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GEOLOGICAL AND STRUCTURAL REPORT OF SOUTH - EAST SKOROVAS
CONTRIBUTION TO THE GRONG PROJECT

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CONTENTS:

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GEOLOGICAL AND STRUKTURAL REPORT

OF

SOUTH-EAST SKOROVAS

CONTRIBUTION TO THE GRONG PROJECT

TO ELKEM-SPIGERVERKET A/S, SKOROVAS GRUBER

SEPTEMBER 27, 1974

CONTENTS

I. INTRODUCTION

The area mapped lies south-east of Skorovas in the central Norwegian Caledonides, consisting of basic to intermediate metavolcanics or "greenstones" of predominant island arc low-potash tholeiitic composition. The greenstones contain thin keratophyric flows, pyroclastics and numerous minor intrusions of "acid" and gabbroic composition, the former being strongly predominant. Also intruded into the greenstones sequence is an extensive complex intrusive sheet having gabbro, Trondheimite and "mixed" rocks as components. The complex outcrops in a broad angular arc, closing to the west of the mapping area along a north-south line, , the northern and southern "arms" of which extend across the northern edge of the area, and into the southern-most greenstones respectively.

The adjoining area eastward to Ingulsvatn was mapped in 1973 by C. Halls and R. White of Imperial College, London. In 1974, it was decided that detailed mapping should be carried out, extrapolating the stratigraphy of the area of 1973, to determine the structure and any changes in stratigraphy in the southern zones of the Skorovas mine region.

The workers of 1974 were Andrew Rankin, Christopher Halls and Ian Ferriday.

II GREENSTONE LITHOLOGIES

The greenstones in the area may be divided into three major units in the field, the division being based on a) morphology i.e. fabric and internal structures, often reflected by the weathering surface b) visible composition, and c) colour, this being conducted using the standard range of colours established by the Geological Society of America.

Major and trace-elemental analysis of type specimens is to be carried out by Dr. C. Halls at Imperial College, London; the results of which will clarify the field division of greenstones by assigning the greenstones into magma-types.

The three major units are as follows:-

c) Upper unit of calc-rich flows and possibly flattened pillow lavas.
b) Lower pillow unit
a) Massive epidote-rich unit.

The units may contain relatively subordinate facies.

GREENSTONE UNIT CHARACTERISTICS AND SUB-FACIES

i)a) Massive Epidote-rich Unit

Structurally and lithologically, these are the oldest greenstones in the area, are characteristically massive, colour around 5G. 4/1. (dark greenish gray), containing abundant epidote in knots, strings, amygdales and in a distinctive "boxwork" vein structure. These lavas outcrop in the northernmost parts of the area, in a zone trending E.N.E.-W.S.W. from the Trondheimite contacts near Olatjern toward Nesåklumpen. As structures further south-west and west are relatively complex and flat-lying, the greenstones outcrop irregularly and sporadically west of Y. 6.000 and north of X. 67.000.

The greenstones have been intruded by thin, stratiform acid material with minor pyritic impregnation being common (Y. 1.400, X. 68.750). The minor intrusives will be discussed in the relevant part of this report, including those of gabbroic composition which have apparently locally replaced the greenstones on a small scale, together with local minor pyritic impregnation.

No exhalite horizons are exposed within this greenstone unit.

The unit is in contact with the lowermost members of the lower pillow unit, also higher in the structural succession, to the south, the contact being gradational over 15 - 25 m, this zone locally containing thin keratophyric flows with abundant associated minor intrusions.

ii)b) Lower Pillow Unit

About 1 km. south of Olatjern, the lower pillow greenstones rest on the massive epidote greenstones, and are clearly the right way-up at the contact. The southern contact is unclear in many localities, a large volume of the Southernmost greenstones of the upper unit having been strongly altered by the main Trondheimite, an armlike sheet of which extends into the sequence, almost stratiformally from Nesåflyen to Lake 753. A contact is apparent near the southern tip of the latter lake however, trending eastward, toward the conglomerate contact, locally a fracture contakt, on the upper southern slopes of Svartberget.

The greenstones of the lower pillow unit do not commonly display well-developed pillows, the original 0.3 - 0.5 m "type" pillows which may be seen at (Y. 5.320, X. 66.780), (Y. 2.480, X. 66.990), (Y. 2.370, X. 67.840) often occur flattened to varying degrees the most extreme flattening being represented by strongly schistose chloitic greenstones where original pillow structures are often unrecognisable. Flattening may occur in tight fold hinge zones, in fracture zones or within 2 - 3 m of contacts with acid minor intrusions.

The greenstones of this unit are, similar to the ~~lower~~ massive unit, calc-rich. Epidote is the most common visible calcic mineral, occurring in pillow cusps, or as knots and strings in thin discontinuous massive horizons which occur within the pillow sequence, the latter no doubt being equivalent to the greenstones of the lower unit. Calcite is also present in amygdales, or may reach quite high proportions within the fabric of certain pillow horizons, reducing the grennstone to a soft non-brittle fracture consistency.

The Lower Pillow Unit contains abundant discontinuous horizons where the greenstones may have a crude schistosity, being rich in vesicles appearing of to be a less viscous nature. Colour shades may vary discernibly several times over a dip-traverse of 300 m, though the greenstones are all of lavaflow origin. The variation may thus reflect sporadic changes in grain size and possibly minor compositional changes, i.e. thin discontinuous wedges of slightly differing lava flows within the bulk of the pillow sequence, perhaps representing brief time intervals between major flow periods.

iii)

The Lower Pillow Unit greenstones do, however, contain horizons where the nature of material is distinctly different. These occur as:-

a) relatively light green (G.S.A. 5G 5-6/1-pale gray-green) massive greenstones with dark green chloritic flecks or clumps which vary in size from 1 - 3 mm and widely in concentration. Where this rock is relatively thickly developed it appears there is a tendency for the chloritic clumps to decrease in quantity until hardly discernible. The rock is evidently a pyroclastic, having a variable "ignimbritic" texture. However this can only be confirmed in thin section.

b) Dark green schistose greenstones containing lenticular cherty clasts which are predominantly magnetite-rich, ranging in length from less than 0.5 cm to 8 cm, and varying widely in concentration. This lithic-tuffaceous rock forms discontinuous horizons to a maximum thickness of approximately 40 m. Locally, the greenstone matrix of this rock is pyritic (Y. 4.700, X. 67.300).

c) Ferruginous greenstones weathering cream-brown with a distinctly "bedded" appearance. In fresh section this rock is dark green-grey (G.S.A. 5G 4-5/1) containing pyrite and carbonate, with fine siliceous scams. Horizons of such material are often hosts for distinct exhalite horizons, and occur developed to a maximum thickness of approximately 25 - 30 m.

d) Highly vesicular, dark green commonly with a heavily and deeply pitted weathering surface, calc-rich greenstone, weathered pits being up to 10 x 5 cm. These greenstones have a distinct "frothy" appearance and are apparently developed in flow-top horizons, being developed to a maximum thickness locally of 10 - 20 m.

The above greenstones are evidently genetically associated with relatively explosive phases of volcanism after major eruptive periods, and are often visibly intimately associated with ferruginous exhalite horizons which often include bedded cherts. A discussion of the exhalite horizons follows this section.

To summarise, therefore, the Lower Pillow Unit is composed of a number of pillow-lava flow-piles representing major eruptive PERIODS of a single dominant lava-type, each flows pile containing thin, relatively minor variations of original lava, together with laterally extencive, locally thickly developed horizons of pyroclastic material with variably ferro-mineralized exhalite horrizons between the major flows piles.

iv)c) Upper Unit

Greenstones of the Upper Unit outcrop in the south of the area, having an original erosion-surface contact with the conglomerates which is often fractured parallel to the f_1 trend. Outcrop of greenstone relatively unaltered by the Trondheimite is relatively restricted to the area to the south and south-east of lake 763.

The greenstones are often dark green crude to good-schistose vesicular lavas. They are calc-rich, often containing a high proportion of carbonates, noteably siderite, which may reach up to 15 - 20 % as deformed rhombs of 2 - 3 mm. Pyritic impregnation is also common, locally resulting in the occurrence of gossans, an extensive example occurring at (Y. 2.690, X. 64.620). The latter example is part of an impregnation zone occurring within 30 m and trending parallell to the conglomerate contact, and which is often a persistent phenomena.

The greenstones of the upper unit may represent original pillow lavas, which they appear to resemble in composition, though no recognisable pillow structures occur. This, however, may be due to the relatively high degree of flattening with shearing which occurs at this horizon.

III EXHALITE HORIZONS AND EXHALATIVE MINERALISATION

Exhalite horizons often occur associated with apparently relatively felsic greenstones and tuffaceous-agglomeratic greenstones in the pillow lavas. The simplified genetic aspects of exhalites, also termed vasskis horizons, have been discussed in previous reports by undergraduates from Imperial College, and these aspects will not be repeated.

