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Tittel
The molybdenite-province of South-Western Norway

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Sammendrag
This report reviews the geological mapping and exploration work that has been carried out in the area. A/S Sydvaranger´s exploration manager Thor L.Sverdrup and the geologists Øivind Gvein and Kristen Mørk, have gone through the archiv at the Inspector of Mines for Western Norway in Bergen, where most of the material concerning the mining operations and prospecting activities in the Knaben area is stored. Further we have studied the records which are filed at Norges geologiske undersøkelse (NGU) (The Geological Survey og Norway) - NGU-Bergarkivet - in Trondheim.

T H E   M O L Y B D E N I T E - P R O V I N C E   O F
S O U T H   W E S T E R N   N O R W A Y

A compilation of available data and proposals for further exploration-work.

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Lysaker, 9-3-1979.

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S U M M A R Y.

1. The Area of Agreement is situated in the Precambrian of South-West Norway, and covers an area of approximately 7000 km^2. For the western part of the Area a geological map in scale 1:100 000 is available. For the eastern part a preliminary geological map in scale 1:250 000 has been worked out.

   The Area consists of highly metamorphosed, folded gneisses (para- and ortho-gneisses), and various intrusive rocks.

2. Molybdenite mineralization is associated with zones of socalled "layered gneiss" which comprice the following three main rock types :
   a) grey gneiss, containing pyroxene/hornblende and biotite,
   b) quartz-feldspar-gneiss,
   c) amphibolite.

   MoS_2 appear to be especially connected to the grey gneiss type (a). This rock type is often characterized by oxidation of Fe-sulphides.

3. MoS_2-mineralization occur on secondary quartz- and quartz-feldspar-lenses and dikes in grey gneiss, along the border of younger aplitic intrusions in grey gneiss (Knaben, Flottorp) and as impregnation in grey gneiss and aplite.

   At Knaben II, which is by far the largest Mo-deposit in the Area - 8,6 mill. tons of ore with an average grade of 0,2 % MoS_2 has been mined here - the main mineralization types are :
   a) as impregnation in a granittic gneiss "lense" (the "gangfjell lense" - the genesis of this rock type is a matter of discussion i.e. whether it is an intrusive body or a metasomatically altered gneiss),

   b) as mineralization in a system of secondary quartz-veins in grey gneiss below and adjacent to the "gangfjell" lense.

4. Prof. Schetelig and Dr. Bugge, who worked as consultant geologists for The Knaben Mining Company, advocated a magmatic theory for the genesis of the ore :

MoS_2-mineralization took place at a late stage pneumatolytic/hydrothermal phase of a magmatic sequence, involving intrusion of aplite/pegmatite and deposition of quartz-veins.

Geologist from Folldal Verk emphasize the association between molybdenite and the grey gneisses, which they regard as sedimentary horizons, and hence consider the mineralization as being stratiform deposits. They believe that MoS_2 was mobilized during metamorphism and was partly deposited in low pressume zones in the host rock, together with quartz/feldspar.

5. During the "molybdenum-boom" in 1916-1920, the area was intensely explored by geologist from The Knaben Mine, from prospectors from other companies and also, and not least important, by local people. More than 800 registrations of molybdenite were done in this period, most of them of no economic value, but one can assume that most of the uncovered bedrock in the area was examined.

After 1965, a number of companies and institutions have been engaged in exploration in the area (Folldal Verk A/S, Elkem-Spigerverket A/S, A/S Sydvaranger and The Geological Survey of Norway, NGU), but no new deposit have been discovered. The chances of finding economic ore bodies at the surface in exposed bedrock must therefore be characterized as rather limited.

In the Flottorp, Gursli, Sira and Ovedal areas, relatively small scale mining operations were carried out during 1916-1920. Recent investigations (by Folldal Verk) have indicated that these deposits are too small to be considered as objects for renewed mining.

6. Future prospecting has to be carried out on two scales :
a) The Knaben Area.
b) Regional prospecting.

Prof. Vokes, consultant for The Knaben Mines during the latest years of operation, has proposed a program for exploration in The Knaben II mining area, which has to be discussed further. Geochemical investigations appear to be the most suitable method for regional prospecting.

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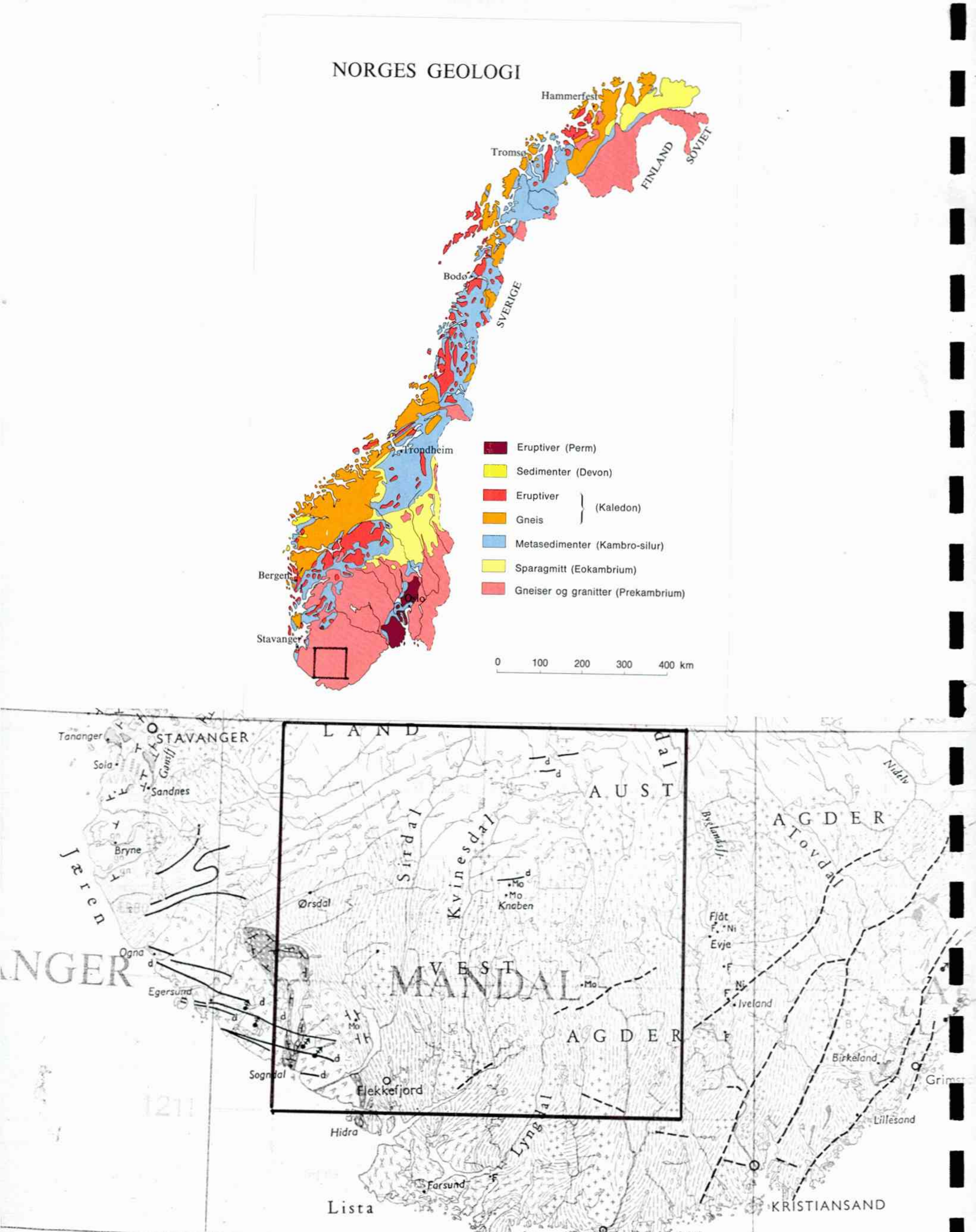


Fig. 1
Keymap with Area of Agreement outlined.

THE MOLYBDENITE PROVINCE OF SOUTH-WESTERN NORWAY.

A compilation of available data concerning geological mapping and Mo-exploration within the Area of Agreement.

1. INTRODUCTION.

This report reviews the geological mapping and exploration work that has been carried out in the area. A/S Sydvaranger's exploration manager Thor L. Sverdrup and the geologists Oivind Gvein and Kristen Mørk, have gone through the archiv at the Inspector of Mines for Western Norway in Bergen, where most of the material concerning the mining operations and prospecting activities in the Knaben area is stored. Further we have studied the records which are filed at Norges Geologiske Undersøkelse (N.G.U.) (The Geological Survey of Norway) - NGU Bergarkivet - in Trondheim.

In the 1960s, two Norwegian mining companies - Folldal Verk A/S and Elkem-Spigerverket - carried out a relatively extensive exploration program in this region. Folldal Verk's material is partly available at the Inspector of Mines, and we have from the company obtained a description of the area they have worked in, and a summary of the reports that was written. For a more detailed study of this material, and for permission to use the results, the companies will expect a certain compensation.

2. DEFINITION OF AGREEMENT AREA, TOPOGRAPHIC CONDITIONS AND PROSPECTING/MINING RIGHTS.

2.1 Limitation of the Area.

The area of Agreement is restricted to that part of the 1:250 000 map sheet MANDAL which is covered by the 1:50 000 sheets AMS 1312 I-IV, 1412 I-IV, 1311 I and parts of 1311 IV, 1411 I and 1411 IV, corresponding to an area between longitude 6°13' and 7°43', and latitude 58°15' and 59°N. (Fig. 1, and map enclosed as an appendix)

2.2 Topographic conditions.

The area lies in rough, mountainous terrain, with NS-extending valleys. General altitude of the mountain plateaus increase from

south to north.
Morphologically it is a typical glacially eroded landscape. Quartenary deposits are scarce and restricted to the valleys.

The timberline is approximately 600 m above sea level, In higher terrain, small bushes and large heather covered areas dominate the vegetation.

During the warmest summer months, the average temperature reaches 14-15°C. Average rainfall is 1-2 m pr. year (mainly in the autumn).

The relatively few inhabitants mainly live in the valleys.

A topographic map (MANDAL, scale 1:250 000) is enclosed as an appendix.

2.3 Prospecting/mining rights.

Every Norwegian citizen is in right to apply for claims (in Norwegian : "muting") against the local Government Inspector of Mines. Claimable are minerals containing elements with sp.w. 5 (titanium is however claimable), other minerals are the landowner's. The "muting" is valid for 7 years after the new law of 1972. If economic ore is proven in the 7-years time, the claimer applies for "utmål" which has a 10 years validity. "Utmål" older than the new law of 1972 is not limited in time, so far.

When The Knaben Mine was closed down in 1973 the company's rights were transferred to the Government in accordance with the law. A/S Sydvaranger has hired these rights, 194 "mutings" and 23 old "utmål". The "mutings" are not valid after April 1st, 1981, but The Government make the condition that new rights inside this spesific area shall be claimed in the name of The Government.

3. GEOLOGY.

3.1 General.

The geological map, enclosed as appendix 1 shows a section of the map sheet MANDAL (1:250 000). This is a preliminary, unpublished map compiled by geologist Dr. T. Falkum at the

University of Århus, Denmark, in cooperation with NGU.

Only the central and eastern part of this map is copied, since the Western part, i.e. W of Sirdalsvannet (Lake Sirdal) has been mapped and described by Hermanns & al. in NGU Publication No. 318. This publication is also enclosed.

The entire Agreement is situated within the Precambrian of South Norway. To the SW it borders an anorthosite complex, and to the E occur the generally quartzittic rocks of the Telemark Formation, which, with its associated sedimentary and volcanic subunits, are regarded as lying stratigraphically above the quartz-feldspar-rich gneiss complex of the Agreement Area.

3.2 Western part of the Agreement Area.

The following abstract is quoted from Hermanns & al. (1975) : "Charnockitic migmatites in low-pressure granulite facies grade into amphibolite-facies migmatites towards the east. Recent geochronological date suggest the existence of at least two metamorphic/intrusive cycles, one between 1500 and 1200 Ma and the other between 1000 and 850 Ma. In both cycles, a regional high-temperature metamorphism at relatively shallow depth appears to be associated with the intrusion of anorthosites, monzonites or syenites, and of dolerites, all of alkali-basaltic parentage. The isoclinal folding may belong to the first cycle; most of the subsequent folding characterizing the present structure must have occurred between the two cycles. The pre-metamorphic stratigraphy of the magmatites is unknown, but the lithologies should have included shales and some limestones and sandstones".

Concerning the structural geology he says :
"In the mapped area, at least four phases of folding are distinguishable. The oldest one is an isoclinal folding, probably coeval with the migmatization.
Younger folds with axes trending N og NW and axial planes dipping $40-60^{o}$ towards the east mainly define the structure of the migmatites. They are especially conspicuous along the NE boundary of the intrusive massifs, where they have subhorizontal fold axia and steep axial planes. Within the larger framework created

by these folds, smaller areas with NE-trending folds occur in the north of the mapped area. Some field observation suggest that these are older than the NW-trending system. The fourth and youngest phase is represented by flexures with eastward plunging axes and steep axial planes.

Numerous younger faults mainly with ENE and N trends occur in the migmatites. Some of them appear to be the primary cause of the large valleys intersecting the area. The fault zones are usually marked by retrograde metamorphism, and in places also by mylonites or tectonic breccias; displacements, however, are only rarely observed".

3.3 Eastern part of the Agreement Area.

As mentioned, the geological map of this eastern area (appendix 1) is a preliminary survey map, where only a few geological units are included.

For the central part of the area, Leake (1973) (engaged by Folldal Verk A/S) has prepared a more detailed map, but his descriptions are not available.

3.3.1 Quartz-feldspar-rich gneisses
(orange on the map) cover most of the ground. Leake has divided them into different varieties, but the impression is that they represent only nuances within a relatively uniform rock complex. The rocks are generally foliated, but in some parts only a faint gneiss-texture is detectable.

The dominant rock type in the Knaben and Flottorp areas is a socalled "porphyry granite", which belongs to this feldspar-quartz-rich gneiss unit.

3.3.2 "Grey, layered gneiss with much basic material"
is of major importance as far as Mo-exploration is concerned. Layers of such rocks are folded together with alternating zones of quartz-feldspar-rich gneiss.

A Danish geologist, J.L. Pedersen, has in detail described the rock of the Gursli and Sira mining areas for his Ph.D. Thesis.

He found that the grey layered gneiss unit comprise 3 sub-units:

1) quartz-feldspar-gneiss,
2) hypersthene gneiss
3) amphibolite/pyribolite

The hypersthene gneiss often contain sulphides (pyrite, pyrrhotite, chalcopyrite and molybdenite), which are recognized by their brown, rusty weathering products on the surface.

For details about the Gursli and Sira areas, we refer to chapter 5.

