The geology of the Bidjovagge mining field, western Finnmark, Norway

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Bidjovagge copper mines are situated on the Caskias mountain 69°17' N, 22°29' E, 700 m a.s.l. (Fig. 1) in Finnmark, north Norway.

The mineralizations occur in what is known as the Caskias-Stuorajaure Group, which includes greenschists, hornblende-schists, graphitic-schists, greenstones, and plagioclase-carbonate rocks. Amphibolites and diabases, which presumably represent rocks of intrusive character, are common (Holmsen et. al. 1957, Mathiesen 1957, 1959, 1967).

What is known of the discovery of the mineralization dates back to the late 1940's or early 1950's when two Lapps found sulphides on the Caskias mountain. Some rumours, however, indicate that it was known as early as in the 1920's. Whatever the truth, the claims were staked in 1952. Boliden Mining Company, Sweden, started their field work the same year. The application for a concession was, however, rejected.

In 1955 the Norwegian government made an agreement with the owners of the claims, bought the geological and geophysical reports from Boliden, and started investigations. In 1954–1956 Norges geologiske undersøkelse (NGU) made a regional geological mapping. From 1956 geological mapping, geophysical measurements, geochemical sampling, and diamond drilling were carried out by Kautokeino Kobberfelter Statens Undersøkelser (KKSU), which was specially formed for prospecting this area. The C-mineralization was investigated in 1960–1962 by mining and diamond drilling at 600 m a.s.l. In 1963 KKSU was taken over by NGU, which continued the investigations in the next three years resulting in the following estimates of the tonnage of the mineralizations (i.e. Ingvaldsen, Paulsen & Mathiessen 1966):

<table>
<thead>
<tr>
<th></th>
<th>Proven reserves (ton)</th>
<th>% Cu</th>
<th>Probable reserves (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A:</td>
<td>302,000</td>
<td>2.10</td>
<td>100,000</td>
</tr>
<tr>
<td>B:</td>
<td>253,000</td>
<td>1.83</td>
<td>50,000</td>
</tr>
<tr>
<td>C:</td>
<td>2,065,000</td>
<td>1.84</td>
<td>250,000</td>
</tr>
<tr>
<td>D:</td>
<td>360,000</td>
<td>1.84</td>
<td>200,000</td>
</tr>
<tr>
<td>Total:</td>
<td>2,980,000</td>
<td>1.80</td>
<td>600,000</td>
</tr>
</tbody>
</table>

In addition 1/2 ppm Au was indicated.

In 1967 A/S Bidjovagge Mining Company was formed by A/S Bleikvassli Mining Company. The plant was completed in 1970. Production started the same year. In 1974 A/S Sydvaranger bought A/S Bleikvassli Mining Company and thereby also Bidjovagge. A systematic evaluation of the mine and prospecting in the surroundings started in 1974. During 1974–1975 the author was in charge of the geological work in the mining field as well as the regional prospecting in western Finnmark.

Due to the falling prices of copper and small production the mine was closed down in mid-1975.
Geology

General

From west to east the rocks around the C-mine are carbonate-rich rocks, fels, amphibolite, carbonaceous schist, diabase, alternating fels, and carbonaceous schist locally very rich in chalcopyrite and pyrite, and finally greenstone with amphibolite and diabase (Figs. 1 and 2). These rocks form part of the Caskias-Group which represents a period of intense and widespread rather basic volcanic activity in the Karelic geosyncline. The present survey has, however, been carried out in much greater detail than the earlier ones. Generally, Mathiessen's map (1970) compares well with the present one.

Rocks

Carbonate rich rocks. – These have only been found in two outcrops but are recognized in many cores west and southwest of the C-mine. They are diffusely layered, light brown-grey, slightly weathered, fine to medium grained rocks consisting of dolomitic and ankeritic carbonate minerals with some amphibole. Pyrite occurs as an accessory mineral in the eastern limestone (lying around 800 E south of profile 1100 S) which is fairly clean. The western carbonate rock (situated between 600 and 775 E) is rich in hornblende and to some extent also biotite. Locally it contains actinolite and is slightly schistose.

Diabase (metadiabase). – The diabase stretches from profile O in the north to the south and southeast, forming the upper central part as well as part of the eastern limb of the big anticline. The upper central part of the fold is filled with the above mentioned carbonate-rich rock and the diabase.

It is massive greenish black, fine to medium grained rock consisting mainly of hornblende and quartz with some plagioclase and magnetite. The colour changes to dark grey and greyish green as the feldspar content increases. Carbonate veins and lenses occur as well as tremolite and some chalcopyrite towards the contact with the fels in the eastern limb.

Amphibolite. – Amphibolite occurs east as well as west of the fels and carbonaceous schist in the eastern limb. It is a massive, locally slightly schistose, greenish black, fine grained rock consisting of hornblende, biotite, quartz, albite-rich plagioclase, carbonate, magnetite and pyrrhotite, and some chlorite. Aggregates (1.5–10 mm) of hornblende are common.

Fels. – This name is introduced to describe a felsic, fine grained, massive, metamorphic rock consisting of albite, quartz, and calcite. It has a diffuse layering and/or heterogeneous bedding with < 5 mm thick bands, white to greyish white, grey or redbrown with a grain size of 0.1–0.3 mm. The main mineral is albite, quartz and calcite occurring in smaller amounts. Hornblende and biotite exist in small quantities. Muscovite has been found but is rare. Sometimes the quartz exists in 1/2 mm lenses. 1/2 mm aggregates of sericite and pyrophyllite (probably secondary after sericite) talc and small zircon crystals were found in drillhole 1440 S, 915 E, at 477 m, a.s.l. The fels is locally very rich in chalcopyrite, pyrite, and pyrrhotite. Magnetite is usually an accessory mineral. Galena and sphalerite have been found. The fels is sometimes so fine grained (<0.01 mm) that identification of the minerals in thin sections becomes impossible. The rock is cut by irregular veins (< 5 cm) filled with calcite and dolomite, some quartz and albite, with accessory biotite and iddingsite. They can locally be very rich in chalcopyrite. The fels is very similar to the leptites found in the Precambrian of northern and middle Sweden.

Carbonaceous schist. – Diffusely bedded to homogeneously layered, only locally schistose or even brecciated, black to greyish black with thin light grey to greyish white bands. The dark bands are less than 10 mm thick and the light ones less than 2 mm. The difference in colours depends on the relative amounts of light and dark minerals. The rock is very fine grained (<0.03 mm) containing graphite, plagioclase, carbonate, and quartz. Aggregates (less than 30 mm) consisting of biotite, plagioclase, and quartz up to 0.06 mm in size as well as 5 mm big spots of phlogopite, sulphides, plagioclase, and quartz of up to 0.2 mm size. Pyrrhotite and pyrite occur as a fine impregnation, in thin layers or in carbonate filling. The graphite which exists as impregnation and thin layers is enriched in discordant zones in the C-ore. Transition to the
fels is continuous, the difference lying mainly in
the amount of carbonaceous material. The
graphite, which probably was formed from or­
ganic material, is too fine grained to be economi­
cally concentrated.

*Sedimentary greenstone.* – A homogeneously
layered or diffusely bedded rock with 2–20 mm
thick layers, dark green to greyish green, fine
gained with biotite, chlorite, amphibole, and
white feldspar and traces of pyrite. Zones rich in
amphibole and layers of fels occur. The tran­
sition to fels is continuous.

**Mineralizations**

The mineralizations are localized to the fels and
carbonaceous schist of the legs of an isocline.
The amount of sulphides is varying and although
generally poor it increases rapidly in the faulted
and brecciated areas.

The best mineralizations in the field – called B,
A, D, and C – are situated around the profiles 900
N, 100 N, 450 S, and 1200 S respectively. The
present paper, however, does not consider the
B- and D-mineralizations.

**The A-mineralization.** – The main mineralization
occurs in fels and schist on the eastern limb of
the big anticline (Fig. 1), where the fels and the
interstratified carbonaceous schist form a
slightly broken synform.

The ore minerals are chalcopyrite, pyrrhotite,
and pyrite, all of which occur as impregnation
and in carbonate veins mainly in the fels but also
in the adjacent parts of the schist. Accessory
minerals are magnetite, hematite, and complex
Ti-V-minerals (Mathiesen 1969).

The mineralization is fairly rich in gold; the
analyses showed 2–7 ppm Au in ore giving
20–102 ppm in 23% copper concentrate. The
lying wall between 140 and 80 N showed the
highest gold content.

Although the age relationships between the
minerals have not yet been studied, the prelimi­
nary observations showed that the sulphides of
the veins are younger than the gangue minerals.
Most of the pyrite seems to be older than the
chalcopyrite; pyrite is found in idiomorphic
crystals which are brecciated and replaced by
chalcopyrite.

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The A-mineralization is limited to the north by
a N 80°E striking fault, dipping 85° SSE. The
northern block was lifted as compared to the
southern one. Southwards the mineralization
gradually disappears from profile 60 N. It was
only mined to profile 50 N.

Some poor mineralization was also found in
the same rocks in the western limb where it
extends southwards for some kilometres.

**The C-mineralization.** – The best copper
mineralization in the field – the C-ore – also lies
in the eastern limb of the big N-S-striking
anticline (Fig. 2). It consists of a good eastern
ore lying between 890 and 925 m east and a west
ore between 850 and 880 m east (Figs. 3–5). The
northern end of the east ore lies at profile 1040 S
and the southern one at 1200 S in the open pit
(650–670 m a.s.l.) On level 600 (m a.s.l.) in the
mine the ore lies between 1050 and 1260 S. It is
known down to 480 m a.s.l. extending from
approximately 1100–1160 S. The west ore is
between 1085 and 1220 S on this level. In the
southern part it combines with the east ore. The
northern limit on levels between 650 and 670 is
indicated to 1070 S while the southern end lies
around 1180 S. The mineralizations extend both
north- and southwards in the eastern limb of the
fold, but are normally of very low grade.

The mineralizations consist of chalcopyrite,
pyrite, and some pyrrhotite; they occur as im­
pregnation, in irregular coarse grained albite­
carbonate (ankerite and calcite) veins, and in
irregular layers concordant to the diffuse layer­
ing of the albite fels. The carbonate veins also
contain some muscovite, chlorite, and actinolite.
The west-ore is rich in pyrite. Magnetite occurs
in the westernmost parts. Chalcopyrite is found
in varying amounts close to the carbonaceous
schist together with some pyrrhotite. The west
ore contains an impregnation of galena and
sphalerite (max. 0.4% Pb and 1.5% Zn per ton of
ore).

Around 910 E the fels normally has only
pyrite. The east ore, however, also contains
pyrrhotite with galena and sphalerite (max. 0.4% 
Pb and 2.4% Zn per ton) together with
chalcopyrite. The central parts only contain
traces of sphalerite and even less amounts of
galena.

The central and synclinal fels is rich in
chalcopyrite with pyrite, minor pyrrhotite, and
magnetite. South and above the ore pyrrhotite
with magnetite is common.

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*Fig. 2. Geological map of the Bidjovagge mining field, western
Finnmark, Norway: 750–1600 S.*
The carbonaceous schist contains pyrrhotite with some pyrite and chalcopyrite at the contacts with fels.

The sulphides are mainly found in the fels and adjacent parts of the schist. In lower parts of the mine good mineralization occurs in the underlying schist in the copper-bearing synform around 900 E. Fig. 5 on the level 636 in the mine shows that the eastern fels and its contact with black schist are dipping steeply towards east around 915–925° E and striking north to north 5° west. The western part of the black schist (between 880–900 E in profile 1120 S at 636-level) strikes north 5–10° E. Dip is 60–80° E. The black schist forms a synclinal with the closure to the north. The fold axis dips 20–30° S, the central part being filled with partly mineralized fels.

Just south of the C-ore there is another
chalcopyrite mineralization. Lying on the west side of the eastern carbonaceous schist this probably corresponds to the west ore in the C mine. It was found between approximately 1250–1380 S from 600–500 m a.s.l. in the northern part to 560–490 m a.s.l. in the southern part. This mineralization is probably connected with the one observed between 1440–1480 S roofing at 500 and 480 m a.s.l. respectively and with a vertical extension of approximately 100 m. Mineralogically and petrographically these are of the same type as the C-ore.

The ore reserves in the eastern C-ore are estimated as follows:

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>Ore Reserve (t)</th>
<th>Cu Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between 600–650 m a.s.l.</td>
<td>550,000</td>
<td>1.5%</td>
</tr>
<tr>
<td>Between 540–600 m a.s.l.</td>
<td>150,000</td>
<td>1.3%</td>
</tr>
<tr>
<td>Between 480–540 m a.s.l.</td>
<td>100,000</td>
<td>1.3%</td>
</tr>
</tbody>
</table>

The ore estimates in southern C-ore (as mentioned above) are:

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>Ore Reserve (t)</th>
<th>Cu Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between 540–640 m a.s.l.</td>
<td>515,000</td>
<td>1.6%</td>
</tr>
<tr>
<td>Between 480–540 m a.s.l.</td>
<td>785,000</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

In addition there are 225,000 tons with 1.4% Cu in the west ore. The reserves total approximately 2.3 million tons with 1.5% Cu.

**Tectonics**

The rocks in the Bidjovagge area are dominated by a generally north-south striking anticline (F₁) with a central part from 500 E in profile 0 to 650 E in profile 1400 S (Fig. 1). The western limb strikes north-south at 500 E, while the eastern one stands from 700 to 1,000 E. North of profile 700 S the fold axis dips to the north (15–30° at profile 0). The carbonaceous schist just north-west of D forms a syncline dipping north. The dip varies from 10° N to 10° S between 700 and 1000 S. South of 1000 S the dip gradually increases to 25–30° around profile 1200 S. These changes are due to flat-lying east-west striking foldaxes (F₂) which exist in the Caskias region.

The folding has been very important for the localization of the sulphides. Both the fels and carbonaceous schist are highly folded and often
disrupted. This caused the main mobilization of the sulphides – both laterally towards troughs but especially the crests of the folds, and transversely into cross-fractures. It appears that the relative mobility increases in the sequence pyrite-sphalerite-pyrrhotite-galena. The thickening at the crests and troughs has been coupled with thinning out along limbs. This mobilization has resulted in increased copper values in strongly folded beds as compared with their less deformed equivalents.

In addition it seems that faulting and fissuring were of significant importance for improving the ore grade, i.e. it was observed that as faulting decreases the amount of ore minerals also decreases. The faulting has taken place after the folding. The most prominent faults occur in N 40–50° E. Another system strikes N 45–55° W. In addition there is a third one (very weakly shown) in east-west. These represent a combination of blockfaulting and fissuring. As noted above, the A-mineralization is limited to the north by east-west faulting. The C and D mineralizations lie in areas with movements in north-easterly direction. In many other parts the rocks are broken with secondary chloritization along fractures but with no signs of displacement.

The ore genesis

The original geological setting of the rocks in Caskias was a sedimentary basin in which there was a widespread volcanic activity. The fels probably represents the volcanic ashes settling in a reducing milieu of organic black clays alternating with more carbonate material. The sulphides could have come from submarine syngenetic exhalations being precipitated in the smaller depths in various amounts. Later folding and faulting mobilized the sulphides and provided new space for deposition and concentration across the original sedimentary boundaries.

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In the field the author had great help from geologists H. Delin and S. E. Bull. He is most grateful to the technical staff at the laboratory of the mining office in Kirkenes for all chemical analyses, and to Saga Petroleum a. s. for the extensive drafting.

References


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Fig. 5. Geological map of the C-mine of the Bidjovagge mining field: 636 m above sea level.