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Dei av et NTNF støttet post dr. forskningsprosjekt under NTH og Grong Gruber.
Beskriver bergartene i den regionale stratigrafi med alle typer grønnsteiner og sure komplexser, likeså strukturgeologien.
Utenom skjerpet med massive sulfider på Gjersvikklumpen, er påvist ennå en massiv mineralisering ca 800 m mot SW. Mineraliseringene beskrives.
Konklusjoner gis og den paleotectoniske setteing foreslås.
Vedlagt listerover prøver, analyse skjema og kart med prøveposisjoner.

Brief Summary of Mapping Work in The Gjersvikklumpen-Royrvatnet Area of the Gjersvic, Grong District

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1 Introduction

The present study has been undertaken as part of the post-doctoral research project, funded jointly by N.T.N.F., Department of Geology and Mineral Resources Engineering, N.T.H., and Grong Gruber A/S. Dr. Sun has been in possession of a two year post-doctoral fellowship from N.T.N.F. from October 1, 1989 to September 30, 1991. The main aims of the project are to study the paleotectonic setting, meta-igneous lithologies, stratigraphy and geochemistry of and to establish geological relationship between the massive sulphide deposits and their country rocks in the Gjersvik area, Nord-Trondelag in central Norway.

The Gjersvikklumpen-Royrvatnet area is situated in the west of the Limigen Lake and the northeast of the Royrvatnet Lake in the Gjersvik area. Detailing geological mapping of the area about 18 kilometers squares was carried out on the scale of 1:5000, which spent a total of nine weeks from June 19 to Augest 24. However, complete mapping of the area was impossible due to the heavy cover and lack of good outcrop exposure on the surface in some areas.

It must be emphasized that this report is only a stage brief summary of the mapping work on the basis of field geological investigations and microscope study of some of rock specimen collected from the mapping area. Thus, some conclusions should be preliminary and discussing. The results of comprehensive study of paleotectonic setting, stratigraphy, lithologies and geochemistry of massive sulphide deposits and their countary rocks in combining mapping area with regional geological investigations in the Gjersvik area will be givern in final report of the project.

2 Regional Stratigraphy

The Gjersvik area is located in north and northwest of the Limingen Lake, northeastern part of the Grong district, Nord-Trondelag in central Norway. Geologically, the Gjersvik Nappe belongs to the middle Koli structural level of the Upper Allochthon in the central Scandinavian Caledonides.

The rocks in the western part of the area belong to the high-grade metamorphic sequences of the Helgeland Nappe (Ramberg, 1967) or the Helgeland Nappe Complex (Gustavson, 1973), belonging to the Uppermost Allochthon in the Scandinavian Caledonides. The Helgeland Nappe overlies in structure and thrusts directly to the east on the greenstone of the Gjersvik Nappe. The eastern part of the area consists mainly of intercalated layers of greenstone, quartzitic phyllite and graphitic phyllite of the Leipikvattnet Napper, which is seperated to the west from the overlying Limigen Group of the Gjersvik Nappe by major

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thrust.

The main features of geology in the Gjersvik Nappe were first described by Steinar Foslie through the mapping work during the 1920's and 1930's. This work was published later by the Geological Survey of Norway in a series of 1:100000 map-sheets and synthesized by Oftedahl (1956) and Foslie & Strand (1956). In recent years, the detailed descriptions of geology and lithology in the area were contributed by several authers (Halls et al., 1977; Kollung, 1979; and Lutro, 1977, 1979), of which, especially, a detailed mapping on the scale of 1:50000 in the Gjersvik area completed by Lutro in 1977 has been served as a basis for further detailed mapping and investigation of geology and ore deposits. The geological setting and genesis of the Gjersvik deposit were further discussed by Lutro (1979), Mellin (1979), Reinsbakken (1980) and Stephens & Reinsbakken (1981, 1986).

The present term, Gjersvik Nappe, has been defined by Halls et. al.(1977), which was suggested to use the name Limigen Nappe by Kollung (1979). It consists of a sequence of metamorphosed rocks up to lower middle greenstone schist facies, including both of the Limigen Group comprising predominantly a succession of metasedimentary rocks of polymictic conglomerates and flysch-like sediments (Halls et. al., 1977; Lutro, 1977) and of the Gjersvik Group, a bimodel trondhjemite - basalt suite composed mainly of metatrondhjemite, quartz keratophyre, metagabbro and greenstone (Halls et. al., 1977; Lutro, 1977). The sequence has been subjected to several phases of deformation (Mellin 1979; Reinsbakken 1980). The Limigen Group is structurally overlain to the west by the Gjersvik Group. Geological investigations have shown that debris within the conglomerates in the Limigen Group can be matched directly with the magmatic complex, i.e. trondhjemite, quartz keratophyre and greenstone of the Gjersvik Group (Lutro 1979; Reinsbakken 1980). The Limigen Group has, thus, been interpreted as being stratigraphically younger than the Gjersvik Group and the sequence in the Gjersvik Nappe has been considered to be generally inverted.

The Gjersvik Group is mainly made up of metavolcanic and meta-intrusive rocks, which have previously been called the Gjersvik Nappe (Oftedahl 1956, Foslie & Strand 1956) and the Skorovass Greenstone (Oftedahl 1974), but have been refined as a group, the Gjersvik Group (Halls et al. 1977, Lutro 1977). The sequence was originally subdivided into three Formations (Lutro, 1979) or into four major units (Arne. Reinsbakken, 1981). Present work by the author suggests division of the metavolcanites into two major Formations and several units:

Formation 1: (oldest, including Kleiva and Bjorkvassklumpen
formations of Lutro, 1979), comprising mainly
massive amphibolites

Formation 2: which can be subdivided into three units:

Unit 1, (older) dark greenstones, which can be classed into
two parts: Lower part (relative old) consisting largely
of massive biotite- and stilpnomelane-bearing greenstones;
Upper part (relative young) comprising predominantly
varying schitory, pillow, epidote-rich, chlorite-dominate
greenstones.
Unit 2, felsic volcanic complexes (quartz keratophyre), massive
sulphides (including sulphide mineralization) and cherts.
Unit 3, (youngest) pale greenstone.

Formation 1: This Formation occurs at the highest westernmost levels of the Gjersvik

Nappe directly beneath the high metamorphic grade Helgeland Nappe Complex and corresponds to the Kleiva and Bjorkvassklumpen Formations of Lutro (1979). It consists of dark massive and banded amphibolites in the west and fine-grained actinolite schists to the east away from the thrust contact to the Helgeland Nappe Complex. Occasionally, closely-packed pillow structure and thin magnetite bands or iron formation attest to the submarine origin of at least some of the amphibolites and actinolites. The amphibolites are intruded by gabbro-diorite complexes. Some petrochemical data show that the massive amphibolites have a MORB affinity and it is thought that they probably represent the remnant of an ocean-floor base on which the Gjersvik volcanic arc was built (A. Reinsbakken, 1981). The Formation 1 is, thus, interpreted as the oldest unit of the Gjersvik Group.

Formation 2: This formation constitutes the major, eastern part of the Gjersvik Group and correspond to the Bjorkvatnet Formation of Lutro (1979). It lies structurally below and has contact in sharp to the western, older the Formation 1. The formation consists of a thick sequence of a bimodel trondhjemite - basalt suite of metavolcanic and meta-intrusive rocks comprising mainly coarse-grained trondhjemite, middle to fine-grained porphyritic trondhjemite, gabbro, metafelsic volcanic complexes and greenstones. The dominating rock-types within the formation are massive to variably schistose metavolcanic greenstones of tholeiitic composition, which were deposited either as pillow lavas and pyloclastic rocks or as massive flows, whereas the metafelsic volcanic complexes, i.e. quartz keratophyre of rhyodacitic composition, are only a subordinating type of rocks in comprison with the greenstones. The sequence can be subdivided into three stratigraphic units:

Unit 1: dark greenstone

The dark greenstone occurs predominently in middle part of the area and constitutes dominating rock-types of the formation. The succession of the dark greenstone is extended along NE - SW trend and is structurally in direct contact to the northeast with metasedimental formation of the Limigen Group. The dark greenstone is characterized by dark green in color, Fe-rich, slightly magnetic property and massive to variably schistose structures. Several subtypes of the dark greenstone, i.e. epidote-, stilpnomelane-, biotite-bearing and chlorite-dominating greenstones, can be distinquished. The massive, pillow and amygdaloidal, and fragmental structures are extensively associated with, but occur variantly in different subtypes of the dark greenstones. This featyre appears to indicate that they were originally deposited by different styles as pyloclastic breccias and tuff, pillow lavas and massive flows.

The dark greenstones are cut by a major N.N.E. - S.S.W. trending fault, which divides the dark greenstones into two distinct regions. Based on the field mapping in the Royrvatnet-Gjersvikklumpen area, it has been noted that the western region of the fault consists mainly of variably schistose epidote-bearing and chlorite-dominanting greenstones that are characterized by basalitic breccias, tuff and pillow lava. Around and just east of Royrvatnet via Bjorkvatnet towards the north, pillow and amygdaloidal structures are well developed in the dark greenstone. Metabasaltic breccias are often associated with the pillow greenstone. These metabasaltic pillow, amygdaloidal and pyloclastic dark greenstones appear to belong to the same stratigraphic horizon and have been interpreted to represent the upper level of volcano - stratigraphic sequence of the dark greenstones. The region to the eastern and near part of the fault are predominantly composed by massive to slightly shcistory, stilpnomelane- and biotite-bearing greenstones. In comprison with the dark greenstones occurring in the western region, pillow and pyloclastic structures are obviously poorly developed within them. This feature appears to point to be originally deposited by massive basaltic flow. The stilpnomelane associated with the dark greenstone was proposed as a product in response to a secondary process in some way related to the intrusion of felsic dikes (Mellen, 1979). The presence of biotite has been considered as a possibility representing probably higher metamorphic grade of the dark greenstone produced in deeper depth. However, more detailing work are required to deal with the origin of the biotite. The stilpnomelane- and biotite greenstones in the eastern and near region of the fault have been interpreted as being stratigraphically lower in volcanic sequence of the dark greenstones.

The pillows are usually 0.3 to 1.5 m across and round to somewhat flattened in cross section. The interiors of the pillows comprise mainly either chlorite or epidote. The former is generally dark, massive, Fe-rich and slightly magnetic, and contains a few vesicles. The pillows composed mainly of chlorite are often associated with chilled margins marked by a 0.5 to 2 cm thick zone rich in epidote. The chilled margins are frequently associated with strong sulphide mineralizations. The latter is usually moderate green, massive, Fe-poor, and associated with the chilled margins rich in dark chlorite, for instance in the northeastern part about 1 km of the Royrvatnet. This kind of pillows was formed either by the replacement or by the filling up of pillows emptied during extrusion with epidote and some quartz. The stratigraphic layers associated with pillowed dark greenstone are in places strongly folded. The pillow structure indicates that the dark greenstones were deposited in a submarine environment (Wilson 1960; MacDonald 1968) and the vesicle and variolitic textures of some of the pillows suggest that they were formed under deep-water conditions (Jones 1969; Furnes 1973).