For the Knaben area, a more detailed description, mainly based on reports and publications by Schetelig and Bugge, will be given later in this report (chapter 4). In this area however, occur zones of grey gneiss (with associated amphibolites and sulphide-containing bands, i.e. "grey layered gneiss") alternating with a red "porphyry granite", and nearly all molybdenite deposits of importance are connected to these grey gneisses.

At Flottorp, SE of Knaben, and Ovedal, NE of Sirdalsvannet, similar conditions are found.

3.3.3 Augen-gneisses
occur both in the western and eastern part of the mapped area (appendix 1). Pedersen consider the augen-gneisses in the Sira area as being intrusive rocks, which were emplaced at an early stage of the geological evolution.

Falkum believes that the augen-gneisses-zones in the south-eastern part of the mapped area are of the same type as at Sirdalsvannet, while the north-eastern augen-gneisses possibly are older.

3.3.4 Younger intrusives.
To the SE, the gneisses are intruded by anorthosites. To the east and south-east, there are a number of intrusive granites - quartz-monzonites. At Knaben and Flottorp there occur a number of "aplitic" intrusions, which, according to Schetelig, Bugge and others, played a significant role in the genesis of Mo-ore (see chapter 3.4, 4.16).

3.4 Hypothesis about ore genesis.

Two main models have been proposed for the genesis of molybdenite in South-Western Norway :

a) A magmatic model.

This hypothesis was first put forward by prof. Schetelig, and was later elucidated by Dr. A. Bugge (1963), both working as consultants for the Knaben Mines for many years :

An old gneiss complex ("grey gneiss") was intruded by younger granite (red "porphyry granite"), leaving fragments of the old gneisses as elongated inclusions in the magmatic rock. Dikes of aplite and pegmatite, and quartz veins are late stage emanations from the granitic magma.

Molybdenite occur partly as impregnation in aplite/pegmatite, but is mainly connected to the quartz veins, indicating that it was concentrated in the late pneumatolytic and hydrothermal phase of the magmatic evolution.

b) A model involving metamorphic mobilization of originally sedimentary mineralization.

This model has been advocated by prof. Urban (1974), who was the leader of Folldal Verk's prospecting team, and Pedersen, who was one of his students.

They emphazise that :

a) molybdenite occur mainly within certain horizons of the grey layered gneiss.
b) graphite in this rock type has been determined to be of sedimentary origin.
c) Mo and other metals are generally enriched in the inorganic part of sapropel sediments.

On this basis they conclude that molybdenite is stratabound and connected to certain horizons of metamorphically altered pelitic rocks. MoS_2 was mobilized during metamorphism, but because of its relatively low mobility it stayed within its host rock, but was deposited together with mobilized quartz and feldspar in zones of minimum pressure.

4. DESCRIPTION OF THE VARIOUS FIELDS IN THE KNABEN AREA.

4.1 Introduction.

In this chapter we give a more detailed description of the areas in which mining has taken place. A number of the mineralizations were discovered during the "molybdenite boom" of 1916-1918. At that time almost every farmer in this part of southern Norway took part in molybdenite prospecting, and some 800 skjerp (skjerp = prospecting pit, i.e. small excavations to examine the mineralization a few feet below the surface) were registered and listed during that period. There are probably a lot more which have not been officially registered. Geologists from the Geological Survey, who have tried to localize and describe these old "skjerps" have told us that most of them are insignificant : some blasting has been done almost everywhere, on indications of just a few grains of molybdenite. The chanses of finding new deposits on the surface seem therefore rather limited.

4.2 Geology of the Knaben Area.

The dominant rock type in this area is a red, relatively massive, but usually slightly foliated, granitic rock. Phenocrysts of red microcline results in a porphyritic texture, hence the name "porphyry granite" has been applied.

Within a 1-1,5 km wide, NS-extending belt, (The Knaben Mineralized Zone, se below) of this granite complex, there occur a number of conformable zones or lenses of grey, generally finegrained gneissic rocks, alternating with the red, porphyritic granite, and parallell to the foliation of the granite, i.e. NS to NNE-SSW, with dip 20-40^{o}E. The grey gneiss contain bands or elongated lense-shaped bodies of amfibolitic material (partly altered to biotite-rich rocks), and impregnations of sulphides are also often encountered as zones in the grey gneiss. By oxidation of the sulphides, the rock gets a characteristic rusty appearence on the surface. These sulphide-containing zones are termed "fahlbands".

Aplitic and pegmatic dikes are common in the area, and occur both in the grey gneiss and in the porphyry granite. Cross cutting dikes have been recorded, but generally they occur as sills, i.e. conformable to the foliation of the rocks.

As mentioned earlier, Bugge (1963) and Schetelig regard the grey gneisses (with their amfibolites and fahlbands) as relicts of an old gneiss complex, partly assimilated by younger granite. The aplites and pegmatites - and also the quartz-veins (see below) - are regarded as pneumatolitic and hydrothermal late emanations from the granite.

Thc most important molybdenite deposits, as far as we know today, are located within NS-running zones of grey gneiss, for instance in the Knaben Area, in the Gursli - Sirdal Area to the west, and the Flottorp deposit to the east.

Of these, the "Knaben Mineralized Zone" was by far the most productive, a zone extending from the Kvina Mine in the north, via the central Knaben Mines, to Litlådalen in the south, i.e. over a NS distance of more than 10 km.

4.3 Description of the Knaben Mineralized Zone.

Quartz-veins and -lenses are very common in the Knaben Zone, and occur both in the grey gneisses and in the red porphyry granite. They are generally concordant with the foliation of the rocks, range in width from a few cm to a few tens of cms, and can be followed along the strike for up to 1 km. But generally they occur as shorter lenses which, as they die out laterally, are then followed by a new lense, often with a small drop/rise in stratigraphic level (an en echelon arrangement). The quartz is generally a brown "smoky" variety, rarely the white "milky" quartz.

The majority of MoS_2-mineralizations in the Knaben Zone are associated with such quartz-veins, and particularly when they occur within the grey gneissic zones.

Mineralized quartz-veins are also associated with aplite- and pegmatite dikes, either as lateral extensions of the lense-shaped dikes, or as enveloping bands or veins around them.

MoS_2 occur in the quartz mass, but are often enriched as coarser flakes along the boundaries of the quartz-veins. Examples of impregnation a few cm into the surrounding gneiss are also reported.

Of major economic importance during the operation of the Knaben II mine was a type of MoS_2-impregnation in a finegrained, grey granitic rock. This rock type is apparently similar to the grey gneisses, but lack the characteristic fahlbands and amfibolites. Chemically it is also similar to the porphyry granite, but is somewhat enriched in SiO_2. This higher SiO_2-content is manifested through a higher content of secondary quartz, both as replacement of the other rock-forming minerals, and as lenses and veins. For this rock type the name "gangfjell" ("gangue rock") was originally applied. At Knaben II it crops out as an approx. 700 m long and less than 100 m wide lense-shaped body, concordant with the surrounding porphyry granite. There is a transitional zone between the two rock types. MoS_2 occur as impregnation in the grey rock and in the transition zone, and also on quartz veins and -lenses.

In the deeper parts of the Knaben II Mine this "gangfjell"-lense grades into a grey gneiss, in which MoS_2-mineralization is connected primarily to quartz veins, and only to a minor extent occur disseminated in the rock. Nevertheless, the term "gangfjell" was also applied for this deeper grey gneiss, and eventually it was used synonymously with "grey, finegrained gneiss".

Bugge and Schetelig seem to favour the view that the "gangfjell"-lense in the upper part of the Knaben II Mine is a pneumatolytically altered (greisen alteration) porphyry granite, and hence is different from the fahlband- and amfibolite-containing grey gneisses, which they, as mentioned, consider to be relicts of old gneisses in younger granite.

Bugge (1963) classified the various MoS_2-mineralizations in the Knaben Area according to the following types :

Type I : Molybdenite in the oldest mineralized gneiss zones (fahlband). Numerous, but small occurences in widespread, narrow quartz veins.

Type II : Molybdenite as impregnations in "gangfjell" ("gangue-rock") and in (associated) quartz veins. The aplite veins (cutting the gangfjell) are in parts molybdenite bearing. Large deposit at Knaben II.

Type III : Molybdenitebearing quartz veins and -lenses,
A : as parallell veins at "gangfjell" deposits of type II,
B : enveloping a pegmatite lense (Kvina),
C : as large veins and lenses of the type found at Knaben I. In parts rich veins, but the deposits have little extension in strike and dip directions.

Type IV : Molybdenitebearing quartz vein systems (in the southern part of the Knaben II field (Hommen). .... approaching a breccia structure at depth.

One additional type should be mentioned :
Several records have been made of molybdenite mineralizations on fractures, joints and narrow shear zones or -planes, both in the grey gneiss and in the red porphyry granite. This type indicate that MoS_2 was formed at a late stage of the geological evolution.

In the southern part of the Knaben Area, the map (appendix 2) show an EW-running feature called Hommenforkastningen ("The Hommen Fault"). South of this fault the rocks are dipping 70-80° E, whereas the dip north of this line is approximately 50°E. No indication of any horizontal movement along this suspected fault has been recognized. The significance of this fault, as far as mineralization is concerned, has not been clearly established. However, MoS_2-mineralizations are distinctly weaker south of this line than to the north.

A short description of the various deposits/areas from the Knaben Mineralized Zone will be given in the following order (from north to south) :

Kvina Mine - Knaben I - Bergtjern N - Bergtjern - Lille Knaben - Reinshommen - Ørnehommen - Roma - Vannmagasin - Benkeheiknuten - Benkehei Mine - Knaben II - Risna - (Svoen - Beritshei - Hommen-Øyevann - Tor Hålands) Area - Sjerlevann and Litlådalen (see map appendix 2). Some less important mineralizations will also be mentioned.

4.4 Kvina Mine.

Location : The mine is located approx. 1.5 km NNE of the Knaben I Mine, north of lake Smalvann, 850 m above sea level, in mountainous terrain.

History : Small mining operations (test mining) were performed during the years 1904 - 1909, and some 30 tons of ore of unknown grade were excavated. A company was formed in 1911, and workings to expose the ore, road constructions and technical installations were completed in 1913.

Regular mining started in 1915, and the mine was closed in January 1919, due to a combination of a workers strike and a government imposed export ban.

Attempts to reopen the mine were made during three later periods : in 1925, in 1943-44 and in 1952-55. The ore grade was nearly constant during all these operations (see below), but all attempts failed to make an economic proposition of the project.

Ore production : The following table summarizes the available figures for the various mining periods :

Year	Tonnage	Conc/grade ton % MoS_2	Contained MoS_2(100%)	Ore grade	Reference
1904	1 t				J.Norman,1907
1905	2 t				
1906	3 t				
1907	4 t				
1908	1173 t				C.Bugge & al. 1921
1909	1000 t				
1912	1004 t				
1913	1075 t	4 t á 64 %			
1914	3270 t	85 20.3 t á 72.5 %	14.7 t	0.45 %	"
1915	6750 t	22.5 t á 72 %	16.2 t	0.24 %	"
1916	18250 t	58.1 t á 77 %	44.7 t	0.245 %	"
1917	17710 t	50.6 t á 77 %	39.0 t	0.22 %	"
1918	12460 t	34.6 t á 78 %	27.0 t	0.217 %	
	62700 t	190 t	141.6 t		

Year	Tonnage	Conc/grade ton % MoS_2	Contained MoS_2(100%)	Ore grade	Reference
1925	12640 t	24 t á 80.8%	19.5 t		A.Bugge, 1963 I.Rosenquist, 1953
1943 - 1944 : No production, test mining.					
1952 1955		73 t á 87-94 %	65 t	0.27 %	A.Mugås, 1955
Total	100 000t (see below)	287 t	226 t		

For the period 1952-1955 the total production, based on the figures above, should be approx. 24 700 tons of mined ore.

Conclusion : During the various mining operations, a total in the order of 100 000 tons of ore was mined, yielding approx. 290 tons of concentrate, with an average grade of 78-80 % MoS_2 (varying between 72-94 %), corresponding to 225-230 tons of 100 % MoS_2. Ore grades varied from 0,45 to 0,22 % MoS_2.

Geology : The Kvina Area forms the northernmost extension of the socalled Knaben Mineralized Zone. Appearently the amount of grey gneiss inclusions in the red porphyry granite has decreased markedly in this area, as compared to the areas further south, indicating a fundamental change in the geological conditions.

MoS_2-mineralization is connected to a pegmatite body and is concentrated in a nearly pure quartz border zone toward the surrounding gneiss.

The pegmatite-quartz body has a lense shape, and lies concordant to the foliation of the porphyry granite. Average strike : N22°E, dip : 30°SSE. The lense has a slight plunge (10°) to the south. Maximum width is 16 m. It has been followed by mining for 240 m along the axis. Maximum horisontal extension is approx. 80 m. It outcrops to the north, and in the southern workings the width of the quartz vein is only 2 m.

The lense has a central core of pegmatite. Appearently this pegmatite is quartz-dominated, some workers have described it as a coarsegrained quartz mass. This central core is virtually barren of MoS_2. Enveloping the pegmatite is a zone of MoS_2-containing dark, smoky quartz (max. width : 7 m). Aplitic dykes cut this system.

Most of the workings have been done on the quartz zone, both to the hanging wall and to the footwall of the pegmatite. In the immediate vincinity of the quartz, the surrounding gneiss is a grey, quartz-rich, MoS_2-impregnated "gangfjell" variety, which has been mined to a minor extent. This rock grade over a short distance into almost barren red porphyry granite (except for some thin MoS_2-mineralized joints).

3 diamond drill holes have been drilled in this area. Hole no. 1 was drilled under the main part of the ore zone, and the object was to examine the deeper extension of the ore-containing lense. Only traces of MoS_2 was found, showing that the lense has a termination downwards.

The other 2 drill holes were done to examine some smaller mineralized zones 500 and 1200 m SW of the Kvina ore-body. Only traces of molybdenite were found.

No drilling has been carried out directly to the south of the Kvina orebody, with the purpose to explore the deeper extension along the assumed axis of the pegmatite-quartz-lense.

Although the conditions in the southern workings of the mine indicate that the lense wedges out here, there is a chance that a pinch-and-swell model for the pegmatite-quartz-body may be actual. So if one more hole was to be drilled, we would suggest that this should be the target.

4.5 Other deposits in the Kvina Area.

Immediately north of Kvina are the following "skjerp" (skjerp = prospecting pit, i.e. small sub-surface excavations, to examine the mineralization a few feet down the dip) :

Aslak skjerp, Isac and Jacobs skjerp and the Begtefjell Mine. They were worked during the period 1916-1918.

At Aslak skjerp some 75 tons of mineralized rock has been mined out.

Isak and Jacobs skjerp is a 9,5 m long adit.

Begtefjell mine is situated NW of Kvina, on the southern slope of the hill Grudevassknuten, ½ hours walk from Kvina. Red granite dominates the field. A 30 m wide, NS-extending zone consists of finegrained silicified granite, which on both sides grade into a coarsergrained, pale granite. With a gradual increase in red feldspar, this rock in turn grade into a normal red granite.

