Geological Survey of Finland

Bulletin 257

(formerly Bulletin de la Commission Géologique de Finlande)

On the stratigraphic and structural geology of the Rukatunturi area, northeastern Finland

by Ahti Silvennoinen

Geologinen tutkimuslaitos · Otaniemi 1972

Geological Survey of Finland, Bulletin 257
(formerly Bulletin de la Commission Géologique de Finlande)

ON THE STRATIGRAPHIC AND STRUCTURAL GEOLOGY OF THE RUKATUNTURI AREA, NORTHEASTERN FINLAND

BY

AHTI SILVENNOINEN

WITH 20 FIGURES AND 9 TABLES IN TEXT AND TWO APPENDICES

GEOLOGINEN TUTKIMUSLAITOS
OTANIEMI 1972

Silvennoinen, A. 1972: On the stratigraphic and structural geology of the Rukatunturi area, northeastern Finland. Geological Survey of Finland, Bull. 257. 48 pages, 20 figures, 9 tables, 2 appendices.

The Karelian sedimentary-volcanic sequence of the Svecokarelidic orogen (revolution 1 900 m.y. ago) is over 2 500 m thick in the Rukatunturi area. It is divided into thirteen formations. The sequence rests with first order unconformity on the Saamian granite gneiss complex (revolution 2 800 m.y. ago).

The studied sequence is composed of cratogenic sediments, interrupted by three volcanic units (greenstones), one of which directly overlies the basal formation. The deposition was controlled by tectonism in the Svecokarelian foreland; thus the characteristics of the formations are quite variable. The upper part of the sequence (Rukatunturi Quartzite Formation and Dolomite Formation) shows a steady course of sedimentation and it forms a typical orthoquartzite-carbonate association. This association is overlain by amphibole schists with dolomite and black schist intercalations (Amphibole Schist Formation).

The Svecokarelian folding of the sequence was partly induced by faulting of the basement, otherwise being of the decollement type. The axial planes of the folds are curved, and the folding was controlled by resistant blocks in the east, against which the sedimentary-volcanic cover was thrusted from the west.

The lower parts of the sequence are difficult to correlate with other areas in the Karelidic schist belt, whereas the Dolomite Formation and the Amphibole Schist Formation are readily correlative with the marine Jatulian formation in southeastern and eastern Finland and southern Karelia of the U.S.S.R..The marine Jatulian formation is practicable as a rock-stratigraphic key unit in the Karelidic schist belt.

ISBN 951 — 690 — 002 — X

Helsinki 1972. Valtion painatuskeskus

CONTENTS

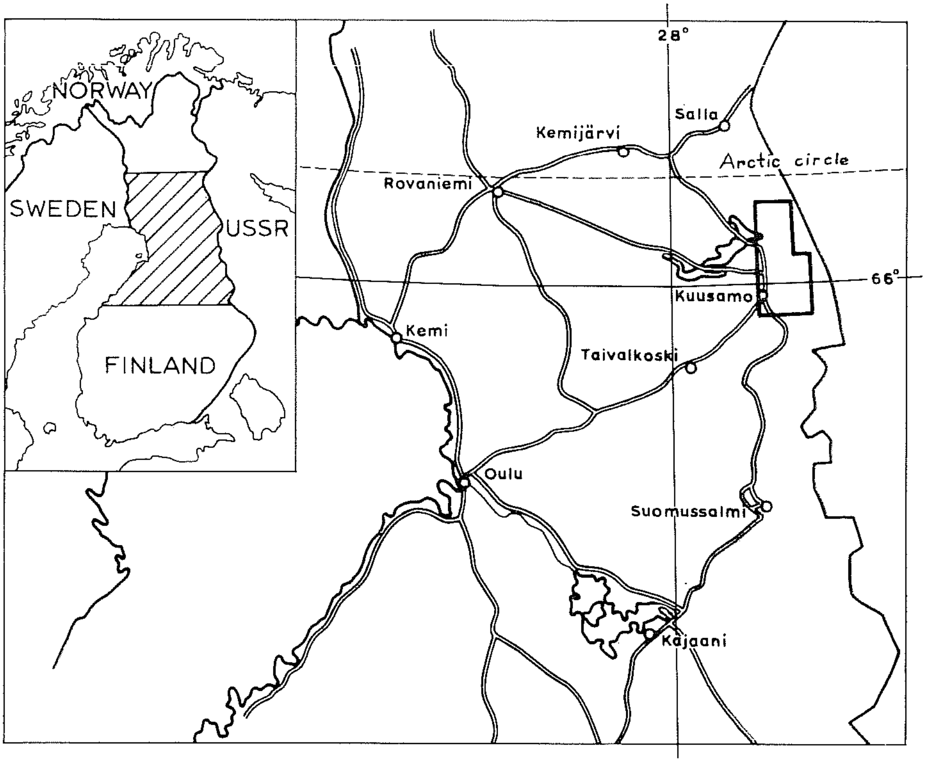


FIG. 1. Location of the Rukatunturi area (encircled by heavy lines).

INTRODUCTION

The Geological Survey of Finland began geological remapping of the so called Karelidic schist belt in the Finnish part of the Fennoscandian Shield in the early 1960s. The work was concentrated on areas earlier known to be important as shedding more light on the geology of the Karelidic schist belt. One of the key areas was the Kuusamo schist area, and the aim of this study was to elucidate the stratigraphy and structure in the eastern part of it. This task turned out to be more important than ever when, during the work, it became evident that the stratigraphy in the Kuusamo schist area is much more complicated than had been known to be the case here or elsewhere inside the Finnish part of the Karelidic schist belt.

Location and physiography of the area

The region studied is situated in northeastern Finland, about 30 km south of the arctic circle and near the eastern border of Finland (Fig. 1). It covers about 1 300 km^2, most of which lies in the Kuusamo district, only a small part in the north belonging to the Salla district.

The southern part of the area is characterized by long, west-easterly lakes and rather smooth topography, but in the north the topography is more variable. Maximum steepness and height differences occur in a succession of ridges extending from Pyhätunturi across Rukatunturi to the north. The highest summit, Valtavaara, is 492 m above sea level, while the lakes in the flatter, southern part of the area lie about 250 m above sea level.

Owing to the movement of the continental ice sheet from west to east during the Ice Age, many outcrops occur on the western slopes of hills and rises in the ground, while the eastern slopes are usually covered by surficial deposits. In places, there occur outcrops enough to produce a rather detailed geological map, but they are not evenly distributed over the whole area.

Previous works

After Inberg (1876) published his very general description and geological map of the Kuusamo and Kemi—Rovaniemi schist areas, systematic geological mapping of the Kuusamo area was begun in the year 1899. The general geological map and its explanatory text were published by Hackman and Wilkman (1925 and 1929, respectively). Now the eastern part of the area on the Kuolajärvi map sheet belongs to the Soviet Union, and therefore many of the opinions expressed earlier could not be re-examined in the fieldwork done for the present study.

During the last twenty years, some ore prospecting activity has taken place in the Kuusamo area, but no general geological studies have been done since the work of Hackman and Wilkman. Certain prospecting results are reported in several unpublished theses done in the universities of Oulu and Helsinki (Paakkola, 1964; Airas, 1965; Pekkala, 1967 and Juhava, 1969).

In their licenciate theses, the author (1969) described the stratigraphy and structure of the southeastern part and Piispanen (1970) mainly the igneous rocks of the southwestern part of the Kuusamo schist area. Lestinen (1969) investigated the granite gneiss complex in the southern part of the area under discussion in this paper. Earlier, Lauerma and Piispanen (1968) had described a worm-shaped cast in a quartzite in the southwestern part of the Kuusamo schist area.

Mapping methods

Topographic maps on a scale of 1: 20 000 were consulted to locate the outcrops found on the field excursions, and the geological connections were drawn mostly on that scale. The appended geological map was finished on a 1: 50 000 scale map and printed on the scale 1: 100 000.

Aerial photograps were exceedingly important in interpreting structural features and drawing the geological map. Contact prints of aerial photographs taken on a scale of 1: 60 000 and 1: 20 000 scale enlargements of them were used. When the photographs were examined, stereoglasses were used along with an Old Delft stereoscope in the field and in the laboratory.

The total field aeromagnetic maps made by the Geological Survey proved quite helpful during the mapping work. Flights for these maps were made at an altitude of 150 m and along parallel lines spaced at 400 m intervals. To obtain more information out of these maps and other magnetic measurements, the susceptibilities of the rock types were determined on outcrops using a field susceptibility meter constructed by the Geological Survey. Susceptibilities of hand specimens were determined at the geophysical laboratory of the Geological Survey.

A Jalander flux gate magnetometer (vertical component) was used for the magnetic measurements on the ground. By these measurements the contacts of magnetic formations were outlined in many places all over the area. The measured lines are marked on the simplified aeromagnetic map appended.

GENERAL GEOLOGICAL SETTING

The Precambrian metamorphic rocks of Finland can be divided into three main units (Simonen 1960 a):

— the granite gneiss and granulite complex in eastern and northern Finland
— the Svecofennidic schist belt in western and southern Finland
— the Karelidic schist belt in eastern and northern Finland

TABLE 1.

Stratigraphic classification of the Precambrian rocks in Finland (Simonen, 1960 a).

			Age
Cambrian quartz sandstone			500 m.y.
post-Jotnian diabase			diagenesis
unmetamorphic Jotnian sediments in Satakunta and Muhos			1 300 m.y.
anorogenic granites (rapakivi)			1 620 m.y.
orogenic plutonic rocks { late-kinematic (migmatites, granitization) synkinematic (regional metamorphism)			1 750—1 850 m.y.
metamorphic rocks:			
Svecofennidic belt	Karelidic belt		
	Eastern Finland	Northern Finland	
Upper Svecofennian: argillaceous sediments		Kumpu formation: arkoses and conglomerates	
Middle Svecofennian: basic volcanics and intercalated sedimentary rocks	Kalevian: argillaceous sediments	Lapponian: argillaceous sediments basic volcanics quartz sandstones	
Lower Svecofennian: graywacke-slates and quartz-feldspar rocks	Jatulian: marine Jatulian; argillaceous sediments and dolomites Kainuan quartz sandstones Sariolian arkoses and conglomerates		
		Belomorides: orthogneisses paragneisses Tuntsa—Savukoski formation	1 900—2 000 m.y.
Basement unknown	Pre-Karelian basement; orthogneisses and paragneisses		2 600 m.y.

The Karelidic schist belt was long thought to be younger than the Svecofennidic schist belt, with its stronger metamorphism, but after long deliberations Metzger (1959) and Simonen (1960 a and 1960 b) suggested that both belong to the same orogenic cycle. This conclusion was supported by the radiometric datings made by Kouvo (1958) and Gerling and Polkanov (1958). The same view was earlier taken by T. Mikkola (1953 and 1961) on a stratigraphical basis. Later Simonen (1971, p. 1419) gave the name Svecokarelidic to this orogen. A stratigraphic classification of Precambrian rocks in Finland was compiled by Simonen (1960 a) and this classification is given in Table 1.

The Jatulian in eastern Finland begins with basal conglomerates and arkosic sandstones lying unconformably on the pre-Karelian granite gneiss basement (Table 1). These Sariolian deposits occur only sporadically as the basal bed of the Karelian sequence in eastern and northern Finland (Simonen, 1960 a, p. 24). After the deposition of the Sariolian formation, the deposits underwent intense weathering and the Kainuan quartzites (Table 1) were deposited on them. The widely distributed Kainuan quartzite formation begins with quartz conglomerates and sericite quartzites, and the upper part of the formation is composed of pure quartzites. Simonen (1960 a, p.25) defined the Kainuan quartzite formation as a marker horizon in the Karelidic schist belt.

Jatulian deposits in East Karelia form isolated synclinores, which have been traced from Jänisjärvi in the south to Kuolajärvi in the north. The Jatulian is divided into three sedimentary-effusive units (lower, middle and upper) each of which corresponds to a definite tectono-magmatic cycle (Negrutsa, 1965). A quite detailed description of the Jatulian with lower, middle and upper units in Central Karelia was given by Sokolov et al. (1970).

The Kuusamo schist area is traditionally regarded as a part of the Karelidic schist belt (Hackman and Wilkman, 1929; Sederholm, 1932; Väyrynen, 1954; Simonen, 1960 a). Hackman and Wilkman (1929) describe it as a triangular basin of folded Karelian sediments and basic rocks. The pre-Svecokarelian (cf. Simonen, 1971, p. 1419) or the Saamian (cf. Polkanov and Gerling, 1960; Kratz et al., 1970) granite gneiss complex, 2 800—2 600 m.y. old (Kouvo, 1958), borders the schist area in the south and east and a late-Karelian granite in the northwest.

The sides of the triangle so formed are about 120 km long, the eastern part being Soviet territory (Fig. 2). The northern part of the triangle is occupied by a large unit called the Salla greenstone complex, which on its western side is granitized and on its eastern side rests discordantly on the granite gneiss complex.

The division of the Karelian sequence into the Kalevian (older) and Jatulian (younger) groups was applied on the Kuolajärvi map sheet (Hackman and Wilkman, 1925) as was done at that time in the southern part of the Karelidic belt (Sederholm, 1907). An unconformity was believed to exist between these groups, and many occurrences of basal formations of the Jatulian were described by Hackman and Wilkman (1929, p. 92).

The area now under discussion is composed mainly of the Jatulian quartzites, as they were called by Hackman and Wilkman (Fig. 2), with the Saamian granite gneiss basement in the southern part of the mapped area, and of a belt of greenstones on the southern and northern sides of the quartzite area. These greenstones and the schists occurring in association with them in the northern part of the Rukatunturi area were interpreted by Hackman and Wilkman to be Kalevian. Granites were not found in the area mapped for the present study, but according to Hackman and Wilkman (1929) and Lauerma (1969 a and b) there is granite traversing the Salla greenstone complex.

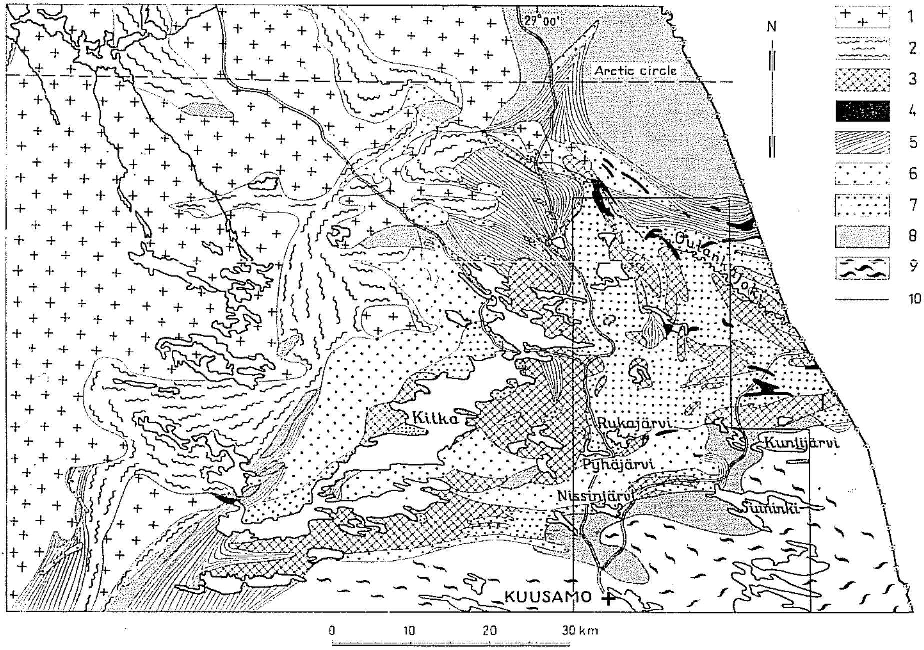


FIG. 2. Main geological features of the Kuusamo schist area and the surroundings according to Hackman (1910) and Hackman and Wilkman (1925). 1. Late Karelian granite. 2. Migmatitic mica gneiss. 3. Jatulian metabasite. 4. Dolomite (Jatulian and Kalevian). 5. Kalevian mica schist and hornblende schist. 6. Kalevian quartzite. 7. Jatulian quartzite. 8. Kalevian metabasite. 9. Pre-Karelian basement gneiss. 10. The Rukatunturi area.

