



# Bergvesenet

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## THE GEOLOGY OF THE LØKKEN AREA

Gudmund Grammeltvedt

## SUMMARY

The Løkken Area is geologically a part of the Norwegian Caledonides. The ores occur in Lower Palaeozoic, mainly Lower Ordovician, greenstones, often pillowed and mainly of basic character. Bodies of massive, coarse-grained metagabbro and minor layered metagabbro are conspicuous features of the geology. The environments of the ores are characterised by the presence of stratigraphical layers of mixed oxidic-sulphide iron formation. The largest ore body in the area, the Løkken ore body, is in the range of 25 - 30 million tonnes.



## THE GEOLOGY OF THE LØKKEN AREA

### Introduction

The Løkken Area is situated about 50 km southwest of Trondheim. Its location can be limited by the points Svorksjøen (UTM coordinate 47.02), Svorkmo (37.05), Lommundsjøen (20.03), Rindal (10.98 and 10.90), Resvatnet (27.83), Å (38.84) and Svorksjøen (47.97 and 47.02) -

In this area the biggest Cu - Zn sulphides deposit in Norway is situated, the Løkken Mine. The total tonnage of the deposit is probably in the range of 25 - 30 million tonnes of which, about 20 million tonnes have been mined.

### General

The Løkken Area (fig. 1) is geologically a part of the Norwegian Caledonides, the most important geological formation for base metals (Cu - Zn - Pb) in Norway. The area is characterized metallogenetically by massive sulphide deposits which, as regards both orebody characteristics and environments of deposition, show considerable similarities to the Cyprus massive sulphides.

A geological description of the area can be verified in a publication concerning the western Trondheim district. (Grenne, T., Grammeltdt, G., Vokes, F.M.: Cyprus-type sulphide deposits in the Western Trondheim District, central Norwegian Caledonides. In press)

The biggest deposits are situated in the northern part of the area (Løkken, Høidal, Dragset and Åmot deposits, see Fig. 1). All deposits occur in a certain stratigraphic level.

The Løkken deposit is verified 4 km westward down to 1000 m depth. A prospecting-target is to search for parallel mineralization of the Løkken deposit at the same stratigraphic level, both south and north of it.

There are geological evidences for an axial depression along the Orkla river. The level of the Løkken deposit is therefore expected to rise further westward from the Orkla river.

Expected depth is considerable concerning both parallel ore and ore in the elongation of the Løkken deposit. A testprofile with high resolution reflection seismic west of the Orkla river, indicates interesting reflections (preliminary interpretations).

The Høidal deposit is situated at the same stratigraphic level as the Løkken deposit. The copper mineralization occurs both as massive ore and as disseminated ore. Small lenses

with massive Zn-rich ore are also present. The area is well known by geological and geophysical investigations and by diamonddrilling.

Further prospecting in the whole northern area is assumed to be promising. This assumption is based on our knowledge of the Løkken and Høidal deposits.

There are evidences for the same geological formation in the Grefstadfjell and the Resfjell - Rindal areas as in the northern area. In both areas a sheeted dyke complex with sulphide mineralization occurs connected to the overlying volcanic lavasequence. The known mineralizations are situated in the same stratigraphic positions as in the northern area. The possibility of finding workable deposits in the Grefstadfjell and Resfjell-Rindal area is assumed to be good.

In the past, most of the prospecting work has been concentrated in the northern area due to the presence of the Løkken deposit.

Our geological knowledge of the Løkken area is to day much better than few years ago. Through the IGCP Project no 60 "Correlation of Caledonian Stratabound Sulphides" (CCSS) a broader discussion about the occurrence and deformation of the mineralizations and the host rocks has been, and will be carried out.

#### The geology of the Løkken - Høidal area

The area to be described is shown in the geological map, Fig. 2. It stretches from the east of the Høidal deposit, westwards beyond the Dragset deposit, a distance of some 12 km, and has a N-S extent of about 6 km.

The area is situated in the westernmost part of the western Trondheim district, where the geology is dominated by a series of fairly tight synforms and antiforms with axes striking roughly E-W and with gentle, variable, plunges. These structures interfold a series of basaltic greenstones together with stratigraphically overlying sediments. The succession in the area, is however, inverted in its present position.