Unit 2: metafelsic complexes and sulphide mineralization

The metafelsic volcanic complexes, i.e. quartz keratophyre of rhyodacitic composition, do occur extensively as rather thin dikes or small complex in the formation although they are a subordinating type of rocks in comprison with the greenstone. They appear to spread out discontinuely in two zones extending roughly along N - S direction in occurrence: One is to the eastern and near part of the major N.N.E. - S.S.W. trending fault in where the metafelsic complexes are mainly associated with dark greenstones, especially with massive stilpnomelane- and biotite - bearing greenstones; Another is to the western part of the fault in where they occur mainly in or near the boundary between dark greenstone and pale greenstone.

The felsic complexes are a massive or lightly schistory, hard and very fine-grained rock, light grey or brown in color. According to lithologic association and occurrence, the felsic rocks appear to be divided into two groups: First is these being massive, homogeneous, very hard and fine-grained, and occurring as dykes or sills several to tens meters wide, and tens to hundreds meters long; Second is those with relative larger scales occurring as complexes consisting mainly of metafelsic pyroclastic rocks, which mostly represent recrystallized felsic agglomerate and tuff. It seems reasonable to suppose that the felsic dykes or sills are probably sub-volcanic phasea of the extrusive pyroclastic complex.

In the south of Bjorkvatnet a felsic complex consisting predominantly of the felsic agglomerate was mapped and described by Lutro (1979), which is dominated by felsic agglomatate setting the matrix of felsic tuff. However, In the eastern part of Royrvatnet and Gjersvikklumpen area, it has been noted that the felsic complexes comprise mainly felsic tuff with a small amount of fragments. The fragments in these felsic complexes are largely felsic volcanic rocks and generally angular to subangular, about several mm to tens cm in size. The sulphide mineralizations are entensively associated with the groundmass of the felsic complexes.

Sulphide mineralizations are extensively associated with the felsic rocks, especially with the felsic complexes, and also occur frequently within dark greenstones and pale greenstone. Two outcrops of the massive sulphides were found in the Gjersvikklumpen area. They are predominantly associated with the felsic complexes and often occur in the junction between felsic rocks and greenstones. The massive sulphide body is generally associated directly with a strong hydrothermal alteration zone characterized by both of extensive silicification (some up to altered quatzite) and vein and veinlet and disseminated sulphide mineralizations occurring within the felsic rocks, which have been interprateded as feerder zone. In contrast with this, the greenstones are seldom altered although they also contact directly with the massive sulphides. These features of the massive sulphides are similar with that of the biggest Gjersvik massive sulphide deposit to has so far found in the Gjersvik area.

Sulphide mineralizations occurring within the greenstones can be subdivided into two types based on their occurrence and host-rock associations: One occurs mainly within dark greenstones characterized by vein and disseminated sulphide mineralizations; Another is predominantly associated with the cherts occurring largely in or near contact boundary between pale greenstone and dark greenstone characterized by banded and disseminated sulphide mineralizations. From the Royrvatnet towards north, the eight, at least, outcrops on the surface in where cherts associating with sulphide mineralizations occur in or near boundary between pale and dark greenstone have so far been recognized. Four of them were found in the mapping area. These cherts probably represent the same stratigraphic horizon although they occur discontinuely. If felsic rocks - massive sulphides (including sulphide mineralization) - cherts can be proposed as product of the contemporaneous geological event in relation in some ways to the volcanic activity, the relationship among them appears to indicate that the felsic rocks - massive sulphides - charts were formed later than the dark greenstone, but earlie than the pale greenstone. Thus, the relationship of distal exhalites (cherts) related to the sulphide mineralization and of associating massive sulphides with felsic pyroclastic rocks indicates that the massive sulphide deposits in the Gjersvik area are associated with an episode of explosive felsic volcanism which occurred between depositions of the dark and pale greenstones of tholeiitic composition.

Unit 3: pale greenstone

The pale greenstone occurs mainly in the northwestern and southeastern parts of the area, respectively. In the southeastern part of the area, especialy in the east of the Tunnsjoen Lake, the pale greenstone comes structurally in direct contact to the east with the Limigen Group and is overlain to the west by the dark greenstone. The relationship among them appears to indicate that the dark greenstone is stratigraphycally older than the pale greenstone. Few felsic rocks have been found to be associated with pale greenstone. In contrast with this, felsic volcanic rocks are mostly associated with the dark greenstone. This has been proposed as a evidence that the pale greenstone belongs stratigraphically to the youngest unit of the Gjersvik Group.

The pale greenstone is mainly massive to variably schistory, light green in color and Fe-poor. Pillow and fragmental structures are poorly developed although they do occur in places within the pale greenstone. Thus, it appears reasonable to be considered that the pale greenstone occurs dominantly as basaltic flow.

Metavolcanic stratigraphic sequence of the Formation was intruded by a series of plutonic infrastructure of intrusive rocks. Three different types of the intrusive rocks have been recognized: metagabrro, coarse-grained metatrondhjemite and middle to fine-grained porphyrytic metatrondhjemite. The gabbro and trondhjemite have been considered, respectively, to form the roots of contempeous, submarine volcanic sequences of the dark greenstone of basaltic composition and of felsic conplexes of rhyodacitic composition. The gradual transitional contact between coarse- and fine-grained trondhjmites was observed in outcrop on the surface in the north of Royrvatnet, which indicates that they probably belong to different deep-, and shallow-seated intrusive phases of contemporaneous magmatic activity. Enclusions of the gabrro have locally been found to occur within coarse-grained trondhjemite as sub-angle to sub-round blocks from several centemeters to meters in size, and some of them still remain the resorpted rims (Photo. 1-36). The trondhjemites, however, sometimes occur within the gabbro as bands or lenses (Photo. 2-1). This phenomenon has been considered as two possibilities: One is that the gabbro blocks occur as xenoliths within the coarse-grained trondhjemite which indicates that intrusion of the trondhjemite is later than that of the gabbro; Another is that enclusions of the gabbro represent remains of partial melting producing trondhjemite magma in gabbro or basaltic sources. Clear primary contact between both of coarse-grained as well as fine-grained trondhjemites and greenstones is scarce because the present contact between the two is mostly tectonic. This tectonoc contact has clearly been observed in the eastern and eastnorthern parts of the Royrvatnet, west of the major NE - SW trending fault, which seem that the thrusting brought the coarse-graind trondhjemite (Photo. 2-2) and the fine-grained porphyritic trondhjemite (Photo. 2-3) into contact with the greenstones, respectively. However, the contact between the fine-grained porphyritic trondhjmite and the massive, dark biotite-bearing greenstone occurring in the Gjersvikklumpen area, east of the major NE - SW trending fault, appears to be more primary.

3 Lithological Descriptions in the Mapping Area

A sequence of the Gjersvik Group has been subdiveded into two formations and several units on the basis of rock associations and field contact relationship to each other. Among them the formation 1 consists mainly of massive to banded amphibolite and fine-grained actinolite schist with a MORB affinity that has been proposed as the remnant of an ocean-floor base on which the Gjersvic volcanic arc was built (A. Reinsbakken 1981), whereas the formation 2 constitutes not only the Gjersvik volcanic arc consisting mainly of metavolcanic and meta-intrusive rocks which dominate mostly the sequence of the Gjersvik Group, but also the hosting rocks of the massive sulphide deposits which have so far been found in the Gjersvik area. Thus, the descriptios of lithologies below will only focus in the different rock-types of the formation 2. Detailing description for the formation 1 was made by Lutro (1979) and Reinsbakken (1980).

The succession of the Gjersvik volcanic arc comprises mainly a bimodal trondhjemite - basaltic suite consisting of
metavolcanic rocks, both of the greenstones of tholeiitic basaltic composition and of quartz keratophyre complex of rhyodacitic composition, and meta-intrusive rocks, both of the coarse-grained trondhjemite, fine-grained porphyritic trondhjemite and gabbro. These rock types are seperated from colour, textural, mineral associations and contents, chemical compositions as well as their spacial relationship to each other.

3.1 Metavolcanic rocks

On the basis of field relationships of the different rock types, the metavolcanic succession of the formation 2 consist, at least, of three different stratigraphic units which were formed respectively in different stages of the magmatic process during construction of the Gjersvik volcanic arc. The three stratigraphic units are dominated by three different rock-types, respectively, i.e. metafelsic complexes (quartz keratophyre), dark and pale greenstnes. The dark greenstone appears to be formed earlier than the pale greenstone, whereas the felsic volcanic complexes are associated with an episode between depositions of the dark and pale greenstones. The greenstone dominates the metavolcanic succession, whereas the felsic volcanic complex is only subordinate type of the rocks. Whether the greenstones or metafelsic complexes is all characterized by Na-rich which albite constitutes one of the most dominant rock-forming minerals, and the greenstones are intensively associated with submarine sedimentary structures such as pillows and amygdales. Thus, the greenstones and metafelsic complexes have been considered as the variety of spilite and quartz keratophyre formed by the submarine volcanic activities, respectively. These features appear to indicate that the Gjersvik volcanic arc was constructed on the ocean floor under the submarine environment. The massive sulphides to have so far been found in the Gjersvik

Nappe all are associated with the felsic complexes, whereas the cherts and sulphide mineralization have been proposed respectively as a distal exhalite or a product related to convective hydrothermal system caused in some ways by felsic magmatic processes on the ocean floor.

Dark Greenstone

The dark greenstone constitutes the most dominant rock-type in the area. It is exposed about 7 km thick on the surface in the south, but thins out towards the north so rapid that the succession of the dark greenstone becomes only about 100 m thick in the north. Stratigraphic trend of the dark greenstone extends roughly along the N.N.E. - S.S.W. although the intense tectonic deformation and metamorphic reconstruction of the rocks in the area makes it difficult to erect a meaningful volcano-stratigraphy.

The dark greenstone is characterized by dark green in colour, fine-grained, rarely visibly porphyritic crystals, Fe-rich and slight-magnetism, and massive to varying schistosity in hand specimen and field outcrops. It consists mainly of chlorite, epidote and albite with considerable, but variable amounts of stilpnomelane, biotite, quartz and carbonate. Magnetite and pyrite are common fine-grained anhedra or euhedra accesory minerals, with less abundant sphene. The essential mineral assemblage obviously results from the regional metamorphism up to lower-middle greenstone facies. Due to the fact that the proportions of the essential minerals vary considerably, several subtypes of the dark greenstone can be classified on the basis of assciations of the minerals, that is, stilpnomelane-bearibng, biotite-bearing, epidote-bearing and chlorite-dominating greenstones. These subtypes of the dark greenstones tend to occur in different regions with associating some typical structures, which is considerably valuable in divisions of succession of the dark greenstone.

The stilpnomelane- and biotite-bearing greenstones tend to occur in the eastern or near part of the major N.N.E. - S.S.W. trending fault in the Gjersvik area that was concluded from the field mappings in the Royrvatnet - Gjersvikklumpen area by the auther (1990) and in the Lillefjell area by the Mellin (1979). They are often intercalated with the ordinary dark greenstones but there are no clear contact between the two. In addition to occurrence of the stilpnomelane and biotite with considerable contents in the rocks, the greentones are characterized by even darker in colour, stronger magnetic, massive to slight schistory with lessly pillow structure. The features of massive to slight schistory and with lessly associating the pillowed and fragmental structures appear to show that the stilpnomelane- and biotite-bearing greenstone was mainly deposited by massive basaltic flows.