MoS_2-mineralization mainly occur on quartz veins and- "blebs", and on narrow (1-2 cm) pegmatite lenses. Rich MoS_2 is also found on joints and narrow shear zones. The finegrained, silicified granite also contain some disseminated MoS_2, and a fine impregnation in the pale granite has also been observed. (Reference : Neumann - Adamson 1950. NGU Bergarkivet no. 1300).

Between the Kvina Mine and the Knaben I Mine are the Sandtjern Mine (149 [x]) and the Sanne Mine (150). Small-scale test mining was performed during the period 1916-1917, but no geological records exist from these places.

4.6 The area of Grundevassknuten - Smalvann (147) - Tobias Mine (146) - Hunsbedtskjerpene (148).

Ref. : A. Bugge. Report from 1937.
The main rock at Grundevassknuten is the red porphyry granite. MoS_2 in this red granite is rare, but there are many examples of mineralizations on smaller shearzones or joints lying adjacent to quartz veins.

At Smalvann relatively rich MoS_2 occur in a 1.5 m wide and 15 m long quartz vein. 4 m of the hangingwall rock is well impregnated. It has a possible continuation towards south. A smaller parallell zone is mentioned. Because of its relatively rich mineralizations, this deposit deserve some attention and should be given priority in any future prospecting.

About the Tobias Mine it has only been mentioned that it was examined in 1915.

From the Hunsbedt skjerp no records are available.

4.7 Knaben I (145).

History : Knaben I is the oldest mine in the Knaben district. It was claimed to the Ministry of Mines for the first time in 1884.

x) Figures in brackets refer to Map of Norwegian Mines and ore-deposits by S. Foslie (1925).

Small scale mining operations were performed during the periods 1885-1887 and 1894-1897. In 1904 the mine was sold to "The Blackwell Development corp. Ltd, Liverpool" and regular mining started in 1905. A concentrator was installed, and a concentrate of 70-80 % MoS_2 was produced. In 1909 all operations were stopped.

In 1913 another british company,-Cammel, Laird & Co., Shieffield, - reopened the mine and worked it until 1917.

In January 1918 the mine was bought by A/S Knaben Molybdængruber, who by then owned both Knaben I and Knaben II Mines. The mine was, however, not in production until 1934. In addition to new ore, some MoS_2 was produced by running the old waste through the concentrator. All activities ceased in 1939.

Ore production : Detailed figures for ore production for the various mining periods are not available, but it is mentioned that a total of 80 000 tons of crude ore has been mined, yielding approx. 570 tons of MoS_2 (contained). For the years 1904-1909 the MoS_2-content of the concentrate was 70-80 %. For the period 1914-1917 the figures 75-77 % has been mentioned.

MoS_2 occur on quartz-lenses which are concentrated in the border zone between granite to the west and a 10 m wide amfibolite body to the east. The amfibolite forms part of a "fahlband"-zone.

At the surface the amfibolite dip approx. 30^{o}E. The strike is NS in the southern part of the area and NE-SW in the north, i.e. the amfibolite boundary form a flexure or a bend. Also in cross section there is a change towards a steeper dip in the lower levels of the mine.

MoS_2-containing quartz veins appear to be concentrated immediately north of this bend, and die out to the north. They have been followed for approx. 100 m along the strike and 25 m west of the amfibolite. Downwards they die out approx. 20 m below the surface. Generally the quartz lenses are small (max. width : 10 m).

Some rich MoS_2 occur as coatings on the actual amfibolite border plane, and some uneconomic impregnation was also found in the granite.

The ground underneath the known ore lenses has been explored by drifts and diamond drilling, which showed that the ore zone terminates downwards. Some exploration work has also been done on the eastern flank of the amfibolite, but no economic mineralization was found.

4.8 Lille Knaben (142) and Spillbrokskjerpene (144)

were mined in the period 1914-1917.
At Lille Knaben MoS_2-containing quartz veins are associated with an aplite dike. The ore contained 0,39 - 1,0 % MoS_2.

At Spillbrokskjerpene only 5 m^3 of rock has been mined. Quartz dikes can be followed for 500 m, but MoS_2-mineralization is irregular along the vein, and much of the quartz is almost barren (Ref.: Schetelig, 1915).

4.9 The Ørnehommen Field (141).

Within this area - which is located between the Knaben II and Lille Knaben Mines - are the Jelå - Rubens - and Hommen Mines and the Ljosland skjerp.

Schetelig (1915) believed that this field had a relatively deep extension downwards. We have not been able to find data (diamond drilling etc.) which can verify this assumption.

Anders K. Olsen has given a description of the field. MoS_2 occur mainly as impregnation in gneiss and quartz in a border zone between granitic gneiss and porphyritic granite. Quartz veins parallell to the strike contain MoS_2, and impregnation of the gneiss is concentrated near the quartz veins.

Transversal quartz veins and the porphyry granite are virtually barren of MoS_2.

MoS_2 occur abundantly on narrow shear planes as flat "cakes" covering a few m^2, and a few cm thick. They are always concordant. Crosscutting shear planes contain no MoS_2.

Chalcopyrite, pyrite and pyrrhotite are associated with MoS_2 in places. Fluorite is also present, and Olsen therefore conclude that the mineralization is formed pneumatolytically.

Ljosdal skjerp is the northern deposit in this area. Very rich MoS_2 occur in a 10-15 cm wide quartz vein on the boundary between granitic gneiss and porphyry granite. The gneiss adjacent to the quartz vein is impregnated.

An impregnation zone can be followed more or less continously to the Jelå Mine, 380 m to the south. Here the zone is cut by a diabase dike, but reappear on the southern side of the diabase, and can be followed further to the Rubens Mine.

At Jelå Mine a number of parallell MoS_2-containing quartz- and gneiss bands have been worked together. Total width of the orecontaining zone is 3,5 m. This system has been followed for 120 m to the north. The orebody has a horizontal area at the surface of approx. 360 m^2. This means a hypothetical 1000 tons of ore pr. m sinking of the mine.

To the south the ore zone is cut by a diabase.

At The Rubens Mine, which lies south of the diabase, the molybdenite content in the ore is somewhat lower than at Jelå. The mineralized zone is difficult to follow on the surface, but there are indications from the underground workings that it continues to the south. The ore zone dips 35-40^{o}E. The mine is situated approx. 180 m above the bottom of the Ørnehommen valley.

Hommen Mine is situated approx. 200 m NE and 100 m below the Rubens Mine, and dips 40^{o}E. The mineralization is of the same type as abov· i.e. parallell quartz and gneiss bands on the border between underlying porphyry granite and granitic gneiss above. The largest quartz lense was approx. 15 m long, and had a max. width of 0,5 m. The ore containing zone has a total width of approx. 2,5 m. It has been followed on the surface for 120 m, and show over the whole distance relatively even and good mineralization (1,5-2 % MoS_2 has been mentioned).

4.10 <u>Reinshommen (140) and Roma (143) Mines.</u>

References :

Schetelig	1917	NGU Bergarkivet	no. 2940
Vikøren	1918	" "	" 2938
Blekum	1918	" "	" 2939

References :

C.Bugge & Rieber,	1919	NGU Bergarkivet	no. 2352
Smith	1934		
A.Bugge	1937	Ministry of Mines, Bergen	
Brun		" " " "	
Christensen	1961	NGU Bergarkiver	no. 3349

At Reinshommen some work was done in 1917, but it was not until 1937 that a more comprehensive investigation was performed, in the form of diamond drilling and small scale surface mining in the southern parts of the field. No economic mineralization was registrated.

To the north little work has been done, but a 2-3 m of "good ore" was discovered in a few prospecting trenches. Despite this, the field has been regarded (without any explanation) as being of little interest.

The Roma Mine is situated between Knabetjern and Bergetjern (tjern = small lake). Relatively extensive underground workings were done on two quite small but relatively well mineralized quartz veins. Some MoS_2 also occur on and adjacent to joints in the red granite, associated with CaF_2.

Fossgruven (the Foss Mine) is situated in the southern part of this field. No records are available.

4.11 Benkeheia (139).

From this area, which also comprise the Benkeheiknuten deposit, we have a number of reports :

Report from the Inspector of Mines, Ministry of Mines, Bergen.

A.Bugge	1937	Benkeheia	"
Kragh Wehn	1938	"	"
A.Bugge	1940	Knabendalsskjerpene	"
Adamson - Naumann	1950	NGU Bergarkivet. No. 3310	
Report on diamond drilling (unknown author)			No. 713 A
Geological report (unknown author)		"	No. 3671

Location : The Benkehei Deposit forms the northern extension of the Knaben II Mine, and extends northwards to the Roma Mine.

History and production : In 1916 some development work was done on this deposit, and 8 tons of ore was transported to the coast.

In 1917 a newly formed company - Benkehei Grube A/S - built a flotation plant. 1380 tons of ore was treated to a 60 % MoS_2 concentrate, containing 1560 kg of MoS_2.

The concentrator was not in operation in 1918, but in 1919 4200 tons of ore was treated, yielding a 81,9 % MoS_2 concentrate, containing 6301 kg of MoS_2. Mining ceased in August 1919.

In 1938 all the company's properties were taken over by A/S Knaben Molybdængruber. Some diamond drilling was done in 1938 (see below).

Geology : Mineralized quartz veins and disseminated MoS_2 in the adjacent gneiss can be followed from Knaben II for 240 m.

Bugge (1963) believed that the Benkehei deposit lie approx. 100 m east of the Knaben II ore zone, while other workers seem to think that there is a direct continuation between the two deposits.

The ore zone strikes N 19°E and dips 30°E.

The amount of impregnation type ore in gneiss is less than at Knaben II, and although the mineralization in the quartz veins was quite rich, the average MoS_2-content of the crude ore reached only 0,25-0,30 %.

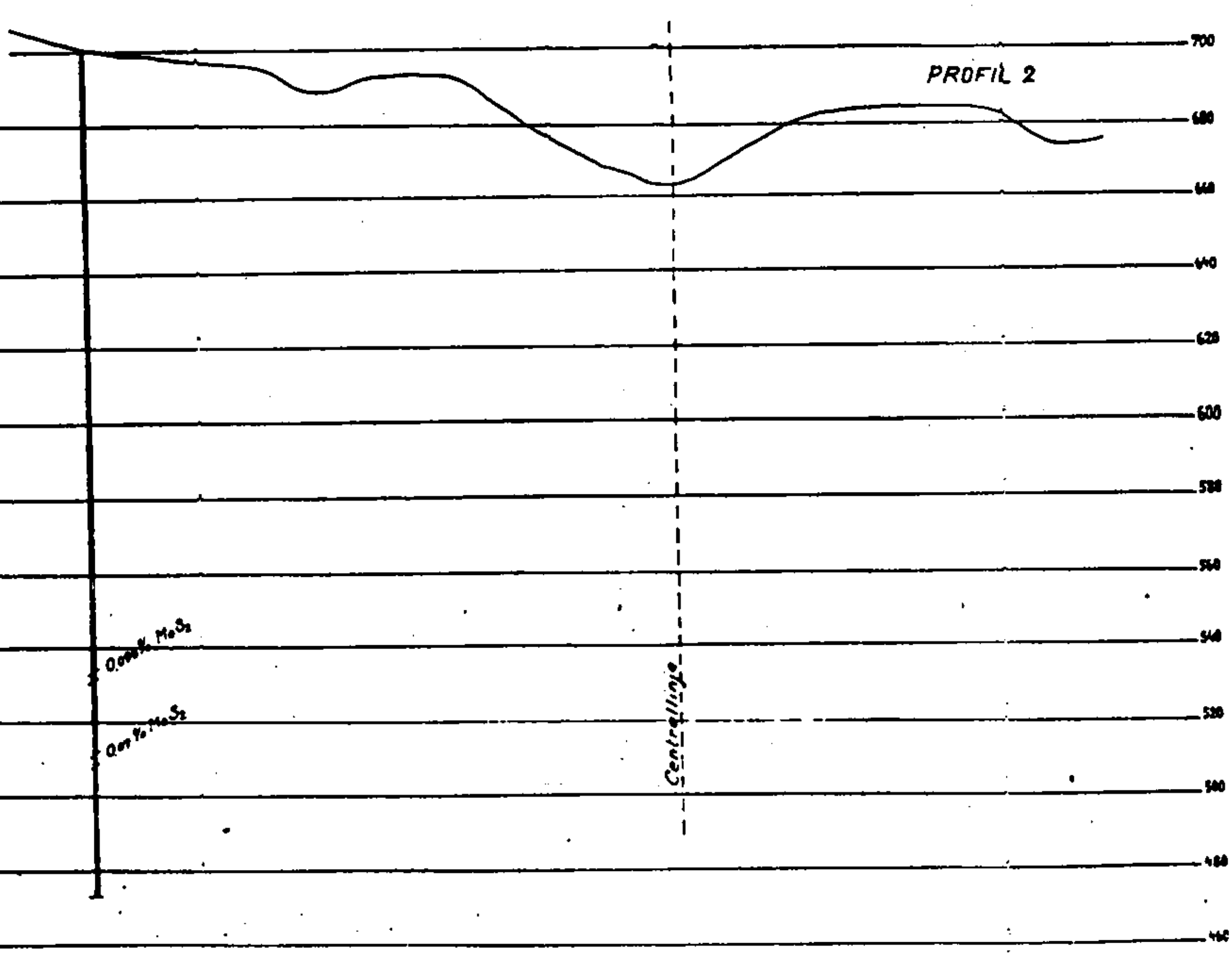
Molybdenite on shear planes is however more common than at Knaben II. CaF_2 is often associated with molybdenite.

The average width of the ore zone was 2-3 m. In the mining area it seems to wedge out downwards, but diamond drilling done in 1938 has revealed that mineralization (7 m of 0,184 % MoS_2 in DDH no. 2 profile 1, see accompanying sketch fig. 2 and fig. 3) occur 150 m below the surface. The connection from this intersection to the mined ore zone above is not clear.

Diamond drilling results.

Profile 1 DDH 1 : Vertical hole. The red granite is barren. MoS_2 on quartz veins and on pegmatites in "gangfjell" (grey gneiss).
Assay result : 0,173 % MoS_2 over 4,15 m.

BENKEHEI



DIAMANTBORING BENKEHEI.

