Final Report

Field trip Finland/Sweden 2008

Chair of Mining Engineering

and Mineral Economics

Leoben, December 2008

OVERVIEW

page

1 Impressions of our excursion


CAT

Picture 1: Impressions of our excursion; (11 pictures)

2 Preface

DI Wolfgang Hohl, organizer of the field trip to Scandinavia

To be the organizer of a student´s field trip could be a very exhausting, challenging duty. First, you have to find a destination everybody is accepting. The students could complain about that it is too hot, too cold, too far north, too far south, that there are too much mosquito´s and so on and so on. Second you have to keep to your budget, dictated to you by your professor. Third, you have to take into account, that most of the lecturers you steal lecture time during the absence of the students will hate you for this. Fourth, the companies you are trying to contact for a visit are not interested at all. If they are willing to grant you an audience they just take it as disturbance of their regular day to day work. Finally fifth, potential sponsors from the industry interpret your polite request for a small financial support as annoying begging letter and therefore don´t even think about answering.

This and many more things could make the life of an organizer a very hard one. Fortunately I can tell you at this point of my introduction that all of the things that I described before COULD have happened.

The students agreed to almost every proposed plan and every rule. My professor granted me a very generous budget., the lecturers barely complained about the time I´ve stolen them. The companies were remarkable cooperative and offered us visits and insights in a way which is almost suspicious, and finally, most of the companies we contacted for sponsoring granted us a generous financial support.

We always have to bear in mind that a field trip is not for our or for the students pleasure, at least it is not the primary meaning. A field trip is a very rare chance to teach and show things to students that cannot be shown in a lecture room. I can tell you from my own experience that if you ask a student a few years after graduation which part of his study he or she has still in mind, most of them will answer: This one remarkable and fascinating field trip.

There´s nothing more for me to say but **"Thank you"** to everybody who helped to make this experience possible!!!!

Best regards,

Wolfgang Hohl

3 Sponsors

Bernegger Bau GmbH

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Fachverband Bergbau/Stahl

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4 Overview about our tour

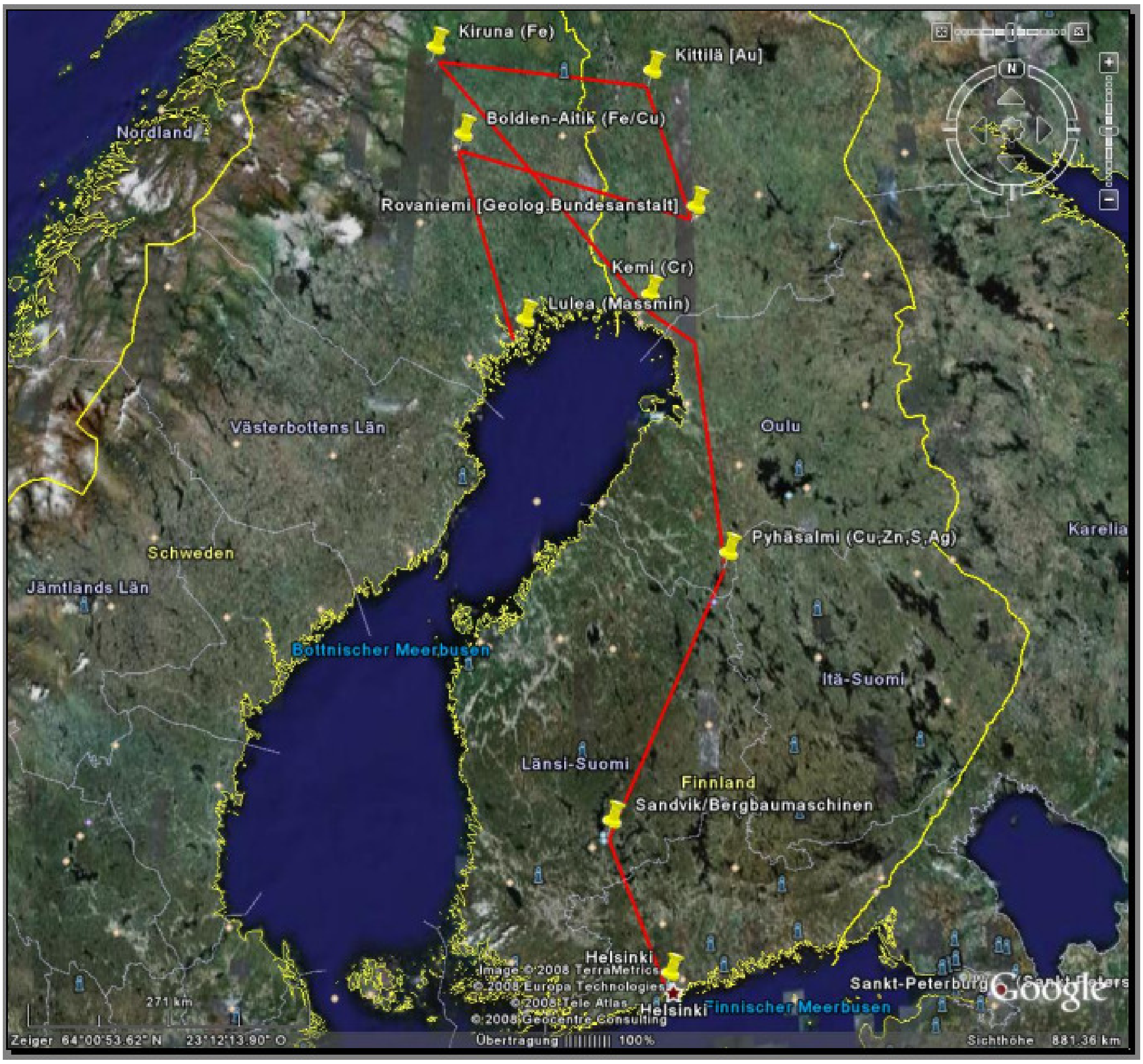

Figure 1: Overview about the field trip [1]

4.1 Timetable

Date	from	to	distance [km]	Company/University
30.05.2008	Vienna	Helsinki	Flight	
31.05.2008				TU Helsinki
01.06.2008	Helsinki	Tampere	177	
02.06.2008				Sandvik
03.06.2008	Tampere	Pyhäsalmi	334	Inmet [Cu,Zn,Ag,S]
	Pyhäsalmi	Kemi	268	
04.06.2008				Ouokumpu Mine [Cr]
	Kemi	Kiruna	392	
05.06.2008				LKAB Kiruna [Fe]
06.06.2008	Kiruna	Kittilä	284	Agnico-Eagle Oy [Au]
	Kittilä	Rovaniemi	151	
07.06.2008				Geological Survey
08.06.2008	Rovaniemi	Gällivare	295	
09.06.2008				Boliden Aitik [Cu]
	Gällivare	Lulea	242	
10.06.2008				Massmin
11.06.2008				Massmin
12.06.2008	Lulea	Vienna	Flight	TU Lulea

Table 1: Timetable

4.2 Participants

- **Professor:**
  - DI Dr. mont. Moser Peter
- **Research assistants:**
  - DI Hohl Wolfgang (organisation of the excursion)
  - DI Heiss Christian
  - DI Bauer Florian
  - DI Unterweissacher Thomas
- **Staff:**
  - Albert Eisner
- **Students:**
  - Tschugg Julia
  - Eggenreich Stefan
  - Amberger Christoph
  - Bartl Raimund
  - Toferer Reinhard
  - Ottacher Alexander
  - Schmid Andreas
  - Maierhofer Erhard
  - Nussbacher Hanspeter
  - Eder Johann
  - Dif Abdelouahab

5 Geology

handed in by DI Thomas Unterweissacher

5.1 Pyhäsalmi [2]

Pyhäsalmi is the oldest operating metal mine in Finland and the deepest in Europe. It is a Zn-Cu VMS-deposit with hydrothermally altered host rocks subsequently being metamorphosed, deformed, recrystallised and partially remobilised under amphibolite facies conditions. The ore is hosted by felsic pyroclastic rocks and quartz-porphyries. Mafic volcanic rocks in the area are coarse-grained tuff breccias and lavas, the latter containing pillowed units. Mafic and felsic dykes are common. The volcanic host rocks belong to the Palaeoproterozoic (ca. 1.92 Ga) Svecofennian island arc succession near the margin of the Archaean Karelian craton.

The composition of the Pyhäsalmi ore varies both horizontally and vertically. To the depth of about 1000 m, sphalerite is concentrated in the central part and chalcopyrite near the outer margins of the ore. In deeper levels, there is massive pyrite (low Cu, Zn) in the centre, which is enveloped by chalcopyrite ore and further outwards by Zn ore. The highest barite contents are generally encountered in the sphalerite-rich areas. The ore is a massive pyrite ore with 70% sulphides. The sphalerite-rich ore is in some places finely banded and thin pyriteporphyritic bands are common. A pyrite dissemination, which in some places has a breccia structure, exists around the massive ore. Pyrrhotite has replaced pyrite in the southern end of the ore.

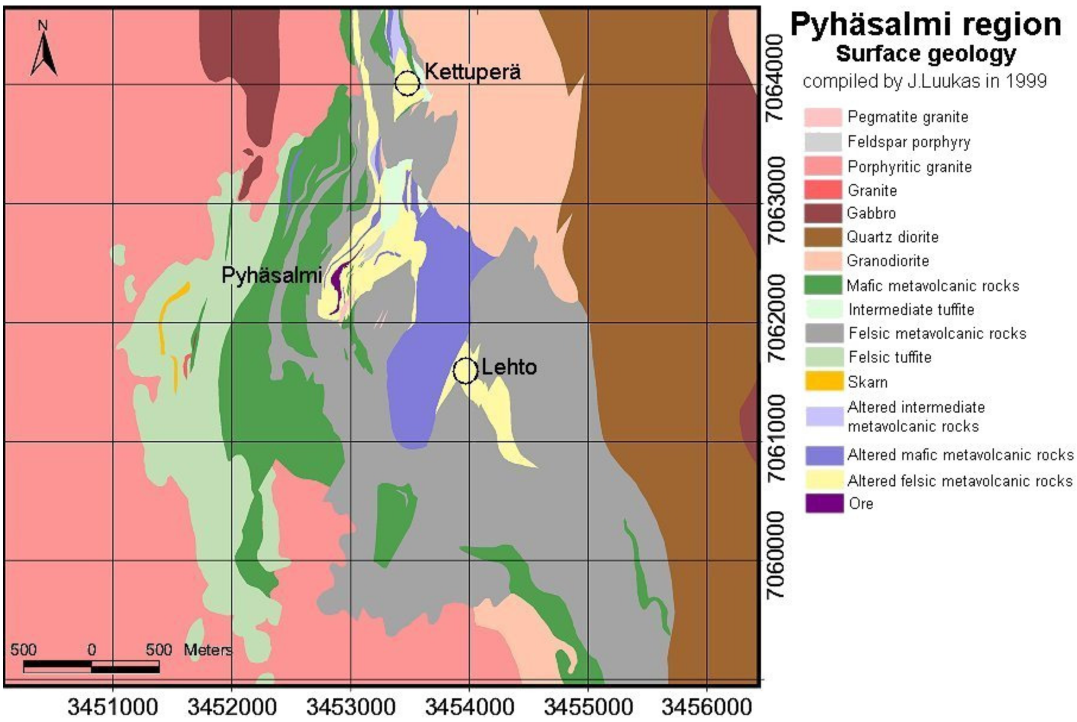

Figure 2: Regional geology map 1

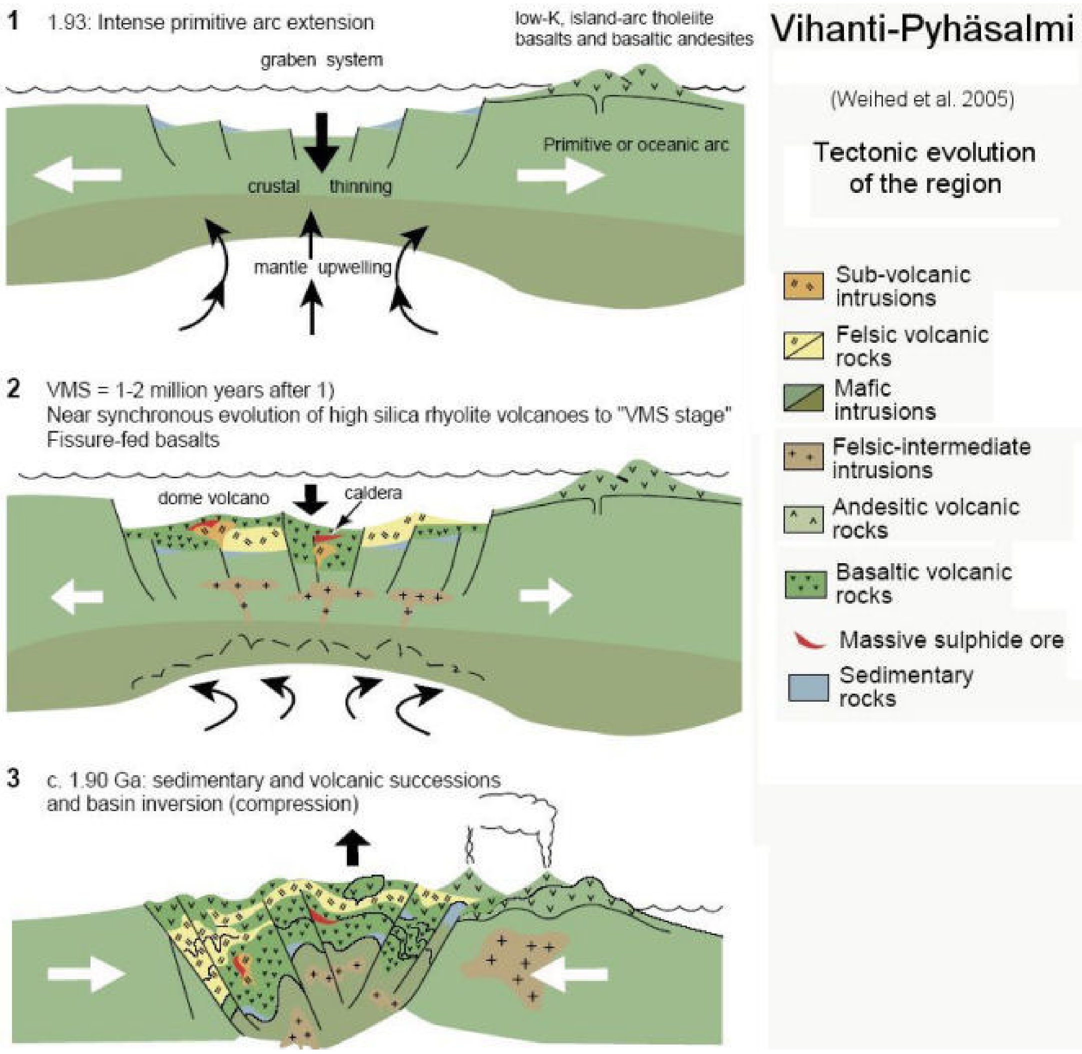

Figure 3: Schematic model 1

5.2 Kemi [3]

The Kemi Layered Intrusion can be considered the most signihcant of the Fennoscandian layered intrusions, since it contains the sole mine presently active within these intrusions. The chromitite deposit is hosted by a layered intrusion extending some 15 km northeast of Kemi, a town on the coast of the Gulf of Bothnia. U-Pb zircon data yield an age of 2.44 Ga for the Kemi Intrusion (Patchett et al. 1981), and the whole rock Pb-Pb data dehne an age of 2.44±0.16 Ga (Manhes et al. 1980).The chromite mineralisation was discovered in 1959, when a fresh-water Channel was being excavated in the area. Mr. Martti Matilainen, a local diver who was interested in ore prospecting, discovered the first chromite-bearing blocks. Geological Survey of Finland (GTK) immediately began exploration which led to the discovery of a chromitite-rich layer. From 1960 onwards, the exploration was conducted by Outokumpu Oy under contract from the government of Finland. The decision to exploit the deposit was made in 1964, by which time 30 million metric tons of chromite ore had been located in the basal part of the intrusion.

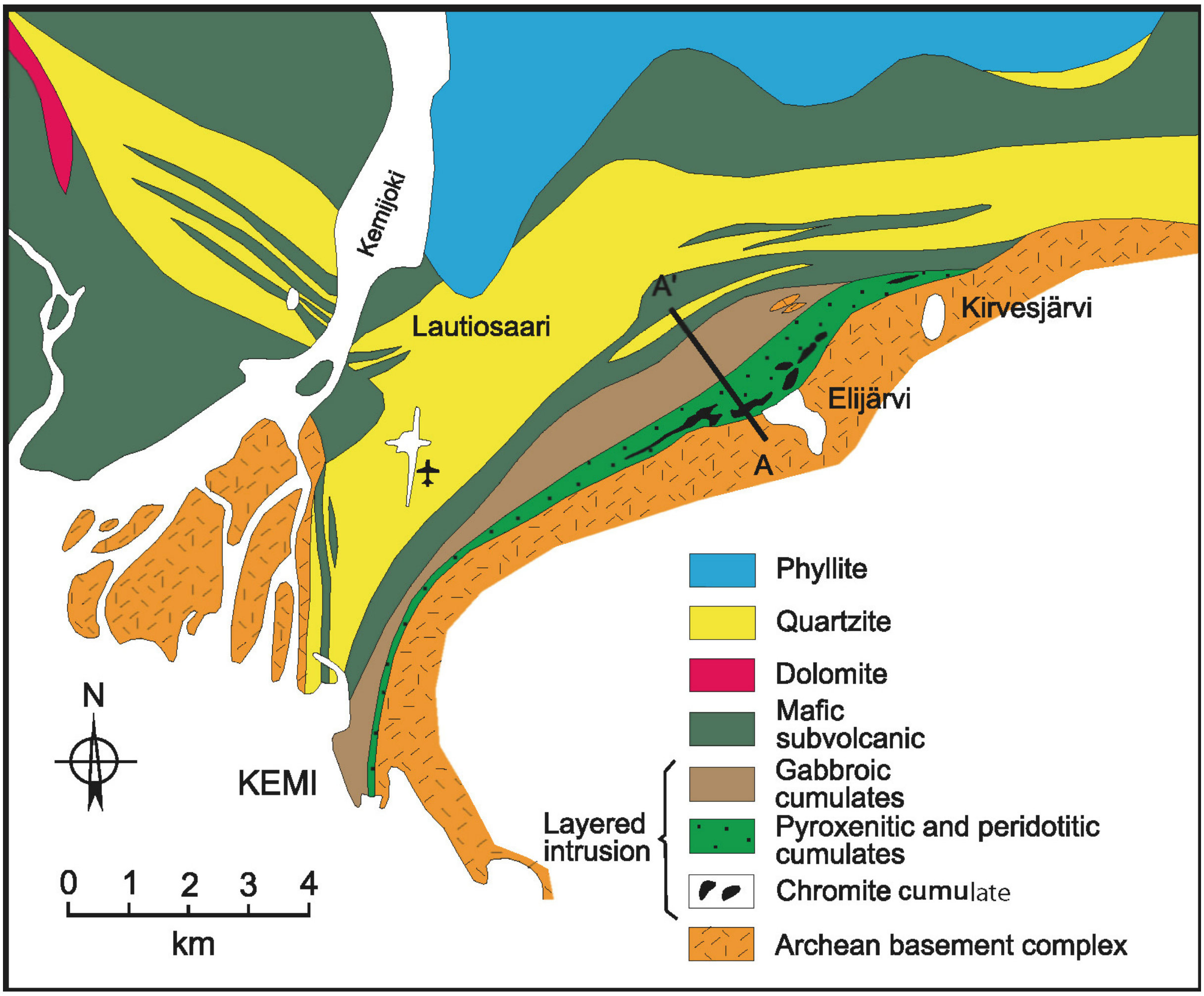

Figure 4: Generalised geological map of the Kemi region

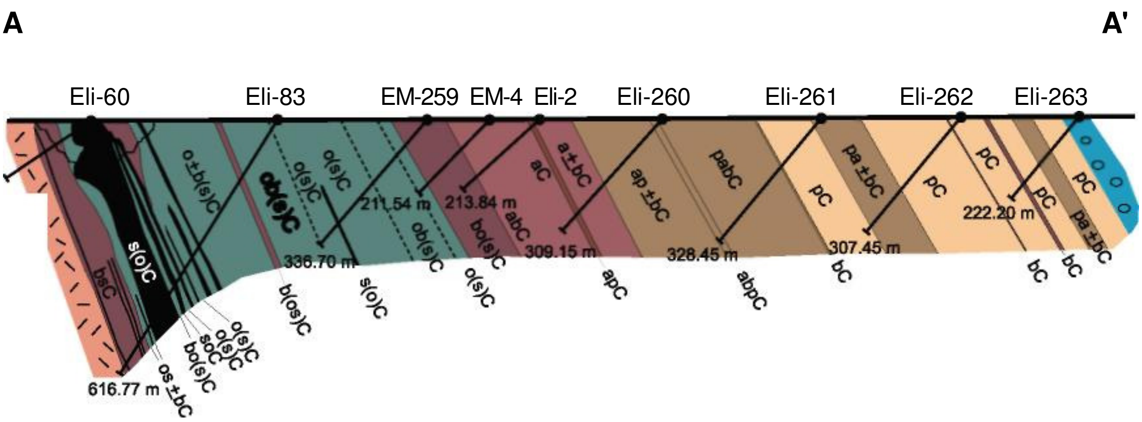

Figure 5: Cross section of the Kemi Intrusion based on the drilled proflle A-A'

Full-scale open pit mining commenced in 1968, and was carried out until December 2005, when the main open pit had reached a depth of approximately 200 meters. Construction of the Underground mine began in 1999, and the Underground mine was officially opened in September 2003. Annual production during recent years has amounted to around l.2Mt of ore.

The mine's proven ore reserves total approximately 40 Mt. In addition, it is estimated that there are some 85 Mt of mineral resources (Outokumpu Oyj 2005). The average chromium oxide content of the ore is about 26 percent and its average chrome-iron ratio is 1.6.

The ore feed is concentrated into upgraded lumpy ore and fine concentrate. In the first stage of the process, the ore is crushed and screened to a diameter of 12-100 millimetres. After crushing, ore lumps are processed by heavy medium Separation. In this process, upgraded lumpy ore is separated from the ore. Further processing takes place in the concentrating plant where the ore is first ground in rod and ball mills. The fine concentrate is produced by gravity Separation using spirals and Reichert cone Separators. In addition, high-gradient magnetic Separation is used for fine material unsuitable for gravity concentration. Annual production of lumpy ore and fine concentrate is about 210,000 tonnes and 390,000 tonnes, respectively.

The associated industrial facilities were built close to the harbour of Tornio, a town situated some 25 km from the Kemi mine. Production of ferrochrome commenced in 1968. The ferrochrome works was expanded with the second smelting furnace in 1985. The construction process of the stain-less steel works at Tornio was completed in 1976. The unique production chain from chrome ore to stainless steel coils and plates was completed in 1988, when the hot rolling mill was inaugurated. Further Investments in the 1990's and during recent years have increased the annual production capacity of Tornio Works to 1.7 Mt of rolled products.

Layering of the Kemi Intrusion

The present surface section of the Kemi Intrusion is lenticular in shape, being about 15 km long and 0.2-2 km wide. It represents a cross-section of an originally funnel-shaped intrusion which was tilted by tectonic movements during the Svecokarelidic orogeny to form a body dipping about 70° to the NW and, according to geophysical survey, extending down for at least 2 km. The intrusion comprises an ultramafic lower part and a gabbroic upper part. The individual cumulate layers are thickest in the middle part of the intrusion and become thinner toward the ends. This feature is well established from the Variation in thickness of the ultramafic cumulates.

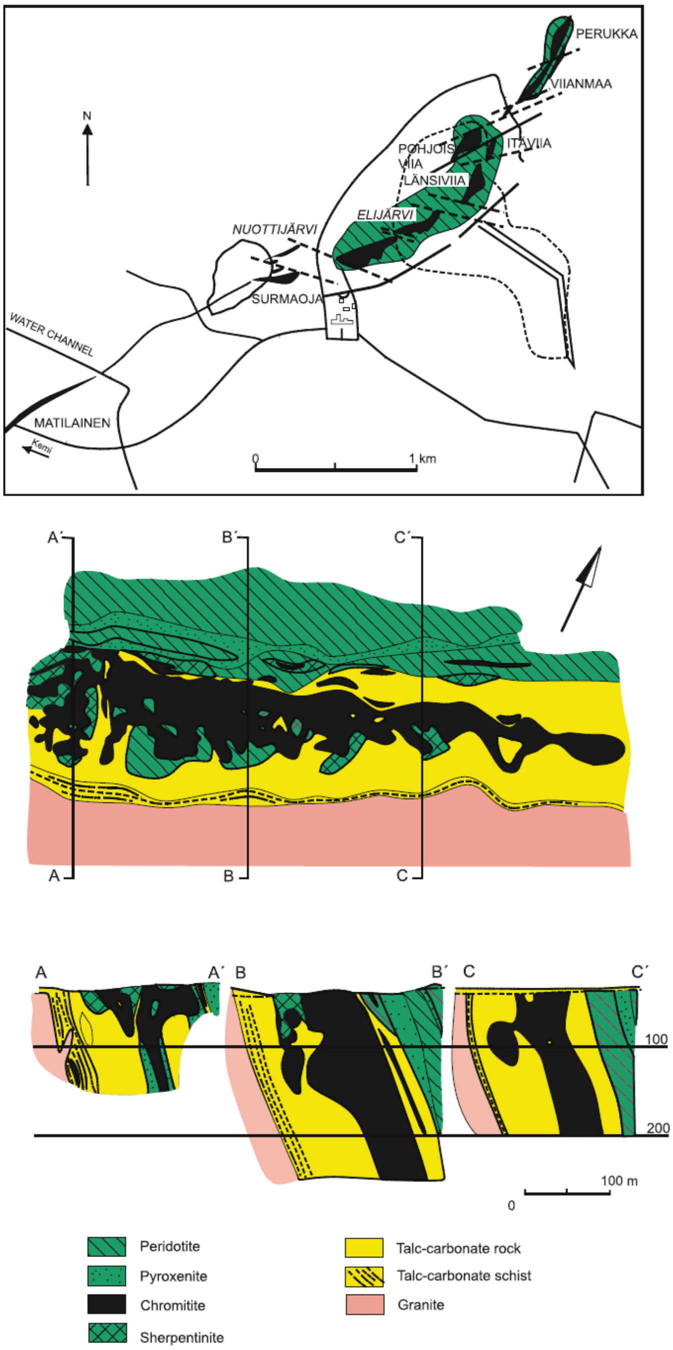

Figure 6: Surface plan and sections across the Elijärvi ore body

Exploration form Underground inclined tunnels has recently proved that the magmatic conduit which fed the magma Chamber was located just below the thickening, as already suggested. This feeder dike comprises fine-grained, uralitised rock types close to the contacts which grade into more coarse grained ones inward, and the middle part of the dyke is composed of a few meter thick chromitite.

The footwall of the intrusion consists of Neoarchaean granitoids, and the hanging-wall rocks are either younger mafic volcanics or subvolcanic suis 2,150 Ma in age, or a polymictic conglomerate of unknown age but younger than the intrusion. This indicates that the present upper contact is erosional, implying that the original roof rocks and the uppermost cumulates of the layered series, together with the possible granophyre layer, have been obliterated by erosion. The feeder dikes of the subvolcanic suis, referred to as albite diabase, intersect the Kemi Intrusion.

The area of the Kemi Intrusion underwent lower-amphibolite facies metamorphism during the Svecokarelidic orogeny, probably during 1.9-1.8 Ga. The original magmatic Silicates have been completely altered to secondary minerals in the lower and upper parts of the intrusion, whereas those in the middle have been preserved and are fresh in appearance. Many chromites have nevertheless preserved their original composition in their cores, even though the Silicates of the same rock have been completely altered. The altered rocks have preserved their cumulate textures fairly well and despite alteration, many of the primary minerals can still be recognised by means of pseudomorphs, thus enabling the cumulate sequences to be determined.