The stilpnomelane- and biotite-bearing greenstones are mainly composed of albite, chlorite, epidote, stilpnomelane and biotite with small amounts of quartz and carbonate. Magnetite as a common accesory mineral becomes richer in the stilpnomelane- and bioitte-bearing greenstone. The contents between felsic and mafic minerals are aproximately equivelant, but proportions of the mafic minerals vary, especially epidote, stilpnomelane and biotite. The epidote is about few to 30 percent in content, whereas content of the stilpnomelane and biotite ranges usually from n to 10 or more percent, respectively. Stilpnomelane and biotite can coexist together in the dark greenastone such as in the Royrvatnet-Gjersvikklumpen area, but also occur respectively in different horizons of the dark greenstone, for example in the Lillefjell area (Mellin 1979). However, it is often difficult to distinquish biotite from stilnomelane in hand specimen and field outcrops but is distinctive in thin section. When stilpnomelane and biotite are associated to occur together in the dark greenstone, the propertion between the two is not constant, for instance, they both are approximately equivalent, each about 10 percent in content in the thin section M 15-17, on the other hand, each of them can be dominating component of minerals, only with a small amount of or disppearence of the another.

Stilpnomaline is brown or dark brown in colour under thin section and occurs as lath and needle crysrals about o.2 - 1 mm in length and 0.01 - 0.05 mm wide, frequently showing rediating aggregates of the needle crystals. The stilpnomelane laths tend to occur without preferred oriatation and to cut all existing textures and fabrics. This suggests that the growth of stilpnomelane had probably been remianed after the formation of the tectonic fabrics and has strong crystalloblastic tendancies. Stilpnomelane can occurs within the dark greenstone and is also associated with hydrothermal veins consisting of quartz and carbonate occurring within it. Especialy. near boundary of the veins the stilpnomelane often becomes more concentrating in each side of vein and greenstone. These features appear to show that the stilpnomelane is not a primary but secondary mineral related probably with the hydrothermal activity. Biotite associating with the stilpnomelane in the Royrvatnet-Gjersvikklumpen area is ease to be distinquished under thin section because it is green in colour. It occurs usually as subeuhedron to euhedron platy or scaly porphyritic crystals with perfect cleavage, about 0.1 - 0.2 mm in size. The texture that the stilpnomelane often cuts or replaces the biotite along its edges or cleavages has been observed under the microscope. Thus, they both appear to have existed as two unequilibrium phases. The presence of biotite has been interperated as a result representing higher metamorphic grade of the rocks.

The epidote-bearing and chlorite-dominating greenstones are dark green, massive to very schistose. They tend to occur in the west of the major N.E. - S.W. trending fault. In comprison with the stilpnomelane- and biotite-bearing greenstones, two features are distinct, that is, they are associated with only few amount of biotite and stilpnomelane, but with obvious pillowed, clastic and amygdaloidal structures. The pillow dark greenstone has been found to occur in several outcrops on the surface from the east of the Royrvatnet towards the north on outcrops of the surface . The pillows are generally flattened or irregular, lessly rounded, ranging from several cm to 1.5 m in diameters. In the eastnorthern part of Royrvatnet within the mapping area, it has been recognized that the pillow consists mainly of epidote with a chilled rim rich in chlorite and that the stratigraphic layrer associated with the pillowed greenstones is deformed so strong that it is impossible to distinquish any original sedimentary characteristics. However, in comprison with this, the pillow is largely composed of chlorite with a chilled rim marked often by a 0.5 to 2 cm thick zone rich in epidote with\without intensive sulphide mineralization in some plaecs, for instance, in the eastern and northeastern parts of the Borvatnet. This kind of the pillow usually occurs with less deformation and remains in some ways certain features of the primary sedimentation. The fragment-bearing greenstones characterized by clastic sedimentary origin are often associated with or occur near horizon of the pillow greenstones. They comprise fragments of the dark greenstone setting in the matrix consisting mainly of chlorite. The fragments are usually irregular, elongated, about several to hundrods cm long and several mm to tens cm width, and roughly oriated (Photo 1-25). The fragments layers are often very schistory. The greenstones are frequently vesicular in both recognisable pillowed and unpillowed successions, which are often infilled by a variety of secondary minerals to form the amydaloidal structure. The amygdales are generally rather round, ranging from 0.1 mm to tens cm in maximum dimension and tend to occur in certain horizons of the succession of the epidote-bearing and chlorite-dominating greenstones, for instance, three, at least, different levels which concentrate amygdales have been recognized to occur in the drilling core #4. They consist mainly of ctystalline individaul or aggregate of the epidote, lessly importantly of mineral assemblages of epidote + quartz or epidote + chlorite + quartz. Some relative larger amygdales are often associated with obvious interior structures composed of quartz and\or carbonate surroned by epidote (Photo 1-3). All amygdales are surronded by the schistority. The amygdaloidal structure is relatively lessly associated with the stilpnomelane- and biotite-bearing greenstones although it does occur within them. Thus, the succession of epidote-bearing and chlorite-dominating greenstones occurring in the western part of the major fault was originally deposited mainly by the pillow lava and volcanic clastic material, and has been proposed as being stratigraphically younger, upper level of sequence of the dark greenstone.

The epidote-bearing and chlorite-dominating greenstones consist mainly of albite, chlorite and epidote with small amounts of quartz, carbonate and biotite, occasionally, of augite in case that metamorphic grade of the rocks is relative lower such as pillow greenstone (thin section No. RS 4-7). The contents of felsic and mafic minerals are approximately equivalent, but proportions of the mafic minerals are variable, most of the greenstones being very chloritic with only minor amount of epidote, whereas others are very epidote-rich with lesser chlorite. Albite is the most dominant mineral, ranges generally from 40 to 50 percent in content. It is anhedron granular or euhedron laths about 0.05 to 0.5 mm in size, and often associated with obvious twinning of albite. The refractive index of the euhedron laths is lower than that of the jaffaite. Chlorite is tabular or scaly, very irregular but often orientated to constitute the schistory. Epidote occurs mainly as very irregular granular individual or aggaragates or as the filling metarial in the vesiculars and some of pillows. Biotite occurs mainly as porphyroblastic crystals, being generally flakes with one perfect basal cleavage. Carbonate and quartz are mainly secondary minerals, and variable in content, ranging generally from 1 to 5 percent. Augite only remains in some of pillow lava which is relative low in the metamorphic grade. It is subeuhedrol, granular or tabular, and cleavage length fast. Some crystals are associated with two cleavages, one good and another imperfect, at near 90. It represents the residue of the original minerals formed before reginal metamorphism.

The dark greenstones are characterized by holocrystalline-porphyritic and holocrystalline-homogeneous textures. The former tends to occur in the schistose greenstones, whereas the latter is mainly associated with massive and pillowed greenstones. The porphyritic texture is mainly composed of lath-shaped albite, ranging generally from 0.1 to 0.5 mm, setting in matrix consisting largely of felsic minerals, chlorite and epidote, usually being less 0.05 mm in size. Content of the porphyritic minerals ranges generally from 15 to 25 percent. Almost all porphyritic crystals of the albite are orientated and surrounded by schistory. These features indicate that the porphyritic greenstones appear to be originally deposited by crystal tuff. The homogeneous greenstones are often associateded with the relics of typical metagabbro textures, that is, the chlorite, epidote and augite tend to occupy the spaces between laths of albite which has no obvious orietation. It must be emphasized that the intergranular texture was mostly destroyed by secondary prosesses due to the fact that whether massive or pillowed greenstones are all metamorphosed up to greenshist phase. The residual augite is also associated with this kind of the dark greenstone. These features show that the massive and pillowed greenstones were originally deposited by basaltic lava.

Pale greenstone

Pale greenstone occurs mainly in the northwestern and southeastern parts of the area. The contact between pale and dark greenstones is not clear in the field. The pale greenstone is light green in colour, fine-grained, massive to schistose, Fe-poor and without magnetism. In comprison with dark greenstones, pillowed and plastic structures are lessly associated with the pale greenstone although they do occur in local places.

The pale greenstone is mainly holocrystalline-homogeneous, but lessly porphyritic. Main mineral assemblages of the pale greenstone is similar to the dark greenstones, but is characterized by higher property of carbonate in content and present of iron-poor actinolite. Carbonate ranges generally from 10 to 15 percent, whereas actinolite varies among 0 to 20 percent in content. Felsic minerals are usually very fine in grain, about or less 0.05 mm in size, but some of them are associated with obvious twinning of albite. They range from 20 to 40 percent in content. Sometimes, biotite occurs as the euhedron and flake-shaped porphyroblastic crystals, about 0.05 -0.3 mm in size. It is often associated with veins consisting of quartz and carbonate, which shows that it is related with secondary process.

Felsic complexes

Felsic extrusive rocks occur extansiely as rather thin complexes, which are often associated with dark greenstone or occur in junction between pale and dark greenstones. They have previously been called keratophyres (Oftedahl 1956) and trondhjemites (Foslie & Strand 1956). The felsic complexes are white to light grey or to light rose in colour, very fine-grained, hard and dense with at times associating recognisable free quartz in hand specimen and outcrops in the field. However, morphologies of the felsic complexes are very irregular and their scales are variable. Some felsic complexes with relative larger scales are usually several tens meters in width and hundronds meters long, and often associated with felsic fragments, whereas others with relative smaller scales are only several to tens meters in width and length, and are homogenerous in mineral components and structures of the rocks. The felsic agglomerate occurring in the south of Bjorlvatnet was already described and mapped by Lutro (1979). However, it has been noted that the felsic complexes with relative larger scales in the east of Royrvatnet and in the Gjersvikklumpen area are only associated with small amounts of felsic breccias or fragments. The fragments are generally angular to subangular, ranging from several to tens cm across, and mainly composed by felsic rocks. Thus, the close association with agglomarats and fragments and very thin but extensive nature of the felsic complexes indicate a pyroclastic origin rather than an origin as a felsic lava. The felsic complexes most probably represent recrystallized felsic tuff and fragmental tuff, but some of them with relatively small scales also probably occur as felsic sills or dikes.

The felsic complexes of rhydacitic composition (Lutro, 1979) are characterized by albite-rich, which the albite is the most abundant rock-forming mineral component, less mafic minerals in content and no recognisable potash feldspar. This feature appers to point to a submarine origin and undergoing submarine weathering. Thus, they also probably represent a variety of quartz keratophyre.

The rocks consist of albite, quartz with small amounts of chlorite, epidote, biotite, sericite and carbonate. Magnetite and pyrite are mainly subanhedron to anhedron fine grained, up to 2 percent in content, whereas apatite and sphene are lessly important euhedron fine-grained accessory minerals. The felsic minerals are most abundant, ranging usually from 80 to 95 percent in content, among them the albite being dominant. The mafic minerals are dominated by chlorite with small amounts of biotite and epidote.

Thr felsic rocks are characterized by holocrystallin-porphyritic texture consisting of phenocrysts setting in a very fine-grained, usually less 0.05 mm in size, matrix of quartz and albite with subordinate chlorite and epidote. Content of the phenocrysts is generally less 20 percent. The phenocrysts are composed mainly of euhedron to subeuhedron tabular albite, ranging generally from 0.1 to 0.6 mm in size, or aggregates of albite with obvious twinning of albite or Carlsbad. A few roundish quartz and subeuhedron biotite phenocrysts also frequently occur. The biotite phenocrysts associated with one perfect cleavage are often locally or wholly replaced by chloride. All phenocrysts are in certain extent oriented and surrounded by schistory. Some of phenocrysts are associated with flow texture.

3.2 Meta-intrusive rocks

Three main different types of intrusive rocks have been recognized to occur within the formation: fine-grained porphyritic metatrondhjemite, coarse-grained metatrondhjemite and metagabbro, which were called as fine-grained porphyritic metagranodiorite, coarse-grained metagranodiorite and metagabbro (Lutro, 1979).

The fine-grained porphyritic metatrondhjemite and coarse-grained metatrondhjemite in the area between Royrvatnet and Bjorkvatnet are obviously in contact tectonically with the greenstones. The greenstones near the contact are extensively schistose, whereas the pluton of the metatrondhjemites itself is associated with the foliated zone parallel or subparallel to the contact, emphasized by obvious oriention of the albite and quartz tablets which must be related to regional tectonics rather than emplacement of the pluton. The contact relationship between greenstones ans trondhejmites indicates that the trondhjemites were brought to thrust over the greenstones. In the north of Royrvatnet about 1.5 km the coarse-grained trondhjemite is immediantly in contact with fine-grained porphyritic trondhjemite. Clear contact was not observed in the outcrop in the field because the relationship between the two is obviously transitional.

The fine-grained porphyritic metatrondhjemite and coarse-grained metatronhjemite are all holocrystalline, leucocratic, greyish in colour, massive to slight schistose. Main mineral assemblages in the both intrusive rocks are similar, that is, they consist of plagioclase, dominating albite or oligoclase, quartz with small amounts of chloride, epidote, muscovite, sericite and carbonate. Only a trace of potassic feldspar is present. Pyrite is are main accessory minerals. On the basis of combining main mineral assemblages with relationship in contact between the fine-grained porphyritic trondhjemite and coarse-grained trondhjemite, it has been proposed that they represent deep- and shallow-seated plutonic phases of comagmatic processes, respectively. This conclusion has been supported by the evidence that the intrusive body of coarse-grained trondhjemite in the north of Royrvatnet is associated with a narrow zone of fine-grained porphyritic marginal facies near the contact between the greenstone and trondhejmite, which is similar in mineral assemblages and textures with the fine-grained porphyritic trondhejmite.

The fine-grained porphyritic trondhjemite and coarse-grained trondhjemite are all characterized by the low content of mafic minerals, ranging usually from 2 to 3 percent and occasionally up to 10 % (chlorite after epidote, chloritized biotite), the high proporty of albite with obvious twinning but without zoning, generaly about 60 per cent in content, and the very few presence of potassum faldspar. The fine-grained porphyritic trondhjemite consists of phenocrystals ranging usually from 1 to 2 mm in size setting in the matrix composed mainly of albite, quartz, chlorite, carbonate, muscovite and sericite, generally less 0.1 mm in size. The phenocrystals, ranging usually from 20 to 30 percent in contant, are dominantly anhedron to euherdon, tabular albite with obvious twinning, but a few amount of subrounded quartz also present. Phenocrystals of the albite occur as either individual or aggregate of the crystals, and some of them are altered by muscovite and sericite. The coarce-grained trandhjemite is similar in main mineral assemblages with the fine-grained porphyritic trandhjemite, but not associated with the porphyritic textures. In thin section it is typical holocrystalline with approximately equigranular granitic texture, although recrystallization of quartz is common, resulting in the development of a mosaic texture. The albite is mainly euhedron and tabular grains with obvious twinning, about 1 - 3 mm in size and about 60 percent in content. The albite is locally clotted with secondary sericite and muscovite. The quartz is anhedron grains, varying from 0.2 to 2 mm in size, and about 35 percent in content. The mafic minerals are low, generally less 5 percent in content, and consist mainly of chlotite with small amounts of epidote and chloritized biotite. These petrogtaphic features classify the tocks as trondhjemite according to the definition of Goldschimidt (1916), " leucocratic acid plutonic rocks, whose essential constituents are soda-rich plagioclase and quartz. Potash feldspar is entirely wanting or is present only in subordinate amounts. Biotite is the most important of the mafic constituents, although it is present in small quantity".

Gabbro often occur to be associated with or as xenoliths within the coarse-grained trondhjemite. The xenoliths are irregular to subrounded, about several cm to meters in diameters. Some of them are associated with a resorpting rim, but others are clear in contact between the trondhjemite and blocks of the gabbro. Thus, the xenoliths of the gabbro has been interpreted as the residual enclusions derived from the source producing the tronhejmite magma through partial melting of basalt or gabbro. The gabbro is composed of chlorite, clinozoisite, chloritized biotite and amphibolite with small amounts of secondary quartz ans carbonate. The clinozoisite often keep in pseudomorphs of the plagioclase and is about 40 - 50 percent in content. The biotite is anhedron, scaly, with perfect cleavage, but frequently chloritized. The amphibolite have two good cleavages.

4 Structure Geology in the Mapping Area

The rocks of the Gjersvik Nappe have suffered three, at least, major (A. C. Mellin, 1979) or five major and minor phases of Caledonian deformation (Lutro, 1979). The relationship among these phases of deformation was well elucidated in sequence of metasedimentary rocks of the Limigen Group (Lutro 1979; Mellin, A. C. 1979), but is very difficult to be distinquished within metavolcanic stratigraphic sequence of the Gjersvik Group. However, the structures to be preserved in the eruptive sequence in the mapping area do display that the metavolcanic stratigraphic sequence underwent strong deformation, which is descriped in follow.

Fold

Only a few folds can be observed in the sequence of metavolcanic and meta-intrusive rocks in the Gjersvik Group. It appears that the folds have mainly been reserved in two styles: one is open structure with steeply approximately dipping NE -SW axial planes occuring in the deforming trondhjemites, quartz keratophyre and greenstones; another is more tightly structure with steeply dipping and different striking trends existing mainly in reenstones. In the east of the Royrvatnet the pillow horizon of dark greenstone is obviously folded with dipping NW of angle about 40. The axial planes are approximately parallel with the regional shcistory. In the Gjersvikklumpen area the strong fold of dark greenstone occurs between two blocks of the felsic rock (Photo. 3-21), which is steeply dipping SWW - NEE axial planes. The dark geenstone is associated with laminaes of the obvious sulphide mineralization that are contemporaneously folded.

Thrusting

The main thrusts which seperate the Nappes such as occurring as the boundaries between both of the Helgeland Nappe and the Gjersvik Nappe in the west of the Gjersvik area as well as the Gjersvik Nappe and the Royrvik Group in the east have been described by Lutro (1979). However, minor thrusts within the metavolcano-stratigraphic sequence of the Gjersvik Group are not often obvious because the earlier phase of thrusting is rather possibly eradicated by the effects of later recrystallization and deformation of the volcanic rocks during metamorphism and toctonism. Geological investigation in the mapping area indicates that they do occur in places below the coarse-grained and fine-grained intrusive trondhjemites as boundaries between trondhjemites and greenstone, especially in the weatern area of the major NE trending fault. These trondhjemites are frequintly bordered by minor thrusts.

In the north of Royrvatnet, the contact which the coarse-grained trondhjemite overlays or thrusts on the dark greenstone has clearly been recognized in several places (Photo. 2-3). The contact plane generally dips deeply to the NW 320 - 350 (graduations of 400 degrees in the compass) with dipping angle ranging from 45 to 65. With associating the thrusting, the dark greenstone near the contact, on the one hand, is very schistory, and the coarse-grained trondhjemite itself, on the other hand, is intensively deformed along northeastern contact. The compression fissures and schistosity with a dominant NE - SW trend, essentially parallel or subparallel to the thrusing plane, occur extensively within intrusive of the coarse-grained trondhjmite. The dark greenstone has often been brought into planes of the compression fissures occurring as thin layers or lenses of structure filling (Photo.1-35), whereas quartz and feldspar tablets or rods as major rock-forming minerals comprising the course-grained trondhjmite are obviously oriated along schistose structure. Contact of same relationship between the fine-grained trondhjmite and the dark greenstone has also been found further to the north of Royrvatnet (Photo. 2-2).

Faulting

Brittle faulting appears to represent the latest event in the deformation history. Several minor faults and a series of fractures have been recognized in the Gjersvik area. Among them relative larger faults have been distinquished as lenear structures in the aerial photographies of the scale 1:10000 and generally very well marked topographically. These faults, however, are not often easely recognized on the surface.

A NE - SW major trending high-angle fault extending several tens kilometres passing from the east of Royrvatnet to near western shore of the Limigen Lake is most important in the area. Lithologies occurring in two sides of the fault are frequently different. In the north, the fault occurs mainly as the boundary seperating metavolcanic sequence of the Gjersvik Group from metasedimental sequence of the Limigen Group, whereas in the south, the eastern and near part of the fault consists predominantly of dark, massive, biotite-bearing greenstone of, but the western part is largely composed of dark, varing schistory, epidote-bearing or chlorite-dominating greenstone of the Gjersvik Group mentioned just above. With associating the fault, strong compression zones occur frequently in the metaextrusive and meta-intrusive rocks near two sides of the fault.

Other minor faults of different tends such as extending along N.W. - S.E., N.W.W. - S.E.E., and near N - S directions are common. These faults have in certain extent made the influence in the stratigraphic sequence. In the north of Royrvatnet the coarse-grained trondhjmite is cut by and displaced up to several hundreds metres along the near NS trending fault of approximately 3 km strike extent. In the Gjersvikklumpen area the faults of extending N.W.W. - S.E.E. trend have cut and moved the metafelsic complex with obvious sulphide mineralization up to tens meters.

5 Occurrence of massive sulphides and sulphide mineralization in the mapping area

A series of massive sulphide deposits and cherts of distal exhalites related to the sulphide mineralization have so far been found within the Gjersvik volcanic arc. The msaaive sulphide deposits were associated with an episode of the felsic volcanic extrusion which occurred between depositions of the dark and pale greenstones of tholeiitic composition. In correspodence with this, the massive sulphides, sulphide mineralization and cherts have also been recognized to occur extensively in the mapping area.

massive sulphides

Two outcrops of the massive sulphides have been recognized in the Gjersvikklumpen of the mapping area. One of them occurs in the east of major NE - SW trending fault, which has been marked in the geological map of the scale 1:50000 (Lutro, 1977); and another is situated about 800 m in the southwest of outcrop of the massive sulphides just mentioned, in the west of and near the fault, which was discovered by the author during the mapping of scale 1:5000 in this summer. These two outcrops of the massive suphides are similar in the geological features with the Gjersvik massive sulphide deposit, which is the biggest one of the volcanogenic massive sulphide deposits to be so far known in the Gjersvik area.

The outcrop of massive sulphides in the east of the fault is about 2 m square on the surface. The massive sulphide body occurs in the boundary between felsic complex and dark greenstone, and comprises mainly massive and banded ores with small amount of disseminated ores. The massive ores contain sulphides over 90 per cent in volume consisting largely of pyrite, and lessly of chalcopyrite, pyrrhotite and magnetite. The banded ores with sulphides about 50 per cent display banding of pyrite interbanded with dark greenstone. The hanging wall in the west of the massive sulphides is composed of intensive altered felsic complex. The dip-angle between the felsic complex and massive sulphide body is about 40 to 50. The hydrothermal alterations are mainly silicification, and lessly carbonitization which are directly overlain in the massive sulphides. Sometimes, the silicification is so strong that the felsic complex near massive sulphide body becomes altered quartzite. The veinlet and disseminated sulphide mineralizations, consisting mainly of pyrite and lessly importantly of chalcopyrite, are extensively associated with the wall-rock hydrothermal alterations ocurring within the felsic complex, which have been interperated as the feerder zone. In contrast with this, the foot wall in the east of the massive sulphides is mainly composed of dark greenstone which has no obvious hydrothermal alteration. This succession, from hanging wall of felsic complexes associated with extensive hydrothermal alternations and pyrite-dominating veinleted and disseminated sulphide mineralization in the west toward the east, via massive sulphides to foot wall of dark greenstome without hydrothermal alteration, is rather similar with that of the Gjersvik massive sulphide deposit. The succession has generally been interpreted to be reversed.

Outcrop of the massive sulphides in the west of the fault, indeed within the fault zone, is less 1 m square on the surface. It consists of massive and disseminated sulphide ores. The massive sulphides are mainly pyrite over 90 per cent in volume. The hanging wall in the west of the massive sulphides consists mainly of the felsic complex associated with silicification and disseminated sulphide mineralization, whereas the foot wall is the dark greenstone associated with very few hydrothermal altemations. The feature is similar with that at the outcrop of the massive sulphide in the east of the fault just described. Due to the fact that the outcrop just occur in the major fault zone, toctonic effect made the altered felsic complex and the dark greenstone form compressive schistory zone in which the felsic minerals, especialy quartz, are intensively oriated along the direction of the major fault trend.

Sulphide mineralization

The sulphide mineralizations occur wide spreadingly within the metavolcanic stratigraphic sequence in the mapping area. They are in some ways related to felsic volcanism and connected hydrothermal system occurring in the ocean floor. According to relationship between sulphide mineralizations and their hosts, three situations can be distinquished: (1) They occur mainly as veinlet- and disseminated-types within the felsic complexes and are often associated with intensive hydrothermal alterations, especialy silicification, which have been interperated as feeded zone associated with massive sulphides; (2) They occur mainly as vein-, veinlet- and disseminated-types in near boundary between felsic volcanic complexes and dark greenstone or within the dark greenstone away from the felsic rocks and are grequently associated with some hydrothermal alterations consisting mainly of epidotization, chloritization, silicification and carbonatization or hydrothermal altered veins comprising quartz and carbonate. They probably represent a product related to connected hydrothermal system formed in the ocean floor; (3) They are mainly associated with the cherts, and occur largely as disseminated- and laminae-types in or near boundary between pale and dark greenstones. This kind of sulphide mineralizations is only associated with few hydrothermal alterations.

Cherts

Cherts as a distal exhalite related with sulphide mineralizations often occur conforambly within the greenstones of the Gjersvik Group away from the massive sulphide bodies. Four places where outcrops of the cherts on the surface were found from Royvetnat towards north in the mapping area. The cherts occur mainly within the very schistose dark greenstone which has been proposed as upper part of metavolcanic stratigraphic succession of the dark greenstone. They are mainly lenses or thin layres, generally several tens cm to meters in thick and several to tens meters in length. Some of them are synchronously folded together with wall rocks. The cherts consist mainly of quartz and magnetite. The magnetite varies greatly in content ranging from several to over 80 per cent. Sulphide mineralizations are often associated with the greenstone near lenses of the cherts. The cherts by themselve are, sometimes, also associated with disseminated sulphide mineralization, especially when dominated by quartz.

6 Preliminary Conclusion and Discussion

(1) Stratigraphic sequence of the Gjersvik Group

When the felsic volcanic rocks - massive sulphides (including sulphide mineralization) - cherts have been considered as a product of contemperous geological event related to the felsic volcanic activity, they could be reasonably considered as a mark dividing stratigraphic seuqence of the Gjersvik Group. On the basis of field mapping and regional geological investigation, some geological aspects have been proposed as evidences of subdivision of the sequence: That is, (a) The felsic volcanic complexes related in some ways to sulphide mineralization are mainly composed of felsic dykes or sills and pyloclastical and tuffic rocks. According to regional geological investigation in the area, it has been noted that the felsic volcanic complexes are pedominantly associated with the dark greenstone or occur mainly in the junction between pale and dark greenstones , but very few of them are associated with the pale greenstone. This relation appears to indicate that the formation of the felsic rocks is originally later than deposition of the dark greenstone, but might be earlier than that of the pale greenstone; (b) From Royrvatnet towards north, the eithght, at least, places where the cherts occur in or near boundary between pale and dark greenstones were recognized on outcrops of the surface (four places of them occur in the mapping area). As a result of that the cherts probably represent a product of distal exhalite related to the sulphide mineralization, they have been interpreted as a same stratigraphic horizon even if occurring discontinuely. Thus, the cherts have been proposed as a key horizon occurring between dark and pale greenstones; (c) The sulphide mineralizations occur extensively in different types of rocks. According to occurrence and host associations of them, three situations have been considered: First, that the sulphide mineralizations associated with the felsic volcanic complexes are characterized by both of intensive hydrothermal alterations and pyrite-veinlet and disseminated type, which were proposed as feeder zone underlain directly massive sulphide deposits. Second, that the sulphide mineralizations occurring in or near boundary between felsic rocks and dark greenstone or within the dark greenstone away from the felsic rocks are also generally characterized by pyrite-vein and disseminated-types but only associated with weak alterations such as epidotization, albitization and silicification and/or quartz and carbonate hydrotherma veins. The relationship seems to indicate that the sulphide mineralizations were formed later than dark greenstone; Third, that the sulphide mineralizations associated with cherts occur mainly in or near the boundary between pale and dark greenstone. Few hydrothermal alterations are associated with them; (d) The chilled margins of pillows of the dark greenstone are sometimes associated with abundant sulphides and cherts; (e) In southeastern part of the Gjersvik area, especially in the east of the Tunnsjoen Lake, the pale greenstone is in direct contact with the Limigen Group and the relationship between dark and pale greenstones appears to show that pale greenstone is stratigraphically younger than the dark greenstone.

On the basis of above considerations, the sequence of the Gjersvik Group has now been proposed to be subdivided into two formations and several units:

Formation 1: (oldest, including Kleiva and Bjorkvassklumpen

formations of Lutro, 1979), comprising mainly
massive amphibolites

Formation 2: which can be subdivided into three units:

Unit 1, (older) dark greenstones, which can be roughly seperated into two parts by the major NE - SW trending fault: Lower part (relative old) consisting largely of massive biotite- and stilpnomelane-rich greenstones; Upper part (relative young) comprising predominantly varying schitory, pillow, epidote-rich, chlorite-dominate greenstones.
Unit 2, felsic volcanic complexes, massive sulphides (including sulphide mineralization) and cherts.
Unit 3, (youngest) pale greenstone.

(2) Some features of metavolcanic and meta-intrusive rocks in the formation 2

Except reasonably economic significance of the massive sulphide deposits occurring within a sequence of the formation 2, some features of the metavolcanic and meta-intrusive rocks have also been interested because they might be important in dealing with geological inveronment and paleotectonic setting of magmatic activity and massive sulphides. They include: (a) that the sequence of metavolcanic and meta-intrusive rocks is characterized by obviously bimodel feature, that is, the spectrum of rock chemical compositions both of the metavolcanic and meta-intrusive rocks are mainly basic and acidic, but seldom intermidiate. The metavolcanic rocks consist mainly of felsic complexes (quartz keratopyre) of rhyodacitic composition and greenstones of tholeiitic basaltic composition, whereas the meta-intrusive rocks are largely composed of metatrondhjemite and less importantly of metagabbro; (b) that the greenstone dominates over rock-type of the sequence, whereas felsic rocks, i.e. quartz keratophyre, is only subordinate. In comprison with this, the meta-intrusive rocks are dominated by the trondhjemite. Thus, the sequence is constituted by a bimodal trondhjmite - basalt suite comprising metavolcanic and meta-intrusive rocks; (c) whether metavolcanic or meta-intrusive rocks are all characterized by low-K and rich-Na because the albie conswtitutes the most important rock-forming mineral component in every type of the rocks but only very few potasum faldspars present in some types of the intrusive rocks. They mostly probably represent the veriaties of spilite and quartz keratophyre, which point to the submarine origin. The study of the present volcano and volcanic petrology has illustrated that the low-K series consisting mainly of tholeiite basalt and basaltic andesite associated with small amounts of SiO2-rich volcanics occur predominantly within intraoceanic islands far removed from continental crust in the present island-arc volcanic series (Hess, P.C. 1989).

(3) Dark greenstone

The dark greenstone as the most dominating rock-type of the sequence consists mainly of chlorite, epidote and albite. According to some rock-forming mineral associations, several subtypes can be further divided, that is, stilpnomelane-bearing, biotite-bearing, epidote-rich and dominating-chloride greensrones.

The major NE - SW trending fault which is extended in whole Gjersvik area cuts dark greenstone into two regions within which features of the dark greenstones appear to be different. The western region consists mainly of variably schistose epidote-bearing and chlorite-dominanting greenstones that are seldom associated with stilpnomelane and biotite. These types of the dark greenstones are generally characterizeded by pillow, breccia and amygdaloidal structures which indicate that they were originally deposited by basalitic breccias, tuff and pillow lava. They have been proposed as a stratigraphic horizon representing probably upper level of volcano - stratigraphic sequence of the dark greenstone. In contrast with this, the region to the eastern and near part of the fault are predominantly composed by massive and/or slightly shcistory, stilpnomelane- and biotite-bearing greenstones within which pillow and pyloclastic structures are obviously poorly developed, which show that they were probably deposited by massive basaltic flow. This kind of the dark greenstones is characterized by rich- or bearing- stilpnomelane and biotite although chlorite and epidote are still dominating rock-forming minerals. The previous work proposed that the stilpnomelane was probably a product in response to a secondary process in some way related to the intrusion of felsic dikes (Mellen, 1979). At present study under microscope, the texture relation between stilpnomelane and biotite point to them being unequivelent phase. The presence of biotite has been proposed as a possibility representing probably higher metamorphic grade of the dark greenstone produced in deeper depth. However, more detailing work are required to deal with the origin both of them. Thus, the region to the eastern and near part of the fault has been interpreted as being stratigraphically lower in volcanic sequence of the dark greenstones.

(4) Relationship among different types of the igneous rocks

The sequence was intruded by a series of plutonic infrastructure of intrusive rocks composed mainly of coarse-graine trondhjemite and fine-grained porphyritic trondhjemite and subordinately of gabbro. The coarse- and fine-grained potphyritic trondhjemites have been proposed as different deep-, and shallow-seated intrusive phases of contemporaneous magmatic activity based on both of the clear transational contact and similarity of mineral associations of the two. The trondhjemites, including the coarse-grained and fine-grained porphyritic trondhjmites, are spacially associated with the metavolcanic greenstone of basaltic composition. However, the evidences of the primary contact between trondhjemites and greenstones is scarce because the present contact between the two is mostly tectonic, which seems that the thrusting brought the trondhjemites into contact with the greenstones. Enclusions of the gabrro have in places been found to occur frequently within coarse-grained trondhjemite. The trondhjemites, however, sometimes occur as tectonic bands or lenses within the gabbro. This phenomenon has been considered as a possibility that enclusions of the gabbro probably represent remains of the partial melting producing trondhjemite magma in the gabbro or basaltic sources. Thus, the gabbro and trondhjmite have been proposed, respectively, to form the roots of contempeous, submarine volcanic sequences of basaltic (dark greenstone) and rhyodacitic (felsic rock) compositions in the Gjersvik volcanic arc.

(5) Massive sulphides and sulphide mineralization

The massive sulphide deposits mainly occur in the boundary between felsic rocks and greenstone and are often associated with "feeder zone" characterized by both of intensive hydrothermal alterations and dominant pyrite-veinlet and disseminated-type which occors within the felsic volcanic complexes. The disseminated sulphide mineralization associating mainly with the cherts of distal exhalites often occurs along certain horizon in or near the boundaries between dark and pale greenstone successions. The vein-, veinlet- and disseminated-types sulphide mineralization occurring mainly near the felsic volcanic complexes and within the dark greenstone has been proposed as a product of hydrothermal path within convective hydrothermal system in ocean floor. Thus, these features suggest a synvolcanic exhalative origin for the sulphide mineralizations related in some ways to felsic volcanic processes.

Owing to that the trondhjemite has been proposed as the root to the consanguineous submarine felsic volcanic complexes, the plutonic infrastructure of the felsic volcanic rocks in the Gjersvik volcanic arc probably play a important role as a heat source during fomrmation of the massive sulphide deposits. This interpretion appears to be reasonable because the felsic volcanic complexes are so small in size so that it is doubted whether they themselve could supply enough heat producing convective hydrothermal system related to the sulphide mineralization in ocean floor.

Two outcrops of the massive sulphides have so far been found in the Gjersvikklumpen area. They are associated with felsic volcanic complexes and have similar in features with the Gjersvik massive sulphide deposits. Meanwhile, the Gjersvikklupen is also one of concentrating areas where occur the felsic volcanic complexes with relatively larger scales. The felsic complexes themselve and the greenstone occurring near them are often characterized by intensive sulphide mineralization. Thus, the Gjersvikklumpen is probably important as a target for further local exploration that purposes an attempt for discovery of the new ore bodies that are similar with the Gjerwvik massive sulphide deposits.

(6) Paleotectonic setting

The metavolcanic rocks of the Gjersvik Group have generally accepted as a dominantly an island arc (Gale & Robert 1974, Hall et al 1977, Lutro 1979, Arny Reinsbakken 1981,) or ensimatic arcs and rifted arcs magmatic arc (M. B. Stephens 1984, F.M.Vokes 1987). When the problem of paleotectonic setting of the Gjersvik volcanic arc and massive sulphide deposits occurring within it will be deal with, it is probably important for some aspects to be consided in follow: (1) Regioanl geological investigation has been indicated that the Gjersvik Nappe consists of a sequence of metasedimentary rocks of the Limigen Group and metavolcanic and meta-intrusive rocks of the Gjersvik Group, and, more importantly, the Gjersvik Group is older than the Limigen Group; (2) The metavolcanic complexes of the Gjersvik Group are dominated by the greenstome, with intensive original submarine structures, of low-K tholeiitic basaltic composition and subordinated by the quartz keratophyre of rhyodacitic composition; (3) The metavolcanic sequece is characterized by distinct bimodel compositions; (4) Trondhjemite and gabbro as dominant plutonic infrastructure of metavolcanites probably constitute respectively the roots of the greenstone and quartz keratophyre; (5) The metavolcanic and meta-intrusive rocks are characterized by low-K and rich-Na; (6) The massive sulphide deposits and sulphide mineralization are mainly associated with episode of the felsic magmatic processes formed between dark and pale greenstones of tholeiitic composition, which formation of the dark greenstone was earlier than that of the pale greenstone.

7 Acknowledgements

The project has been carried out while the author has held a two year, N.T.N.F. post-doctoral fellowship since October 1989. Futher financial support for field work and chemical analysis come from Grong Gruber A/S. Thanks go to the Gjersvik project steering committee; Prof. F. M. Vokes, A. Haugen and A. Reinsbakken, for their discussion and advice. A. Reinsbakken is especially thanked for his discussions and some cooperative geological investigations during whole field work.

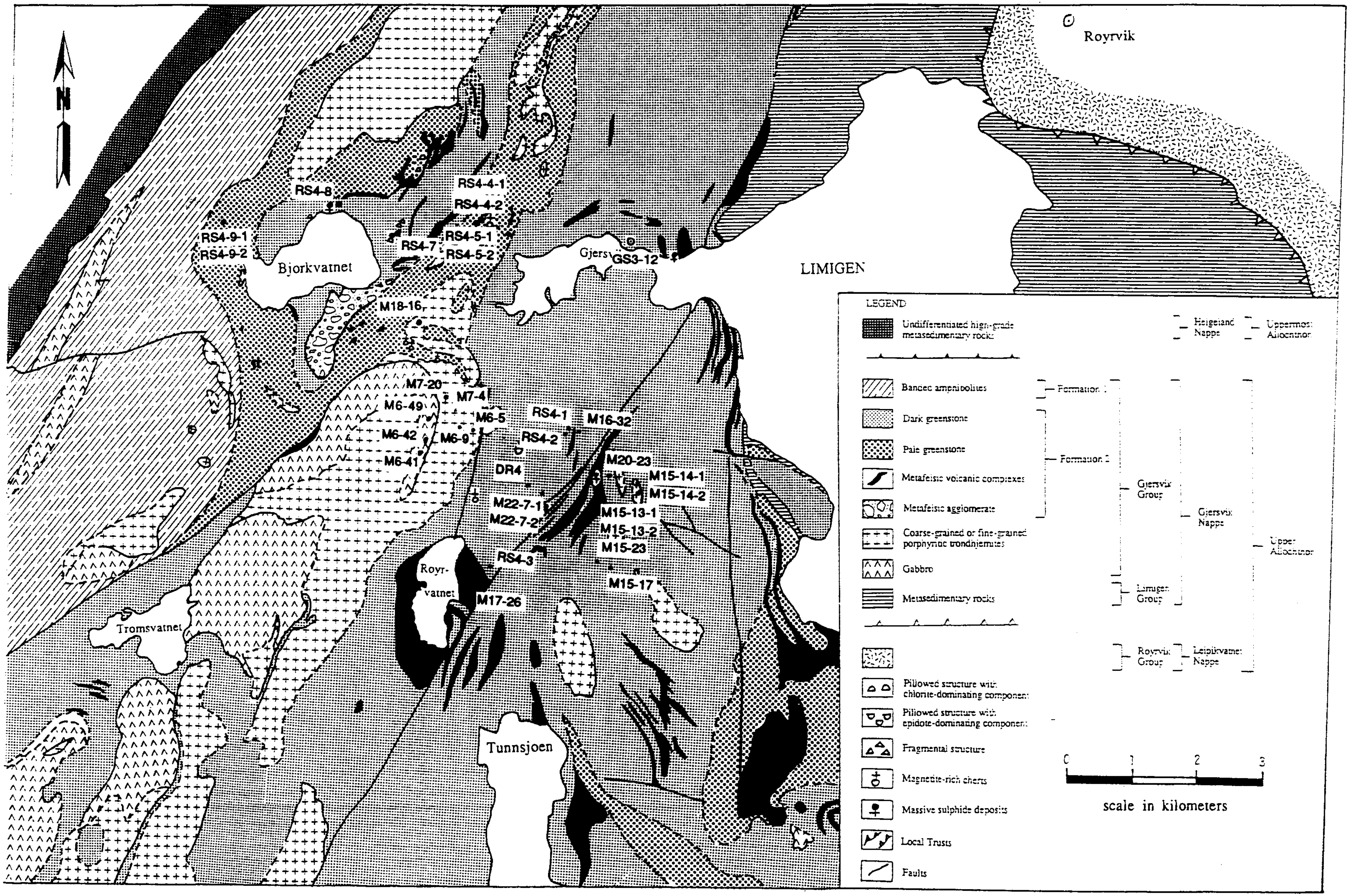

N
Royrvik
LIMIGEN
Gjersv
GS3-12
Bjorkvatnet
RS4-8
RS4-9-1
RS4-9-2
RS4-4-1
RS4-4-2
RS4-5-1
RS4-5-2
RS4-7
M18-16
M7-20
M7-4
M6-49
M6-5
M6-42
M6-9
M6-41
RS4-1
RS4-2
M16-32
DR4
M20-23
M15-14-1
M15-14-2
M22-7-1
M22-7-2
M15-13-1
M15-13-2
M15-23
RS4-3
M15-17
Royr-vatnet
M17-26
Tromsvatnet
Tunnsjoen
LEGEND
Undifferentiated high-grade metasedimentary rocks
Banded amphibolites
Dark greenstone
Pale greenstone
Metafelsic volcanic complexes
Metafelsic agglomerate
Coarse-grained or fine-grained porphyritic trondhjemites
Gabbro
Metasedimentary rocks
Pillowed structure with chlorite-dominating component
Pillowed structure with epidote-dominating component
Fragmental structure
Magnetite-rich cherts
Massive sulphide deposits
Local Trusts
Faults
Helgeland Nappe
Uppermost Allochthon
Formation 1
Formation 2
Gjersvik Group
Gjersvik Nappe
Limigen Group
Upper Allochthon
Royrvik Group
Leipikvatnet Nappe
0
1
2
3
scale in kilometers

Fig. Geological map and positions of the samples of the Gjersvik deposit

(Original map from the Gjersvik Malmfelt Report by Pettersen, 1973)

1 - Gjersvik felsic complex; 2 - Dark greenstone; 3 - Massive sulphide horizon; 4 - Road; 5 - Locations and numbers of collected samples.

GS3-1, GS3-2, GS3-3, ..., GS3-6

weak altered felsic rock

GS3-7, GS3-8

strong altered felsic rock (with weak mineralization

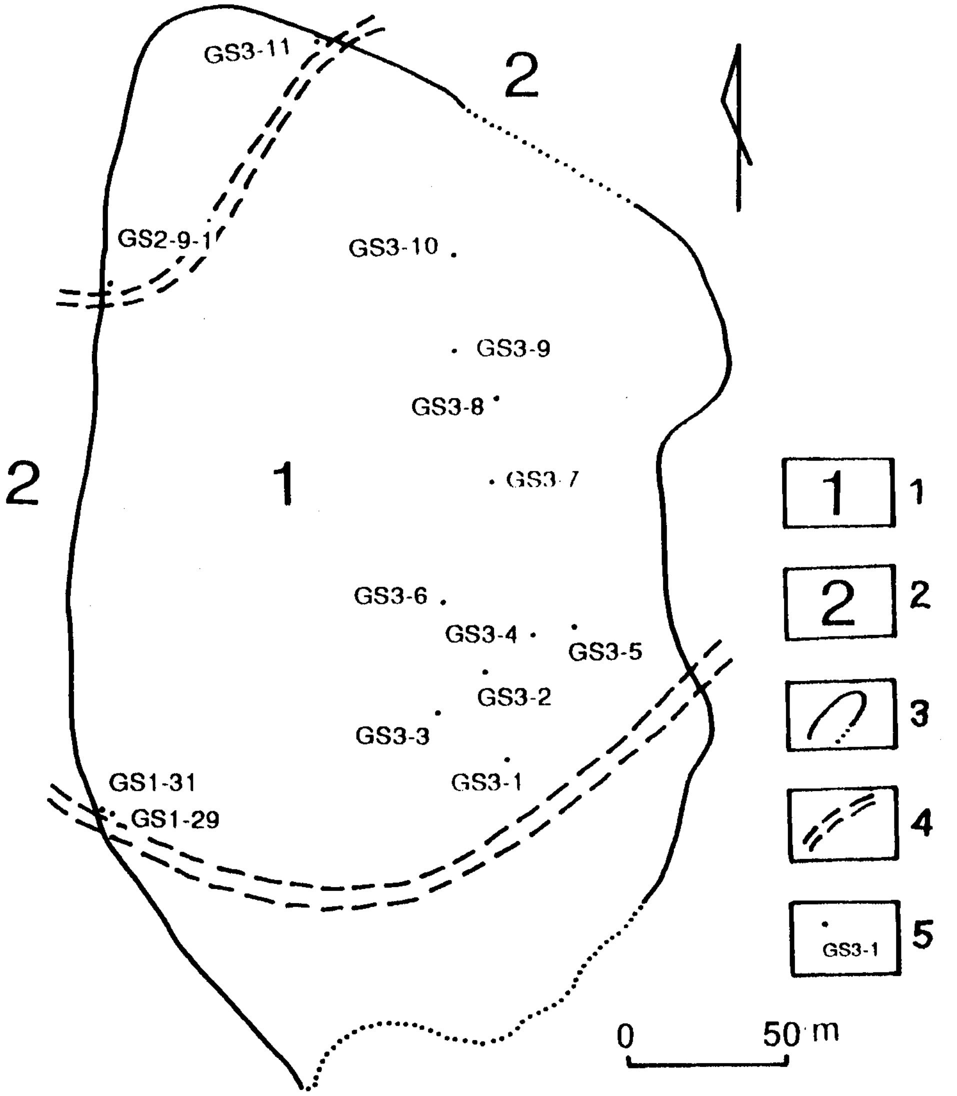
GS3-9, GS3-10, GS3-11

strong altered felsic rock (with intensive mineralization)

GS2-9-1, GS1-29, GS1-31

strong - moderate altered felsic rock

(with extensive interconnected sulphide veins and veinlets).


GS3-11
2
GS2-9-1
GS3-10
GS3-9
GS3-8
2
1
GS3-7
GS3-6
GS3-4
GS3-5
GS3-2
GS3-3
GS1-31
GS3-1
GS1-29
1
1
2
2
3
4
GS3-1
5
0
50 m

UNIVERSITETET I TRONDHEIM
NORGES TEKNISKE HØGSKOLE
INSTITUTT FOR GEOLOGI
OG BERGTEKNIKK
Vår saksbehandler, innvalgstelefon
I.Rømme, 4826

Vår dato 010291 – referanse IR/lis

Deres dato – referanse

Sun Haitian
Geologi og Bergteknikk

ANALYSERESULTATER J.nr. 903262-93.
Alle resultater oppgitt i prosent.

Prøve mrk.	RS4-4-1	RS4-4-2	RS4-5-1	RS4-5-2	RS4-9-1
SiO_2	50,07	51,10	48,40	47,55	47,30
TiO_2	0,62	0,63	0,76	0,81	0,52
Al_2O_3	15,50	15,70	15,63	15,35	13,75
Fe_2O_3 tot	9,09	9,30	9,79	10,30	9,24
MnO	0,15	0,14	0,18	0,19	0,17
MgO	7,53	7,55	8,03	7,97	11,46
CaO	7,22	6,72	7,46	7,17	8,45
Na_2O	4,76	4,90	4,63	4,51	3,11
K_2O	0,53	0,52	0,44	0,42	0,52
P_2O_5.	0,11	0,11	0,11	0,13	0,06
Glødetap	4,53	4,11	5,78	5,72	6,78
SUM	100,11	100,78	101,21	100,12	101,36

forts. neste side

POSTADRESSE:
INSTITUTT FOR GEOLOGI
OG BERGTEKNIKK
Høgskoleringen 6
N 7034 Trondheim

TELEFONER:
Generell geologi (07)59 48 10
Petroleumsgeologi (07)59 48 10
Malmgeologi (07)59 48 20
Ingeniørgeologi (07)59 48 25
Gruvedrift (07)59 48 50
Oppredning (07)59 49 10

TELEX:
55637 NTHAD N
(Att.: Geologi)

TELEFAX:
(07) 59 48 14

UNIVERSITY OF TRONDHEIM
NORWEGIAN INSTITUTE OF TECHNOLOGY
DEPARTMENT OF GEOLOGY AND MINERAL
RESOURCES ENGINEERING

ANALYSERESULTATER J.nr.903236-93 forts.

Prøve mrk.	RS4-9-2	RS4-1	RS4-2	RS4-3	RS4-7
SiO_2	47,04	53,43	49,83	51,07	50,80
TiO_2	0,52	1,65	1,20	1,35	0,87
Al_2O_3	13,65	14,31	15,11	14,92	13,93
Fe_2O_3 tot	9,22	14,02	13,39	14,47	10,83
MnO	0,17	0,27	0,27	0,19	0,18
MgO	11,62	2,75	7,83	5,20	6,00
CaO	8,39	3,70	4,38	3,69	6,27
Na_2O	3,05	5,70	4,96	6,06	5,73
K_2O	0,52	0,06	0,09	0,19	0,07
P_2O_5	0,06	0,53	0,11	0,11	0,10
Glødetap	6,76	4,14	3,23	2,92	3,99
SUM	101,00	100,56	100,40	100,17	98,77

Prøve mrk.	RS4-8	M16-32	M15-17	M15-23	M20-23
SiO_2	49,81	53,53	52,15	51,03	53,22
TiO_2	2,04	1,67	1,40	1,43	1,34
Al_2O_3	13,61	13,97	14,95	14,47	15,09
Fe_2O_3 tot	13,19	13,96	14,04	13,81	13,72
MnO	0,16	0,29	0,22	0,22	0,21
MgO	4,91	3,39	4,68	4,20	4,15
CaO	6,23	3,62	4,97	5,36	7,54
Na_2O	4,41	5,05	5,32	5,16	2,09
K_2O	0,02	0,05	0,61	0,45	0,06
P_2O_5	0,17	0,56	0,13	0,13	0,13
Glødetap	5,70	4,47	1,78	1,96	2,83
SUM	100,25	100,38	100,25	98,22	100,38

forts. neste side

ESULTATER J.nr. 903236-93 forts.

Prøve mrk.	Dr4	M22-7-1	M22-7-2	M15-13-1	M15-13-2
SiO_2	53,19	75,20	75,05	72,78	72,40
TiO_2	1,33	0,21	0,22	0,37	0,37
Al_2O_3	14,33	11,90	12,00	12,95	12,77
Fe_2O_3	13,43	4,33	4,46	5,04	5,28
MnO	0,22	0,06	0,06	0,11	0,11
MgO	3,89	0,64	0,73	0,62	0,68
CaO	4,65	0,73	0,75	0,80	0,83
Na_2O	5,67	6,07	6,02	5,51	5,57
K_2O	0,13	0,27	0,27	0,96	0,79
P_2O_5	0,18	0,03	0,03	0,06	0,07
Glødetap	3,17	0,56	0,60	1,22	1,28
SUM	100,19	100,00	100,19	100,42	100,15

Prøve mrk.	M17-26	GS3-12	M15-14-1	M15-14-2	M18-16
SiO_2	66,73	71,28	74,10	74,14	74,28
TiO_2	0,54	0,35	0,23	0,22	0,36
Al_2O_3	14,24	12,94	13,18	13,05	13,65
Fe_2O_3	8,53	5,05	3,52	3,61	2,66
MnO	0,10	0,05	0,04	0,05	0,17
MgO	1,21	0,96	0,31	0,27	0,32
CaO	0,51	0,23	0,88	1,00	0,67
Na_2O	7,28	6,47	5,36	5,43	5,14
K_2O	0,04	0,14	1,24	1,06	1,55
P_2O_5	0,07	0,06	0,04	0,05	0,07
Glødetap	0,85	0,90	1,05	1,09	1,40
SUM	100,10	98,43	99,95	99,97	100,27

forts. neste side

ANALYSERESULTATER J.nr. 903236-93 forts.

Prøve mrk.	M6-5	M6-9	M7-20	M7-4	M6-41
SiO_2	73,25	74,99	70,32	74,92	47,54
TiO_2	0,41	0,22	0,17	0,19	0,80
Al_2O_3	13,72	12,80	14,80	14,19	15,36
Fe_2O_3	3,05	2,23	2,10	1,60	13,21
MnO	0,10	0,06	0,08	0,04	0,20
MgO	0,46	0,30	0,34	0,28	5,64
CaO	1,02	1,67	2,05	1,41	8,87
Na_2O	6,88	4,90	4,63	4,49	2,21
K_2O	0,32	1,24	2,01	1,85	0,04
P_2O_5	0,08	0,05	0,05	0,04	0,08
Glødetap	1,00	1,96	2,73	1,22	6,57
SUM	100,29	100,42	99,28	100,23	100,52

Prøve mrk.	M6-42	M6-49
SiO_2	44,65	50,13
TiO_2	1,55	0,63
Al_2O_3	17,44	11,97
Fe_2O_3	15,18	10,33
MnO	0,19	0,19
MgO	4,77	11,93
CaO	10,42	11,39
Na_2O	2,14	1,53
K_2O	0,03	0,05
P_2O_5	0,10	0,09
Glødetap	2,55	1,87
SUM	99,02	100,11

Med hilsen

Ivar Rømme

Ivar Rømme

SUN

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      UNIVERSITETET I TRONDHEIM. GEOLOGISK INSTITUTT          12-MAR-91 13:20
Sample: 910670  NO 1   GS 3-3                   AP: SILIKAT   12-MAR-91 13:20
Concentrations                    Tr: 1.4
File: SILIKAT.CFS

    Al2O3           TiO2           Fe2O3          MgO            CaO            MnO
    11.62%          0.39% 0,38      7.04% 6,89    2.36% 2,31     0.06% 0,06     0.06% 0,06
    11,37           ϑ
     K2O            P2O5            NA2O           SiO2           SUM            L.O.I.
     0.30% 0,29     0.04% 0,04      3.88% 3,80    74.71% 73,14  ~~100.47%~~       2.10%

                                                                100,44
```

```
      UNIVERSITETET I TRONDHEIM. GEOLOGISK INSTITUTT          12-MAR-91 13:29
Sample: 910671  NO 2   GS 3-6                   AP: SILIKAT   12-MAR-91 13:29
Concentrations                    Tr: 1.5
File: SILIKAT.CFS

    Al2O3           TiO2           Fe2O3          MgO            CaO            MnO
     9.76% 9,65     0.21% 0,21      5.11% 5,05    1.36% 1,34     0.71% 0,70     0.11% 0,11

     K2O            P2O5            NA2O           SiO2           SUM            L.O.I.
     0.21% 0,21     0.03% 0,03      3.52% 3,48    79.49% 78,61  ~~100.52%~~       1.11%

                                                                100,50
```

```
      UNIVERSITETET I TRONDHEIM. GEOLOGISK INSTITUTT          12-MAR-91 13:37
Sample: 910672  NO 3   GS 3-7                   AP: SILIKAT   12-MAR-91 13:37
Concentrations                    Tr: 1.6
File: SILIKAT.CFS

    Al2O3           TiO2           Fe2O3          MgO            CaO            MnO
    12.98% 12,62    0.31% 0,30      3.54% 3,44    2.98% 2,90     0.12% 0,12     1.01% 0,98

     K2O            P2O5            NA2O           SiO2           SUM            L.O.I.
     1.15% 1,12     0.05% 0,05      2.17% 2,11    76.70% 74,54  101.01%          2.81%

                                                                100,99
```

```
      UNIVERSITETET I TRONDHEIM. GEOLOGISK INSTITUTT          12-MAR-91 13:47
Sample: 910673  NO 4   GS 3-9                   AP: SILIKAT   12-MAR-91 13:47
Concentrations                    Tr: 2.1
File: SILIKAT.CFS

    Al2O3           TiO2           Fe2O3          MgO            CaO            MnO
    16.77% 15,31    0.51% 0,47     16.68% 15,23   0.12% 0,11     0.02% 0,02     0.03% 0,03

     K2O            P2O5            NA2O           SiO2           SUM            L.O.I.
     2.97% 2,71     0.03% 0,03      1.34% 1,22    62.60% 57,16  101.06%          8.69%
```

```
        UNIVERSITETET I TRONDHEIM. GEOLOGISK INSTITUTT          12-MAR-91  13:56
Sample: 910674   No 6    GS 3-11                 AP: SILIKAT    12-MAR-91  13:56
Concentrations                  Tr: 2.2
File: SILIKAT.CFS

    Al2O3            TiO2           Fe2O3            MgO            CaO            MnO
    8.62% 7,51       0.22% 0,19     28.24% 24,61     0.51% 0,44     0.02% 0,02     0.04% 0,03

    K2O              P2O5           NA2O             SiO2           SUM            L.O.I.
    1.71% 1,49       0.02% 0,02     0.47% 0,41       58.96% 51,39   98.80%         12.84%

                                                                    98,95
```

```
        UNIVERSITETET I TRONDHEIM. GEOLOGISK INSTITUTT          18-MAR-91  16:43
                                                 AP: SILIKAT    18-MAR-91  16:43
Sa ple: 910675 NO 6
Concentrations               GS 2-9-1
File: SILIKAT.CFS

    Al2O3            TiO2           Fe2O3            MgO            CaO            MnO
    14.91% 14.61     0.34% 0.33     6.44% 6.31       1.67% 1.63     2.14% 2.09     0.14% 0.13

    K2O              P2O5           NA2O             SiO2           SUM            L.O.I.
    0.94% 0.92       0.06% 0.05     6.44% 6.31       66.36% 65.05   (99.45%)       1.96%

                                                                    99.39
```

```
                     I TRONDHEIM. GEOLOGISK INSTITUTT           12-MAR-91  14:13
Sample: 910676   NO 7    GS 1-29                 AP: SILIKAT    12-MAR-91  14:13
Concentrations                  Tr: 2.4
File: SILIKAT.CFS

    Al2O3            TiO2           Fe2O3            MgO            CaO            MnO
    9.43% 9,35       0.19% 0,19     3.43% 3,40       0.03% 0,03     2.70% 2,68     0.28% 0,28

    K2O              P2O5           NA2O             SiO2           SUM            L.O.I.
    0.27% 0,27       0.04% 0,04     5.13% 5,09       78.72% 78,08   100.24%        0.81%

                                                                    100,22
```

```
        UNIVERSITETET I TRONDHEIM. GEOLOGISK INSTITUTT          12-MAR-91  14:22
Sample: 910677   NO 8    GS 1-31                 AP: SILIKAT    12-MAR-91  14:22
Concentrations                  Tr: 2.5
File: SILIKAT.CFS

    Al2O3            TiO2           Fe2O3            MgO            CaO            MnO
    13.78% 13,36     0.32% 0,31     10.85% 10,52     2.87% 2,78     0.98% 0,95     0.16% 0,16

    K2O              P2O5           NA2O             SiO2           SUM            L.O.I.
    0.65% 0,63       0.05% 0,05     5.03% 4,88       67.28% 65,22   101.98%        3.02%

                                                                    101.88
```

Samples for chemical analysis
of major and trace elements

1.	RS4-4-1	pale greenstone
2.	RS4-4-2	" "
3.	RS4-5-1	" "
4.	RS4-5-2	" "
5.	RS4-9-1	" "
6.	RS4-9-2	" "
7.	RS4-1	massive dark greenstone
8.	RS4-2	" " "
9.	RS4-3	schistose " "
0.	RS4-7	pillowed " "
1.	RS4-8	schistose " "
2.	M16-32	massive " "
3	M15-17	dark biotite- and stilpnomelane greenston
4	M15-23	" " "
5	M20-23	" " "
6.	Dr 4	dark greenstone (from drill hole Bh 4)
7.	M22-7-1	felsic rock
8	M22-7-2	" "
9	M15-13-1	" "
0	M15-13-2	" "
1	M17-26	" "
2	GS3-12	" "
3	M15-14-1	fine (intermediate)-grained porphyritic trondhjemi
4	M15-14-2	" " " "
5	M18-16	" " " "

6.	M 6 - 5	marginal phase of coarse-grained trondhjemite
7.	M 6 - 9	coarse - grained trondhjemite
8.	M 7 - 20	" " "
9	M 7 - 4	" " "
30	M 6 - 41	gabbro
1	M 6 - 42	"
2	M 6 - 49	"
3	GS 3 - 3	weak altezed felsic rock (from Gjersvik body
4	GS 3 - 6	" " "
5	GS 3 - 7	strong " " " ~~without wea~~ with weak mineralization
6	GS 3 - 9	strong altezed felsic rock with intense mineralization
7	GS 3 - 11	" "
38.	GS 2 - 9 - 1	feeder zone strong - moderate alterations with extensive interconnected sulphide veins and veinlets
39	GS 1 - 29	" "
40	GS 1 - 31	" "

Sun Haitian

June 17th, 1991.

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INSTITUTT FOR GEOLOGI
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Vår saksbehandler, innvalgstelefon
I.Rømme, 4826

Vår dato 140691 – referanse IR/lis
Deres dato – referanse

Sun Haitian
Geologi og Bergteknikk

ANALYSERESULTATER J.nr. 903262-93 , 910989-96.
Alle resultater i ppm.

	RS4- 4-1	RS-4 4-2	RS4- 5-1	RS4- 5-2	RS4- 9-1	RS4- 9-2
Pb	18	16	16	26	19	15
Cu	61	62	72	76	15	12
Zn	73	75	80	81	90	88
Ni	71	69	87	82	221	216
Co	42	40	47	49	57	61
Ba	37	37	27	28	95	101
V	271	270	265	265	208	212
Cr	298	305	337	327	527	529

forts. neste side

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Malmgeologi (07)59 48 20
Ingeniørgeologi (07)59 48 25
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Alle resultater i ppm.

	RS4-1	RS4-2	RS4-3	RS4-7	RS4-8	M16-32
Pb	18	18	20	17	19	21
Cu	11	22	36	36	27	13
Zn	113	127	113	93	112	116
Ni	<2	20	<2	63	14	<2
Co	17	44	38	45	31	20
Ba	<20	<20	<20	<20	<20	<20
V	90	477	552	311	635	83
Cr	12	57	22	257	56	9

	M15-17	M15-23	M20-23	Dr4	M22-7-1	M22-7-2
Pb	20	20	22	16	13	16
Cu	48	25	47	19	30	30
Zn	109	99	67	112	58	66
Ni	10	<2	<2	<2	6	2
Co	38	34	41	34	<2	<2
Ba	102	68	117	32	25	12
V	453	362	439	346	<10	<10
Cr	47	16	36	15	83	63

forts. neste side

ANALYSERESULTATER J.nr. 903262-93, 910989-96 forts.
Alle resultater i ppm.

	M15-13-1	M15-13-2	M17-26	GS3-12	M15-14-1	M15-14-2
Pb	17	14	17	11	12	12
Cu	<2	<2	10	4	<2	<2
Zn	146	139	107	39	33	40
Ni	<2	<2	<2	<2	<2	3
Co	<2	<2	8	4	<2	<2
Ba	342	286	<20	<20	184	173
V	11	13	56	13	<10	<10
Cr	82	79	51	39	107	139

	M18-16	M6-5	M6-9	M7-20	M7-4	M6-41
Pb	12	8	15	16	14	17
Cu	13	<2	<2	6	<2	64
Zn	71	91	48	41	22	73
Ni	47	<2	<2	<2	<2	15
Co	2	<2	4	<2	<2	43
Ba	344	77	544	795	917	<20
V	<10	<10	<10	<10	<10	452
Cr	59	52	96	93	86	70

forts. neste side

ANALYSERESULTATER J.nr. 903262-93, 910989-96 forts.
Alle resultater i ppm.

	M6-42	M6-49	GS3-3	GS3-6	GS3-7	GS3-9
Pb	20	17	15	17	20	50
Cu	46	62	34	222	<2	183
Zn	69	75	78	62	138	1103
Ni	11	166	<2	3	<2	<2
Co	39	56	<2	4	<2	<2
Ba	<20	<20	25	34	745	834
V	472	237	24	<10	<10	<10
Cr	32	793	41	81	58	74

	GS3-11	GS2-9-1	GS1-29	GS1-31
Pb	24	958	57	37
Cu	833	32	<2	449
Zn	287	7572	248	420
Ni	<2	<2	<2	<2
Co	6	<2	<2	4
Ba	472	652	22	156
V	<10	<10	<10	76
Cr	89	49	54	32

Med hilsen

Ivar Rømme

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ANALYSERESULTATER J.nr. 903262-93, 910989-96.

(?) Nb to be used carefully.

	ppm Zr	ppm Nb	ppm Y	ppm Sr	ppm Rb
RS4-4-1	35	<5	3	78	5
" 2	56	2	<2	74	7
RS4-5-1	31	18	<2	111	8
" 2	63	<5	8	106	6
RS4-9-1	47	"	2	38	9
" 2	43	"	5	38	7
RS4-1	71	12	15	73	<1
" 2	45	<5	8	63	"
" 3	45	9	11	45	"
" 7	43	<5	7	54	"
" 8	112	19	20	105	"
M16-32	38	<5	12	53	"

forts. neste side

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ANALYSERESULTATER J.nr. 903262-93, 910989-96 forts.

??

	ppm Zr	ppm Nb	ppm Y	ppm Sr	ppm Rb
M15-17	62	<5	11	70	<1
" 23	42	"	11	110	3
M20-23	44	"	12	156	<1
Dr 4	103	20	11	85	"
M22-7-1	168	61	55	116	8
" 2	207	65	52	109	10
M15-13-1	157	36	43	41	10
" 2	202	61	56	51	8
M17-26	137	14	36	12	2
GS3-12	172	53	57	35	3
M15-14-1	134	23	34	85	38
" 2	124	27	27	102	33
M18-16	186	62	54	100	39
M6-5	140	66	36	122	17
" 9	137	30	23	200	40
M7-20	114	<5	7	296	65
" 4	83	5	17	223	61
M6-41	55	<5	2	107	<1
" 42	36	"	7	134	"
" 49	53	"	4	96	"
GS3-3	130	29	41	58	5
" 6	158	38	33	60	9
" 7	151	65	79	77	19
" 9	107	43	40	60	17

forts. neste side

ANALYSERESULTATER J.nr. 903262-93, 910989-96 forts.

	ppm Zr	ppm Nb	ppm Y	ppm Sr	ppm Rb
GS3-11	61	<5	7	2	6
GS2-9-1	140	35	24	95	5
GS1-29	98	27	32	77	10
" 31	107	22	27	28	2

Med hilsen

Ivar Rømme