The area covered by Fig. 2 is dominated by a synform which has been termed the Løkken synform. As can be seen, the metavolcanities form roughly the core of this synform, with the younger, but structurally underlying, sedimentary rocks flanking it to the north and south. The Løkken-Høidal sulphide horizon is located in the southern part of the synform. In this part, the rocks have been subjected to only moderate deformation and there is nothing to suggest there is any repetition of the succession due to the folding. However, deformation increases considerably towards the north and the folding is here quite complex. Pillow structures have been strongly affected. A later folding along N-S axes has been responsible for the undulating character of the main E-W fold axes.



The metavolcanic rocks can be divided, roughly, into two subgroups, an upper and a lower. The lower subgroup comprises mainly massive flows, developed partly as pillow lavas. In the lower part of the subgroup metagabbros, of variable composition, occur in considerable volume. It is not possible to demonstrate intrusive contacts against the lavas and the grain size and composition of the metagabbros varies from coarse-grained, dioritic varieties in the central parts to fine-grained gabbroic types outwards. The latter appear to grade into a fine-grained metabasalt. The metagabbroic bodies have been interpreted as subvolcanic intrusives. This lower subgroup of metavolcanites forms generally the core of the Løkken synform.

The upper metavolcanic subgroup consists of generally thinner lava flows, very often pillowed, which are separated from each other by horizons of reddish jasper, black chert with sulphides ("vasskis", below) and/or sediments of volcanic derivation (conglomerates, sedimentary breccias). The individual lava flows are often massive at their bases, but are developed as pillow lavas towards their tops.

At the base of the upper subgroup, or along the boundary between this and the lower subgroup, there often appears an horizon of pillow breccias, about 10 - 20 m thick, which can be followed for several kilometres. Fractured pillows are also of frequent occurrence locally all over the area. Hyaloclastic textures are common in these rocks. The ore deposits of the Løkken-Høidal sulphide horizon are located in the lowest part of the subgroup, stratigraphically under the black cherts, jaspers and volcanoclastic sediments, on the southern limb of the Løkken synform. At the upper boundary of the subgroup occurs a conglomerate horizon of varying thickness marking the beginning of the younger sedimentation.

#### The Løkken deposit

Mining started at Løkken in 1654, and up to the present time some 20 million tonnes of ore have been produced; the total tonnage of the deposit is probably of the order of 25 - 30 million. This makes Løkken the largest of the Norwegian Caledonian polymetallic base metal sulphide deposits, on the basis of present knowledge. The deposit consists of several separate bodies of sulphide which may be parts of the same horizon of sulphide deposition. The main sulphide mass had the form of an elongated lens of varying cross-sectional shape, having a total length of about 4 km, an average width of between 150 - 200 m and an average thickness of about 50 m. It has been variously described as cigar- or pencil-shaped (see Fig. 3). The largest axis of the body is oriented E-W, parallel to the fold axial directions in the enclosing rocks.

Fig. 4 is a schematic cross-section through the Løkken deposit and its immediate country rocks showing the lithostratigraphical relationships in the present, inverted, sequence. The lavas lying stratigraphically above the massive sulphide horizon are interlayered with several horizons of reddish jasper and of a black cherty-sulphidic sedimentary facies known collectively in Norwegian terminology as "vasskis". These "vasskis" horizons are generally 0,5 - 2 m thick and consist of very fine-grained to microcrystalline quartz-magnetite-stilpnomelane rock, interbedded with layers of very fine-grained pyrite which often shows framboidal texture.



