Tittel

Oversikt over Løkken Grubers geologi. Særtrykk av Guide-book for excursion C 10

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Sammendrag

OVERSIKT

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ORKLA GRUBE-AKTIEBOLAG

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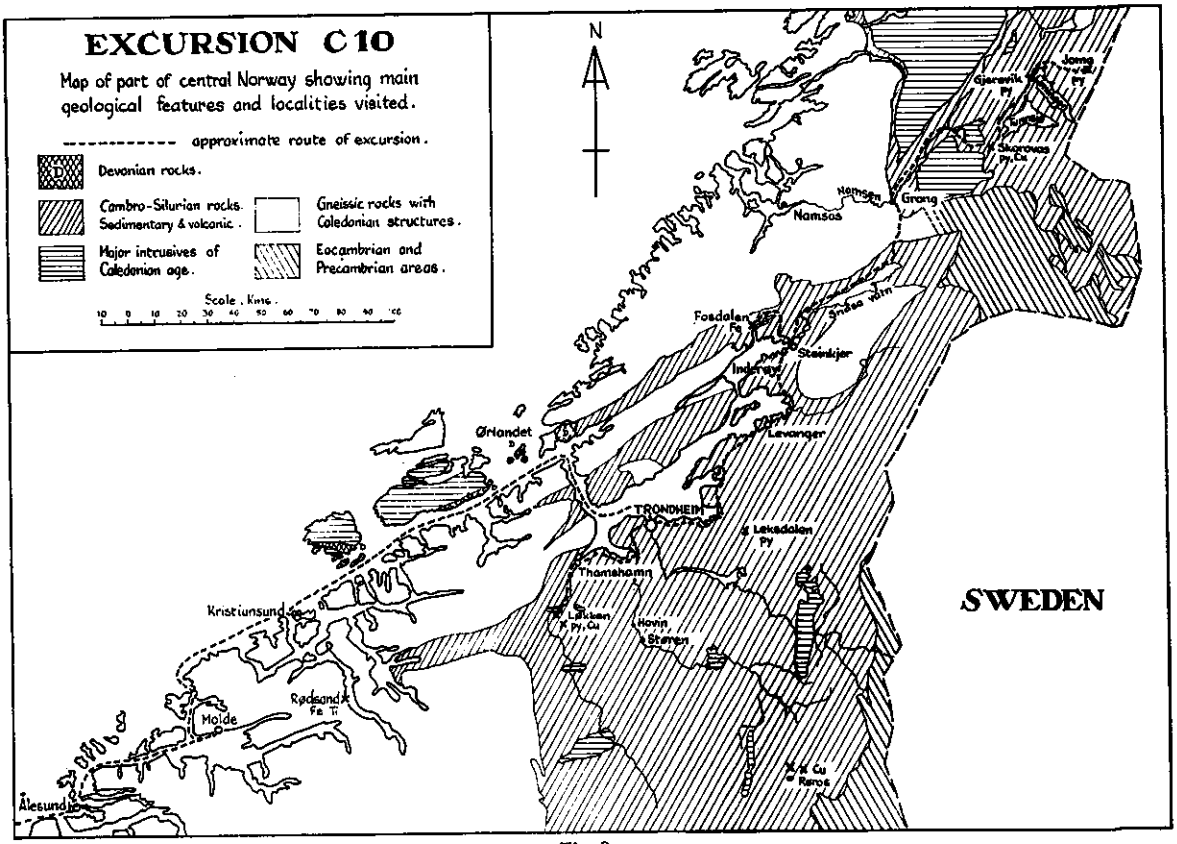

Fig. 2.

Map showing the excursion route in Trøndelag.

Løkken Pyrite Mine

(Orkla Grube-Aktiebolag)

Introduction and history.

Løkken mine lies in the county of Sør-Trøndelag, about 70 kilometres southwest of Trondheim. It is at the present day the largest Norwegian producer of cupriferous pyrite, with a run-of-mine capacity approaching half a million tons a year. The mine is connected to the shipping harbour of Thamshamn on Trondheimsfjord by a 25 km. long privately owned electric railway. Thamshamn is also the site of the company's smelter.

