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Diamond drilling in the Segelvann/Sugustad area, geological report of drillholes 1, 2 and 3.

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ORKLA INDUSTRIER A·S

MINING SECTION
EXPLORATION

GULF ORKLA
LØKKEN VENTURE

Report no: L.V. 13 Date: 6.5.1982

Title: Diamond drilling in the Segelvann/Sugustad area, geological report of drill-holes 1, 2 and 3.

ORKLA INDUSTRIER A.s.

MINING SECTION, EXPLORATION

Report no: L.V. 13	Date: May 6th 1982
Title: Diamond drilling in the Segelvann/Sugustad area, geological report of drill-holes 1, 2 and 3.	
Prepared by: Åse Bollingmo and Tor Grenne	Areas name: Segelvann/Sugustad
Map no., name: 1521 III Løkken	Coordinates (UTM): Dh 1: 308017 Dh 2: 304012 DH 3: 295019
Field work period(s): Diamond drilling: March 1981 - March 1982	Pages: 15 Map enclosures: 4

Summary (purpose, execution, results):

The three bore-holes drilled in 1981 and 1982 in the Segelvann/Sugustad area were located with consideration to geophysical and/or geological anomalies.

The seismic reflections in the area seem to be caused by foliated shear/thrust zones.

The magnetic and electromagnetic anomalies near Segelvann appear to be related to a magnetite-rich alteration zone and a 'vasskis' horizon.

Dh 3 supports the theory about the saucer-shaped structure in the area.

The alteration of lavas seen in Dh 3 took place under less reducing conditions than would be expected in the central part of a feeder-zone, A sulphidic stringer-zone and possible massive ores should be looked for further south.

Key words: Diamond drilling, shear-zones, thrust-zones, hydrothermal alteration

Project initiated (date):	Report finished (date): 6.5.1982

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INTRODUCTION

During 1980, 1981 and until the end of March 1982, the Segelvann/Sugustad area (Fig. 1) has been the object of detailed geological and geophysical investigations (Reports number: ÅB,L.V.6,1981/GGr,L.V.1,1981/GGr,L.V.8,1981).

On the basis of these, three diamond drillholes were drilled during 1981 and the beginning of -82. The geology of these holes is summarized in the present report; hard-rock chemical and further geopysical investigations will be reported separately.

The targets for Dh1 (Drill-hole 1) and Dh2 were seismic reflections. Dh3 was first and foremost meant to give geological information. The location of this drill-hole was mainly based on the geological mapping, but to a certain degree, AMT-, magnetometer- and VLF measurements were taken into account.

DIAMOND DRILLING

The diamond drill-holes Dh 1, Dh 2 and Dh 3 are all situated in the eastern half of the Segelvann/Sugustad area. Exact location is shown on fig.1.

The deviations of Dh 1 and Dh 2 were controlled regularly during the drilling. The deviation of Dh3 will be measured later.

The table (see below) shows the initial directions, lengths and tot. deviation in the bottom of the holes.

	initial direction	length	tot. deviation in the bottom
Dh1	$222^g/72,3^o$	1030 m	56,4 m
Dh2	$393^g/84^o$	960 m	60 m
Dh3	$200^g/70^o$	490 m	-

Rock mechanical tests were done on cores from Dh1 and Dh2. Besides, when Dh1 was finished, seismic logging was performed on Dh1.

Deviation measurements, rock mechanical tests and the seismic logg is reported separately.

