

A/S SULFIDMALM INNER FINNMARK PROJECT

REPORT ON GEOLOGICAL MAPPING AND

EXPLORATION WORK 1965-1966

PART II,

GENERAL INFORMATION

REGIONAL GEOLOGY AND PETROLOGY

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C O N T E N T S

	page
1. <u>GENERAL INFORMATION. (E.G.H.)</u>	1
A. Location	1
B. On the choice of the area	1
C. Access	2
D. Topography and vegetation	2
E. Climate	3
F. Hydrology	4
2. <u>REVIEW AND SCOPE OF INVESTIGATIONS. (E.G.H.)</u>	6
3. <u>REGIONAL GEOLOGY. (E.G.H.)</u>	10
4. <u>PETROLOGY AND METAMORPHISM. (V.H.W.)</u>	13
A. Introduction	13
B. Rocks of supracrustal origin	14
1. Quartzites	15
2. Mica gneiss/mica schist	15
3. Quartzofeldspathic gneisses	17
C. Amphibolites	19
1. Sill-type amphibolites	19
2. Amphibolites of metagabbro type	20
3. Amphibolites of the Hestfossen sequence	20
D. Rocks of igneous origin	22
1. Gabbro	22
2. Ultrabasic rocks	24
3. Intrusive granite	28
4. Pegmatites	28
5. Dolerite and other basic dyke rocks	30
E. Rocks of unknown origin	30
1. Albite gneiss (Albitite)	30
2. The Røesjø Trench rock	32
F. Local metamorphic effects	33
G. Scapolitization	33
5. <u>ON MINERALIZATIONS AND ASSOCIATED PHENOMENA. (E.G.H.)</u>	34

C O N T E N T S (cont'd)

TABLES

- I Meteorological data
- II Mineral composition of ultrabasic rocks

ILLUSTRATIONS

- Fig. 1 Key map
- Fig. 2 Topographical map
- Fig. 3 General distribution of field work
- Fig. 4 Geological setting
- Fig. 5 Regional geology
- Fig. 6 Occurrences of ultrabasic rocks
- Fig. 7 Scapolite occurrences
- Fig. 8 Generalized geological map

PHOTO PLATES

ENCLOSURES

Geological maps in scale 1:20'000:

- | | | |
|----------------|-------------------------|----------------|
| 1. Pandefjell | 7. Copolskaidde | 13. Grinvann |
| 2. Gavnevann | 8. Mokkejavrre | 14. Golmak |
| 3. Røesjø | 9. Røsvann | 15. Storfossen |
| 4. Våkdalsvann | 10. Gurbis | 16. Massuorne |
| 5. Gavnehaugen | 11. Hugstfjell | 17. Jorgastak |
| 6. Noarvas | 12. Helligskogen/Angeli | |

1. GENERAL INFORMATION (E.G.H.)

A. LOCATION

The investigated area of Inner Finnmark extends over the southern Karasjok District and the easternmost Kautokeino District (Karasjok Herred and Kautokeino Herred, Finnmark Fylke). It totals nearly 1500 square kilometers.

The situation with regards to distances from main roads and the coast is shown on the key map Fig. 1.

B. ON THE CHOICE OF THE AREA

Around Njullas, in the southern part of the area, H. Bjørlykke discovered ultrabasic rocks in the course of a brief reconnaissance in 1938. It was not known whether these ultrabasics carried a sulphide mineralization. However, Bjørlykke had reported pyrrhotite with nickel from shears in amphibolites of the lower Gorzzejokka valley.

The area was selected by FALCONBRIDGE in 1962 with a view of assessing its nickel potential. In the same year, an agreement was made between the newly formed Norwegian exploration company A/S SULFIDMALM, a wholly-owned subsidiary of FALCONBRIDGE NIKKELVERK A/S, Kristiansand, and NORGENS GEOLOGISKE UNDERSØKELSE, Trondheim, concerning Finnmark as well as other projects. N.G.U. agreed to administer exploration work for A/S SULFIDMALM.

A certain tendency to partition off Finnmark into spheres of interest probably dates back to this time or earlier. All of eastern Finnmark from the Pasvik to as far west as Lakselv-Karasjok and south towards the Gorzzejokka valley was considered A/S SYDVARANGER country, and N.G.U. was concentrating exploration work in the Kautokeino greenstone belt and also administered exploration and development work at the Bidjovagge copper deposit. The area from the Gorzzejokka south to Njullas and the Finnish border was in fact one of the few remaining portions of the Precambrian terrain of Finnmark which looked interesting.

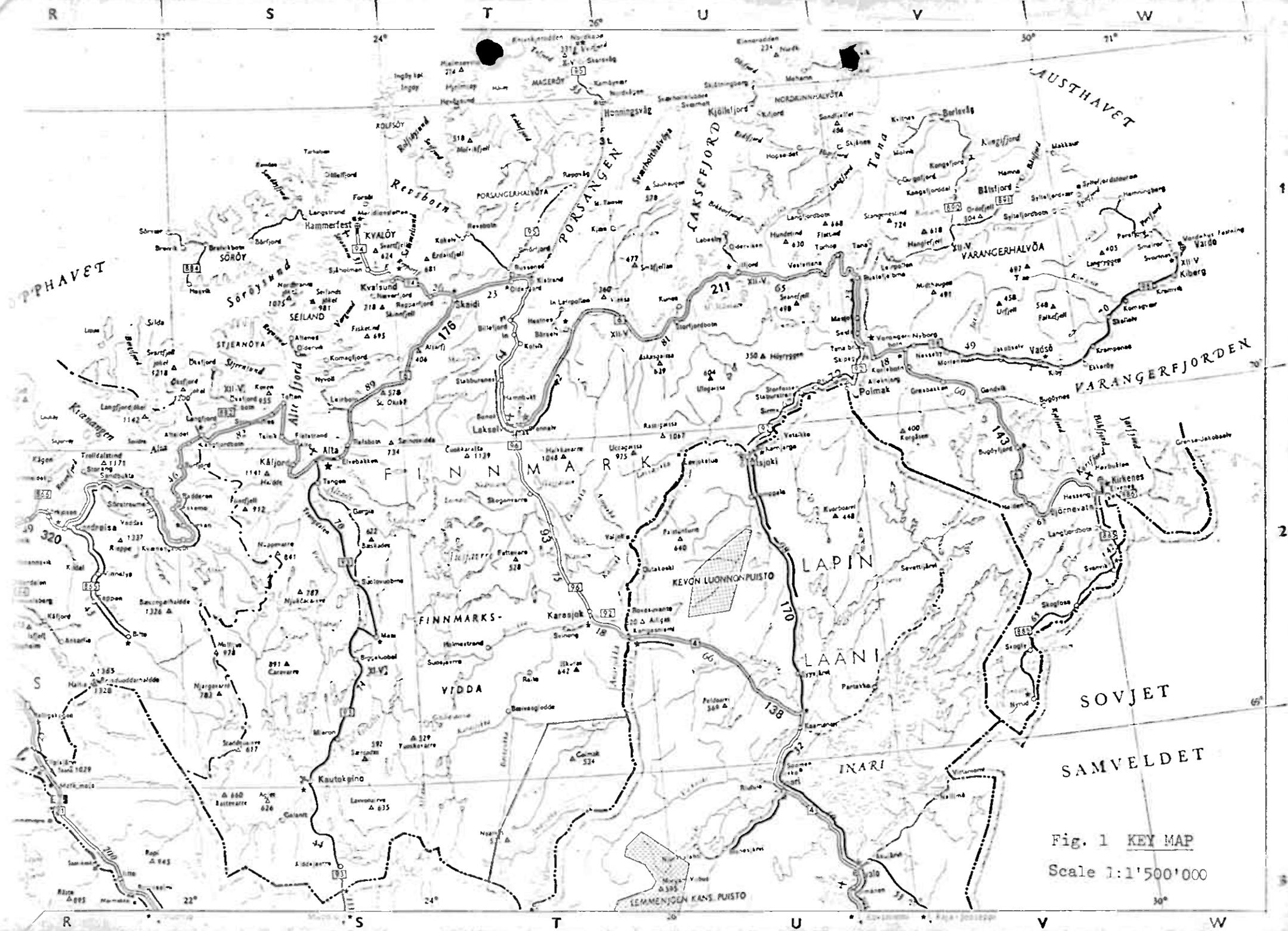


Fig. 1 KEY MAP
 Scale 1:1'500'000



Photo E.G.H.

5.7.1965.

View of Storfossen (big rapids) in a northerly direction downstream. The "elvebåt" seen ascending the rapids was used for transport in the first phase of the field work. Coniferous forest on either side of the Anarjokka is characteristic for this part of the area. Finland is to the right, the river being the border.



Photo E.G.H.

7.7.1965.

The Anarjokka at Beskuk looking downstream. Here, the river is governed by the northerly foliation strike of amphibolites and granulites, and practically marks the western border of the granulite complex of Finnish Lapland.

The area chosen by A/S SULFIDMALM is not, however, a concession area in a legal sense. It is a gentleman's agreement with A/S SYDVARANGER that the parties concerned shall not interfere with each others prospecting areas.

The statement made by J.A.W. Bugge in "Geology of Norway" (N.G.U. No.208, 1960, p.90) that the Petsamo formation known for the worked sulphide nickel ores (Pechenganikel complex, U.S.S.R.) "has a much larger western extension than previously known" probably also influenced the choice of the area.

C. ACCESS

The area is not permanently inhabited with the exception of Angeli, a small village on the Finnish side of the Anarjokka. There is a dirt road from Angeli to Karigasniemi on the Karasjok-Inari road.

Access to the area posed some problems during the early stages of the preparations and field work. In 1965, river boats were used from Iskuras to the upper Gorzzejokka, along the Anarjokka to Ulvefossen and in the Skiecanjokka to south of Jorbaluobbal. Canadian light-metal canoes were also used by the prospectors in the Gorzzejokka. The camps in the southern area were based on lakes which could be reached by hydroplane and, in 1966, transport to the Njullas Camp was by helicopter.

All the mentioned methods of transport were of rather limited use with regard to the actual mapping and prospecting work. Hence a total of over 3000 kilometers was covered on foot by the prospectors and geological parties.

D. TOPOGRAPHY AND VEGETATION

The main topographic features are quite well portrayed on the 1:50'000 AMS maps: "Beivasgiedde", "Jorgastak", "Noarvas", "Hugstfjell", and "Njullas". They are enlargements of the 1:100'000 maps surveyed in 1906. All these maps show form-lines only and are rather inaccurate as far as details are concerned.