FIG. 2

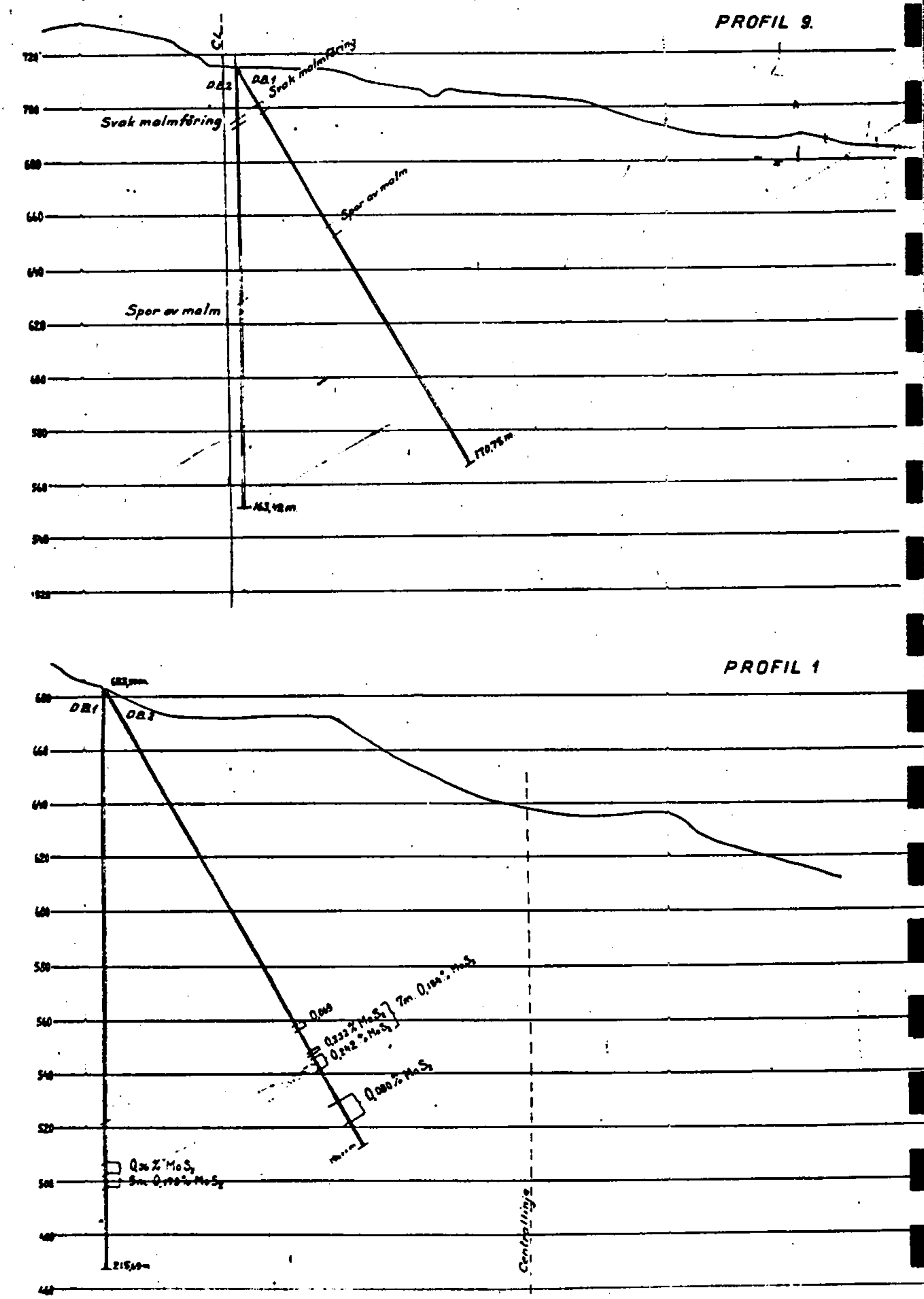

PROFIL 9.
CL
DB.1
DB.2
Svak malmføring
Svak malmføring
Spor av malm
Spor av malm
170,75 m
163,48 m
PROFIL 1
DB.1
DB.2
0,232 % MoS2
0,242 % MoS2
7m. 0,184 % MoS2
0,080 % MoS2
0,36 % MoS2
215,60 m
Centrallinje

Fig. 3

Profile 1 DDH 2 :	-60°E. Geology as in DDH 1. Assay results : 0,242 % MoS_2 over 4,15 m (0,184 % over 7,0 m).
Profile 2 DDH 1 :	Vertical hole. Rocks as above, but less quartz and pegmatite. More aplite. Assay results : 0,096 % MoS_2 over 1,7 m.
Profile 4A DDH 3 : (not on sketch)	Assay results : 0,102 % MoS_2 over 3,65 m. 1,3 m core loss, but drillers report that 0,4 m of this zone contained "pure molybdenite". Assay of drilling mud gave 62,0 % MoS_2 for this zone.
Profile 4A DDH 1 :	Red granite is sterile. "Gangfjell" contain MoS_2. Assay results :
	103,85-105,80 m : 0.021 % MoS_2
	109,50-112,60 m : 0,100 % "
	112,60-115,75 m : 0,450 % "
	115,75-119,05 m : 0,025 % "
	135,45-138,65 m : 0,265 % "
Profile 4A DDH 2 :	Negative ? (no assay results recorded).

Knabedalsskjerpene in the Benkehei area is presumably a direct continuation of the quartz vein system from Knaben II.

Benkeheiknuten is situated between Knabeelven (the Knaben River) and Benkeheia. A number of small MoS_2-containing quartz veins are cutting the granite.

4.12 Knaben II Mine.

As mentioned previously, this is by far the most important deposit in the Knaben Mineralized Zone, and hence most of the geological work has been concentrated on this deposit. Numerous reports, notes and even University thesis have been written, and hundreds (thousands ?) of maps and sketches are stored in the various files we have had access to.

It is an insuperable task, and, as we regard it, beyond the scope of this report, to present a detailed survey of all this material, and we therefore take the liberty to just refer to all these records, which are available for any future study.

However, everything that has been said previously (and later) about the general geological conditions in the Knaben area is based on our knowledge from the Knaben II Mine.

A few facts and figures from the history of the mine will, however, be submitted (with reference to A.Bugge, 1963) :

History : During the first years of operations in the Knaben field, the Knaben II was given little attention since the mineralization at the surface was mainly of the finegrained impregnation in gneiss type, and hence not suitable for concentration by hand picking.

It was not until the flotation process was introduced that this ore type became important, and the owners of the Old Knaben Mine (Knaben I) - Cammel Laird & Co. -
Shieffield - installed a flotation plant and started processing the ore in 1916.

Development mining in 1916 and 1917 had proven 1.170.000 tons of 0,5 % MoS_2.

In January 1918 the property was transferred to the newly formed A/S Knaben Molybdængruber. Since 1918 this company operated the mine until it closed down in 1972 (except for a shut down from May, 1919 to July 1923). In 1930 a swedish company, Axel Johnson, Stockholm, became a majority share holder.

Crude ore production was in 1927 : 54.900 tons, in 1928 : 69.000 tons and in 1933 : 164.200 tons. A concentrate containing 80 % MoS_2 was produced. In 1934 the concentrator was damaged by fire, and a new plant was completed in 1935, with a capacity of 300.000 tons of crude ore pr. year, giving a concentrate of 94-97 % MoS_2.

During these years the mining was done in the upper levels of the socalled "gangfjell" lense (i.e. disseminated MoS_2 in grey, granitic gneiss), and the average ore grade was 0,306-0,345 % MoS_2. But during the 1930s the ore became gradually poorer (in 1939 it was 0,183 % MoS_2.

Extensive investigations by diamond drilling was carried out, and it became evident that the "gangfjell" lense died out at depth. But it also revealed that the deeper lying quartz vein type of mineralization was of economic grade.

In 1943 the plant was damaged by bombing, but the Germans constructed a concentrating plant underground and continued mining the upper (and relatively low grade by that time) "gangfjell" lense. In 1944 the MoS_2-content of the ore was down to 0,137 % (average 0,152 % for the period 1940-1945). Highest yearly production was 360.000 tons, despite the fact that the Germans increased the working force from 400 to 1000 men.

After the war a totally new plan for the whole mining operation had to be worked out. The concentrator was again moved out and rebuilt on the surface, and development work was carried out in the deeper quartz vein deposit. It was not until 1951 that ore production again reached 100.000 tons. After that it steadily increased and was in 1960 : 207.000 tons, giving 410 tons of MoS_2 (see fig. 4).

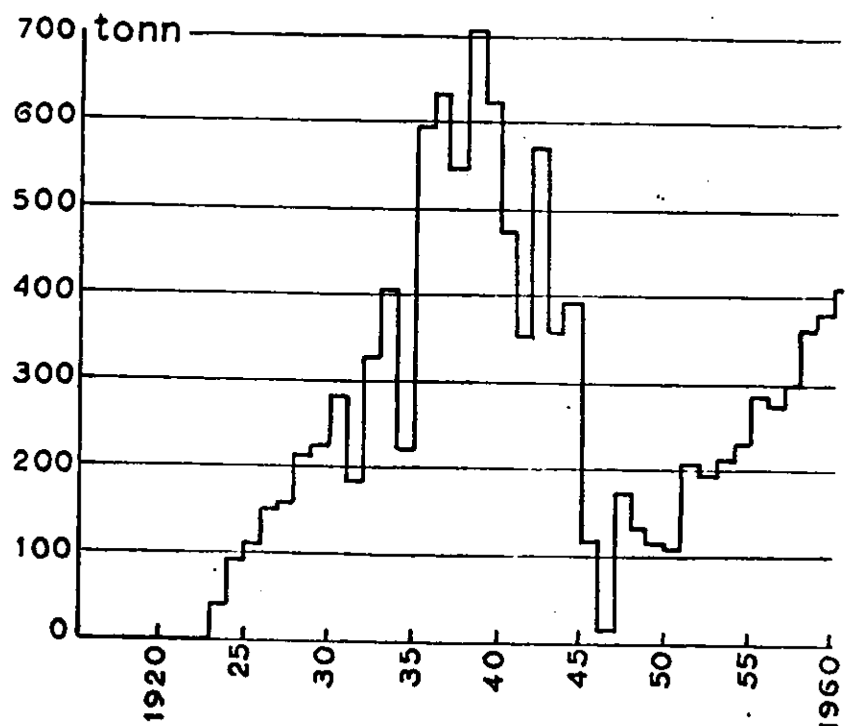


Fig. 4.
Production of molybdenite from Knaben II - mine.

Effective average ore grade for 1947 was as low as 0,147 % MoS_2, but this was improved to 0,161 % for the period 1950-1956. During the following 4 years (1957-1960), i.e. at a time when the whole mine and plant was developed according to the new plans, the effective grade increased to 0,19 % MoS_2. For the last years of operation, an average grade of 0,22 % was obtained.

Altogether, a total of 8,6 million tons of crude ore with an average content of 0,21 % MoS_2 has been mined from the start of the Knaben II, until 1973.

Ore reserves.

Vokes (1969) did a calculation of ore reserves for the Knaben II Mine, which resulted in the following tonnages :

Probable ore :	5,7	mill.	tons	á	0,15	%	MoS_2	
(In 1973 :	5,0	"	"	"	"	"	"	Ross & al.)
Possible ore :	7	"	"					

4.13 Beritshei - Svoen Field.

Svoenfeltet (the Svoen field) is situated approx. 1,5 km W of Knaben II. A number of widespread MoS_2-mineralizations follow NS-extending hills of red granite. The northern part of the field lies ½ km W of the southern end of Store Knabetjern. A number of prospecting pits have been excavated along this approx. 1.5 km long zone.

Lenses of grey granite ("gangfjell") is surrounded by red granite. Aplitic dykes, which cut through the area, are MoS_2-containing. MoS_2 in the red granite is only rarely observed. In the southern part of the field there occur some MoS_2 on quartz veins.

The field as a whole gives a negative impression.

In the Etestøl - Svoen - Moserinnhommen area MoS_2 is also associated with aplite dykes in red granite. They vary in width from 1 cm to 10-20 cm. Som diamond drilling has been done in the Bjørvann - Svoen area (1938-1940), but no valuable mineralization was detected.

Beritshei was claimed in 1971. Some diamond drilling was done, but these data are not available.
(Ref. : A.Bugge, 1938 and 1940.
Report from the Inspector of Mines, 1973).

4.14 Risna Mines (136) - The Risnes Field.

Informations about this area are taken from a report written in 1918. This report also contain the results of some diamond drilling.

Prospecting pits have been excavated, and in some of these "relatively good" ore on quartz veins in "gangfjell" was observed. The best result was obtained in pit no. 3, with $\approx$ 0,385 % MoS_2 over 4,5 m.

4 holes were diamond drilled underneath the ore zone, but they were negative, showing that the ore zone dies out downwards.

4.15 Hommenforkastningen (The Hommen Fault).

The EW-extending, nearly vertical Hommenforkastningen is marked on the map, appendix 2 . As mentioned previously, there has been some discussion as to the significance of this fault.

According to Bugge (1963), the old fahlband-containing gneisses are displaced some 50 m along this line, whereas the ore-containing quartz vein "belts" do not seem to be affected. However, there appear to be a radical change in the size of the ore zones at this point : south of the line there are only small and widespread MoS_2-containing quartz veins.

A pegmatite lense, which lies in the actual fault zone, is MoS_2-mineralized, indicating that MoS_2-containing solutions did find their way up through the fault itself.

Whereas the strike of the rocks are the same on both sides of the fault, there is a marked change in the dip : from 30°E north of the line, to much steeper dip to the south. This may indicate that some kind of rotational movement has occurred.

4.16 Summary on the geological conditions of the Knaben Mineralized Zone between Hommenforkastningen and Beritshei.

Within this section occur the most significant deposits in the area, and all known types of mineralizations are represented here.

In reports from 1955 and 1963 Bugge summarizes his knowledge about this field, and on this basis he presents a hypothesis for the ore genesis.

Bugge pays much attention to the rock type commonly described as "aplite". The term was initially applied to a finegrained, massive feldspar-quartz rock, but was later also used for coarsegrained varieties. Common to the various types are their unoriented, non-foliated dike- or vein-type nature, and they are therefore regarded as younger intrusives in the surrounding gneisses.

At lower levels of the Knaben II Mine, the number and size of such dykes increase, and they seem to converge towards a coarsegrained intrusive body, with both aplitic and pegmatitic varieties. In some parts the aplitic dikes form eruptive breccias.

Quartz veins occur in the aplites as narrow, semi-parallell stringers, but where the aplitic bodies wedge out, they concentrate and form more massive quartz dikes, which continue along the strike of the gneisses. Along the edges the aplite bodies are often enveloped by a quartz "sheet". It is often difficult to define the exact boundary between quartz and pegmatite/aplite. The amount of feldspar crystals increase gradually to form a transitional border zone.

In some places there are transversal pegmatite dikes cutting the quartz veins, indicating that pegmatite deposition also took place after the quartz formation.

MoS_2 occur as impregnation in aplite/pegmatite, but is significantly more associated with the quartz-phase. Although the MoS_2-containing quartz veins are widespread and occur all along the Knaben Mineralized Zone, it is only within the 1,5 km section between Hommenforkastningen to the south and Benkehei to the north, that really significant molybdenite deposits are found.

Bugge explains this by assuming that within this section, geological conditions were such that deepseated magmas were able to penetrate towards the present surface, and that this magmatism - with deposition of aplitic/pegmatitic dykes and quartz veins - was responsible for the concentration of MoS_2.