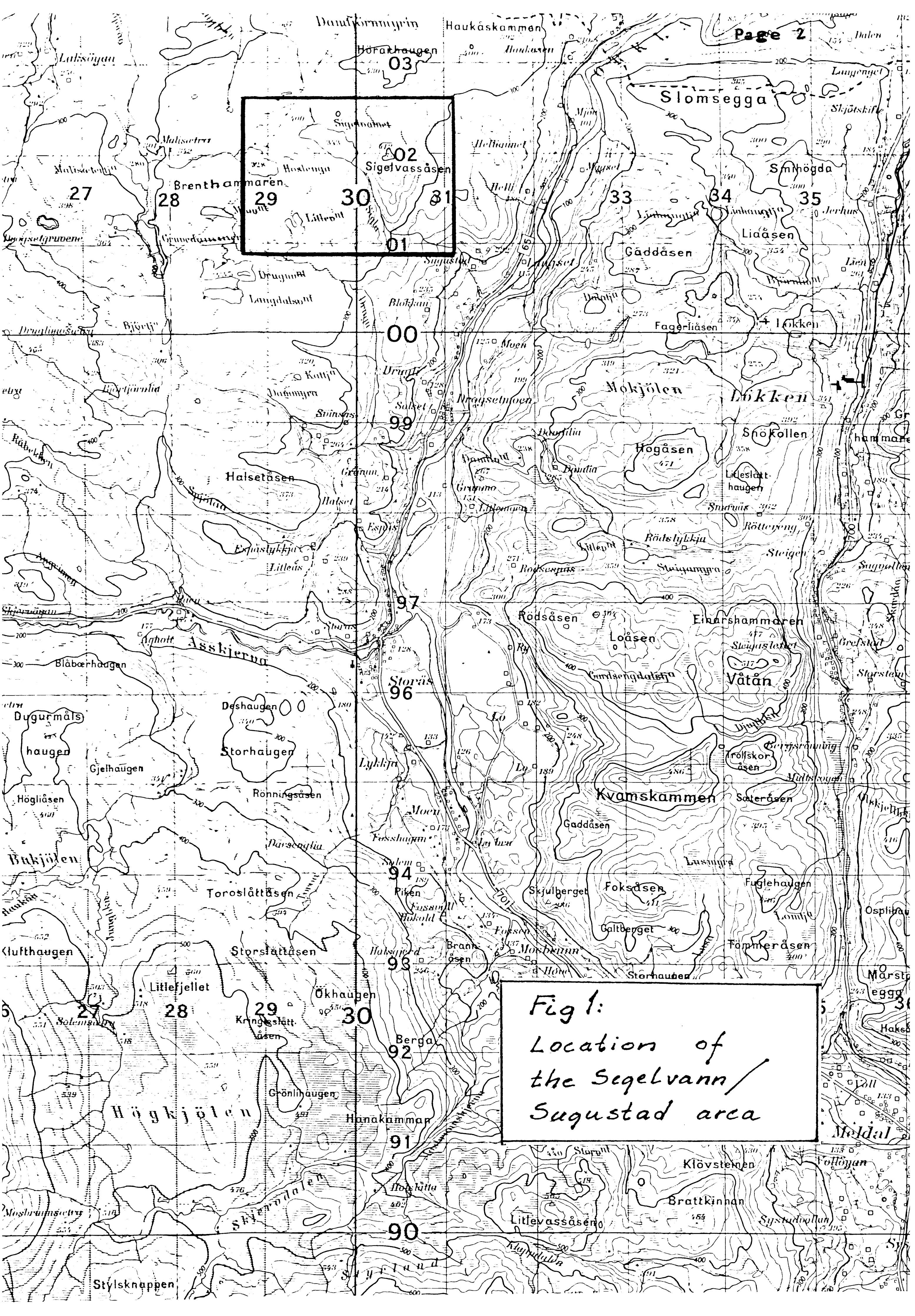

Fig 1: Location of the Segelvann/Sugustad area

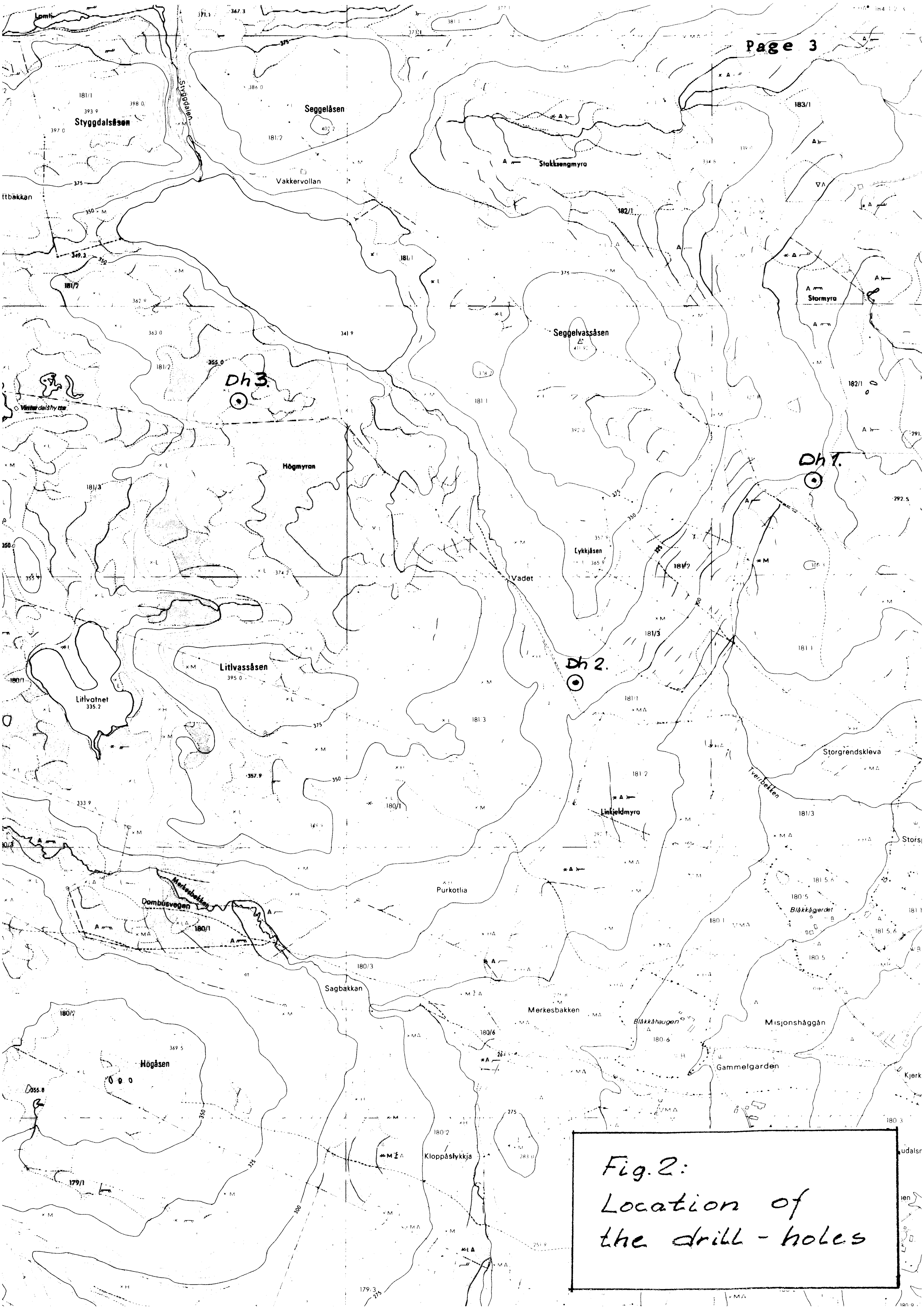

Fig. 2: Location of the drill-holes

LITHOLOGY

The greenstone complex

Lavas are found in the upper parts of drillholes 2 and 3, down to about 50 and 310 metres, respectively (enclosures 2 and 3). Fine grained pillow lava can be seen in both holes, and is obviously the most frequent lava type. Pillows are in general close-packed, apparently with very little hyaloclastite material between. In drillhole 3, the lavas are clearly variolitic down to at least 70 metres, with relatively small varioles - of varying density - arranged in a zone along the pillow rims. In the same hole, highly variolitic pillows occur also at about 215 metres. Otherwise, possible variolitic structures can be seen here and there down to the 'vasskis' at 310 metres; however, some of those may not necessarily represent true varioles (but rather be epidote rich spots originally formed as zeolite spots during sea-floor devitrification/metamorphism).

Vesicles are relatively rare in the lavas, occuring mainly in the lower portion of the lava section in drillhole 3, from about 254 to 275 metres. Here small vesicles (locally up to 5 mm across) filled with calcite seemingly occur together with varioles in a pillow lava. Quite locally, vesicles filled with calcite and with an epidote rich rim are found in a doleritic greenstone - possibly a lava - at 76-77 metres in the same hole.

Massive doleritic greenstones occur alternating with the pillow lavas. However, in drill-core it is often difficult to distinguish between massive flows and subvolcanic intrusions like sills and dykes, unless one can see the characteristic fine grained chilled dyke margins. Gradational contacts between the dolerites and pillow lava seem to suggest that at least some of them represent flows.

Vasskis. In Dh 3, a 20 cm thick 'vasskis' horizon occurs at a depth of about 310 metres. Between the compact, fine-grained pyrite/pyrrhotite layers, chert-like, grey bands occur.

The 'vasskis' seems to be quite strongly tectonized, showing a tight to isoclinal folding.

Diabase dykes can be seen in all three drill-holes, intruding both lavas and gabbro. On the average they constitute about 5-6% of the cores.(fig. 3 next page).Dyke thickness range from a few centimetres up to 6-7 metres, with the majority being relatively thin - less than 0.5 metre. Usually the dykes show a normal greenstone mineralogy and are aphyric, but plagioclase-phyric varieties also occur several places with feldspar phenocryst of millimetre to one centimetre size. In some cases an asymmetrical distribution may be seen; the phenocrysts being concentrated particularly along the 'upper' margin of the dyke.

Most dykes cut the gabbro or lavas with clear, fine-grained chilled margings, generally at an angle of about 45^{o} to the core axis. Multiple dykes occur occasionally. Flow-banding and variolitic structures are found within the chilled margins here and there, but they are not at all common structures in these drill-holes. A few dykes within the gabbro show signs of a not so rapid chilling, with coarser grained, more vague margins.

A conspicuous feature of several dykes, particularly in the gabbro, is a cataclastic breccia-like structure with dyke fragments usually of centimetre size embedded in an epidote-rich matrix This structure commonly constitutes thin zones, often along the chilled margins of the dykes.

Gabbro The mineralogy and texture of the gabbro vary.

The most common variety is a relatively light gabbro. The colour is caused by a fairly high plagioclase content. The pyroxene is almost totally altered to amphibole - most often actinolite and to chlorite.

Extreme varieties of the gabbro, what concerns mineralogy, are a very light type, and a dark grey, sometimes almost black gabbro.

The colour of the extremely light gabbro is caused by a high content of plagioclase and epidote. Parts of this rock also have some quartz, and in such occations "quartzbearing leucogabbro" would be a more correct term.

The dark gabbro variety also has a high content of plagioclase, but at the same time, dark minerals such as chlorite, sphene and primary igneous magnetite, are important here. The resulting colour is dark grey or dark greenish grey to black.

Ilmenite is likely to be abundant in non-magnetic varieties of the dark gabbro, but this is not yet confirmed by polished section studies.

Apatite-bearing gabbros may also occur.

Most often the minerals in the gabbro are randomly oriented. Ophitic textures are common, and this is the only texture seen in the dark gabbro variety.