In this report, an exhalative horizon is defined as a distinct volcano-sedimentary horizon characteristically having a cherty facies of varying compactness and colour, which may be accompanied by pyritic or cupriferous pyritic mineralisation. Magnetite is almost universally present in varying quantity and form, while hematite is often present in specular form within the cherts.

Distribution in the greenstone sequence:

Almost all the exhalite horizons mapped outcrop within the Lower Pillow Unit. In the Upper Lavas, no definite exhalative horizons appear to occur, although rocks from this unit are of limited outcrop as a high degree of veining and silicification by the Trondheimites has occurred through an extensive thickness of the Upper lavas. However, the local occurrence of high magnetite-chert clast concentrations in conglomerates less than ten metres from a "conformable" greenstone contact indicates the former presence of exhalites in this horizon. This is supported in that the erosional size differential between chert and calcareous clasts in the conglomerates has not been attained, indicating short transport distance of eroded greenstone fragments. A relatively fine conglomerate often occurring in contact with the greenstones is almost an in situ-erosion-deposition greenstone sediment.

Silica of exhalite horizons:

Silica in colloidal or semi-crystalline form may be said to act as a host matrix for the varying iron mineralogy of exhalite horizons. Two types of distinctly siliceous exhalite facies are recognised, both tending to occur at or near the stratigraphic tops of exhalite horizons. A distinctly siliceous facies may be completely absent however, this being a result of a) original restricted deposition, b) tectonic extension with boudinaging.

i) compact cherts
ii) massive, relatively soft cherts.

i)

The compact cherts are distinguished by their high compactness and hardness, appearing colloidal to semi-crystalling. The cherts vary in colour from brick-red to blood-red with varying content and grain size of specular hematite, or from blue-black to grey where iron is in very fine-grained magnetite. The cherts may vary laterally within 100 m from red (jasper) to blue-grey (blau quartz), while a similar gradation can be seen in very thin compact cherts over a metre. Purple cherts occur where both magnetite and hematite are present.

The compact cherts vary in thickness from 0 to 1,5 m. During deformation, the cherts appear to have behaved both as semi-brittle solids and plastic solids, the degree to which one state predominates over the other no doubt being dependent on several factors.

Being relatively competent, the cherts have acted as directing anisotropies for fracturing in the area. This clear by the common occurence of fractures in greenstones in the horizonal vicinity of exhalites.

Examples of compact cherts occur where original blood-red cherts have been diluted by the introduction of non-ferruginous silica which is evidently not vein quartz. The siliceous invasion is irregular, while contacts between the two siliceous facies are gradational, never sharp. This may be a result of the introduction of silica from below by silica-laden "steam" solutions relatively shortly after deposition. (Y. 4.415, X. 68.665).

The compact cherts are occasionally found grading into the softer cherts, having distinct "seams" or concentrations of relatively coarse-grained magnetite.

ii)

The relatively soft cherts are evidently distributed in an opposing relationship with respect to the compact cherts. Rarely do the two siliceous facies occur equally developed in a single exhalite section. Three types may be distinguished:

a) White-grey chert
b) Black chert
c) Pink-cream banded cherts.

a)

The white or grey cherts predominantly act as hosts for pyritic or cupriferous pyritic iron mineralisation, locally together with minor magnetite. They are relatively extensively developed in the exhalite horizon south of Vestre Øverste Nesåvatn, but occur universally where pyrite mineralisation is relatively extensive, producing on weathering the rusty siliceous sinter found on many gossans including those immediately above the mine. With decreasing pyrite content, the cherts may grade with increasing compactness into compact grey cherts containing very fine-grained magnetite. With increasing pyrite, the rock tends toward that forming relatively thick bedded sulphides which occur, for example, at Finkjerringhullet Skjerp, where the siliceous matrix is grey to dark grey in colour.

b)

The "black" cherts may in fact be blue-black to blue-grey or deep non-metallic black in colour.

The former contain very fine-grained magnetite in varying content together with local minor pyrite. There is a tendency for the black magnetic cherts to occur as a capping above siliceous facies containing pyrite or cupriferous pyrite.

The black non-magnetic cherts are also associated with pyritic mineralisation. South of Vestre Øverste Nesåvatn, this chert acts as a host for lenticular clouds of fine-grained pyrite. (Y. 5.940, X. 66.970).

c)

The banded cherts are a very distinctive multiple exhalite, consisting of multiple bedded cherts varying in colour from cream-pink where relatively pure, to green-grey or brown with pyritic or greenstone impurity. Thin compact chert horizons ranging from jasper to blau-quartz may also be multiple components of a section (Fig. 1). More usually, compact chert forms a distinct horizon above or below the banded cherts, the two facies having an opposing relation of development.

The banding of the cherts is evidently due to the occurrence of local multiple short depositional periods, though their precise genesis is an interesting problem. Certain multiple exhalites are traceable along strike for up to 1,5 km, with minor development of a distinct compact chert horizon. While others are developed to a thickness of only 7 - 8 cm, associated with 1 - 1,5 m of compact chert. The banded cherts vary somewhat laterally, locally including sub-horizons rich in oriented actinolite. Fig. 1 shows the sectional variation in 100 m along strike for the multiple exhalite on the north-east shore of Østre Øverste Nesåvatn. Variation is evident, but it is also clear that certain horizons within the exhalite may be correlated (dashed lines). The multiple exhalites never show signs of a turbid depositional environment, but it is likely that their formation "locally" in space and time is strongly controlled by certain submarine current environments.

Rarely, south of Vestre Øverste Nesåvatn, the multiple exhalite horizons are brecciated, representing either a slump or flow-foot breccia (Y. 5.660, X. 67.025).

The multiple exhalites appear to grade crudely into a distinctive greenstone in many localities, the latter having an orange-brown or grey-brown banded appearance, which in fresh section is a dark carbonate/pyrite greenstone having a crude schistosity. This greenstone is often a characteristic host horizonal type for exhalites.

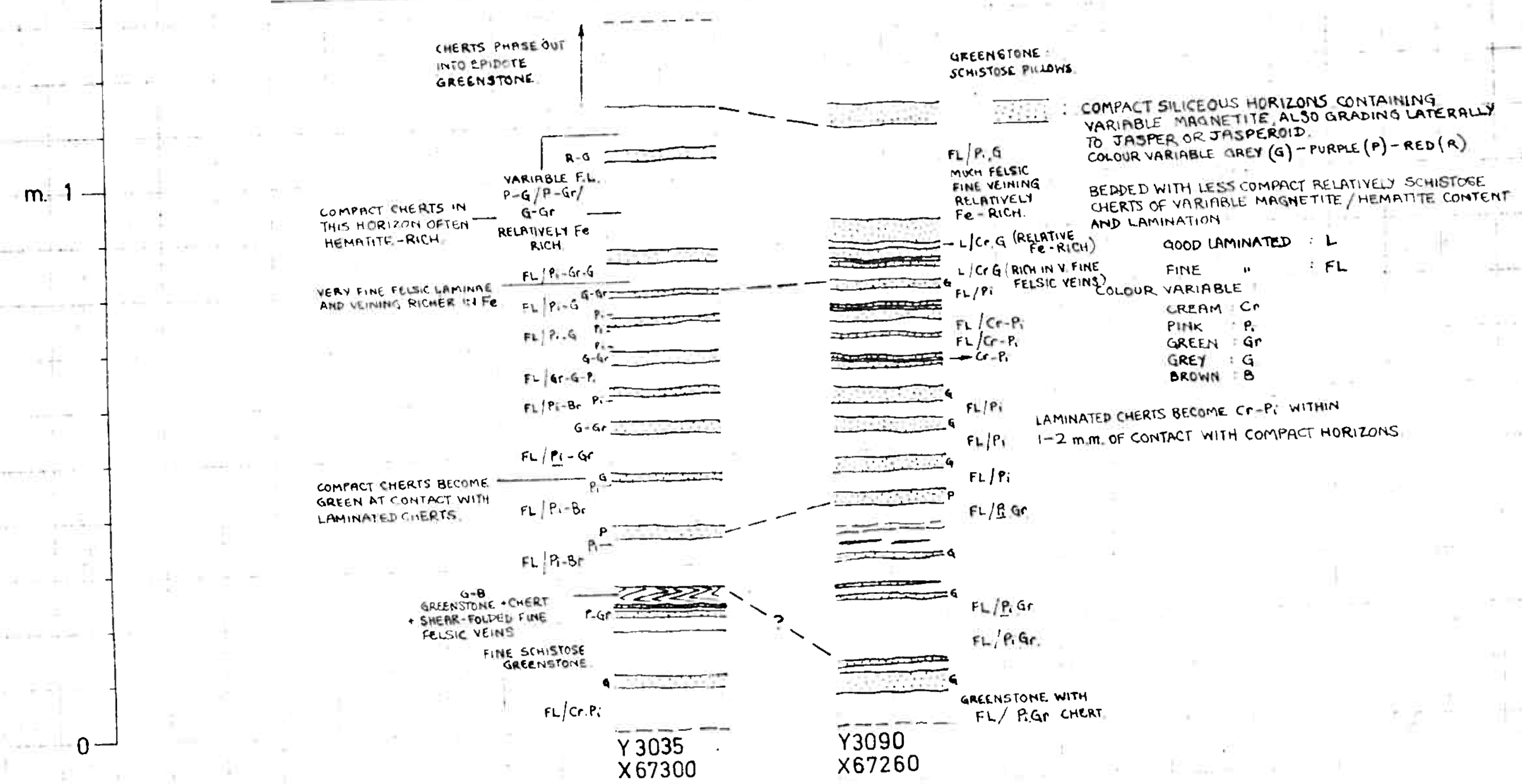
iv)

The wide variety of exhalite assemblages that occur, together with textural varieties of magnetite and pyrite, and the relative development of facies may be explained by chemical variations of depositional environment, especially with respect to fo_2 and fS_2, together with physical variations. It is evident that within a single exhalite horizon the oxidation/reduction balance varies both laterally and vertically, resulting in lensoid oxidate and reducate facies. Also, within facies, sub-systems appear to have formed, the nett result bein the complex variation in exhalite horizons which is observed (Figs. 2 a-i).

Using stratigraphical/structural lines of trend and trends of variation of exhalite horizons, it is possible to use the horizons as stratigraphic "markers" within the volcanic pile, and although the character of exhalite horizons may vary over relatively short distances, greenstone host-horizons are often quite characteristic in appearance. Thus, provided shearing and displacement is not extensive and provided the limits of correlation are realised, an accurate structural/stratigraphic three-dimensional model for the region may be envisaged.

Fig.1.

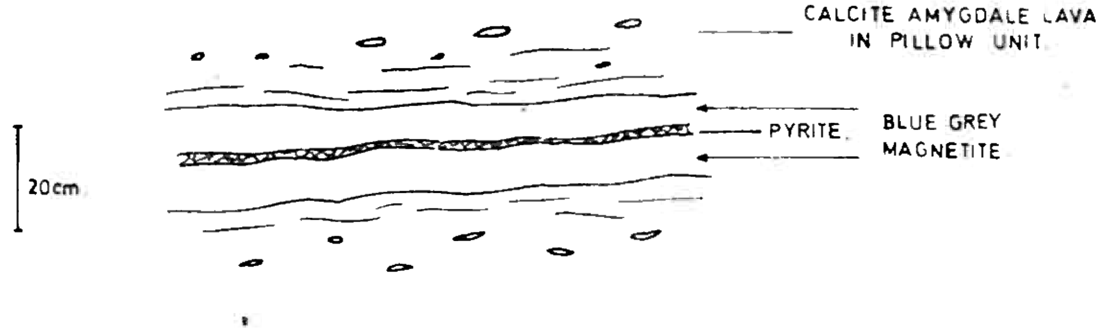
SECTIONAL VARIATION IN 100m.
MULTIPLE EXHALITE HORIZON, NORTH-EAST ØSTRE ÖVERSTE NESAVATN.



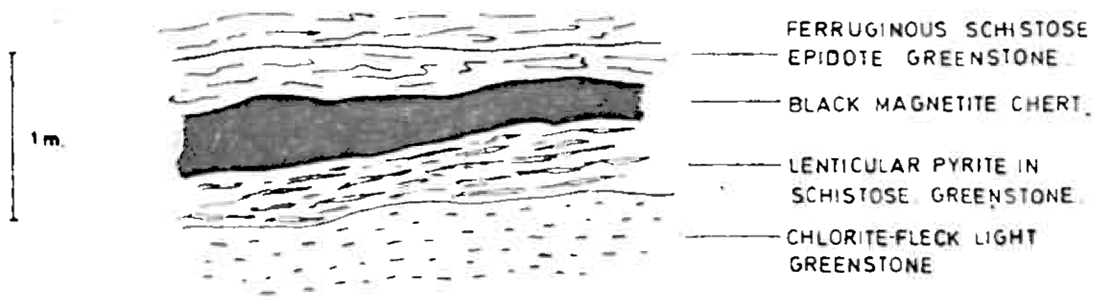
SECTIONS OF EXHALATIVE ASSOCIATED HORIZONS.

Fig. 2.

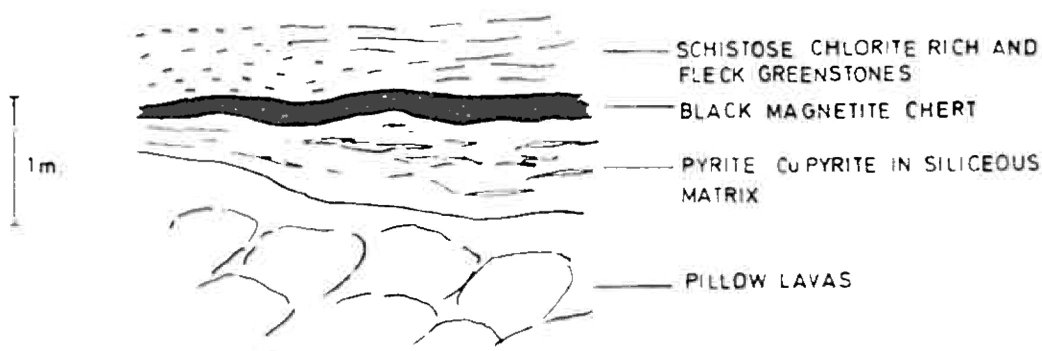
a) Y. 2350 X. 67730



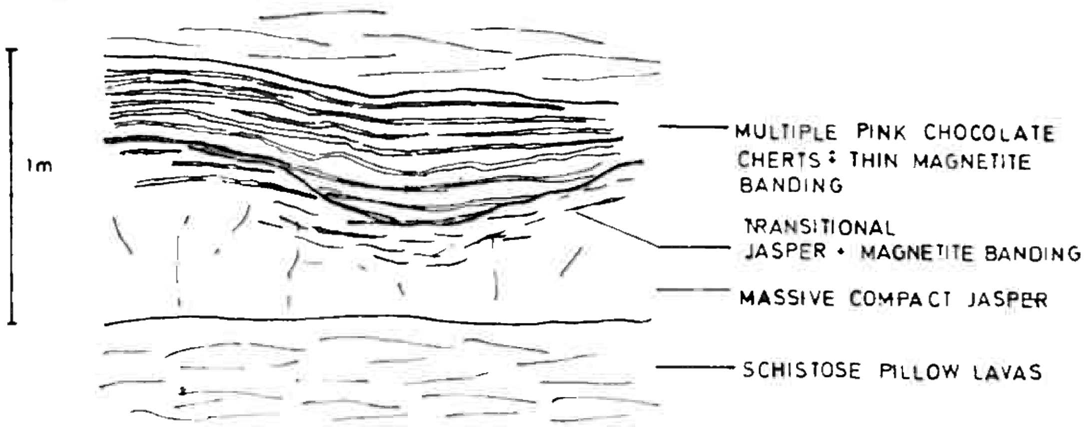
b) Y. 4810 X. 68230



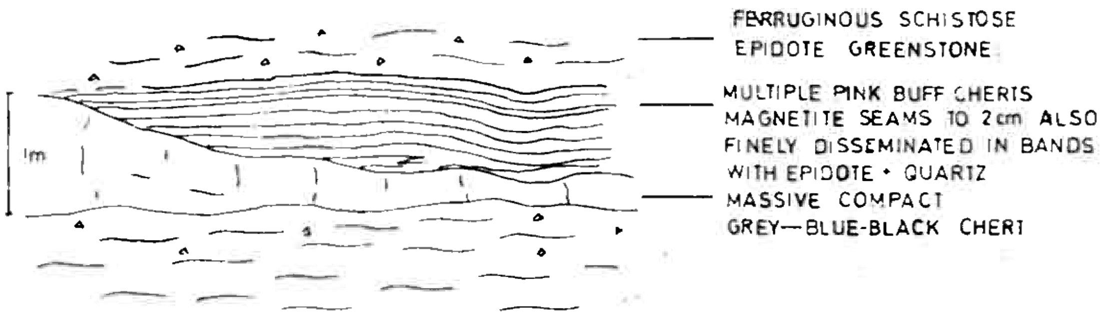
c) Y. 2300 X. 67490



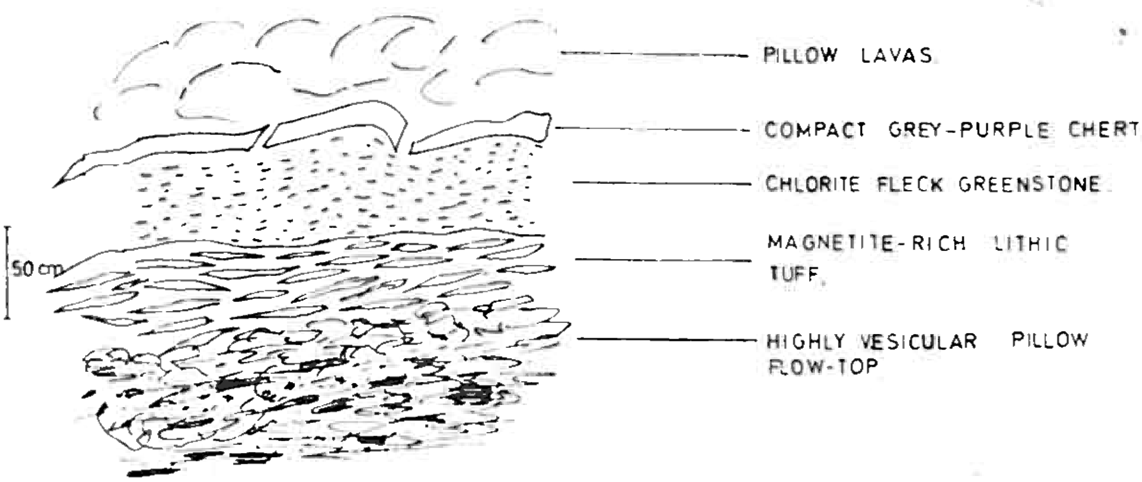
d) Y.3000 X.66930



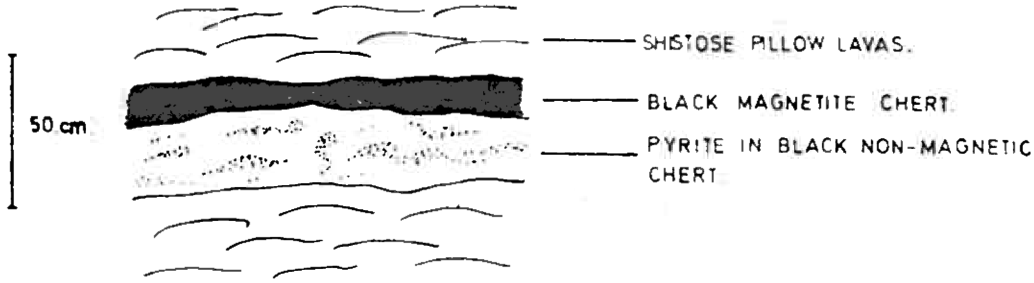
e) Y.4700 X.68940



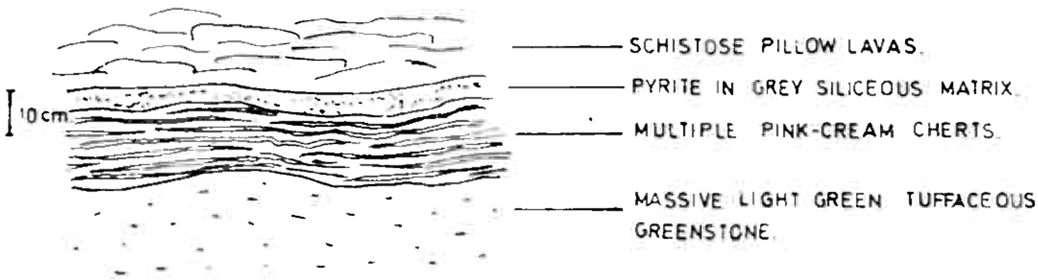
f) Y.4950 X.69150



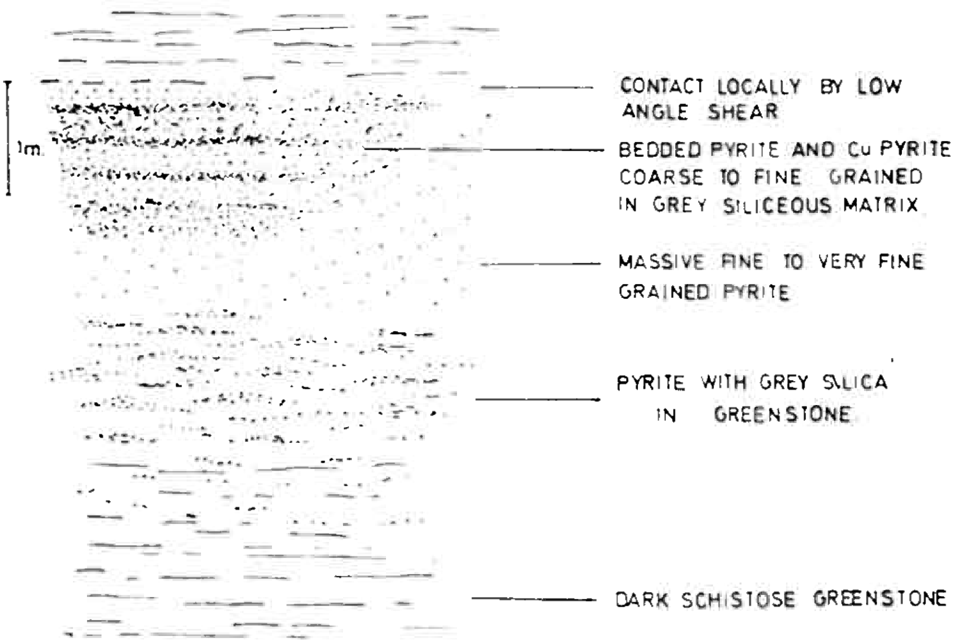
g) Y.5940 X.66970



h) Y.5120 X.66510



i) Pyrite showings at Finnkjerringhullet Skjerp
Y.6010 X.68090.



IV INTRUSIVES

i) Metagabbros

Undoubtedly the earliest intrusives are of gabbroic composition, being intruded pre f_1 and f_2, occurring as small lenses and discontinuous stratiform sheets less than 300 m in length, outcropping randomly in the greenstones at or below the main complex intrusive sheet horizon; while in that part of the intrusive sheet west of Nesåflyen and south of Vestre Overste Nesåvatn, gabbro occurs extensively, having a complex relationship with later Trondheimites, The intrusive zone west of Nesåflyen has been described by Scott (1973), whose treatment is satisfactory, thus this will not be repeated.

The gabbros, now represented by dark hornblende-feldspar medium to coarse-grained rocks, with local pegmatitic facies, appear to be of similar composition throughout the area. A crude planar fabric may be developed.

Contacts with the greenstones are sometimes relatively sharp, but often it appears that gabbroic fluids have stoped or permeated the greenstones. This is indicated by contact zones with variably developed gabbroic texture including relict greenstone structures including pillows. West of Østre Soettecuol the transitional zone between greenstone and gabbro is about 75 m thick. In other areas, around small gabbroic bodies, the zone varies from 0 to 0,5 m. Locally gabbro/greenstone contacts are of low-angle shears. Minor pyritic impregnation is not uncommon near the contacts.

ii) Trondheimites

The Trondheimites and related minor intrusives were intruded pre-f_1 and f_2. The bulk of Trondheimitic rocks occur as the greater component of the complex intrusive sheet, being fine to medium-grained rocks which are often of an epidotised feldspar-chlorite-actinolite-quartz assemblage. A crude planar fabricis occasionally developed. Pyrite is also locally present.

West of Nesåflyen, the Trondheimites are intruded into the gabbro of the complex intrusive sheet, where they have often formed a transitional rock with the gabbro, termed by Foslie "silicified gabbro", essentially ranging from a quartz gabbro to a mafic Trondheimite. Contacts between Trondheimite and gabbro are thus often completely gradational. This phenomena has been accurately described by Scott (1973).

East of Nesåflyen, the Trondheimite has apparently heavily veined and often silica-saturated the greenstones above its upper contact, forming greenstone "hybrids" which are very similar in appearance to the Trondheimites on weathering surfaces. The zone of influence extends for a thickness of approximately 1 km, extending to the sediment contact in the southern uplifted block south of Kronglefjell.

In a more acid Trondheimite minor intrusion north-east of Nesåklumpen, stoping of the greenstones is clearly shown by the extension of a compact red-chert horizon across the greenstone/intrusive contact to 50 m inside the intrusive, which has diluted the cherts to a light pink colour.

iii) Minor acid intrusions

Minor "acid" intrusions occur in every horizon of the greenstones in the area.

They may be sub-divided into:

a) Those of apparently keratophyric or quartz-keratophyrid composition.
b) Those of Trondheimitic composition.

a)

The dyke-rocks vary in colour from light buff-brown to grey-white, are a cherty appearance and fracture. Texturally the rock is fine-grained and may often have a quartz-porphyritic facies irregularly and gradationally associated. Certain dykes are pyritic, with minor pyritic impregnation of the host greenstones. This is a common occurrence to the south and west of Trolltjönna. In one locality for example (Y. 1.460, X.68.740) pyrite content is approximately 3 - 4 %, about 5 - 10 % of which is cupriferous. Maximum grain size is 1 mm in a pink-grey glassy groundmass also containing quartz phenocrysts to 1 - 2 mm. To the west along strike an extensive gossan is developed around a similar body (Y. 2.470, X. 68.495). The host greenstones are of massive epidote-rich type, which have apparently been locally silica-permeated by the dyke material. At certain localities very near that mentioned above, a crude grading from greenstone to quartz-porphyritic and non-porphyritic dyke material takes place over 12 - 15 cm, this zone having a glassy appearance of variable homogeneity.

Further south, higher into the greenstone sequence and into the lower pillow unit, quartz-porphyritic massive dykes are intimately associated with thin crudely schistose keratophyric flows which are locally quartz porphyritic. It is evident that at least locally, the dykes are of high level crystallisation.

Quartz porphyries also occur north of Neskålumpen, where they are near-stratiform.

The minor "acid" intrusives vary greatly in thickness both individually and laterally.

Minor intrusions of evident Trondheimitic composition occur widely, noteably at or above the horizon of the complex intrusive sheet.

Minor pyritic impregnation is not uncommon at or near the contact with greenstones.

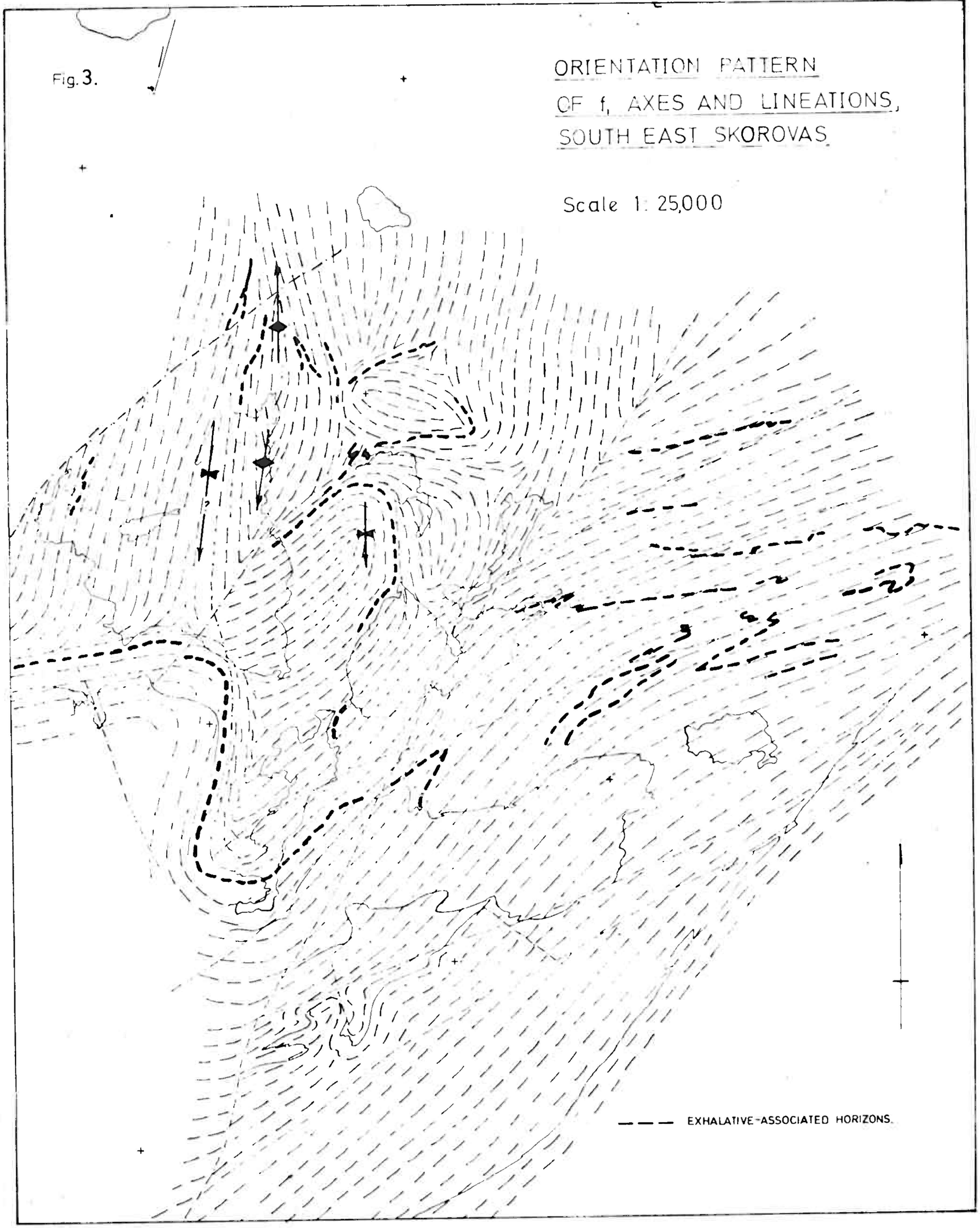
It is interesting that Trondheimitic dykes occur within the conglomerates near their contact with the greenstones.

CONGLOMERATES

The conglomerates have an erosion-surface contact with the greenstones, which is often fractured along f_1 planes and locally complex due to combined f_1 folding and shearing. Where the conglomerate sequence has a "normal" stratigraphic contact with the grennstones, a fine clastic facies is commonly found which appears essentially an in situ-erosion and deposition greenstone sediment. Two other distinctive conglomeratic facies are a) coarse polymict conglomerate, which makes up the bulk of sediment in the area and b) a facies containing fine sediment with graded bedding and cross bedding, including horizons up to 30 cm of coarse-clastic conglomerate. The latter facies is only locally developed.

It is most interesting to note that, south-east of Svartberget and in other localities, acid minor intrusives of apparent Trondheimitic composition vein the conglomerates, indicating Trondheimitic intrusive activity to have occurred after the orogenic phase exposing the submarine lava pile and resulting in the deposition of clastic sediments.

Fig. 3.


ORIENTATION PATTERN
OF f, AXES AND LINEATIONS,
SOUTH EAST SKOROVAS
Scale 1: 25,000
EXHALATIVE-ASSOCIATED HORIZONS.

V STRUCTURE

Three phases of folding are distinct in the area, two being major folding episodes, together with the latest folding of shear type associated with fracturing. Evidence for a possible third important folding episode will also be discussed.

i) f_1 Phase

It is clear that the major period of regional metamorphism occurred during the f_1 phase of deformation, resulting in the impression of a strong but locally variably developed schistosity trending approximately 067°, dipping south-eastward at 35° - 50°, seen in that part of the area not strongly affected by later folding. The f_1-fold style is of isoclinal mixed similar or shear type, although to the west of Østre Overste Nesåvatn, further inside the structural zone of influence of the enveloping complex intrusive sheet, f_1 folds have been flattened and often sheard along limbs. This is evidently the result of compensation and re-orientation due to the f_2 phase together with major fracturing. The western half of the area is clearly a volume of relatively high a complex stress pattern. Fig. 3 demonstrates this.

In the area mapped, three orders of f_1 fold are recognised.

F_{1a}: $\lambda > 100$ m
F_{1b}: $\lambda <$ 100 m $>$ 1 m
minor folds $\lambda <$ 1 m

F_{1a} probably have an upper limit of λ = 1 km, though this is difficult to prove.

Fig. 4, a section from Trolltjönna through Svartberget to the conglomerate contact shows F_{1a} folds. In the field, this order is recognised by the attitude of pillows through extensive stratigraphical horizons and by gross changes in attitude of exhalite horizons.

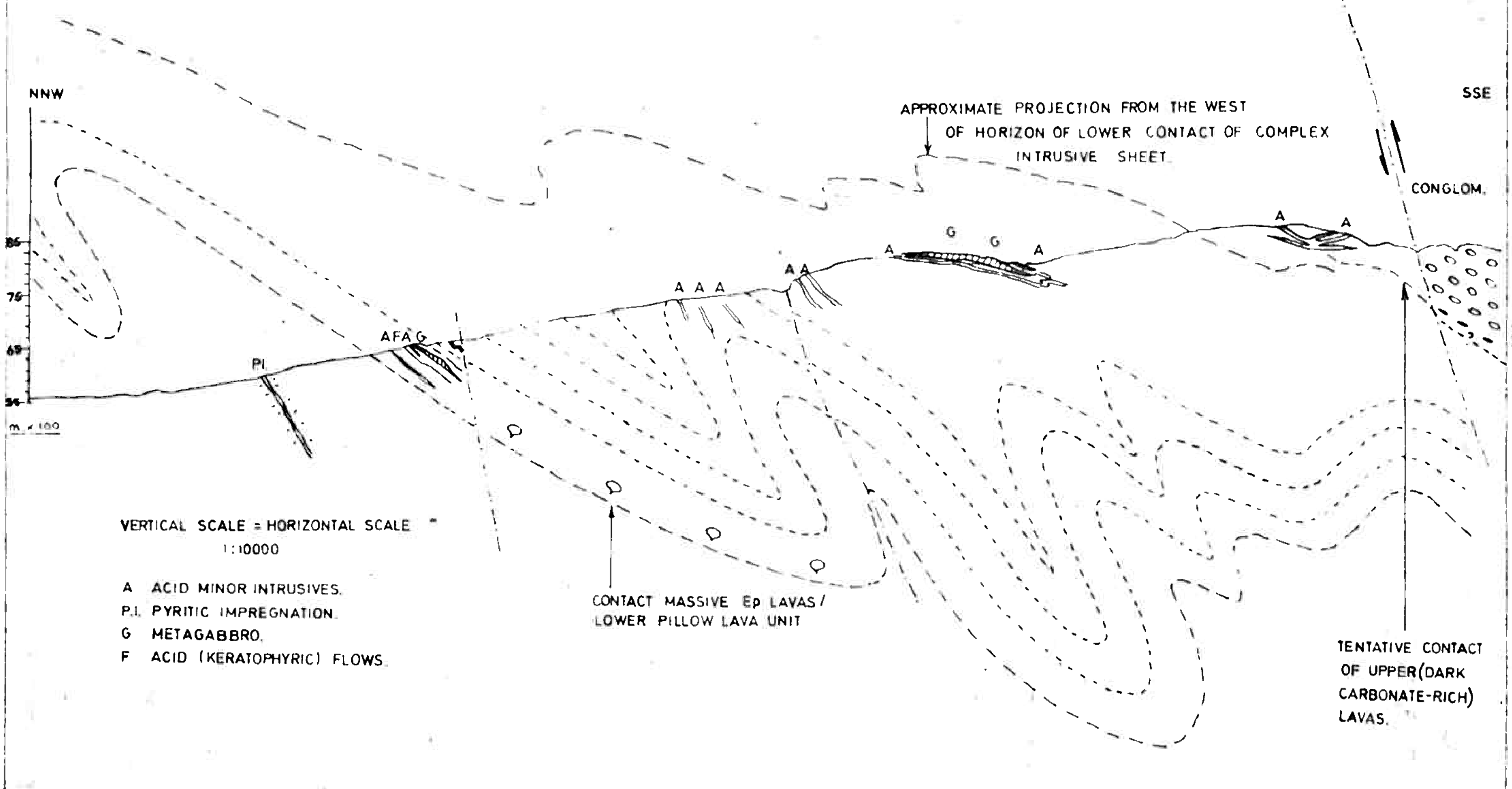
Well developed F_{1b} folds are recognised in many localities including (Y. 3.450, X. 67.900; Y. 5.500, X. 67.830) and south of Vestre Overste Nesåvatn, where the locally extensively developed exhalite horizon is multiple folded by 4 - 5 F_{1B} folds which appear to be a major part of re-orientated F_{1A} antiform.

ii) f_2 phase

The f_2 phase consisted of relatively broad folding on axes trending approcimately 045°, plunging south-west at intermediate angles. Only relatively large scale f_2 folds occur in the area, with λ of the order of 0,5 - 1,0 km.

The f_2 phase appears to be more strongly developed in those volumes closer to the complex intrusive sheet, the relatively competent sheet acting as a pincer-like stress concentrator. Within the volume enveloped by the intrusive sheet, f_1 folds have been re-oriented to trend in a predominant north-south direction north of Vestre Overste Nesåvatn, Nesåklumpen and in the large f_2 antiform around Nesåflyen. On Nesåklumpen itself, and south toward Östre and Vestre Overste Nesåvatn, the f_1 pattern has been made complex by interference, resulting in domal or basin-like f_1 surfaces plunging south and south-west. Vestre Overste Nesåvatn is situated within a broad f_2 basin-like structure where f_1 structures plunge into the lake area from the north and east, and south-south-west

Fig. 4. SECTION TROLLTJÖNNA—SVARTBERGET
(Y.1570 X.69210)—(Y.0900 X.66590)



from the southern and south-west lake area. North of Nesåklumpen and the north-east tip of Vestre Overste Nesåvatn, f_1 structures plunge northward.

This reverse in plunge direction which takes place along a line trending approcimately 100º may be due to a third fold phase, or may be part of a culmination-depression type of f_2 folding, since it is not developed elsewhere. To ascertain which origin is correct would involve study of the area north and north-west toward the mine.

iii) Fracturing

Four groups of fractures are recognised:

a) Trending 065° - 070°, dipping south-east at 55° - 70° (tending parallel to the f_1 trend)

b) Trending 035° - 045°, predominantly vertical (tending parallel to the f_2 trend)

c) Fractures of extent 1 km or less, clearly second-order to (a).

d) Low-angle thrust-like fractures often locally occurring at or near greenstone/intrusive contacts.

a)

Many fractures do not have recognisable displacement greater than the order of a few 10's of metres, most of which have less than 10 m. horizontal displacement. However, an anomalous reverse fracture zone south of Kronglefjell has down faulted an extensive slice or elongate block to the south by approximately 1.200 m vertical.

b)

These fractures, which may extend up to 10 km, do not appear to have horizontal displacements greater than 10 - 50 m. Vertical displacement is difficult to ascertain. Associated with these fractures are compact breccias locally reaching 5 - 10 m thickness.

The nett effect of the fractures on outcrops is greatest in the west and north-west, where f_1 structures have been re-oriented to be relatively flat-lying.

It appears that fracturing of a limited nature may have first taken place during the f_1 phase along intrusive/greenstone contacts locally, perhaps together with a build-up of stress by flexural slip along other anisotropies in the greenstones, such as dyke/greenstone or compact chert/greenstone contacts or calcareous horizons within the sediments.

Freacturing appears to have taken place after a'freezing' of the stress direction with the onset of brittle-rock properties after the f_2 phase, resulting in the extensive vertical fractures trending close to the f_2 trend. During this fracturing period, compensation by diagonal slip along f_1 planes, possibly utilising early-established high-stress horizons, resulted in those fractures trending close to f_1 together with second-order minor fractures influenced by both the f_1 and f_2 trending fractures. Concurrently, it is likely that pre-existing small-scale thrust features were re-activated. The occurrence of a singel dominant period of fracturing in several structure-lithology controlled trends is also inferred by the general minor displacing influence between fractures.

The high displacements observed in the south and south-west may well due to slip on f_1 planes where the greenstones approach the hinge zone of a combined f_1 - f_2 fold.

iv) Tentative regional structure

Sections across the area indicate:

a)

A sheet dip of F_{1A} and F_{1B} folds to the south from the Trolltjönna locality.

b)

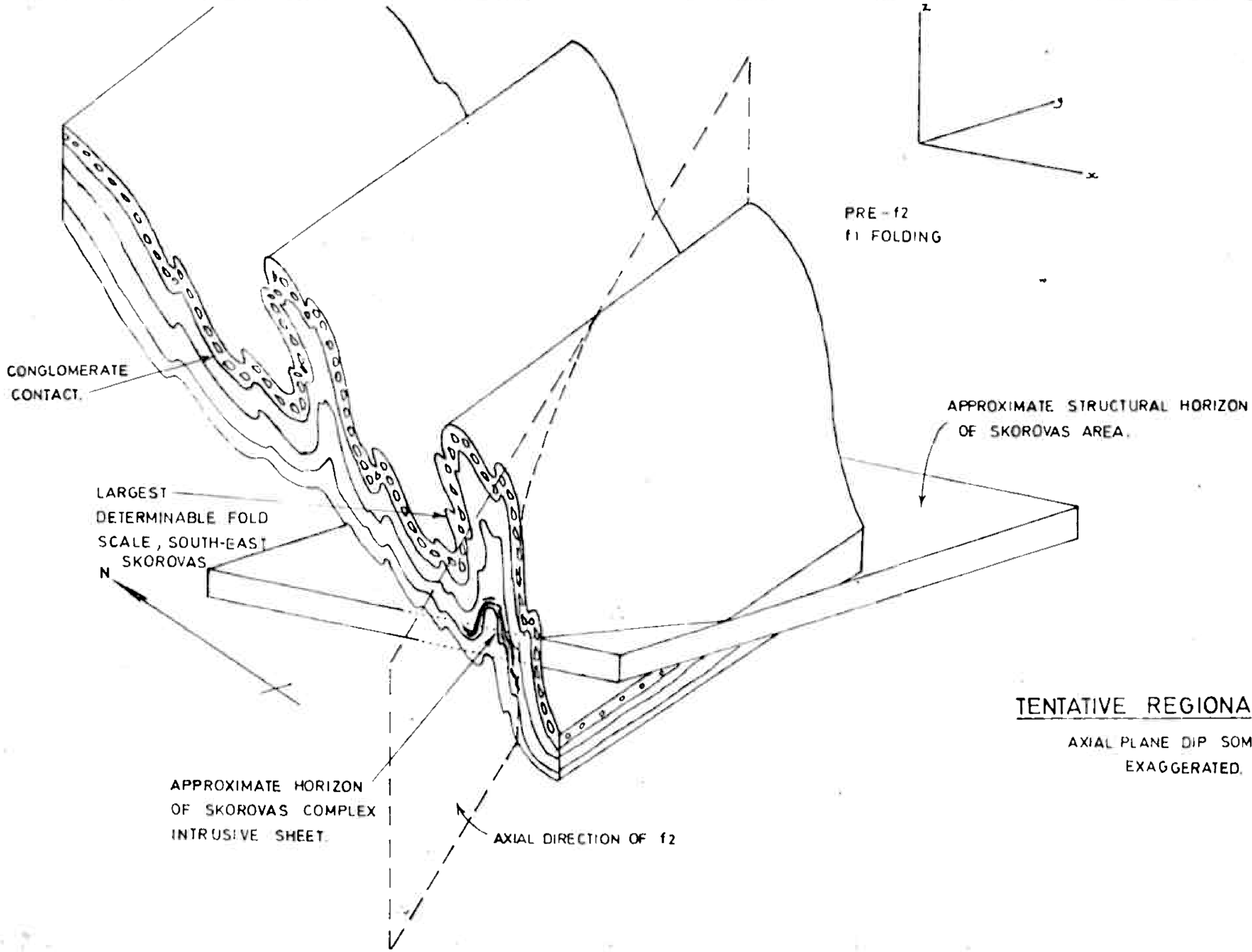
That the intrusive sheet is an enveloping complex body

c)

Minor acidic intrusives occur almost universally, but roof-zone type silica-permeation of greenstones is restricted to the southern or upper contact of the intrusive sheet, indicating this region of the intrusive to be the correct way-up and inferring the intrusive continuous from Skorovas eastward to be inverted if the intrusive is considered a complex multi-lithological laccolithic body which was originally strati-form or almost so.

This leads to the intrusive outcrop delineating an original large scale f_1 antiformal fold as part of a larger south-dipping sheet-dip system, with increasing age of lithologies and possibly metamorphic grade to the north of Skorovas. This major f_1 fold would have been modified by a flattening of its westward-pointing nose and part of the northern limb, and given a relatively strong south-westerly plunge by f_2 folding, so as to produce an outcrop very similar to that observed.

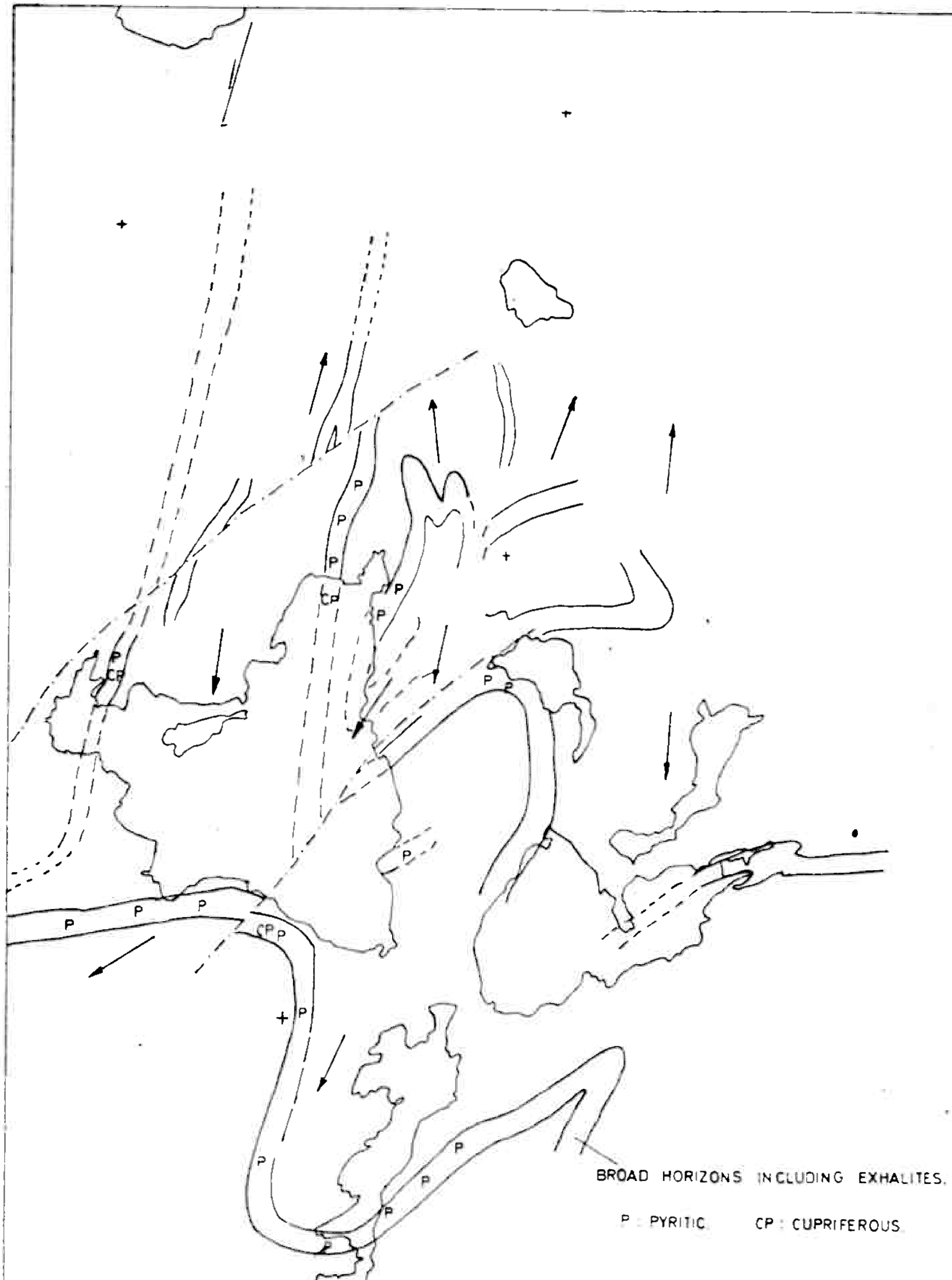
Fig. 5 demonstrates this tentative regional structure, though it is important to note that the folded limb shown may be interpreted as the upper limb of a large nappe structure if the large-scale folds shown are of Z assymetry instead of S. Which type of assymetry occurs is of course impossible to determine in the relatively small area mapped, as either structure would result in the same lithological pattern and younging trend in the area.



TENTATIVE REGIONAL STRUCTURE

AXIAL PLANE DIP SOMEWHAT EXAGGERATED.

Fig. 5.



RELATION OF EXHALITES AND MINERALISATION TO STRUCTURE.(simplified)

Fig.6

VI CONCLUSIONS AND POSSIBLE FUTURE INVESTIGATION

The stratigraphy of the Havdalsvatn - Ingulsvatn area mapped in 1973 (White, 1974) may be projected into the area mapped in 1974. The greenstone units young continuously over a structural-dip-section across the eastern half of the area, evidently being part of a south-easterly dipping, south-westerly plunging sheet-dip system of isoclinal folds of several orders. To the west ~~east~~ of the area, within the volume apparently encompassed by the complex intrusive sheet, structure becomes relatively complex as the effects of a major f_2 phase become apparent; the f_2 phase being more or less coaxial in the extreme east and area mapped in 1973, while axially inclined at approximately 20° to the f_1 axial direction over the majority of the area mapped in 1974. Similarly, fracturing at angles to the f_1 trend increases rapidly westward, although the majority of fractures appear to be of minor displacement. The occurrence of exhalite horizons appears to be increased in the area mapped in 1974, although this is no doubt attributable to increased repetition due to the relatively strong interfering effect of the f_2 phase in the area. The chemical variation in the greenstones has not yet been ascertained.

It is apparent that the equivalents of the greenstones of the mine area outcrop repeatedly in the west of the area, noteably around Vestre Overste Nesåvatn and Nesåklumpen, and further north due to the effect of f_2 folding combindes with f_1. Further east, equivalent greenstones occur in the Lower Pillow Unit extending toward Havdalsvatn in the mid-south of the area. To the north of the area, equivalent greenstones in all probability extend from the zone north of Nesåklumpen in a north-eastward trend toward the northern outcrop of the Trondheimite sheet.

Thus possible areas for future detailed investigation include the area to the north and north-east of Nesåklumpen; with possible core-drilling in and on the eastern flank of Vestre Overste Nesåvatn, as it is apparent that greenstone equivalents of the mine horizon extend in a basin-like structure beneath the lake. Greenstone equivalents in the mid-southern and mid-south-eastern area are in relatively steeply dipping structures, while outcropping pyrite mineralisation is generally weak.

I. Ferriday.

September 27, 1974 I. L. Ferriday

VII BRIEF DESCRIPTION OF GREENSTONE SPECIMENS AND LOCALITES

Colour classification using G.S.A. standard range where e.g. in 5G. 6/1, "5" represents divisjon 5 in a certain hue where 1 and 10 are the boundaries of that hue; "G" represents the hue (= green or (green + variable white to black)); "6" represents a light valve of 6 in a scale of 10 where 1 = black, 10 = white; "/1" represents a valve of 1 in a scale of colour stauration where 1 is least saturated i.e. most white or greyish.

1.	"Pale green greenstone"	Y. 1.950, X. 67.480. 5G. 6/2 massive	(G.13)
2.	"Dark bluish-green grey"	Y. 5.900, X. 68.360 5B 6/1 crude-schistose	
3.	"Medium green-grey"	Y. 5.540, X. 68.170 5G. 5/1 massive, small chloritic clumps. pyrite + carbonate.	
4.	"Dark green-grey"	Y. 5.670, X. 68.470 5G. 4/1 crude schistose.	
5.	"Dark green-grey"	Y. 6.020, X. 68.440. 5G. 4/1 massive pyrite + magnetite + (carbonate).	
6.	"Very dark green-grey"	Y. 1320, X. 67.780. 5G. 3/1 schistose (carbonate)	(G.11)
7.	"Medium green-grey"	Y. 2.440, X. 66.450 5G. 5/1 schistose (carbonate), chloritic clumps.	(G.10)
8.	"Medium green-grey"	Y. 3.270, X. 66.080 5G. 5/1 massive carbonate + pyrite.	(G.9)
9.	"Green-grey"	Y.1.030, X.66.630 5G. 6/1 schistose siderite rhombs + pyrite	(G.8)
10.	"Dark green-grey"	Y. 1.930, X. 65.720 5G. 4/1 massive amygdaloidal carbonate + pyrite	(G.7)

11. "Very dark green-grey"
Y.4.220, X. 6.856
5G. 3/1
massive
(carbonate)

12. "Dark green-grey"
Y. 1.300, X. 67.850 (G.1)
5G. 4/1
schistose
(carbonate)

13. "Dark green grey"
Y. 2.390, X. 66.120 (G.6)
5G 4/1
massive amygdaloidal
epidote + (carbonate).

14. "Medium-dark green-grey"
Y. 4.450, X. 68.530
5G. 4-5/1
crude schistose, fine siliceous seams.
pyrite + (carbonate)

15. "Green-grey"
Y. 2.350, X.66.320
5G. 6/1
schistose
(pyrite + magnetite + carbonate)

16. "Medium-grey-green"
Y. 5.055, X. 68.930
5G. 6/1 - 5G. 5/1
massive
high concentration of chloritic
clumps

17. "Dark to very dark green-grey"
Y. 4.910, X.68.600 (G.15)
5G. 3/1
schistose

18. "Medium green-grey"
Y. 1.335, X. 67.710 (G.16)
5G. 4-5/1
massive
small chloritic clumps

19. "Dark to very dark green-grey"
Y. 1.680, X. 66.170
5G. 3/1
crude schistose vesicular
pyrite + (carbonate).

20. "Dark green-grey"
Y. 2.690, X. 64.620
5G. 3-4/1
crude schistose
pyrite

21. "Dark green-grey"
Y. 4.700, X. 67.300
5G 4/1. (matrix)
schistose
matrix contains lenticular
magnetite-cherts

22. "
metrix locally relatively strongly
pyrite

22. "Dark green-grey"
Y. 5.170, X. 69.510 approx (G.12)
5G. 4/1
massive
pyrite.

THE GEOLOGY OF SOUTH-EAST SKOROVAS.
1:10,000
Olatjern
Trolltjönna
Nesaklumpen
Finnkjerringhullet skjerp
Vestre Överste Nesåvatn
Östre Överste Nesåvatn
Östre Sættecuol
Nesaflyen
Svartberget
763
Kronglefjell
Y 7000
X 69
X 68
67
66
65
X 64000
Y 0
X 69
UPPER UNIT.
LOWER PILLOW UNIT.
MASSIVE UNIT.
CONGLOMERATES
Py IMPREGNATION
ZONE OF INTENSE VEINING + SHEARING.
ZONE OF SILICEOUS PERMEATION.
HORIZON OF COMPLEX TRONDHEIMITE / GABBRO SHEET.
WITH LOCAL MINOR PYRITIC IMPREGNATION.
FLOW TOP HIGHLY VESICULAR
EX. HOR. ± PYRITE, MAGNETITE
LITHIC TUFF.
CHLORITE-FLECK-PYROCLASTIC.
EXHALITE HORIZON
± COMPACT CHERTS
Fe MINERALISATION VARIABLE.
Cp. CUPRIFEROUS PYRITE
QUARTZ-PORPHYRY AND THIN KERATOPHYRIC FLOWS.
KERATOPHYRE, QUARTZ-PORPHYRY WITH LOCAL PYRITE IMPREGNATION.
METAGABBRO.
COARSE POLYMICT
FINE ; GRADED OR CURRENT BEDDED.
CALC-RICH ?PILLOW LAVAS.
SCHISTOSITY CRUDE TO GOOD.
COMMONLY RICH IN CARBONATE n.b. SIDERITE
ALSO PYRITE IMPREGNATION.
CALC LAVAS WITH PILLOWS WELL DEVELOPED TO HIGHLY FLATTENED.
CALCITE LOCALLY HIGH
EPIDOTE IN PILLOW CUSPS AND KNOTS.
THIN VARIATIONS SCHISTOSE, VESICULAR.
CONTAIN BULK OF EXHALATIVE HORIZONS + PYROCLASTICS.
EVIDENTLY CONSTITUTING SEVERAL FLOW-PILES.
MASSIVE FINE-GRAINED UN-PILLOWED CALC LAVAS.
EPIDOTE HIGHLY ABUNDANT IN KNOTS, STRINGS, AMYGDALES AND BOX-VEIN STRUCTURE.
STRIKE & DIP OF PRIMARY CLEAVAGE.
FRACTURE.
(PYRITISED).
0
0.5
1.0 Km.
GEOLOGY OF SOUTH-EAST SKOROVAS.
Målestokk
1:10,000
Tegn.
I.F.
Trac.
Kfr.
Erstatning for:
Erstattet av:


STRUCTURE and NATURE OF EXHALITE HORIZONS.
Olatjern
Trolltjönna
Nesåklumpen
Finnkjerringhullet skjerp
Vestre Överste Nesåvatn 722
Östre Överste Nesåvatn
Svartberget 886,9
763
Östre Sættecuol
Nesåflyen
Kronglefjell
Čevoker 783,9
Y 7000
69
68
X 67000
67
66
65
X 64000
EXHALATIVE MINERALISATION
pyrite
cupriferous pyrite
magnetite:
fine disseminated
fine seamed
fine multiple banded
multiple ferruginous exhalite
compact siliceous horizons:
grey - black
pink - red
indicate minority relative to other components
STRUCTURES : f1
primary cleavage
" with plunge
fold axes (λ < 1m.)
synformal axes (λ > 1, < 100 m.)
" (λ > 100 m.)
boulder elongation
" f2
synformal axes
fracture
folds associated with fractures
SCALE 1:10,000
0
0,5
1,0 Km.
Antall
Gjenstand
Nr.
Material
Anmerk.
STRUCTURE and NATURE OF EXHALITE HORIZONS.
Målestokk
1:10,000
Tegn.
I.F.
Trac.
Kfr.
Erstatning for:
Dato
Forandr.
Elkem-Spigerverket a/s
Skorovas Gruber
Erstattet av: