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On the geology of the South Puolanka area, Finland

by Kauko Laajoki

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ON THE GEOLOGY OF THE SOUTH PUOLANKA AREA, FINLAND

BY

KAUKO LAAJOKI

WITH 26 FIGURES AND TWO TABLES IN TEXT AND ONE APPENDIX AND 8 APPENDED MAPS

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The Karelidic metasediments of the South Puolanka area, which folded during the Svecokarelidic orogeny (about 1 800—1 950 m.y. ago), form two lithosomes: the psammite lithosome (Jatulian) in the east and the pelite lithosome (Kalevian) in the west. The former is composed of close-cratonic sediments, of which the Arkosite Formation and Quartzite I were deposited during the initial, unstable stage of sedimentation characterized by early Karelidic volcanism. Quartzite II and Quartzite III represent sediments of a more stable, transgressive stage of sedimentation.

The change from psammite lithosome to pelite lithosome is indicated by the Mäntykangas Quartzite and the Dolomite-Phyllite Formation (Marine Jatulian) in the lateral and vertical directions, respectively.

The western pelite lithosome is composed of four formations. Phyllite I represents the earliest flysch and Phyllite II the latest flysch in the area. The stratigraphic position of the Garnet-Mica Schist seems to be between Phyllites I and II. The Staurolite-Mica Schist Formation is allocthonous.

The early Karelidic metavolcanics—metadiabase association is typical of the psammite lithosome. The metagabbros and ultrabasic rocks of the pelite lithosome are the most typical representatives of the initial magmatism in the area.

The tectonic history of the area is divided into two main stages. The first stage is characterized by concentric folding and overthrusting and the second, by shear folding and relative low-angle thrusts.

The classification of the Karelides in eastern Finland into the Jatulian, Marine Jatulian and Kalevian is recommended. The terms Kainuan and Jaurakka facies are abandoned.

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CONTENTS

INTRODUCTION

Location and physiography of the area

The South Puolanka area is situated in the Kainuu region, north-eastern Finland, about 50 km north of the town of Kajaani (Fig. 1). The area investigated comprises 390 km^2.

The western and southwestern parts of the area are gently sloping and characterized by swamps, moors and eskers. The eastern and southeastern parts are more hilly. The highest hills (Pihlajavaara, Kurikkavaara, Latolanvaara, Hietavaara and Kaitavaara) rise up to about 300 m above sea level. The trend of the range of hills is about N20—30°E.

In the western lowlands, vast tracts are lacking in outcrops. In the eastern parts, the western flanks of the hills are moderately exposed. The outcrops are mostly flat and small in size. The contact zones of the rock units are as a rule covered by Quaternary deposits.

Previous investigations

General geological mapping was started in the rural commune of Puolanka in 1905. The main part of the present area is included in the geological map sheet of Kajaani, which was published in 1929 (Wilkman 1929 and 1931). The completion of the map sheet of Oulu—Tornio took much more time, and the sheet was not published until 1952 (Enkovaara et al. 1952 and 1953).

The kaolin occurrence of Pihlajavaara was investigated by the Geological Commission of Finland in 1921. In this connection, a great part of the South Puolanka area was mapped in detail (Väyrynen 1928, Map 2). The results of this exploratory work were described by Väyrynen (1924, 1928, 1929, 1933 and 1954).

During the years 1949—1951 the Exploration Department of the Geological Survey of Finland engaged in prospecting in the vicinity of the village of Törmänmäki. Then the southern part of the present area was briefly mapped by V. Yletyinen and one drill hole was made in the Tulijoki valley.

The small soapstone occurrence of Leskisensuo, about 2 km northeast of the hill of Hulmivaara, was studied by Vesasalo (1965, p. 53).

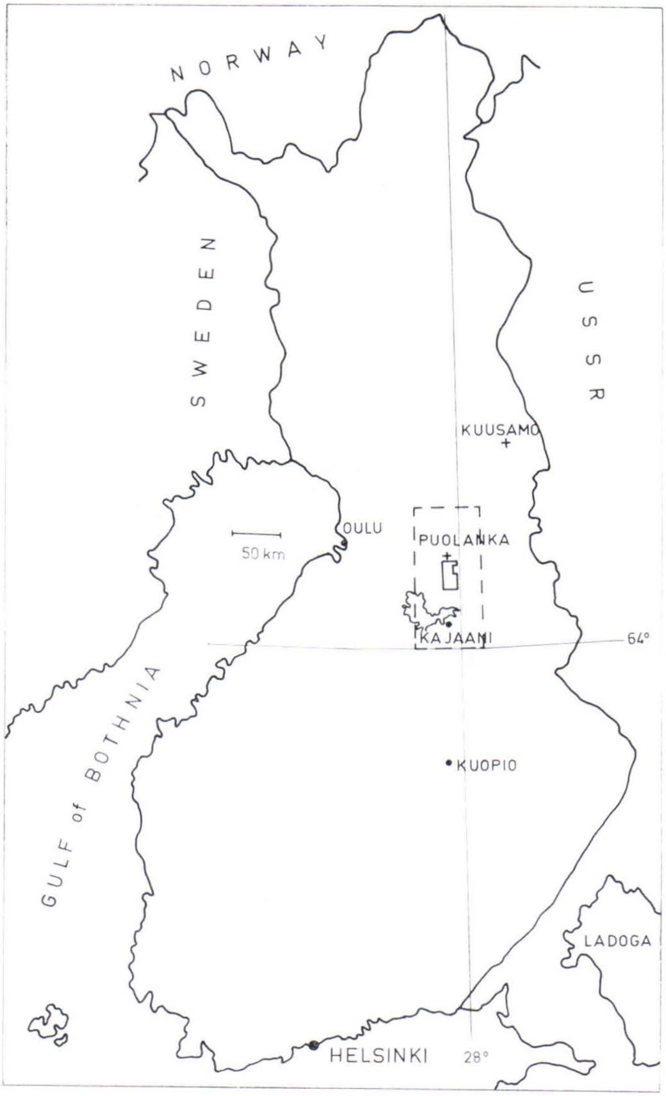

FIG. 1. Index map. The situation of the South Puolanka area is shown by heavy contours and the area of Fig. 2 and Appendix I by broken lines.

Recent investigations

In the summer of 1965, in response to the discovery of a zinc ore erratic on the summit of Pahkavaara, geological, geophysical and geochemical investigations were started by the Exploration Department of the Geological Survey of Finland in the South Puolanka area. The prospecting has continued more or less intensively up to the present and is still partly unfinished. The field prospecting work has been directed by Dr. Pentti Ervamaa.

The geological mapping of the surroundings of Pahkavaara and Salmijärvi was carried out in the summer of 1965 by Pentti Ervamaa, Erkki Ristimaa and the author. During the following summer, the author extended the geological mapping operations to the valley of Liejeenjoki in the north. The vicinities of Kotila and Törmänmäki were mapped by the author in the summer of 1969 and the northernmost parts of the area in the summers of 1969 and 1971. The base maps used were aerial photographic maps on a scale of 1 : 20 000. At the revision stage, in the summer of 1971, unfinished topographic maps on a scale of 1 : 10 000 were used, too.

In the years 1966—1969, 23 drill holes, totalling 3 953 m in length, were drilled in the vicinity of the lakes of Salmijärvi.

The areas measured magnetically, electromagnetically and gravimetrically on the ground during the years 1965, 1966 and 1970 appear on Maps 6, 7 and 8, respectively.

Aerogeophysical data are available from the greatest part of the area investigated (Maps 4 and 5). When Maps 4 and 5 are used upon the other maps included in this study, the corresponding lakes must be superimposed.

The present study is based on the author's unpublished licenciate's thesis (Laajoki 1971).

GENERAL GEOLOGICAL SETTING

The Precambrian metamorphic rocks of Finland are divided into three main units (Simonen 1960 and 1971). The oldest is the Presvecokarelidic basement (about 2800 million years) in eastern Finland. It is mainly composed of granitoidic orthogneisses. On its western margin, the basement is bounded on the Finnish side of the border by the Karelidic belt, which trends from the southeast towards northern Finland. The Karelidic belt is characterized by a succession of basal conglomerate, quartzite, dolomite, phyllite and mica schists. Southern and western Finland is occupied by the pelitic and psammitic schists of the so-called Svecofennidic belt. The supracrustal rocks of the Karelidic belt and the Svecofennidic belt are considered to represent the sediments of the evolutionary and geosynclinary stages of the Svecokarelidic orogeny.

The South Puolanka area belongs to the part of the Karelidic belt called the Kainuan schist belt (Fig. 2). The Kainuan schists have been preserved in the axial depression of Oulunjärvi (Wegmann 1928).

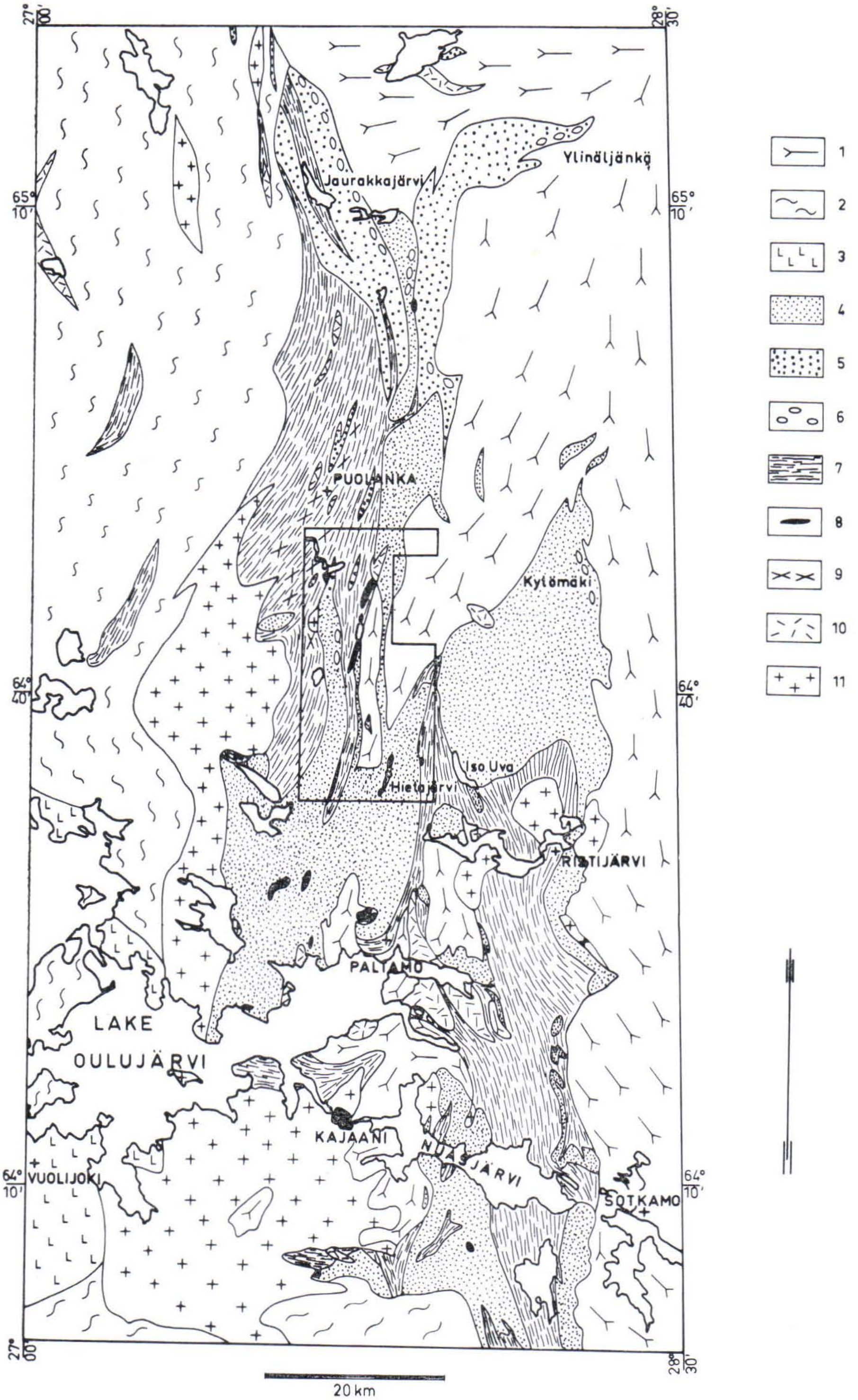

FIG. 2. Geology of the Kainuan schist belt. Simplified from the general geological maps of Finland on a scale of 1 : 400 000 (Wilkmann 1924 and 1929, Enkovaara et al. 1952 and Matisto 1954). The location of the South Puolanka area is marked by heavy contours.

1) Eastern granite gneiss. 2) Western granite gneiss. 3) Otanmäki granite. 4) Quartzite. 5) Jaurakka quartzite (separated only in the northern parts of the belt). 6) Conglomerate. 7) Phyllite, mica schist and mica gneiss. 8) Dolomite. 9) Staurolite. 10) Metadiabase, metagabbro and ultrabasic rocks. 11) Karelidic granite.

Largely on the basis of his detailed studies (Väyrynen 1924 and 1928) in the northern parts of the Kainuan schist belt, Väyrynen (1933, 1954) presents the following standard section of the Karelidic formations in eastern Finland:

Kalevian Group	Kalevian phyllite and mica schist, Jaurakka Formation: quartzite and conglomerate
	.... Erosion, Karelidic metadiabases ....
	Postjatulian folding
Jatulian Group	Marine Jatulian phyllite and dolomite
	Kainuan Quartzite
	Sariolan arkosite and conglomerate
	——— GREAT DISCORDANCE ———
	Granite Gneiss Basement

In Kainuu, Sariolan rocks are lacking and thus the Kainuan Quartzite was deposited directly on a stable, deeply eroded platform. The formation begins with a quartz pebble conglomerate, containing a sericite matrix, associated with sericite schists, sericite quartzite and kaolin deposits. With a decrease in the sericite content, the schists grade into pure Kainuan quartzite.

The Marine Jatulian sediments were deposited during the transgression stage of the Jatulian Sea, which spread from the west over the Jatulian continent in the east.

The Kalevian phyllites and mica schists represent the flysch sediments deposited in the geosyncline that developed farther in the west.

The occurrence of the Jaurakka conglomerates and Jaurakka quartzites is restricted to the northern parts of the Kainuan schist belt. They are considered to be molasse sediments accumulated in front of an overthrust plate (Väyrynen 1954, p. 171).

In the South Puolanka area, the quartzites east of Salmijärvi were classified by Väyrynen (1954) as Jatulian. The dolomites and black schists in the vicinities of Salmijärvi and Poikkijärvi belong to the allochtonous Marine Jatulian formations and the phyllites west of Salmijärvi preferably to the Jatulian group. The quartzites and conglomerates of Somervaara, Mäntykangas and Akanvaara were correlated with the Jaurakka Formation.

Matisto (1958) has described the lowermost horizons of the Karelidic succession from Kytömäki and Yli-Näljänkä, in the northeastern margin of the Kainuan schist belt. Here the Karelidic succession begins with basal conglomerates and impure quartzites. He also states that the sericite-rich schists seem to be connected with tectonized zones (op. cit., p. 48).

The southern end of the Kainuan schist belt is composed of the so-called Nuasjärvi—Ristijärvi basin, where the Jatulian quartzites occupy the marginal areas and the Kalevian phyllites the middle part (Väyrynen 1954).

One of the Karelidic basic complexes typical of the Paltamo area has recently been studied by Rastas (1969).

The orogeny of the Karelidic belt was described by Wegmann (1928 and 1929) as being of an alpine type. The folding of the Karelidic sediments took place against the resistant basement complex in the east. Especially the surroundings of Oulunjärvi had been a scene of intensive overthrusting. The studies made by Väyrynen (1939) and Gaál (1964), Gaál and Rauhamäki (1971) have cast more light on the tectonics of the Karelidic belt.

The Prekarelidic basement orthogneisses and the Karelidic granite in Kainuu date back, according to Asa (1971), about 2700—2800 million years and 1900 million years, respectively.

OUTLINE OF THE STUDY

The South Puolanka area contains almost the entire region covered by Väyrynen (1928) in his classical study of the Karelidic stratigraphy. The stratigraphic schemes of Väyrynen (1933, 1954) have later been revised by several authors (Härme 1949, Mikkola 1949, Piirainen 1968, Nykänen 1968, 1971 a and b). During the prospecting carried out by the Exploration Department of the Geological Survey of Finland, the author was obliged to go into the geology of the South Puolanka area. Because it appeared that we were after an ore type controlled by sedimentary rocks, a great deal of attention has to be paid to the stratigraphy of the area. Thus the stratigraphy of the Karelidic schists became a conspicuous part of this study. Especially the Kainuan and Jaurakka facies were critically restudied.

In the course of the research, it became evident, however, that the stratigraphy cannot be worked out without examining the structure and the tectonics of the area. In the poorly exposed areas, the structure cannot be determined without geophysical data. That is why so many geophysical maps (Maps 4—8) are included in the present study. In order to give the reader a better view of the alpine tectonics of the Kainuan schist belt, an aerogeophysical map (Appendix I) comprising the area of Fig. 2 is also appended.

In the first section, a lithologic and stratigraphic description of the rocks is given. In the following sections, the main structural features of the area are set forth, the main orogenic history of the Karelidic schists is discussed, and finally correlations with other Karelidic areas are made.

STRATIGRAPHY

Introductory statements

Geologically, the present area can be divided into four oblong subareas trending roughly N 20°E. The middle part is called the Hietajärvi district. Here the psammites of the hills of Pihlajavaara, Kurikkavaara, Latolanvaara, Pahkavaara, Kaitavaara, Hietavaara, Hulmivaara and the psammites north and south of Tulijärvi fringe the basement gneisses. The parts west and southeast of the Hietajärvi district, named the Salmijärvi and the Poikkijärvi districts, are characterized by the association of psammites, pelites, tuffites and dolomites (main colour combination of green and blue on Map 1). The remaining part in the west, occupied by psammites and pelites, is called the Vihajärvi district. The borderline between the latter and the Salmijärvi district is marked by the psammites and psephites of Jalka-Aho, Mäntykangas and Somervaara.

Columnar sections of the different districts are given in Fig. 3. The structure of the Hietajärvi district is relatively simple (p. 40). That is why its stratigraphy was easy to solve. The stratigraphic interpretation of the Salmijärvi district is based on the few top observations (Map 1) and the ground-geophysical data (Maps 6—8). In this respect, the immediate vicinity of the Seppola farm (west of Salmijärvi), where the schists form a little syncline (Map 2), is one of the key points. The stratigraphic column drawn of the Vihajärvi district is based mainly on the top observations made in the northern part of the subarea (Map 1). The interpretation that the psephites of Somervaara, Mäntykangas and Jalka-Aho lie under the tuffites, dolomites and black schists of the Salmijärvi district rests on the top observations made from the quartzite in the southern end of the hill of Somervaara. The stratigraphy of the Poikkijärvi district is a little uncertain owing to few outcrops and to the lack of geophysical data.

Roughly, we might say that the Karelidic schists in the South Puolanka area consist of two lithosomes: an eastern psammite lithosome and a western pelite lithosome. The psammites are divided into five formations, which are, reading from the oldest upwards: Arkosite Formation, Quartzite Formation I, Quartzite Formation II, Quartzite Formation III and the Mäntykangas Quartzite Formation. The Dolomite-Phyllite Formation, overlying Quartzite Formation III in the Salmijärvi district, represents a gradational vertical change from psammite lithosome to pelite lithosome.

