

Massive sulphide occurrences in the Vaddas Mining Field

Rune Wilberg

June 2011

For Scandinavian Resources AB

Vaddas Mining Field

Scandinavian Resources AB was granted exploration licences covering the Vaddas Mining Field in 2011. The purpose of this report is to make a short summary of historical exploration and geology of the area.

The Vaddas – Birtavarre area includes several Caledonian semi-massive to massive sulphide deposits at four stratigraphic levels in the Oksfjord Group of the Vaddas Nappe in the Upper Allochthon of the Reisa Nappe Complex. The lower boundary of the Oksfjord Group is marked by unconformity to the underlying metasedimentary Kvænangen Group, whereas the upper boundary is a thrust contact to the overlying Kåfjord Nappe. The Oksfjord Group is dominated by pelitic metasediments, but also includes a greenstone unit, the Loftani Greenstone Member, which partly comprises pillow basalts. The greenstone unit is situated in the lower part of the group in the area around Vaddas, where it attains a thickness up to 500m.

The first reported finding of sulphide mineralisation in Vaddas was in 1896, consequently initiating the first exploration period by local prospectors. In 1900 the English Oxfjordalen Copper Mining Company Ltd was founded. Mining rights were transferred to A/S Sulitjelma Gruber in 1906 which conducted extensive exploration up to 1910. They were main shareholders in A/S Vaddas Gruver which was founded in 1914. They received concession for 60 years exploitation in 1916 and conducted extensive exploration work, mainly drifting adits, towards 1920. The first flotation tests of Vaddas ore was done in 1929 with good results.

Between 1920-1950 exploration activity was dormant. Between 1952 and 1957 the publicly owned mining company A/S Norsk Bergverk conducted extensive exploration activity, initiated by a political decision to finance the mining development in the Vaddas area by the governmental budget. They continued drifting adits, did geophysical surveys, diamond drilling and flotation tests of Vaddas ore. During the period 1962-64 NGU conducted geological mapping and a stream sediment survey and in 1968 flotation testing, was done on the Rieppe ore, with particular emphasize on Zn-flotation.

A/S Bleikvassli Gruber were permitted to utilize the governmental mining rights between 1968-72 and conducted geological mapping, geophysical surveying and diamond drilling. This work and a summary of previous exploration are comprehensively described in a thesis by Lindahl (1974).

The major, volcanogenic, massive sulphide deposits in the Vaddas district are located on top of the Loftani Greenstone Member. The deposits are Cu-Zn to Zn-Cu dominated, with a minor lead content. One major deposit, the Rieppe deposit, is located in a lower part of the greenstone. Smaller sulphide deposits with higher base-metal grades occur in the Vaddas area in the greywacke succession above the greenstone, in a similar position to that of the deposits in the Birtavarre district (Vokes 1957). The upper part of the Oksfjord Group is a monotonous greywacke unit, known as the Ankerlia Formation (Lindahl et al. 2005). A fourth and lowermost mineralised stratigraphic level is represented by one single deposit, the Lower Njoammeloalgi, in calc-biotite schist just above the lower part of the Loftani greenstone Member.

The Vaddas horizon contains the main mineralisation in the area and the Vaddas deposit is the main deposit within this zone, which can be followed for 35 km along strike from Reisadalen in SW to Doaresgaisa in the NW. Massive to semi-massive sulphides occur in separate bodies linked together by sulphide disseminations or thin sulphide bands. The Vaddas zone mineralisations are pyrrhotitic, with varying amounts of pyrite, copper ores. The copper content are between 1 and 2 % on average. The zinc content in the Vaddas deposits is generally below 0.1 %, but there is a change along strike from Doaresgaisa to Nedre Lankavarre, where the Zn content increases to the south, from 0.1 to about 1 %. The lead content is very low. Precious metals in the ore, based on analyses of chalcopyrite concentrates from flotation, are low (24 ppm Ag and 1.7 ppm Au). The sulphide deposits in the region rarely contain more than 50-60 % sulphides. They have been strongly deformed both before and during metamorphism, resulting in `durchbewegung` whereby fragments from the wall rock have been incorporated, and rounded wall rock and quartz fragments are enclosed in the sulphide matrix (Lindahl et al. 2205).

Some short comments on each deposit, particularly size and grades (where found), grouped in occurrence levels: 1. Vaddas horizon, 2. Within Loftani greenstone, 3. Ankerlia Formation, and 4. Base of the Oksfjord Group.

1. Vaddas horizon

The *Vaddas* occurrences crop out in 25 small showings SW of Vaddas, on a mountainside 500-750 m.a.s.l. Several kilometres of exploration tunnels have been driven from seven adits (named A-G). There is continuous outcrop of ore over a length of about 1000 m between adits B and E, but the ore is concealed between adits A and B (lengths of 400 m), partly because of a fault with a 20 m throw on the ore zone. An en-echelon pattern of ore concentration along the zone is apparent from geophysical data. The average thickness of the ore varies from 0.7 m (assaying 1.4 % Cu) in adit D to 2.8 m (1.8 % Cu) in adit E. It is a pyrrhotite-pyrite copper ore with clasts of greenstone and quartz. The zinc content is generally very low, <0.1 % Zn. The contents of Ag and Au are also low. So-called `massive ore` only contains 40-60 % sulphides, corresponding to approximately 25 % S. The deposit has been evaluated for mining several times, especially if combined with the larger Rieppe deposit (see below). Resource calculation on the Vaddas deposit shows a reserve of 715 000 t at 1.37 % Cu with an ore thickness of 1.5 m, or 853 000 t at 1.15 % Cu with a thickness of 2 m (Lindahl 1974).

Doaresgaisa

Rather inaccessibly located in a cliff 900 m.a.s.l. at the NW`ern end along the Vaddas horizon. Due to bad accessibility, only limited work is conducted. According to Lindahl (1974) the 800 m long mineralisation, which dips 15-20° southwards, has a thickness up to 3-4 m in an irregular zone, however only parts of this is massive sulphides. The copper grade is 2.5 %, higher than in Vaddas, and zinc assays vary between 200-1300 ppm (in the same representative composite sample!). It is a relatively high Ag content, 119 ppm, in copper concentrate from Doaresgaisa.

Heindal

The Vaddas level can be traced to Heindal where it crops out at an elevation of 500 m.a.s.l. in flat terrain. Dip 30° south. Due to moraine cover and strong weathering of exposed bedrock neither assays nor mineralogical studies are conducted. Vogt (1919) describes the mineralisation as impregnation in schist. A geophysical ground survey (ABEM Minigun) was conducted in 1972. A relatively strong EM-anomaly indicates a 500 m long conductor, and in addition a 200 m long conductor 10-20 m above.

Ytre Gressdal

No deposit, just a large ore boulder. Probably derived from the cliff to the east or from the valley in the south. EM survey conducted in 1972 – no anomalies.

Grytlia (Stoll I)

This mineralisation is hosted in amphibolite above the greenstone contact, and about 200 m higher in the stratigraphy than the Vaddas horizon. It is outcropping 760 m.a.s.l. in the inaccessible cliff west of adits A and B in the Vaddas mine. It is drifted about 90 m of underground workings. Outcropping strike length of rust zone is 400 m and the dip is 50-80° to the west. A strong EM-anomaly of 50 m length is connected to the mineralisation, which is more irregular than the Vaddas deposit. Repeated sulphide banding occur within 10 m thickness. According to Vogt (1920) massive sections are up to 2-3 m thick, with associated impregnations. The mineralisation is coarse-grained pyrite-pyrrhotite copper ore with < 0.05 % Zn. Along the wall-rock contacts magnetite-banding occur.

The copper content is about the same as in the Vaddas mine, 1.4-2.2 % Cu in massive ore and 0.7-1.4 % in impregnation. Assays of ore and concentrates show high Co, in average 0.3 % Co in the ore.

Loftani

South of the Vaddas mine and slightly higher in the stratigraphy, this mineralisation is outcropping along 1.8 km strike length at an elevation of 600 m.a.s.l., proven by several excavations and in 1972 by diamond drilling. A geophysical survey shows a 3 km long continuous EM-anomaly associated with the mineralisation. According to Holmsen (1910) the thickness is between 1.2 and 1.8 m and the grade is around 1 % Cu. Compared to the Vaddas ore Loftani ore carries more pyrite (about equal amounts of pyrite and pyrrhotite), contains more silicates, less copper and are less tectonised.

The content of Co and Ni are about the same as in Vaddas, 300-600 ppm Co and 60-100 ppm Ni. Cd in sphalerite is relatively high, but distinctly lower than in Vaddas. The zinc level is 0.1-0.2 % in the richer part of the mineralisation and the silver content in copper concentrate is 41 ppm.

The outcrop is tested with short drill holes over a length of almost 2 km. Within this length it is approximately 600 m where the Cu-grade is above 1 % within workable thickness.

The drill holes intersect the mineralisation at about 20 m depth. Calculated down to 50 m depth tonnage is 220 000 t with 1.2 % Cu. Two of the holes drilled in 1954 by A/S Norsk

Bergverk were drilled from the same spot and hit the mineralisation with 17 m interval. The upper hole intersected 3.9 m thick ore with 1.04 % Cu and 19.50 % S, and the lower showed 1.3 m thickness grading 0.87 % Cu and 19.27 % S.

Øvre Nomilolgi – Nomilgorssa

Øvre Nomilolgi is a direct southern continuation of Loftani and the Nomilgorssa mineralisation is a continuation of Øvre Nomilolga south of a fault. The outcropping mineralisation is incompletely exposed and rather intensely excavated over a length of 600 m. All diggings show massive ore. EM measurements in 1954 indicated a conductor of 1000 m length.

The ore type is a pyrrhotite with variable pyrite (far less than Loftani) and chalcopyrite content. It is more fine-grained and distinctly more Zn-rich than the other deposits, c 1 % in Øvre Nomilolgi and c 2 % in Nomilgorssa. A high Co-content in the ore is reflected in assays of the pyrite concentrate, 0.50 % Co. The content of precious metals is low.

The length of mineralisation tested by 8 short drill holes in 1971 is 600 m. Calculated tonnage down to 50 m down-dip is approximately 150 000 t with average thickness 1.5 m and 0.88 % Cu (the high Zn-content (see above) given among others by Lindahl (1974) is not verified by this drill program – drill logs (Lindahl 1978) show the Zn grades to be below 0.1 % in the ore intersections in 6 of the 8 holes!). The best part of the mineralisation has a length of 400 m, containing close to 1 % Cu.

Jiekkejavre

Judged from geophysics and geological observations it can be seen that the mineralisation is split in parallel conductors, manifested in rust zones. It can be followed as a distinct EM-anomaly over a length of 700 m. The excavations expose an ore thickness of 2-3 m (Lindahl 1974). The tectonised mineralisation contains pyrite and pyrrhotite in about equal amounts, chalcopyrite and minor sphalerite. Earlier exploration gives Cu grades between 1.5-3 % and a thickness of 1.5 m.

Two Pack-sack holes were drilled in 1971. One of them intersected two mineralised horizons with 1.5 m separation. Upper zone: 3.5 m thickness with 0.93 % Cu and 0.1 % Zn. Lower zone: 8.3 m with 0.48 % Cu and < 0-1 % Zn.

Nedre Lankavarre

Two parallel rust zones can be followed “quite far” southwards, as a continuation of the mineralisation from Jiekkejavre, at an elevation of 950 m.a.s.l. in a steep cliff. The upper contains semi-massive to massive mineralisation over a length of c 300 m and average thickness is less than 1 m, varying between 0.2-2.0 m.

The ore is heavily tectonised, with chloritised and talc-altered schist fragments in sulphide matrix. The wall-rock boundaries are sharp but irregular, with only traces of sulphides in the wall-rocks, which is also brecciated.

The ore is pyrrhotitic with pyrite, chalcopyrite and sphalerite. Samples by Jensen (1912) assayed 2.8 % Cu over 0.6-0.8 m thickness. The Zn grade seems to be as high as 1.5 % (Lindahl 1974).

Øvre Lankavarre

The mineralisation is outcropping in a cliff 1050 m.a.s.l., 150 m stratigraphically above Nedre Lankavarre and at about the same lithostratigraphic level as the Grytlia/Stoll I deposit. It is mainly concordant (local discordances) and dips 30° to the WNW. Outcropping massive sulphides is only 60 m long, varying between 1 and 3 m total thickness (including dissemination). The Cu content is estimated to be 2-3 % and Zn slightly above 1 %. Precious metal content is lower than in the other deposits (Lindahl 1974).

The Vaddas horizon can be followed more or less continuously from Nedre Lankavarre and 7 km south-westwards to *Gæiradalen*, and even further SW.

2. Within Loftani Greenstone

Rieppe

The Rieppe deposit, hosted in the Loftani Greenstone, is located about 8 km south of the Vaddas deposit, south of a major fault, the Rieppe Fault Zone which has a vertical throw of 800 m. The mineralisation has an along-strike extent in outcrop of about 2 km, part of it found in a high, vertical cliff. The concordant mineralisation is strongly tectonised, containing fragments of greenschist, commonly altered to talc. The ore consists of pyrrhotite with varying amounts of chalcopyrite and sphalerite, whereas pyrite and galena are generally accessory phases. The strong deformation leads to a very large variation in metal content (metre-sections of drill core can contain as much as 14.6 % Zn, and the Pb grade can reach 2.4 % in half-metre sections) and ore thickness (2-20 m). Lenses of barren wall-rock up to several metres in size form inclusions in the ore, as well as greenschist fragments with sulphide impregnation (Lindahl 1974, Lindahl et al. 2005).

The Rieppe deposit drilled (7476 m totally) and delineated, and contains an identified resource of 3 Mt at 0.5 % Cu and 2 % Zn (at 0.2 % Cu cut-off). Below the main zone there is an additional probable resource of 1 Mt with 0.4 % Cu and 0.04 % Zn. Gold is not an economic element in the ore, but the silver content in the copper concentrate is 48 g/t. Flotation tests have shown that also talc may be exploited from the deposit (Digre 1972, Lindahl et al. 2005).

3. Ankerlia Formation

Indre Gressdal

This mineralisation has an outcropping strike length of c 1000 m and is incompletely exposed. An adit is drifted 52 m inwards, where it intersected the ore which is dipping 75-80° to the east. It is a pyrrhotitic ore which is more Cu-rich than the deposits of the Vaddas horizon. Pyrite is lacking and arsenopyrite is common. Ore thickness is variable, up to 3-4 m, but average is assumed to be c 1 m, and assays of typical ore samples show from 1.2 to 14.4 % Cu and up to 1.5 % Zn (Lindahl 1974).

The deposit was covered by an EM survey in 1972 which proved a good conductor with weak indications towards the south, in the direction of the Røieldalen deposit which is located south of the Rieppe Fault.

Moskodal

The mine has produced c 40 000 t ore at an average grade of 2.7 % Cu during three periods, 1904-07, 1917-18 and 1929-30.

The ore stock is controlled by an axial plunge of 1.5° towards ENE. Length of mineralisation is 170-200 m and width up to 100 m. A massive pyrrhotite-chalcopyrite ore grading 3-4 % Cu is 0.5-1.5 m thick and including wall-rocks with sulphide-bands and –impregnation total thickness is varying between 4 and 10 m. The western part of the deposit is displaced down by a north-south-running fault with a throw of 15 m. The western continuation is proven by a drill hole that intersected 4.8 m of ore with 2.67 % Cu (Poulsen 1950). Ore Database samples assay up to 7.4 % Zn.

According to Kleine-Hering (1973) three ore types can be distinguished: Breccia ore, massive ore without breccia fragments, and impregnation.

Outside the claim area, north-east of Moskodal, is a similar type of mineralisation, *Høggjellvatnet*. The 2 km long and 1-2 m thick deposit with Cu-grade approximately 3.6 % is hosted in metagreywacke close to the gabbro contact.

4. Base of the Oksfjord Group

Nedre Nomilålgj

This semi-massive, lensoid deposit is hosted in mica schist occupying a level between Upper and Lower Loftani Greenstone. Outcropping length is 400 m and an EM-survey outlines a conductor of equal length. Thickness is hard to judge due to limited exposure. Sulphide content in the richer parts is 20-40 vol %. The sulphide zone is intensely tectonised, with chloritised and crumbled schist fragments in sulphide matrix.

Sulphide paragenesis is pyrrhotite with minor chalcopyrite and sphalerite. The Cu-grade is probably at the same level as the Vaddas deposit, and the Zn-grade is approximately 0.75 % (Lindahl 1974).

Drill cores from the Vaddas district stored at Løkken

Rieppe: 43 holes totalling 3930m

Moskodal: 5 holes totalling 75m

Loftani: 14 holes totalling 243m

Jiekkejavri: 1 hole totalling 10m

Vaddas: 17 holes totalling 69m

Store Ste: 24 holes totalling 119m

(Some of these holes have only sections stored)

Recommendations

Even though the extensive Vaddas Mining Field has been subject to repeated exploration programs, partly sponsored by investments from the state, the assumed limited sizes of each single deposit has not encouraged to any exploration activity the last 40 years.

In his evaluation of the last program by Bleikvassli Gruber, Lindahl (1974) concludes that the majority of deposits are not sufficiently explored.

In many cases the inhospitable nature of the terrain, with the mineralised horizon outcropping in an almost vertical cliff, has prevented geophysical surveys and drilling. However, from a mining perspective, one could gain rather than struggle by this terrain relief. Main adits could be drifted in the cliffs at desired elevation, below the outcropping mineralisations.

In fact, drilling is possible at quite a few deposits where, up to now, only 10-20 m long Pack-sack holes close to outcrop, or no drill-testing at all, has occurred. Such drilling would yield reliable assay values, which is a concern in the historic work, as Lindahl (1974) emphasises. One example is, according to him, the Rieppe deposit: "It must be emphasised that the assays that are basis for the resource calculation most probably are incorrect." Another is, he says (concerning the Vaddas deposit): "First of all one has to come up with correct assays in order to conduct reliable evaluations. This reassaying/assay control must have priority one in the development of the mining field". As a consequence we should reassay selected core sections from the historic drilling stored at Løkken.

The historic drilling might lack proper control of lower-grade mineralisation along the contacts to the massive ore, which in some cases could increase the ore thickness. In the Vaddas deposit Lindahl (1974) points to the fact that foot-wall impregnation seldom is included in the drill collars, due to the location of the adits along the foot-wall contacts of the massive ore (drilling was conducted from the adits).

Even if it is frequently remarked in the historic reports that precious metal contents are low (in massive ore?), one should still keep the possibility open that Au and/or Ag can have the ability to concentrate in the impregnation zones away from the massive ore. This was experienced in the Rana Mining Field where elevated gold was detected in the impregnated wall-rocks after the massive ore was mined and the mine closed.

According to Lindahl it is conducted too few and possibly too random precious metal assays to be conclusive about the content.

Lindahl recommend giving priority to follow-up along the Vaddas – Loftani-part of the mineralisation, but not prior to having considered the possibilities to exploit a deposit of such dimensions and tonnages as known. He recommends drilling from the glacier in Grytliå, which could potentially increase ore resources significantly.

He also points to the extent of the Vaddas horizon, with outcropping massive sulphides along 35 km strike length, and that the hidden dimension, down-dip, would be expected to

have a certain proportion to the strike extent. The Rieppe Fault, with a throw of c 800 m, indicates this – it is still mineralisations in the same level at both sides of the fault.

References and other reports

Kleine-Hering, R. 1973: Der Geologische Rahmen und die Mineralogie der Pyrit-freien, Zinkblende-führenden Kupferkies-Magnetkies-Erzvorkommen des Moskodal, Nordreisa, Troms, Nord-Norwegen. Dr Avh, Joh. Gutenberg Univ., Mainz.

Lindahl, I. 1974: Økonomisk geologi og prospektering i Vaddas-Rieppe-feltet, Nord-Troms. Dr Ing Thesis, NTH, Trondheim.

Lindahl, I. 1978: Borkjernelog for diamantboring på strekningen Vaddas-Jiekkejvri, 1971 og 1972. NGU-rapp. 1650/47A.

Lindahl, I., Stevens, B.P.J. & Zwaan, K. B. 2005: The geology of the Vaddas area, Troms: a key to our understanding of the Upper Allochton in the Caledonides of northern Norway. NGU Bull. 445, 5-43.

Poulsen, A.O. 1950: Moskodal Gruber. NGU rapp BA1310.

For complete list of references, see Lindahl (1974).