The formations of the eastern part of the Kuusamo schist area have undergone a low-grade regional metamorphism. The mineral assemblage quartz-muscovite-chlorite-albite, which is typical of the eastern part of the Kuusamo schist area, indicates that conditions were in the range of the quartz-albite-muscovite-chlorite subfacies of the greenschist facies (Turner and Verhoogen, 1960). According to Hackman and Wilkman (1929), the late-Karelian granite northwest of the Kuusamo schist area has raised the grade of the metamorphism in that part of the schist area.

STRATIGRAPHY

The order of the descriptions in the following chapters dealing with different formations is mainly the same as in the stratigraphic succession for the study area (Fig. 3) from the oldest to the youngest. Only slight attention is given to the description of the Saamian granite gneiss complex, because it comprises a very large and complicated problem as a whole and the main purpose of this study was to describe the stratigraphy and the structure of the Karelian schists. The petrographic descriptions are also given only to the extent necessary to throw light on the origin of the formations.

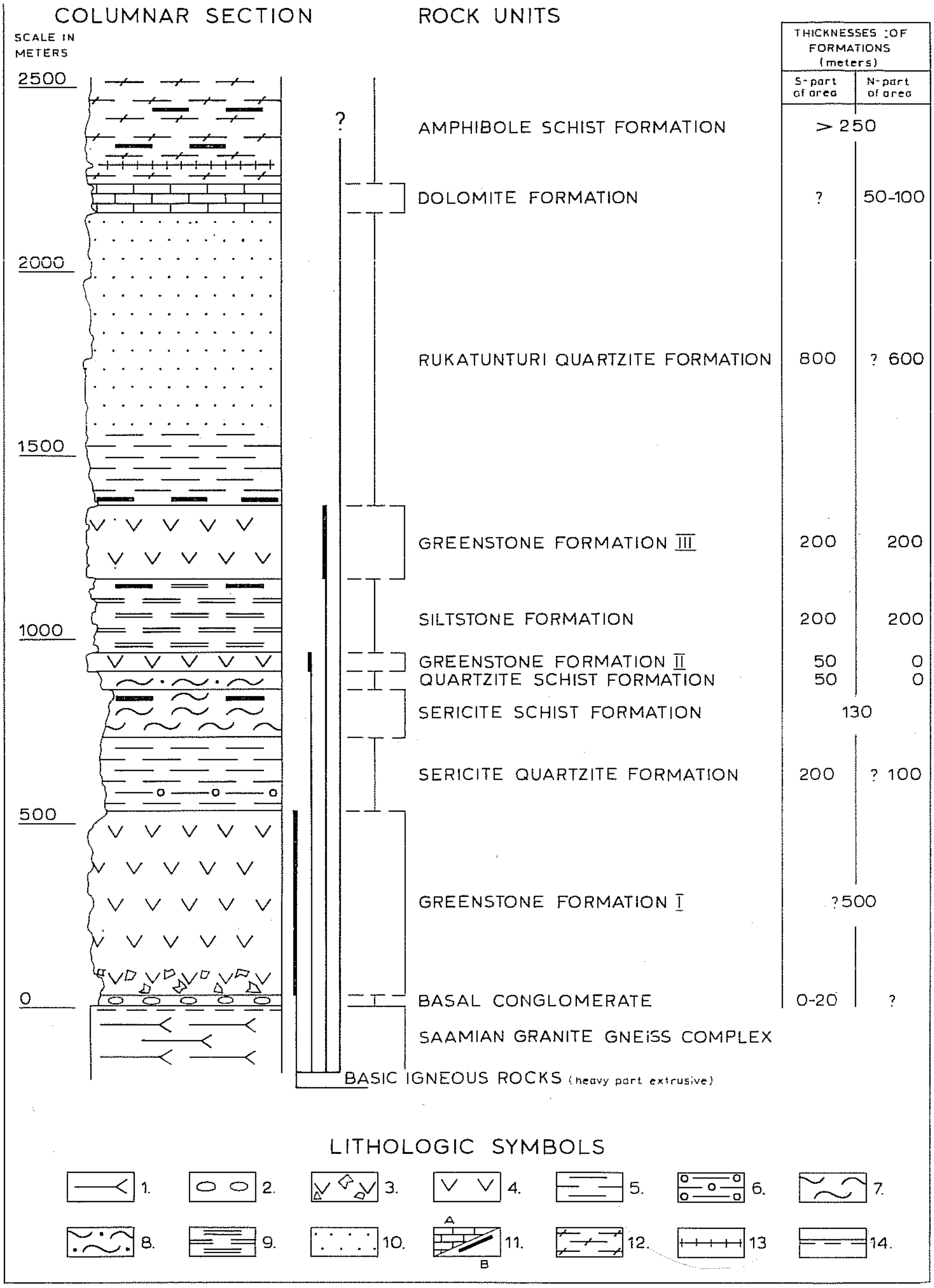


FIG. 3. Stratigraphic section of the Rukatunturi area. 1. Saamian granite gneiss complex. 2. Basal conglomerate. 3. Volcanic breccia. 4. Basic volcanics. 5. Sericite quartzite. 6. Arkose conglomerate. 7. Sericite schist. 8. Quartzite schist. 9. Arkosic, argillaceous and dolomitic schists of siltsized grain. 10. Orthoquartzite. 11. Dolomite (A) and dolomite intercalations (B). 12. Amphibole schist. 13. Black schist. 14. First order unconformity.

Saamian granite gneiss complex

In the study area, the Saamian granite gneiss complex is composed of trondhjemitic, quartz-dioritic, granodioritic and granitic gneisses, which grade into each other. Mica gneiss and hornblende gneiss were found to be present as inclusions of varying size. Granite, pegmatite and diabase occur as intersecting dikes, and epidote and quartz veins are common. Near the contact of the Karelian schists, the granite gneiss alters in many instances into strongly foliated chlorite and sericite-rich schist.

The magnetite content of the granite gneiss types is low and so the susceptibility is usually only from $0 \cdot 10^{-6}$cqs to $20 \cdot 10^{-6}$cqs. The area of the granite gneiss complex is rather even on the aeromagnetic map, the level being 5 500—5 600 gammas.

The trondhjemitic gneisses are light grey in color, some with a pink tone. The main mineral constituents are albitic plagioclase, quartz and in some instances mica minerals. The grain size is usually 1—2 mm. This granite gneiss type is common in the northeastern part of the Saamian granite gneiss complex in the study area.

The quartz-dioritic gneisses are dark grey, often seen to be greenish in color. Main minerals are plagioclase (mostly oligoclase, rarely albite), biotite, hornblende and quartz. Grain size is about 2—5 mm, but mixed potash feldspar-albite porphyroblasts are up to 3 cm in diameter. Quartz-dioritic gneiss together with granodioritic gneiss is the most common type of rock in the granite gneiss complex in the area studied.

The granodioritic gneisses are reddish in color and differ from the quartz-dioritic gneisses by containing potash feldspar. Mixed porphyroblasts of potash feldspar and albite 1—2 cm in diameter are common.

The granitic gneisses are pink in color. Main mineral constituents are potash feldspar, plagioclase and quartz. Grain size is usually 1—2 mm. Granitic gneisses commonly occur together with trondhjemitic gneisses in the northeastern part of the study area.

Mica gneiss is observed as inclusions in the gneisses previously mentioned. The mica gneiss is dark grey in color and the main mineral constituents are albitic plagioclase, biotite, muscovite and quartz. The size of the inclusions is mostly less than one meter. Larger inclusions are cut by trondhjemitic, granitic or pegmatitic veins as a rule. The inclusions are usually foliated. They are to be seen all over the area studied, but mostly in trondhjemitic and granitic gneisses in the northeastern part of the Saamian granite gneiss complex in this area.

The hornblende gneiss inclusions differ from the mica gneiss inclusions in that they contain amphibole. Some of the amphibole crystals are as much as 10 mm long, and they are embedded in a mica gneiss matrix. The trondhjemitic, granitic or pegmatitic veins cutting these inclusions are sometimes seen to contain amphibole crystals, too. The boundaries of both types of inclusions are mostly gradual and migmatized.

The Saamian granite gneiss complex is cut by d i a b a s e s of at least two age groups, as pointed out by Matisto (1958). The diabase dikes are usually from 5 m to 20 m broad, steeply dipping and hundreds of meters long. They have a rather constant, nearly east-westerly orientation throughout the area. Mineralogically, the diabases are more or less metamorphosed pyroxene diabases. Uralitization has been a common phenomenon and uralite diabases are the most typical ones. Piispanen (1970) has given in detail the mineralogical and chemical characteristics of the diabases cutting the granite gneiss complex west of the area under discussion. He considers the composition of them to lie within the tholeiite basalt field, after the classification of Kennedy (1933) and Yoder and Tilley (1962).

Tension cracks filled by quartz veins running in a north-southerly direction were observed all over the area.

Karelian sequence

Basal conglomerate

A basal conglomerate of the Karelian sequence was found overlying the Saamian granite gneiss complex in the eastern part of the schist area. Only one find of local boulders is in the southern contact zone, which has an east-westerly strike. The place is about three kilometers to the northeast of the village of Kuusamo, and the conglomerate bed was drawn according to these local boulders. The main occurrences of the basal conglomerate are near the east side of the mapped area in the district of the lakes Kuntijärvi and Koverusjärvi.

The lower contact of the basal conglomerate is bounded by the granite gneiss complex, and basic volcanics of Greenstone Formation I overlie it. The lower contact on the north shore of Kuntijärvi is sharp (Fig. 4), beginning with a layer of brecciated granite gneiss a few tens of centimeters thick containing fine-grained debris between the fragments. The fragments increase rapidly in roundness upwards. The upper contact of the conglomerate bed is gradual, and intermediate variants containing fragments of granite gneiss and basic volcanics are referred to in this work as volcanic breccias. The granite gneiss fragments diminish in amount little by little upwards and are replaced by fragments of basic volcanics. The matrix material turns upwards to a tuffitic one.

Some of the fragments of conglomerate reach a diameter of 50 cm but usually are from 5 cm to 20 cm (Fig. 5). Trondhjemitic gneiss fragments are most common along with mica- and quartz-dioritic gneiss and a few diabase fragments, which may have originated from older diabases cutting the Saamian granite gneiss complex. The gneiss fragments of the conglomerate are very poor in potash feldspar, which is a rather common mineral in the granite gneiss farther from the contact. Otherwise, they resemble mineralogically the characteristics of granite gneiss types.

FIG. 4. Contact between the Saamian granite gneiss basement and basal conglomerate of the Karelian sequence. North shore of Kuntijärvi. Diameter of the coin is 16 mm. Photo by author.

FIG. 5. Basal conglomerate of the Karelian sequence. Tuffitic matrix. Angular fragment in the lower right corner is of recrystallized mylonite (see text). North shore of Kuntijärvi. Diameter of the coin is 16 mm. Photo by author.

The matrix of the conglomerate is composed of quartz, albite, mica minerals and of varying amounts of carbonate material. Magnetite, chlorite, tourmaline and apatite are accessory minerals. In the upper parts of the conglomerate bed, the amount of chlorite increases and the matrix, which turns dark-colored (Fig. 5.), contains idiomorphic pyrite crystals some millimeters in diameter.

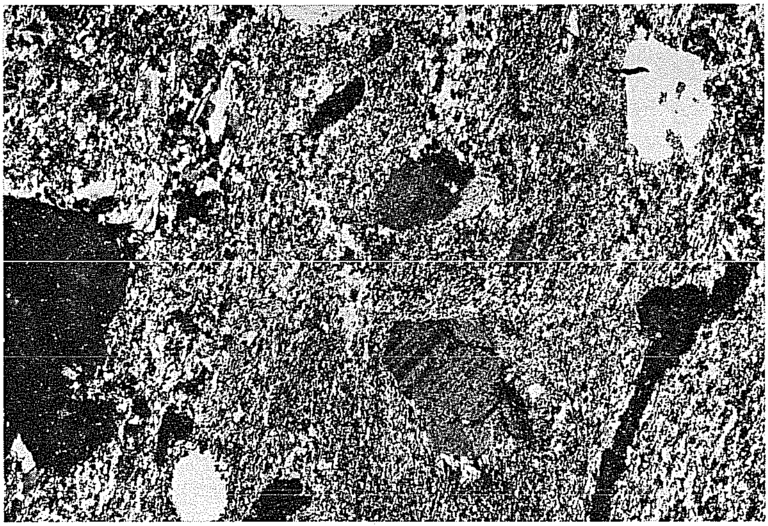


FIG. 6. Recrystallized mylonite fragment in basal conglomerate. South shore of Kuntijärvi. No. 171c/PL/68. Crossed nicols, 16.5 x. Photo by Erkki Halme.

An odd type of fragment in the basal conglomerate is that termed quartz-porphyry by Hackman and Wilkman (1929, pp. 28—31) (see Fig. 5). They found this rock type in many places to the east of the area now studied in Soviet territory. They report that the thickness of the quartz-porphyry formation is apt to attain 15—20 m. The quartz-porphyry-like fragments in the basal conglomerate are grey, sometimes reddish in color, and composed of fine-grained matrix, in many instances with idiomorphic grains of feldspar about 5 mm in diameter and slightly smaller ellipsoidal or rounded quartz grains, which show sometimes idiomorphic features, too (Fig. 6). The matrix is composed of quartz and muscovite with minor amounts of epidote, sphene, biotite and apatite. The larger feldspar grains are albite, often observed with idiomorphic features and irregularly shaped inclusions of the matrix. The larger quartz grains are macroscopically bluish in color, which may be due to the fact that the grains are crushed. The elongations of the grains conform to the direction of the generally strong foliation of the matrix.

The microscopical features of these porphyritic fragments indicate that they originated from recrystallized mylonites more probably than from acidic extrusives.

The thickness of the conglomerate bed in exposed places is only about ten meters, and it seems quite likely that it is nowhere much thicker. Bedding is very rare; it has been observed only in the upper part of the conglomerate unit on the northern shore of Koverusjärvi, and the sorting of the material in the conglomerate is poor, which indicates that the formation was deposited mostly above the water level.

Greenstone Formation I

The southern and southeastern parts of the schist area are occupied by basic volcanics of Greenstone Formation I. The formation is composed of amygdaloidal rocks, homogeneous lavas, tuffite schists and volcanic breccias. Greenstone Formation I overlies the basal conglomerate or in a straight line the Saamian granite gneiss complex. Sericite Quartzite Formation overlies Greenstone Formation I and tuffite schists with some thin carbonate beds are the uppermost part of Greenstone Formation I. Smaller occurrences of Greenstone Formation I were observed in the zone from Särkivaara to WSW and at the west end of Säkkiläjärvi, in the central part of the area.

Magnetically, the basic volcanics of Greenstone Formation I belong to the same low-susceptibility group as the granite gneisses. The 416 measurements on seven outcrop groups gave an average result of $75 \cdot 10^{-6}$cgs. Density determinations of 23 hand specimens resulted in an average of 2.85 g/cm^3.