The "vasskis" horizons are normally concordant to the quite sharp hanging wall contact of the massive pyritic ore, the stratigraphically lowest horizon being some 1 - 2 m from the contact. In places, however, this horizon may show a slight discordance due to post-depositional tectonic movements. Stratigraphically below the massive ore and in sharp contact with it, is a lenticular unit of quartz-rich (felsic) lithology, varying in thickness between one and four metres and thinning out in both north and south directions. Mineralogically, this unit varies from a nearly pure quartzite to an almost pure albite rock. The term quartz-albite felsite is normally applied. The felsite is often heavily mineralized with pyrite in the form of thin layers and irregular stringers. Stratigraphically below the quartz-albite felsite comes a greenstone with pyrite disseminations. This unit is usually somewhat schistose near its contact with the felsite, but 3 to 4 m below this it has a massive appearance. In places pillow structures can be seen, in which pyrite is distributed in a concentric arrangement within each pillow. The amount of pyrite in the lavas gradually decreases stratigraphically downwards, while in the area to the north of the ore, disseminated magnetite occurs in the lavas in addition to pyrite.

At a stratigraphically even lower level, a large body of metagabbro occurs in the greenstone sequence beneath the Løkken deposit, one of the several metagabbroic bodies present in the lower subgroup of the Løkken greenstones. As can be seen from Fig. 3, the metagabbro is located in the present day (structural) hanging wall country of the western part of the Løkken ore deposit. The lavas between the sulphide bodies and the metagabbro are intersected by a westerly-dipping, fault- or(?) thrust-plane, often carrying a considerable clay-gouge. The structural significance of this plane is difficult to assess. In the area between Wallenberg and Astrup shafts it approaches close (2-4 m) to the ore, but is not known to intersect it.

The Løkken ore has a very fine- to fine-grained texture. The mineralogical composition is simple; 70 - 75% pyrite, 6% chalcopyrite and 3% sphalerite, with variable, but generally minor amounts of magnetite. The chief gangue mineral (comprising 12-14% of the ore) is a fine- to microcrystalline quartz. Accessory amounts of calcite, chlorite and stilpnomelane are also present.

The ore is rather variable both in chemical composition and physical properties, though no regularity has been recognised in these variations. As a rule, however, the most quartz-rich ore has usually the highest content of chalcopyrite and this often occurs nearest the true (stratigraphical) hanging wall. In spite of the general, overall low metamorphic nature of the ore, some local recrystallisation and growth of pyrite crystals can be observed, as well as local remobilization of chalcopyrite and sphalerite.

Though the Løkken ore has generally a massive, cataclastic texture, in some places, especially towards the margins of the ore, a certain layering of its mineralogical components can be seen, probably a relict depositional feature.



### The Høidal deposit

The Høidal deposit is situated 2 km east of Løkken, along the same stratigraphical horizon.

The deposit was worked at intervals during the period 1660-1860 from two open pits and some minor underground workings. The total quantity of ore produced has been of the order of 100.000 tonnes, averaging about 45% and 1,5% Cu. Recent geophysical investigations and diamond-drilling have given a fairly clear picture of the deposit.

Fig. 5 shows a horizontal section on the 400 m level of the Høidal deposit and a vertical cross-section at about its midpoint. As in the case of the Løkken deposit, the sequence is overturned. The greenstone lavas lying stratigraphically above the mineralized zone are characterized by interlayers of jasper and "vasskis" at several horizons. Immediately on top of the sulphide is an horizon of volcaniclastites usually developed as a sediment consisting of boulders or fragments of greenstone in a very fine-grained, schistose matrix. Apart from the abovementioned "vasskis" horizons, sulphides are absent in, or above this horizons of volcaniclastic sediments.

The sulphides occur in a heterogeneous, stratigraphical, zone consisting of the so-called quartz-albite felsite and basic volcanic greenstones. As at the Løkken deposit, the felsite is heavily mineralized with pyrite as stringers and disseminations. Down dip there appears to be a gradual decrease in the amount of felsitic material and of pyrite disseminations in the stratigraphically lower parts of the sequence. Relict pillow structures, hyaloclastic textures and silicified plagioclase grains have been observed within the felsite, features that would tend to point to the rock being a strongly altered part of the basic volcanites underlying the ore zone, probably forming part of a feeder zone for the sulphides. The sulphide in the altered zone is pyrite, mainly in the form of disseminations and irregular stringers. However, in places near the stratigraphical top of the zone, usually underlying a jasperoid horizon, occur thin lenses of massive pyrite ore. This ore has typically a copper content of 1-2% in the form of chalcopyrite and a zinc content usually below 1%. In some places, however, small lenses of sphalerite-rich ore, with up to 20% Zn occur, usually at a lower stratigraphical position than the massive, more cupriferous pyrite.