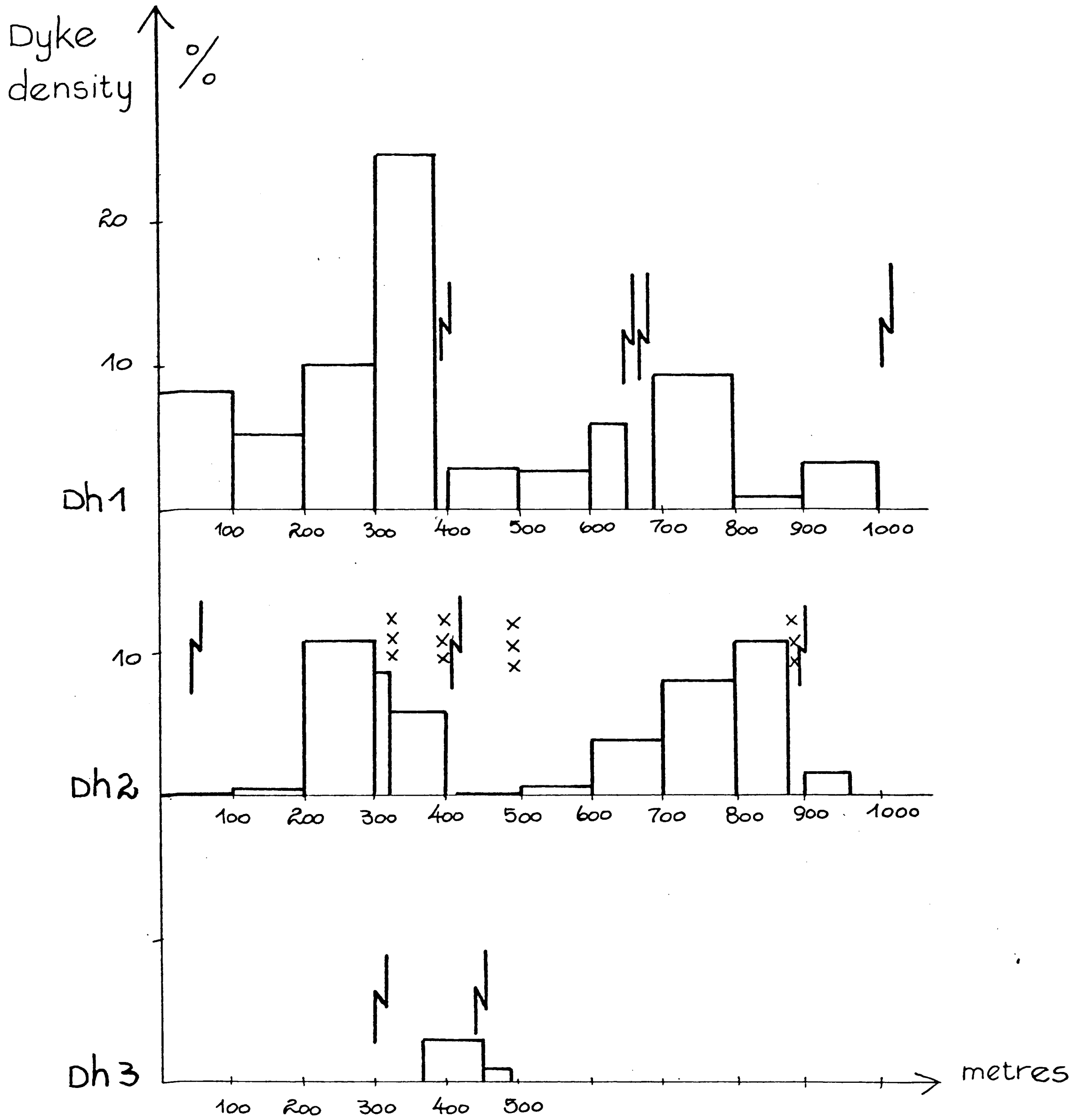

Fig. 3. Dyke density distribution in gabbro, 100 metres core intervals

Shear/thrust zones

Fracturing

Only very rarely, possible cumulate textures can be seen. This indicates that the gabbro is predominantly static.

In the light variety of the gabbro, or the leucogabbro as it should be called, a spherulite-like quartz/plagioclase intergrowth texture occurs in between the euhedral to subhedral plagioclase grains. The quartz and plagioclase grow radially from a nucleus or a crystal surface. The size of these "spherulites"is about the same as average grainsize in the rock. Some of these quartz-bearing leucogabbros are apparently transitional to true plagiogranites.

The grain-size of the gabbros shows rapid variations from fine to pegmatitic, although medium grain-size is the most common.

Brecciation is frequently seen within the gabbro. Thin zones, a few centimetres thick, may show cataclastic structures and textures. Generally, the fragments are up to 1 cm across. In thin-section one can see the gabbro almost completely crushed with irregular fragments of plagioclase crystals. The cement is composed mainly of carbonate and epidote. This cataclastic texture most probably represents an early faulting, related to the ocean-floor spreading.

Ultrabasic rocks are found in a narrow zone at ca. 675 - 680 metres in bore-hole no. 1. Here a slice of massive or strongly tectonized ultrabasites occur in a zone of intensely sheared gabbro, probably a kind of thrust zone. The rocks are soft, light green and resemble soapstone. Individual minerals are difficult to identify even in microscope , due to an extremely fine grain size. However, both in the strongly foliated and the massive variety, talc, serpentine and a carbonate - possibly magnesite - seem to be abundant minerals.

Later intrusives.

Felsites and related porphyrites are found in Dh 1 and Dh 3, in Dh 1 only very rarely, and in Dh 3 quite frequently.

Varieties of these rocks are

- felsite
- quartz - feldspar porphyrite
- feldspar porphyrite, intermediate type

Between these three varieties there are all kinds of transitional types.

The felsite is extremely fine-grained, so that in thin-sections it is almost impossible to estimate the content of different minerals. However, X-ray diffraction analysis of surface samples from this area shows that quartz, feldspar, sericite, chlorite, carbonate and actinolite is present together with several other, less important minerals.

XRF shows SiO_2 contents of the size 70 - 80 %.

The quartz - feldspar porphyrite has a very fine-grained matrix, most probably composed of quartz, feldspar, sericite and some carbonate. Quartz and plagioclase phenocrysts may occur as euhedral to subhedral grains, or they may be strongly corroded. Sometimes feldspar phenocrysts seem to lack.

The margins of the felsites and quartz-feldspar porphyrites frequently show a clear intrusive nature, but also diffuse contacts are common.

The feldspar porphyrite is an intermediate rock type observed only in Dh 3 where it has intruded the gabbro. Thin-sections show a considerably higher content of basic minerals - mainly actinolite - than in the related, more acid rocks. Additionally the feldspar porphyrites contain plagioclase with inclusions of actinolite and other unidentified minerals. The amount of feldspar phenocrysts varies irregularly. Most often they are only a few mm across. The upper margin of the feldspar porphyrite is strongly sheared, and rich in epidote, towards the tectonic contact to the greenstones.

The lower contact is clearly intrusive into gabbro, and shows a transitional zone with alternations between the two rock types. One can also see gabbro xenoliths within the feldspar porphyrite.

Hølonda porphyrite occurs only in Dh 1, by 850,8 metres and from 863 - 902 metres. A characteristic feature is feldspar phenocrysts of varying grain-size. Only rarely they are oriented, and then forming a kind of flow banding.

The upper contact of the thickest porphyrite, is clearly instrusive with decreasing grain-size and amount of phenocrysts.

Hydrothermal alteration and mineralization

In all the drill-holes there are thin or more extensive zones of anomalously coloured rocks that seem to indicate some kind of hydrothermal alteration. Very often these features are associated with sulphide or magnetite/hematite mineralizations in the form of fine or coarser grained disseminations and veins. The most extensive alteration zones are found in the lava sequence in drill-hole 3, and in parts of the gabbro in the same hole. Here a variety of purplish, bluish-grey and dark grey rocks are found both as pillow lavas, massive dolerites within the lavas (possible dykes or alternatively thick massive flows), gabbro and dykes within the gabbro. Also in drill-holes 1 and 2 one can see the same alteration, particularly in the dykes. Characteristically the rocks are lacking epidote, albite and actinolite ± chlorite ± carbonate being the main constituents together with accessory sphene or lencoxene and opaque minerals. Although they have not been analysed geochemically, the mineralogical composition thus seems to indicate a calcium depletion of the alteration zones, similar to what is found in stringer-feeder zones near massive sulphides in the Løkken area. However, in most cases the alteration does not seem to be very advanced.