V o l c a n i c b r e c c i a s were found to be the lowermost member of Greenstone Formation I. Typical outcrops occur at Juurikkavaara and on north shore of Kuntijärvi. They are intermediate types between basal conglomerate and lavas. Fragments of the volcanic breccia are fine-grained basic rocks together with varying amounts of granite gneiss fragments. The matrix material is mostly tuffitic (Fig. 7). The basic fragments are mostly even-grained, and it is highly likely that they originated from earlier crystallized lavas. The volcanic breccias were regularly found in connection with basal conglomerates.

A m y g d a l o i d a l r o c k s together with homogeneous lavas are the most common constituents of Greenstone Formation I. Typical outcrops were found at Juurikkavaara and Palovaara, to the west of Lake Suininki. Described as a typical amygdaloidal rock is one at Palovaara, where the rock is rich in chlorite and also contains pale green amphibole and albite as the main constituents. Quartz is the prominent accessory constituent. The color of the rock is pale greyish green. Amygdules occur in places as layers (Fig. 8) so that the strike and dip of the lava beds can be measured. The amygdules are filled mostly with quartz and, sometimes, with calcite, epidote or amphibole.

T u f f i t e s c h i s t s occur as the uppermost member of Greenstone Formation I. Because this type of rock is soft and easily disintegrates, the contact with overlying sericite quartzites is not exposed. Tuffite schists occur in a zone extending from Juurikkavaara across Piskamojärvi to the western end of Lake Suininki. The same horizon is exposed also to the east of Hukkavaara, and from there it continues to the northwest. Tuffite schists are exposed at Särkivaara, about 5 km to the east of Rukajärvi and in the central part of the schist belt, near the west end of Säkkiläjärvi.

The tuffite schists are carbonate-bearing or carbonate-rich, greyish green schists, which are mostly conspicuously foliated and from place to place strongly dragfolded.

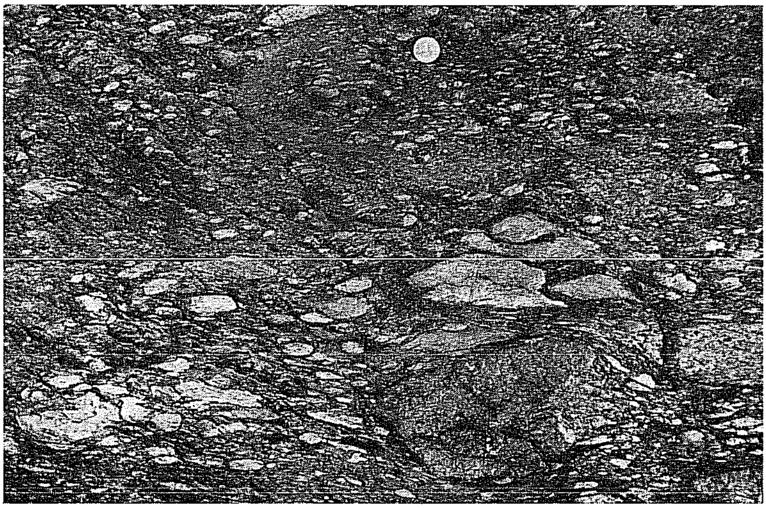


FIG. 7. Volcanic breccia with tuffitic matrix. 2.5 km south of Pyhäjärvi. Diameter of the coin is 16 mm. Photo by author.

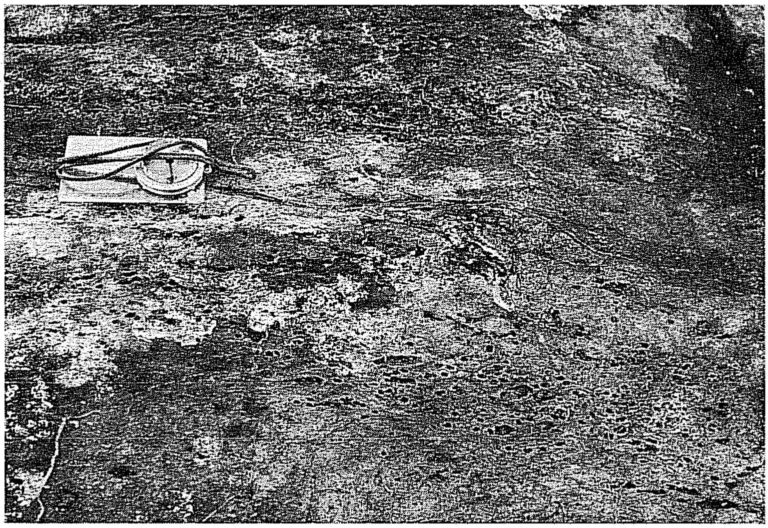


FIG. 8. Amygdaloidal rock of Greenstone Formation I. Palovaara. Photo by author.

The main mineral constituents are chlorite, carbonate, albite and quartz. Sphene and apatite occur as accessory constituents. The content of sericite is variable, types richest in sericite occur near the contact of tuffite schist and sericite quartzite at Juurikkavaara, Määttälänvaara and Soukkeloharju, in the southeastern part of the area.

D o l o m i t e intercalations in the tuffite schists of Greenstone Formation I were observed on the western slope of Juurikkavaara, where prominently foliated tuffite schists are exposed. Dolomite intercalations are there at least ten meters thick. Dolomite is light grey on a fresh surface, and a reddish brown weathering surface is typical. Besides a recrystallized carbonate mineral, quartz, chlorite and a light mica mineral occur in the dolomite.

The thickness of Greenstone Formation I is hard to estimate because only a few observations of the bedding could be made; hence the estimate of 500 m in the stratigraphic column (Fig. 3) must be taken liberally. The thickness of the formation seems to diminish towards the west, as can be seen on the southeastern shore of Lake Nissi, where Greenstone Formation I must be quite thin. Perhaps these lowermost lavas filled an uneven surface so that high areas were not covered. The tuffite schist member of Greenstone Formation I very likely consists of disintegration products of basic lavas, perhaps together with volcanic ashes. The dolomite beds which constitute the uppermost part of the formation, indicate that marine conditions possibly prevailed during their deposition.

Sericite Quartzite Formation

Upwards from Greenstone Formation I, the sedimentary sequence of the study area continues with a unit of quartzites and schists interrupted by two formations of basic volcanics. The lowermost formation of this unit is called the Sericite Quartzite Formation. Besides sericite-rich quartzites, the formation contains a few beds of a conglomeratic variety, called arkose conglomerate in this paper. The formation was named after its main type of rock.

Magnetically, the Sericite Quartzite Formation belongs to the low-susceptibility group, typically under $10 \cdot 10^{-6}$cgs; and thus it occurs in low-level areas of the aeromagnetic map. Ten determinations of density yielded an average of 2.63 g/cm^3.

The type section of the Sericite Quartzite Formation is on the western slope of Juurikkavaara, to the east of Lake Nissi. The lower contact was not found exposed; but probably the tuffite schists, as the uppermost member of Greenstone Formation I, represent types intermediate to the Sericite Quartzite Formation. Upwards, the sericite quartzites gradually turn into sericite schists. The formation is exposed in many places around the syncline, which trends from east to west in the southern part of the area.

The sericite quartzite is yellowish grey in color and often appears a little brownish on the weathered surface. The foliation is usually strong. The grain size is 0.2—2 mm, in some instances even greater. The formation is rather homogeneous and the sedimentary structures are limited to the rare bedding and the faint traces of ripple marks sometimes observed. The boundaries of beds are not sharp if found at all. But in the uppermost parts of the Sericite Quartzite Formation there occur well-

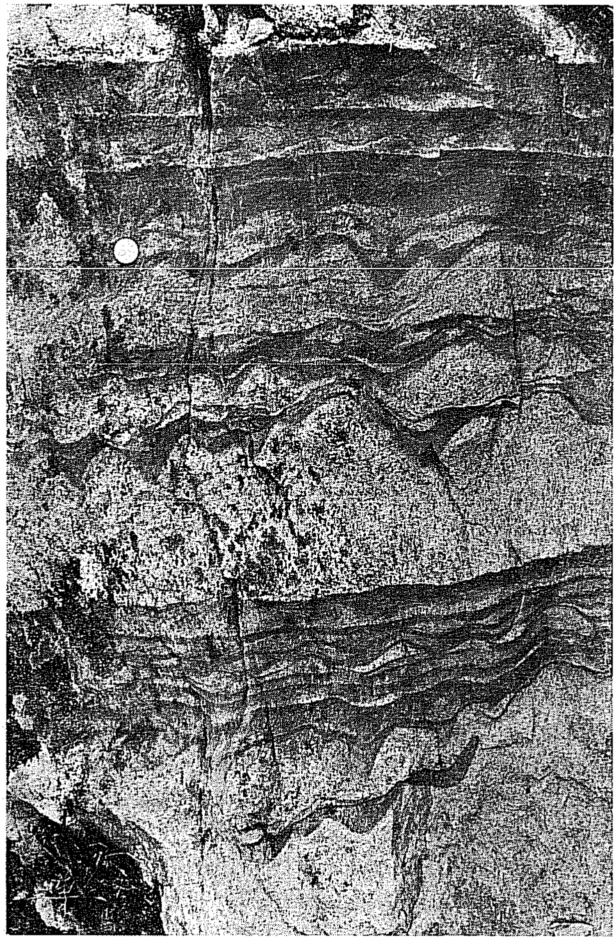


FIG. 9. Graded bedding in the contact zone between the Sericite Quartzite Formation and the Sericite Schist Formation at Erivaara. Diameter of the coin is 16 mm. Photo by author.

shaped sedimentary structures in the contact zone against the Sericite Schist Formation. The part of the Sericite Quartzite Formation right at the upper contact has a graded bedding (Fig. 9).

The main mineral constituents of the sericite quartzite are quartz, which occurs as rounded grains, and sericite, present as interstitial material. Besides the quartz, there occur varying amounts of potash feldspar and plagioclase. Zircon, apatite and tourmaline are regular accessory minerals. Porphyroblasts of dolomite are common and it also occurs as a matrix material with sericite. The matrix is usually so abundant that the grains are completely surrounded by it and the clastic texture is quite clear. The matrix is usually strongly foliated. Chemical analysis of the sericite quartzite

TABLE 2

Chemical composition of sericite quartzite of the Sericite Quartzite Formation on western slope of Juurikkavaara. No. 25/AAS/67. Analyst, P. Ojanperä. The specimen for the determination of mineral composition was not exactly the same as for chemical analysis.

SiO_2	84.52 %	Mineral composition (Point counting method)	
TiO_2	0.10 »	Quartz	53 %
Al_2O_3	8.30 »	Feldspars	12 »
Fe_2O_3	0.88 »	Sericite	34 »
FeO	0.29 »	Accessories	1 »
MnO	trace		100 %
MgO	0.88 »		
CaO	0.03 »		
Na_2O	0.07 »		
K_2O	3.87 »		
P_2O_5	0.02 »		
CO_2	0.00 »		
H_2O+	1.28 »		
H_2O-	0.04 »		
	100.28 %		

(Table 2) shows a high aluminium content owing to the sericite matrix and feldspars. The rather high K_2O-content is due to the sericite and potash feldspar commonly found in sericite quartzites. They indicate long weathering of the material.

Arkose conglomerate was found as intercalations in sericite quartzite. Typical outcrops of arkose conglomerate occur at Hukkavaara, about 5 km to the northwest of Lake Suininki and on the southern slope of Suolavaara. In both places, the thickness of the bed is probably about ten meters only.

The arkose conglomerate is grey in color and contains bluish quartz grains and small magnetite accumulations, which are clearly visible macroscopically. Microscopically, it was found that the matrix is composed of quartz, feldspars and sericite. The fragments are composed of granoblastic quartz or quartz and feldspars together (Fig. 10). No schist fragments were found. The roundness of the fragments is from weak to moderate and the grain size is up to 20 mm.

The chemical composition of the arkose conglomerate at Hukkavaara (Table 3), together with the microscopical features, shows that the material of the arkose conglomerate was not so heavily weathered as the material of the sericite quartzite member of the same formation.

The thickness of the Sericite Quartzite Formation was estimated on the western slope of Juurikkavaara, where the folding structure is known. Certain other estimations were made on the western slope of Särkivaara. The thickness given in the stratigraphical column (200 m) is a rather good estimation for the southern part of the area. In the northwestern part of the study area, this formation seems to be much thinner.

The mineral composition and chemical analysis show that the material of the sericite quartzites came from acidic rocks. The Saamian granite gneiss complex is a very likely source of the material of this formation.

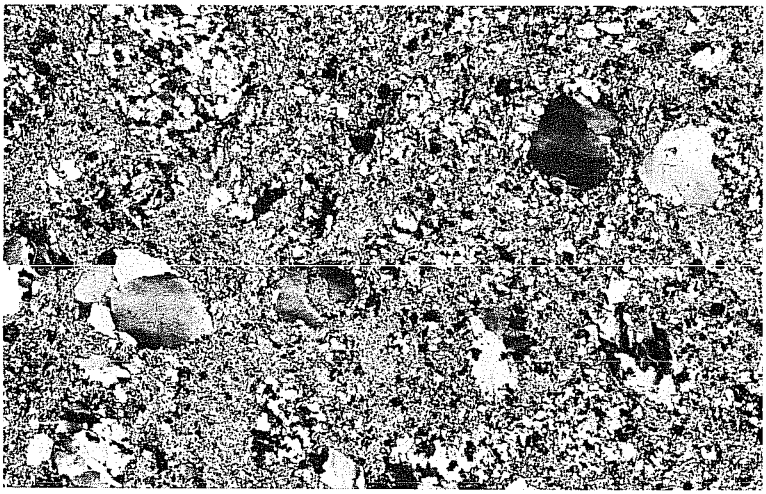


FIG. 10. Arkose conglomerate. Hukkavaara. No. 144/AAS/67. Crossed nicols, 8.5 x. Photo by Erkki Halme.

TABLE 3

Chemical composition of arkose conglomerate of the Sericite Quartzite Formation. Hukkavaara. No. 144/ AAS/67. Analyst, P. Ojanperä.

SiO_2	69.99 %
TiO_2	0.92 »
Al_2O_3	7.49 »
Fe_2O_3	4.51 »
FeO	1.90 »
MnO	0.06 »
MgO	1.02 »
CaO	4.63 »
Na_2O	0.12 »
K_2O	3.20 »
P_2O_5	0.08 »
CO_2	4.07 »
H_2O+	1.77 »
H_2O-	0.03 »
	99.79 %

Sericite Schist Formation

The Sericite Schist Formation is composed of schists, which vary from quartzites very rich in sericite to sericite-rich dolomites, the latter being the uppermost part of the formation. The susceptibility of the schists of this formation is the same as that of sericite quartzites (less than $10 \cdot 10^{-6}$cgs), whereas the density is higher, 2.73 g/cm^3, the average of five measurements.

TABLE 4

Chemical and mineralogical composition of sericite schist. Western slope of Juurikkavaara. No. 3/AAS/66. Analyst, P. Ojanperä.

SiO_2	53.21 %	Mineral composition	
TiO_2	0.49 »	(Point counting method)	
Al_2O_3	9.64 »	Dolomite	32 %
Fe_2O_3	0.44 »	Quartz	30 »
FeO	0.80 »	Sericite	29 »
MnO	0.04 »	Accessories	9 »
MgO	7.27 »		100 %
CaO	8.54 »		
Na_2O	0.08 »		
K_2O	3.59 »		
P_2O_5	0.09 »		
CO_2	13.34 »		
H_2O+	2.28 »		
H_2O-	0.04 »		
	99.85 %		

The Sericite Schist Formation overlies the sericite quartzites, and on it there occur fine-grained greenish quartzite schists, which contain no carbonate material. Both contacts are gradational. The Sericite Schist Formation was named according to the main rock type of it.

Typical outcrops of the Sericite Schist Formation occur on the western slope of Juurikkavaara, to the east of Lake Nissi. Generally, the outcrops of the sericite schists occur together with sericite quartzites and the greenstones of Greenstone Formation I, sericite schists being the most easily disintegrated of these rocks. The formation was also observed in the zone running WSW from Särkivaara in association with sericite quartzite.

The sericite schists are grey in color and their weathered surfaces are rusty brown from their dolomite content. The foliation is mostly quite prominent, and it has generally disturbed the sedimentary structures. Dragfolding is a common feature in this formation and it confuses further the sedimentary structures. Where the bedding is preserved, it occurs as varying amounts of mica in different beds and it is visible as different grey tones on a fresh surface or as disintegration differences on a weathered surface. The bedding is laminar and the boundaries of the beds are sharp. When the amount of dolomite was found to be nearly 50 %, the rock was called dolomite. The dolomite-rich varieties and the dolomites are lighter than the sericite schist member of the formation, but the sedimentary structures are the same in both.

The grain size of the sericite schist is small (0.05—0.20 mm) and the main mineral constituents are sericite and dolomite present as matrix material, and quartz occurring as larger grains. Chlorite occurs with sericite and dolomite as a matrix material; and accessory constituents are feldspars, zircon, sphene and a pigmentary opaque material.

The chemical analysis (Table 4) of the sericite schist on the western slope of Juurikkavaara shows a rather high aluminium content, which is due to the fact

TABLE 5

Chemical composition of dolomite of the Sericite Schist Formation. Erivaara. No. 153b/AAS/67. Analyst, R. Saikkonen.

	Wt. %	Mol. %
FeO	1.42	2.26
MnO	0.11	0.23
MgO	8.85	25.06
CaO	11.54	23.36
CO_2	18.21	46.94
Al_2O_3	0.98	2.15
Insoluble	59.04	—
	100.15	100.00

that the sericite accounts nearly 30 % of the modal composition. The dolomite content is high, and when this analysis is compared with that of the sericite quartzite (Table 3, p. 10), it seems to be the main difference between these rocks. The chemical analysis of carbonate at Erivaara (Table 5) shows that dolomite is the main constituent of that part which is soluble in acid. The insoluble material accounts for roughly 50 % which seems to be a typical amount of sericite and quartz in the dolomite member of this formation.

The thickness of the Sericite Schist Formation was estimated at Erivaara, to the northwest of Lake Suininki, and on the southern slope of Hukkavaara. The value, 130 m, broadly fits other occurrences of the Sericite Schist Formation, too.

The gradational contact between the sericite quartzite and the sericite schist is exposed at Erivaara, to the northwest of Lake Suininki (Fig. 9, p. 18). In a section of about ten meters, the quartzite beds diminish in number and the underlying sericite quartzite changes to sericite schist. This contact shows a transgressive development of the sedimentation. The contact between the sericite schist and the quartzite schist overlying it is gradational, too. The contrast in this contact is not one of grain size but pertains to the materials of the sediment. The amount of dolomite diminishes and quartz takes up the space, which is perhaps due to a change in the sedimentation conditions in the basin.

As already noted the sedimentary materials of the sericite schists are probably the same as those of the sericite quartzites except the presence of carbonate material, which seems to be a chemical precipitate. Residual material could thus originate from the Saamian granite gneiss basement.

Quartzite Schist Formation

The Quartzite Schist Formation is composed of very fine-grained, usually sericite- and chlorite-rich quartzitic schists that show the same sedimentary features as the underlying sericite schists. The Quartzite Schist Formation is overlain by Green-

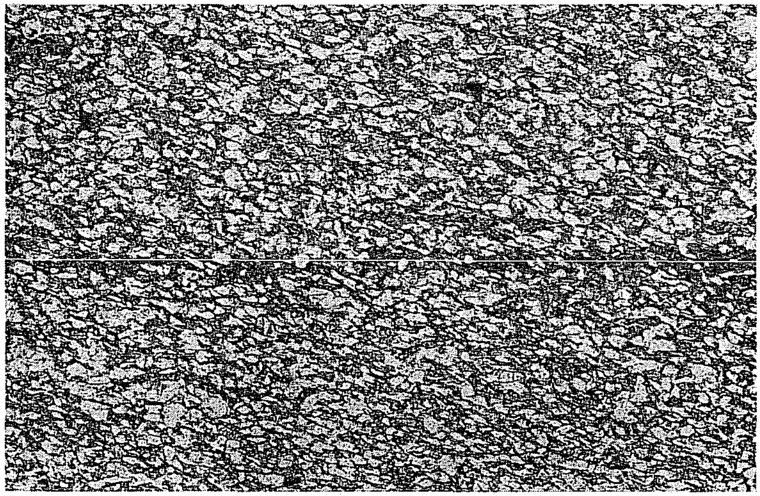


FIG. 11. Quartzite schist. Bed rich in sericite and tourmaline appears horizontally in middle of picture. South shore of Piskamojärvi. No. 92b/AAS/67. One nicol, 18 x. Photo by Erkki Halme.

stone Formation II, which is composed of basic volcanics. The quartzite schist, having a very prominent cleavage and being homogeneous and fine-grained, was used as whetstones by local inhabitants and it is still used as flagstones.

The susceptibility of the quartzite schists is low (around $15 \cdot 10^{-6}$cgs), as was found by four determinations on hand specimens. This formation thus belongs to the low-susceptibility group, which does not cause magnetic anomalies in the area. The density was determined on seven specimens giving an average value of 2.68 g/cm^3.

Typical outcrops of the Quartzite Schist Formation were found in the district of Määttälänvaara and Erivaara. Outcrops usually occur in connection with greenstones (Greenstone Formation II), which have sheltered quartzite schists through the action of the continental ice sheet. The Quartzite Schist Formation was observed only in the southern and central parts of the area studied.

A very conspicuous feature of the quartzite schists is the green or pale-green color, which is probably due to the chlorite content of this rock type. The bedding was hard to observe because the schists are fine-grained and massive. Where bedding was observed, it was laminar and caused by the variation in the amounts of sericite and chlorite.

Under the microscope, the clastic structure of quartzite schist is clearly seen (Fig. 11) and the main constituent is quartz. Sericite and chlorite constitute the matrix material. Besides quartz, there also occur albite grains, and recrystallized tourmaline is quite common, especially in sericite-rich parts of the quartzite schist.

The thickness of the Quartzite Schist Formation was estimated to be 50 m. The estimation was done by examining the outcrops on the northern slope of Juurikka

FIG. 12. Chlorite-rich beds in the upper contact zone of the Quartzite Schist Formation. Tahkolampi, north of Särkivaara. Photo by author.

vaara and the estimation carried out on the southern slope of Hukkavaara led to nearly the same result. The formation is not very thick and because it was not observed in the northern part of the area studied it very likely wedges out northward, as shown on the geological map.

The contacts against both underlying Sericite Schist Formation and the overlying basic volcanics are gradational. It is likely that the contact on the lower side of the Quartzite Schist Formation was due to a change in the sedimentation conditions in the basin so that precipitation of carbonate material became impossible. The upper contact is characterized by chlorite-rich beds (Fig. 12), which are the first signs of the volcanic activity.

The content of sericite in the quartzite schists possibly indicates that the material came from the same source as the material of the sericite schist and the sericite quartzites i.e., from the Saamian granite gneiss complex. The features of the sediments in Quartzite Schist Formation show that the deposition occurred below the water level.

Greenstone Formation II

On the Quartzite Schist Formation rests a formation composed of basic volcanics. This relatively thin formation is composed mainly of a rock type interpreted to be agglomerate. Greenstone Formation II occurs only in the southern part of the study area; thus it seems to wedge out northward. The same observation was also made regarding the Quartzite Schist Formation. Greenstone Formation II is covered by the Siltstone Formation.

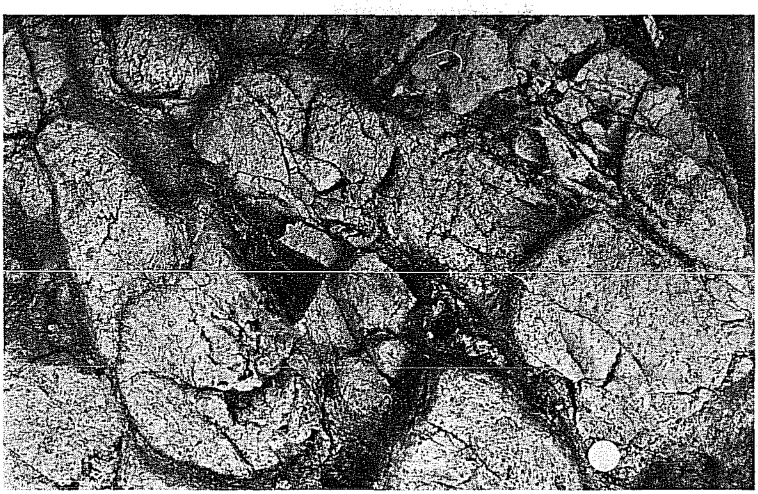


FIG. 13. Agglomerate of Greenstone Formation II. Tahkolampi, north of Särkivaara. Diameter of the coin is 16 mm. Photo by author.

The susceptibility of the rocks of Greenstone Formation II is rather variable. The lowest measured value was $30 \cdot 10^{-6}$cgs and the highest $14940 \cdot 10^{-6}$cgs. The average of 147 measurements on five exposures gave a susceptibility value of $1590 \cdot 10^{-6}$cgs. According to this average value of susceptibility and the estimated thickness of the formation (50 m), the magnetic anomalies over this formation can reach only some hundred gammas at a height of 150 m. The mean value of the density determinations on three hand specimens was 2.86 g/cm^3.

Typical outcrops of Greenstone Formation II occur on the south shore of Piskamojärvi and on the northwestern slope of Petäjävaara, northeast of Rukajärvi. The main constituent of the formation is a volcanic rock composed of concentric spheres, 10—20 cm in diameter, (Fig. 13) assumed to have crystallized from erupted lava in the air. Massive parts occur also, but they are rare compared with the agglomerate portions. The agglomerate is green or greyish green in color and the surfaces of the outcrops are very rough. The shells of fragments are fine-grained and the inner parts are coarser, in many cases containing amygdules.

The mineral constituents of the agglomerate are chlorite and light green amphibole with varying amounts of albite and quartz. Epidote occurs generally and sphene and magnetite are common accessory constituents.

Greenstone Formation II was in many places estimated to be only about 50 m thick. It is bounded on both lower and upper sides by water-laid sediments. Thus it is highly likely that the volcanics also extruded below the water level and these volcanics may perhaps be pillow lavas with very small pillows (cf. Shrock, 1948, p. 361). Because homogeneous parts consisting presumably of lava flows combined with agglomerate occur in this formation, it is quite plausible that the volcanic vent, or vents, were not very far from the place of deposition.

Siltstone Formation

The Siltstone Formation is a heterogeneous unit of usually reddish schists. It is characterized by very fine-grained beds varying in lithologic composition from arkose to dolomite. The Siltstone Formation rests on Greenstone Formation II and is overlain by a thick formation of basic volcanics (Greenstone Formation III). The formation was named according to the typical grain-size range.

Magnetically, the Siltstone Formation belongs to the low-susceptibility group together with granite gneiss and the sediments of the area studied. The 26 determinations on three outcrops resulted in an average of $32 \cdot 10^{-6}$cgs varying from $0 \cdot 10^{-6}$ cgs to $75 \cdot 10^{-6}$cgs. The mean value of 28 density determinations was 2.66 g/cm^3.

Typical outcrops of the upper parts of the Siltstone Formation occur at Ruukinvaara, northeast of Lake Nissi and at the east end of a syncline trending to the east from Ruukinvaara. Many good exposures and cuttings of the middle and upper parts of the formation were observed in the Kitkajoki valley to the east and west of Lake Ala-Juuma. As a whole, the Siltstone Formation is a common occurrence in the study area, and there occur plenty of outcrops. The areas of the Siltstone Formation are lowlands, indicating that the formation disintegrates more easily than other units in the schist area.

The Siltstone Formation is composed of alternating fine-grained arkosic, argillaceous and dolomitic members, which are typically reddish in color. These members of the formation are not indicated on the geological map (App. I) because the different beds could not usually be traced very far. In the uppermost part of the Siltstone Formation, some coarser quartzitic beds with cross bedding and some schist beds with mud cracks occur. Graded bedding occurs throughout the formation, and the bedding is usually laminar with sharp boundaries.

Breccias were commonly observed in the Siltstone Formation, usually in connection with albite diabases. Presumably, the breccias were formed in part when albite diabase intrusions took place but some of them are very likely of tectonic origin, having formed during the folding of the schist sequence. Also sharpstone conglomerates (Shrock, 1948, p. 257) formed during the sedimentation occur to the east of the area now under consideration.

The lowermost member of Siltstone Formation in a section extending from the west end of Piskamojärvi to Ruukinvaara, in the southern part of area, is an arkosic, very thin bedded unit resting on Greenstone Formation II. The formation is continued by an argillaceous, dolomite-bearing member about 40 m upwards in the section. After 200 m without any exposure, the section is continued by an argillaceous member on the southern slope of Ruukinvaara. This is followed by a unit about 40 m thick composed of arkosic beds containing some cross bedded parts. The upper parts of this unit contain schist beds with mud cracks and, just below Greenstone Formation III, there occur some coarse quartzite beds with cross bedding (Fig. 14). The thickness of the formation is there about 200 m.

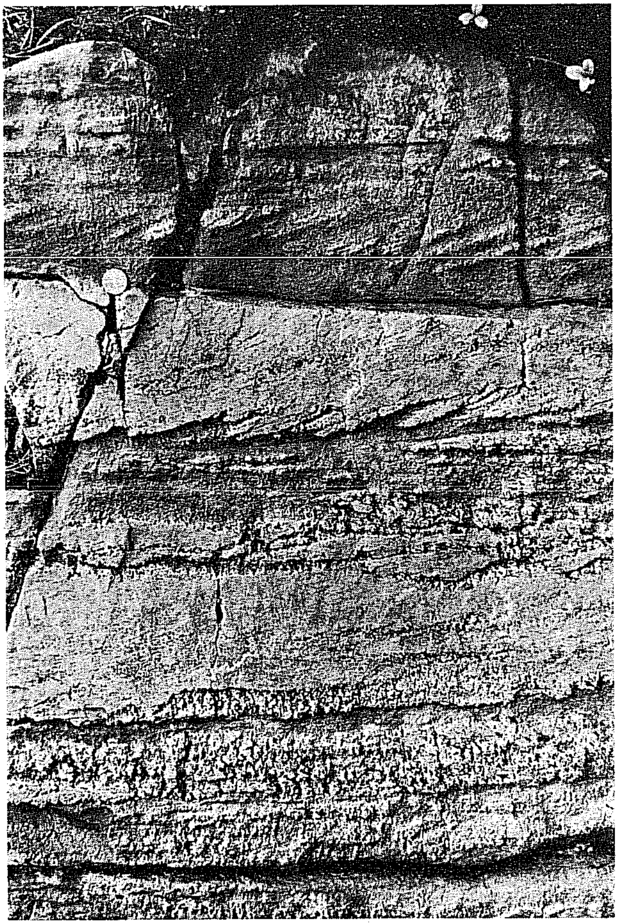


FIG. 14. Cross bedded coarse quartzite about one meter below the contact of the Siltstone Formation and Greenstone Formation III. Ruukinvaara. Diameter of the coin is 16 mm. Photo by author.