The first ore at Løkken was discovered in 1654 and for the first 200 years the mine was worked for its copper content. A smelter was erected at Svorkmo, about 7 kilometres north of the mine, and, eight years later, another one at Grutsaeter, 15 kilometres southeast of Løkken.

By the year 1770, the mine reached a depth of 166 metres, at which depth a water filled fracture plane was met with. The influx of water proved too much for the existing pumping machinery and the mine filled to a depth of 14 metres. Nevertheless a limited production was obtained from the upper parts of the mine until 1845, when working was stopped and the mine allowed to fill with water.

During this early period of 190 years, there were produced all in all 11 300 tons of copper. At first the ore held 4.7 % Cu, but later it diminished to about 2.5 %.

The second period in the history of the mine began in 1855, based on the export of relatively small quantities of pyrite to England for sulphuric acid manufacture. However, gradually worsening prices for the ore made the work unprofitable so that in 1891 the mine was once more closed down.

Shortly before 1900 the very imposing task of dewatering the mine was commenced and this work lasted 4 years. Prospecting work was carried on at the same time.

In 1904 the present company was formed and it undertook the sinking of a new shaft, building of a concentrating plant, and construction of the 25 km. long electric railway to the harbour of Thamshamn. This work of rehabilitation was completed by 1910, when production once more started.

In 1912 the known reserves at Løkken were about 2 million tons, but late in 1913 a faulted continuation of the ore body was located, and, following an extensive diamond drilling programme, these reserves were increased to 17 million tons by 1920.

At first production was planned at the rate of 100 000 tons per annum, but after the discovery of the faulted ore, capacity was increased to 400 000 tons.

In 1931 the smelter at Thamshamn was blown in and the well-known Orkla method was used to produce copper matte and elemental sulphur.

The highest annual output of the mine was attained in 1937 when run-of-mine production reaced 562 000 tons containing 41.08 % S and 2.14 % Cu. Since then the annual rate of mining has fallen off somewhat and in 1959 totalled 342 300 tons.

Geology.

The Løkken area in a wider sense (Carstens, 1951) occupies an area of about 250 square miles (about 650 km²) in the western part of the Trondheim region. The Løkken ore-body is the largest of the many occurrences of cupriferous pyrite in the Trondheim region. The area that concerns us here is the Løkken area in a restricted sense, comprising the immediate surroundings of the ore-body (see map, fig. 21). Here the rocks belong to the Lower Ordovician Støren group and are predominantly greenstones of andesitic to basaltic composition, metamorphosed in the greenschist or low epidote-amphibolite facies. They are partly schistose, and partly massive. In the latter case they are very often developed as pillow lavas.

While the more compact greenstones may be with certainty designated as metamorphosed lavas, the greenstone schists in most cases represent sediments or tuffs.

The colour of the greenstones varies from light grayish to greenish and to deep green, or even black in the case of highly altered types.

These greenstones have in places, especially near the ore, been exposed to alteration. The most common alteration is a carbonitization which is ascribed to the action of CO_2-bearing solutions. Superimposed on this form of alteration in the close proximity of the ore bodies are the results of a more through-going metasomatic alteration of the greenstones, which has involved not only the leaching of Ca, but also the addition of other substances. According to C. W. Carstens the rocks nearest the ore contact contain large amounts of added quartz, as well as much chlorite, with or without sericite. Further out sericite and chlorite are the main mineral components, while even further away, sericite becomes the chief mineral. Quartz is present in large quantities in all these types. Carstens concluded that the mineral associations show definitely that the metasomatism had involved the addition of SiO_2, K_2O and H_2O.

T. Strand has also described rocks rich in albite (at times wholly composed of that mineral) which he ascribes to an addition of Na (or to a local enrichment of that element).

