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**Sammendrag**

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This puts some constrains on the types and size of the mineralizations likely to be found.

New models for the genesis og gold and noble-metal deposits in Arcaean volcanic-sedimentary terrains suggest that increasing attention should be derected towards the prospecting for gold, Pt, Pd and W - particularly in the south Karasjok area.

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SAKSBEARBEIDER Helge Henriksen, geolog.

RAPPORT VEDPØRENDE:

GEOLOGICAL MAPPING IN THE KARASJOK AREA, 1981.

RESYMÉ:


A zonal division of geological units: a) a granite-gneiss complex, b) a basal sedimentary series, c) the Karasjok Complex, d) the Hornblende Gneiss Complex and e) the Granulite Complex, - is recognized.

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FORDELING

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KOMMENTAR:

HH/bs

## INTRODUCTION.

The Precambrian basement terrain in the Karasjok area has been devided into five northwesterly trending belts as shown in fig. 1. With one exception, the division of geological units is the same as in last years report (rep. no. 1122), where a review of the general geological setting of the Karasjok area was given.

The former term "Karasjok Group" is not used in this report. The basal arkosite-quartzite has been distinguished as a separate unit; and the new term the Karasjok Complex has been introduced for the remaining members of the former Karasjok Group. The Karasjok Complex is recognized as a polyphasally deformed and metamorphosed sedimentary-volcanic sequence in an allochtonous position above the basal arkosite-quartzite unit.

The geological field work this year started 18/6 and was finished 22/9. Geological mapping was carried out mainly in the Karasjok Complex both north and south of Karasjok as follows :

18/6 - 22/6 and 8/9 - 16/9 : South Karasjok area.
23/6 - 7/9 and 16/9 - 22/9 : North Karasjok area.

The geological mapping was carried out by H. Henriksen, who was assisted by M. Einarson (18/6-17/8) and H. Pantdalsli (18/8-22/9).

The topographical map series M 711 in the scale 1:50 000 has been used as a base for the geological map.

The geological map has been compiled from outcrop observations, geophysical data and interpretations of aerial photographs.

With the exception of a small area just north of Karasjok, the whole Karasjok Complex is covered with geophysical maps (Mag., Em/VLF) in the scale 1:50 000. These provide valuable additional information in compiling the geological map. The trend of the geophysical anomalies reflect the general structure - and certain rock types (e.g. graphite schists, ultramafic intrusives and extrusives, gabbros) are easily picked out on the geophysical maps. So is also certain geological boundaries and faults.

## THE GRANITE GNEISS COMPLEX.

So far, no mapping has been carried out in this complex, and only a few observations have been made. Most of this complex appears to consist of grey, homogeneous gneisses of granodioritic composition. Here and there, thin pegmatitic veins may be found as rootless intrafolial folds. A few thin amphibolite bands have also been observed.

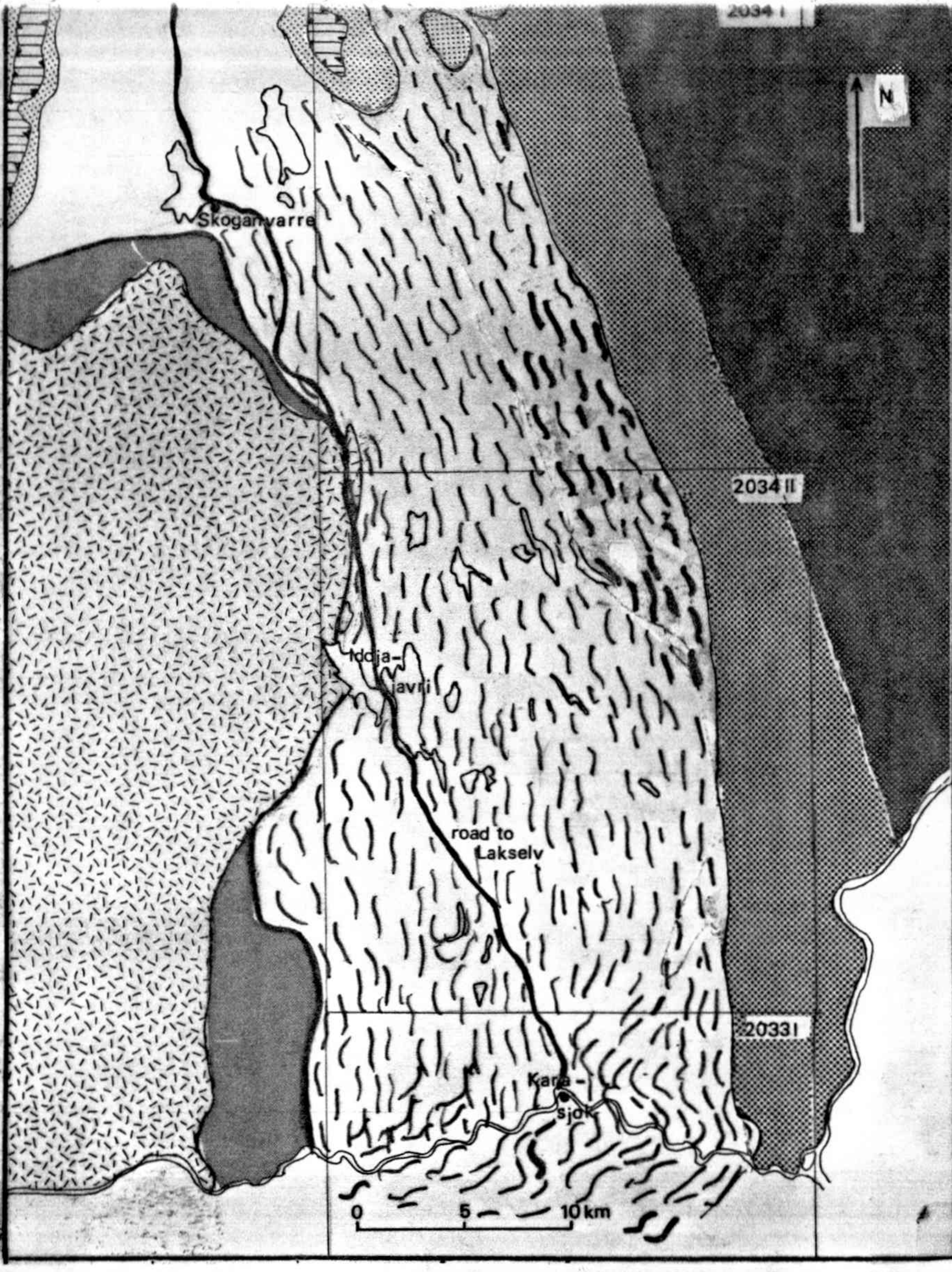



Fig.1 Principal geological units in the Karasjok area.

Granite gneiss complex
Basal arkosite/quartzite
Karasjok Complex
Hornblende Gneiss Complex
Granulite Complex

The complex is intruded by later pegmatites, and locally, migmatization and emplacement of reddish microcline-granites has occured. These late granites are often found along the contacts between the granite-gneiss complex and the basal arkosite-quartzite, thus effacing the original contact relationships between these two units.
A U/Pb age of 2800 M.yr. has been reported from the granite-gneiss complex (Skålvoll 1971).

THE BASAL ARKOSITE-QUARTZITE.

This unit is found along the eastern margin of the granite-gneiss complex. At one locality south of Skoganvarre (288.411) a primary unconformity is exposed between these two units.

A thin zone with basal conglomerate and grits is succeeded by arkosic sediments. The conglomeratic - and arkosic sediments are practically undeformed, and the original clastic grains and granules are discerned in the gritty and arkosic lithologies. Carbonate is the major matrix mineral in these rocks.

The non-deformed sedimentsare succeeded by more deformed and folded metaconglomerates, quartzites and arkosites.

NE of Savgnujavri (square grids 25.42 & 25.43) occurs a similar sequence of conglomerates, quartzites and carbonate-rocks. Thin bands of fuchsite schists are also found in the metasedimentary sequence.

They may be as thick as 1 - 2 m, and consist of about 50 % fuchsite with quartz and carbonate in about equal amounts.

The fuchsite schists may have formed by ( chemical) weathering of pre-existing ultramafic rocks. Such rocks have, however, not been found in the Granite Gneiss complex, which is the main source area for the basal arkosite-quartzite unit.

Another possibility is that the fuchsite-schists were deposited contemporaneously with subaqueous ultramafic volcanic activity in the nearby area. Within the Karasjok Complex, pillowed ultramafic volcanics indicating formation under marine conditions are found (see p.4 ).

These rocks could be the source for the chromium necessary for the formation of the fuchsite-schists (see also p.16 ).

Fig. 2. Cross-bedded feldspathic quartzite, Jiesvarre (250.058).

By Jiesvarri - a thin zone of conglomerate and pelitic schists is succeeded by a thick unit with feldspathic quartzites and quartzites. The quartzites contain primary features such as cross-bedding (fig. 2) and occasional heavy mineral horizons. Layers of carbonate are found in the quartzites northeast of Jiesvarre (270.070).

Towards the east, increasing deformation and obliteration of the primary sedimentary structures is noted.

The pelitic schist above the conglomerate west of Jiesvarre has completely recrystallized to the metamorphic mineral assemblage :

quartz + plagioclase (albite) + K-feldspar + biotite + muscovite.

This indicates the metamorphic grade within the basal sedimentary unit. The mineral assemblage appears to have formed by prograde metamorphism of the original sedimentary rock.

Judged by the rock-types, the basal arkosite-quartzite unit may represent ancient, shallow-water shelf sediments.

## THE KARASJOK COMPLEX.

"In the Karasjok Complex, mafic- and ultramafic metavolcanics and gabbros form the major portion ( 70 %). Metasedimentary rocks, felsic schists and small granite intrusions make up the remaining part. The rocks are variably deformed; and the metamorphic grade varies from the middle greenschist to the low amphibolite facies."

### Chlorite-tremolite rocks (komatiitic greenstones).

These rocks crop out as a central axial-belt within the amphibolites; where they also are found as thinner impersistent bands. The unit comprises a series of predominantly high magnesian (MgO>18%) extrusives.

The most common member is a greenish-grey chlorite-tremolite rock, which has an average MgO content of 24%. A foliaton - formed by the parallel alignement of Mg-chlorite and tremolite - is variably developed. Particularly along the margins and in localized interior zones the rock is a typical chlorite-tremolite schist.

By Gukkesjarĉåbma (square grid 38.33), where the chlorite-tremolite rocks have a maximum outcrop width, a good section exposes units of massive and pillowed chlorite-tremolite rocks, a volcanic breccia and fragmental/agglomeratic rocks.

The pillowed unit (about 10 m thick) shows unambiguous pillow structures (fig.3), the pillows varying in size from 20 cm to 1,5 m along their longest dimension. Their shapes vary from round/oval to bulbeous.

The interior of the pillows consist of finegrained chlorite and tremolite with a chlorite-rich outer rim. Often - the intersticies between adjacent pillows is filled with carbonate-rich sediments (fig. 3).

Fig. 3. Pillowed chlorite-tremolite rocks, Gukkesjarĉâbna (382.338).

The volcanic breccia consists of angular fragments of amphibolite (hbl.+ plag.) set in a felsic tuffaceous matrix. It has an outcrop width of about 5-10 m, and occurs adjacent to the pillowed unit. The volcanic breccia may represent a former volcanic centre through which the ultramafic flows initially were erupted.

The fragmental/agglomeratic rocks have a groundmass of chlorite and tremolite and have sub-angular fragments of the same composition. The fragments are only discernable from the groundmass on the weathered outcrop surface.

Other primary volcanic structures met with in the chlorite-tremolite rocks are polygonal joints and amygdyles.

The polygonal joints divide the rock into a mosaic of angular fragments from a few cm to 30 cm size. Such joints may form by thermal contraction of cooling lava flows.

Oval to elongate-shaped pods (max. 2 cm in longest dimension) may represent former amygdyles. These are now filled with carbonate, chlorite and pyrrhotite.

Rocks with an MgO content > 30% are found by Addjatskaidi/Target area 11 (square grid 45.25). The most common mineral assemblages recorded from these rocks are :

1) Mg-chlorite + tremolite + carbonate.
2) Olivine + clinopyroxene + antigorite ± Mg-chlorite ± talc ± carbonate.

Within the type 1) assemblage-tremolite is found as bundles of acicular blades forming radial aggregates, thus suggesting pseudomorphosed spinifex-textures (see also p. 8 ). Such textures have also been observed at the outcrop scale by Addjatskaidi (Target area 11) and Geidnučåkka (square grid 49.19).

Other textures indicating an extrusive origin of the type 1) ultramafic by Addjatskaidi is the occurrences of polygonal joints and structures reminiscent of flow banding.

The type 2) mineral assemblage contains olivine and clinopyroxene as relic minerals, and may represent the lowest cumulate zone in the ultramafic lava flow. An intrusive origin for rocks with the type 2) assemblage is also possible.

Chemical results.

It was suggested in last years report that the chlorite-tremolite rocks might have formed by extrusions of ultramafic lavas with komatiitic compositions. As komatiites have been recognized to host Cu-Ni deposits, it was decided to carry out a major - and trace element analysis of the chlorite-tremolite rocks. The samples selected for analysis were cut clean with diamond saw, and obviously altered and oxidized samples were excluded.

The XRF-compositions (hydrous values) of the analysed samples are shown in table 1, together with comparative date from the litterature (table 2). It is seen that the chlorite-tremolite rocks have strong chemical similarities with komatiites from Archaean greenstone terrains. The komatiitic affinity of the analysed samples is also evident when the results are plotted in conventional discrimination diagrams. In the AFM-diagram (fig. 4 a), the samples are

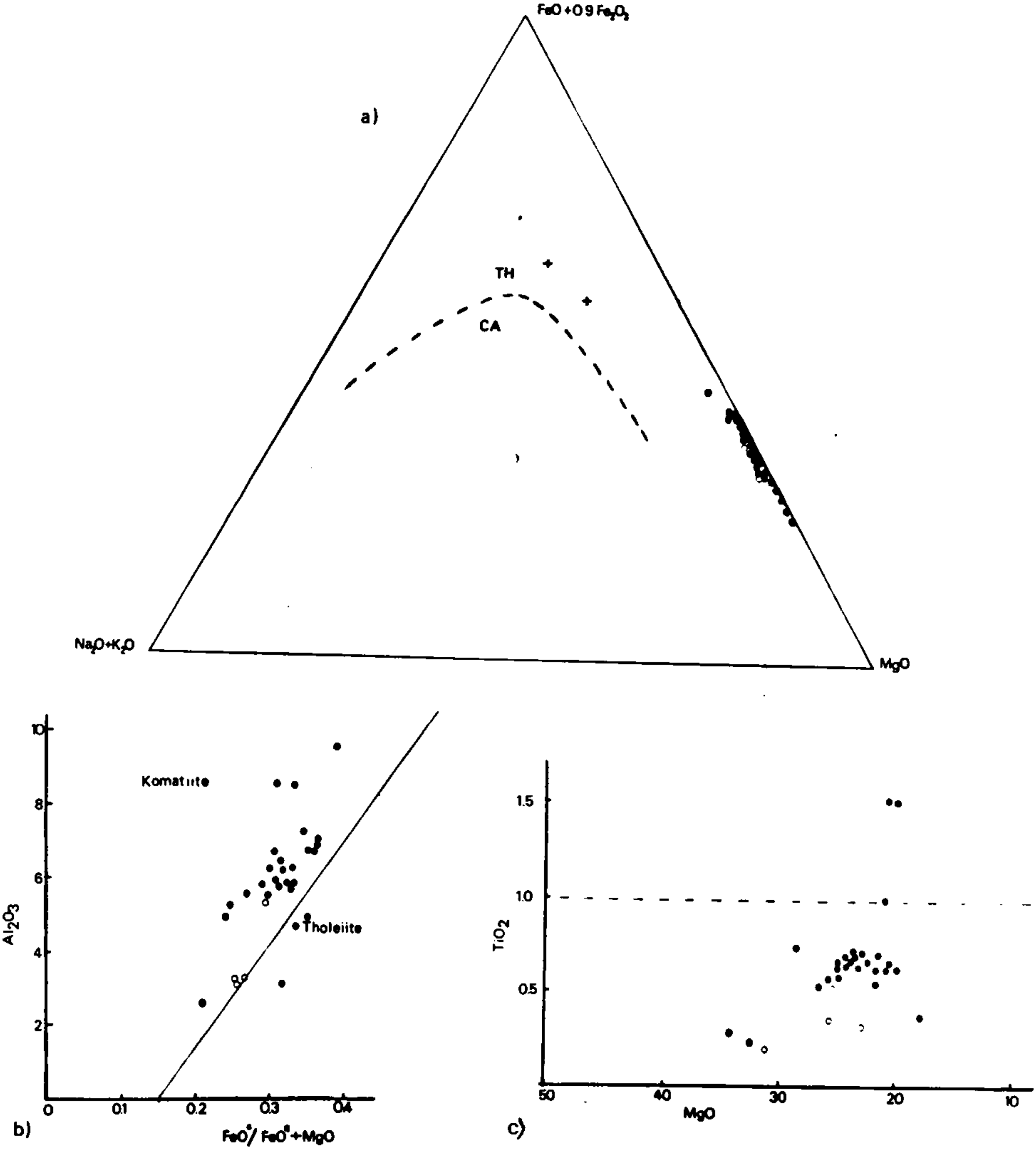



Fig. 4. a) AFM-diagram showing the location of the Karasjok mafic- and ultramafic rocks. The broken line is the boundary between the tholeiitic (TH) and the calc-alkalic (CA) field after Irvine & Baragar (1971).

b) $Al_2O_3$ vs. $FeO^x/FeO^x$+MgO diagram showing the location of the Karasjok ultramafics.

c) $TiO_2$ vs. MgO diagram of the Karasjok ultramafics.

<u>Symbols</u> :
- ● chlorite-tremolite rocks MgO<30%
- ⊗ " " " MgO>30%
- ○ other ultramafics
- ✚ gabbro/amphibolite

located in the tholeiitic field close to the MgO-$FeO^x$ ($FeO+0,9\cdot Fe_2O_3$) side, illustrating their deficiency in alkalies and their high Mg-content.

In the $FeO^x/FeO^x$+MgO vs. $Al_2O_3$ plot - which is commonly used to discriminate between komatiites and tholeiites - all but three samples fall in the komatiite field (fig. 4 b).

The analysed samples have also a low $TiO_2$-content (< 1) for any value of MgO, as do rocks belonging to the komatiite series (fig. 4 c). With respect to other major element variation diagrams (e.g. CaO vs. $Al_2O_3$, $TiO_2$ vs. $Al_2O_3$, etc.) the analyses fall within the komatiite fields.

The analyses show a trace element content which is very consistent with Archaean komatiites (table 2), characterized by high Ni and Cr and relatively low Cu-contents.

Preliminary results for the LREE La and Ce show that the analysed samples are strongly depleted in these elements, a feature characterizing komatiites, but not picrites which otherwise may have a similar major element composition.

Summary.

Chemically, the chlorite-tremolite rocks clearly belong to the high Mg-komatiite suite as defined by Arndt et.al. (1976), and could be classified as picritic (MgO: 20-30%) and peridotitic (MgO>30%) komatiites.

The identification of spinifex-textures, diagnostic for komatiites, is difficult due to the effects of metamorphism and deformation. One must also remember that only small portions of komatiite-flows are spinifex-textured (e.g. Coad 1979, Arndt et al 1979).
The result of prograde metamorphism of spinifex-textured rocks into the upper greenschist /low amphibolite facies is to destroy the original spinifex-texture made up of olivine and/or clinopyroxene. Olivine is pseudomorphosed by platy/fibrous Mg-chlorite crowded with Fe-oxides, while clinopyroxene is replaced by acicular tremolite. Pseudomorphosed spinifex-textures have been described by Hanski (1980), Blais et.al. (1978) and Willet et.al. (1978).

Textures made up of radiating bundles of acicular tremolite and platy/fibrous Mg-chlorite are found in some of the chlorite-tremolite rocks. These are very similar to those described from the litterature - and presumably represent pseudomorphosed spinifex-textures of the random orientated type.

Economic potential of komatiitic rocks - consequences for the exploration work.

Rocks of komatiitic compositions are considered as promising objects for nickel-prospecting. A number of case-histories are found in the litterature, and a series of significant features, which may serve as guide-lines for the practical exploration may be listed (e.g. Coad 1979). Two of the most important features are :

1) Komatiites with high MgO contents (> 40% in anhydrous values) are the most promising for Ni-Cu deposits; although komatiites with lower MgO contents also host such deposits (e.g. Hanski 1980).

2) Extrusive komatiites are the most favourable. These host massive and/or disseminated deposits. Intrusive komatiites generally host disseminated deposits.

This leaves the peridotitic komatiites in Target area 11 the most interesting object, as :

a) they have the highest MgO content (table 1 , fig. 5),
b) the apparent extrusive nature of these rocks
c) the strong SP- and magnetic anomalies above the western margin of these rocks,
d) moreover - anomaleous concentrations of Zn appears to be associated with some komatiite-hosted Ni-Cu deposits (Coad 1979 p. 57).
   Close to Target area 11, a Zn soil-sample anomaly is found.

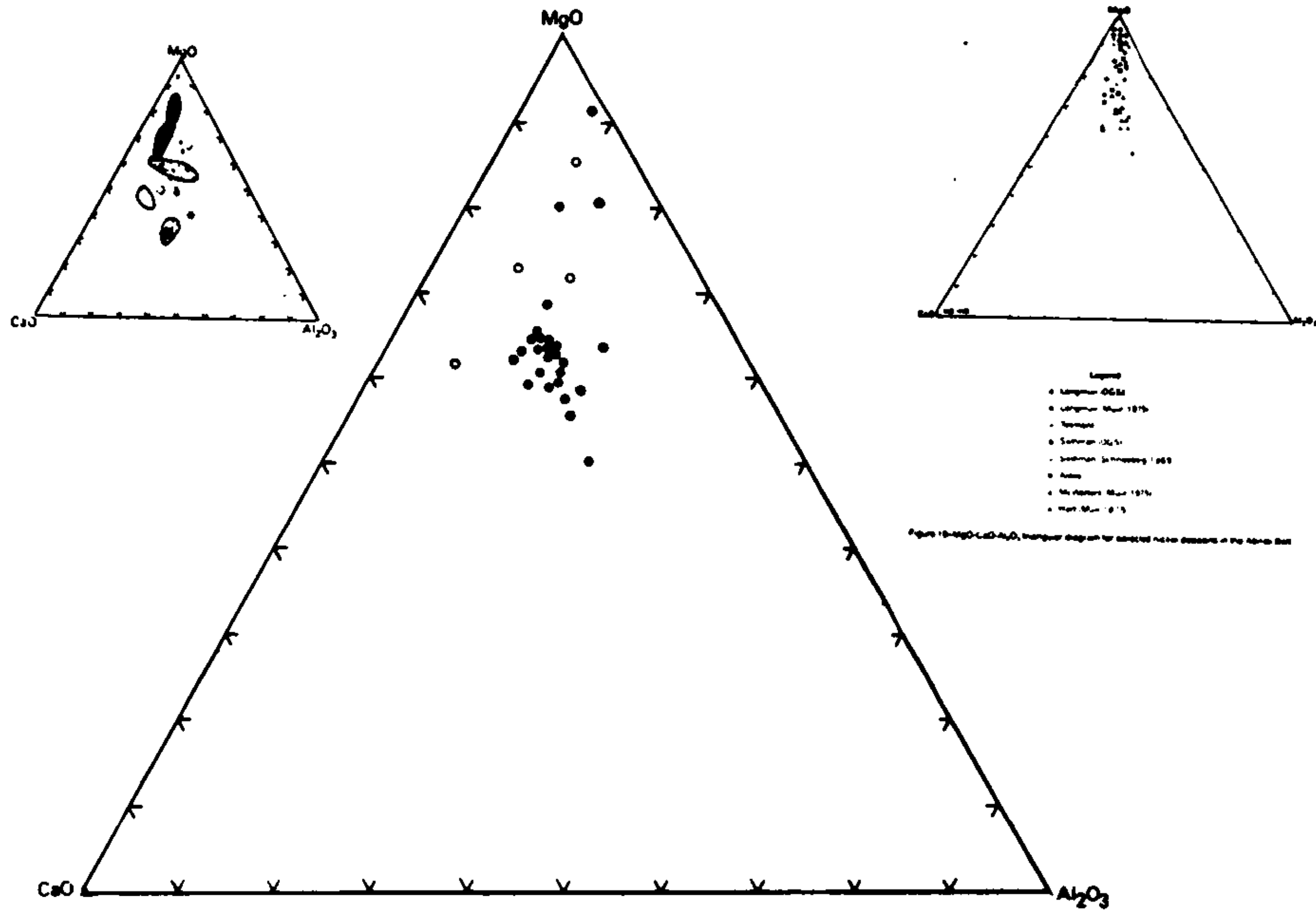



Fig. 5. Location of the Karasjok ultramafics in the MgO-CaO-$Al_2O_3$ diagram, compared with komatiites from Archean greenstone belts (left) and komatiitic-host-rocks for Ni-Cu deposits in the Timmins area, Canada (after Ćoad 1979).

Amphibolites.

The amphibolites form a heterogeneous group with a large outcropping area. They are, however, characterized by the common mineral assemblage :

plagioclase + hornblende $\pm$ quartz $\pm$ biotite $\pm$ chlorite $\pm$ epidote $\pm$ garnet

The observed banding in some amphibolites is caused by variable proportions of these minerals, mainly plagioclase/quartz and hornblende/biotite.

The bulk of the amphibolites are fine grained, well foliated hornblende schists which retain no primary features. Presumably they had their origin as (massive) lava flows. Only at one locality possible pillow structures have been observed.

Distinctly plagioclase-striped amphibolites have gabbros as their parent rocks (see also p.11).

Banded amphibolites with thin calcareous bands may represent original tuffaceous rocks or impure limey sediments.

Metasedimentary rocks.

Banded paragneisses.

This group occurs to the east of the basal arkosite-quartzite unit and comprises a variety of metasedimentary rocks which are interbanded from the metric to decimetric scale.

Micaschists, biotite-schists, graphite-schists, phyllites and psammites are the indivídual members of the banded paragneisses. In addition, thin amphibolite bands may occur.

Arkosic gneisses.

These form a rather large outcropping area in the central parts of the Karasjok Complex. They are greyish rocks with a well developed gneissic banding. The banding is folded by small scale intrafolial isoclines, accompanied by the formation of an axial-plane mica-foliation. Hence, the banding bears no obvious relation to any primary feature, but may represent the original bedding in the transposed stage.

A few examples of cross bedding have been found in loose-blocks in the quarry just north of Karasjok. The texture of the arkosic gneisses is entirely metamorphic, as quartz, plagioclase (albite/oligoclase) and K-feldspar form a recrystallized mosaic of small polygonal grains. Muscowite, biotite, chlorite and epidote occur in variable amounts.

The arkosic gneisses contain thin bands of micaschists and quartzites.

Micaschists, quartzites and graphite-schists.

Micaschists and quartzites are also found as thin impersistant bands in the amphibolites.

Systematic examinations and deep-soil sampling has shown that many of the long EM anomalies in the amphibolites are caused by graphite-schists.

Felsic schists.

These form a band which can be traced as far north as Vaddevarri (square grid 43.35).

The felsic schists are fine-grained pink rocks which consist of a recrystallized mosaic of quartz, K-feldspar and plagioclase. Muscowite is the main mica-mineral and defines the foliation of the rock.

The finegrained nature of the rock and the absence of any metasedimentary layers may suggest that this rock was an acid volcanite.

East of Gæssajavri (square grid 44.32), this rock appears in an $F_2$-antiformal fold-culmination, flanked by amphibolites. This explains the circular-shaped, low magnetic anomaly in this area.

Meta-igneous rocks.

Ultramafics.

These occur as small, lens-shaped and concordant bodies within the metasediments and amphibolites. The ultramafic bodies are variably affected by serpentinization and carbonitization, and display a wide range of mineral assemblages. The most common assemblage is :

1) Antigorite $\pm$ tremolite $\pm$ cummingtonite $\pm$ chlorite $\pm$ carbonate $\pm$ talc

Some of the ultramafics are completely altered into finegrained, dark "mesh-serpentinites" - whilst other may still preserve relic primary minerals and texture. Judging from the alteration products and relic minerals, the most common primary mineral appears to have been forsteritic olivine. Other relic minerals observed are clinopyroxene and orthopyroxene (enstatite).

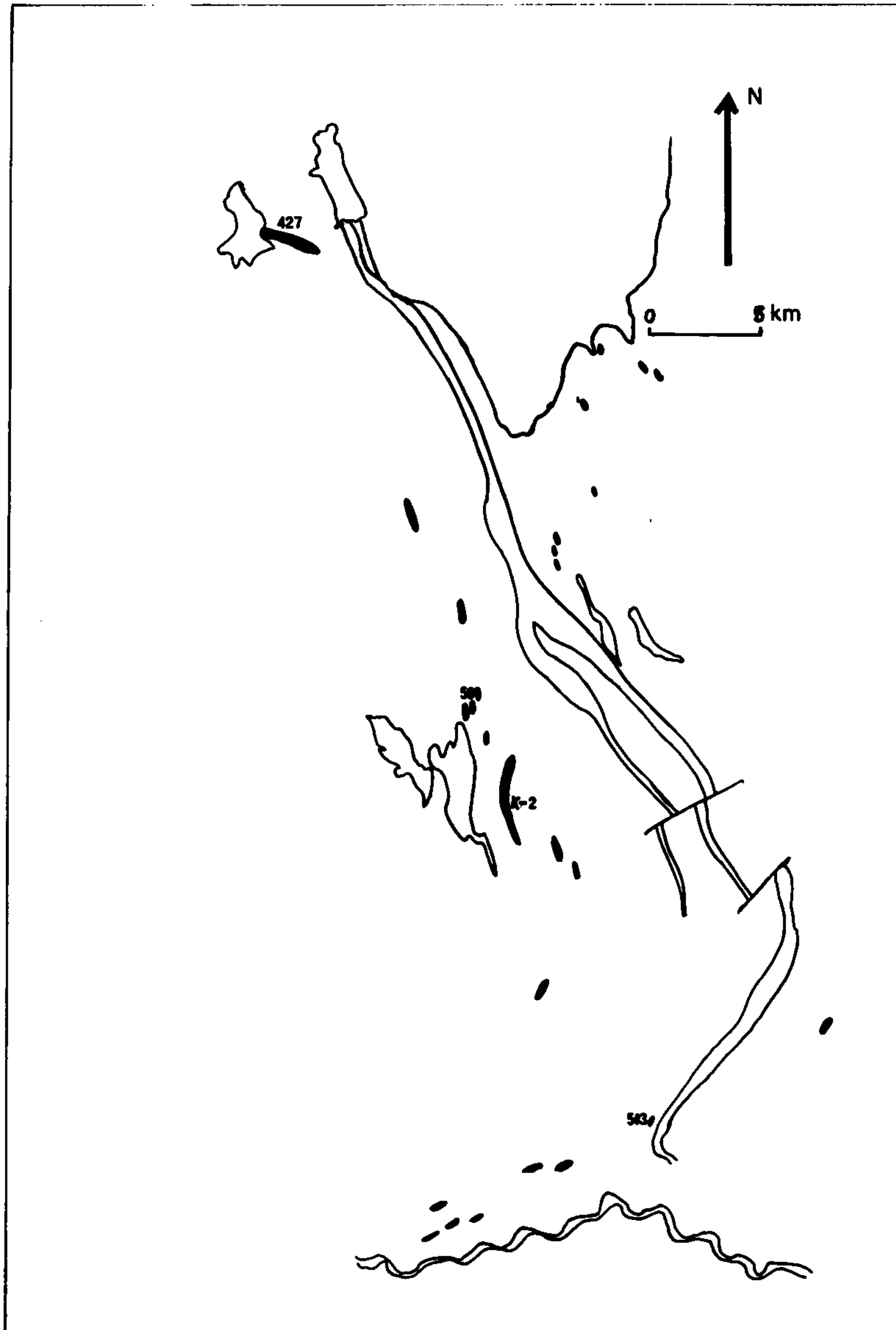



Fig. 6. Distribution of ultramafic intrusives north of Karasjok.

Towards the east - an increasing metamorphic grade is reflected in the ultramafics by the appearance of such metamorphic mineral assemblages as

tremolite + diopside $\pm$ Mg-chlorite

Especially the serpentinized ultramafic bodies give strong magnetic anomalies, caused by finegrained disseminated magnetite-dust.

The magnetite dust is formed as a result of alteration and oxidation of the primary olivine grains. Magnetite is also found along cracks in the primary olivine grains.

The only mineralization found in these rocks is the disseminated Cu-Ni (chalcopyrite and pentlandite) mineralization at Gallujavre (report no. 1090, 1979).

Whole rock major - and trace element analyses are available from a few of the ultramafic bodies (59, 503, K-2 and 427).

The chemistry of these rocks - which is quite similar to that of the extrusive komatiitic chlorite-tremolite rocks - may indicate that these were formed from the same or a similar komatiitic liquid.

The distribution of the intrusive ultramafics in distinct linear belts (fig. 6) may reflect an inheritated primary feature, possibly related to the emplacement of these rocks along deep seated faults or rifts.

Gabbro.

A few new gabbro-bodies have been found during this years mapping. The central portions of the gabbros may be massive and display nice igneous structures. A marginal foliation parallel to that of the side-rocks is, however, always developed, and the transition gabbro ⟶ flaser-gabbro ⟶ striped amphibolite is often observed.

So far, no interesting mineralizations have been observed in the gabbros. An IP-anomaly over the gabbro by Stuorra-Guorbmet (square grid 40.14) is caused by magnetite-impregnations.

Granite.

A greyish granodioritic rock occurs near Vaddevarri (square grid 43.37). It is folded together with the adjacent side rocks, and is either a pre- or syntectonic intrusion.

The texture of the rock is characterized by granulation and recrystallization, and a gneissic foliation is sometimes developed.

Mineralizations.

Thin, often brecciated zones with pyrrhotite, pyrite and graphite are common in the amphibolites, and give good EM-anomalies. These rust zones follow the general strike direction and appear to be more numerous in the northern parts.

Within the striped amphibolites/tectonized gabbros - mineralizations with chalcopyrite, pyrite and magnetite are observed.

The mineralizations, which occur in impersistent narrow zones of maximum a few meters width - are found both as impregnations and as cross-cutting veins associated with quartz. Such mineralizations are found by Gædgevaddevarri (390.392) and by Akkesvarri (square grid 27.51).

Just north of Luostejåkka (square grid 39.44) occurs a persistant, shallow dipping zone with pyrrhotite locally banded with chalcopyrite. The same zone is probably encountered further north (373.479) some 4-5 kms along strike.

## THE HORNBLENDE GNEISS COMPLEX

This complex forms a belt between the Karasjok Complex and the Granulite Complex, and has an outcrop width of 3 - 5 km. Amphibolite facies hornblende gneisses with the mineral assemblage

$$\text{Plag.} + qz + hbl + bi \pm cpx \pm gt$$

make up the major part of this unit. At the outcrop scale, alternating quartzofeldspathic, quartzitic and amphibolitic layers give the rocks a banded appearance. A supracrustal (sedimentary - volcanic) origin is likely for the rocks of the hornblende gneiss complex.

Both textural - and field relations suggest a gradual transition from the hornblende gneisses to the granulites per se in the east. The amphibolite- and granulite facies bandings are conformable; and incipent formation of orthopyroxene at the expense of biotite, quartz and hornblende may be observed in the hornblende gneisses.

On the other hand, the clinopyroxene - bearing hornblende gneisses contain more quartz than the amphibolites of the Karasjok Complex. This makes the assertion, that the hornblende gneisses are formed from the amphibolites by prograde metamorphism, not likely - as prograde reactions to produce clinopyroxene (and orthopyroxene) require the consumption of quartz.

Lenses of quartz-diorite / diorite (plag +qz + bi + hbl) and ultrabasic rocks (tremolite + olivine + spinel) make up a minor portion of the hornblende gneiss complex.

The western margin of the hornblende gneiss complex concides with a marked and consistent EM/VLF anomaly.

Cataclastic rock-types (mylonites and breccias) occur in this zone, which is also the site for mineralizations ("rust-zones") with pyrite and pyrrhotite.

This zone appear to represent a tectonic contact (thrust contact) between the Karasjok Complex and the higher grade rocks of the hornblende gneiss / granulite complex.

## STRUCTURAL RELATIONS / INTERPRETATION OF THE GEOLOGICAL UNITS.

Three phases of deformation have been recognized in the Karasjok Complex. To each of these deformations is associated folds, foliations and lineations of varying intensity and development (cfr. report 1122, 1981).

The metamorphic grade in the Karasjok Complex varies from middle greenschist facies to low amphibolite facies.

The production of the first foliation was accompanied by metamorphism which locally reached into the low amphibolite facies, attested by the occasional presence of such "$M_1$" minerals as staurolite. The second deformation transposed the first foliation into the limbs of tight- to isoclinal folds, and was associated with a widespread retrogression into the middle greenschist facies.

The basal arkosite- quartzite, which lies close to the unconformity with the Granite Gneiss Complex, contains less complex structures at the smaller scale. Only one deformation, associated with a prograde middle greenschist facies metamorphism, is recognized in these rocks. Towards the contact with the Karasjok Complex, increasing deformation and mylonitization of this basal sedimentary unit is observed - and the regional map-picture (fig. 7) shows a clear tectonic discordance between these two geological units. Together, all these features are suggestive of a tectonic (thrust) contact between the two units.

A tentative model, which attempts to reconstruct the geological setting of the various units prior to deformation and metamorphism, is presented below and in fig. 8. In this model, the Karasjok Complex and the basal arkosite-quartzite are considered to have been deposited in the same marine basin, but in rather different structural / geographical settings.

In this way, the presence of fuchsite-schists in the basal arkosite-quarzite unit (cfr.p. 2 ) and the apparent structural and metamorphic diversity between the geological units could be explained.

The following sequence of events could have lead to the formation and subsequent deformation of the rocks:

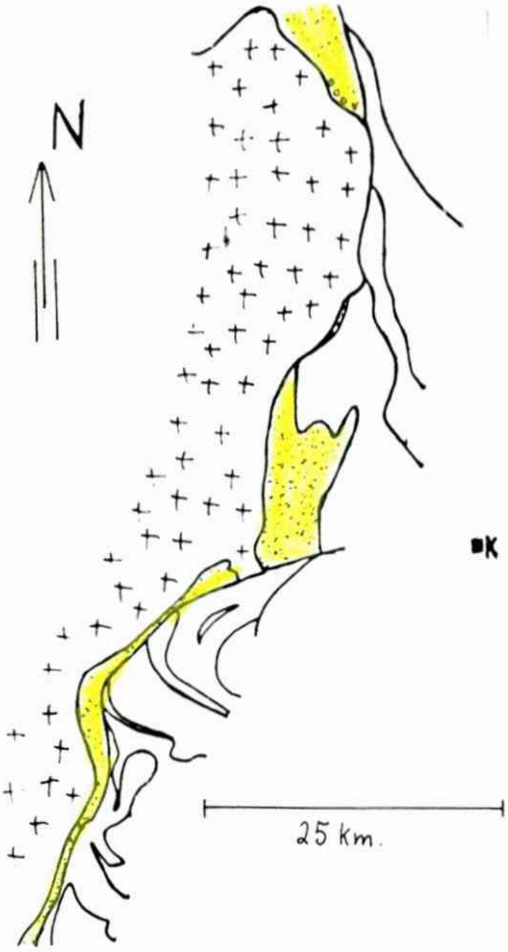



Fig. 7 Regional map, which shows the discordance between the basal arkosite-quartzite (in yellow) and the Karasjok Complex.

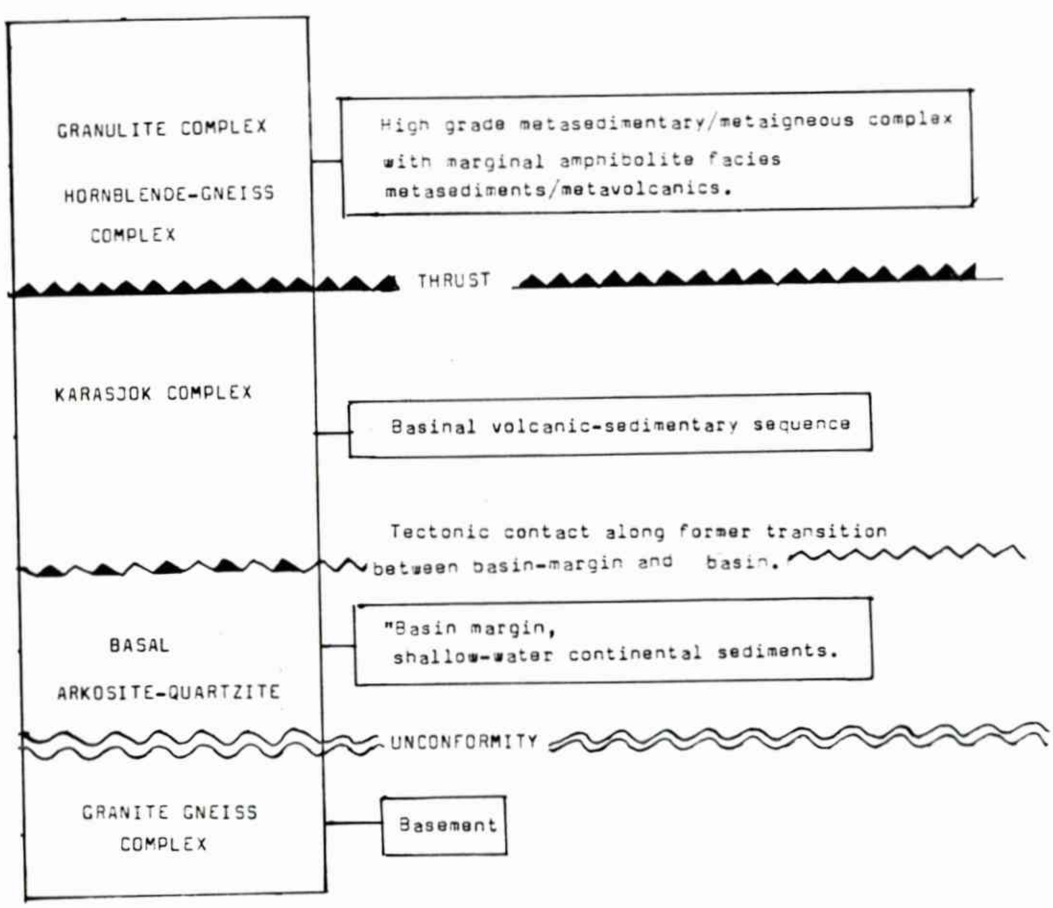



Fig. 8 Interpretation of the geological units in the Karasjok area.

1. Initial formation of a shallow basin by crustal thinning/rifting of the Granite Gneis Complex. The lowest members of the basal arkosite-quartzite are deposited along the margin of the basin.

2. Continued rifting leads to the formation of a deeper, small oceanic basin. High Mg-ultramafic volcanics, mafic volcanics, gabbros and ultramafics are emplaced along deep seated rifts and fissures.

   By sea water action - chromium is released from the ultramafic volcanics - to be later redeposited as Cr-rich, carbonate-bearing sediments in the shallower carbonate-facies parts of the basin where the sedimentation of the basal arkosite-quartzite is still going on.

3. Rifting has ceased, and arkosic sediments are deposited on top of the ultramafic/mafic volcanic pile. These correspond to the arkosic gneisses in the Karasjok Complex.

4. Initial compression of the central basin causes upper greenschist/low amphibolite facies metamorphism and deformation of the Karasjok Complex. This early deformation apparently did not affect the basin-margin sediments.

5. The final closure of the volcanic/sedimentary basin is associated with the eastward thrusting of the Granulite/Hornblende Gneiss Complex. During this event, penetrative deformation affected all the units - and the marginal basal arkosite-quartzite was deformed and metamorphosed for the first time.

   Smaller thrust-movements took place along the former transition between the basin-margin and the deeper central basin - creating the tectonic discordance between the basal arkosite-quartzite and the Karasjok Complex.

## THE AREA SOUTH OF KARASJOK

In the area south of Karasjok (fig.9),reconnaissance structural-and geological mapping was carried out during the periodes 19.6-23.6 and 9.9-15.9.The area is extensively covered,and only along the rivers Karasjokka and Noaidatjokka reasonably good outcrops are found.The accompanying geological map is chiefly based upon outcrop observations along these two rivers.Three east-west profiles between the two rivers provided some additional outcrops.On the map,the Raitevarre gneiss is drawn according to earlier maps of Røsholt (e.g. report 1149,1981).

Some key-words: structural geology,carbonate-rocks and veins,gold prospecting models.

### The local geology

One may distinguish between three geological units:a) a granite-gneiss complex,b) a basal arkosite-quartzite unit and c) a mixed metasedimentary and metavolcanic sequence.This last unit which belongs to the Karasjok Complex,has been the subject of the geological mapping.

The metasedimentary rocks comprise micaschists,quartz-sericite scists ,psammites,graphite-schists and biotite-amphibole schists.The micaschists,which have the general mineral assemblage:

quartz+plagioclase+biotite+muscovite+garnet

are always found together with the quartz-sericite schists and psammites.These rocks are mapped as one unit.

The amphibole-biotite schists are greenish -to dark coloured rocks which always have a contorted and knottled appearance due to the presence of numerous quartz and quartz-carbonate veins which are often folded and disrupted.The major mineral constituents of this rock are biotite,amphibole,quartz and plagioclase.Chlorite occurs as an alteration product after amphibole.Tourmaline is always found,which may point towards a sedimentary parent (greywacke) for this rock.The rock is here and there weakly impregnated with pyrite and chalcopyrite.

Layers of sedimentary carbonate rocks (up to 1m thick) and psammite occur within the amphibole-biotite schists.

The intrusion of quartz,carbonate and quartz-carbonate veins appears to have been a continuous process during the progressive deformation of these rocks,as these veins may be folded,refolded or be discordant to the different small-scale tectonic structures (cfr.p.22)

Field tests by staining methods using potassium ferricyanide in 2% HCl have identified ankerite as an important constituent in both the carbonate bearing veins and the carbonate rocks.

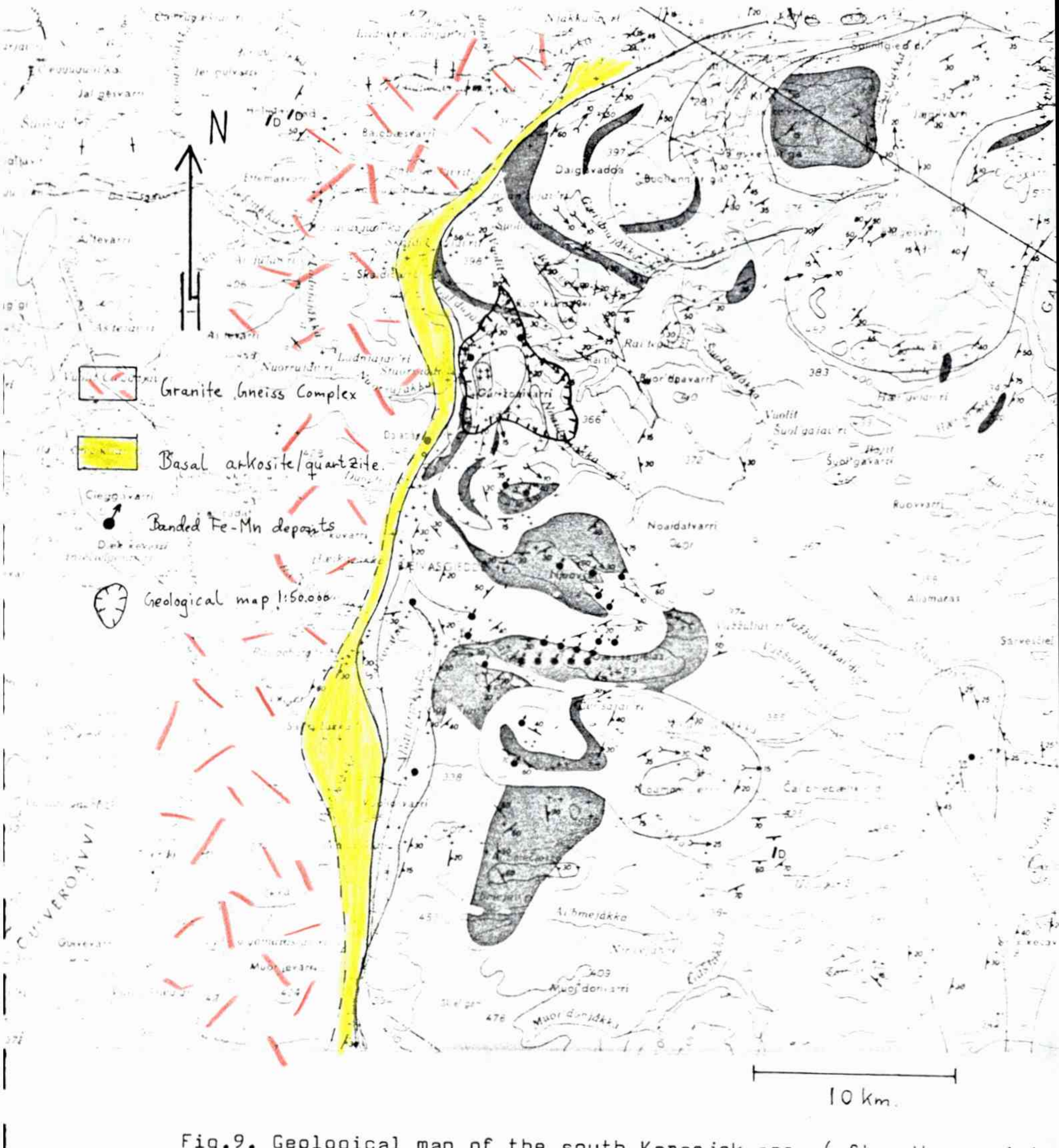



Fig.9. Geological map of the south Karasjok area (after Wennervirta 1962), showing the area mapped.
The black-shaded rocks are chlorite-tremolite rocks which in the southern parts are associated with banded Fe-Mn formations.

The metavolcanic rocks comprise amphibolites and chlorite-tremolite rocks.The latter are similar to the komatiitic chlorite-tremolite rocks north of Karasjok.These rocks south of Karasjok are more deformed and foliated,and only at one locality (173.909) are structures reminiscent of pillows observed.Further south,by Njuovcokka,chlorite-tremolite rocks with agglomeratic structures occur (Wennerwirta 1960). The chemical composition of this rock is shown in table 1 (analysis 25).This rock falls within the komatiite fields in the discrimination diagrams on fig.4.

In the amphibolites,thin rust-zones with graphite and pyrrhotite are often found.These rust-zones are often brecciated.

The meta-igneous rocks comprise gabbro,granite and dioritic rock. The granite by Storfossen is a rather fine grained,pink to white granite.It is often cut by mylonite zones and quartz-veins.Along the river Karasjokka (142.886-143.888) the rock is best described as a mylonitic gneiss.

North of Storfossen (147.898) occurs a lens with a coarser grained meta-granite.The granitic rock is intruded by pure quartz-veins which may attain a thickness of several meters.

The Raitevarre gneiss is known for its disseminated Cu-mineralization.Thin section studies from drill-cores show that the gneiss contains relic textures which can leave no doubt that this once was an igneous rock with a mineral composition corresponding to a diorite or quartz-diorite.Flattening,alteration and recrystallization has modified the original texture to produce a strongly foliated gneiss with the mineral assemblage:

quartz+albite/oligoclase+bi.+mu:+chl.± ep. ±hbl.±gt. ± carbonate .

An interpretation of the Raitevarre gneiss consistent with a non-sedimentary origin is shown in fig.12 .The alteration between metasediments (blackschists and micaschists) and gneiss in the upper parts (drill-holes 1,2 and3) is attributed to folding of the gneiss-metasediment interface.

## Structural geology

Several mesoscopic outcrops show that the sedimentary and volcanic pile has passed through a complex sequence of structural events:

1. Transposition of the primary layering ($S_0$) into the limbs of isoclinal intrafolial folds $F_1$ with the formation of an axial-plane foliation $S_1$ (fig.10 a)

2. Folding of $F_1/S_1$ by tight to isoclinal folds ($F_2$) of the reclined type. In mica-rich lithologies an $S_2$ crenulation cleavage may develop into a pervasive schistosity-, while the more competent lithologies deform by folding and extension.

A variety of structures, such as shear-and mylonite zones, boudinage etc. are generated during these two fold phases.

3. Late, open buckle-folds ($F_3$) are locally developed and appear to cause only a weak bending of the earlier structures.

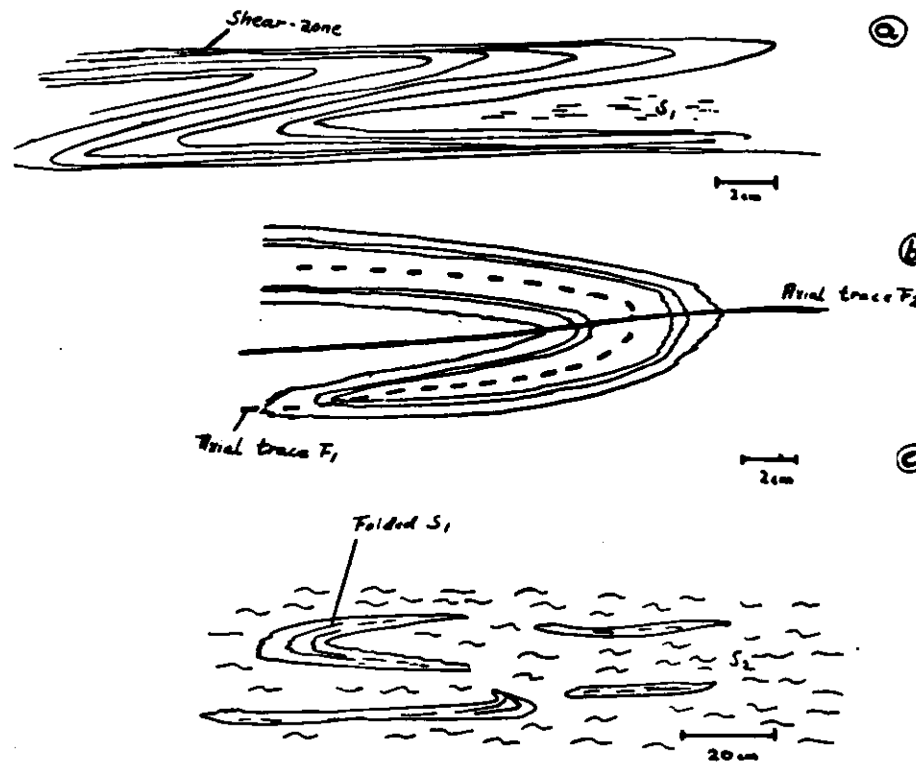



Fig. 10. Small-scale tectonic structures from outcrops along the river Karasjokka.

a) Transposition of primary bedding in calcareous psammite into the sheared limbs of isoclinal $F_1$-folds (148.903).

b) Refolding of $F_1$ by tight $F_2$-fold (148.903).

c) Boudinaged $F_2$-fold in $S_2$-foliated **biotite** -amphibole schist (144.894).

The $F_2$-folds appear to be responsible for the major structural pattern The orientation of the $S_1$-poles, $F_2$ fold-axes and axial-planes (fig. 11) may be consistent with the existence of major $F_2$-folds of the reclined type, with easterly dipping axial-planes and fold-axes which plunge down the dip **direction** (i.e. easterly) of the axial-planes. Such $F_2$ reclined folds were also described from the area north of Karasjok in last years report (no. 1122).

A few parasitic $F_2$-folds indicate that the Raitevarre gneiss is situated on the eastern upper limb of a larger $F_2$ synformal structure which closes towards the south.

The isolated and sparse outcrops have,to summarize,rendered any detailed structural mapping and interpretation of the major structures difficult or even dubious.It must,however,be considered likely that the small-scale structures observed (fig.10) only models the macroscopic structures and the general tectonic styles in the area.

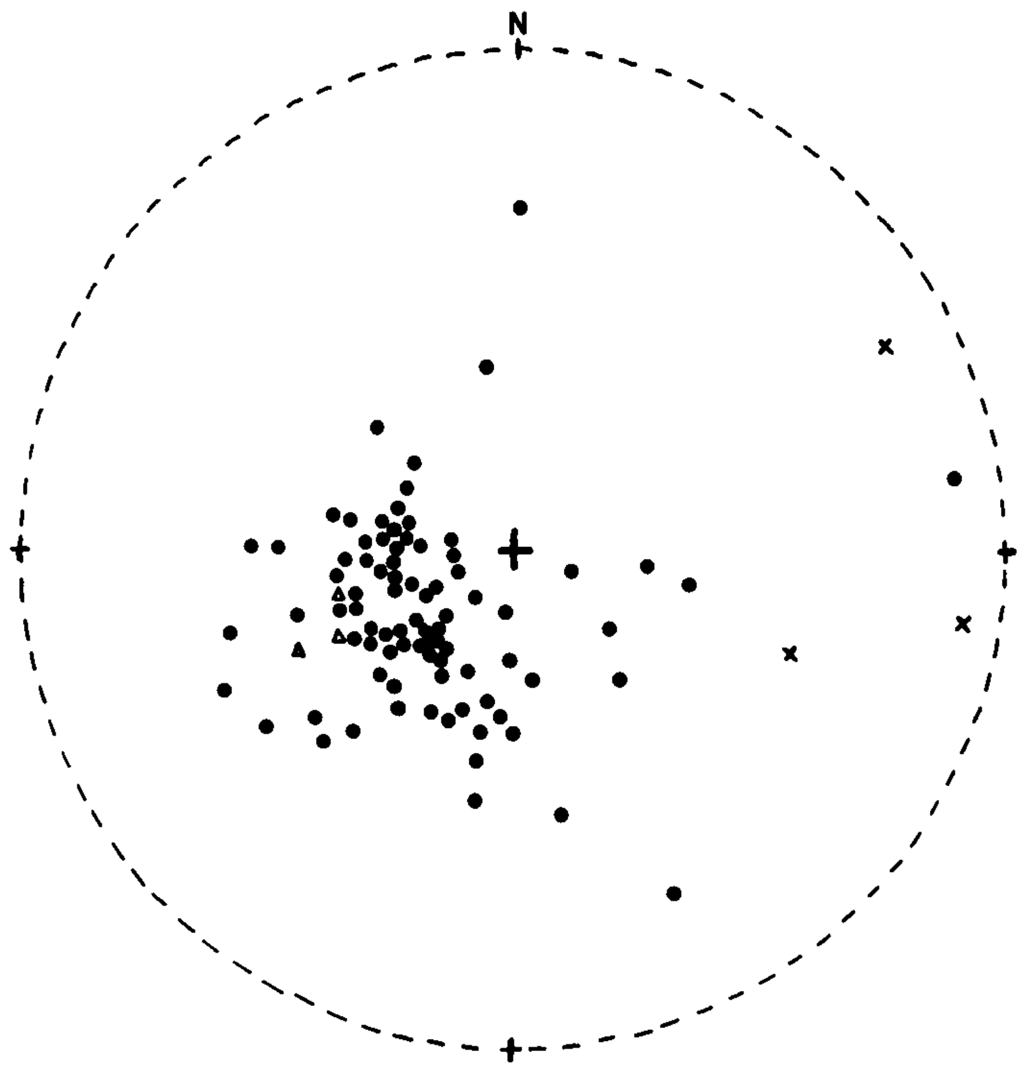
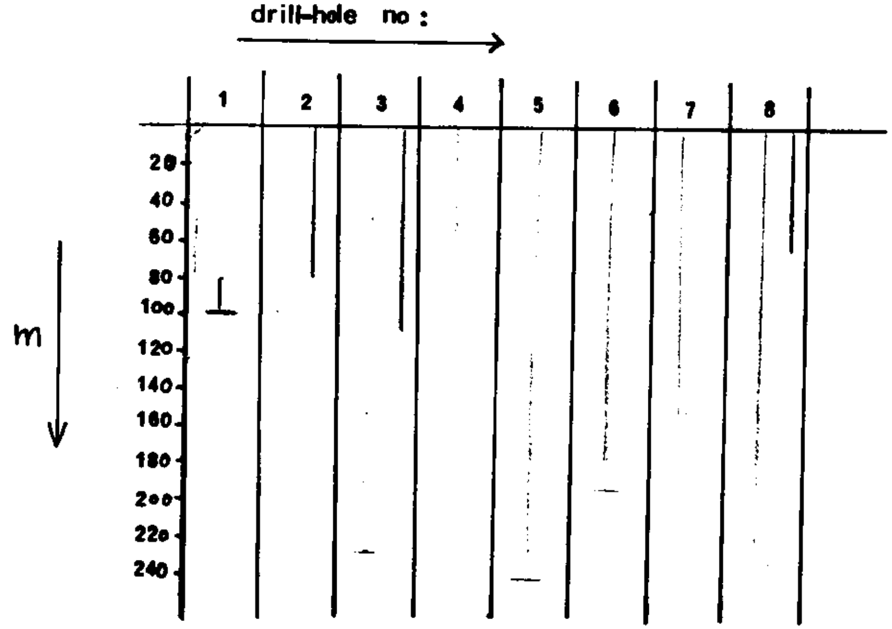



Fig.11. Orientation of poles to $S_1$ ( • ), $F_2$ axial-planes ( Δ ) and poles to $F_2$ fold-axes ( x ).



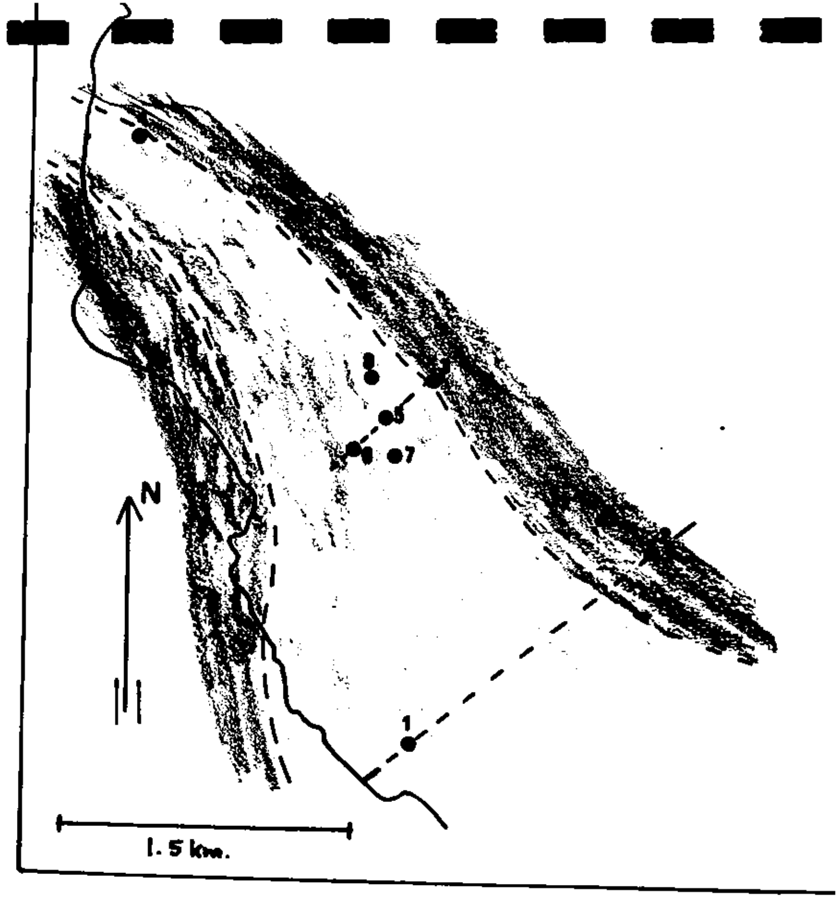




**Fig.12** Interpretation of the Raitevarre-gneiss based on drill-hole data

gneiss ——
metasediments ——

## Gold prospecting models

New,volcanic-exhalative models for the genesis of gold have drawn increasing attention towards the occurrence of gold and noble metals above the lowe mafic/ultramafic parts in Arhaean greenstone-belt sequences.The Karvinen model (included in report 1149,1981) stresses the enrichment of gold in carbonate-rich sediments above the lower mafic/ultramafic members of the greenstone-belt sequence.During deformation,further enrichment of gold may take place in quartz-carbonate (ankerite) veins.

According to the model of Hutchinson et.al (1980)-hot geothermal brines are major agents for the leaching and transportation of Fe,Mn and minor amounts of base,transition and noble metals from the lower parts of the volcanic-sedimentary sequence.Particularily, metals such as tungsten,palladium,platinium and gold may be leached, transported and redeposited if

1) Appropriate source rocks (i.e. high Mg-ultramafics/volcanics) are present.

In the Timmins area,veins and stratiform sediments in the lower mafic/ultramafic stratigraphic level contain concentrations of Au, Pt,Pd and W which are 10 to 1000 times their normal values in basalts (fig.13)

Fig. 13

**TABLE 1**
**ABUNDANCES OF SELECTED METALS IN PRIMARY IGNEOUS ROCKS**

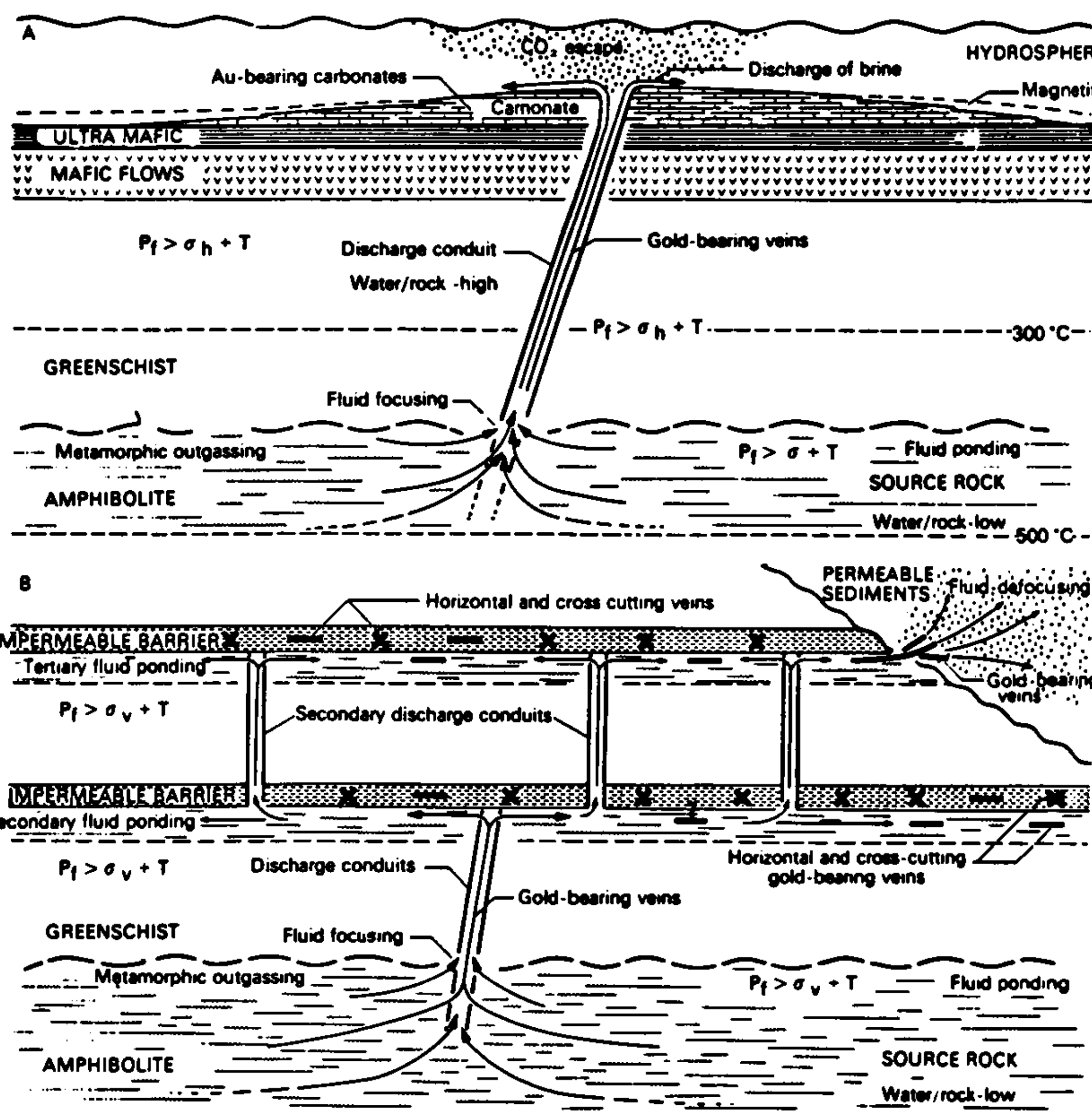
| | Ultramafic | Mafic | Felsic |
|---|---|---|---|
| Chromium | 1 600 | 170 | 22 |
| Cobalt | 150 | 48 | 7 |
| Nickel | 2 000 | 130 | 15 |
| Copper | 10 | 87 | 30 |
| Zinc | 50 | 105 | 60 |
| Lead | 1 | 6 | 15 |
| Gold | 0,8 | 1,7 | 1,2 |
| Silver | 60 | 110 | 51 |
| Palladium | ~9 | ~16 | ~2 |
| Platinum | ~11 | 9 | 8 |

Abundances expressed in p.p.m.; gold, silver, platinum, palladium in p.p.b.
Data compiled from Turekian and Wedepohl[85] (chromium, cobalt, nickel, copper, zinc, lead, silver), Kwong and Crocket[86] (gold), and Parthé and Crocket[87] (palladium, platinum)

## CHEMICAL DATA FOR SELECTED GOLD-BEARING VEINS AND SEDIMENTS FROM ARCHAEAN GREENSTONE BELTS OF CANADA

| | YELLOWKNIFE | TIMMINS | | | RED LAKE | KIRKLAND LAKE |
|---|---|---|---|---|---|---|
| | hydrothermal quartz veins[1] | hydrothermal quartz veins[2] | carbonate chemical sediment[2] | carbonate chemical sediment[3] | carbonate silicate iron formation[4] | carbonate iron formation[5] |
| Chromium (ppm) | 180 | 1030 | 300 | 280 | 180 | 1800 |
| Nickel (ppm) | 150 | 250 | 150 | 120 | 910 | 970 |
| Tungsten (ppm) | 80 | 110 | 60 | 40 | 90 | 80 |
| Platinum (ppb) | 70 | 160 | | 60 | 170 | |
| Palladium (ppb) | 180 | 240 | | 140 | 220 | |
| $Fe^{2+} / \Sigma Fe^{(6)}$ | 0,95 | 0,97 | 0,86 | | 0,74 | 0,92 |
| $\delta^{18}O$ quartz ($^0/_{00}$SMOW) | 11,5–12,5 | 14–15 | 17,6 | 17,8 | 19,2 | 18,4 |
| $\Delta^{18}O$quartz-muscovite | 3,8–3,5 | 3,8–3,4 | | | | |
| Isotopic temperature °C$^{(7)}$ | 400–450 | 400–450 | | | | |
| Number of determinations | 28 | 18 | 17 | 5 | 8 | 15 |

1 – Con Mine; 2 – Dome Mine; 3 – Aunor Mine; 4 – Dickenson Mine; 5 – Kerr Addison Mine.
6 – The oxidation state, expressed as $Fe^{2+}/\Sigma Fe$, is for mafic host rocks of veins and chemical sediments.
7 – Isotopic temperatures calculated from the equations given by Clayton *et al.*,[88] and O'Neil and Taylor.[89]




*Schematic diagram illustrating deposition of metals during high temperature outgassing of crust.*
*A. Direct discharge into hydrosphere.*
*B. Ponding beneath permeability barriers.*

2) Conditions of low red-ox potential prevail.

Some important guide-lines in the practical exploration for these elements are,according to Karvinen and Hutchinson et.al:

* Recognition of strata-bound carbonate horizons.These may serve as indicators of volcanic hydrothermal exhalative activity.

* Identify regions of former high geothermal energy (volcanic centres and marine volcanic-sedimentary sequences)

* Recognition of domains of regional oxidation and reduction

* Appreciate the occurrence of exhalative Fe-Mn iron-formations,as these may form " cap rocks" to ores deposited under lower Eh conditions.

The application of the prospecting models outlined above to the south Karasjok area is justified by:

a) the general rock association —

volcanic/sedimentary sequence

banded exhalative Fe-Mn formations
Graphite-schists,micaschists/psammites
Metagreywacke with carbonate bands and veins
amphibolites
high Mg-ultramafics

— bears similarities to the stratigraphy in other gold-associated areas in greenstone belts

b) the south Karasjok area is known for the occurrences of alluvial gold.Native platinium and palladium-minerals have also been found together with the gold.

Concluding remarks.

It is suggested that the prospecting in the south Karasjok area is followed up along the lines outlined on the preceeding pages.The geological work should be directed towards a regional reconnaissance mapping,with special emphasis on the recognition of rock types favourable for Au,Pt,Pd and W mineralizations (cfr.p.24 ).