To the east of Lake Ala-Juuma, near the Jyrävä waterfall, the following succession occurs, reading from top to bottom:

(Greenstone Formation III)

Argillaceous schist with arkosic beds in upper part	thickness	c.	150 m
Orthoquartzite	»	»	10 m
Argillaceous schist, at places brecciated	»	»	30 m
Albite diabase	»	»	100 m
Dolomitic siltstone	»		unknown

TABLE 6

Mineralogical compositions of members of the Siltstone Formation. Point counting method. 1. 48b/AAS/66, 2 km east of Lake Nissi. 2. 89b/AAS/66, Soukkeloharju. 3. 29b/AAS/66, southern slope of Ruukinvaara.

	1.	2.	3.
Quartz	28 %	36 %	30 %
Feldspars	51 »	22 »	27 »
Carbonate minerals	11 »	—	14 »
Mica minerals	—	35 »	27 »
Accessories	10 »	7 »	2 »
	100 %	100 %	100 %

This succession is quite typical in the district to the west of Lake Ylä-Juuma, too. Because the lower contact of the formation was not found in these sections, it can only be said that the whole thickness of the formation in this part of the schist area is more than 200 m (excluding the albite diabase).

The mineral constituents of the members of the Siltstone Formation are quartz, feldspars, mica mineral and dolomite. Accessory amounts of oxidic ore minerals (mainly hematite), zirkon, sphene, tourmaline and apatite, occur. Some typical mineral compositions of members of the Siltstone Formation are given in Table 6. The grain size is usually very small (0.05—0.2 mm), but, in the uppermost part of the formation, there occur some coarser beds containing well-rounded quartz and feldspar grains up to 1 mm in diameter.

Schists of the Siltstone Formation are recrystallized and clastic features are no longer seen, but quartz and feldspars form a granoblastic mass. The reddish color is quite likely due to a typical content of pigmentary hematite which often occurs as large crystals in quartz veins. Albitization is striking in connection with albite diabases cutting the Siltstone Formation. Albite crystals have grown in the schist and taken the place of the original minerals. This adinolization (cf. E. Mikkola, 1941, pp. 253—256) is a prominent feature of the breccias situated near albite diabases.

In the uppermost part of the Siltstone Formation, recrystallized d o l o m i t e occur on the north shore of Kurikkalahti, at the west end of Lake Suininki and about 5 km west of that place, on the east shore of Vaimojärvi. This type of dolomite occurs as roundish bodies about 20—50 cm in diameter and as thin layers. The dolomite is exceedingly pure, as shown by the analysis (Table 7). Only minor amounts of albite, quartz, muscovite, ore minerals and tourmaline occur. The weathered surface is a rusty red in color while the fresh surface is nearly white. No sedimentary features were found.

The main part of the Siltstone Formation deposited in the water, but mud cracks and cross bedding in the upper parts indicate that the basin was filled and that the emergence occurred at least in places. It is not possible to verify the source of the

TABLE 7

Chemical composition of dolomite of the Siltstone Formation. 4 km northwest of Lake Suininki. No. 89/AAS /67. Analyst, R. Saikkonen.

	Wt. %	Mol. %
FeO	1.14	0.79
MnO	0.19	0.15
MgO	20.26	25.17
CaO	28.52	25.27
CO_2	42.75	48.26
Al_2O_3	0.36	0.35
Insoluble	6.64	—
	99.86	100.00

sediments, but the scarcity of the coarser sediments in the formation indicates that the source was rather far away. The particle size is of such an order that the material may have moved as a suspension in water (Bubnoff, 1963, p. 16).

Greenstone Formation III

A formation of basic volcanics about 200 m thick rests on the Siltstone Formation, and it is overlain by the sericite quartzite of the Rukatunturi Quartzite Formation. Since Greenstone Formation III is usually strongly magnetic, it can serve as a key horizon in geological mapping. It can be followed on aeromagnetic maps, and details can be found by magnetic measurements on the ground.

The susceptibility of the rocks of Greenstone Formation III is $1965 \cdot 10^{-6}$cgs, the average yielded by 359 measurements on 10 outcrops. It was found that foliated parts of the formation have lower susceptibility values than preserved parts, and this must undoubtedly cause breaks in the magnetic anomalies. The density was measured from 13 samples, which gave an average value of 2.91 g/cm^3.

Basic volcanics are resistant to disintegration and that is why outcrops of Greenstone Formation III are numerous. The lower contact zone is exposed at Ruukinvaara, northwest of Lake Nissi and in the tract around the Jyrävä waterfall, east of Lake Ala-Juuma. Near Kuusijärvi, southeast of Lake Ala-Juuma, both lower and upper contact zones are exposed and there occur large areas of exposed volcanics, too. The upper contact is exposed in several places, as shown on the geological map.

Typical outcrops of Greenstone Formation III occur in the valley of Merioja, running from Merilampi to Oulankajoki. Near the lower contact, the volcanics are fine-grained and partly tuffitic, but some meters upwards volcanic structures, mainly amygdules, occur. The formation is composed of massive lava layers, some tens of

FIG. 15. Amygdule-rich part of Greenstone Formation III. Southwest of Lake Verkas. Diameter of the coin is 16 mm. Photo by author.

meters thick, with amygdule-rich upper surfaces (Fig. 15). The homogeneous parts are medium- or coarse-grained.

The main minerals are pale green amphibole, albite and, in many places chlorite. Smaller amounts of epidote, magnetite and sphene occur. The amygdules are filled with quartz, carbonate minerals or epidote.

Because Greenstone Formation III is usually visible on aeromagnetic maps and often distinguishable in aerial photographs, it was possible to draw a rather detailed map without outcrops, as in the case of the area east of Rukatunturi and Valtavaara. During the mapping work, this kind of interpretation was used to produce the framework and details of the geological map.

The wide areal distribution of Greenstone Formation III is a striking feature and the rather constant thickness of the formation indicates that the area was flat when lavas were flowing over the surface. No lava vents were observed in the area. Mud cracks occur in the Siltstone Formation under the lavas and in the lower parts of the Rukatunturi Quartzite Formation over them; hence lavas flowed either over dry surface or in very shallow water.

Rukatunturi Quartzite Formation

On Greenstone Formation III, the stratigraphic succession is continued by a thick formation of quartzites (Fig. 3). The internal succession of the members of this Rukatunturi Quartzite Formation was observed to be the following from the oldest to the youngest:

— dark, fine-grained tuffitic schist with graded bedding and cross bedding (0—20 m)
— coarse, mostly pink dolomite and sandy quartzite with cross bedding (5—15 m)
— sericite-rich medium- to coarse grained, yellowish or pink quartzite with graded bedded, mud cracked, red or reddish grey schist intercalations containing generally ripple marks, mud breccias and low-angle cross beds (20—50 m)
— yellowish to white sericite quartzite in which the amount of sericite diminishes upwards to produce arkosic quartzite (100—200 m)
— orthoquartzite containing some mud cracked schist intercalations with graded bedding (up to 600 m).

The Rukatunturi Quartzite Formation is overlain by the Dolomite Formation. Since orthoquartzites are highly resistant to disintegration, the highest hills of the Rukatunturi area are composed of the orthoquartzite member of this formation. The Rukatunturi Quartzite Formation was named after the high peak Rukatunturi, which belongs to the series of quartzite fells in the central part of the area studied.

The susceptibility was determined from 13 hand specimens of the Rukatunturi Quartzite Formation; the highest value yielded was $30 \cdot 10^{-6}$cgs and the average $8 \cdot 10^{-6}$cgs. The formation belongs to the low-susceptibility group, which causes no magnetic anomalies in the aeromagnetic maps. The densities were measured from 27 specimens, the mean value obtained being 2.62 g/cm^3.

Typical outcrops of the Rukatunturi Quartzite Formation occur in the syncline structure striking from Pyhäjärvi through Rukatunturi to the north. This syncline is here called the Rukatunturi syncline. The lower contact zone of the formation is exposed at numerous places together with outcrops of Greenstone Formation III. The southernmost occurrence is in the syncline structure around Lake Kivi-Piskamo. Outcrops near the upper contact were found in tracts north of Rukatunturi, south of Lake Ylä-Juuma and at Kiutaköngäs. No angular unconformity was observed at the lower contact, but some breccias near Kiutaköngäs in the upper contact zone perhaps indicate an unconformity.

The sericite quartzite member of the Rukatunturi Quartzite Formation is the lowermost of the ones that have a wide areal distribution. A dark, fine-grained tuffitic member with graded bedding occurs only at the northwestern end of Pyhäjärvi and at the northern end of the long cape of Lake Porontima. Usually the formation begins with a few meters of dolomite, which gradually changes to sericite quartzite. Sericite quartzite is rich in dolomite in the lower part. A reddish shade is typical of the lower part of the member, the upper parts are yellowish white in color. Red or reddish-brown schist intercalations occur regularly in the sericite quartzite member near its lower contact. Low-angle cross bedding and ripple marks (Fig. 16) are typical features of sericite quartzites and schist beds have abundant mud cracks (Fig. 17), which here and there have caused the formation of mud breccias or sharp-

FIG. 16. Low-angle cross bedding and ripple marks in the sericite quartzite member of the Rukatunturi Quartzite Formation. Eastern slope of Rukatunturi. Photo by author.

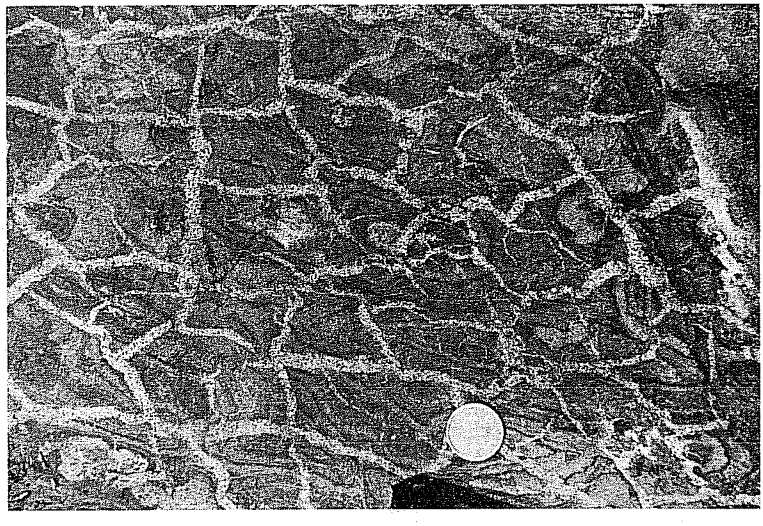


FIG. 17. Mud cracks in the sericite quartzite member of the Rukatunturi Quartzite Formation. Western end of Lake Verkas. Diameter of the coin is 16 mm. Photo by author.

stone conglomerates (Shrock, 1948). Foliation is common and in many places marked owing to the sericite matrix.

The mineral constituents of sericite quartzites are quartz and feldspars, which occur as well-rounded grains; and the matrix is composed of sericite, often seen to

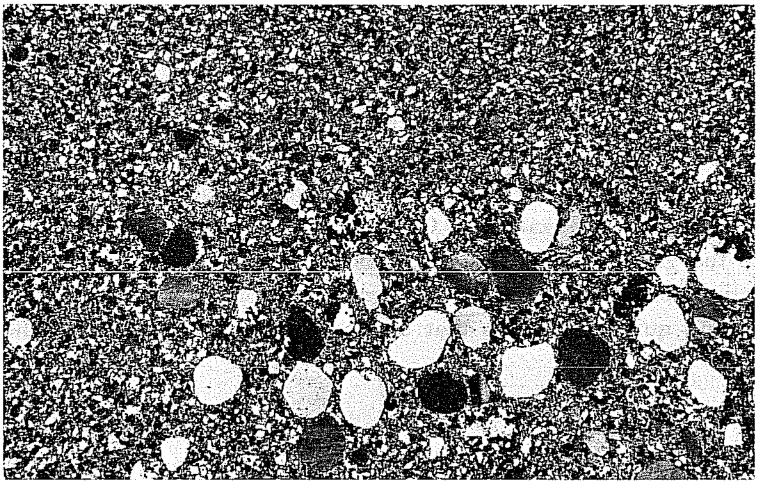


FIG. 18. Sericite quartzite of the Rukatunturi Quartzite Formation. A granoblastic fragment composed of quartz is seen in middle of picture. One kilometer south of Pyhäjärvi. Crossed nicols, 8.5 x. Photo by Erkki Halme.

contain small, poorly rounded quartz and feldspar grains. The grain size of the larger grains is 0.5—2.0 mm and the matrix is fine-grained. Granoblastic fragments composed of quartz occur also (Fig. 18), but their origin could not be determined.

The thickness of the sericite quartzite member of the Rukatunturi Quartzite Formation was measured on the western flank of Rukatunturi syncline to be about 200 m.

O r t h o q u a r t z i t e s make up most of the Rukatunturi Quartzite Formation. The sericite quartzite changes gradually to the orthoquartzite through arkosic variants. The orthoquartzites are usually light reddish in color, especially in lower parts of the member containing small amounts of feldspars. Cross bedding is common in the orthoquartzites, but it was difficult to measure owing to the brecciation of the rocks and the rough surfaces of outcrops. The orthoquartzites are usually cut by small, lenticular quartz veins. Ripple marks were observed especially in the lower part of the member. In addition to the quartz, the orthoquartzites contain accessory feldspars and usually a little sericite. Pure orthoquartzites are recrystallized to glassy rocks, which show no original structures; and this type forms the uppermost part of the formation.

The thickness of the orthoquartzite member was measured in the Rukatunturi syncline to be 600 m. Nearly the same values were estimated at several other places in the area. In the north, there occur much thicker schist intercalations in the orthoquartzite than in the southern part of the area.

Mud cracks of the schist intercalations of the Rukatunturi Quartzite Formation indicate that the sedimentation surface at times emerged. The ripple marks and cross bedding were formed in shallow water. These features, together with the observation that the lower contact of the formation is characterized by the same features all over the area, show that the formation was deposited on a plane surface that emerged occasionally. Observations in the district of Rukatunturi faintly indicate that the formation was deposited in three cycles, each represented by grading from fine-grained schist through arkosic quartzite to orthoquartzite.

The material of the Rukatunturi Quartzite Formation derived from acidic rocks and hence the granite gneiss basement undoubtedly formed the erosion area for this formation. The matureness of the components of this formation indicates that the basin sank quite slowly, so that erosional agents could rework the material thoroughly.

Dolomite Formation

Between the orthoquartzite of the Rukatunturi Quartzite Formation and the Amphibole Schist Formation (see Fig. 3, p. 10) lies a unit composed of dolomite usually rich in quartz, here referred to as the Dolomite Formation. This formation was observed especially in the northern part of the study area as well as in the syncline around Lake Ylä-Juuma.

The Dolomite Formation at Kiutaköngäs begins with red-colored brecciated dolomite beds resting on the fractured and brecciated upper surface of the orthoquartzite. These breccias possibly indicate an unconformity between the Rukatunturi Quartzite Formation and the Dolomite Formation. On the other hand, the contact surely has been a highly favorable boundary for tectonic movements during the folding of the schist belt and the breccias may be tectonical ones, as well.

The section of the Dolomite Formation at Kiutaköngäs is composed of red-colored, bedded dolomites containing varying amounts of sharply bounded, finely laminar beds of quartzite. The upper parts of the formation are composed of yellowish white, grey or reddish dolomite. Calcite veins were encountered here and there. The contact of the Dolomite Formation against the amphibole schists to the north of Kiutaköngäs, is gradational.

The grain size of the dolomites near Kiutaköngäs varies from fine to coarse. Hackman and Wilkman published a chemical analysis of a coarse-grained, red dolomite at Kiutaköngäs (1929, p. 102), and it is reproduced in Table 8.

