A reconnaissance study of Rävliden VHMS-deposit, northern Sweden

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Table of contents

Cover Picture: Drill core from drill hole 262, Rävliden.

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Abstract: In the Skellefte district today there are about 85 known VHMS-deposits, in the Kristinebergs area there are five known deposits, one of them being Rävliden. The supracrustal rock primarily consists of metavolcanic rock of rhyolitic composition and also metasedimentary volcanic rock. The district has gone through at least two metamorphic events. This resulted in the presence of large scale folding. Rävliden lies next to an antiform (compression N-S) that plunges to the west. In this study five drill cores from the Rävliden mine were logged. Six main lithologies were found; rhyolite, sandstone, graphite schist, sericite quartzite, tremolite skarn and carbonate rock. The logging of the five drill cores resulted in two profiles. The result is an interpretation of the geology, matching core with similar properties. In the sandstone there are areas locally rich in graphite which probably derives from sediment on the seafloor, the graphite schist is also probably seafloor-sediment. Alteration in the rock is extensive making it hard to see primary structures. The application of alteration index implies that the area is hydrothermally altered. This information and the findings of graphite imply that the area of study is in a transition zone between the footwall and hanging wall. It is also probable that the area is in a limb of an antiform when looking at the profiles.

Keywords: VHMS, VMS, Skellefte district, Rävliden

Supervisors: Dr. Nils Jansson (Boliden Mineral Ab), Mac Fjellerad Persson (Boliden Mineral Ab), Ulf Söderlund

Subject: Bedrock Geology

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En rekognoserande studie av Rävliden’s VHMS-fyndighet, norra Sverige

JESSICA SIDENMARK

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Sammanfattning: I Skelleftefältet finns idag runt 85 kända VHMS-fyndigheter, i Kristinebergs-området finns fem av dessa fyndigheter, en av dem är Rävliden. Berggrunden består mestadels av meta- vulkaniter med ryolitisk komposition samt en meta- sedimentär vulkanisk bergart. Skelleftefältet har genomgått åtminstone två metamorfa event. Detta har resulterat i storskalig veckning av området. Fyndigheten i Rävliden ligger i närheten av en antiform (kompression N-S) där veckaxeln stupar till väster. Fem borrhål från Rävliden har karterats för denna studie. Resultatet av karteringen blev en framställning av två profiler. I dessa profiler beskrivs sex huvudsakliga litologier; ryolit, sandsten, grafitskiffer, sericitkvartsit, tremolitskarn och karbonat bergart. Resultatet är en tolkning av geologin där borrkärna med liknande egenskaper matchas. I sandstenen finns det grafitrika områden som förmodligen kommer från sediment på havsbotten, samma sak gäller med grafiten i grafitskiffern. Omvandligen i borrkärnorna är hög, detta gör det svårt att se primära strukturer i kärnorna. Tillämpandet av omvandlings-index tyder på att området är hydrotermalt omvandlat. Denna information och fynden av grafit tyder på att området som är undersökt i studien är i en övergångszon mellan liggvägg och hängvägg. Det är troligt att det karterade området utgör en del av en antiforms veckben när profilerna tolkas.

Nyckelord: VHMS, VMS, Skellefte fältet, Rävliden

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1 Introduction

1.1 Background

Sweden is a big contributor to Europe's total production of base metals (Zn, Pb, Cu, Ag and Au). In the Skellefte district in northern Sweden there are 85 known deposits all rich in base metals. Exploration in these parts is still ongoing and prospecting in search for new deposits is intense and widespread.

In the area around the Kristineberg mine, the largest mine in the district, extensive field exploration is conducted by the Boliden Mineral AB. The Kristineberg area also hosts other abandoned mines such as Kimheden, Hornträskviken, Rävlidmyran and Rävliden. All these mines are of interest for exploration activities in the area.

This report will look into a small area beside the Rävliden mine on behalf of Boliden and their department of field exploration.

1.2 Purpose and aim

The purpose of this study is to get a brief insight in some of the bedrock lithologies in Rävliden. This is accomplished by logging drill core and then finally to draw profiles based on the studies of the drill core (Fig. 1).

The report will also provide brief information about the Skellefte district and formation of VHMS (Volcanic Hosted Massive Sulfide)-deposits. This is given in order to get a basic understanding of how deposits form.

The overall aim of this is to provide Boliden with useful information for more efficient exploration in the Kristineberg area.

2 Setting

The Rävliden-mine is located approximately 5 km west of Kristineberg in the municipality of Lycksele in

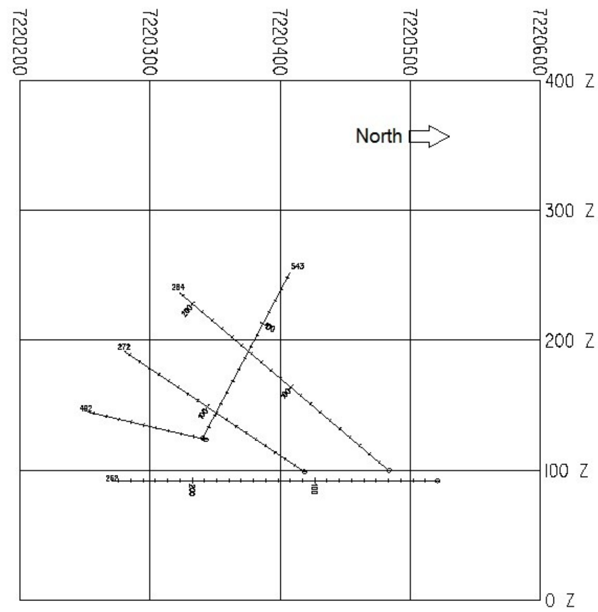

Fig. 1. Drill holes logged during study. RT 90 grid system.

the county of Västerbotten (Fig. 2). The mine was in operation between 1941 and 1988, and the total amount of ore yield was 1.94 Mt, with average grades of 4.2 % Zn, 0.9 % Cu, 0.8 % Pb, 19 % S, 0.4 g/t Au and 90 g/t Ag (Schlatter et al., 2003).

2.1 Geology

The Skellefte district is one of the major VHMS (Volcanic-hosted Massive Sulfide)-districts in the world according to Gifkins et al. (2005). The Skellefte district covers an area of 30 kilometers by 120 kilometers starting in Boliden and stretching west to Rävliden (Fig. 3) (Allen et al., 1996). Inside the district there are 85 known deposits and about 30 of them have been or are mined today.

The Skellefte district is hosted by Paleoproterozoic volcanic rocks mainly of felsic composition of low to medium metamorphic grade (Allen et al., 1996). These

Fig. 2. Setting of the Rävliden mine. Modified after eniro.se

authors also discuss which tectonic setting the ore was formed during. There are different theories but the preferred interpretation implies a marine volcanic arc environment with each deposit being formed under varying conditions. The stratigraphic unit referred to as the Skellefte-group (SG) metavolcanics is thought to be formed from pyroclastic activity when submarine caldera volcanoes erupted (Allen et al., 1996). Another unit is called the Vargfors- group (VG) and consists of metasedimentary rocks. The SG is overlain by the VG to the west of Rävliden (Fig. 3). The majority of deposits are found near the contact between the VG and the SG (Jansson et al., 2013). The SG is aged around 1.88 billion years whereas the VG was formed during the cessation of the volcanic activity with continued deposition for some time thereafter (Allen et al., 1996).

The districts history does not end with deposition of the VG. Shortly after the VHMS-deposits formed, around 1.85 billion years ago the Svekokarelian orogenesis caused regional metamorphism. According to Allen et al., 1996, the supracrustal rocks experienced at least two metamorphic events. The Kristineberg area now consists of folds mainly antiforms with hinge lines plunging to the west (Fig. 3). According to an exploration report from SGU (Swedish Geological Survey) the bedrock is isoclinally folded with a hinge line plunging at about 20° in the Rävliden area. The hinge line plunge at the Kristineberg mine is around 38°. In the VHMS-deposits in the Skellefte district the most important sulfides extracted are chalcopyrite ($CuFeS_2$), sphalerite (ZnS) and galena (PbS). Other valuables are Ag and Au which predominantly occurs as inclusions in other minerals (Allen et al., 1996).

3 Hydrothermal systems & VHMS-deposits

The origin of VHMS-deposits in the earlier mentioned marine volcanic arc environment is due to hydrothermal fluids derived from extension tectonics and volcanic activity (Fig. 4). In this study a caldera system is used to explain a possible way of a deposit being formed. With this it is not said to be the only way these deposits form. Hydrothermal systems require two conditions; first a heat source and secondly the presence of fluids (Pirajno, 2009). The heat source in this case would be the geothermal heat generated from a cooling magma chamber, in some depth, whereas the fluids presumable are derived from the sea water. The water is forced down in the ground via fault-zones that are abundant near the caldera. As the water successively reach high temperatures metals and other ions are leached out from the surrounding rock (Pirajno, 2009).

The caldera-system is still hotter than surrounding rock volumes, which results in vents forming on the seafloor to release the increasing pressure. These vents are thought to be the equivalents to black smokers along some mid-ocean ridges active today. Above the heat source seawater reacts with the rock from which metallic-ions are leached. The mix of water, ions and gases ascend through the vents, discharging on the seafloor in contact with cold water, and participates as massive sulfide lenses (Fig. 4). Over time when heat reduces, the vents themselves and the feeder channels can be filled with disseminated zoned sulfides, with the zoning reflecting changes in composition and temperature (Pirajno, 2009).

3.1 Alterations in VHMS-deposits

Alteration of rocks is common in VHMS-environments. In the host rock also known as the foot

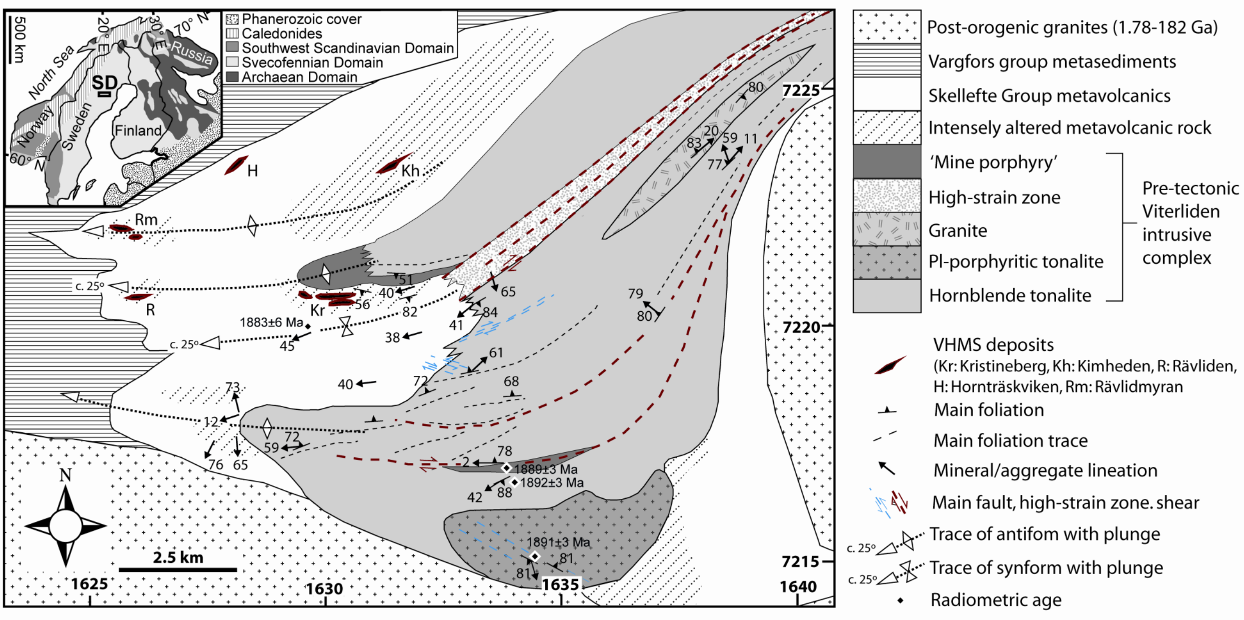

Fig. 3. Close up of the geology in the Kristineberg area, the western part of the Skellefte district (map of Skellefte districts position in Fennoscandia seen in top left corner). The Rävliden deposit is marked with an R. RT 90 grid system (Jansson et al., 2013)

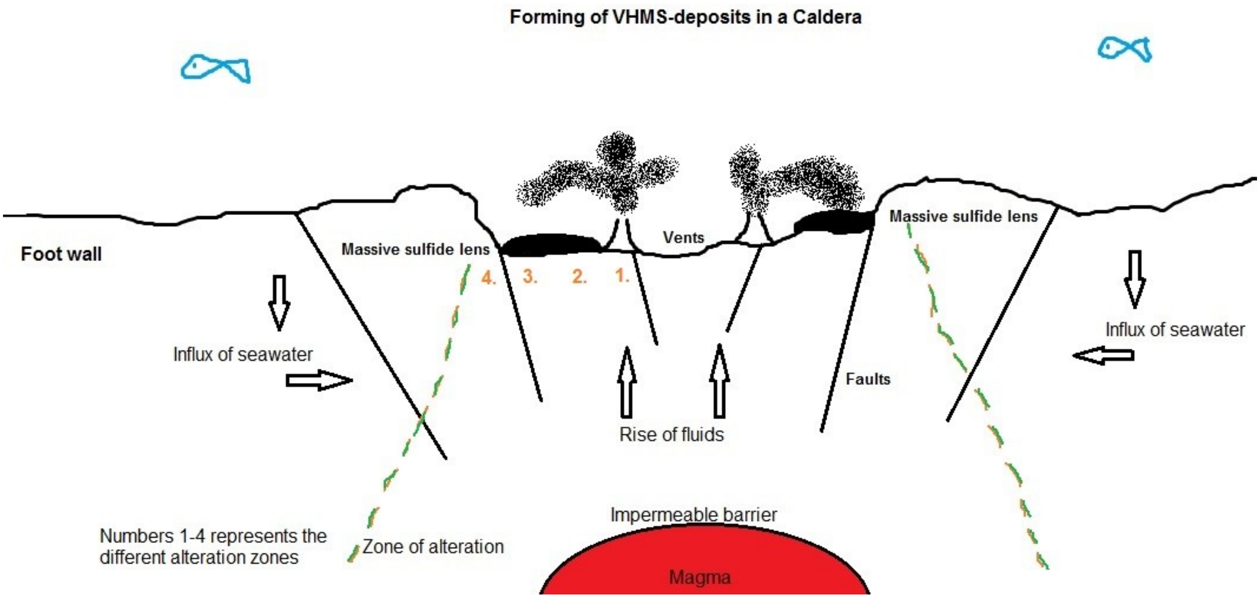

Fig. 4. General model of a hydrothermal system in a Caldera environment. Explanation of the different alteration zones can be read in chapter 2.2.1.1. Modified after Pirajno, 2009

wall (Fig. 4) from where the sulfides originate, alteration takes place when the hydrothermal fluids pass through. This metasomatic process can change the chemistry in the alteration product as well as the chemistry in the host rock (Robb, 2005).

Metasomatism can appear in hydrothermal systems and is controlled by ambient temperature, pressure, host rock composition, fluid composition and the ratio of fluid to rock in the alteration process (Robb, 2005). This may result in alteration zonation and can be seen in endless shapes (Pirajno, 2009 and Gifkins et al., 2005)

Pirajno, 2009 describes a model, this model assumes that this type of zonation is controlled by its position to the feeder channel of the hydrothermal vents rather than closeness to the ore-lenses. Gifkins et al., 2005 have a similar view of alteration zonation. Their model is seen proximal from the core of the feeder channels to more distal areas and is illustrated with numbers 1 to 4 in Fig. 4 (Gifkins et al., 2005);

1. Siliceous core zone. This represents the most intensely altered zone, common to find in these zones are stringers of sulfides like pyrite and chalcopyrite. Primary structures in these rocks is completely overprinted or destroyed. This zone represents the highest temperature when it comes to alteration.
2. Chlorite + Carbonate zone. This zone consists mainly of chlorite alteration and may also contain silica- and sericite-alteration. Carbonate alteration is most commonly present in the proximity of the ore-body. The chlorite can appear schistose. This zone often contains pyrite and chalcopyrite and no primary structures are visible.
3. Sericite zone. This zone consists mainly of sericite alteration but may also contain chlorite- and silica- alteration. The sericite alteration can like the chlorite appear schistose. Sulfides can be found in these areas as well but often in lesser extent than the zones above.
4. Sericite + quartz zone. This zone represents the volume with the least alteration. In this area it would still be possible to see some primary structures of the host rock.

Sericite alteration occurs when feldspar is transformed by heat and pressure to white mica. Sericite is often described with the same chemistry as muscovite although other feldspar minerals can be converted to sericite (Gifkins et al., 2005). Chlorite alteration gives the rock a dark and fine-grained appearance. Chlorite is the alteration product of silicates rich in Mg and Fe such as pyroxene, amphiboles and biotite (Klein & Dutrow, 2007). Carbonate alteration is sparsely described in literature despite these zones are common in some VHMS deposits and are often rich in Fe, Mg and Mn. In the siliceous core zone stringer mineralization is common, this means that sulfides occur in what can be described as a branching network, filling fractures in the rock (Gifkins et al., 2005).

There are ways of calculating alteration in hydrothermal systems which can be a helpful tool in exploration. The Ishikawa Alteration Index (AI) is one and the Chlorite- Carbonate- Pyrite Index (CCPI) is another. The AI (3.1) was first used at the Kuroko deposit to illustrate the components gained during sericite- and chlorite- alteration. It has been proven useful on other deposits as well (Gifkin et al., 2005).

According to Gifkins et al., 2005, the AI has two limitations regarding to its disability to separate chlorite- from sericite- alteration. Secondly it fails to show carbonate alteration which when present show a decrease in AI. Because of AI's limitations CCPI (3.2) can be used to show the abundance in chlorite and

$$AI = \frac{100\,(MgO + K_2O)}{MgO + K_2O + CaO + Na_2O} \quad (3.1)$$

FeO- and MgO- rich carbonate (dolomite) (Gifkins et al., 2005).

$$CCPI = \frac{100(MgO + FeO)}{MgO + K_2O + FeO + Na_2O} \quad (3.2)$$

4 Methods

4.1 Core logging

Core logging is an effective way to obtain data and is an essential part of a geologist's task in a mining company like Boliden. The personnel at Boliden follow certain guidelines when logging core. For example there is a list of rock types, structures and minerals that are used. The list is a result of years of work, however it's a dynamic list that has been reworked over the years since interpretations and terminology in mining geology constantly changes with increased knowledge. The remainder of this chapter describes core logging at Boliden Mineral AB, although the overall essentials most likely are the same in a lot of mining companies.
The core logging takes place in buildings assigned for this purpose, where there are 10 meter long tables. This makes it possible to put up a number of boxes with core so that it's possible to see a continuous length of core which makes it easier to get an overall picture. The core arrives in wooden boxes put on pallets delivered by diamond drillers operating under or on ground depending on which project they are working with. Boliden uses core drilling both as an exploration tool and as a tool in mines to control that a good ore-grade is maintained and to minimize involvement of waste rock.

The tools provided for geologists to investigate the core are hand lenses, folding rulers, scratchers, acids, hammers, magnets, water and brushes to clean the core and of course the most important tool of all: a geologist's eyes. With these tools the cores are described by color, texture and structures. When the geologist is finished describing the core the log is sent to an administrator whose job is to put the information into the company database. If there are any interesting portions in the core it is sawn in half and one of the half is sent to a lab for analysis on metal content and in some cases petrographic studies. The core is then photographed and stored on site. The core that will be logged in this study is at most 330 meters below surface.

4.2 Literature study

The result in this report is based primarily on core logging since drawing profiles is the main task. However in order to make it clearer to the readers and for credibility there have been time set for literature study to find appropriate references and make this report understandable for people not acquainted with the mining part of geology. Most of the material collected comes from published reports from Boliden and from the library at Boliden.

4.3 Profile drawing

Profile drawing is a qualified guess of what the geology looks like. Profiles are vertical interpretations based on information from drill holes. When drilling today a grid-pattern is used to get vertical and horizontal planes when interpreting. The difficult part is to get a three-dimensional view of the environment, but when putting profiles and levels in to a computer-program this problem can be avoided. What to look for when drawing profiles is if it's possible to match rock types between drill holes and consider structures at the same time. Apart from this it is also important to notice individual minerals, textures and alterations. It helps to better correlate rock types and differentiate the stratigraphic hanging wall from footwall.

5 Results

This chapter explains the geology in the study area. The results are based upon core logging of two profiles that consists of five drill cores drilled from the Rävliden mine before it closed down in the end of the 1980's (Fig.1).

5.1 Found Lithologies

These descriptions are made on logs from drill core. The names of rock types are chosen to fit within Boliden's terminology, application of these lithologies in other environments aren't recommended.

5.1.1Rhyolite

Rhyolite is a felsic rock which means it has a high content of SiO_2. It can be described as the extrusive equivalent to granite. The rhyolite found in the drill cores vary in different tones of grey with a fine-grained matrix were grains can't be distinguished with the naked eye, the rock is aphanitic (Fig. 5). Many parts of the rock have been hydrothermally altered resulting in feldspar being altered to sericite. The rock also got silicified which also brought with them some pyrite (FeS_2) and pyrrhotite (FeS) which appears as stringers or as fine graines in matrix. Banding is common in this rock type, this could be a result of the magmas high viscosity, foliation or layering.

One of the drill cores, R2B 262 has been tested on its litho-geochemistry as a part of a doctoral thesis by Denis Martin Schlatter. He concludes that rhyolite is the predominant rock type in and around Rävliden, although there are variations in itself mainly due to alteration. (Schlatter et al., 2003).

5.1.2 Sandstone

The sandstone appears with a fine-grained grayish matrix similar to the rhyolite but also contains crystals of quartz in sand-sized fraction up to 2 mm in diameter. Larger crystals were rarely found (Fig. 6). The

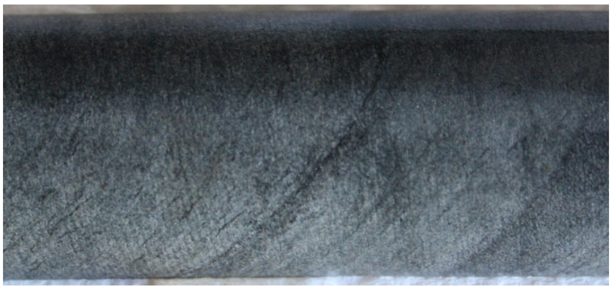

Fig. 5. Rhyolite, core diameter 32 mm. From drill hole 262

crystals mostly appear randomly throughout the rock but are sometimes found in higher concentration as well. The sandstone found is probably of volcanoclastic origin, reworked volcanic sediment where quartz has crystalized. In most parts there are also moderate amounts of pyrite and pyrrhotite. Chalcopyrite and sphalerite only occur locally as traces.

Sandstone with graphite in matrix locally occurs in the cores, the richness varies and it seems the graphite is circulating around more siliceous lenses (Fig. 7). In areas where there is graphite in sandstone more sulfides appear than in sandstone without graphite. The

Fig. 6. Sandstone, some quartz crystals are circled. From drill hole 262.

bulk-composition of sandstone (excluding graphite) is most likely felsic since it is rich in quartz.

5.1.3 Graphite schist

The graphite schist is dark grey to black and has a clear foliation (Fig. 8).The schist is accompanied with abundant pyrrhotite and locally some chalcopyrite.

Fig. 7. Sandstone with graphite in matrix. From hole 284.

Quartz- veins are common. The graphite is probably derived from the VG.

5.1.4 Sericite quartzite

Sericite quartzite here refers to rocks that are anomalously rich in sericite and quartz, inferred as having

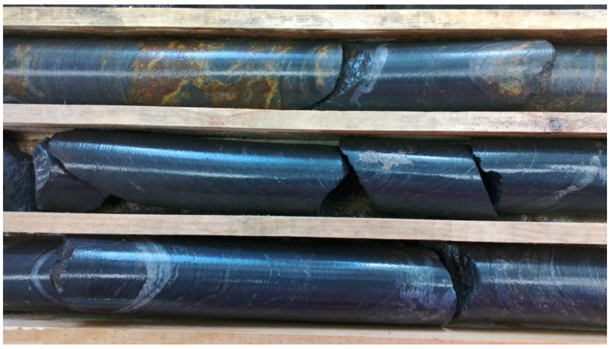

Fig. 8. Graphite schist with oxidised pyrrhotite and quartz-veins. From drill hole 543. The core diameter is 32 mm.

resulted from strong-intense hydrothermal alteration. These rocks are locally chlorite-altered and locally contain patches of talc. In these rocks, it is hard to tell what the precursor rock type was. Visible sulfides are pyrite (very common) and pyrrhotite (common) as well as traces of sphalerite, galena, chalcopyrite and arsenopyrite. These rocks have color similar to the sandstone and rhyolite.

5.1.5 Tremolite skarn

Tremolite skarn is a metamorphic rock rich in the mineral tremolite. The tremolite shows elongated prismatic grains with a silky shine (Fig. 9). The skarn generally occurs in zones with carbonate rock or in zones with carbonate alteration, which then typically contain sphalerite, chalcopyrite and galena. These rocks are host to much of the mineralization in Rävliden. The skarn is commonly accompanied with chlorite schists.

5.1.6 Carbonate rock

The carbonate rock is another example of a rock that is

Fig. 9. Tremoliteskarn, from drill hole 262. The core diameter is 32 mm.

common in heavily altered environments, here the main constituent is carbonate altered rock and it's impossible to see the precursor rock type (Fig. 10). They are commonly associated with tremolite skarn, chlorite schists, and to some extent with sericite quartzite. Pyrrhotite is the most common sulfide with traces of sphalerite and chalcopyrite. The skarn minerals found are mostly tremolite though actinolite also occurs .

5.1.7 Alterations

The most abundant alteration minerals found in the cores at Rävliden are chlorite, sericite, quartz, carbonates and skarn minerals (Table 1). These are interpreted to reflect chlorite alteration, sericite alteration, silicification, carbonization and skarn alteration, respectively.

The alterations found are here featured in table 1. This table should be seen as a general description of Rävliden, variations in alterations are always present and results are established by viewing the core, no chemical data to support this exist.

Fig. 10. Carbonate rock (strong alteration), with amphodelite (altered feldspar with contamination). From hole 262, the core diameter is 32 mm.

5.1.7.1 Alteration calculations

As mentioned earlier in chapter 2.1.1.1 the use of both AI and CCPI can be used as tools in exploration of VHMS-deposits. Calculations have been made on data from Schlatter, 2003 in which chemical analyses were based on composition (Appendix I). These calculations are presented here in diagram seen in Fig. 11. The calculated values are all positioned in the top right corner which indicates high alteration. All values situated above the line that cuts 100:100 are hydrothermally altered.

Table 1. Alteration facies in Rävliden (associated alterations can appear but not as strongly as main alteration.)

Alteration	Sulfide Minerals	Associated alterations	Associated rock-type	Other common minerals
Silica alteration (intense)	Pyrite Pyrrhotite Chalcopyrite Sphalerite Galena Arsenopyrite	Carbonate alteration Chlorite alteration	Rhyolite Sandstone Carbonate rock Sericite quartzite Graphite schist	
Chlorite alteration	Pyrite Pyrrhotite Chalcopyrite Sphalerite	Carbonate alteration Skarn alteration	Tremoliteskarn Sericite quartzite Sandstone Rhyolite Carbonate rock	Talc Biotite
Carbonate alteration	Pyrrhotite Chalcopyrite Sphalerite	Skarn alteration Silica alteration Chlorite alteration	Carbonate rock Rhyolite Sandstone	Amphodelite
Skarn alteration	Pyrrhotite Sphalerite Chalcopyrite Galena	Chlorite alteration Carbonate alteration	Tremoliteskarn Carbonate rock Rhyolite Sandstone	Tremolite Actinolite
Sericite alteration	Pyrite Pyrrhotite	Silica (moderate) alteration Chlorite alteration	Sericite quartzite Rhyolite Sandstone	

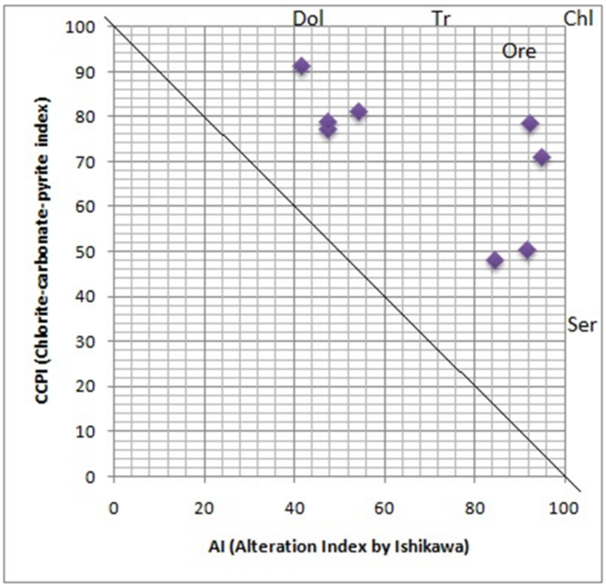

Fig. 11. Alteration calculations on drill hole 262.

5.2 Profiles

To make these profiles is the main objective with this study and the five drill holes have resulted in two profiles (Fig. 12 and 13). Originally, it was intended to draw one profile, but because the drill holes were positioned too far from each other it was decided to make two profiles instead. The lithologies in the profiles are described in chapter 5.1. The profiles are drawn by matching similar lithologies between drill cores.

6 Disscusion & conclusion

6.1 Core logging

What can be said is that the result is a description of the drill cores based solely on viewing them. The rocks has clearly been altered and transformed and describing them isn't a textbook explanation of what these rocks should look like, the descriptions are most likely only applicable to this deposit however similarities in textures and mineral composition could be compared to other deposits.

In literature about the Kristinebergs area there is no clear evidence that a certain environment created these deposits other than the overall idea of a submarine extensional volcanic environment which is the accepted theory. The explanation of a caldera environment forming these deposits should only be seen as a suggestion and probable possibility.

The structures found like foliation, probable fault zones and mylonites were measured but to use this data, information about the cores position in the ground must be known to be able to draw conclusions on the direction of these structures which could be helpful when interpreting geology and drawing the profile. Since these cores are old, such information doesn't exist.

6.2 Profile drawing

The result of the logging is shown by the making of two profiles. At first only one profile was intended but when looking at the logs and the horizontal space between some of the holes a decision was made to make two profiles.

The profiles are done by matching units that appear

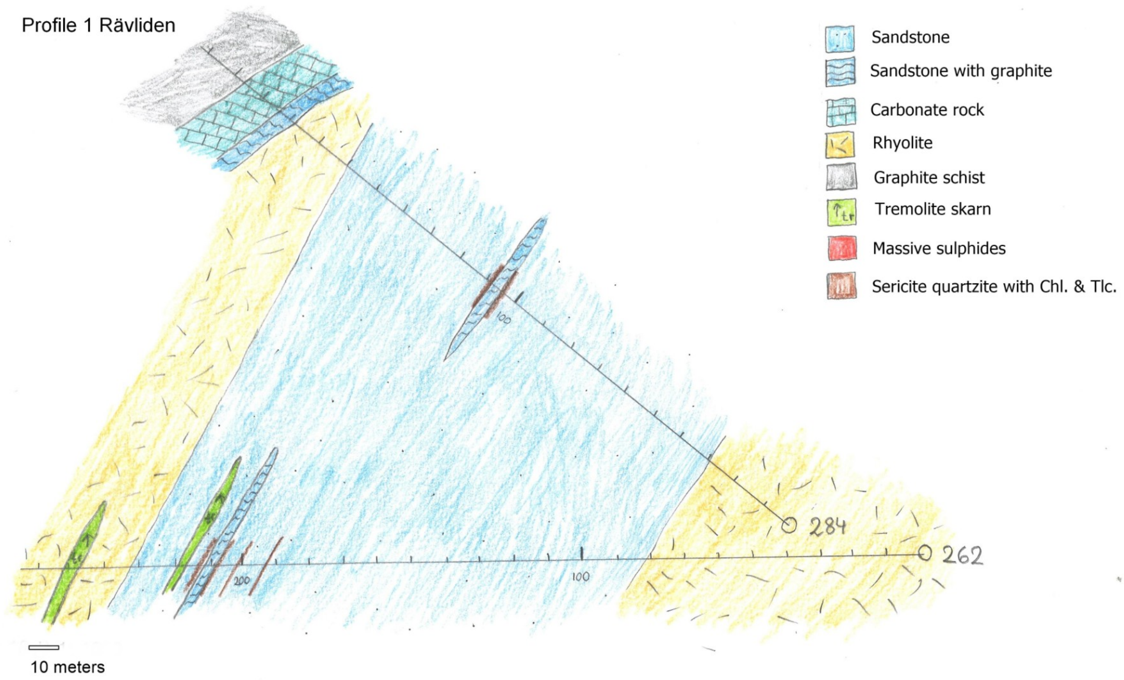

Fig. 12. Profile 1. The brown lines indicate zones with mylonite or crushed drillcore which often indicate faults.

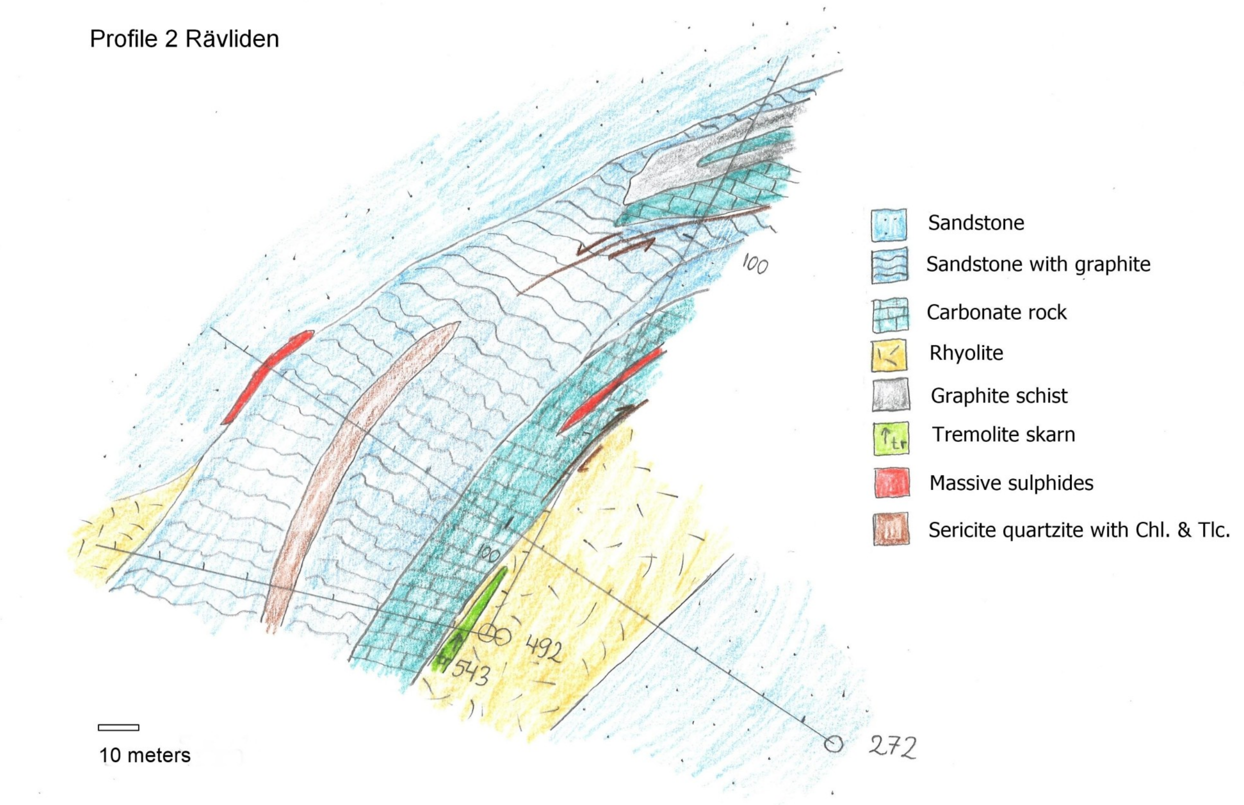

Fig. 13. Profile 2. The brown lines indicate a possible fault zone

alike in color, texture, alteration and mineral composition. Knowing that the area consists of antiforms plunging to the west one can conclude that in the profiles drawn the shapes can resemble the limb of an antiform.

The profiles are not perfectly vertical this needs to be taken in consideration when interpreting this data further. This is partly because of the thin record of drill core that has been saved and partly to the lack of grid-patterned drilling in the past.

6.3 Use of alteration index

With the help of alteration-indexes like AI and CCPI and sampling on the cores it might have been possible to get a better idea of the zonation around the deposit and therefore also get a better understanding of the formation process. The purpose of this report is however not that to compose a forming theory but to aid to a better illustration of the area. From the alteration calculations one can suggest that the entire study area is within a strongly altered area. This area should be in proximity to a hydrothermal feeder channel because of local stringer mineralisation and strong silicification.

6.4 Conclusion

- In consideration of knowing areas structural geology and viewing the profile it is likely that the area of study is part of a limb of an antiform.
- The area of study is within a stratigraphic transition zone between the footwall (Skellefte-group) and hanging wall (Vargfors-group). This because of the presence of graphite in rocks which most defiantly originate from the sedimentary VG and strong alteration common in foot wall rock.
- Both visual inspection of drill core and calculations have shown that the area is strongly altered as well as literature about the Skellefte district does.

7 Acknowledgements

I would like to thank my family and friends for believing in me and encourage me during these three years.

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Appendix I

Chemical data on drill hole R2B 262 from Rävliden. Selected parts only.

ID	Rock type	Chemical rock type	SiO2 %	Al2O3 %	Fe2O3 %	MgO %	CaO %	Na2O %	K2O %
R2B BH262 20.25m	Least altered fine to medium grained rhyolite	Rhy. A	75,61	12,06	2,26	2,18	0,54	0,64	4,13
R2B BH262 54.25m	Calc silicate altered rhyolite	Rhy. A	72,53	11,77	2,54	4,81	4,24	0,69	1,01
R2B BH262 93.0m	Rhyolite, possibly banded	Rhy. A	74,14	12,18	2,11	4,10	3,56	1,44	0,37
R2B BH262 115.1m	Moderate calc silicate altered rhyolite	Rhy. A	77,05	9,97	2,53	3,52	2,37	1,59	0,02
R2B BH262 197.1m	Moderate calc silicate altered fine to medium grained rhyolite	Rhy. B	57,45	13,63	4,62	8,36	11,79	0,75	0,47
R2B BH262 211.0m	Vein copper-rich zone, chlorite±tourmaline altered rhyolite, cpy	Rhy. A'	78,51	6,65	7,00	0,62	0,09	0,13	1,94
R2B BH262 233.7m	Weak altered medium-grained rhyolite	Rhy. A'	66,93	15,36	4,35	4,62	0,25	0,21	3,40
R2B BH262 256.35m	Silicified massive rhyolite	Rhy. A	73,68	13,66	2,28	1,94	0,38	0,16	3,97

ID	Rock type	Chemical rock type	Al2O3 /TiO2	Zr/ Al2O3	Zr/TiO2	Zr/Y	Zr/Nb
R2B BH262 20.25m	Least altered fine to medium grained rhyolite	Rhy. A	35,5	18,9	672	9,3	20
R2B BH262 54.25m	Calc silicate altered rhyolite	Rhy. A	35,7	21,6	770	10,2	23
R2B BH262 93.0m	Rhyolite, possibly banded	Rhy. A	33,8	20,9	707	11,6	22
R2B BH262 115.1m	Moderate calc silicate altered rhyolite	Rhy. A	36,9	20,4	753	12,8	25
R2B BH262 197.1m	Moderate calc silicate altered fine to medium grained rhyolite	Rhy. B	26,7	16,3	436	8,5	20
R2B BH262 211.0m	Vein copper-rich zone, chlorite±tourmaline altered rhyolite, cpy	Rhy. A'	30,2	18,0	544	9,2	21
R2B BH262 233.7m	Weak altered medium-grained rhyolite	Rhy. A'	30,7	19,2	589	9,7	22
R2B BH262 256.35m	Silicified massive rhyolite	Rhy. A	33,3	18,6	620	10,9	21

From Schlatter, 2003, although the data itself have not been published.

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