

# **Petrology and lithogeochemistry of the host rocks to the Nautanen Cu-Au deposit, Gällivare area, northern Sweden**

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**Department of Earth- and Ecosystem Sciences  
Division of Geology  
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Master's Thesis

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## **Abstract**

The Nautanen Cu-Au deposit is located 75 km north of the Arctic circle, and 10 km northeast of the town of Gällivare in northern Sweden. Nautanen is just 8 km west of the giant Malmberget apatite-iron ore deposit and 15 km north of one of Europe's largest copper producers, the Aitik Cu (Au) porphyry deposit. Nautanen is described as an Iron Oxide Copper Gold (IOCG) deposit or hybrid IOCG and contains a core of high grade resources of 0.63 Mt with 2.36% Cu, 1.3 ppm Au, 11 ppm Ag, or using a lower cut-off some 3 Mt with 0.75% Cu, 0.52 ppm Au, and 2 ppm Ag.

Nautanen is hosted in strongly altered and tectonically deformed Svecofennian volcanoclastic rocks on a major shear zone, the Nautanen Deformation Zone (NDZ). Alteration is dominated by scapolite, K-feldspar, epidote, sericite, and amphibole. Nautanen host rocks consist of steeply dipping, repeating layers of shoshonitic andesites, that were formed in a continental arc setting. The Nautanen rocks have lithogeochemical values characteristic of the low titanium, low zirconium Porphyry Group of metavolcanics found in Norrbotten and are lithogeochemically similar to the volcanic host rocks to the Aitik deposit.

The high amount of magnetite and locally apatite at Nautanen, suggests a possible connection to the Malmberget apatite-iron ore. Titanite and allanite ages of c. 1.78 Ga at Nautanen correspond to the timing of IOCG overprinting noted at Aitik. Similar high salinity fluid inclusions as those noted as porphyry-related in the Aitik deposit have also been observed in Nautanen, indicating that porphyry type mineralization may have been present at the Nautanen locality as well. Multiple episodes of circulation of fluids and remobilization of ore minerals along the NDZ between Nautanen and Aitik have probably occurred.

Variations in tectonic processes, alteration, and magma fractionation have likely led to the small differences seen between the lithogeochemically indicated origins of the host rocks to the Nautanen and Aitik deposits.

## **Abstrakt**

Koppar-guld fyndigheten Nautanen är belägen 75 km norr om polcirkeln, och 10 km nordost om Gällivare i norra Sverige. Fyndigheten ligger endast 8 km från den stora apatit-järnmalmen i Malmberget och 15 km norr om en av Europas största kopparproducenter, porfyrokoppar-(guld)malmen Aitik. Nautanen beskrivs som en järnoxid-koppar-guld (IOCG) fyndighet eller en hybrid IOCG med en kärna av höghaltiga reserver på 0.63 Mt med 2.36% Cu, 1.3 ppm Au, 11 ppm Ag, och med en lägre cut-off 3 Mt med 0.75% Cu, 0.52 ppm Au och 2 ppm Ag.

Nautanen sitter i kraftigt omvandlade och tektoniskt deformerade Svekofenniska vulkanoklastiska bergarter belägna på en större skjuvzon, Nautanen Deformation Zone (NDZ). Omvandlingen domineras av skapolit, kalifältspat, epidot, sericit och amfibol. Värdbergarterna utgörs av upprepade lager av brant stupande shoshonitiska andesiter, bildade i en kontinental öbåge-miljö. Bergarterna i Nautanen har en litogeokemisk signatur liknande den i de låg-Ti, låg-Zr metavulkaniska bergarter tillhörande porfyritgruppen i Norrbotten, och sammanfaller litogeokemiskt med Aitikmalmen vulkaniska värdbergarter.

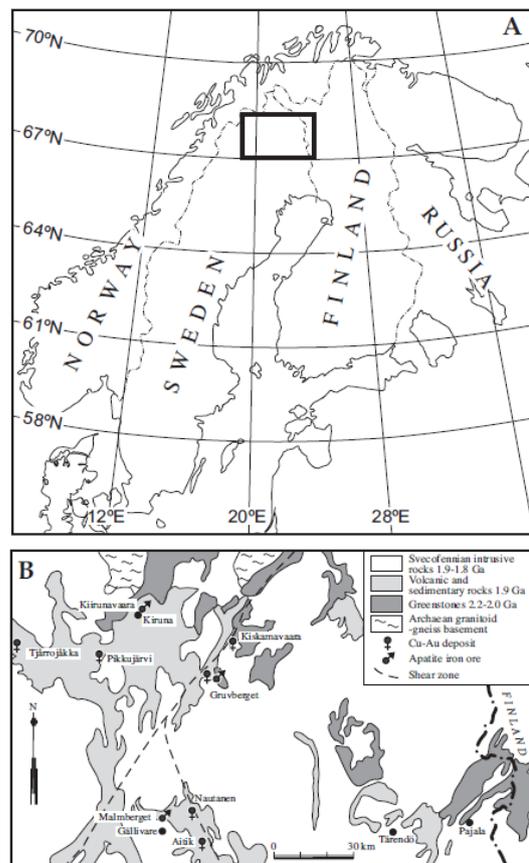
Den stora mängden magnetit och ställvis apatit i Nautanen, antyder om ett möjligt samband mellan Nautanen-fyndigheten och Malmbergets apatit-järnmalm. Titanit- och allanit-åldrar på ca 1.78 Ga i Nautanen överensstämmer med tidpunkten för IOCG-överprägling observerad i Aitik. Liknande hög-salina vätskeinneslutningar som de som tolkats som porfyrokoppar-relaterade i Aitikmalmen, har också observerats i Nautanen, vilket tyder på att en mineraliseringshändelse av porfyrokoppar-typ även kan ha skett i Nautanen. Multipla episoder av cirkulerande fluider och remobilisering av malmmineral längst NDZ mellan Nautanen och Aitik har troligtvis ägt rum.

Variationer i tektoniska processer, omvandling och magmafraktionering har sannolikt lett till de små skillnader som observerats mellan det litogeokemiskt indikerade ursprunget hos värdbergarterna till Nautanenmineraliseringen och Aitikmalmen.

## 1. Introduction

The Nautanen Cu-Au (Ag, Mo) deposit is located 75 km north of the Arctic circle, and 10 km northeast of the town of Gällivare in northern Sweden. Mining in the area has been going on since the 18<sup>th</sup> century, with iron ore being taken from the ground at the Malmberget apatite iron ore deposit, just 8 km west of Nautanen (Martinsson et al. 2001). In 1898, ten years after the railway was built from Luleå to Gällivare, copper ore was discovered at Nautanen and mined from 1902 to 1907 (Geijer 1918). Sweden's largest sulphide mine, the Aitik deposit, was discovered in 1933 and went into production in 1968, it is located just 15 km south of Nautanen. The Nautanen deposit is much smaller than the two giant mines that it neighbours and has been estimated by the Swedish Geological Survey (SGU) to contain a core of high grade resources of 0.63 Mt with 2.36% Cu, 1.3 ppm Au, 11 ppm Ag, or using a lower cut-off some 3 Mt with 0.75% Cu, 0.52 ppm Au, and 2 ppm Ag (Danielsson 1985). The location of the Nautanen deposit close to two world class deposits offers a reasonably high potential for increasing the known reserves of the area, and this has encouraged mineral exploration by several companies throughout the past 50 years.

The Nautanen area has relatively well exposed bedrock and the original ore bodies were mostly found in outcrop. Between 1902 and 1907, some 71 835 tonnes of ore with grades of 1 to 1.5% copper and some gold were mined in the area by Nautanens Kopparfält AB (Geijer 1918). Aerial geophysics were undertaken in the area in



**Figure 1.** Geographical location of the Norrbotten mining district, northern Sweden (A), and a simplified geological map of the area including locations of significant Cu-Au and apatite iron ore deposits (B). (from Wanhainen 2005)

the 1960s and geological mapping was undertaken by the Swedish State Mining Property Commission (NSG) in the late 1960s, early 1970s. The largest drilling campaigns were also undertaken by NSG/Swedish Geological Co. (SGAB) in the late 1970s and from 1983 to 1985. In total over 100 drill holes were made by NSG/SGAB and the resulting 10 000+ meters of core most of which are housed at the SGU core warehouse in Malå. In 1997, 1998 the Nautanen area was investigated

and drilled by North Atlantic Natural Resources AB, whose core is also in Malå. In 2000-2008 Phelps Dodge drilled and investigated the area before optioning the area to an Australian Junior company, which subsequently dropped it. In 2009 the property was claimed by Boliden Mineral AB, who also owns the Aitik mine.

A limited amount of research has been done on the Nautanen deposit and its ore paragenesis, structural history, metamorphic events, age and relation to other deposits in the area are all poorly understood. Ore emplacement has been proposed to have taken place over various stages (Martinsson & Wanhainen 2004). The mineralization style has been described as an Iron Oxide Copper Gold (IOCG) deposit (Edfelt 2007, Gleeson & Smith 2009), IOCG hybrid-style deposit (Barton & Johnson 2004), and the possibility of a porphyry copper connection has been suggested (Martinsson & Wanhainen 2004).

The purpose of this work is to characterize the Nautanen host rocks lithologically and lithochemically in order to compare the deposit to other deposits in the area and begin to develop a better understanding of the geological history of the deposit and its relationship to other deposits in the area, notably the Aitik deposit. To this end the methods undertaken have been the graphical logging of 1999 meters of drill core, descriptive analysis of 20 polished thin sections with plane polarized, reflective light and scanning electron microscopes, and the analysis of 35 high quality lithochemical samples.

## **2. Regional geology**

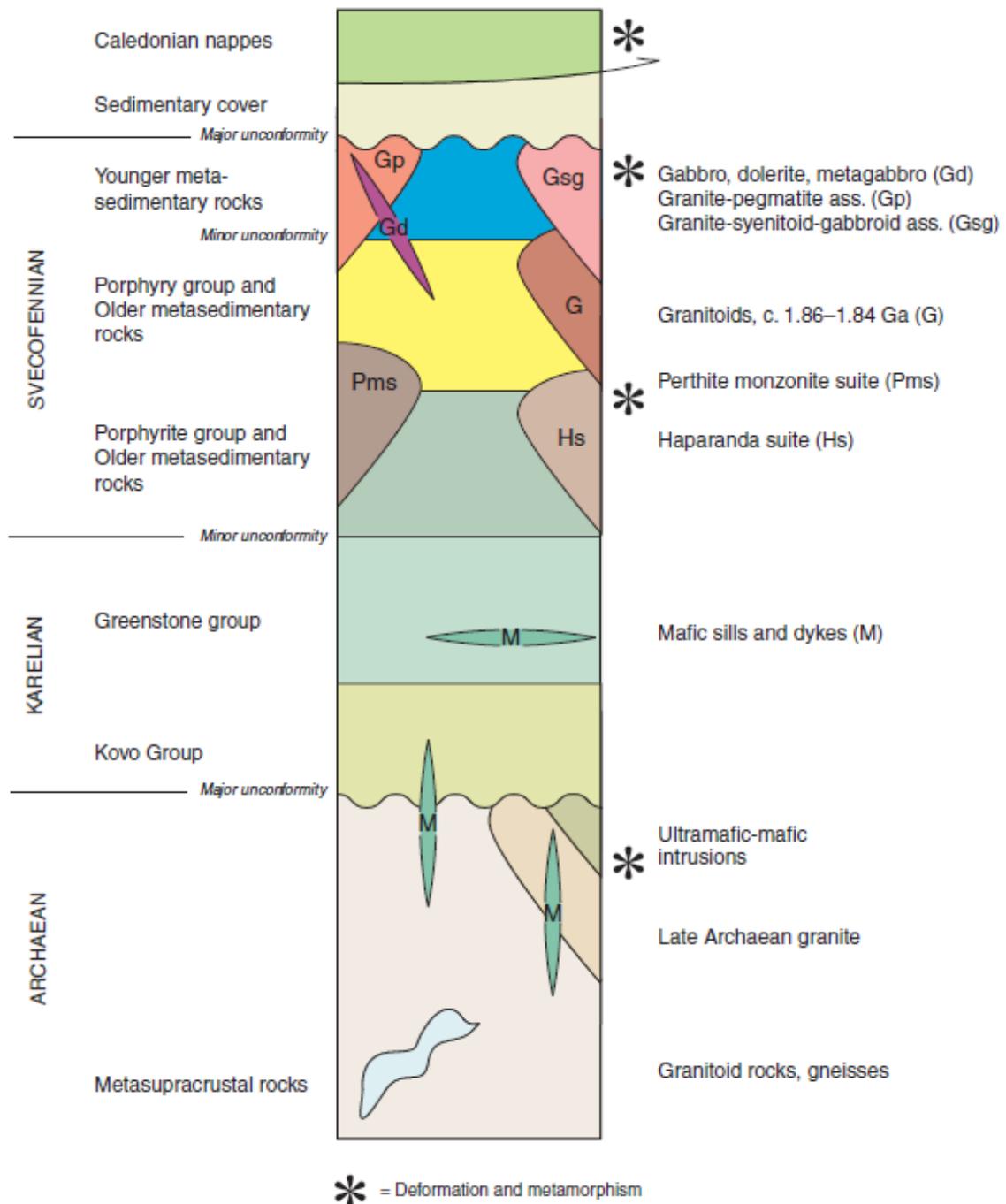
The Northern Norrbotten area of Sweden is a major iron-copper-gold province and accounts for about 90% of the total tonnage of ore that is produced in Sweden (Wanhainen et al. 2005). It is an area that measures 200 by 100 km and is one of three important ore provinces in Sweden. The main ore bodies are hosted in Palaeoproterozoic rocks, mostly Karelian (2.5-2.0 Ga) and Svecofennian (1.9-1.88 Ga) in age.

The basement in the northern Norrbotten region is a 2.8 Ga Archaean granitoid gneiss which is unconformably overlain by Palaeoproterozoic successions of greenstone, porphyry and sedimentary successions (Martinsson et al. 2004). The 2.4-1.98 Ga Karelian units are rift related and lowest stratigraphically (Martinsson 1997) and are now preserved in deformed metamorphic belts intruded by granitoids (Smith et al. 2009). The Karelian units are overlain by the >1.9 Ga Greenstone Group which consists of tholeiitic to komatiitic volcanic rocks (Martinsson 1997).

Svecofennian calc-alkaline andesites and related clastic sediments of the Porphyry Group lie on top of the Greenstone Group and were formed in a continental arc setting (Martinsson 2004). The Porphyry metavolcanics can be split into two groups, the low titanium, low zirconium Porphyry andesites and the overlying high titanium, high zirconium basalts and thachyandesitic Porphyry Group (Martinsson 2004). The Porphyry Group is overlain by the Kurravaara Conglomerate, the Kiirunavaara

Table 1. Main characteristics of Porphyry Cu-Au and IOCG deposits. (from Wanhainen 2005)

<b>Main features</b>	<b>Porphyry Cu-Au</b>	<b>IOCG</b>
<b>Tectonic setting</b>	Subduction-related island arc, continental margin	Intra-continental Extension along subduction-related continental margin
<b>Age</b>	Archaean to present, majority Mesozoic-Cenozoic	Archaean to present, majority Proterozoic
<b>Main host rocks</b>	1. Intermediate porphyritic intrusions 2. Intermediate volcanic and sedimentary rocks	1. Felsic-intermediate volcanic and sedimentary rocks 2. Felsic intrusions
<b>Ore paragenesis</b>	1. Magnetite 2. Chalcopyrite, pyrite $\pm$ pyrrhotite, chalcocite, molybdenite, bornite	1. Magnetite, hematite 2. Chalcopyrite, bornite, pyrite $\pm$ molybdenite, pyrrhotite
<b>Alteration paragenesis</b>	1. Biotite, K-feldspar, quartz (potassic) 2. Quartz, sericite, pyrite (phyllic) 3. Epidote, chlorite, calcite (propylithic) 4. Quartz, kaolinite, chlorite (argillic)	1. Albite, scapolite, amphibole 2. K-feldspar, magnetite, hematite, biotite quartz 3. Chlorite, muscovite (sericite), calcite, quartz
<b>Mineralization style</b>	Disseminated, vein, quartz stockwork	Disseminated, breccia infill, vein network, massive lenses, replacement
<b>Ore fluid composition</b>	Cation: Na $\pm$ K, Fe, Ca, Mn + CO <sub>2</sub> Solids: halite $\pm$ calcite 30-50 wt.% NaCl T: 300-700°C	Cation: Na $\pm$ Ca, K, Fe, Mg + CO <sub>2</sub> Solids: halite $\pm$ calcite, FeP, hem 20-60 wt.% NaCl T: 200-500°C
<b>Structural control</b>	Regional faults	Shear zones and faults
<b>Assoc. with igneous activity</b>	Temporal and spatial	Temporal
<b>Parental magma</b>	I-type	I-type, oxidized A-type
<b>Other common minerals</b>	Tourmaline, anhydrite	REE- and U-minerals, baryte, fluorite, tourmaline, apatite



**Figure 2.** A schematic illustration of main rock units and events in Norrbotten. Not to scale. (from Martinsson et al. 2004)

Group, and the Hauki Quartzite. The Porphyrite Group is suggested to have formed in a subduction related event, while the Kiirunavaara Group has a geochemical signature suggesting within-plate volcanics (Martinsson 2004). The Hauki Quartzite is believed to have formed by uplift and erosion of the area (Martinsson 2004).

The Palaeoproterozoic sequence of volcanic and sedimentary rocks were deformed and metamorphosed ca. 1.88 Ga when the Haparanda suite of intrusions (1.89-1.87 Ga) were succeeded by the Perthite Monzonite suite (1.88-1.86) (Bergman et al. 2001). These plutonic intrusions have a calc-alkaline to alkali-calcic character and are believed to be comagmatic with the Porphyrite and Kiirunavaara Groups respectively (Bergman et al. 2001). The Lina suite of granitoids followed these intrusions ca. 1.79 Ga and they are related temporally to the Transscandinavian Igneous Belt (TIB) 1 intrusions in the Kiruna-Narvik area. Metamorphism of the supracrustal sequence during these intrusions peaked in the upper greenschist or lower amphibolites facies (Bergman et al. 2001). The youngest magmatic pulse to occur in the northern Norrbotten region was the intrusion of the ca. 1.71 Ga TIB 2 granitoids (Romer et al. 1992).

Northern Norrbotten is affected by regional scapolitization and albitization and at deposit scale in association with both iron oxide and copper-gold deposits (Smith et al.

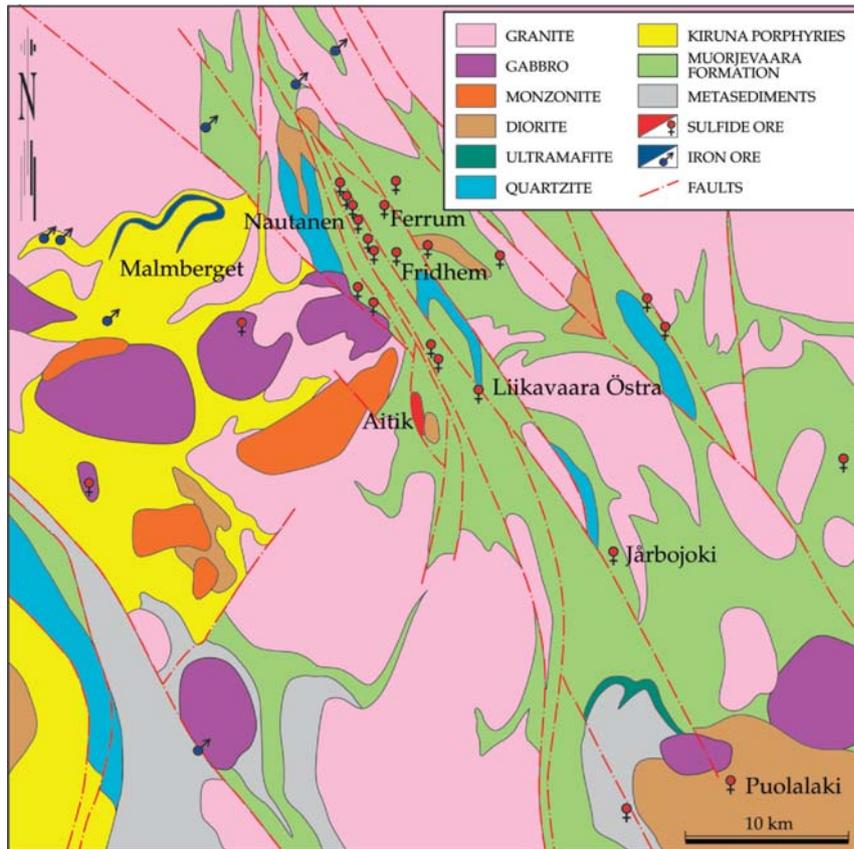
2009). Apatite Iron Ores occur in the Porphyry and Kiirunavaara groups while IOCG and copper porphyry deposits occur in the Porphyrite Group (Martinsson 2004).

### **3. Local geology**

#### **3.1 Gällivare area**

The Gällivare area of northern Norrbotten hosts both epigenetic Cu-Au ores and apatite iron ores. Most of the epigenetic Cu-Au deposits around Gällivare are located within or adjacent to the major shear zone known as the Nautanen Deformation Zone (NDZ) and are hosted in Svecofennian metavolcanics and metasediments. These rocks are known locally as the Muorjevaara Group and formed in an arc environment (Wanhainen & Martinsson 2004). Apatite iron ores are located in the Kiirunavaara Group which is restricted to the western part of the area (Fig. 3). These volcanics of intermediate to felsic composition have characteristics of an intraplate source (Wanhainen & Martinsson 2004). The NDZ is the most prominent tectonic structure in the area, and several parallel branches of schistose to mylonitic rocks occur within a zone up to 3 km wide that strikes north-northwest (Bergman et al. 2001).

A large-scale zoning pattern of metal association and alteration minerals is present along the NDZ. Deposits in the northwest contain magnetite and locally apatite as important minerals, which indicate a relationship to the nearby apatite iron ores in Malmberget. Alteration of the



**Figure 3.** Geology of the Gällivare area (from Wanhainen & Martinsson 2004)

host rock in the northwest is dominated by strong scapolite and K feldspar alteration. In the southeast, pyrite increases in abundance while magnetite decreases, at the same time the Au/Cu ratio increases and alteration is dominated by biotite and sericite (Wanhainen & Martinsson 2004). Mineralization in the NDZ occurs in both disseminated and vein style. Disseminated mineralization is interpreted as an early phase that is related to synorogenic 1.9 Ga intrusions, while vein style mineralization is a later phase related to remobilization and possibly addition from magmatic and hydrothermal processes active around 1.8

Ga (Wanhainen & Martinsson 2004). Several repeating hydrothermal events and remobilizations along the structures of the NDZ have led to the current distribution of mineralization in the area.

### **3.2 Nautanen**

The rocks in the Nautanen area belong to the Muorjevaara Group of metavolcanics. The internal stratigraphy of the Muorjevaara Group is poorly understood, but is interpreted to consist of alternating layers of pelites and lithic arenites that are of mainly andesitic volcanoclastic origin

**Table 2.** Characteristics of Cu-Au mineralization in the Gällivare area (from Wanhainen & Martinsson 2004)

	Mineralization				Host rock	Alteration	Vein minerals
	Grades and tonnage	Occurrence	Main ore mineralogy	Metal association			
Aitik	0.4% Cu 0.2 ppm Au 4.2 ppm Ag 400 Mt <sup>1</sup>	Disseminated veins	Chalcopyrite Pyrite Magnetite Pyrrhotite	Cu-Au-Ag(-Fe)	Volcaniclastics Quartz-monzodiorite	Biotitization Sericitization K feldspar/epidote Tourmalinization Scapolitization	Amphibole-biotite Quartz (zeolites) Tourmaline Barite Apatite
Nautanen	<sup>2</sup> 2.36% Cu 1.30 ppm Au 11 ppm Ag 0.63 Mt <sup>3</sup> <sup>4</sup> 0.34% Cu 0.3 ppm Au 2.3 Mt <sup>5</sup>	Veins disseminated	Chalcopyrite Magnetite Pyrite	Cu-Au-Ag-Fe	Volcaniclastics Mafic dykes	K feldspar/epidote Scapolitization Tourmalinization Sericitization Garnets	Quartz (zeolites) Tourmaline Barite Carbonate Apatite
Ferrum	1.45% Cu	Veins	Chalcopyrite Bornite	Cu-Au(-W-Mo)	Volcaniclastics	Tourmalinization Scapolitization	Quartz Tourmaline Amphibole-pyroxene
Fridhem		Veins	Chalcocite Bornite Native gold (Hematite)	Au(-Cu)	Volcaniclastics	(Epidote)	Quartz Zeolites
Liikavaara	0.58% Cu 0.2 ppm Au 8 ppm Ag	Disseminated veins	Chalcopyrite Pyrrhotite	Cu-Au-Ag(-W-Mo-Zn-Pb)	Volcaniclastics	Biotitization Chloritization	Quartz Carbonate (Tourmaline)
Järbojoki	0.2% Cu 0.4 ppm Au	Veins Disseminated	Pyrite Chalcopyrite (Magnetite) (Hematite)	Au-Cu(-Fe-W)	Volcaniclastics Diorite Mafic dykes	K feldspar Sericitization Epidotization Scapolitization	Quartz Carbonate (Tourmaline)
Puolalaki	7.61 ppm Au 3.36% As 0.18% Cu 0.15% W 0.11 Mt <sup>3</sup>	Veins Disseminated	Arsenopyrite Pyrrhotite (Chalcopyrite)	Au-As-Cu-W(-Co-Ni)	Paragneiss Granodiorite Aplite	Biotitization	

<sup>1</sup> Total production

<sup>2</sup> Mainly of vein-type

<sup>3</sup> Resources

<sup>4</sup> Mainly of disseminated character

<sup>5</sup> Indicated resources

(Martinsson & Wanhainen 2004). Amygdaloidal andesite lava and volcanogenic conglomerates are minor constituents (Ros 1980).

Intrusions from the Haparanda suite of diorite and granodioritic composition are common in the Muorjevaara Group and at Aitik have the character of a porphyritic high-level intrusion (Wanhainen & Martinsson 2001). A younger phase of intrusions known as the Lina Suite of granites is extensive in the area and pegmatites related to the Lina Suite can be found within the Muorjevaara Group (Martinsson & Wanhainen 2004).

The Nautanen deposit is hosted by strongly altered and deformed rocks set within the NDZ. Alteration and deformation are so pervasive that the original character of the rock is difficult to interpret, however less-deformed clastic metasedimentary rocks of the Muorjevaara Group are found on both sides of the shear zone adjacent to the Nautanen deposit (Bergman et al. 2001). The original rock is believed to consist of volcanoclastic sediments with an intermediate composition. Mafic dikes are also present, constituting a minor component mainly found in the eastern area. A more mafic component occurs in the ore zone,

which has been heavily scapolitized to the point where all primary textures and contact relations have been destroyed (Bergman et al. 2001).

Alteration minerals mainly include scapolite, microcline, epidote, biotite, sericite, amphibole, tourmaline and garnet. Scapolite dominates alteration in the east, garnet-biotite-microcline in the central area and sericite-garnet-tourmaline dominates to the west (Geijer 1918). Garnets show considerable variability. Barton and Johnson (2004) have identified distinct populations of garnets including REE-bearing grossular garnet, spessartine-rich garnet, and almandine-rich garnet. They interpret the spessartine-rich variety, which is found in sericite schists, to have formed early and the almandine-rich variety to have formed late at peak metamorphic conditions. All types of garnet are interpreted to have formed after the introduction of metals in the area and the increased abundance of garnet in mineralized zones is thought to have resulted from favourable bulk conditions (Barton & Johnson 2004). Danielsson (1985) observed garnet porphyroblasts that have been brecciated with quartz and sulphides indicating that some garnet may have formed previous to mineralization or at least before that latest episode of remobilization. Rotated garnet porphyroblasts and boudinaged tourmaline veins have been interpreted to indicate that alteration and mineralization are pre-tectonic to syntectonic (Ros 1980).

Magnetite is often the most common ore mineral, occurring in disseminated form throughout much of the deposit as well as in near massive pods, veins and lenses in

association with garnet and amphibole-pyroxene-epidote skarn (Martinsson & Wanhainen 2004). Chalcopyrite is the main copper mineral and occurs in association with quartz-K-silicate rich assemblages, actinolite  $\pm$  garnet-Ba-rich K feldspar, and in skarns composed of pyroxene-amphibole-quartz  $\pm$  epidote  $\pm$  Kfeldspar (Barton & Johnson 2004). Gold often occurs in association with copper and it is rare that high grades occur without significant copper mineralization. In disseminated mineralization the copper/gold ratio is about 1/1 (ppm/vol. %), but in rich copper mineralization the gold ratio is lower, approximately 0.1/1 (Martinsson & Wanhainen 2004). Pyrite is the next most common sulphide after chalcopyrite. An enrichment of cobalt has been observed in the pyrite and is related to the gold mineralization (Hålenius 1983). Other ore minerals that occur in accessory amounts include pyrrhotite, sphalerite, galena, carrolite, bismuthinite, molybdenite, and sheelite (Hålenius 1983).

Titanite and allanite dating from Nautanen has yielded an age of c. 1.78 Ga (Smith et al. 2009). This age is comparable to the timing of a late IOCG-type overprinting event identified in the Aitik deposit at c. 1.8 Ga (Wanhainen 2005). This suggests a relationship between IOCG-type deposition at Nautanen and IOCG overprinting at Aitik and indicates the remobilization of metals along the structures of the NDZ at this time. This age does not completely constrain the timing of mineralization in the Nautanen deposit however, as thermal metamorphic events near this time may have been responsible for resetting existing titanite and

allanite grains. There is evidence of multiple stages of mineralization which have occurred during pre-, early, ductile, and brittle stages of deformation (Barton & Johnson 2004).

#### **4. Methodology**

A total of 1999 meters of drill core were logged, 443 assay samples, 35 lithochemical samples, and 15 petrographic samples were taken. Polished thin sections were prepared from the petrographic samples by Vancouver Petrographics Ltd, Canada. The drill core consisted of 7 holes drilled by SGAB between 1977 and 1985 from the 5040 N profile of the Nautanen deposit. An additional 5 polished thin sections from SGU, taken from other drill holes, were also studied in order to describe mineralization typical of the deposit. The drill core was provided by SGU and logged at both the Malå SGU core logging facilities and the Boliden AB core logging facilities in Boliden.

Assay samples were taken roughly every 5m from the top of the hole to the bottom. Samples were prepared in Piteå by ALS Laboratory Group and analysed at their labs in Vancouver, Canada. Samples were analysed for trace level gold by fire assay and ICP-AES (inductively coupled plasma atomic emission spectrometry), and for ore grade gold by fire assay with gravimetric finish. Silver, molybdenum, and copper were analysed by aqua regia digestion and AAS (atomic absorption spectrometry). Total sulphur was analysed by Leco furnace. Lithochemical samples were taken as representatives of the major rock and alteration types, 35 samples were taken in

total. Samples for lithochemical analysis were analysed for major elements by ICP-AES (inductively coupled plasma atomic emission spectrometry), and for trace elements by ICP-MS (inductively coupled plasma mass spectrometry). Samples were prepared in Piteå and analysed in Vancouver by ALS Laboratory Group.

The thin sections and polished thin sections were examined microscopically in transmitted and reflected light. Polished thin sections were also analysed by energy dispersive X-ray (EDS) in a scanning electron microscope (SEM), using a backscatter detector (BSE) for sample images. Samples were analysed on a Hitachi S3400 N using INCA 4.06 software at the Department of Geology in Lund.

#### **5. Petrological discription of the rocks**

The host rock to the 5040 N profile consists of altered gneisses grading into schists in the heavier mineralized areas. The rocks are porphyritic with a very fine grained matrix and porphyroblasts of scapolite and garnet. Scapolite porphyroblast typically are around 2 mm in diameter (Fig. 4c), while garnets generally range from 2 mm up to 1 dm. Garnets increase in size and frequency with higher mineralization and it is uncommon to find Cu mineralization in rocks that do not contain garnet.

Alteration minerals are extensive and varied, with the least altered rock still showing strong scapolitization. The degree of alteration increases from scapolite ± garnet gneiss with the addition alteration minerals, to epidotized scapolite ± garnet gneiss, to a K-feldspar and epidotized scapolite ± garnet gneiss, to a completely skarnic heavily K-

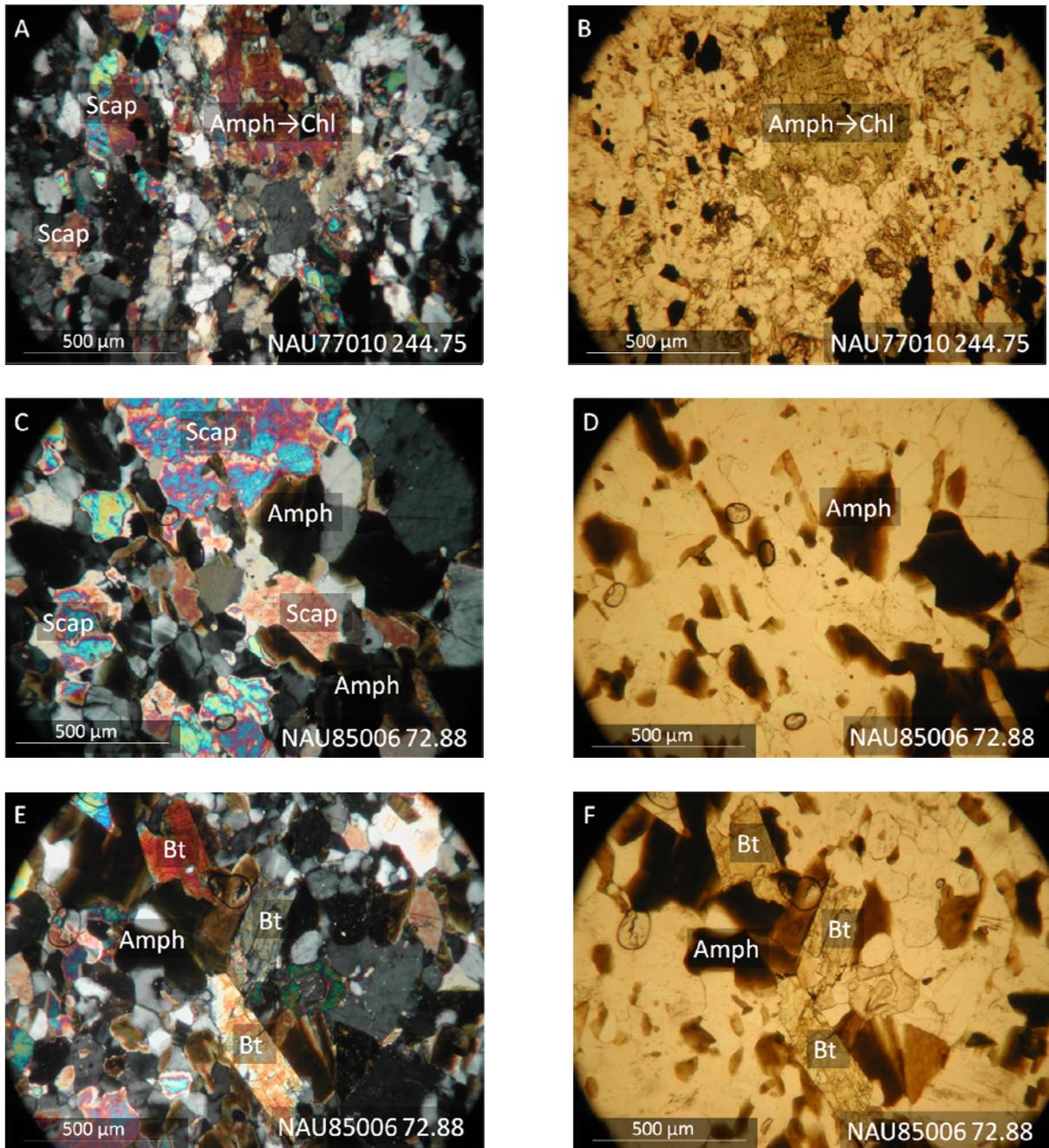
feldspar and epidotized gneiss (Fig 4). As shown in table 3, it can be seen from point counts that the addition of epidote alteration is largely at the expense of biotite and amphibole which are also altered to chlorite. Along with the alteration of biotite to amphibole, plagioclase is at the same time breaking down to sericite. K-feldspar alteration occurs as matrix-sized secondary growth crystals. Alteration at the microscopic level is shown in figure 4. Magnetite is the most common ore mineral, both in the economically mineralized zones and throughout the host rock. It commonly makes up 3-4% of Nautanen rocks (Monro 1988). In profile 5040 N magnetite is found in disseminated grain form nearly everywhere and also in solid bands, sometimes with chalcopyrite. Magnetite bands are often accompanied by epidote.

The disseminated magnetite is aligned to the same foliation as the biotite indicating early crystallisation, before shearing. Hematite is also found in trace amounts and has been observed locally as blebs in strongly K-feldspar altered rock. In places, pyrite has been partially oxidized to magnetite, leaving traces of concentric magnetite growth rings around a pyrite core (Monro 1988).

Chalcopyrite is the most common sulphide ore mineral followed by pyrite. Other ore minerals are native gold and silver, molybdenite, sphalerite, cuprite, pyrrhotite, scheelite, galena, carrolite, bismuthinite, tellurobismuthite, and bornite. These minerals are found in accessory amounts with the exception of bornite which can sporadically be found in more significant amounts.

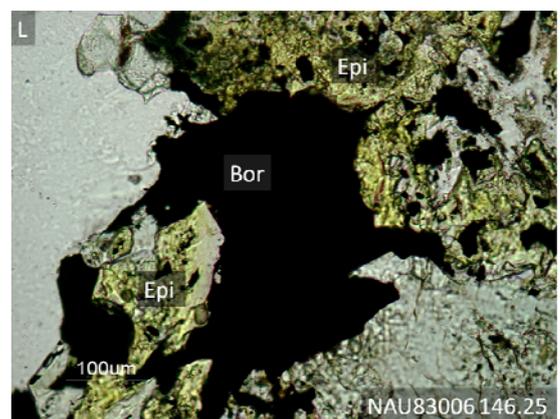
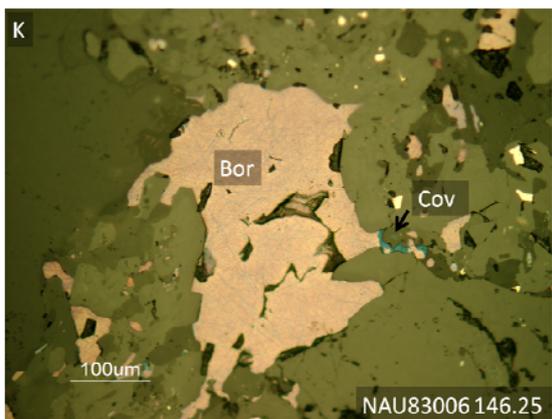
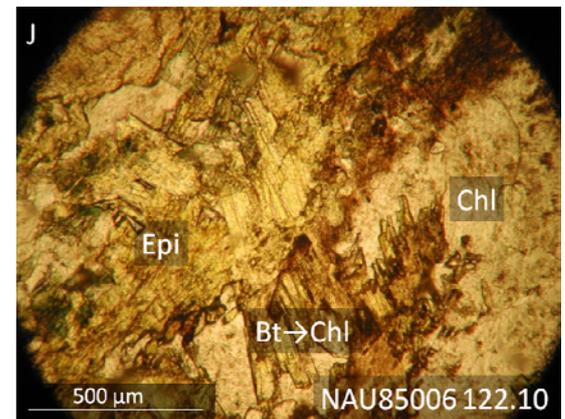
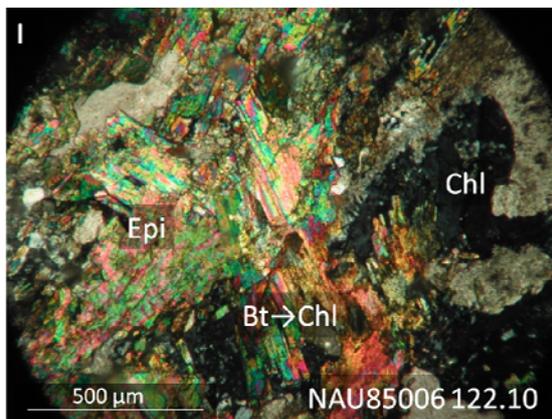
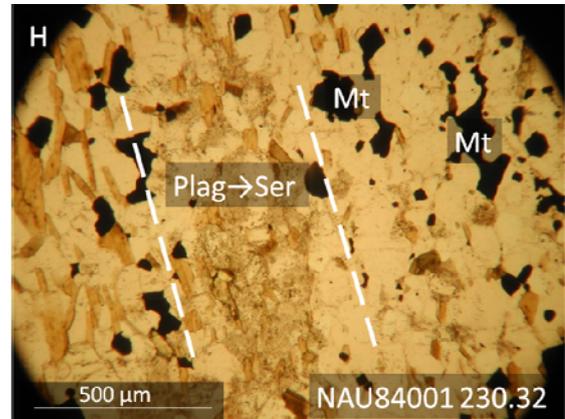
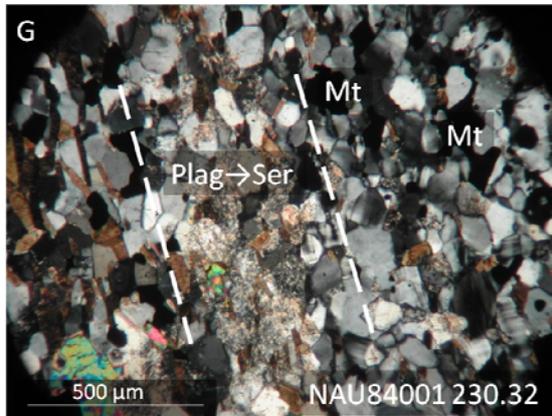
**Table 3.** Main Nautanen host rock types of the 5040 N profile. Based on point counts from six thin sections.

Mineral (vol %)	Scap-Bt Gniess (low alt.)	Scap-Bt Gniess (Epidote alt.)	Scap-Bt Gniess (K-spar/epi alt.)	Gt-Ser Gniess	Banded Gniess	Skarn
K-feldspar	4	5	13	8	4	
Quartz	15	10	6	5	21	
Plagioclase	15	17	29	15	16	
Sericitic Plag	2	12	21	31	11	
Biotite	29	2	2	15	11	
Amphibole	7	3			3	
Chlorite		18	14	8	7	18
Scapolite	17	8		2	9	
Epidote	8	19	13	1	1	70
Calcite		1				11
Garnet	2			1		
Tourmaline		2				
Apatite	1	1				
Titanite		1				1
Opaques	1	2	3	8	17	



**Figure 4.** Nautanen alteration in thin section. Images are taken in cross polarized (left) and plane polarized (right) transmitted light. Image K (next page) was taken in plane polarized reflective light. A,B, Amphibole-biotite banded gneiss. Chloritization of amphibole, early stages of sericitization of plagioclase, scapolite porphyroblasts. C, D, E, F, Garnet-scapolite-biotite-amphibole gneiss. Large scapolite porphyroblasts are shown in C. In E and F, light coloured biotite is being altered to epidote, Dark brown minerals are former biotite grains altered to amphibole.

Figure 4 continued:



G, H, Garnet-sericite gneiss. Very fine grained, strongly foliated. Sericite occurs in bands parallel to foliation, high amounts of magnetite, and usually low grade disseminated chalcopyrite.

I, J, K-feldspar/epidote skarnic gneiss. Primary textures mostly destroyed, biotite altered to epidote, extensive chloritization, calcite also common.

K, L, Mineralization, in this case bornite with blue covellite, is accompanied by epidote, light yellow/green on right.

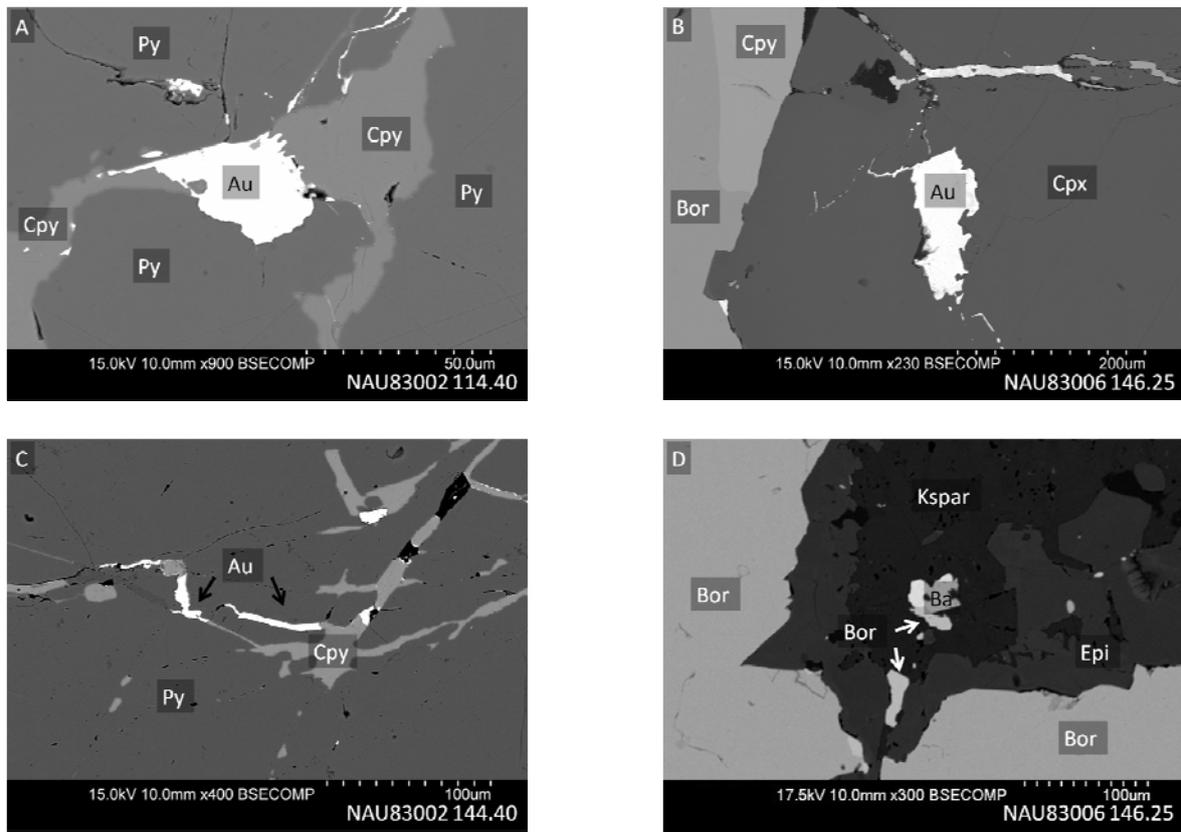
Chalcopyrite is found as disseminated grains in the rock and as well as in veins of fairly large grains greater than 100  $\mu\text{m}$ . Chalcopyrite is also commonly found filling microscopic fractures in pyrite and magnetite (Fig. 5). The accessory ore minerals are usually found with chalcopyrite and most filling fractures. Chalcopyrite and to some extent bornite, have been oxidized to malachite and chrysocolla as evidenced by boulders at the Nautanen site. Covellite, observed in thinsection, is also a result of oxidation of the copper minerals. Gold is found mainly as individual grains in association to chalcopyrite, and it is rare to find high values of gold that are not associated with high copper values. The gold grains vary in composition. Silver is typically a major component, usually making up more than 50wt% of the grain, and mercury is often a minor component, <10wt% (Table 4). Silver also occurs separate from gold in aggregates with telluride. The Au/Ag ratio is highly variable

and most of the gold grains occur in small fractures in pyrite and magnetite grains indicating that gold precipitation occurred late and might be the product of remobilization of earlier gold mineralization that occurred associated with the chalcopyrite (Fig. 5).

Enrichment of cobalt has been noted in the pyrite grains by Hålenius (1983), and these Co-rich pyrite grains occur with gold grains, as does bismuthinite (Table 4). Future assaying for cobalt and bismuth could allow for better evaluation of this relationship and its potential for use in future exploration. Barite occurs as veins in the mineralized area and an enrichment of barium in microcline near gold rich zones has been noted. Barium has similar chemical properties to potassium, and seems to substitute for K in feldspars. Enrichment in barium is seen at a larger scale as well for both the Nautanen and Aitik deposits, making it a potential tool for exploration in the Gällivare area.

**Table 4.** SEM point analysis. Samples carbon coated, acceleration voltage 17.5, standardized with pure cobalt. INCA standards were used and this introduced a high degree of error in the results. Ideally total weight percent values should be between 97% and 103% so the values obtained here should only be used for a general idea of the wt% of identified elements

Sample	Point	wt%								Total
		Au	Ag	Hg	Bi	Pb	Co	Fe	S	
NAU83006 146.25	1	21.67	70.53	11.83						104.03
	2	19.94	69.75	12.53						102.22
	3	22.52	67.98	13.65						104.16
NAU83002 114.4	1	86.9	27.47							114.37
	2	2.48	24.04		49.74	10.73			15.76	102.76
	3(Py)						1.48	45.51	54.4	101.39
NAU83002 144.40	1	32.11	79.75							111.86
	2	71.59	45.65							117.24
	3	53.94	58.2							112.14



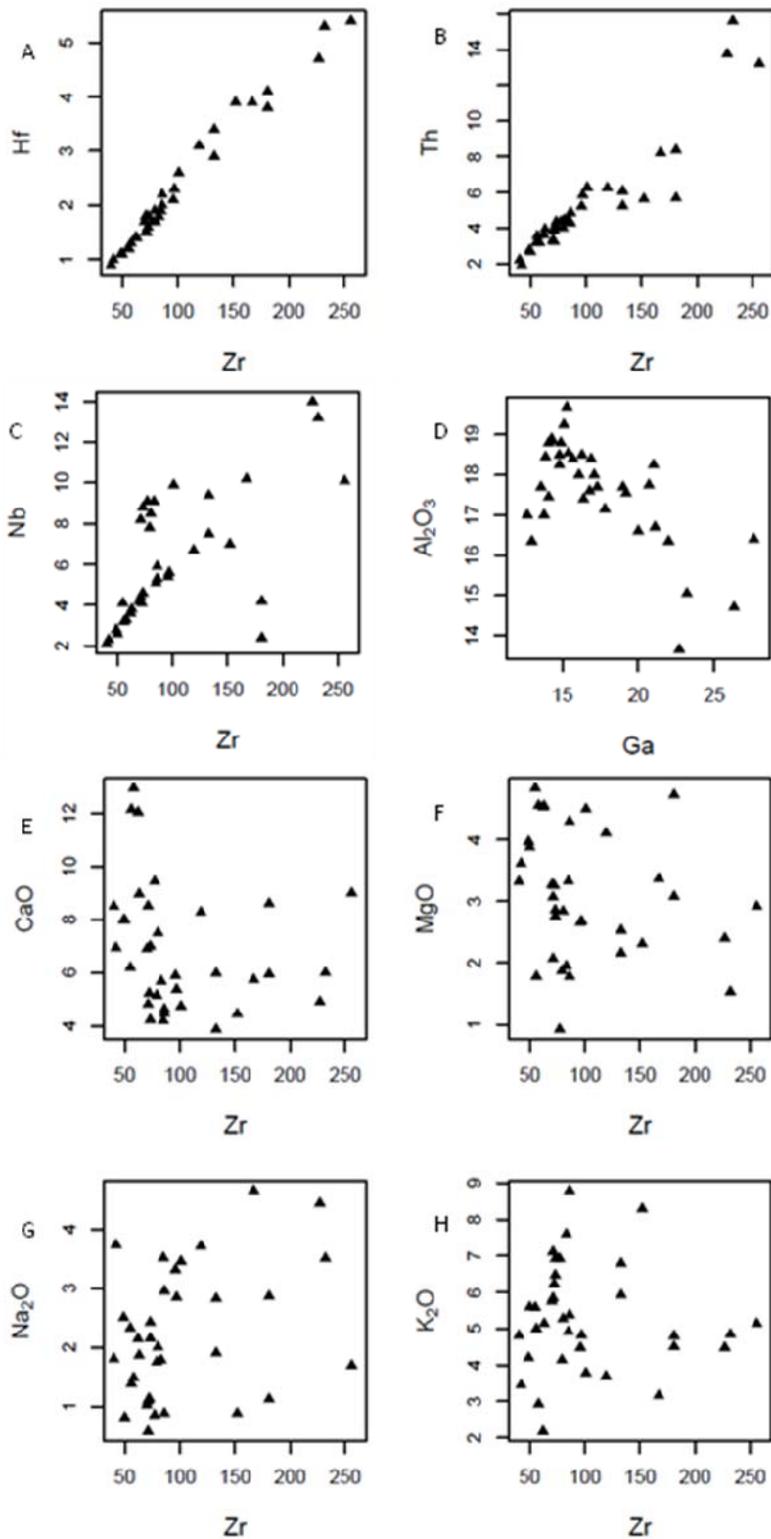
**Figure 5.** SEM images of gold (Au) found as grains and in microscopic veins in association with chalcopyrite (Cpy) filling fractures of pyrite (Py) and pyroxene (Cpx). Figure D shows barite (Ba) occurring with bornite (Bor) in feldspar (Kspar). The bornite is being rimmed by epidote (Epi).

## 6. Geochemistry

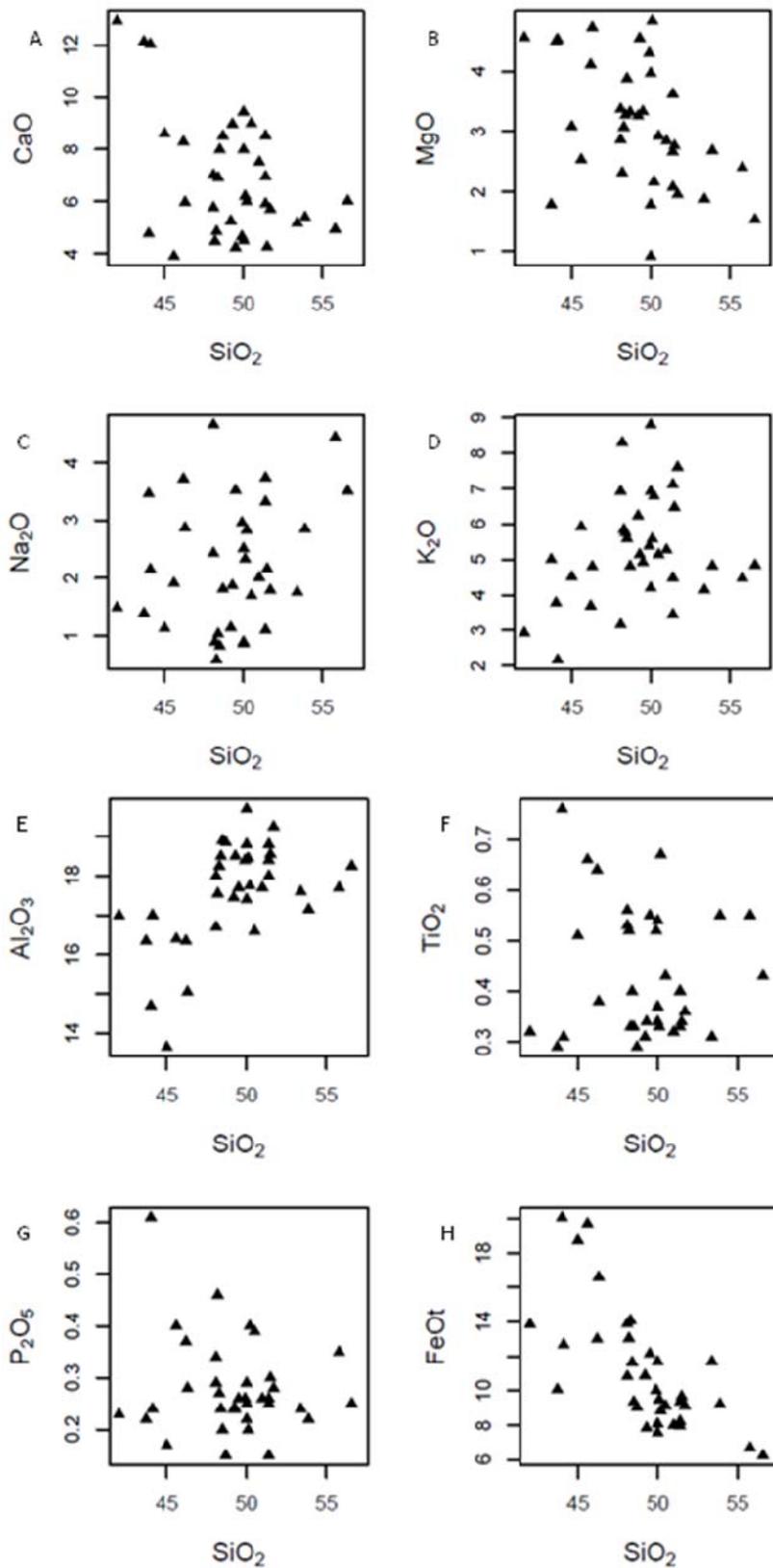
Analytical results for the major and trace elements of representative samples of the Nautanen host rock are presented in Table 5. Since the host rocks to the Nautanen deposit have undergone heavy alteration, geochemical data records a compound of primary signatures with secondary alteration and metamorphic mass changes (Fig. 6 and Fig. 7). Geochemistry diagrams in this section use elements that are believed to be immobile, but interpretations as the origin of the rocks must be taken with care since it is not clear if traditionally immobile elements

really have been immobile in this area. The absence of fresh samples and the degree of tectonic deformation in the area makes it difficult to interpret the evolution of the magmas.

Samples taken from profile 5040 N can be broken into three groups by using the Nb/Y – Zr/Ti discrimination plot (Pearce 1996). The discrimination plot shows one group of andesites or basaltic andesites, another group of trachyandesites, and a final third group is made up of three samples that plot as rhyolite/dacite (Fig. 8). When compared to the observed rock types only the



**Figure. 6** Trace element lithochemistry. Immobile elements Zr-Hf-Th-Nb (a, b, c) show a strong correlation suggesting rocks derived from a single suite. The non-correlated Ga- Al<sub>2</sub>O<sub>3</sub> plot (d) and the Zr vs Alkali elements plots (e, f, g, h) show that mobile elements have been strongly effected due to alteration and mass changes



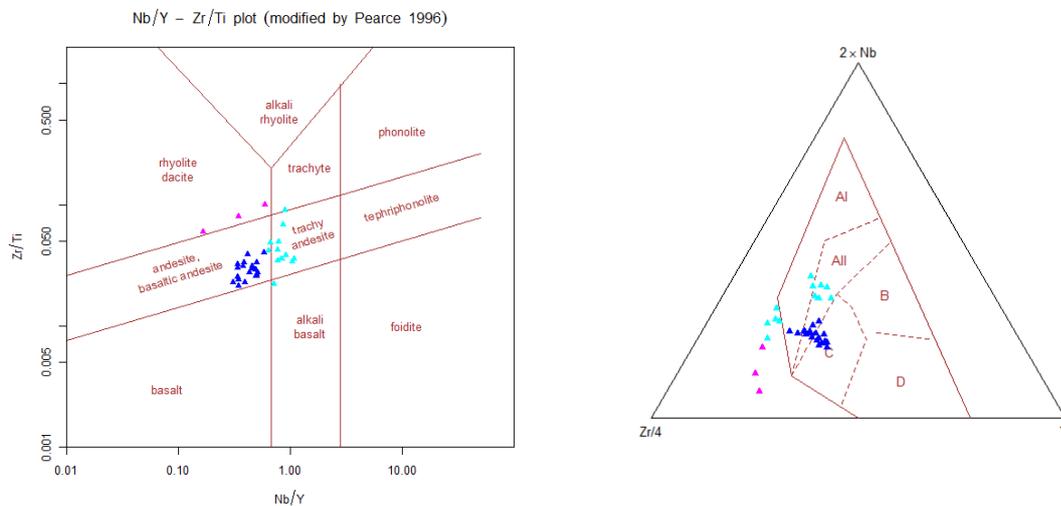
**Figure. 7** The major elements plotted against SiO<sub>2</sub> show that there has been strong movement of mobile elements, making them unreliable for identifying rock types

**Table 5.** Major and trace element analyses of representative samples from the Nautanen host rock. Major element and S data are shown in wt%. Trace element data are shown in ppm. LOI= Loss on ignition.

Sample	93020 10	93020 20	93020 23	93020 26	93020 49	94001 3	95005 7	77011 60	77011 5	93020 43
Rock Type	Et-Ot Gneiss	Et Gneiss	Sp4-Et-Ot Gneiss	Stromic Et-Ot Gneiss	Banded Gneiss	Et-Anorth. Gneiss	Se-Et-Ot Gneiss	Et Gneiss	Et-Ot Gneiss	Et-Ot Gneiss
SiO <sub>2</sub>	48.5	50.1	49.2	43.7	51	53.9	48.2	44	53.4	49.3
Al <sub>2</sub> O <sub>3</sub>	18.9	18.45	17.45	16.35	17.7	17.15	17.55	14.7	17.6	18.25
Fe <sub>2</sub> O <sub>3</sub>	10.4	10.55	12.1	11.2	8.9	10.25	14.5	22.3	13	15.65
CaO	7.99	6.2	5.24	12.15	7.51	5.38	4.46	4.75	5.16	4.83
MgO	3.88	4.84	3.26	1.78	2.84	2.68	2.31	4.5	1.87	3.07
Na <sub>2</sub> O	0.82	2.33	1.14	1.39	2.01	2.85	0.89	3.46	1.76	0.98
K <sub>2</sub> O	5.59	5.58	6.23	5	5.27	4.82	8.29	3.78	4.14	5.84
CaO <sub>2</sub>	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TiO <sub>2</sub>	0.33	0.33	0.31	0.29	0.32	0.55	0.52	0.76	0.31	0.33
MnO	0.79	0.55	0.61	0.71	0.54	0.42	0.72	0.43	0.83	0.89
P <sub>2</sub> O <sub>5</sub>	0.2	0.2	0.24	0.22	0.26	0.22	0.46	0.61	0.24	0.27
SeO	0.02	0.03	0.02	0.05	0.03	0.02	0.03	0.06	0.03	0.02
BaO	0.34	0.15	0.26	0.18	0.21	0.14	0.41	0.1	0.2	0.34
LOI	2.19	1.39	2.4	5.36	1.88	0.8	1.28	0.4	0.96	1.7
Total	100	100.5	98.5	98.4	98.5	99.2	99.6	99.9	99.5	100
Ba	2630	1215	2120	1405	1670	1210	3310	809	1610	2630
Co	23.4	43.1	35.9	26.4	38.1	21.2	51.5	44.9	20.5	37.2
Cr	60	90	60	60	10	30	30	10	10	10
Ce	2.91	15.95	6.14	2.69	4.04	11.7	4.85	17.35	6.13	11
Cu	5	<5	28	18	28	17	132	<5	91	22
Ga	14.3	13.9	14.1	13	17.3	17.8	19.2	26.3	16.8	14.8
Hf	1.1	1.2	1.5	1.2	1.7	2.3	3.9	2.6	1.9	1.5
Mo	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Nb	2.6	4.1	4.1	3.2	8.5	5.6	7	9.9	7.8	8.2
Ni	19	33	23	17	14	19	18	21	12	21
Pb	<5	5	5	5	6	7	10	6	6	<5
Rb	175	218	265	193	171	288	209	170	165	255
Sr	<1	<1	<1	<1	1	1	1	2	<1	1
Th	177	232	173.5	391	247	186	246	425	199.5	193.5
U	0.1	0.2	0.2	0.1	0.4	0.3	0.3	0.3	0.3	0.3
Vb	2.67	3.17	4.13	3.56	4.46	5.85	5.63	6.28	4.02	3.86
Tl	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U	1.75	2.67	1.66	1.07	0.95	1.37	1.85	1.62	1.68	0.96
V	121	109	113	75	92	165	128	318	91	76
W	3	4	12	7	13	2	13	<1	6	11
Y	7.7	6.1	9.9	9.5	13.4	12.2	10.6	13.9	10.2	9.8
Zn	72	65	54	50	70	50	86	127	64	137
Zr	50	55	72	56	80	97	152	101	79	71
La	18.2	21.8	31.5	32.8	40	26.1	26.4	43.4	25.5	17.1
Ce	38	45.4	61.2	63.4	79.3	52.2	50.1	82.3	49.1	34.9
Pr	4.78	5.77	7.49	7.95	9.96	6.51	6.46	9.85	5.71	4.39
Nd	17.2	21	26.1	27.4	34.6	22.2	24.4	33.2	22.1	15.7
Sm	3.14	3.44	4.51	4.61	5.67	3.96	4.03	5.32	3.79	2.77
Eu	1.08	1.19	1.65	1.53	1.66	1.18	0.89	1	1.23	0.8
Gd	2.67	3.04	4.04	3.85	4.81	3.56	3.49	4.82	3.42	2.54
Tb	0.34	0.37	0.48	0.46	0.59	0.47	0.4	0.59	0.44	0.34
Dy	1.61	1.69	2.1	1.98	2.65	2.43	1.9	2.59	2	1.76
Ho	0.3	0.31	0.37	0.35	0.48	0.48	0.36	0.48	0.37	0.35
Er	0.82	0.85	0.97	0.94	1.4	1.36	1.07	1.43	1.03	1.01
Tm	0.08	0.09	0.08	0.09	0.16	0.16	0.15	0.18	0.14	0.11
Yb	0.7	0.72	0.73	0.74	1.16	1.26	1.1	1.25	0.9	0.89
Lu	0.11	0.11	0.11	0.11	0.18	0.19	0.16	0.21	0.13	0.14

Table 5 continued:

Sample	00001 34	00001 37	00001 39	72000 34	72011 37	03020 38	72011 72	72000 41	72000 49	72011 47
Rock Type	Dr.-Amph Gabbro	Altered Dr.- Amph Gabbro	Dr.-Amph Gabbro	Dr.-Cr. Gabbro	Dr.-Amph Gabbro	Diseased Gabbro	Diseased-Cr. Gabbro	Dr.-Amph Gabbro	Dr.-Amph-Cr. Gabbro	Hpl-Dr.-Amph Gabbro
SiO <sub>2</sub>	51.1	30	51.7	43.0	40.1	33.0	30.0	43	30.3	44.3
Al <sub>2</sub> O <sub>3</sub>	10.25	10.7	10.25	16.4	16.7	17.7	10.25	13.05	16.6	15.05
FeO	10.75	0.41	10.15	21.9	15.45	7.43	4.94	20.0	10.15	10.45
CaO	4.34	4.44	4.05	3.00	3.71	4.93	4.01	4.01	0	3.04
MgO	2.76	0.02	2.05	2.53	2.37	2.4	1.53	2.00	2.02	4.72
MnO	2.16	0.06	2.99	1.91	1.06	1.11	3.51	1.13	1.7	2.07
K <sub>2</sub> O	0.07	0.98	7.0	1.99	3.10	4.00	4.04	4.31	1.14	4.0
Cl <sub>2</sub> O <sub>3</sub>	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TiO <sub>2</sub>	0.34	0.37	0.36	0.66	0.56	0.55	0.43	0.51	0.43	0.30
Na <sub>2</sub> O	0.25	0.33	0.31	0.54	0.61	0.26	0.30	0.03	0.30	0.44
PHO <sub>3</sub>	0.3	0.20	0.20	0.4	0.34	0.33	0.23	0.17	0.30	0.20
ZnO	0.04	0.04	0.03	0.07	0.05	0.12	0.07	0.00	0.00	0.07
BaO	0.26	0.44	0.30	0.46	0.26	0.10	0.27	0.54	0.24	0.15
LOE	1.9	1	1.1	0.1	1.00	0.2	0.26	1.49	1.4	0.39
Total	99.4	99.7	100.1	100.1	100	99.0	100.1	100.1	99.2	100
Ca	2000	3300	2000	3000	2000	1000	2000	1100	1000	1200
Co	20	17.0	23	30.1	29.9	20.7	11.3	30.9	23	11.3
Cr	00	00	00	<100	<100	<100	00	00	00	00
Cu	7.11	2.01	6.00	14.0	5.4	7.20	7.4	4.37	0.25	20.0
Fe	17	23	14	450	121	<3	43	013	403	01
Mn	13.4	13.3	21.1	27.0	21.1	10	21	22.7	20	23.2
Ni	1.6	1.7	1.0	2.0	2.0	1.7	3.3	2.0	3.4	1.1
Na	<0	1	4	3	<0	<0	2	<0	<0	<0
Si	0.0	9.1	9.1	9.4	10.2	10	13.2	9.4	10.1	4.2
Mg	15	11	11	00	7	<5	00	13	0	16
Pb	7	5	5	7	7	5	7	7	0	4
Rb	200	203	230	210	01.9	100	120	123	177	120.3
Sr	1	1	<1	2	1	1	1	2	1	2
U	341	343	101	336	340	051	490	300	401	403
V	0.3	0.3	0.4	0.2	0.5	0.0	0.7	0.1	0.4	0.2
Zn	4.03	4.30	<4.0	3.20	0.23	13.73	13.0	3.00	13.2	0.37
Tl	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
U	0.96	3.30	2.31	1.94	2.06	4.5	3.99	2.20	2.05	3.13
V	20	91	111	304	120	100	00	220	103	210
W	0	20	0	3	<1	<1	3	1	1	<1
Y	0.1	11.0	00	0	13	10.2	10.7	10.5	17.2	12.3
Zn	77	54	50	111	70	54	50	101	130	100
Zr	73	77	03	133	107	207	230	101	220	101
La	31.7	30.3	30.1	32.7	11.0	33.0	31.3	30.5	35.4	30.3
Ce	61	39.3	35.1	61.1	25.1	112	100.5	51.9	70.7	30.9
Pr	7.97	7.40	4.90	4.93	3.07	13	11.9	0.77	9.23	1.03
Nd	27.6	23.6	30.1	22.7	10.6	01.7	04.1	23.2	31.0	21.7
Sm	4.33	4.34	<0.0	3.46	3.90	6.35	6.74	4.17	5.54	3.91
Eu	1.07	1.04	2.23	0.90	0.90	1.00	1.30	1.10	1.43	0.91
Gd	2.5	2.90	2.90	2.00	2.13	3.00	3.00	2.71	4.03	2.02
Tb	0.4	0.40	0.44	0.20	0.46	0.07	0.05	0.53	0.65	0.45
Dy	1.7	2.20	2.00	1.00	2.00	3.10	2.77	2.07	3.20	2.2
Hf	0.31	0.43	0.30	0.33	0.40	0.01	0.36	0.23	0.03	0.43
Er	0.03	1.20	2.00	0.04	1.41	1.0	1.00	1.54	1.00	1.31
Th	0.11	0.15	0.10	0.1	0.21	0.23	0.23	0.21	0.25	0.10
Yb	0.00	1.07	0.93	0.03	1.33	1.02	1.04	1.30	1.02	1.23
Lu	0.15	0.17	0.15	0.16	0.2	0.20	0.20	0.20	0.21	0.20



**Figure 8.** Left, Nautanen profile 5040 N lithochemical samples plotted on Nb/Y – Zr/Ti discrimination diagram for volcanites (modified by Pearce 1996). Right, Andesites 2 plot separately, and similar to rhyodacites (Meschede 1986, geotectonic for basaltoids). Samples are colour coded based on classification, dark blue = basaltic andesite, light blue = trachyandesite, pink = rhyodacite.

three banded gneiss samples can be constrained to one geochemically interpreted rock type, which is the trachyandesites. The trachyandesites and basaltic andesites are expected in this area while the rhyodacites are not. The three samples that fall into the rhyodacite category do not consistently plot in a tight group when compared for various trace elements and a possible explanation for this is that this rock is sourced from sediments thus providing a greater amount of variables to the chemical make up of the rock, another possibility is strong alteration, and a third possibility is that they show the effects of a fractioning magma. Within the trachyandesite group a further subdivision can be made with the use of the Meschede geotectonic plot for basaltoids (1986) (Fig. 8). A larger degree of alteration or a sedimentary source vs an igneous one could

be responsible for the difference within this group. The presence of similar but compositionally slightly different andesites probably indicates that the host rocks are derived from several different magmas, or that the magma(s) are showing signs of weak fractionation.

When the interpreted protoliths are plotted on the cross section a series of steeply dipping repeating lithologies is apparent. This is consistent with what would be expected in the Nautanen area, where strong isoclinal folding and a strong penetrative NNW-SSE trending tectonic fabric has been documented (Monro 1988). Mineralization cuts across these layers while still steeply dipping and following the general structural controls of the host rock. Alteration of all types can also be found in all the lithologies.

Appendix A shows the steeply dipping and repeating nature of the geochemically defined layers, Appendix B shows the strongest zones of mineralization.

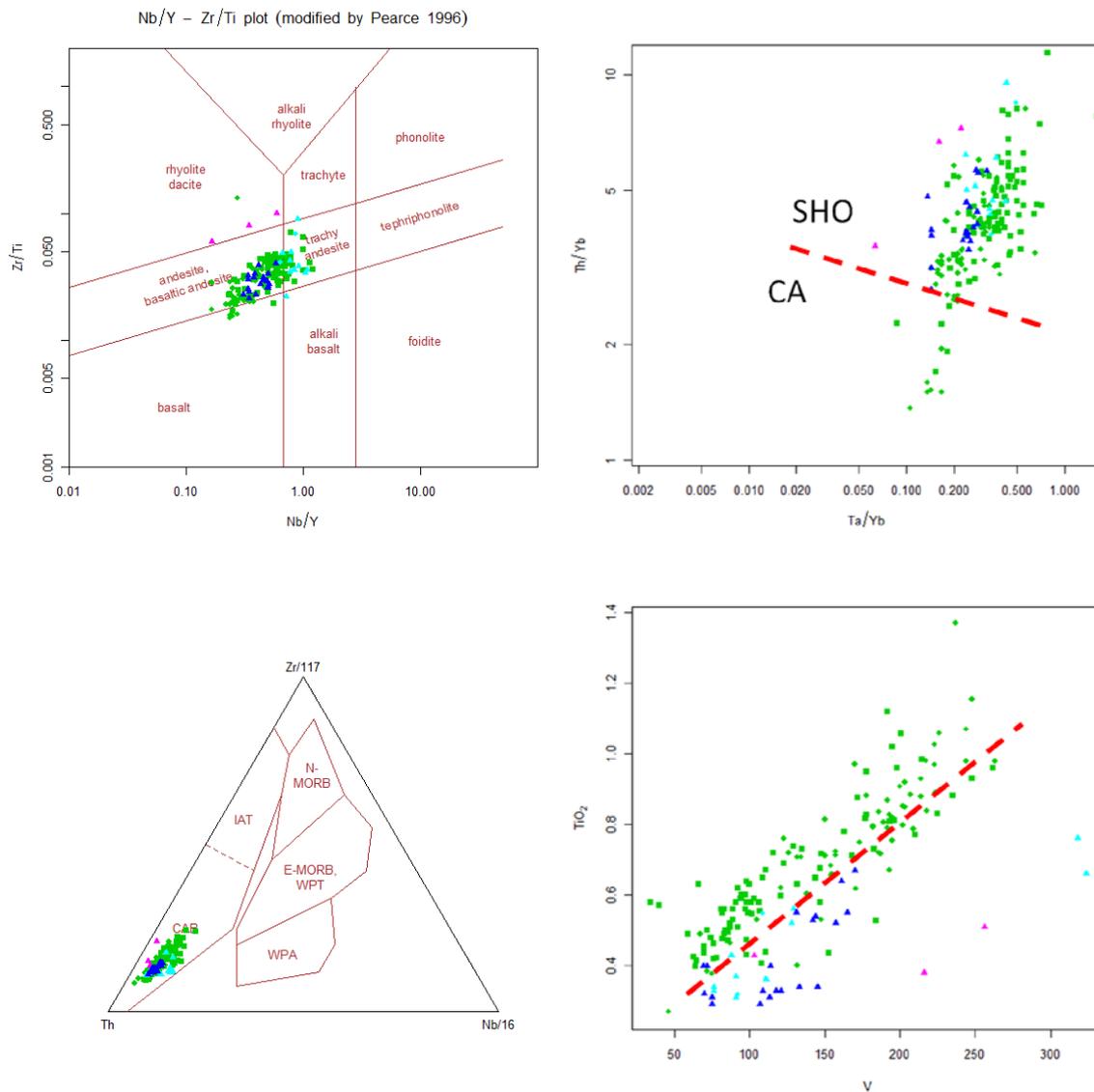
When compared to volcanoclastic rocks from the Aitik deposit, Nautanen rocks appear to be very similar. By the Nb/Y – Zr/Ti discrimination diagram (Pearce 1996) Aitik rocks fall primarily into the andesite, basaltic andesite category, with some samples also indicating trachyandesites (Fig. 9). In a Th/Yb – Ta/Yb binary diagram Nautanen rocks plot values determined to be characteristic of shoshonites by Pearce (1982) (Fig. 9). Some of the lower values overlap calc-alkaline rocks and the general pattern is characteristic of rocks of the Porphyrite group, it is also very similar to the values of volcanoclastic rocks in the Aitik deposit. The rocks from both deposits are indicated to have formed in a continental arc setting (Fig. 9) from the Woods Zr/117 - Nb/16 – Th geotectonic classification diagram (1980). There is a positive correlation to TiO<sub>2</sub> and V values for both deposits and it is possible to distinguish between Aitik rocks and Nautanen rocks through these values since TiO<sub>2</sub> values are lower in Nautanen rocks (Fig. 9).

## 7. Discussion

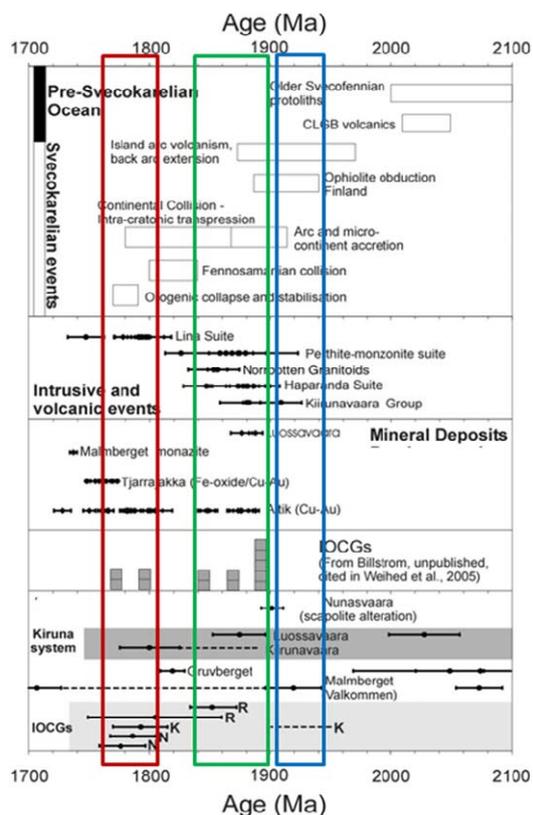
A petrological and geochemical examination of the host rocks in the 5040 N profile shows them to fit with what has previously been described in the area, they appear to be highly altered andesites that formed in a continental arc environment. The host rocks to the Nautanen deposit are very similar to the volcanoclastic host rocks of the Aitik deposit. The type of alteration identified fits

best with what is typically associated with an IOCG type deposit (Hitzman et al. 1992). What remains poorly known is the degree of influence other ore forming processes and the remobilization of earlier deposited metals had on the deposit and the timing and duration of these events.

Titanite and allanite have been dated by U–Pb analysis and have been determined to have formed c. 1.78 Ga. in the Nautanen area (Smith et al. 2009). This likely determines the age of the last major hydrothermal event, which at around 1.78 Ga is a fit with what is thought to be widespread regional IOCG mineralization and associated alteration described throughout the Gällivare area (Broman & Martinsson 2000). The nature of the extreme alteration that occurred during this event at the Nautanen locality makes it difficult to study previous influences on the deposit but some hypothesis can be made. The proximity to the Malmberget apatite-iron ores combined with the abundance of magnetite and presence of apatite in Nautanen suggests a connection between the two. However, apatite is also found in Aitik, weakening this argument. The apparent early emplacement of magnetite seen in mineralized thin sections from Nautanen supports the idea of an early connection to Malmberget, and it is thus possible that mineralization at the Nautanen deposit began around 1.92 Ga (Smith et al. 2009) during the formation of the Malmberget apatite-iron ores. Porphyry style mineralization related to the Haparanda suite of intrusions began c. 1.89 Ga at the Aitik deposit (Wanhainen 2005) and it is possible that similar mineralization



**Figure 9.** Top left, Nb/Y – Zr/Ti discrimination diagram (Pearce 1996). Top right, Th/Yb versus Ta/Yb binary diagram. Red dotted line indicates location of fields for shoshonite and calc-alkaline magmatic origin. Based on the Th/Yb – Ta/Yb discrimination diagram for volcanic arc basalts (Pearce 1982). Bottom left, Th - Zr/117 – Nb/16 geotectonic classification diagram (Wood 1980). All Nautanen and Aitik samples plot together in the continental arc field. Bottom right, TiO<sub>2</sub> vs V binary diagram shows a slight difference between the Aitik volcanics and the Nautanen host rocks. Blue and Pink points represent Nautanen samples, Aitik volcanics are in green for comparison.



**Figure 10.** (modified from Smith et al. 2009). N= Nautanen, K= Kallosalmi, R= Rakkurijärvi. Blue rectangle= possible introduction of magnetite at Nautanen corresponding to early mineralization at Malmberget. Green rectangle= porphyry mineralization at Aitik, period of Haparanda suite intrusions and possible porphyry mineralization at Nautanen. Red rectangle= IOCG event at Nautanen, corresponding to timing of Lina suite intrusions and IOCG overprinting at Aitik.

events were taking place during this period at Nautanen from local Haparanda suite intrusions there (Martinsson et al. 2001). Extensive tectonic remobilization along the NDZ is likely to have taken place, possibly several times between the first and last

major mineralization events in the region. Early mineralization in the Nautanen deposit is believed to be responsible for the disseminated distribution of ore whereas the veining is believed to be related to the later mineralization and possibly to significant remobilization of the disseminated ore at that time (Martinsson & Wanhainen 2004). The late mineralization, which is IOCG in nature, is believed to be connected to the granite intrusions of the Lina Suite due to the presence of tourmaline, scheelite, and molybdenite (Martinsson & Wanhainen 2004), and occurred during the same time that widespread IOCG mineralization is believed to have occurred throughout northern Norrbotten.

There has clearly been a late IOCG event at circa 1.78 Ga that has had a strong influence on the deposits current attributes. There is also the possibility that early disseminated mineralization of Cu-Au is sourced from intermediate intrusions, similar to the porphyry type mineralization described at Aitik (Martinsson & Wanhainen 2004). Due to the large size and economic importance of Cu porphyry deposits, understanding the possible presence and degree of influence of this type of mineralization at Nautanen is of high significance for exploration companies. It has been noted by Wanhainen (2005), that statistically speaking there is a possibility of another major porphyry deposit in the northern Norrbotten region when taking the size of favourable terrain into account and comparing it to the frequency and spacing of other major Cu porphyry districts in the world.

Similar high salinity fluid inclusions as those noted as porphyry-related in the Aitik

deposit have also been observed in Nautanen (Broman & Martinsson, 2000), indicating that porphyry type mineralization may have been present at the Nautanen locality as well. Investigation of Haparanda suite granodiorites in the Nautanen area, and high salinity NaCl-CaCl<sub>2</sub> fluid inclusions in the Nautanen area could further indicate Aitik type porphyry mineralization (Wanhainen 2005). Due to glacial deposits covering much of the surrounding area geophysics is crucial for better understanding the geology and structures in the area. It is also possible that investigating through drilling to the outer edges of the area where the SGU/SGAB focused may increase the current level of knowledge as well as drilling deeper than the approximately 200 m depth that has previously been explored.

## 8. Conclusion

The extensive alteration and deformation of the Nautanen deposit makes it difficult to reconstruct the deposit's early history. Lithochemical analysis of immobile elements shows Nautanen host rocks consist of steeply dipping, repeating layers of shoshonitic andesites, that were formed in a continental arc setting. The Nautanen rocks have lithochemical values characteristic of the low titanium, low zirconium Porphyry Group of metavolcanics found in Norrbotten and are lithochemically similar to the volcanic host rocks to the Aitik deposit. Variations in tectonic processes, alteration, and magma fractionation have likely led to the small differences seen between the host rocks of the Nautanen and Aitik deposits.

## 9. Acknowledgements

This work was financed by Boliden Mineral AB, and thanks are due to Boliden Mineral AB and the many employees there who offered their help to me during the completion of this project. This work was also made possible through materials made available by the Geological Survey of Sweden, special thanks goes out to the staff at the survey's Malå office for their help. I would like to express my gratitude to my supervisors who helped guide me through the writing of this thesis, from Lund University, Anders Scherstén, Ulf Söderlund, and Leif Johansson, from the Luleå University of Technology, Christina Wanhainen, and from Boliden Mineral AB, Roger Nordin.

I would also like to thank the many students I met and made friends with throughout my years of studying, they made the years I spent completing this degree some of the most enjoyable. Last, but certainly not least, I would like to thank family for endless support along the long path of my education. I could not have made it to where I am today without the positive thoughts they sent me from a world away.

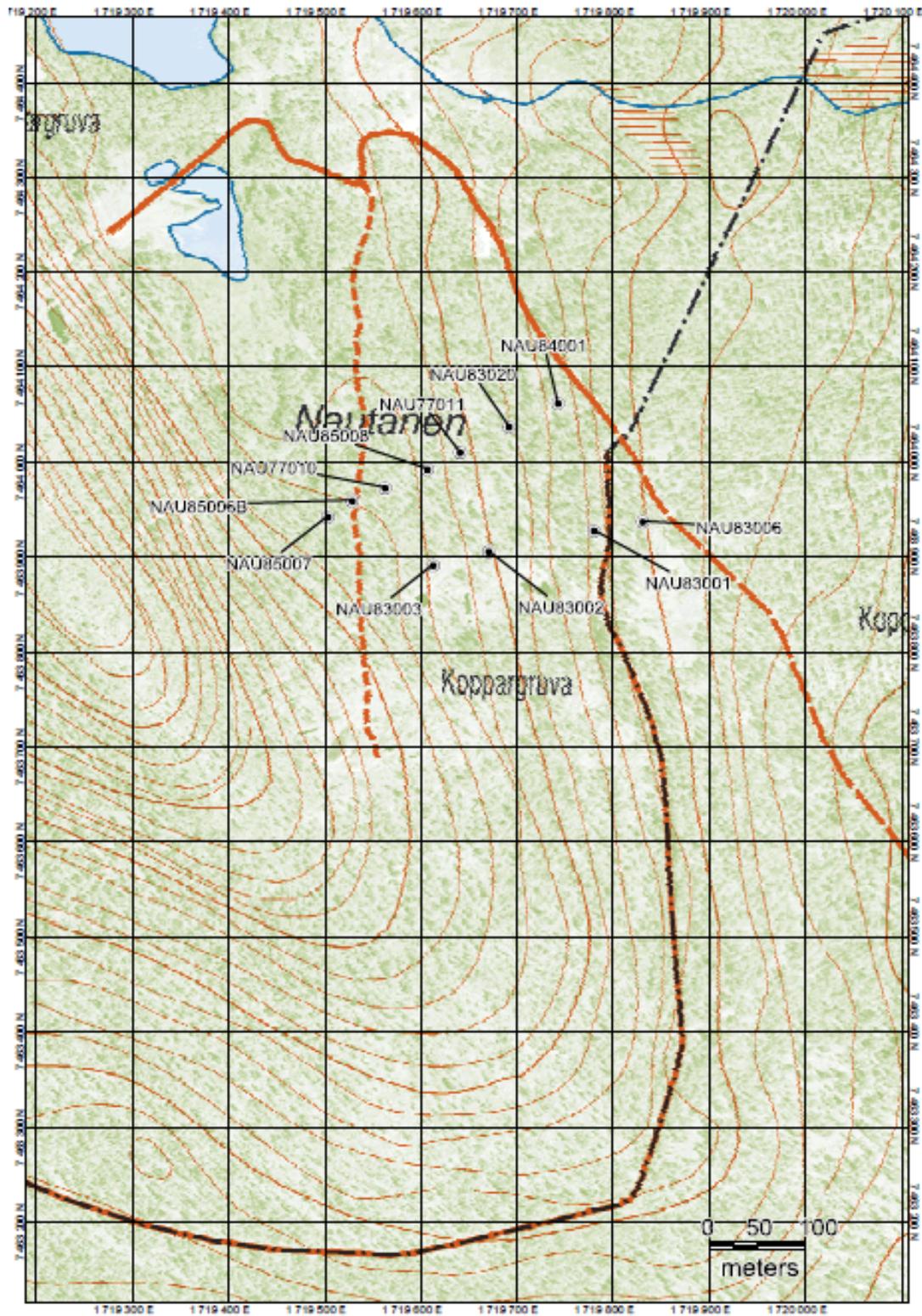
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Appendix A. Location of drill holes studied in this thesis



## Appendix B. Thinsection locations and descriptions

### Profile 5040N

Sample	Depth (m)	Rock Type	Comment
NAU77010 1	214.50	Scap-Bt-Amph Gniess	Magnetite band, with epidote
NAU77010 2	233.75	Scap-Gt-Bt-Amph Gniess	Amphibole bands with epidote
NAU77010 3	244.50	Banded Gniess	
NAU77011	269.05	Epi-Gt-Bt Gniess	Magnetite impregnation
NAU83020 1	9.74	Scap-Bt Gniess	
NAU83020 2	45.55	Epi-Scap-Bt Gniess	
NAU83020 3	60.69	Scap-Gt-Bt Gniess	
NAU83020 4	196.55	Scap-Gt-Bt Gniess	Calcite veined, epi/K altered
NAU84001	230.32	Gt-Ser Gniess	Metasedimentary(?)
NAU85006 1	33.75	Epi-Scap-Gt-Bt-Amph Gniess	
NAU85006 2	72.88	Scap-Gt-Bt-Amph Gniess	
NAU85006 3	122.10	Skarnic Bt-Amph Gniess	K, epidote altered
NAU85007 1	108.30	Scap-Bt Gniess	Albite haloed amphibole bands
NAU85007 2	124.57	Hem-Skarnic Gniess	Hematite, K alteration
NAU85007 3	215.40	Scap-Bt Gniess	Calcite veined

### Supplementary thin sections prepared by the SGU

Relative frequency of ore minerals in selected thinsections as described by Hälenius (1983)													
DDH	Depth (m)	Mag	Cpy	Py	Po	Au	Bor	Sph	Mo	Bis	Bis Tell	Car	Gal
NAU83001	270,50	3	5	4		1		1		1	1		
NAU83002	114,08	5	4	3		1				1			1
NAU83002	144,40	5	5	3		1		1	2				1
NAU83003	197,68	5	3	3	1	1		2	1				
NAU83006	146,25	4	5	1		1	3		1	1	1	1	1

Appendix C. Profile 5040N logs- code answer key

CHA	ROCK TYPES	ROCK TYPES	ROCK TYPES
B Start of rock type S Start of structure M Start of matrix O Start of object V Section Comment A General Comment	82 Pyroclastic 83 Micro Crystals 84 Amphibolites 85 Garnet 86 Supracrustals 87 Amphibolites 94 Metasediments 95 Metovolcanics 189 Skarn 190 MIO CONG 191 BIOT-SKARN 192 AGYD GROUND 193 SPT 194 COG LOGS	82 Pyroclastic 83 Micro Crystals 84 Amphibolites 85 Garnet 86 Supracrustals 87 Amphibolites 94 Metasediments 95 Metovolcanics 189 Skarn 190 MIO CONG 191 BIOT-SKARN 192 AGYD GROUND 193 SPT 194 COG LOGS	For structure - mineralized grain - additional digits can be used For example: xyz1xyz2 1 = Rock, little, diffuse 2 = Strong, much, obvious/strong leptonation etc. 3 = Here and there, locally, in places can be used to clarify the codes
			<b>STRUCTURES</b> 59 basal 60 basal 61 vertical 62 horizontal 63 heterogeneous 64 foliated 65 folded 67 altered 70 Biotite bands 71 Amphibole bands 72 Sphinct - Sph 73 Sphinct - Sph 74 Sphinct 75 Sphinct 76 Sphinct 77 Quartz interbed 78 Foliation interbed 79 Metamorph 80 Sphinct 81 Sphinct 82 Sphinct 83 Sphinct 84 Sphinct 85 Sphinct 86 Sphinct 87 Sphinct 88 Sphinct 89 Sphinct 90 Sphinct
			<b>MINERAL</b> 1 Actinolite 2 Amphibole 3 Amphibole 4 Amphibole 5 Amphibole 6 Amphibole 7 Amphibole 8 Biotite 9 Biotite-amphibole 10 Chlorite 11 Epidote 12 Epidote 13 Epidote 14 Epidote 15 Epidote 16 Epidote 17 Epidote 18 Epidote 19 Epidote 20 Epidote 21 Epidote 22 Epidote 23 Epidote 24 Epidote 25 Epidote 26 Epidote 27 Epidote 28 Epidote 29 Epidote 30 Epidote 31 Epidote 32 Epidote 33 Epidote 34 Epidote 35 Epidote 36 Epidote 37 Epidote 38 Epidote 39 Epidote 40 Epidote 41 Epidote 42 Epidote 43 Epidote 44 Epidote 45 Epidote 46 Epidote 47 Epidote 48 Epidote 49 Epidote 50 Epidote 51 Epidote 52 Epidote 53 Epidote 54 Epidote 55 Epidote 56 Epidote 57 Epidote 58 Epidote 59 Epidote 60 Epidote 61 Epidote 62 Epidote 63 Epidote 64 Epidote 65 Epidote 66 Epidote 67 Epidote 68 Epidote 69 Epidote 70 Epidote 71 Epidote 72 Epidote 73 Epidote 74 Epidote 75 Epidote 76 Epidote 77 Epidote 78 Epidote 79 Epidote 80 Epidote 81 Epidote 82 Epidote 83 Epidote 84 Epidote 85 Epidote 86 Epidote 87 Epidote 88 Epidote 89 Epidote 90 Epidote



Appendix C. Profile 5040N logs- NAU85007

Grafisk beskrivning		Bolliden Mineral AB		BasSystem	Kartblad	Datalod	Borrplan	Bl. Nr.						
Namn: 1041		Datum: Dec 1 / 07		N/A				25 av 7						
N-koordinat (Y)	E-koordinat (X)	Z-koordinat (Z)	Leita (grader)	Rikt. (grader)	Plan. Hög (m)	Diameter (mm)	Körhast							
m	Struktur	Kornstruktur	Prov		C B A	Bergart	Struktur	Mineral	Korn- størrelse	Färg	Obj.		V-B 1 av 20	Typ
			Pa	Ta							Sida			
0		Jord	0.00	2.63	T	87			3	75	20	20		30
2.63			2.63	5.83	T	87	half core	91	3	75				41
5	SA		5.83	11.00	T	87	with also half core	91	3	75				41
10	SA		11.00	16.00	T	87	half core	91	3	75				41
15	SA 70		16.00	21.00	T	82	half core	91	3	75	20	20		45
20			21.00	26.00	T	82	half core	91	3	88				41
25	SA 70		26.00	31.00	T	87	half core	91	3	88				41
30	SA		31.00	36.00	T	87	half core	91	3	73				41
35	SA		36.00	42.25	T	87	half core	91	4	88	20	20		41
40			42.25	48.58	T	87		91	3	88				41
45														
50														

Appendix C. Profile 5040N logs- NAU85007 (cont)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datakod	Borrplats		Bh. Nr.								
Namn: <i>lan</i>		Datum: <i>Dec 2 / 09</i>		<i>NAU</i>					<i>85007</i>								
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)		Lutn. (grader)	Rikt. (grader)	Plan. längd (m)	Diameter (mm)		Krökmått								
m	Struktur	Kornstorlek				Prov		C H A	Bergart	Struktur	Mineral	Korn- storl.	Färg	Obj. Sida	V-I 2	V-II av	Typ 20
		lera	0.5	2	8	32	Från										
50	<i>SA</i>	<i>CPY</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	48.50	53.50	<i>83</i>	<i>48</i> <i>67.3</i> <i>78.3</i> <i>82</i>	<i>85</i> <i>92</i>	3	73				91
55	<i>SA</i>	<i>CPY</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	53.50	56.85	<i>83</i>	<i>half core</i> <i>67.3</i> <i>78.1</i>	<i>49</i> <i>12</i>	3	73				91
60	<i>SA</i>	<i>CPY</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	56.85	60.00	<i>83</i>	<i>half core</i> <i>67.3</i> <i>78.1</i> <i>82</i>	<i>49</i> <i>12</i>	3	73	20	20		20 91
65	<i>SA</i>	<i>CPY</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	60.00	65.00	<i>83</i>	<i>48</i> <i>67.3</i> <i>78.1</i> <i>82</i>	<i>19</i> <i>85</i>	3	73				91
70	<i>SA</i>	<i>CPY</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	65.00	70.00	<i>83</i>	<i>with albite</i> <i>48</i> <i>67.3</i> <i>78.1</i> <i>82</i>	<i>85</i> <i>99</i>	3	73				91
75	<i>SA</i>	<i>CPY</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	70.00	76.00	<i>83</i>	<i>48</i> <i>67.3</i> <i>78.1</i> <i>82</i>	<i>85</i> <i>99</i>	3	73	20	20		23 91
80	<i>SA</i>	<i>CPY</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	76.00	81.40	<i>83</i>	<i>48</i> <i>67.3</i> <i>78.1</i> <i>82</i>	<i>49</i> <i>12</i>	3	73				91
85	<i>SA</i>	<i>CPY</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	81.40	87.53	<i>83</i>	<i>48</i> <i>67.3</i> <i>78.1</i> <i>82</i>	<i>49</i> <i>12</i>	3	73	20	20		20 91
90	<i>SA</i>	<i>CPY</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	87.53	91.43	<i>83</i>	<i>48</i> <i>67.3</i> <i>78.1</i> <i>82</i>	<i>85</i> <i>99</i>	3	73				91
95	<i>SA</i>	<i>CPY</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	91.43	95.10	<i>83</i>	<i>48</i> <i>67.3</i> <i>78.1</i> <i>82</i>	<i>85</i> <i>99</i>	3	73				91
100	<i>SA</i>	<i>CPY</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	<i>OS</i>	95.10	98.40	<i>83</i>	<i>48</i> <i>67.3</i> <i>78.1</i> <i>82</i>	<i>85</i> <i>99</i>	3	73				91

Appendix C. Profile 5040N logs- NAU85007 (cont)

Grafisk kartering		Boliden Mineral AB		Bas/System		Kartblad	Datakod	Borrplats	Bh. Nr.										
Namn: IAN		Datum: Dec. 3 109		NAU					85007										
N-koord. (Y)		E-koord. (X)		Z-koord. (Z)		Lutn. (grader)		Rikt. (grader)		Plan. längd (m)	Diameter (mm)		Krökmått						
m	Struktur	Kornstorlek					Prov		c H A	Bergart	Struktur	Mineral	Korn- storl.	Färg	Obj.	V-I	V-II	Typ	
		lera	0.5	2	8	32	Från	Till											Sida
100	b9 b10 SA	os	os	os	os	os	98.80	103.80	NAU	83	with albite 48 81.3 99	58 79 99	3	73	20	20		20 91	
							103.80	108.80	NAU	83	with albite 48 81.3 99	58 79 99	3	73				91	
105	TS gaochum SA	os	os	os	os	os	108.80	113.80	NAU	83	with albite T.S. for gaochum	58 79 99	3	73	108.30	m			91
							109.40	113.80	NAU	83	with albite 48 81.3 99	58 79 99	3	73				91	
110	b10 SA	os	os	os	os	os	113.80	118.80	NAU	83	with albite 48 81.3 99	58 79 99	3	73	20	20		20 91	
115	b11	os	os	os	os	os	118.80	123.80	NAU	83	with albite 48 81.3 99	58 79 99	3	73				91	
120	SA	os	os	os	os	os	123.80	124.38	NAU	87	with albite 48 81.3 99	58 79 99	3	7				91	
125	b12 TR	os	os	os	os	os	124.38	128.80	NAU	87	gaochum 78.3 81.1 99	72 99 99	3	73				91	
							128.80	133.80	NAU	83	with albite 48 81.3 99	58 79 99	3	73	20	20		20 91	
135	b12 b13 SA	os	os	os	os	os	133.80	138.80	NAU	83	with albite 48 81.3 99	58 79 99	3	73				91	
140		os	os	os	os	os	138.80	143.80	NAU	87	with albite 48 81.3 99	58 79 99	3	88				91	
145	SA	os	os	os	os	os	143.80	148.80	NAU	83	with albite 48 81.3 99	58 79 99	3	73				15 91	
150	b13 b14	os	os	os	os	os			NAU		with albite 48 81.3 99	58 79 99							

Appendix C. Profile 5040N logs- NAU85007 (cont)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datakod	Borrplats		Bh. Nr.								
Namn: Lau		Datum: Dec 3/09		NAU					85007								
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)		Lutn. (grader)	Rikt. (grader)	Plan. längd (m)	Diameter (mm)	Krökmått									
m	Struktur	Kornstorlek				Prov	CH	Bergart	Struktur	Mineral	Korn-storl.	Färg	Obj.	V-I	V-II	Typ	
		lera	0.5	2	8	32	Från	Till					Sida	4	av	20	
150	TR/SA					148.80	153.80	R	87	48 67.3 48.3 83 99.3	55 12 19 2	3	73				91
155	SA					153.80	158.80	R	87	48 67.3 83 99.3	55 17 2	3	73				91
160	b14 b15 SA/TR					158.80	163.70	R	87	48 67.3 78.3	19 12	3	73				91
165	SA/TR					163.70	168.20	R	87	48 81.1 99	55 22 30	3	73	20	20		25 91
170	b15 b16 SA/TR					168.20	173.20	R	87	48 67.3 111.1 83.3	19 55 15 85 2	3	73				91
175	SA					173.20	178.2	R	83	48 81.1 99.1	12 5	3	73				22 91
180	b16 b17 SA					178.20	183.50	R	83	10 cm section of rest is unaltered 48 81.1 99.1	78.1 99 46 55 85	3	73				91
185	SA					183.50	188.50	R	83	48 48.1 83.3 67.1	29 25 85 12	3	73	20	20		30 91
190	SA					188.5	193.5	R	83	48 48.1 111.3 67.3	29 25 85 12	3	73				91
195	b17 b18 SA/TR					193.5	198.5	R	83	48 111.1 83.3	29 25 85 12	3	73				91
200	SA/TR					198.5	201.80	R	87	NO halo 48 67 52	10 27 17	3	88				91

Appendix C. Profile 5040N logs- NAU85007 (cont)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datakod	Borrplats		Bh. Nr.									
Namn: IAN		Datum: Dec 3/09		NAU					85007									
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)		Lutn. (grader)	Rikt. (grader)	Plan. längd (m)		Diameter (mm)		Krökmått								
m	Struktur	Kornstorlek				Prov		C	Bergart	Struktur	Mineral	Korn-storl.	Färg	Obj.	V-I	V-II	Typ	
		lera	0.5	2	8	32	Från	Till	H					Sida	5	av	20	
200	SA					201.80	206.35		87	48	19 55 12 30	3	88	20	20			91
205	SA b18 b19 b20					206.35	211.00		83	48 half core	49 19 55 12	3	73					91
210	SA					211.00	215.65		83	48 blebs of calcite	48 55 12	3	73					91
215	SA b19 geochem b20					215.65	216.50		83	TS @ 215.40m	81	55						91
220	SA					216.50	222.5		83	geochem	48 81	3	73					91
225	SA					222.5	227.5		83	48 hematite	48 55 12	3	73					91
230	SA b20 b21					227.5	232.5		83	48	48 55 12	3	73					91
235	SA					232.5	237.5		83	48	48 55 12	3	73	20	20			91
240	SA b21 b22					237.5	242.0		83	48 with albite	48 55 12	3	73					91
245	SA					242.0	246.65		83	48	48 55 12	3	73					91
250	SA					246.65	251.65		87	48 calcite, hematite concentrated in of spacs, blebs, and small veins	19 55 12	3	73					91

Appendix C. Profile 5040N logs- NAU85007 (cont)

Grafisk kartering		Boliden Mineral AB				Bas/System		Kartblad	Datakod	Borrplats		Bh. Nr.						
Namn: <i>IAN</i>		Datum: <i>Dec 3/09</i>				<i>NAU</i>						<i>85007</i>						
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)				Lutn. (grader)		Rikt. (grader)	Plan. längd (m)		Diameter (mm)		Krökmått					
m	Struktur	Kornstorlek					Prov		C H A	Bergart	Struktur	Mineral	Korn- storl.	Färg	Obj. Sida	V-I 6	V-II av	Typ 20
		1en	0.5	2	8	32	Från	Till										
250	<i>b22</i> <i>b23</i>	<i>SA</i>	<i>06</i>	<i>05</i>	<i>06</i>	<i>06</i>	<i>251.65</i>	<i>256.65</i>	<i>UNKN</i>	<i>87</i>	<i>48</i>	<i>19</i> <i>55</i> <i>12</i>	<i>3</i>	<i>75</i>				<i>91</i>
255		<i>SA</i>	<i>06</i>	<i>05</i>	<i>06</i>	<i>06</i>	<i>256.65</i>	<i>261.65</i>	<i>UNKN</i>	<i>87</i>	<i>48</i>	<i>19</i> <i>55</i> <i>12</i>	<i>3</i>	<i>73</i>				<i>91</i>
260	<i>b23</i>	<i>SA</i>	<i>06</i>	<i>05</i>	<i>06</i>	<i>06</i>	<i>261.65</i>	<i>264.5</i>	<i>UNKN</i>	<i>87</i>	<i>48</i>	<i>19</i> <i>55</i> <i>12</i>	<i>3</i>	<i>73</i>				<i>91</i>
265	<i>b24</i>	<i>SA</i>	<i>06</i>	<i>05</i>	<i>06</i>	<i>06</i>	<i>264.5</i>	<i>268.9</i>	<i>UNKN</i>	<i>87</i>	<i>48</i>	<i>14</i> <i>55</i> <i>12</i>	<i>3</i>	<i>73</i>	<i>20</i>	<i>20</i>		<i>25</i> <i>91</i>
270	<i>b24</i> <i>b25</i>	<i>SA</i>	<i>06</i>	<i>05</i>	<i>06</i>	<i>06</i>	<i>268.9</i>	<i>274.10</i>	<i>UNKN</i>	<i>83</i>	<i>48</i>	<i>49</i> <i>55</i> <i>12</i>	<i>3</i>	<i>73</i>	<i>20</i>	<i>20</i>		<i>30</i> <i>91</i>
275	<i>b25</i>	<i>SA</i>	<i>06</i>	<i>05</i>	<i>06</i>	<i>06</i>	<i>274.10</i>	<i>278.35</i>	<i>UNKN</i>	<i>83</i>	<i>48</i>	<i>49</i> <i>55</i> <i>12</i>	<i>3</i>	<i>73</i>				<i>91</i>
280		<i>SA/TR</i>	<i>06</i>	<i>05</i>	<i>06</i>	<i>06</i>	<i>278.35</i>	<i>283.35</i>	<i>UNKN</i>	<i>83</i>	<i>48</i>	<i>50</i> <i>55</i> <i>12</i>	<i>3</i>	<i>73</i>				<i>91</i>
285	<i>b25</i> <i>b26</i>	<i>SA</i>	<i>06</i>	<i>05</i>	<i>06</i>	<i>06</i>	<i>283.35</i>	<i>287.65</i>	<i>UNKN</i>	<i>87</i>	<i>48</i>	<i>46</i> <i>55</i> <i>12</i>	<i>3</i>	<i>73</i>	<i>20</i>	<i>20</i>		<i>25</i> <i>91</i>
290		<i>SA</i>	<i>06</i>	<i>05</i>	<i>06</i>	<i>06</i>	<i>287.65</i>	<i>291.95</i>	<i>UNKN</i>	<i>87</i>	<i>48</i>	<i>48</i> <i>55</i> <i>12</i>	<i>3</i>	<i>73</i>				<i>91</i>
295																		
300																		

Appendix C. Profile 5040N logs- NAU85006

Grafisk kartering		Boliden Mineral AB		Bas/System		Kartblad		Datakod		Borrplats		Bh. Nr.							
Namn: <i>IAN</i>		Datum: <i>Nov 24/09</i>		<i>NAU</i>								<i>85006</i>							
N-koord. (Y)		E-koord. (X)		Z-koord. (Z)		Lutn. (grader)		Rikt. (grader)		Plan. längd (m)		Diameter (mm)							
m	Struktur	Kornstorlek					Prov		CH	Bergart	Struktur	Mineral	Korn-storl.	Färg	Obj. Sida	V-I	V-II	Typ	
		lera	0.5	2	8	32	Från	Till											
0		Jord					0.00	1.50	R	187									
		<i>sericite</i>					1.50	6.50	R	83	48	49 19 55 35	3	73	20	20			20 91
5		<i>SA</i>					6.50	11.95	R	83	48	49 14 55 30	3	73					91
		<i>ser.</i>									81.3 99 52.1	91							
10		<i>B1 SA</i>					11.95	16.95	R	83	48	49 19 55 30	3	73	20	20			20 91
		<i>B2 SA</i>									81.1 99	30							
15		<i>SA</i>					16.95	23.05	R	83	48	49 19 55 30	3	73					91
		<i>ser.</i>									81.1 99	91							
20		<i>B2 SA</i>					23.05	29.05	R	83	48	49 19 55 30	3	88					91
		<i>ser.</i>									67 78.3 99 52	30							
25		<i>B3 SA</i>					29.05	33.90	R	83	48	49 19 55 30	3	73					91
		<i>ser.</i>									67.3 78.1 99 52	30							
		<i>epi/kyan</i>									81.1 99	91							
		<i>foliation parallel TCA. Qtz vein runs down axis</i>									81.1 99	91							
30		<i>B3 SA</i>					33.90	34.50	R	83	48	49 19 55 30	3	73	20	20			15 91
		<i>ser.</i>									81.1 99	91							
35		<i>B4 SA</i>					34.50	39.43	R	83	48	49 19 55 30	3	73					91
		<i>ser.</i>									81.1 99	91							
		<i>parallel TCA 34.50 to 36.50, then back to 20° TCA</i>									81.1 99	91							
40		<i>SA/TR</i>					39.43	41.67	R	83	48	49 19 55 30	3	73	20	20			20 91
		<i>ser.</i>									81.1 99	91							
45		<i>B4 SA</i>					41.67	44.50	R	83	48	49 19 55 30	3	73	20	20			20 91
		<i>ser.</i>									81.1 99	91							
50		<i>B5 SA</i>					44.50	46.60	R	83	48	49 19 55 30	3	88					91
		<i>ser.</i>									81.1 99	91							

Appendix C. Profile 5040N logs- NAU85006 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System		Kartblad		Datakod		Borrplats		Bh. Nr.						
Namn: Ian		Datum: Nov. 24/09		NAU								85006						
N-koord. (Y)		E-koord. (X)		Z-koord. (Z)		Lutn. (grader)		Rikt. (grader)		Plan. längd (m)		Diameter (mm)						
m	Struktur	Kornstorlek				Prov		C H A	Bergart	Struktur	Mineral	Korn- stori.	Färg	Obj.		V-I	V-II	Typ
		lera	0.5	2	8	32	Från							Till	Sida			
50	SA TR		OG			46.60	51.50		87	48	14 55 12	3	88	20	20			91
			OG			51.50	54.40		87	48 78.3 48	19 55 12	3	73					91
55	SA TR SA SA		OG			54.40	57.00		albite 83	46 46 67.3 90 51.1	19 55 12	3	75					91
60	SA Q		OG			57.00	61.00		87	48 67 78.3 81.3	19 55 12	3	75					91
65	SA		OG			61.00	64.80		87	48 67 78.3 81.3	19 55 12	3	73					91
70	SA SA		OG			64.80	70.15		87	48 67 78.3 81.3	19 55 12	3	73					91
75	SA		OG			70.15	70.75		87	48 67 78.3 81.3	19 55 12	3	73	20	20			91
	SA		OG			70.75	76.08		87	48 67 78.3 81.3	19 55 12	3	73					91
80	SA		OG			76.08	81.08		87	48 67 78.3 81.3	19 55 12	3	73	20	20			91
85	SA		OG			81.08	86.08		87	48 67 78.3 81.3	19 55 12	3	73					91
	SA		OG			86.08	91.08		87	48 67 78.3 81.3	19 55 12	3	88	20	20			91
90	SA TR		OG			91.08	95.10		87	48 67 78.3 81.3	19 55 12	3	73					91
95	SA		OG			95.10	100.10		87	48 67 78.3 81.3	19 55 12	3	73					91
100																		

Appendix C. Profile 5040N logs- NAU85006 (cont.)

Grafisk kartering		Boliden Mineral AB				Bas/System		Kartblad	Datakod	Borrplats			Bh. Nr.					
Namn: IAN		Datum: Nov 25/09				NAU							85006					
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)		Lutn. (grader)		Rikt. (grader)		Plan. längd (m)		Diameter (mm)		Krökmått						
m	Struktur	Kornstorlek				Prov		C H A	Bergart	Struktur	Mineral	Korn- storl.	Färg	Obj. Sida	V-I 3	V-II av	Typ	
		lera	0.5	2	8	32	Från											Till
100	SA/TR	os	os	os	os	os	106.10	106.0	R	83	48 48.1 67.1 81.1 81.1	55 19 12 30	3	73	20	20		20 91
105	b9 b10 SA/TR	os	os	os	os	os	106.0	109.6	R	83	48 67 78.3	19 55 12	3	73				91
110	SA	os	os	os	os	os	109.6	13.59	R	83	48 67 78.3	19 55 12	3	73	20	20		12 91
115	b0 b1 SA/TR	os	os	os	os	os	13.59	18.50	R	83	48 67.1 81.1 99.3	55 19 12 22	3	73				91
120	geochem TS SA/TR	os	os	os	os	os	121.50	122.10	R	87	94 78 27	12	3	88				91
							122.10	127.50	R	87	94 78 27	12	3	88				91
125	b11 b12 SA	os	os	os	os	os	127.50	132.40	R	87	81.1 11.1 52 67 78.1	37 32 55 91 19 55	3	88				91
135	b12 b13 SA/TR	os	os	os	os	os	132.40	137.0	R	87	49.3 52 83 48 67 78.1 81.1 81.1	91 2 55 12 22	3	73	20	20	20 91	
							137.0	141.50	R	87	48 67 78.1 81.1 67.1	55 12 22	3	73			91	
140	SA	os	os	os	os	os	141.50	144.70	R	87	48 48.3 52.3 67.1	55 19 12	3	73	20	20		22 91
							144.70	149.70	R	83	48 52.3	55 48	3	73	20	20		22 91
145	SA/TR	os	os	os	os	os			R	metased	81.3 67.1 99	30 12						
150	SA	os	os	os	os	os			R	qtz vein								

Appendix C. Profile 5040N logs- NAU85006 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System		Kartblad	Datakod	Borrplats		Bh. Nr.							
Namn: lan		Datum: Nov 30/09		NAU						85006							
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)	Lutn. (grader)	Rikt. (grader)	Plan. längd (m)	Diameter (mm)	Krökmått										
m	Struktur	Kornstorlek				Prov		C H A	Bergart	Struktur	Mineral	Korn- storl.	Färg	Obj. Sida	V-I 4	V-II av	Typ 20
		100	50	20	8	32	Från										
150	b14 SA	os og mag os og				149.70	154.60	R	83	52.1 48 83 with a bit of 94.1 67.1	48 19 55 2	3	73	20	20		30 91
155	SA	os og mag os og				154.6	159.10	R	83	52.1 48 83 94.1 67.1	48 19 55 2	3	73				91
160	SA	os og mag os og				159.10	163.70	R	83	52.1 48 83 94.1 67.1	48 19 55 2	3	73	20	20		30 91
165	b14 b15 SA TR	os og mag os og				163.70	168.70	R	87	48 48.3 67.3 99.3 99.1	55 19 2	3	73				91
170	SA	os og mag os og				168.70	173.70	R	87	48 48.3 67.3 99.3 99.1	55 19 2	3	73	20	20		30 91
175	b15 b16 SA	os og mag os og				173.70	178.70	R	87	48 48.3 67.3 99.3 99.1	55 19 2	3	73				91
180	SA	os og mag os og				178.70	183.70	R	87	48 48.3 67.3 99.3 99.1	55 19 2	3	73				91
185	b16 b17 SA TR	os og mag os og				183.70	188.0	R	87	48 48.3 67.3 99.3 99.1	55 19 2	3	73				91
190	SA TR	os og mag os og				188.0	192.0	R	83	48 48.3 67.1 81.1 82	44 19 55 17 99 30 91	3	73				91
195	b17 b18 SA TR	os og mag os og				192.0	196.0	R	47	48 48.3 67.3 99.3 99.1	55 19 2	3	73				91
200	SA TR	os og mag os og				196.00	200.0	R	67	48 48.3 67.3 99.3 99.1	55 19 2	3	73				91

Appendix C. Profile 5040N logs- NAU85006 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datalod	Borrplans	Bh. Nr.								
Name: IAN		Datum: Nov 30/09		NAU				85006								
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)	Lata. (grader)		Rikt. (grader)	Plan. Hög (m)	Diameter (mm)		Krökmitt							
m	Struktur	Kornstorlek				Prov		Bergart	Struktur	Mineral	Kornstorl.	Färg	Obj. Sida	V-I 5	V-II av	Typ 20
		100	0.5	2	4	100	20									
200		200.0	202.4	87	48	19 31	3	75	20	20					90	
		202.4	206.85	87	48	19 31	3	75								91
205		206.85	210.0	87	48	19 31	3	88								91
210		210.0	214.50	87	48	19 31	3	88	garnets up to 5.0cm. Half core							91
		214.50	219.00	87	48	19 31	3	78	half core, 1.8cm garnets in places							91
215		219.00	224.0	87	48	19 31	3	73	garnet 5-30% in core, up to 3cm							91
220		224.00	229.10	87	48	19 31	3	77	half core, imp. garnet							91
225		229.10	232.10	87	48	19 31	3	73	half core core missing, no explanation							
		232.10	234.95	87	48	19 31	3	73								91
235		234.95	238.50	87	48	19 31	3	73	half core weak garnet pollution much smaller							90
240	238.5	243.0	87	48	19 31	3	88	end of hole							91	
245																
250																

Appendix C. Profile 5040 logs- NAU77010

Grafisk kartering		Boliden Mineral AB		Bas/System	Karthlad	Datadod	Borrplats	Bh. Nr.						
Namn: 5040		Datum: Nw20/09		NAU			Nautama	77010						
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)	Luts. (grader)		Rikt. (grader)	Flas. lingsl (m)	Diameter (mm)		Krdkmett					
5040	1470		55		270									
m	Struktur	Kornstorlek		Prov		Bergart	Struktur	Mineral	Kornstorl.	Färg	Obj. Sida	V-I	V-II	Typ
		kv	0.5	2	4	12	Fels	78	C					
0	Jord													
0	SA						187							
0	Reduced						93							
0							48							45
3.31							reduced part of sample 83							91
3.31							48							
8.31							half core remaining							91
8.31							83							
13.31							garnet after 12.31							
13.31	b1						half core							
13.31	b2						83							
15.31							48							55
15.31							48							41
18.00							half core							
18.00							83							91
22.70							half core							
22.70	b2						83							91
22.70	b3						48							
27.70							half core							
27.70							83							91
32.70							half core							
32.70	b3						83							91
32.70	b4						48							
37.70							about 5cm between half core							
37.70							83							91
41.64							half core							
41.64							83							
46.40							half core							
46.40							83							45
46.40	b4						48							91
46.40	b5						48							
51.40							half core							
51.40							83							91
57.1							half core							
57.1							83							
78.1							half core							
78.1							83							

Appendix C. Profile 5040 logs- NAU77010 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System		Kartblad	Datad	Borrplats		Bh. Nr.							
Namn: <i>lav</i>		Datum: <i>Nov 20/09</i>		<i>NAU</i>						<i>77010</i>							
N-koordinat (Y)		E-koordinat (X)		Z-koordinat (Z)		Längd (grader)		Bredd (grader)		Plan. längd (m)		Diameter (mm)		Körknävt			
m	Struktur	Korastorlek					Prov		Bergart	Struktur	Mineral	Kornstef.	Fleg	Obj. Sida	V-I	V-II	Typ
		10	25	2	8	32	10	78									
50							51.40	86.0	R	85		3	73	20	20		49 91
55	<i>b5</i> <i>b6</i>						56.00	61.00	R	85		3	73				91
60							61.00	66.00	R	85		3	73				91
65	<i>b6</i> <i>b7</i>						66.00	71.00	R	85		3	73	20	20		91
70							71.00	76.00	R	85		3	82				91
75	<i>b7</i> <i>b8</i>						76.00	81.47	R	85		3	73	20	20		65 91
80							81.47	86.00	R	85		3	73				91
85							86.00	91.00	R	85		3	73				91
90	<i>b8</i> <i>b9</i>						91.00	96.00	R	85		3	73				91
95							96.00	101.00	R	85		3	73				91
100																	

Appendix C. Profile 5040 logs- NAU77010 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datakod	Borrplats	Bh. Nr.						
Namn: <i>AN</i>		Datum: <i>Nov 21 / 09</i>		<i>NAU</i>				<i>77010</i>						
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)	Lata. (grader)		Rikt. (grader)	Plan. längd (m)	Diameter (mm)	Körskikt						
m	Struktur	Kornstorlek lex 0.5 2 3 32	Prov		C R A	Bergart	Struktur	Mineral	Korn- stort.	Färg	Obj.	V-I	V-II	Typ
			Fids	TR							Sida	3	av	20
100			101.00	106.00		S3	with albite half core	2 12	3	75				91
105			106.00	111.00		S3	with albite half core	2 41	3	73				91
110			111.00	116.00		S3	after S3 half core	2 42	3	75				91
115			116.00	121.00		S3	half core	2 41	3	73				91
120			121.00	126.00		S3	half core	2 41	3	73				91
125			126.00	131.00		S3	half core	2 41	3	73				91
130			131.00	136.00		S3	half core	2 41	3	75				91
135	L12 L13		136.00	141.00		S3	with albite half core	2 41	3	75				91
140			141.00	146.00		S3	half core	2 41	3	73				91
145	L13 L14		146.00	151.00		S3	half core	2 41	3	73				91
150	ST						half core	2 41	3	73				91











Appendix C. Profile 5040 logs- NAU77011 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datadok	Borrplats	Bh. Nr.									
Name: 194		Datum: Nov 16/09		NAU				779/1									
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)	Latn. (grader)	Rikt. (grader)	Plas. längd (m)	Diameter (mm)		Krökmitt									
m	Struktur	Korasterlek				Prov		C H A	Bergart	Struktur	Mineral	Kora- storl.	Färg	Obj. Sida	V-I 3	V-II av	Typ 20
		1m	0.5	2	8	32	Fila										
100	SA b9 b10 b11	[Diagram]	98.98	102.81	83	48.3	81	83	48.3	12	3	75					91
105			102.83	107.88	109	78	78	11									
110	SA b10 b11	[Diagram]	107.83	112.48	109	67	49	0.3	0m between	100	34	100	34	100	34	100	22
115			112.48	117.48	83	67	49	0.3	garnets	83	3	98	20	20			50
115			117.48	123.75	83	67	49	0.3		83	3	98	20	20			50
120	R SA/TR b12 b13	[Diagram]	123.55	126.57	83	78.1	48	49	intrusive	83	3	73	20	20			55
125			126.57	131.45	83	48	99		meta-sediment?	83	3	73	20	20			60
130	SA/TR b12 b13	[Diagram]	131.45	135.98	83	48	99		half core	83	3	73	20	20			91
135			135.98	139.57	83	48	99			83	3	73	20	20			60
140	SA/TR b13 b14	[Diagram]	139.57	146.70	83	48	99		biotite at top. Ser schist	83	3	73	20	20			91
145			146.70	151.70	83	48	99		half core	83	3	73	20	20			60
150																	

Appendix C. Profile 5040 logs- NAU77011 (cont.)

Gruftisk kartering		Boliden Mineral AB		Bas/System		Kartblad		Datakod		Borrplats		Bå. Nr.					
Namn: Jan		Datum: Nov 17/09		NAU								77011					
N-koordinat (Y)		E-koordinat (X)		Z-koordinat (Z)		Lata. (grader)		Rikt. (grader)		Plan. längd (m)		Diameter (mm)		Körkmått			
m	Struktur	Kornstorlek					Prov		Bergart	Struktur	Mineral	Kornstorl.	Färg	Obj. Sida	V-I av	V-II av	Typ
		100	63	2	2	32	70	10									
150							161.70	166.70	87	with	48-3	3	75	20	20		91
155							156.70	161.70	82	~2mm	48-3	3	75	20	20		91
160	b14 TR						161.70	166.70	87	very well	48-3	3	75				91
165	b15 SA						166.70	167.40	87	at	48-3	3	75				91
170	b15 SA						167.40	171.70	87	thin bands	48-3	3	75				91
175	b16 SA						171.70	176.70	83		48-3	3	75	20	20		91
180	b17 SA						176.70	181.70	83		48-3	3	75	20	20		91
185	b17 SA						181.70	186.70	83	thin lines	48-3	3	75				91
190	b17 SA						186.70	191.70	83	half core	48-3	3	75				91
195	b17 SA						191.70	196.70	83	194.90	48-3	3	75				91
200	b19 SA						196.70	201.70	83	from 202	48-3	3	75				91



Appendix C. Profile 5040 logs- NAU77011 (cont.)

Gruftsk kartering		Boliden Mineral AB		Bussystem		Kartblad		Datakod		Borrplats		Bl. Nr.						
Namn: <i>14w</i>		Datum: <i>Nov 19/09</i>		<i>NAU</i>								77011						
N-koord. (Y)		E-koord. (X)		L-koord. (Z)		Lutn. (grader)		Rikt. (grader)		Plan. längd (m)		Diameter (mm)		Körknutt				
m	Struktur	Kornstorlek					Prov		C	Bergart	Struktur	Mineral	Korn-storl.	Färg	Obj. Sida	V-I 6	V-II av 20	Typ
		ltm	0.5	2	8	22	Fila	TR										
250	b22 SA						249.0	253.0		82	82	12 30 91	3 75					91
255	b23 SA						253.0	257.0		82	half core	12	3 75					91
260	b23 SA						262.0	264.44		82	flour. to log 82	49 80 83	3 77	20	20			83 97
265	b23 SA/TR						264.44	264.44		82	with a bit with halo	47 83	3 73					91
270	b24 SA/TR						264.44	267.74		82	4 sections, but is very dark, with 4-5% 264.44	12 12 12 12	3 73	20	20			83 91
275	b25 SA/TR						273.35	273.35		83	is dark green quartz	54.3 83	3 73					91
280	b25 SA/TR						278.24	278.96		83	is dark green quartz	41 95	3 73					91
285	b26 SA						278.95	283.95		83	thin line of in vugs white + pink w/ thin. + 3 in wide	22 91	3 73	20	20			83 91
290	b26 SA						288.95	288.95		83	thin line of in vugs white + pink w/ thin. + 3 in wide	22 91	3 73					91
295	b26 SA						293.95	297.75		82	half core	22 91	3 73					91
300	b26 SA						297.75	300.28		81	half core	12 91	3 73					91

Appendix C. Profile 5040 logs- NAU77011 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datadod	Beskrivning	Bh. Nr.				
Namn: <i>Jan</i>		Datum: <i>Nov 19/09</i>		<i>NAU</i>				<i>77011</i>				
N-koordinat (Y)	E-koordinat (X)	Z-koordinat (Z)	Längd (grader)	Bredd (grader)	Plan. Höjd (m)	Diameter (mm)	Körkvalitet					
m	Struktur	Kornstorlek	Prov	Bergart	Struktur	Mineral	Kornstorl.	Färg	Obj. Sida	V-I av	V-II av	Typ
		100 0.5 2 4 32	Fals TA	C H A					7	7	20	
300	SA	Q + feldsp.	300.88 304.88	87	94.5 81.3 67.5 67.5	38 12	5	88				71
	SA	geochim	304.00 304.66	87	67 69 11.1	12	3	88				91
305	SA	geochim	304.66 309.66	87	94 67	1 12 82 82	3	88				91
310	SA	geochim	309.66 314.66	87	67 47.5 11.1 11.1 48.3 48.3	12	3	88	20	20		88
315	SA	geochim	314.66 319.66	87	48 99.3 82.3 82.3	8 12 91	3	73				91
	SA	geochim	319.66 322.48	82	48 48.3 82.3 82.3	19 88	3	75	20	20		88 91
320	SA	geochim	322.48 323.08	82	48 67.3	19 12	3	75				91
	SA	geochim	323.08 326.99	82	48.3 82.3 82.3	19 12	3	75				91
325		EOH		slut!								
335												
340												
345												
350												

Appendix C. Profile 5040 logs- NAU85008

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datadkod	Borrplans	Bk. Nr.							
Namn: /au		Datum: Nov 27/09		NAU				85008							
N-koordinat (Y)	E-koordinat (X)	Z-koordinat (Z)		Lats. (grader)	Rikt. (grader)	Plan. Rngl (m)		Diameter (mm)		Krdkvalitet					
m	Struktur	Kornstorlek				Prov	Bergart	Struktur	Mineral	Kornstorl.	Färg	Obj. Sida	V-I I	V-II av 20	Typ
		100	0.5	2	4	32									
0	Jord	0.00	2.00	2.00	187										
		2.00	4.90	4.90	83										91
5		4.90	10.50	10.50	83										91
10		8.50	11.10	11.10	83										91
15		11.10	16.40	16.40	83										91
20		16.40	19.00	19.00	83										91
25		19.00	22.30	22.30	87										91
30		22.30	27.30	27.30	87										91
35		27.30	32.30	32.30	87										91
40		32.30	37.30	37.30	87										91
45		37.30	42.30	42.30	87										91
50		42.30	46.22	46.22	87										91
		46.22	50.22	50.22	87										91
					83										91

Appendix C. Profile 5040 logs- NAU85008 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datakod	Borrplans		Bh. Nr.								
Namn: 1201		Datum: Nov. 29/09		NAU					5040								
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)		Lutn. (grader)	Rikt. (grader)	Flsa. Bldgd (m)	Diameter (mm)		Krökmått								
m	Struktur	Kornstorlek					Prov	C H A	Bergart	Struktur	Mineral	Korn- storl.	Flög	Obj. Sida	V-I 2	V-II av	Typ 20
		100	63	2	0.5	0.2											
50						50.22	54.00	LS	87	48	12 12 12	3	75	20	20		41
						54.35	59.30	LS	87	foliation varies from 30° to 45° TCA	12 12 12	3	7				91
55	b5 b6					59.30	62.25	LS	87	48	19 12 12	3	73	20	20		23 91
60						62.25	68.60	LS	87	48	19 12 12	3	88				91
65	b6 b7					68.60	69.15	LS	87	48	19 12 12	3	75				91
70						69.15	73.10	LS	87	48	19 12 12	3	88				91
75	b7 b8					73.10	79.00	LS	87	half core	19 12 12	3	73	20	20		27 41
						79.00	84.30	LS	87	with albite	19 12 12	3	73				91
85						84.30	89.60	LS	87	48	19 12 12	3	73				91
						89.60	94.60	LS	87	48	19 12 12	3	73	20	20		20 41
90						94.60	99.00	LS	87	48	19 12 12	3	73				91
95																	
100																	

Appendix C. Profile 5040 logs- NAU85008 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System		Kartblad		Datakod		Borrplats		Bl. Nr.						
Namn: IAN		Datum: Nov 29, 09		NAU								85008						
N-koord. (Y)		E-koord. (X)		Z-koord. (Z)		Lutn. (grader)		Rikt. (grader)		Plan. Bngd (m)		Diameter (mm)						
m	Struktur	Kornstorlek					Prov		c	Bergart	Struktur	Mineral	Korn-storl.	Flög	Obj. Sida	V-I 3	V-II av	Typ
		les	0.5	2	8	32	Fsk	TR										
100	b10	os	os	os	os	os	105.00	105.21	NAU	87	49 81.1 73.3 67.1	53 22	3	73	20	20		40 41
	sk/TR	os	os	os	os	os	107.74	107.50	NAU	87	foliation various 94.1 86.3 67	12 19 28 25 20	3	88				91
105		os	os	os	os	os	107.50	112.50	NAU	83	48 81.1 81.1 99.1	28 25 20	3	73				91
110	b10	os	os	os	os	os	112.50	117.50	NAU	83	48 81.1 81.1 99.1	28 25 20	3	73				91
	sk/TR	os	os	os	os	os	117.50	122.50	NAU	87	48 81.1 81.1 99.1	28 25 20	3	73				91
115		os	os	os	os	os	122.50	126.90	NAU	87	48 81.1 81.1 99.1	28 25 20	3	73				91
120	b11	os	os	os	os	os	126.90	131.90	NAU	87	48 81.1 81.1 99.1	28 25 20	3	73				91
	sk/TR	os	os	os	os	os	131.90	136.90	NAU	83	48 81.1 81.1 99.1	28 25 20	3	73	20	20		40 41
125		os	os	os	os	os	136.90	140.83	NAU	83	48 81.1 81.1 99.1	28 25 20	3	73				91
130	b12	os	os	os	os	os	140.83	144.80	NAU	87	48 81.1 81.1 99.1	28 25 20	3	73				91
	sk/TR	os	os	os	os	os	144.80	148.80	NAU	87	48 81.1 81.1 99.1	28 25 20	3	73				91
135	b13	os	os	os	os	os	148.80	150.80	NAU	87	48 81.1 81.1 99.1	28 25 20	3	73				91
	sk/TR	os	os	os	os	os	150.80	150.80	NAU	87	intrusive upto 0.4cm scapolite	65 22 12	3	73				91
140	b14	os	os	os	os	os	150.80	150.80	NAU	87	intrusive upto 0.4cm scapolite	65 22 12	3	73				91
145		os	os	os	os	os	150.80	150.80	NAU	87	intrusive upto 0.4cm scapolite	65 22 12	3	73				91
150		os	os	os	os	os	150.80	150.80	NAU	87	intrusive upto 0.4cm scapolite	65 22 12	3	73				91

Appendix C. Profile 5040 logs- NAU85008 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System		Kartblad	Datadkod	Borrplats		Bh. Nr.						
Name: <i>IAN</i>		Datum: <i>Nov 29/09</i>		<i>NAU</i>						<i>85008</i>						
N-koord. (Y)		E-koord. (X)		Z-koord. (Z)		Lutn. (grader)		Rikt. (grader)		Plan. Högd (m)		Diameter (mm)		Körkmit		
m	Struktur	Kornstorlek				Prov		Bergart	Struktur	Mineral	Kornstorl.	Flög	Obj.	V-I	V-II	Typ
		ltv	0.5	1	4	32	Fria						T8	Sida	4	av
150	st					160.80	164.43	87	48	68	3	75				91
	SA/TR					154.43	159.43	87	94.3	46	3	88	2.0	2.0		40
155	b14 b15					163.43	164.43	87	48	78.3 48 87.3 99.1	3	88				91
160	st					164.43	170.60	87	48	22	3	98	2.0	2.0		40
165	st					170.60	172.0	87	48	19 78.3 94.3 99.1	3	98				91
170	b16 b17					172.0	177.0	87	48	22	3	75				91
175	SA					177.0	182.0	87	48	19 52 40 77 88	3	73				91
185	b16 b17					182.0	187.0	87	48	12	3	73	2.0	2.0		30
185	SA					187.0	190.50	87	48	19 55 17 47 88	3	68				91
190	b17 b18					190.50	193.95	82	48	19 55 17 47 88	3	73	2.0	2.0		30
190	SA					193.95	199.20	82	111	85	3	73	2.0	2.0		40
195	SA/TR								81.3	38						41
200	SA								81.3	22						



Appendix C. Profile 5040 logs- NAU83020

Grafisk kartering		Boliden Mineral AB		Bas/System		Kartblad		Dated		Borrplats		Bl. Nr.							
Namn: <i>100 M Gimpsey</i>		Datum: <i>Nov 9/09</i>		NAU								83020							
N-koord. (Y)		E-koord. (X)		Z-koord. (Z)		Lata. (grader)		Rikt. (grader)		Plan. lmgd (m)		Diameter (mm)							
m	Struktur	Korastorlek					Prov		C H A	Bergart	Struktur	Mineral	Korn- storl.	Flög	Obj. Sida	V-I 1	V-II av	Typ	
		100	200	300	400	500	Prova	Till											20
0						3.00	2.57	R	187										
	Jord					2.57	8.56		83				3	73	20	20			30 91
5						8.56	9.12		83				3	73					91
10						9.12	14.26		83				3	73	20	20			30 91
15						14.26	14.26		83				3	73	20	20			30 91
20						19.26	24.26		83				3	73					91
25						24.26	29.26		83				3	73	20	20			30 91
30						29.26	34.26		83				3	73	20	20			91 30
35						34.26	40.05		83				3	73					91
40						40.05	44.79		83				3	73	20	20			30 91
45						44.79	49.85		83				3	73					91
50									83				3	73					

*Handwritten notes in the table include: "with albite altered after 7.00 at 8.00", "epi. white mica", "epi. altered scap", "mag-gt skarn with epi. kspite alt.", "thin section 45.46 to 45.55, epi altered scap - Gt - Bt glns".*

Appendix C. Profile 5040 logs- NAU83020 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datadod	Borrplats	Bh. Nr.									
Namn: 1a.u		Datum: Nov 10/09		NAU				83020									
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)		Lutn. (grader)	Rikt. (grader)	Plan. längd (m)	Diameter (mm)		Krökmät								
m	Struktur	Kornstorlek				Prov		C	Bergart	Struktur	Mineral	Korn-storl.	Färg	Obj. Sida	V-I 2	V-II av	Typ
		mm	0.5	1	5	Fe	TE										
50					47.35	54.71			87	48	33	3	88	20	20		91
	SA				54.71	58.40			87	48	33	3	88	20	20		91
	SA/TS				59.46	60.88			83	48	33	3	73				91
60	SA				64.84	64.80			Hydrated	48	60	3	73	20	20		32
	SA/TS				64.80	68.40			83	48	33	3	73				91
70	SA				68.40	75.85			87	48	33	3	73				91
	SA				75.85	77.75			83	48	33	3	73	20	60		40
	SA/TS				77.75	85.88			83	48	33	3	73	20	20		32
	SA				85.88	90.59			83	48	33	3	88				91
85	SA				90.59	96.55			83	48	33	3	88	20	20		32
90	SA				96.55	101.55			83	48	33	3	73				91
95	SA/TS								101.65	48	33	3	73				

Appendix C. Profile 5040 logs- NAU83020 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datakod	Borrplats	Ba. Nr.								
Namn: 1901		Datum: Nov 10/09		NAU				87020								
N-koordinat (Y)	E-koordinat (X)	Z-koordinat (Z)	Lata. (grader)	Rikt. (grader)	Plas. Hög (m)	Diameter (mm)	Körkmit									
m	Struktur	Kornstorlek					Prov	Bergart	Struktur	Mineral	Korn-storl.	Flög	Obj. Sida	V-I 3	V-II av 20	Typ
		100	50	20	10	5										
100	SH		101.55	106.55	83		garnmat	40 67.3 22	3	73					91	
105	b9 b10 SH		106.55	111.55	83		garnmat	40 67.3 22	3	73					91	
110	SH		111.55	116.55	83		garnmat	40 67.3 22	3	73					91	
115	b10 b11 SH		116.55	121.55	83		garnmat	40 67.3 22	3	73	2.0	2.0			91	
120	SH		121.55	126.55	83		garnmat	40 67.3 22	3	73	2.0	2.0			91	
125	b11 b12 SH		126.55	131.55	83		garnmat	40 67.3 22	3	73					91	
130	SH		131.55	136.55	83		garnmat	40 67.3 22	3	73	2.0	2.0			91	
135	SH		136.55	141.55	83		garnmat	40 67.3 22	3	73					91	
140	b12 b13 SH		141.55	147.90	83		garnmat	40 67.3 22	3	73					91	
145	SH		147.90	152.90	83		garnmat	40 67.3 22	3	73					91	
150	SH						garnmat	40 67.3 22	3	73					91	

Appendix C. Profile 5040 logs- NAU83020 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System		Kartblad		Dated		Borrplats		Bl. Nr.					
Namn: AN		Datum: Nov 10/09		NAU								83020					
N-koordinat (Y)		E-koordinat (X)		Z-koordinat (Z)		Lata. (grader)		Rikt. (grader)		Plan. Bågd (m)		Diameter (mm)					
m	Struktur	Kornstorlek					Prov		Bergart	Struktur	Mineral	Korn-storl.	Färg	Obj. Sida	V-I 4	V-II av	Typ
		less	0.5	2	8	32	Fels	TR									
150	b13 b14	very fine mag epi v. quartz					152.48	155.35	83	garnet 1.5cm	garnet 0.2-0.5 epi v. quartz 2% mag	3	75				91
155	SA	epi v. quartz mag epi v. quartz					152.35	160.53	83	only half core remains	epi v. quartz garnet mag	3	75	20	20		40 91
160	b14 b15	epi v. quartz mag epi v. quartz					160.55	165.40	83	garnet only half core remains	epi v. quartz garnet mag	3	73				91
165	SA	epi v. quartz mag epi v. quartz					162.4	168.29	83	half core left	epi v. quartz garnet mag	3	73				91
170	b15 b16 b17	epi v. quartz mag epi v. quartz					162.69	173.69	83	along fall line meto garnet 7	epi v. quartz garnet mag epi v. quartz	3	73	20	20		40 91
175	SA	epi v. quartz mag epi v. quartz					173.69	179.30	83	garnet with alb. 1.0 cm	epi v. quartz garnet mag epi v. quartz	3	73				91
180	SA	epi v. quartz mag epi v. quartz					179.30	182.65	83		epi v. quartz garnet mag epi v. quartz	3	73				91
185	b16 b17	epi v. quartz mag epi v. quartz					182.65	185.70	83	along fall line meto garnet 7	epi v. quartz garnet mag epi v. quartz	3	73	20	20		42 91
190	SA	epi v. quartz mag epi v. quartz					185.70	190.0	82	along fall line meto garnet 7	epi v. quartz garnet mag epi v. quartz	3	73				91
195	garnet TS b17	epi v. quartz mag epi v. quartz					189.00	195.62	82	garnet with alb. 1.0 cm	epi v. quartz garnet mag epi v. quartz	3	75	20	20		50 91
200	b18	epi v. quartz mag epi v. quartz					195.0	195.62	82		epi v. quartz garnet mag epi v. quartz	3	75				91
		epi v. quartz mag epi v. quartz					195.62	200.62	82	garnet with alb. 1.0 cm	epi v. quartz garnet mag epi v. quartz	3	75				91

Appendix C. Profile 5040 logs- NAU83020 (cont.)

Grafisk kartering		Bolliden Mineral AB		Bas/System	Kartblad	Datalod	Borrplans	Bl. Nr.										
Namn: <i>lan</i>		Datum: <i>Nov. 11/09</i>		<i>NAU</i>				<i>83020</i>										
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)	Latn. (grader)	Rikt. (grader)	Plan. Hög (m)	Diameter (mm)	Körkmit											
m	Struktur	Korastorlek					Prov		C R A	Bergart	Struktur	Mineral	Korn- stør.	Flög	Obj. Sida	V-I 5	V-II av	Typ
		1/2	0.5	2	8	32	Fv	TG										
200	SA						200.49	205.0		82	48 49.3 67.1 78.3 81.1	10 12 22	3	73	20	20		50 91
205	SA b18 b19						205.0	209.70		82 with a white at contact rock becomes more calc. to and scapolite indicates	10 12 22	3	73	20	20			50 91
210	SA/TR						209.70	214.70		83	48 67.3 78.3 81.1	10 12 22	3	73				91
215	SA						214.7	219.7		83	48 67.3 78.3 81.1	10 12 22	3	73	20	20		50 91
220	b19 SA b20						219.7	224.7		83	48 67.3 78.3 81.1	10 12 22	3	73				91
225	gachsen SA						224.7	228.30		83	48 67.3 78.3 81.1	10 12 22	3	73	20	20		50 91
							228.30	230.30		gachsen	48 67.3 78.3 81.1	10 12 22	3	73	20	20		45
	b20/6A b21						230.30	235.30		83	48 67.3 78.3 81.1	10 12 22	3	73	20	20		50 91
							235.30	239.78		83	48 67.3 78.3 81.1	10 12 22	3	73				91
235	SA						239.78	242.37		83	48 67.3 78.3 81.1	10 12 22	3	73	50			50 91
240	SA/TR						242.37	247.37		83	48 67.3 78.3 81.1	10 12 22	2	73	20	20		50 91
	SA/TR						247.37	252.37		83	48 67.3 78.3 81.1	10 12 22	3	73				91
245	SA									83	48 67.3 78.3 81.1	10 12 22	3	73				91
250																		

Appendix C. Profile 5040 logs- NAU83020 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Dataskod	Borrplats	Bh. Nr.									
Namn: AN		Datum: Nov 11/09		NAU				83020									
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)		Lata. (grader)	Rikt. (grader)	Plan. lmgd (m)	Diameter (mm)		Krökmått								
m	Struktur	Kornstorlek				Prov		C	Bergart	Struktur	Mineral	Kornstorl.	Färg	Obj.		V-II	Typ
		mm	63	3	8	32	Fels							Til	Sida		
250	SA b22 b23				252.31	251.40		82				3	75	20	20		91
255	SA				257.48	261.4		83				3	73				91
260	SA				261.48	266.38		83				3	75				91
265	b23 b24 geochem				266.38	267.0		83				3	73				91
270	SA				267.0	272.0		83				3	77	20	20		91
275	b24 b25				272.0	277.84		82				3	75	20	20		91
280	SA				277.84	283.19		82				3	75				91
285	SA				283.19	283.79		82				3	75	20	20		91
290	b25 b26 SATR				283.79	289.95		82				3	75	20	20		91
295	SA				289.95	293.0		83				3	73				91
300	SA				293.0	298.0		83				3	73				91
					298.0	303.0		83				3	73				91

Appendix C. Profile 5040 logs- NAU83020 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datukod	Borrplans		Bh. Nr.					
Namn: <i>Jan</i>		Datum: <i>Nov 12/09</i>		<i>NAU</i>					<i>P1020</i>					
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)	Lutn. (grader)	Rikt. (grader)	Plan. linsp. (m)	Diameter (mm)	Körkmitt							
m	Struktur	Korastorelek km 0.5 2 4 32	Prov		C M A	Bergart	Struktur	Mineral	Korn- storl.	Färg	Obj. Sida	V-I 7	V-II av	Typ 20
			Fvls	TE										
300	<i>626</i> <i>627</i> <i>SA</i>		<i>305.0</i>	<i>309.3</i>	<i>NAU</i>	<i>SS</i> <i>half core</i>	<i>CPY</i> <i>mag</i> <i>epi</i>	<i>epi</i> <i>mag</i> <i>CPY</i>	<i>3</i>	<i>75</i>	<i>2.0</i>	<i>2.0</i>		<i>55</i> <i>91</i>
305			<i>309.5</i>	<i>312.14</i>	<i>NAU</i>	<i>SS</i>	<i>CPY</i> <i>mag</i> <i>epi</i>	<i>epi</i> <i>mag</i> <i>CPY</i>	<i>3</i>	<i>75</i>	<i>2.0</i>	<i>2.0</i>		<i>50</i> <i>91</i>
310	<i>627</i> <i>628</i> <i>SA</i>		<i>313.14</i>	<i>316.11</i>	<i>NAU</i>	<i>SS</i>	<i>CPY</i> <i>mag</i> <i>epi</i>	<i>epi</i> <i>mag</i> <i>CPY</i>	<i>3</i>	<i>75</i>				<i>91</i>
315			<i>318.11</i>		<i>2</i>	<i>end of Hole</i>								
320														
325														
335														
340														
345														
350														

Appendix C. Profile 5040 logs- NAU84001

Grafisk kartering		Boliden Mineral AB		BasSystem		Kartblad		Databod		Borrplats		Bh. Nr.									
Namn: Jan		Datum: Nov. 3/09		NAU								54001									
N-koord. (Y)		E-koord. (X)		Z-koord. (Z)		Lutn. (grader)		Rikt. (grader)		Plan. längd (m)		Diameter (mm)									
m	Struktur	Kornstorlek					Prov		C	Bergart	Struktur	Mineral	Kornstorl.	Färg	Obj. Sida	V-I av	V-II av	Typ			
		mm	0.5	1	2	32	Fila	TR											H	A	
0	S.O.H F <sub>1</sub> 20-40						0.00	1.12	D	87	48 21 19 12 9 8.5	19 21 19 12 9 8.5	3	73	20	20					91
5	SA						6.69	11.90	D	87	48 48.3 49 49.1	55 19 55	3	73	20	20			45 41		
10	SA						11.70	16.60	D	87	48 48.1 49.1	55 14 72 30 30	3	73	20	20			46 47		
15	SA						16.60	21.60	D	87	48 48.3 49 52.1	55 22	3	73	20	20			45 41		
20	SA						21.60	26.60	D	87	48 48.3 49 49.1	19 21 21 41	3	73	20	20			45 41		
25	SA						26.60	30.64	D	87	48 48.3 49 49.1	19 21 21 30	3	73	20	20			40 47		
30	SA						30.64	34.64	D	87	48 48.3 49 49.1	19 21 21 30	3	73					91		
35	SA						34.64	39.60	D	87	48 48.3 49 49.1	19 21 21 12	3	77	20	20			35 41		
40	SA						39.60	44.60	D	87	48 48.3 49 49.1	55 12	3	73	20	20			43 41		
45	TR						44.60	49.5	D	87	52 78.1 72.1 81 48.3 49.1 45.3	12 24 12 12	3	88	20	20			40 41		
50	SA								D	87											

Appendix C. Profile 5040 logs- NAU84001 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datadod	Borrplats		Bh. Nr.											
Namn: <i>log</i>		Datum: <i>11/24/09</i>		<i>Nass</i>					<i>5001</i>											
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)		Lutn. (grader)	Rikt. (grader)	Plan. Hög (m)		Diameter (mm)		Krökmät										
m	Struktur	Kornstreck					Prov	C	Bergart	Struktur	Mineral	Kornstrel.	Färg	Obj.	V-I	V-II	Typ			
		lss	os	z	k	tz	746	TR						Sida	2	av	20			
50							47.3	54.59	garn	foliation	epi + ksp	85 12 40 50 73	3 5 50	73	20	20		91		
55	TR						54.59	54.55	garn		epi + ksp	65 12 22	3	73	20	20		91		
60	TR						59.95	63.60	garn		epi + ksp	12 22	3	73					91	
65	SA						63.60	64.50	garn		epi + chl	65 12 24	3	75	20	20		91		
70	SA						69.50	75.00	garn		epi + chl	65 12 24 27	3	75	20	20		91		
75	SA						75.20	90.00	garn		epi	65 12 21	3	75	20	20		91		
80	TR						80.00	95.00	garn		epi + ksp	65 12 22	3	75	20	20		91		
85	TR						85.00	90.77	garn		epi + ksp	67 12 24	3	73	20	20		91		
90	TR						90.70	95.40	garn		epi + ksp	67 12 24	3	75	20	20		91		
95	SA						95.70	100.60	garn		epi + ksp	67 12 24	3	75	20	20		91		
100																				

Appendix C. Profile 5040 logs- NAU84001 (cont.)

Grafisk kartering		Beliden Mineral AB		Bas/System	Kartblad	Datakod	Borrplats	Bh. Nr.										
Namn: /A/		Datum: Maj 5/09		NAU				84001										
N-koordinat (Y)	E-koordinat (X)	Z-koordinat (Z)	Latn. (grader)	Rikt. (grader)	Plan. längd (m)	Diameter (mm)	Körknävt											
m	Struktur	Kornstorlek					Pröv		C H A	Bergart	Struktur	Mineral	Korn- storl.	Färg	Obj. Sida	V-I 3	V-II av	Typ 20
		100	200	400	800	1600	Fels	TB										
100	SA						100.60	105.60		87	qtz vein with minor calcite	55 42 22 30 23.1 104.35 to 104.55m	3	75				91
105	SA						105.60	111.60		87	angle varies between 40°-50°	48.1 49.1 67.1 83.3	5	75	20	2.0		50 91
110	SA						111.60	117.20		87	varies between 40°-50°	48.1 49.1 67.1 83.3	5	75	20	2.0		45 91
115	SA						117.20	122.60		87	qtz vein with calcite	48.1 49.1 67.1 83.3	5	75	20	2.0		50 91
120	SA/Tr						122.60	128.60		87	points to 122.60 and 128.60	48.1 49.1 67.1 83.3	3	75	20	2.0		58 91
125	SA									87	qtz vein with calcite	48.1 49.1 67.1 83.3	5	75	20	2.0		45 91
135	SA/Tr						134.60	139.60		87	lighter grey	48.1 49.1 67.1 83.3	3	88	20	2.0		50 91
140	SA						139.60	144.60		87	little bit	48.1 49.1 67.1 83.3	3	88				91
145	SA						144.60	149.75		87		48.1 49.1 67.1 83.3	5	78	20	2.0		55
150																		

Appendix C. Profile 5040 logs- NAU84001 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datad	Borrplats	Bl. Nr.							
Namn: 5040		Datum: 19/5/09		NAU				84001							
N-koörd. (Y)	E-koörd. (X)	Z-koörd. (Z)		Lats. (grader)	Rikt. (grader)	Plan. längd (m)	Diameter (mm)	Körkmit							
m	Struktur	Körnstorlek				Prov	Bergart	Struktur	Mineral	Körn-storl.	Färg	Obj.	V-I	V-II	Typ
		mm	0.5	2	32	Fels	TH	C H A				Sida	4	av	20
150	SA					147.95	152.70	87	150.10 - 150.22 m. mostly cpy in rust of section. base sampled D4. Half core left	19, 12, 71, 91	3	73	2.0	2.0	85 91
155	SA					152.20	156.04	87	half granite 15.70m	19, 12, 71, 91	3	73	2.0	2.0	80 91
160	b14 SA					156.04	161.10	87	varies from 45 to 50 TEA	19, 12, 71, 91	3	73	2.0	2.0	80 91
165	SA					161.10	166.10	87		19, 12, 71, 91	3	73	2.0	2.0	45 91
170	SA					166.10	169.65	87	varies from 45 to 50 TEA	19, 12, 71, 91	3	75	2.0	2.0	80 91
175	b15 SA					169.65	173.20	87	from 169.65 - 171.70m. contains weak imp. cpy, py, mag	19, 12, 71, 91	3	73			91
180	SA					173.20	177.20	87	para. calc. area 174.20 to 175m	19, 12, 71, 91	3	73	2.0	2.0	80 91
185	b16 SA					177.20	182.20	87	parasitic folding of quartzite HW can be seen many locations @ 181.20	19, 12, 71, 91	3	73			91
190	SA/SH					182.20	187.20	87	often in strongly magnetic bands. abruptly ends and scapolite appears	19, 12, 71, 91	3	73	2.0	2.0	80 91
195	SA/TR					187.20	192.95	87	seen as calc. for dolomite	19, 12, 71, 91	3	73	2.0	2.0	80 91
200	b17 SA					192.95	196.00	87	beechen felsen 187.20 to 187.80m	19, 12, 71, 91	3				91
	b18 SA					196.00	199.45	87	mag. altered zone bands look like mica. half core remains	19, 12, 71, 91	3	73	2.0	2.0	80 91

Appendix C. Profile 5040 logs- NAU84001 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System		Kartblad		Datum		Borrplats		Bh. Nr.						
Namn: 1a31		Datum: Mars 6/04		NAU								S4001						
N-koord. (Y)		E-koord. (X)		Z-koord. (Z)		Lutn. (grader)		Rikt. (grader)		Plan. längd (m)		Diameter (mm)						
m	Struktur	Kornstorlek					Prov		C H A	Bergart	Struktur	Mineral	Korn- storl.	Färg	Obj. Sida	V-I 5	V-II av	Typ
		100	63	2	8	32	F1a	F2a										
200	gneiss						199.95	204.10		87	49 199.48 ± gneiss 200.45 to 201.10, calc lined	17 22 12 42 91	3	73	20	20		45 91
205	b18 b19 SA						206.10	210.00		85	1.5 to 2cm amphiboles envelope	12 27 91	3	73				91
210	SA						210.10	214.95		87	49 78.1 49.1	19 12 91	3	73	20	20		50 91
215	SA b19 b20						214.85	220.00		85	garnets from 1cm up to 10cm masses epi cpy within the cracks in garnet and in low pressure spots around garnets	41 30 25 46	3	73				91
220	SA						220.0	225.0		87	48 48.1 59.3	19 31 95	3	73	20	20		50 91
225	SA 227.66 b20 b21 SA						225.0	230.35		87	48 48.3 94 smaller garnets, more laminated, sericite at contact the gneiss	17 19 73 86 91	3	73				41
230	SA						230.76	235.50		87	234.79 to 235.10, 10-20% magnetite	12 85 82	3	73				91
235	SA gneiss						235.5	241.00		87	237.68 L. magnetite epidote garnet, search 235.50 to 236.00 gneiss	22 22 19 91	3	73	20	20		65 91
240	b11 b12 SA						241.0	246.0		87	adult veins follow dissolution breakdown of the host mineral cross cut by calcite veins	12 17	3	73				91
245	SA gneiss						246.0	253.7		87	246.0 to 246.6 for epi, Mg spar + cc, to gt 250.90 to 251.37 as gneiss/now SA in altered, same as	12 22 22 79	3	73	20	20		65 91

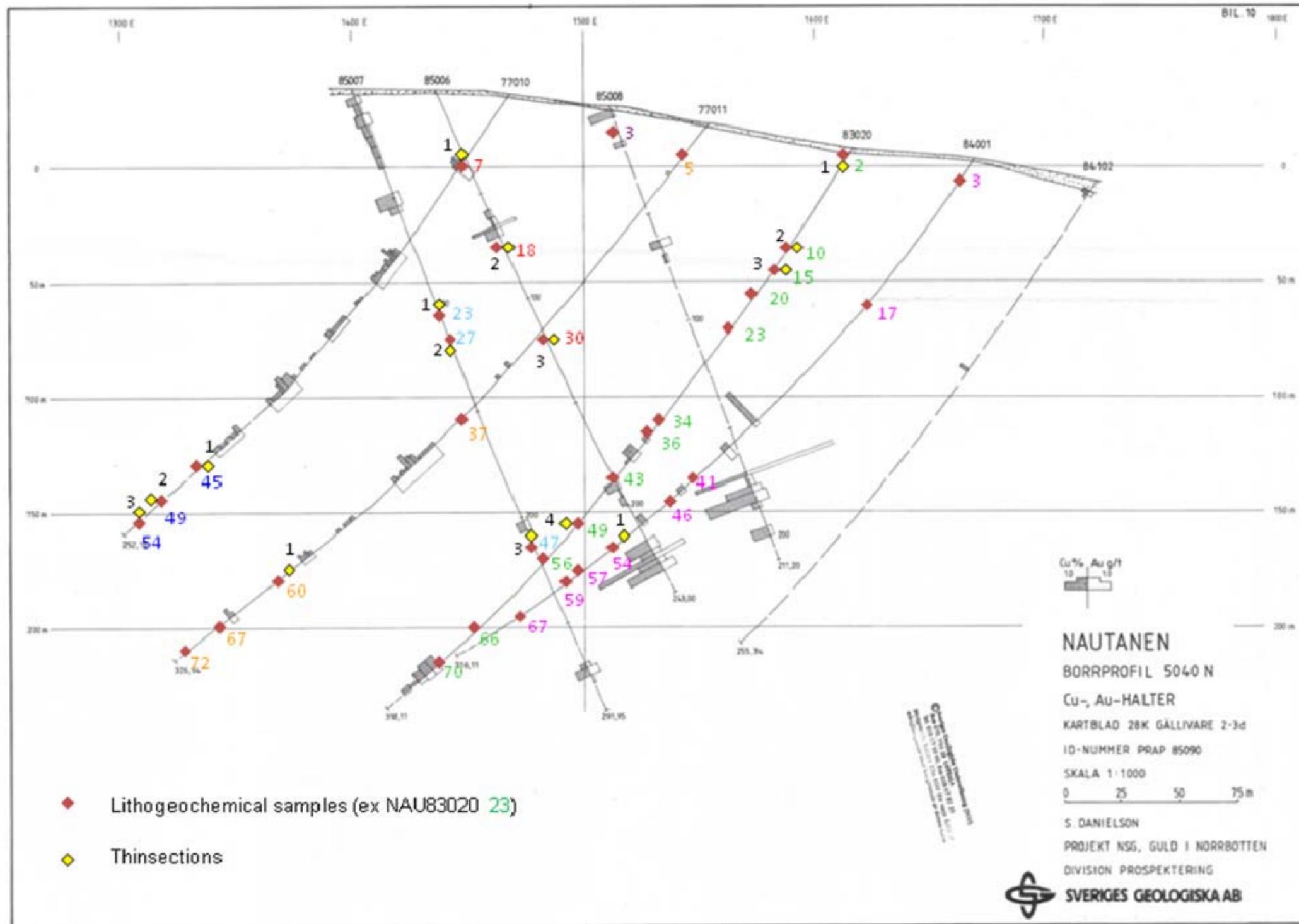
Appendix C. Profile 5040 logs- NAU84001 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datakod	Borrplats		Bl. Nr.						
Namn: Ja v		Datum: Nov 9/09		NAU					84001						
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)	Lata. (grader)		Rikt. (grader)	Plan. lmgd (m)		Diameter (mm)		Krökmitt					
m	Struktur	Korastorlek			Prov	C	Bergart	Struktur	Mineral	Korn-storl.	Färg	Obj. Sida	V-I 6	V-II av	Typ
		1ca	0.5	2	4	12	70	H							
250	b22 b23 SA					259.37	259.37	87	around 254.3 78.1 19 30	22 3	73	20	20		70 91
255	SA					258.37	262.64	87	Varies 60-70 46 91 22 91	3	73				91
260	b23 SA/TP b24							87	at contact garnets reappear	12					
265	SA/TP					262.44	268.53	87	2mm v. 254.3 267.25 to 267.75 in assoc. with 267.1 267.3 267.5 267.7 267.9 268.1 268.3 268.5 268.7 268.9 269.1	19 70 24 41 92 12 12	3	73	20	20	60 91
270	SA					268.43	271.70	87	at contact no more garnets reappear	10	73				91
275	b24 b25 SA					271.70	274.45	87	only 10 garnets reappear	22 36 36	3	73			91
280	SA					274.45	278.45	87		30 46	3	20	20		60 91
285	gneiss white feldspar plagioclase hornblende					278.45	288.0	87	gneiss 278.45 to 280.0m hb-ht gneiss matrix of ortho	22 30 15	3	73			91
290	b25 b26					288.00	290.00	87		22 30 15	3	73	20	20	60 91
295	SA					290.00	295.00	87		22 30	3	73			91
300	b26 b27					295.0	300.0	87		24 30 12	3	73			60 91

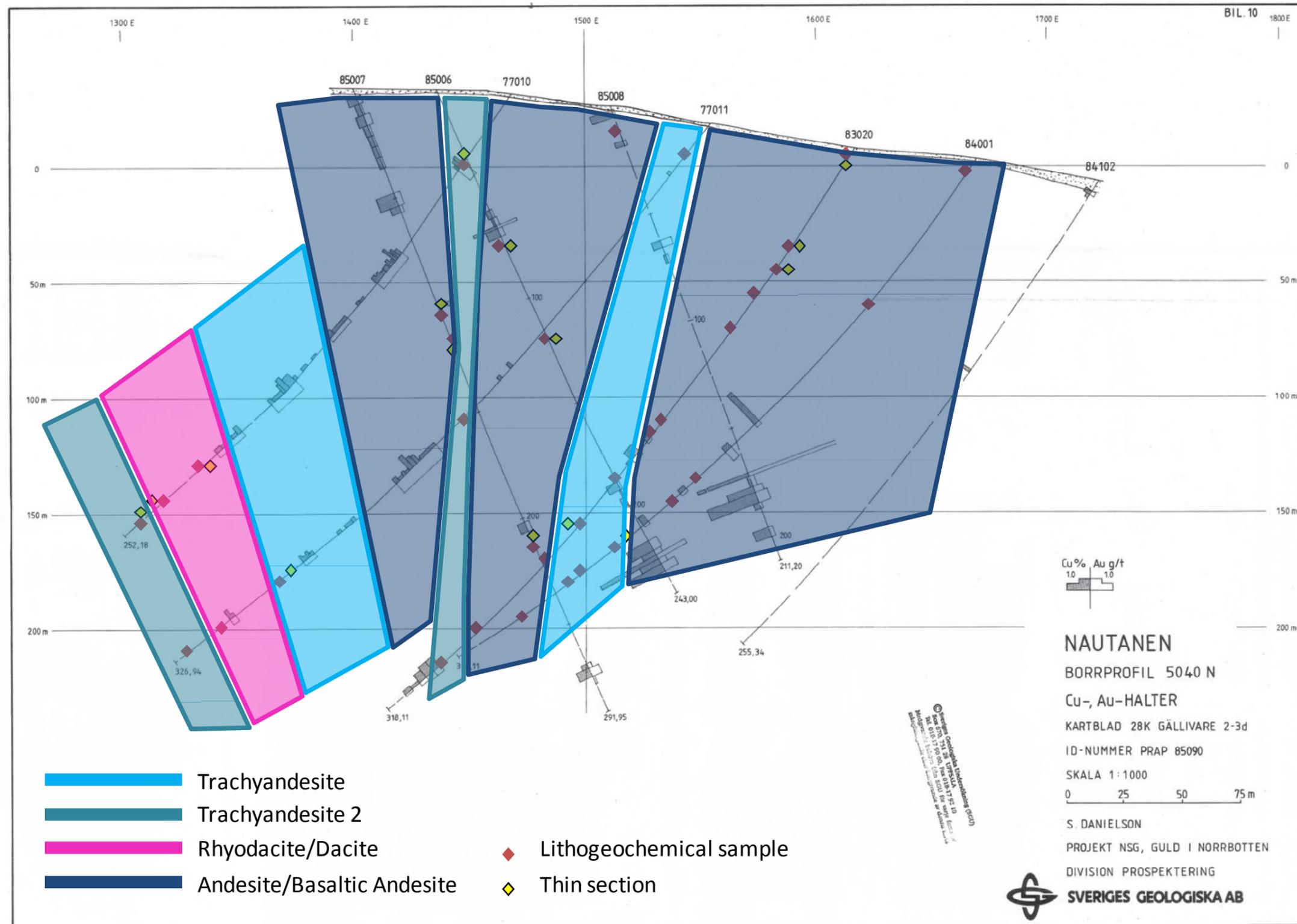
Appendix C. Profile 5040 logs- NAU84001 (cont.)

Grafisk kartering		Boliden Mineral AB		Bas/System	Kartblad	Datakod	Borrplats	Bh. Nr.											
Namn: Gyn		Datum: Nov 8/09		NAU				2400											
N-koord. (Y)	E-koord. (X)	Z-koord. (Z)	Latn. (grader)	Rikt. (grader)	Plan. längd (m)	Diameter (mm)	Krökmått												
m	Struktur	Kornstörlek					Prov		c	Bergart	Struktur	Mineral	Kornstör.	Färg	Obj. Sida	V-I 7	V-II av	Typ	
		100	0.5	2	8	32	Fda	Til											20
300							300.0	305.0	NAU	97	alterat 61.3 67.3 72 74	20 24 72	3	73					97
305	SA						305.0	310.0	NAU	97	alterat 48.3 48.3 67.3 70.7 78.1 79.3	15 12 22 91	3	73	2.0	2.0			70 91
310	SA						310.0	316.11	NAU	97	alterat 78.3 82.3 84.1	4 15 12 24	3	75	2.0	2.0			97 91
315	SA/FOH						316.11		C		alteration and stripping zone after 311.70m 311.70 could be in contact to new rock type or altered version of previous rock								
320																			
325																			
335																			
340																			
345																			
350																			

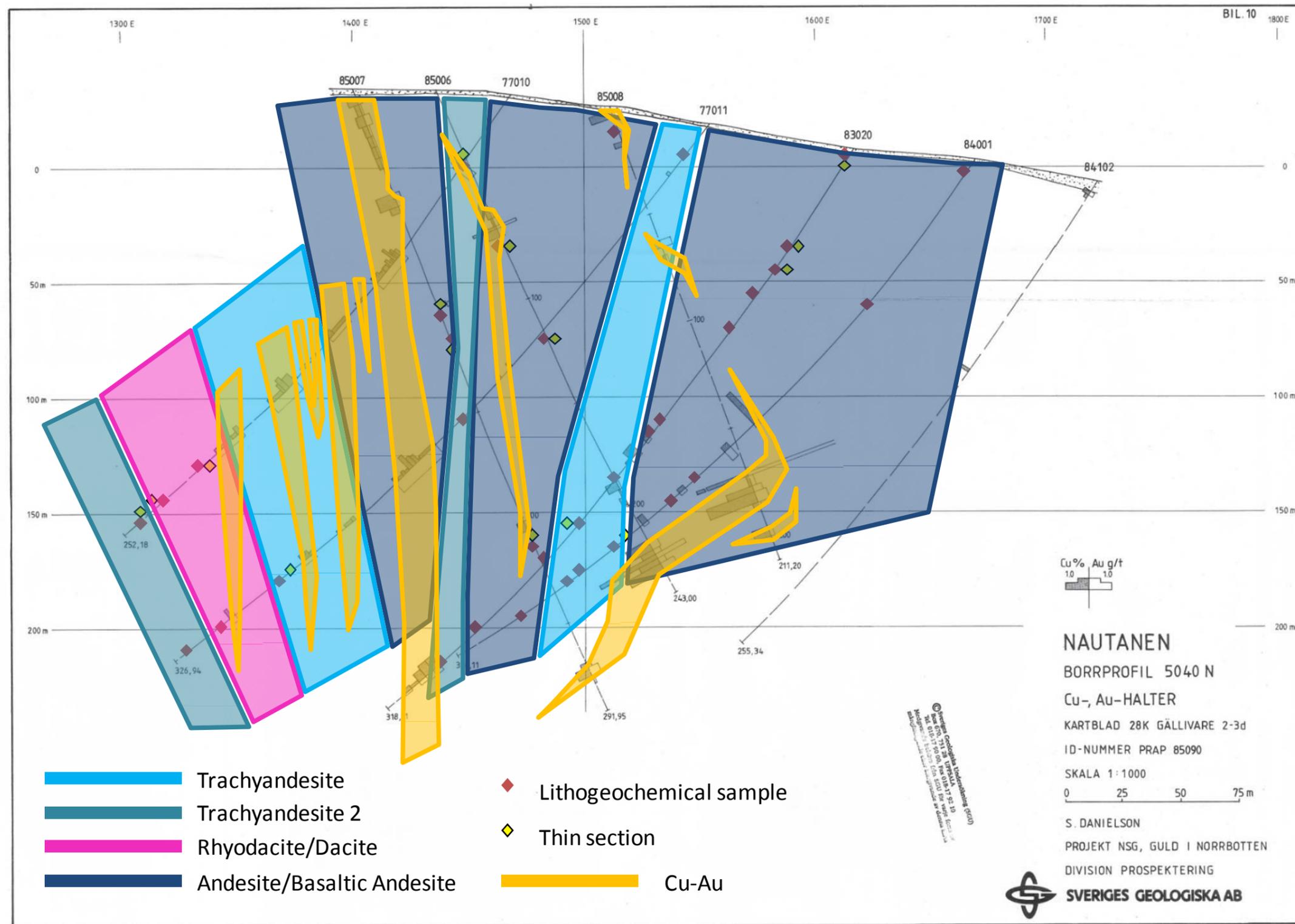
Appendix D. Location of lithochemical samples and thin sections from profile 5040 N (modified from Danielsson 1985)



Appendix E. Lithochemical based cross section of profile 5040 N (modified from Danielson 1985)



Appendix F. Lithochemical based cross section of profile 5040 N with areas of strong mineralization added (modified from Danielson 1985).



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