The pelite lithosome is composed of four formations. The lithosome begins with Phyllite Formation I, which in the Vihajärvi district overlies the Arkosite Formation and underlies the Mäntykangas Formation. Phyllite Formation II overlies the Mäntykangas Quartzite in the Vihajärvi district and the Dolomite-Phyllite Formation in the Salmijärvi and Poikkijärvi districts. The stratigraphic positions of the two remaining formations, the Garnet-Mica Schist Formation and the Staurolite-Mica Schist Formation, have not been determined for sure. The former, the occurrence

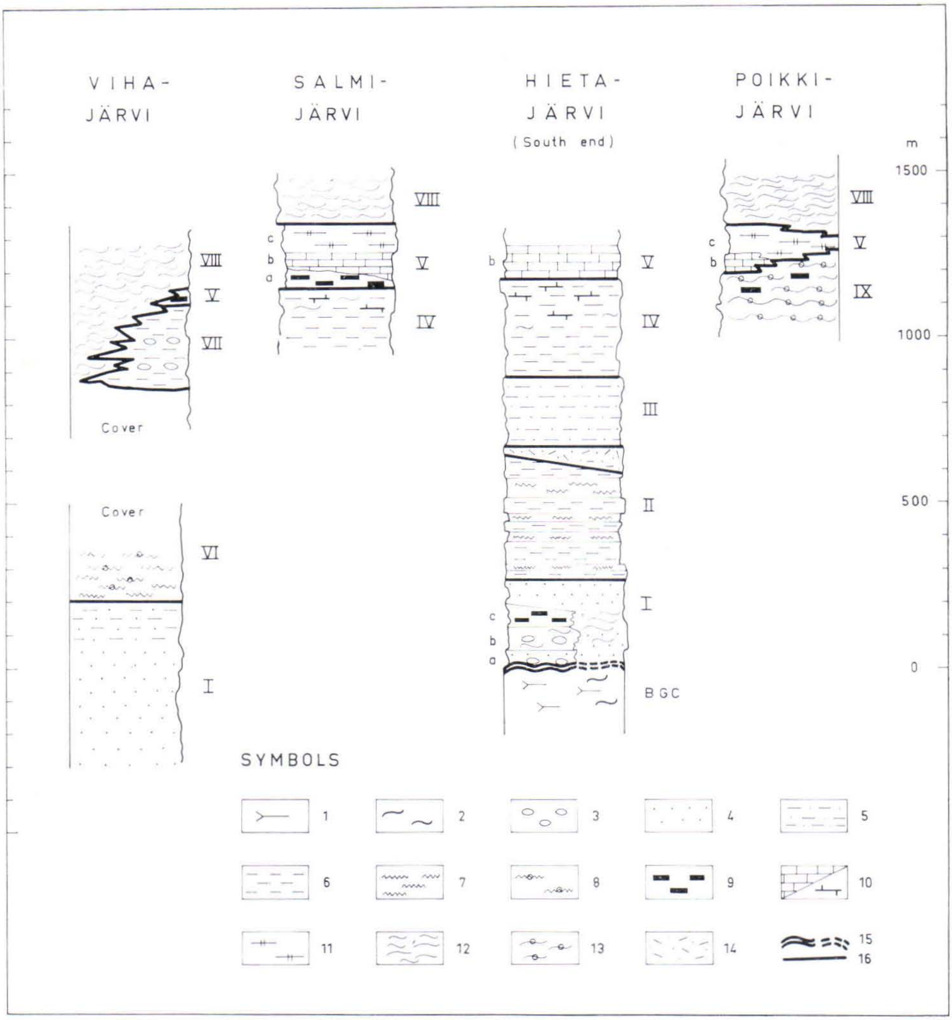

FIG. 3. Stratigraphic sections of the subareas into which the South Puolanka area is divided. Rock-stratigraphic units: BGC) Basement gneiss complex. I) Arkosite Formation; a) Honkala Arkosite Member, b) Honkala Conglomerate Member, c) Honkala Tuffite Member. II) Quartzite Formation I. III) Quartzite Formation II. IV) Quartzite Formation III. V) Dolomite-Phyllite Formation; a) Seppola Tuffite Member, b) Salmijärvi Dolomite Member, c) Salmijärvi Phyllite Member. VI) Phyllite Formation I. VII) Mäntykangas Quartzite Formation. VIII) Phyllite Formation II. IX) Garnet-Mica Schist Formation.

Symbols: 1) Orthogneiss. 2) Paragneiss and migmatitic gneiss. 3) Conglomerate. 4) Arkosite. 5) Sericite quartzite, feldspar-bearing quartzite. 6) Quartzite and orthoquartzite. 7) Sericite schist and sericite phyllite. 8) Scapolite-bearing schist. 9) Tuffite. 10) Dolomite/calcareous interbeds. 11) Black schist and mica schist. 12) Phyllite and mica schist. 13) Garnet-bearing mica schist. 14) Differentiated metadiabase. 15) Great discordance, marked with dashes where it is diffuse owing to rheomorphism. 16) Contact of formation.

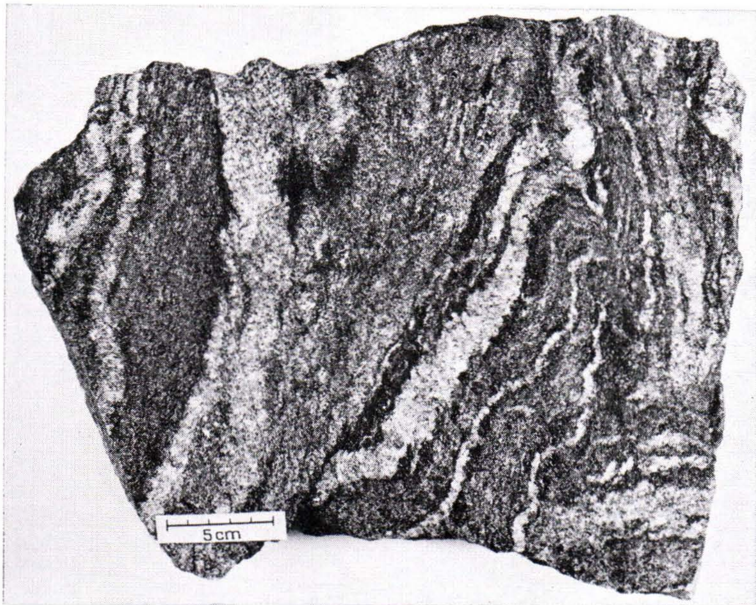

FIG. 4. Migmatitic gneiss, Basement gneiss complex. Lehtojoki. Photo E. Halme.

of which is restricted to the Poikkijärvi district, seems to underlie the Dolomite-Phyllite Formation. The Staurolite-Mica Schist is considered as allocthonous.

Volcanic rocks have been encountered within the Arkosite Formation, the Dolomite-Phyllite and Phyllite Formation I.

The youngest rock is pegmatite granite, which penetrates the Karelidic schists in the Vihajärvi district.

Prekarelidic basement gneiss complex

The basement of the Karelidic metasediments is exposed in the middle parts of the Hietajärvi district. The complex is composed mainly of granodiorite gneisses and migmatitic gneisses. The former predominate in the western parts and the latter in the middle and the eastern parts of the complex.

Migmatitic gneisses and paragneisses

The greatest part of the basement complex area is occupied by migmatitic gneisses. These are striped gneisses containing dark, biotite-rich stripes and pale, feldspar- and quartz-rich stripes in varying proportions (Fig. 4). Moreover they often contain thin, penetrating veins of granitic or granodioritic composition.

TABLE 1.

Mineral compositions of the basement orthogneisses and of the orthogneiss clasts in the conglomerates of the Arkosite Formation. Percentages by volume.

Minerals	1	2	3	4	5	6	7	8	9
Quartz	2.5	0.1	25.4	21.0	46.9	38.0	26.6	28.2	31.3
Plagioclase	84.7	80.6	65.8	73.7	39.6	16.2	46.6	38.6	26.1
(An-%)	(8)	(6)	(2—6)	(12)	(8)	(8)	(6)	(4)	(20—25)
Microcline	0.2		+		4.2	2.9	25.1	30.3	20.9
Biotite	11.2	0.3	2.4	4.7	3.8	26.7	1.2	2.4	20.3
Sericite	0.2	15.0	0.3		5.4	14.3	0.3		0.6
Chlorite	1.1	+	0.8	+			0.1	0.4	0.2
Carbonate		4.0	5.0					0.1	
Epidote	0.1			0.5				0.1	
Apatite	0.1	+	0.1	0.1	+	0.2			0.4
Zircon	+	+	+	0.1	+	0.2			
Opaque	+		0.2			+			
Others						1.5 *)	0.1		0.2

*) fine-grained feldspar
+ = detected

1. Granodiorite gneiss, east of Heinijoki conglomerate, Hepokõngäs.
2. Granodiorite-gneiss clast, Pääkkö conglomerate, Väyrylänkylä.
3. Granodiorite gneiss, Väyrylänkylä.
4. Granodiorite-gneiss clast, Heinijoki conglomerate, Hepokõngäs.
5. Granodiorite-gneiss clast, Honkala conglomerate, Honkala.
6. Darker granodiorite-gneiss clast, Honkala conglomerate, Honkala.
7. Granite gneiss, Honkala.
8. Granite-gneiss clast, Pahkapuro conglomerate, Pahkapuro.
9. Granodioritic vein in paragneiss, Hietajärvi.

Towards the Karelidic schist formations, especially in the vicinity of Hietajärvi, migmatitic gneisses grade into biotite- or sericite-rich paragneisses penetrated by granodioritic veins (Table 1, No. 9). Paragneisses grade into the schists of the lower horizons of the Arkosite Formation (p. 23). The diffuse nature of the contact between the basement complex and Karelidic schists is evidently due to rheomorphism. The remobilization and refusion of the Prekarelidic basement have been pointed out by Eskola (1948 b) and Härme (1949).

Orthogneisses

The dominant orthogneiss is a gray, medium-grained, leucocratic granodiorite gneiss poor in potash feldspar (Table 1, Nos. 1 and 3). The rock is often sheared very conspicuously (Fig. 5). Red granite gneisses (Table 1, No. 7) are uncommon. In places they penetrate granodiorite gneisses and migmatitic gneisses. The orthogneisses of the basement wedge of Väyrylänkylä, between Salmijärvi and Latolanvaara, frequently contain microcline porphyroblasts. Near the contacts of the wedge these porphyroblastic orthogneisses have sheared to augen gneisses.

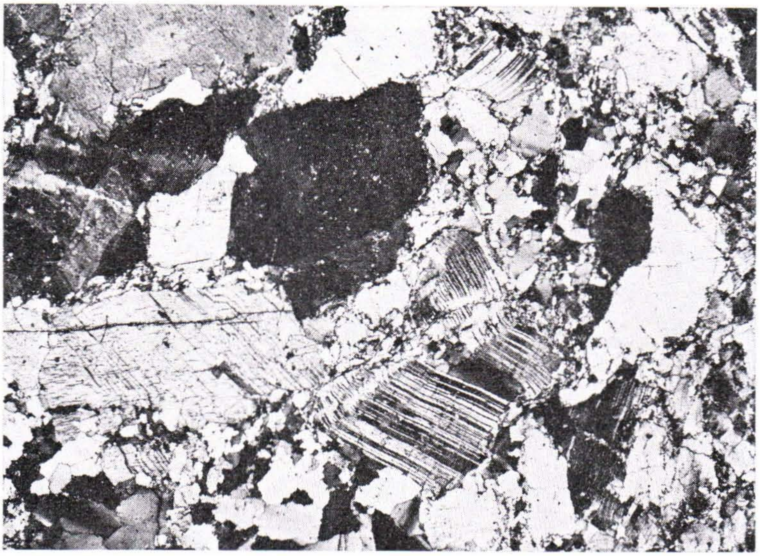

FIG. 5. Cataclastic granodiorite gneiss, Basement gneiss complex. Pahkapuro. Nicols +, 10 x. Photo E. Halme.

Karelidic supracrustal rocks and hypabyssal intrusive rocks

Arkosite Formation

The lowermost part of the Karelidic metasediment succession, consisting mainly of arkosites, impure quartzites and pelitic schists, is named the Arkosite Formation. The contact against the basement complex is not exposed. However, the several basal conglomerate occurrences afford undisputed evidence of a great discordance between the basement complex and the Karelidic metasediments. The upper contact of the formation is gradational. In the Hietajärvi subarea, the Arkosite Formation is overlain by Quartzite Formation I and in the Vihajärvi subarea by Phyllite Formation I. The thickness of the Arkosite Formation is 200—300 m in the Hietajärvi district and at least 500 m in the surroundings of Vihajärvi. A continuous section of the formation is nowhere exposed. The very lowest parts of the formation are exposed south of the Honkala farm, where the three lowermost members have been defined. These members are called, reading from the bottom upwards: Honkala Arkosite Member, Honkala Conglomerate Member and Honkala Tuffite Member. The middle and uppermost parts of the formation are best exposed in the vicinities of the lakes of Hietajärvi and Vihajärvi.

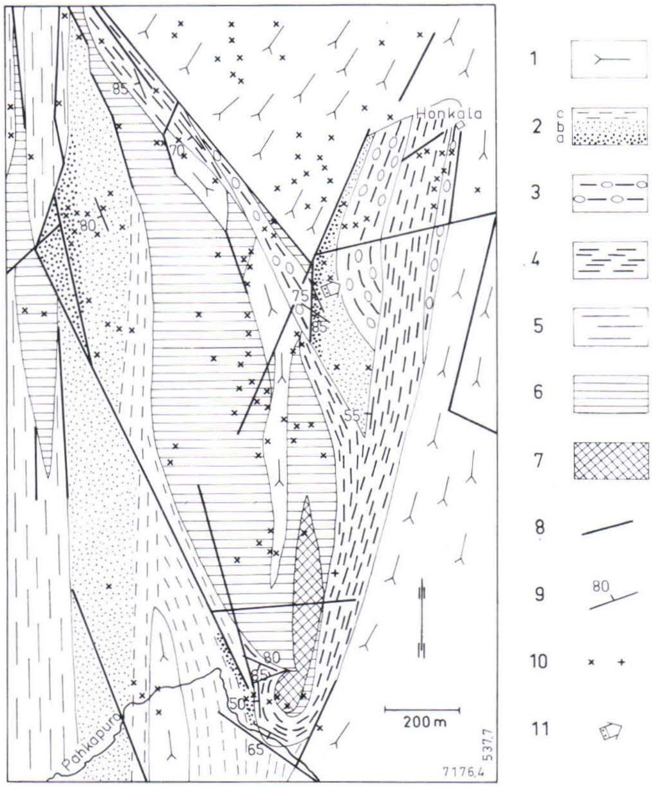

FIG. 6. Geological map of the surroundings of the Honkala farm.

1) Basement orthogneiss. 2) Honkala Arkosite Member, a) arkosite conglomerate, b) arkosite, c) sericite quartzite or sericite schist. 3) Honkala Conglomerate Member. 4) Honkala Tuffite Member. 5) Phyllites of the Dolomite-Phyllite Formation. 6) Metadiabase or metagabbro. 7) Ultrabasic rock. 8) Lineament. 9) Bedding. 10) Outcrop and boulders of the local rocks. 11) Top determined on graded bedding.

Honkala Arkosite Member

About 0.5 km southeast of the Honkala farm (Fig. 6), the Honkala Arkosite Member begins with an arkosite conglomerate bed at least 20 m thick. The conglomerate contains pebbles of orthogneiss and vein-quartz in a sericite-rich matrix (Table 2, No. 1). The diameter of the pebbles is generally 2—10 mm. Only rarely does it rise up to 30 mm. Owing to intensive shearing, the primary sedimentary structures have been almost totally destroyed. In one place, however, well-preserved graded bedding was detected. Here, also the matrix is arkositic. It seems evident that the matrix of the conglomerate has been primarily rich in feldspars, which have altered to sericite in shear zones.

TABLE 2.
Mineral compositions of the metasediments in the Arkosite Formation. Percentages by volume.

Minerals	1	2	3	4	5	6	7	8	9	10
Quartz	40.4	33.2	60.6	22.3	30.6	37.7	19.1	27.8	65.6	80.1
Plagioclase ..	15.2	35.4		7.4	12.7	23.7	1.3	24.6	18.2	0.9
(An-%)	(2)	(6)		(6)	(8)	(8)		(c. 20)	(c. 15)	
Microcline ..	2.9 *)			14.7 *)	5.0 *)	12.5	15.1	18.3	8.5	3.0
Amphibole ..						4.5				
Biotite	4.6	3.3		52.9	40.8	9.2	15.8	18.3	0.9	8.9
Sericite	36.8	19.3	39.1	2.5			38.9	0.6	6.4	6.4
Chlorite		8.1			7.7	0.3		+		0.4
Carbonate ...						5.9				
Epidote						6.1	6.3	9.9	+	
Apatite		0.1			0.3	+	0.2	0.3	+	0.2
Zircon	+		+	0.1		+	+	0.1	+	+
Titanite			0.1	0.1						
Tourmaline .			0.1				0.2		+	0.2
Opaque		0.6	0.2	0.1	2.8	0.2	3.2	0.2	0.3	+

+ = detected, *) including the feldspar not identified more exactly

1. Matrix of arkosite conglomerate, Honkala Arkosite Member, Honkala.
2. Arkosite, Honkala Arkosite Member, Honkala.
3. Sericite quartzite, Honkala Arkosite Member, Pahkapuro.
4. Matrix of Honkala conglomerate, Honkala.
5. Matrix of Pääkkö conglomerate, Honkala Conglomerate Member, 0.5 km east of Pääkkö, Väyrylänkylä.
6. Matrix of Pahkapuro conglomerate, Honkala Tuffite Member, Pahkapuro.
7. Microcline and epidote porphyroblasts-bearing sericite schist, Hietajärvi.
8. Mica schist, Hietajärvi.
9. Arkosite, Akanvaara.
10. Quartzite, Suksiharju.

The diameter of the pebbles in the conglomerate decreases topwards and the conglomerate grades to reddish or brownish arkosite (Table 2, No. 2). The total thickness of the member is about 50—70 m in its type section.

About 1 km southwest of Honkala, the arkosite conglomerate is overlain by a member of arkosites and sericite quartzites (Table 2, No. 3) about 100 m thick.

In the Liejeenjoki and Heinijoki valleys, west of the hills of Pihlajavaara and Kurikkavaara, there occur arkosites and feldspar-bearing quartzites in abundance. These rocks have been described to some extent by Väyrynen (1928, pp. 29—30 and 83, 84). Moreover, there are arkosite conglomerate interbeds. The mutual relationships of the rocks cannot be determined owing to strong shearing and certain structural complications. The quartz pebble conglomerates, which Väyrynen (1928, pp. 26, 27) considered to be basal conglomerates of his Kainuan Quartzite Formation, are interpreted by the present author to be boudinated quartz veins in quartzite. The sericite schists included by Väyrynen (1928, pp. 30—32) in the lowermost horizon of the Kainuan Quartzite are regularly associated quite closely with shear

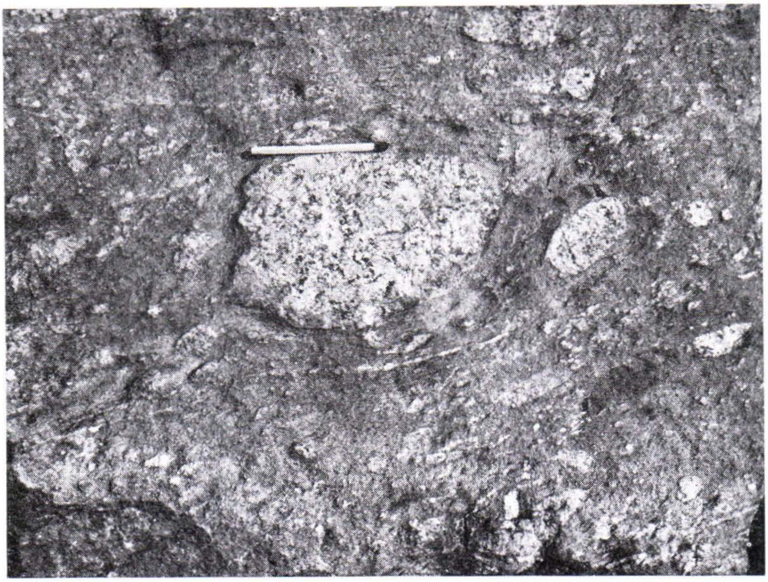

FIG. 7. Honkala conglomerate, Arkosite Formation, 400 m southwest of the Honkala farm. The length of the match is 5 cm.

zones. They are strongly foliated and their grain size is greater than in the clearly sedimentary sericite schist. They thus seem to be of tectonic origin (cf., Väyrynen 1933, p. 63).