At the southeastern end of Lake Ylä-Juuma, there occur the same kinds of dolomites as at Kiutaköngäs. But there the lower contact of the formation is not exposed. The dolomites are white grey, and their weathered surfaces are rusty brown. They are clearly bedded with finely laminar quartz-rich beds. A chemical analysis of a dolomite near Lake Ylä-Juuma was published by Hackman and Wilkman (1929, p. 102), and it is reproduced in Table 8.

TABLE 8

Chemical composition of coarse- grained red dolomite at Kiutaköngäs (I) and light red dolomite at southeastern end of Lake Ylä-Juuma (II) (Hackman and Wilkman, 1929, p. 102).

	I	II
CaO	28.66 %	36.78 %
MgO	17.30 »	12.40 »
$Al_2O_3+Fe_2O_3$	2.30 »	0.68 »
CO_2+H_2O	44.95 »	44.00 »
Insoluble	8.88 »	6.84 »
	102.09 %	100.70 %

The Dolomite Formation is also exposed on the south shore of Lake Kuopunki. There it forms an anticline, the fold axes of which gently dips southward. At the south end of the Rukatunturi syncline, the Dolomite Formation appeared, too. There, however, the formation seems to be very thin and it is not marked on the geological map.

The thickness of the Dolomite Formation is quite likely less than 100 m; but any exact measure is difficult to obtain because of prominent folding and dragfolding of the unit. The formation is thicker at Kiutaköngäs than in the Rukatunturi syncline.

The carbonate material of the Dolomite Formation was deposited under marine conditions, and it may be either of organic origin or a chemical precipitate. The deposition perhaps originally took place as calcium carbonate, which was dolomitized either during the deposition or later. The characteristics and the stratigraphic position of the Dolomite Formation are the same as those of the one in the Kemi area containing stromatolites (Härme and Perttunen, 1964, pp. 79—82). Reliably identifiable stromatolites have not, however, been found as yet in the Rukatunturi area.

Amphibole Schist Formation

The uppermost part of the stratigraphic succession in the area (see Fig. 3, p. 10) was named the Amphibole Schist Formation after its main rock type. Intercalations of dolomite and black schist occur in the formation. The upper parts of the Amphibole Schist Formation, especially in the north, contain mica schist intercalations. Amphibole schists occur in the Rukatunturi syncline to the north of Rukatunturi and in the district of Lake Ylä-Juuma. The same formation surrounds the quartzite belt in the north. The Amphibole Schist Formation is penetrated by coarse-grained hornblendite sills.

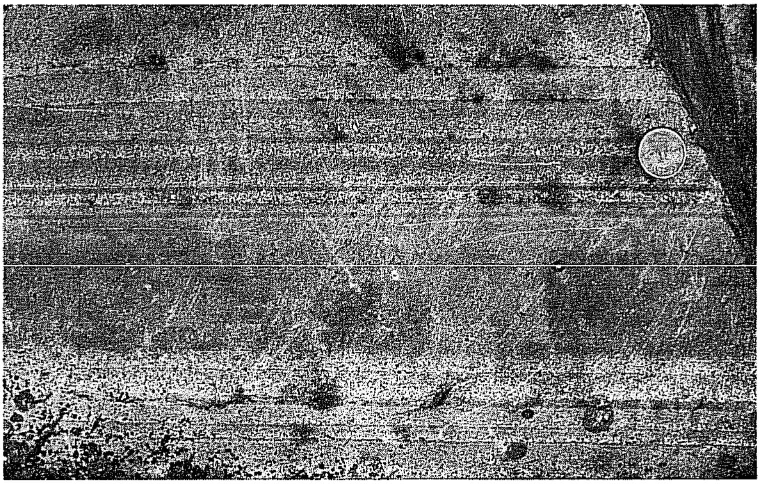


FIG. 19. Amphibole schist with graded bedding. About one kilometer west of Lake Konttainen. Diameter of the coin is 16 mm. Photo by author.

The susceptibility of the amphibole schists was measured to be $85 \cdot 10^{-6}$cgs, representing the average of 17 hand specimen determinations. The values usually varied from $24 \cdot 10^{-6}$cgs to $144 \cdot 10^{-6}$cgs, only one specimen giving a value as high as $10692 \cdot 10^{-6}$cgs — indicating that some iron-rich layers occur in the formation. The densities of these 17 hand specimens resulted in an average of 2.80 g/cm³. The black schist intercalations undoubtedly cause electromagnetic anomalies because of the generally high content of graphite and pyrite .

The amphibole schists rest on the dolomites and the contact between them is gradational. On the south shore of Lake Kuopunki, the internal succession of the Amphibole Schist Formation was observed to be as follows:

— amphibole schist with some mica schist beds	thickness unknown
— hornblendite sill	» c. 40 m
— amphibole schist	» » 20 »
— black schist	» » 20 »
— amphibole schist resting on Dolomite Formation	» » 20 »

The amphibole schists are green in color and the bedding is clearly visible as tone variations. The grain size is generally small, but in some places there occur large amphibole porphyroblasts. Graded bedding is a common feature (Fig. 19), and the determination of the tops of beds is usually easy. The bedding is generally finely laminar and beds are rather variable in thickness, but continuous.

TABLE 9

Mineralogical composition of fine-grained amphibole schist. 1 km west of Valtavaara. Point counting method.

Amphibole	81 %	Amphibole: $c \wedge \gamma = 19°$
Quartz and plagioclase	15 »	weak pleocroism:
Accessories	4 »	α = yellowish green
	100 %	γ = bluish green

The main minerals of the amphibole schists are pale green amphibole and smaller amounts of quartz and plagioclase (Table 9). Light minerals form a granoblastic mass where the needle- like amphibole crystals are embedded. Pigmental graphite is a common accessory constituent of the amphibole schists. Amphibole porphyroblasts, up to 10 mm in length, were often met with in the schists. Magnetite porphyroblasts are common.

The b l a c k s c h i s t s occur as intercalations in the amphibole schists, and they are very fine-grained graphitic schists usually containing pyrite. The black schist beds have gradational contacts with the surrounding amphibole schists.

The d o l o m i t e in the Amphibole Schist Formation occurs as intercalations 10—50 cm thick and these beds have in some instances been deformed to boudinage-like inclusions (Fig. 20). The inclusions are ellipsoidal in cut and they mostly occur as strings in exactly the same bed. This kind of »boudinage» occurs rather commonly in the amphibole schists to the west of Valtavaara, in the Rukatunturi syncline. The boudinage-like structures presumably originated during the diageneses of the sediments.

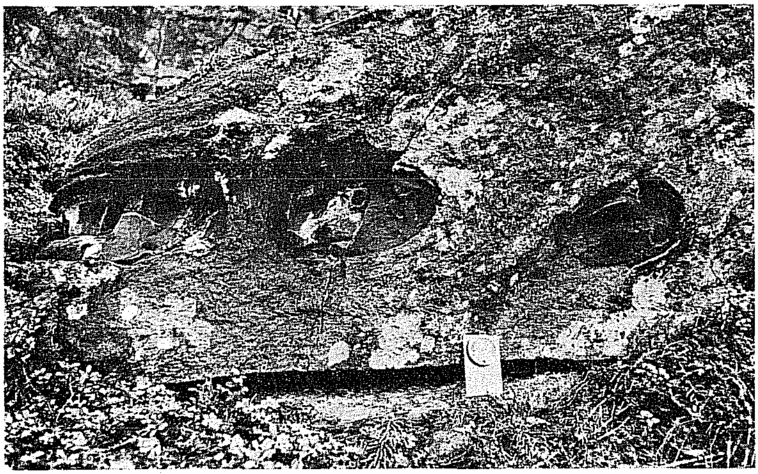


FIG. 20. Dolomite inclusions in amphibole schist. One kilometer northwest of Valtavaara. Shorter side of the compass is 65 mm. Photo by author.

The dolomite in both the beds and the inclusions is recrystallized and, in addition to carbonate, contains needle-like, pale green amphibole crystals and some albite. A point-counter analysis of a medium-grained, relatively light dolomite occurring one kilometer northwest of Valtavaara, yielded: 70 % of dolomite, 26 % of amphibole and 4 % of accessory constituents (mainly albite). The color of the dolomite depends on the content of graphite, which is a prominent constituent of fine-grained and dark dolomite layers and inclusions.

The Amphibole Schist Formation was measured in the Rukatunturi syncline to be at least 250 m thick. The characteristics of the formation suggest calm sedimentation and a slow rate accumulation. The amphibole schists were deposited below water level, as is shown by the sedimentary features. The black schist intercalations seem to indicate restricted circulation of water in the basin of sedimentation.

The material of the lower beds of the Amphibole Schist Formation is basic as a whole, and it originated either as tuffs or from basic volcanics as weathered, fine-grained material. The carbonate material and the material of the black schists are presumably at least in part of organic origin, though no proof of this was found. The mica schist beds in the upper parts of the formation are normal clastic sediments.

Intrusive rocks

Sills and dikes of differentiated albite diabases were observed, especially in the central part of the study area. To this formation belong differentiates ranging from hornblendites through albite-rich diabases to albite carbonate rocks. Coarse-grained hornblendite without more acidic differentiates occurs as sills in the Amphibole Schist Formation.

The albite diabases are strongly magnetic and the susceptibility measurements revealed that the content of magnetite is greatest in the light, albite-rich differentiates of diabases. The susceptibility varied in the range from $690 \cdot 10^{-6}$cgs to $14353 \cdot 10^{-6}$cgs, resulting in the mean value of $5880 \cdot 10^{-6}$cgs for the albite diabases measured in 82 places in the area of outcrops to the west of Lake Viipus, on the western flank of the Rukatunturi syncline. According to the susceptibility measurements, albite diabases cause the highest magnetic anomalies in the Kuusamo schist area. It is noteworthy that, owing to a typical sulphidic ore mineral content, the albite diabases undoubtedly cause small eletro-magnetic anomalies, too. The density of the albite diabases varies in different varieties.

Typical outcrops of the albite diabase formation were observed on the northwestern flank of the Rukatunturi syncline near Lake Viipus. The albite diabase sill there is situated along the contact between Greenstone Formation III and the Rukatunturi Quartzite Formation.

The color of the albite diabases varies from dark green to reddish white depending on the amphibole content. The grain size is generally about 2—5 mm, and the ophitic texture is clearly visible, especially in albite rich varieties. Light differentiates of the albite diabase are usually coarser than the dark ones.

Albite, pale green amphibole and, in some places epidote are the main minerals of the albite diabases. The magnetite content is high, and usually it occurs together with leucoxene lamellae. The carbonate mineral is a common accessory constituent and in light differentiates, it is a prominent main mineral together with albite. Pyrite is rather common in carbonate-rich varieties. The differentiation of the diabase sills occurred so that dark, amphibole-rich varieties crystallized on the lower side of the sill and the diabase turns lighter towards the upper parts of the sill, as is seen at Lake Viipus.

The intrusion of the albite diabases took place before the main folding of the schist belt, as can be concluded, for example, in the vicinity of the Jyrävä waterfall, where a diabase sill is folded together with sedimentary formations. It seems quite likely that the albite diabases intruded mainly as nearly horizontal sills. The source of the albite diabase magma presumably was the same as that of the basic volcanics in the schist area.

The hornblendites occur as coarse-grained sills in the amphibole schists. Unlike the albite diabase series, the hornblendites penetrating the amphibole schists are undifferentiated. The sills are generally only some tens of meters thick, and they have a rather definite stratigraphic position above the black schist member of the Amphibole Schist Formation. At Lake Kuopus, a sill in this position was found to extend nearly two kilometers. The sill is there folded together with the surroundings. At Lake Lukkolainen, as well as in the Rukatunturi syncline, a hornblendite sill occurs in the same stratigraphic position.

The contacts of the hornblendite sills are obscure because of the recrystallization of the surrounding amphibole schist beds. On the south shore of Lake Lukkolainen, the contact zone is some meters wide and it contains ghost-like remnants of amphibole schist in fine- or medium-grained hornblendite. The middle part of the sill is coarse-grained (0.5—1.5 cm) and quite homogeneous.

Hornblendites are composed of large amphibole crystals ($c \wedge \gamma = 23°$; α = grass green, γ = brownish green) with inclusions of saussuritized plagioclase laths. Epidote, quartz, biotite and oxidic ore mineral are accessory constituents.

The hornblendites penetrate the uppermost formation in the area investigated and they indicate that the basic magmatism continued until this stage. The intrusions took place before the main folding of the schist belt.

STRUCTURE

The structure of the Svecokarelian formations of the study area is rather complicated,but the mapping was facilitated by the fact that there is a magnetic volcanic formation in the middle of the sedimentary column (Greenstone Formation III). Moreover, the schists have dissimilar disintegration characteristics, so the aerial photographs were exceedingly helpful in the interpretation of the structural features. The area is typified by folding with curved, mostly steeply dipping axial planes and by steeply dipping faults in various directions.

Folding

All the Svecokarelian formations in the Rukatunturi area have undergone folding. Greenstone Formation I was perhaps gently folded before the deposition of the overlying formations, as is suggested by its inhomogeneous occurrence in the area. The axial planes of folds are given on the appended tectono-magnetic map (App. II).

In the southern and southeastern parts of the area, the trends of the folds are in the directions 260—290°. This area is cut by faults with strikes of 50—70° and 260—290° and dips of from 60° to 80° northward. These faults have caused a prominent shear cleavage in the southern and southeastern parts of the area. The representative of folding in this part of the area is the syncline striking through Lake Nissi to Lake Suininki and the anticline north of it. This folding was probably controlled by faulting and thrusting of the granite gneiss basement, and the folds presumably actually have more angular features than is represented on the maps (App. I and App. II).

The central and northern parts of the area are characterized by a fold striking from Pyhäjärvi across Rukatunturi to the northern border of the area; it is here referred to as the Rukatunturi syncline. This open syncline has a curved axial plane dipping 50—80° to the west. It has two depressions, one to the north of Rukatunturi and the other in the district around Lake Ylä-Juuma, occupied by the uppermost formation. The forms of this syncline are rounded and it appears to be of the decollement type of fold (Douglas, 1950). Folds of the same type occur east of Rukatunturi and in the northeastern part of the area. That is why the folding in the district to the east of Lake Ala-Juuma is complicated, as it is typical of an area where folds of different trends merge.

A simple model representing the folding of the sequence is a fold system formed by a single phase of deformation. A force acting from the west pushed the sedimentary-volcanic cover in partly decollement folds and partly fault-controlled folds against two blocks, one to the northeast, the other to the southeast of the area. The southeasterly block was the Saamian granite gneiss complex. The same complex seems to have acted as another block on the northeastern side of the folded belt as well, since the greenstone complex of Salla rests in the east on the Saamian granite gneiss complex.

Faults

Some faults were delineated in the Rukatunturi area, and doubtless many more actually exist. Most of the faulting certainly took place during the folding of the sedimentary-volcanic cover, but faults of both the prefolding and the postfolding period undoubtedly also occur. The recrystallized mylonite fragments of basal conglomerate indicate that there were also faults of predeposition age. The different age groups are, however, hard to verify. The positions of known and inferred faults are shown on the geological map (App. I) and on the tectono-magnetic map (App. II).

A fault system running in the direction 260—290° is observed in the southern part of the area. The dips of these faults are around 60—80° northward and the northern side is mostly thrust upward. Faults in the same direction were found also south of Rukatunturi and on the east shore of Lake Ylä-Juuma.

A fault system with sharply cutting features strikes in the direction 50—70°. This fault system appears to slope rather gently to the northwest. It was observed especially in the zone running from Rukajärvi to the northeast. The northwestern side is thrust up in this fault system.