The top of this magmatic intrusive body reached a level corresponding to somewhere between the 5th and 10th level of the Knaben II Mine. Extending out from this body are dikes and veins of aplite and pegmatite. Variations in grain size are results of local variations in pressure, which also caused a cracking of the rock complex. Late emanations of SiO_2 (and accompanying MoS_2) crystallized on the cracks.

Hydrothermal solutions and gasses penetrated further into the red, granitic gneiss, causing a greissen alteration of this rock, whereby the feldspar was bleached, and quartz and molybdenite were deposited as disseminated grains throughout the rock, thus forming the socalled "gangfjell".

In the southern and deeper parts of the Mine, towards the Hommen Fault, there are an increasing amount of aplite/pegmatite dikes, which in parts contain rich MoS_2-mineralization. The same feature has been registered in deep drill holes. Bugge therefore see the posibility of a deep-seated "aplitic" massive, with possible eruptive brecciation, "gangfjell" formation and quartz-molybdenite deposition, in this area.

4.17 Area south of Hommenforkastningen.

Bragold Mine (135) is located between Knaben and Håland farms, south of Bragtjern. The Nyvold Mine is included in this field.

MoS_2 is associated with quartz veins and lenses in red granite. The quartz approaches a calcedony variety. Some MoS_2 also occur on shear planes as flat "cakes". CaF_2 has been observed.

The area has been divided in a northern and a southern field. In the north very little work has been done. In the southern field there are some prospecting pits. Data on the result of this work are scarce, but appearently the mineralized zone covers a length of 500-600 m. A maximum width of the mineralized zone of 3,5 m has been mentioned. The zone comprise 3 MoS_2-mineralized bands.

A rough estimate of possible ore reserves gives :

Southern field :	length 600 m	x	width 4,5 m	=	2700 m^2
Northern field :	" 600 m	x	" 9 m	=	5400 m^2
			Total	=	8100 m^2

With an average specific weight for the ore of 2,7, a hypothetical 22.000 tons pr. m vertical sinking should be obtained. (Ref. : NGU Bergarkivet No. 3311 (unknown author)).

4.18 Øyvann - Skjerlevann - Tor Hålands Field.

Generally, MoS_2-mineralization in this south-western part of the Knaben area is associated with irregular aplitic dikes, as a fine impregnation (Bugge, 1963). Some small "gangfjell" lenses, which also contain a little MoS_2, indicate initial pneumatolyses.

Diamond drilling has revealed that the mineralized "gangfjell" zones are small and of low grade. Impregnation in aplite is partly richer, but the dikes are too narrow to be of any practical interest.

The prospecting work done in this field therefore show that the area has a low potensial, and no further work is recommended by Bugge (1963).

4.19 Litlådalen.

5 holes have been drilled. Dominant rock type is red granite with narrow zones of "gangfjell", which in parts is weakly mineralized. Blekum (1937) characterizes this field as uninteresting.

4.20 Bjørnehommen.

Dominant rock type is again red granite, with some amfibolite, pegmatite and "gangfjell". "Gangfjell" contains a little MoS_2, but diamond drilling (2 holes) does not indicate any significant deposit.

4.21 Investigations for other valuable elements and minerals in the Knaben Ore.

In a note by Christensen (1958, NGU Bergarkivet no. 3973) mention is made of a study done on the possible presence of Rh in the Knaben ore. The conclusion was that the Rh-content of MoS_2-concentrate was very low, based on an investigation done at the University in Oslo (Dons, 1968).

Siggerud (1955) and Sverdrup et al (1967) state that uraninite has been identified in the tailings from the Knaben concentrator, but no attempts, as far as we know, have been made to determine the quantity of this mineral.

K-feldspar and quartz.

Pursuant to a report from professor M. Digre (Ross èt al 1973) the vaist from The Knaben II Mine is composed of

65 % microcline
30 % quartz
2 % plagioclase
2 % biotite
1 % muscovite

The tailings from the mine are not useable because of rust-contamination on the single mineral-grains, but the report emphasize that it could be possible to produce a total of 60 % K-feldspar, plagioclase and quartz concentrate. The investigations are however never brought so far that the Fe-content in mineral-concentrates are determined.

5. MINES AND OREDEPOSITS OUTSIDE THE KNABEN AREA.

MoS_2-mineralizations in the region is shown on map appendix 3. Mine deposits are briefly mentioned in the following.

5.1 Gursli and Sira areas.

These areas (located on map appendix 1) have been mapped (fig. 5) and described by Pedersen (1975) as a part of Folldal Verk A/S exploration in the region.

Geology.

Intrusive anorthosites occur to the SW and as two small intrusions in the Gursli ore field. The rest of the area is comprised of various concordant gneisses as shown on the map. The mineral composition of the gneisses is shown in table 1.

The interesting rock from our point of view is termed "layered gneiss". This is subdivided according to the following rock types.

Gursli and Sira area

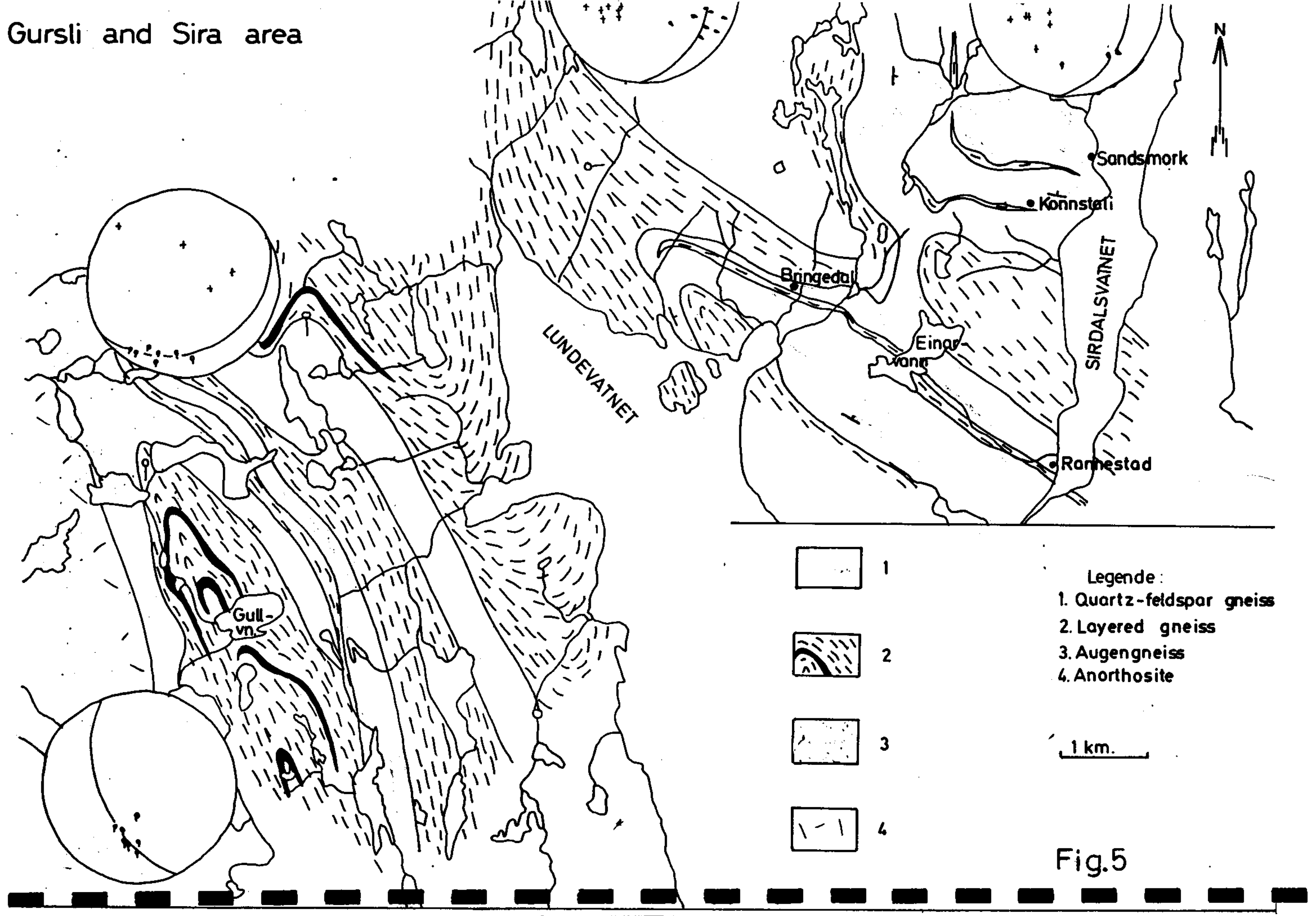


Fig.5

a) Quartz-feldspar-gneiss (very similar to the quartz-feldspar-gneiss outside "the layered gneiss").

b) Amphibolite/pyribolite.

c) Hypersthene gneiss.

Table 1 : Mineral composition of the Gursli - Sira rocks :

	Plagioclase/ Antiperthite	K-feldspar/ Perthite	Quartz	Hypersthene	Diopside	Biotite	Hornblende	Garnet	Fe/Ti-oxides	Sulphides	
Anorthosite	90-95 25-40		0-4	0-8	0-1				1-2		a)
Quartz-feldspar gneiss	15-20	40-45	30-40			1-2					
Amphibolite/ pyribolite	50-60 35-60			20-	30	5-10	10-15		5-10		
Hypersthene gneiss	10-60	10-75	15-60	5-20		5-10		0-15	2-4	0-2(b)	
Augen gneiss	15-40	30-55	15-25	0-7		+-2	0-8		+-2	acc.	

a) An intrusive anorthosite-body in hypersthene gneiss contain MoS_2.

b) Pyrite dominates. In addition : molybdenite, chalcopyrite, pyrrhotite, cubanite, mackinawite, pentlandite and sphalerite.

Hypersthene gneiss appear to be of special significance for Mo-prospecting, and such rocks occur both in the Gursli mining area and as part of the layered gneiss zones in augen gneiss in the Sira area.

Hypersthene gneiss is characterized by its brown, rusty spots after oxidized pyrite. Typical is also accompanying veins and lenses of mobilized quartz-feldspar, which contain sulphides. They have in places been mined for molybdenite.

The general orientation of such lenses rarely deviate more than $10\text{-}20^{o}$ from the foliation of the gneisses.

There appear to be a correlation between the size of the lenses and the width of the hypersthene gneiss horizons (max. width 20-30 m).

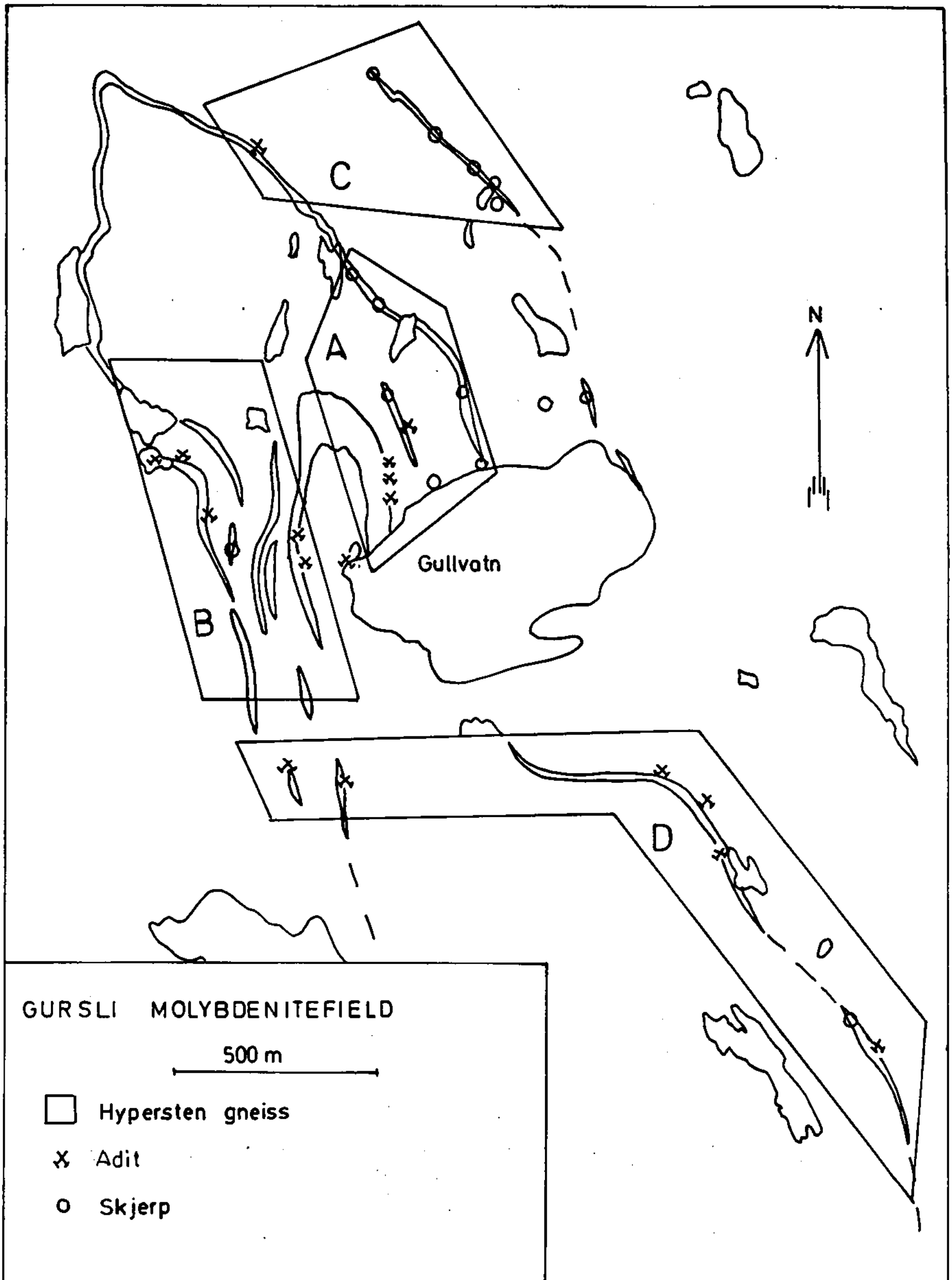


Fig. 6. Gursli molybdenitefield. Gursli mine (A), Mysse-skjerps (B), Skåland mine (C) and Moi mine (D).

Ore deposits and mining operations.

5.1.1 Gursli area.

The map fig. 6 shows the location of the various mines in the Gursli area, with the main mines lying north of the western part of Gullvann.

The deposits were mined during the years 1915-1919. A total of 38.000 tons of crude ore, with an average grade of 0,17 % MoS_2 was taken out.

On the map are also marked the areas which will be shortly described below :

The Moi Field, south of Gullvann.

The largest concentration of molybdenite occur in the widest/thickest part of an approx. 2 km long hypersthene gneiss horizon. MoS_2 occur on joints and narrow quartz-feldspar veins in the gneiss.

Mysseskjerpene (area B).