The basal contact series in the Kemi Intrusion is highly altered. It is at present mainly represented by a mylonitic talc-chlorite-carbonate schist, and in places by a talc-carbonate rock, in contact with the basement granitoid. Recently, in the Underground mine from level -400 downwards, an approximately 10 m thick metagabbro has also been encountered in some of the new tunnels intersecting the basal contact. This metagabbro does not form a continuous layer, however, its contacts commonly being quite irregulär. It can mainly be encountered within the mylonite and the talc-carbonate rock. In a tunnel at level -450, where the basal contact series is quite well preserved, a metapyroxenite is also encountered, overlaying the metagabbro. It seems possible, that the basal contact series may have been partially obliterated by erosion during the magmatic stage, as suggested by the sporadic appearance of the metagabbro.

This sequence is overlain by a markedly altered sequence 50 to 100 m thick, the lower part of which is composed of a bronzite-chromite cumulate and the upper part of an olivine-chromite ± bronzite cumulate, with chromitite interlayers from 0.5 to 1.5 m thick. The bronzitic cumulates typically are characterised by gneissic xenoliths from the under-lying basement complex. In addition to chromitite interlayers, varying amounts of chromite dissemination and roundish lumps of chromitite, whose diameter varies from a few centi-metres up to several meters, can be encountered in this sequence.

The sequence described above is followed by the main chromitite unit which in many intersections is composed of two parts with a more silicate-rich rock between them. The total average thickness of the main chromitite unit is 40 m. Its cumulus minerals are chromite and olivine, and the intercumulus minerals comprise poikilitic bronzite and to a lesser extent augite. The abundance of cumulus olivine in relation to chromite is relatively low in the upper part. Bronzite locally occurs as the cumulus phase in the more silicate-rich interlayer which is typified by annular textures constituting accumulations of small chromite grains around the larger cumulus Silicate minerals.

The main chromitite unit is overlain by about 550 m of peridotitic cumulates with olivine, chromite and occasional bronzite as the cumulus minerals. This thick cumulate sequence contains about 15 chromite-rich interlayers varying in thickness from 5 cm to 2.5 m, the uppermost being about 370 m above the main chromitite layer (Alapieti et al. 1989b). Three, approximately 10-30 m thick pyroxenitic interlayers occur in the lower part of the peridotitic sequence. The uppermost pyroxeneite is situated between sequences of well-developed rhythmic layering patterns approximately 30-50 m thick. The rhythmic pattern is composed of alternating layers of olivine-(chromite) cumulates and olivine-bronzite-(chromite) cumulates, augite being the main intercumulus mineral in both rock types. A similar type of rhythmic sequence occurs in the third megacyclic unit of the Penikat Layered Intrusion, situated some 10 km northeast of the Kemi Intrusion (Huhtelin et al. 1989b). Bronzite becomes the dominant cumulus mineral about 700 m above the basal contact of the intrusion, with olivine and chromite as the other cumulus phases. Then, about 100 m higher up, augite becomes the dominant cumulus mineral alongside bronzite, but olivine and chromite disappear. Even bronzite is so low in abundance in places that the rock could be referred to as a diallagite.

At about 1,000 m above the basement, plagioclase becomes the cumulus phase alongside augite and bronzite. These plagioclase cumulates continue for about 800 m upward to the contact with the hanging wall. In the upper part of the sequence, augite occurs as the intercumulus phase, and there is little or no Ca-poor pyroxene. In conventional terms, these rocks are therefore leucogabbros or anorthosites.

The chromite ores

The chromitite layer which parallels the basal contact zone of the Kemi Intrusion is known over the whole length of the complex. In the central part of the intrusion, the basal chromitite layer widens into a thick chromitite accumulation. The chromite-rich unit has an average dip of 70° to the NW.

The thickness of the main chromitite unit averages 40 meters, but it varies in thickness from a few meters to over 160 meters. The upper contact of the chromitite unit lies stratigraphically 100 to 150 m above the basal contact of the complex, but its Position has been changed by several strike-slip faults. The top of the main chromitite unit is layered in structure, the hanging wall contact of the ore being sharp, whereas the lower part is non-layered and brecciated, characterised by gradually diminishing chromite dissemination towards the bottom of the intrusion accompanied by irregulär ore lumps. The ore boundary at the footwall is, therefore, quite complex. The chromitite unit contains abundant barren ultramafic inclusions, especially in its lower part. Gneissic xenoliths are also locally encountered within the chrome ore.

Economically, the most important portion of the chromitite layer extends from the Elijärvi ore body in the west to the Pohjois-Viia ore body in the east situated below the main open pit. The length of the chromitite unit under mining is about 1.5 km. The chromitite layer is cut into several ore bodies by numerous faults, and these bodies are treated, to a certain degree, as separate units for the purposes of mining, beneficiation, and metallurgy. The reason for this is that the separate ore bodies, due to Variation in the degree of metamorphism, host different secondary gangue minerals in the interstices of chromite grains, which has an effect on hardness and specific gravity of the ore. Also, the natural size of chromite grains, which varies greatly, is characterised by extensive microcracking and brokenness in certain ore bodies, thus reducing the size of purely-ground chromite in concentration.

The Kemi chrome mine is a good example of the exploitation of a low-grade ore, distinctly lower in grade than in the stratiform deposits in southern Africa. The success of the Operation is due to the convenient location of the deposit relative to existing infrastructure, combined with advanced mineral processing and ferrochrome production technology.

5.3 Kirunavaara [4]

Kiimnavaara is the largest of the apatite iron ores in Sweden, comprising about 2000 Mt of iron ore with 60 to 68 % Fe. It was found in outcrop in 1696, but regulär mining started not until 1900 when a railway was built from the coast to Kiruna. Open pit mining ceased in 1962, with a total production of 209 Mt. Underground work started in a small scale during the 1950's and the ore is now mined by large-scale sublevel stoping. The present main haulage level is at 1045 m and the production in 2005 was 23.4 Mt with 46.2 % Fe. Combined reserves and resources were 1242 Mt at the end of 2005.

The tabular ore body is roughly 5 km long, up to 100 m thick, and it extends at least 1500 m below the surface. It follows the contact between a thick pile of trachyandesitic lava (traditionally named Syenite porphyry) and overlying pyroclastic rhyodacite (traditionally named quartz-bearing porphyry). Towards north, the much smaller Luossavaara ore is situated in a similar stratigraphic position.

The trachyandesite lava occurs as numerous lava flows which are strongly albite-altered and rieh in amygdales close to the flow tops. An U-Pb age of 1876±9 is given for titanite oecurring together with actinohte and magnetite in amygdales. A potassic granite is present at deeper levels in the mine on the footwall side of the ore and several dikes of granophyric to granitic character cut the ore. Some of these dikes are composite in character also including diabase. An U-Pb zircon age of 1880±3 Ma has been obtained for the granophyric dikes and gives the minimum age of the ore. This is consistent with an U-Pb titanite age of 1888±6 Ma for magnetite-titanite veins in the footwall to the Luossavaara deposit. The phosphorus content of the ore exhibits a pronounced bimodal distribution with either less than 0.05 % P (B ore) or more than 1.0 % P (D ore). The B-ore may contains up to 15 % disseminated actinohte in a 5 to 20 m wide zone along its borders where it is in contact with the wall rocks. The magnetite is mostly very fine-grained «0.3 mm), but in the central part of larger B ore lenses a zone of coarser magnetite (up to 2 mm) exists together with some calcite and small amounts of pyrite. The D ore locally has a banded strueture and the proportions of apatite and magnetite is widely varied. The age relation between B and D ores is ambiguous, and both ore types can be seen cutting each other. Columnar and dendritic magnetite are locally developed in the ore suggesting a rapid crystallisation in a supercooled magma. Veins of anhydrite, anhydrite-pyrite-magnetite and coarse-grained pyrite are occur in the ore and its wall rocks.

Magnetite-actinolite veining (ore breccia) is developed both in the footwall and hanging wall along the contacts of the Kiirunavaara ore body. Close to the hanging wall contact, the ore typically is rieh in angular to subrounded clasts of rhyodacitic tuff. Actinolite is a common alteration mineral both at the footwall and the hanging wall contacts and it may form massive skarn bordering the ore.

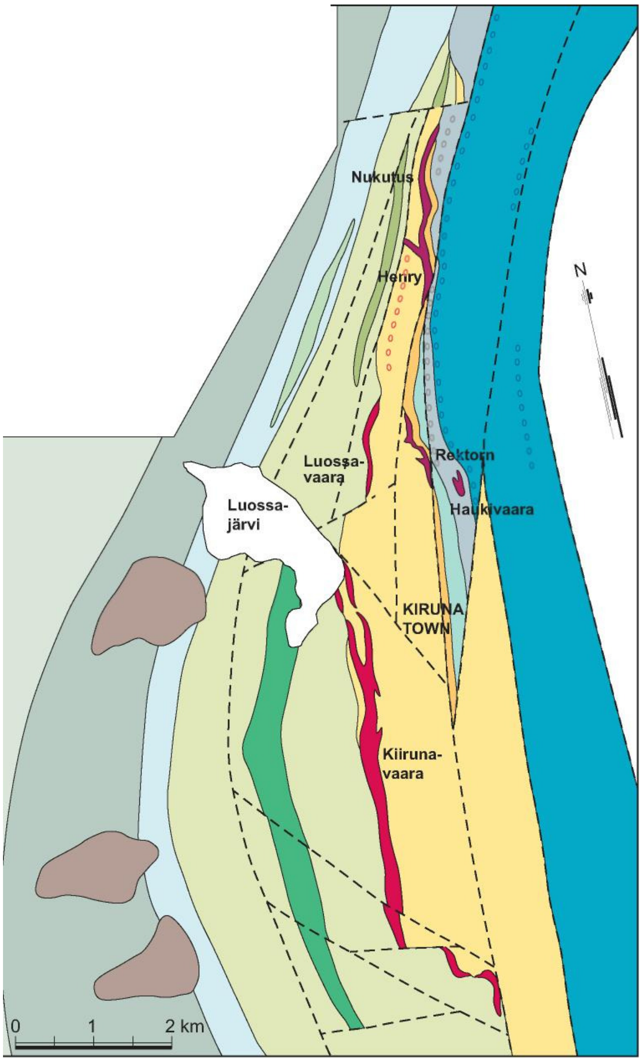

Figure 7: Geology of the Kirunaarea with location of the Kiirunavaara deposit

Actinolite also replaces, partly or completely, clasts of wallrocks in the ore and in the ore breccia. Besides actinolite and magnetite veining close to the ore, the hanging wall is in some areas affected by biotite-chlorite alteration, which commonly is accompanied by disseminated pyrite and a weak enrichment of Cu, Co and Mo.

Under the Underground visit in the northern part of the ore (Sjömalmen), we'll see the ore and its host rocks. The exact localities to be visited depend on the accessibility to different parts of the mine which changes rapidly as a consequence of the mining activities.

5.4 Kittilä [5]

General

The NW-SE-oriented Palaeoproterozoic Northern Fennoscandian greenstone belt contains several dozen deposits with a significant gold content, the main ones among which, i.e. ones that have led to the opening of a mine, are the Aitik and Pahtohavare copper-gold ores in Northern Sweden, the Bidjovagge gold-copper ore in Northern Norway and the Saattopora gold-copper ore, the Pahtavaara gold ore and the Hannukainen iron oxide-cop-per-gold ore of Central Lapland in Finland. With the exception of Aitik and Pahtavaara, however, all the mines have subsequently been closed down, either because of exhaustion of the ore or for some other reason. The largest known gold deposit in Finland in terms of both size and gold reserves and resources is that of Suurikuusikko in the middle part of the Kittilä greenstone area in Central Lapland.

The majority of the gold deposits in Central Lapland are associated with the southern and middle parts of the Kittilä greenstone area, being located in or immediately adjacent to subsidiary shear and fault zones within regional deformation zones. They are characterized almost without exception by pronounced hydrothermal alteration in the host and wall rocks.

The gold deposits will be described here as a group characterized mainly by a set of similar geological features and ore mineral parageneses and resulting metal compositions. The iron oxide-copper-gold (FeOx-Cu-Au) deposits will be dealt with later as a separate ore type. Geographically, the gold deposits may be said to be distributed between the following areas.

<u>Gold deposits hosted by metasedimentary or metavolcanic rocks:</u>

Saattopora-Muusanlammet area	Au-Cu, (Ni, As)
Sirkka-Jerusaleminjänkkä area	Au, Cu, Ni, Co, As
Isomaa-Kaaresselkä area	Au, Cu, (Ni, As)
Pahtavaara area	Au

<u>Gold deposits hosted by banded iron formations:</u>

Suurikuusikko-Rovaselkä area	Au-As
Archaean gold deposits	Au
Palaeoplacer gold deposits	Au
Placer gold deposits	Au

The gold potential of the major banded iron formations of Central Lapland, the Porkonen-Pahtavaara formation in Kittilä and the Jauratsi formation in Pelkosenniemi, will also be considered here, although no actual gold deposits are yet known to exist in them.

The Saattopora-Muusanlammet area, the westernmost gold cluster in Central Lapland, comprises five copper-bearing gold deposits belonging to a geological zone dominated by metasedimentary rocks. Only the Saattopora gold(+copper) ore deposit has been mined so far. The principal sulphide minerals in the deposits are pyrrhotite and chalcopyrite and the host rock is an albitized metasedimentary rock.

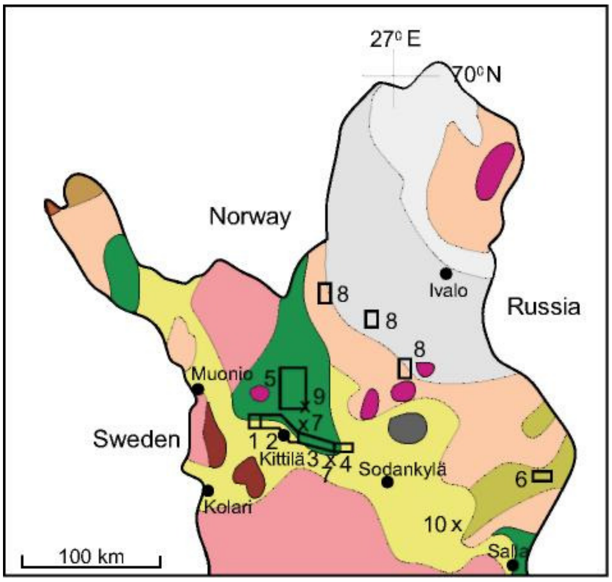

Figure 8: The bedrock of Lapland

Sub-areas with gold deposits:

1) Saattopora-Muusanlammet, 2) Sirkka-Jerusaleminjänkkä, 3) Isomaa-Kaaresselkä, 4) Pahtavaara, 5) Suurikuusikko-Rovaselkä, 6) Archaean gold deposits, 7) Palaeoplacer gold deposits, and 8) Placer gold deposits. Iron formations: 9) Porkonen-Pahtavaara, and 10) Jauratsi.

The eight gold deposits located in a zone of metasedimentary and ultramafic rocks to the east of the Saattopora-Muusanlammet area form a separate group of their own, in which the Sirkka deposit has been an object of test mining. With only a few exceptions, these deposits of the Sirkka-Jerusaleminjänkkä area have, unusually, relatively high nickel, cobalt and arsenic concentrations, and the area possesses large amounts of komatiitic ultramafic rocks, in connection with which most of the deposits are to be found. The main ore mineral in the gold deposits of this area is usually pyrite, or in places gersdorffite.

Further east, in a schist zone lying between the Kittilä greenstone area and the Central Lapland granitoid, is the heterogenic Isomaa-Kaaresselkä cluster, comprising nine gold deposits, some of which are copper-bearing. Among these, the small Kutuvuoma gold deposit has been mined to some extent. These occurrences are connected with a local east-west deformation zone containing highly albitized metasedimentary rocks, mafic and felsic metavolcanic rocks and mafic intrusions. Their principal sulphide minerals are pyrite and pyrrhotite, with albitized metasedimentary or ultramafic metavolcanic rocks as the host rock, with only a couple of exceptions.

The easternmost gold deposit in the southern part of the Kittilä greenstone area is that of Pahtavaara, which is still being mined. This is associated with the extensive, continuous Sattasvaara formation composed mainly of komatiitic metavolcanic rocks. The principal ore minerals are magnetite and pyrite, and the host rock is metakomatiite. The small Hookana gold occurrence south of Pahtavaara also belongs to the same ultramafic area.

The seven most significant gold deposits in the Suurikuusikko-Rovaselkä area are situated in the middle part of the Kittilä greenstone area. The area as a whole consists mainly of metavolcanic rocks and quartz-banded iron formations, with granitoid areas to the north. The gold deposits are associated with a sulphide facies in an iron formation, although some gold has also been detected in the rocks of the oxide facies. The principal ore minerals in the deposits are pyrite and arsenopyrite, whereas the nickel and cobalt sulpharsenides that are typical of many of the gold deposits in the southern part of the Kittilä greenstone area are virtually absent here.

Two small gold occurrences connected with iron formations have been found in the eastern part of Central Lapland, where the host rock is evidently an Archaean iron formation.

Two palaeoplacer gold deposits are known in Central Lapland, both associated with quartzites and conglomerates of the Kumpu group.

A number of placer gold deposits from which gold has been panned for more than 100 years are known to exist in the contact area between the Archaean gneisses and the granulite complex.

The Porkonen-Pahtavaara banded iron formation in the Kittilä greenstone area and that of Jauratsi in Eastern Lapland are described here as areas with a gold potential.

Suurikuusikko-Rovaselkä area

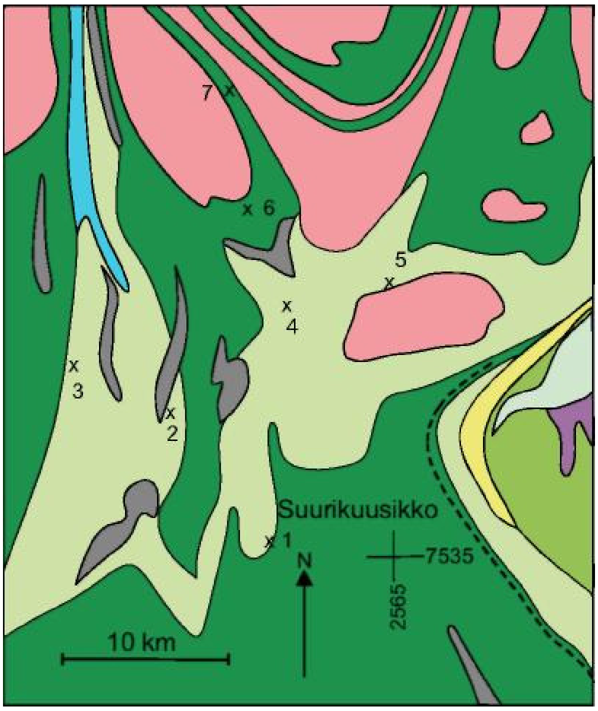

Figure 9: Geology of the Suurikuusikko-Rovaselkä area

Gold deposits: 1) Suurikuusikko, 2) Kapsajoki, 3) Hanhimaa, 4) Kuotko (Iso-Kuotko), 5) Ruop-papalo, 6) Sukseton, and 7) Rovaselkä

The gold deposits hosted by banded iron formations in the middle part of the Kittilä greenstone area are: Suurikuusikko, Kapsajoki, Hanhimaa, Kuotko (Iso-Kuotko), Ruoppapalo, Sukseton and Rovaselkä. These typically have low copper (except Sukseton), nickel and cobalt concentrations but usually a high arsenic concentration.

Suurikuusikko

The Suurikuusikko gold deposit, located near the centre of the Kittilä greenstone area, was discovered by GTK in 1986 in connection with investigations into the gold ore potential of Central Lapland, when visible evidence of gold was observed in the adjacent bedrock. The deposit is associated with a sulphide-rich schist zone in an iron formation situated between two Kittilä group metavolcanites of different composition, the younger being of the Mg-tholeiitic type and the older of the Fe-tholeiitic type.

The host rock to the Suurikuusikko gold deposit is a basic metatuff or metalava with interlayers of graphite schists, cherts and iron formation sulphide facies. The principal ore minerals are arsenopyrite and pyrite, with accessory pyrrhotite and gold and sporadic chalcopyrite. The Suurikuusikko deposit is a refractory ore in which gold is mostly lying within the arsenopyrite or pyrite.

The metal composition of the Suurikuusikko deposit, as indicated by a 9 m diamond drill core, is Au 6.2 g/t, Cu < 0.01 wt%, Zn 0.01 wt%, Pb < 0.01 wt%, Ni 0.02 wt%, Co < 0.01 wt%, Fe 6.90 wt%, As 0.49 wt% and Ag 1.4 g/t, with an S concentration of 3.0 wt%. The total ore resources (indicated and inferred) are 17.7 million tonnes, with an Au concentration of 5.3 g/t.

The gold deposit is connected with a NE-SW-oriented deformation zone intersected by a N-S shear zone that controls the location of the deposit. The Lälleänvuoma (Kettukuusikko), Soretiavuoma N, Hirvilavanmaa and Soretialehto gold deposits lie at the southern end of the same zone.

5.5 Gällivare [6]

Aitik Cu-Au-Ag mine

The Aitik Cu-Au-Ag mine is situated in Norrbotten County, northern Sweden, some 100 km north of the Arctic Circle and 17 km east of Gällivare town . The mine started operating in 1968 at a capacity of 2 Mt of ore annually. Subsequent expansions to 5 Mt (1970-72), 11 Mt (1979-81), have brought the capacity up to 16 Mt (1989-91). The next expansion will be operational in 2010-2011 and will bring the capacity up to 33 Mt of ore in 2010, which will be ramped up to 36 Mt annually.

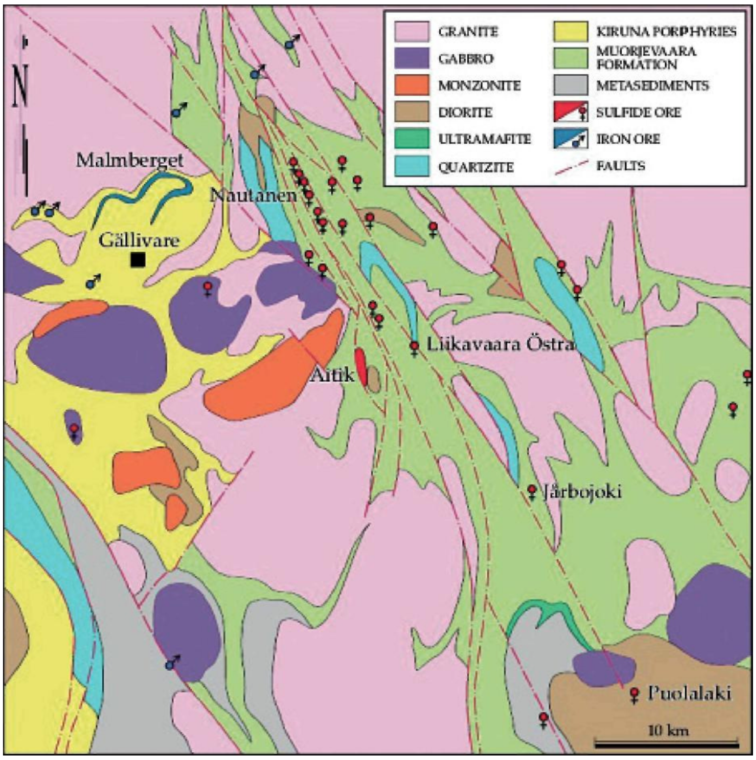

Figure 10: Geology of the Gällivare-Aitik area

The Aitik mine is a conventional large open-pit Operation with an in-pit crusher (18.4 Mt of ore mined 2006). The Cu-Au-Ag ore is moved by trucks carrying 240 tonnes of ore to the crushers. The ore is crushed, milled and processed in the flotation plant yielding a chalcopyrite concentrate. The economic product is a Cu-(Au-Ag) concentrate with an average grade of 27-29 % Cu, 8 ppm Au and 250 ppm Ag. The concentrate is transported by truck to Gällivare and then railed 400 km to the Rönnskär Cu smelter east of Skellefteä, where LME (London Metal Exchange) grade Cu cathodes are produced. By-product gold and silver are also extracted at Rönnskär to produce metallic Au and Ag. Sulphur is captured by the smelter and converted into sulphuric acid. In 2006, Aitik produced about 29 % of the required feed of the Rönnskär smelter, or 240,000 tonnes of Cu concentrate. An average year at Aitik would yield some 60,000 tonnes of Cu-in-concentrate, 1.5-2 tonnes of Au, and some 40-50 tonnes of Ag, from 17-18 Mt of ore.

Since the Start of mining at Aitik in 1968, approximately 450 Mt of ore have been mined from a 3 km long, 1 km wide and 390 m deep open pit. In addition, some 400 Mt of waste rocks have been removed to expose the ore body Proven and probable ore reserves at the Start of 2007 were 625 Mt with 0.28 % Cu, 0.2 ppm Au and 2 ppm Ag. Additional measured and indicated mineral resources were 858 Mt with 0.24 % Cu, 0.2 ppm Au and 2 ppm Ag, with an additional 66 Mt of inferred resources grading 0.25 % Cu, 0.2 ppm Au and 2 ppm Ag (Boliden AB 2006). This makes Aitik the largest Cu deposit in the Fennoscandian Shield and one of the largest Au-rich porphyry copper deposits in the world. The current mine life, including the expansion to up to 36 Mt/a, will allow the mine to continue to operate until 2026. The final dimensions of the open pit in 2026 will be 5000 m long by 1400 m wide and 600 m deep. Exploration in the area is ongoing.