The distribution of chalcopyrite in the mineralized zone at Høidal shows little regularity. The more felsitic rock types have usually a rather low Cu content (0,1-0,5% Cu) while there is a tendency for chalcopyrite to be enriched in areas where there are rapid alternations between felsitic and less silica-rich lithologies.








# THE LØKKEN AREA

## SIMPLIFIED GEOLOGICAL MAP

Gudmund Grammeltvedt, 1973.

### LEGEND

-  Younger sediments
-  Greenstones
-  Gabbro
-  Older sediments
-  Mine

- 1 Løkken
- 2 Område øst
- 3 - " - vest
- 4 - " - syd
- 5 Resfj. - Jungfj. - Tifell
- 6 Rammundstadbygda
- 7 Rindal - Surnadal

0 5 10 km

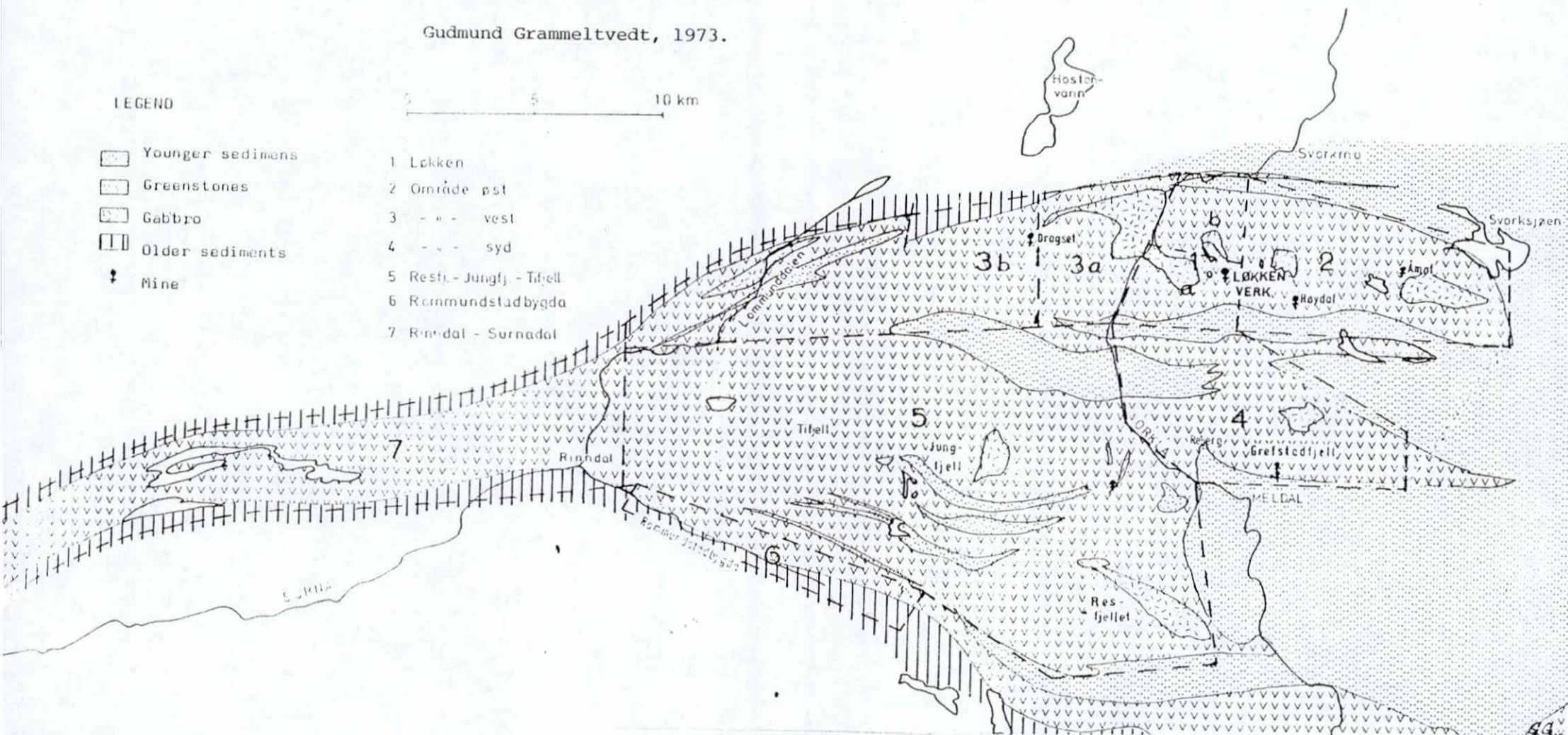
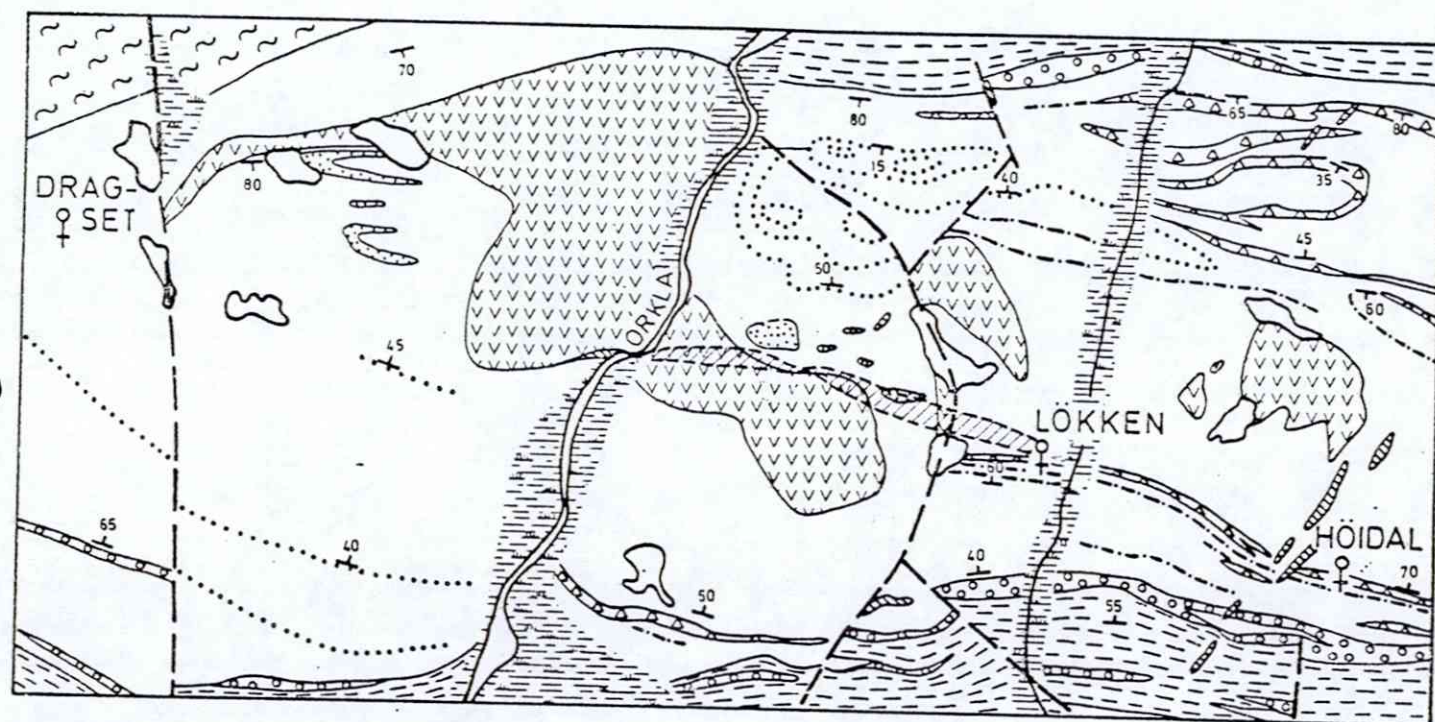


Figure 1. The Løkken Area.  
Simplified geological map.





- |                              |                               |
|------------------------------|-------------------------------|
| Metasediments (L.Hovin)      | Metagabbro                    |
| Conglomerate                 | Strongly folded metasediments |
| Undifferentiated greenstones | Porphyrite                    |
| Volcaniclastic sediments     | Cover                         |
| Felsite                      | Faults                        |
| Jasper/chert horizons        | Projection of Løkken deposit  |
| "Vasskis" horizons           |                               |

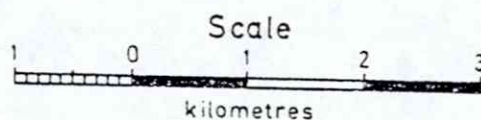


Figure 2. Geological map of the Løkken - Høidal area

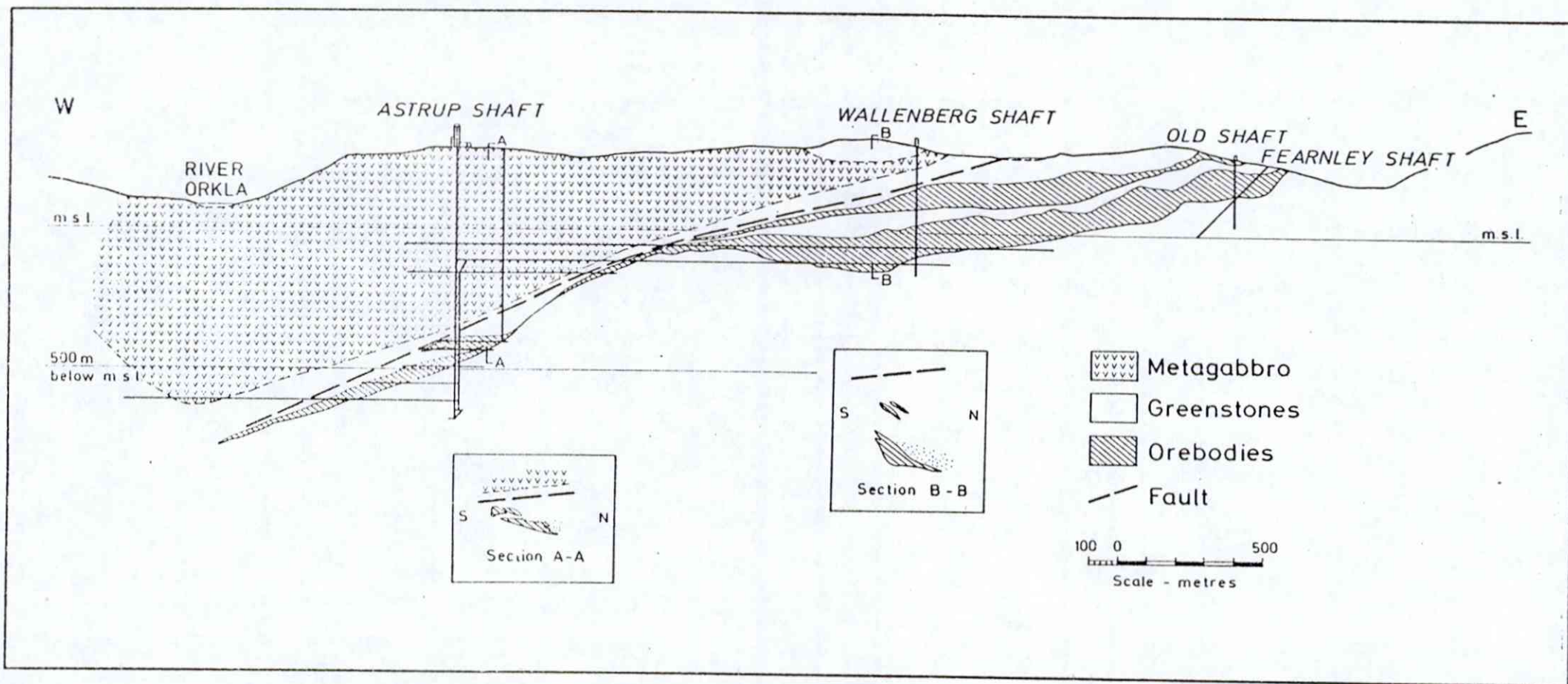


Figure 3. Vertical longitudinal, and cross-section of the Løkken massive sulphide deposit



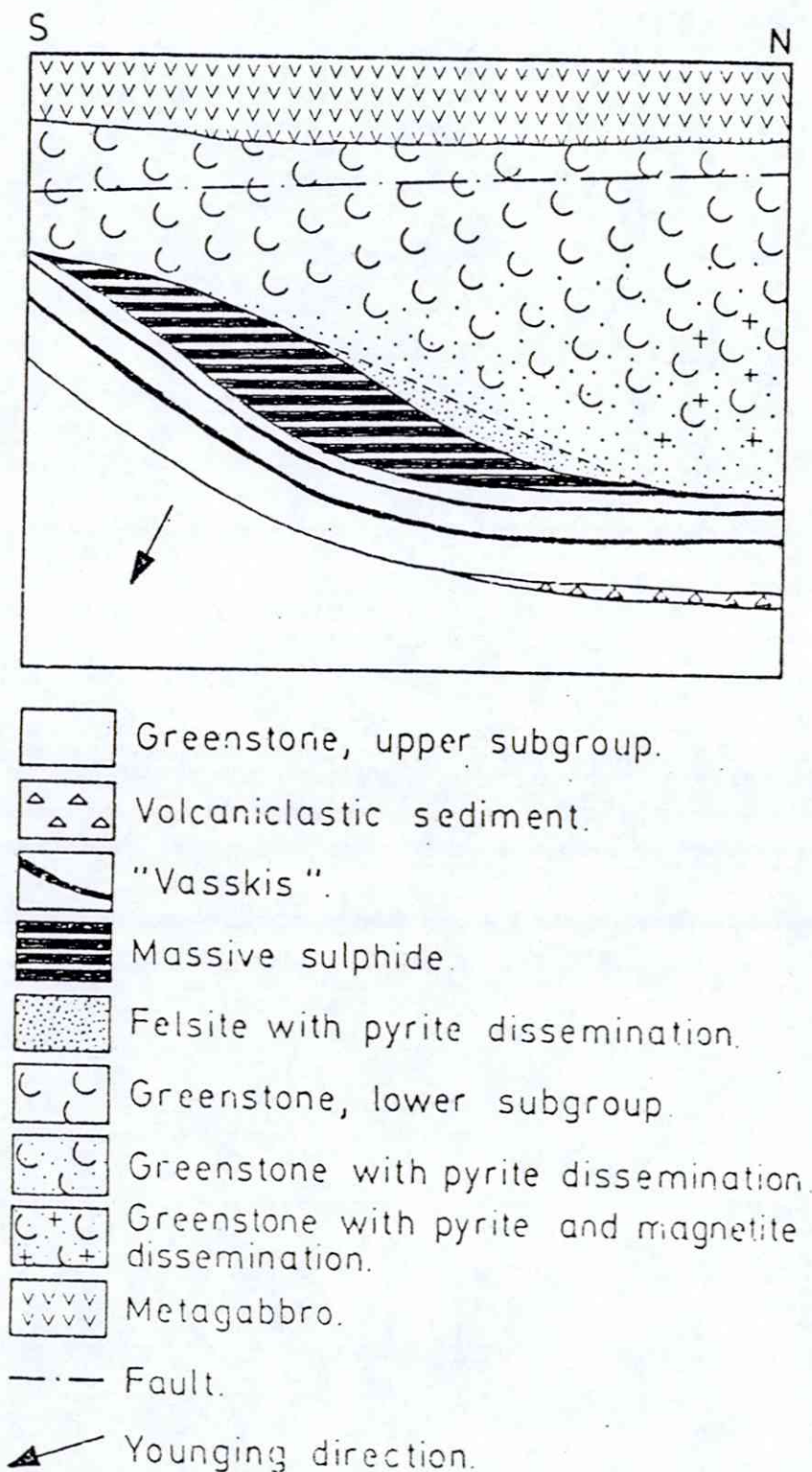


Figure 4. Schematic vertical cross-section through the environs of the Løkken deposit.

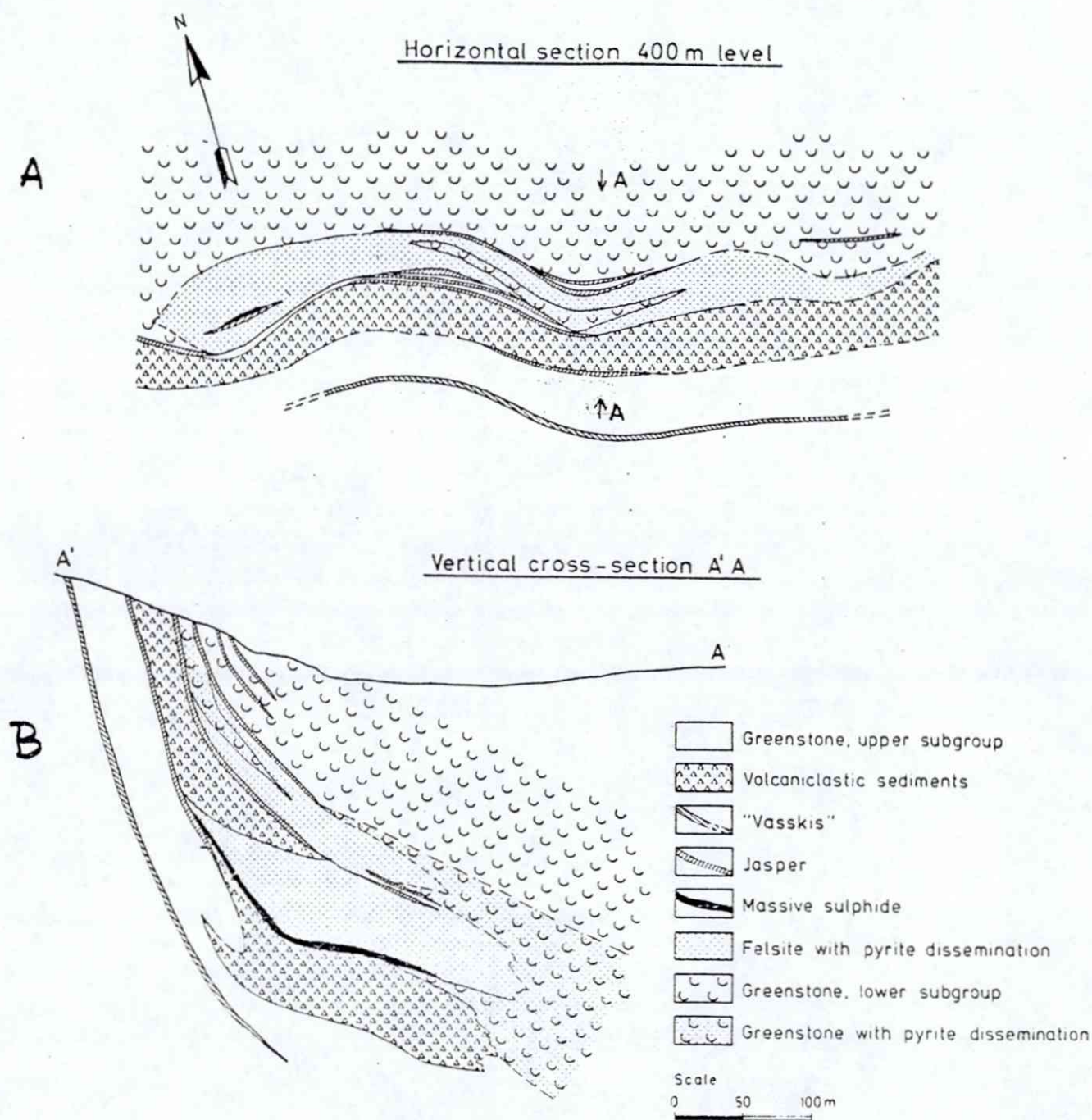


Figure 5. The Høidal deposit. Horizontal section at 400 m.a.l. and vertical cross-section