Generally speaking, the area carries a mountain-vegetation. The woodland in the southern Karasjok District and along the rivers further to the south consists of pines, firs and birches. Stretches of pure coniferous woods are characteristically present on sandy glacial

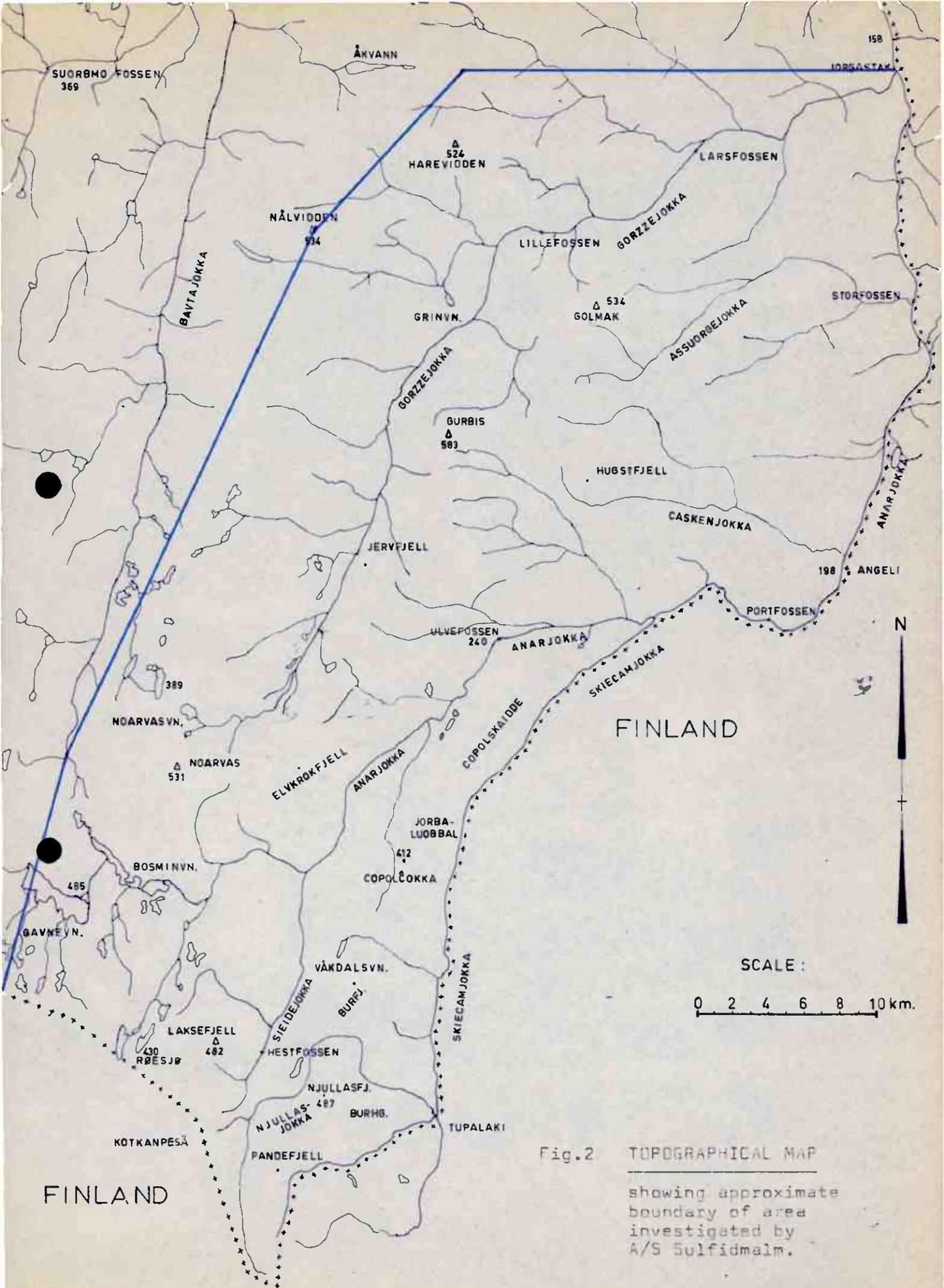


Fig.2 TOPOGRAPHICAL MAP
 showing approximate boundary of area investigated by A/S Sulfidmalm.

deposits along the Anarjokka and lower Gorzzejokka (elevation 180-250 m). There is a very extensive cover of marshland ("myr") between the low hills and along some valleys which, in most cases, marks impeded drainage lines and/or older drainage systems. Golmak (534 m) and Burbis (583 m), the highest mountains in the northern area are covered by grass and reindeer moss (cf. Fig.2).

The general elevation of the southern area is higher with the wide interfluves between the Gorzzejokka and Anarjokka, Sieidejokka-Anarjokka and Skiecamjokka standing at 350 to 420 m. Here, the conspicuous high points in the topography are: Noarvas (531 m), Elvkrokfjell (516 m), Landgudfjell (491 m) and Njullasfjell (487 m). The undulating open country is covered by moorland and patches of sparse woodland made up by the mountain birch. The southern area with its numerous small lakes is part of Finnmarksvidda; it is excellent reindeer grazing ground and is inhabited by reindeer-herding Same in winter time.

E. CLIMATE

Apart from the stations along the coast of Finnmark, there are meteorological stations at Karasjok (135 m), Kautokeino (318 m) and Siccajavrrre (cf. key map). For 1965, the meteorological data for Karasjok and Kautokeino are presented in TABLE I. The figures give a good idea as to the climatic conditions of Inner Finnmark. Our southern area, particularly at E Roesjå and Njullas, is actually colder and rougher than Kautokeino.

The prolonged period of snow cover limits the field season to the relatively warm period June to September. This is, however, the time of maximum rainfall although precipitation recorded in July 1965 was perhaps unusually high. The low number of clear days bears particularly on aerial surveys.

F. HYDROLOGY

The Norwegian Water Resources and Electricity Board (NORGES VASSDRAGS- OG ELEKTRISITETSVESEN) does not maintain a gauging station in Inner Finnmark. Calculated run-off figures are based on measurements carried out with common current recorders in the Alta area, at Skoganvarre and Polmak which are checked twice a year.

For the area under consideration the run-off is less than 10 liter per second per square kilometer. This would appear to be the lowest run-off figure for any larger area in Norway (ref. maps in N.V.E., Hydrologiske Undersøkelser i Norge, Oslo, 1958).

The lakes in the area are usually frozen from October to June and most rivers also freeze over for about six months. In many places between the main rivers, water supply for mining operations and even for diamond drilling would be a problem during the summer months too.

T A B L E I

Months Year 1965	Temperature °C			Humidity Daily Average	Amount of Precipitation mm	Number of days with:									Clear days	Overcast	Snow cover	Months Year 1965	
	Daily Average	Min.	Max.			Temperature °C			Rain	Snow	Sleet	Drizzle	Hail						
						Min.	Max.	Min.											
				<0	<0	<-10													
Karasjok	I	-16.1	-44.0	1.6	85	15	31	28	26	0	17	0	0	0	0	5	13	31	I
	II	-12.1	-35.8	3.6	83	30	28	24	23	0	19	0	0	0	2	11	28	II	
	III	-13.8	-35.0	4.8	80	20	31	29	25	0	11	0	0	0	6	10	31	III	
	IV	- 2.3	-30.0	11.8	77	12	21	11	10	2	7	1	0	0	7	13	26	IV	
	V	0.7	- 7.0	8.0	70	8	28	0	0	5	9	5	1	0	2	9	5	V	
	VI	8.8	- 3.8	23.0	68	29	2	0	0	9	0	0	0	0	3	9	0	VI	
	VII	9.7	1.6	19.6	79	116	0	0	0	21	0	0	0	0	1	16	0	VII	
	VIII	9.8	0.4	21.4	85	81	0	0	0	21	0	0	2	0	0	18	0	VIII	
	IX	6.2	- 4.5	20.0	85	52	8	0	0	13	0	0	1	0	0	14	0	IX	
	X	- 1.3	-19.0	8.4	85	37	25	7	7	7	13	1	2	0	1	12	20	X	
	XI	-12.3	-38.0	4.0	86	18	29	20	20	1	15	0	0	0	4	15	30	XI	
	XII	-19.1	-42.0	-1.0	84	18	31	31	26	0	14	0	0	0	3	16	31	XII	
	Year	-3.5	-44.0	23.0	81	436	234	150	137	79	105	7	6	0	34	156	202	Year	
Kautkeino	I	-15.6	-42.5	0.5	84	20	31	29	26	0	21	0	0	0	3	16	31	I	
	II	-12.8	-34.0	2.9	79	10	28	24	23	2	9	2	0	0	4	9	28	II	
	III	-14.0	-35.5	4.5	79	8	31	28	27	0	12	0	0	0	5	9	31	III	
	IV	- 4.0	-31.5	7.5	78	5	27	11	11	2	6	2	1	0	3	11	30	IV	
	V	- 0.3	-8.5	5.8	73	7	30	0	0	3	11	3	0	3	2	14	27	V	
	VI	8.3	- 2.5	22.0	65	44	2	0	0	11	1	1	0	0	3	10	0	VI	
	VII	9.4	0.6	19.0	75	103	0	0	0	23	1	1	5	0	1	20	0	VII	
	VIII	9.4	0.5	18.5	83	97	0	0	0	21	0	0	4	0	0	20	0	VIII	
	IX	6.0	- 3.0	18.1	86	52	11	0	0	9	2	0	5	0	1	16	0	IX	
	X	- 1.3	-21.5	9.3	83	25	27	9	4	7	13	4	5	0	4	14	16	X	
	XI	-11.8	-35.8	3.7	82	12	30	22	19	2	13	1	0	0	3	15	30	XI	
	XII	-19.5	-39.2	-2.9	83	21	31	31	28	1	19	1	0	0	4	17	31	XII	
	Year	- 3.9	-42.5	22.0	79	404	248	154	138	81	108	15	20	3	33	171	224	Year	

Source: Norsk Meteorologisk Årbok 1965

2. REVIEW AND SCOPE OF INVESTIGATIONS (E.G.H.)

The only geological information on the southern area available at the time the area was selected were copies of field notes by H. Bjørlykke on his rapid traverse in 1938. In 1953, a large portion of the northwestern area (480 square kilometers) was covered by geological reconnaissance mapping by H. Wennervirta. This work was done for GEOFYSISK MALMLETING, now a Branch of N.G.U., and included geophysical and geochemical prospecting in the lower Gorzzejokka valley. Particular attention was paid to occurrences of ferruginous quartzites to the west and north of the Gorzzejokka, and close to our area. Wennervirta's report is an outstanding contribution to the geology of the Karasjok District both from a practical and scientific point of view.

In 1962, an airborne geophysical survey of the strips across the northern and southern area was made by N.G.U. under a contract arrangement with A/S SULFIDMALM (see PART IV, 2).

A geological reconnaissance was carried out in the Njullas area and in the lower Gorzzejokka valley by Boye Flood in July-August, 1962. This work was undertaken by N.G.U. on behalf of A/S SULFIDMALM. In his report on Njullas, compiled under the supervision of Johs. Færden, Flood (1963) described the zone of gabbros which strikes from Njullasfjell in a northerly direction over Burfjell and paid much attention to ultrabasic rocks. The gabbros and amphibolites of the area were interpreted as altered basic lavas and tuffs, and only the ultrabasics were considered worth further examination. No mineralization connected with jointing and shear zones was observed. Sulphide mineralizations in sheared and partly brecciated zones were described in the report on the Gorzzejokka (1962). Flood concluded that the mineralizations are of no economic interest as analyses gave very low nickel and copper values for the collected samples.

In 1963 and 1964, E. Overwien compiled maps of Inner Finnmark (1:250'000) and of Finnmark, Swedish and Finnish Lappland (1:500'000) using all sources available at N.G.U. The latter map provided the necessary regional geological background.