A flexure-like fault zone strikes in the direction 320—340° from Lake Suininki across Säkkiläjärvi to the northwest. Thrusting seems to have occurred in the southern part of this fault so that the northeastern side has been thrust up.

In the district around Lakes Ylä-Juuma and Ala-Juuma, sharply cutting faults occur running in several directions.

DISCUSSION

Sedimentation

The stratigraphic succession in the area investigated is a close cratonic association of the Karelian sandstones, silts and dolomitic sediments with intercalations of basic volcanics. The whole sequence lies with the first-order unconformity on the Saamian craton. In the classification of Krumbein and Sloss (1963, pp. 558—565), it is an arkose association with basal arkoses. Most of the clastic sediments were erosion products of the basement with smaller amounts of nonclastic sediments, mainly dolomites. The sedimentation conditions and the supply of the materials were highly controlled by tectonism, and the complicated stratigraphic sequence of the area clearly indicates that at that time the tectonic activity was intense in the Svecokarelian foreland area.

The slight thickness of the basal conglomerate bed indicates that the area served as a supply of sedimentary material before the volcanic activity that produced Greenstone Formation I. In many places, a thick weathered crust occurs under the Jatulian group in eastern Finland (Sederholm, 1931, p. 77; Saksela, 1933, pp. 33—34; Ojakangas, 1965, p. 69; Piirainen, 1968, pp. 17—18; Nykänen, 1968, p. 60), but here was observed only thin layer of foliated chlorite- and sericite-rich granite gneiss type in the contact zone.

Volcanics of Greenstone Formation I are started by a volcanic breccia highly similar to the one described by Sinitsyn (1969) in the vicinity of Lake Voloma in east Karelia. The basic volcanics extruded mainly on land, and the formation is composed of lavas and tuffs.

Sedimentation represented by the formations from the Sericite Quartzite Formation to Greenstone Formation II was transgressive. Dolomite beds and dolomite-cemented quartzites indicate that the conditions extended to the normal marine. The deposition of carbonate material ceased when the sedimentation of the material of the quartzite schists (Quartzite Schist Formation) started and this presumably took place in such a way that the sea was cut off and sedimentation continued in a different pH-Eh field than earlier (cf. Krumbein and Garrels, 1952).

The sedimentary features of the sericite quartzites are quite scarce and fine-grained beds are lacking, which possibly lends support to Väyrynen's theory that some of the Jatulian quartzites in eastern Finland may have originated as wind-blown desert sands (Väyrynen, 1954, p. 172).

Greenstone Formation II marks deep fractures, through which the basaltic magma welled up on to the surface of the sediments. Vents through which these volcanics extruded were presumably situated on the southern side of the schist area because the formation was observed in the southern part of the mapped area only.

The rather inhomogeneous Siltstone Formation was deposited under restless regressive conditions, and the top of the formation with mud cracked beds and ripple marks, indicates that the emergence happened before the upwelling of the basic volcanics of Greenstone Formation III. These volcanics again mark a restless period in the Svecokarelian foreland and deep fractures in the crust. A part of the basaltic magma intruded the unlithified sediments forming differentiated albite diabases. The constant thickness of Greenstone Formation III indicates that the area was flat when the lavas poured out over the surface.

The upthrown supply area provided material for the Rukatunturi Quartzite Formation, which has a very mature upper unit. The thoroughly weathered material of this formation was deposited in a slowly sinking basin with shallow water. The deposition surface sometimes emerged above the water level. Red beds in the formation possibly indicate that the sedimentation took place under oxidizing conditions.

The Rukatunturi Quartzite Formation and the Dolomite Formation together constitute the orthoquartzite-carbonate association in the sense of Pettijohn (1957, p. 611). This association indicates that the area became flat, and the amount of clastic material entering the basin became negligible. When the sea entered the area, the deposition of the material of the Dolomite Formation, was started.

The Amphibole Schist Formation is uppermost in the study area. The material of the black schist member was deposited under euxinic conditions. The dolomite beds, together with black schists are conceivably in part of organic origin. The Amphibole Schist Formation together with the underlying Dolomite Formation, is in good correlation with the marine Jatulian formation elsewhere in the Karelidic belt (Metzger, 1924; Hausen, 1930; Härme, 1949; Nykänen, 1971). The mica schists in the upper part of the formation indicate that the formation represents the transitional facies to the flysch period (Aubouin, 1965) of the Svecokarelian orogeny. The isolated basins with euxinic sedimentation were formed because of the obstructive effect of the uplifted fold belt on the side of the area adjacent to the sea.

Correlation

Rock-stratigraphic correlation

In the Rukatunturi area, the Svecokarelian sequence begins with basal conglomerates directly overlain by basic volcanics (Greenstone Formation I). No marks of after-deposition weathering were observed in the basal conglomerate and consequently no correlation with the Sariolian formation could be verified. Moreover, according to Negrutsa (1965), there occur three non-contemporaneous weathering crusts of a kaolin type in the Karelian sequence of the Jangozero trough in east Karelia and thus the weathered crust does not represent an exact key horizon for correlating the Karelian sequences of different areas.

The correlation of the Kainuan quartzite formation to the formations in the Rukatunturi area is not straightforward, either, because of the position of Greenstone Formation I. The correlation may best be made with the Sericite Quartzite Formation on the basis of the definition that »the Kainuan quartzites form the lowest member of a transgressive epicontinental succession . . .» (Simonen, 1960 a, p. 25). This rock-stratigraphic correlation gives no information, however, about the age relations between the Kainuan quartzite formation and the Sericite Quartzite Formation in the Rukatunturi area. It is evident that the lower units of the Svecokarelian foreland deposits are complicated and their deposition and internal order of formations depended in great deal on the development of individual basins or zones (cf. Hoffman *et al.* 1970, p. 204).

The marine Jatulian formation in eastern Finland (Väyrynen, 1933, p. 64) form a transitional phase between the underlying terrigeneous Jatulian deposits with the Saamian granite gneiss as the source area and the Kalevian graywacke-flysch sediments (Simonen, 1960 a, p. 25) above them. The marine Jatulian sediments were deposited under euxinic conditions presumably in blocked seas and the theoretical position of this type of transitional condition is clear (cf. lutites of Dewey and Bird, 1970, p. 2638, fig. 10) and the deposits are easily recognized when they overlie the shelf sediments (orthoquartzite-carbonate association) of the foreland. Since the marine Jatulian formation is an easily recognized part of the Karelian sequences and has a fixed theoretical position in relation to the Svecokarelian geosynclinal evolution, it is a practicable rock-stratigraphic unit for correlative purposes. Moreover this unit possesses certain time-stratigraphic aspect, too, because it represents the time of transition from the pre-flysch period (Jatulian) to the flysch period (Kalevian). In other words, it is bound to the wandering of the continental rise towards the foreland (Dewey and Bird, 1970).

The Amphibole Schist Formation, together with the underlying Dolomite Formation, is in good correlation with the marine Jatulian formation elsewhere in eastern and southeastern Finland (cf. Metzger, 1924; Väyrynen, 1928; Hausen, 1930; Piirainen, 1968; Nykänen, 1971), as was stated earlier (p. 42). The Amphibole Schist Formation can readily be correlated with the formation composed of basic schists in the Kemi area in northwestern Finland (Härme, 1949, pp. 14—20).

Time-stratigraphic correlation

The rough limits of the age of the described deposition in the Rukatunturi area, are delineated by the Saamian revolution 2 600—2 800 m.y. ago (see p. 8) and the Svecokarelian revolution 1 800—1 900 m.y. ago (cf. Wampler and Kulp, 1964). The uppermost formation (Amphibole Schist Formation) in the Rukatunturi area is the transitional unit towards the deposits of flysch period. Hence its deposition took place nearer to the upper limit (1 900 m.y.) of this deposition interval.

No age determinations of the sedimentation were carried out in the Rukatunturi area but it is noteworthy that Wampler and Kulp (1962) announced a sedimentation age of 2 050 m.y. for the Karelian dolomite of Kalkkimaa, in the Kemi area. The dolomite of Kalkkimaa occurs in association with the basic schists (Härme, 1949) and those schists are rock-stratigraphically in good correlation with the Amphibole Schist Formation in the Rukatunturi area. If the time-stratigraphic aspects of the marine Jatulian formation (see p. 43) are taken into account, it may be concluded that the upper parts of the Karelian sequence in the Rukatunturi area deposited roughly about 2 000 m.y. ago.

On the basis of age determinations of albite diabases, Sakko (1971) concludes that the sedimentation of the Jatulian quartzites in the Kemi area took place over 2 160 m.y. ago and the same probably is also true of the lower quartzites in the Rukatunturi area.

ACKNOWLEDGMENTS

The present study was connected with the mapping of pre-Quaternary rocks by the Geological Survey of Finland. Professor Herman Stigzelius, Director of the Geological Survey of Finland, and Professor Ahti Simonen, Head of the Petrological Department, let me use the material collected for this study, which was accepted by the former for publication in the series Geological Survey of Finland, Bulletin. Professor Maunu Puranen, Head of the Geophysical Department of the Geological Survey of Finland, arranged for me an opportunity to perform the geophysical measurements.

In the field work, I was assisted by Messrs. Pekka Lestinen, Mag. Phil., Matti Kortesluoma, B. A., Pertti Väänänen and Pauli Laitinen. Mr Uljas Hämäläinen, an engineer, offered me quite valuable assistance in arranging the geophysical measurements. The chemical analyses were carried out in the Chemistry Department of the Geological Survey. The microphotographs were taken by Mr. Erkki Halme, and Mrs. Toini Mikkola, Lic. Phil., helped me in preparing the manuscript. The maps and figures were drawn by Mrs. Elsa Järvimäki, Mrs. Lea Torssonen and Mrs. Anni Vuori. Mr. Paul Sjöblom, M. A., revised and corrected the English of the manuscript.

Dr. Maunu Härme read the manuscript and made many useful suggestions, and Dr. Raimo Lauerma gave me support and good advice from start fo finish.

I wish to express my sincere thanks to all the persons mentioned and to all the others who helped me at various stages of my work.

Special thanks are due to Professor Juhani Seitsaari, my distinguished teacher, for his highly valuable counsel and constructive critisism of the manuscript.

A monetary grant awarded by the Foundation of the Outokumpu company afforded me the opportunity to concentrate on this study.

REFERENCES

AIRAS, K. (1965) Kuusamon Apajalahden kultamalmin ja sen lähiympäristön geologiaa. Unpublished Master Thesis, Department of Geology, University of Helsinki.

AUBOUIN, J. (1965) Developments in Geotectonics 1. Geosynclines. Elsevier, Amsterdam.

BUBNOFF, S. VON (1963) Fundamentals of geology. Oliver & Boyd, Edinburgh.

DEWEY, J. F. and BIRD, J. M. (1970) Mountain belts and the new global tectonics. J. Geophys. Res. Vol. 75 no. 14, pp. 2625—2647.

DOUGLAS, R. J. (1950) Callum Creek, Langford Creek, and Gap Map-areas, Alberta. Geol. Surv. Canada Mem. 255.

GERLING, E. K. and POLKANOV, A. A. (1958) Problema absolyotnogo vozrasta Dokemriya Baltiyskogo Shita. Akad. Nauk SSSR. Geokhimiya 8.

HACKMAN, V. (1910) [Map of Pre-Quaternary rocks], Lehti-sheet C 6, Rovaniemi. Suomen geologinen yleiskartta, 1 : 400 000.

HACKMAN, V. and WILKMAN, W. W. (1925) [Map of Pre-Quaternary rocks], Lehti-sheet D 6, Kuolajärvi. Suomen geologinen yleiskartta, 1 : 400 000.

—»— (1929) Kivilajikartan selitys D 6, Kuolajärvi. Suomen geologinen yleiskartta, 1 : 400 000.

HAUSEN, H. (1930) Geologie des Soanlahtigebietes im südlichen Karelien. Bull. Comm. géol. Finlande 90.

HOFFMAN, P. F., FRASER, J. A. and MCGLYNN, J. C. (1970) The Coronation geosyncline of Aphebian age, district of Mackenzie. Geol. Surv. Canada, Paper 40—70, pp. 201—212.

HÄRME, M. (1949) On the stratigraphical and structural geology of the Kemi area, northern Finland. Bull. Comm. géol. Finlande 147.

HÄRME, M. and PERTTUNEN, V. (1964) Stromatolite structures in Precambrian dolomite in Tervola, North Finland. C. R. Soc. Géol. Finlande 35; Bull. Comm. géol. Finlande 212, pp. 79—82.

INBERG, I. J. (1876) Bidrag till Uleåborgs läns geognosi. Bidr. till känn. af Finlands nat. och folk. 20.

JUHAVA, R. (1969) Kuusamon liuskealueen rakenteesta Posion Hyväniemen—Riisitunturin alueella. Unpublished Master Thesis. Department of Geology, University of Helsinki.

KENNEDY, W. Q. (1933) Trends of differentiation in basaltic magmas. Am. J. Sc., Vol. 25, pp. 239—256.

KOUVO, O. (1958) Radioactive age of some Finnish pre-Cambrian minerals. Bull. Comm. géol. Finlande 182.

KRATZ, K. O., LOBACH-SHUCHENKO, S. B. and CHEKULAYEV, V. P. (1970) Early Precambrian granitogenesis in Baltic Shield (geochemical aspect). Internat. Geology Rev. vol. 13, pp. 234—241.

KRUMBEIN, W. C. and GARRELS, R. M. (1952) Origin and classification of chemical sediments in the terms of pH and oxidation-reduction potentials. J. Geol. 60, pp. 1—33.

KRUMBEIN, W. C. and SLOSS, L. L. (1963) Stratigraphy and sedimentation. Freeman and Company, San Francisco.

LAUERMA, R. (1969 a) Kallioperäkartta, [Map of] Pre-Quaternaty rocks, Lehti-sheet 4621+4623, Salla. Geological map of Finland, 1 : 100 000.

—»— (1969 b) Kallioperäkartta, [Map of] Pre-Quaternary rocks, Lehti-sheet 3643, Kursu. Geological map of Finland, 1 : 100 000.

LAUERMA, R. and PIISPANEN, R. (1968) Worm-shaped cast in Precambrian quartzite from Kuusamo, Northeastern Finland. C. R. Soc. Géol. Finlande 39.

LESTINEN, P. (1969) Kuusamon liuskealueen eteläpuoleisen graniittigneissikompleksin geologiasta. Unpublished Master Thesis. Department of Geology, University of Helsinki.

MATISTO, A. (1958) Kivilajikartan selitys D 5, Suomussalmi, English summary. General Geological Map of Finland, 1 : 400 000.

METZGER, A. A. Th. (1924) Die Jatulischen Bildungen von Suojärvi in Ostfinnland. Bull. Comm. géol. Finlande 64.

—»— (1959) Svecofenniden und Kareliden; eine kritische Studie. Acta Acad. Aboensis, Math. et Phys. XXI, 16.

MIKKOLA, E. (1941) Kivilajikartan selitys B 7—C 7—D 7, Muonio—Sodankylä—Tuntsajoki. English summary. General Geological Map of Finland, 1 : 400 000.

MIKKOLA, T. (1953) Peruskalliogeologian näköaloja. Geologi, Vol. 5, p. 29.

—»— (1961) Sediment groups, particularly flysch, of the Precambrian in Finland. Bull. Comm. géol. Finlande 196, pp. 51—65.

NEGRUTSA, V. Z. (1965) Study of Proterozoic (Jatulian) facies in Central Karelia. Internat. Geology Rev. Vol. 7, pp. 1039—1056.

NYKÄNEN, O. (1968) Kallioperäkartan selitys. Lehti-sheet 4232—4234, Tohmajärvi. English summary. Geological Map of Finland, 1 : 100 000.

—»— (1971) On the Karelides in the Tohmajärvi area, eastern Finland. Bull. Geol. Soc. Finland 43, pp. 93—108.

OJAKANGAS, R. W. (1965) Petrography and sedimentation of the Precambrian Jatulian quartzites of Finland. Bull. Comm. géol. Finlande 214.

PAAKKOLA, J. (1964) Kuusamon pitäjän Virranniemen—Vallioniemen alueen kallioperä. Unpublished Master Thesis, Department of Geology, University of Oulu.

PEKKALA, Y. (1967) Karbonaattikivien koostumus, rakenne ja geologinen asema Liikasenvaaran—Taivalkönkään alueella Pohjois-Kuusamossa. Unpublished Master Thesis, Department of Geology, University of Helsinki.

PETTIJOHN, F. J. (1957) Sedimentary rocks. Harper and Brothers, New York.

PIIRAINEN, T. (1968) Die Petrologie und die Uranlagerstätten des Koli—Kaltimogebiets im finnischen Nordkarelen. Bull. Comm. géol. Finlande 237.

PIISPANEN, R. (1970) Karjalaisen jakson spiliittisistä kivistä Kuusamon liuskealueen länsiosassa. Unpublished Licenciate Thesis. Department of Geology, University of Oulu.

POLKANOV, A. A. and GERLING, E. K. (1960) The pre-Cambrian geochronology of the Baltic Shield. XXI. Internat. Geol. Congress, Norden 1960, Section 9.

SAKKO, M. (1971) Varhais-Karjalaisten metadiabaasien radiometrisiä zirkoni-ikiä. Geologi, Vol. 23, pp. 117—119.

SAKSELA, M. (1933) Die Kieserzlagerstätte von Karhunsaari in Nordkarelien, Finnland. Geol. Fören. i Stockholm Förh. 55, pp. 29—58.

SEDERHOLM, J. J. (1907) Om granit och gneis, deras uppkomst, uppträdande och utbredning inom urberget i Fennoscandia. Bull. Comm. géol. Finlande 23.

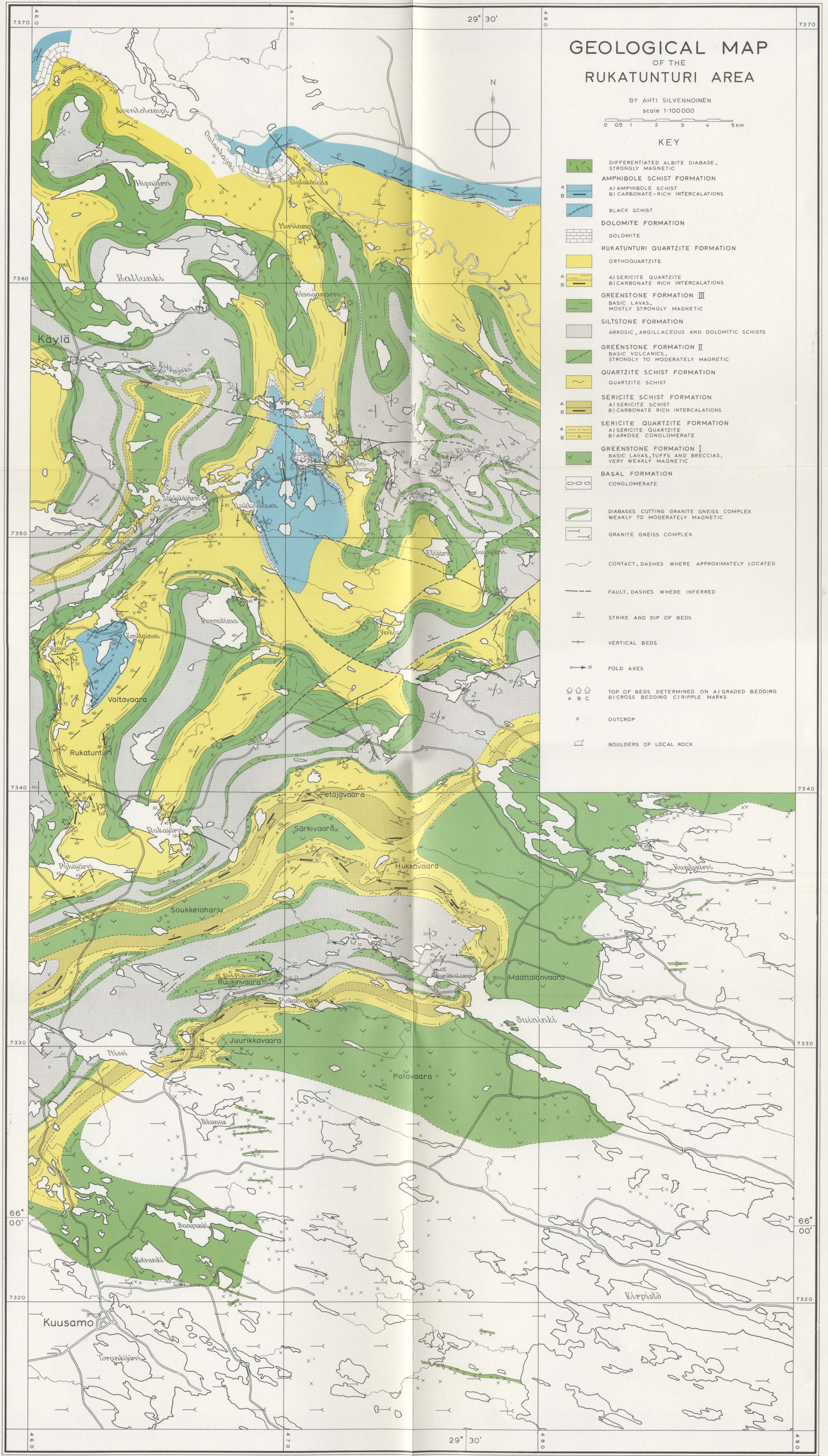
—»— (1931) On the Sub-Bothnian unconformity and on Archean rocks formed by secular weathering. Bull. Comm. géol. Finlande 95.

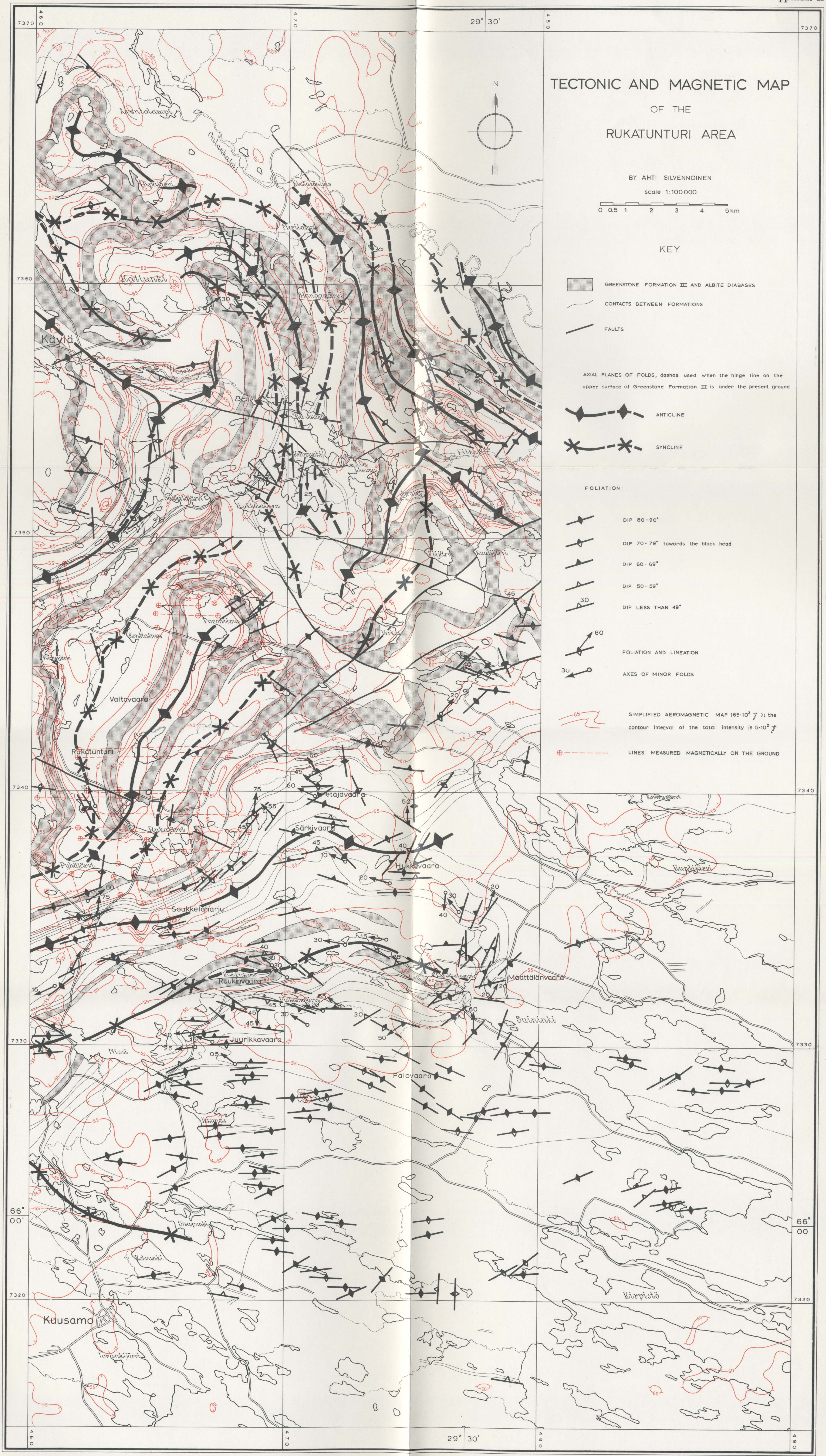
—»— (1932) On the geology of Fennoscandia with special reference to the Precambrian; explanatory notes to accompany a general geological map of Fennoscandia. Bull. Comm. géol. Finlande 98.

SHROCK, R. R. (1948) Sequence in layered rocks. Mc Graw-Hill, New York.

SILVENNOINEN, A. (1969) Kuusamon liuskealueen kaakkoisosan stratigrafiasta ja rakenteesta. Unpublished Licenciate Thesis. Department of Geology, University of Oulu.

SIMONEN, A. (1960 a) Pre-Quaternary rocks in Finland. Bull. Comm. géol. Finlande 191.
—»— (1960 b) Precambrian stratigraphy of Finland. XXI Int. Geol. Congress, Copenhagen, Section IX, pp. 141—152.
—»— (1971) Das finnische Grundgebirge. Geol. Rdsch. 60 (4), pp. 1406—1421.
SINITSYN, A. V. (1969) The Sariolan conglomerate of lake Voloma and the Sariolan problem of the Precambrian of Karelia. Doklady Acad. Sci. USSR., Earth Sci. Sect., Vol. 189, pp. 47—49.
SOKOLOV, V. A. *et al.* (1970) Geologiya, litologiya i paleogeografiya Jatuliya Tsentral'noy Karelii. Akad. nauk SSSR, Karel'skiy filial. Trud. inst. geologii. Vyp. 6, str. 1—367.
TURNER, F. J. and VERHOOGEN, J. (1960) Igneous and metamorphic petrology. McGraw-Hill, London.
WAMPLER, J. M. and KULP, J. L. (1962) Isotopic composition and concentration of lead in some carbonate rocks. Geol. Soc. Amer. Volume in honor of A. F. Buddington, pp. 105—114.
—»— (1964) An isotopic study of lead in sedimentary pyrite. Geochim. Acta, Vol. 28, pp. 1419—1458.
VÄYRYNEN, H. (1928) Geologische und petrographische Untersuchungen im Kainuugebiete. Bull. Comm. géol. Finlande 78.
—»— (1933) Über die Stratigraphie der karelischen Formationen. Bull. Comm. géol. Finlande 101, pp. 54—78.
—»— (1954) Suomen kallioperä. Otava, Helsinki.
YODER, H. S., JR. and TILLEY, C. E. (1962) Origin of basaltic magmas. J. of Petr., Vol. 3, pp. 342—532.


GEOLOGICAL MAP
OF THE
RUKATUNTURI AREA
BY AHTI SILVENNOINEN
scale 1:100 000
0 0.5 1 2 3 4 5 km
KEY
DIFFERENTIATED ALBITE DIABASE, STRONGLY MAGNETIC
AMPHIBOLE SCHIST FORMATION
A) AMPHIBOLE SCHIST
B) CARBONATE-RICH INTERCALATIONS
BLACK SCHIST
DOLOMITE FORMATION
DOLOMITE
RUKATUNTURI QUARTZITE FORMATION
ORTHOQUARTZITE
A) SERICITE QUARTZITE
B) CARBONATE RICH INTERCALATIONS
GREENSTONE FORMATION III
BASIC LAVAS, MOSTLY STRONGLY MAGNETIC
SILTSTONE FORMATION
ARKOSIC, ARGILLACEOUS AND DOLOMITIC SCHISTS
GREENSTONE FORMATION II
BASIC VOLCANICS, STRONGLY TO MODERATELY MAGNETIC
QUARTZITE SCHIST FORMATION
QUARTZITE SCHIST
SERICITE SCHIST FORMATION
A) SERICITE SCHIST
B) CARBONATE RICH INTERCALATIONS
SERICITE QUARTZITE FORMATION
A) SERICITE QUARTZITE
B) ARKOSE CONGLOMERATE
GREENSTONE FORMATION I
BASIC LAVAS, TUFFS AND BRECCIAS, VERY WEAKLY MAGNETIC
BASAL FORMATION
CONGLOMERATE
DIABASES CUTTING GRANITE GNEISS COMPLEX WEAKLY TO MODERATELY MAGNETIC
GRANITE GNEISS COMPLEX
CONTACT, DASHES WHERE APPROXIMATELY LOCATED
FAULT, DASHES WHERE INFERRED
STRIKE AND DIP OF BEDS
VERTICAL BEDS
FOLD AXES
TOP OF BEDS DETERMINED ON A) GRADED BEDDING B) CROSS BEDDING C) RIPPLE MARKS
OUTCROP
BOULDERS OF LOCAL ROCK
Käylä
Rukatunturi
Valtavaara
Kuusamo
29° 30'
66° 00'


TECTONIC AND MAGNETIC MAP
OF THE
RUKATUNTURI AREA
BY AHTI SILVENNOINEN
scale 1:100 000
0 0.5 1 2 3 4 5 km
KEY
GREENSTONE FORMATION III AND ALBITE DIABASES
CONTACTS BETWEEN FORMATIONS
FAULTS
AXIAL PLANES OF FOLDS, dashes used when the hinge line on the upper surface of Greenstone Formation III is under the present ground
ANTICLINE
SYNCLINE
FOLIATION:
DIP 80-90°
DIP 70-79° towards the black head
DIP 60-69°
DIP 50-59°
DIP LESS THAN 49°
FOLIATION AND LINEATION
AXES OF MINOR FOLDS
SIMPLIFIED AEROMAGNETIC MAP (65·10² γ); the contour interval of the total intensity is 5·10² γ
LINES MEASURED MAGNETICALLY ON THE GROUND
29° 30'
66° 00'
Käylä
Valtavaara
Rukatunturi
Porottima
Pyhäjärvi
Rukajärvi
Soukkelaharju
Ruukinvaara
Juurikkavaara
Petäjävaara
Särkivaara
Hukkavaara
Määttälänvaara
Suininki
Palovaara
Kuusamo
Kirpistö
Kuntijärvi
Saapunki

ISBN 851 — 690 — 002 — X