The kaolin deposit of Pihlajavaara is intimately associated with the tectonized schists of the Honkala Arkosite Member. The quarry is nowadays almost totally mouldered. The stratigraphic relationships of the kaolin deposit can therefore no longer be studied in detail.

Honkala Conglomerate Member

The Honkala Arkosite Conglomerate is overlain in its type locality by the Honkala Conglomerate Member about 50 m thick. The most striking feature of the conglomerate is its dark, biotite-rich matrix (Table 2, No. 4 and Fig. 7). The matrix accounts for 60—80 % of the rock. The cobbles, up to 20 cm in diameter, consist mainly of granodiorite gneiss (Table 1, No. 5). Dark mica-schist fragments are not uncommon. To a certain extent, the fragments evidently represent boudinated mica schist interbeds. Moreover, sporadic cobbles of darker orthogneiss (Table 1, No. 6) occur. The conglomerate is very conspicuously foliated. There are numerous thin quartz-feldspar veinlets following the foliation planes, in many cases beginning from the orthogneiss cobbles. The veinlets seem to represent remobilized cobble matter.

Väyrynen (1928, p. 84) was the first to describe the so-called Pääkkö conglomerate situated in the village of Väyrylänkylä about 0.5 km east of the Pääkkö farm. Väy-

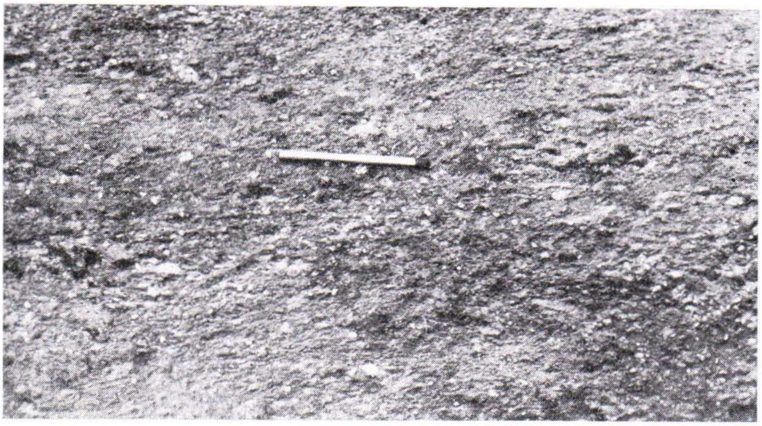

FIG. 8. Graywacke-like interbed in Pääkkö conglomerate, Honkala Conglomerate Member, Arkosite Formation, 0.5 km east of the Pääkkö farm, Väyrylänkylä.

rynen (Enkovaara, Härme and Väyrynen 1953, p. 45) considered this conglomerate as a basal formation of the western, allochthonous Jatulian. The present author has been able to trace the conglomerate for a length of 2 km along the borders of the basement wedge of Väyrylänkylä. The Pääkkö conglomerate is included by the author in the Honkala Conglomerate Member. The total thickness of the member is here at least 100 m. It is composed mainly of dark, thinly bedded conglomeratic mica schist, bearing sporadic gneiss pebbles and cobbles. Sometimes graywacke-like interbeds as much as 0.5 m thick occur (Fig. 8). The conglomerate beds proper (Fig. 9) contain an abundance of granodiorite-gneiss cobbles (Table 1, No. 2) and boulders ranging up to 30—40 cm in diameter. In addition, fine-grained, brownish or grayish pebbles and cobbles commonly occur, being composed of ophitic albite-quartz rock. Sparse metadiabase boulders, up to 0.5 m in diameter, have been also detected in the parts of the conglomerate closely associated with metadiabases and metavolcanics. The mineral composition of the matrix of the Pääkkö conglomerate is given in Table 2, No. 5.

Honkala Tuffite Member

Southwest of the farm of Honkala, the Honkala Conglomerate is overlain by basic metavolcanics and tuffites. The member begins with a bed of volcanics about 50 m thick. The volcanics are dark green, homogenous and dense. They are composed mainly of oligoclase and hornblende. In its upper parts, the member contains volcanic breccia (Fig. 10). The fragments in the breccia consist mainly of the basic volcanics described in the foregoing. Moreover, dark gray fragments rich in biotite and oligoclase occur in abundance. The origin of these fragments, which show no sedimentary features, is unknown. Probably they are derived from biotite-oligoclase-rich varieties of metadiabases, which are not exposed, however, in the vicinity of Honkala. In addition to these small fragments, there occur pillow-like bodies of basic volcanics. The pillows are up to 1.5 m in length. The matrix of the breccia is rich in oligoclase.

About 1.5 km south of Honkala, on the north side of the rivulet of Pahkapuro, the member consists mainly of thinly bedded basic tuffite. Tuffite borders and surrounds a metadiabase intrusion. The main minerals of the tuffite are hornblende and oligoclase. Quartz is present only in slight amounts. There occur interbeds of mica-schist-like tuffite, in places up to 2 m thick (Fig. 11). Near the contacts against the metadiabase intrusion, there are in many places thin concordant metadiabase veins and sills.

The part of the member situated 0.5 km west of Honkala also contains one 0.5 m thick interbed or concordant intrusion of gray, dense, fine-grained rock. The rock is composed almost entirely of albite with minor amounts of quartz and rutile. The texture of the rock is subophitic. The same rock occurs also as fragments in a breccia overlying the interbed. This albite-rich rock resembles the albite-rock cobbles in the Pääkkö conglomerate.

FIG. 9. Pääkkö conglomerate, Honkala Conglomerate Member, Arkosite Formation, 0.5 km east of the Pääkkö farm, Väyrylänkylä. The length of the compass is 11 cm.

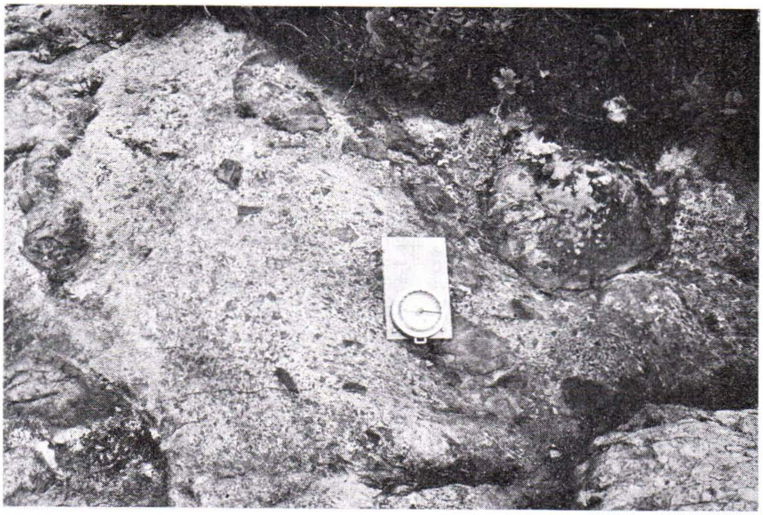

FIG. 10. Volcanic breccia, Honkala Tuffite Member, Arkosite Formation, Honkala.

FIG. 11. Shear folded tuffite, Honkala Tuffite Member, Arkosite Formation, Pahkapuro.

FIG. 12. Northern Heinijoki conglomerate, Honkala Tuffite Member, Arkosite Formation, Hepoköngäs.

The tuffites situated west of the waterfalls of Hepoköngäs in the Heinijoki valley are of the Pahkapuro type. The total thickness of the member is here about 50 m. The tuffite seems to have deposited directly on the basement granite gneiss. Along the north bank of the river, the member contains a conglomerate bed (Fig. 12). The bed is 5 m thick. The boulders in the conglomerate came mainly from the nearby basement gneisses (Table 1, No. 4). Boulders composed of a dark, biotite-rich orthogneiss are common. The latter gneiss type has not been encountered in the basement area. The gneiss clasts decrease in size towards the west and the conglomerate becomes breccia-like in its upper parts. The matrix of the conglomerate is generally green in colour and rich in amphibole. In places, it is pale gray and contains plagioclase in abundance.

The conglomerate interbed situated on the south bank of the river has been previously described by Väyrynen (1928, p. 107). This conglomerate contains only red basemet granite-gneiss pebbles and vein-quartz pebbles. The matrix is here more arkositic than in the northern conglomerate. Väyrynen did not classify this conglomerate with certainty. However, he seems to have considered it to be relatively young in age (Väyrynen 1928, p. 107, 1954, p. 163 and Enkovaara et al. 1953, p. 69).

In close association with the tuffites of Pahkapuro, there occurs a conglomerate bed, at least 10 m thick, of the northern Heinijoki conglomerate type. The matrix is slightly tuffaceous (Table 2, No. 6). In addition to the predominant granodiorite-gneiss clasts there occur granite-gneiss cobbles (Table 1, No. 8).

The thickness of the Honkala Tuffite Member varies from 50 m to 80 m.

Metadiabases and ultrabasic rocks

Closely connected with the schists of the Honkala Conglomerate and the Honkala Tuffite Members, there often occur small concordant metadiabase bodies. The metadiabases are dark green, massive and more or less ophitic. They contain as their main mineral constituents green hornblende (50—80 %) and plagioclase (albite-oligoclase). Often they bear quartz-carbonate amygdales, e.g., east of Pääkkö (Väyrynen 1928, p. 47). Evidently, the greatest part of these metadiabases, which in general show no marks of any differentiation, represent hypabyssal intrusions and/or metavolcanics.

The mineral compositions of these rocks and the tuffites of the lowermost parts of the Arkosite Formation are so similar that we must consider the latter as weathering products of the former.

The small ultrabasic intrusion north of Pahkapuro is composed of massive amphibole rock with minor relicts of pyroxenes.

Other parts of the Arkosite Formation

In the Heinijoki valley, the Honkala Tuffite Member is overlain by a member about 250 m thick composed of psammites. The member begins with a red, thinly bedded arkosite, the thickness of which is at least 50 m. The uppermost 150—200 meters of the member consist mainly of feldspar-bearing quartzite. Very distinctive features of the quartzite are its bluish colour, lightbrown weathered surface and rusty weathering ring about 0.5 cm thick. In addition to the main mineral constituents, quartz and plagioclase, the quartzite contains slight amounts of carbonate and sericite. More arkositic varieties of the quartzite are more reddish and in many places show cross-bedding.

The contact between the paragneisses and the Karelidic metasediments is diffuse on the southern and eastern shores of Hietajärvi (p. 14). In places, the lowermost horizon consists of arkosite and, in other places, of biotite- and/or sericite-rich mica schists. The arkosite is sometimes seen to be cross-bedded. The middle 50 meters of the formation are composed of mica- and feldspar-bearing impure quartzites and of mica schists containing biotite and sericite in varying amounts (Table 2, Nos. 7 and 8). These schists are probably counterparts of the tuffaceous members near Honkala. The topmost parts are composed mainly of arkosite and feldspar- or sericite-bearing quartzites. Moreover, there occur sericite schist intermembers up to 20 m thick. The maturity of the psammites clearly increases topwards. The uppermost unit is a sericite schist bed about 10 m thick. The total thickness of the Arkosite Formation is here at least 200 m.

In the eastern slope of Pahkavaara, the first Karelidic schist bed is a mica schist bed 10 m thick. The mica schist contains thin microcline veins and small microcline porphyroblasts. Farther above there follows for about 100 m a succession of red

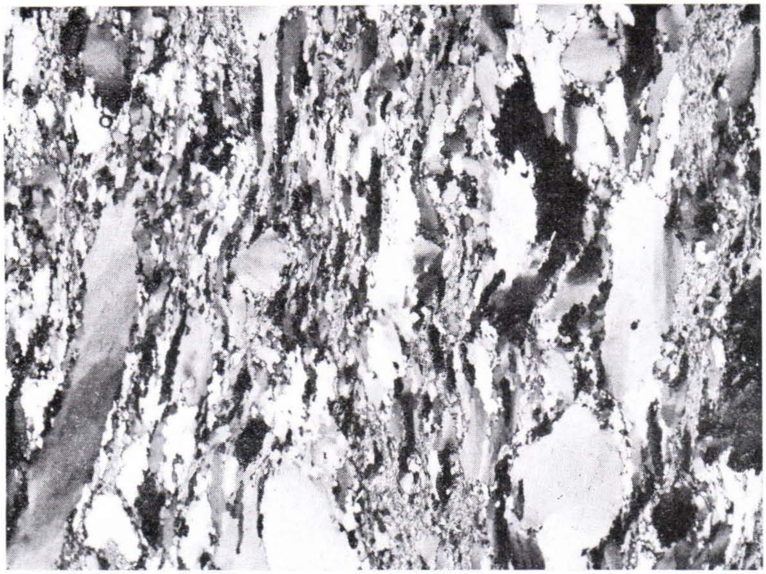

FIG. 13. Deformed quartzite, Arkosite Formation, Akanvaara. Nicols +, 25 ×. Photo E. Halme.

arkosites and greenish feldspar-bearing quartzites with sericite schist and mica schist interbeds.

Compared with the Hietajärvi district, the part of the Arkosite Formation exposed in the Vihajärvi district is very monotonous. The lowermost part is occupied by biotite-rich quartzites. The middle part is composed of red or brown arkosites (Table 2, No. 9) or feldspar-bearing quartzites. Cross-bedding is common. Only rarely do thin yellowish sericite schist interbeds occur. The sericite schists are fine-grained, thinly bedded and in many cases marked by grading. Towards the top the psammites become more mature and pass into quartzites (Table 2, No. 10). Many of the rocks of the district are very markedly deformed (Fig. 13). Southwest of Suksiharju, the topmost parts of the formation contain an abundance of mica schist interbeds.

Northwest of Kapustakangas, the arkosites of the Arkosite Formation gradually change to arkosite gneisses, which are penetrated and migmatized by granite pegmatite veins.

Quartzite Formation I

The name Quartzite Formation I is proposed for the part of the psammite succession in the Hietajärvi district characterized by the association of quartzite and sericite schist. The lower contact of the formation is placed under the first member of reddish orthoquartzite and the upper contact under the metadiabase sill of Hietavaara. The occurrence of the formation is mainly restricted to the Hietajärvi district, where it overlies the Arkosite Formation and in the south underlies Quartzite Formation II and in the north Quartzite Formation III. The thickness of the Quartzite I is about 300 m in the south and about 450 m in the north.

The type section of the formation is given from Hietavaara, east of Hietajärvi. Quartzite Formation I can be divided into nine informal members, which, listed from the youngest to the oldest, are as follows (actual thicknesses are given inside parentheses):

(Differentiated metadiabase sill)

— bluish quartzite, which grades upwards into brownish, sericite-bearing quartzite (25 m)
— yellowish sericite schist with epidote-rich intercalations (60 m)
— bluish orthoquartzite (45 m)
— pale brown, epidote-bearing sericite schist (25 m)
— blue orthoquartzite (35 m)
— pale brown, thinly bedded sericite schist with some epidote (30 m)
— blue, glassy, totally recrystallized orthoquartzite with slight content of hematite and with quartz-hematite veins (50 m)
— pale gray sericite schist (20 m). Lower contact is gradational
— reddish or bluish, glassy orthoquartzite (20 m). Lower contact is sharp.

(Sericite schist of the Arkosite Formation)

Excepting the two lowermost members, the contacts between the members are not exposed and furthermore the sericite schist members are only partly exposed.

North of Olkala, about 7 km north of the type section, one quartzite-sericite schist pair, probably the uppermost, is fairly well exposed. Here a sericite schist rich in epidote grades towards the top into a quartzite with carbonate- and amphibole-rich intercalations. This in turn grades into a blue orthoquartzite.

Compared with the sericite schists in the Arkosite Formation, those of Quartzite Formation I are richer in sericite and poorer in biotite.

The northernmost section of Quartzite Formation I is given from the Heinijoki valley, about 0.5 km west of Hepokängäs. The section is reading from the youngest downwards, as follows (actual thicknesses are given in parentheses):

(Basic, undifferentiated and porfyritic metadiabase)

— pale sericite quartzite with sericite-rich intercalations (65 m)
— bluish gray sericite phyllite with biotite porphyroblasts (45 m)
— blue or brown, glassy orthoquartzite (25 m)
— (differentiated metadiabase (2 m))
— cover (25 m)

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— blue, glassy, blastoclastic and extremely pure orthoquartzite with ripple marks (130 m)
— bluish sericite phyllite with biotite porphyroblasts (35 m)
— blue, glassy orthoquartzite, which shows both ripple marks and cross-bedding (30 m)
— bluish sericite phyllite with biotite porphyroblasts and thin hematite veins (30 m)
— brown or bluish orthoquartzite (45 m).

(Arkosite Formation)

The sericite phyllites are fine-grained. Many of them show graded bedding. In addition to sericite and biotite, the phyllites contain quartz, carbonate, feldspars and hematite. The hematite, which gives the bluish colour to these phyllites, occurs as a fine impregnation and as pseudomorphs of magnetite.

Compared with those in the type section, the quartzites are here purer and distinctly larger in grain size.

Quartzite Formation II

South of Hietajärvi Quartzite Formation I is overlain by a 200—250 m thick succession of sericite quartzites and feldspar-bearing psammites. This succession is called Quartzite Formation II, and it is overlain by Quartzite Formation III. Both the lower and the upper contacts are unexposed, and the lower one seems to be gradational.

Monotonous in its petrography, the formation begins with sericite- and carbonate-bearing quartzite, which comprises its main parts. The quartzite is grayish in colour. In many places, it bears a silky luster, its weathered surfaces being whitish. Only rarely do there occur sericite-rich intercalations. When not sheared, the quartzite is distinctly bedded. The bedding is laminar.

In its uppermost 100 meters, the formation is composed of brown arkosite or feldspar-bearing quartzite. Both rocks contain minor biotite flakes. On top there is a bed of feldspar-bearing quartzite about 40 m thick. Reddish in colour, the rock is also to some extent glassy, with lamellar bedding. Cross-bedding is met with in the quartzite.

The formation thins down and the sericite, carbonate and feldspar contents of its psammites decrease towards the north. The result is that the formation can no longer be mapped north of Liejeenjoki.

Outside the Hietajärvi district, the formation is exposed west of Hongikkokangas. The prevailing schist is here gray sericite quartzite, which is clearly clastic in structure. Under the microscope, graded bedding can also be observed.

Quartzite Formation III

The uppermost psammite unit in the South Puolanka area is named Quartzite Formation III. The formation is composed mainly of bluish, impure quartzite with pelitic and calcareous interbeds in the south, where it overlies the Quartzite II and underlies the Dolomite-Phyllite Formation. In the north, it overlies the Quartzite I. Here the predominant rock is a reddish quartzite. The thickness of the formation is about 300 m in the southern part of the Hietajärvi subarea. Towards the north, the thickness increases quite noticeably, being about 1 000 m north of Heinijoki.

South of Hietajärvi, the formation begins with bluish or reddish quartzite, with distinctive lamellar bedding. The rock is often found to contain some biotite. Towards the top the quartzite rapidly becomes more impure, containing biotite and iron sulphides as its main impurities. In the middle parts, a bluish biotite- and/or carbonate-bearing quartzite is predominant. Thin biotite-rich mica schist intercalations are frequently met with in this quartzite. Closer to the top, the quartzite begins to contain more and more carbonate and pale green tremolite. Moreover, carbonate- and tremolite-rich interbeds begin to appear. These calcareous interbeds increase in quantity and thickness — which reaches as much as 10 m — towards the top indicating a gradual change from this formation into the overlying Dolomite-Phyllite Formation.