Another conspicuous feature of parts of the gabbro and dykes, is a high content of thin,irregular veins rich in epidote, often forming fine networks. These veins may be accompanied by a marked increase of epidote in the dykes or gabbro, often seen as strongly saussuritized, green plagioclase crystals.

Both types of alteration mentioned above are commonly associated with cataclastic brecciation of the gabbro and dykes, and also occur frequently close to dyke margins - both within and just outside the dykes. Obviously, there is a close genetic link between these dyke/gabbro cataclasite zones, the hydrothermal alteration and the sulphide/iron oxide mineralization. The latter is occuring mainly within the shattered and/or altered zones as fine or medium grained disseminations and in irregular thin veins of varying composition: Epidote ± quartz, epidote-calcite, calcite ± quartz, and quartz ± plagioclase. Similar sulphide veins and disseminations are however, found also in apparently normal dykes. Pyrrhotite is the most abundant of the sulphides in the gabbros, while pyrite is dominant within the lavas in drill-hole 3. Pyrite may also occur together with pyrrhotite in the gabbro/dykes. Trace amount of chalcopyrite can be seen several places in gabbro/dykes, accompanying pyrrhotite or sometimes pyrite mineralization, particularly between 400 and 450 metres in drill-hole 3, which is also the "richest" mineralized part of the drill-cores investigated. Smaller amounts of chalcopyrite is found here and there in drill-hole 1, but is not recorded from hole no. 2.

Of special interest is a comparatively thick (30-40cm) quartz vein with very diffuse contacts to the wall-rock, at about 437 metres in Dh 3. This vein contains light reddish-brown sphalerite (?) in addition to a fairly high proportion of chalcopyrite. The sulphides form coarse irregular clusters or aggregates in relatively coarse crystalline quartz with calcite and some scattered pyrite. Although it is found within a zone of increased mineralization and hydrothermal alteration of the gabbro and dykes, the vein is somewhat atypical of known feeder-zones to massive sulphides in the district.

Iron oxides as hydrothermal mineralizations (not in the form of primary igneous minerals) is distributed similar to the sulphides i.e. mainly in alteration zones. However, contrary to the sulphides they are confined to the lavas in drill-hole no. 3. Here the most prominent zone in this respect is found in the interval from 30 metres (in contact with intrusive felsites) down to about 215 metres. In this part of the core, both magnetite, hematite and some pyrite may form fine-grained disseminations and veins both in pillow lavas and massive doleritic rocks. Down to ca. 100 metres hematite can be seen together with magnetite, alternating with zones in which magnetite occur alone or is coexisting with pyrite. From 100 metres magnetite is apparently the sole iron oxide. Zones of magnetite mineralization alternate with pyritic or mt-py greenstones down to about 215 metres, from there pyrite becomes dominant until alteration/mineralization is considerably diminished at ca. 230-240 metres. It has not been possible by the present investigation, to decide whether mt-hem/mt-py have formed in equilibrium during the period of hydrothermal activity. In some cases however, one can see pyrite veins penetrating magnetite-bearing altered rocks, or magnetite/hematite veins cutting greenstones with pyrite, apparently disequilibrium features that seem to suggest changes of the physical-chemical conditions within the hydrothermal system, both through time and spatially.

Shear zones

Shear zones may affect the gabbros, lavas, dolerite, felsites and the 'vasskis'. Most often it is impossible to see what was the original rock, but here and there, small relics which have escaped the most extreme deformation can be seen.

The resulting rock usually is very foliated and quite often soft compared to the neighbouring rocks Depending on the mineralogy, they may also occur as banded, fine-grained, hard rocks. Locally, as seen at 50 metres in Dh 3, the shear zones may show finely grinded cataclastic rocks together with the more typical banding.

The width of the shear zones varies from 1 cm to 20 - 30 metres.

In Dh 1, there are several shear zones to be seen, two of them about 20 - 30 metres wide. These zones are soft and within the lower one, around 680 metres, a more or less massive soapstone occurs. This might be a product of the shear movement, but another possibility is that the soapstone represents the ultramatic part of the ophiolite.

Dh 2 also shows two very distinct, 5 - 10 metres thick, soft shear zones, one at ca. 600 metres and the other near 900 metres.

In Dh 3, one very conspicuous shear zone at about 30 metres is forming the contact between a "vasskis" and a feldspar porpyrite. Both of them are strongly sheared. Further down another strongly sheared zone occur within the gabbro, at ca. 455 metres.

DISCUSSION

Structural and stratigraphical relationships.

Geological mapping in the Segelvann area has revealed that the greenstones occur in inverted position in a large E-W trending synformal or saucer-shaped structure (ÅB, report no. LV 6). The mapping also seemed to indicate that the gabbro north and east of Segelvann is extending down beneath the lavas in the central part of the area and that it may reappear further south.

The diamond drilling discussed in this report has largely confirmed the interpretation mentioned above.(Encl.4) In the core of the area, drill-hole 3 intersects the contact between lavas and the underlaying gabbro at 311 - 312 metres below surface The contact is quite similar to that seen in outcrops north and north-east of Segelvann, a few meter wide zone of strong defomation with the central 1 - 2 metres beeing extremely sheared. Drill-hole 2, which also started in greenstones, cuts the gabbro contact at about 50 metres in less foliated cataclastic finely grinded rocks. Similar zones are found also within the gabbro in all three drill-holes. There is no doubt that the greenstone-gabbro contact represents a thrust. Accordingly, some of the other shear zones may also reflect minor or larger movements, having taken up most of the tectonic deformation of the complex. This picture conforms well to what is seen in other parts of the Løkken greenstones (see report nr. LV 10), with the separate tectonic slices being imbricated in a norterly direction.

Drill-holes 1 and 2 show that the thickness of the gabbro is at least 1 km, in the north and north-eastern areas. There is nothing in the lower part of the cores to suggest that the drill-holes are very close to higher stratigraphic levels of the ophiolite, for instance a dyke complex or the lavas, as dyke density in the gabbro is comparatively low even in the lower portion of the holes. Quite contrary, dyke density distribution as shown in fig. 3 may suggest a tectonic repetition of the gabbro stratigraphy, indicating a considerable increase of the thickness. As can be seen from the diagram, the content of basic dykes varies between 0 and about 25% in 100 metres intervals. At least within some of the tectonic "slices" one can see a general increase in dyke density downwards (for instance from less than 1 to 10% in the 500 metres interval between shear zones at 400 and 900 metres in drill-hole 2), followed by a sudden drop and new increase as one passes shear-zones.

This generally low content of dykes, as well as the composition of the gabbro - mostly leuco-gabbros and quartz - bearing leuco-gabbros grading into plagiogranitic compositions - seem to suggest that one is dealing with the stratigraphically upper parts of the ophiolitic gabbro complex,and lower parts of the transition zone between gabbros and a possible true sheeted dyke complex.

The lava sequence drilled in Dh. 3 is often variolitic, generally non-vesicular, and is cut by several basic dykes. These are features that characterise the lower pillow lavas in the well investigated LØkken-HØydal area, i.e. the lavas occuring stratigraphically below the level of the massive sulphides and most chert - 'vasskis' horizons. Actually 'vasskis' is found also in drill-hole 3 stratigraphically overlaying the lavas mentioned above. This 'vasskis' is thought to correspond to that seen in the old prospects just NE of the small lake Litlvatnet. Further south above this level, one can see vesicular pillow lavas more like "upper lavas" in the LØkken-HØydal area.

Hydrothermal alteration/mineralization.- implications

The geological mapping (report nr. LV 6) delimits a central area of altered volcanics, broadly coinciding with the lavas below the 'vasskis' level. This conforms very well to the general model, with the 'vasskis' reflecting a period of strong sea-floor hydrothermal activity between lower and upper pillow lavas. Consequently this would be the level of interest also with regard to massive sulphides in this area. The upper parts of drill-hole 3 intersects a clear alteration zone. However, before intersecting the level of interest (the 'vasskis' level) one gets out of this zoneand through about 50 - 100 metres of normal, unmineralized lavas. Furthermore, the mineralization seen is mostly in the form of magnetite and hematite, suggesting more oxidizing conditions than one would expect in the central parts of a major feeder-zone. Similar oxidic alteration zones are seen also in the LØkken-HØydal area, and there they seem to reflect hydrothermal activity probably in the outer parts of sea-floor mineralization centres, at some distance from the proximal massive suphide deposition.

Therefore, the area of drill-hole 3 is probably not very promising in itself. On the other hand, the wide-spread deep alteration and its relation to the 'vasskis' level definitely indicates that major sulphide feeder zones may be present not far away . Based on the drill-hole section and field relations a more southerly location seems likely, particularly when one takes the observed sulphide mineralization/alteration towards the Druguvann area into account (ÅB report no. LV 5). This is however, somewhat speculative as yet; the realtionships between these areas have to be studied in detail.

Also within the gabbro, mineralization and alteration is more pronounced towards south, in drill-hole 3. Obviously the hydrothermal system reached great depths within the oceanic crust here. If the structural interpretation, involving imbricate thrusting towards north is correct, these mineralized gabbros have been situated some distance north of the altered pillow lavas in drill-hole 3 (prior to imbrication, but after inversion of the sequence). Anyhow, this very extensive alteration and mineralization - laterally and through the ophiolite stratigraphy - are features that definitely points to the Segelvann - Druguvann area as a whole being very interesting with respect to massive sulphides.

CONCLUSION AND RECOMMENDATIONS

The three diamond drill-holes in the Segelvann/Sugustad area in 1981 - 1982 did not lead to any ore discoveries.

The targets for Dh 1 and Dh 2 were seismic reflections. The reason for these are partly explained during the investigation of the drill-cores, and most of the seismic reflections in the Segelvann/Sugustad area seem to be caused by strongly foliated shear/thrust zones.

The AMT- and VLF-anomalies which contributed to the location of Dh 3, are still not fully understood, although the thin 'vasskis' horizon may explain at least the AMT-data. Additionally, the drilling has shown that the magnetic anomalies just south of Segelvann is caused by magnetite mineralization in hydrothermally altered basalts. The three diamond drill-holes, expecially Dh 3 have given some more detailed information about the geology of the Segelvann/Sugustad area, and in general supported previous theories. The most important results can be summarized as follows:

- The suggested saucer-shaped structure is further supported.
- The greenstone/gabbro contact is obviously tectonic, with the gabbro underlying the greenstones in the area.
- The 'vasskis' horizon extends down to a depth of about 320-330 metres with fairly constant dip, but probably cut by faults. The layering forms an angle with the surrounding schistosity and underlying thrustplane, so that the 'vasskis' approaches the gabbro towards north. Just north of the intersection with Dh 3, the 'vasskis' probably disappears in the shear-zone between greenstones and the gabbro.
- There is nothing in Dh 1 and Dh 2 to suggest that their lower parts are very close to a higher stratigraphic level of the ophiolite. Dyke density in the gabbro is low. Accordingly possible massive sulphides would be far too deep below the gabbro in this area.
- The lava sequence seen in Dh 3 has features characteristic of the level below the massive sulphides and most chert - 'vasskis' horizons in the Løkken-Høydal area.
- In Dh 3 there is an altered and mineralized zone stratigraphically below the 'vasskis' level. The mineralization is seen mainly as magnetite and hematite, with subordinate pyrite in a few places.
- The felsites and related porphyrites often show clear intrusive contacts to gabbro or greenstones, and they are believed to be later than and unrelated to the gabbro-basalt igneous activity.

A structural and ore genetic model based on field investigations and the results of the diamond drilling in the Segelvann/Sugustad area seem to suggest that one should look further south for massive sulphide orebodies,i.e. towards the Druguvatn area. The Segelvann/Sugustad area in itself does not seem to be of any economic interest with regard to massive sulphides.

Enclosure no. 4.

Vertical cross-section of the Segelvann area.
Profile: A-A' (fig. 2).

Scale 1:5000

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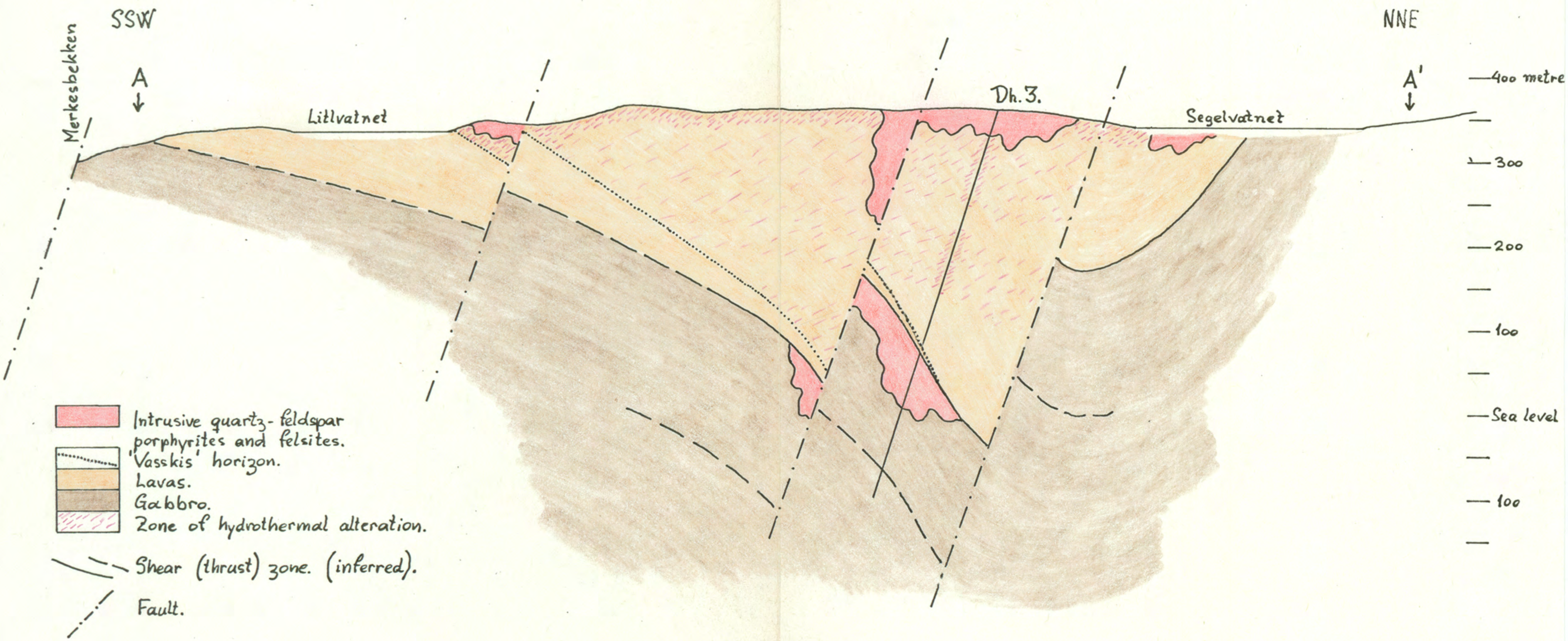