Molybdenite is concentrated, together with pyrite, in a number of separated quartz-feldspar-lenses, which mainly occur in an open fold/flexure-structure in the western hypersthene gneiss zone. The lenses are up to 2 m long and ½ m wide, and may contain 20-30 % sulphides.

Skåland Mine (area C).

Unimportant mineralizations on joints and small quartz veins.

Gursli Mine (area A).

The gneisses are folden in a relatively large, overturned synform, and the largest Mo-deposits occur in hypersthene gneisses on the eastern flank of this fold.

Mining took place at various levels in the nearly vertical host rock, and Pedersen emphazise that the entire mine is located in hypersthene gneiss.

In the mine occur an intrusive body of anorthosite, with a horizontal area of 25 x 10 m, the depth is about 25 m. The anorthosite is sulphide-impregnated, and grades of 0,4-0,6 % MoS_2 have been mentioned in old reports.

Another anorthosite body, 30-40 m W of the hypersthene gneiss is not mineralized.

Generally MoS_2 is associated with quartz-feldspar-biotite lenses, which are discordant (10-20^{o}) to the foliation of the gneiss. The main lense has a horizontal length of 100 m. Max. width is 10 m, wedging out to a couple of m at the edges. Vertical depth is estimated to at least 100 m. It follows the folding of the gneisses.

Pedersen, in an estimation of ore reserves, indicate an area of the orebody of 520 m^2 over a length of a few 100 m, and conclude that this results in too small tonnages to be of economic interest.

5.1.2 The Sira area.

Sandsmork and Konstalli Mines (fig. 5) were examined by small scale test mining in 1917-1919. A total of 600 tons of 0,15 % MoS_2 was excavated.

At both localities, MoS_2 occur on joints and quartz lenses within a relatively narrow (4-5 m) migmatitic zone in augen gneiss.

An approx. 100 m wide zone, consisting of quartz-feldspar-gneiss, amphibolite and biotite-hornblende-gneiss runs through Rannestad - Einarvatn - Bringedal. On 10-20 cm wide quartz veins and on joints in the biotite-hornblende-gneiss occur a little MoS_2, associated with pyrite.

5.2 The Flottorp area.

This area (fig. 7) is situated SE of Knaben. A member of Folldal Verk's prospecting group has mapped and described the area, but the report has not been accessible to us.

A short description is given by A. Bugge (1963) and by H. Bjørlykke in reports from 1942.

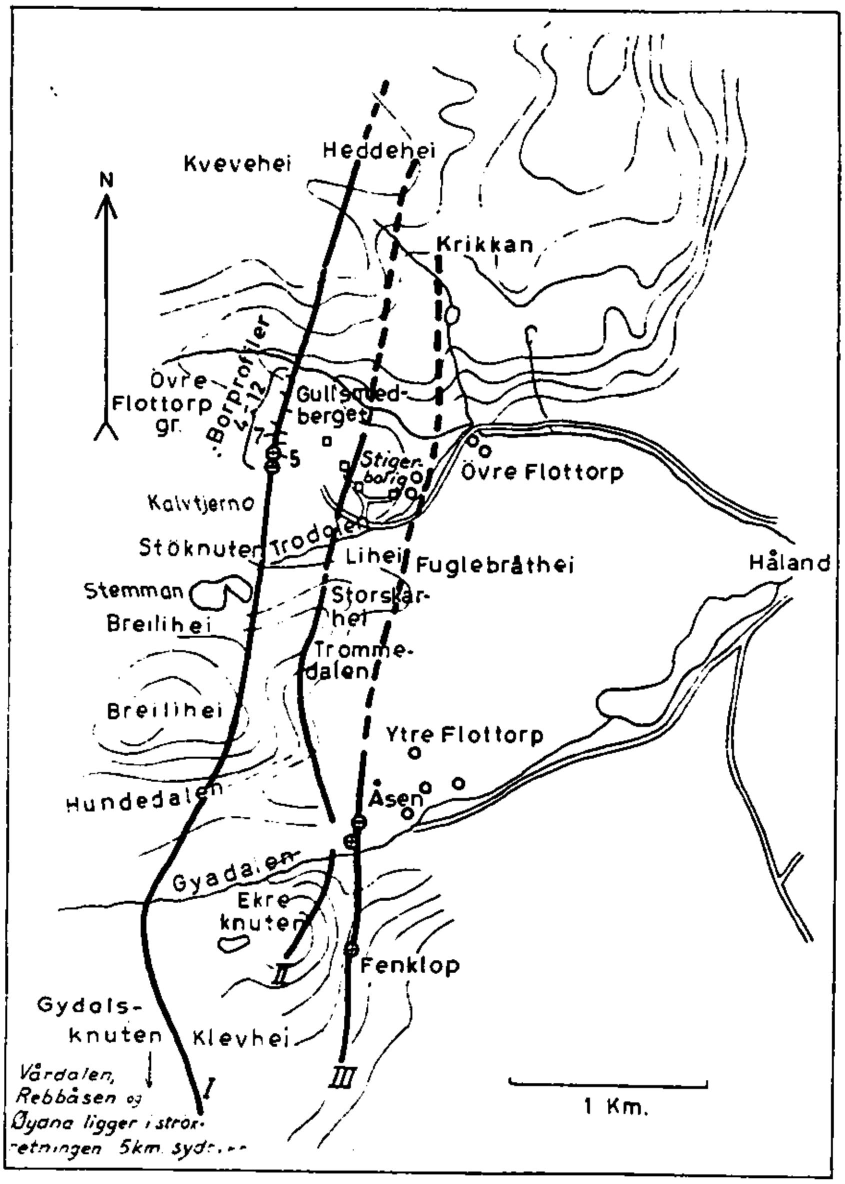


Fig. 7. After A. Bugge (1963)

Flottorp (Undal) Molybdenfelt.

Flottorp (Undal) molybdenum field.

Zones of grey layered gneiss in "porphyry granite"

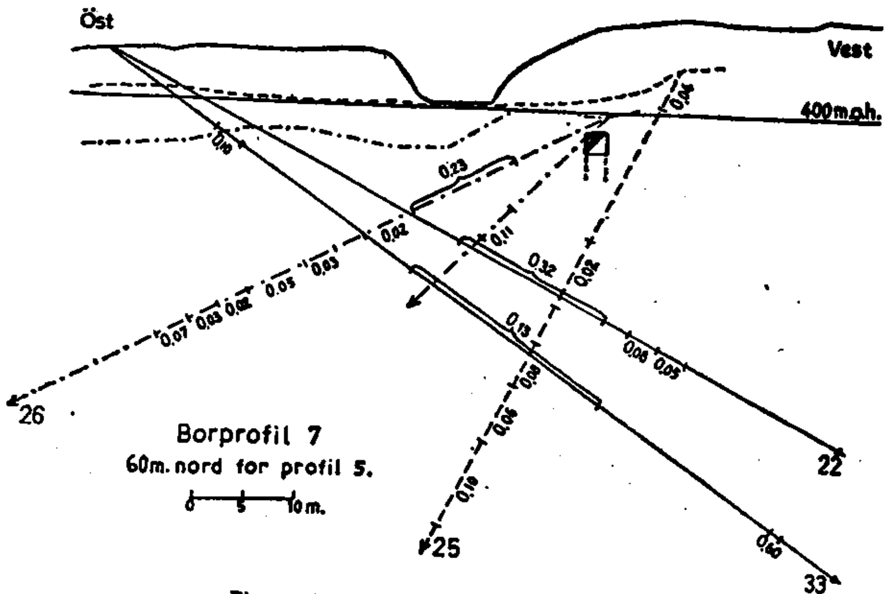


Fig. 29. Borprofil 7, 60 m nord for profil 5.
Diamond drill section 7, 60 m north of section 5.

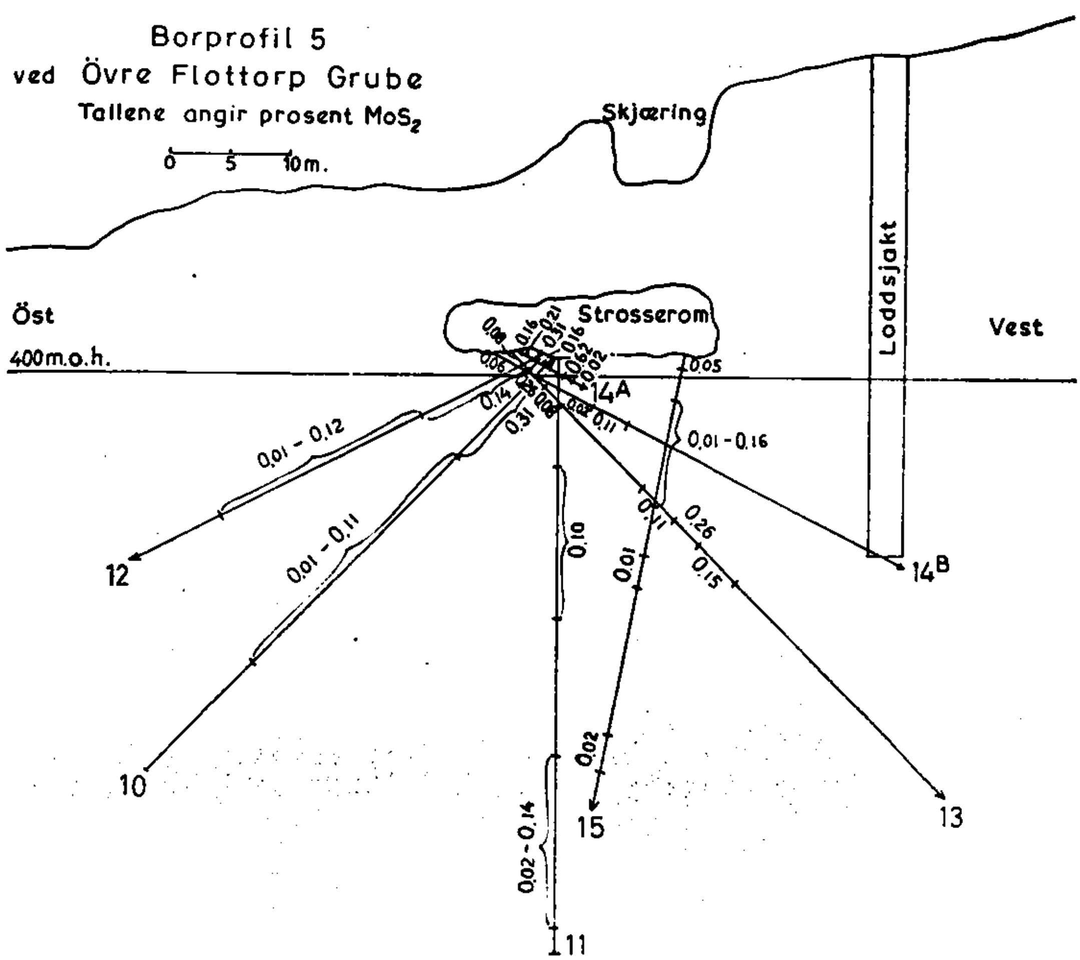


Fig. 28. Borprofil 5 ved Øvre Flottorp Grube.
Diamond drill section 5 at Øvre Flottorp mine.

Fig. 8.

Diamond drill sections at Øvre Flottorp (after A. Bugge 1963). Figures show. MoS_2-content in percent.

At Flottorp MoS_2-mineralization was detected in 1910. In 1911 a concentrator was installed and some 37 tons of 70 % concentrate was produced until 1919 when the work was closed down.

In 1941-42 a quite extensive prospecting was carried out and some 1600 m was diamond drilled. The ore is irregulary (fig. 8) and the quantities small, and the conclusion of the work was that the field was not econimic.

The mining rights in the area are held by private persons.

Geology in the Flottorp area.
The area is geologically similar to the Knaben area : Red porphyry granite is the dominant rock type. NS-extending zones of migmatitic gneiss with layers of amphibolite and mica-gneiss (i.e. "grey layered gneiss") alternative with the granite. At Flottorp there are three main gneiss zones, but in addition a number of widespread gneisses patches occur.

The main zones have an extension of approx. 10 km, of which the northernmost 5 km form the actual Flottorp field. A number of "skjerps" are found all along these zones.

MoS_2 occur as thin "flakes" in quartz veins, and as impregnation in discordant, narrow dikes of aplite and pegmatite. Disseminated MoS_2 in gneiss has also been described. The porphyry granite is virtually barren of MoS_2.

5.3 The Ovedal Field.

The area is situated at the NE side of Sirdalsvannet. This area is also mapped by Folldal Verk's prospecting group, but the report has not been accessible.

Some comments have been made by A.Bugge (1963) and Urban (1972).

Molybdenite occur in an approx. 1 km long and 300 m wide zone, but the main portion is concentrated along 300 m of this belt.

A couple of adits were mined in 1918, and 50 tons of ore was excavated.

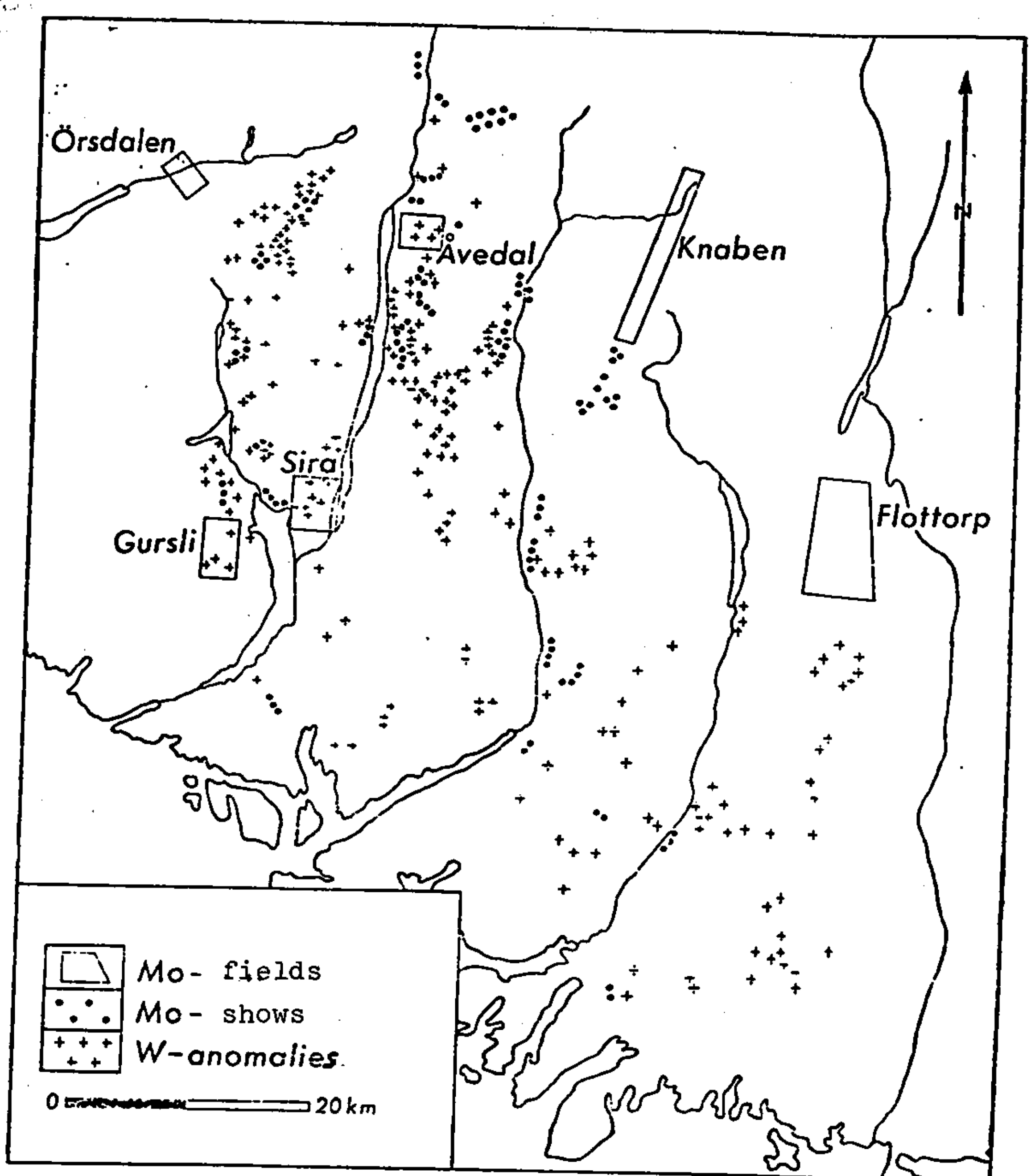


Fig. 9.
Regional distribution of geochemical W-anomalies, shows of Molybdenite and areas where molybdenite has been mined. (After Stendal & Urban 1976).

5.4 Heavy mineral content of stream sediments in the region.

In connection with Folldal Verk's prospecting program, H. Stendal examined the heavy mineral content of stream sediments for his Ph.D. Thesis (unpublished). His work was based on the precence of a small scheelite deposit at Ørsdalen (NW on map fig. 9). This is a stratabound mineralization, occurring in amphibolite, partly associated with molybdenite. Heavy minerals from more that 600 sediment samples have been washed out. Stendal concludes :
"The distribution of the scheelite anomalies are irregular, but have a general NS-extension on both sides of Sirdalsvannet.

9 scheelite mineralizations were detected. None were economic, but they are of interest gentically. They are all connected to amphibolitic rocks. Meta-sedimentary amphibolites contain the largest concentrations of scheelite, and are evidently stratabound. Meta-volcanic amphibolites contain less scheelite, but are in a couple of places distinctly layered. Scheelite mineralization occur widespread over the whole area. The genesis is interpreted as being submarine volcano-sedimentary".

The heavy mineral concentrates contained 70-80 % magnetic material, small amounts of pyrite and a few grains of metallic Cu, Ag and Bi.

W-anomalies are widespread throughout the whole Agreement Area (see fig. 9), both in areas with known molybdenite deposits and also outside, i.e. in areas where no MoS_2-mineralization has been detected.

5.5 Prospecting done by A/S Sydvaranger in the region.

Former A/S Sydvaranger geologist, N.B. Hollander, and 5 of the company's geological assistants (personell with no formal geological education, but especially trained and very skilled minerlogists) did boulder tracing and skjerp-registrations in the area during a shorter period in 1971 (fig. 10).

Hollander concludes : "By boulder tracing, a number of new Mo-mineralizations have been detected, which have one thing in common : they are all small.

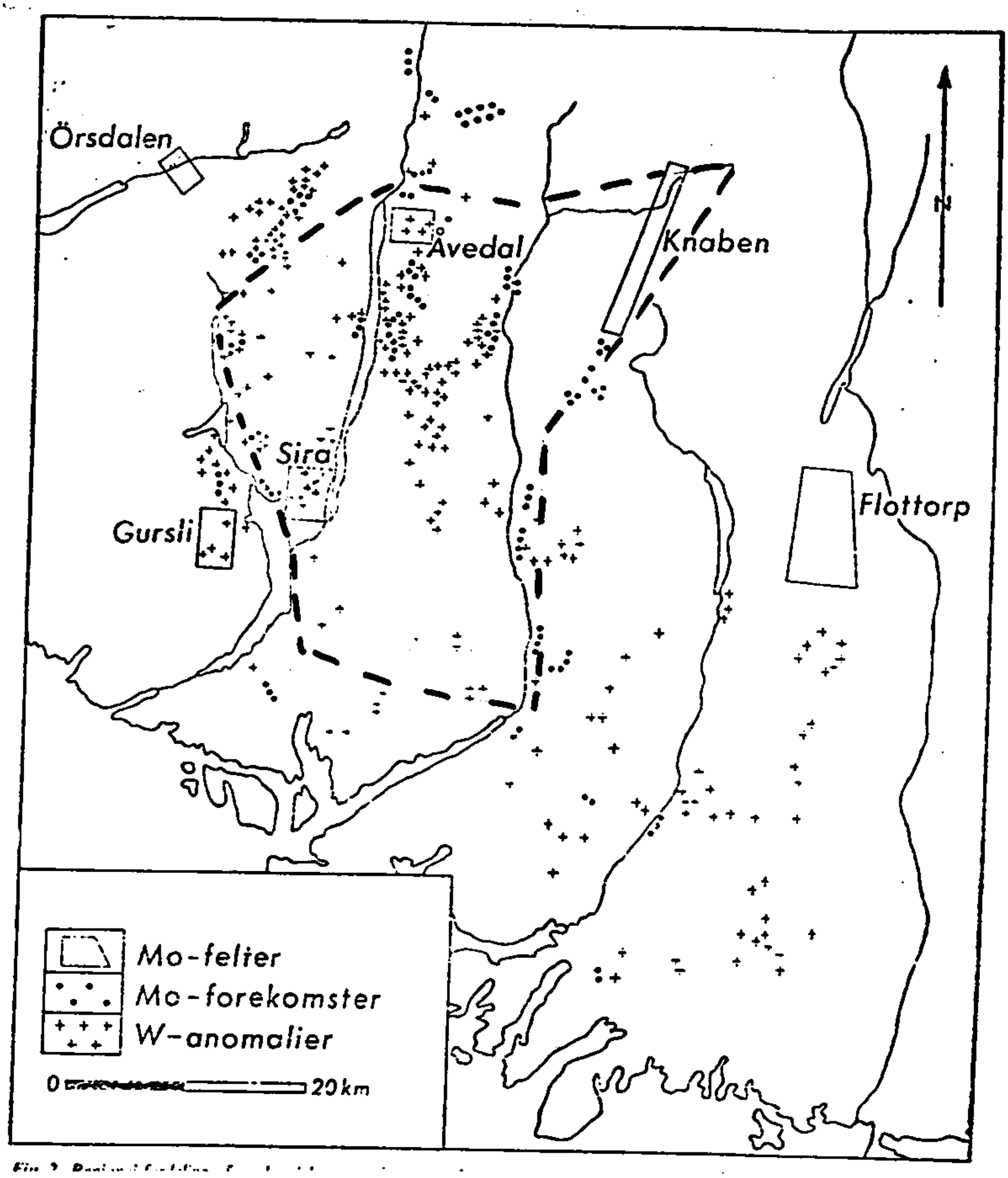


Fig. 10.

A/S Sydvarangers area of Investigation.

MoS_2 is concentrated along certain zones, which are lying concordant to the general strike in the area. Boulders and mineralized zones are mainly found along the slopes and in the bottom of valleys. This may indicate that prospectors have concentrated their search in such areas, but registrations of MoS_2 have also been done in mountainous terrain, showing that prospecting activities have also been carried out here. Our boulder tracing in the mountainous areas was also negative.

Considering that MoS_2 is associated with grey gneiss, one may conclude that the reason why MoS_2 mainly occur in topographic depressions (valleys) is, that this is where most of the rocks occur which are more easily subjected to weathering and erosion, i.e. more so than the barren quartz-feldspar-rich gneisses which build up the higher hills and mountains.

It is therefore our opinion that all MoS_2-mineralizations of a certain size are already known. To localize socalled "hidden ore bodies" will demand more scientific prospecting methods, and also detailed geological mapping and stream sediment sampling".

5.6 NGU's prospecting in the area.

In 1978 NGU carried out a program to examine the scheelite deposite at Ørsdalen, located in NW at map appendix 1 . Some work was also done in the central part of the region to locate old molybdenite skjerps. A report from this work will be presented in the spring of 1979, but we have been verbally informed that this work will be of little importance for Mo-exploration in the area.

Since A/S Sydvaranger has obtained a lease on all the Government's mining rights, NGU has announced that they will not do any further prospecting in the area.

5.7 Comments by Dr. T. Falkum (personal communications).

Dr. T. Falkum, University of Århus, who is responsible for the geological map submitted as appendix 1, emphasize that molybdenite is a rarely occurring mineral in the eastern part of the mapped area. He therefore suggest that this region should be given low priority in any further exploration work.

Falkum also points out that molybdenite mineralizations are associated with inlayers or remnants of grey gneiss in pink quartz-feldspar-gneisses (orange on map 1) which cover large parts of the mapped area. Such remnants of grey gneiss are numerous and widespread throughout the pink quartz-feldspar-gneisses, but most of them are too small to appear on a 1:250 000 map.

6. IDEAS ABOUT PROSPECTING.

Nearly all the workers who have been engaged in exploration for molybdenite in the Agreement Area have opinions on how and where to prospect for new deposits.

In this chapter we will try to summarize the various ideas and also give one own comments :

6.1 The Knaben Zone.

Prof. Schetelig, dr. A. Bugge and prof. F. Vokes have worked as consultant geologists for The Knaben Mining Company, and their reports and comments were the basis for our work in compiling this present report. For the most recent period, Bugge's and Vokes' comments are of major value, and also Trygve Erikson, geologist for the swedish owners, The Johnson Company, have given valuable contributions.

Concerning further exploration work, both Bugge and Erikson regard the area between Kvina and Knaben as the most favourable. We have had some difficulties in obtaining a clear side of what has exactly been done in this part of the field.

Initiated by Bugge a diamond drilling program was conducted on a "gangfjell" zone west of Knaben I. Only short holes were drilled, but impregnations identical to what occur on the surface was found. Good mineralization occur only over ½ m, over a wider zone the grades were reported to be only 0,01-0,03 % MoS_2.

Bugge however regard this type of mineralization as being so interesting that he recommends deeper drilling on this zone.

Further north in The Smalvann area, the situation is similar. A relatively rich mineralization in the southern part of the field should be diamond drilled.

At Kvina only one quartz-pegmatite lense has so far been detected, but southern extension of this body has never been properly examined (i.e. along the axis of the lense). A possible pitch- and swell-model should be tested with a few drill holes in this southern part of the field.

For the northern part of The Bragold area there is very little information available, and this field might therefore deserve a more careful inspection.

The Knaben II Mine.

Just before the mine closed down, prof. Vokes (Note dated 20. June 1972) presented some recommendations for further exploration.

The main problem at that time was according to Vokes, that the MoS_2-content was too low to enable a profitable operation. Based on some deep drill holes it was estimated that the ore reserves contained an average of 0,15 % MoS_2.

The number of drillholes are probably too few for a reasonably accurate estimation of grades and tonnages. There are indications that the average grade might be somewhat higher, but generally there is no reason to believe that grades are markedly higher at depth than what have been encountered in the mine. As far as tonnages are concerned the informations we have today do not indicate that the ore-containing zone wedges out at depth.

In other words : Ore reserves might be large, but the grade is probably not significantly higher than what has been attained during the mining operations.

How, then, would it be possible to obtain richer ore in The Knaben II Mine ? Vokes suggests the following alternatives :

A. By selective mining within the Knaben mineralized quartz-vein zone in the southern and deeper parts of the mine.

B. By detection of mineralizations with higher average grade than the known reserves are based on.

A. Selective mining.

The irregular and erratic distribution of MoS_2 in the quartz-vein ore has made it difficult to discover any form of pattern or trend in MoS_2 distribution within the ore limits. By careful and detailed mapping and sampling it might be possible to separate out blocks or areas with higher MoS_2-grades. Diamond drilling is unsuitable for this purpose. Such investigation program would require that the mine was accessible at all levels, and it is our opinion that to clear the mine for such a purpose is not feasible at this stage.

B. Detection of higher grade mineralizations.

Considering the various known types of mineralization in The Knaben II Mine, it is only one which fullfill the requirements, namely the socalled "gangfjell" type of mineralization, which occur in the upper parts of the mine. Here a few million tons of this ore type has been mined, which partly contained well above 0,3 % MoS_2.

So what we have to search for is a large new deposit of the "gangfjell" type !

Despite its vital importance for the mining at Knaben II, the "gangfjell" lense is not well defined in all dimentions. It is commonly described as a lense which wedges out at depth (at approx. Xth level) and to the north along the strike (confirmed by surface observations).

One of the problems, as stated previously, is to define the relationship between the "gangfjell" lense and the mineralized quartz-vein-containing grey gneiss in the deeper and southern parts of the mine.

Maps and profiles presented by Mr. Gustavsen (mine geologist) seem to indicate a continous transition between the two types of mineralizations. They also give reason to suspect that there is a possible "gangfjell" structure at depth, lying en echelon above (to the hanging wall) of the "gangfjell" lense mined in the open pit.

It is difficult to correlate these two "gangfjell" zones without constructing some rather spectacular fold-structures.

The deeper "gangfjell" zone has to some extent been investigated by adits and diamond drilling, but the informations are not good enough to acertain wether this really is a new "gangfjell" body.

Anyway, prof. Vokes regard this as the only target which may reprecent a large tonnage deposit of the "gangfjell" ore type. Vokes would prefer to drill a few short holes from the surface which would hopefully prove the existence of a new "gangfjell" lense. If the results are positive, they should be followed by deeper holes to examine the continuation of the possible ore body.

To what extent prof. Vokes proposed program - which we, based on the impressions we are left with, accept as sensible and well founded - was actually carried out during the latest stage of the operation of the mine, is presently not known. If it was not followed up, we would like to do a more thorough review of this particular area and discuss it in more detail with prof. Vokes, before working out a detailed diamond drilling program.

6.2 <u>Prospecting outside the Knaben Zone</u>.

The following factors have to be considered in a regional expenation program.

1. Molybdenite is associated with grey, layered gneiss which often are rust-stained as a result of oxidation of Fe-sulphides. (MoS_2 may also occur outside sulphide-rich zones).

2. Molybdenite-enrichment occur in areas which contain large quantities of secondary quartz.

3. Mafic rocks within grey, layered gneiss contain 5-10 % Fe-Ti-oxides. Grey layered gneiss also contain sulphide-rich bands. This will have an effect on geofysical measurements (IP,VLF).

4. Dr. Falkum points out (pers. comm.) that molybdenite rarely occur in the eastern part of the Agreement Area.

5. According to the map, appendix 3, molybdenite appear to be concentrated in a NS-extending belt in the central part of the area.

6. The Elkem/Spigerverket Company has systematically investigated old prospecting pits in the area. They have no plans for further work, which indicate that the results of their work was negative.

7. Referring to the rather extensive prospecting work that has been carried out, one can conclude that the chance of finding new economic mineralizations in uncovered areas, is rather limited.

Based on the factors listed above, we have the following comments regarding prospecting methods :

A. Geology.

The general geological features are well documented. Additional detailed information may be obtained by visiting Dr. Falkum in Århus, Denmark, to discuss and study the field maps which his 1:250 000 map is based on.

It is our opinion that to start a new detailed geological mapping program, before sensible targets can be pointed out as a result of other methods (geochemistry/geophysics), is not advisable.

A better understanding of the genetic problems involved in the interpretation of these actual types of deposits, is of importance, and for this purpose it is advisable that one geologist gets the opportunity to study in some detail the various mineralization types occurring in the Agreement Area.

B. Geophysics.

The use of electromagnetic/electric geophysical methods will probably be complicated by 2 main factors :

1. The effect of Fe-sulphides and Fe/Ti-oxides will be considerable, and probably over-shadow the effect of MoS_2-mineralizations.

2. The types of mineralization we are dealing with, and especially the impregnation type, are probably poor electromagnetic/electric conductors.

Since the molybdenite in general is associated with the same rock types as the sulphides and Fe/Ti-oxides, geophysical measurements over such zones will still be of value, in that they might outline the limits of possible host rocks.

The whole area has been covered by aeromagnetic measurements (by NGU). The results may indicate the location of the mafic, magnetic-containing units within the grey layered gneiss. A closer study of the aeromagnetic maps (and possibly also the raw data from these measurements) should therefore be carried out.

Generally, the IP-method is regarded as best suited for picking up impregnation type of mineralizations. The method is, however, time consuming and expensive and therefore not very attractive in a regional prospecting phase.

For detail work, i.e. after restricted targets have been established, this method will possibly be of help. Such measurements will, however, be complicated by the presence of other conductive minerals than MoS_2. The method should therefore be tested on known deposits, to get an idea of to what extent such factors will effect the results.

The VLF-method was developed after mining at Knaben was ended. It has, to our knowledge, never been tried in this area, and it might therefore be an idea to run a few test profiles across known ore bodies, with various types of mineralizations.

Geochemistry.

Stream sediment sampling is a commonly used method in regional prospecting in Norway, and we feel that this is a sensible way of attacting this field. According to Norwegian standard procedure, the streams are sampled every 250 m, and the samples are sieved in wet condition with a-180 μ screen.

We suggest that the samples should be analysed for Mo, W, Cu and Ba (barite has been detected in a similar geological environment at Lindesnes, on the southern coast, i.e. outside the Agreement Area).

Sydvaranger has obtained some experience in assaying watersamples for fluor. The idea is that fluorite in many instances may act as a "guide-to-ore". Besides, fluorite may itself be an economic proposition. Watersamples should therefore be collected together with the streamsediment samples.

Recommodations for regional prospecting work.

1. Additional informations concerning the geological map should be collected from dr. Falkum, Århus.

2. Some geological mapping over known deposits should be carried out, in order to obtain more experience concerning genetic interpretations.

3. Interpretation of the aeromagnetic maps will be discussed with director Ålstad, NGU's Geophysical Division.

4. VLF test profiles should be run across known deposits.

5. Stream sediment sampling in one or two areas between Sirdalsvannet and Lygnevannet (map. appendix 1), and in an area north of Kvina, should be carried out. Assay for Mo, W, Cu and Ba is recommended. Fluor-assays on watersamples should also be done.

6. This last winter, local inhabitants have informed A/S Sydvaranger geologists about the existence of a number of possibly new Mo-mineralizations. These should be surveyed.

R E F E R E N C E S.

The following list of references concerns litterature which is used in compiling this report. Nordrum (1978) gives a more extensive list (see subsequent appendix), but parts of that material is in our opinion out of date and therefore of less value.

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Usignert/udatert: Bænkehei, geologi. NGU. Ba.nr. 3671, 1 s.

Usignert/ udatert: Bragold gruber. NGU. Ba.nr. 3311, 4 s.

Usignert/udatert: Bragold, geologi. NGU. Ba.nr. 3672, 1 s.

Usignert/udatert: Lagerstattliche und allgemeine Beschreibung der Knabengrube. NGU. Ba.nr. 1113, 15 s.

Usignert/udatert: Gamle Knaben, geologi (1s.) og Knaben II, geologi (2 s.). NGU. Ba.nr. 3672.

Usignert/udatert: Knabengrube (på tysk). NGU. Ba.nr. 3972, 11 s.

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Usignert/udatert: Kvina, geologi. NGU. Ba.nr. 3674, 1 s.

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Usignert/udatert: Roma, geologi. NGU. Ba.nr. 3675, 1 s.

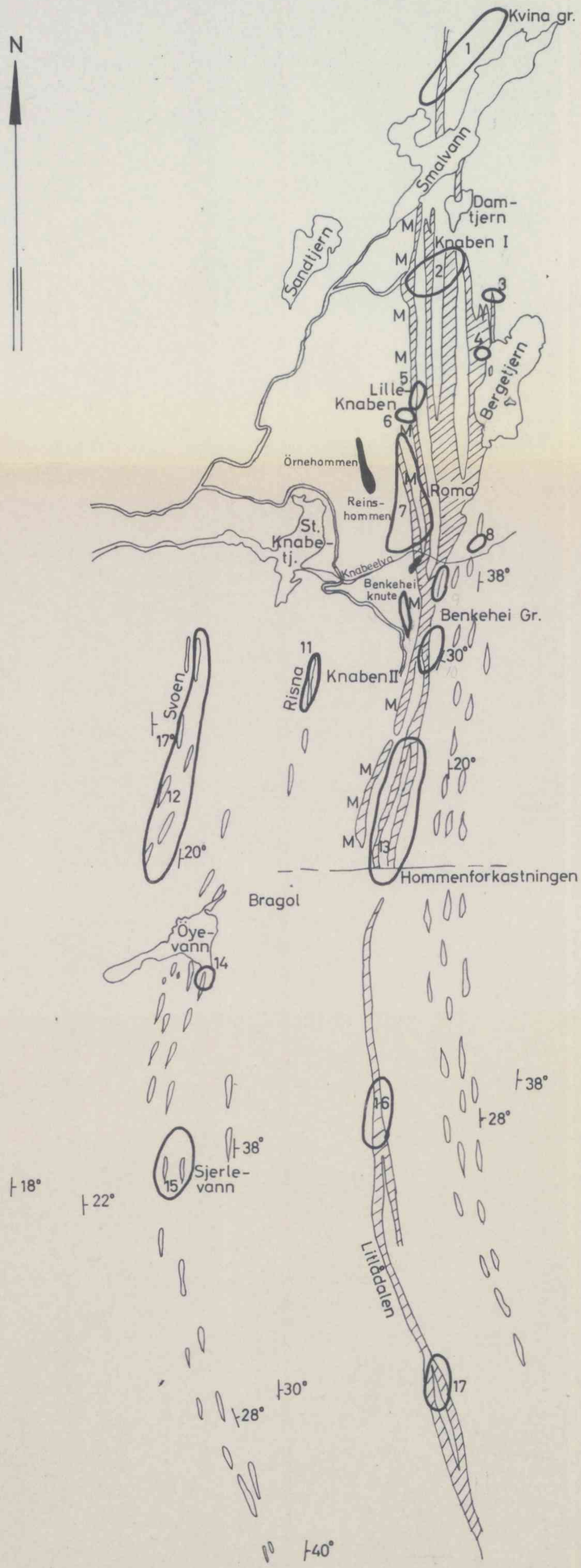
Usignert/udatert: Ørnehommen, geologi. NGU. Ba.nr. 3676, 1 s.

Data from PRELIMINARY MAP by T. Falkum
(Unpublished data. Copyright reserved)

After Leake (1972) inside area bordered by stippled line

- Quartzites of the Telemark formation
- Equigranular poorly foliated granite
- Massive porphyritic felsic gneiss with some layering
- Massive porphyritic felsic gneiss
- Layered felsic gneiss
- Layered biotite feldspar gneiss
- Nondifferentiated pink gneiss
- Grey layered gneiss with much basic material
- Feldspar augen gneiss
- Charnokitic gneiss
- Younger granite intrusives
- Quartz monzonite - intrusive
- Elder granite
- Pyroxen syenite or - monzonite
- Anorthosite
- Possible eastern border of Mo

SHEET MANDAL EASTERN PART	M 1:250 000	1979
A/S SYDVARANGER	APP. 1.	



LEGENDE:

Grey gneiss with sulfidcontaining zones (Fahlbands)

Widespread fahlbands and „aplitic" dikes.

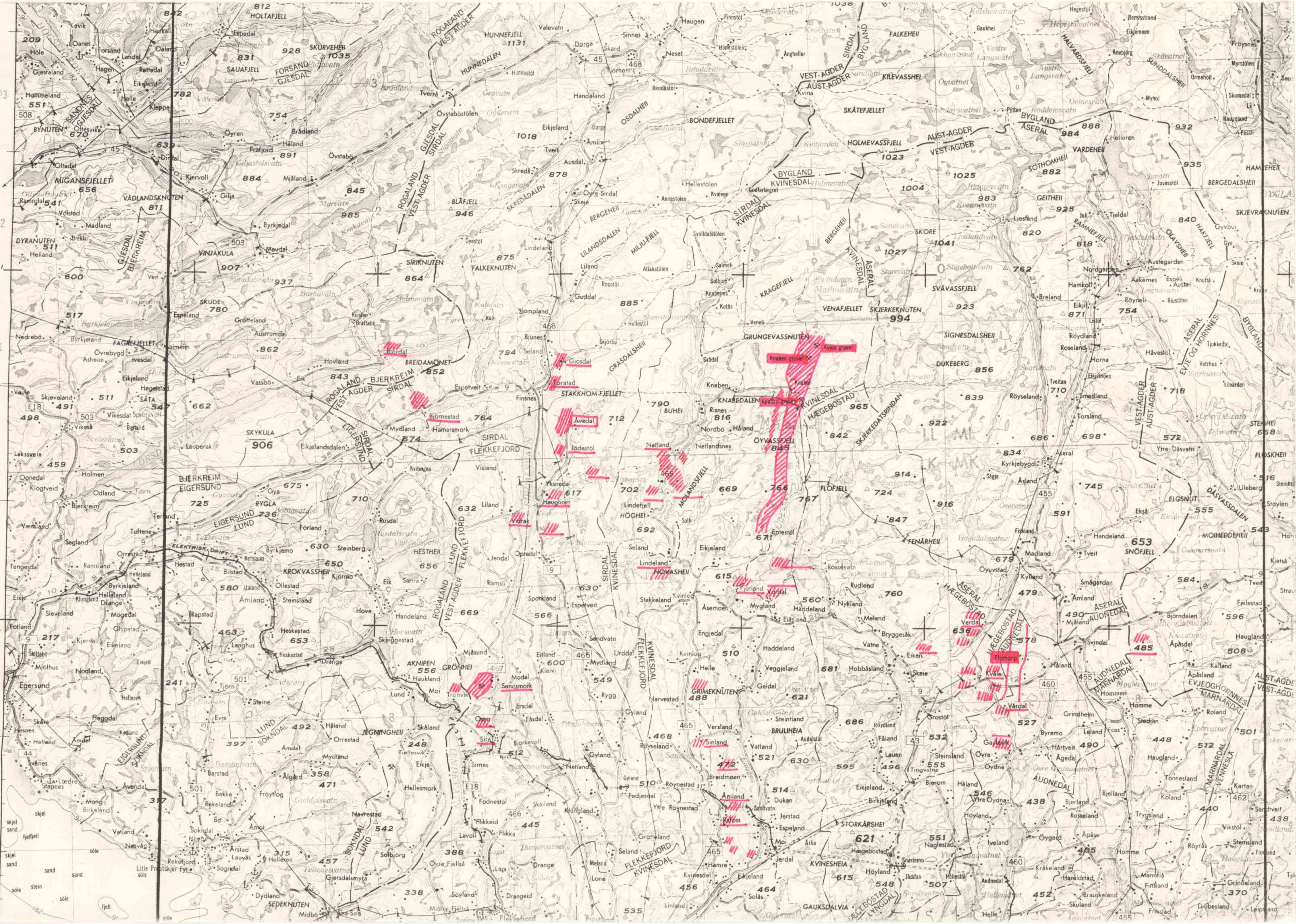
„Aplite" linses in the orezone M.

Specially investigated areas. Ross et al. 1973

General view over diamonddrilling

Area	Number of holes	Length
1. Kvina	3	400,50m
2. Knaben I	6	553,75m
3. Bergetjern	1	510,43m
4. Bergetjern	1	392,05m
5. Lille Knaben	10	577,88m
6. Vestre Reinshommen	3	411,44m
7. Reinshommen	5	439,21m
8. Vannmagasin	1	295,00m
9. Benkehei	5	1181,81m
10. Knaben II	7	531,00m
11. Risna	4	240,69m
12. Beritshei	9	641,58m
13. Hommen	37	8150,30m
14. Öyevann	1	99,34m
15. Sjerlevann	6	424,32m
16. Litlådalen	3	475,39m
17. Björnehommen	2	303,77m
Sum	104	15628,46m

Map over the orefilds in the Knaben area KVINESDAL, VEST-AGDER	MÅLESTOKK 1 : 30 000	MÅLT TEGN. TRAC. KFR.
A/S SYDVARANGER	App. 2	KARTBLAD 1412 III



Knaben gruver
Kvina gruver
Knaben
KNABEDALEN
Flottorp
Bjordal
Giosdal
Tonstad
Åvedal
Jødestøl
Netland
Haughom
Vidrak
Lindeland
NOVASHEII
Flotland
Vardal
Verdal
Sandsmork
Tronvik
Sira
Sinland
Åmland
Kvåle
Vårdal
Gauksøk
ÅLGÅRD 10 KM.
ÅLGÅRD 18 KM.
45′
30′
ROGALAND
VEST-AGDER
AUST-AGDER
SIRDAL
KVINESDAL
HÆGEBOSTAD
ÅSERAL
AUDNEDAL
FLEKKEFJORD
EIGERSUND
BJERKREIM
GJESDAL
FORSAND
SANDNES
LUND
SOKNDAL
BYGLAND
EVJE OG HORNNES
MARNARDAL
SKJERKEKNUTEN 994
GRUNGEVASSNUTEN
ØYVASSFJELL 845
STAKKHOM-FJELLET
BREIDAMONET 852
ELEKTRISK DRIFT
Egersund
Moi
Kvina
Tjørhom
Ålgård
Helleland
Fedjesdal
Flekkefjord