In the Hietajärvi district, the quartzites become purer and the mica schist intercalations and the calcareous interbeds vanish towards the north. Thus at the northern end of Pihlajavaara, the formation is monotonous, consisting of relatively pure quartzites. The prevailing quartzite is streaked with red, green or brown. It is in many places cross-bedded (Fig. 14). The bedding is either lamellar or laminar. As a rule, the laminar types are also blastoclastic. In addition to the quartz, the quartzites contain minor amounts of sericite, carbonate and feldspars. Orthoquartzitic varieties are not rare. Only in the very lowermost parts of the formations do there occur thin sericite phyllite intercalations and small sericite phyllite fragments. The change from Quartzite Formation I into Quartzite III is thus here gradational.

In the Salmijärvi district, the formation can be described as typical in the surroundings of the lakes of Salmijärvi. The prevailing quartzite is generally blue and biotite-bearing. Quite characteristically, it contains iron sulphides in minor quantities. Mica schist interbeds up to 10 m thick are common. A very distinctive quartzite variety is a dark blue, glassy and totally recrystallized orthoquartzite. The rock is, as a rule, brecciated very intensively by quartz veins. The parts of the formation underlying the Salmijärvi Dolomite Member (p. 30) consist of brownish, carbonate-bearing quartzite. Rust-coloured and porous weathering surfaces are characteristic features.

The dark, carbonate-bearing quartzite on the eastern shore of Poikkijärvi, which was described in detail by Wilkman (1931, p. 193), probably belongs to the uppermost parts of Quartzite Formation III.

FIG. 14. Cross-bedding in orthoquartzite, Quartzite Formation III, Pihlajavaara. Photo P. Ervamaa.

Dolomite-Phyllite Formation

The tuffites, dolomites and phyllites overlying Quartzite Formation III compose the Dolomite-Phyllite Formation. The type locality is the area west of the lakes of Salmijärvi. By means of ground-geophysical data (Maps 6—8), the formation is here divided into three members, which are, from the lowest to the top: Seppola Tuffite Member, Salmijärvi Dolomite Member and Salmijärvi Phyllite Member. In places, the formation begins with the Salmijärvi Dolomite. The contact against the overlying Phyllite Formation II is not exposed. The members can be traced by means of aero-geophysical data (Maps 4 and 5) from the northern part of the Salmijärvi district to Törmänmäki in the South. The middle part of the Poikkijärvi district consists mainly of the phyllites of this formation. Owing to few outcrops and complete lack of geophysical data, the detailed stratigraphy of this part of the formation is uncertain. In the Hietajärvi district, the formation is exposed only in the vicinity of Iso Kaitanen.

Seppola Tuffite Member

The member is named after the few small tuffite exposures in the immediate vicinity of the Seppola farm, about 1.5 km west of Salmijärvi. The tuffite is basic,

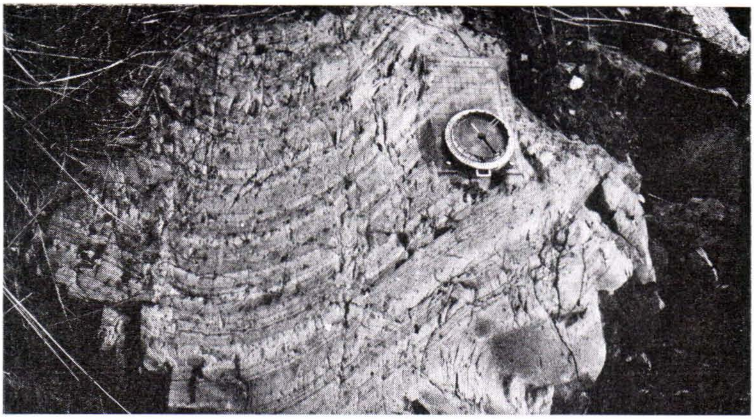

FIG. 15. Seppola tuffite, showing transverse foliation, Dolomite-Phyllite Formation, Seppola. The length of the compass is 11 cm.

graded and thinly bedded (Fig. 15). The top parts of the strata are rich in amphibole and the bottom parts rich in oligoclase and quartz. One local boulder observation indicates that the member also contains conglomeratic parts. The scanty matrix of the conglomerate is basic and tuffitic. The cobbles in the conglomerate are composed of arkosite, metadiabase and tuffite.

The thickness of the member is at least 50 m. Both the lower and upper contacts are unexposed.

Along the western margin of the Dolomite-Phyllite Formation, from Seppola to Voipuanjärvi in the south, there runs a belt of positive aeromagnetic anomalies (Map 4). The anomalies are not accompanied by any electromagnetic anomalies (Maps 5 and 7). However, some weak positive gravimetric anomalies (Map 8) occur within the belt. This belt as well as the other parts of the Salmijärvi subarea characterized by the same combination of geophysical anomalies are marked on Map 1 as tuffites of the Seppola Member. This interpretation is verified by the tuffite outcrops south of Somervaara and in the valley of Liejeenjoki.

The tuffites on the eastern shore of Poikkijärvi are coarse-grained and rich in amphibole. They alternate with impure quartzites, phyllites and massive amphibolites.

Metadiabases and metavolcanics

The Seppola Tuffite is closely associated with hornblende-rich metadiabase near Seppola, with a basic amygdale-bearing metadiabase and/or metavolcanics in the Liejeenjoki valley and with coarse-grained, massive amphibole-rich rocks in Somervaara. This intimate association clearly indicates that the Seppola Tuffite represents the detrital material derived from the metadiabase or metavolcanics bodies lying nearby.

Salmijärvi Dolomite Member

The type exposures of this member occur in the vicinities of the lakes of Salmijärvi. The member has also been drilled in many places. However, the tectonics of the area is so complicated that no drilled type section can be presented. The lower parts of the member consist of more or less pure dolomites and the upper parts of marly and sandy schists. In its type locality, the Salmijärvi Dolomite lies directly on Quartzite Formation III. The upper contact of the member is gradational.

The type dolomite is a light brown rock containing some quartz and micas as impurities. Typically bluish, often carbonate-bearing quartzite interbeds occur in these parts of the member. Dolomite occurs as lens-shaped bodies, which vary from 50 m to 80 m in thickness.

The upper half of the member is composed of a mixture of dolomite, quartzite, calcareous phyllite and mica schist, calcareous amphibolite and black schist.

In the Salmijärvi district, the total thickness of the Member is about 100—200 m.

In the Poikkijärvi district, only impure dolomite occurs. Impurities are quartz, sericite and diopside. Tourmaline is a typical accessory mineral. The thickness of the dolomite is here only 10—30 m.

West of Iso Kaitanen, the member consists of a tremolite-bearing dolomite bed at least 100 m thick. Phyllitic intercalations are to be frequently observed.

Salmijärvi Phyllite Member

The Salmijärvi Phyllite Member consists of black schists, phyllites and mica schists. In the lower half, the black schists dominate. The distribution of the black schists is revealed by the electromagnetic anomalies on Maps 5 and 7. The upper contact of the member lies over the phyllites and mica schists, causing the weak magnetic anomalies associated with the black schist horizons. The total thickness of the member is about 100—200 m.

Black schists are carbonaceous phyllites or mica schists containing sulphides, mainly pyrite and pyrrhotite, in varying amounts. Many of them are calcareous and penetrated by thin quartz-carbonate veins. Dark blue dolomite interbeds are common. Black schist horizons include lenses of magnetit- and/or amphibole-rich phyllite.

The phyllites and mica schists are dark gray and rich in biotite. They are in many instances thinly bedded. Cross-bedding is exceptional; then the schists are graywacke-like and the thickness of the individual beds increases up to 1 m.

Phyllite Formation I

East of Ahvenvaara and southwest of Suksiharju the Arkosite Formation is overlain by phyllites and mica schists. These schists compose Phyllite Formation I. Only the lowermost parts of the formation are exposed. If there are no structural

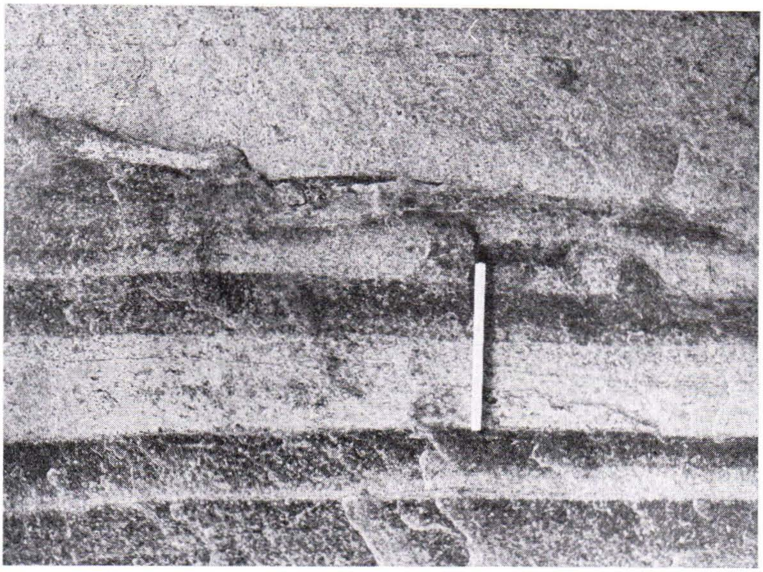

FIG. 16. Sericite phyllite, Phyllite Formation I, Ahvenvaara. The actual thickness of the bed under the match is 2 cm. The dark parts are rich in sericite and the light parts rich in quartz.

complications between Ahvenvaara and Jalka-Aho, the total thickness of the formation is about 800—1 000 m. Northeast of Suksiharju, the thickness seems to be only 300—400 m.

Northeast of Suksiharju, the exposed part consists of pale yellowish sericite phyllite or darker sericite-biotite-chlorite phyllite. Both of the phyllites have a graded bedding; the former also exhibits cross-bedding. Both of the rocks bear biotite porphyroblasts and the latter also contains chlorite porphyroblasts. The thickness of the phyllite bed is at least 15 m.

The only exposure east of Ahvenvaara is composed of yellowish sericite phyllite (Fig. 16). The thickness of this extremely biotite-poor phyllite, which is exposed only in ditches in a swamp, is at least 20 m. About 5 km north of this exposure, outside Map 1, there occur sericite and sericite-biotite phyllites. Both of the phyllites are scapolitized very intensively. The scapolitization seems to be a very typical feature of this part of the formation. The scars in the middle of Vihajärvi are composed of dark biotite-rich phyllite in the west and of scapolite-bearing amphibolite in the east.

The middle and upper parts of the formation are not exposed in the study area. The observations made by the author in the northern continuation of the formation indicate that the magnetic anomalies (Map 6) inside the formation are caused by spilitic metavolcanics and/or metadiabases and that the uppermost horizon consists of dark mica schist.

FIG. 17. Mäntykangas conglomerate, Mäntykangas Quartzite Formation, Mäntykangas.

Mäntykangas Quartzite Formation

The zone about 2 km broad trending from Jalka-Aho to Voipuanjärvi shows very distinctive features. The most distinctive one is the occurrence of the so-called Mäntykangas conglomerate members. The second typical feature is the alternation of quartzites, arkosites and mica schists. The part where psammites and psephites are dominant is named the Mäntykangas Quartzite Formation. Mäntykangas, situated about 2 km west of Iso Salmijärvi, is the place where the Mäntykangas conglomerate was first described (Väyrynen 1928, p. 105).

The Mäntykangas Quartzite overlies Phyllite Formation I. The lower contact is not exposed. The contact against Phyllite Formation II, which overlies the western parts of the Mäntykangas Formation, is gradational. The most eastern parts are overlain by the Dolomite-Phyllite Formation.

The Mäntykangas conglomerate contains a great abundance of cobbles derived from the basement complex, the Arkosite Formation, Phyllite Formation I and the Mäntykangas Quartzite Formation itself (Fig. 17 and 18). Moreover, metadiabase cobbles and dark siliceous siltstone pebbles are present. The matrix is either arkosic or rich in biotite.

The highly varying nature of the Mäntykangas Formation is revealed by the following typical sections:

The type section in Mäntykangas is from the uppermost bed exposed downwards (actual thicknesses are given in parentheses)

— brownish or grayish, impure, feldspar- or biotite-bearing quartzite, interbedded in its upper parts with mica schists and phyllites of the Phyllite Formation II type (100 m)

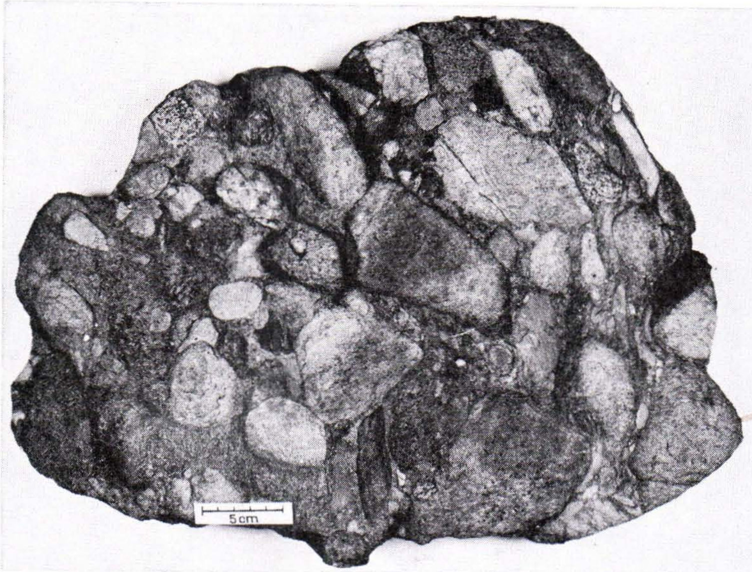

FIG. 18. Mäntykangas conglomerate, Mäntykangas Quartzite Formation, Seppola. Photo E. Halme.

— bluish or grayish, cross-bedded quartzite (50 m)
— Mäntykangas conglomerate (c. 30 m)
— dark mica schist, rich in biotite, strongly sheared (at least 30 m).

In the eastern part of Jalka-Aho, the rock succession is from the west to the east (top uncertain, very probably to the west).

(Phyllite Formation II)
— cover (15 m)
— Mäntykangas conglomerate (40 m)
— graywacke-like Mäntykangas conglomerate with pebbles only 2—3 mm in diameter. Matrix is rich in biotite and quartz, but very poor in feldspars (20 m)
— Mäntykangas conglomerate (10 m)
— cover (20 m)
— brown quartzite (at least 10 m).

The most western section is given from the western part of Jalka-Aho, where the section is, proceeding towards the bottom, as follows:

— brown, cross-bedded quartzite (at least 30 m)
— alternating beds of Mäntykangas conglomerate, mica schist and bluish or reddish quartzite (60 m)
— bluish or brown, hematite- or magnetite-bearing and cross-bedded, impure quartzite (at least 50 m).

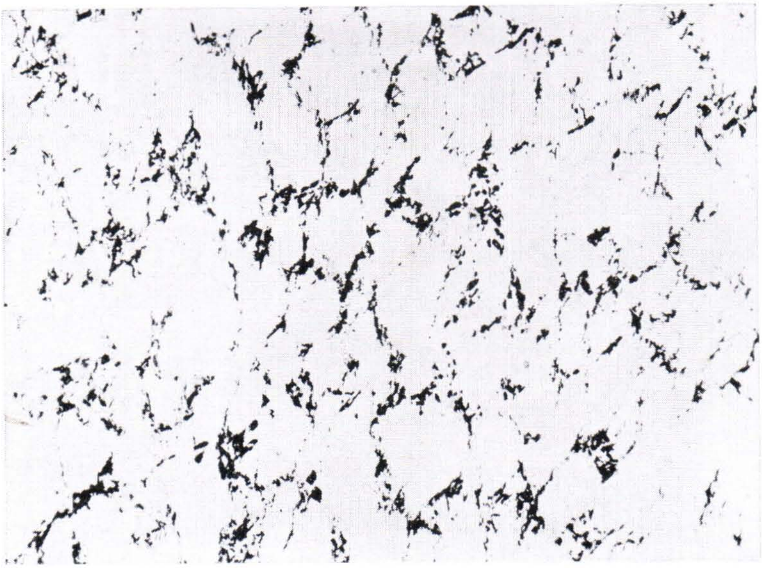

FIG. 19. Quartzite cemented with hematite, Mäntykangas Quartzite Formation, Somervaara, Nicols //, 25 ×. Photo E. Halme.

The most eastern part of the formation is exposed at the southern end of Somervaara. The succession here runs from the youngest downwards:

(Seppola Tuffite Member)

— blue, glassy quartzite (at least 20 m)
— brown arkosite or feldspar-bearing quartzite (80 m)
— blue, glassy, ripple-marked, cross-bedded, hematite-bearing orthoquartzite and quartzite (80 m) (Fig. 19). Iron-oxide-bearing, dark blue or yellow sericite-phyllite interbeds occur. This part of section is clearly correlative with the schists of Quartzite Formation I and the northern lower parts of Quartzite III
— dark sericite- or biotite-rich phyllite (30 m)
— strongly sheared Mäntykangas conglomerate (at least 5 m).

The maturity of the formation clearly decreases from the east to the west. The minimum total thickness of the formation is 150—200 m.

Phyllite Formation II

The eastern section of the Mäntykangas Quartzite Formation at Jalka-Aho is overlain by a formation at least 200 m thick consisting mainly of phyllites and mica

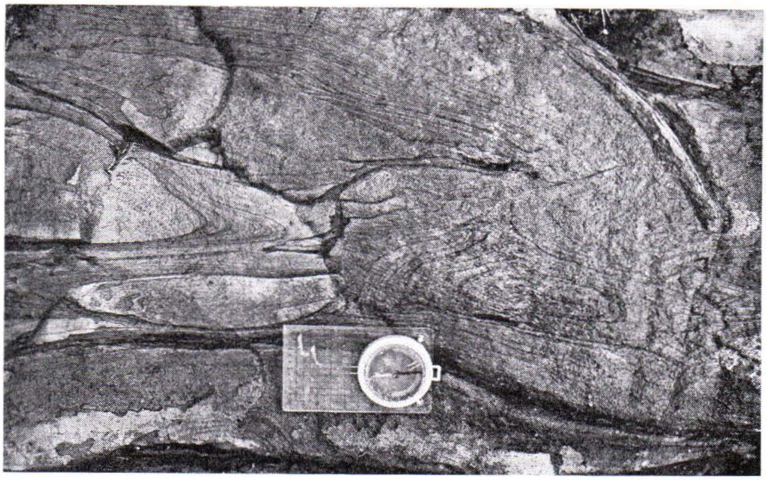

FIG. 20. Slumped sandy interbeds (on the left) in mica schist, Phyllite Formation II, Jalka-Aho.

schists. Characterized by a total lack of any ground- or aeromagnetic anomalies (Maps 4 and 6), it is designated as Phyllite Formation II. It can be traced geophysically (Map 4) from Jalka-Aho to Hongikkokangas, where the second moderately exposed part of the formation exists. The horizons lacking positive magnetic and electromagnetic anomalies in the Salmijärvi district and overlying the Salmijärvi Phyllite Member are included in this formation.

At Jalka-Aho, the whole exposed part is composed of dark or pale gray phyllite and mica schist, which in many cases show graded bedding and sometimes cross-bedding, too. Pale brown, sandy interbeds up to 1 m in thickness are quite typical. These parts are often seen to bear slump structures (Fig. 20). In places, the sandy interbeds are penetrated by quartz veins, which, however, do not extend outside the bed. In places, the schists contain calcareous, epidote- and amphibole-bearing concretions.

At Hongikkokangas, the prevailing rock is more or less sericite-bearing phyllite. Here sandy interbeds are less common, while calcareous concretions are more common than in the Jalka-Aho area. The phyllites are in general rich in sericite, and they commonly contain biotite and chlorite porphyroblasts. The graded bedding in the phyllites is of an exceptional character: the top parts of the strata are lighter than the bottom parts. This is due to the fact that the former are rich in sericite and the latter rich in biotite.

In the Salmijärvi subarea, there is only one mica schist exposure included in Phyllite Formation II. The phyllites in the Poikkijärvi subarea are of the Hongikkokangas type.

Garnet-Mica Schist Formation

The northern part of the Poikkijärvi district is occupied mainly by garnet-bearing mica schists. The contact zone of these schists against the psammites of the Hietajärvi district is not exposed. Because also the geophysical data are lacking throughout the Poikkijärvi area, the stratigraphic relationships of the schists are not exactly known. At least one part of these schists seems to underlie the Dolomite-Phyllite Formation and thus to have a special stratigraphic position. That is why the schists are treated as a unit named the Garnet-Mica Schist Formation. As the schists are prominantly shear-folded, their original thickness is impossible to estimate.

The most western exposures are sericite-bearing mica schist with biotite porphyroblasts. This schist is insignificant in amount compared with the prevailing schist. The latter is a dark gray, biotite-rich mica schist with graded bedding, which regularly contains considerable amounts of garnet.

Eeast of Särkijärvi, there occur quartzite interbeds up to 20 m in thickness. The quartzite is reddish and relatively pure.

Basic, tuffaceous intermembers up to 10—20 m thick are typical of the part immediately below the impure dolomite of Poikkijärvi. The tuffites are very rich in amphibole and generally in garnet, too. Often amphibole occurs as radial boundles. Dark phyllite intercalations are quite typical of this part of the formation.

Staurolite-Mica Schist Formation

The mica schists east of Ahvenvaara and Akanvaara and at Kapustakangas commonly contain staurolite and/or garnet. These schists constitute the Staurolite-Mica Schist Formation. They have metamorphosed under the conditions of the staurolite-almandine subfacies of almandine-amphibolite facies (cf., Turner and Verhoogen 1960). The nearby schists of Phyllite Formation I have metamorphosed under the conditions of distinctively lower grade (greenschist facies). This fact confirms the tectonic interpretation (p. 42) according to which the Staurolite-Mica Schist is allocthonous. The thickness of the formation is unknown. It is evidently many hundreds of meters or even over 1 000 m thick. As the Formation is allocthonous, its stratigraphical relationships with the other formations are unknown. Very probably the formation is correlative with Phyllite Formation I and/or the Garnet-Mica Schist Formation.

Staurolite-mica schist is the dominant rock in the formation. The schist is frequently seen to have graded bedding. The top parts of the strata are rich in biotite. Commonly, the staurolite and garnet porphyroblasts have become concentrated in these parts. The lower parts are pale and rich in quartz and plagioclase. The thickness of the strata rarely exceeds 2 cm.

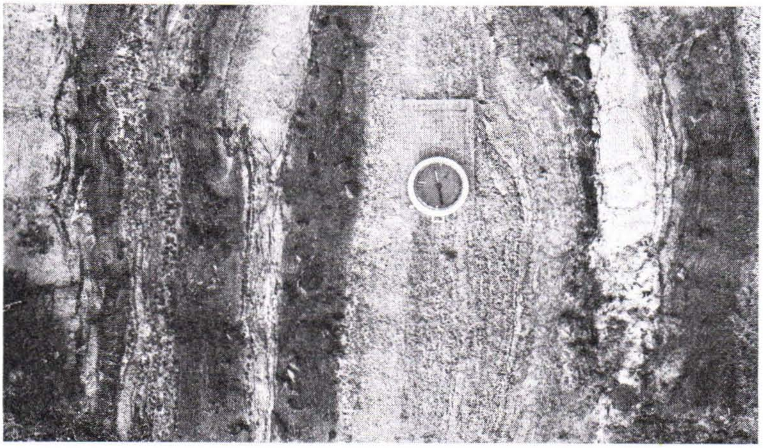

FIG. 21. Alternating beds of staurolite-mica schist and arenaceous schists. Staurolite-Mica Schist Formation, Ahvenvaara.

Feldspar- or sericite-rich psammite interbeds are typical of the northern part of the formation (Fig. 21). Moreover, reddish, garnet-rich intercalations and amphibolite interbeds occur. Evidently, the latter are schistosed metagabbros.

Small bodies of u l t r a b a s i c r o c k s occur among the staurolite-mica schists. The ultrabasic rocks are mainly massive amphibole or amphibole-serpentine rocks. The weathered surface of the former is dark green and that of the latter dark brown.

The m e t a g a b b r o s associated with the ultrabasic rocks are medium-grained and rich in hornblende. Their plagioclase is distinctly more basic (andesine-labradorite) than that (albite-oligoclase) of metadiabases and metavolcanics in the more eastern formations. At their contacts against staurolite-mica schists, the metagabbros contain garnet in abundance.

Taking the top observations made in the enclosing schists into consideration, it is evident that the ultrabasic rocks, together with the intimately associated metagabbros, form gravitationally differentiated intrusive bodies. The main part of the bodies consists of ultrabasic rocks. Metagabbros compose the relatively thin top layers.

On the northern shore of Vihajärvi, the easternmost and probably also the topmost schists of the formation are massive, biotite- and chlorite-rich mica schists. These schists contain sporadic cordierite knobs up to 5 cm in diameter. Judged on the basis of local boulder observations, the schists are closely associated with cordierite-bearing amphibole gneisses. These schists are situated in the southern extension of the zone of cordierite-bearing schists described by Väyrynen (1928, p. 118) from Törisevänpuro, north of the village of Puolanka.

Psammites of unknown age

In the environs of Tulijärvi and in the area between Törmänmäki and Kaitavaara, there occur psammites that cannot for sure be correlated with any of the formations described.

The psammites south of Tulijärvi are more or less arkositic quartzites. They might belong to the Arkosite Formation.

The psammites east of the Dolomite-Phyllite Formation near Tulijärvi are reddish, laminated quartzite. The psammites east of Törmänmäki and west of Iso Kaitanen and the quartzite of Varsavaara are of the same type. Structural interpretations suggest that at least some of these psammites may overlie the Dolomite-Phyllite Formation.

Metadiabases and metagabbros of unknown age

In the basement complex area, there are small metagabbro and ultrabasic rock intrusions the relationships of which with the surrounding rocks are unknown. Probably some of them are of Prekarelidic and some of Karelidic age.

At Hepokönkäs, the lowermost members of the Arkosite Formation are penetrated by coarse-grained, slightly differentiated metadiabase. In the Liejeenjoki valley, there exist within the Arkosite Formation separate metadiabase and albitite exposures. Southeast of the Vesala farm, arkosites and impure quartzites of the Arkosite Formation are penetrated by basic and intermediate metadiabases and albitites. Fragments of these supracrustal rocks commonly occur in the latter rocks.

The metadiabase sill overlying Quartzite Formation I at Hietavaara is differentiated. The core is composed of reddish, albite-rich metadiabase and the margins of dark green, hornblende-rich metadiabase. Small, separate exposures of the albite-rich metadiabase also occur in many other places at Hietavaara, Kaitavaara and Latolanvaara.

Closely associated with the dolomite occurrence of Kaitavaara are exposed biotite- and carbonate-rich metadiabases that Wilkman (1931) termed kersantite.

Pegmatite granite

In the Vihajärvi subarea, west of Suksiharju, the staurolite-mica schists are penetrated by relative thin pegmatite veins. In addition, there occur two pegmatite granite lenses about 50 m thick. The lenses are concordant with the foliation.

The pegmatite granite is reddish. The main mineral constituents are microcline, plagioclase, quartz, biotite and muscovite. The granite contains mica schist fragments (Fig. 22). The mica schists commonly contain an abundance of black tourmaline at their contacts against the pegmatite granite.

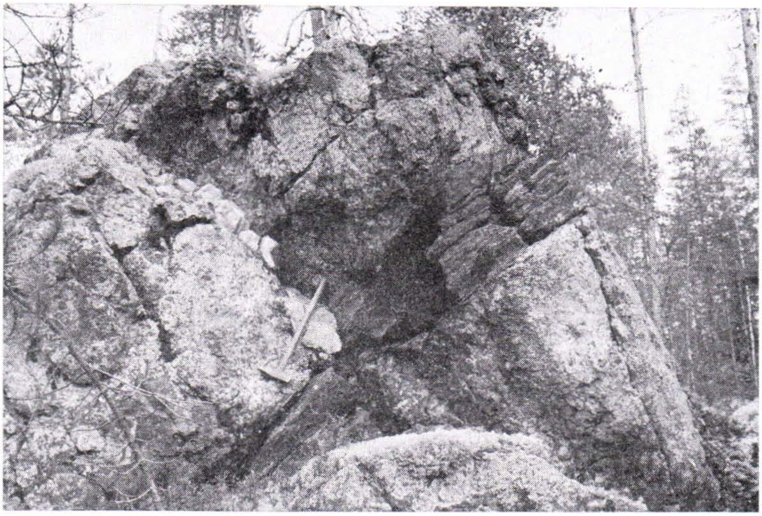

FIG. 22. Mica schist fragment in pegmatite granite, southwest of Suksiharju. Seen from the southwest.

STRUCTURE

When the structure of the South Puolanka area was analyzed, the scantiness and the uneven distribution of the outcrops were compensated by the use of the geophysical data (Maps 4—8, Appendix 1) together with the geologic field observations. In this respect, the ground-geophysical measurements (Maps 6—8) played a decisive role. They gave a highly detailed picture of the structure in the northern parts of the study area.

Lineations and minor fold axes [1])

In the vicinity of Hietajärvi, the shear lineation resulting from the intersection of bedding and foliation planes is about 190—210°, 15—40° (Fig. 23). The minor fold axes in the adjacent basement gneisses have about the same strike and plunge, suggesting that the basement area has undergone rheomorphism.

In other places, especially the vicinity of the lakes of Salmijärvi, the plunge of the linear elements is generally 70—90°. The steep plunge suggests that these elements are genetically related to shear folding.

[1]) In the text, the linear elements are marked by two numbers or two groups of numbers, of which the first indicates the compass reading of the direction and the second the dip of the element. The plane elements are marked in the same manner. The direction of their dip is indicated by the main points of the compass.

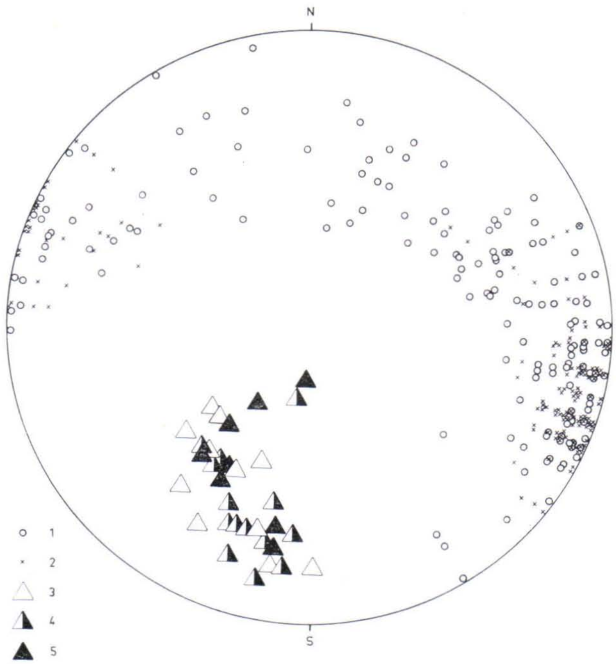

FIG. 23. Structural elements of the relatively autochthonous parts (Pihlajavaara—Pahkavaara—Vesala and Kaitavaara—Hietavaara—Olkala) of the supracrustal rock formations in the Hietajärvi subarea: 1) Bedding (131 observations), 2) foliation (124 obs.), 3) mineral elongation (11 obs.), 4) shear lineation (14 obs.), 5) axis of minor fold (8 obs.). Schmidt net, lower hemisphere.

Folds and bedding

According to the bedding (Fig. 23) and top observations (Map 1), the Hietajärvi district forms an anticlinorium, which is slightly overturned towards the east. In the south, its regional axis is about 200°, 20°. Because the formations do not seem to have thickened or thinned during the folding, the Hietajärvi anticlinorium is considered to be a concentric fold. Seen in the light of the mapping work done by the author on the north side of the area of Map 1, the plunge of the axis must be towards the north at Hepokängäs. Thus the area between Väyrylänkylä and Kotila, where the basement complex is at its broadest, represents a culmination point. The western flank and the crest of the Hietajärvi anticlinorium are evidently composed of anticlines and synclines. These folds may be large drag folds, the axes of which coincide with the regional axis.

At Hulmivaara, the bedding in the psammites is exceptional. Here the beds dip towards the north, against the basement. This fact suggests overthrusts (p. 42).

On the basis of the ground-geophysical data (Maps 6—8) and the top determinations, the structure of the Salmijärvi area is interpreted to be a synclinorium (Map 1, profile A—B). Owing to the greater plasticity of the prevailing rocks, the amplitude of the folds is here noticeably shorter than in the Hietajärvi anticlinorium. As the different rock units can be traced by geophysical means over the length of several kilometers, the axes of the folds must be almost horizontal. Near Seppola, the bedding in the Seppola Tuffite is about 280°, 60—30°N. Because the beds are not overturned, the fold axis must here have a northern plunge. The Honkala-Seppola line therefore seems to be a minor culmination zone.

According to structural and lithological analogies with the Salmijärvi district the Poikkijärvi district must be a western margin of a synclinorium plunging to the south. The lake of Poikkijärvi itself is situated in a minor syncline, the axis of which is about 190°, 50—60°. The relatively steep plunge of the fold axis indicates that the area underwent a later shear folding.

Within the Mäntykangas Quartzite, the prevailing bedding is 0—20°, 90°—60°W. The tops face east at Somervaara and in the western part of Jalka-Aho, but towards the west in Mäntykangas and west of Seppola. If the top observation made of the Seppola Tuffite is taken into account, this variation in the directions of the tops cannot be explained by simple overfolding, but we must consider the part of the formation from Mäntykangas to the eastern margin of Jalka-Aho to be relatively more allochthonous.

The structure of the Vihajärvi district is complicated. But it is evident that the Arkosite blocks of Ahvenvaara, Akanvaara and Suksiharju are remnants of the core of an anticlinorium that is the counterpart of the Hietajärvi anticlinorium. Also the Vihajärvi anticlinorium is slightly overturned towards the east.

The bedding in the Staurolite-Mica Schist Formation is regularly overturned. Thus the formation represents the lower flank of a recumbent anticline. The dip of the axial plane of the anticline is about 40—50°SW. The strike of the axial plane at Kapustankangas is about 290°. Towards the north, it turns until it achieves the direction 340—360° in the area west of Vihajärvi. Also in the part of Phyllite I northeast of Suksiharju, the beds are overturned and have a northwestern strike.

At Hongikkokangas, the bedding in Phyllite II, where not destroyed by shearing, is subhorizontal. Southwest of Hongikkokangas, just outside Map 1, the bedding in Quartzite II is 0—5°, 55°W. A top observation made from a sericite quartzite with graded bedding indicates that the beds are overturned here, too.

Foliations, faults, and lineaments

Foliations

The prevailing foliation is 20—30°, 90—75°. The western dips are most common. Excluding the northern part of the Vihajärvi district, the whole study area is transversed by this foliation, which at least in the Hietajärvi district seems to be an axial plane schistosity. Another possibility is that it is a regional shear foliation that developed during the second deformation stage (p. 47).

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In places (e.g., west of Honkala), this regional foliation is seen to be caught by shear and fault zones, the strikes of which deviate slightly from 20°.

West of Suksiharju, a foliation of 45°, 35—60°NW is predominant (Fig. 22). The low dip of the foliation suggests that the foliation is caused by thrust movements.

In the eastern flank of the Hietajärvi anticlinorium, there are two observations of a foliation striking 320° and dipping 50—70° to the southwest.

Faults and lineaments

The South Puolanka area is intensively faulted. The faulting is indicated by geophysical data (Appendix I, Maps 4—8) and also, especially in the parts composed mainly of more competent rock units, by lineaments (Map 3). Moreover, the lithologic evidence bears witness to faulting (Map 1). The complicated fault pattern can be divided into three main sets. The first set is composed of a couple of sinistral wrench faults and thrust faults, the second mainly of dextral shear faults[1]) and thrusts, and the third of N—S striking faults.

The faults of the first set are predominant in the Hietajärvi district and in the northern parts of the districts of Salmijärvi and Vihajärvi. The sinistral wrench faults strike 290—310°. The strong maximum at 295° in the lineament rose diagrams Nos. 1 and 4 (Map 3) is exaggerated by the clearing of the continental ice sheet. A wrench fault of this kind produced the rapids of Hepokönġäs. Here the horizontal component of the displacement is about 150 m long. The thrust faults striking about 0—30° are almost perpendicular to the wrench faults. One major thrust zone trends from Salmijärvi to the Heinijoki valley. Here the schists of the Arkosite Formation have been displaced over Quartzite Formation III (Map 1). Other thrust zones are situated in the vicinities of the lakes of Vihajärvi, Hietajärvi and Hulmijärvi. The dip of these thrusts is evidently steep, probably 60—80°NW.

The faults of the second set are prominent in the Vihajärvi district and especially in the zone of Jalka-Aho—Mäntykangas—Somervaara—Voipuanjärvi (Maps 1 and 2). The shear faults are mainly dextral. They are curved, striking about 45° at their southern ends. At their northern ends, the shear faults curve more and more towards the north and the shear movements seem to change to relatively low-angle thrusts. The curving of the shear faults is due to the resistant nature of the Salmijärvi district. The major shear faults of this set are those situated in the vicinity of Vihajärvi (Map 2). The horizontal displacements between the arkosite blocks of Suksiharju and Akanvaara are here of the order of 1 000 m (Map 1). The western margin of the Vihajärvi subarea is composed of the major thrusts of the second fault set (Map 1, profile C—D). The shear faults and thrusts near Iso Kaitanen and Varsavaara also belong to this set of faults. The sinistrality of the shear faults is due to the differences of competence between the Hietajärvi and Poikkijärvi districts.

[1]) A strike-slip fault at more or less acute angle to applied force

The lineaments of the eastern and middle parts of the present area, with a strike of about 20° (Map 3, diagram 2 and 3), are due to the prevailing foliation and the thrusts of the first fault set. In the western parts, the lineaments striking 30—40° (Map 3, diagram No. 1) are mainly caused by the shear faults of the second fault set. The lineaments striking 325° may be genetically associated with the thrusts of the same fault set.

The whole South Puolanka area, especially the vicinity of Väyrylänkylä (Map 3, diagram No. 2), is characterized by the lineaments striking N—S. Drillings have revealed that these lineaments are associated with strong brecciation and faulting. The nature of the faults is unknown. They are either normal faults or dextral shear faults. The author is more disposed to accept the latter possibility.

OROGENIC DEVELOPMENT OF THE KARELIDIC BELT IN THE SOUTH PUOLANKA AREA

Depositional history

Although the dimensions of the South Puolanka area are relatively small, both close-cratonic (miogeosynclinal) and flysch sediment associations occur within the area, being due to intensive lateral compression and overthrusting. Thus when reading this chapter, one should comprehend that the metasediments now seen compressed within a relatively small area have primarly been spread over a zone scores or even hundreds of kilometers wide. The former association is composed of the eastern psammite lithosome (Arkosite Formation, Quartzite I, Quartzite II, Quartzite III, Mäntykangas and Dolomite-Phyllite Formation) and the latter of the western pelite lithosome (Phyllite I and II, Garnet-Mica Schist and Staurolite-Mica Schist). A change from the psammite lithosome to the pelite lithosome is represented in the lateral direction and in the vertical direction by the Mäntykangas Quartzite and the Dolomite-Phyllite Formations, respectively.

The mineral compositions of the psammites (Table 2, p. 17) and the clasts in the psephites (Table 1, p. 14) clearly suggest that the sedimentary material of the psammite lithosome have been derived from acidic rocks. The Prekarelidic basement in the east and north is the most evident source of this material. As the source area of the sediment material of the pelite lithosome, we must assume the existence of an island arc belt or eugeosynclinal ridge (cf. Aubouin 1965) situated farther west.

Graded bedding and cross-bedding observations made of the Arkosite Formation prove that the Karelidic sedmentation in the South Puolanka area occurred from the very beginning into water. The psephites and tuffites (Honkala Arkosite, Honkala Conglomerate, and Honkala Tuffite Members) and the alternation of pelite and psammite members within both the Arkosite Formation and Quartzite I (pp. 24—26) clearly indicate that the sedimentation conditions in this initial stage were unstable.

The contact relationships of the intermembers in Quartzite I bear evidence sometimes of regression, sometimes of transgression (p. 25). Thus the bottom of the sedimentation basin must have oscillated intensively during this stage. The sharp lower contact of the Quartzite I (p. 25) indicates that there must have also occurred fault movements. The sediments of these two lowermost formations thus seem to have accumulated into a marginal basin (miogeosynclinal basin) caused or at least accompanied by faulting. Along the faults there took place extrusions of basic volcanic material (metavolcanics-metadiabase association). As the maturity of the schists increases from the bottom upwards (p. 24), this stage of sedimentation was in its entirety regressive. The Arkosite Formation is to be compared with the wedge arkosite association of Krumbein and Sloss (1963, pp. 559—563). A connection with high-angle faults, a relatively great thickness and the occurrence of volcanics together with arkosites are typical of this association.

The deposition of the Arkosite Formation and Quartzite I was followed by a long period of quiet sedimentation during which Quartzite II and III accumulated. The more immature schists in Quartzite II and in the southern parts of Quartzite III prove that probably during this stage the depth of the water was greater in the southern than in the northern parts of the basin. The appearance of pelitic and calcareous interbeds in the southern and western parts of Quartzite III (p. 27) indicates that a transgression had spread towards the north and east.

After the deposition of the Arkosite Formation, the course of sedimentation in the Vihajärvi district deviated from that of the eastern parts just described. A striking feature of the Vihajärvi area is the alternation of pelitic and psammitic schists. This alternation appears both on the scale of interbeds — in the upper parts of the Arkosite Formation (p. 24), in the Mäntykangas Quartzite (pp. 32-34), in the Phyllite II (p. 35) and in the Staurolite-Mica Schist (Fig. 21) — and on the scale of formations (Fig. 3). The alternation of psammitic and pelitic beds is one of the most distinctive features of the flysch (Aubouin 1965, pp. 131—132). As the position of the Vihajärvi district is also most internal in the study area, the conclusion is inescapable that the rocks of the Vihajärvi area are representatives of the Karelidic flysch facies. The occurrence of orthoquartzites in this association (p. 34) indicates that the island arc belt had been situated relatively close to the foreland.

In view of the absence of the Mäntykangas conglomerate from the psammites of Hietajärvi district, it must be assumed that a geanticline (a miogeosynclinal ridge) rose between the foreland and the island arc belt. When the geanticline had risen above the sea level, the psephitic and psammitic material derived from the geanticline itself were mixed with the extracratonic pelitic material on the western flanks of the geanticline (p. 33, sections in Jalka-Aho and Mäntykangas) and with the relatively mature cratonic psammites continously deposited into the marginal basin east of the geanticline (p. 34, section in Somervaara). Gradually, the sedimentation conditions changed in this basin into those of a restricted marginal basin (Krumbein and Sloss 1965, p. 507) and the Dolomite-Phyllite began to be deposited. In the basin west of the geanticline (eugeosynclinal furrow), the flysch continued to accumulate. Later on, the flysch overpassed the geanticline and reached the marginal basin. During this stage, the sediments of the uppermost parts of Phyllite II were deposited upon the Dolomite-Phyllite. Phyllite II of the Salmijärvi and Poikkijärvi districts is thus the latest flysch of the South Puolanka area.

The metagabbro-ultrabasic rock association of the Vihajärvi district (p. 37) shows gravitative differentation and has the most internal position in the study area. Thus we must consider these rocks as typical representatives of the initial magmatism in the sense of Stille and Aubouin (Aubouin 1965, p. 23 and pp. 149—159).

The early Karelidic magmatism represented by the metavolcanics and metadiabases of the Hietajärvi and Salmijärvi districts seems to be somewhat antiactualistic. This magmatism is wide-spread within the whole Karelidic belt (Eskola 1925, Väyrynen 1928, Härme 1949, Paakkola 1971, Nykänen 1971 a, Piispanen 1972 and Silvennoinen 1972). The occurrence of the rocks of this stage of magmatism in conjunction with the true quartzites of the evolutionary phase of the Karelidic cycle of sedimentation is probably due to the fact that the crust was thinner during the Precambrian than it is today and hence more easily pierced by fissures, as proposed by Mehnert (1969, p. 518).

Tectonic history

In the preceding chapter it was stated that the Karelidic sedimentation began with deposition into a marginal basin that had originated through faulting. The stress field, which caused this faulting, can no longer be determined. If we apply the plate tectonic model, it is natural to connect this faulting and the attendant early Karelidic magmatism with the continental intraplate magmatism. The latter magmatism is assumed to have been caused by regional tension (Sawkins 1972, p. 382).

The diversified fault and lineament systems (pp. 42—43, Maps 2 and 3) indicate that the tectonic history of the Karelidic belt in the South Puolanka area has been a complicated one. The fact that the fold structures in the main eastern parts of the area are overturned towards the east (p. 40) and, on the other hand, that the schist beds north of Suksiharju in the Vihajärvi district are overturned to the northeast (p. 41, Map 1) justify dividing the traceable tectonic history of the present area into two main stages. The first deformational stage is characterized by concentric folding and overthrusting and the second one by shear folding and low-angle thrusts.

First deformational stage

In view of the regional fold axis (p. 40) and the general principles of folding and faulting (de Sitter 1956), the greatest principal stress acted subhorizontally during this first stage in a roughly W—E direction. The smallest principal stress was exerted perpendicular to the surface of the crust. The orientation of this stress field is shown in Fig. 24. The apparent stress field indicated by heavy lines has been drawn on the

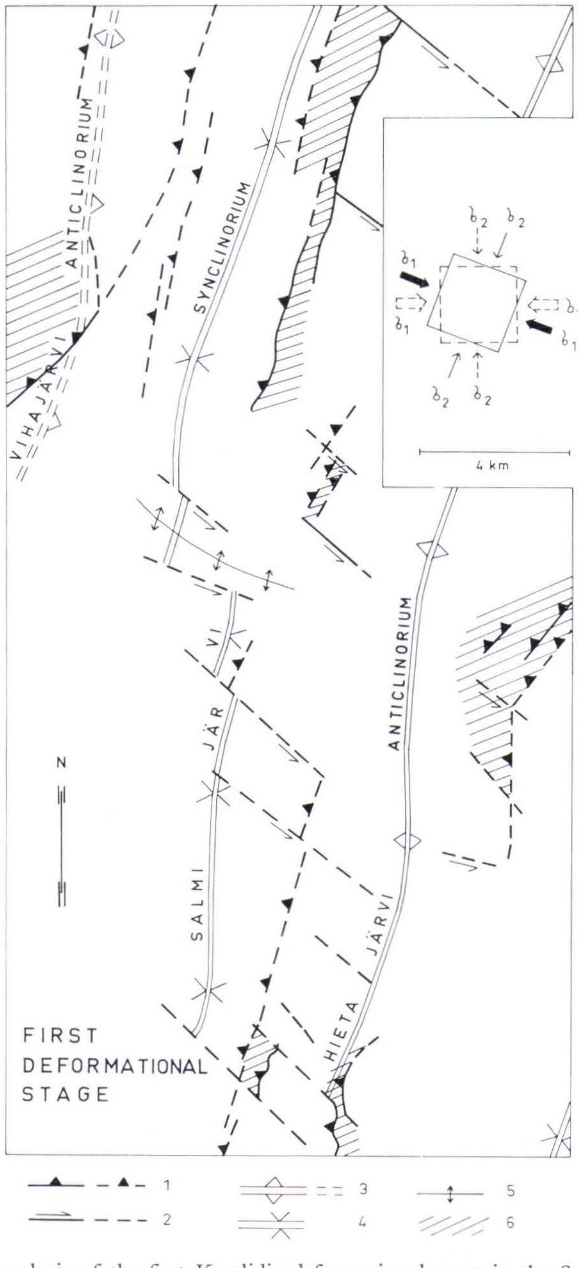

FIG. 24. Dynamic analysis of the first Karelidic deformational stage in the South Puolanka area. 1) Thrust zones, indicated by dashes where inferred. 2) Normal cross fault, indicated by dashes where inferred. 3) Trace of axial plane of anticlinorium, indicated by dashes where inferred. 4) Trace of axial plane of synclinorium. 5) Culmination zone. 6) Allochthon.
The apparent orientation of the stress field is shown by heavy lines and the probable primary orientation by dashes.

basis of the present position of the fold and fault structures. Primarily the trend of the fold axis must have been closer to the general N—S trend of the Kainuan schist belt (Appendix I). Thus the stress field shown by dashes is nearer to the truth.

The rise of the geanticline (p. 44) was probably the very first deformation caused by this primary stress field.

When the greatest principal stress increased, the concentric folding began and finally the shear stress was relaxed by overfolding, thrusts and wedges. It was during this deformational stage, that the Hietajärvi and Vihajärvi anticlinoriums, the Salmijärvi synclinorium and the thrusts trending approxinately N—S (p. 42) originated. The part of the Arkosite Formation west of Pihlajavaara (Map 1) is a representative of the roots of these thrusts. The foliation with the exceptional flat dip in the vicinity of Suksiharju (p. 42) is connected with these thrusts. The intrusion of the pegmatite granite following this foliation (Fig. 22) had begun probably as early as this stage.

In addition to the thrusts, shear movements also occurred along the normal cross faults, of which the Hepokörgäs fault (p. 42) is an example.

Second deformational stage

Evidently owing to the pilement of the nappes and recumbent folds formed during the first deformational stage the smallest principal stress changed its orientation and began to act in the N—S direction (Fig. 25). This change in orientation of the stress field caused shear folding in a nearly vertical plane striking about NE—SW. The shear folding wrenched the originally ca. N—S trend of the Karelidic schists of the whole Puolanka area to its present more easterly position (Appendix I, stress fields in Fig. 24).

The shear faulting of the Vihajärvi anticlinorium into the arkosite blocks of Suksiharju, Akanvaara and Ahvenvaara can be verified by both lithological and structural evidence (Map 1) as having taken place at this stage.

The border zone between the Vihajärvi and Salmijärvi districts seems to be characterized by shear faults (Map 1). This interpretation is based only on the geophysical data (Maps 4—8). The block-like nature of this border zone is most evident in the parts east of Vihajärvi (Maps 6 and 7).

The Staurolite-Mica Schist and the plate west of Hongikkokangas, including rocks of Dolomite-Phyllite Formation, are representatives of facies strange to the Vihajärvi district. They must have been overthrust from somewhere in the southwest outside the mapped area.

Instead of faulting into blocks, the areas occupied by more plastic schists were shear-folded along nearly vertical axes. The Poikkijärvi district (Map 1) is an example of this kind of deformation.

The relative age of the N—S-striking faults of Väyrylänkylä (p. 43) is unknown. Probably they represent an earlier faulting and the basement wedge bordered by them at Väyrylänkylä may represent an earlier thrust of this second deformational stage.

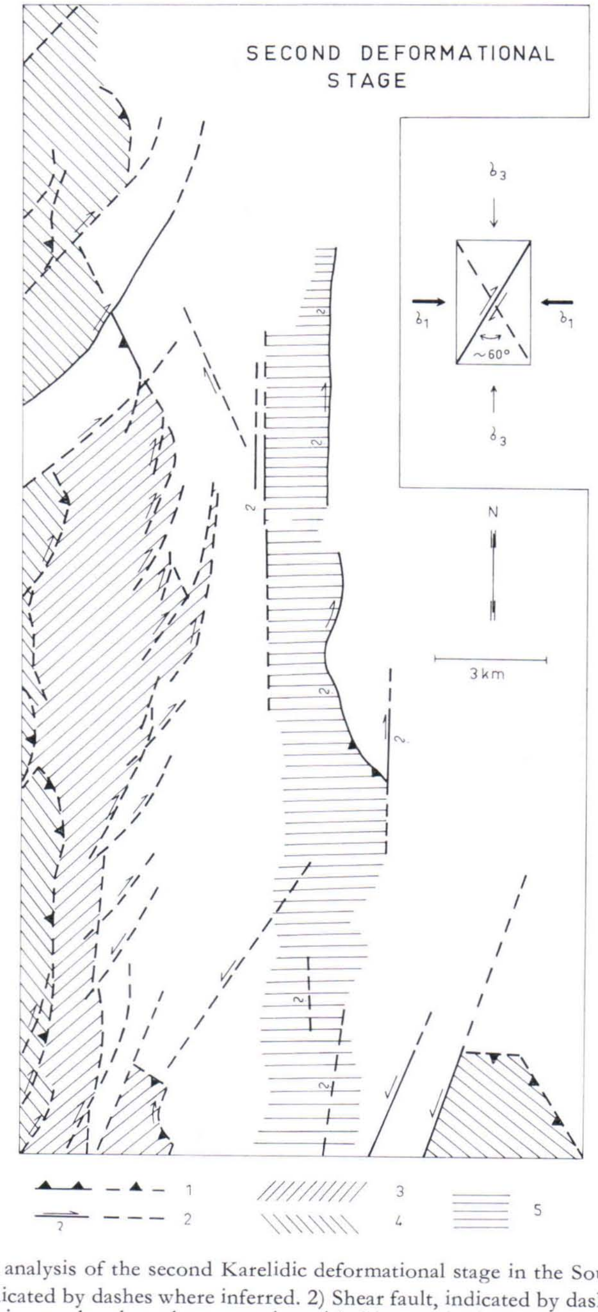

FIG. 25. Dynamic analysis of the second Karelidic deformational stage in the South Puolanka area. 1) Thrust zone, indicated by dashes where inferred. 2) Shear fault, indicated by dashes where inferred; provided with question marks where the connection with this stage is highly questionable. 3) Relatively slightly allochthonous units. 4) Relatively more allochthonous units. 5) Basement wedge of uncertain age.

The main difference between the first and second deformational stages is that in the former the extension occurs vertically, whereas in the latter it runs mainly along the horizontal plane.

CORRELATION

Lithostratigraphic correlation

The presence of the kaolin weathering crust that separates the Sariolan and Kainuan (Väyrynen 1954) or the Sariolan and Jatulian formations (Negrutsa 1965) has not been verified in the South Puolanka area. No signs have been seen, either, of the hiatus reported by Eskola (1948 a, p. 155) to separate the Sariolan rocks from the Jatulian quartzites. The lithology of the Arkosite Formation is, however, very much like the rocks described from the southern parts of the Karelidic belt and included in the Sariolan formation (Eskola 1919, Väyrynen 1938, Sinitsyn 1969, Nykänen 1971 a and 1971 b).

The association of the sericite phyllites with the quartzites and orthoquartzites, which characterizes Quartzite I and the lower northern parts of Quartzite III, is the exact counterpart of the Jaurakka quartzite of Väyrynen (1928, 1954). The Mäntykangas Quartzite involves the western extensions of Quartzites I, II and III (Fig. 26). Thus the Mäntykangas conglomerate is correlative with the Jaurakka conglomerate as pointed out by Väyrynen (1954, p. 170). The more western parts of the Mäntykangas Quartzite with their thicker psephite members, biotite-rich pelite interbeds and more immature psammites are more likely to be correlated with the conglomerate-arkosite-mica schist association of Utajärvi (Mäkinen 1916, cf., also Väyrynen 1954, p. 211) and that of the Salahmi area (Savolahti 1965).

The monotony and lack of pelitic intercalations in the northern upper parts of Quartzite III are the only facts that in the present area tally with the description given by Väyrynen (1928, 1954) of the Kainuan quartzite. Contrary to Väyrynen's statements, also this quartzite is regularly cross-bedded. Thus the stratigraphic and lithologic descriptions of the Kainuan facies (Väyrynen 1933) are not valid in the South Puolanka area. To summarize the foregoing, it might be said that in the South Puolanka area the Sariolan sediments are overlain by Jaurakka facies and this again by Kainuan quartzite. This result deviates so decisively from the ideas of Väyrynen (p. 9) that it is recommended that the use of the names Kainuan and Jaurakka facies be abandoned. Also the Sariolan unit seems to need redefining (cf., Sinitsyn 1969).

The Marine Jatulian rocks are the only Jatulian unit readily recognized in the South Puolanka area (cf., Silvennoinen 1972, p. 43). The Seppola Tuffite and the Dolomite Members are readily correlated with the amphibole-limestone horizon in the Kuopio district (Preston 1954). The Salmijärvi Dolomite and the Salmijärvi

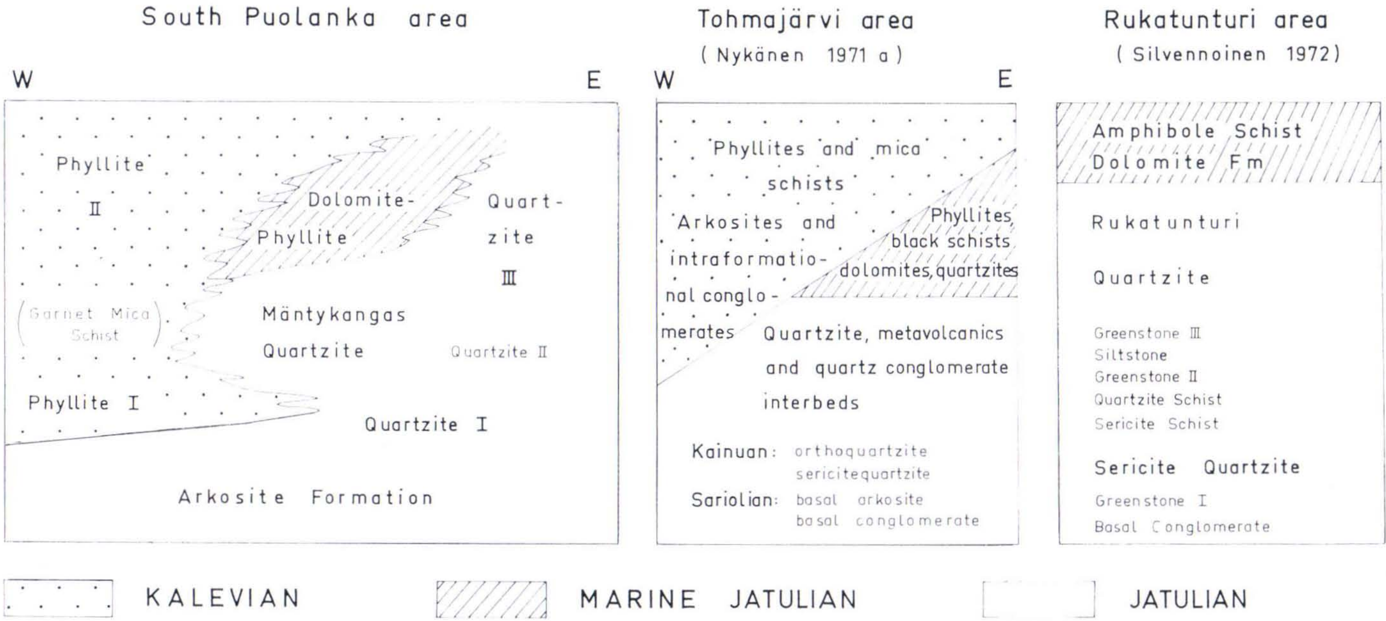

FIG. 26. A schematic comparison between the stratigraphy of some Karelidic schist areas in Finland. The vertical scale is quite approximate and the horizontal scale is wholly arbitrary. The facies changes in the W—E direction in the Tohmajärvi area have been modified by the present author.

Phyllite Members are in close correlation with the Marine Jatulian dolomites and phyllites in the Tohmajärvi area (Nykänen 1971 a) and with the Meso- and Neojatul in the Suojärvi area (Metzger 1924).

As a whole, the western pelitic lithosome (Phyllites I and II and Staurolite-Mica Schist) is a counterpart of the Kalevian mica schists and phyllites.

A reasonable classification (cf., Wegmann 1928, Väyrynen 1933, 1954 and Eskola 1963) of the Karelidic sequence in eastern Finland seems to be the following: the Jatulian Group (psammites of the pre-flysch stage), the Marine Jatulian Subgroup (dolomites and pelites of the restricted marginal basin or the miogeosynclinal furrow) and the Kalevian Group (flysch). The lateral change from the miogeosynclinal Jatulian sediments to the eugeosynclinal Kalevian sediments is marked by psephites (Mäntykangas conglomerate) in the South Puolanka area (Fig. 26). In this respect, the South Puolanka and Tohmajärvi areas resemble each other quite closely. The Jatulian, Marine Jatulian and miogeosynclinal Kalevian sediments are characterized by rocks of subcratonic volcanism (metavolcanics-metadiabase association) and the eugeosynclinal Kalevian sediments by those of initial magmatism (metagabbro-ultrabasic rock association).

The sedimentary environments and sedimentary tectonics of the Karelidic belt in northern Finland (Härme 1949, Nuutilainen 1968, Paakkola 1971, Perttunen 1971, Piispanen 1972 and Silvennoinen 1972) differ greatly from those in the South Puolanka area. That is why only rough correlations can be made with these Karelidic areas. Both in the Rukatunturi area, eastern Kuusamo, and in the South Puolanka area, the Marine Jatulian sediments are underlain by a formation of relatively pure quartzites (Rukatunturi Quartzite and Quartzite III), the thicknesses of which are many hundreds of meters. The beginning of the Karelidic sedimentation was less restless and more close-cratonic in the Rukatunturi (Silvennoinen 1972, pp. 41—43) than in the South Puolanka area. Moreover, the early Karelidic magmatism was here, as in northern Finland in general (Härme 1949, Paakkola 1971 and Piispanen 1972), more common than in the Puolanka area.

Time-stratigraphic correlation

No absolute age determination of the rocks in the South Puolanka area has yet been made. The determinations carried out by Asa (p. 10), however, give about the same time span (from 2 700—2 800 m.y. to about 1 900 m.y.) for the Svecokarelidic orogeny in Kainuu as previously worked out for other parts of Finland (Kouvo 1958).

According to Sakko's personal communication, a preliminary result obtained from a concordia plot for the zircon age of a metadiabase at Latolanvaara is 2 050 $\pm$50 m.y. Owing to the preliminary nature of the result, the exact time-stratigraphic correlations with the other Karelidic schist areas must be left to the future. In this connection, the reader is only referred to the papers of Sakko (1971) and Silvennoinen (1972).

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The microphotographs were taken by Mr. Erkki Halme. Dr. Jaakko Siivola helped me write the manuscript in English. Miss Marjo-Riitta Kujala drew the maps and figures. Dr. Maunu Härme read the manuscript and gave much useful advice. Mr. Paul Sjöblom, M. A., corrected the English of the manuscript.

In the summer of 1971, I visited the Rukatunturi and Kemi areas. My guides, whose clear ideas straightened out my thinking about the Karelidic geology, were Dr. Ahti Silvennoinen and Mr. Vesa Perttunen, M. A..

To all the persons mentioned and to all the rest of my colleagues who helped me, I wish to express my warmest thanks.

Especially do I want to thank Professor K. J. Neuvonen, my open-minded teacher, who through his inspiring teaching and personal example has strengthened my belief in the values of life.

In praise of the Lord, I should like to close this study with the words, which flashed through my mind last summer in Iceland while viewing the Thingvellir graben and the Almannagjá fracture: »For the mountains shall depart and the hills be removed; but my kindness shall not depart from thee, neither shall the covenant of my peace be removed, saith the Lord, who hath mercy on thee» (Isaiah 54 : 10).

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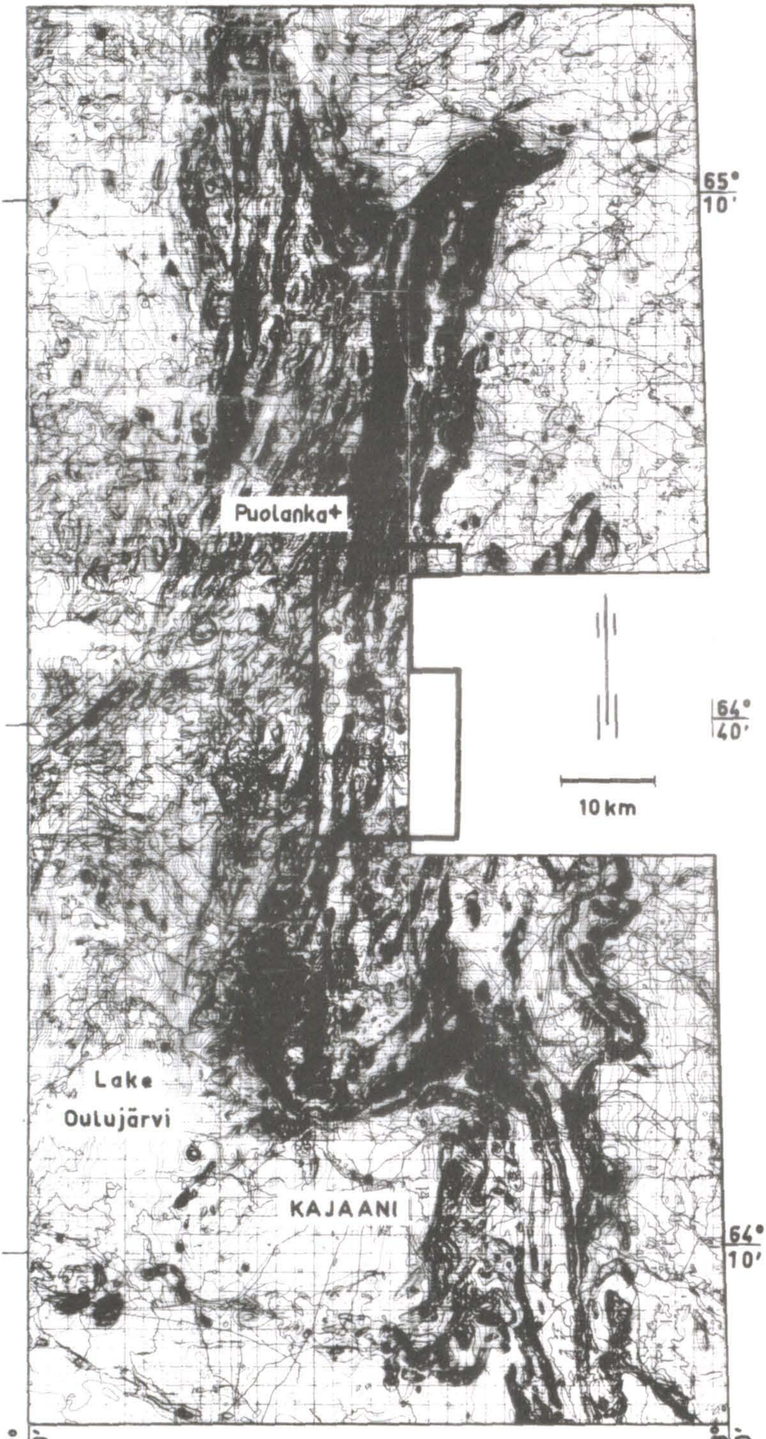
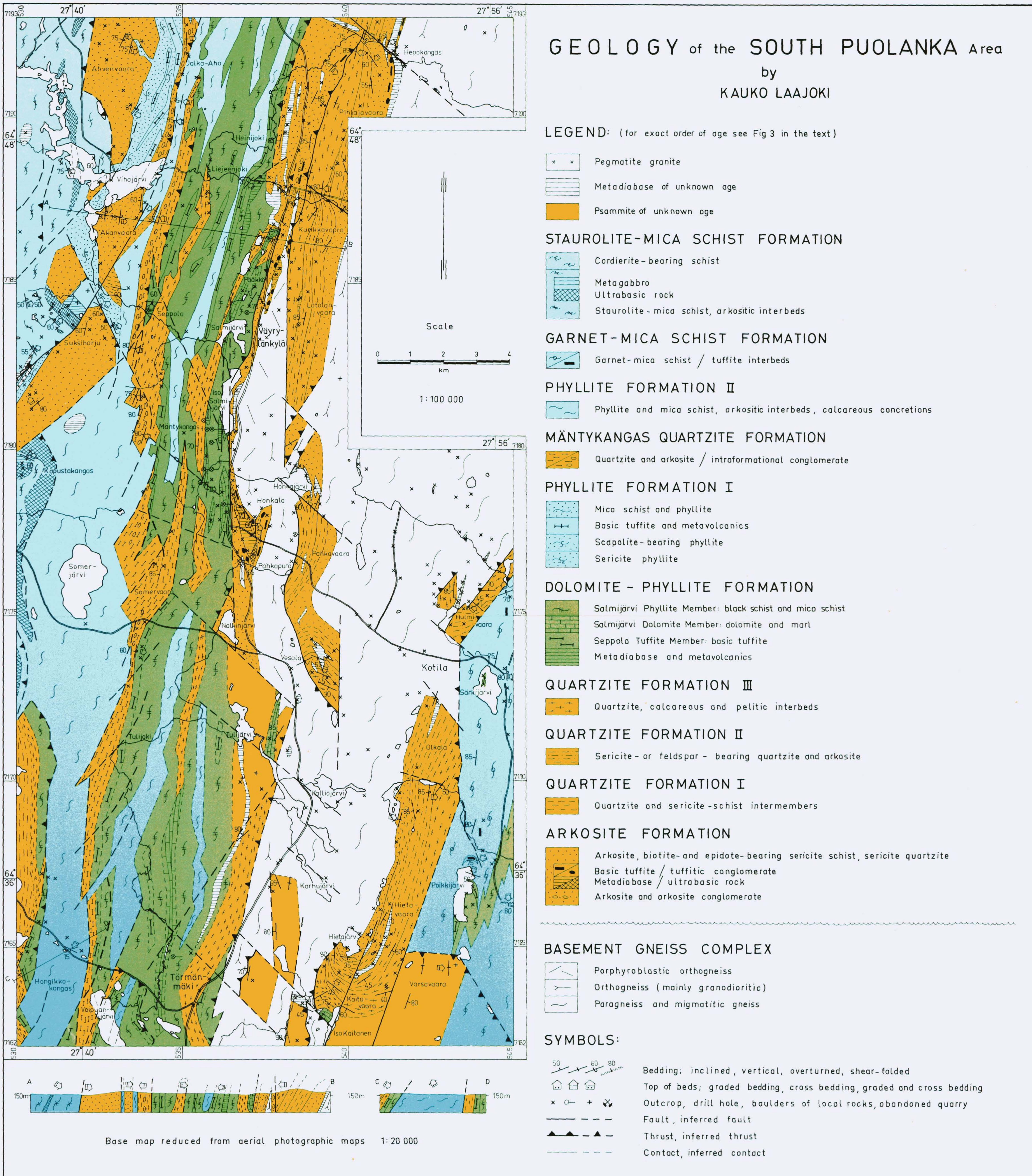
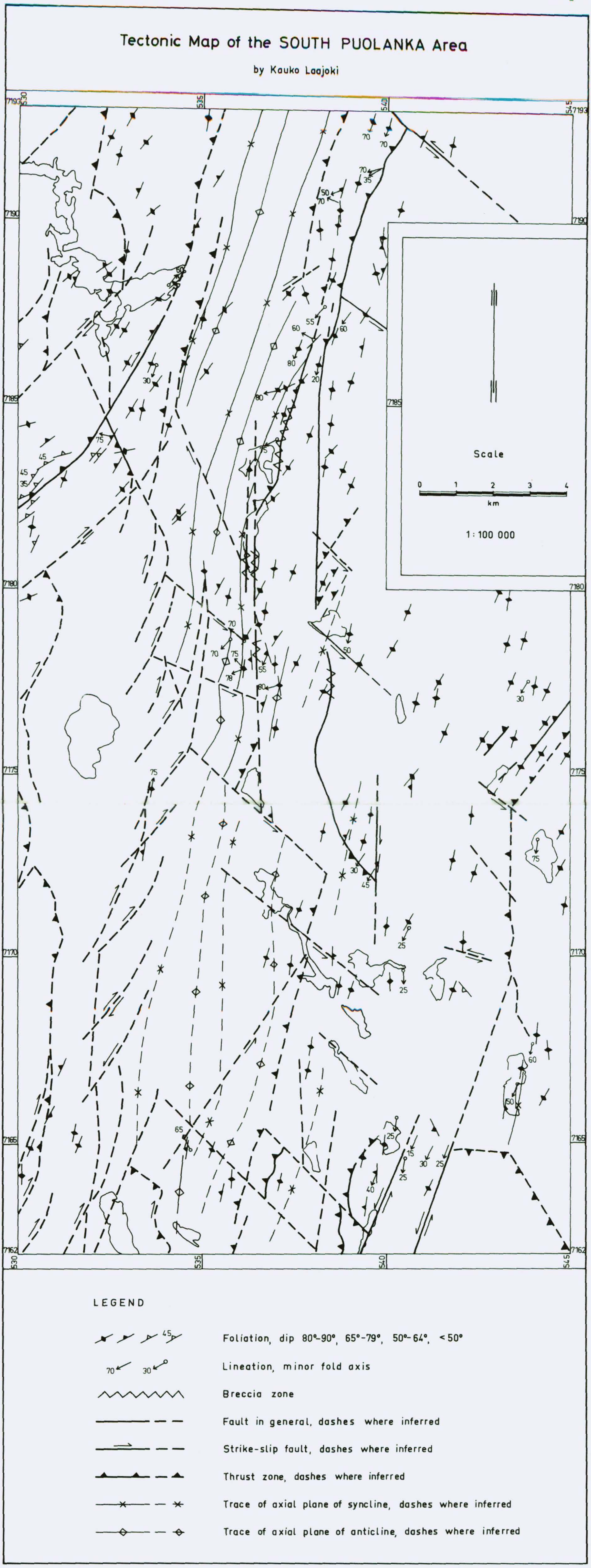
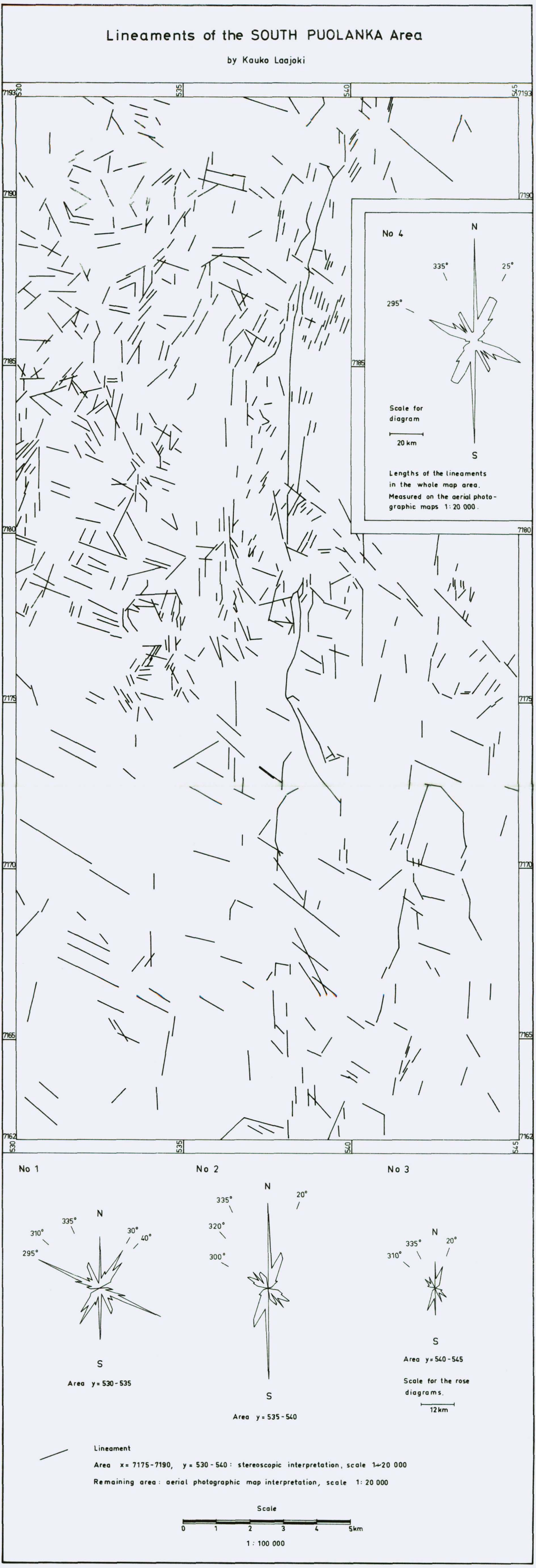
AEROMAGNETIC MAP (total field intensity) of the KAINUAN SCHIST BELT by Geological Survey of Finland




GEOLOGY of the SOUTH PUOLANKA Area
by
KAUKO LAAJOKI
LEGEND: (for exact order of age see Fig 3 in the text)
Pegmatite granite
Metadiabase of unknown age
Psammite of unknown age
STAUROLITE-MICA SCHIST FORMATION
Cordierite-bearing schist
Metagabbro
Ultrabasic rock
Staurolite-mica schist, arkositic interbeds
GARNET-MICA SCHIST FORMATION
Garnet-mica schist / tuffite interbeds
PHYLLITE FORMATION II
Phyllite and mica schist, arkositic interbeds, calcareous concretions
MÄNTYKANGAS QUARTZITE FORMATION
Quartzite and arkosite / intraformational conglomerate
PHYLLITE FORMATION I
Mica schist and phyllite
Basic tuffite and metavolcanics
Scapolite-bearing phyllite
Sericite phyllite
DOLOMITE-PHYLLITE FORMATION
Salmijärvi Phyllite Member: black schist and mica schist
Salmijärvi Dolomite Member: dolomite and marl
Seppola Tuffite Member: basic tuffite
Metadiabase and metavolcanics
QUARTZITE FORMATION III
Quartzite, calcareous and pelitic interbeds
QUARTZITE FORMATION II
Sericite- or feldspar-bearing quartzite and arkosite
QUARTZITE FORMATION I
Quartzite and sericite-schist intermembers
ARKOSITE FORMATION
Arkosite, biotite- and epidote-bearing sericite schist, sericite quartzite
Basic tuffite / tuffitic conglomerate
Metadiabase / ultrabasic rock
Arkosite and arkosite conglomerate
BASEMENT GNEISS COMPLEX
Porphyroblastic orthogneiss
Orthogneiss (mainly granodioritic)
Paragneiss and migmatitic gneiss
SYMBOLS:
Bedding; inclined, vertical, overturned, shear-folded
Top of beds; graded bedding, cross bedding, graded and cross bedding
Outcrop, drill hole, boulders of local rocks, abandoned quarry
Fault, inferred fault
Thrust, inferred thrust
Contact, inferred contact
Scale
1 : 100 000
km
Base map reduced from aerial photographic maps 1: 20 000

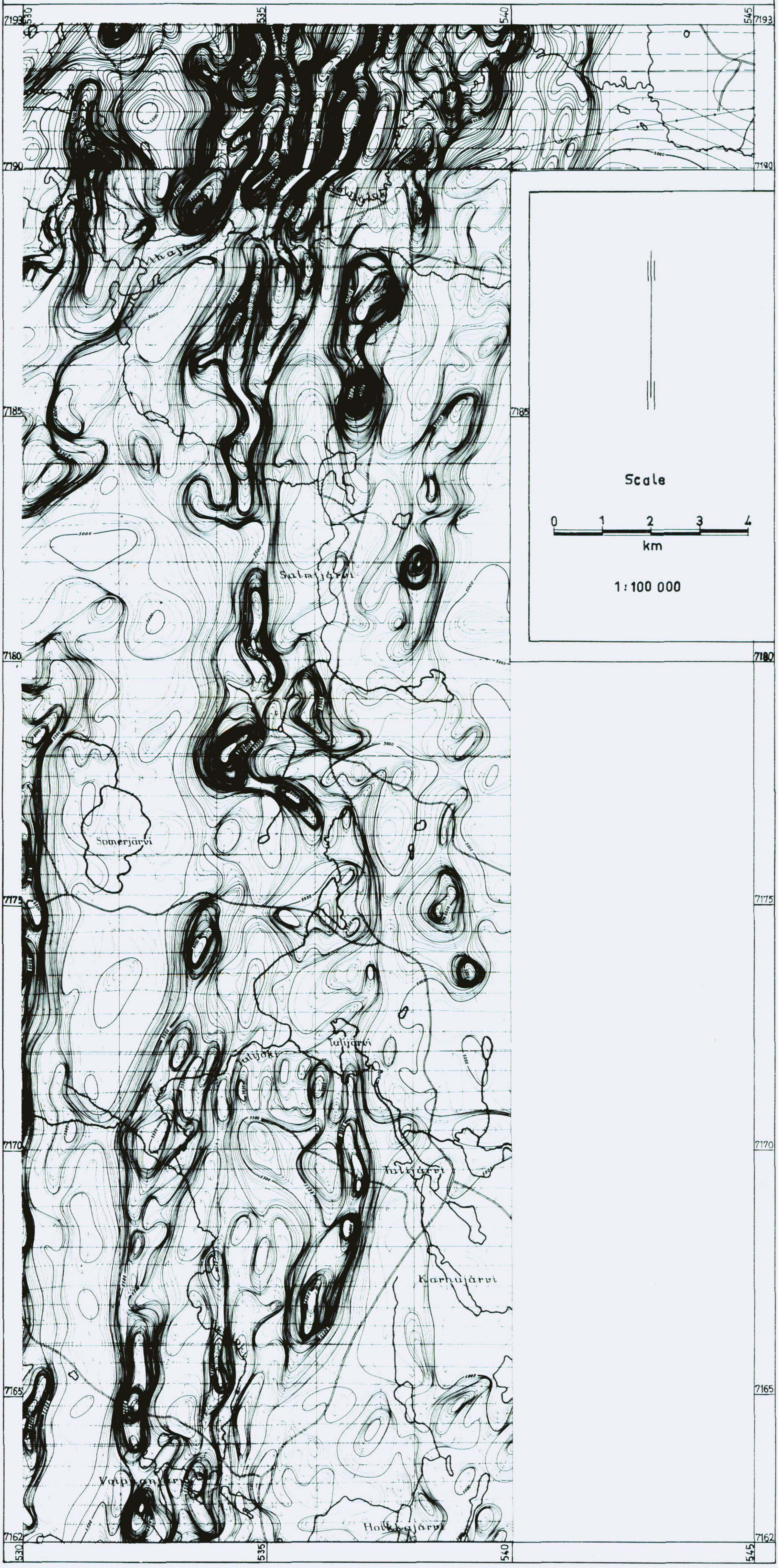

Tectonic Map of the SOUTH PUOLANKA Area
by Kauko Laajoki
Scale
0 1 2 3 4
km
1 : 100 000
LEGEND
Foliation, dip 80°-90°, 65°-79°, 50°-64°, < 50°
Lineation, minor fold axis
Breccia zone
Fault in general, dashes where inferred
Strike-slip fault, dashes where inferred
Thrust zone, dashes where inferred
Trace of axial plane of syncline, dashes where inferred
Trace of axial plane of anticline, dashes where inferred


Lineaments of the SOUTH PUOLANKA Area
by Kauko Laajoki
No 4
N
S
335°
25°
295°
Scale for diagram
20 km
Lengths of the lineaments in the whole map area. Measured on the aerial photographic maps 1: 20 000.
No 1
No 2
No 3
Area y = 530 - 535
Area y = 535 - 540
Area y = 540 - 545
Scale for the rose diagrams.
12 km
Lineament
Area x = 7175 - 7190, y = 530 - 540 : stereoscopic interpretation, scale 1:20 000
Remaining area : aerial photographic map interpretation, scale 1: 20 000
Scale
0 1 2 3 4 5km
1 : 100 000

Aeromagnetic Map of the SOUTH PUOLANKA Area

by

Geological Survey of Finland

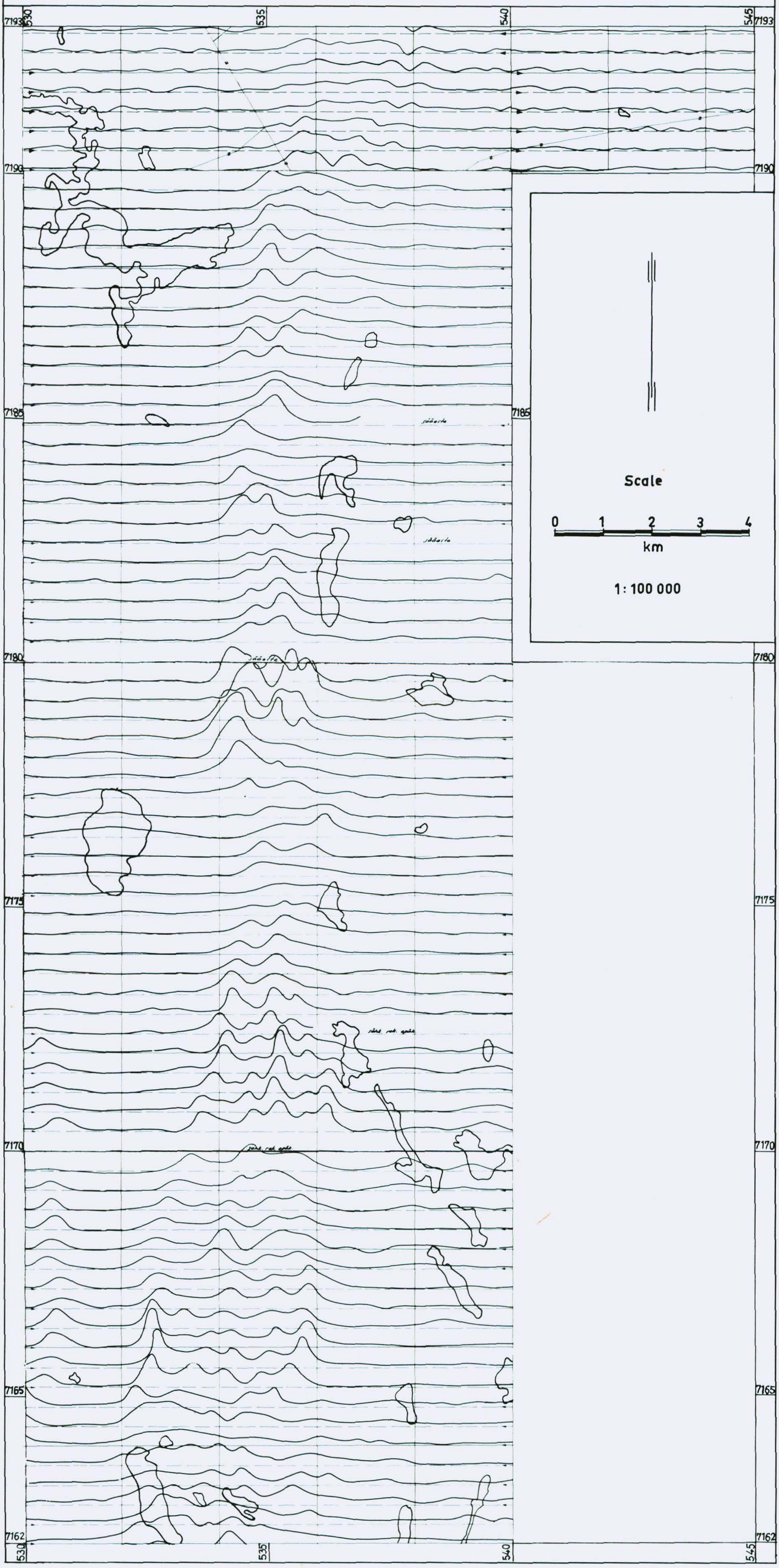


Base-map reduced from old preliminary aerial photographic maps scale 1:20000. Anomalies inaccurate in regard to coordinates. Total field intensity.

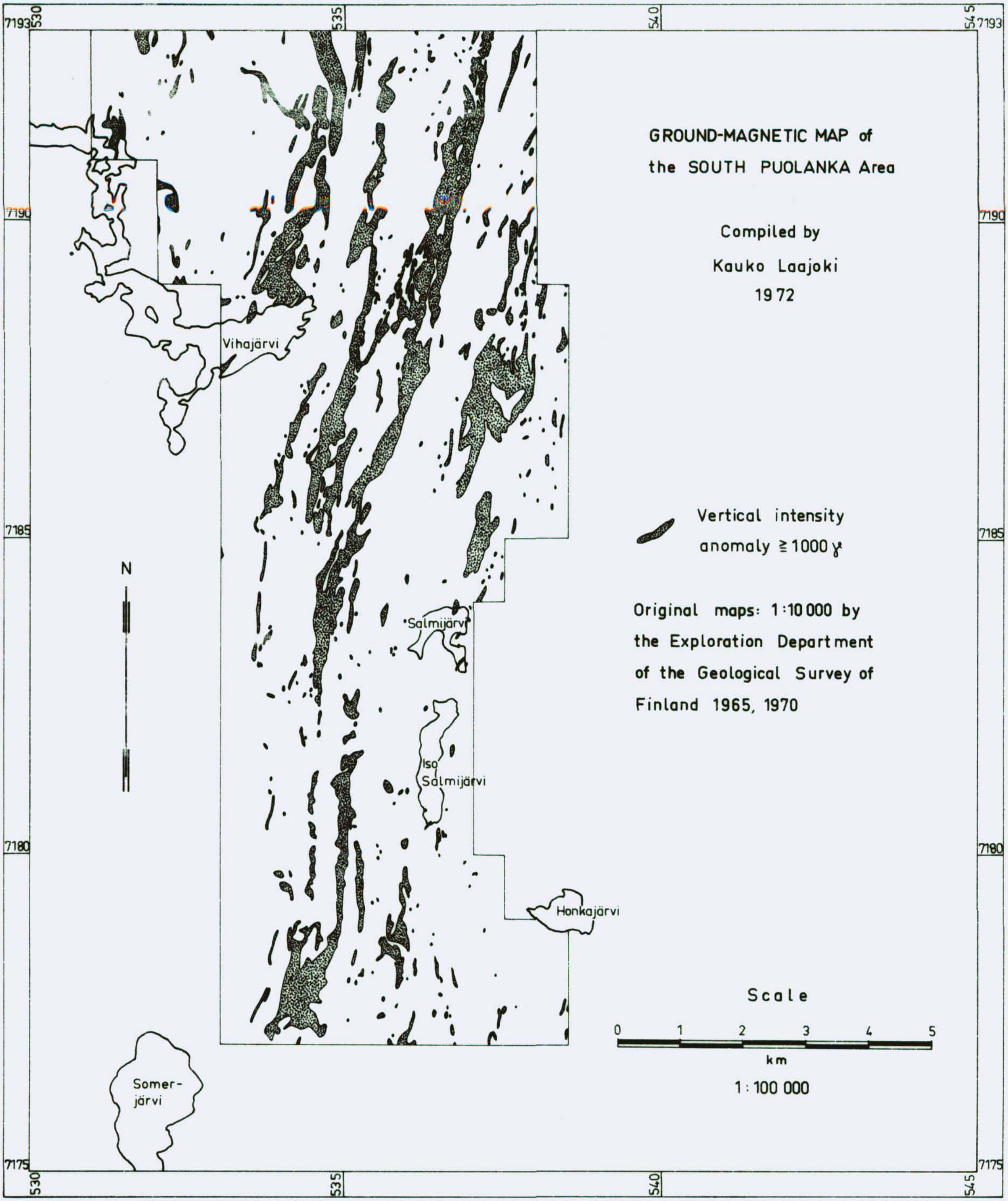
Aeroelectromagnetic Map of the SOUTH PUOLANKA Area

by

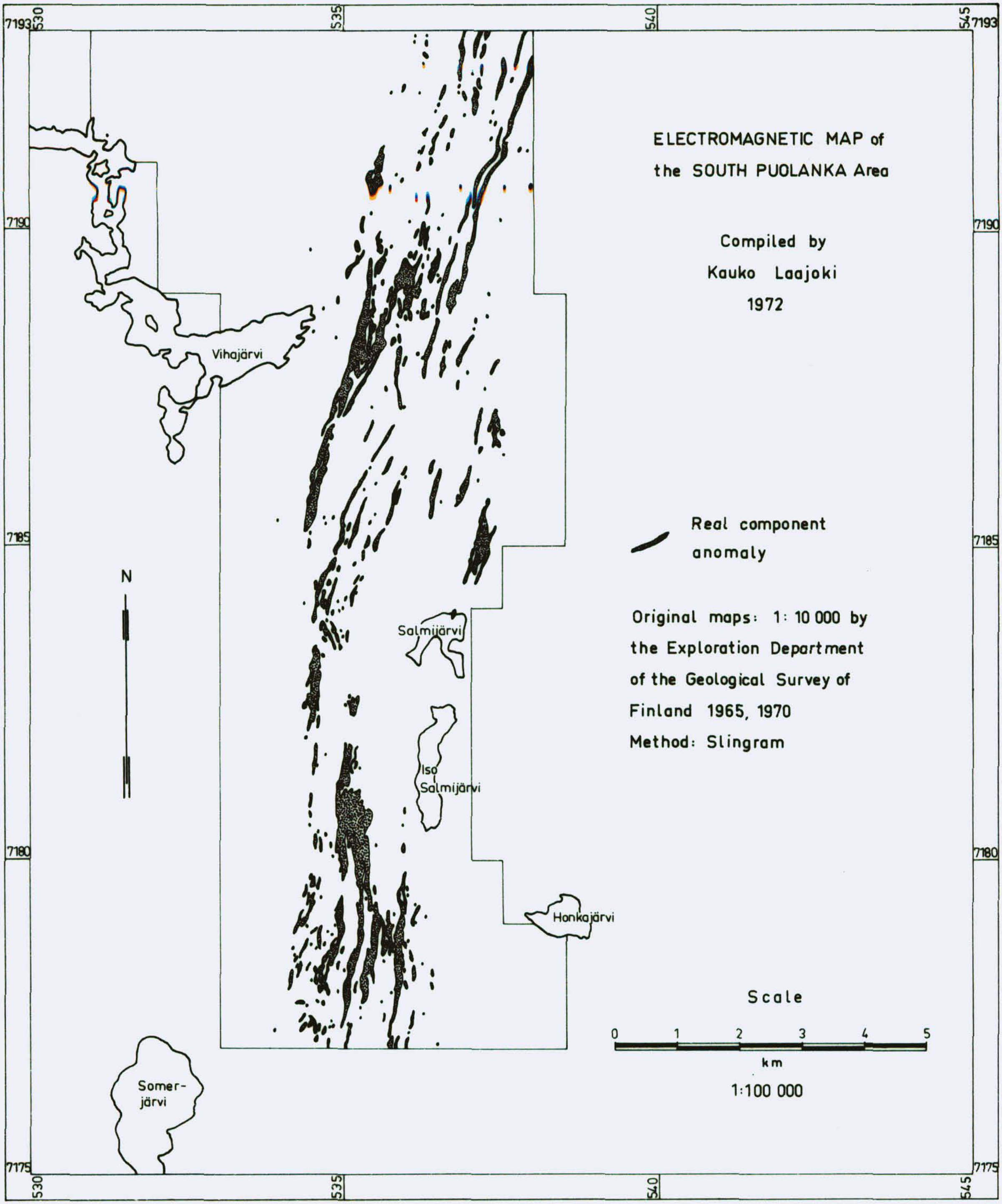
Geological Survey of Finland

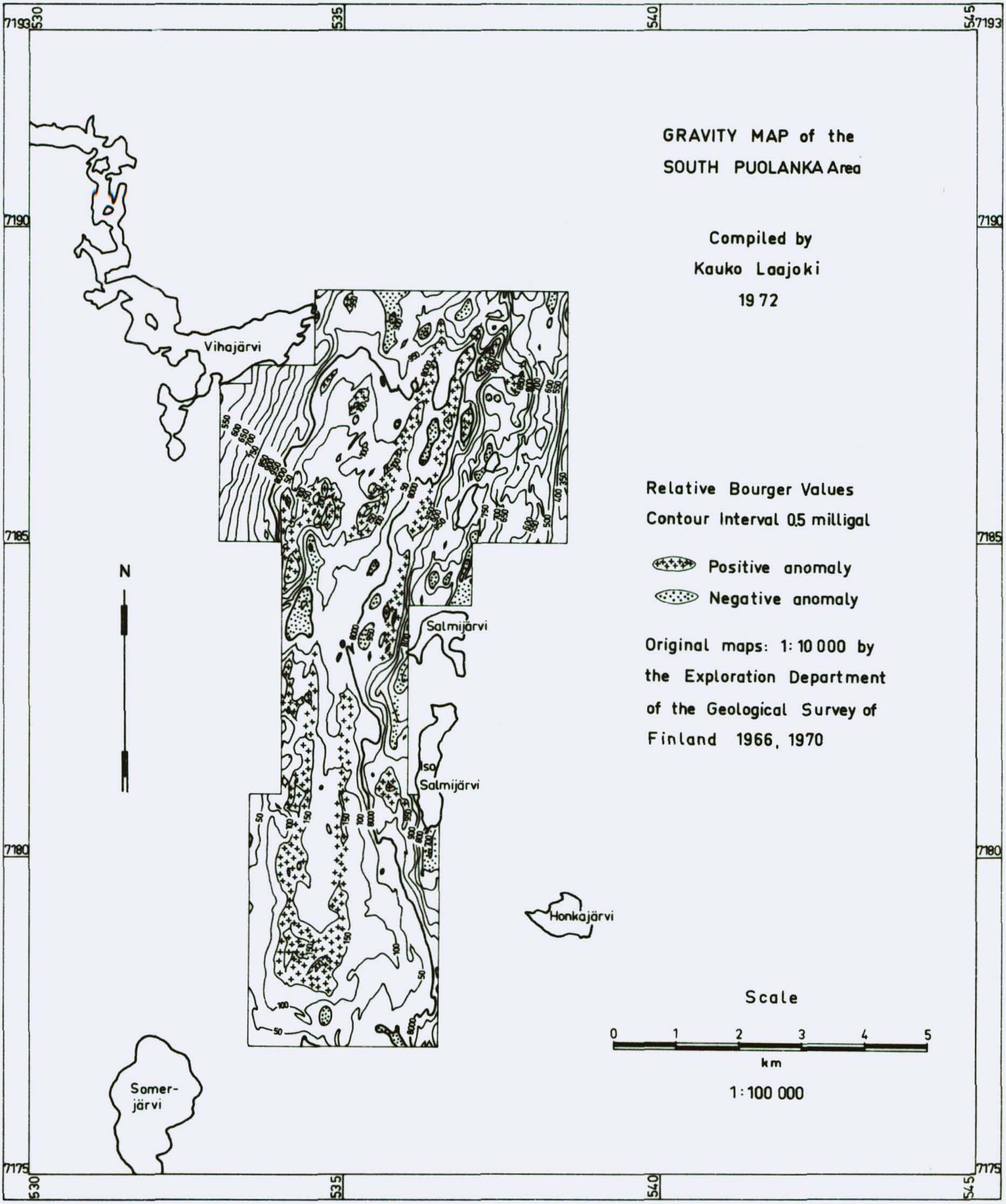


Base-map reduced from Map 4. Anomalies inaccurate in regard to coordinates.
X < 7190 ; imaginary component. X > 7190 ; amplitude of electromagnetic field.



Kauko Laajoki: On the geology of the South Puolanka area, Finland.


ELECTROMAGNETIC MAP of
the SOUTH PUOLANKA Area
Compiled by
Kauko Laajoki
1972
Real component
anomaly
Original maps: 1: 10 000 by
the Exploration Department
of the Geological Survey of
Finland 1965, 1970
Method: Slingram
Scale
0 1 2 3 4 5
km
1:100 000
N
Vihajärvi
Salmijärvi
Iso
Salmijärvi
Honkajärvi
Somer-
järvi
530
535
540
545
7193
7190
7185
7180
7175



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