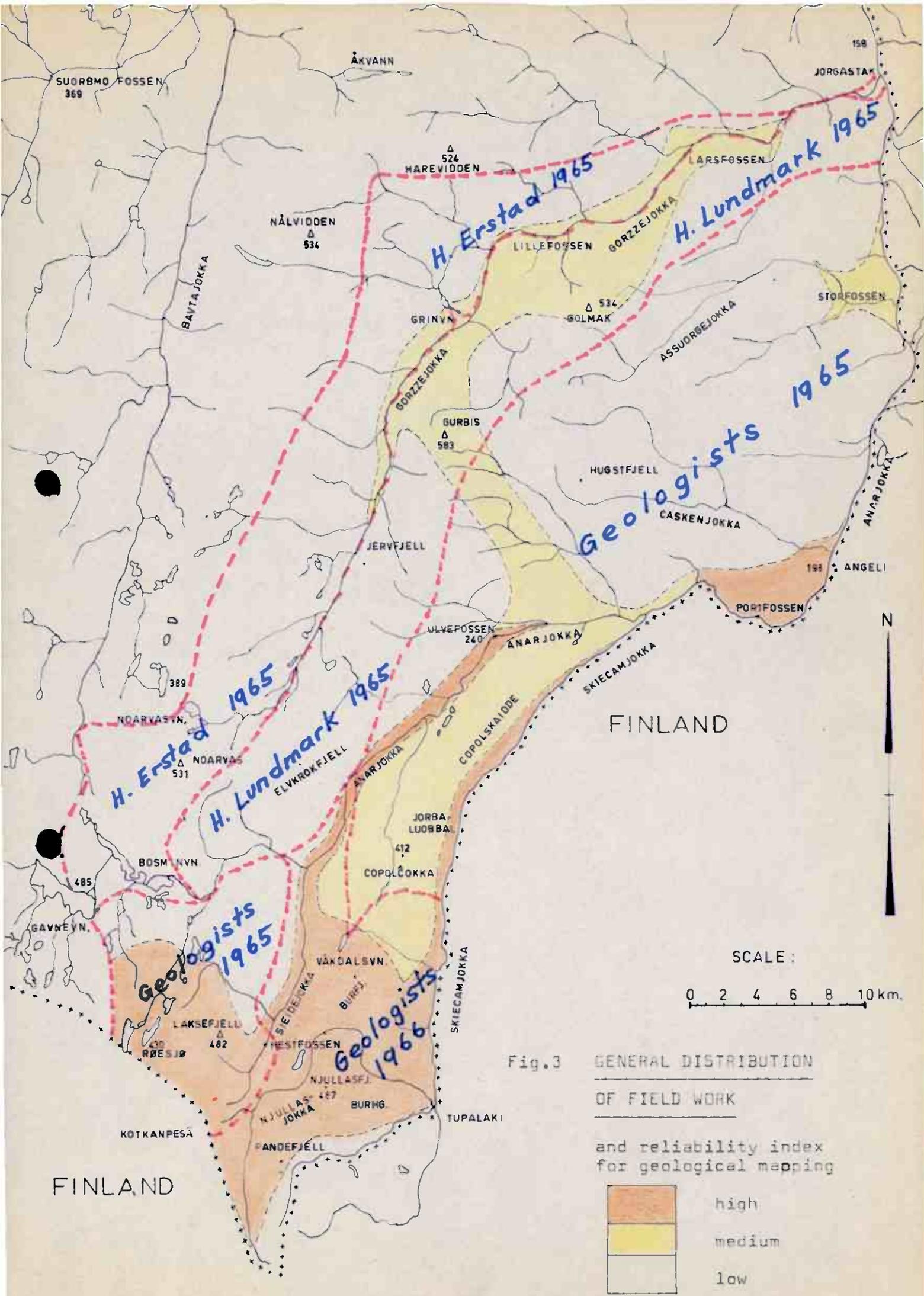
The whole area was flown by WIDERØE's FLYVESELSKAP A/S in July and September 1964, after a delay of two years. The first set of about 600 photographs at a scale of \pm 1:20'000 was received in October 1964 and photomosaics at the same scale were available early in 1965.

N.G.U. compiled topographic sheets 1:20'000 based on the photomosaics for the northern and southern part of the area, and these sheets were then used to plot the data from the airborne geophysical survey in 1962. According to an agreement with N.G.U., A/S SULFIDMALM paid for all this work and reserved exclusive rights to the information. Eight topographic sheets of the central area which was not included in the agreement with N.G.U. were drawn by E. Overvien. The compilation of all the topographic sheets provided by N.G.U. was very poor; all sheets had to be completely redrawn by us before they could be used to plot geological field data.

Plans for field work 1965 made by S. Charteris late in 1964 reckoned that the whole area could be examined in one field season of four months. They also provided for two Canadian prospectors and Canadian field equipment including two canoes. According to the contracts between FALCONBRIDGE NICKEL MINES LIMITED, Toronto and the prospectors, the latter were to prospect for any and all minerals and examine the area in relation to its mining potentials and geological characteristics. The Gorzzejokka area where best use could be made of river transport was to be covered by the prospectors and the remaining part by geological field parties.

Early in 1965, when the writer took over the direction of the project, it was quite apparent that the project had to aim at more than an assessment of the nickel potential alone, although this remained the main target. There was also a tacit agreement with N.G.U. that geological observations or maps were eventually going to be made available to N.G.U. Changes made to the previously set up programme included a new time schedule for the 1965 field season.

During the period June 16th to August 31st, 1965, the Canadian prospectors with their two assistants operated quite independently from the geological parties. The latter were first based on Helligskogen "fjellstue", opposite Angeli, on the Anarjokka. The four geologists of the parties were: E. Overvien, V.H. Wiik, Lars Kirksøther and the writer; four students served as assistants. In August, when the geologists moved to a base camp on the E. Røesjø, E. Overvien and two students carried out EM and magnetometer prospecting work (see PART IV). The writer also spent some days with Messrs. H. Lundmark and H. Erstad, the Canadian prospectors.



From June 26th to August 14th, 1966, the geophysical and three geological teams concentrated on detailed investigations in the Våkdalsvann-Njullas area (see Fig.3).

Geophysical prospecting and geological mapping carried out by E. Overwien and the writer around Grinvann (Gorzzejokka area) between June 28th and July 5th, 1967, will be described in a separate report.

The scope of the investigations can be summarized as follows:

(a) Geological Mapping: About 1500 square kilometers were covered using air photographs 1:20'000. As implied by the reliability index given on Fig.3, 15% of this total was mapped in some detail. Very large areas of moorland, where outcrops are extremely rare and far between, and where traverses were widely spaced, are given a low reliability index. The enclosed geological maps 1:20'000 are essentially outcrop maps and the blank spaces generally indicate "no outcrops".

(b) Photogeology: As a rule, all geological traverses were preceded by photogeological studies using a WILD ST4 stereoscope in the field. Most of the southern and eastern area was interpreted for structural features. The photomosaics and individual photographs were used again when the geological and geophysical maps were compiled in 1966/67. However, no systematic photogeological interpretation of the whole area was made by a specialized firm.

(c) Geophysical Surveys: Airborne magnetometer and EM surveys cover a strip along the lower Gorzzejokka in the north and the Njullas area in the south; thus airborne survey maps are available for about 50% of the investigated area.

In the southern area, anomalies recorded by the airborne survey were checked by ground surveys (see PART IV). Traverses with the hand-magnetometer were carried out over several occurrences discovered by geological parties in the eastern and southern areas, and EM traverses over such targets were made in two cases. All anomalies in the Gorzzejokka area were examined by the prospectors.

(d) General Prospecting Work: All minerals and indications of mineralizations discovered are recorded on the enclosed geological maps. Interesting samples were analyzed and the minerals determined in the lab. are given in special squares on the maps.

Detailed geological examinations and sampling of shear zones and ultrabasic rocks were made in numerous places. Geiger counter checks were carried out wherever called for. In 1966, a prospecting trench was dug and blasted across the Røesjø anomaly (see PART IV, 1).

All parties concerned recorded blocks and boulders of ultrabasics and other interesting rocks as a matter of course (cf. enclosed geological maps).

(e) Research Work: Apart from the usual lab. examinations and analyses some extra microscopy was considered necessary since so little was known about the nature of the rocks encountered in the central and southern part of our area. It was believed that this work might provide some clues as to the nature of certain rocks and mineral associations including the sulphides. The result of this work is presented by V.H. Wiik in chapter 4 below.

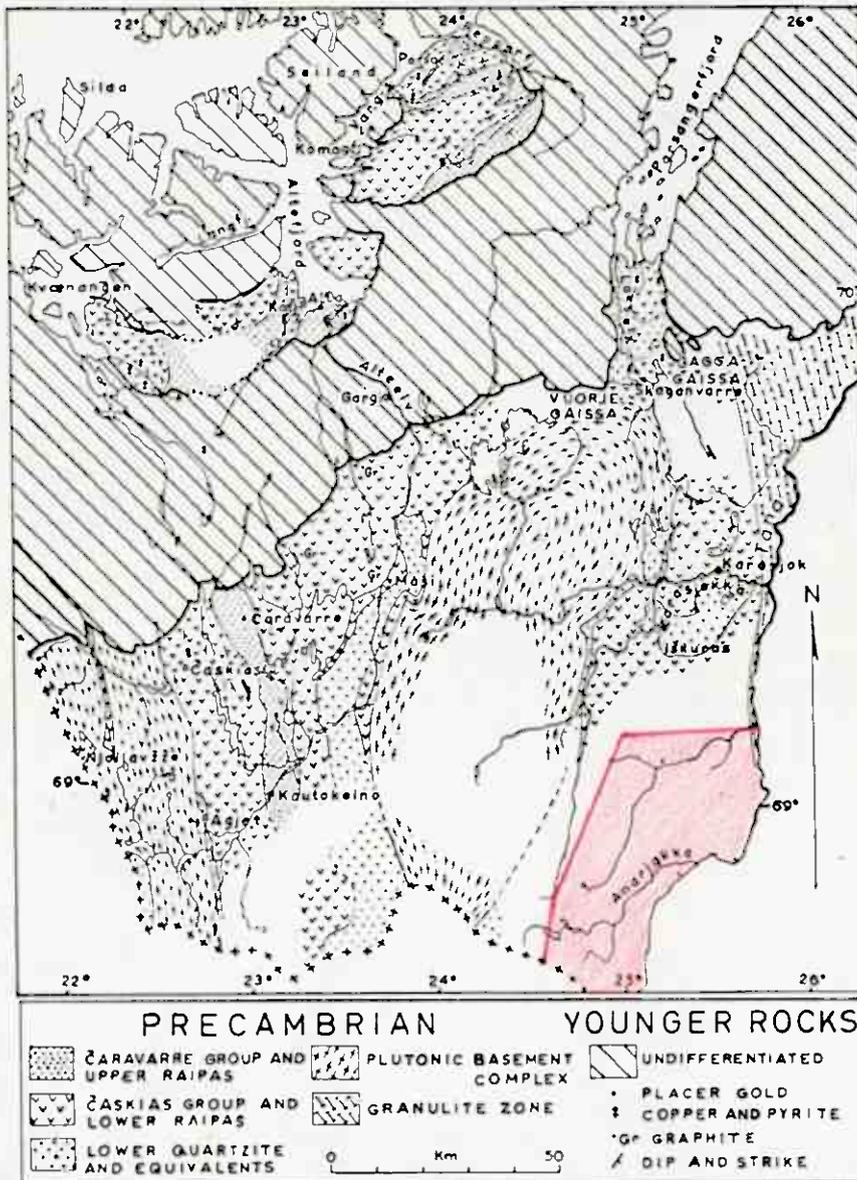


Fig. 22. Stratigraphic correlations in western and central Finnmark. Map compiled by Reitan, based on references cited plus unpublished material and personal communication by Padget, Reitan, and Skálvoil.

(from N.G.U. No.208 Geology of Norway, 1960)

Fig.4

GEOLOGICAL SETTING

3. REGIONAL GEOLOGY (E.G.H.)

The investigated area is situated in Precambrian terrain in the northern part of the Fennoscandian Shield. The present day southern boundary of the Caledonides is 80 to 110 kilometers to the north and northwest (see Fig. 4).

Metamorphosed supracrustal rocks, both metasediments and metavolcanics, are dominant amongst the encountered rock types. Rocks of igneous origin include gabbros and ultrabasics, and their metamorphic derivatives, and the Røesjø granite (cf. chapter 4 below). Granitic gneisses and microcline granite of the eastern boundary zone are the product of potash metasomatism and migmatization. The original nature of these granitized rocks is difficult to determine and the possibility that some rocks were involved which did not belong to the main suite of supracrustals cannot be ruled out. Generally, the mineral composition of the rocks indicates a regional metamorphism in the amphibolite facies with variations in the range almandine-amphibolite down to albite-epidote amphibolite.

The regional strike is in a northerly direction and the dip is at moderate angles to the east. Locally, however, the strike and dip may vary considerably and easterly plunging fold axes are present in the northern area. Northerly trending thrust zones recognized in the southern area also pertain to the characteristic structural features described in PART III of this report.

The supracrustal rocks belong to the Karasjok zone of the Karelidic belt which trends from Finnmark and Finnish Lapland to southeastern Finland. Many separate basins of sedimentation have been recognized in the Karelian belt and differences exist between these basins concerning lithological facies, nature of intrusives, metamorphism and migmatization, structural events and mineralization. It may be recalled that the Outokumpu ore zone and its surrounding schist area is also situated in the Karelian belt. The absolute age of the Karelian sedimentation is not known but age determinations concerning metamorphism and plutonic activities indicate that the Karelian cycle falls within the limits 1700 - 1900 m.y.

In the east, the area borders on the granulite complex of Finnish Lapland which contains rocks of different origin. Paragneisses include garnetiferous quartzofeldspathic gneisses, garnet-cordierite gneisses, quartzite and graphite bearing bands. Charnockitic quartz diorites and hypersthene gneisses, and gabbroic rocks represent orthogneisses of the granulite complex. There is a gradational relationship between the granulite complex and the so-called granite-gneiss complex which is regarded by Scandinavian geologists to form the sedimentation floor for Karelian supracrustal rocks. The granulite complex is thus considered a part of the granite-gneiss basement which has undergone a higher degree of metamorphism than the surrounding rocks. The granite-gneiss complex is correlated with the Belomorian (1900 - 2000 m.y.) cycle. The age of a quartz diorite from Inari is 1880 to 1900 m.y. Other age determinations which would support the contention that the granulite-gneiss complex of Finnish Lapland represents a "pre-Karelian basement" are not known to the writer.

It is generally believed that the granulite complex has been thrust in a westerly direction over the Karelian supracrustals of our area. The border zone between the granulite region of Finland and our area is situated in the Anarjokka valley to the north of Angeli. At some points, granulitic rocks occur on the west side of the Anarjokka. Hornblende granulite was noted at Beskuk as bands in amphibolitic rocks and a charnockitic rock was found in the Storfoss area. The possibility that some of the quartzofeldspathic rocks of our border zone belong to the granulite complex has not been studied. From our limited observations in this border zone it would appear that the thrust relationship cannot readily be proved in the field.

Arcuate and often boudin-shaped outcrops of amphibolites, greenstones and associated mica gneisses, and a few small outcrops of ultrabasic rocks, in the granite-gneiss to the north of Inari and east of the granulite complex, are interpreted by J.A.W. Bugge (verbal communication) as a westerly extension of the Petsamo formation. This extension is said to strike back into Norway and to finally disappear under the Caledonides near Polmak. Bugge postulates a Karelian age for the Petsamo formation. It may be recalled that,

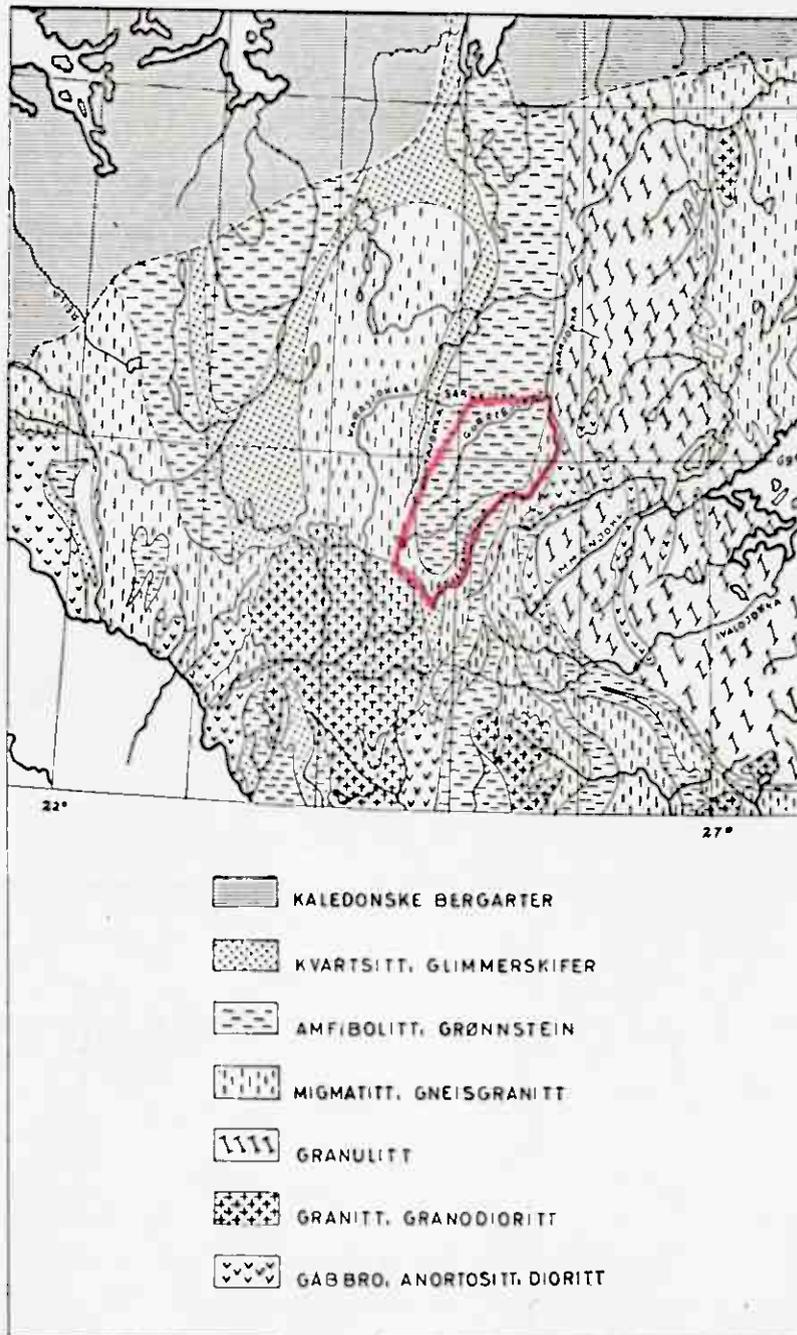


Fig. IX Fjellgrunnskart over Finnmarksvidda og tilstøtende deler av Finland, sammenstillet av H. Skålvold.

Fig.5 REGIONAL GEOLOGY

(Source: N.G.U. No.236 De Alluviale Gullforekomster i Indre Finnmark. H.Bjærlykke 1966)

in the type locality, the Petsamo formation is a folded sequence of low-metamorphic volcanics with interbedded slates and phyllites. The sulphide nickel ores are localized in strongly sheared and brecciated ultrabasic sills in this sequence. The existence of a westerly extension of the Petsamo formation beyond the Pasvik area is open to some doubt. We have certainly no proof that the Petsamo formation extends into our area.

In the southwest, our area borders on the central zone of granite-gneiss of Finnmark. This central zone separates the supracrustal rocks of the Karasjok zone from those of the Kautokeino region (see Fig.5). At its northern end, H. Skålvold of N.G.U. has discovered a conglomerate on the granite-gneiss in two places. From this it is concluded that the Karelian supracrustals overlie the granite-gneiss complex which is correlated with the Belemorian. Actually, the central zone of Finnmark has never been systematically explored by a geologist.

4. PETROLOGY AND METAMORPHISM (V.H.W.)

A. INTRODUCTION

The area under consideration displays a great variety of rock types. Although for the purpose of clarity the geological map distinguishes between a small number of rock types only, it should be pointed out that most of these rock types embrace, in fact, rather broad categories. The following description emphasizes the average characteristics of each rock type, but an attempt is made to outline also the variability displayed within each category.

In addition to the field observations, data relating to the rock types have been obtained by microscopic examination of thin-sections, polished sections, and also to some extent by powder microscopy. For a number of specimens, qualitative spectrographic analyses and, in some cases, special wet chemical analyses and fire assays were made. Laboratory investigations were carried out by R. Buchan, Thornhill, and A. Wagner, Paleolab., Nyon, Switzerland, as well as at the Nikkelverk, Kristiansand.

The investigated area consists of a sequence of Precambrian supracrustal rocks generally referred to the Karelian cycle, regionally metamorphosed in the amphibolite facies. Within this basement, larger intrusions of gabbro and granite occur, as well as dikes and minor bodies of ultrabasics, pegmatites and doleritic rocks.

The geological picture is one of great complexity seen as the result of several superimposed phenomena

1. The regional distribution of primary lithological units.
2. The regional metamorphism. This displays a generally uniform trend within the range of the amphibolite facies, but with local and irregularly distributed partial anatexis and metasomatism.
3. Emplacement of intrusives and related metasomatic effects.
4. Retrograde metamorphic effects produced by subsequent tectonisation.

Consequently, one and the same lithologic formation might appear in one area as amphibole schist and in another area as flow-folded migmatite with patches of hornblendite in a quartzofeldspathic groundmass.

In an attempt to obtain maximum readability of the geological maps, a legend has been devised in which colours serve to distinguish the various primary lithologic formations or units, whereas secondary effects like migmatization, granitization etc. are indicated by symbols superimposed on the colouring.

The advantages are that in this way the primary rock distribution may be read more or less directly from the map, undisturbed by the distribution pattern of the secondary effects. In the same way, the distribution pattern of some of the named secondary effects might also be more easily inferred.

The disadvantages are caused by the fact that an interpretation of the origin of the transformed material has been worked into the maps. Thus confusion might arise if e.g. a granitized amphibolite is mapped as hornblendegneiss or an intrusive granodiorite is assigned to the group of quartzofeldspathic gneiss. In reading the maps, the possibility of such mis-interpretations should be kept in mind.

B. ROCKS OF SUPRACRUSTAL ORIGIN

For quartzite, mica gneiss/mica-schist and quartzofeldspathic gneiss a supracrustal origin is postulated. There should be general agreement as to the sedimentary nature of the first two. However, the group of rocks termed quartzofeldspathic gneiss is rather heterogeneous, and even if, in some cases, the supracrustal and probably sedimentary nature of certain suites of quartzofeldspathic gneiss seems evident, there are other occurrences which could be explained as sills or other stratiform intrusions of a trondhjemitic (quartzdioritic) magma at an early orogenic stage.

No conclusive evidence has been found, however, for an intrusive origin of any occurrence of quartzofeldspathic gneiss. Therefore, in the absence of such evidence, a supracrustal origin for all rocks of the quartzofeldspathic gneiss group is assumed.

1. Quartzites

Rather pure quartzites occur in a wide zone between Njullasfjell and Skiecamjokka, and also as benches, one to several meters wide, in a series of alternating quartzofeldspathic gneiss and zones of amphibolite to the west of Pandefjell. In some places these pure quartzites are observed to grade over into impure, micaceous, chlorite-rich or feldspathic quartzites, as for example south-east of Burhaugen and along the eastern boundary of the granite intrusion west of western Røesjø.

Normal quartzite is a light greyish to white rock, mostly fine-grained and often showing a fine lamination which is visible only on weathered surface. A certain content of sericite is ubiquitous, but also plagioclase (An_{10-20}), biotite, chlorite and opaques may be present in minor amount. Zircon and apatite are common accessories. The quartzites normally exhibit a granoblastic texture, the quartz grains often having undulatory extinction and slightly sutured grain boundaries.

The fact that quartzite often is distinctly more fine-grained than adjacent gneiss and amphibolite may be caused partly by cataclastic degradation of grains in a late phase of regional metamorphism, partly by the presence of impurities like mica which might have the ability to prevent grain growth even during peak metamorphism by altering surface energy conditions.

2. Mica gneiss/Mica-schist

A considerable range in grain size as well as in mineralogical composition is covered by the members of this rock group. The major constituents are in general: Biotite (Z = Y = brown), muscovite, quartz and plagioclase. Fine-grained quartz-biotite (or chlorite in some places) schists occur transitional to impure quartzites. Fine- to medium-grained quartz-mica schists with a notable graphite content have been observed in Njullas as well as in the Helligskogen area.

The dominant type of mica gneiss is a slightly porphyroblastic two-mica gneiss, medium-grained, and with plagioclase (oligoclase) slightly exceeding quartz in abundance. Garnet is often present in this rock, in some zones it may make up as much as 20% by volume.

Disthene (kyanite) may also be a prominent constituent in certain zones of this mica-gneiss (e.g. south-east of Burfjell).

There is a general tendency for the biotite to be replaced by chlorite, and even if this retrograde effect in most areas is slight only, it may in places be very pronounced, such as in the quartz-chlorite schist associated with impure quartzites in the area south-east of Burhaugen.

A peculiar greyish, fine-grained biotite-plagioclase-quartz gneiss with light grey nodules, about 5 mm in diameter, occurs along the Njullasjokka Anomaly Zone. Specimens of the same rock type have also been collected from a rusty shear zone near Bordermarker 339 at Kotkanpesä and from the vicinity of the mineralized shear at Grinvann. The nodules are aggregates of chlorite, and the findings of relict garnet in some nodules indicate that these are pseudomorphs after garnet. This rock is identified as normal garnet-biotite-quartz-plagioclase gneiss which has experienced shearing and recrystallization in a somewhat lower metamorphic facies. The fact that this variety of mica gneiss has a distinctly higher content of ore minerals (mostly pyrrhotite and ilmenite) than the normal garnet-mica gneiss, is explained by relating the mineralization to the shearing.

This observation indicates that one phase of sulphide mineralization is associated with shearing after the peak of regional metamorphism while relatively high metamorphic conditions still prevailed. Garnets had formed previous to the shearing, biotite is stable, and there has been no epidotization of the plagioclase.

In the southern part of the region the two-mica gneiss shows intense small-scale folding, whereas the same rocks in areas further north have a well-developed undeformed planar structure.

The rocks of the mica gneiss group are interpreted as argillaceous sediments which, in some areas, occur in an original depositional relationship with psammitic rocks (quartzites).

3. Quartzofeldspathic gneisses

Light, gneissic rocks with feldspar and quartz as their dominant constituents make up a considerable proportion of the country rock and an understanding of their origin is essential for a correct interpretation of the geology of the region.

The quartzofeldspathic gneisses represent a very heterogeneous group of rocks. The difficult task of systematically mapping out various formations within this group was considered outside the scope of the present work. In places, where such information was directly available specifications as to the type of quartzofeldspathic gneiss are given on the 1:20'000 maps.

Four types of quartzofeldspathic gneiss are differentiated. Of these, the granitic gneiss, the quartzofeldspathic biotite gneiss and the quartzofeldspathic hornblende gneiss are fairly well defined, whereas the fourth referred to as quartzofeldspathic gneiss, comprises a variety of rocks. In areas where the necessary information is lacking, rocks of the three first mentioned types may also be included among rocks of the fourth type.

The average quartzofeldspathic gneiss may be described as a medium- to fine-grained rock of a yellowish to greyish white, rarely reddish colour. A more or less distinct foliation is outlined by sub-parallel orientation of dark minerals, normally biotite or hornblende.

As the name implies, feldspar and quartz are essential constituents of all four types. In the granitic gneiss, microcline is present in amounts from 10% to more than 50% of the rock. Under the microscope these rocks show textural evidence of tectonization and microcline is seen replacing older plagioclase or intergranular together with quartz. The wide occurrence of granitic gneiss in the Røesjø-area is interpreted as a granitization of ordinary quartzofeldspathic gneisses, related to the young granite intrusion west of W-Røesjø.

The ordinary quartzofeldspathic gneiss, including the biotite and the hornblende-rich varieties, has a quartzdioritic composition.

The plagioclase, which for the salic types make up 50 - 70% of the rock, generally has a composition in the range albite-andesine. Albite-oligoclase has been observed in certain salic varieties and andesine in quartzofeldspathic hornblende gneiss. Quartz makes up at most 30 - 40% of the rock. Biotite is a normal minor constituent also of the salic varieties, but sometimes muscovite or a clin amphibole may take its place. Occasionally biotite is partly altered to chlorite, and epidote occurs. Sphene and apatite are almost invariably present as accessories and less commonly, zircon, rutile and opaques. Microcline may be found in small quantities also in quartzofeldspathic gneisses other than those of granitic type, but this is not generally so. Very often quartzofeldspathic gneisses show signs of slight tectonization and more or less complete recrystallization, producing a heteroblastic texture.

The biotite and the hornblende types differ from the above described rock in having one of the mentioned minerals as a major constituent along with feldspar and quartz. Hornblende-gneiss passes into amphibolite, and for the more hornblende-rich gneisses and some amphibolites the distinction becomes purely arbitrary.

The difference between biotite gneiss and hornblende gneiss may in some cases be a question of metamorphism only, biotite being able to form from the hornblende during retrograde metamorphism.

Along certain zones, the quartzofeldspathic gneiss has been observed to have a rather strong reddish tinge, which may lead to its incorrect interpretation as granitic gneiss. A plagioclase in the range An_{10} to An_{30} is the dominant constituent, and its colour is caused by tiny, brownish inclusions (hematite). The red-colouring seems to be related to tectonic zones, and could be a secondary effect produced by Fe-carrying ascending solutions.

Common to most rocks included in the described group of quartzofeldspathic gneiss is the prevalence of a rather acid plagioclase. The composition of the plagioclase varies from andesine to pure albite, and variations in An-content has been observed within the single thin-sections. The general impression is that of an older more basic plagioclase suffering mechanical and chemical break-down and more or less being replaced by a fresh, more acid plagioclase.

In the instances where epidote is present, this phenomenon of the plagioclase becoming more albitic is readily understood as a result of retrograde metamorphism, and this probably applies to the whole group of quartzofeldspathic gneiss.

Provided the above interpretation is correct and the original plagioclase of the quartzofeldspathic rocks was indeed an intermediate to basic one, then the question of origin of these rocks turns into the problem of explaining a supracrustal material composed of andesine, quartz and variable amounts of hornblende and biotite. Lavas or volcanic ashes of a tonalitic composition would fit the case.

C. AMPHIBOLITES

The amphibolites comprise a group of rocks the original nature of which is, as a rule, difficult to determine. Some amphibolites undoubtedly represent rocks of supracrustal origin, while others are meta-igneous rocks.

The geological mapping led to the recognition of the following types of amphibolites:

1. Sill-type: Benches or bands of amphibolite in the suite of quartzofeldspathic gneisses and quartzites.
2. Metagabbro-type: Amphibolitic rocks closely related to the gabbros along the Njullasfjell - Burfjell - Copolcokka belt.
3. The Hestfossen sequence of amphibolites.

1. Sill-type amphibolites

Amphibolites occur as numerous bands in the Kotkanpesa section. The bands or zones are strictly concordant, their width varying from 1/2 m to more than 10 m with an average around 5 m. In the Tupalaki section of the Skiecamjokka zone, amphibolites also form part of the supracrustal suite together with quartzites, micagneiss and quartzofeldspathic gneisses. In this area bands or zones of amphibolite are wider, and banded hornblende gneiss becomes very prominent in the quartzofeldspathic gneisses.

This type of amphibolite is medium- to fine-grained, rather homogeneous, with a fresh, granoblastic texture. Gradual transition into dioritic hornblende-gneiss has been observed to take place over a distance of 5 - 10 cm at one locality near Skiecamjokka. Three specimens from this locality near Skiecamjokka show the amphibolite to consist of plagioclase (\pm An₃₀) about 35%, hornblende about 35%, and 10% fresh scapolite. The paragenesis hornblende, plagioclase (An₃₀) and epidote points to a regional metamorphism in the almandine-amphibolite facies, as is also indicated by the widespread occurrence of almandine garnet in the amphibolites. (The presence of scapolite is considered to be a local phenomenon.)

2. Amphibolites of metagabbro type.

In connection with the various bodies of gabbro in the Njullasfjell - Copolcokka belt, an amphibolitic rock is found, which has a characteristic streaky appearance. This streaky appearance is produced by a separation of the salic material consisting essentially of plagioclase, epidote and sometimes scapolite from the dark greenish, fine-grained hornblende.

The plagioclase in coexistence with epidote is in the range An₃₅₋₄₀. The characteristic structure must have been produced by shear movements in a solid or semi-solid rock. From the plagioclase-epidote equilibrium and the development of garnet in particular zones, it follows that this recrystallization took place under regional metamorphism in the almandine amphibolite facies.

At some localities this type of amphibolite is observed to strike into fresh two-pyroxene gabbro. It is assumed that it formed through shearing of the border zones of the gabbro intrusions, the shearing having taken place under conditions of fairly deep-seated metamorphism.

3. Amphibolites of the Hestfossen sequence.

The wide zone of amphibolite rocks referred to as the Hestfossen sequence forms the largest continuous rock unit in the investigated area. It can be traced from the Finnish border in the south, northwards over the Jervfjell and Gurbis mountains and along the Gorzzejokka into the folds of the Grinvann-Lillefossen area.

Good sections through major parts of the sequence are found along Njullasvann and Njullasjokka to the west of Njullasvann, and in the gorge called Hestfossen.

As distinct from the other amphibolites, the Hestfossen rocks are generally fine-grained and show a pronounced schistosity or rather fissility. Certain zones within the sequence have an ultramafic character, being made up of chlorite and actinolite exclusively. Thus, in detail, the Hestfossen sequence is heterogeneous, having alternating zones of fine-grained but otherwise normal amphibolite, fissile amphibolite and chlorite-actinolite schists. There are also portions which have a more coarse-grained appearance, due to secondary growth of hornblende in a fine-grained matrix. Small-scale, acute folding was observed in outcrops of banded amphibolite.

Microscopic examination of specimens revealed that thorough shearing and partial recrystallization is very common in rocks of the Hestfossen sequence. In addition to hornblende and plagioclase (An_{30-40}) which presumably, at the outset of the tectonization, were the dominant minerals, epidote is abundant in some zones (epidosite was recognized). Quartz is present in variable quantities and minor amounts of carbonate were noticed in some thin sections. Sphene is a common accessory. The carbonate and specks of pyrite and chalcopyrite seem to have been introduced during more recent tectonic events which produced the Hestfossen fracture zone.

The present investigations have not led to a clear picture as to the origin of the Hestfossen sequence. Some evidence indicates that we are dealing with thoroughly sheared rocks of a basic composition. The Hestfossen sequence can be traced for more than 50 km within our area; if possible repetitions by folding or imbricate structures are disregarded, its thickness must have exceeded 1000 m. Sequences of such composition and thickness are known to be produced by basaltic volcanism, belonging to the later phases of an orogenic cycle. This could be an explanation for the origin of the Hestfossen sequence of amphibolitic rocks.



Photo E.G.H.

18.7.1965.

View of Ulvefossen in upper Anarjokka looking from the northern bank in a southerly direction. The fall is caused by backward erosion along E-W striking, sheared, amphibolitic rocks which cut an older river stretch with a northerly direction. The falls are about 12 m high.



Photo E.G.H.

31.7.1966.

Copolcokka Pt.412, the northernmost hill formed by gabbro of the Njullasfjell-Burfjell gabbro belt, as seen from the air looking in a SE direction. Low area in background is Skiecamjokka valley and the ridges further back are in Finland.

On the other hand, the rocks could represent metamorphic derivatives of impure limestones and marls. This latter explanation is actually considered the more likely one.

The zones within the Hestfossen sequence mapped as ultrabasic rocks, with the exception of a sheared, talcose serpentinite, are all chlorite-actinolite schists. These might be explained as having formed from intensely sheared normal amphibolite according to the principles of kinematically controlled metamorphic differentiation as proposed by Tuominen and Mikkola. (Compt. Rend. Soc. Geol. Finl., XXIII, 1950). In this case they are not related to the rest of the ultrabasic rocks of the mapped area (cf. D. Rocks of Igneous Origin, section 2, below).

Another possibility, however, is that these ultramafic zones derived from sediments having a similar chemical composition (e.g. dolomitic marls). In the areas west and north of Grinvann, extensive outcrops of chlorite-actinolite schists are recorded which can certainly not be readily explained as products of tectonization.

D. ROCKS OF IGNEOUS ORIGIN

1. Gabbro

Rocks of a metagabbroic character have been reported from various parts of the mapped area, but sizable bodies of more or less fresh gabbro occur only in a belt, 1 - 2 km wide and 15 - 20 km long, extending from Njullasfjell towards Copolskaidde. Outside this belt fresh gabbro has been found in two small bodies located along the Skiecamjokka to the east of Vaakdalsvann.

The mapped gabbros represent, in fact, a variety of rocks. Over distances of centimetres to decimetres, fresh gabbro can pass into black-and white-spotted hornblendegabbro, which again may grade into one of the numerous sheared and folded varieties of amphibolites of the metagabbro type. No regular pattern is recognized, which governs these complex structural and mineralogical transitions. The described conditions are such as might be expected in the outer zones of gabbro bodies which were intruded during an active stage of dynamometamorphism. The almandine amphibolite facies of the metagabbroic amphibolite must not necessarily be matched by equally high regional metamorphism

at the time of emplacement of the gabbros, since the hot intrusives probably created their own thermal milieu.

The fresh gabbro is normally medium-grained but, in places, coarse gabbro also occurs. A fine-grained variety of fresh, hyperitic gabbro was found near the border of one of the gabbro bodies north-east of Vaakdalsvann. On account of poor exposure, it could not be clarified whether this represents the chilled margin of the original intrusion or some younger doleritic intrusion.

Within the main gabbro bodies, wherever primary structures still obtain, the rock shows laths of plagioclase in a sub-ophitic arrangement among grains of rhombic and monoclinic pyroxene. The observed texture is characteristic of thick volcanic flows, sills and dikes of gabbroic composition. The geometric appearance of the gabbro intrusions is indeed one of tabular bodies occurring along a narrow belt.

The fresh gabbro is composed of plagioclase 30-40 % (by vol.), and ortho- and clinopyroxenes in subequal amounts. The plagioclase composition varies from one locality to the other. Precise determinations show An_{43-45} in a specimen from the southernmost gabbro body (Njullasfjell) and An_{58-60} in a specimen from the northernmost one along the belt (Copolcokka). The latter shows normal zoning and is clouded by tiny, brownish inclusions. Whereas the Njullasfjell sample shows slight autometamorphism only, with rims of bluish-green amphibole around grains of pyroxene, secondary, brownish, green hornblende is well developed in the Copolcokka specimen. Plagioclase here exhibits bent twin lamellae, and interstitial quartz is present.

The above descriptions relate to specimens from widely separated localities within the belt and may indicate the range of lateral variation. However, insufficient data are available to say whether the variability within each gabbro body exceeds the differences between geographically separated bodies.

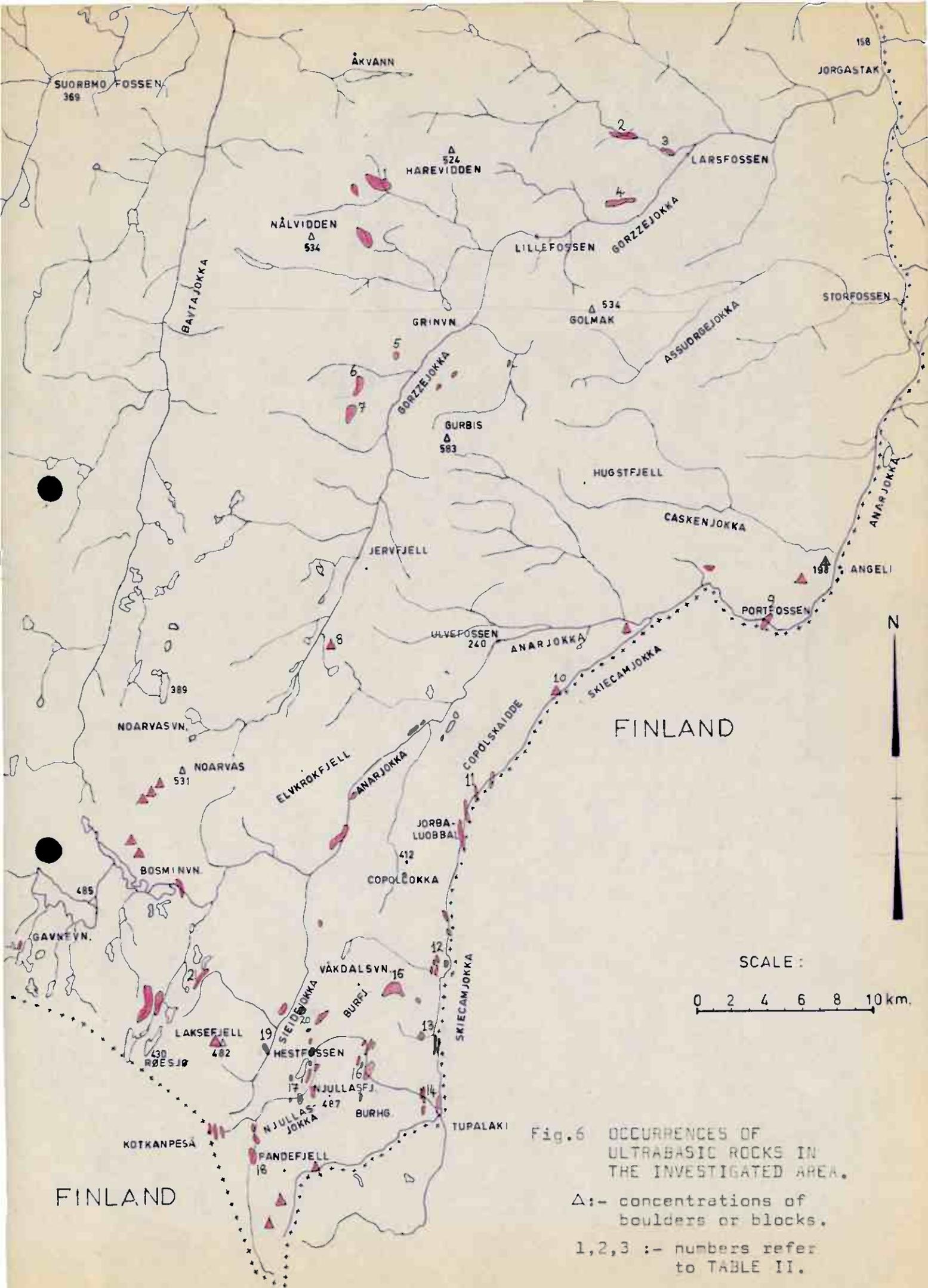


Fig.6 OCCURRENCES OF ULTRABASIC ROCKS IN THE INVESTIGATED AREA.

△:- concentrations of boulders or blocks.
 1,2,3 :- numbers refer to TABLE II.

A number of specimens of altered gabbro or meta-gabbro have been investigated from the "gabbro belt" as well as from localities elsewhere in the area. Characteristic of these is the dominance of hornblende with relics of clinopyroxene together with intermediate to basic plagioclase and epidote. In some places scapolite is present and more or less completely replaces the plagioclase. The occurrence of scapolite appears to be related to the border zones of the intrusive bodies in the gabbro belt.

Ilmenite, magnetite, sphene and apatite are common accessories in both the fresh gabbro and the meta-gabbros. The content of the mentioned oxides might locally be in excess of 10 % (by vol.) of the rock.

2. Ultrabasic rocks

Rocks of ultramafic composition were found in many parts of the investigated area. They vary considerably in size and shape as well as in mineralogical composition. The recorded observations were somewhat inconsistent with regard to the classification of ultrabasics. When drawing the 1:20'000 maps, it was therefore decided to lump all ultramafic rocks together under one and the same colour. Where possible, the rock was assigned to one of the following rock types: "serpentinite", "pyroxenite", "chlorite-actinolite schist" or "hornblendite".

A more systematic study of field observations and laboratory results led to a subdivision of the ultramafic rocks into three genetically different categories:

- (1) Intrusive ultrabasics and their metamorphic derivatives.
- (2) Ultramafic paleosome generated by partial anatexis.
- (3) Chlorite-actinolite schists formed in zones of shearing through kinematically controlled metamorphic differentiation (Tuominen & Mikkola, 1950).

The last two categories have no Ni-potential, and are not further considered in the present context.

The ultrabasic rocks of category (1) represent an element lithologically alien to the supracrustal or metavolcanic environment in which they occur. It can be assumed that these rocks represent intrusions of dunite and harzburgite which were emplaced some time during the regional metamorphism, and which subsequently suffered various degrees of metasomatism and retrograde metamorphism. This explains the great variability in mineralogical composition of these ultrabasics as well as their structural relationship to surrounding rocks. TABLE II illustrates roughly the paragenetic variations within the group of ultrabasic rocks of category (1).

As seen from TABLE II, there are relatively few ultrabasics in which significant amounts of primary olivine or pyroxene are preserved to classify them as dunites or harzburgites. In addition to these two types, porphyritic metaharzburgite has been observed, thus increasing the number of types of primary ultrabasic intrusions to three: dunites - harzburgites - porphyritic harzburgites.

Most ultrabasic rocks had their mineralogical composition modified through serpentization, CO_2 -metasomatism and addition of silica from the environment or from circulating solutions. One and the same intrusive body may display all these effects, and no significant regional differences in metamorphism can be recognized. In TABLE II, the specimens have been arranged roughly in order of increasing transformation. Slight metamorphism causes serpentization of the olivine and converts orthopyroxene to talc (H_2O -metasomatism). Introduction of carbon dioxide facilitates the breaking down of the primary silicates, producing serpentine, talc, anthophyllite, actinolite, chlorite etc. in addition to carbonates. Magnesite and calcite have been identified in some cases. Addition of silica may lead to a transformation of ultrabasics into actinolite-chlorite rock or pure actinolite fels.

It is evident from the structures and textures of the various ultrabasics here described that the metasomatism related to dynamo-metamorphism. Tectonization probably provided the strain energy and necessary permeability to make possible the transformation of dunites and harzburgites to soapstones and actinolite-chlorite schists. In any case it was noted in the field that many olivine - serpentine rocks have an outer zone of actinolite-chlorite schist.

Our observational material does not permit the establishment of systematic variation trends with regard to primary composition and frequency of occurrences of ultrabasics. It would appear, see Fig.6, that ultrabasics are more common in the southern part of the area, but this may be partly accounted for by the fact that there, the bedrock is better exposed. The general impression is that the distribution of ultrabasics is controlled essentially by faults and shear zones.

SiO_2 and potassium-rich solutions related to the nearby Røesjø granite appear to have produced the actinolite-rich varieties of ultrabasics to the north of W. Røesjø.

TABLE II

MINERAL COMPOSITION OF ULTRABASIC
ROCKS FROM INNER FINNMARK.

X - Dominant constituent >60%
x - Major constituent >10%
+ - Minor constituent

Spec.no.	No.	Locality	Olivine	Serpentine	Orthopyroxene	Anthophyllite	Clinopyroxene	Clinos amphibole	Chlorite	Talc	Carbonate	Phlogopite/Mg-Biotite	Opaques	Remarks
L 17-9	4	Lillefossen		X										
M 17-30	3	Haalkeelven	x	x			+	+						
BF 33 ^{II}	12	Skiecamjokka		X									x	
G 18-1	8	Jervfjell		X							x			
O 69 ^A	11	Jorbaluobbal	+	X				+	x					
BF 33 ^I	13	Skiecamjokka		X					x	x				
M 17-4	2	Haalkedalen	X	x	x									
O 62 ^A	11	Jorbaluobbal	x	x	x						+			
BF 13 ^B	16	Njullasjokka		x						x	X			
W 268 ^I	20	Kirksæther Ravine	x	x							x	+		
W 104	21	NNW of Laksefjell		X						+	x	x		
O 111	17	Njullasjokka		x							x	x		
BF 5	17	Njullasvann		x						+	x	x		
O 110 ^I	17	Njullasjokka		+	x		+	x			x	x		
G 25-7	6	W of Gorzzejokka	+	+	x		+	x			x	x		
O 110 ^{IIx}	17	Njullasjokka			x	x	+	x			x	x		
G 25-8	6	W of Gorzzejokka		x		x	+				x	x		
H 27-4	5	Gorzzejokka		x		x				+	x	x		
O 110 ^{II}	17	Njullasjokka		+			+	x		+	X	x		
BF 2	19	Hestfossen area		+							x	x		
G 25-4	7	W of Gorzzejokka					+	x			x	x		
O 90-8	17	Njullasjokka						X	x		x	x		
BF 6	17	Njullasvann					+	X	+		x	x		
O 99	17	Njullasjokka-zone		x				x	x	+	+	+		
O 69 ^B	11	Jorbaluobbal					+	x	+	x	+	x		
EGH 533	20	Kirksæther Ravine		X				x	x	x		x		
O 47	10	Baltofeltet	x	+			+	x		x		+		
W 268 ^{II}	20	Kirksæthers Ravine		X				x	+	+		+		
W 227	15	Aagaardtoppen	x					x	x			x		
W 340	14	Skiecamjokka		+				X	x	+		+		
O 62 ^B	11	Jorbaluobbal		+				X		+		+		
W 294	14	Skiecamjokka		+				x	x	+		x		
W 216 ^C	14	Skiecamjokka		+				x	x	+		+		
BF 26	16	W of Burhaugen						x	x	+		+		
E 7-4	1	Ravkocokka						x	x			+		
BF 13 ^A	16	Njullasjokka						X				x		
BF 14	18	Pandefjell						X	+	+		+		
C 18	9	Portfossen					X	+				x		

Harz-
Dunites
burgites
Serpentini-
zation

Increasing Si-
metasomatism
Tectonization
Silica and CO₂-
metasomatism



Photo E.O.

August 1965

Shear in outcrop of meta-ultrabasic rocks (serpentinite) in Njullasjokka to the west of Pandefjell.



Photo E.O.

August 1965

Veins of coarse-grained plagioclase-hornblende rocks which intersect meta-ultrabasics shown on above picture.



Photo E.G.H.

26.8.1965.

Contact late-kinematic Roesja granite (left) and quartzitic rocks as seen looking in a northerly direction along the contact which can be noted to the left and above Lars Kirksæther. The foliation of the quartzitic rocks parallels the granite contact. No contact-metamorphic phenomena were observed. According to V.H.Wiik, the granite was emplaced at a high level in crust " as a mush of solid crystals".

3. Intrusive granite

An intrusive body of granite is well exposed just to the west of W. Røesjø. Here, massive medium- to coarse-grained granite intruded impure, micaceous quartzite, fragments of which are found embedded in the granite of the contact zone. Hydrothermal quartz and pegmatitic feldspathic material was found in fractures in the border zone. No contact-metamorphic phenomena were observed. The granite intrusion seems to have taken place at the now exposed level as a mass of solid crystals, forcing aside and locally brecciating the surrounding rock.

According to Buchan's description of a specimen from the contact zone, the major components of the granite are:

orthoclase 30%, microcline 20%, plagioclase (\pm An₃₄) 10%, quartz 10%, and biotite 8%.

From the evidence in the mapped area it would appear that this granite has not been affected by regional metamorphism, it is therefore interpreted as a late-kinematic granite.

4. Pegmatites

In the field the term pegmatite was used to cover a variety of quartzofeldspathic rocks with a grain size ranging from 5 mm to about 10 cm.

In the eastern part of the area there is evidence that such pegmatites represent the coarse-grained metasome (Barth Theoretical Petrology, 1962) of veined migmatites, and this may be the case also for most pegmatites in the center and northern area.

In the south where the rocks are better exposed, it is possible to distinguish between three types of pegmatites:

- (1) Between Njullas and Skiecamjokka many concordant zones, 5 to 10 meters wide, of pegmatite occur within the sequence of mica- and hornblendegneiss. Their major constituents are albitic plagioclase and quartz. Aplite and cross-cutting small veins may be found associated with the pegmatites. These pegmatites probably represent mobilized metasome intruded in a zone of movement (thrusting).

- (2) To the west of Njullas, pegmatites are not found in significant numbers until the Kotkanpesä suite is reached. In this suite of quartzofeldspathic gneiss and quartzite with interlayered zones of amphibolite, certain portions of the quartzofeldspathic gneiss have less dark minerals and a larger grainsize than the surrounding gneiss or amphibolite. Schlieren or patches may sometimes reach considerable dimensions (up to 5 meters wide), and these were mapped as pegmatite. They consist mainly of albitic plagioclase and quartz. Through their distribution and boundary relations, it is suggested that these pegmatites represent zones in the gneiss which have suffered tectonization accompanied by increased fluid circulation and recrystallization, perhaps with some removal of femics.
- (3) On the border and in Finland in the Kotkanpesä area, huge masses of pegmatite stand out as hilly features in the landscape. They are clearly intrusive, in places cutting across beds in the supracrustal formations, but there is a general tendency for them to form conformable lense-shaped bodies. These pegmatites are distinguished from the other types mentioned in that they have a high K-feldspar content. Subordinate to microcline, an acid plagioclase and quartz are essential constituents. Biotite, partly altered to chlorite, occurs in minor amounts mostly in the form of clusters or stripes. Textures show microcline in this type of pegmatite to be replacing plagioclase, whereas the remaining plagioclase and quartz bear evidence of tectonization. It is possible that these pegmatites relate to the Røesjø granite intrusion.

Microscopically, no minerals of economic interest have been noted in any of the described pegmatites. The field evidence thus suggests that the pegmatites are barren. Spectroscopic examinations for trace elements were not, however, carried out.

5. Dolerite and other basic dyke rocks

Dolerites are very scarce in our area, but a few occurrences of metadolerites were mapped. Outcrops of a dolerite dyke were found on the Gorzzejokka northeast of Grinvann. It is a fresh, finegrained and massive rock with a porphyric intersertal texture. It is mainly composed of plagioclase (An_{60}) and a clinopyroxene, probably sodic augite.

On the northern shore of W. Røesjø occurs a dark, fine-grained rock which under the microscope shows a subophitic texture with more or less lath-shaped grains of sodic plagioclase as the dominant constituent. Light-green clin amphibole, biotite, sphene and opaques are present in subordinate amounts. This rock is to a large extent transformed into a sheared metamorphite, and the primary igneous texture is preserved locally only.

The "gabbro pegmatite" to the west of Helligskogstua is a very coarse-grained rock with biotite, actinolite or hornblende, garnet, plagioclase (An_{35-50}) and clinostatite as the main constituents. Specks of molybdenite were noted in this rock. According to its mode of occurrence the rock must be interpreted as a dyke. However, some specimens suggest that one is dealing with a skarn phenomenon or a zone of silicification at the contact between amphibolite and metagabbro. Fist-sized almandine garnets and large plagioclase and pyroxene crystals influenced the choice of the field term "pegmatite" for this rock.

E. ROCKS OF UNKNOWN ORIGIN

1. Albite gneiss (Albitite)

The name albite gneiss was given to a peculiar group of rocks occurring mainly along the gabbro-belt. Certain indications suggest that there is a genetic relationship between the gabbro-intrusions and these rocks. In places, albite gneiss is found to envelope gabbro bodies. It forms a transition between the border of the gabbro intrusion and amphibolite west of Burfjell and to the north of Njullasfjell.

The colour of the albite gneisses varies from reddish or greenish white, aplitic, and streaky, finely banded types to dark varieties transitional to amphibolite. Common to the whole group is the fine-grained, equigranular, sugary appearance.

The mineral composition varies considerably, but albite is always a major constituent. Quartz may, or may not be present. The femics vary in quantity as well as in quality, most frequently found is a light, bluish-green clin amphibole. In some albite gneiss, a light greenish diopside is the major femic constituent, making up 20 - 30 % of the rock, with minor amounts of the above mentioned clin amphibole. Sphene and apatite are often found as accessories, and occasionally also rutile and opaques.

The compositional variability of the albite gneisses is readily noted in outcrops. One often gains the impression that a transformation has taken place which irregularly converted amphibolitic rocks into light albitite. Relics of darker, amphibolitic rock are recognized in various stages of transformation in an albitite matrix.

A series of thin sections taken from normal amphibolite across the irregular transitional zone and into aplite-like greenish albitite have shed some light on the nature of this transformation. In the first stage, common hornblende is transformed into a hastingsitic variety of amphibole, characterized by very strong absorption and a small 2 V. The plagioclase of the amphibolite becomes sericitized (paragonite?) and is in a further stage converted to fresh albite (An_{0-10}). In the successive stages albite becomes more and more abundant. The hastingsite disappears, and fresh, hypidiomorphic, light green clin amphibole (2V=large) or diopside constitute the femics. Sphene remains a conspicuous accessory. In the intermediate stages of this transition, relatively large, anhedral grains of apatite occur, particularly along certain zones. It was observed in one thin section that the replacement of amphibole grains by albite led to a precipitation of iron as oxide. In the field, a particularly high content of magnetite was noted in a certain zone within the albite gneiss.

The above observations are taken to indicate a metasomatic origin of the albite gneiss group of rocks. Along with the intruding gabbros,

emanations ascended which were capable of transforming the sheared basement rocks above and around the intruding gabbros.

2. The Røesjø Trench rock

A trench across the EM-anomaly at eastern Røesjø revealed a peculiar feldspathic rock, the nature of which is not yet fully understood. The rock has a rather massive appearance, but hand specimens show a considerable variation in grain size and colour. Weathered surfaces have a brown coating, but there are also brown irregular patches of coarse-grained potassium feldspar among denser, greyish or white, quartzofeldspathic material. Other varieties show dark greyish, irregular streaks and small aggregates of felds and opaques, surrounded by a white, aplitic matrix composed of albite, with subordinate quartz and microcline. Scattered specks of molybdenite occur, occasionally having a grain size of 5 mm or more.

The feldspathic rock is well jointed and minor concentrations of sulphides occur on these joint fractures. However, the total sulphides, (both disseminated sulphides and enrichments on fractures) never add up to more than 10% of the rock. Pyrrhotite appears to be the primary mineral, but extensive transformation to marcasite and pyrite has taken place.

Thin sections show a considerable variation in the relative amounts of the major constituents. Albite dominates in most sections, with quartz, oligoclase and microcline each making up from 5 to 25% of rock volume. Biotite, chlorite, sphene and apatite are common accessories.

A few thin sections show a dominance of microcline, and textural evidence of microcline replacing plagioclase was noted. Plagioclase, quartz and biotite display protoclastic features, whereas microcline is fresh.

The Røesjø trench rock is probably a product of metasomatic processes. It may have been a quartzofeldspathic biotite gneiss which was albitized prior to the development of microcline. Similarities between this rock and the pegmatites of type (3) as well as its spatial situation point to a possible genetic relationship to the Røesjø granite.

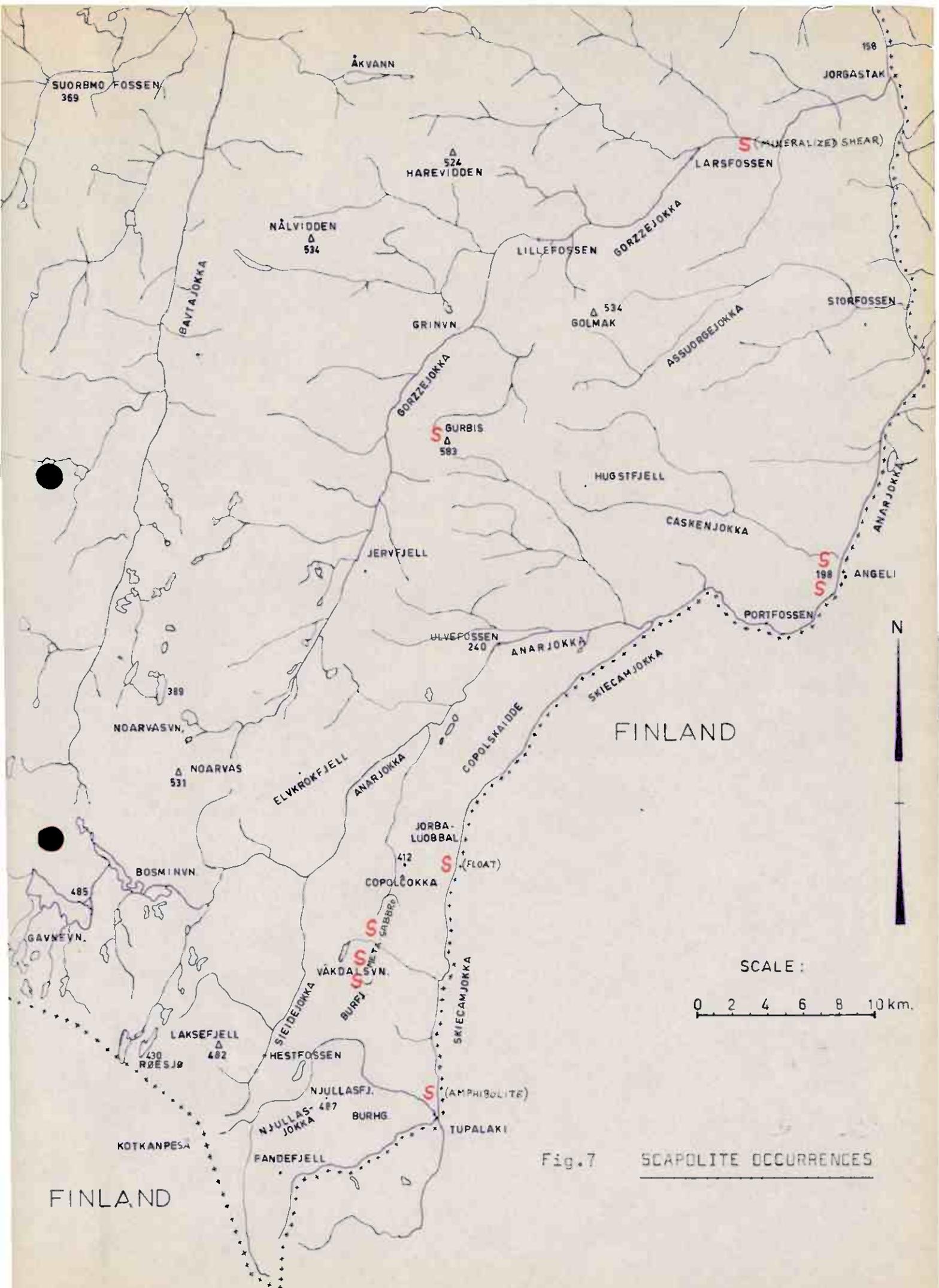


Fig.7 SCAPOLITE OCCURRENCES

The disseminated iron sulphides could be primary and the molybdenite may have been introduced during the phase of potash metasomatism, when the microcline was produced. The enrichment of iron sulphides along joint planes demonstrates that a redistribution or new influx took place after the structural event that caused the jointing.

F. LOCAL METAMORPHIC EFFECTS

In addition to the rocks described, which have undergone regional metamorphism in the amphibolite facies and subsequent retrograde adjustments on a regional scale, some rocks were noted which have obviously suffered secondary transformation or alteration on a local scale. The nature of these transforming processes is variable. Along certain zones and in restricted areas local rise in temperature has led to partial anatexis and the formation of migmatites, whereas in a later phase mechanical deformation gave rise to a variety of tectonites along the shear zones. Local metasomatism, normally accompanied by one or both of the two first mentioned factors also produced rocks which are at variance with any of the rock types previously described.

G. SCAPOLITIZATION

Rocks with a notable scapolite content have a restricted occurrence in our area. The localities are shown in Fig.7. Apart from the two localities in the Helligskogen area, where scapolite occurs in pegmatitic basic rocks, scapolite is found in metagabbroic and amphibolitic rocks only. In the Vaakdalsvann area there are strong indications of the scapolitization being related to the intrusions of gabbro, the border zones of the gabbros themselves being slightly autometamorphosed and scapolitized. This is not in accordance with the findings from northern Sweden, where regional scapolitization occurs. There the source of the scapolitizing agents is found to be the Lina granite. Whereas in Sweden chalcopyrite goes along with the scapolitization, there is no evidence of such a relationship in our area.

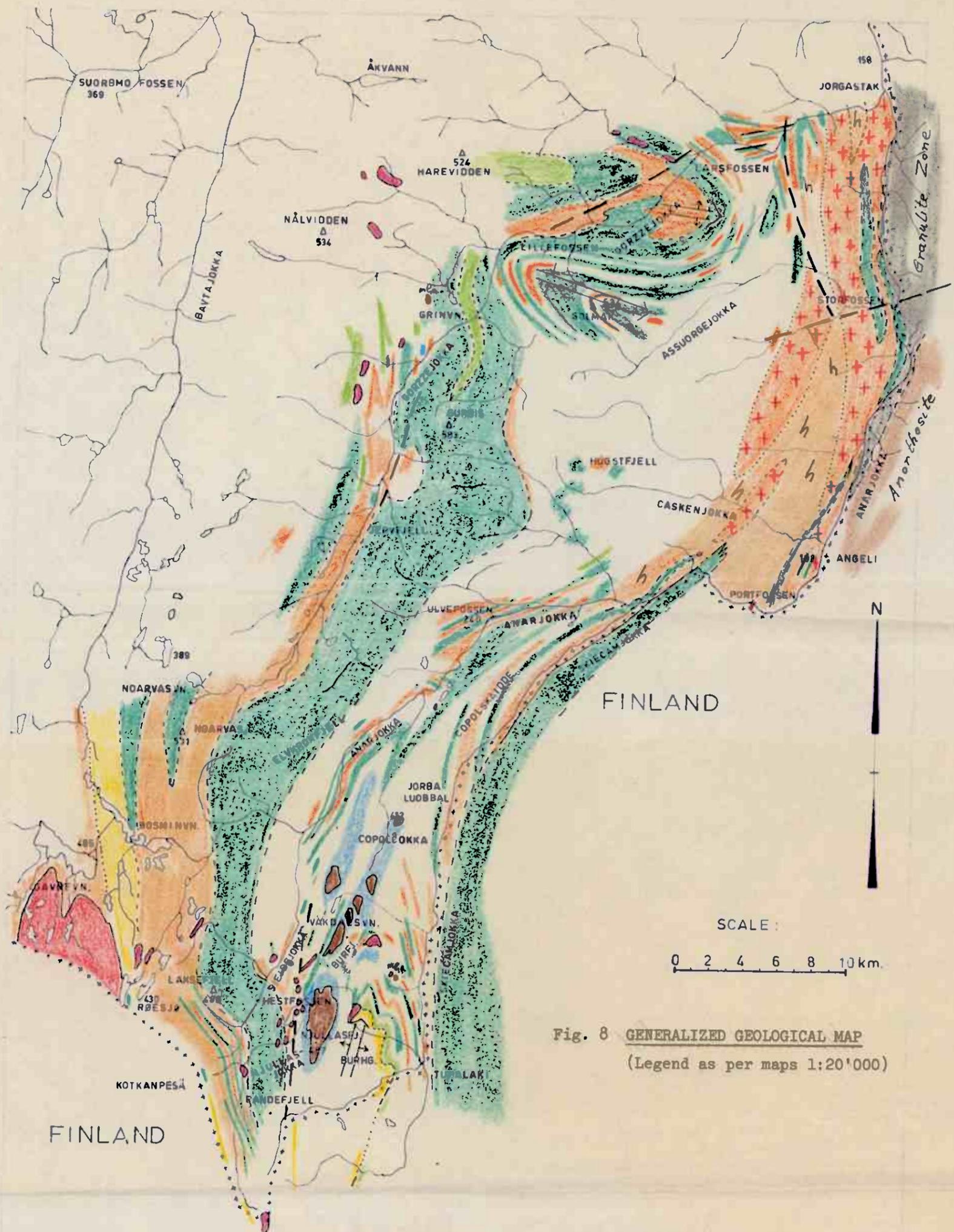


Fig. 8 GENERALIZED GEOLOGICAL MAP
 (Legend as per maps 1:20'000)

5. ON MINERALIZATIONS AND ASSOCIATED PHENOMENA

The Karelian belt is not a uniform province, neither from a petrological nor from a metallogenetical point of view. With regard to the nature of the petrological province to which our area pertains, our observations revealed the following: The supracrustal rocks include rocks of sedimentary and volcanic origin. The generalized geological map, Fig. 8, demonstrates that several of the originally stratiform rocks, or suites of rocks, can still be traced over considerable distances inspite of subsequent changes produced by metamorphism(s) and tectonics. However, the original chemical composition of the metavolcanic rocks is difficult to assess. For instance, an interpretation of the amphibolites of the Hestfossen sequence as product of a basaltic volcanism is very much on the speculative side. Some evidence was put forward that much of the quartzofeldspathic gneiss derived from lavas or volcanic ashes of a tonalitic composition. The intrusive rocks seem to provide more reliable information as to the nature of the magma. There is sufficient evidence from the composition of the basic rocks that the province included a primary olivine basalt magma from which gabbros and ultrabasic rocks (peridotites and pyroxenites) formed by differentiation and plutonic crystallization. The late-kinematic Røesjø granite, on the other hand, testifies to the presence of a primary granite magma in a late phase of the orogenic cycle. The nature of veins and fracture-fillings in the border zone of the Røesjø granite indicates, however, that the hydrothermal solutions related to this granite magma did not carry any economic minerals. Wiik's petrological study did not produce clear-cut evidence that parts of the quartzofeldspathic rocks derived from earlier (synkinematic) granodiorites.

In the pegmatites, the phenomenon of sodic feldspar being replaced by potash feldspar - rather than the other way round - was observed. It is worth noting that the pegmatites carry none of the more interesting accessory minerals one could expect. This is taken to indicate a paucity of residual solutions or of certain elements in the province and seems significant from a metallogenetic point of view. The Røesjø trench rock may represent the only known exception if, indeed, it is a pegmatite s.str. and the small amounts of molybdenite belong to the pegmatite minerals and are not part of the iron-sulphide mineralization.

No economically significant primary mineralization was found. The investigated ultrabasic rocks carry minor amounts of sulphides only and no continuous massive sulphide areas were located in, or in association with, ultrabasic rocks. The titanium content in parts of the Njullas gabbros is in the range produced by accessory minerals. Stratiform minor sulphides occur in association with graphite-bearing horizons in the Maritskogen anticline (see PART IV, p.4).

As a rule, a higher content of metallic minerals in rocks and mineralizations occur in shears or tectonic alignments interpreted as thrusts; a few were located in joints and fractures which seem to relate to comparatively young tectonic events. Sulphide mineralizations and typical metasomatic mineral assemblages sometimes occur together. One mineralized shear in the lower Gorzzejokka shows massive pyrrhotite (22%) and a little chalcopyrite in association with scapolite (20%); (see PART IV, p.5). On the other hand, no concentration of sulphides occurs together with the slight scapolitization which accompanies some of the gabbros of the Njullasfjell-Burfjell belt.

The massive sulphide breccia from the Grinvann shears was produced by the "soaking" of a heavily shattered zone by iron-sulphides (Buchan). In one sample, marcasitized massive pyrrhotite forms more than 98% of the total sulphide assemblage. The examined samples from the mineralized Gorzzejokka shears in which no ultrabasics occur, showed a very low nickel content. No pentlandite was recognized in any of them and the ratio chalcopyrite to iron-sulphides seems to be most unattractive.

The best example of a mineralization in a structural zone which includes ultrabasics as well as other rocks is provided by the Njullasjokka EM anomaly zone. Here, the sulphides have been re-distributed and were noted in graphite-bearing mica (-chlorite) schists and other sheared rocks as well as in the ultrabasics. Disseminated sulphides found in a talcose serpentinite in the river section amounted to nearly 10% (est.% by vol), but in most cases they average less than 5%. Magnetite + chrome spinel is present in equal to slightly lesser amounts. The sulphide assemblage of this zone consists of pyrrhotite, pentlandite and minor chalcopyrite, but practically no pyrite. The ratio pentlandite to pyrrhotite

found so far is in the range 1 : 3 to 1 : 4. Two analyses made in Kristiansand showed that the nickel to copper ratio ranges from 13 : 1 to 20 : 1.

Kristiansand,
26th October, 1967.

LEGEND 2

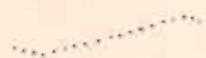
Geological boundary:



observed



approximate



inferred



Strike and dip of foliation, (dip in 90° circle).



Strike observed on air photograph.



Lineation.



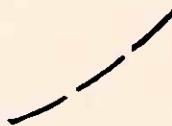
Strike and dip of joint.



Major fold axis.



Minor fold axis.



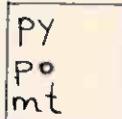
Fault. (Mostly inferred from air photographs.)



Block.



Concentration of blocks.



Mineralisation: pyrite, pyrrhotite, magnetite.
(Abbreviations as per geophysical maps.)