Carbonate rocks and quartz-carbonate and quartz-veins should be systematically sampled and analysed for the above mentioned elements.

# REGIONAL CORRELATIONS

The Karasjok Complex and the Hornblende Gneiss Complex may be correlated with similar belts of supracrustal formations in northern Finland.

## Karasjok Complex

High Mg-komatiites are almost exclusively found in Archaean greenstone-belt terrains. The existence of such rocks in the Karasjok Complex provides a link for a correlation between this complex and the now well established greenstone belts in eastern and northern Finland (e.g. Gaal et.al. 1978).

The greenstone-belt association in Finland consists of several isolated patches in a NNW-trending zone (fig. 14), which may be the remnants of a former continuous greenstone belt. Abundant geochronological dates show that the rocks of the greenstone-belt association were deposited in the time span ca. 2900 - 2600 M.YR. The rocks display middle- to upper greenschist facies metamorphism.

High Mg-komatiites are characteristic members of these belts (Mutanen 1976, Blais et. al. 1978) - and the chemical similarities between these rocks and the komatiitic chlorite - tremolite rocks in the Karasjok Complex is striking (tables 1 & 2).

Within the finnish greenstone belts, one may distinguish between:
a) a lower komatiitic/tholeiitic volcanic series, b) an essentially metasedimentary formation with minor volcanics and c) an upper calc-alkaline volcanic series (intermediate to acid volcanics/tuffs).
In many areas the upper unit is either missing or poorly developed.

The contact between the basal komatiitic/tholeiitic unit and the granite-gneiss basement is often not exposed or camoflaged by late granitic intrusions. According to Gaal et.al. (1978) - tectonic movements and mylonite-production has taken place in the transitional zone between the basement and the greenstone belt association. Kröner et.al. (1981) describes a basal sedimentary series between the basement and the lower komatiitic/tholeiitic unit in the Koitelainen part of the Kittilä greenstone belt.

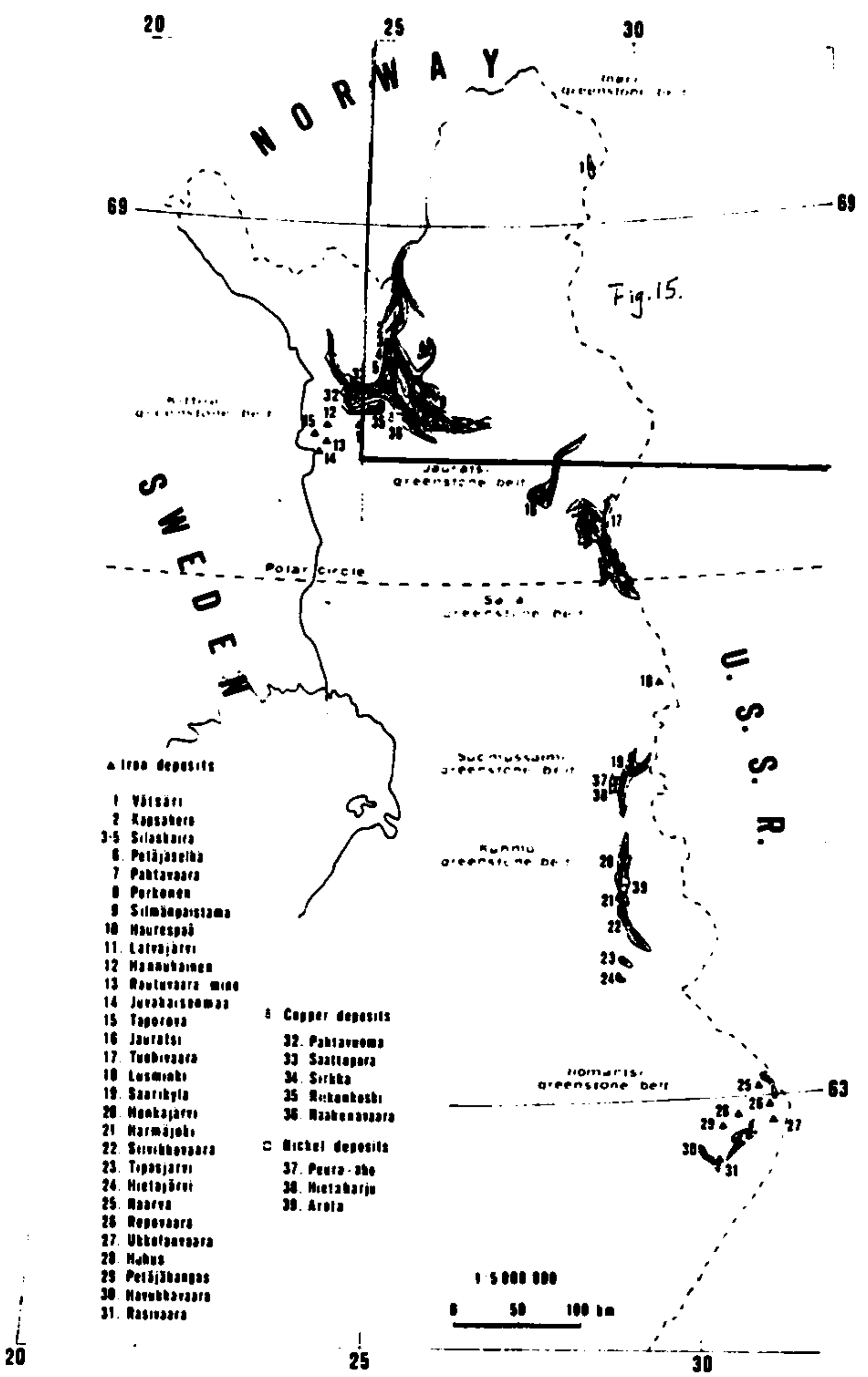



Fig. 14. Outcrops of Archaean greenstone belts in Finland. The types of mineralizations are also shown. After Gaal et.al. (1978).

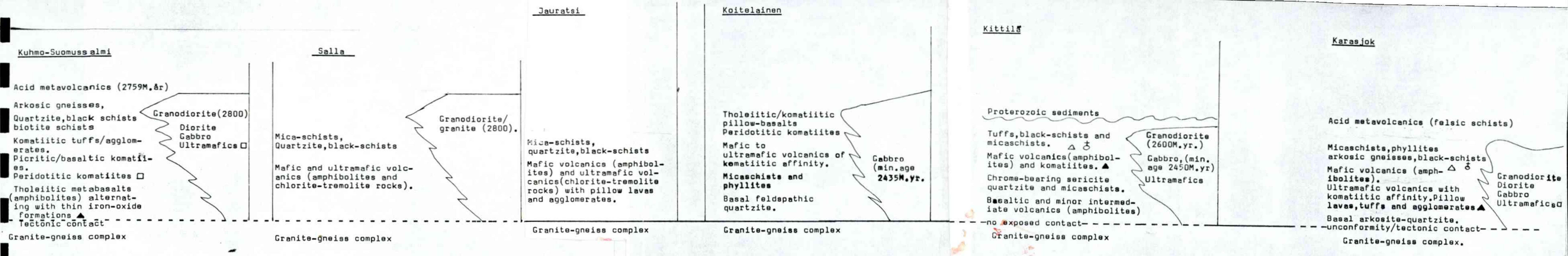



Plate 1. General stratigraphy and types of mineralizations in Archaean greenstone belts in Finland compared with the Karasjok area.( ▲ banded iron-oxide formations,△ stratabound Fe-sulphides, ♁ copper deposits , □ nickel-copper deposits.
Compiled from: Mikkola (1980),Silvennoinen (1980),Gaal et.al (1978),Krøner et.al.(1981) Hanski (1980) and Kojonen(1981).

It is thus clear that a basement to the greenstone belt association exists; and that members of this association is found in either autochtones and/or allochtonous positions in relation to this basement.

The lithostratigraphy for some finnish greenstone-belt successions is shown in Plate 1, and compared with the general rock stratigraphy in the Karasjok Complex. Although some variations exist, it is seen that the lithostratigraphical columns are largely comparable.

As with regards to mineralizations, the finnish greenstone belts contain the following types (Mikkola 1980, Hanski 1980, Kojonen 1981) :

a) banded quartz-magnetite or quartz-haematite ores associated with Mn-Fe carbonaceous sediments. These ores are frequently found above komatiites in the lower volcanic unit.

b) Ni-Cu deposits associated with intrusive ultramafic rocks.

c) Massive Ni-Cu deposits associated with extrusive volcanics of komatiitic affinity.

d) Fine grained disseminated copper deposits and brecciated pyrrhotite/pyrite ores in the metasedimentary/metavolcanic sequences.

With the exception of the type c deposit - all types of mineralizations listed above are met with in the Karasjok Complex (iron-oxide formations south of Karasjok, the Gallujavre and the Raitevarre-type mineralizations).

The geophysical anomaly above the extrusive komatiitic rocks in target area 11 (see p. 9 ), may be caused by a mineralization of type c.

## The hornblende gneiss complex.

Between the Granutite complex and the Kittilä belt/West Inari schist zone runs a belt of predominantly amfibolite-facies hornblende gneisses. These gneisses were termed the southwestern marginal zone (SWMZ) of the granulite complex (Meriläinen 1976), and the Tana River Belt by Barbey et.al. (1980). They appear to belong to the same geological unit as the granulite complex, but were metamorphosed under conditions of the amphibolite facies. A volcanic (tholeiitic) - sedimentary origin has been assumed for these rocks.

The rocks of the hornblende-gneiss complex in Karasjok are in every respect (i.e. rock types, field characteristics, petrology) similar to the Tana River Belt / SWMZ rocks as described by Barbey et.al. (1980), Hörmann et.al. (1980) and Meriläinen (1976).

Henriksen and Pantdalsli made a profile from Inari to Pokka (fig. 15) passing from the Granulite complex via its SWMZ and into the West Inari schist zone / Kittilä belt. The rock types and successions of geological units corresponded closely with that observed in the Karasjok area.

The preceeding regional review and correlations have pointed out the similarity between the Karasjok Complex and the finnish greenstone belt association. It is therefore suggested that these two formations are correlatable, and that the Karasjok Complex may be Archaean[1] rather than Proterozoic as traditionally assumed.

The Karasjok Complex appears to represent the northern extension of the Kittilä belt as indicated by Gaal et.al. (1978), (fig. 15). This northern branch of the Kittilä belt has also been called the West Inari schist-zone (Meriläinen 1976, Hörman et.al. 1980).

In the Kautokeino area, there appears to be two volcanic-sedimentary formations of different ages; a Proterozoic rift/aulacogen related formation and an older, more deformed formation whose age is not clear. It is possible that this older formation may be correlated with the Karasjok Complex.

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[1] From Karasjok, Meriläinen (1976) published a date on zircons from an albite-diabase in "the Karasjok quartzite" which gave an age of 2720 M.YR.

Samples of arkosic gneisses and granulites are under preparation for age determinations at the geological museum, Oslo.

This year, fresh samples from pillowed komatiites by Gukkesjarcåbma were collected for dating by the Sm-Nd method.

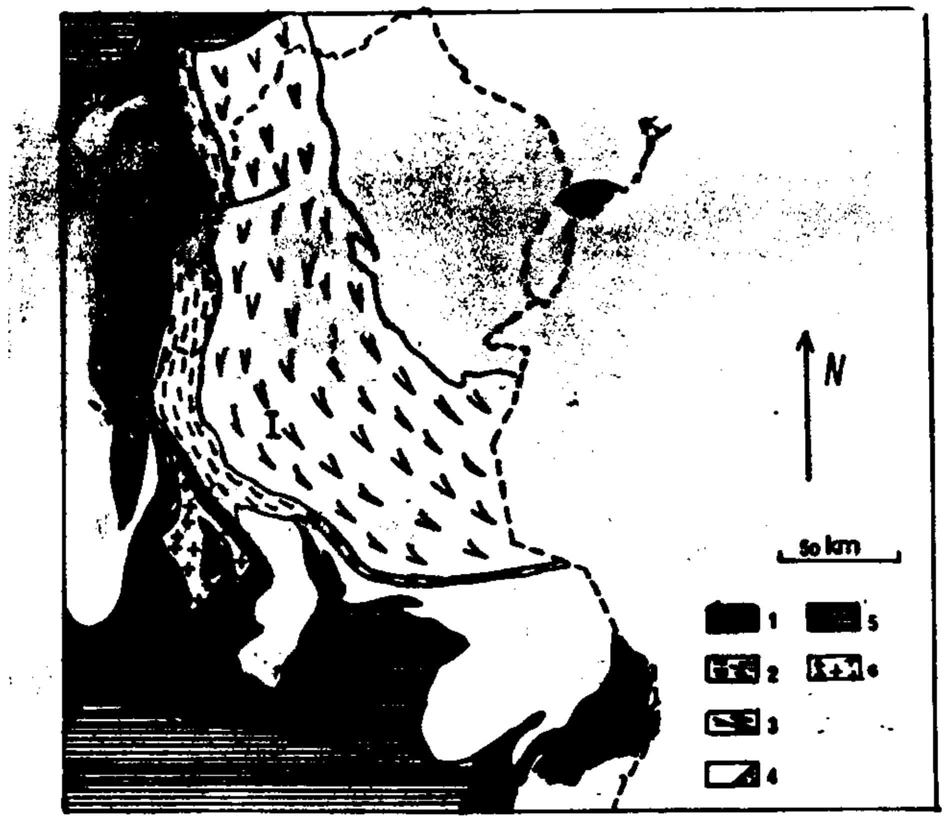


Fig. 15 The main geological units in northern Finland and central Finnmark, slightly modified from map compiled by Barbey et.al. 1980.

1. Greenstone belt association / West Inari schist zone / Karasjok Complex.
2. Tana River Belt / SWMZ of granulite complex / Hornblende-gneiss complex.
3. Granulite Complex.
4. Granite Gneiss Complexes / basal sedimentary series.
5. Post - Archaean formations.
6. Granites.

K - Karasjok    I - Inari    P - Pokka

It is therefore considered that the supracrustal formations in the Archaean basement of northern Finland have their analogous formations in Finnmark, and that they are part of the same Archaean basement terrain (fig. 15). The zonal arrangement of supracrustal formations has been interpreted in terms of various plate-tectonic models (e.g. Barbey et.al. 1980, Hörman at.al. 1980).
The main features of these models are listed in fig. 16.

| | KARASJOK-BELT/ WEST INARI SCHIST ZONE | HBL.GNEISS COMPLEX/ TANA RIVER BELT/ SWMZ | GRANULITE COMPLEX |
|---|---|---|---|
| BARBEY ET.AL | Archaean greenstone belt younger than Tana River Belt | Fragment of oceanic crust.Later site of suture zone. | Marginal sedimentary basin located between a stable continental block in the east and oceanic crust(Tana River Belt). in the west. |
| HØRMANN ET.AL. | Outer tholeiitic island arc complex | Calc-alkaline inner volcanic arc in front of continental block. | |

Fig. 16. Interpretation of the geological units according to plate-tectonic models. Compiled from Barbey et. al (1980) and Hörmann et. al (1980).

The deformation and tectonic juxtaposition of this system is attributed to continent-continent collision in Karelian (Proterozoic) time (Hörmann et. al 1980)

Based on the zonal division of geological units (fig. 7, fig. 15) actualistic plate-tectonic models could also be constructed for the Karasjok-area.

The value of such models may, however, be limited - as too little is known about Archaean plate-tectonics and the processes involved in the formation and destruction of Archaean plates.

## RECOMMENDATIONS FOR THE FUTURE PROSPECTING AND GEOLOGICAL WORK

If one accepts an Archaean age for the Karasjok Complex, certain guide lines to where the practical exploration should be directed, and what is likely to be found, can be given.

Firstly, Ni-Cu deposits may be found associated with the ultramafic intrusives and extrusives in the Karasjok Complex. A survey of the mineral deposits in the finnish greenstone belts based on Gaal et.al. (1978), Hanski (1980), Mikkola (1980) and Kojonen (1981) shows a distribution of the various types as follows (cfr. fig. 14): Iron deposits (72 %), Ni-Cu deposits associated with ultramafic intrusives (7 %), Ni-Cu deposits associated with ultramafic extrusives (9 %) and Cu deposits (12 %).

None of these known deposits are at present of any economic importance.

Secondly, in view of the new models for the genesis of gold and noble-metal deposits in Archaean volcanic-sedimentary terrains (cfr. p. 24) it is suggested that increasing attention should be directed towards the prospecting for gold and associated metals (Pt, Pd and W) in the south of Karasjok area.

On the geological side, therefore, much effort should be made to identify the deeper, marine parts of the volcanic/sedimentary basin. Especially sequences where Mg-rich ultramafic volcanics are overlain by sediments should be closely inspected - as these may have potentials for both massive Ni-Cu deposits and deposits of Au, Pt, Pd and W.

Table 1. XRF-compositions of mafic-and ultramafic rocks from the the Karasjok area.

1-24: komatiitic greenstones (picritic komatiites)
25: Chlorite-amphibole rock,Njuovcokka south of Karasjok.
From Wennerwirta (1960),anal.Statens Råstofflab.Trondheim.
36,425: ultramafics(peridotitic komatiites) target area 11
59: fine-grained ultramafic,north of Iddjajavri
503: fine-grained ultramafic,NE of Karasjok

424:gabbro,target area 11
43: pillowed amphibolite,near target area11
K-2 : Mafic intrusive,Gallujavre
427 : ultramafic,Skoganvarre

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 46.16 | 43.18 | 43.80 | 44.45 | 47.20 | 40.03 | 40.23 | 40.64 |
| $Al_2O_3$ | 5.39 | 6.56 | 5.92 | 6.28 | 5.80 | 4.90 | 5.89 | 6.33 |
| $TiO_2$ | 0.54 | 0.72 | 0.72 | 0.70 | 0.82 | 0.69 | 0.73 | 0.66 |
| $Fe_2O_3$ | 3.72 | 5.24 | 5.05 | 5.73 | 3.81 | 5.48 | 3.83 | 5.14 |
| FeO | 5.91 | 6.66 | 7.34 | 6.26 | 7.38 | 7.02 | 7.72 | 5.92 |
| MnO | 0.21 | 0.17 | 0.20 | 0.20 | 0.21 | 0.20 | 0.20 | 0.21 |
| MgO | 26.56 | 24.87 | 23.79 | 24.23 | 21.17 | 22.48 | 22.00 | 23.77 |
| CaO | 6.06 | 8.29 | 7.31 | 7.60 | 0.81 | 0.06 | 0.25 | 7.33 |
| $Na_2O$ | 0.01 | 0.08 | 0.13 | 0.06 | 0.30 | 0.30 | 0.07 | 0.27 |
| $K_2O$ | 0.06 | 0.08 | 0.10 | 0.08 | 0.00 | 0.09 | 0.07 | 0.12 |
| $P_2O_5$ | 0.05 | 0.04 | 0.13 | 0.04 | 0.04 | 0.01 | 0.05 | 0.06 |
| Ign.loss | 4.90 | 5.00 | 4.60 | 4.70 | 4.00 | 3.20 | 4.20 | 8.70 |
| Total | 100.36 | 100.89 | 99.17 | 100.26 | 90.43 | 90.06 | 90.24 | 100.15 |
| V (ppm) | 106 | 171 | 175 | 168 | 184 | 100 | 241 | 169 |
| Cr | 2710 | 1882 | 2135 | 1950 | 2069 | 2300 | 2491 | 2094 |
| Co | 91 | 91 | 105 | 95 | 80 | 79 | 92 | 96 |
| Ni | 1000 | 1050 | 1169 | 1029 | 881 | 874 | 812 | 1158 |
| Cu | 58 | 17 | 44 | 36 | 43 | 8 | 173 | 80 |
| Zn | 53 | 61 | 66 | 105 | 98 | 86 | 67 | 88 |
| Rb | 7 | 8 | 7 | 7 | 7 | 6 | 6 | 7 |
| Sr | 17 | 48 | 61 | 36 | 30 | 37 | 43 | 17 |
| Y | 7 | 7 | 9 | 7 | 7 | 6 | 10 | 7 |
| Zr | 25 | 43 | 40 | 23 | 23 | 22 | 43 | 25 |
| Nb | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 3 |

| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 45.89 | 45.21 | 38.13 | 43.32 | [illegible] | 46.04 | 44.04 | 46.40 | 46.09 |
| $Al_2O_3$ | 4.88 | 7.30 | 3.27 | 6.82 | 8.00 | 6.76 | 8.05 | 5.00 | 5.70 |
| $TiO_2$ | 0.76 | 1.00 | 0.77 | 0.08 | 0.04 | 0.67 | 0.52 | 0.63 | 0.04 |
| $Fe_2O_3$ | 5.92 | 4.42 | 10.57 | 5.86 | 2.30 | 4.86 | 2.58 | 3.63 | 5.76 |
| FeO | 6.45 | 7.92 | 4.06 | 6.16 | 6.70 | 8.10 | 8.06 | 6.73 | 5.05 |
| MnO | 0.18 | 0.20 | 0.16 | 0.24 | 0.17 | 0.16 | 0.20 | 0.16 | [illegible] |
| MgO | 22.86 | 21.95 | 20.15 | 24.31 | 20.72 | 21.00 | 22.47 | 24.20 | 24.02 |
| CaO | 8.27 | 8.07 | 3.72 | 6.86 | 6.30 | 8.10 | 7.22 | 6.30 | 7.60 |
| $Na_2O$ | 0.17 | 0.06 | — | 0.30 | 0.08 | 0.07 | 0.20 | 0.21 | [illegible] |
| $K_2O$ | 0.15 | 0.17 | 0.04 | 0.11 | 0.09 | 0.10 | 0.11 | 0.08 | [illegible] |
| $P_2O_5$ | 0.01 | 0.00 | 0.00 | 0.06 | [illegible] | 0.15 | 0.00 | [illegible] | [illegible] |
| Ign. loss | 8.70 | 2.50 | 10.20 | 5.40 | [illegible] | 4.40 | 5.00 | 4.20 | [illegible] |
| Total | 98.21 | 98.78 | 100.10 | 98.97 | 98.86 | 98.92 | 98.90 | 100.78 | 98.76 |
| V (ppm) | 208 | 206 | 130 | 200 | 187 | 187 | 190 | 168 | 172 |
| Cr | 2428 | 1546 | 2000 | 2434 | 2018 | 2083 | 2121 | 1974 | 2048 |
| Co | 95 | 96 | 98 | 104 | 96 | 100 | 95 | 96 | 98 |
| Ni | 1052 | 830 | 1206 | 1200 | 880 | 943 | 806 | 955 | 1121 |
| Cu | 72 | 107 | 72 | 10 | 10 | 8 | 10 | 41 | 34 |
| Zn | 84 | 71 | 74 | 77 | 70 | 82 | 73 | 78 | 75 |
| Rb | 7 | 8 | 9 | 7 | 7 | 6 | 6 | 6 | 6 |
| Sr | 62 | 56 | 7 | 38 | 16 | 24 | 37 | 52 | 50 |
| Y | 7 | 7 | 5 | 8 | 8 | 5 | 10 | 7 | 8 |
| Zr | 16 | 35 | 10 | 36 | 40 | 18 | 21 | 30 | 32 |
| Nb | 2 | 4 | 2 | 3 | 3 | 2 | 4 | 3 | 3 |

| | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 44.72 | 43.83 | 44.20 | 43.05 | 44.30 | 43.64 | 44.88 | 40.80 |
| $Al_2O_3$ | 5.56 | 6.30 | 5.06 | 5.82 | 7.80 | 7.10 | 6.72 | [illegible] |
| $TiO_2$ | 0.04 | 0.74 | 0.30 | 0.56 | 1.90 | 1.52 | 0.60 | 0.34 |
| $Fe_2O_3$ | 6.32 | 5.00 | 5.20 | 5.14 | 6.56 | 5.50 | 3.03 | 1.27 |
| FeO | 5.60 | 6.94 | 6.90 | 5.10 | 7.34 | 7.58 | 8.01 | 10.90 |
| MnO | 0.17 | 0.19 | 0.15 | 0.20 | 0.22 | 0.19 | 0.16 | 0.14 |
| MgO | 24.22 | 23.10 | 24.82 | 25.40 | 21.83 | 21.20 | 21.47 | 18.31 |
| CaO | 7.99 | 7.05 | 7.78 | 7.80 | 7.30 | 7.40 | 8.08 | 8.22 |
| $Na_2O$ | 0.43 | 0.21 | 0.20 | 0.10 | 0.67 | 0.52 | 0.14 | 0.02 |
| $K_2O$ | 0.11 | 0.10 | 0.00 | 0.10 | 0.11 | 0.14 | 0.14 | 0.07 |
| $P_2O_5$ | 0.14 | 0.11 | 0.04 | 0.10 | 0.17 | 0.13 | 0.04 | 0.11 |
| Ign. loss | 4.30 | 5.80 | 4.00 | 6.30 | 2.90 | 4.90 | 5.40 | 5.41 |
| Total | 100.20 | 98.17 | 100.02 | 98.93 | 100.00 | 98.84 | 98.27 | 98.74 * |
| V (ppm) | 177 | 202 | 162 | 140 | 234 | 245 | 179 | |
| Cr | 2014 | 2200 | 2025 | 1504 | 1330 | 1316 | 2255 | |
| Co | 84 | 104 | 90 | 83 | 103 | 100 | 102 | |
| Ni | 800 | 1122 | 1033 | 920 | 857 | 848 | 951 | |
| Cu | 46 | 113 | 66 | 18 | 78 | 27 | 10 | |
| Zn | 70 | 73 | 68 | 81 | 85 | 51 | 130 | |
| Rb | 7 | 7 | 7 | 8 | 7 | 6 | 8 | |
| Sr | 53 | 58 | 73 | 60 | 105 | 110 | 31 | |
| Y | 7 | 7 | 6 | 7 | 8 | 9 | 9 | |
| Zr | 20 | 22 | 32 | 24 | 94 | 70 | 36 | |
| Nb | 3 | 3 | 3 | 3 | 7 | 6 | 2 | |

* includes

$Cr_2O_3$ : 0.32 %
NiO : 0.16 %
BaO : 0.01 %
S : 0.10 %

| | 36 | 425 | 59 | 503 | 427 | 424 | 43 | K-2 |
|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 39.9o | 37.40 | 4o.86 | 42.27 | 46.57 | 48.48 | 50.62 | 50.98 |
| $Al_2O_3$ | 2.66 | 5.15 | 3.31 | 5.38 | 3.08 | 14.20 | 13.64 | 3.00 |
| $TiO_2$ | 0.26 | 0.35 | 0.21 | 0.56 | 0.35 | 0.99 | 1.71 | 0.27 |
| $Fe_2O_3$ | 5.10 | 3.32 | 6.85 | 4.46 | 3.87 | 2.94 | 4.10 | 1.14 |
| FeO | 5.10 | 6.95 | 5.30 | 7.60 | 6.52 | 9.67 | 10.30 | 7.71 |
| MnO | 0.22 | 0.18 | 0.25 | 0.22 | 0.16 | 0.18 | 0.21 | 0.18 |
| MgO | 34.65 | 30.92 | 31.58 | 26.03 | 25.20 | 6.70 | 5.06 | 21.97 |
| CaO | 0.58 | 2.52 | 2.34 | 5.17 | 6.37 | 10.67 | 8.69 | 10.86 |
| $Na_2O$ | --- | 0.04 | --- | 0.63 | 0.30 | 2.63 | 3.21 | 0.46 |
| $K_2O$ | 0.06 | - -- | 0.05 | 0.19 | 0.43 | 0.68 | 0.37 | - -- |
| $P_2O_5$ | 0.06 | 0.04 | 0.02 | 0.06 | 0.04 | 0.05 | 0.20 | 0.06 |
| .loss | 11.40 | 13.54 | 9.70 | 6.32 | 6.58 | 2.50 | 1.50 | 2.09 |
| Total | 99.99 | 100.41 | 100.47 | 98.89 | 99.47 | 99.69 | 99.61 | 98.72 |
| (ppm). | 73 | | 72 | | | | 361 | |
| r | 3451 | 2225 | 3948 | 3315 | 2355 | 125 | 105 | 3315 |
| o | 122 | | 124 | | | | 91 | |
| i | 1838 | 1683 | 1206 | 1571 | 1387 | 150 | 42 | 823 |
| u | 48 | 30 | 32 | 79 | 350 | 244 | 146 | 326 |
| n | 59 | 83 | 58 | 118 | 71 | 122 | 78 | 125 |
| b | 10 | | 7 | | | | 9 | |
| r | 7 | | 16 | | | | 182 | |
| | 4 | | 4 | | | | 14 | |
| r | 12 | | 15 | | | | 66 | |
| b | 3 | | 4 | | | | 6 | |

*Table 2. Chemical analyses of Finnish komatiites.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 36.25 | 43.83 | 42.67 | 41.19 | 45.26 | 43.97 | 46.04 | 46.77 | 40.06 | 46.20 |
| $TiO_2$ | 0.41 | 0.90 | 0.80 | 0.88 | 0.72 | 0.22 | 2.03 | 1.33 | 1.00 | 0.62 |
| $Al_2O_3$ | 0.54 | 7.13 | 7.10 | 6.59 | 8.08 | 10.43 | 5.87 | 10.24 | 7.68 | 10.95 |
| $Fe_2O_3$ | 3.19 | 4.24 | 3.80 | 4.00 | 1.27 | 1.47 | 1.75 | 1.55 | 2.36 | 1.84 |
| FeO | 4.43 | 10.76 | 8.24 | 6.05 | 14.84 | 7.14 | 11.93 | 9.98 | 8.75 | 9.76 |
| MnO | 0.18 | 0.17 | 0.11 | 0.25 | 0.31 | 0.20 | 0.27 | 0.28 | 0.20 | 0.06 |
| MgO | 30.75 | 18.33 | 24.47 | 26.55 | 14.42 | 23.44 | 16.61 | 12.14 | 25.98 | 12.25 |
| CaO | 1.80 | 9.26 | 6.55 | 6.04 | 8.54 | 6.84 | 10.78 | 12.40 | 5.43 | 12.10 |
| $Na_2O$ | 0.09 | 1.10 | 0.30 | 0.24 | 0.22 | 0.30 | 0.16 | 1.24 | 0.34 | 0.60 |
| $K_2O$ | 0.01 | 0.36 | 0.28 | 0.15 | 0.18 | 0.19 | 0.15 | 0.50 | 0.07 | 0.12 |
| $P_2O_5$ | 0.02 | — | 0.26 | — | 0.07 | 0.09 | 0.24 | nd. | nd. | 0.03 |
| $CO_2$ | 14.83 | nd. | nd. | nd. | 0.00 | 4.74 | nd. | nd. | 2.58 | 2.09 |
| $H_2O^+$ | 6.18 | 3.51 | 4.96 | 6.16 | 5.16 | 0.77 | 4.39 | 3.19 | 5.84 | 2.08 |
| $H_2O^-$ | 0.02 | 0.13 | 0.14 | 0.17 | 0.04 | 0.05 | 0.02 | 0.02 | 0.09 | 0.09 |
| | 98.70 | 99.72 | 99.68 | 99.74 | 99.11 | 99.85 | 100.24 | | 100.38 | 99.61 |

1. Soapstone-like lava-born rock. Kuolavaara, Kittilä. Anal. P. Ojanperä. (Paakkola 1971, Table 7, p. 52). In addition: Cr = 0.336, Ni = 0.396, Co = 0.0088, V = 0.0290. Cu = 0.0004.
2. Amphibole rock. Keikkuma-aavan saari (the »island» on the marsh of Keikkuma-aapa), NNW of Koitilainen fell, Sodankylä. Anal. H. Lönnroth. (Mikkola 1941. Table 19, p. 239).
3. Amphibole-chlorite rock. Kummitsoiva hill, ab. km E of the church, Pelkosenniemi. Anal. H. Lönnroth. (Mikkola 1941, Table 18, p. 238).
4. Chlorite-amphibole rock. Sattasvaara hill, N. of Sattasjoki river, Sodankylä. Anal. H. Lönnroth. (Rankama 1939, p. 8).
5. Lava-born amphibole-chlorite rock. Rovanpää, Kittilä. Anal. P. Ojanperä. (Paakkola 1971, Table 7, p. 52).
6. Amphibole-enstatite-spinel rock. Kussuolinkivaara hill, 7 km E of the village Mutenia, Sodankylä. Anal. H. Lönnroth. (Mikkola 1941, Table 20, p. 240).
7. Greenstone. Saarijärven alue, Lamminaho, Suomussalmi. Anal. P. Ojanperä. (Matisto 1958, Table IX, p. 69).
8. Amphibolite. Pyyvaara, Suomussalmi. Anal. H. B. Wiik. (Matisto 1958. Table X. p. 72).
9. Olivine peridotite. Kotvala, Suomussalmi. Anal. H. B. Wiik. (Matisto 1958, Table XII, p. 75).
10. Coarse-grained amphibolite. Tipasjärvi, Sotkamo. Anal. P. Ojanperä. (Vartiainen 1968. Table VII, p. 118).

## Komatiites from the Kuhmo greenstone belt

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 45.47 | 45.20 | 42.50 | 46.90 | 48.90 | 47.50 | 47.70 | 48.70 | 48.90 |
| $TiO_2$ | 0.33 | 0.40 | 0.61 | 0.51 | 0.68 | 0.60 | 0.68 | 0.63 | 0.71 |
| $Al_2O_3$ | 7.81 | 8.35 | 11.21 | 8.41 | 10.90 | 11.30 | 11.32 | 9.88 | 12.73 |
| FeO* | 9.61 | 10.96 | 12.62 | 11.02 | 12.54 | 12.08 | 13.34 | 12.19 | 12.13 |
| MnO | 0.19 | 0.18 | 0.20 | 0.20 | 0.28 | 0.32 | 0.28 | 0.23 | 0.21 |
| MgO | 22.04 | 21.80 | 19.40 | 19.00 | 11.80 | 12.60 | 12.00 | 13.60 | 11.10 |
| CaO | 7.46 | 5.59 | 6.65 | 8.35 | 9.32 | 11.02 | 10.57 | 9.24 | 7.72 |
| $Na_2O$ | 0.28 | 0.20 | 0.18 | 0.07 | 2.18 | 1.06 | 1.40 | 2.04 | 3.15 |
| $K_2O$ | 0.01 | 0.01 | 0.01 | 0.01 | 0.26 | 0.15 | 0.15 | 0.07 | 0.09 |
| $P_2O_5$ | 0.00 | 0.02 | 0.05 | 0.05 | 0.09 | 0.07 | 0.09 | 0.02 | 0.07 |
| Ign. loss | 5.80 | 6.27 | 6.09 | 5.18 | 1.96 | 2.15 | 1.89 | 2.58 | 2.50 |
| Total | 99.00 | 98.98 | 99.52 | 99.70 | 98.91 | 98.87 | 99.42 | 99.18 | 99.31 |
| Co (ppm) | 90 | 80 | 90 | 100 | 70 | 60 | 70 | 70 | 50 |
| Cr | 2450 | 2620 | 1540 | 1300 | 1010 | 1090 | 760 | 1260 | 580 |
| Cu | 40 | 10 | 0 | 10 | 170 | 10 | 0 | 0 | 30 |
| Ni | 1110 | 1040 | 680 | 890 | 660 | 390 | 330 | 390 | 180 |

1—2. Peridotitic komatiite, massive lava, Siivikko Member.
3. Peridotitic komatiite, microspinifex texture, Siivikko Member.
4. Peridotitic komatiite, cumulate zone of a spinifex-textured lava flow, Siivikko Member.
5—6. Pyroxenitic komatiite, massive lava, Mäkinen Member.
7. Pyroxenitic komatiite, pillow lava, Siivikko Member.
8. Pyroxenitic komatiite, pillow lava, Mäkinen Member.
9. Basaltic komatiite, spinifex texture, Siivikko Member.

| | A-27 Peridotitic Komatiite | Barberton Type | | | DN-3 Gabbro |
|---|---|---|---|---|---|
| | | BK-2 Basaltic Komatiite | BK-3 Basaltic Komatiite | BK-4 Basaltic Komatiite | |
| $SiO_2$ | 42.9 | 53.7 | 51.4 | 53.6 | 50.7 |
| $Al_2O_3$ | 2.6 | 7.8 | 8.8 | 6.8 | 6.9 |
| $Fe_2O_3$ | 2.5 | 1.3 | 0.8 | 1.0 | 1.3 |
| FeO | 7.2 | 8.6 | 9.8 | 9.8 | 8.5 |
| CaO | 1.8 | 11.8 | 10.7 | 11.2 | 10.5 |
| MgO | 30.0 | 10.9 | 10.5 | 11.5 | 13.2 |
| $Na_2O$ | 0.03 | 2.9 | 3.0 | 3.0 | 2.4 |
| $K_2O$ | 0.01[e] | 0.04[e] | 0.19[e] | 0.06[e] | 0.04[e] |
| $H_2O^+$ | 9.3 | 1.7 | 2.2 | 1.6 | 3.4 |
| $H_2O^-$ | 0.4 | 0.1 | 0.2 | 0.2 | 0.2 |
| $TiO_2$ | 0.31 | 0.66 | 0.53 | 0.64 | 0.69 |
| $P_2O_5$ | 0.02 | 0.07 | 0.04 | 0.06 | 0.07 |
| MnO | 0.13 | 0.18 | 0.19 | 0.23 | 0.17 |
| $CO_2$ | 1.95 | 0.15 | 1.36 | 0.23 | 1.83 |
| Total | 99.2 | 99.9 | 99.7 | 99.9 | 99.9 |
| Total Fe as $Fe_2O_3$ | 10.5 | 10.9 | 11.7 | 11.9 | 10.7 |
| Sc | 13.4 | 37.0 | 31.4 | 34.2 | 31.3 |
| Cr | 1470 | 1090 | 735 | 1180 | 1690 |
| Co | 55 | 45 | 37 | 46 | 41 |
| Ni | 2000 | 690 | 5[illegible]0 | 850 | 570 |
| Cu | 40 | 13 | [illegible]8 | 92 | 72 |
| Zn | 75 | 77 | 80 | 100 | 77 |
| Ga | 3.8 | 9.0 | 9.9 | 7.9 | 8.3 |
| Rb | 0.577[e] | 0.450[e] | 5.41[e] | 0.929[e] | 0.685[e] |
| Sr | 49.1[e] | 38.4[e] | 67.6[e] | 32.3[e] | 25.2[e] |
| Cs | 0.35 | <0.1 | 0.30 | 0.05 | <0.6 |
| Ba | 285[e] | 10.8[e] | 22.7[e] | 28.2[e] | 34.5[e] |
| Hf | 0.5 | 1.3 | 0.7 | 1.2 | 1.4 |
| La | 0.82 | 3.5 | 2.6 | 6.0 | 2.8 |
| Ce | 2.3 | 8.7 | 8.0 | 14.1 | 8.6 |
| Nd | 2.1 | 6.9 | 4.5 | 7.2 | 5.9 |
| Sm | 0.58 | 1.9 | 1.40 | 2.13 | 1.97 |
| Eu | 0.21 | 0.59 | 0.48 | 0.70 | 0.72 |
| Gd | 0.7 | 2.3 | 1.8 | 2.4 | 2.3 |
| Tb | 0.14 | 0.44 | 0.32 | 0.45 | 0.47 |
| Dy | 0.89 | 2.8 | 2.0 | 2.9 | 2.9 |
| Ho | 0.20 | 0.64 | 0.45 | 0.73 | 0.65 |
| Er | 0.50 | 1.6 | 1.0 | 1.6 | 1.7 |
| Yb | 0.49 | 1.56 | 1.19 | 1.47 | 1.60 |
| Lu | 0.08 | 0.24 | 0.18 | 0.24 | 0.25 |

Table 3: Komatiites from Komatii-formation, South Africa.

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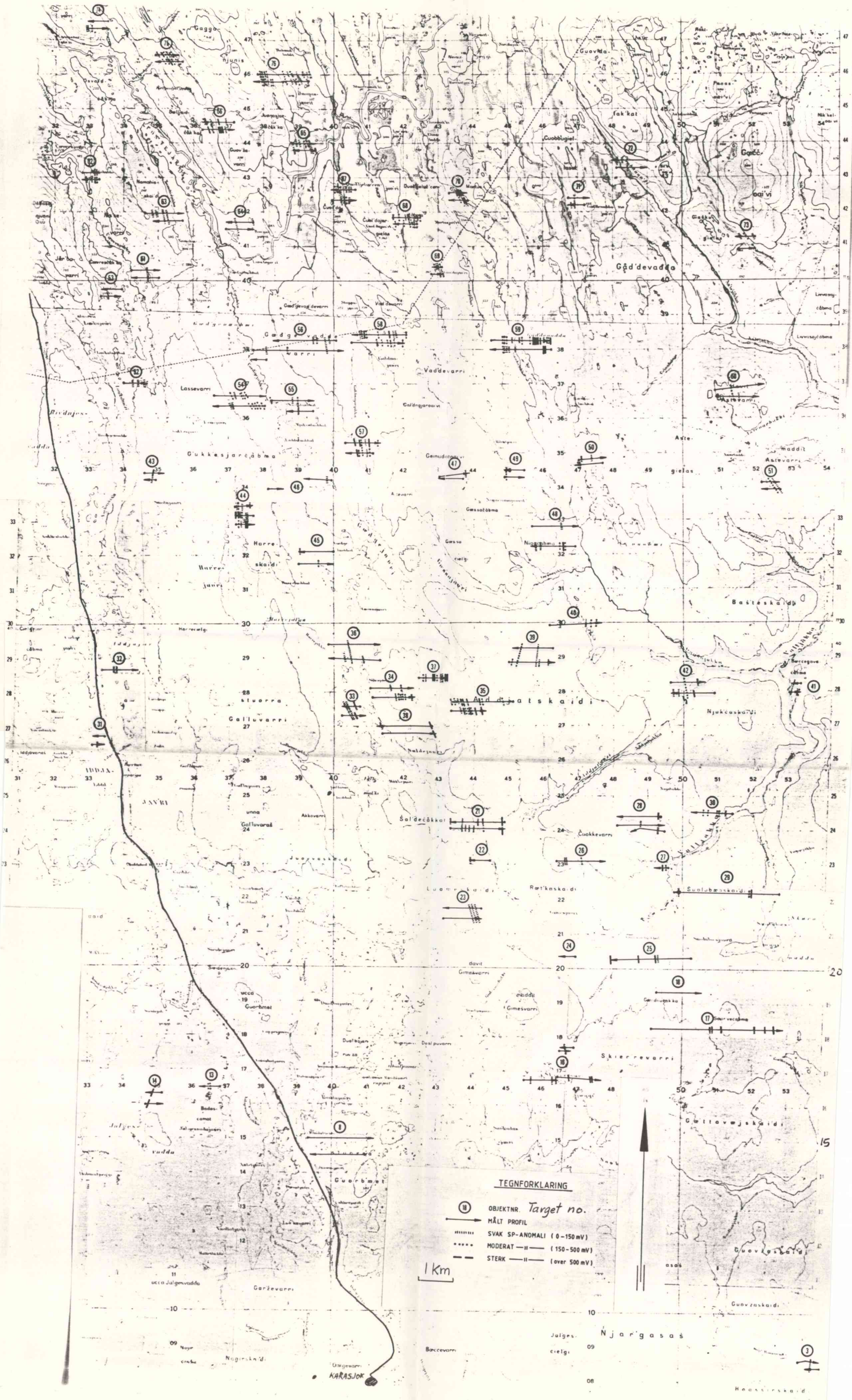
TEGNFORKLARING
OBJEKTNR. Target no.
MÅLT PROFIL
SVAK SP-ANOMALI (0-150 mV)
MODERAT (150-500 mV)
STERK (over 500 mV)
1 Km
KARASJOK
Gåd'devadda
Njukcaskaidi
Njar'gasaš
Guorbmet
Garževarri
Gimesvarri
Skierrevarri
Lassevarri
Harrejavri
Galluvarri
Šal'decåkkai
Čuokkevarri
Guovzaskaidi
Vad'devarri
Gællavæjskaidi