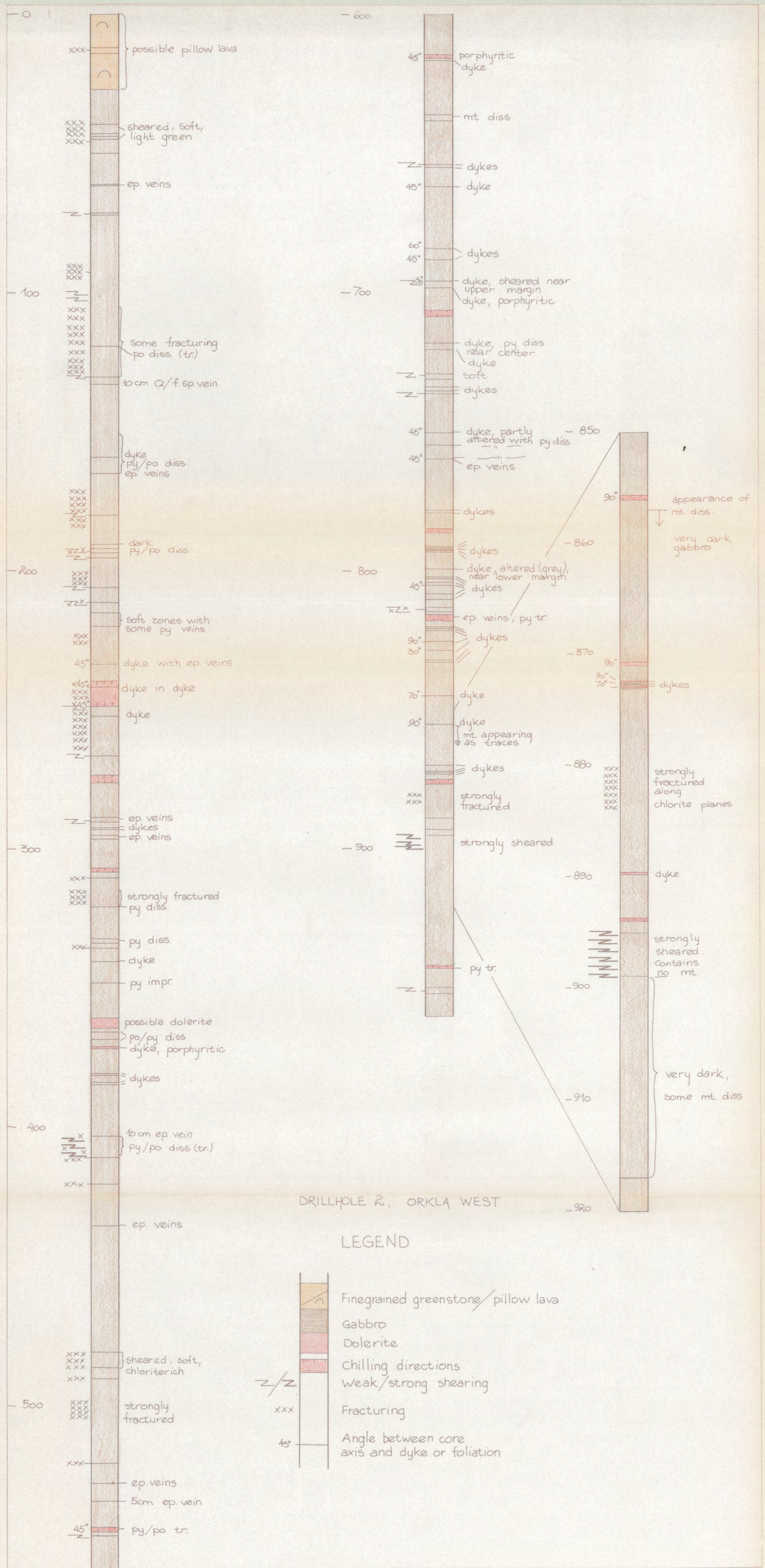

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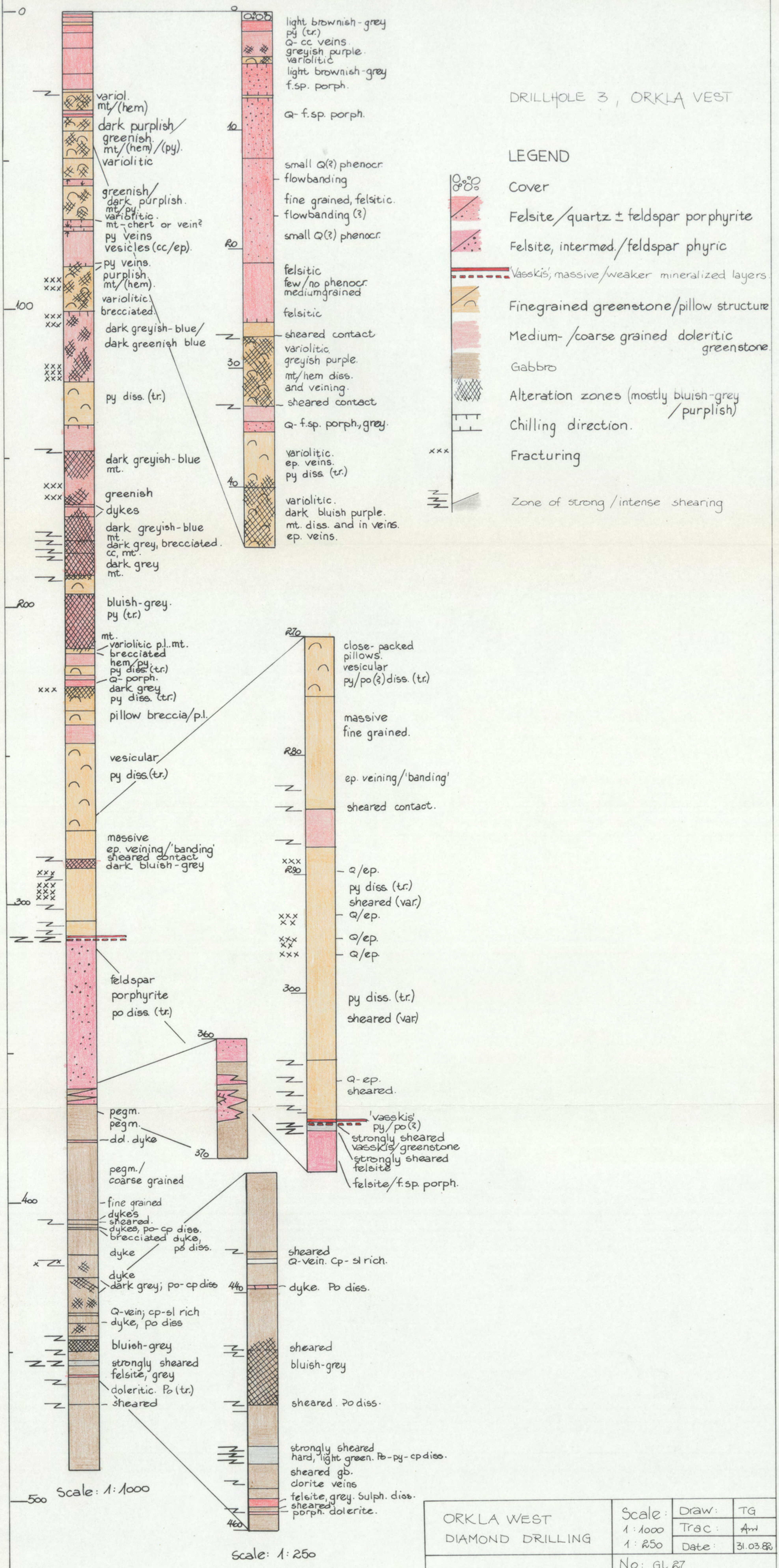
Gulf - Orkla Venture	Enclosure no 2	

DRILLHOLE 3, ORKLA VEST



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Orkla Industrier A.s 7332 LØKKEN VERK	Enclosure no: 3		
Gulf-Orkla Venture	Report no:		

ORKLA WEST
DIAMOND DRILLING

Scale: 1:1000 1:250 | Draw: ÅB | Trac: Arn | Date: d.04.82

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Enclosure no: 1

Report no: