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Contribution to the Grong Project

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GEOLOGICAL REPORT

FINNKRUDÅMA - NESÅPIGGEN

Contribution to the Grong Project.

October 3rd 1975

Ian L. Ferriday

CONTENTS

2. STRATIGRAPHY

Lower massive lavas.

The stratigraphically lowermost 'greenstones' occurring in the area, predominantly underlying acid flow, pyroclastic and exhalite material, consist of relatively dark but intermediate lavas. The lavas are typically relatively epidote-rich, both in groundmass and in fine fracture fillings, and locally epidote vesicular. No groundmass carbonate is evident, while carbonate may rarely occur in late fracture filling. Colour may vary, but is generally a darkish green grading to a bluish hue as groundmass magnetite content increases, this 'greenstone' lithology apparently being relatively enriched with respect to the latter. The lithology has a variably developed fine homogeneous granular texture, macroscopically identical to basaltic-andesites ('andesitic greenstone') occurring beneath the Skorovas orebody (Company Report: Southern Main Orebody: I.F. 1975), and it is both mineralogically and texturally evident that the lithologies are correlateable. The lithology forms relatively massive-looking, smooth exposure surfaces, having no recognisable pillow structures.

It is evident for structural reasons that this 'greenstone' lithology has relatively little outcrop area in the area mapped. The lithology is most exposed to the north-east of Tredjevatnet, and is also sporadically exposed beneath, and laterally in contact with, exhalative mineralisation over the entire area.

Acid flows.

Acid flow material is generally restricted in occurrence to two paralleltrending, stratigraphically cohorisonal belts, i.e. a northern belt including the northern Finnkrudåma and west to north-west Tredjevatnet mineralised zones; and a southern belt extending from Nesåfoten to the Nesåa mineralised zone to the west and thence toward the trondhjemites around Midtre Nesåvatn summit. No strong fundamental lithological differences exist between the acid flows of the respective belts, although 'keratophyric' flows occurring in the northern belt are locally pyrite-impregnated.

Acid flow material is variable in an apparently irregular manner between quartz-porphyry, having a fine-grained quartz-feldspar groundmass, to fine-grained variably fine-feldspar-porphyritic dacite to relatively aphanitic, locally quartz-porphyry 'keratophyre', which commonly weathers to a buff colour rather than white to light-grey which is typical of the former facies. Quartz porphyry and dacite flow material easily form the bulk of acid flows in the area, while quartz porphyries are slightly more abundant than dacites.

Acid flow material certainly predominantly occurs stratigraphically underlying acid to intermediate, variably textured pyroclastics, but in a natural manner may laterally occur having upper contacts with pillow lavas, feldspar porphyritic intermediate to basic flows, or facies of exhalite horizons. Acid flows may also locally contain fragmental material (e.g. X64060 Y7230).

1. INTRODUCTION

Geological mapping was carried out in 1975 from July to September in the Finnkrudåma - Nesåpiggen area at a scale of 1:10.000 based on photogrammetrically derived maps. The northern limit of the area is approximately 6 km due south-west of Skorovas mine and is continuous to the north-east with the mapping area of 1974. (South-East Skorovas report.)

Generally speaking, the area includes well exposed, greenschist metamorphosed extrusives, pyroclastics and exhalative mineralisation from dacitic to basaltic-andesite composition falling between the calc-alkaline and low-K tholeiitic provinces; together with, and almost surrounded in outcrop by, calc-alkaline intrusives are overlain by flysch sediments, the overall environment being part of an island arc system. The area is part of the Grongfeltet greenstone - gabbro- trondhjemite- flysch sediment belt of Nord Trøndelag of the Norwegian Caledonides, the work being a contribution to the Grongfelt project while based in Skorovatn.

The following report is based on field observations and all rock terminology is subject to analytical confirmation to be carried out at the Royal Scholl of Mines, London.

The workers of 1975, as in 1974, were A. Rankin, I. Ferriday and C. Halls.

Intermediate-basic porphyritic flows.

Flow and associated intrusive distinctly porphyritic material of intermediate-basic composition is restricted in outcrop to the northern Finnkrudåma - west Tredjevatnet belt. Flow material is variable from intermediate, an andesite porphyry, to basic, consisting of medium to coarse feldspar-hornblend porphyry.

Andesite porphyry is restricted to the vicinity of the Finnkrudåma skjerp zone and to Vestre Sættuǒuol and consists of 1-3 m.m. chlorite-replaced hornblend phenocrysts in a fine-grained light grey-green intermediate matrix.

Andesite porphyry material is apparently laterally gradational into variable feldspar- feldsparhornblende porphyry flow material toward the west shore mineralised zone of Tredjevatnet. The latter flow material is porphyritic from 1 to 10 m.m., phenocryst development having an inverse relationship to that of epidotic vesicles, which reach a maximum density in the south (X63600 Y7200) within relatively weak, fine porphyritic flow material. The latter feldspar porphyry, epidote vesicular flows are themselves gradational northward into a central, evidently vent proximal zone composed of epidote-poor, relatively coarse, feldspar-hornblend porphyritic flows containing abundant carbonate in fine vesicles; together with feldspar-hornblend porphyry feeder material. Feeder intrusives of the latter type extend north-eastward in the direction of Sættuǒuol and the Skorovas complex intrusive 'arc', where similar lithologies occur intimately within the varied gabbro facies (X66060 Y6440).

In the mineralised zone to the north-west of Tredjevatnet (X Y), flows are predominantly finer feldspar-chlorite replaced hornblend porphyritic. Typical of the porphyry material, the feldspar porphyritic flows in this zone underlie pyroclastics variable from fine acid ashes to lapilli tuffs and agglomerates which locally contain feldspathic fragments, and also locally fine angular jasperoid fragments. Thin fine acid tuffs or thin magnetic (<1 cm) cherts may occur within the porphyritic flows. Thus it is evident that in the west Tredjevatnet zone, a relatively complex multi-exhalative phase stratigraphy exists consisting of practically contemporaneous extrusion of porphyritic and acid flows, followed by further extrusion of both exhalative material (on a small scale) and feldspar porphyritic material, and terminated by deposition of compact magnetite-hematite bearing cherts. Carbonate rich pillow lavas stratigraphically overlie the latter horizon immediately north west of Tredjevatnet, while to the south, at the start of the Nesåa and north of Nesåfoten, the chert horizon overlying the feldspar-porphyry flows is stratigraphically overlain by carbonate poor pillow lavas having chert cusps.

Pyroclastics.

Pyroclastics vary both in acidity and texture in the area mapped. However, the most commonly occurring facies is of material containing lapilli-sized (0,5 to 1,0cm) clasts which are commonly enriched in magnetite. Lapilli-tuffs occur most voluminously associated with the southern acid extrusive belt, where the tuffs are distinct in weathering appearance from similarly textured lapilli tuffs occurring associated with the northern acid extrusive belt.

In the Nesåfoten - Nesåa belt, the lapilli tuffs occur predominantly stratigraphically above acid flows, but may also have basal contacts with, and be replaced by intermediate flows locally having clastic and lithophysal textures (X62980 Y7530). The lithophysal structures are developed at a horizon laterally continuous with the Nesåfoten and Nesåa mineralised zones to east and west respectively. The structures commonly resemble vesicles in shape, but are formed by skins, and are concentrated so densely that they are invariably in mutual contact. The texture is developed by extreme 'frothing' of fluid material, and the facts that (a): it occurs approximately at at broad culminative horizon i.e. of pyroclastic-exhalative mineralisation association and (b) that the facies contains clasts to ~ 10 cms, are testament to a vent proximal environment of formation where localities of concentrated ascension of volatiles existed. The paucity of directly associated exhalative cherts with this facies and the overall lack of coherent competent chert horizons over parts of the Nesåfoten - Nesåa mineralised zone is also evidence for the siting of an extrusive centre in the proximity of the former zone. This will be discussed further.

The lapilli tuffs of the southern belt are generally non-mineralised except for finely disseminated magnetite and local minor sulphidic impregnation. However where the horizon of tuffs has been exposed by structural repetition in the zone (X62900 Y8500), the facies contains pyritic impregnation on a relatively concentrated and extensive scale. This zone, termed the Nesåa mineralised zone, extends discontinuously in a north-west - south-east trend across the Nesåa. The mineralised pyroclastics evidently represent a vent proximal environment of deposition, where sorting of clastic material from Fe-laden solutions was not effected, or where already deposited tuffs have been saturated by ascension of Fe-bearing volatiles. Aphanitic keratophyric and quartz-porphyritic extensions occur associated locally. No trace of Cu is apparent, while the maximum volume of 'buried' impregnation appears to be $<$ m^3. North of the Nesåa, the mineralised tuffs are replaced by non-mineralised lapilli tuffs, which are themselves replaced by pyroclastics of coarser texture associated with magnetitic chert andathin horizon of relatively dense pyritic impregnation (X63600 Y8400).

As the Nesåfoten skjerp zone itself is approached (X63200 Y7200) the lapilli tuffs are replaced by fine acid ashes which to some extent act as host to local pyritic impregnation, the bulk of mineralisation at this locality being as massive, fine sedimentary-banded sulphides.

As has been stated, no lapilli-tuffs of the facies typical of the southern belt occur in the north-Finnkrudåma - west Tredjevatnet belt. In this case, pyroclastic material is variable from fine acid ashes,(similar to Nesåfoten), to lapilli tuffs and agglomerates consisting of $<$ 1 to 10cm acid clasts in an intermediate to acid tuffaceous matrix. Similar to the southern belt however, pyroclastic material lies predominantly stratigraphically above acid flow material, and stratigraphically below the horizon of deposition of exhalative mineralisation. Also similar to the southernmost pyroclastics, those in the north may laterally be in contact with underlying intermediate flows.

Pyroclastics of the northern belt are locally feldspar crystal fragmental, due to the relatively voluminous occurence of earlier feldspar porphyritic flow and intrusive material that occurs with this belt.

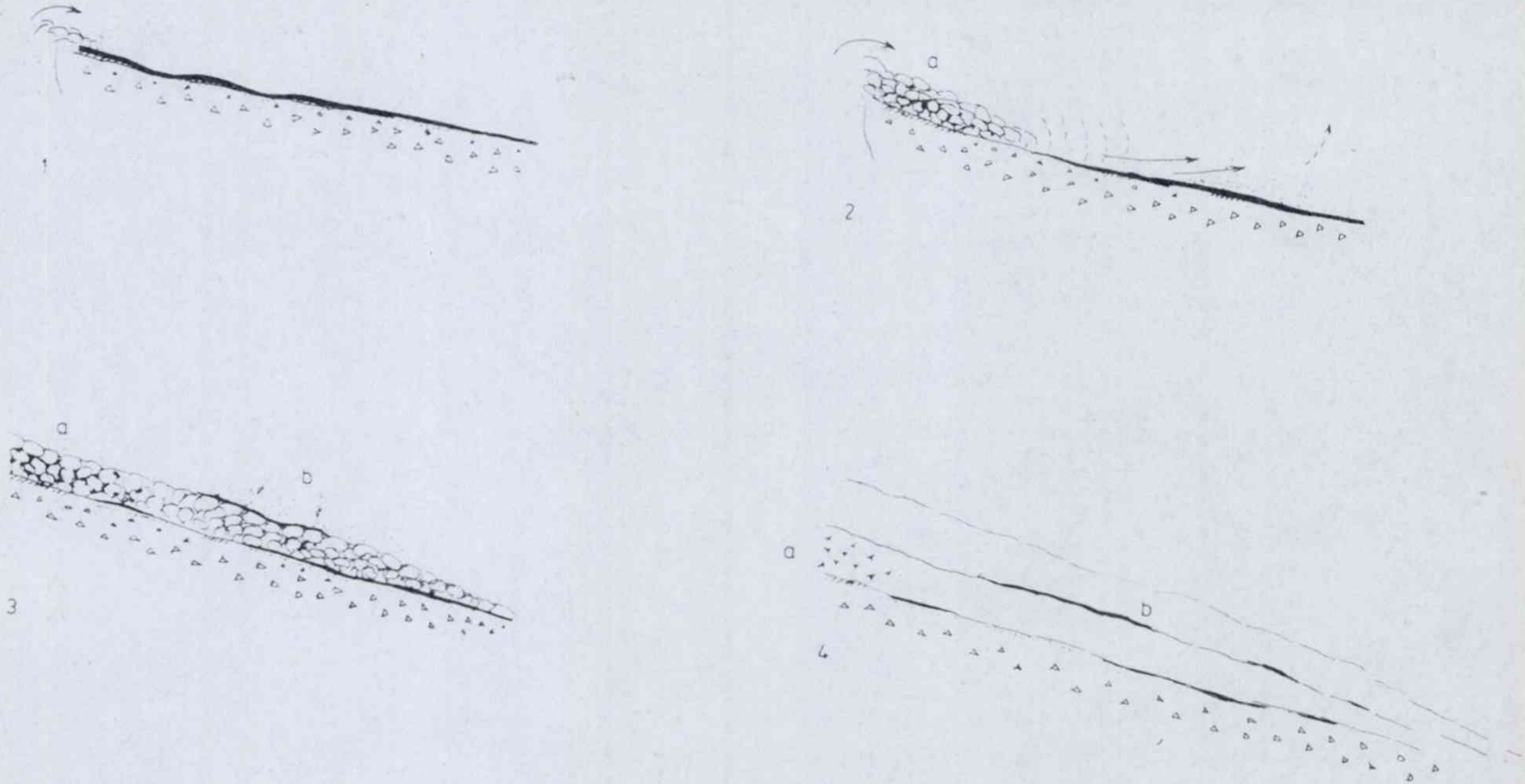
Exhalative mineralisation.

Two main belts of exhalative mineralisation occur in the area, both trending parallel to one another approximately N.W. - S.E., and swinging to a N.E. - S.W. direction towards Tredjevatnet and further east. Both belts are associated intimately with belts of acid extrusive material, and are stratigraphically cohorizonal. Associated pyroclastic material varies between the belts and the feldspar-porphyry intermediate flows associated with and underlying the culminative exhalite horizon in the northern belt is not present to the south, but no fundamental difference exists between underlying acid flow material of the two belts. Mineralisation in both belts is overlain by variable pillow to massive flows of general intermediate character. Between the belt outcrops, within the upper lavas, rolls and coherent horizons of exhalative chert occur, but with no evident pattern, this being due to primary distribution and subsequent tectonism, which will be discussed further on. The terminology and definitions of the 1974 Report On South-East Skorovas will be used in the following description and discussion on exhalative mineralisation in the area mapped.

The nature of exhalative mineralisation in the area is most variable with respect to both morphdogy and mineralogy. This is evidently due to a primary variation in the physico-chemical environment of the submarine deposition surface, governed largely, it is thought, by the siting of vent localities or localities of concentrated ascension of volatiles, in the relatively narrow time span leading up to and including deposition of Fe-bearing colloids over relatively large areas. According to primary concentration distribution and local relative 'strenghts' of reducate and oxidate facies, the former colloids are now represented by compact to relatively non-aphanitic cherts containing variable ratios of magnetite: hematite, usually tending to be underlain by a sulphidic facies which may have colloidal material, or fine acid to intermediate tuffaceous material as host.

Compact cherts: The compact cherts vary from hematite to magnetite rich to Fe-poor, deep red hematitic cherts predominating overall. They may occur with varying relationships with respect to underlying and overlying lithologies laterally, but certainly most commonly occur stratigraphically capping horizons of sulphidic impregnation which in turn overlie pyroclastics of variable texture which may be mineralised. Laterally, the cherts may occur with a basal contact against acid flows or early intermediate flows. This is to be expected with increasing distance from the vent, due to the considerable ease with which primary brines could be dispersed and distributed compared with coarser pyroclastic and lava flow material. Thus with increasing distance from the vent, it is to be expected that the cherts form a time-stratigraphic horizon actually crossing lithological boundaries but which nevertheless separates major eruptive cycles, with lithological assymetry across the exhalite horizon.

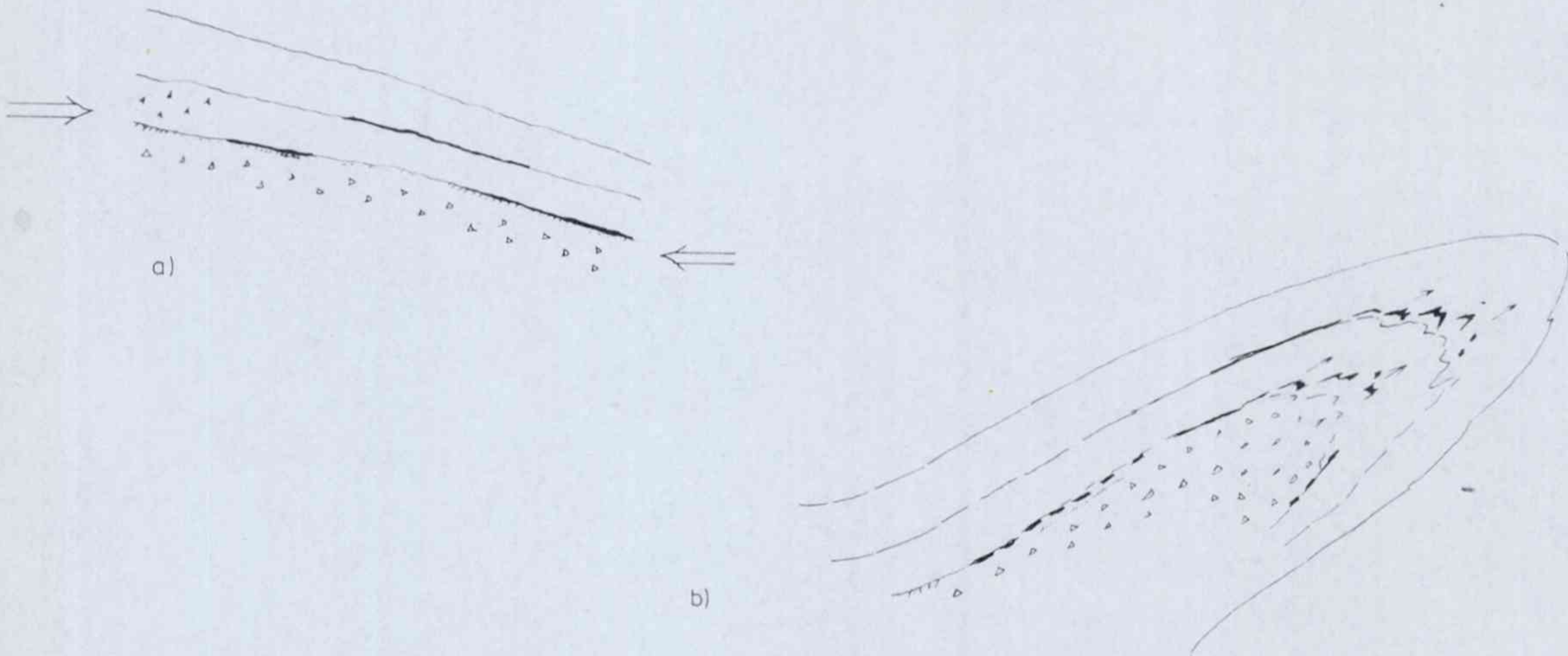
However, in the area mapped and also locally in the area of South-East Skorovas, coherent horizons of exhalative chert (unaccompanied by sulphides) occur without assymetry e.g. within the pillow sequence west of Tredjevatnet (X64200 Y8000).



Possible origins of cherts occurring within homogeneous pillow flows as cusps (a) or horizons (b)

Fig 1

I.F. 1975



Behaviourof compact exhalative chert during strong deformation

Fig. 2.

Such occurences are thought due to a redistribution of already deposited but unconsolidated colloids by strong current action as would be produced by submarine pressure waves travelling before an advancing later lava flow. At a particular, probably relatively extensive, distance from the vent, the lava flow could have ceased movement before the colloids began to re-settle, resulting in the eventual formation of a coherent but discontinuous chert horizon enclosed within the later flow pile. The lack of associated sulphides can be explained by the relatively strong oxidation that would result from redistribution. (See figs. 1. 1-4)

A somewhat similar process explains the occurence of compact cherts forming pillow cusps and skins in the pillow lavas stratigraphically overlying the Nesåfoten mineralised zone. In this case, redeposition of colloids has evidently taken place contemporaneously with pillow formation. Here also, no coherent chert horizon occurs overlying the sulphide mineralisation, this no doubt having been almost completely erased by, and to provide cusp material for, the later pillowed flows, which also evidently engrossed on the upper horizons of sulphide mineralisation as chert cusps locally contain pyritic impregnation. Such characteristics imply the proximal siting of a vent in the Nesåfoten - Nesåa belt. (See figs. 1. 1-4)

Blocks and isolated rolls and closures of compact chert may also occur in essentially homogeneous material, without apparent assymetry. In this case it is clear that the distribution is due to the great difference in mechanical properties and behaviour, under strong folding and associated shearing, between the competent cherts and other lithologies such as pillow lavas and pyroclastics. The latter lithologies will tend to flow around the relatively stable but bondinaged and dislocated compact cherts. (See figs. 2. a, b.) Thus, where deformation is strong and where compact chert occurs so distributed, the original nature of cherts, whether redepositional or not, is more difficult to ascertain. However, on a small scale, the proximity of pyroclastic and/or acid flow material can be reasonably conclusive of non-redepositional origin.

<u>Banded magnetite-cherts and T-bands:</u> Relatively non-aphanitic cherts containing relatively high magnetite content, having a distinct blackish appearance and frequent bluish tarnish, frequently crudely interbedded with fine magnetite-poor siliceous material, are distributed in an inverse relationship with respect to the compact cherts. Such cherts occur in the northern exhalative-acid extrusive belt sporadically around, overlying mineralisation in the Finnkrudåma skjerps; and overlying non-sulphide mineralised intermediate epidotic greenstones north-east of Čevoker where they occur at the erosive contact between effusives and arkosic sediments. These cherts have no outcrop in the southern (Nesåfoten - Nesåa) belt.

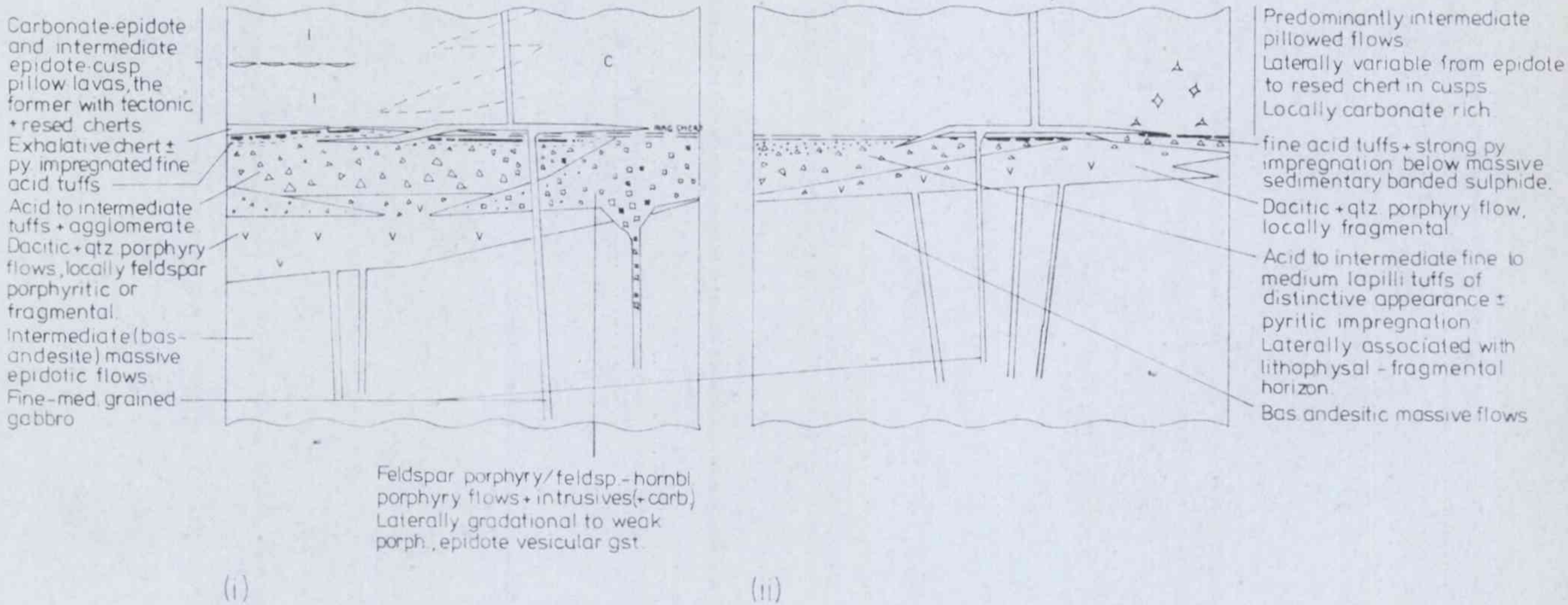
Development of T-band type of exhalative sedimentation is very rare in the area. At (X63150 Y7920) and (X63560 Y7290) such facies, consisting of finely interbedded magnetite-rich and magnetite-poor pink cherts occur.

<u>Sulphide impregnation and massive sulphides</u>: Relatively extensive occurences of sulphidic mineralisation are restricted to the belts of exhalite-acid intrusive material, and the nature and hosts of outcropping sulphide mineralisation vary widely over the area. Mineralisation of sulphides in the area is macroscopically pyritic, no Cu being evident.

Sulphidic impregnation occurs predominantly within fine grained acid ash or siliceous colloidal material e.g. Nesåfoten and north west of Tredjevatnet (X64580 Y7090), lying stratigraphically below the horizon of deposition of magnetite-hematite compact cherts. In the Nesåa zone, however, pyritic impregnation occurs within part of the fine lapilli tuffs, this relativelh extensive occurrence having been described earlier. Sulphide impregnation may also locally occur in keratophyric flow material e.g. Finnkrudåma (X64900 Y7500).

Massive sulphides occur in the northern belt, forming the Finnkrudåma skjerps, where they are stratigraphically underlain by a graphitic horizon representing the local concentration of organic detritus, this being instrumental in the reduction of ferric hydroxides in the primary depositional environment. Massive sulphides also occur in the southern belt forming the Nesåfoten skjerp zone, being typical 'vasskis' - having fine intercalations of sedimentary banded dark siliceous material, containing no detectable magnetite. These massive sulphides are most similar to those occurring at other localities in the Skorovas region, e.g. south of Vestre øverste Nesåvatn (X67000 Y5800) where similar dark non-magnetic cherts are interbedded with sulphides, having a capping of magnetite-rich cherts. (South east Skorovas report-74)

<u>Relation of sulphide occurrences to relative proportions of components of exhalite horizons</u>: It is clear that the occurrence of massive or disseminate sulphides within the lateral extent of an exhalite horizon has no particular dependence on particular morphological type of underlying pyroclastic or on type of acid flow material, except that massive sulphides apparently tend to occur where fine-grained acid ashes are more strongly developed. There does appear to be a weak correlation of sulphide occurrence with that of magnetite however, where the latter may occur within cherts or underlying pyroclastic material. Thus, zones of sulphidic impregnation tend to grade laterally into zones poor in sulphide but with cherts enriched in magnetite relative to hematite. This is to be expected somewhat in primary conditions consisting of lensoid reducate and oxidate zones, with a grading of sulphidic mineralisation to that of magnetite followed by hematite as the oxidate zone is reached. However, in the area mapped, such zones of predominantly magnetitic mineralisation marginal to sulphide occurrences are of small extent and somewhat irregular. It is possible however that, as volume of sulphides increases, the magnetite-enriched wallrock marginal zone expands according to a function related to sulphide volume and no doubt other factors.



Diagrammatic stratigraphic comparison : exhalative mineralised zones of NW Tredjevatnet (i) and Nesåfoten - Nesåa (ii)

Differing lithological facies of the belts: As has been stated, the two belts of exhalite-pyroclastic-acid flow association, trending approximately parallel to one another through the combined f_1/f_2 structural grain of the area, have fundamentally differing types of lithologies in some respects: a) the nature of pyroclastic material is distinctly different in appearance, though lapilli tuffs constitute the bulk of such material in both belts. b) Intermediate feldspar- og feldspar-hornblend-porphyritic material is an important component of the northern belt, but does not occur in the southern belt. c) While distribution of fine acid ashes, acid flows and sulphides is apparently equal between the belts.

Both belts include evident vent-vicinity lithologies e.g. 1) dispersed pyrite in intermediate lapilli tuffs (Nesåa) and overlying pillows containing chert cusps (Nesåfoten) in the southern belt, and 2) coarse and rapid transition from porphyry feeders to porphyry flows and complex stratigraphy of the west and north-west Tredjevatnet mineralised zone, northern belt, including crystal and chert fragmental tuffs. Outcropping between the belts are predominantly varied pillowed and non-pillowed flows containing some vent distal characteristics in a relative sense i.e. resedimented cherts.

It is therefore proposed that, although time/stratigraphically continuous, the two belts, or dhe culminative horizon forming the belts, is the result of eruption and exhalation from several separate but closely spaced centres. Certainly the eastern zones of the northern belt are fed at least demonstrably in part by the Skorovas complex intrusive arc. The southern belt, however, appears to have been fed from the direction of the massive trondhjemite intrusive to the west and south west. This raises the possibility of original continuity between the two, presently outcrop-separate, intrusive masses, which will be discussed further on.

Upper lavas.

Flows lying stratigraphically above the exhalative mineralised horizons of the area are widely variable laterally. The following fundamental types are recognised; according to morphology/ mineralogy.

a) Composed of recognisable pillow structures
   i) carbonate rich with epidote-(carb.) cusps
   ii) carbonate poor, intermediate, epidote cusps
   iii) " " " chert cusps.

b) Having no recognisable pillows, intermediate epidotic, carbonate visible where tectonised.

In the Nesåfoten - Nesåa zone, upper flows are of type a) iii) with local a) i). Along lithological strike to the northwest and into southern Finnkrudåma - Midtre Nesåvatn (674,3m) these become predominantly types a) ii) and b) with local a) i). Flows above the Finnkrudåma - west Tredjevatnet zone are predominantly of type a) i), apparently becoming a) ii) and b) toward the south and south-west, into the central area lying between the two outcrop-belts.

It is evident that the present variations in morphology and mineralogy can be explained to a large extent by a combination of slight variations in chemical composition, settling distance from the volcanic vent and tectonism. The occurrence and origins of chert pillow cusps has been discussed earlier.
The effect of tectonism, notably strong shearing, has been to produce tectonic facies within the greenstones, this consisting of release of Ca from feldspars and concentration with redistribution of existing fine groundmass carbonate, to form lenses within the body of, and discontinuous fine sheets in the fabric of the lavas. Such shearing would not necessitate great displacement being rather of a combined translational/rotational nature, while in the final stages, any pre-existing pillow structures would have become destroyed beyond recognition.
In the Finnkrudåma - North-west Tredjevatnet zone, carbonate has been separated from the matrix of pillow lavas to form pods up to 20 x 5 x 5 cm in zones of strong shearing with development of minor f_2 shear-type and crenulation folding approximately coaxial with local f_1 trends. Similarly, north of the Nesåfoten skjerp zone, chert-cusp pillow lavas, with no obvious carbonate and intermediate character, have been transformed into a schistose f_2-minor folded greenstone containing concentrations of free carbonate adjacent to a fracture zone.

Basic intrusives.

Skorovas complex intrusive arc: In the north-east of the area, the occurrence and outcrop of gabbros in this intrusive zone is complex, not only by primary complexity (combined intrusive sheet/ feeder body) but also by later extensive intrusion of trondhjemitic material as relatively large coherent masses and as zones of pervasive minor sheets. Thus the 'gabbros' of this body vary from being coarse grained with common pegmatitic facies; to fine grained, locally feldspar porphyritic feeder gabbros resembling greenstones in the field; with alteration apparently relatively shortly after intrusion to quartz-bearing hybrid gabbros, together with extensive fine trondhjemitic net-veining (the latter occurring most commonly on the Sættèuol plateau (X65700 Y6500). Although small-scale cumulate textures occur rarely, no mineralised zones occur within this gabbro.

Nesåpiggen composite intrusive: Banded gabbros form the bulk of the outcrop of this intrusion, which is relatively extensive and occurs in the south of the area. The northern contact of the intrusive is tectonic, dipping steeply northward. Similarly, the eastern and southern contacts are also tectonic, being formed jointly by a steep westerly dipping fracture and a strong low angle fracture dipping north to n.n.west beneath the lower eastern shoulder of Nesåpiggen. Thus the form and depth of the intrusive body is not evident.

Within the gabbro of this intrusive zone, occurs cumulate layering consisting of alternate gabbroic/lencogabbroic facies, the ferromag (invariably hornblend): felsic ratio varying widely. The more mafic layers are composed of $>50\%$ hornblend, felsic layers having $<30\%$, on average the gabbros being composed of $\sim 35\%$ hornblend with 65% basic feldspar plus or minus pyrite in amounts $<0{,}5\%$.

Considering the Nesåpiggen intrusive zone as a whole, there appears to be a coarse, but discontinuous continuum between gabbro and trondhjemite, including dioritic and quartz-dioritic facies. Intruded approximately parallel to cumulate layering at an early stage are leucocratic, locally quartz bearing facies, locally forming hybrids with primary gabbroic material. Relatively late trondhjemitic material also locally occurs intruded approximately parallel to layering. Greenstone schlieren occur locally associated with the numerous steep northerly dipping fractures which dissect the layered gabbros.

Not uncommonly, cumulate and/or deuteric crystallisation is accompanied by concentration of pyrite, chalcopyrite, magnetite, pyrrhotite and probable pentlandite. Noteable localities for such mineralisation include (X62185 Y7380) and (x62000 Y8800), but the exposed and local extent of such mineralisation is relatively small.

Occurring locally (X62650 Y9000) as a tectonically bounded lens on the northern contact of the banded gabbro, is ultramafic material, composed essentially of pyroxene together with included olivines which have been serpentinised, and fine disseminated magnetite, which is also concentrated along minor fractures within the ultramafic.

Intermediate facies of the Nesåpiggen intrusive: Dioritic and quartz-dioritic material forms an extensive outcrop to the north-east of Nesåpiggen, being tectonically bounded by a steep westerly-dipping fracture to the west and by a low-angle thrust-like fracture to the north, east and south. Underlying the latter fracture are predominantly sediments, which structurally underlie the eastern and south-eastern shoulders of Nesåpiggen. No zones of concentrated mineralisation occur within these lithologies.

Minor gabbro-diorite intrusions: Minor intermediate to basic intrusive sheets outcrop over the entire area, being fine to medium grained and of apparently limited mineralogical variation. Due to the mechanical anisotropy presented by exhalite horizons, gabbroic sills very frequently occur along basal or upper contacts of exhalative mineralisation, and also cross-cutting at shallow angles. Gabbroic intrusions in greenstone, commonly later intruded by minor trondhjemitic material, occur within predominantly tectonically defined 'slices' to the extreme south-west and south-east of Tredjevatnet. Shearing within such slices has produced flaser textures within gabbroic material.

Acid intrusives.

Western trondhjemite: Massive trondhjemites outcrop in the west of the area toward Midtre Nesåvatn, which form the bulk of a large intrusive body in west Grongfeltet (~100km^2 - Foslie). In the area mapped, such trondhjemite outcrops having a north-south trending tectonic contact with effusives, coming into contact with the Nesåpiggen intrusive zone in the extreme south-west. The tectonic contact, of low to high angle nature, dips eastward beneath the Finnkrudåma - Nesåa area and is associated with the development of low angle west-dipping fractures within the effusives in the vicinity of the contact. The trondhjemite is typically coarse-grained, consisting of quartz and low Ca feldspar with <1% ferromagnesian minerals. No zones of mineralisation occur in the area mapped. This trondhjemite is apparently relatively free from contamination, containing only minor local greenstone schlieren. However, south-west of the Nesåa, as the Nesåpiggen intrusive is approached, zones occur consisting of intense trondhjemitic intrusion of greenstone and, due also to the presence of flaser gabbroic material, contact relations are vague.

<u>Skorovas complex intrusive arc</u>: Outcrops of trondhjemite within this zone are irregular and gradational into zones of pervasive minor sheet intrusion and net-veining of gabbro and to a lesser extent, greenstones. It is, however, evident that the intrusive complex west of Nesåflyen (705) is continuous in a complex manner with the trondhjemitic belt east of Nesåflyen and extending ENE toward Stamnestjønna (South-east Skorovas report 1974). Similar to the trondhjemite east of Nesåflyen, those in the area are variably contaminated, but also form hybrids with the earlier gabbro.

<u>Nesåpiggen - Tredjevatnet zone</u>: Coarse trondhjemite containing minor greenstone schlieren occurs south of Nesåpiggen, and on the north-eastern shoulder, also occurring in contact with flysch sediments and diorite- quartz diorite on the lowest northeast slopes of Nesåpiggen. In this zone, contacts with the layered gabbro and diorite of the Nesåpiggen composite intrusion may be somewhat gradational but frequently tectonic. No mineralised zones occur within this lithology.

<u>Relatively minor trondhjemite intrusions</u>: Such intrusions occur at all levels in the stratigraphy of the area and are variable from coarse, quartz-porphyritic to aphanitic. Minor acid intrusive sheets may resemble and be continuous with flow material of quartz-porphyry to keratophyric nature, but are distinguished by the obvious lack of associated exhalative mineralisation. This is clearly visible in the area north of the Nesåa (X63800 Y8800) where a trondhjemitic feeder zone is continuous into a belt of acid flows together with pyroclastics and exhalite mineralisation of cherts and sulphides. Minor trondhjemite intrusives of the extreme south east are evidently extensions of, and fed by, the trondhjemite body being part of the Nesåpiggen intrusive zone. In this area, trondhjemites occur in flaser gabbro and greenstone material within part tectonically defined slices, within a zone of relatively concentrated fracturing; generally dipping north to north-north-westward, parallel to f_1 schistosity; that trends north eastward across Tredjevatnet and into the southernmost areas of the 1974 mapping area. Flaser gabbros, trondhjemites and greenstones occur along the length of this zone. The minor trondhjemites of this southern area are commonly relatively epidote rich.

It is clear that at least two phases of minor acid intrusive activity have occurred in the area, as intrusions may be terminated at the reosive effusive/sediment contact, or may continue into the sediments.

From sections across the area, the possibility that the effusives of the area are at least underlain in part by intrusive material in a broad basinal structure becomes apparent. Similarly, it has been earlier noted that the two outcrop belts of acid effusives and associated pyroclastics and exhalative mineralisation have been fed from the Skorovas complex intrusive 'arc' and from the western trondhjemite/associated Nesåpiggen intrusive zone; although both belts are in fact 'exposures' (in a structural sense) of the same time / stratigraphic horizon. Thus the possibility that the intrusive 'arc' is or was continuous with the western trondhjemite and Nesåpiggen intrusive zone, the three zones being facies variations of the magma resvoir underlying the area, becomes reasonable to propose but as yet difficult to prove.

Sediments.

Flysch sediments outcrop in the east and south-east of the area, having a predominantly inverted contact with effusives, trondhjemites and gabbros, which is commonly tectonised and locally purely tectonic. The contact is disconformal, this being clear from the convergence of the erosive contact toward and across an exhalite horizon, along a strike length of approximately km i.e. from the Kronglefjell area (1974 report - South-east Skorovas.) to the Čevoker area - where magnetite cherts occur at the contact - and thence westward where the f_1/f_2 folded contact cuts across an exhalite horizon and where local secondary Cu minerals occur in the sediments - north east of Tredjevatnet (X64900 Y6900).

The basal sediments consist of fine to coarse-clastic arkoses containing greenstone, trondhjemite, gabbro, chert and epidote clasts in a grey matrix. It is most significant that the occurrence of abundant epidote clasts in such basal sediments is conclusive of sea-floor metamorphism of the lava flow-pile prior to erosion. Sedimentary structures including current bedding, cut-and-fill and channel-fill structures, and repeated cycles of graded bedding commonly occur.

The basal arkoses have a somewhat gradational contact with relatively dark, greenish sediments composed of generally coarse greenstone, marble, chert and trondhjemite clasts in a chlorite-Fe carbonate matrix.

Due to combined f_1/f_2 folding, the relatively carbonate-rich sediments outcrop around the summit and upper southern slopes of Čevoker. In the area south of Čevoker, pervasive f_1 folding, with axial planes dipping relatively steeply north, combined with multiple axial-plane-parallel fracturing has produced a 'sliced' zone containing sheared mixed greenstone, gabbro and trondhjemitic material within the main outcrop area of the sediments. The sediments themselves are intruded by late stage minor trondhjemitic material, while gabbroic minor intrusion has not been recorded.

3. STRUCTURE

Phase f_1

The intrusives and extrusives and sediments of the Finnkrudåma - Nesåpiggen area have been pervasively deformed by tight, almost recumbent type f_1 folding along axes trending ~060° to ~040°, resulting in the impression of a variably developed schistosity dipping predominantly south-west to south in the northwest, north and northeast parts of the area; but due to subsequent open f_2 folding; dipping predominantly north to n.n.w. in the south and southeastern parts of the area (see profiles). The form of f_1 folding, both in order and style is similar to that occurring in the volume containing the Skorovas orebody (Company reports: Southern Main Orebody, Southern Eastern Orebody, East Skorovas-I.F.). Folding of smaller scale is rarely found, due to the shearing that has taken place in the waning stages of f_1 deformation.

Folding of this style has evidently led to the early establishment of shear surfaces parallel to f_1 axial planes, low-angle to thrust fractures occurring predominantly in the vicinity of contacts of the large intrusive masses, this being typical of the Skorovas region as a whole. Such fractures, early-initiated in the structural region of fold limbs, occur preferentially along stronger lithological/competence anisotropies. Within the extrusive-sediment sequence their displacements are apparently minor, movement being of a combined translational/rotational nature, but probably taking place both during the waning of f_1 folding and to a smaller extent during f_2 folding, when such planes would act as planes of readjustment. Therefore, such low angle fractures are commonly accompanied by strong f_2 shear folding and crenulation practically coaxial with f_1. The displacements of the low to high dipping fractures forming contacts of the western trondhjemite are most difficult to determine. Certainly, considering the occurrence of exhalative mineralisation within 10 m. of the tectonic contact on Midtre Nesåvatn summit, and the relatively large volume of relatively competent intrusive material compared to that of the relatively incompetent effusives, the vertical displacement involved must be of the order of kilometres. In the south, northerly dipping, f_1 associated fractures occur beneath and around the eastern and south-eastern slopes of Nesåpiggen, continuing north eastward in a broad zone south-east of Čevoker and into the area of south-east Skorovas (1974 report.)

Phase f_2

Post-schistosity, f_2 folding is of a broad, open style, commonly occurring along two axes which are mutually inclined at high angles. No development of schistosity is developed with this style of folding. The most consistent f_2 trend in the area is approximately coaxial with f_1, occurring as a gentle synformal fold trending ~NE-SW and traceable from north of Čevoker, across Tredjevatnet and the Nesåa, into the proximity of the Nesåa (s) mineralised zone. The f_2 axial direction occurring at a high angle to the latter is somewhat variable. Such f_2 folding, of antiformal nature, is traceable trending ~ north-south through Čevoker, having an amplitude approximately equal to that of the NE-SV axial direction. In the south-Finnkrudåma - Nesåa area, f_2 folding axially inclined to the latter f_2 synform occurs along a north-west - south-east trend. Here the folding is of a synformal nature, having an amplitude slightly greater than that trending north-east - south-west, the combination having resulted in an f_2 basin structure aligned approximately north-west - south-east in the Nesåa area. The Nesåa mineralised zone thus occurs within f_1 folding on the south and west flanks of this structure. In the south Finnkrudåma area, the NW - SE f_2 synformal structure is accompanied by a parallel trending but very weakly developed f_2 antiform, barely effecting reorientation and modification of f_1 minor fold axes and plunges.

In the south Finnkrudåma - Nesåa area it is clear that such a superimposition pattern of f_2 folding has been produced by the mechanical effect of the relatively competent and voluminous intrusive masses on the effusives, producing during f_1 and f_2 a 'pincer' effect which has resulted in a) reorientation of early f_1 folds to be aligned approximately parallel to intrusive contacts, b) shearing of the effusive volumes against the intrusive masses to give the observed tectonic contact with shears within the effusives as the contact is approached, c) post-schistosity (f_2) folding related to the varying stress pattern created by the intrusive masses' movement against the effusives, with development of medium to high-angle fractures to act as planes of minor compensation, and compensatory re-activation of early, predominantly low-angle fractures with development of small-scale f_2 shear and crenulation folding.

In the Nesåa area, it is evident that the NW-SE f_2 folding preceded that of the NE - SW trend. The NW - SE f_2 folding has apparently taken place associated with or shortly later than the re-orientation of f_1 folds in the vicinity of intrusive/extrusive contacts. This has resulted in the complex structure of an almost rectilinear post-schistosity fold pattern superimposed on relatively flat lying tight f_1 folding. The 'primary' and relatively unaltered f_1 lithological trend (~ 060° - Havdal to South-east Skorovas) occurring in the Čevoker - South-west Tredjevatnet area is therefore swung round to a NW - SE trend, approximately parallel to the earliest and strongest f_2 axial direction.

Thus, in conclusion, the effect of the multi-axial direction pattern of post-schistosity folding on primary tight, almost recombent f_1 folding has been great in determining the outcrop pattern in the area mapped. The structural phenomena are most similar to those occurring in the Damtjønna - Nesåklumpen - Nesåvatn area (east and southeast of Skorovas mine), where a weak but important rectilinear f_2 system is superimposed on tight isoclinal f_1 folding of generally low axial plane dip. Within the area mapped, the effect of the f_2 folding of synformal nature trending ~ NE-SW has been to repeat an f_1 synform (the axial trace of which runs through the lower northern slopes of Čevoker and thence through the Nesåfoten zone) to reappear as an apparent f_1 antiform further to the north (on the southern slopes of Sættečuol and thence southwestward into the west Tredjevatnet zone. (See profiles.)

4. CONCLUSIONS AND RECOMMENDATIONS

Within the area mapped in 1975 it is evident that all outcropping exhalative mineralisation is of equivalent age, now outcropping as two distinct belts with underlying acid flow and pyroclastic material a) Finnkrudåma - west and north-west Tredjevatnet, b) Midtre Nesåvatn (674,3m) - Nesåfoten. To the east, exhalative mineralisation continues in a complex manner into the Skorovas intrusive 'arc' complex and into the area of south-east Skorovas (Report 1974). The complex outcrop patterns are the result of the superimposition of a near-rectilinear post-schistosity, f_2, open-fold system upon primary, near-recumbent tight f_1 folds having axial trends approximately parallel to one of the component trends of the f_2 system, at ~ NE-SW. Thus, broadly speaking, the f_1 folded effusives lie within an f_2 synformal structure trending approximately NE-SW and flanded by voluminous intrusive masses having tectonised contacts and marginal zones and which may be continuous beneath the Finnkrudåma - Nesåa area.

Before and during the culminative mineralising event, several small eruptive centres operated practically contemporaneously, resulting in varied flow and pyroclastic stratigraphy and the restriction of certain lithologies to certain areas. This has also evidently resulted in variation of flow material overlying mineralisation, while the effects of tectonism, in particular shearing, has been to create pseudo-lithological facies or rather tectonic facies within the greenstones.

The f_1 / f_2 folded contact is disconformal and predominantly inverted in the area, while abundance of clastic epidote is conclusive of extensive sea-floor metamorphism of the lava flow-piles prior to erosion.

The observed rapid variation in both flow and pyroclastic material, and of flows overlying exhalative mineralisation, which forms a widespread and consistent time stratigraphic horizon, emphasizes the importance of investigation of time stratigraphic horizons as well as of litho-stratigraphic horizons in the exploration for massive sulphide mineralisation. Litho-stratigraphy being favourable in any area, it is then logical that the key to the present or former lateral occurrence of mineralisation lies in the investigation of that material which has behaved, in its primary distribution, in the same manner to that of relatively concentrated Fe (and possibly Cu - Zn - Pb etc.) bearing hydroxides i.e. fine acid pyroclastics and cherts, which themselves contain varying quantities of Fe mineralisation.

In the area mapped, ground and structural evidence does not support the possibility of economic mineralisation at shallow depth.

Skorovatn, Oct. 3. 1975.
I.L. Ferriday

5. LIST OF SAMPLES WITH LOCATIONS AND BRIEF DESCRIPTIONS

	X	Y
Schistose acid tuff (?) even fine disseminated pyrite	62900	8530
Sericite-quartz-feldspar-chlor(?) trondhjemite dyke	61210	4110
ultramafic: pyroxene - olivine - magnetite		
finely quartz-carbonate vesicular feldspar porphyritic with chlotitic clots.	63920	6970
arkosic sediment, north Tredjevatnet	64530	6920
fine grained, quarts-porphyry, no visible impregn.	62970	6100
fine grained acid flow material," " "	62860	8080
strong pyrite impregn. intermediate tuff-chloritic	62900	8530
epidote μ veined, epidote basaltic andesite, fine grained	65430	6860
intermediate pyroclastic, fine pyritic impregnation	63210	8190
coarse quartz-carbonate vesicular flow, feldspar porphyritic	63940	7000
carbonate rich vesicular greenstone, chloritic clots	63290	7300
hornblend-feldspar porphyry, carbonate vesicular (transitional to feeder material.)	64080	7000
chlorite (after hbl.)-feldspar porphyritic, carbonate vesicular	63110	7170
basaltic andesite relatively magnetite enriched fine pyrite	62860	8080
massive carbonate rich greenstone	64020	6950
andesite-dacite, trace pyrite	62860	8080
coarse chlor-fleck gst. (?equivalent of porphyry) no py.	62880	7120
T. band	63017	7940
andesite porphyry trace magnetite		7910
dacite, magnetite concentrated on fractures	63017	7940
talc-carbonate-chlorite + trace pyrite	64690	8100
intermediate magnetitic pyroclastic	62980	7530
carbonate pillow lavas (mn-carbonate)	65050	7205
lapilli tuff	63017	7940
dacite, minor pyrite disseminate	64700	6850
lithophysal structures	62980	7530
diorite: hbl.~30% feldspar (+orthoclase)~25%, ep.~ 45% coarse	62060	7100
layered gabbro: hbl. + fine actinolite,~2-3% pyrite, coarse	62185	7380
as above, coarser with 'vermicular' texture,≤Cu Py 1%	62175	7380
quartz-diorite (?)hbl ~15-20%, feldspar 80-85% ep, qtz, trace py., medium grained	62185	7380
deuteric concentration of py. in chlor-hbl. zone with feldspathic margin	62190	7440

	X	Y
layered gabbro hbl.: ~35-40% feldspar~65% epidote, py.~2%	61980	6730
variable grain layered gabbro hbl: ~35% feldspar~65% py. (Cu) ≤1%	61690	7425
fine-med. grained layered gabbro hbl:~35-40%, feldspar/epidote: ~60-65%. trace pyrite.	61690	7425
layered gabbro hbl: ~45%, feldspar: ~50-55%, trace pyrite	62175	7380
gabbro-diorite hbl: ~35%, feldspar~65%, trace pyrite	63080	7910
trondhjemite, femags:~3-5%, rest qtz.-fel.-ser.-ep.	62890	5850
" " ~5-7%, qtz: ~5%, feld: ~65%, epidote: ~25%	62430	6090
quartz diorite (?) fe.mags: ~15%, rest qtz-feldspar	63700	7970