Many of these altered rocks are impregnated to a greater or lesser degree with sulphides—mainly pyrite, but also zincblende.

Other rocks in the Støren group, of sedimentary derivation, include jasper, sedimentary pyrite (vasskis, see below), quartzites, arkosic quartzites and metalimestones. These are of minor importance quantitatively.

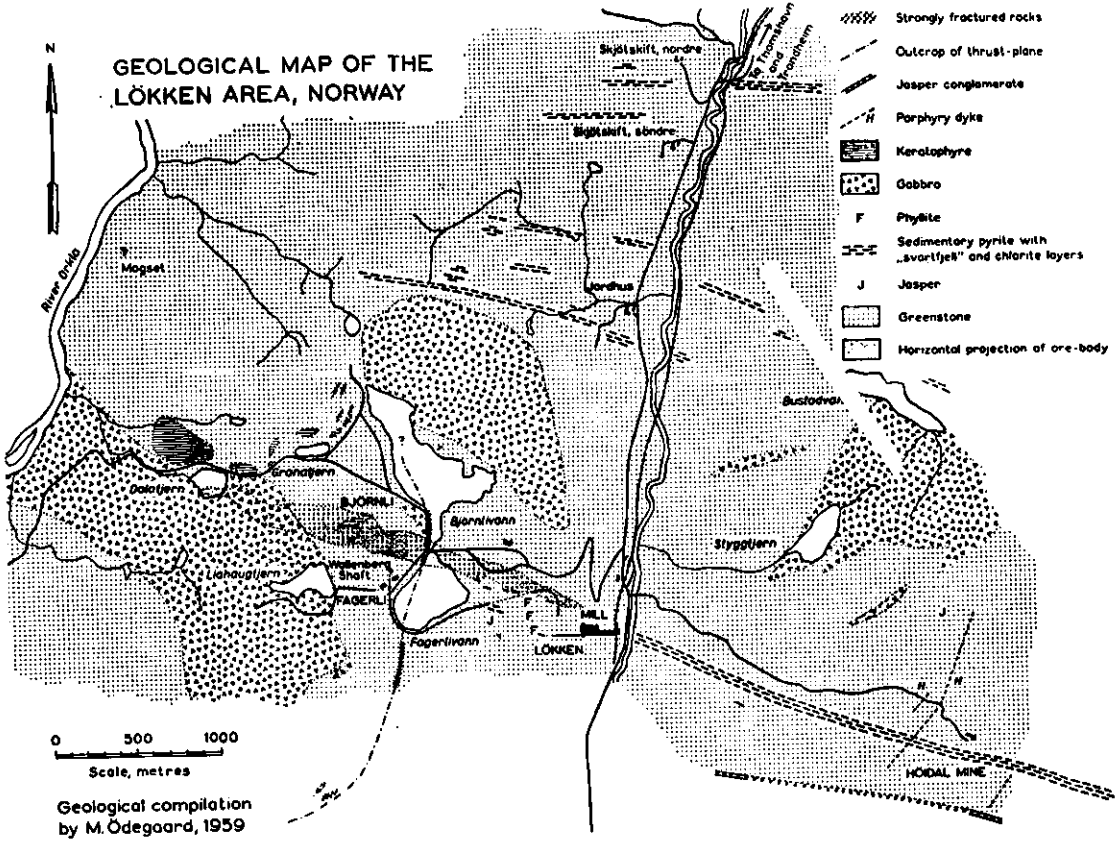

Fig. 21.

Geological map of the area surrounding Løkken mine.

Quartz keratophyres, showing phenocrysts of albite in a micro- to cryptocrystalline groundmass, occur as lens-shaped bodies in the Støren group and are probably of intrusive origin.

The Løkken area contains three larger intrusive bodies of coarse-grained gabbro. These gabbro bodies exhibit an almost identical chemical and mineralogical composition. The usual minerals are basic plagioclase (partly epidotic), and pyroxene (usually altered to colourless hornblende).

As will appear from the map (fig. 21) folding on axes striking west-northwest is a dominant tectonic feature in the Løkken area.

Ores.

The Løkken ores are situated as concordant bodies in greenstones containing layers of sedimentary pyrite ore (vasskis). The greenstones enclosing the ores dip to the north and probably form the limb of a syncline, the axis of which pitches to the west-northwest at about 15°. A culmination occurs just to the east of Løkken, so that in the eastern part of the field the plunge is again gently to the east.

The ore bodies are situated close beneath a thrust plane which dips at about 20° to the west-northwest. This was originally discovered in the mine as a clay gouge one or two decimetres in thickness. It marks an upthrusting to the east-southeast of the block of ground lying above the ore. At the surface the outcrop of the thrust plane can be followed for a distance of some kilometres to the south from the mine.

The ore bodies are situated some distance beneath the thrust plane in the eastern parts of the mine, while in the western parts the petering out "tails" of the ore bodies lie adjacent to the thrust gouge. Whatever may be the origin of the ores, their location seems to be distinctly determined by the tectonic conditions. They are situated in a bend in the greenstones above a layer of syngenetic, sedimentary sulphides, constituting a zone of weakness in which an opening of the bent layers might take place. Furthermore a release of stress by the thrust might create a minimum of pressure that would drive the ore bearing fluids to the spot.

C. W. Carstens recognised two types of sulphide mineralization: epigenetic ("gangkis"), and syngenetic ("vasskis").

As in the case of many other Norwegian epigenetic sulphide deposits, the Løkken ore bodies were originally linked genetically with the bodies of gabbro in the area, but recent work has almost totally discredited this theory. Parts of the deposits accur in close proximity to

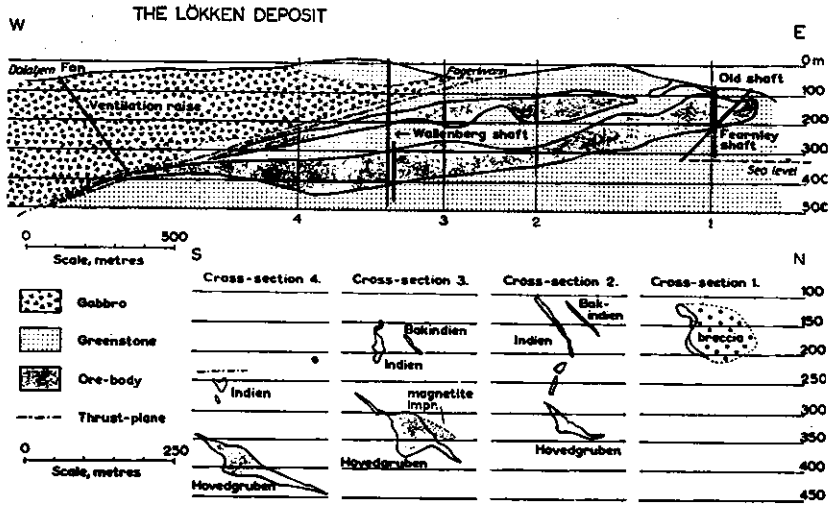

Fig. 22.

Vertical, longitudinal and transverse sections through the Løkken ore-bodies.

an overlying gabbro body (fig. 22), but the relation is probably only a spatial one.

The epigenetic deposits are characteristically in the form of elongated lenses or plates, or are pencil- or cigar-shaped. The longest axis of these ore bodies is always parallel to the lineation and fold axis direction in the enclosing rocks. At Løkken mine working has taken place on three ore bodies which have been called, respectively Hovedgruben (main mine); Indien (India), and Bakindien (Behind India) (see fig. 22). They show an E—W strike and northerly dip. The plunge of their long axes is around 9° to the west-northwest. The wall-rocks dip generally about 45° to the north.

"Hovedgruben" constitutes the largest of the ore bodies. "Indien" and "Bakindien" lie in its hanging wall and are nowhere near so long or thick. The size relations between Hovedgruben, Indien and Bakindien are roughly 30 : 3 : 1.

In the east, towards the original outcrop, the three ore bodies lie practically parallel to each other, but they converge westwards. Hovedgruben has a known length (along its plunge) of about 2500 metres. Indien and Bakindien gradually approach each other towards the west and have almost converged at the point where Bakindien peters out,

about 1150 metres from the outcrop. Still further westwards, Indien and Hovedgruben come closer and closer together before Indien, too, disappears, at a point 1700 metres from the outcrop.

In vertical section at right angles to the longest axis, the ore bodies have a lens like shape. (See fig. 22.)

The Løkken ore has a fine- to very fine-grained texture. Grain size is generally between 0.01 and 0.1 mm. The mineralogical composition is very simple: pyrite forms 70–75 % of the ore, while there is about 6 % chalcopyrite and 2.5 % zincblende, now and then also some magnetite. As gangue minerals appear 12–14 % quartz and small quantities of calcite and chlorite. The fine grained texture and the relatively high quartz content results in the Løkken ore being exceptionally hard. However, the mineralogical composition of the ore is somewhat different in the three ore bodies. In Hovedgruben, too, the ore is very variable, both in chemical composition and in hardness, in different parts of the mine. No regularity has been observed in these variations. It is most usual to find the parts richest in copper and sulphur nearest the centre of the ore body as seen in vertical transverse section. Towards the foot wall the ore is often especially hard and holds more quartz and less copper and sulphur than normally. The same is also the case with the upper and lower edges of the ore lens. Towards the hanging wall, the main ore body has, as a rule, lower copper and quartz contents than usually. In crushed parts, e. g. near faults, the copper content is at times especially low on account of leaching. On the other hand, there is usually very copper-rich ore in the near vicinity. In one or two limited areas near the foot wall of the ore body, exceptionally rich copper ore, carrying bornite as well as chalcopyrite, has been found.

Magnetite occurs on the hanging wall of Hovedgruben, east and west of Wallenberg shaft. The magnetite-bearing zones are impregnated with pyrite. (Fig.22, cross-section 3.)

In the eastern part of the deposit, in the hanging-wall of the main ore, there occurs a body of breccia ore which has a strike length of over 200 metres and a thickness of up to 100 metres. (Fig. 22, cross-section 1.) This breccia ore consists largely of fractured greenstone which is cemented together with veins of cupriferous pyrite. Further west there occurs a zone of pyrite impregnation in the hanging-wall of the ore body. The orebody's foot wall contact is in generall sharp, which is also the case as regards the hanging wall of the compact ore.

There normally occurs a bed of the sedimentary pyrite (vasskis) along

the foot wall of the main ore, and in places along its hanging wall. Other beds of sedimentary pyrite lie in the greenstones, some distance below the foot wall of the ore. Normally only the epigenetic type of ore is mined. The following may be taken as a typical analysis:

Sulphur	42.0 %	Arsenic	0.05 %
Iron	38.0 %	Lead	0.02 %
Insolubles	14.3 %	Cadmium	0.01 %
Copper	2.3 %	Selenium	0.007 %
Zinc	1.8 %	Nickel	0.001 %
Cobalt	0.08 %	Silver	16 gr./ton
Manganese	0.07 %	Gold	0.2 gr./ton

The second type of sulphide deposit in the Løkken area—the so-called "vasskis"—is of syngenetic origin, being formed contemporaneously with the greenstones. Carstens in 1922 assigned an exhalative-biochemical origin to this type of pyrite deposits, which he named Leksdal type, from a locality east of Trondheim.

The sulphidic layers contain pyrite, pyrrhotite and quartz. Their sulphur content is most often between 20 and 40 %, only occasionally rising over 40—45 %. The copper and zinc contents of the "vasskis" are normally extremely low to absent and the trace elements present in the epigenetic ore, notably selenium, have not been found in it. The texture is extremely fine-grained, much more so than in the epigenetic ore. The sulphide occurs in layers varying in thickness from a few centimetres to about 1 metre, very seldom more. The layers are interbedded with thicknesses of jasper, magnetite-chlorite rock, chlorite schist and graphite schist. The sulphide-bearing layers normally have very considerable areal extents. Normally it is not at all difficult to distinguish between these two types of sulphide mineralization.

Origin.

Following J. H. L. Vogt's theory of formation as injections of magmatic sulphides derived from the gabbro magma of the area, C. W. Carstens proposed that the ores were formed as hydrothermal replacements of the greenstones. In 1944 he described a pillow-structure from the Løkken ore which he claimed was a relict structure from the original pillows of the lava flow.

The latest worker in the Løkken area, T. Strand, has reported

seeing similar structures in the ore without being convinced that they really represent relict pillows.

In view of the position of the ore above the sedimentary "vasskis" with the greatest ore thickness coinciding with the maximum curvature of the fold, he thinks that the possibility cannot be excluded that the ore, for the greater part, is intrusive, in the sense that the sulphides were deposited in spaces opening between the "vasskis" and the massive greenstone.

Ore-prospecting.

During the years 1906 to 1920 the main features of the Løkken ore bodies were determined by diamond drilling and, in all, 78 holes with a total length of 14 650 m. were drilled. Since then the exploration work has been continued within the area where there are possibilities for similar ore occurrences and which has been mapped geologically.

In the last 25 years geophysical methods have been applied to a considerable degree and altogether about 150 km^2 have been investigated by one or other of these methods. The investigations have often been repeated in order to solve new problems which have arisen.

The electrical resistivity of the Løkken ore is very low, down to 0.01 ohm.cm., while the resistivity of the surrounding crystalline rocks is of the order of 10^6—10^7 ohm.cm. The overburden is on the average very thin and, in addition weakly conducting. The conditions, therefore, are very favourable for the application of electrical prospecting methods, and these are the ones that have been used most.

Apart from the economically valuable sulphide ores, there occur in the Løkken area extensive zones of sedimentary sulphides (vasskis) and graphite schists. These also have correspondingly low resistivities and give strong electromagnetic indications. The work of interpretation can, therefore, be often difficult, especially as regards deep lying indications. Diamond drilling is often necessary in this connection.

Of the electrical methods, the electromagnetic ones have been applied to the greatest extent, in several different variations. Alternating electric current is fed into the rocks partly inductively from large loop cables, and partly conductively or combined inductively/conductively from earthed cables with electrode separations of up to 10 kilometres. Experience has shown that the depth-range is very dependent on the size of the primary lay-out and its situation and orientation in rela-

tion to the mass of rock towards which the survey is directed. This is especially the case when searching for ores at great depth. Indications at depth which appear in one layout may be totally absent in another.

Ore prospecting in recent years has been concentrated in the immediate neighbourhood of the deeper parts of the mine. An extensive diamond drilling programme has been undertaken from the bottom levels, and electromagnetic measurements have been carried out in the drill holes. These measurements can give indications of possible electrically conducting ores on either side, or in continuation of, the drill holes. This method is considered to be useful, especially in the investigation of irregular and displaced ores.

Electromagnetic measurements have also been carried out from aircraft, employing large earthed cables to supply the current as well as airborne inductive energizing. The extensive and shallow lying zones of conducting rocks, "vasskis" and graphite schists, have produced indications. On the whole it is considered that airborne methods are not suitable for the special ore prospecting problems which present themselves at Løkken.

Electric potential measurements with direct current have been carried out in drill holes and have provided information on the presence or absence of connections between ore intersections in various drill holes. Potential measurements are further considered to be of use in providing information on the areal extent of the ore intersected in the holes.

Magnetic measurements have been carried out from aircraft, on the ground, and in the mine. The magnetic anomalies correspond, in part, to known geological structures.

Finally it may be mentioned that gravity measurements have been carried out in exploratory workings in the mine. Positive gravity anomalies have been connected, partly, with abnormally high epidote contents in the adjacent greenstones.

Reference:

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