure 42 shows that the above moraine types represent the average transport circumstances

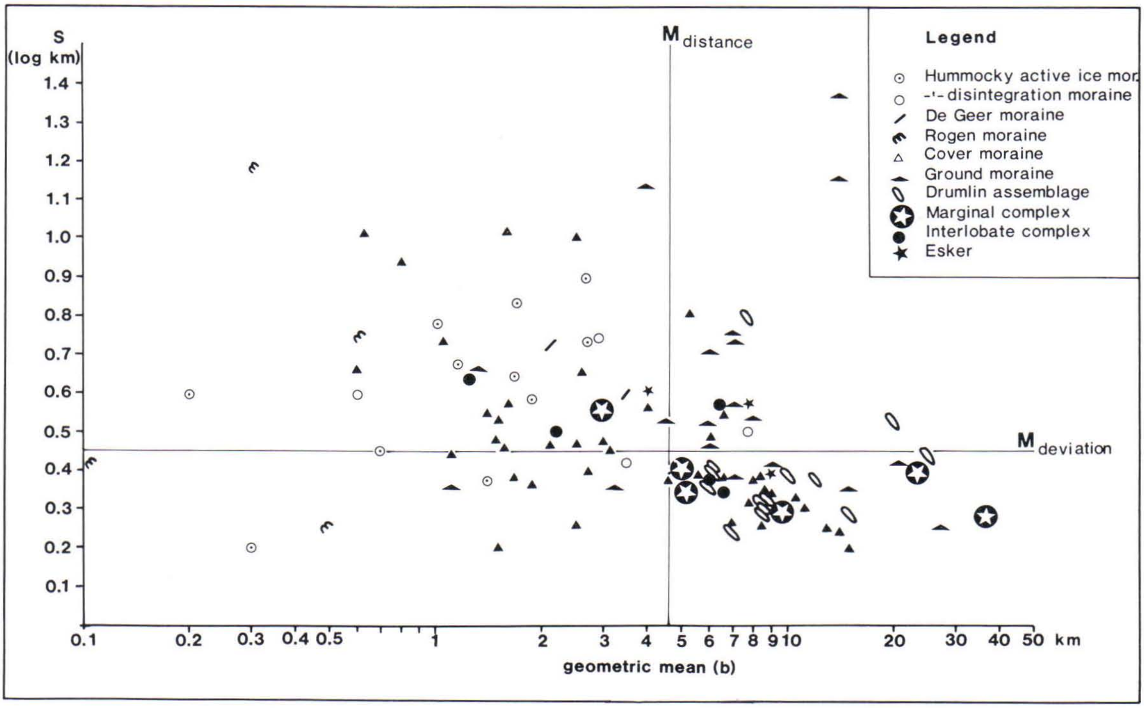


Fig. 42. Plot of the geometric means (b) of transport distance distributions (n = 111) versus their standard deviation (s). Solid lines indicate median values of the statistics.

well, but that the variations within this group are large.

The shortest boulder transport distances were measured in hummocky moraines. Especially the Rogen moraines and active ice hummocks have vast quantities of surface boulders of local origin, in agreement whith earlier reports on extremely short transport distances in such environments (e.g. Salonen and Kokkola 1981, Aario *et al.* 1986). On the other hand, the surface boulders in drumlin assemblages constitute a compact group, characterized by a relatively long transport distance (b = 6—25 km). The standard deviation for the drumlin samples is low.

In this study, only a few samples that had undergone glaciofluvial boulder transport were analysed. However, observations from eskers and marginal complexes show that the length of the transport distance varies within a wide range, as shown theoretically by Boulton (1984). According to him, the glacial meltwater transport can be either long distance linear or short distance widespread in character.

As a rule, the sample sites with a great dispersion index (s) are associated with ground moraine areas with complex till stratigraphy. Regionally, these samples are encountered in Central Ostrobothnia and Central Lapland. Some active ice hummocky moraines are also characterized by high standard deviation.

From these data it can be concluded that the transport distance distribution of surface boulders is affected by two principal variables:

1. The depositional interactive system of morainic landforms associated with regularity in the erosion-transport-deposition system of one glacial cycle. The distance distributions

form a series from hummocky moraines through cover moraines to drumlin areas (Fig. 43 A).

2. The mixing of boulder materials of two different depositional cycles (Fig. 43 B). The cycles may represent different glaciations (e.g. ground moraines in Central Lapland consisting of several till beds) or two basal thermal zones of a single glaciation (see Hughes 1981). Such transport distance distributions have been found in many places in western Finland. A specific feature of them is the increase in the standard deviation (s).

This result permits us to estimate the parameters for the transport distance distribution of surface boulders in different depositional environments. For hummocky moraines the geometric mean varies between 0.4 and 3.0 km, and the standard deviation is approximately 0.6 log km.

The geometric mean for the transport distance of surface boulders of cover moraine

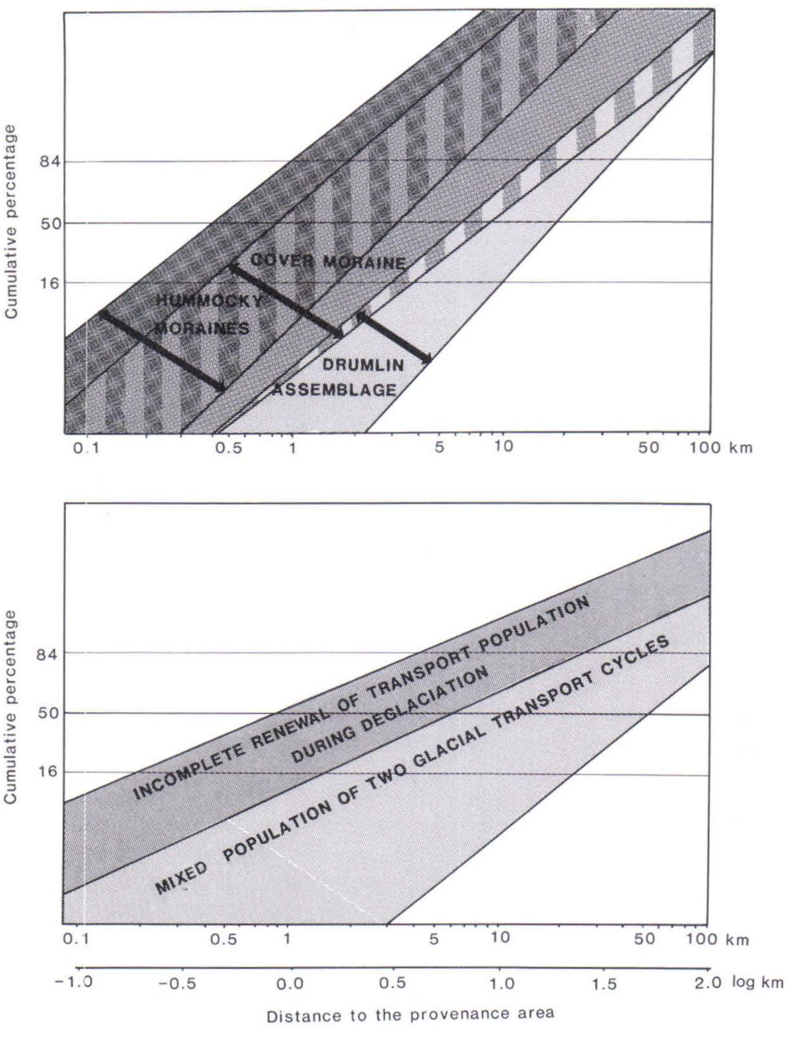


Fig. 43 A). The transitional series of morainic landforms and their generalized transport distance distributions. The transport distance increases from hummocky moraines to drumlin assemblage with a simultaneous decrease in their standard deviation. B) The mixing of two (or more) transport populations increases the dispersion index (s) of the total transport distribution. The geometric mean may indicate either short transport distance (some hummocky moraines) or long glacial transport (e.g. ground moraine in Lapland in areas of ice divide).

varies between 0.8 and 10 km. The deviation index (s) is ca. 0.45 log km. The surface boulders of drumlins have a geometric mean of 5 — 17 km and a standard deviation of 0.35 log km as parameters for their transport distance distribution.

Transport distance of surface boulders in Finland

The areal variability and systematics in glacial deposits have been described by Ignatius *et al.* (1980), Hirvas *et al.* (1981) Punkari (1980, 1984), Kujansuu and Niemelä (1984), and most recently by Salonen (in press), who has proposed areal types for the glacial geology of Finland. His proposal explains the observed variation in glacial activity with the following variables:

— repeated weak glacial erosion (Niemelä 1979)

— early stages in glaciation (cf. Boulton 1984)

— lobe activity during deglaciation (Punkari 1984)

— long-term ice marginal and oscillation positions.

When the areal variability of these factors is combined with the observations of the present study, the regional variability in boulder transport distances in Finland can be roughly outlined (Fig. 44). In the dark areas, the transport distance of surface boulders is short and the dispersion is small. Hence, the amount of local bedrock material is high and its dispersion pattern is simple. These areas are favourable for explorational boulder tracing and lithologic mapping with aid of surface boulders. It is obvious that the boulder fans in these areas are short and dense.

In the light areas, the transport distance of surface boulders is generally long or its dispersion index is high or both. Hence, long-distance material is often predominant on the surface of overburden. Detection of the provenance area of a single erratic can be very difficult. In the lightest areas, the till stratigraphy is often complicated; multistage glacial transportation is a common phenomenon, and in field prospecting, till stratigraphic methods are needed to aid ore boulder investigations.

Applications of the method

The advantage of the total transport distribution method is that it gives a numeric estimate for probable transport distance at a given site. The distributions can be used to establish whether the boulder samples are local or distant in origin. They also permit the determination of the reaching-surface distance (Fig. 1). Information of this nature may be valuable in exploration.

Exploration in Finland is often based on ore boulders lying on the surface of moraine, and exploratory work often starts with a single float. Use of the transport distance distribution method at the site will give numeric information that may help in evaluating the importance of the ore indication and in planning future operations.

An important question in explorational till geochemistry concerns the areal regularities in glacial transport distances. It would be of interest to study the relationship between the transport distance distributions of surface boulders and finer till fractions. The 'shift distance' of till magnetic anomalies (Puranen and Kivekäs 1979) can give parameters comparable with boulder transport parameters.

The results produced by the transport distance distribution method are closely related to glacial depositional assemblages. Continental glacial dynamics have been discussed largely on the basis of morphological evidence (e.g. Sudgen 1978, Punkari 1984, 1985). The theoretical models (e.g. Denton & Hughes 1981) need field evidence to confirm the variations in glacial activity on a continental scale (Boulton *et al.* 1985). The boulder transport distribution

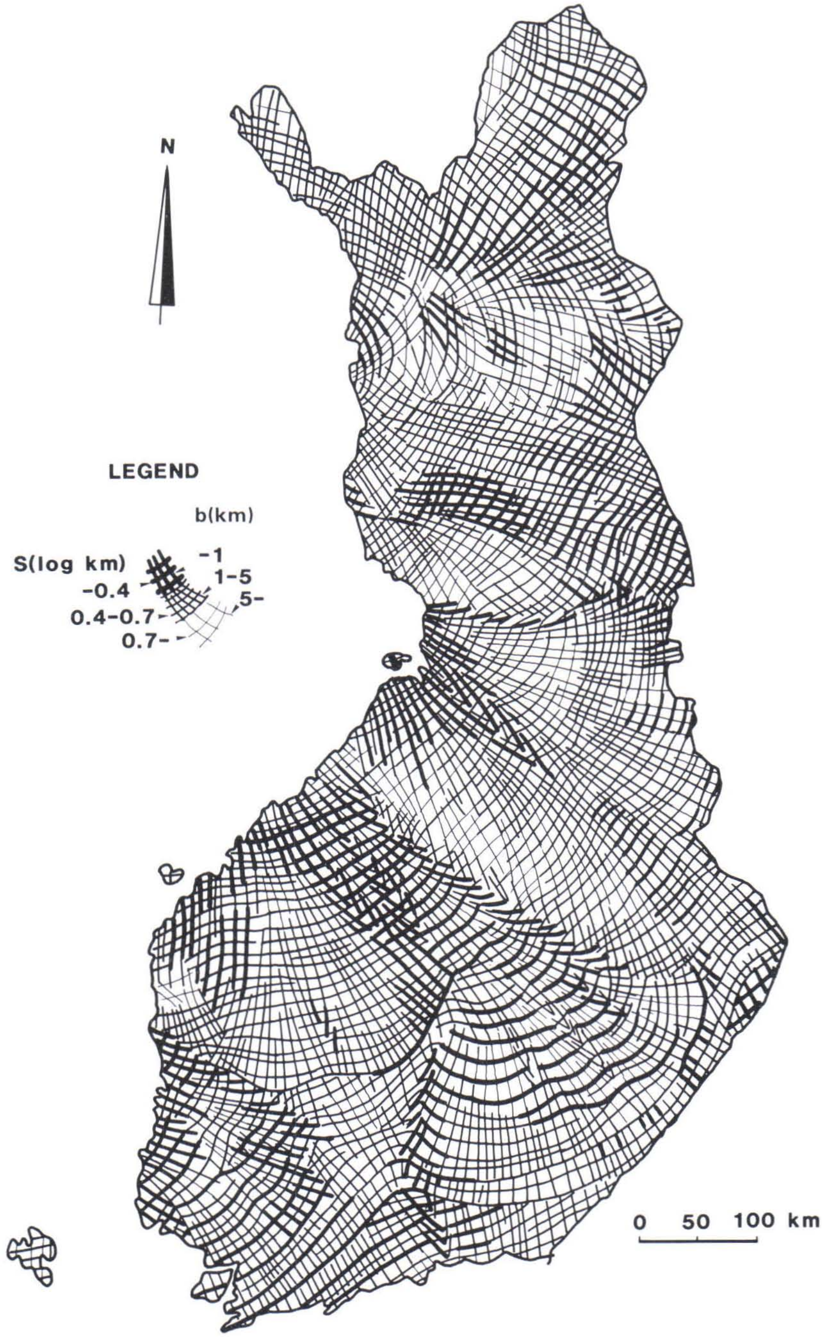


Fig. 44. Areal variation in surface boulder transport in Finland. The thickness of the line perpendicular to the main boulder transport direction is proportional to the value of the geometric mean (b) of transport distance. The thickness of the line transverse in relation to ice flow reflects the standard deviation (s) of distance distribution. In the darkest areas, the boulder fans are expected to be short and narrow, and in the lightest areas, the boulder transport tends to be long and complicated.

method of the present study may be usefull in constructing models for the behaviour of previous glaciers.

First, however the reliability of the method should be analysed more closely and the log-normality of the distribution curves examined carefully. Then the results of the transport distance distribution method can possibly be correlated with the genesis of the coarsest till fraction and, furthermore, with the actual glacial processes. Large open pits in polygenetic formations (e.g. Salpausselkä marginal complexes) would be an advantage in future studies.

There are also problems with local relevance that may likewise be solved using the transport distribution method. For example, study of the relation between glaciofluvial and glacial transport could be rewarding. Furthermore, individual formations such as drumlins and Rogen moraine ridges may contain boulder material of several transport populations. The populations can be identified with the method.

The present study was restricted to the surface of glacial deposits. Analysis of the vertical variation in the values of the geometric mean and its standard deviation could possibly be connected with the sedimentology and genesis of the till. Characterizing glacial transport in this way could be of importance when classifying tills in relation to the transport of debris in glacial ice (Dreimanis & Schlüchter 1985).

CONCLUSIONS

The glacial transport distance of surface boulders was measured with a new *Transport distance distribution method*. It was developed during this study and compared with the *Half-distance method*. The new method has demonstrated well its feasibility for characterizing the length of glacial transport.

Both methods represent models with a certain relationship to glacial processes and are affected by secondary factors. The values of the half-distance method are intimately related to such variables as the rock type studied, and the topography and width of the indicator rock area investigated. The transport distance distribution method gives more reliable estimates for glacial transport distance than does the half-distance method.

The results of the present study showed that the log-normal distribution describes well the transport populations of surface boulders. The parameters for the mean value and its deviation could be connected with depositional morainic landforms and, furthermore, with the areal regularities of glacial activity in Finland.

The geometric mean of boulder transport distance varies between 0.4 and 3.0 km, the average standard deviation being 0.6 log km. The average transport distance (median of geometric means) varies from 0.8 to 10.0 km in cover moraine areas and is as long as 5.0—17.0 km for surface boulders in drumlin assemblages. The standard deviation for the former deposits is 0.45 log km and for the latter 0.35 log km. The transport distance distribution of these deposits formed a transitional series. The glacial activity of the last Weichselian stade was found to be the main factor explaining the distribution of this series.

In some areas, where the erosional effects of the continental ice have been repeatedly weak, the transport distance distributions of surface boulders represent a mixture of two transport populations. The standard deviation is high in these areas. If two glacial transport cycles have affected the distance distributions of surface boulders, the geometric mean of boulder transport was also high (5—50 km).

In places, basal thermal conditions of the glacial ice during the course of deglaciation have caused an increase in local boulder material. This kind of mixture in surface boulder material is found in some Rogen type and active-ice hummocky moraines, which are characterized by a low value, 0.7 to 5.0 km for the geometric mean of the transport distance of surface boulders.

The transport distance of surface boulders in Finland was found to be quite uniform and short in general. The mean value of the geometric means is 4.6 km and of half-distance values 3.6 km; the mean length of boulder fans is only 3.0km. However, some areas were found to be more promising for ore boulder tracing than others.

The transport distance distribution method has demonstrated its value as a practical tool for solving many glacial geological problems. The most important future applications may be exploration and study of the genetic variations in boulder populations. Further development of the method requires more vertical sampling, analyses of till genesis and statistical examination.

ACKNOWLEDGEMENTS

This thesis is the outcome of observations made in 1983 — 1985 during the 'Ore-boulder Project' in the Department of Quaternary Geology of the University of Turku. The research was supported by the Ministry of Trade and Industry of Finland.

I wish to acknowledge my debt to my supervisor, Professor Veikko Lappalainen, head of the department of Quaternary Geology at the University of Turku for his encouraging attitude towards my research work and for his moral support throughout its various stages.

Much of this study is based on detailed knowledge of petrographic variability in Finnish bedrock. I am deeply grateful to all the bedrock geologists who helped and advised me during the field work. Those deserving special mention are Tauno Huhtala, Martti Kokkola, and Esa Sandberg of Outokumpu Oy, and Mrs Raili Aumo, Timo Kilpeläinen, Dr Kalevi Korsman and Olli Äikäs of the Geological Survey of Finland.

I should like to thank Professor Raimo Kujansuu, Dr Kari K. Kinnunen and Jukka-Pekka Palmu for their critical reading of the manuscript and for suggesting many improvements. Associate professor Gunnar Glückert and Associate professor Matti Saarnisto were the official readers of the manuscript and their constructive criticism is much appreciated. Associate professor Glückert has followed my studies right from the start and been a continuous source of support.

I wish to express my gratitude to Professor Kalevi Kauranne, director of the Geological Survey of Finland, for accepting the manuscript for publication in the Bulletin of the Geological Survey of Finland.

The English of the manuscript was corrected by Mrs Gillian Häkli to whom I am grateful for her careful work. For final preparation of the work, the grants awarded by the Turun Suomalainen Yliopistoseura and the Turun yliopiston Hallitus are acknowledged.

REFERENCES

Aario, R., 1977. Classification and terminology of morainic landforms in Finland. Boreas 6, 87—100.

Aario, R. & Forssström, L., 1979. Glacial stratigraphy of Koillismaa and North Kainuu, Finland. Fennia 157, 49 p.

Aario, R., Pääkkönen, K. & Saarenketo, T., 1985. Glaciodynamic dispersion of uranium in a Rogen environment, Finland. INQUA Till Symposium, Finland 1985, Abstracts. Geol. Surv. Finland, Espoo 1985.

Aartolahti, T., 1972. On deglaciation in southern and western Finland. Fennia 117, 84 p.

Agassiz, L., 1840. Études sur les glaciers. Neuchatel, Jent et Gassmann 1840.

Aumo, R., 1983. The Proterozoic metasedimentary and metavolcanic mantle of the Kuopio domes. *In* Exogenic processes and related metallogeny in the Svecokarelian geosynclinal complex, ed by K. Laajoki & J. Paakkola. Geol. Surv. Finland, Guide 11, 86—99.

Aumo, R. & Salonen, V-P., 1986. Uvarovite and glacial transportation distance as provenance indicators of ore mineralization in the southern part of the Outokumpu district, North Karelia, Finland. Prospecting in areas of glaciated terrain 1986, proceedings, 17—23. IMM, London 1986, 269 p.

Aurola, E., 1955. Über dir Geschiebeverfrachtung in Nordkarelien. Geologinen tutkimuslaitos, Geotekn. julk. 56, 52 p.

Björklund, A., 1976. Korsnäs: lead prospecting by till geochemistry. J. Geochem. Explor. 5, 253—258.

Brander, G., 1934. Maalajikartan selitys C 3, Kuopio. Suomen geologinen yleiskartta 1:400 000, 67 p.

Boulton, G.S., 1984. Development of a theoretical model of sediment dispersal by ice sheets. Prospecting in areas of glaciated terrain 1984, proceedings, 213—224. IMM, London 1984, 232 p.

Boulton, G.S., Smith, G.D., Jones, A.S & Newsome, J., 1985. Glacial geology and glaciology of the last midlatitude ice sheets. J. geol. Soc. London, 142, 447—474.

De Geer, G., 1881. Några ord om bergarterna på Åland och flyttblocken derifrån. Geol. Fören. Stockh. Förh., 1881.

Denton, G.H. & Hughes, T.J. (Ed.), 1981. The Last Great Ice Sheets. John Wiley & Sons, New York 1981, 484 p.

Donner, J., 1986. Weichselian indicator erratics in the Hyvinkää area, southern Finland. Ann. Acad. Sci. Fennicae A. III. 140. 20 p.

Dreimanis, A. & Vagners, U.J., 1971. Bimodal Distribution of Rock and Mineral Fragments in Basal Tills. *In* Till a Symposium, ed by R.P. Goldhwait. Ohio State University Press, 237—249.

Dreimanis, A. & Schlüchter, Ch., 1985. Field criteria for the recognition of till or tillite. Plaeogeogr., Palaeoclimatol., Palaeoecol., 51, 7—14.

Ekdahl, E., 1982. Glacial history and geochemistry of the till/bedrock interface in prospecting in the Pielavesi area of Central Finland. Prospecting in areas of glaciated terrain 1982, proceedings, CIMM, 213—227.

Eskola, P., 1933. Tausend Geschiebe aus Lettland. Ann. Acad. Sci. Fenniae A. XXXIX. 5. 41 p.

Flint, R.F., 1971. Glacial and Quaternary Geology. John Wiley & Sons, New York 1971. 892 p.

Forsström, L., 1982. The Oulainen Interglacial in Ostrobothnia, western Finland. Acta Univ. Oul. A 136. Geol. 4. 123 p.

Gillberg, G., 1965. Till distribution and ice movements on the northern slopes of the South Swedish Highlands. Geol. Fören. Stockh. Förh. 86, 433—484.

Glückert, G., 1973. Two large drumlin fields in central Finland. Fennia 120, 37 p.

Glückert, G., 1976. The Kuhmo drumlin field, Eastern Finland. Publications of the Department of Quaternary Geology, University of Turku. 11 p.

Griffiths, J.C., 1967. Scientific method in analysis of sediments. McGraw — Hill, New York. 508 p.

Grip, E., 1953. Tracing of glacial boulders as an aid to ore prospecting in Sweden. Econ. Geol. 48, 715—725.

Haavisto, M., Grönlund, T., Lahermo, P. & Stén, C-G., 1980. Someron kartta-alueen maaperä. Lehti — Sheet 2024, Somero. Summary: Explanation to the map of Quaternary deposits. Geological map of Finland, 1:100 000.

Haldorsen, S., 1981. Grain-size distribution of suglacial till and its relation to glacial crushing and abrasion. Boreas 10, 91—105.

Härme, M., 1958. Kivilajikartta — Pre-Quaternary rocks. Lehti — Sheet B1, Turku. General geological map of Finland, 1:400 000.

Harris, S.A., 1958. Probability curves and the recognition of adjustment to depositional environment. J. Sedim. Petrol. 28, 151—163.

Hausen, H., 1912. De sydfinska ledblockens spridning i Ryssland, jämte en öfversikt af is-recessionens förlopp i Ostbaltikum. Deutsches Referat: Studien über die Ausbreitung der südfinnischen Leitblöcke in Russland, nebst einer Übersicht der letzten Eisrezession im Ostbaltikum. Fennia 32. 32 p.

Havola, M., 1981. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 3433, Sotkamo. Geological map of Finland 1:100 000.

Helaakoski, A.R., 1940. Mannerjäätikön liikuntosuunnista Pohjanmaan rannikolla ja Tampereen ympäristössä. Deutsches Referat: Über die Bewegungsrichtungen des Inlandeises an der Küste der Pohjanmaa end in der Umgebung von Tampere. Fennia 67 (1). 36 p.

Hellaakoski, A., 1930. On the transportation of materials in the esker of Laitila. Fennia 52 (7). 42 p.

Hirvas, H., 1977. Glacial transport in Finnish Lapland. Prospecting in areas of glaciated terrain 1977, 128—137. IMM, London. 140 p.

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

Hirvas, H., Alftan, A., Pulkkinen, E., Puranen, R. & Tynni, R., 1977. Raportti malminetsintää palvelevasta maaperätutkimuksesta Pohjois-Suomessa vuosina 1972—1976. Summary: A report on glacial drift investigations for ore prospecting purposes in northern Finland 1972—1976. Geol. Surv. Finland, Rep. Invest. No 19. 54 p.

Hirvas, H., Korpela, K. & Kujansuu, R. 1981. Weichselian in Finland before 15,000 B.P. Boreas 10, 423—431.

Hirvas, H. & Nenonen, K., in press. The till stratigraphy of Finland. Geol. Surv. Finland, Spec. Paper.

Holmes, C.D., 1952. Drift dispersion in west-central New York. Geol. Soc. America Bull. 63, 993—1010.

Hughes, T.J. 1981. Numerical Reconstruction of Paleo-Ice Sheets. *In* The Last Great Ice Sheets, ed. by G.H. Denton & T.J. Hughes. John Wiley & Sons, New York, 221—261.

Huhma, A., 1971. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 4222 & 4224, Outokumpu and Kontiolahti. Geological map of Finland, 1:100 000.

Hyppönen, V. 1973. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 4412, Hiisijärvi. Geological map of Finland, 1:100 000.

Hyppönen, V. 1976. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 4411, Ontojoki. Geological map of Finland, 1:100 000.

Hyvärinen, L., Kauranne, K. & Yletyinen, V. 1973. Modern boulder tracing in prospecting. Prospecting in areas of glaciated terrain 1973, 87—95. IMM, London.

Ignatius, H., Korpela, K. & Kujansuu, R., 1980. The deglaciation of Finland after 10,000 B.P. Boreas 9, 217—228.

Ikävalko, O., 1981. Makkolan — Kokonkylän suprakrustinen vyöhyke. Pro gradu tutkielma (Unpubl. M.Sc. thesis), University of Helsinki, Department of Geology and Mineralogy. 1981.

Johansson, P., 1980. Pohjamoreenin petrografisesta ja mineralogisesta koostumuksesta Heinolan maalaiskunnan ja Kangasniemen alueella. Pro gradu tutkielma (Unpubl. M.Sc. thesis), University of Turku, Department of Quaternary Geology. 1980.

Kauranne, L.K., 1958. On prospecting for molybdenum in the basis of its dispersion in glacial till. Bull. Comm. géol. Finlande 180, 31—43.

Kauranne, K., 1970. Abrasion and impact strength of gravel and rocks in Finland. Bull. Comm. géol. Finlande 243, 64 p.

Kinnunen, K.A., 1979. Ore mineral inclusions in detrital quartz contained in basal till and the glacial transport from the Ylöjärvi copper — tungsten deposit, southwestern Finland. Geol. Surv. Finland, Bull. 298, 55 p.

Kivekäs, E.K., 1946. Zur Kenntniss der mechanischen chemischen und mineralogischen Zusammensetzung der Finnischen Moränen. Acta Agralia Fennica 60 (2), 122 p.

Korpela, K., 1969. Die Weichsel-Eiszeit und ihr Interstadial in Peräpohjola (Nördliches Nordfinnland) im Licht von submoränen Sedimenten. Ann. Acad. Sci. Fennicae Ser. A. III, 99 p.

Korsman, K., 1973. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 3233, Rantasalmi. Geological map of Finland, 1:100 000.

Korsman, K., 1977. Progressive metamorphism of the metapelites in the Rantasalmi — Sulkava area, southeastern Finland. Geol. Surv. Finland, Bull. 290, 82 p.

Korsman, K. & Pääjärvi, A., 1980. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 3234, Varkaus. Geological map of Finland, 1:100 000.

Krumbein, W.C., 1937. Sediments and exponential curves. J. Geol. 45, 577—601.

Kujansuu, R., 1967. On the deglaciation of western Finnish Lapland. Bull. Comm. géol. Finlande 232, 98 p.

Kujansuu, R. & Niemelä, R. (Ed.), 1984. Quaternary deposits of Finland 1:1 000 000. Geol. Surv. Finland 1984.

Laajoki, K., 1973. On the geology of the South Puolanka area, Finland. Geol. Surv. Finland, Bull. 263, 54 p.

Laiti, I.O., 1983. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 4242, Eno. Geological map of Finland, 1:100 000.

Lavikainen, S., 1985. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 4214, Rääkkylä. Explonation to the map of rocks. Geological map of Finland, 1:100 000.

Lehtonen, M., 1981. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 2714, Kihlanki. Geological map of Finland, 1:100 000.

Lehtonen, M., Manninen, T., Rastas, P., Väänänen, J., Roos, S.I. & Pelkonen, R., 1984. Geological map of Central Lapland 1:200 000. Geol. Surv. Finland.

Lepeltier, C., 1969. A Simplified Statistical Treatment of Geochemical Data by Graphical Representation. Econ. Geol. 64, 538—550.

Lindén, A., 1975. Till Petrographical studies in an Archaean Bedrock Area in Southern Central Sweden. Striae 1, 57 p.

Lindroos, P., Hyyppä, J., Stén, C-G. & Tuittila, H., 1983. Rauman — Kokemäen seudun maaperä. Lehti — Sheet 1132, 1134. Summary: Quaternary deposits in the Rauma and Kokemäki map-sheet areas. Geological map of Finland, 1:100 000.

Lundqvist, G., 1935. Blockundersökningar, historik ock metodik. Zusammenfassung: Geschiebeuntersuchungen Historik und Methodik. Sver. Geol. Unders. C 390, 45 p.

Lundqvist, J., 1969. Problems of the so-called Rogen moraine. Sver. Geol. Unders. C 648, 32 p.

Lundqvist, J., 1983. Tills and moraines in Sweden. *In* Glacial deposits in north-west Europe, ed. by J. Ehlers. A.A. Balkema, Rotterdam, 83—90.

Lyytikäinen, A., 1982. Pohjois-Karjalan harjumaiseman kehitys sekä nykyisen tilan ja maankäytön yleispiirteet. Summary: The development and present state of esker landscape of North Karelia, Eastern Finland. The Nation-wide Esker Investigation, Rep. 22, 150 p.

Mäkinen, K., 1979. Interstadiaalinen turvekerrostuma Tervolan Kauvonkankaalla. Summary: An interstadial peat layer at Kauvonkangas, Finnish Lapland. Geologi 31, 82—87.

Mäkinen, K. & Maunu, M., 1984. Pohjois-Suomen maaperä. *In* Geologinen Pohjois-Suomi, ed. by A. Silvennoinen. Acta Lapponica Fenniae 12, 51—84.

Marcussen, Ib, 1973. Stones in Danish tills as a stratigraphical tool. A review. Bull. Geol. Inst. Univ. Uppsala, New Ser. 5, 177—181.

Marttila, E., 1977. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 3323, Kiuruvesi. Geological map of Finland, 1:100 000.

Matisto, A., 1961. On the relation between the stones of the eskers and the local bedrock in the area northwest of Tampere, southwestern Finland. Bull. Comm. géol. Finlande 193, 53 p.

Milthers, V., 1909. Scandinavian indicator boulders in the Quaternary deposits; extension and distribution. Danmarks Geol. Unders. Ser. 2, 23, 154 p.

Minell, H., 1979. The genesis of tills in different moraine types and the deglaciation in a part of central Lappland. Sver. Geol. Unders. C 743, 83 p.

Mölder, K., 1948. Die Verbreitung der Dacitblöcke in der Moräne in der Umgebung des Sees Lappajärvi. Bull. Comm. géol. Finlande 142, 45—57.

Mutanen, T., 1971. An example of the use of boulder counting in lithologic mapping. Bull. Geol. Soc. Finland 43, 131—140.

Nenonen, K., 1984. Till Stratigraphic Studies as an Aid to Ore Prospecting in Finland. *In* Ten Years of Nordic Till Research, ed. by L-K. Königsson. Striae 20, 101—105.

Niemelä, J. (Ed.), 1979. Suomen sora- ja hiekkavarojen arviointiprojekti 1971—78. Summary: The gravel and sand resources of Finland; an inventory project 1971—78. Geol. Surv. Finland, Rep. Invest. No 42, 119 p.

Niemelä, J. & Tynni, R., 1979. Interglacial and interstadial sediments in the Pohjanmaa region, Finland. Geol. Surv. Finland, Bull. 302, 48 p.

Nykänen, O., 1967. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 4232 + 4234, Tohmajärvi. Geological map of Finland, 1:100 000.

Nykänen, O., 1971. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 4241, Kiihtelysvaara. Geological map of Finland, 1:100 000.

Nykänen, O., 1972. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 4231, Kitee. Geological map of Finland, 1:100 000.

Nykänen, O., 1975. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 4213, Kerimäki. Geological map of Finland, 1:100 000.

Okko, M. 1962. On the development of the First Salpausselkä, west of Lahti. Bull. Comm. géol. Finlande 202, 162 p.

Okko, V. 1941. Über das Verhältnis der Gesteinzusammensetzung der Moräne zum Felsgrund in den Gebieten der Kartenblätter von Ylitornio und Rovaniemi im nördlichen Finnland. Geol. Rundschau Bd. 32, 627—643.

Okko, V. 1949. Maalajikartan selitys. Lehti B 4. Kokkola. Suomen geologinen yleiskartta 1:400 000, 108 p.

Pekkarinen, L.J., 1979. The Karelian formations and their depositional basement in the Kiihtelysvaara — Värtsilä area, East Finland. Geol. Surv. Finland, Bull 301, 141 p.

Peltoniemi, H., 1985. Till lithology and glacial transport in Kuhmo, eastern Finland. Boreas 14, 67—74.

Perttunen, M., 1977. The lithologic relation between till and bedrock in the region of Hämeenlinna, southern Finland. Geol. Surv. Finland, Bull 291, 68 p.

Perttunen, M., Stén, C-G., Hyyppä, J. & Grönlund, T., 1984. Toijalan kartta-alueen maaperä. Summary: Quaternary deposits in the Toijala map-sheet area. Geological map of Finland, 1:100 000.

Perttunen, V., 1971. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 2541 & 2544, Kemi & Runkaus. Geological map of Finland, 1:100 000.

Perttunen, V., 1972. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 2542 + 2524, Karunki. Geological map of Finland, 1:100 000.

Perttunen, V., 1975. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 2543, Simo. Geological map of Finland, 1:100 000.

Perttunen, V., 1984. Pohjois-Suomen kallioperä. *In* Geologinen Pohjois-Suomi, ed. by A. Silvennoinen. Acta Lapponica Fenniae, 7—27.

Pulkkinen, E., 1983. Sattasen karttalehtialueen geokemiallisen kartoituksen tulokset. Summary: The results of the geochemical survey in the Sattanen map-sheet area. Explanatory notes to geochemical maps, sheet 3714, Geol. Surv. Finland. 67 p.

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. Photogramm. J. Finland 9, 77—93.

Punkari, M., 1984. The Relations between Glacial Dynamics and Tills in the Eastern Part of the Baltic Shield. *In* Ten Years of Nordic Till Research, ed. by L-K. Königsson. Striae 20, 49—54.

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

Puranen, R. & Kivekäs, L., 1979. Grain density of till: a potential parameter for the study of glacial transport. Geol. Surv. Finland, Rep. Invest. No. 40, 32 p.

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

Rainio, H., 1985. 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, 70—77.

Rainio, H. & Lahermo, P., 1984. New Aspects on the Distribution and Origin of the So-Called Dark Till. *In* Ten Years Nordic Till Research, ed. by L-K. Kögigsson. Striae 20, 45—47.

Repo, R., 1957. Untersuchungen über die Bewegungen des Inlandeises in Nordkarelien. Bull. Comm. géol. Finlande 179, 178 p.

Saarnisto, M., Nevalainen, R., Peltoniemi, H., Taipale, K. & Tuokko, I., 1981. Kuhmon malmiprojektin maaperägeologiset tutkimukset v. 1980. Summary: Studies in glacial geology in the Kuhmo research project, 1980. Kuhmon ja Kittilän malmiprojekti, Rap. 44, 95 p.

Saarnisto, M. & Peltoniemi, H., 1984. Glacial stratigraphy and compositional properties of till in Kainuu, eastern Finland. Fennia 162, 163—199.

Saarnisto, M. & Taipale, K., 1984. Influence of the Kuhmo Greenstone Belt (Eastern Finland) upon the Lithology and Geochemistry of Till. *In* Ten Years of Nordic till Research, ed. by L-K. Königsson. Striae 20, 39—44.

Salisbury, R.D., 1900. The local origin of glacial drift. J. Geol 8, 426—432.

Salli, I., 1957. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 2432, Pyhäjoki. Geological map of Finland, 1:100 000.

Salli, I., 1962. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 2342, Sievi. Geological map of Finland, 1:100 000.

Salli, I., 1969. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 3312, Pihtipudas. Geological map of Finland, 1:100 000.

Salli, I., 1977. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 3314, Pielavesi. Geological map of Finland, 1:100 000.

Salminen, R., 1980. On the geochemistry of copper in the Quaternary deposits in the Kiihtelysvaara area, North Karelia, Finland. Geol. Surv. Finland, Bull. 309, 48 p.

Salminen, R. & Hartikainen, A., 1985. Glacial transport of till and its influence on interpretation of geochemical results in North Karelia, Finland. Geol. Surv. Finland, Bull. 335, 48 p.

Salonen, V-P., 1984. Examples of Boulder Countings in Ore Prospecting and Glacial Transport Studies in Southern Finland. *In* Ten Years of Nordic Till Research, ed. by L-K. Königsson. Striae 20, 106—108.

Salonen, V-P., 1986. Length of boulder transport in Finland. Prospecting in areas of glaciated terrain 1986, proceedings, 211 — 215. IMM, London, 269 p.

Salonen, V-P., in press. Observations on boulder transport in Finland. Geol. Surv. Finland, Spec. paper.

Salonen, V-P. & Kokkola, M., 1981. Ablaatiomoreenin kivilajikoostumus, kerrostuminen ja lohkarekuljetus Merikarvialla. *In* Pintamoreenin merkitys malmilohkarekuljetuksissa, ed. by P. Lindroos. Geol. Surv. Finland, Rep. Invest. No. 55, 45—52.

Saltikoff, B., 1984. Boulder tracing and the mineral indication data bank in Finland. Prospecting in areas of glaciated terrain 1986, proceedings, 179—191. IMM, London. 232 p

Sauramo, M., 1924. Tracing of glacial boulders and its application in prospecting. Bull. Comm. géol. Finlande 67, 37 p.

Sauramo, M., 1926. Maalajikartan selitys. Lehti C 4. Kajaani. Suomen geologinen yleiskartta 1:400 000, 80 p.

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

Shetsen, I., 1984. Application of till pebble lithology to the differentiation of glacial lobes in southern Alberta. Can. J. Earth Sci. 21, 920—933.

Shilts, W.W., 1976. Glacial till and mineral exploration. *In* Glacial Till An Inter-disciplinary Study, ed. by R.F. Legget. The Royal Society of Canada, Ottawa 1976, 205—224.

Shilts, W.W., 1977. Geochemistry of till in perennially frozen terrain of the Canadian Shield — application to prospecting. Boreas 5, 203—212.

Simonen, A., 1949. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 2131, Hämeenlinna. Geological map of Finland, 1:100 000.

Simonen, A., 1979. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 3133, Ylämaa. Geological map of Finland, 1:100 000.

Simonen, A., 1980. The Precambrian in Finland. Geol. Surv. Finland, Bull. 304, 58 p.

Simonen, A. & Kouvo, O., 1955. Sandstones in Finland. Bull. Comm. géol. Finlande 168, 57—87.

Simonen, A. & Tyrväinen, A., 1965. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 3132, Savitaipale. Geological map of Finland, 1:100 000.

Sinclair, A.J., 1976. Applications of Probability Graphs in Mineral Exploration. Assoc. of Explor. Geoch., Spec. Vol No. 4, 95 p.

Sinclair, A.J. 1983. Univariate analysis. *In* Statistics and Data Analysis in Geochemistry, ed. by R.J. Howard. Handbook of Exploration Geochemistry 2, 59—81. Elsevier, Amsterdam 1983, 437 p.

Sugden, D.E., 1978. Glacial erosion by the Laurentide ice sheet. J. Glaciol. 20, 367—391.

Tanner, V., 1915. Studier öfver kvartärsystemet i Fennoskandias nordliga delar. III. Om landisens rörelser och afsmältning i finska Lappland och angränsande trakter. Résumé: Études sur le système quaternaire dans les parties septentrionales de la Fennoscandia. III. Sur la progression et le cours de la récession du glacier continental dans la Laponie finlandaise et les régions environnantes. Bull. Comm. géol. Finlande 38, 815 p.

Tyrväinen, A., 1979. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 3713, Sodankylä. Geological map of Finland, 1:100 000.

Tyrväinen, A., 1980. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 3714, Sattanen. Geological map of Finland, 1:100 000.

Virkkala, K., 1949. Explanation to the map of superficial deposits. The General geological map of Finland. Sheet D 4. Nurmes, 1:400 000, 54 p.

Virkkala, K., 1960. Explanation to the map of superficial deposits. Geological map of Finland. Sheets 4421, 4422, 4423, 4441, 4424. Hyrynsalmi, Suomussalmi, Vuokkijärvi, Raate, 1:100 000, 62 p.

Virkkala, K., 1969. Maaperäkartan selitys. Summary: Explanation to the map of Quaternary deposits. Geological map of Finland. Sheet 2131, Hämeelinna, 1:100 000, 69 p.

Vorma, A., 1964. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 3134, Lappeenranta. Geological map of Finland, 1:100 000.

Vorma, A., 1971. Kallioperäkartta — Pre-Quaternary rocks. Lehti — Sheet 3232, Pieksämäki. Geological map of Finland, 1:100 000.

Appendix

Location of sample sites and determination of provenance areas for boulder countings 1—111. Legend: x, y = map coordinates, map = number of the topographic map 1:20 000, n = number of boulders in the sample, ref = lithologic mapping.

1. Merikarvia, Kultaoja 1
x = 6868.80
y = 536.10
map = 1231 10, n=600 Ref: Salonen & Kokkola 1981

rock type	f(%)	distance (km)	cumulative percentage
granodiorite	38.8	0.0— 3.0	38.8
porph. granodiorite	3.0	0.8— 2.0	41.8
local granite	9.9	1.0— 2.5	61.7
acid volcanics	4.2	2.2— 5.0	65.9
quartz-feldspar gneiss	7.5	2.5— 5.0	73.4
biotite-plagioclase schist	0.8	3.0— 5.0	74.2
gneissose granodiorite	2.7	3.2—20.0	76.9
mica schist	10.6	5.0— 8.0	87.5
basic volcanics	1.7	5.0— 9.0	89.2
mica gneiss	9.5	6.0—30.0	98.7
basic intrusives	0.7	>30.0	99.4
Siipyy granite	0.6	>50.0	<100

2. Merikarvia, Kultaoja 2
x = 6868.15
y = 536.60
map = 1231 10, n=100Ref: Salonen & Kokkola 1981

rock type	f(%)	distance (km)	cumulative percentage
granodiorite	60.0	0.0— 2.0	60.0
porph. granodiorite	8.0	1.0— 2.0	68.0
local granite	5.0	1.5— 3.0	73.0
acid volcanics	11.0	3.0— 4.5	84.0
hornblende gneiss	1.0	6.0— 7.0	85.0
uralite porphyrite	1.0	8.0— 9.0	86.0
mica schist	9.0	8.0—20.0	95.0
mica gneiss	4.0	8.0—20.0	99.0
basic intrusives	1.0	>20.0	<100

3. Merikarvia, Kultaoja 3
x = 6869.10
y = 536.00
map = 1231 10, n=100 Ref: Salonen & Kokkola 1981

rock type	f(%)	distance (km)	cumulative percentage
granodiorite	72.0	1.0— 2.5	72.0
local granite	16.0	1.2— 2.2	88.0
acid volcanics	2.0	2.2— 3.0	90.0
mica schist	4.0	2.6— 5.0	94.0
gneissose granodiorite	4.0	3.3—20.0	98.0
mica gneiss	2.0	>5.7	<100

4. Merikarvia, Kultaoja 4
x = 6867.70
y = 533.80
map = 1231 10, n=100 Ref: Salonen & Kokkola 1981

rock type	f(%)	distance (km)	cumulative percentage
local granite	11.0	0.0— 0.2	11.0
acid volcanics	75.0	0.2— 0.6	86.0
quartz-feldspar schist	5.0	0.5— 3.0	91.0
mica schist	3.0	2.5— 7.0	94.0
mica gneiss	2.0	5.5—10.0	96.0
augen gneiss	2.0	>15.0	98.0
diabase	1.0	>20	99.0
Siipyy granite	1.0	>30	<100

5. Merikarvia, Kultaoja 5
x = 6866.55
y = 535.95
map = 1231 10, n=100 Ref: Salonen & Kokkola 1981

rock type	f(%)	distance (km)	cumulative percentage
local granite	32.0	0.0— 4.0	32.0
granodiorite	7.0	0.0— 5.0	39.0
acid volcanics	4.0	3.2—10.0	43.0
quartz-feldspar schist	8.0	4.0— 8.0	51.0
gneissose granodiorite	6.0	4.5—30.0	57.0
basic volcanics	13.0	7.0—11.0	70.0
mica gneiss	27.0	7.5—40.0	97.0
diorite	1.0	>30.0	98.0
sandstone	1.0	>40.0	99.0
diabase	1.0	>50	<100

6. Merikarvia, Pitkäjärvi
x = 6873.50
y = 534.55
map = 1231 11, n=100 Ref: Salonen & Kokkola 1981

rock type	f(%)	distance (km)	cumulative percentage
granodiorite	4.0	0.0— 3.0	4.0
intermediate volcanics	3.0	2.2— 4.5	7.0
quartz-feldspar gneiss	41.0	2.5—10.0	48.0
gneissose granodiorite	4.0	3.0—30.0	52.0
mica gneiss	37.0	3.5—30.0	89.0
basic intrusives	6.0	>20.0	95.0
Siipyy granite	5.0	>30	<100

7. Kuvaskangas 1
x = 6869.90
y = 534.95
map = 1231 10, n=100 Ref: Salonen & Kokkola 1981

rock type	f(%)	distance (km)	cumulative percentage
local granite	3.0	1.0— 1.5	3.0
volcanic rocks	12.0	1.5— 5.0	15.0
quartz-feldspar schist	40.0	2.0—10.0	55.0
gneissose granodiorite	2.0	2.5—20.0	57.0
mica schist	30.0	4.5—30.0	87.0
augen gneiss	9.0	>20.0	96.0
sandstone	1.0	>40.0	97.0
Siipyy granite	3.0	>50.0	<100

8. Kuvaskangas 2
x = 6870.90
y = 533.05
map = 1231 11, n=100 Ref: Salonen & Kokkola 1981

rock type	f(%)	distance (km)	cumulative percentage
quartz-feldspar gneiss	16.0	1.5— 2.5	16.0
granite	36.0	2.0— 7.0	52.0
gneissose granodiorite	3.0	0.5—30.0	55.0
mica gneiss	34.0	2.5—25.0	89.0
augen gneiss	1.0	>20.0	90.0
Siipyy granite	3.0	>40.0	93.0
sandstone	3.0	>50.0	96.0
unknown	4.0	>100.0	<100

9. Koosanmaa
x = 6781.70
y = 462.00
map = 2114 02, n=111 Ref: Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
mica gneiss	18.9	0.0— 1.0	18.9
graphite gneiss	9.9	0.8— 1.4	28.8
migmatite	10.8	1.0— 2.0	39.6
diorite	5.4	1.0— 1.7	45.0
quartz diorite	0.9	1.3— 1.6	45.9
granodiorite gneiss	16.2	1.5— 2.0	62.1
gabbro	0.9	1.8— 2.0	63.0
mylonitic granite	19.0	2.5— 4.0	82.0
intermediate volcanics	13.5	>3.5	95.5
pegmatite	1.8	>4.0	97.3
granite, even grained	0.9	>5.0	98.2
granite, porphyroblastic	0.9	>5.5	99.1
granite, fine grained	0.9	>6.0	<100

10. Vesilahti
x = 6804.70
y = 462.25
map = 2123 01, n=150 Ref: Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
granite	57.8	0.0—0.2	57.8
mica gneiss	32.0	0.2—0.4, 0.5—0.9	89.8
ultramafics	1.8	0.4—0.5	91.6
pegmatite	1.7	>0.9	93.3
granodiorite	6.7	>0.9	<100

11. Herajärvi
x = 6801.00
y = 455.20
map = 2121 10, n=219 Ref: Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
mica gneiss	27.8	0.2— 7.0	27.8
schollen migmatite	2.6	0.5— 1.0	30.4
granite	61.6	3.2—10.0	92.0
schollen of Stormi	1.0	4.5— 6.0	93.0
ultramafic rocks	1.9	6.3— 6.6	94.9
granodiorite	5.1	8.0—20.0	<100

12. Jalonoja
x = 6800.30
y = 422.20
map = 2121 01, n=1050 Ref: Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
peridotite	0.1	0.0— 0.2	0.1
quartz diorite	63.4	0.0— 3.0	63.5
graphite gneiss	1.4	0.8— 1.0	64.9
biotite-plagioclase gneiss	5.4	1.4— 2.0	70.3
augen gneiss	0.6	1.5— 2.0	70.9
biotite gneiss	0.7	>1.6	71.6
amphibolite	1.4	1.5— 3.0	73.0
pegmatite	4.4	1.0— 2.0	77.4
aplite	5.7	2.1— 2.2	83.1
diorite	0.2	4.4— 4.6	83.3
mica gneiss	12.1	4.0— 6.0	95.4
hornbl.-plagiocl.gneiss	2.7	6.0— 7.0	98.3
diabase	0.1	7.5—10.0	98.4
skarn rock	0.1	7.7— 8.0	98.5
amphibole gneiss	0.6	8.0—12.0	99.1
granite	0.9	>15.0	<100

13. Laitilan harju
x = 6737.00
y = 550.60
map = 1044 06, n=189 ref: Härme 1958

rock type	f(%)	distance (km)	cumulative percentage
mica gneiss	57.2	1.0— 6.0	57.2
granodiorite	2.6	4.0— 7.0	59.8
contact granite	1.6	5.5— 6.5	61.4
rapakivi	31.7	6.0— 32.0	93.1
diabase	1.1	25.0— 30.0	94.2
granite	3.7	30.0— 60.0	97.9
red sandstone	1.6	80.0—100.0	99.5
grey sandstone	0.5	>150	<100

14. Laitila, de Geer moraine
x = 6736.90
y = 551.70
map = 1044 06, n=175 Ref: Härme 1958

rock type	f(%)	distance (km)	cumulative percentage
granite	23.4	0.0— 0.8	23.4
pegmatite	5.1	0.0— 6.6	30.8
mica gneiss	40.6	0.8— 6.6	71.4
contact granite	3.4	6.0— 7.0	74.8
rapakivi	21.1	6.6—34.0	95.9
diabase	0.6	25.0—30.0	96.5
red sandstone	3.5	>80.0	<100

15. Vehmaa, de Geer moraine
x = 6727.20
y = 543.80
map = 1022 02, n=270 Ref: Härme 1958

rock type	f(%)	distance (km)	cumulative percentage
contact granite	3.7	0.0— 0.5	3.7
Vehmaa granite	68.5	0.0—15.0	72.2
Laitila granite	4.8	12.0—20.0	77.0
mica gneiss	19.7	15.0—30.0	96.7
trondhjemite	1.6	30.0—60.0	98.3
diabase	0.7	>60.0	99.0
red sandstone	1.0	>80.0	<100

16. Liipola, Salpausselkä II
x = 6677.80
y = 468.60
map = 2014 03, n=225 Ref: Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
acid volcanic rock	26.7	0.0— 0.5	26.7
subvolcanics	2.2	0.5— 0.7	28.9
sericite rock	19.6	0.7— 0.9	48.5
skarn rock	4.9	0.8— 0.9	53.4
intermediate volcanics	4.9	1.0— 1.4	58.3
gneiss	2.2	1.0— 1.6	60.5
granodiorite	1.3	1.6— 1.7	61.8
mylonite	0.9	1.7— 1.8	62.7
contact granite	0.4	1.8— 1.9	63.1
Perniö granite	35.9	>1.8	99.0
diabase	1.0	>10.0	<100

17. Tömäjärvi,1
x = 6765.70
y = 515.90
map = 2131 06, n = 173 Ref: Simonen 1949, Rautaruukki Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
pegmatite	8.7	0.0— 0.6	8.7
plagioclase porphyrite	12.7	0.5— 1.2	21.4

diorite	2.3	0.6— 1.7	23.7
mica schist	32.4	1.3— 2.5	56.1
intermediate volcanic rock	6.9	2.0— 4.0	63.0
uralite porphyrite	19.0	3.0— 7.0	82.0
mylonite	0.6	3.0— 5.0	82.6
basic volcanic rock	9.3	5.0— 9.0	91.9
granite	5.8	10.0—20.0	97.7
granodiorite	2.3	17.0—20.0	<100

18. Tömäjärvi 2
x = 6764.50
y = 515.40
map = 2131 06, n=134 Ref: Simonen 1949, Rautaruukki Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
plagioclase porphyrite	4.5	0.0— 0.3	4.5
diorite	2.2	0.2— 2.0	6.7
mica schist	52.2	0.2— 2.5	58.9
basic volcanic rock	3.7	2.5— 6.0	62.6
uralite porphyrite	29.9	2.5— 6.0	92.5
plagioclase uralite porphyrite	2.2	5.0—10.0	94.7
granodiorite	1.5	10.0—17.0	96.2
granite	3.8	>15.0	<100

19. Tömäjärvi 3
x = 6765.70
y = 515.10
map = 2131 06, n=179 Ref: Simonen 1949, Rautaruukki Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
mica schist	2.2	0.2— 0.5	2.2
basic volcanic rock	31.2	0.4— 0.8	33.4
uralite porphyrite	53.1	0.7— 4.2	83.3
acid volcanic rock	2.1	3.5— 6.0	85.4
intermediade volcanic rock	5.6	5.0— 7.0	91.0
granite	8.4	8.0—17.0	99.4
mica gneiss	0.6	>17.0	<100

20. Tömäjärvi 4
x = 6763.60
y = 517.05
map = 2131 06, n=140 Ref: Simonen 1949, Rautaruukki Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
diorite	70.4	0.0— 4.0	70.4
mica schist	4.5	2.0— 4.0	74.9
plagioclase porphyrite	0.6	2.5— 2.7	75.5
uralite porphyrite	7.1	3.7— 8.0	82.6
basic volcanic rock	4.5	5.0—10.0	87.1
acid volcanic rock	1.3	7.5— 9.5	88.4
intermediate tuffite	0.6	8.0—10.0	89.0
granodiorite	1.9	10.0—17.0	90.9
granite	6.6	>12.0	97.5
mica gneiss	2.5	>20.0	<100

21. Tömäjärvi 5
x = 6765.70
y = 515.90
map = 2131 06, n=183 Ref: Simonen 1949, Rautaruukki Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
diorite	2.2	0.0— 0.3	2.2
mica schist	3.8	0.0— 1.0	6.0
basic volcanic rock	38.5	0.7— 1.5	44.5
uralite porphyrite	38.8	1.0— 5.0	83.3
intermediate volcanic rock	3.3	4.0— 7.0	86.6
acid volcanic rock	5.5	5.0— 7.0	92.1
feldsparporphyry	2.6	5.0— 8.0	94.7
granite	3.8	9.0—16.0	98.5
mica gneiss	1.5	>17.0	<100

22. Vuohiniemi
x = 6759.90
y = 506.60
map = 2131 02, n = 219 Ref: Simonen 1949, Rautaruukki Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
microcline granite	26.5	0.0— 0.9	26.5
mica schist	4.6	0.9— 2.0	31.1
plagioclase porphyrite	0.9	0.5— 2.5	32.0
uralite porphyrite	4.6	2.0— 3.3	36.6
basic volcanic rock	6.8	3.0— 5.0	43.4
intermediate volcanic rock	1.4	3.3— 4.0	44.8
basic tuffite	0.5	4.0— 5.0	45.3
acid volcanic rock	0.9	5.5— 6.0	46.2
granodiorite	14.7	6.5—20.0	60.9
mica gneiss	5.5	15.0—20.0	66.4
grey granite	34.6	>20.0	<100

23. Korkeakangas
x = 6872.70
y = 566.80
map = 3233 08, n = 128 Ref: Korsman 1973, 1977, Korsman & Pääjärvi 1980

rock type	f(%)	distance (km)	cumulative percentage
porphyritic granite	0.8	0.0— 3.0	0.8
granite, even grained	8.6	0.0—10.0	9.4
quartz-feldspar schist	3.1	3.0— 4.0	12.5
oriented granite	4.7	4.0— 7.0	17.2
K-feldspar-sillm.zone, S	1.6	4.0— 8.0	18.8
K-feldspar-sillm.zone	1.6	4.0—13.0	20.4
amphibolite	17.1	5.0— 8.0	37.5
tonalite, S	11.7	6.0— 9.0	49.2
K-feldspar-sill.zone, N	14.1	10.0—15.0	63.3
Kolkonjärvi shear rocks	9.3	12.0—17.0	72.6
Pirilä granite	12.5	12.0—15.0, 16.0—20.0	85.1
sill/mica schist isograd	3.9	15.0—18.0	89.0
mica schist zone, S-part	6.3	17.0—25.0	95.3
mica schist zone, N-part	1.6	23.0—30.0	96.9
granite	2.4	40.0—70.0	99.3
Pieksämäki granite	0.7	40.0—70.0	>100

24. Joroinen
x = 6898.40
y = 543.70
map = 3234 01, n = 175 Ref: Korsman 1973, 1977, Korsman & Pääjärvi 1980

rock type	f(%)	distance (km)	cumulative percentage
mica schist	35.3	0.0— 5.0	35.3
quartz-feldspar schist	11.4	2.0— 7.0	46.7
graphite schist	12.5	4.0—10.0	59.2
tonalite	13.6	5.0—10.0	72.8
pegmatite	13.0	7.0—12.0	85.8
porphyritic granodiorite	2.7	8.0—15.0	88.5
porphyritic granite	3.3	9.0—20.0	91.8
mica gneiss	2.6	10.0—20.0	94.4
amphibolite	1.6	15.0—30.0	96.0
diorite, granite, etc.	3.9	20.0—60.0	<100

25. Sääksjärvi
x = 6885.80
y = 549.30
map = 3233 03, n = 155 Ref: Korsman 1973, 1977

rock type	f(%)	distance (km)	cumulative percentage
metapelites	14.2	0.0—12.0	14.2
basic volcanic rock	11.0	4.0—10.0	25.2
tonalite	48.4	6.0— 8.0	73.6
acid volcanic rock	3.9	7.0—13.0	77.5
granite	14.8	10.0—20.0	92.3
amphibolite etc.	5.1	15.0—50.0	97.4
veined gneiss	1.9	20.0—30.0	99.3
porphyritic granite	0.7	25.0—40.0	<100

26. Pirttiselkä 1
x = 6883.80
y = 551.80
map = 3233 06, n = 130 Ref: Korsman 1973, 1977

rock type	f(%)	distance (km)	cumulative percentage
Pirilä granite	15.2	0.0— 2.0	15.2
K-feldspar-sill.zone	0.8	0.8— 1.2	16.0
mica schist	10.8	1.0—15.0	26.8
tonalite	28.5	2.0— 4.0, 9.0—11.0	55.3
basic volcanic rocks	3.8	6.0—11.0	59.1
acid volcanic rocks	7.7	9.0—15.0	66.8
mylonite	3.1	ca.15.0	69.9
granite	2.7	10.0—22.0	91.6
veined gneiss	6.2	15.0—60.0	97.8
porphyritic granite	2.2	25.0—40.0	<100

27. Pirttiselkä 2
x = 6884.60
y = 550.80
map = 3233 06, n = 143 Ref: Korsman 1973, 1977

rock type	f(%)	distance (km)	cumulative percentage
metapelites	7.7	0.0—15.0	7.7
black schist	2.1	2.0— 6.0	9.8
greywackes	21.7	2.0— 8.0	31.5
basic volcanic rocks	2.1	4.0—10.0	33.6
tonalites	28.7	7.0—10.0	62.3
acid volcanic rocks	9.7	8.0—15.0	70.0
granites	21.7	8.0—20.0	91.7
veined gneiss	4.9	15.0—60.0	96.6
porphyritic granite	3.4	25.0—40.0	<100

28. Pirttiselkä 3
x = 6883.70
y = 551.70
map = 3233 06, n = 157 Ref: Korsman 1973, 1977

rock type	f(%)	distance (km)	cumulative percentage
granite	14.0	0.0—12.0	14.0
K-feldspar-sill.isograde	0.6	0.8— 1.2	14.6
metapelite	3.7	1.0—15.0	18.3
black schist	0.6	5.0— 7.0	18.9
tonalites	20.4	5.0— 8.0, 9.0—11.0	39.3
carbonate rocks, skarns	4.4	5.0—10.0	43.7
basic volcanic rocks	5.1	6.0—11.0	48.8
acid volcanics	9.6	9.0—15.0	58.4
granites	21.7	10.0—22.0	80.1
veined gneiss	11.6	15.0—60.0	91.7
amphibolite etc.	5.7	20.0—60.0	97.4
porphyritic granite	2.6	26.0—40.0	<100

29. Kolkonranta
x = 6878.10
y = 557.2
map = 3233 05, n = 193 Ref: Korsman 1973, 1977

rock type	f(%)	distance (km)	cumulative percentage
coarse grained granite	5.7	0.0— 5.0	5.7
K-feldspar-sill.zone, N	23.4	0.0— 7.0	29.1
amphibolite	0.5	0.5— 2.0	29.6
mica schist of Kolkonjärvi	1.6	2.0— 5.0	31.2
quartz diorite	13.5	2.0— 6.0	44.7
Pirilä granite	5.2	3.0— 4.5	49.9
K-feldspar-sill.isograd	4.7	6.0— 8.0	54.6
Pirilä granite, N	11.5	6.0— 9.0	66.1
mica schist zone, S	7.8	7.0—14.0	73.9
mica schist zone, central	3.1	11.0—15.0	77.0
mica schist zone, N	12.0	14.0—20.0	89.0
tonalite	5.2	15.0—20.0	94.2
mica schist of Pieksämäki	1.0	23.0—26.0	95.2
amphibolite etc.	3.6	25.0—40.0	98.8
pyroxene granite	1.2	30.0—50.0	<100

30. Peltue
x = 6876.40
y = 558.10
map = 3233 05, n = 144 Ref: Korsman 1973, 1977

rock type	f(%)	distance (km)	cumulative percentage
pegmatite	18.0	0.0— 0.7	18.0
sillimanite gneiss	18.0	0.5— 7.0	36.0
amphibolite	2.8	1.0— 2.0	38.8
tonalite	13.1	1.0— 4.0	51.9
quartz-feldspar gneiss	0.7	1.5— 3.0	52.6
black schist	3.5	3.0— 5.5	56.1
Pirilä granite	4.9	5.0— 6.5	64.5
basic volcanics	1.4	5.0— 7.0	65.9
sillimatite gneiss, north	5.6	5.0—10.0	71.5
mica schist zone, isograd	5.6	9.0—10.0	77.1
metapelites	18.1	9.5—23.0	95.2
others	4.8	>25.0	<100

31. Kolkonpää
x = 6872.80
y = 562.60
map = 3233 08, n = 107 Ref: Korsman 1973, 1977

rock type	f(%)	distance (km)	cumulative percentage
cordierite gneiss	5.6	0.0— 3.0	5.6
granite	17.8	1.0— 3.5	23.4
quartz diorite	32.7	3.0— 8.0	56.1
sillimanite gneiss	15.0	4.0—15.0	71.1
amphibolite	1.9	5.0— 7.0	73.0
tremolite skarn	1.8	5.0— 8.0	74.8
basic volcanics	3.7	5.0—10.0	78.5
greywacke schist	4.7	8.0—15.0	83.2
mica schist	10.3	16.0—25.0	93.5
diorite etc.	4.7	>30.0	98.2
porphyritic granite	1.8	40.0—70.0	<100

32. Halttula
x = 6867.70
y = 570.10
map = 3233 10, n = 134 Ref: Korsman 1973, 1977

rock type	f(%)	distance (km)	cumulative percentage
cordierite gneiss	15.7	0.0—12.0	15.7
migmatite granite	31.3	4.0— 8.0	47.0
quartz-feldspar schist	2.2	9.0— 9.5	49.2
volcanic & carbonate rocks	3.6	10.0—13.0	52.8
quartz diorite, S	4.5	10.0—14.0	57.3
amphibolite	1.5	12.0—14.0	58.8
quartz diorite, Tuusmäki	20.1	12.0—20.0	78.9

sillimanite gneiss	9.7	12.0—25.0	88.6
metapelite	3.0	20.0—35.0	91.6
foreign rocks	5.9	>40.0	97.5
porphyritic granite	25	50.0—70.0	<100

33. Seppälä
x = 6860.80
y = 574.60
map = 3233 10, n = 139 Ref: Korsman 1973, 1977

rock type	f(%)	distance (km)	cumulative percentage
mica gneiss/granul.zone	28.8	0.0—10.0	28.8
quartz vein	23.7	0.0—15.0	52.5
quartz diorite	9.3	3.0—10.0	61.8
pegmatite	3.6	10.0—15.0	65.4
pyroxene quartz diorite	0.7	10.0—20.0	66.1
garnet granite	0.7	15.0—20.0	66.8
quartz-feldspar gneiss	1.4	18.0—19.0	68.2
mica gneiss of Kolkonjärvi	5.8	21.0—27.0	74.0
quartz diorite, S	9.4	22.0—26.0	83.4
quartz diorite, N	5.0	25.0—31.0	88.4
sillimanite gneiss	1.4	25.0—33.0	89.8
amphibolite	0.7	29.0—33.0	90.5
metapelite, S	2.2	33.0—36.0	92.7
metapelite, N	1.4	35.0—45.0	94.1
tonalite/mica schist zone	1.4	35.0—40.0	95.5
foreign granites	4.5	>55.0	<100

34. Suokylä
x = 6876.30
y = 578.20
map = 3233 11, n = 201 Ref: Korsman 1973, 1977

rock type	f(%)	distance (km)	cumulative percentage
metagreywacke	12.0	0.2— 3.0	12.0
quartz diorite	31.0	2.5— 3.6, 8.0—20.0	43.0
diorite	16.0	3.5— 8.5	59.0
gabbro	1.0	4.0— 5.0	60.0
granodiorite	3.0	8.0—20.0	63.0
granite	29.0	10.0—35.0	92.0
mica gneiss	2.0	20.0—40.0	94.0
porphyritic granite	6.0	50.0—80.0	<100

35. Kerimäki
x = 6875.00
y = 469.20
map = 4213 02, n = 182 Ref: Nykänen 1975

rock type	f(%)	distance (km)	cumulative percentage
granite	4.8	0.0— 1.0	4.8
mica gneiss	7.1	1.0—13.0	11.9
gabbro	1.1	4.5— 5.0	13.0
diorite	6.6	5.0— 6.5	19.6
quartz diorite	17.6	5.0— 7.5	37.2
hornblende gneiss	1.1	7.0— 9.0	38.3
graphite gneiss	10.5	8.0—15.0	49.8
veined gneiss	32.9	10.0—25.0	82.7
granites	17.3	>40.0	<100

36. Solkeinkylä
x = 6790.75
y = 543.40
map = 3134 03, n = 159 Ref: Vorma 1964

rock type	f(%)	distance (km)	cumulative percentage
quartz diorite	35.8	0.2— 2.0	35.8
mica gneiss	10.7	0.5— 2.0	46.5
porphyritic granite	6.9	1.7— 6.0	53.4
diorite	6.9	2.0— 5.0	60.3
unakite	6.3	2.2— 3.0	66.6
pegmatite, veined gneiss	22.0	6.0—15.0	88.6
amphibolite	1.9	7.0—10.0	90.5
granodiorite	7.7	15.0—40.0	98.2
metadiabase	1.2	>20.0	<100

37. Savitaipale
x = 6785.40
y = 533.30
map = 3132 11, n = 173 Ref: Simonen & Tyrväinen 1965

rock type	f(%)	distance (km)	cumulative percentage
porphyritic rapakivi gr.	7.5	0.4— 4.0	7.5
quartz porphyry	1.7	3.0— 4.5	9.2
mica gneiss	12.1	3.5— 8.0	21.3
pyroxene schist	4.0	4.0— 7.0	25.3

pegmatite	8.1	5.0— 8.0	33.4
porphyritic granodiorite	1.2	9.0—12.0	34.6
rapakivi granite	10.0	6.5— 9.0	44.6
quartz diorite	11.6	6.5—14.0	55.2
rapakivi granite	31.2	6.5—22.0	86.4
granite	7.5	20.0—30.0	93.7
veined gneiss	6.3	>25.0	<100

38. Hepokivi 1, Savitaipale
x = 6781.90
y = 522.00
map = 3132 08, n = 129 Ref: Simonen & Tyrväinen 1965

rock type	f(%)	distance (km)	cumulative percentage
wiborgite	17.8	0.0— 2.5	17.8
pyroxene schist	3.1	2.7— 3.0	20.9
veined gneiss	0.8	3.0— 3.3	21.7
migmatite	19.4	3.0— 6.0, 25.0—35.0	41.1
pegmatite	5.4	3.0— 8.0	46.5
quartz porphyry	1.6	3.5— 4.5	48.2
quartz-feldspar schist	2.3	5.0— 6.5	50.4
rapakivi granite	37.2	5.0—20.0	87.6
granodiorite	0.8	7.0— 8.0	88.4
granite	3.1	20.0—35.0	91.5
metadiabase	0.8	21.0—24.0	92.3
quartz diorite	7.7	>35.0	<100

39. Hepokivi 2, Savitaipale
x = 6780.10
y = 523.10
map = 3132 08, n = 125 Ref: Simonen & Tyrväinen 1965

rock type	f(%)	distance (km)	cumulative percentage
wiborgite	47.2	0.0— 5.0	47.2
migmatite	0.8	4.5— 6.0	48.0
mica gneiss	1.6	4.5— 8.5	49.6
quartz porphyry	1.6	5.5— 6.5	51.2
granodiorite	1.6	9.0—10.0	52.8
rapakivi granite	41.6	6.0—22.0	96.0
granite	2.4	22.0—40.0	98.4
quartz diorite	1.6	>35.0	<100

40. Lappeenranta, Vihtola
x = 6766.60
y = 560.60
map = 3133 09, n = 157 Ref: Simonen 1979, Vorma 1964

rock type	f(%)	distance (km)	cumulative percentage
rapakivi granite	47.1	0.0— 3.0	47.1
dark coloured rapakivi	2.5	2.5— 5.0	49.6
porphyritic rapakivi	1.9	3.0— 3.2	51.5
quartz porphyry	13.2	2.9— 5.0	64.7
quartz diorite	11.2	3.0—12.0	75.9
hornblende gneiss	1.9	3.2— 6.0	77.8
mica gneiss	3.8	3.5— 6.5	81.6
wiborgite	18.0	6.0—15.0	99.6
mica schist	0.4	E 30.0	<100

41. Kitee, Juurikka
x = 6877.50
y = 506.60
map = 4231 02, n = 156 Ref: Nykänen 1972

rock type	f(%)	distance (km)	cumulative percentage
granodiorite	4.0	0.0— 0.5	4.0
pegmatites	63.3	0.0— 0.8, 2.5— 3.0	67.3
granodiorite	0.7	0.5— 0.7	68.0
quartz diorite	3.3	0.7— 0.9	71.3
veined gneiss	3.3	0.7— 1.0	74.6
mica schist	18.0	1.0—50.0	92.6
graphite schist	5.4	1.3—50.0	98.0
others	2.0	E 6.0	<100

42. Tohmajärvi
x = 6895.30
y = 516.90
map = 4232 04, n = 140 Ref: Nykänen 1967

rock type	f(%)	distance (km)	cumulative percentage
greywacke schist	40.0	0.0— 2.2	40.0
phyllite	22.2	0.0— 3.0, 6.0—50.0	
pegmatite	3.6	1.4— 2.0	65.8
quartzite	10.0	2.5— 4.0	75.8

graphite schist	7.1	2.5—10.0	82.9
quartz-feldspar porphyry	0.7	3.5— 6.0	83.6
albite diabase	0.7	4.0— 5.0	84.3
black schist	1.4	4.0—10.0	85.7
garnet-mica schist	0.7	7.0—40.0	86.4
andalusite schist	0.7	8.0—40.0	87.1
gneissose granite	4.2	45.0—50.0	91.3
granite etc.	8.7	>80.0	<100

43. Kokonkylä, hummocky moraine
x = 6885.10
y = 468.50
map = 3213 03, n = 134 Ref: Ikävalko 1981

rock type	f(%)	distance (km)	cumulative percentage
granodiorite porphyry	31.4	0.0— 0.8	31.4
mica gneiss	12.7	0.8— 1.5	44.1
intermed. volcanic rock	10.4	1.6— 2.0	54.5
black schist	1.5	1.9— 2.1	56.0
acid volcanic rock	4.4	2.4— 3.0	60.4
basic volcanic rock	3.8	3.0— 3.4	64.2
metagreywacke	6.7	4.0— 4.5	70.9
quartz porphyry	2.3	4.5— 5.5	73.2
quartz diorite	17.9	>7.6	91.1
granite	8.3	>10.0	99.4
hornblendite	0.6	>30.0	<100

44. Kokonkylä, drumlin
x = 6885.50
y = 468.20
map = 3213 03, n = 134 Ref: Ikävalko 1981

rock type	f(%)	distance (km)	cumulative percentage
granodiorite porphyry	10.5	0.0— 0.4	10.5
veined gneiss	5.9	0.4— 2.0	16.4
intermed. volcanic rock	3.7	1.2— 1.6	20.1
acid volcanic rock	3.7	2.0— 2.6	23.8
basic volcanic rock	4.5	2.6— 3.0	28.3
metagreywacke	0.8	>3.0	29.1
quartz diorite	38.8	>7.2	67.9
granite	32.1	>10.0	<100

45. Kontiolahti, Kuusijärvi
x = 6971.70
y = 502.30
map = 4242 03, n = 249 Ref: Laiti 1983

rock type	f(%)	distance (km)	cumulative percentage
basement gneiss	14.0	0.0— 0.4	14.0
quartzite	24.0	0.1— 0.42	38.0
conglomerate	4.0	0.5— 1.1	42.0
sericite quartzite	26.0	1.0— 1.9	68.0
metadiabase	13.0	1.7— 2.6	81.0
greywacke	14.0	2.4— 6.0	95.0
mica schist	5.0	5.6—50.0	<100

46. Renginsuo
x = 6958.50
y = 504.70
map = 4242 01, n = 210 Ref: Laiti 1983

rock type	f(%)	distance (km)	cumulative percentage
epidote granite	23.4	0.0— 0.4	23.4
quartzite/conglomerate	11.5	0.4— 0.9	34.9
metadiabase	5.3	0.5— 0.7	40.2
polymictic conglomerate	2.9	0.6— 0.7	43.1
mica schist	27.2	0.9— 4.0	70.3
basement gneiss	29.7	4.0—13.0	<100

47. Karsikkojärvi
x = 6933.50
y = 513.60
map = 4241 05, n = 197 Ref: Nykänen 1971, Pekkarinen 1979

rock type	f(%)	distance (km)	cumulative percentage
granite, grey	30.0	0.0— 1.5	30.0
arkositic conglomerate	6.1	0.2— 0.4	36.1
metadiabase	4.1	0.3— 0.4	40.2
arkosite	3.6	0.3— 6.0	43.8
sericite schist	3.6	0.6— 1.6	47.4
orthoquartzite	24.4	> 1.3	71.8
sericite quartzite	3.6	2.0— 3.5	75.4
mica schist	22.9	> 2.5	98.3
mica gneiss etc.	1.7	>30.0	<100

48. Kaltimojärvi
x = 6970.50
y = 504.10
map = 4242 03, n = 202 Ref: Laiti 1983

rock type	f(%)	distance (km)	cumulative percentage
metadiabase	21.5	0.0—1.4	21.5
basement granite	8.0	0.2—0.9	29.5
orthoquartzite	14.5	0.8—2.5	44.0
meta-arkose	5.0	1.0—5.0	49.0
basement gneiss	5.0	2.2—3.0	54.0
conglomerate	2.5	3.0—3.5	56.5
sericite schist	17.5	3.0—9.0	95.5
greywacke schist	3.5	4.0—5.0	99.0
mica schist	1.0	>8.5	<100

49. Romo
x = 6965.40
y = 493.90
map = 4224 11, n = 251 Ref: Huhma 1971

rock type	f(%)	distance (km)	cumulative percentage
basement gneiss	35.2	0.0— 0.4	35.2
quartzites, metadiabases	13.6	0.4— 0.7	48.8
mica schist	48.8	0.5—30.0	97.6
mica gneiss etc.	2.4	>30.0	<100

50. Petäinen
x = 6921.20
y = 458.20
map = 4221 10, n = 183 Ref: Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
graphite schist	3.8	0.0— 2.0	3.8
skarn and quartzite	14.7	0.2— 0.6	18.5
serpentinite	9.8	0.3— 0.5	28.3
mica schist	50.3	1.0— 7.0	78.6
mica gneiss	10.3	6.0—40.0	88.9
basement gneiss	7.1	10.0—25.0	96.0
granodiorite of Heinävesi	4.0	>25.0	<100

51. Sivi
x = 6918.80
y = 461.80
map = 4214 03, n = 158 Ref: Lavikainen 1985

rock type	f(%)	distance (km)	cumulative percentage
mica schist	68.4	0.0—15.0	68.4
Outokumpu assemblage	3.1	3.5— 4.5	71.5
granodiorite of Heinävesi	9.0	12.0—50.0	90.5
mica gneiss	1.9	40.0—70.0	92.4
basement gneiss	7.6	>60.0	<100

52. Petäjäsaari
x = 6917.60
y = 462.10
map = 4214 03, n = 139 Ref: Lavikainen 1985

rock type	f(%)	distance (km)	cumulative percentage
mica schist	77.7	0.0—15.0	77.7
tremolite skarn	0.7	0.5— 1.0	78.4
serpentinite	0.7	5.0— 6.0	79.1
mica gneiss	4.3	8.0—50.0	83.4
granodiorite of Heinävesi	13.7	15.0—40.0	97.1
basement gneiss	2.9	30.0—60.0	<100

53. Paskosaari
x = 6916.40
y = 465.80
map = 4214 03, n = 174 Ref: Lavikainen 1985

rock type	f(%)	distance (km)	cumulative percentage
mica schist	70.6	0.0—15.0	70.6
skarn rock	0.6	6.0— 7.0	71.2
serpentinite & quartzite	1.2	9.0—10.0	72.4
mica gneiss	5.2	13.0—40.0	77.6
granodiorite of Heinävesi	21.3	20.0—50.0	98.9
basement gneiss	1.1	35.0—60.0	<100

54. Hietasaari
x = 6915.50
y = 465.90
map = 4214 03, n = 172 Ref: Lavikainen 1985

rock type	f(%)	distance (km)	cumulative percentage
percentage mica schist	63.5	0.0—16.0	63.5
serpentinite	0.4	9.0—10.0	63.9
mica gneiss	5.8	13.0—40.0	69.7
granodiorite of Heinävesi	28.5	20.0—50.0	98.2
basement gneiss	1.8	35.0—60.0	<100

55. Muljuniemi
x = 6915.30
y = 467.80
map = 4214 03, n = 213 Ref: Lavikainen 1985

rock type	f(%)	distance (km)	cumulative percentage
mica schist	83.5	0.0—18.0	83.5
serpentinite	1.0	11.0—12.0	84.5
mica gneiss	0.9	15.0—40.0	85.4
granodiorite of Heinävesi	13.6	22.0—50.0	99.0
basement gneiss	1.0	37.0—60.0	<100

56. Munasaari
x = 6919.80
y = 478.00
map = 4214 06, n = 158 Ref: Lavikainen 1985

rock type	f(%)	distance (km)	cumulative percentage
mica schist	93.7	0.0—30.0	93.7
granodiorite of Heinävesi	4.4	25.0—50.0	98.1
granite	0.6	30.0—55.0	98.7
basement gneiss	1.3	45.0—60.0	<100

57. Kivisalmi, basal till
x = 6912.10
y = 474.90
map = 4214 06, n = 264 Ref: Lavikainen 1985

rock type	f(%)	distance (km)	cumulative percentage
mica schist	85.6	0.0—50.0	85.6
garnet-mica gneiss	0.4	12.0—15.0	86.0
granodiorite of Heinävesi	9.1	30.0—60.0	95.1
basement gneiss	3.8	50.0—70.0	98.9
metadiabase	1.1	65.0—80.0	<100

58. Kivisalmi, ablation till
x = 6913.40
y = 474.40
map = 4214 06, n = 326 Ref: Lavikainen 1985

rock type	f(%)	distance (km)	cumulative percentage
mica schist	73.1	0.0—50.0	73.1
tremolite skarn	0.1	19.0—20.0	73.2
mica gneiss	7.4	25.0—70.0	80.6
granite	6.4	30.0—60.0	87.0
granodiorite	1.2	40.0—70.0	88.2
basement gneiss	9.7	50.0—95.0	97.9
metadiabase	0.9	65.0—80.0	98.8
amphibolites etc.	1.2	>90.0	<100

59. Kiihtelysvaara
x = 6925.60
y = 507.60
map = 4241 01, n = 100 Ref: Nykänen 1971, Lavikainen 1985

rock type	f(%)	distance (km)	cumulative percentage
mica schist	74.0	0.0— 60.0	74.0
basement gneiss	3.0	30.0— 40.0	77.0
mica gneiss	2.0	55.0—100	79.0
granodiorite	7.0	57.0— 90.0	86.0
granite	13.0	75.0—100	99.0
amphibolite	1.0	80.0—100	<100

60. Selkie
x = 6946.00
y = 504.50
map = 4241 03, n = 343 Ref: Nykänen 1971

rock type	f(%)	distance (km)	cumulative percentage
mica schist	44.9	0.0—60.0	44.9
basement gneiss	18.3	20.0—40.0, >60	63.2
metadiabase	5.8	25.0—35.0	69.0
sericite quartzite	7.0	25.0—40.0	76.0
conglomerate	0.9	35.0—40.0	76.9
fuchsite quartzite	0.6	40.0—45.0	77.5
granites	19.0	60.0—90.0	96.5
amphibolites etc.	3.5	70.0—85.0	<100

61. Outokumpu
x = 6957.90
y = 450.30
map = 4222 10, n = 195 Ref: Huhma 1971

rock type	f(%)	distance (km)	cumulative percentage
black schist	25.1	0.0— 2.0	25.1
serpentinite	4.1	0.4— 1.4	29.2
tremolite skarn	2.5	0.5— 1.6	31.7
fuchsite quartzite	4.1	0.6— 1.7	35.8
Cu-ore boulders	0.5	1.4— 1.5	36.3
mica schist	51.8	1.7— 8.5	88.1
pegmatite	3.2	2.5— 7.0	91.3
granite	4.6	8.0—12.0	95.9
veined gneiss	0.5	8.0—15.0	96.4
granodiorite gneiss	1.0	10.0—30.0	97.4
porphyritic granite	1.5	14.0—20.0	98.9
quartz diorite	1.1	>20.0	<100

62. Alavi
x = 6954.80
y = 448.70
map = 4222 07, n = 180 Ref: Huhma 1971

rock type	f(%)	distance (km)	cumulative percentage
mica schist	76.8	0.0— 2.0, 3.0—11.0	76.8
black schist	6.1	1.0— 3.0	82.9
Outokumpu assemblage	5.6	1.5— 3.0	88.5
pegmatite	2.8	3.5— 7.0	91.3
graphite schist	2.9	4.0—11.0	94.2
veined gneiss	2.3	9.0—23.0	96.5
gneissose granite	1.1	15.0—40.0	97.6
quartz diorite	1.1	23.0—35.0	98.7
porphyritic granite	0.7	>40.0	99.4
andalusite schist	0.6	>50.0	<100

63. Ahonkylä
x = 6951.40
y = 455.40
map = 4222 10, n = 250 Ref: Huhma 1971

rock type	f(%)	distance (km)	cumulative percentage
mica schist	79.2	0.0—17.0	79.2
black schist	6.4	5.0—10.0	85.6
Outokumpu assemblage	1.2	8.0—10.0	86.8
pegmatite	2.4	10.0—13.0	89.2
veined gneiss	0.8	16.0—30.0	90.0
granite	7.6	17.0—25.0	97.6
granodiorite gneiss	0.8	18.0—40.0	98.4
gneissose granite	0.8	25.0—40.0	99.2
gabbro	0.8	>40.0	<100

64. Horsmanaho
x = 6968.40
y = 462.20
map = 4224 02, n = 199 Ref: Huhma 1971

rock type	f(%)	distance (km)	cumulative percentage
serpentinite	0.5	0.0— 0.9	0.5
black schist	3.5	0.0— 2.5	4.0
fuchsite quartzite	1.0	0.4— 0.8	5.0
tremolite skarn	1.6	0.9— 1.2	6.6
graphite schist	4.0	1.0—10.0	10.6
mica schist	56.2	1.1—15.0	66.8
pegmatite	2.5	10.0—15.0	69.3
basement gneiss	14.1	12.0—40.0	83.4
hornblende gneiss	0.9	13.0—16.0	84.3
granite	11.0	20.0—50.0	95.3
porphyritic granite	4.0	>30.0	99.3
gabbro	0.7	>40.0	<100

65. Sotkuma
x = 6958.90
y = 470.60
map = 4224 04, n = 122 Ref: Huhma 1971

rock type	f(%)	distance (km)	cumulative percentage
pegmatite	5.8	0.0— 2.0	5.8
gneissose granite	39.2	0.0— 3.0	45.0
amphibolite	2.5	0.1— 0.8	47.5
orthoquartzite	0.8	0.5— 1.2	48.3
meta-arkose	4.1	1.0— 2.7	52.4
mica schist	23.7	1.7— 30.0	76.1
tremolite skarn	2.5	2.0— 3.0	78.6
black schist	2.5	3.0— 7.0	81.1
graphite schist	4.1	3.0— 15.0	85.2
serpentinite	3.3	6.0— 8.0	88.5
veined gneiss	2.5	24.0— 40.0	91.0
granodiorite gneiss	6.6	25.0— 35.0	97.6
porphyritic granite	2.4	30.0—100.0	<100

66. Kuopio
x = 6971.40
y = 533.60
map = 3242 12, n = 142 Ref: Aumo 1983

rock type	f(%)	distance (km)	cumulative percentage
quartzite	9.2	0.0— 0.1, 0.3— 0.5	9.2
hornblende gneiss	2.8	0.1— 0.3	12.0
pegmatites	9.9	0.2—10.0	21.9
mica schist /Petonen fm.	2.8	0.4— 0.7	24.7
antoph.schist	1.4	0.6— 0.7	26.1
amphibolite /Vaivanen fm.	4.2	0.7— 1.1	30.3
Mica schist /Rauhamäki fm.	40.7	0.9— 5.0	71.1
basement gneiss	27.9	3.6—10.0	99.0
granite	1.0	>10.0	<100

67. Kangasjärvi
x = 7031.80
y = 456.30
map = 3312 12, n = 141 Ref: Salli 1969

rock type	f(%)	distance (km)	cumulative percentage
diopside amphibolite	37.6	0.0— 4.5	37.6
acid volcanic rocks	15.6	0.4— 0.6	53.2
sericite schist	2.8	0.5— 4.0	56.0
graphite gneiss	0.7	1.0— 4.0	56.7
porphyritic granite	6.4	4.0— 5.0	63.1
granodiorite	12.8	4.5— 8.0	75.9
quartz porphyry	3.5	8.0—11.0	79.4
greywacke gneiss	6.4	12.0—14.0	85.8
granite	13.5	15.0—25.0	99.3
diorite	0.7	>30.0	<100

68. Kolujärvi
x = 7032.10
y = 466.90
map = 3314 03, n = 132 Ref: Salli 1977

rock type	f(%)	distance (km)	cumulative percentage
amphibolite	7.6	0.0— 2.5	7.6
granite	13.6	1.0—10.0	21.2
diorite, gabbro	1.5	1.5— 2.0	22.7
arkosite	3.8	2.5— 3.0	26.5
mica gneiss	15.9	2.9—10.0	42.4
porphyritic granite	37.9	4.0—20.0	80.3
granodiorite	19.7	14.0—50.0	<100

69. Sarvimäki
x = 7018.80
y = 491.00
map = 3314 10, n = 162 Ref: Salli 1977

rock type	f(%)	distance (km)	cumulative percentage
granite, coarse grained	20.4	0.6— 6.0	20.4
quartz-feldspar schist	3.1	1.5— 4.5	23.5
quartz diorite	17.9	2.5— 6.0, 7.0—15.0	41.4
gabbro	3.1	3.0— 5.0, 7.0— 8.5	44.5
greywacke schist	6.2	3.5— 8.5	50.7
porphyritic granite	9.3	5.0—11.0	60.0
mica schist	2.5	9.0—10.0	62.5
veined gneiss	23.4	10.0—20.0	85.9
pyrox. porph. granite	1.2	11.0—14.5	87.1

pyroxene granodiorite	2.0	12.0—18.0	89.1
amphibolite	1.9	15.0—17.0	91.0
pyroxene diorite	0.6	21.0—25.0	91.6
basic volcanics	1.2	20.0—25.0	92.8
gneissose granite	7.2	25.0—50.0	<100

70. Autio
x = 7055.30
y = 482.10
map = 3323 08, n = 204 Ref: Marttila 1977

rock type	f(%)	distance (km)	cumulative percentage
mica gneiss	49.0	0.0— 7.0	49.0
volcanics	1.0	1.0— 5.0	50.0
porphyritic granite	3.5	2.0— 4.0	53.5
hornblende gneiss	3.5	2.0— 6.0	57.0
diabase	1.0	4.0— 6.0	58.0
pegmatite	10.0	4.0— 7.0	68.0
pyroxene rocks	2.0	4.5—10.0	70.0
granites	25.0	5.0—20.0	95.0
quartz diorite	3.0	6.0— 7.0	98.0
granodiorite	2.0	6.0—25.0	<100

71. Juntti
x = 7055.60
y = 481.80
map = 3323 08, n = 241 Ref: Marttila 1977

rock type	f(%)	distance (km)	cumulative percentage
mica gneiss	37.0	0.0— 6.0	37.0
porphyritic granite	15.0	2.0— 3.0	52.0
hornblende gneiss	3.0	2.0— 5.0	55.0
pyroxene rocks	10.0	4.5—10.0	65.0
pegmatite	2.5	5.0— 6.0	67.5
granite	15.0	5.0—20.0	82.5
granodiorite gneiss	7.5	6.0— 7.0	90.0
granodiorite	6.5	6.0—25.0	96.5
acid volcanic rocks	0.5	10.0—11.0	97.0
arkosite	3.0	20.0—30.0	<100

72. Kotajoki, five samples
x = 7063.60
y = 485.50
map = 3323 09, n = 1028 Ref: Marttila 1977

rock type	f(%)	distance (km)	cumulative percentage
local granitoids	67—80	0.0— 9.0	67—80
mica gneiss	11—19	7.0—20.0	84—91
hornblende gneiss	3.5—7.5	13.0—17.0	90—96
pyroxene granite	0.4—2.0	20.0—22.0	91—97
skarn quartzite	1.0—2.0	20.0—25.0	92—99
volcanic rocks	1.0—8.0	25.0—30.0	<100

73. Reisjärvi, Kangaskylä 1
x = 7062.30
y = 539.90
map = 2341 12, n = 280 Ref: Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
quartz diorite	71.4	0.0— 2.0	71.4
quartz diorite, sheared	2.9	0.5— 1.0	74.3
feldspar porphyry	7.2	1.2— 3.0	81.5
feldspar porphyry, sheared	1.8	1.7— 3.0	83.3
quartz porphyry	1.2	1.7— 3.0	84.5
volcanic rocks	7.4	2.0— 7.0	91.9
monzonite	1.4	6.5—11.0	93.4
granitoids	6.0	12.0—30.0	99.3
mica gneiss	0.7	15.0—40.0	<100

74. Reisjärvi, Kangaskylä 2
x = 7062.70
y = 539.60
map = 2341 12, n = 260 Ref: Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
quartz diorite	80.8	0.0— 5.0	80.8
quartz diorite, sheared	2.7	0.2— 0.4	83.5
feldspar porphyry,sheared	0.8	0.4— 0.6	84.3
feldspar porphyry	3.5	0.6— 0.9	87.8
quartz porphyry	0.8	0.9— 1.5	88.6
volcanic rocks	6.7	1.0—15.0	95.3
granitoids	4.3	15.0—30.0	99.6
mica gneiss	0.4	>20.0	<100

75. Reisjärvi, Kangaskylä 3
x = 7062.80
y = 539.50
2341 12, n = 226 Ref: Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
quartz diorite	88.5	0.0 — 0.5	88.5
quartz diorite, sheared	1.3	0.25— 0.5	89.8
feldspar porphyry	1.3	0.5 — 0.8	91.1
feldspar porphyry,sheared	1.2	0.75— 1.2	92.3
quartz porphyry	0.4	1.0 — 1.2	92.7
volcanic rocks	2.6	1.75— 6.0	95.3
monzonite	0.9	7.0 —11.0	96.2
granitoids	3.5	10.0 —20.0	99.7
mica gneiss	0.3	>17.0	<100

76. Reisjärvi, Kangaskylä 4
x = 7062.60
y = 539.60
map = 2341 12, n = 137 Ref: Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
quartz diorite	75.9	0.0— 0.8	75.9
quartz diorite, sheared	4.4	0.4— 0.7	80.3
feldspar porphyry	4.4	0.4— 0.9	84.7
feldspar porphyry, sheared	4.4	0.6— 1.0	89.1
volcanic rocks	4.4	1.0— 6.0	93.5
monzonite	2.2	7.0—11.0	95.7
granitoids	4.3	10.0—20.0	<100

77. Eskola 1
x = 7088.60
y = 509.90
map = 2342 02, n = 222 Ref: Salli 1962, Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
plagioclase porphyry	38.3	0.2— 0.5	38.3
intermed. tuffite	4.5	0.5— 0.7	42.8
intermed. tuffite, contact	5.4	0.7— 0.8	48.2
granodiorite, contact	2.3	0.8— 0.9	50.5
quartz-monzodiorite	2.7	0.9— 1.2	53.2
granodiorite	36.0	1.2—13.0	89.2
porphyritic granodiorite	6.8	9.0—14.0	96.0
intermed. volcanic rocks	1.0	15.0—20.0	97.0
granite	3.0	>20.0	<100

78. Eskola 2
x = 7088.20
y = 511.40
map = 2342 02, n = 280 Ref: Salli 1962. Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
plagioclase porphyrite	18.2	0.0— 1.4	18.2
plagioclase porphyry	6.8	0.2— 0.6	25.0
intermediate tuffite	17.2	0.9— 1.2	42.2
intermed.tuffite, contact	1.8	1.4— 1.6	44.0
granodiorite, contact	0.4	1.6— 1.8	44.4
quartz-monzodiorite	22.1	1.8— 3.0	66.9
granodiorite	25.0	3.0—10.0	91.9
porphyritic granodiorite	4.6	10.0—16.0	96.5
granite	3.5	>20.0	<100

79. Eskola 3
x = 7088.60
y = 509.40
map = 2342 02, n = 249 Ref: Salli 1962, Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
plagioclase porphyry	1.6	0.0 — 0.1	1.6
intermediate tuffite	12.6	0.06— 0.3	14.2
intermed.tuffite, contact	4.8	0.36— 0.6	19.0
granodiorite, contact	0.8	0.6 — 0.7	19.8
quartz-monzodiorite	6.8	0.7 — 1.0	26.6
granodiorite	49.0	1.0 —13.0	75.6
porphyritic granodiorite	7.2	9.0 —14.0	82.8
intermed.volcanic rocks	3.6	15.0 —20.0	86.4
granite	13.6	>20.0	<100

80. Eskola 4
x = 7086.70
y = 512.10
map = 2342 05, n = 331 Ref: Salli 1962, Outokumpu Co, unpublished map

rock type	f(%)	distance (km)	cumulative percentage
intermediate tuffite	33.2	0.0— 2.4	33.2
plagioclase porphyry	42.0	1.0— 2.6	75.2
plagioclase porphyrite	9.7	1.6— 3.3	84.9
plag.-hornblende porphyrite	2.7	2.6— 3.0	87.6
quartz-monzodiorite	2.1	3.0— 4.0	89.7
granodiorite	6.9	3.5—14.0	96.6
porphyritic granodiorite	1.8	10.0—15.0	98.4
granite	1.6	>20.0	<100

81. Pyhäjoki 1
x = 7149.40
y = 531.10
map = 2432 11, n = 291 Ref: Salli 1957

rock type	f(%)	distance (km)	cumulative percentage
quartz-feldspar schist	0.3	0.0— 0.5	0.3
quartz diorite	19.2	0.5— 2.5	19.5
granite	27.1	2.4— 5.5, 11.0—16.0	46.6
gabbro	9.3	4.5— 6.0	55.9
plagioclase porphyrite	3.4	6.0— 7.0	59.3
mica gneiss	3.8	7.0—11.0	64.5
volcanic conglomerate	7.9	9.0—10.0	72.4
acid volcanic rock	4.0	10.0—11.0	76.4
basic volcanic rock	23.6	>20.0	<100

82. Pyhäjoki 2
x = 7155.10
y = 517.10
map = 2432 06, n = 243 Ref: Salli 1957

rock type	f(%)	distance (km)	cumulative percentage
granite	28.0	0.0— 1.0	28.0
diorite, gabbro	21.0	1.0— 2.5, >10.0	49.0
quartzite	0.4	2.0— 2.2	49.4
greywacke conglomerate	7.4	2.0— 7.0	56.8
volcanics etc.	41.4	>10.0	98.2
Jotnian sandstone	1.8	>30.0	<100

83. Pyhäjoki 3
x = 7152.70
y = 522.50
map = 2432 09, n = 189 Ref: Salli 1957

rock type	f(%)	distance (km)	cumulative percentage
volcanic conglomerate	4.2	0.0— 0.8	4.2
pegmatite	2.1	0.0— 1.5	6.3
mica gneiss	4.2	0.8— 1.4	10.5
granite	43.4	1.4— 7.0	53.9
diorite, gabbro	8.4	7.0— 8.0	62.3
greywacke conglomerate	1.0	8.0—13.0	63.3
volcanics etc.	36.7	>15.0	<100

84. Sotkamo, Kivijoki x=7103.10
y = 556.20
map = 3433 07, n = 138 Ref: Havola 1981

rock type	f(%)	distance (km)	cumulative percentage
pegmatite	19.6	0.0— 4.0	19.6
basement gneiss	13.0	0.0— 6.0	32.6
metadiabase	2.9	4.0— 6.0	35.5
arkosite	5.7	5.5— 7.2	41.2
orthoquartzite	14.4	6.5— 8.5	55.6
black schist	8.7	7.5—10.0	64.3
diopside skarn	0.7	8.0— 9.0	65.0
mica schist	18.8	8.0—18.0	83.8
quartzite, dark	8.0	18.5—22.0	91.8
greywacke schist	5.1	20.0—25.0	96.9
amygdaloidal rock	0.7	27.0—30.0	97.6
granite	2.4	30.0—60.0	<100

85. Sotkamo, Vaarakylä
x = 7109.20
y = 559.50
map = 3433 04, n = 147 Ref: Havola 1981

rock type	f(%)	distance (km)	cumulative percentage
black schist	4.1	0.2— 1.0	4.1
garnet-mica schist	1.4	0.8— 1.3	5.5
mica schist	40.7	1.0— 9.0	46.2
serpentinite	0.7	8.6— 9.0	46.9
greywacke schist	4.1	9.5—14.0	51.0
arkosite	17.7	10.0—15.5	68.7

metadiabase	2.0	13.0—14.0, 16.5—19.0	70.7
basement gneiss	21.2	20.0—32.0	91.9
orthoquartzite	2.7	26.0—30.0	94.6
granite	5.4	30.0—60.0	<100

86. Kuhmo, Ontojärvi
x = 7116.00
y = 467.30
map = 4413 02, n = 153 Ref: Hyppönen 1973, 1976

rock type	f(%)	distance (km)	cumulative percentage
greenstone	16.2	0.0—11.0	16.2
soapstone	2.7	2.0— 6.0	18.9
mica schist	4.6	2.5— 8.0	23.5
diabase	5.9	7.0— 9.0	29.4
acid volcanic rock	8.5	8.5—11.0	37.9
quartzite	7.2	9.0—12.0	45.1
basement rocks	54.9	11.0—50.0	<100

87. Kuhmo, Järvenpää
x = 7126.90
y = 458.10
map = 411 12, n = 103 Ref: Hyppönen 1973

rock type	f(%)	distance (km)	cumulative percentage
basic volcanic rock	52.3	0.0— 6.0	52.3
ultramafic rocks	15.6	2.5— 5.5	67.9
mica schist	7.8	5.0— 6.0	75.7
basement rocks	21.4	5.0—37.0	97.1
orthoquartzite	2.9	35.0—80.0	<100

88. Kuhmo, Havula
x = 7139.40
y = 459.10
map = 4412 10, n = 160 Ref: Hyppönen 1973

rock type	f(%)	distance (km)	cumulative percentage
mica schist	0.6	0.0— 0.5	0.6
basic volcanic rocks	6.9	0.0— 1.5, 4.0—5.0	7.5
serpentinite	1.9	0.8— 1.1	9.4
basement rocks	10.0	1.5— 2.5	19.4
diabase	5.6	2.5— 4.0	25.0
quartz rock	9.7	3.0— 4.0	34.7
acid volcanic rock	12.5	3.5— 4.5	47.2
basement rocks	52.8	5.0—50.0	<100

89. Puolanka, Paljakkavaara
x = 7176 20
y = 536.90
map = 3441 11, n = 152 Ref: Laajoki 1973

rock type	f(%)	distance (km)	cumulative percentage
sericite quartzite/arkosite	6.0	0.0— 0.7	6.0
gneissose granodiorite	13.7	0.6— 1.7	19.7
basic volcanics	13.2	1.6— 2.8	32.9
mica schist	11.2	2.4— 5.5	44.1
quartzite, conglomerate	4.6	5.2— 5.7	48.7
greywacke schists	7.2	5.5— 9.5	55.9
serpentinite etc.	2.7	8.5—11.0	58.5
pegmatite/even grained granite	32.7	10.5—24.0	91.3
gneissose granite	8.6	23.0—50.0	<100

90. Puolanka, Nalkki
x = 7175.10
y = 536.80
map = 3441 11, n = 156 Ref: Laajoki 1973

rock type	f(%)	distance (km)	cumulative percentage
arkosite	3.8	0.0— 0.7	3.8
mica, black schist	4.4	0.7— 2.4	8.2
basic metalava	13.5	0.7—10.0	21.7
basic tuffite	1.3	2.0— 2.4	23.0
quartzite, conglomerate	8.2	2.3— 4.3	31.2
mica gneiss	2.6	4.0—10.0	33.8
serpentinite etc.	3.2	6.7— 8.5	37.0
pegmatite/even grained granite	19.2	9.5—23.0	56.2
basement rocks	43.8	22.0—49.0	<100

91. Sompujärvi
x = 7313.70
y = 554.70
map = 2544 04, n = 115 Ref: V. Perttunen 1971, 1972, 1975

rock type	f(%)	distance (km)	cumulative percentage
granite	54.8	0.0— 3.2	54.8
basement gneiss	6.1	2.0— 3.5	60.9
peridotite	1.7	3.2— 4.0	62.6
gabbro	4.3	3.5— 5.0	66.9
anorthosite	8.7	4.0— 5.2	75.6
greenstone	0.8	5.0— 6.0	76.4
quartzite	13.9	5.5— 8.2	90.3
amygdaloidal rock	3.5	8.0—11.0	93.8
dolomite	0.9	10.0—13.0	94.7
phyllite	1.7	13.0—21.0	96.4
quartz diorite etc	3.4	>25.0	<100

92. Leilisuo
x = 7296.30
y = 552.70
map = 2543 05, n = 131 Ref: V. Perttunen 1971, 1972, 1975

rock type	f(%)	distance (km)	cumulative percentage
basement rocks	55.6	0.0— 13.0	55.6
pyroxenite	3.1	12.5— 14.0	58.7
gabbro, peridotite	9.2	13.0— 15.5	67.9
greenstone	4.6	15.0—16.0, 19.0—25.0	72.5
quartzite	16.8	16.0— 20.0	89.3
phyllite	6.1	25.0— 37.0	95.4
conglomerate/Taivalkoski	0.8	>30.0	96.2
quartz diorite	1.5	40.0— 50.0	97.7
amphibolite, mica gneiss	2.3	50.0—100	<100

93. Länsimaa
x = 7297.00
y = 551.40
map = 2543 05, n = 142 Ref: V. Perttunen 1971, 1972, 1975

rock type	f(%)	distance (km)	cumulative percentage
granite	31.7	0.0—11.0	31.7
pyroxenite etc	12.8	10.8—14.0	44.5
greenstone	12.7	14.0—15.0, 18.0—24.0	57.2
quartzite	32.2	14.5—18.5	89.4
mica schist	6.3	21.0—40.0	95.7
gabbro of Ruottala	0.8	32.0—35.0	96.5
quartz diorite	2.1	35.0—45.0	98.6
granites/Haaparanta suite	1.4	>50.0	<100

94. Jokikylä
x = 7294.30
y = 553.80
map = 2543 05, n = 100 Ref: V. Perttunen 1971, 1972, 1975

rock type	f(%)	distance (km)	cumulative percentage
basement gneiss	9.0	0.0— 7.0	9.0
basement granite	37.0	2.0—15.0	46.0
gabbro	3.0	14.5—17.0	49.0
anorthosite	16.0	15.0—18.0	65.0
greenstone	4.0	17.5—28.0	69.0
quartzite	18.0	19.0—22.5	87.0
dolomite	2.0	26.0—30.0	89.0
phyllite	7.0	28.0—40.0	96.0
quartz diorite	3.0	>50.0	<100

95. Torosuo
x = 7294.70
y = 550.80
map = 2543 05, n= 163 Ref: V. Perttunen 1971, 1972, 1975

rock type	f(%)	distance (km)	cumulative percentage
basement rocks	46.0	0.0—10.0	46.0
layered intrusion	32.5	8.0—15.0	78.5
greenstone	7.4	14.0—16.0, 19.0—25.0	85.9
quartzite	9.2	15.0—20.0	95.1
dolomite	1.2	20.0—23.0	96.3
mica schist	2.4	22.0—40.0	98.7
quartz diorite	1.3	37.0—43.0	<100

96. Louhola
x = 7294.60
y = 545.90
map = 2543 02, n = 154 Ref: V. Perttunen 1971, 1972, 1975

rock type	f(%)	distance (km)	cumulative percentage
basement rocks	50.8	0.0— 8.0	50.8
gabbro	4.5	7.5— 9.0	55.3
greenstone	11.6	8.7— 9.5, 12.0—16.0	66.9
quartzite	20.1	9.3—13.5	87.0
mica schist	6.8	15.0—40.0	93.8
quartz diorite	6.2	37.0—45.0	< 100

97. Varvikko
x = 7292.70
y = 542.10
map = 2543 02, n = 137 Ref: V. Perttunen 1971, 1972, 1975

rock type	f(%)	distance (km)	cumulative percentage
basement rocks	58.4	0.0—11.0	58.4
anorthosite	1.5	9.5—10.5	59.9
basic tuffite	1.5	10.0—11.0	61.4
quartzite	5.8	10.0—12.0	67.2
greenstone	10.2	11.5—14.0	77.4
dolomite	1.5	12.0—13.0	78.9
phyllite	18.2	12.5—40.0	97.1
quartz diorite	2.9	36.0—50.0	< 100

98. Musta-aapa
x = 7292.90
y = 538.60
map = 2541 11, n = 114 Ref: V. Perttunen 1971, 1972, 1975

rock type	f(%)	distance (km)	cumulative percentage
basement rocks	62.9	0.0— 8.7	62.9
gabbro	9.7	8.5— 9.5	72.6
greenstone	5.3	9.0—10.0, 11.0—14.0	77.9
quartzite	9.6	9.2—11.5	87.5
phyllite	12.5	12.0—60.0	< 100

99. Maksniemi
x = 7289.80
y = 536.20
map = 2541 10, n = 166 Ref: V. Perttunen 1971, 1972, 1975

rock type	f(%)	distance (km)	cumulative percentage
basement rocks	62.8	0.0— 9.5	62.8
gabbro	10.8	9.4—11.2	73.6
peridotite	3.6	9.5—10.0	77.2
greenstone	5.4	11.0—11.5, 14.0—15.0	82.6
quartzite	6.6	11.3—14.0	89.2
phyllite	6.0	14.5—30.0	95.2
Haaparanta granite	0.6	20.0—40.0	95.8
dolomite	0.6	22.0—26.0	96.4
quartz diorite	3.6	30.0—36.0	< 100

100. Keminmaa, Ruottala 1
x = 7306.70
y = 524.80
map = 2541 09, n = 167 Ref: V. Perttunen 1971, 1972, 1975

rock type	f(%)	distance (km)	cumulative percentage
basic volcanic rock	20.4	0.0— 4.0	20.4
basic tuffite	4.8	4.0— 5.0, 13.0—17.0	25.2
dolomite	6.6	4.5— 9.0	31.8
phyllite	1.8	5.0—24.0	33.6
diorite	7.2	12.0—18.0	40.8
quartzite	17.4	14.0—16.0, 30.0—50.0	58.2
gabbro	3.0	19.0—21.0	61.2
Haaparanta granite	34.0	50.0—60.0, > 70	95.2
basement gneiss	4.8	50.0—80.0	< 100

101. Keminmaa, Ruottala 2
x = 7306.20
y = 524.30
map = 2541 09, n = 210 Ref: V. Perttunen 1971, 1972, 1975

rock type	f(%)	distance (km)	cumulative percentage
basic volcanic rock	5.7	0.0— 5.5	5.7
basic tuffite	3.8	5.0— 9.0	9.5
dolomite	6.7	5.5—10.0	16.2
phyllite	8.2	6.0—25.0	24.4
acid porphyry	0.5	13.0—14.0	24.9
diorite	2.4	14.0—20.0	27.3
jaspilite	2.9	15.0—17.0	30.2
quartzite	12.4	15.0—17.0, 30.0—50.0	42.6
gabbro	2.9	20.0—22.0	45.5
Haaparanta granite	45.1	50.0—60.0, >70.0	90.6
basement gneiss	9.4	50.0—80.0	<100

102. Sodankylä, Juontomaa
x = 7485.00
y = 484.70
map = 3713 09, n = 212 Ref: Tyrväinen 1979, Lehtonen *et al.* 1984

rock type	f(%)	distance (km)	cumulative percentage
gabbro	50.2	0.0— 1.0	50.2
sericite quartzite	18.3	0.6— 2.0	68.5
arkositic quartzite	7.6	1.6— 3.0	76.1
quartz vein	2.2	3.0— 4.0	78.3
basic/ultrabasic volcanics	12.3	4.0—20.0	90.6
adinole association	1.7	5.0— 5.5	92.3
hematite quartzite	1.3	6.0—15.0	93.6
granite	4.7	16.0—50.0	98.3
diabase	0.4	>20.0	98.7
hornblendite	0.4	>30.0	99.1
Kumpu conglomerate	0.9	60.0—70.0	<100

103. Sodankylä, Pitkäjänkä
x = 7485.40
y = 482.50
map = 3713 09, n = 139 Ref: Tyrväinen 1979, Lehtonen *et al.* 1984

rock type	f(%)	distance (km)	cumulative percentage
arkositic quartzite	20.9	0.0— 0.6	20.9
mica schist	12.1	0.6— 1.7	33.0
volcanic rocks	14.5	1.4—15.0	47.5
adenoli association	2.1	4.5— 5.0	49.6
sericite quartzite	19.4	4.5—20.0	69.0
black schist	0.7	7.0—10.0	69.7
gabbro, diorite	7.1	17.0—30.0	76.8
granite	21.6	20.0—30.0	98.4
gneissose granite	0.7	>27.0	99.1
Kumpu conglomerate	0.9	60.0—70.0	<100

104. Petkula, Posto
x = 7509.70
y = 489.60
map = 3714 08, n = 117 Ref: Tyrväinen 1980, Lehtonen *et al.* 1984

rock type	f(%)	distance (km)	cumulative percentage
albite diabase	0.8	0.0— 0.2	0.8
quartz vein	0.8	0.0— 0.5	1.6
arkositic quartzite	42.4	0.4— 5.5, 9.0— 17.0	44.0
gabbro	3.0	2.0— 3.0	47.0
sericite quartzite	10.6	4.0— 5.5, 9.0— 15.0	57.6
volcanic rocks	18.1	5.0— 8.0	75.7
chlorite schist	0.8	7.0— 8.0	76.5
basement rocks	3.1	22.0— 40.0	79.6
granite of Pomovaara	2.3	25.0— 30.0	81.9
jasperoid	0.8	40.0— 50.0	82.7
Kumpu conglomerate	1.5	50.0— 60.0	84.2
acid volcanic rock	0.7	70.0— 80.0	84.9
granite of Tepasto	15.1	90.0—100.0	<100

105. Petkula, Laakso
x = 7510.30
y = 489.70
map = 3714 09, n = 160 Ref: Tyrväinen 1980, Lehtonen *et al.* 1984

rock type	f(%)	distance (km)	cumulative percentage
mica schist	3.1	0.0— 0.5	3.1
quartzite	31.3	0.4— 5.5	34.4
gabbro	2.5	2.0— 3.0	36.9
sericite quartzite	30.6	4.0— 5.0, 9.0— 15.0	67.5
basic/ultrabasic volcanics	23.8	5.0— 8.0	91.3
hornblende granite	1.2	22.0— 40.0	92.5
porphyritic granite	0.6	25.0— 30.0	93.1
granite of Tepasto	6.9	90.0—100.0	<100

106. Kittilä, Alalaki
x = 7543.00
y = 551.90
map = 2743 06, n = 194 Ref: Lehtonen *et al.* 1984

rock type	f(%)	distance (km)	cumulative percentage
acid volcanic rock	7.5	0.0— 0.6	7.5
basic volcanic rock	27.4	0.2— 3.0, > 30	34.9
intermed. volcanic rock	3.2	3.0— 10.0	38.1
chert	0.5	9.0— 20.0	38.6
mica gneiss	3.2	13.0— 20.0	41.8
Hetta granite	46.4	13.0— 44.0	88.2
Tepasto granite	10.5	20.0— 30.0	98.7
gabbro	0.5	22.0— 25.0	99.2
monzonite	0.8	50.0—100.0	<100

107. Kittilä, Nilipirtti
x = 7557.20
y = 560.80
map = 2744 07, n = 197 Ref: Lehtonen *et al.* 1984

rock type	f(%)	distance (km)	cumulative percentage
Hetta granite	52.7	0.0— 1.5, 23.0—50.0	52.7
basic volcanic rocks	21.8	0.6— 6.0	74.5
chert	3.0	1.2— 6.0	77.5
quartz-feldspar schist	4.5	12.0—16.0	82.0
mica schist	2.0	13.0—14.0	84.0
intermed. volcanic rocks	1.5	12.0—22.0	85.5
diabase	0.5	20.0—21.0	86.0
Tepasto granite	12.2	30.0—50.0	98.2
Kumpu quartzite	1.8	38.0—52.0	<100

108. Kittilä, Hanhilaki 1
x = 7524.80
y = 557.50
map = 2743 04, n = 202 Ref: Lehtonen *et al.* 1984

rock type	f(%)	distance (km)	cumulative percentage
Kumpu conglomerate	1.9	0.0— 0.9	1.9
basic volcanic rock	81.9	1.0—26.0	83.8
jaspilite	0.5	22.0—24.0	84.3
arkosite	1.5	24.0—26.0	85.8
Tepasto granite	4.4	30.0—40.0	90.2
Hetta granite	6.8	26.0—90.0	97.0
quartz diorite	2.5	>100	99.5
Caledonian rocks	0.5	>200	<100

109. Kittilä, Hanhilaki 2
x = 7525.50
y = 555.30
map = 2743 04, n = 218 Ref: Lehtonen *et al.* 1984

rock type	f(%)	distance (km)	cumulative percentage
basic volcanic rocks	86.0	0.0—22.0	86.0
chert	0.9	19.0—22.0	86.9
Hetta granite	11.1	25.0—60.0	98.0
Tepasto granite	0.9	28.0—35.0	98.9
gabbro	1.1	35.0—40.0	<100

110. Tapojärvi, Muonio
x = 7495.20
y = 484.00
map = 2714 07, n = 175 Ref: Lehtonen 1981

rock type	f(%)	distance (km)	cumulative percentage
andalusite-mica schist	37.3	0.0— 1.0	37.3
greywacke schist	15.3	1.0— 1.3	53.0
orthoquartzite	3.2	1.3— 1.5	56.2
arkositic quartzite	6.3	1.4— 2.5	62.5
sericite quartzite	11.3	1.5— 2.0	73.8
monzonite	5.7	2.5— 6.0	79.5
granites	17.0	> 5.0	96.5
quartz diorite	1.9	7.0—12.0	98.4
basement gneiss	1.6	>22.0	<100

111. Kolari, Hannukainen
x = 7495.90
y = 496.30
map = 2714 10, n = 177 Lehtonen 1981

rock type	f(%)	distance (km)	cumulative percentage
monzonite	58.6	0.0— 2.0, 14.0—20.0	58.6
granite vein	1.1	1.0— 2.0	59.7
arkositic quartzite	1.1	1.2— 3.0	60.8
granite	35.5	2.0—30.0	96.3
quartzite	1.6	5.0— 6.0	97.9
basic volcanic	2.1	12.0—20.0	<100

Geological Survey of Finland, Bulletin 338 — *SALONEN, VELI-PEKKA*

Tätä julkaisua myy

VALTION PAINATUSKESKUS

POSTIMYYNTI
PL 516
00101 Helsinki
Puh. (90) 566 0266
Vaihde (90) 56601
Teleksi 123458 vapk sf

KIRJAKAUPAT HELSINGISSÄ

Annankatu 44
(Et. Rautatiekadun kulma)
Vaihde (90) 173 4396

Eteläesplanadi 4
Puh. (90) 662 801

Denna publikation säljs av

STATENS TRYCKERICENTRAL

POSTFÖRSÄLJNINGEN
PB 516
00101 Helsingfors
Tel. (90) 566 0266
Växel (90) 56601
Telex 123458 vapk sf

BOKHANDLARNA I HELSINGFORS

Annegatan 44
(I hörnet av S. Järnv.g.)
Växel (90) 173 4396

Södra esplanaden 4
Tel. (90) 662 801

This publication is available from

GOVERNMENT PRINTING CENTRE

MAIL ORDERS
P.O.B. 516
SF-00101 Helsinki Finland
Phone internat.
+358 0 56601
Telex 123458 vapk sf

BOOKSHOPS IN HELSINKI

Annankatu 44
Phone (90) 173 4396

Eteläesplanadi 4
Phone (90) 662 801

ISBN 951-690-237-5
ISSN 0367-522X