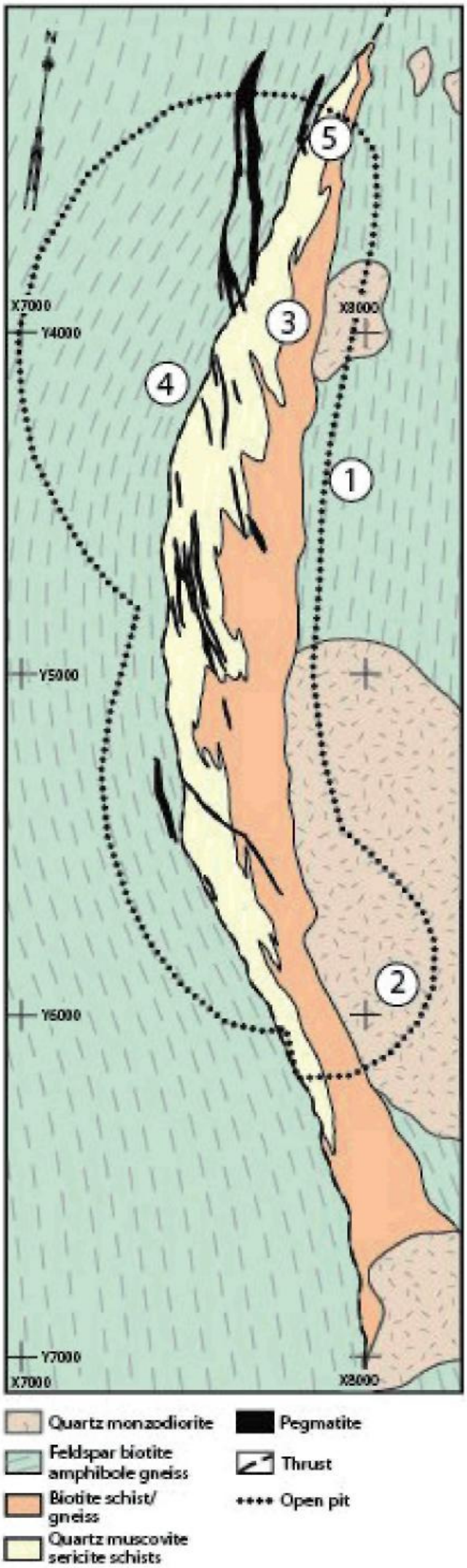

Figure 11: Local geology and excursion stop at the Aitik mine

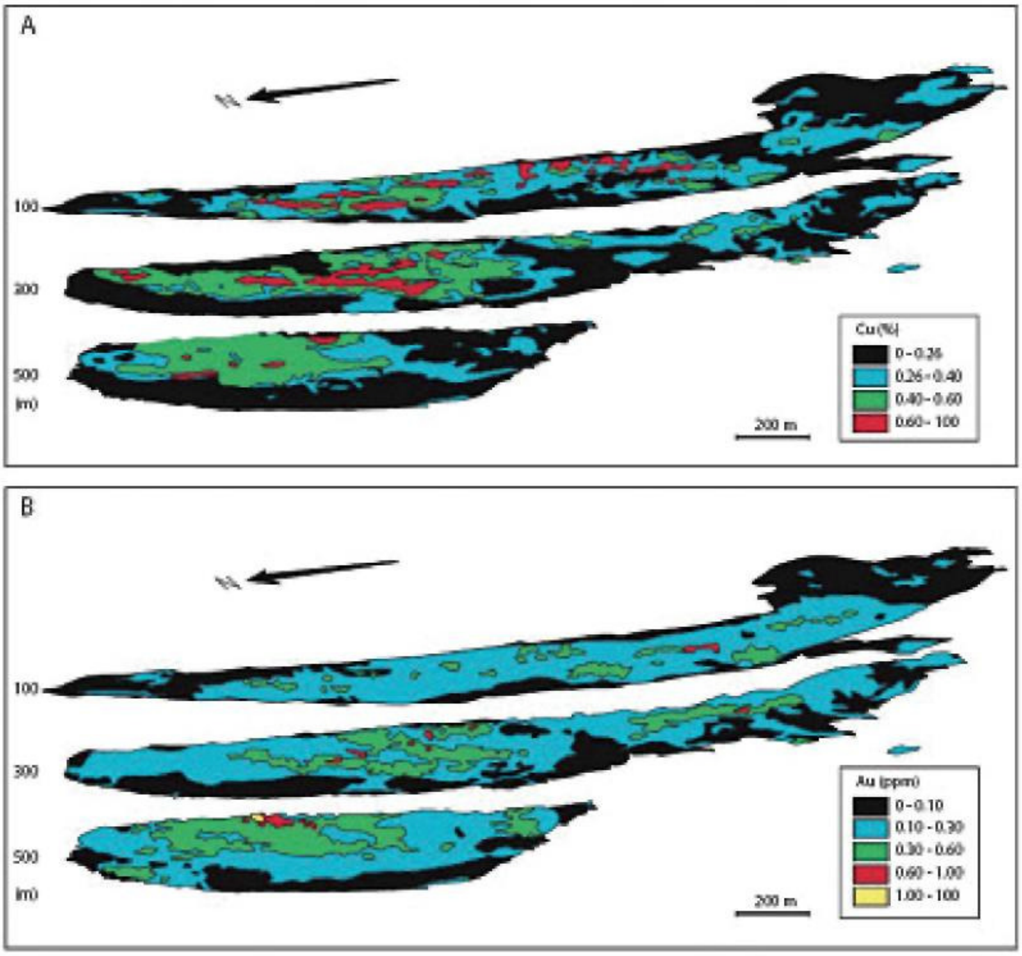

Figure 12: Metal distribution at Aitik for copper (A) and gold (B) for the 100, 300 and 500 m horizontal levels

6 Company Presentations

6.1 Helsinki (University of technology) [7]

handed in by Erhard Maierhofer

6.1.1 Introduction

This Year the University of Leoben spent two weeks in Finland for the Main Excursion.

The first Station was the University of Technology in Helsinki (TKK).

Saturday, 31.05.2008 at ten o'clock we visited the Helsinki University of Technology also known as TKK. Prof. Pekka Särkkä from the University was our guide. He gave us some short reports about the University and showed us the laboratory's and their own Mine near the University.

Picture 2: TKK

6.1.2 About the University

- **History**

In the year 1849 the University started teaching as a technical school with a chemist as a director (Olivier Saelan). In the year 1872 the University became a polytechnic school and in the year 1879 an institute.1904 there were 400 students and 4 years later the institute got the status of a University. This year the University of Technology in Helsinki celebrates 100 years of existence.

The Mission of the University has 3 Main-Points :

- Scientific research
- Top-level teaching linked with research
- Promote education in science and arts

The TKK also fosters freedom in science, art and teaching

- **Key Figures 2007**

<u>1297 Degrees</u>

1068 Master Degrees

(37,5 % female and 6,6 % international Students)

67 Licentiate degrees

162 Doctoral degrees

(19,8 % female and 12,4 % international Students)

15201 Students

12387 Pursuing a master’s degree

(20,3 % female and 4,8 % international Students)

8087 Master-level students of Technology and Architecture

4300 Pursuing a Bachelor of Science

2814 TKK Postgraduate

(28,2 % female and 11,7 % international Students)

928 International Students

82 Full-time students enrolled at the Open University

9441 Students at the continuing education level

(41 % of Master of Science degrees and 52 % of Licentiate of Science)

Objectives by the Ministry of Education

600 foreign degree students (598/year 2007)

360 foreign doctorial students (330/year 2007)

15 % of graduate schools students are foreign (13,5 % year 2007)

15 % of doctorial degrees taken by foreigners (18 % year 2007)

- **Education**

  - Master's and doctorial degrees
  - By 2010 all units will offer at least one master's degree programme in English
  - Students and teachers are encouraged to take part in international exchange and practical training abroad
  - Special attention is paid on pedagogical education and teaching arrangements
  - Number of admitted students to be reduced in a controlled manner

- **Focus areas for education & research**

  - Internationalisation
  - Quality and capacity for innovation
  - Impact on society
  - Digitalisation
  - Energy and the environment
  - Forest cluster
  - Health and well-being
  - Information and communications industry and services
  - Metal products and mechanical engineering
  - Micro- and nanotechnology

- **Erasmus Mundus Programms**

TKK coordinates one and participates in two Erasmus Mundus Programmes.

- NordSecMob – Master's Programme in Security and Mobile Computing (Coordinator)
- SpaceMaster – Joint European Master in Space Science and Technology
- EMMEP – Erasmus Mundus Minerals and Environmental Programme

- **Master degree programms in English**

TKK offers eleven master's programmes in English, four non-degree programs in English, three Erasmus Mundus Programmes and individual courses in English.

- Bio- informatics
- Communications Engineering
- Electrical Engineering
- Forest Products Technology
- Foundations of Advanced Computing
- Geoinformatics
- Machine Learning and Data Mining
- Micro- and Nanotechnology
- Mobile Computing – Services and Security
- Process Systems Engineering
- Real Estate Investment and Finance

- **Masters Degree (1990-2007)**

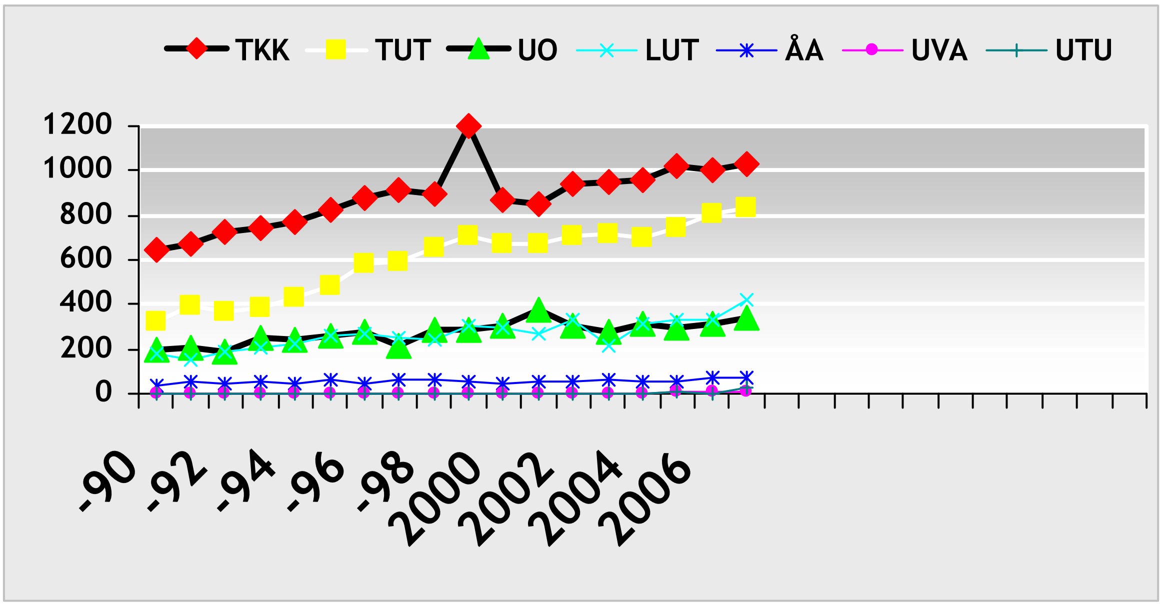

Table 2: TKK Presentation (Master's degree)

- **Doctorial Degree (1990-2007)**

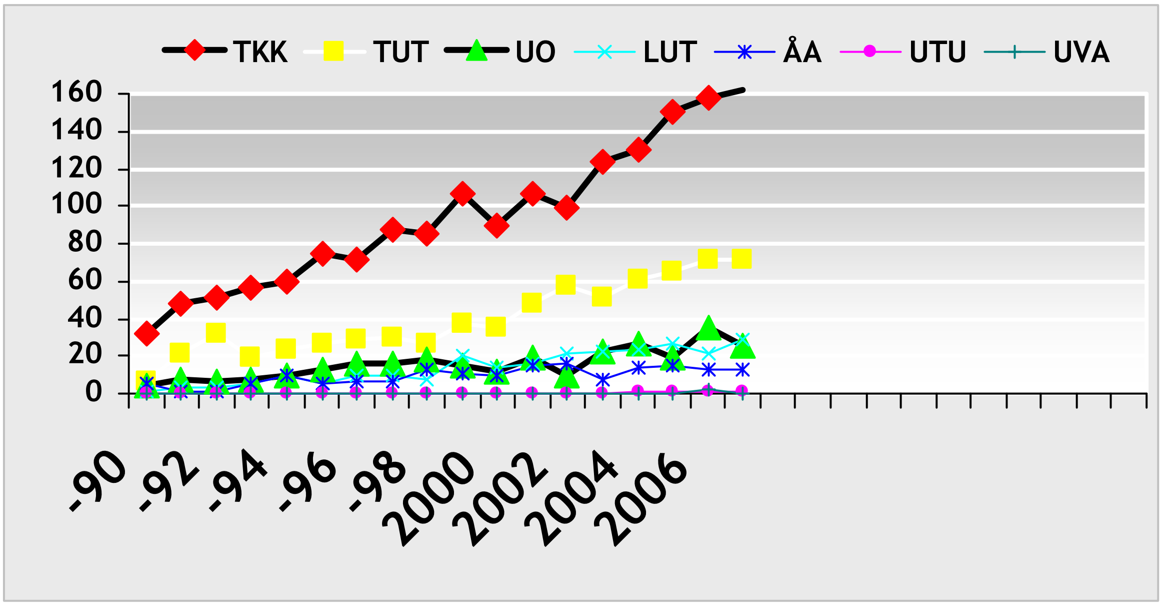

Table 3: TKK Presentation (Doctorial degree)

- **Graduates in Rock Engineering (Master of Science)**

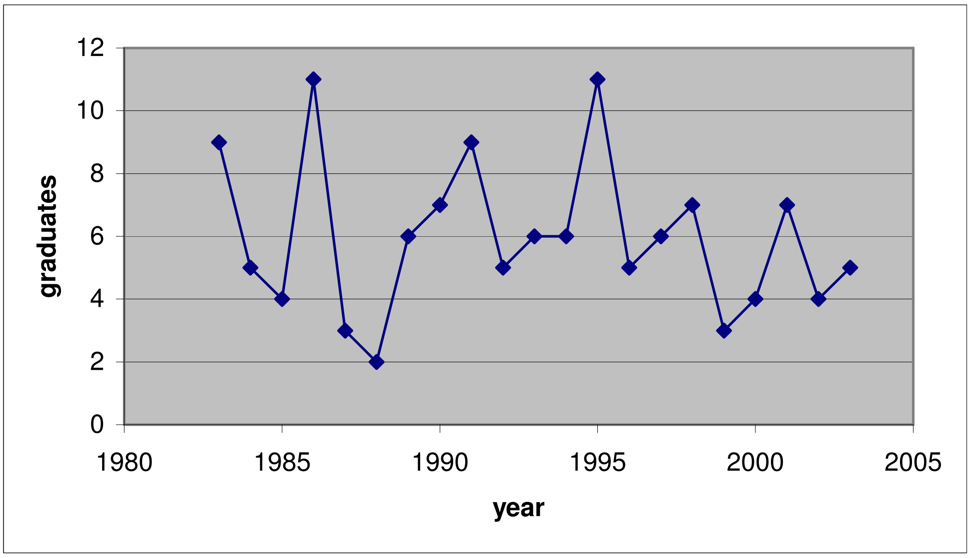

Table 4: HUT Presentation (Graduates in Rock Engineering)

- **Cooperation with Finish Companies**

6.1.3 Test Mine

Picture 3: Underground Test Mine (TKK); (5 pictures)

6.1.4 Overview of Finish Mining

- **Mining Base in Finland**

Geologically part of the Baltic Shield

- Old, eroded bedrock
- Strongly methamorphosed

Several glaciation periods

- Flat surface
- No sedimentary rocks
- Few meters of soil above hard rock

- **Overview**

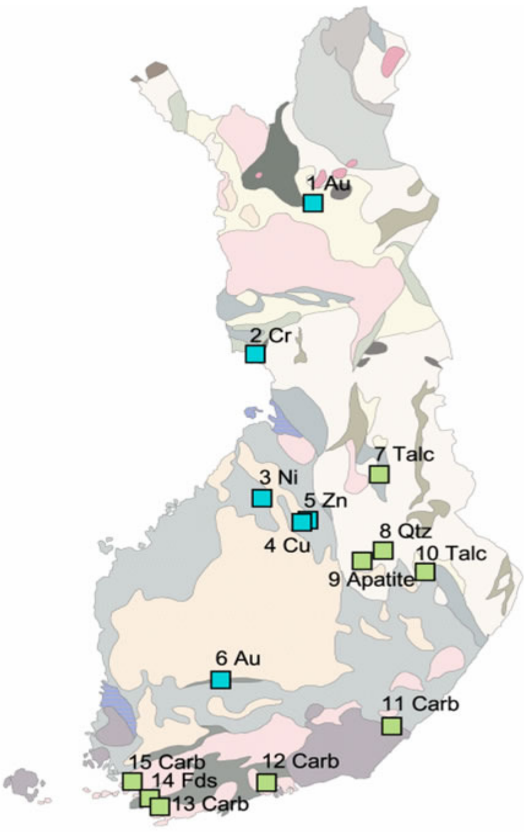

Figure 13: Overview of Finish Mines

- **Ore outputs**

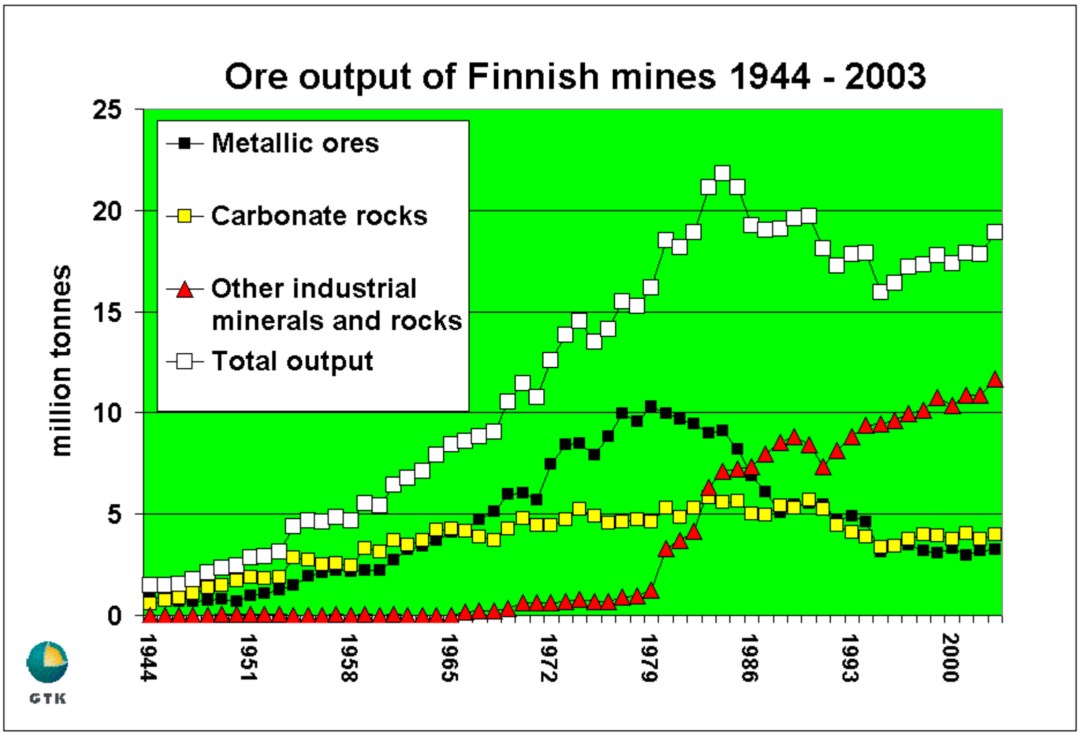

Figure 14: Ore outputs of Finish Mines

- **New Projects**

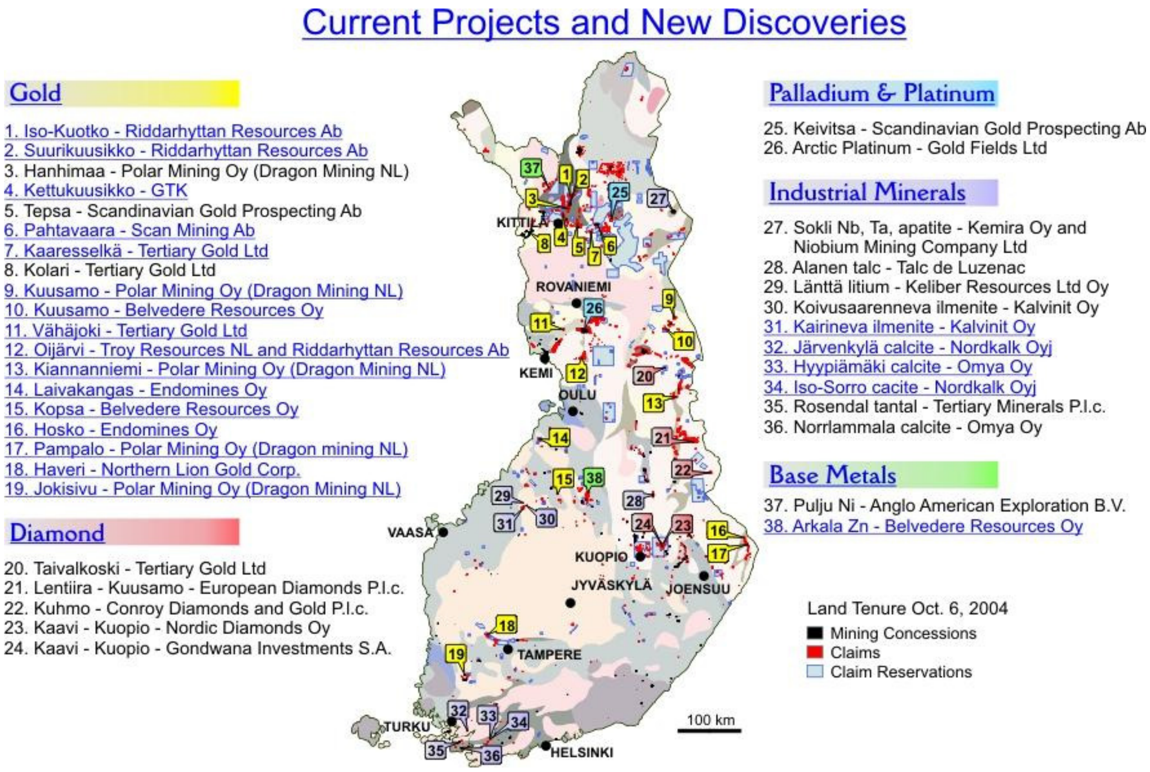

Figure 15: New Finish projects

6.1.5 Group Picture

Picture 4: Group picture at TKK; Underground Mine

The Students from Leoben had a good time at the University of Technology (TKK) in Helsinki, and we say thank you for the nice tour!

6.2 Sandvik (Mining equipment) [8]

handed in by Johann Eder and Andreas Schmid

6.2.1 Introduction

On the third day of our excursion we visited the Sandvik mining company in Tampere.

Lasse Schulz, Human ressources Manager Underground Hardrock Segment and Sari Lahdemäki were showing us the schedule for the whole day and the first part of a presentation.

Time	What?	Name
9:30	Company presentation	Lasse Schulz
10:30-12:30	Test mine visit	Jani Korpela
12:30	Lunch in the canteen	
13:30	Factory tour	Jane Perkolla, Kimo Perkolla
14:30-14:50	UHRM, R&D	Markku Keshiniva
14:50-15:30	Mechanics of drilling	Markku Keshiniva
15:30	Sandvik as an employer	Sari Lahdemäki
16:00	Summary discussions	
In the evening	Dinner and Sauna	

Table 5: schedule

6.2.2 Company Presentation

Sandvik is a global industrial group with advanced products and world-leading positions in selected areas. Since its founding in Sandviken in Sweden in 1862, Sandvik has developed into a global enterprise, with a multifaceted expertise in the field of materials technology. During 2007 the Group had 47,000 employees, representation in 130 countries and sales of more than SEK 86 billion (US $ 13 billion).

Every product is backed by extensive R & D (Research & Development), application expertise, a network of authorized dealers, on-site service and training, and aftermarket support. The company spends more than 2.7 billion SEK in R & D and about 2300 employees are working for R & D. In order to that they are able to call more than 4800 patents their own. The acquisitions in the years 1997 to 2007 were more than 50 companies in 20 countries (22 SEK billion, 15.000 employees).

The three business areas are shown in the following picture.

	Sandvik Tooling	**Mining and Construction**	**Materials Technology**
employees	24.700	33.100	22.500
Margin-%	24,2	15,1	10,8
ROCE-%	33,5	31,2	14,5
	For tools and tooling systems for metalworking	Equipment, tools and services	Alloy materials and value added products

Table 6: business areas

Sandvik has no big shareholders, but there are some common owners of Sandvik and Atlas Copco.

The five key elements of the company are:

- Strong product portfolio
- Focused R & D resources
- Diversified customer base

- Strength to add acquisitions
- Global and local presence

The core values of Sandvik are:

- Open Mind (to create an atmosphere, no dirty tricks, team players across boarders)
- Fair play
- Team spirit

- **Mining and Construction Segment**

In the year 1998 Tamrock and Sandvik Rock Tools merge to create Sandvik Mining and Construction. The segment is divided into three customer segments, mining (50 %), construction (75 %) and materials handling (25 %).

The key figures of the segment are shown in the following table.

Key figures	2007
Growth	9 %
ROCE	25 %
EBIT	15,1 % profit

Year	Sales [BSEK]
2004	16,6
2005	20,6
2006	25,0
2007	33,1

Table 7: key figures

The main business drivers and trends of Sandvik are shown in the following table:

Market	**Technology**	**Customers**
Continuing high demand	Mechanization and automation to safety	Junior miners
	From drill and blast to continuous mining	Globalization, search for energies
	Surface to underground	

Table 8: business drivers

The industry approach of Sandvik is:

- Technically advanced
- Safety focused
- Environmentally conscious
- Global approach
- Cross disciplined workforce

Sandvik has a lot of different customers and they expect the following facts:

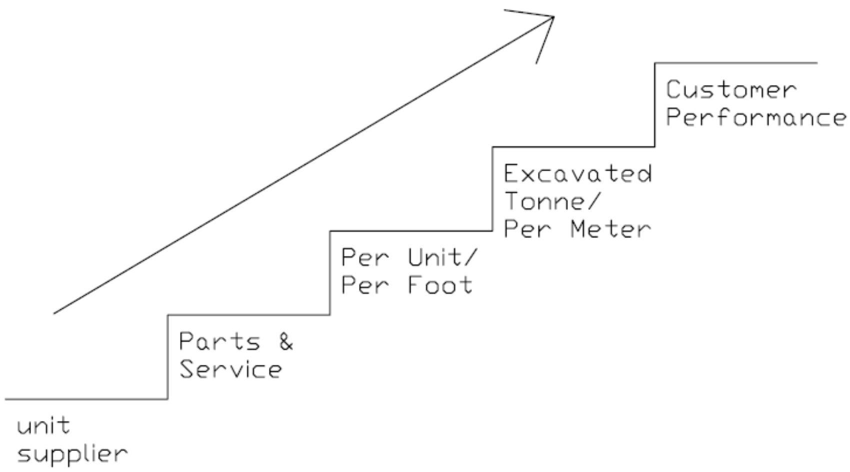

Figure 16: customer expectations

Sandvik and six international mining universities started a unique collaboration partnership in 2007 - the Sandvik International Mining School, to get more educated people for the mining industry.

In order to find the best solution for customers, they work with them together and so they have a customer focused organization.

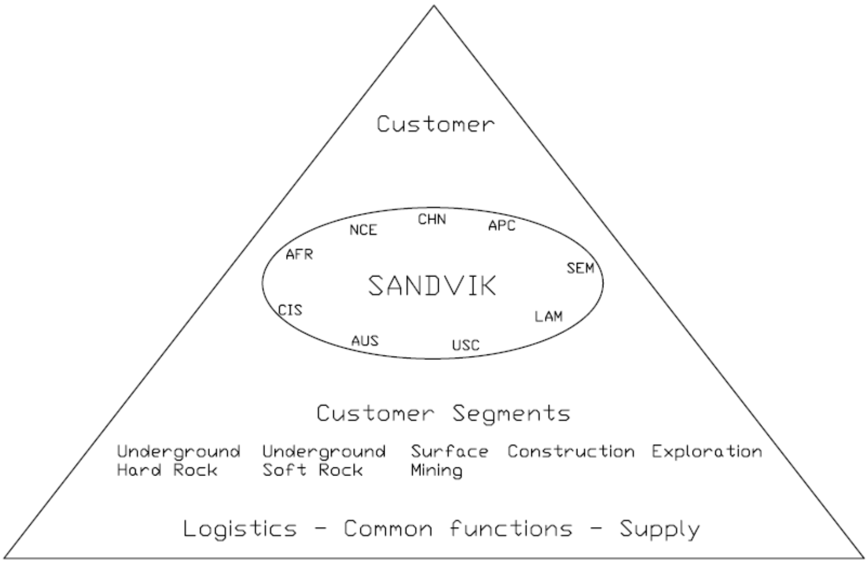

Figure 17: customer focused organisation

Sales by customer industries

Segment	Percent
Underground Hard Rock (UHR)	1/3
Underground Soft Rock (USR)	20
Surface Mining	25
Construction	
Exploration	5

Table 9: sales by customer industries

An advantage of the Sandvik company is the wide product range in the industry. In order to that there are a lot of production plants all over the world, e.g. Lyon, Burlington, Santiago, Johannesburg, Pune, Shanghai, Tampere, Turku where the biggest segments are produced. In the future there is the need to get more capacities for production, because there is an enormous increase in sales expected. Whenever they build a new factory, one experienced person of the company is sent to establish the factory. In each factory there are only one or two products manufactured to keep a high level of quality.

For Sandvik the Chinese market is a very small one so far, but it grows rapidly each year. A philosophy of the company is that it won't work to keep the knowledge locally; as a company you have to think globally for becoming a leader (the company must go to the market and not the other way around).

The official market shares of the year 2006 are shown in the following table.

Kind of product	Percent	Units
Drills	53	850
Loaders and trucks	47	

Table 10: market shares

- **Test Mine**

The totally length of tunnels and facilities in the Test Mine are approximately 2,5 km. The number of accidents in the mine are 2-3 per million hours worked. There are 10 people working at the test mine which also includes a maintenance area, where prototypes are built. Before visiting the test mine we were shown a safety instruction on a TV-screen (called safety in action) and special clothes had to be worn (e.g. hard hat).

➢ **Auto Mine System**

In the Test Mine there is a testing and measurement area for a fully automatic loader. The area is isolated for people, because there is an enormous danger. If a fence of the area is opened, the system will stop all the machines immediately. To get permission by the operator of the Auto Mine System a staff has to ask per telephone. An employee of Sandvik SMC (Jani Korpela) has shown us the whole system underground. In big mines the automatic area can be divided into two parts, so that in one part the machines are able to work and in the other part the mine can be visited. In the Test Mine there was a Toro 7 LHD machine for tests. On the machine are laser scanners assembled, in the front as well as at the back to scan the tunnel to 20 m distance before the machine passes. The distance is also measured by a photometer and cameras. The operator can control the machine any time in his operating office. In the office there are the same hand gears like in the machine to control because loading is done always by the operator. After the loading process the machine is steered into automotive mode.

There are the following reasons to do such a system:

- To make operation safer
- To get people out of the mine
- To control more than one machine by one person (e.g. 8 trucks in South Africa)
- Lots of benefits
- Tons are exactly known
- Operator is sitting at the surface

The system is still working in five mines all over the world, e.g. diamond mine of De Beers (Finsch Mine), Pyhäsalmi mine. Drilling and blasting operations are still done by employees but they are working on a new fully automatic system.

- **Training facility**

In the training facility a trainer showed us the new training simulator for stockhammer drilling. This one year old training center was built because training becomes more and more important for the company and their suppliers. The company noticed that there was no chance to train the people. So two years ago the new training simulator was presented at Bauma. It is very important to know a lot of the different systems on a drill rig to have more experience and to point out the important role of the operator.

The simulator is used for/has:

- Practice in different rock conditions
- To be utilized with the condition
- The same cabin like in the rigs
- The same Control system; also for technical training by creating some problems
- R & D people to do changes on the simulator

There are three simulators delivered (in a school for drilling and blasting, in the United States and in Sweden). On the simulator are working 4 to 5 people permanently. A test person has done a small introduction of the drill rig with the trainer.

6.2.3 Underground drilling rigs production [9]

The presentation was done by Jane Perkolla and Kimo Perkolla. They have shown us a presentation about the drill rig production in Tampere. In the factory are seven platform stations. The stations are transported by air controlled carrier. The steps are done in the production are shown next:

- Station 1:
  - Axles, frames, cylinders, carrier hosing, electricity
- Station 2:
  - Tank, engine, electricity, step boxes
- Station 3:
  - Installation of electricity, carrier hosing
- Station 4:
  - Water reel, boom support, compressor
- Station 5:
  - Electric motors, front mud guards, electric cable, water hose
- Station 6:
  - Fuel tank, gearing reel, rear mud guards, shank
- Station 7:
  - Air conditioning, dust filter, cabin, lights

After the seven steps the machine is customized by lifting up with the cylinders and the booms and feeders are fitted. At the end the wheels are put on the machine and fueling (oils, diesel…) is done. The next part is testing the machine by electric inspectors and the calibration of the booms and feeders. A test drilling is done at the test mine for every rig. It is the final quality control by doing 20-30 holes per boom. After testing the machines are washed and painted and prepared for finishing by covers and stickers. It takes about 4-6 weeks for producing a drill rig from start to end. There are about 10+/-1 underground rigs and 20 surface rigs produced per week. The whole output of Tampere factory are about 1000 rigs per year (300 underground drill rigs and 700-800 surface rigs). In every machine is 70 % standard and 30 % can be chosen by customers (e.g. feeders, booms, information systems). There are also different types of carriers which depend where the machine is going. Till the year 2010 the order books are full. After the short presentation about the factory we were going to visit the production lines. Before that a safety instruction was done. There are four parts of the production (MP1, MP2, MP3 and MP4). MP4 is the test mine.

- **Factory visit**

We all were wearing warning vests and glasses for safety. First we have seen the commando which is the smallest product of drill rigs (100-200 rigs per year). The production line is just in time organized and the working time is two shifts within 16 hours.

There are 250 people working in the production (including underground testing personnel/final assembling 90 people). The machines are moving from station 1 to 7. For surface drill rigs the production is quite different. The surface rigs are produced in parts somewhere near Tampere by subcontractors and these parts are combined at nine stations and two production lines. It takes about two weeks to produce a surface drill rig. Nowadays the material price for steel and components is a big problem as well as getting enough material.

6.2.4 Basics of drilling [10]

Mr. Markku Keshiniva is Research Manager for R & D and Engineering in Underground Hard Rock Mining. The most important research parts are:

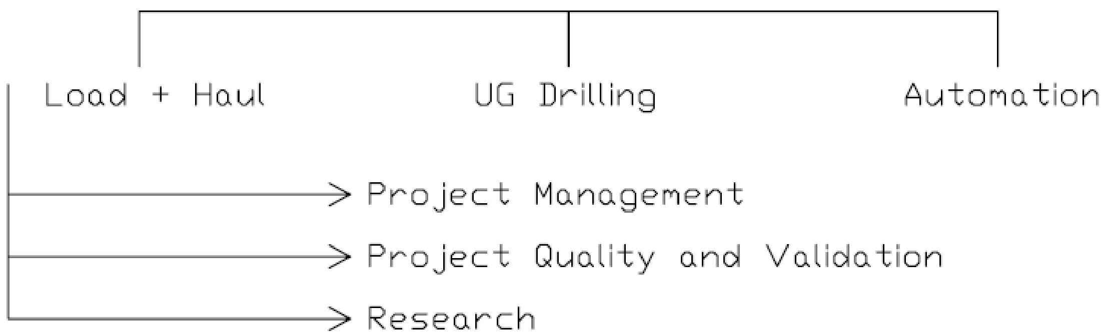

Figure 18: research parts

He is responsible for technology development

Area of focus for near future:

- New drilling concept (drills)
- Future energy systems (LHD)
- Underground communication and localization (Mine Automation)

- Technology network, e.g. universities

A very important part of underground hard rock mining is drilling. The most important facts about drilling are shown next.

Drilling can be divided into two different parts:

- Percussive drilling
    - Impact induced stress wave
- Top hammer drilling
    - Stress wave transmitted through the drill string into rock

The four basic functions of drilling are percussion, feed, rotation and flushing. The most important part is percussion.

For drilling are two key factors most important:

- Efficiency: how to utilize the stress wave energy
- Controlling the stress wave

Real facts for drilling parameters:

- Power: 1-5 MW
- Stress wave 0,2-0,3 ms
- Velocity 5190 m/s
- Frequency 30-100 Hz

Efficiency of stress wave

a) Energy transmission through the drill string

b)

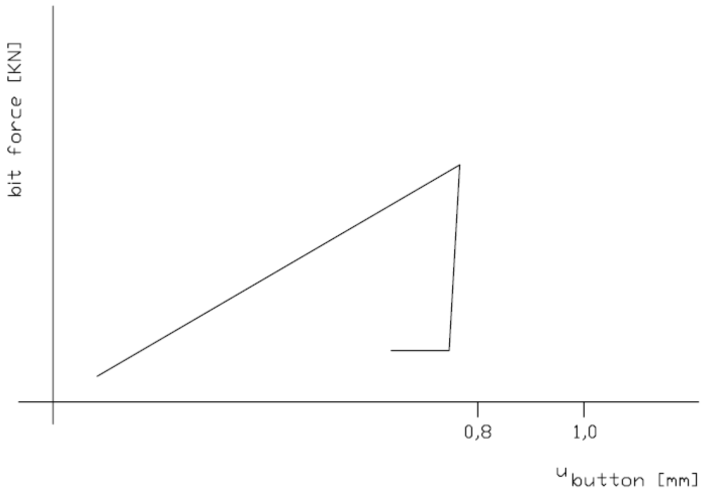

Figure 19: bit force vs. u_{button}

Stress recorded in the middle of the first rod

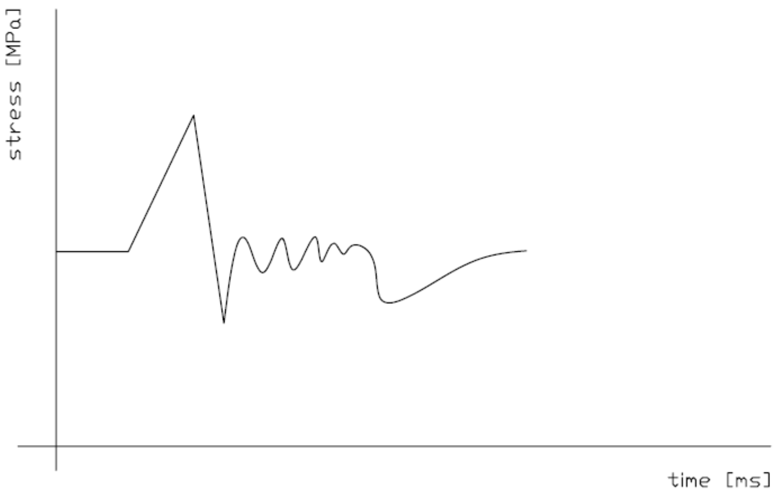

Figure 20: stress vs. time

6.2.5 Controlling the stress wave

The most critical issue is to avoid tensile reflection waves:

- E.g. in couplings
- Tensile waves are directly responsible for premature failure

- **Primary tensile waves**

Why do we get tensile waves and influence?

- Drilling into cavity
- Underfeed
- Drilling with too low penetration resistance is close to the underfeed situation

An important factor is that you have always to change between hard- and softrock drilling the bit buttons to get an acceptable result.

- **Secondary tensile waves**

They are caused by the compressive reflections in cases when no absorbing mechanism is provided at the shank end as:

- Piston contact
- Drill body contact
- Stabilizer/dampening device

6.2.6 Interaction between percussion and rotation

The impact always interferes the rotation. A picture was shown where the rotation was stopped during the impact. The important facts for the interactions are:

- Positive torque waves tightening the threads
- Negative torque waves opening the threads

6.2.7 Optimum Feed

Underfeed:

- Poor bit rock contact
    - high tensile stresses
- Low rotation resistance
    - Couplings running open
    - Threads wearing out

The problems in practice are tensile reflections

Rule 1)

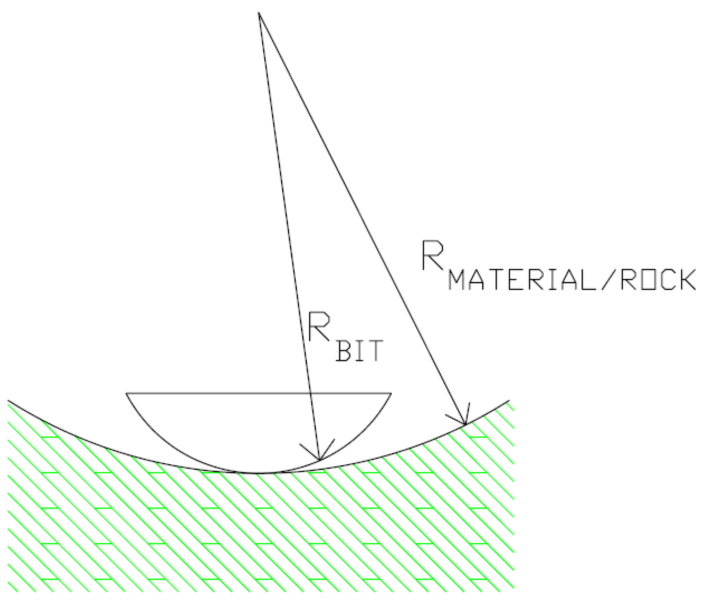

Figure 21: problems in practice

Rule 2)

Rock penetration resistance of the bit: $K_{Bit} = \Sigma K_{Button}$ (in contact)

Rule 3)

Between impacts only one button is in contact = VERY BAD; you have to look for more bits in contact to get resistance force higher and no more tensile stresses

6.2.8 Sandvik as an employer

Tampere is the 3rd largest city in Finland and it is known for its textile industry. Sandvik has about 1700 employees in Finland. The following table will show the production cities with its number of employees.

City	Number of employees	Segment
Hollola	100	Sandvik Mining and Construction (SMC)
Lahti	200	SMC
Tampere	1000	SMC, Tooling
Turku	365	SMC
Vantaa	40	SMC, Tooling, Sandvik Materials Technology (SMT)

Table 11: production cities and employees

6.2.9 Strategy

There are a lot of ways to develop competencies:

- Introduction programs
- On the job training
- Job rotation
- Mentoring
- External or internal training programs, e.g. Sandvik International Mining School

6.2.10 Expectations of Sandvik from employees

- Occupational degree
- Versatility
- Ability to apply learned things into practice
- Language and cultural skills

- IT skills
- Customer orientation
- Understandment of our business
- Innovativeness
- Motivation and willingness to develop
- Readiness to change
- RIGHT ATTITUDE
- Willingness to travel

- **Offers to employees**
    - Interesting job with world class products and talents
    - Possibility to develop oneself in a innovative and international business environment
    - Versatile employee benefits
    - A work community that follows ethical, environmental and safety guidelines

The career opportunities are shown on the homepage of Sandvik:

www.sandvik.com/career

At the end there is a very apposite saying:

"When you know the direction, even a little fog along the way won't disturb you."

6.3 Pyhäsalmi (Cu, Zn, S, Ag) [11];[12]

handed in by Reinhard Toferer

6.3.1 Introduction

On the 3 June we visited the Pyhäsalmi Mine located on Lake Pyhäjärvi in central Finland. The mine is the deepest underground mine in Europe with 1400 meters below surface. The mine belongs to the Inmet Mining Corporation.

Ilpo Mäkinen the mine manager showed us a short presentation and then the underground mine.

6.3.2 Company

Inmet Mining Corporation is a Canadian-based global mining company that produces copper, zinc and gold. They have operations and development projects in Turkey, Finland, Canada, Papua New Guinea, Spain and Panama. The company are also actively exploring and seeking out other growth opportunities around the world. Inmet have approximately 3,200 employees worldwide.

They produced in the Year 2007 79.000 tonnes copper, 85.000 zinc and 223.000 ounces gold in their mines. Because of the high metal prices in the last year they had a cash balance of 840 Millions $.

Next picture shows an overview of their mines:

	Çayeli Turkey	Pyhäsalmi Finland	Troilus Canada	Ok Tedi Papua New Guinea	Las Cruces Spain	Cerattepe Turkey	Petaquilla Panama
Ownership	100%	100%	100%	18%	70%	100%	48%
Primary metal	copper	copper	gold	copper	copper	copper	copper
Secondary metal	zinc	zinc	copper	gold	—	—	gold
Mine type	underground	underground	open pit	open pit	open pit	underground	open pit
Mine life	2016	2018	2009	2013	2008-2022	2009-2014	23 years

Figure 22: Mine overview

Pyhäsalmi is an underground copper and zinc mine located on Lake Pyhäjärvi in central Finland. It produces three types of concentrates: copper, zinc and pyrite.

6.3.3 History

The ore body of the Pyhäsalmi mine was found in 1958. 1962 the mining started with an open pit mine, after 5 years the activities in the open pit were finished and the underground mining started. 1995 the underground mine was 1050m deep and this part of the deposit was mined out in 2000. 1995 they found a deposit with 50 Mio. tonnes of ore in a level of 1440 meters below surface. In the year 2015 probably the mine will closed.

6.3.4 Geology

The deposit is located in the N-S trending, Svecofennian, Ruotanen Schist Belt of the Pyhäsalmi Volcanic Complex, in the Eastern Volcanic Sequence of the Pyhäsalmi area. The schist belt is dominated by felsic metavolcanic rocks with smaller volumes of mafic metavolcanic and felsic metasedimentary rocks, and is cut by younger granitoids in its northern parts. The deposit is in the central part of the RSB: It is dominantly hosted by sericite-rich rocks formed by alteration from felsic volcanic and metasedimentary rocks. Within the schist belt, dolomitic marbles are only detected locally in the Pyhäsalmi ore and in its immediate footwall rocks. The host volcanic sequence is composed of a bimodal complex of low- to medium-K rhyolites, transitional between calc-alkaline and tholeiitic, and sub-alkaline low- to medium-K tholeiitic basalts and basaltic andesites. Trace element chemistry of the volcanic rocks indicates a mature island arc setting. Major host rocks Pyroclastic rhyolite. Minor host rocks Rhyolitic lava, mafic lava and tuff breccia, dolomite. Intrusives 1875 Ma plagioclase porphyries post-date mineralisation, as they, and quartz porphyries and certain 'amphibolites', cut across the massive ore, although also are deformed, as the dykes are fragmented, possibly into large boudins. Granitoid intrusions in the area date at 1886-1867 Ma and they intrude the entire volcanic sequence. Pegmatites intruded the deposit during D4.

The next pictures show a map of the regional surface geology around the Pyhäsalmi mine and a geological slice through the mine.

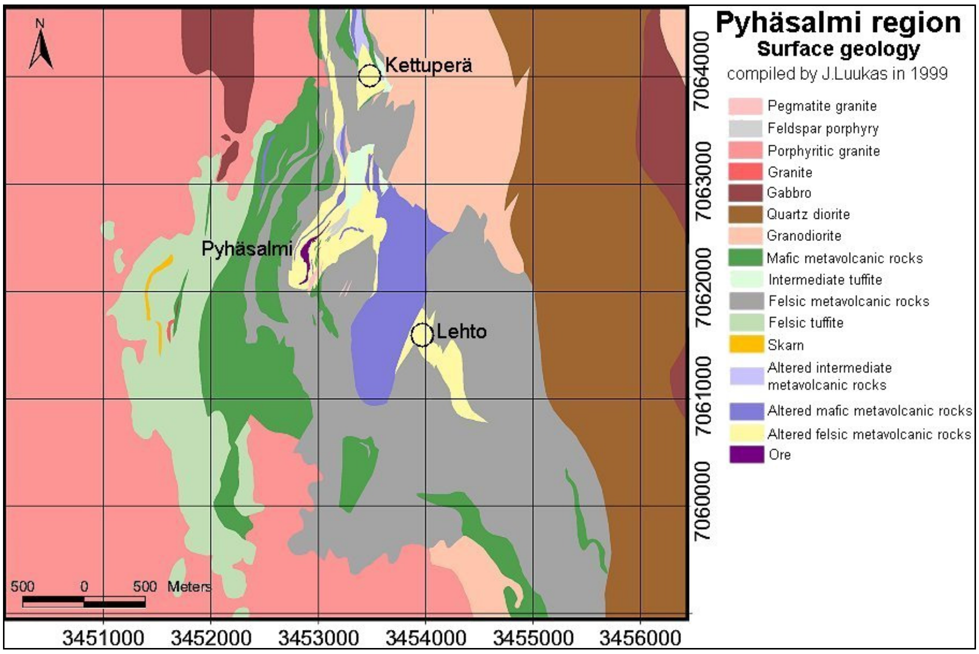

Figure 23: Regional Geology

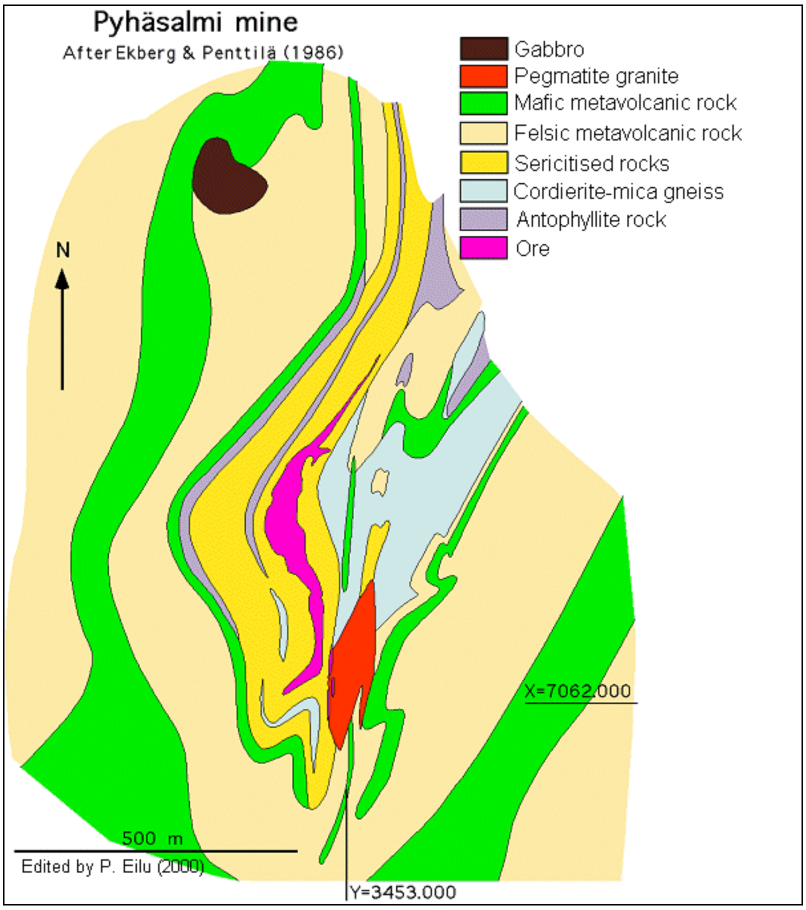

Figure 24: Geological slice through the mine

- **Deformation history**

Collision against the Archean Karelian Craton started at 1.91 Ma and culminated with voluminous granitoid intrusion at about 1.885 Ma: peak regional metamorphism and D2 deformation took place at 1.89 Ma and was followed by transpressional D3 deformation at 1885 Ma; later, the retrograde D4 shearing followed Polyphase deformation post-dating sulphide mineralisation, at about 1900-1875 Ma. The dominant feature is the isoclinal D2 folding of the ore with an axial plunge to the S at 40-60°.

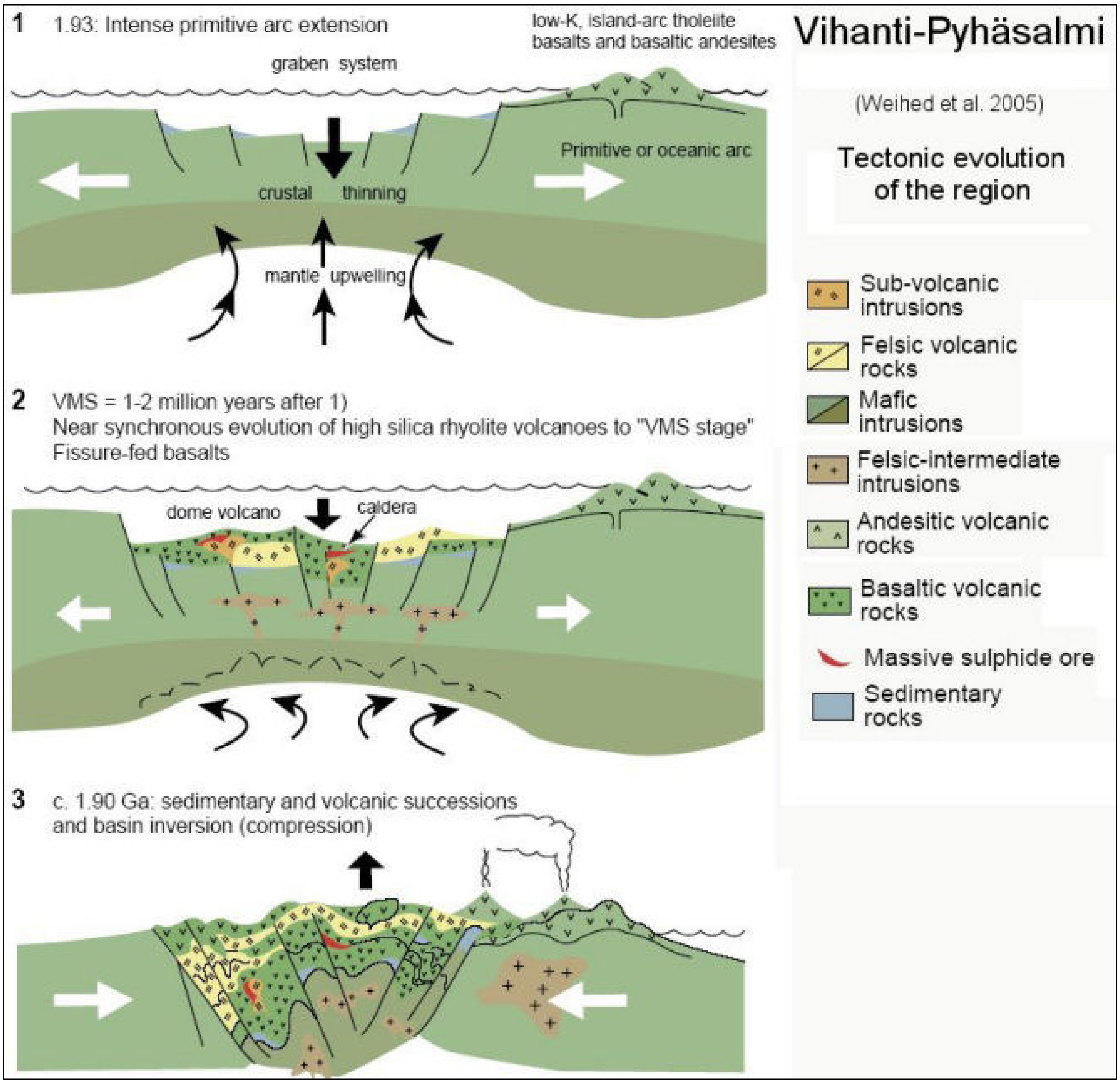

Figure 25: Tectonic evolution of the region

6.3.5 General

The Pyhäsalmi mine is like the next picture organized.

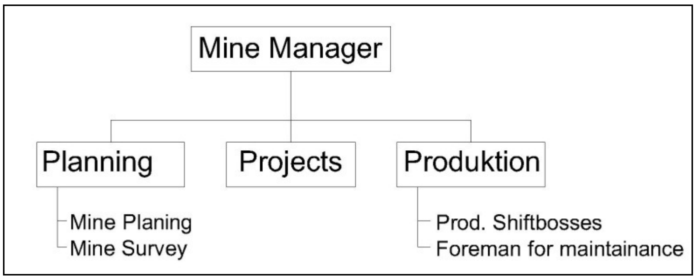

Figure 26: Mine organization

The Pyhäsalmi mine mined 2007 ~ 1,4 mio. tonnes of ore and produced in the processing plant the following concentrates:

CuC	46.325 tonnes
ZnC	71.812 tonnes
SC	485.780 tonnes
Cu	1,03 %
Zn	3,10 %
S	40,33 %

Figure 27: Production

The next chart show the productivity of the Pyhäsalmi mine for the last 8 years. We can see that the productivity increases every year.

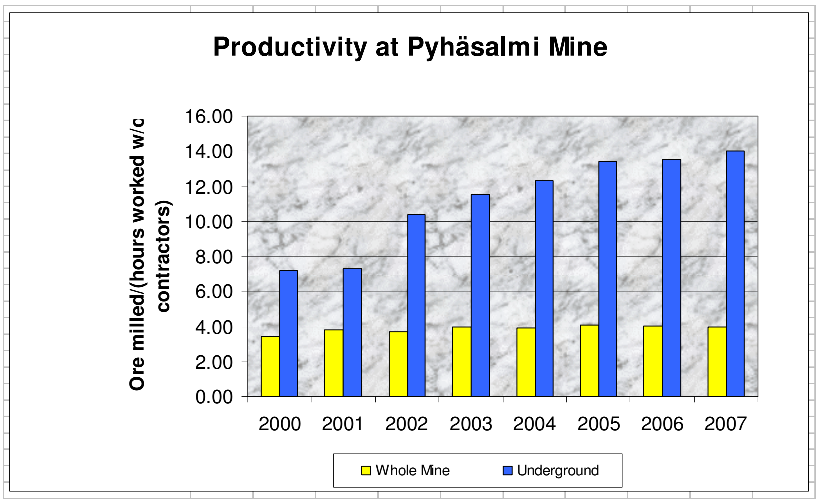

Figure 28: Mine productivity

The mine employ 58 persons, 54 from these are miners, they work in two shifts (first shift from 6.00 am until 14.00 pm and the second shift from 14.00 pm until 22.00 pm) per day 5 days the week. General there are 206 shifts a year.

6.3.6 Mining Method

The general mining method is sublevel stoping with backfill in 3 different principles. The 3 different principles distinguish in the floor geometry and for the first principle they need a third drift. You can see the 3 principles in the next 3 pictures. The general stope is 55 meter high and 15 – 18 meters wide. for the extraction they drill fans downwards from the drifts.

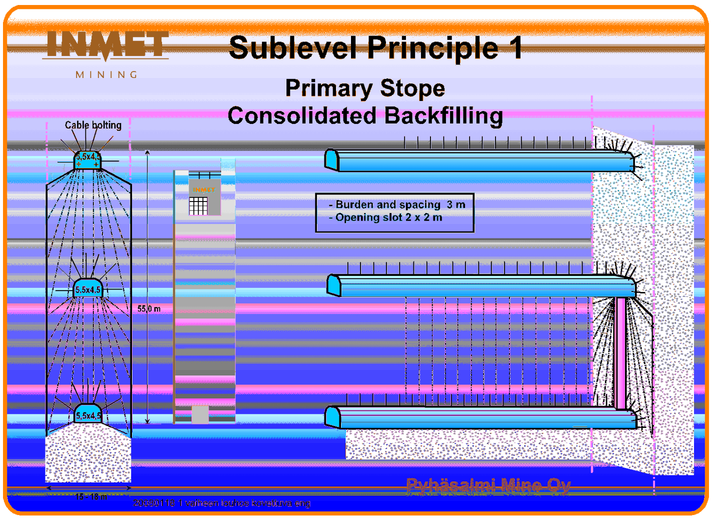

Figure 29: Minig principle 1

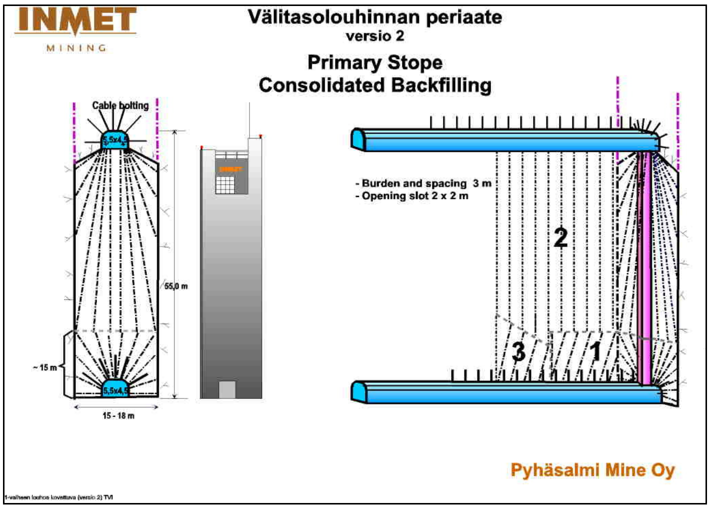

Figure 30: Minig principle 2

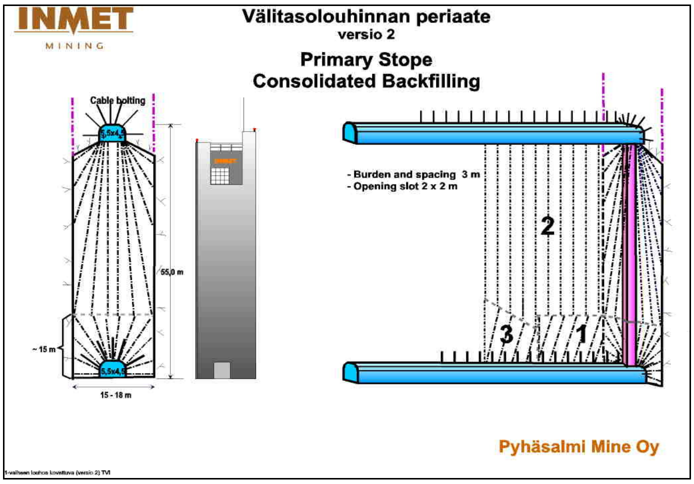

Figure 31: Minig principle 3

The next picture shows the mining sequences for the whole level. First they extract the lower left and right stope, then they backfill the stopes and extract the upper left and right stope. The next step is to backfill the upper left and right stopes and finally they extract the middle stopes.

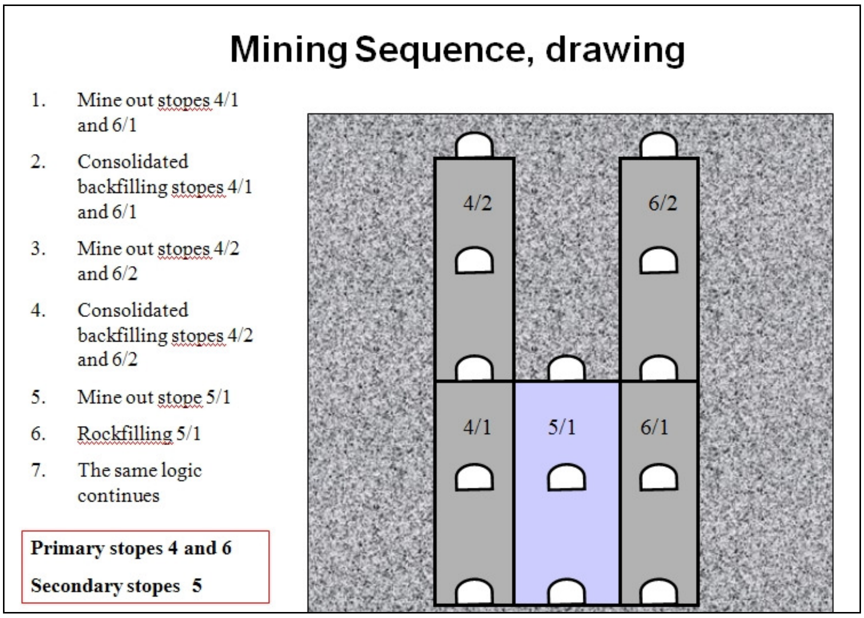

Figure 32: Mining sequence

The next picture shows a general map from the mine with the drifts and shafts.

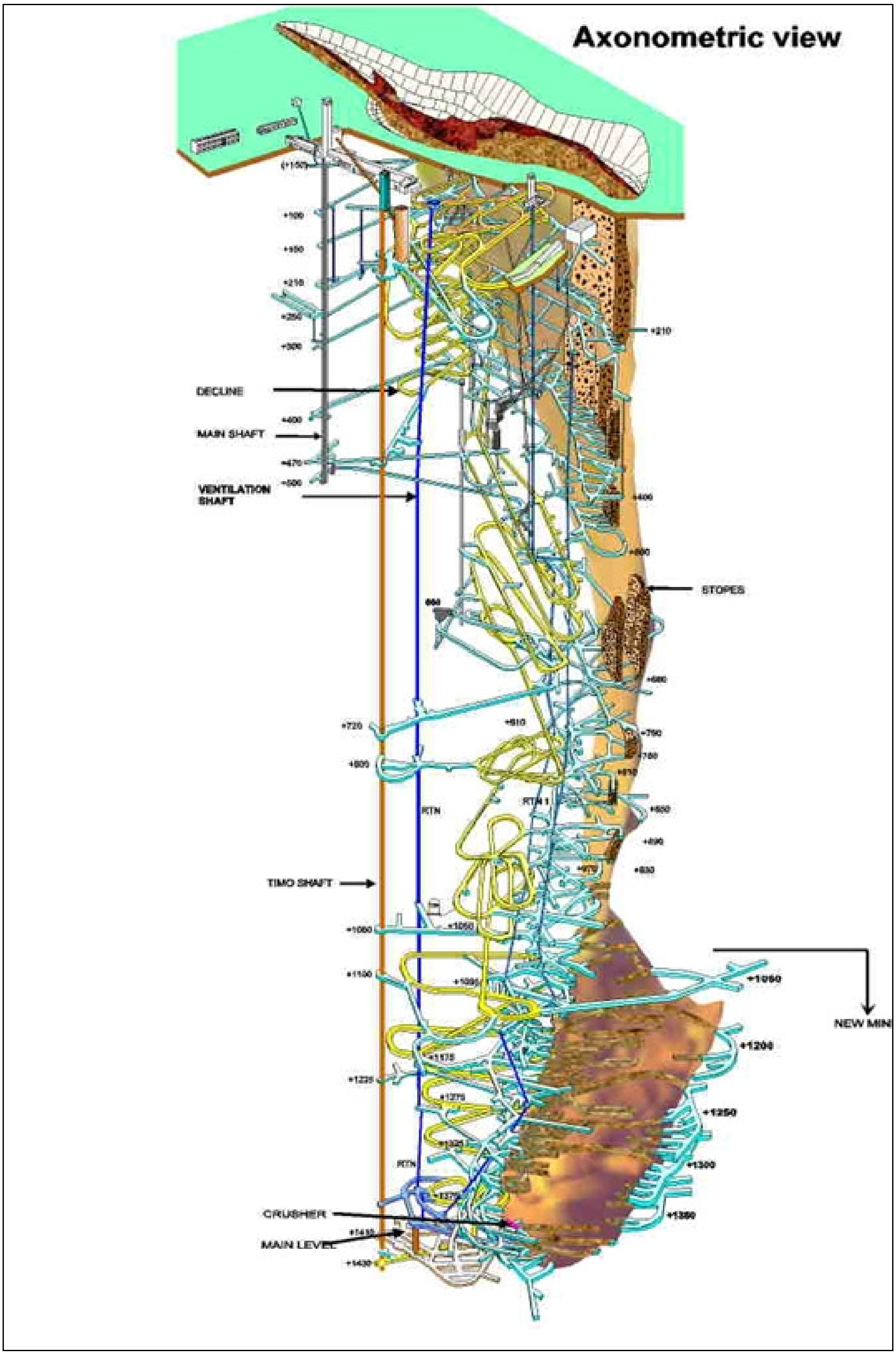

Figure 33: Mine map

6.3.7 Mine Equipment

The next table shows the whole mining equipment from the Pyhäsalmi mine.

Mobile Equipment – Mining	
Drilling	Axera D07S-260
	Para 306-60 as back-up unit
Charging	Charmec 1525BE (emulsion)
	NT 60/2 (Anfo)
Bolting	Robolt 320
Shotcreting	Spraymec 1050WP
Hauling (waste)	Toro 40D 1 units
Mobile Equipment – Mining	
Drilling	07 – 7F DATA
Charging	NT/00/2 CHARMEC
Cable Bolting	Cabolt 530
Shotcreting	Spraymec 1050WP
Mucking	Toro 0011
	Toro 0011 AutoMate
	Toro 11 AutoMate
	LH517
Secondary breaking	Toro 501 Rammer
Mobile Equipment – Others	
Diamond drilling	Diamec 264
	Diamec U6
Sludge drilling	Solo 506 RTS
Working platform	NT 100/1 Utilift
Scaling	Normet Scamec
Road grader	NV 15
Fire truck	Toro 40 D carrier
Light vehicles	~20 units

Table 12: Mining equipment

6.3.8 Haulage system

The following picture show the haulage system for the ore in the Pyhäsalmi mine.

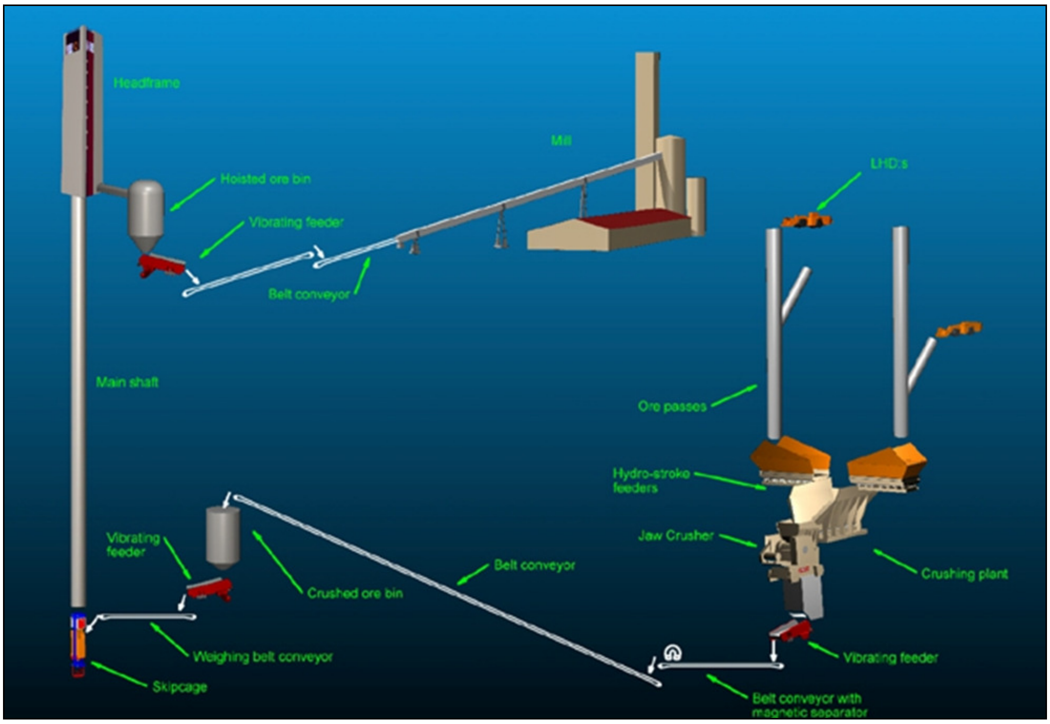

Figure 34: Haulage system

Head frame
▪ height 52 m ▪ 10,5 m x 10,5 m
Hoist
▪ rope guided friction hoist ▪ capacity 275 t/h ▪ skip payload 21,5 t ▪ hoist velocity 15,5 m/s / 12 m/s ▪ 6 guide ropes, 4 hoist ropes, 3 balance ropes ▪ pulley ø4,5 m ▪ power 2,5 MW

Table 13: Head frame and hoist

Crushing plant +1400
▪ two ore passes between +1175 - +1400 (ø3,1 m), ▪ hydro-stroke feeders on the bottom ▪ middle hydro-stroke feeder (can be tipped by trucks/LHD's)
Jaw crusher Lokomo C200B
▪ capacity > 500 t/h ▪ setting 150 mm
Roxon feeders

Table 14: Crushing

Figure 35: Haulage shaft

Figure 36: Crusher

6.3.9 Backfill

They have two types of backfill:

Hydraulic Fill

- Used in primary stopes with waste rock
- As aggregate cyclonized waste
- As binder blast-furnace slag, activated by lime
- Consumption in 2007: 73 431 m^3
- Transported underground via drill holes and PEH-pipelines
- One line in use, other ø 56 mm as back-up
- New line, ø76 mm under construction

Waste Rock Backfill

- Used in some secondary stopes
- In primary stopes hydraulic fill + waste rock
- Waste rock from development works or from side rock pit
- Consumption: 2007 total 277 130 m^3
- Transported with trucks or LHD and tipped into stopes

Figure 37: Backfill types

6.4 Kemi (Cr) [13];[14];[15]

handed in by Alexander Ottacher and Abdelouahab Dif

OUTO KUMPU

6.4.1 Introduction

Outokumpu is an international stainless steel company. Its customers are located in the process industry, construction and electrical industry as well as in the information technology and households. The Outokumpu Group employs today approx. 8000 people in over 30 countries and the Group's sales were about EUR 6.9 Billion, whereas 5% were generated in Finland. The Group's headquarters is located in Espoo, Finland.

This short report is focused on the Kemi chrome mine, which is part of the mine-to-mill operation Tornio works in northern Finland.

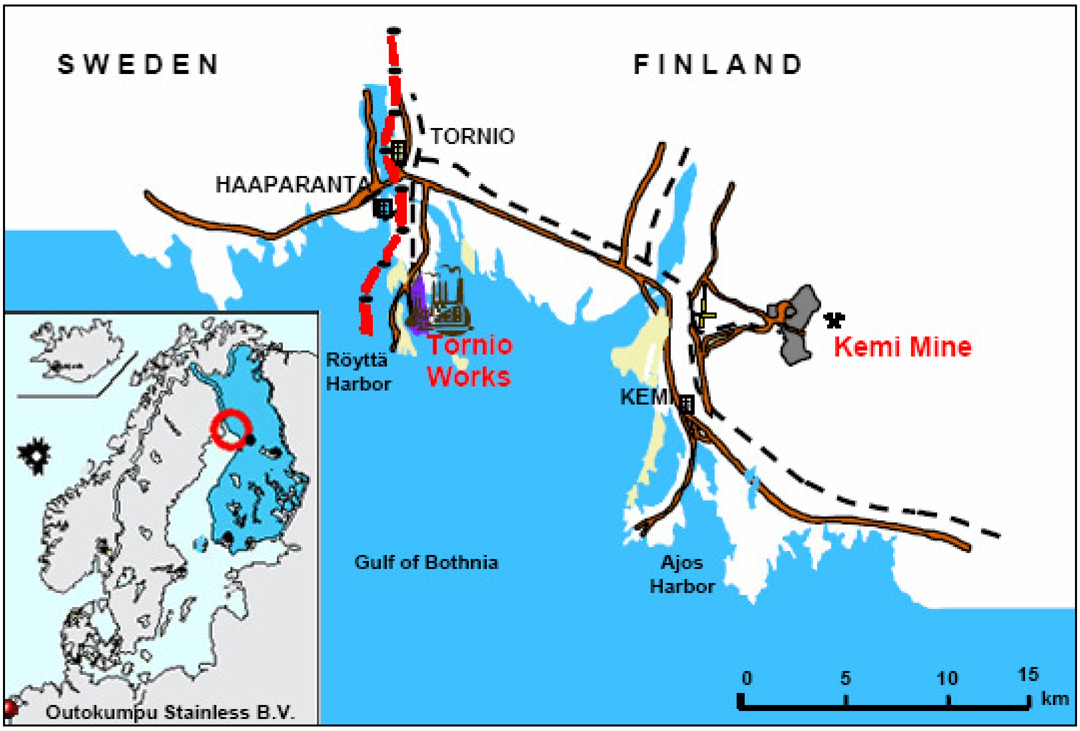

Figure 38: Geographical location

6.4.2 Geology

The Kemi deposit is hosted by a 2.4 billion year old mafic-ultramafic layerd intrusion. The Chromite mineralization was discovered in 1959, when a fresh-water channel was excavated in the area. Geological Survey of Finland began exploration, which led to the discovery of a chromite-rich layer. From 1964 the exploration was carried put by Outokumpu Oy, which decided to exploit the deposit 4 years later, after location about 30 million tonnes of chromite ore.

The present surface section of the Kemi Intrusion is lenticular in shape, being about 15 km long and 0.2 – 2.0 km wide. The chromite-rich horizon appears 50 – 200 m above the bottom of the intrusion and occurs with an average dipping of 70 degrees to the NW. The footwall mainly consists of Talc carbonate, followed by strong granite some 80 m below it. Talc carbonate is also the main material the hanging wall is made of. At present the ore body is seen as a formation with a length of 3 km and an average thickness of 40 m, whereas the depth is unknown yet. It consists of several different ore bodies with ore grades about 25.8% of Cr_2O_3. The proven reserves are indicated at about 27.7 million tonnes.

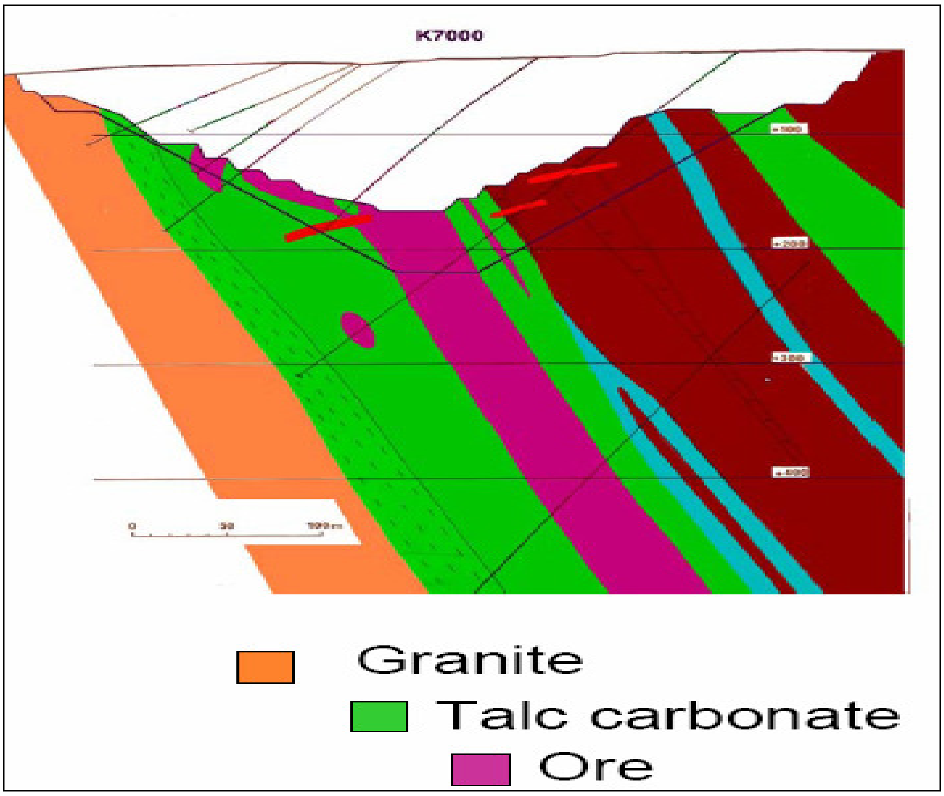

Figure 39: Cross section of Kemi deposit

6.4.3 Underground infrastructure

An open pit operation was commenced in 1968, and was carried out until the end of 2005. The main pit reached a depth approx. 220 m and footprint of 1.5 km x 500 m. Construction of the underground mine started in 1999 and started in 2003 simultaneously to the final production of the open pit. Further, the year 2008 is planned to be the first full production year for the underground mine, mining about 1.2 Mt per annum, which is going to be upgraded to a performance of about 2.7 Mt/a in year 2011.

As shown in the following figure, the main decline starts at about 100 m below the open pit edge. With a profile of ca. 40 m² it descends at 1:7 to a depth of 600m at the base of the hoisting shaft, and connects with several sublevels. There is also a repair shop an level 115 m, a larger one at 350 m, mainly used by contracting companies who are carrying out the loading and hauling operation and a main repair and maintenance shop at level 500 m. The main pumping station is located at 350 m, supported by stations at level 500 and 580 m. A Metso gyratory crusher with a capacity of 1000 t/h is installed on level 560. Fed from three sides, by vibrating feeders from the main ore passes from the 500 m level and by a plate feeder, to which the ore can be dumped from the 550 m level. Crushed ore is transported by a conveyor belt, installed below, to the shaft loading bins 500 m away. Two bins, with a capacity of 4 000 t each, are feeding the 26 t skip, which is able to hoist 100 000 t per month. At the moment it is operated at about 5 000 t per month, but the entire mentioned infrastructure is already designed to handle the planned output of 2.7 Mt per year in 2011.

A further interesting fact is that the fresh air, sucked into the mine through 8 m diameter shafts is heated up during winter time by a 2 MW propane burner and the wasted air is channelled to the decline to leave the mine at the portal instead through the shafts send in the figure below in order to prevent the decline from freezing in the entrance zone. The next figure shows the simplified long section of the Kemi mining operation.

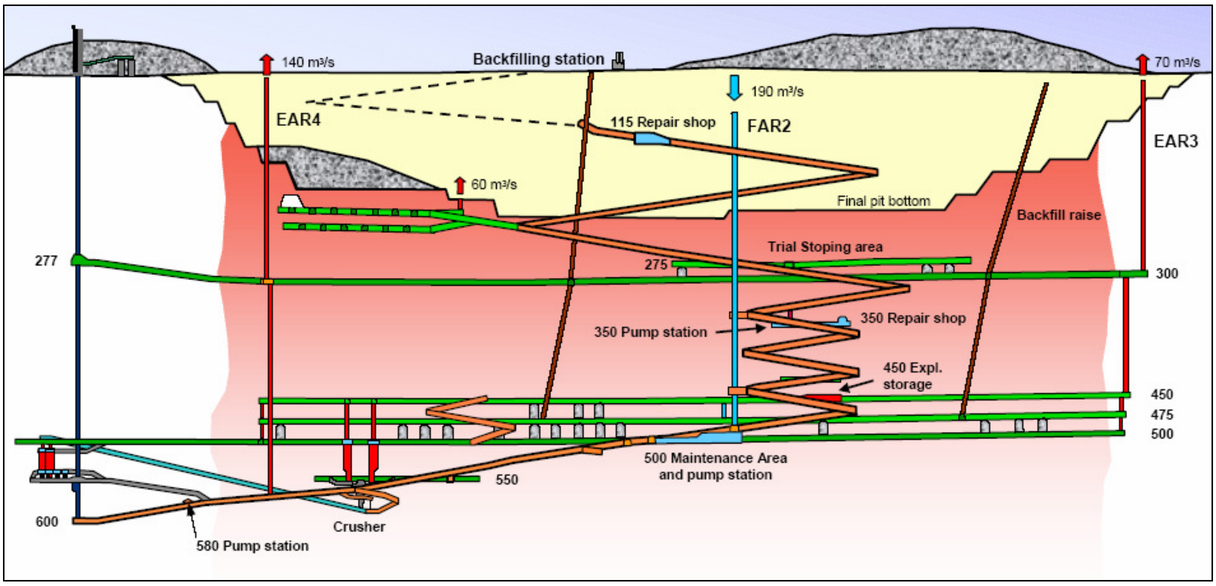

Figure 40: Kemi underground mine - simplified long section

6.4.4 Production

Due to the decision to expand the mining operation at the Kemi mine to the underground trial stopes were mined in an upper area close to the final pit bottom to determine the parameters of the possible mining methods. It turned out that the bench cut-and-fill-method was the most applicable one.

In the first step, as shown in the next figure, in intervals of 100 – 150 m crosscuts are developed perpendicular to the ore body from the main drifts in the granite footwall towards the hanging wall.

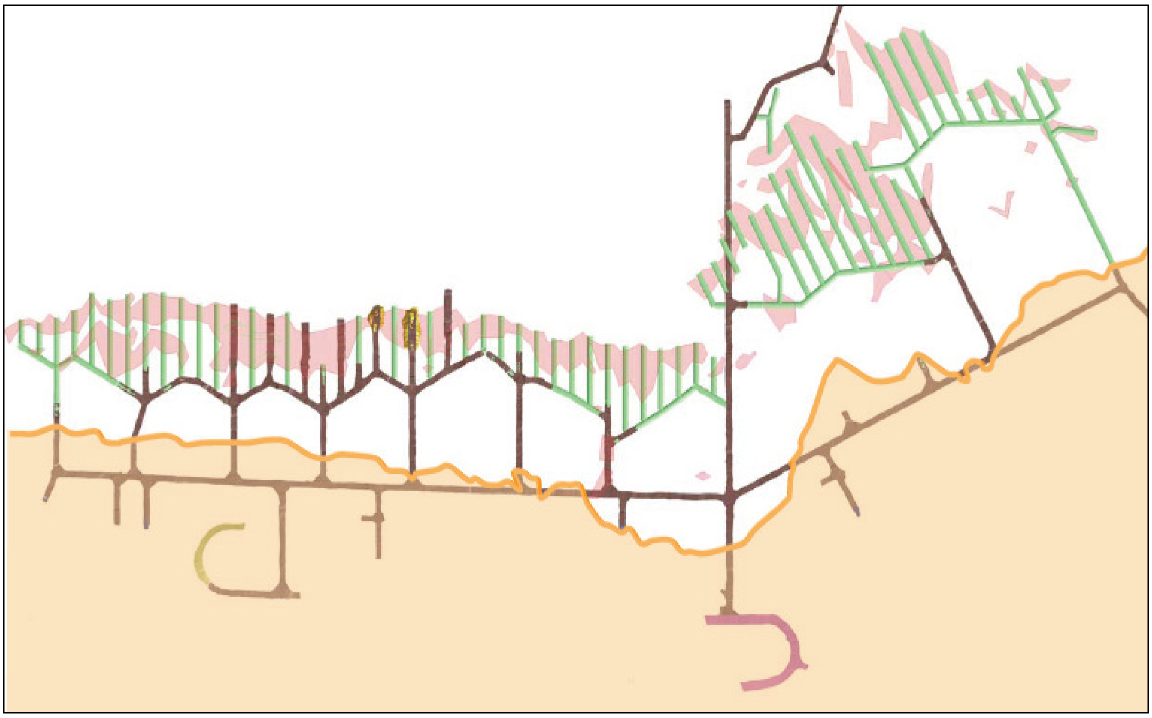

Figure 41: Development schematic

Once this and the access drifts into the planned stopes is done, an Atlas Copco Simba drill rig drills fans of 25 – 30 m long, 51 mm diameter holes downwards leaving 2 m of burden between them. A set of 3 fans forms one blast, using site sensitised emulsion explosives ignited by a NONEL system, producing about 7,000 tonnes of ore. In fact there is a testing of an electronic detonation system carried out at the moment. Even though drilling upwards promised to be more efficient, it was decided to stick to the downward method because of safety issues related to the poor ground conditions in most of the areas and the lack of the experience to handle them in this early stage of the underground operation. Another issue affected by rock stresses is the mentioned production hole diameter. The diameter in areas of higher stresses could be increased to 64 mm, if squeezing of the holes occurs. Stopes are mined, following an order to prevent zones of to high stresses, namely primary stopes which are 15 m wide and secondary stopes which are 20 m wide. Cemented backfill, consisting of cement, slag and fly ash from local industry is used to fill the primary stopes, while the secondary stopes are planned to be backfilled with mined waste rock.

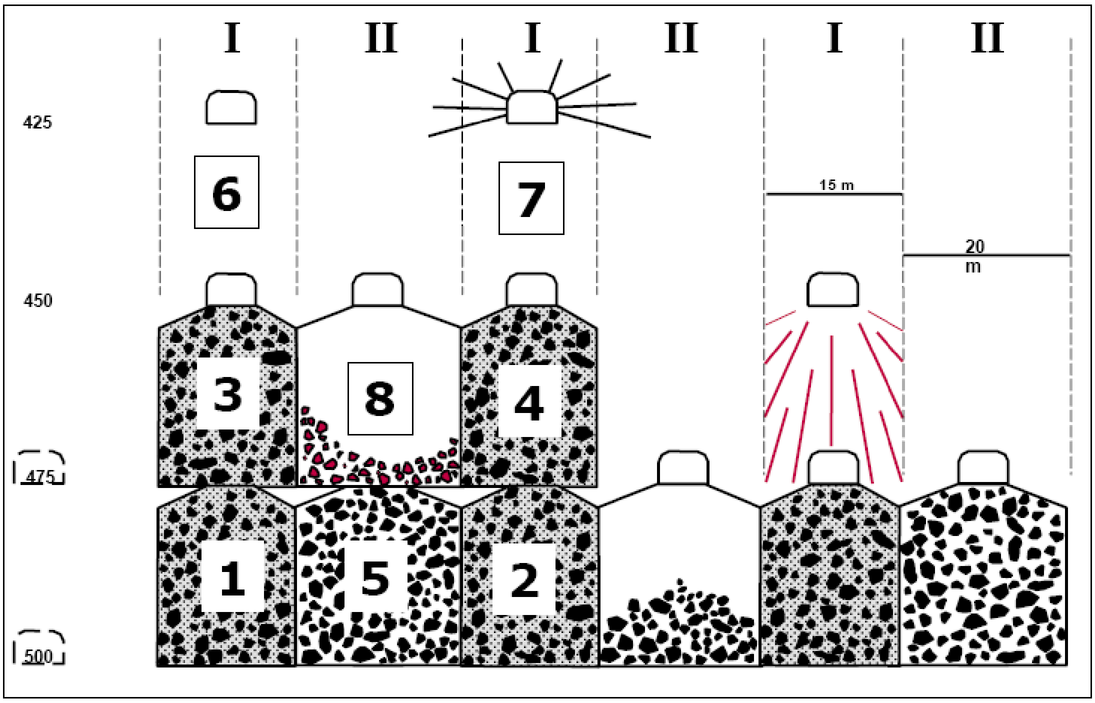

Figure 42: Stoping sequence

To create a void to blast the first shots into, Kemi is carrying out slot hole drilling using a DTH hammer that provides the 305 mm opening hole and the 165 mm blasting holes around it. This pattern allows blasting the 20 m raise in two 10 m lifts via VCR. All the actions mentioned above create the basis to mine out stopes in sizes of 25 m x 15 m x 30 – 40 m, containing between 25,000 and 30,000 tonnes of ore.

Due to safety concerns and distribution of rock stress this mining method is carried out in 5 different section of the ore body, divided by safety pillars. The ground support an the day-to-day basis consists of metal fibre enforced shotcrete in frequently uses drifts and areas and rock bolts. Cable blots and iron meshes are used to support the roof of stopes.

Work related to loading, blasting, mucking, hauling and maintenance is mainly done by contractors which represent about 40% of the 230 employees on site. The mining department it self employs 17 staff members.

6.4.5 Mentionable facts

➢ **Communication System**

One of the most impressive things you can see at the Kemi chrome mine is their communication system. They installed a W-LAN network throughout the entire mine site in a double-loop system to minimize the risk of breaks or failures. The central control room, offices, mining equipment and all the VoIP-phones handed out to every single employee are linked to this network. This provides possibilities like tagging in at the portal when the miner enters the underground area, locating people and equipment in case of emergencies, transferring and updating drill pattern from an to drill rigs or downloading the machines' maintenance status, or keeping the miners informed about air and hazardous conditions in working areas. Installing a network like this also provides less important options in terms of productivity and safety, such as having the up-to-date menu in the mines' canteen, or turning on supporting fans when unventilated areas are entered without getting out of the car.

- **Remote mucking**

Another noticeable fact is that in 2007 this mine started to analyze the potential of using an Atlas Copco ST14 scoop for automated backfilling of stopes in hazardous environments. This means that the operator is able to monitor every move of this vehicle from a comfortable control station that can be set up even on the surface. Equipped with four cameras and laser scans mounted on the scoop and cameras for surveillance at the draw and dumping areas the operator can switch over from automatic to manual mode and take control in the essential phases using a joystick. This in-house solution by Atlas Copco will still pass some more testing and adjusting time in this mine but it already proved that it hadn't improved not only safety but also speeded up the backfilling operation.

6.5 Kiruna (Fe) [16]

handed in by Stefan Eggenreich and Christoph Amberger

LKAB

6.5.1 Introduction

During our main excursion in June 2008 we visited the LKAB mine in Kiruna/Sweden. Kiruna is famous for its high grade iron-ore. The ore-body was discovered in the year 1696, but the phosphor grade made big troubles until the Thomson process was invented in 1878. Beside those problems with the ore, the location has been one of the biggest issues. Situated in the middle of the country without a big river for shipping, a railway track was built at the beginning of the 20th century in two directions. One leads to Norway directly to the harbour of Narvik, where the most of the pellets go. The other one leads to Lulea, located in the south of Kiruna. Both harbours are near the Arctic Circle and so the sea is expected to freeze during a long winter. But due to modern icebreakers the harbour of Narvik can be used the whole year.

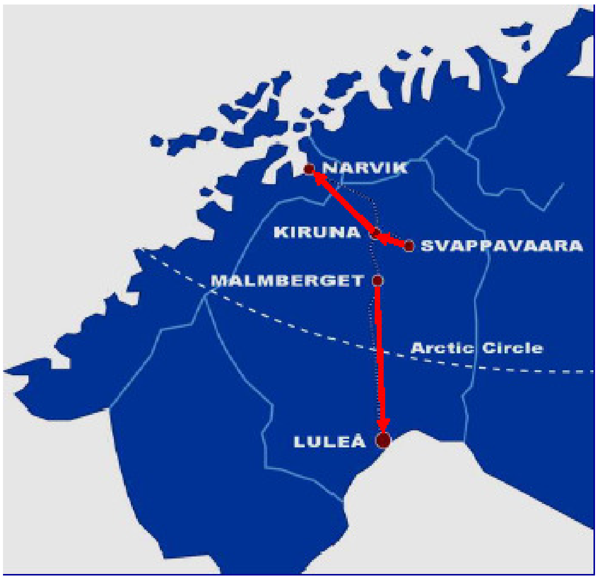

Figure 43: Transport of the ironore

6.5.2 Geology

The ore-body of Kiruna with the name of Kiirunavaara has a length of about 4km and a depth of approximately 2km. It has an inclination of 60 to 70°, falling to the east. The average thickness is around 100m. This great 1.8 to 1.9 billion years old ore-body lies between potassic granite and quartzite on the footwall side and greenstone groups on the hanging wall side.

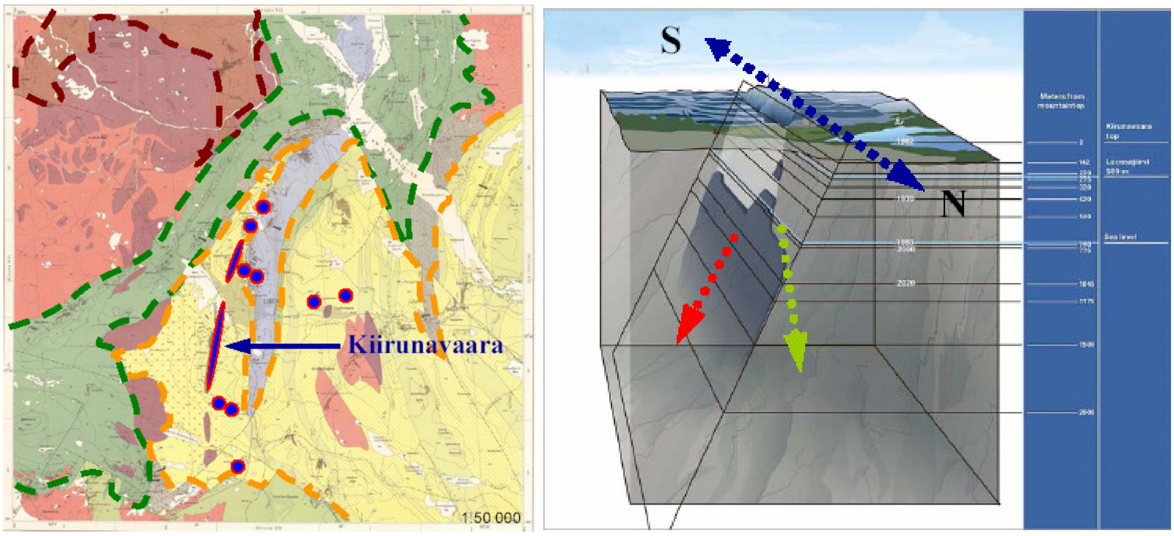

Figure 44: Geology of Kiruna

The Kiirunavaara ore-body is divided into five ore classes.

B1 Fe 68-69% P ~0,02% and a very small grain size lower one millimetre.

B2 Fe 61-63% P <0,1%

The rest of the ore has a lot more phosphor and a lower Fe grade. It is divided in the classes D1, D3 and D5 with and Fe grade from 59 to 61% and phosphor around 1.5%.

6.5.3 Production

To maintain production LKAB has drilled over 60000m exploration holes so far. Because of simple structure of the ore-body the most important information of this exploration is the phosphor grade in the ore. LKAB recognised that the quality of the ore is rising with the depth.

Thanks to the good rock conditions a sublevel caving system was introduced, when the mine started underground production in the 50th of last century. This happened at the same time when LKAB got nationalized. The last blast in the open pit was in 1962. At that time the underground mine was fully developed. During the past years there have been some changes in the height of the sublevels. Today there are ten main mining areas which can be mined separately. The only limiting thing is that always two of them are connected with a ramp and so LKAB is always looking at two areas as a team. Each of those ten mining areas has got four ore passes, which lead to an underground railway system.

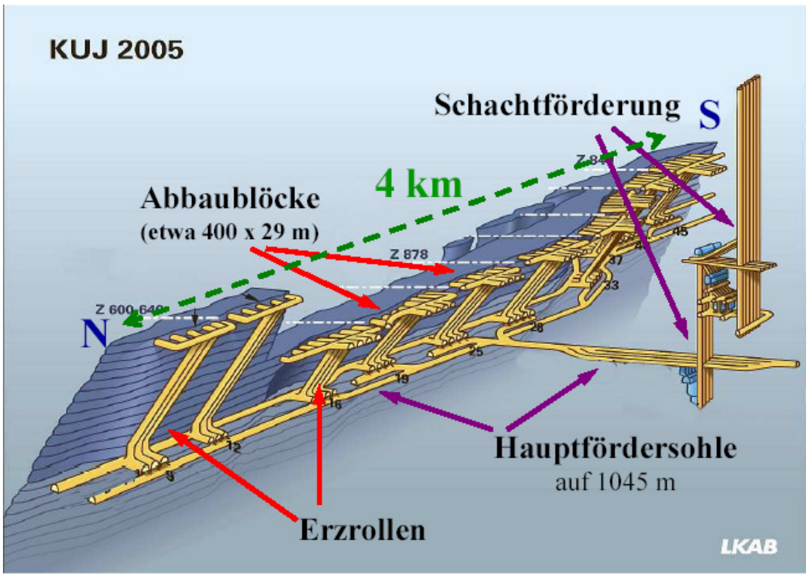

Figure 45: Infrastructure in the mine

Today the vertical distance between the sublevels is 28.5 meters. The horizontal distance between the drifts is 24.5m. Each of those sublevels has got the same production cycle. Every year LKAB is building around 24km of tunnels to connect and built the new mining levels. In those tunnels six bolts per meter are needed to maintain the roof support. The gallery diameter is about seven meters. The next step in the production cycle is the fan drilling. LKAB drills more than one million meters production holes per year with a diameter of 115mm. They are drilled in fans at the top of the drifts.

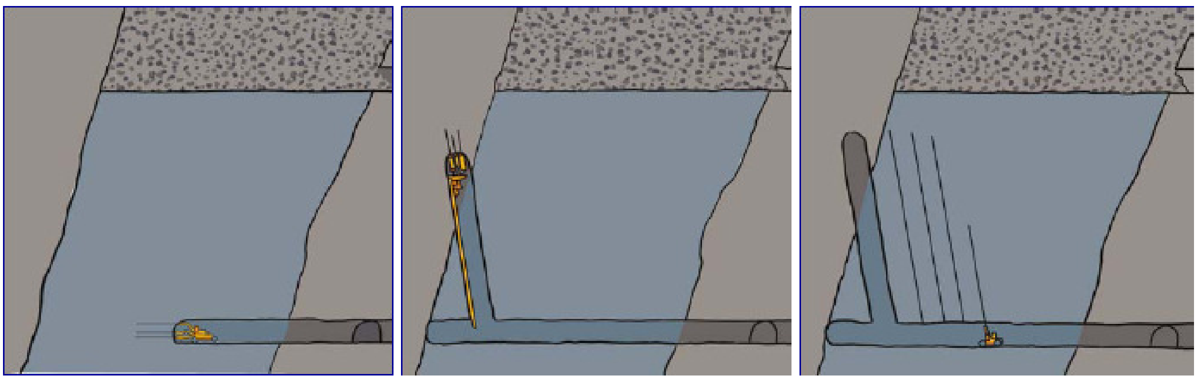

Figure 46: Mining method

The angle of the fan changed from 60° to 34° to raise the productivity. The distance between the fans is about three meters. LKAB's longest blasting holes are 54 meters. The whole drilling operation takes four to six month per drift. After drilling, blasting is the next step. The first opening is made with a large diameter borehole. Then six fans are drilled consisting of 7 holes each. They are charged with emulsified explosives and afterwards blasted against the large diameter borehole. The rest of the fans are getting blasted in groups of one to three. The hauling is done with full automatic LHDs. Those LHDs are controlled from the main building on surface. In contradiction to other mines, LKAB has engineered its own system and is not using a Sandvik or Atlascopco system. The average production time in a drift is two month. In total LKAB is producing 28.5 million tons crushed ore per year, but they want to increase it to 35 million tons per year till 2009. Kirunas fixed reserves are 598 million tons at the moment, but the knowledge of the deeper levels is not funded very well, so a lot more is expected.

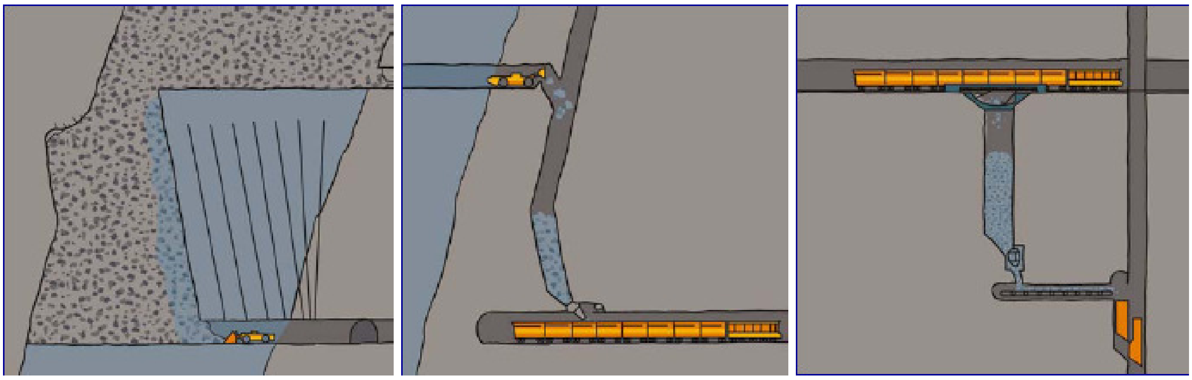

Figure 47: LHD

6.5.4 Processing

After transportation by underground railway, the ore gets crushed by a jaw crusher to make sure the grain size is optimized for the hoisting system. The ore is hoisted in two steps. In the first step four skips are bringing the ore to a sublevel, where quality control is done. From there eight skips are bringing the ore to the production plant on surface.

Two production plants are already in operation and a third one is under construction. We visited plant number two, which was built in1964. Several different grinding lines are located within the facility. Each grinding line has got a ball mill as first step and an auto genius mill as second step. The maximum grain size for the ball mill is 10mm. The output of the milling line is 80% smaller than 80µm. The average production of each ball mill is 200t/h. The capacity of the autogenous mill amounts 600t/h. Between the ball mill and the autogenous mill a magnetic separator is located, which is able to get the concentrate up to 71% Fe. After those two milling steps another ball mill is working within a hydro cyclones screening cycle. Next a flotation step with several different chemical additives is separating the waste from the ore. The target of the flotation is to get the phosphor concentration down to 0,025%. LKAB is not able to sell the fine grained product at a good price and so they are making pellets out of it. The advantage in the pellet production is that LKAB is able to put different additives for each costumer into the final product. To get the suspended solid concentration up to at least 92% vacuum and chamber filters are used. Before pelletizing the ore, LKAB puts about 3% additives to the material. This varies depending on the costumer. The twelve to sixteen millimetre big pellets are dried at 150℃ and sintered between 800℃ and 1300℃. Every year LKAB produces 23.5 million tons pellets, which get transported by train to one of the big harbours.

6.5.5 Mining subsidence damages

Within 100 years of mining history a lot of problems came up. The biggest one is the effect of the underground mine on the surface. Above the ore body lies the city of Kiruna and the destruction area which is caused by the mine method is growing. The primary growing direction is towards the city. To maintain the next 20 years of production LKAB needs to move parts of the city. This includes houses of citizens as well as famous buildings like the church of Kiruna.

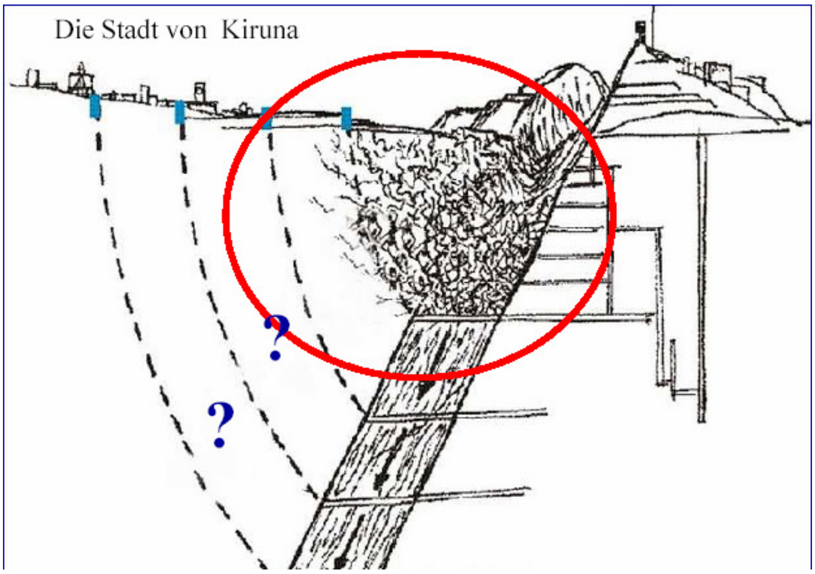

Figure 48: Mining subsidence damages

Figure 49: Kiruna and the subsidence area

6.6 Kittilä (Au) [17];[18];[19];[20];[21]

handed in by Julia Tschugg

6.6.1 Summary

The Kittilä mine is under construction on the Suurikuusikko gold deposit, located approximately 900 km north of Helsinki and 50 km northeast of the town of Kittilä, in northern Finland. Production expected to begin by in September 2008 and extend over 13 years before the deposit is exhausted.

Figure 50: location map of Kittilä Mine Project

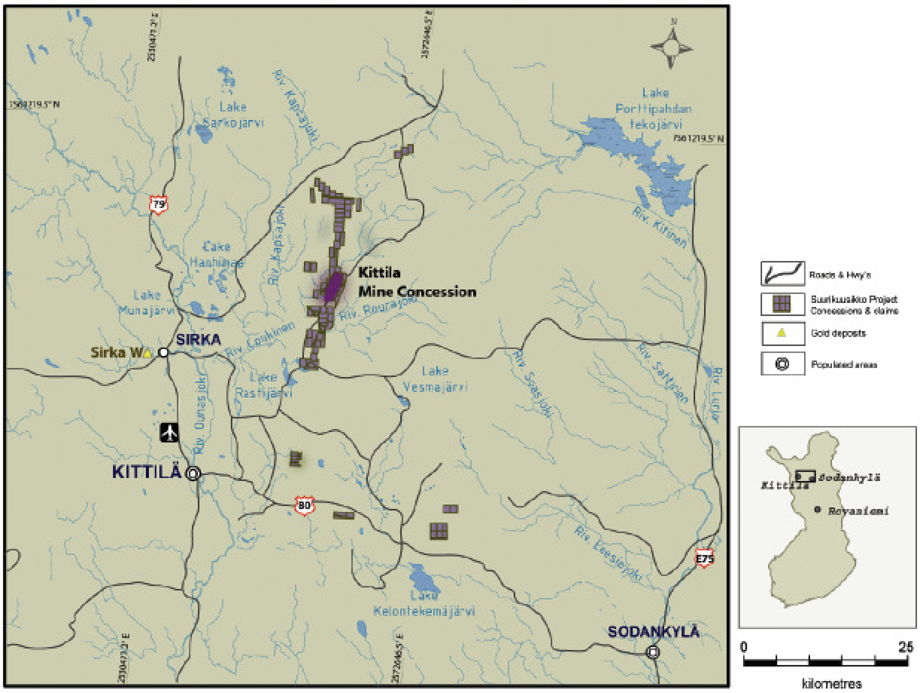

Figure 51: location map of Kittilä Mine Project

At the end of 2007, the Kittilä mine project was estimated to contain probable mineral reserves of 3,0 million ounces comprised of 18,2 million tonnes of ore grading 5,12 g / t – open on strike and at depth. It is expected to produce an average of 150 000 ounces of gold annually at average total cash costs of approximately $ 250-300 per ounce.

6.6.2 Geology, Deposit Type and Mineralization

The gold mineralized zones in the Suurikuusikko field are situated within the Lapland Greenstone Belt which extends from the Norwegian coast, through northern Finland and into Russia. It is the largest gold deposit in northern Europe – It has a current in situ resource of 110 t gold. The bedrock, which is over 2 billion years old, is dominated by different varieties of volcanic rock. It is typically covered by a thin but uniform blanket of unconsolidated glacial till.

Suurikuusikko is a Palaeoproterozoic orogenic gold deposit hosted by albitised, mafic to intermediate, volcanic rock. It comprises a number of subvertical ore bodies (mineralized lenses) in a 4-km long section of the subvertical, compressional, Suurikuusikko Shear Zone. The major rock units trend north to north-northeast and are near vertical. This shear zone is known to be gold-enriched for its entire length of more than 20 km.

Volcanic rocks were further sub-divided into iron- and magnesium-rich tholeiites, respectively located to the west and to the east. The contact between those formations consists of a transitional zone comprising mafic tuffs, graphitic metasedimentary rocks, black chert and banded iron formations. It varies in thickness between 10 and 50 m and is characterized by strong heterogeneous penetrative strain, narrow shear zones, breccia zones and intense hydrothermal alteration (carbonate-albitesulphide) and gold mineralization.

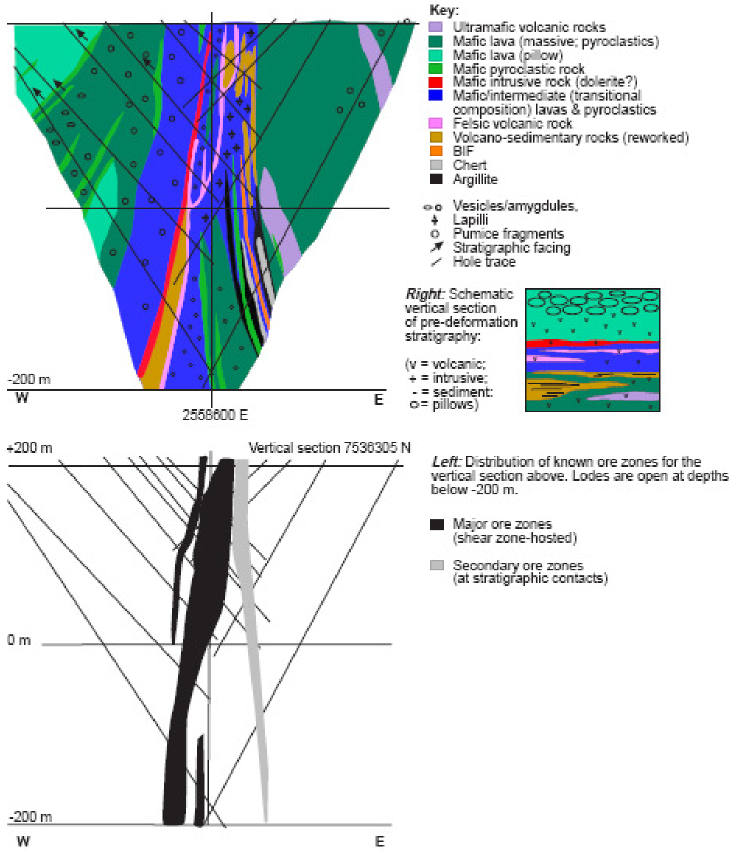

Figure 52: schematic vertical section of the pre-deformation stratigraphy & distribution of the known ore zones

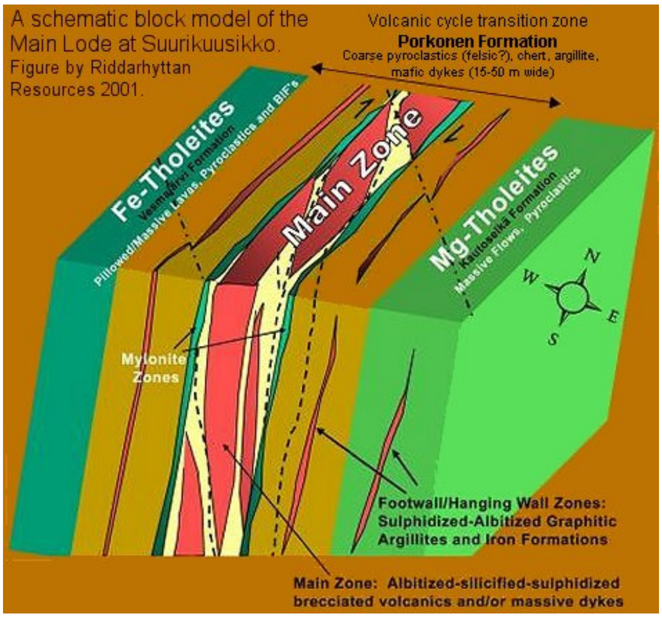

Figure 53: schematic block model of the main lode at Suurikuusikko

The transitional zone defines what is referred to as the “Suurikuusikko Trend” and is the major host for the gold mineralization. The north-south oriented, sub-vertical shear zone is containing multiple mineralized lenses, which have been traced over a strike length of over 15 km. Its internal geometry is very complex and exhibits features consistent with that observed in major brittle-ductile deformation suggesting that this rock unit represents a significant structural discontinuity. Most of the exploration work has been focused on the 4,5 km which host the known gold reserves and resources.

The known gold mineralization on the Suurikuusikko Trend is almost exclusively refractory, meaning that it is mainly found in the lattices of sulfide minerals, is associated hydrothermal alteration and is hosted in the extensive brittle-ductile shear zone. Gold particles are locked inside fine-grained arsenopyrite (approximately 75 %) or pyrite (approximately 23 %), in both thin veins and altered host rock. What remains is ‘‘free gold’’, which is manifested as extremely small grains in pyrite. Most of the free gold is found in the outer, oxidized or eroded sections of the ore. Small amounts of copper pyrite, pyrrhotite, sphalerite, galena, gersdorffite, tetrahedrite, jamesonite, bornite, gudmundite and rutile are also present. The gold deposit is intersected at several locations by small massive bands containing the antimony mineral stibnite. The characteristics of the known gold mineralization are similar to a class of hydrothermal gold deposits referred to as ”orogenic” gold deposits, which typically exhibit a strong relationship with regional arrays of major shear zones.

6.6.3 History and Exploration

The Suurikuusikko Deposit was discovered in 1986 by the Geological Survey of Finland (”GTK”). Coarse visible gold in quartz-carbonate veining was detected in an outcrop 4 km SSW of the Suurikuusikko deposit during regional gold exploration. Following this discovery, GTK initiated regional exploration over the area: Low-altitude airborne geophysical surveys (magnetic, electromagnetic, radiometric), ground geophysical surveys and various soil and till sampling programs.

Drilling programs between 1989 and 1991 (72 diamond drill holes with a total length of 9 km, 5 reverse circulation bore holes with approximately 288 m in length) confirmed the existence of gold mineralization in bedrock. Exploration continued under Riddarhyttan management between 1998 and 2005: 462 core boreholes with more than 136 km were drilled over a strike length of 5,5 km to investigate the main auriferous structure. In-fill and exploration drilling, ground geophysical surveys, mineralogical, petrographic, geochemical and structural studies and low altitude airborne survey have been done to further the understanding of the geological and structural setting of the gold mineralization. The results indicated two new gold zones to the north of the mine construction site, located 1 km and 4 km north of the main Suurikuusikko area. In total Riddarhyttan completed 190 diamond drill holes with 53 km on the Kittila mine project.

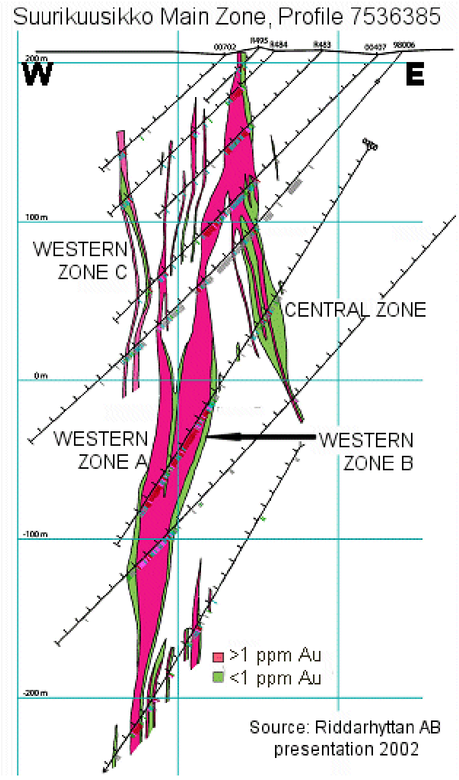

Figure 54: Suurikuusikko Main Zone, Riddarhyttan in 2002

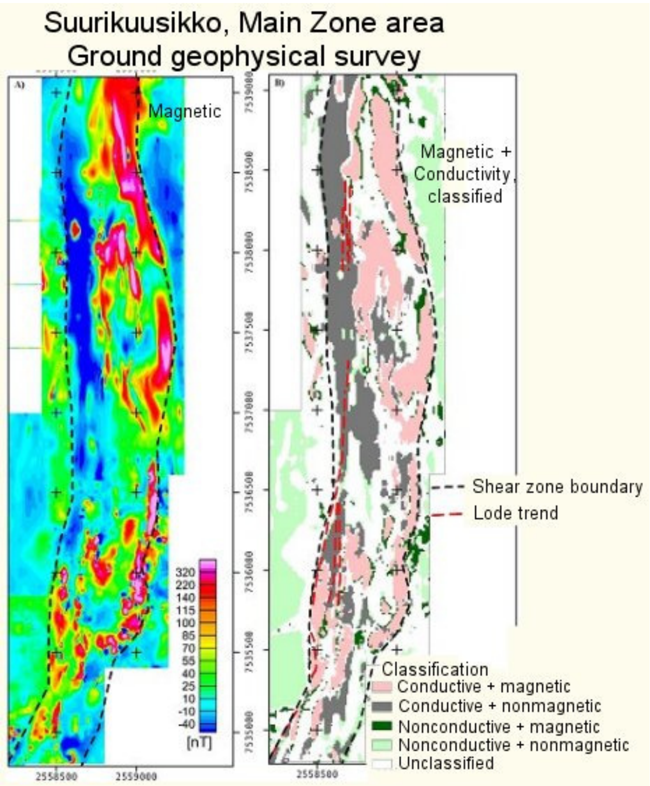

Figure 55: Ground geophysical survey at Suurikuusikko, main zone area

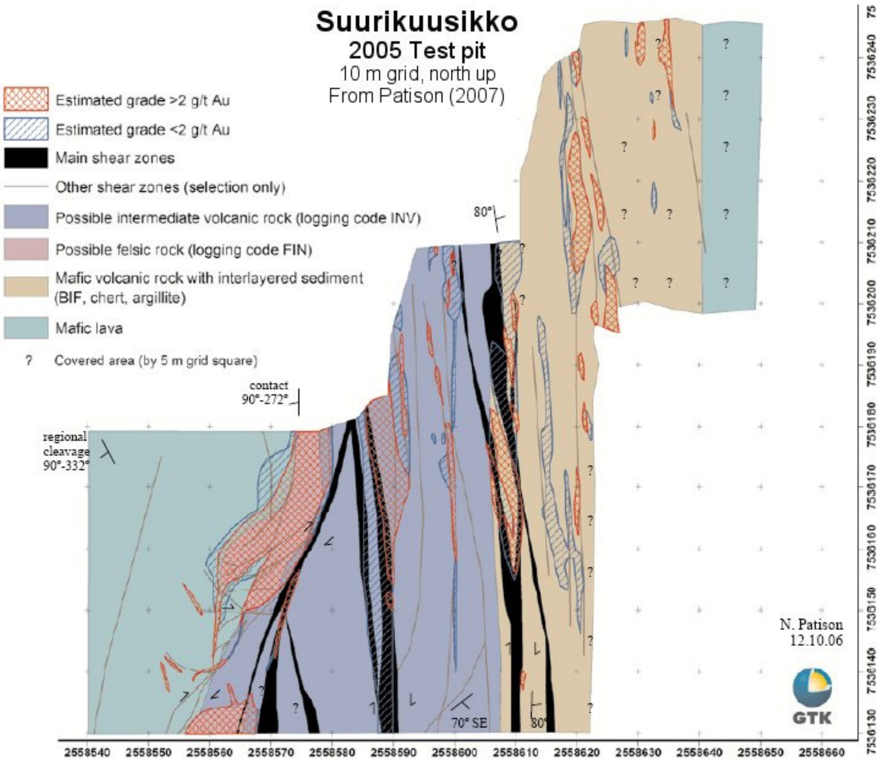

Figure 56: Suurikuusikko, 2005 Test pit, 10 m grid, north up, by Riddarhyttan

Throughout this period, Riddarhyttan continued to investigate the metallurgical properties of the refractory gold mineralization – pilot-plant testing based on a pressure oxidation process for gold extraction – and initiated engineering and environmental studies – feasibility study and the construction of the Kittila mine project were performed. The study was based on an open pit mining scenario followed by underground mining via ramp access and mining of 1 million t of ore per annum to be processed in a surface plant.

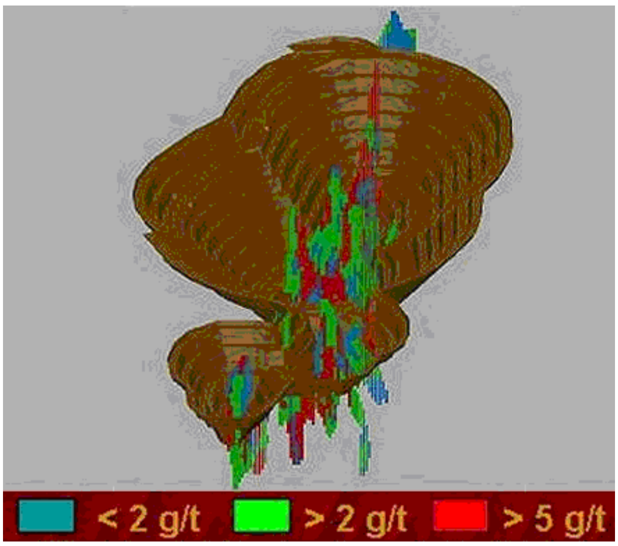

Figure 57: 3D block model of the planned open pit at main lode, Suurikuusikko, by Riddarhyttan in 2001; legend indicates gold grades in the ore blocks

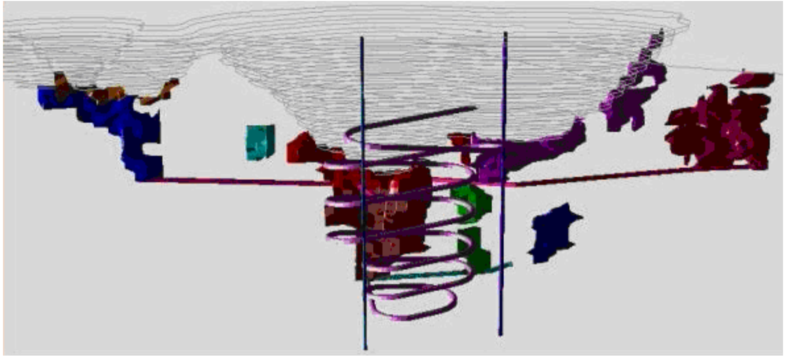

Figure 58: Underground mining model for the main lode, Suurikuusikko, by Riddarhyttan in 2001

Under Agnico-Eagle the diamond drilling program on the mining licence area focused on in-fill drilling, resource conversion and deep exploration below the main Suurikuusikko zones. Results from the deep exploration indicated that the Suurikuusikko zones may extend at least down to 1 km below the surface. In total, 158 diamond drill holes with 33 km length were completed in 2007. Systematic geochemical sampling and diamond drilling also continued outside of the mining licence area on targets along the Suurikuusikko Trend. A new gold zone located approximately 10 km north of the mine construction site has been discoverd.

6.6.4 Reserves and Resources

The Kittilä mine project contains a measured resource of 0,1 million t containing 4,07 g of gold per t, an indicated mineral resource of 1,5 million t containing 4,39 g of gold per t and an inferred mineral resource of 6,7 million t containing 4,35 g of gold per t.

	Grade [g Au / t]	Tonnes [000's]	Gold Ounces [000's]
Probable Reserve	5,12	18 205	2 996
- open pit	5,43	4 169	727
- underground	5,03	14 036	2 268
Indicated Resource	3,03	5 416	527
Inferred Resource	3,39	10 832	1 181

Table 15: Kittilä 2007 Mineral Reserves and Resources (Mineral reserves are not a subset of mineral resources)

The gold grade cut-off used to determine the mineral resources varied between 1,5 and 2,4 g/t for open pit and underground, respectively. A mineral reserve cut-off based on gold grade that varied between 2,0 and 3,2 g / t was used for open pit and underground.

6.6.5 The Kittilä mine

The Kittilä mine project is scheduled to begin production during the third quarter of 2008 with initial production of 50 000 ounces in 2008. The Kittilä mine will initially be extracted via open pit followed by underground mining via ramp access. The mining operation will feed a 3 000 t per day surface processing plant.

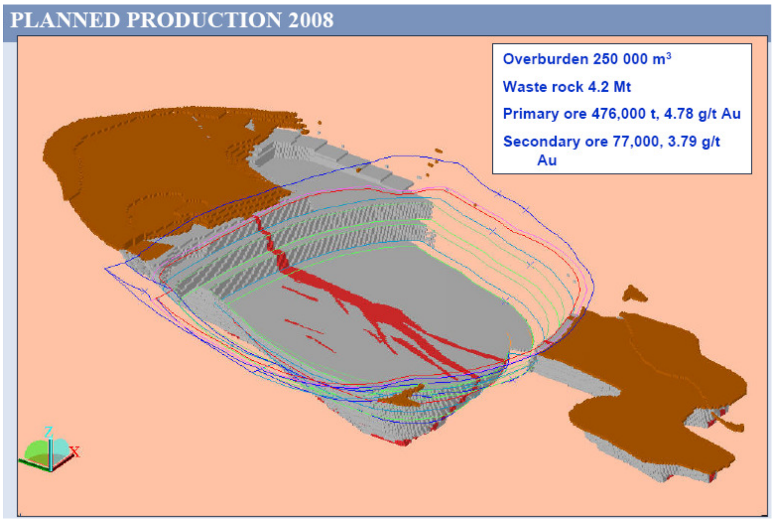

Figure 59: Planned production in 2008

The feasibility study's base case projects an after tax rate of return of 15 %, based on a gold price of $ 450 per ounce, and a US $ / € exchange rate of 1.20. Annual gold production is expected to average 150 000 ounces at total cash costs of $ 300 per ounce, with initial gold production occurring by the middle of 2008. The feasibility study anticipates capital expenditures of $190 million and incorporates mine-site costs per tonne of $34 and sustaining capital expenditures of approximately $ 5 million per year. Current reserves are sufficient for an estimated mine life of 13 year and the creation of more than 200 jobs in the area.

Current estimated capital costs of construction of the Kittilä mine project are $190 million ($100 million in 2007 and $90 million are expected in 2008). Anticipated sustaining capital expenditures at the Kittilä mine project are estimated to be approximately $5 million annually.

Construction in the area of the main Suurikuusikko deposit had progressed: waste rock mining, construction and site infrastructure work have been completed; 263 000 m^3 of overburden and approximately 2,6 million t of waste rock has been removed and excavated to prepare for the open pit mining; work on the 3 km long ramp to access the underground reserves has started; the construction of the tailings dam is in progress; a high voltage power line connects the site to the main Finnish power grid; the office service buildings and the process plant have been nearly completed.

Figure 60: Suurikuusikko (Kittilä) mine in 2007 – the circular road indicates the final extent of the open pit

Figure 61: excavation of good quality vulcanite rock for roads and tailing dams from the western side of the Suurikuusikko pit between September 2006 and July 2007

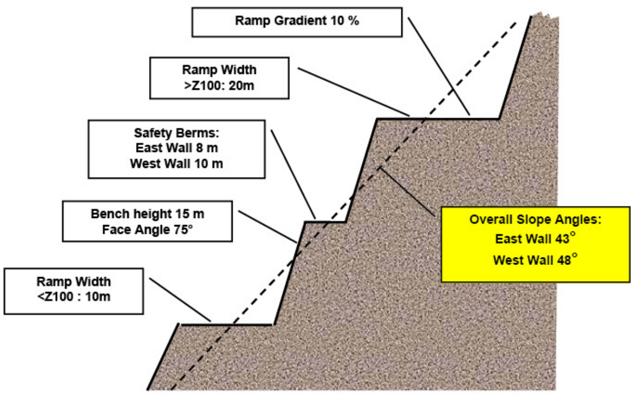

Figure 62: design parameters for the Suurikuusikko open pit mine

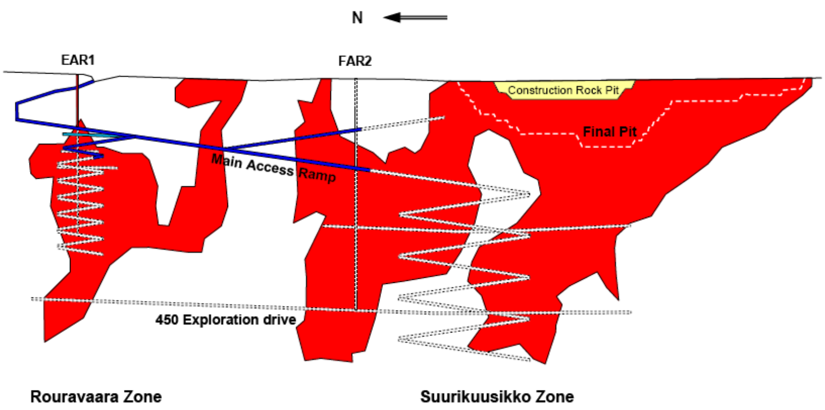

Figure 63: simplified longitudinal view of planned open pit & underground mine

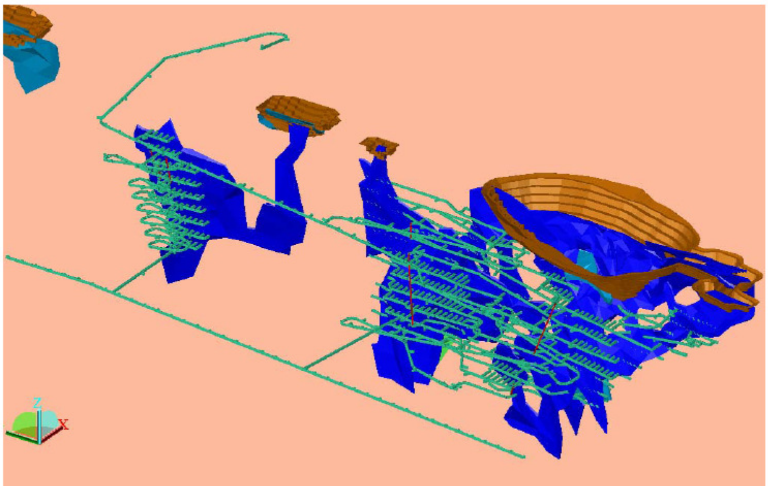

Figure 64: planned open pit and underground mine

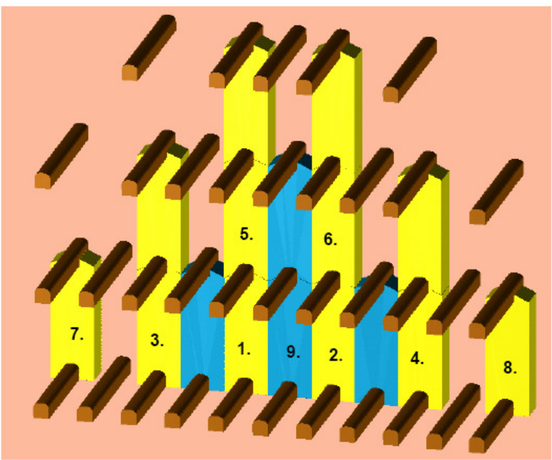

Figure 65: planned underground mining sequence (transversal stopes)

The Kittilä mine project is comprised of 103 individual tenements covering an aggregate area of approximately 8 341 hectares and 1 mining licence covering approximately 847 hectares. The mineral titles form three distinct blocks. The Company currently holds a mining licence and an environmental permit in respect of the Kittilä mine project. The Company has submitted an application to Finnish authorities for an amendment to the environmental permit to allow the change from a biological oxidization process to a pressure oxidation process. This will allow the Agnico-Eagle to use significantly smaller quantities of cyanide.

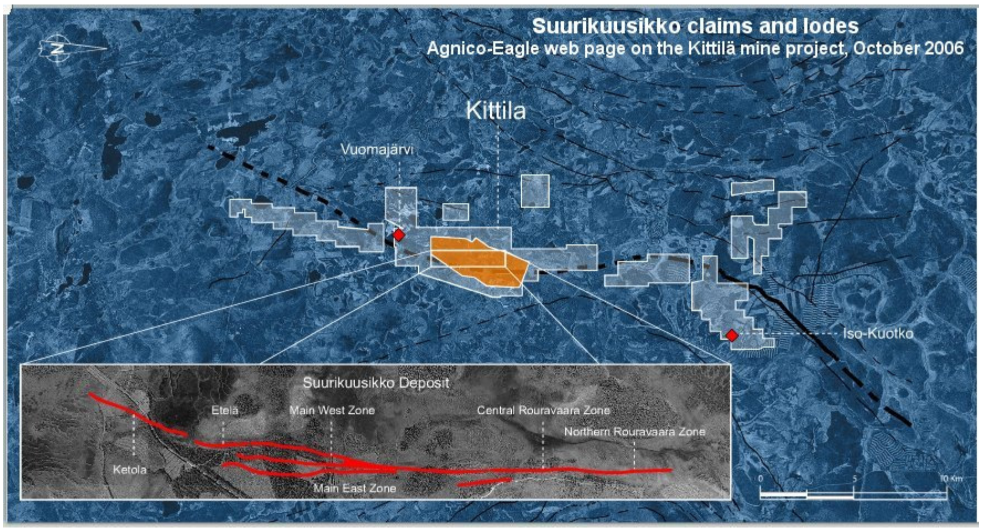

Figure 66: Suurikuusiko claims and lodes, 2005

6.6.6 About Riddarhyttan Resources AB

The Suurikuusikko deposit in northern Finland on which the Kittila mine project is located was formerly owned by Riddarhyttan Resources AB, a Finnish precious and base metals exploration and development company with a focus on the Nordic region of Europe. Agnico-Eagle acquired a 14 % ownership interest in Riddarhyttan in 2004, and in May 2005, announced a bid for all remaining shares of the company.

Riddarhyttan was established under Swedish corporate law in 1996 and commenced operations in 1997 when it was listed on the Stockholm Stock Exchange. In 1998, Riddarhyttan won the public international tender conducted by the Finnish Government for the Suurikuusikko project (now referred to as the Kittila mine project). Since then, the majority of the company's exploration ventures have been targeted in this area. In January 2000, Riddarhyttan conducted a preliminary resource estimation in the Suurikuusikko field. The estimate amounted to 8.3 million tonnes with an average grade of 6,1 g of gold per t. The positive results from rock chip samples in the southern section of the field led to additional areas being covered by claim reservations. By the end of the year, Riddarhyttan had 22 claims for gold within the Suurikuusikko field.

6.6.7 About Agnico-Eagle Mines Limited

Agnico-Eagle is an international growth company focused on gold, with operations in Canada and advanced-stage projects and opportunities in Canada, Mexico, Finland and the U.S.A. The company's operating history includes more than 30 years of continuous gold production primarily from underground operations. Since its amalgamation in 1972 – merger of Agnico Mines Limited, a prominent silver producer in Cobalt, Ontario, and Eagle Gold Mines Limited, a successful gold exploration company – Agnico-Eagle has produced over 4 million ounces of gold. Agnico-Eagle is one of the lowest total cash cost producers in the North American gold mining industry.

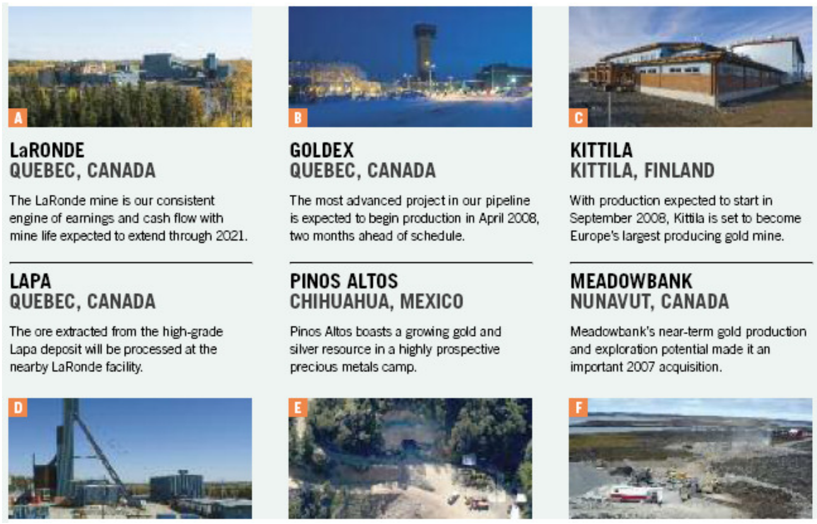

Figure 67: operations of Agnico Eagle at the end of 2007

At the end of 2007, the Company employed 2.425 employees: 1.303 permanent employees and 1.112 contractors of which 60 permanent employees were employed at Kittilä (Finland).

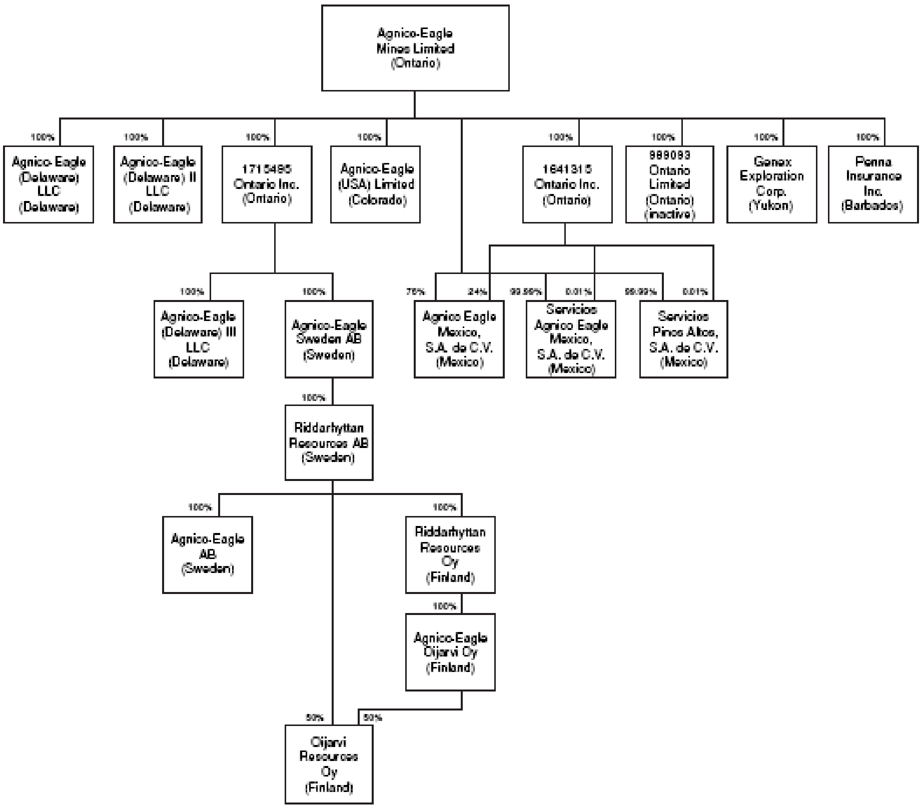

Figure 68: corporate structure of Agnico-Eagle with the subsidiaries' jurisdiction

Agnico-Eagle's shares are listed on The New York Stock Exchange, Toronto Stock Exchange & Frankfurt Stock Exchange's Entry Standard. The shares trade actively, with total daily volume frequently over 3 million shares. Company shares are held approximately 15 % by individuals and 85 % by institutions, primarily in North America. Agnico-Eagle paid a cash dividend to its shareholders for 26 consecutive years. Agnico-Eagle has traditionally sold all of its production at the spot price of gold, in keeping with a policy of not selling forward future gold production. This policy enables shareholders to participate fully in rising precious metal prices.

6.7 Rovaniemi (Geological survey) [22]

handed in by Hanspeter Nussbacher

6.7.1 Introduction

In the course of our field trip across Finland and Sweden, we visited the Northern Office of the GTK which is located in Rovaniemi. The head of the Northern Office, Risto Pietilä, gave us a short presentation how the GTK works. The Geological Survey of Finland (GTK) is Finland's national geoscience agency. As the key government agency involved in the mineral resources sector, the GTK is active in promoting mineral exploration and mining in Finland. GTK's activities range from geological mapping, through exploration, evaluation, and processing of natural resources, with a strong research effort in analysis of geological processes and mineral systems as well as in development and application of exploration and benefication technologies.

Some key facts of the Geological Survey of Finland

- The Geological Survey of Finland (GTK) is a national geological research centre operating under the Ministry of Employment and Economy.
- The GTK was established in 1885.
- 773 persons worked for the GTK in 2007.
- The income from contract services was about € 14.0 million in 2007.
- The total costs of the conducted operations amounted to € 59.3 million in 2007.

6.7.2 Organization of the GTK

Fehler! Verweisquelle konnte nicht gefunden werden. shows the organization chart of the Geological Survey of Finland. As shown in the figure, GTK operates under the Ministry of Employment and Economy and is divided into four regional areas.

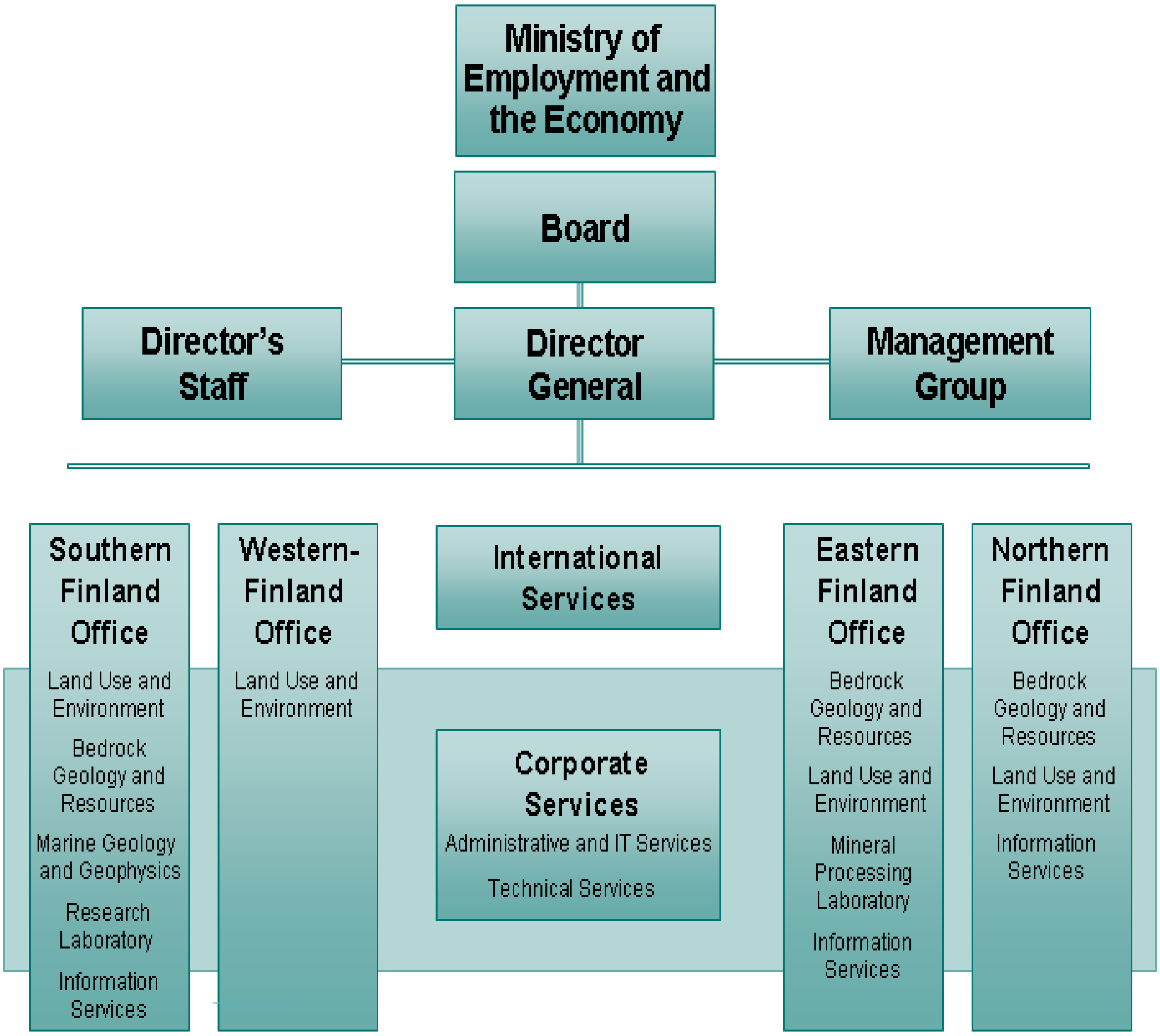

Figure 69: Organization chart of the GTK

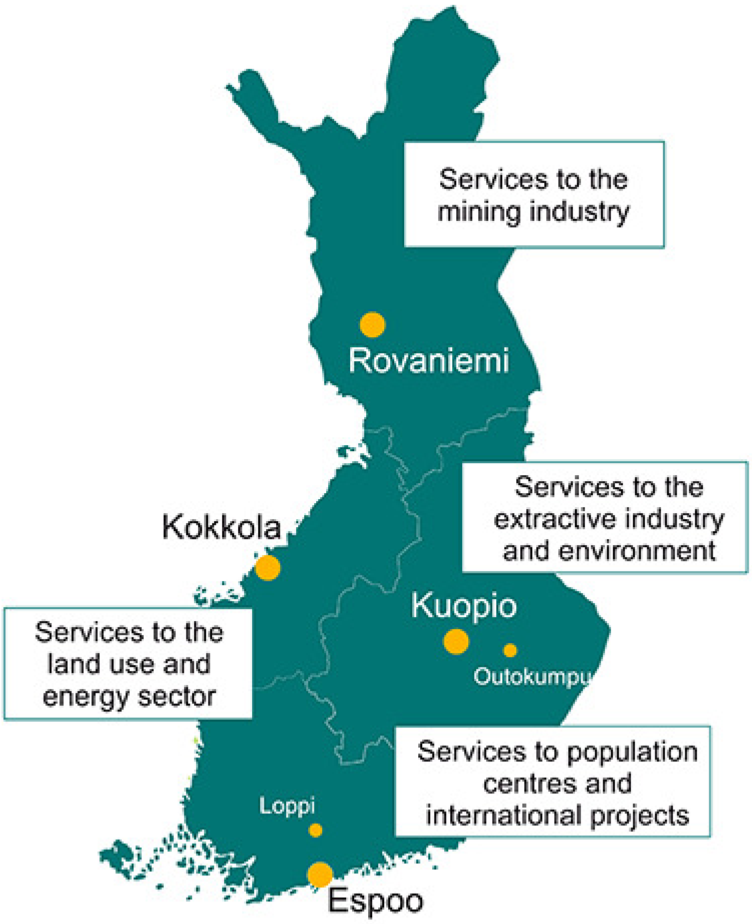

Figure 70: The four divisions of the GTK with the four main offices

6.7.3 Scopes of the GTK

- **Research**

The expertise of GTK is focused on Precambrian geology, Quaternary geology and natural earth resources. The main focus of GTK is in applied sciences.

The current research activities of GTK are carried out in five research programs:

- Geological Modelling
- Land use and Environment
- Sustainable use of natural resources
- Arctic research an global climate change
- Geoinformation

- **Mapping**

GTK's mapping programs produce information for the needs of the mining industry, land use planning, construction and environmental protection.

The current mapping program comprises the following categories:

- Deposits on the surface
- Bedrock
- Marine geology
- Airborne geophysics
- Urban geology
- Graphite mapping

- **Service**

Finland's Geological Survey offers a wide range of data and services to their customers. These customers are the general public, as well as the private sector, state and local agencies and, of course, other geological surveys.

Especially for the mining and minerals industry, the GTK offers a huge expertise in Fennoscandian economic geology, as well as client-tailored exploration services, including geophysical surveys and geochemical, mineralogical and mineral processing laboratory services.

GTK services comprise the following branches:

- Geological Mapping
- Geochemical services
- Geophysical services
- Mining industry services
- Minerals industry services
- Laboratory and industry services
- Groundwater surveys and analysis
- Services for infrastructure projects

- Institutional development
- Other services such as peat surveys or natural stone projects

- **Exploration**

One of the main activities of the Geological Survey of Finland is to promote mineral exploration and mining in Finland. It was interesting to hear that there is an active exploration program which is conducted by the Geological Survey of Finland. That is a difference to, for instance, the Geological Survey of Austria.

The GTK collects information about natural resources and their beneficiation through comprehensive mapping, exploration and research programs. The aim is to support the sustainable use of bedrock resources and surficial deposits.

The programs on natural resources comprise: Metals, industrial minerals, natural stones, aggregates (bedrock and sediments), groundwater and peat.

The GTK is responsible for acquisition and management of any kind of geological information in Finland, with a particular emphasis to provide high quality data to the exploration and mining sector. Through a comprehensive mapping and research program, GTK also identifies and documents areas with mineral potential, in order to encourage follow-up exploration and exploitation by the private sector, with the aim of supporting sustainable use of both, bedrock resources and deposits on the surface. All GTK discoveries are offered to the private sector through an open tendering process arranged by Finland's Ministry of Trade and Industry. This is also a difference to a Geological Survey like the Austrian's one.

- **Geoinformation**

GTK's survey and research activities have generated a substantial amount of information on the Geology of Finland and its natural resources. It's the aim of the GTK to make this geological content and data easily accessible to the public. At present, information services mostly lean on reference data, but the volume of downloadable maps and full-text documents is increasing.

The available geological information has been categorized into four groups:

- Geological Data
    - Geophysical Data
    - Geochemistry Data
    - Data for bedrock, minerals and surface deposits

- Map Products
- Publications
- Archive reports

There is also a huge amount of data available which is achieved by loads of drill cores. The national depot for diamond drill core houses almost 3 million meters of diamond drill core from more than 28000 boreholes. The cores have been obtained from deep drilling operations carried out in mineral exploration, mining, engineering geology etc.

6.8 Aitik (Cu, Fe) [23];[24];[25];[26];[27]

handed in by Raimund Bartl

NEW BOLIDEN

6.8.1 Abstract

Location: Northern Sweden

Ownership: Boliden (100%)

Geology: Mineralised Precambrian shear zone

Mineral types: Chalcopyrite

Reserves: 520Mt proven

Annual production: 18Mt ore, 230,000t copper concentrate, 22Mt waste rock

Mining method: Open pit, drill-blast-shovel loading-truck haulage

Recovery method: In-pit crushing, grinding and conventional flotation

Employment: >450

Open pit Key Equipment:

- Bucyrus and P&H electric cable shovels
- Komatsu H485 hydraulic excavators
- Caterpillar 994 wheel loader
- Caterpillar 789, 793, 797 and Unit Rig haul trucks

Concentrator Equipment:

- In-pit crusher
- Automated crushing and grinding circuits
- Microcel flotation columns and process control software

6.8.2 General Information

Boliden is one of the leading mining and smelting companies in Europe with operations in Sweden, Finland, Norway and Ireland. Boliden's main products are copper, zinc, lead and gold and silver. Exploration and recycling of metals are also important within the company. The number of employees is approximately 4 500 and the turnover amounts to approximately SEK 30[1] billion annually. Its shares are listed on Stockholmsbörsen (Large Cap) list and on the Toronto Stock Exchange in Canada.

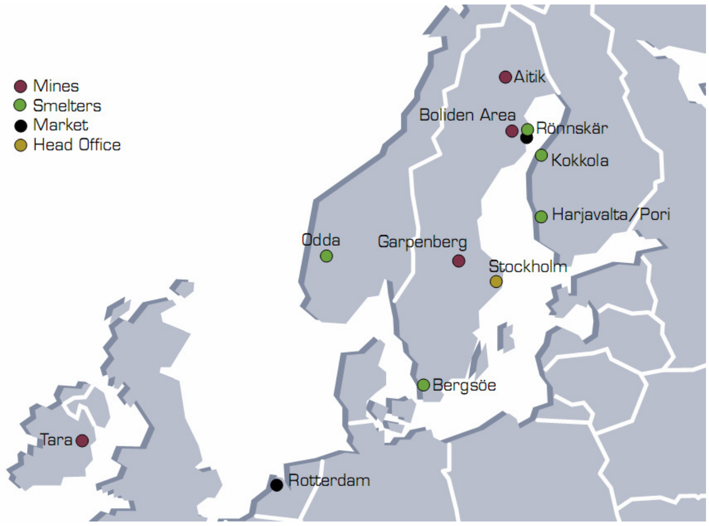

Figure 71: Boliden Operations

The Aitik open pit mine is situated in northern Sweden and outside the town of Gällivare. Aitik is one of Europe's largest copper mines. The ore mined at Aitik is crushed and treated in the large concentrator there. Located near Gällivare in Norrbotten, northern Sweden, the low-grade Aitik copper deposit was discovered in the early 1930s. Bulk-mining technology made exploitation feasible in the 1960s and mining at Europe's first large, low-grade open pit copper mine started in 1968 at a production rate of 2Mt/y of ore. Since then, a series of pushbacks have increased output to approximately 19Mt/y and the want to expand to 36 Mt/a. The increased production has resulted in lower production costs per ton of concentrate, which makes it possible for Boliden to produce copper concentrate at a competitive cost.

The concentrator, expanded in parallel, ships over 200,000t/y to the Ronnskär smelter. Aitik is one of the largest copper concentrate producers in Europe. Aitik employs more than 450 people and is the largest private employer in the municipality of Gällivare.
Since the consolidation of Outokumpu's copper and zinc mining and smelting activities into New Boliden in January 2004, Aitik has been wholly owned by Boliden.

[1] 1 EUR = 9,7243 SEK, 26.10.2008

Figure 72: Aerial view of the large open pit, and the tailings from Google Earth

6.8.3 Geology

The Aitik mine is situated in the shear zone between the Svecofenian and the Karelian plate and are of Precambrian age. The area consists of metamorphosed plutonic, volcanic and sedimentary rocks. The ore body is continuous in the dip direction and strikes from north to south with a dip of about 40° to 50° to the west. Shear zones surrounds the ore body and divides the mine into a northern and a southern part. The footwall, in the west, consists mainly of biotite gneiss and diorite. There is no distinct contact between the footwall rocks and the ore zone, the cut of grade gives the limit. At the footwall the ore zone consists of biotite gneiss and biotite schist with muscovite schist towards the hanging wall. Pegmatite dykes occur within the ore body. The main rock types in the ore zone can be found sporadic anywhere within the ore zone, i.e. lenses of muscovite schist can be found close to the footwall. It can sometimes be difficult to separate the biotite schist and biotite gneiss due to a gradual transition between them. The hanging wall mainly consists of amphibole gneiss and the contact is very distinct. The strength of the rock types in the ore zone has been investigated several times. The results from the investigations have varied to some extent, but the overall result is distinct. Muscovite schist is the weakest and the biotite gneiss is the strongest rock type in the ore, if pegmatite is disregarded.

Biotite schists in the volcanic sequence contain disseminated chalcopyritic mineralisation averaging less than 0.30% copper plus 0.2ppm gold and 3ppm silver. The dominant sulfideminerals are chalcopyrite, pyrite and pyrrhotite. The orebody is situated in Kiruna-Ladoga shearzone. The Main orezone has dimensions of 3000 m x 400 m. The Mineralization are in thin veinlets and dissemination. The Pyrite:Chalcopyrite-ratio increases towards the hanging wall.

The disseminated Cu-Au deposit is situated in northern Sweden in 1.9 Ga Svecofennian, metamorphosed volcanic and sedimentary rocks formed in a volcanic arc environment.

A large-scale vertical metal zoning results from a slight increase of Au with depth. Restricted Cu-rich areas at the surface gradually change into more extensive, medium-grade areas with depth, resulting in approximately the same average Cu content for each level. The vertical metal zoning is accompanied by a lithological change from biotite gneiss to biotite-amphibole gneiss with depth.

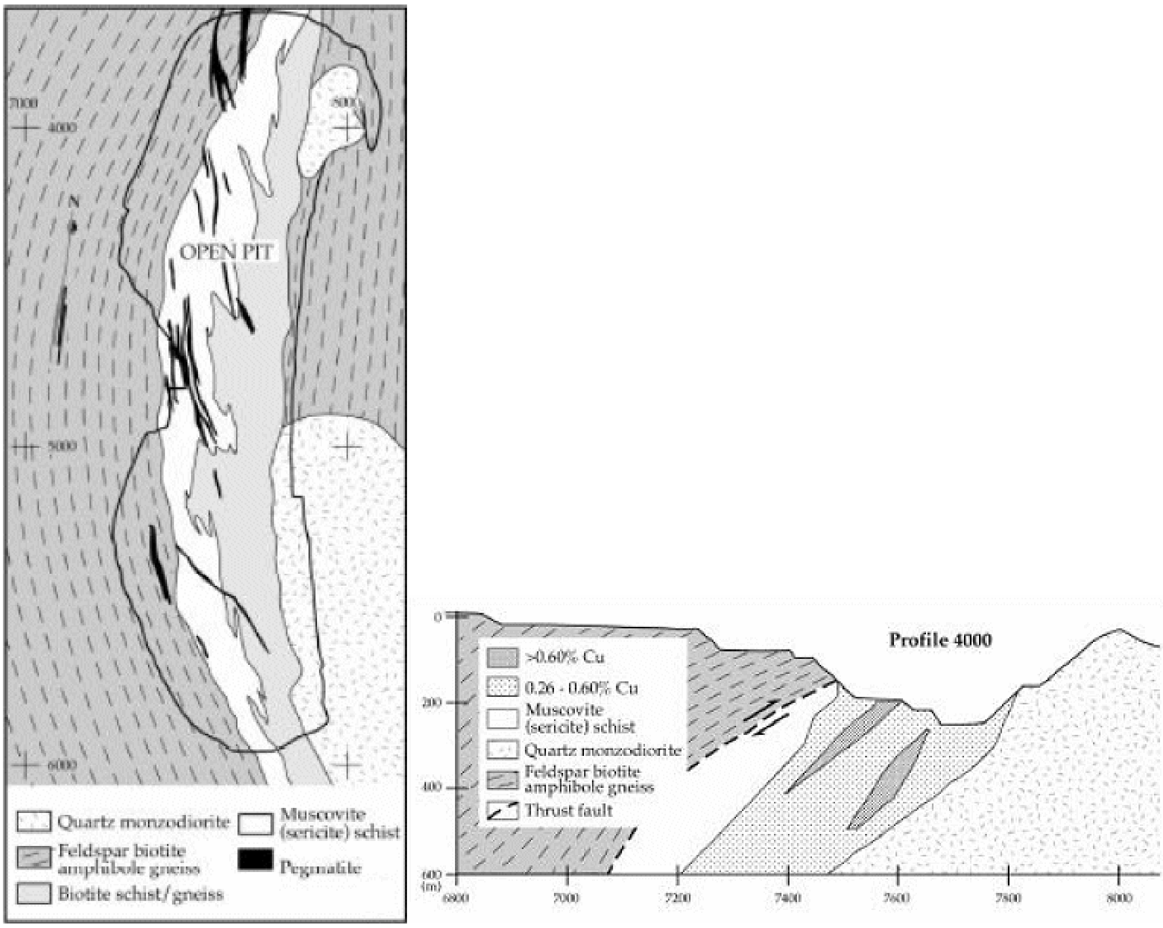

Figure 73: Mining area geological plan view, mining area geological profile

The mineralized areas trend predominantly north-east and north-south, and plunge north-east (Au) and north-northwest (Cu). The ore body also shows horizontal metal zoning. A 'high-grade' area (> 0.6% Cu and > 0.3 ppm Au) of disseminated sulphides is situated in biotite gneiss in the centre of the ore zone. Towards the hanging wall, grades are lower (<

0·4% Cu and < 0·30 ppm Au) and the host rocks are strongly sericite altered, pyrite-rich schists. Cu-dominated mineralization is mainly developed close to the footwall side of the ore, where disseminated sulphides and massive veins of chalcopyrite are common.
A 'gold-rich' area (> 0.6 ppm Au) is located within 50 m from the hanging wall, in a residual part of pyrite-rich biotite schist that is strongly K-feldspar, epidote and quartz altered. Another 'gold-rich' area (> 0.6 ppm Au) is situated below 400 m depth on the footwall side of the ore in the northern part of the deposit, where the amphibole content of the host rock is high.
Mining started on the basis of a 50Mt reserve, but by 1998 Aitik had yielded 300Mt of ore. As of November 2006, total proven reserves were 520Mt grading 0.31% copper, 0.2g/t gold and 2.0g/t silver, while 110Mt of probable reserves have similar precious metals grades and 0.28% copper. Measured resources at January 2006 were 635 Mt grading 0.30% copper, 0.2g/t gold and 2g/t silver. Indicated plus inferred resources totalled 350Mt at similar grades.
A SEK5.2 billion mine expansion, announced in November 2006, will extend the mine’s life until 2025, with Boliden now evaluating equipment tenders. The company now intends to increase ore production to 36Mt/y.

6.8.4 Mining

At the Aitik mine near Gällivare, ore is extracted through open-pit operations. Open-pit mining requires surface ore deposits and/or ores that are not covered by thick overburden or waste rock. After the removal of the overburden and waste rock covering the ore, the ore is mined in horizontal slices called benches.
The Aitik mine will, as will all mines, be reclaimed after it has ceased operations. Thanks to an agreement between Boliden and Stockholm Vatten (the Stockholm Municipal Water Works), the mine has ensured continuous deliveries of sewage sludge, which is used to cover and to improve the soil of the reclamation sites. Reclamation activities are on-going and good results have already been obtained.
Aitik is a single open pit divided into a southern section, where mining reached a final depth of 250m, and a northern area where mining is proceeding towards an ultimate 400m. The strip ratio is just below 1:1 – 1.8Mt/month of waste and 1.6Mt/month of ore. During the 1989–91 expansion, Roxon installed an in-pit crushing station, linked to the concentrator by underground conveyors.
At the Aitik open pit copper mine, the region's severe weather conditions combine with loose and fissured rock and high volumes of water in the holes at certain times of the year to make drilling operations difficult.

Figure 74: The huge open Pit with a length of 3km and a width of 1km and a depth of about 420m

The ore flow in Aitik starts with drilling and blasting, then the ore is loaded with excavators and hauled with trucks to the in pit crusher. The ore is crushed and transported on a conveyor belt, to two ore piles that feeds the grinding mills. After grinding the ore goes through flotation, thickening, dewatering and finally drying. The concentrate is transported to the Rönnskär smelter.

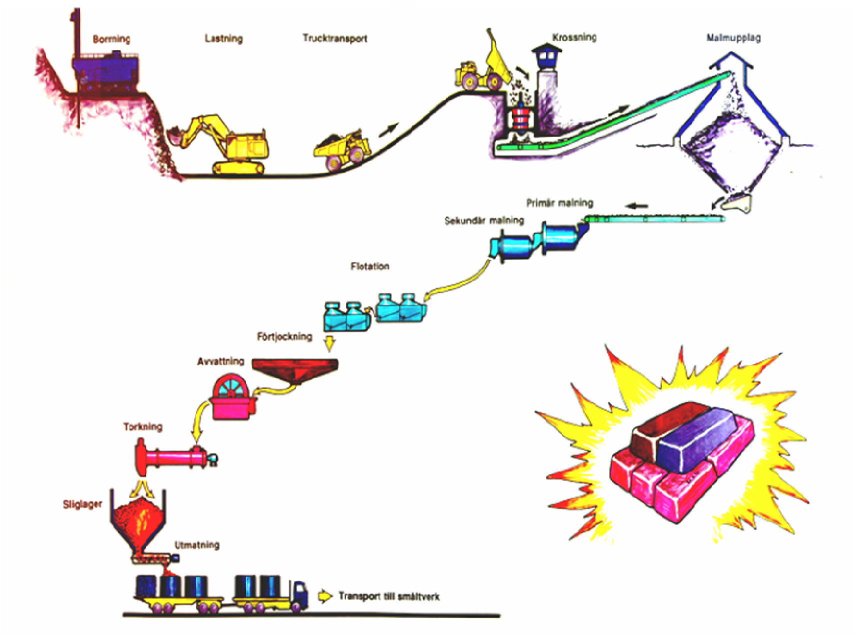

Figure 75: Schematic ore flow from mine to smelter: Mining, transport with trucks, breaking and grinding, floating, dewatering and transport the concentrate to the smelter

- **Drilling and Blasting**

Extraction starts with drilling mainly 311mm holes bored by rotary rigs, in preparation for Nonel blasting – as Aitik is prone to violent thunderstorms.

The drilling of the blast holes can be divided into two categories, one for the contour holes and one for the production holes. A contractor drills the contour holes with five inch and six inch holes. The bench height is 15 m and sub drilling 2 m.

The burden and spacing of the production holes are with the current design 7.75 x 9.75 m. The diameter of the production holes is 311 mm for three of the drill rigs, and 270 mm for the fourth. The average rate of drilling, per drill rig, is about 17 m per hour, but large variations occur due to difference between the drill rigs, operators and the rock characteristics. The production drill rigs are equipped with Aquila measurement while drilling, MWD, systems. Examples of parameters logged by the MWD-systems are torque, weight on bit, rate of penetration etc. The rotational torque is one of the parameters that give an indication of the rock characteristics for each hole drilled. The different MWD parameters can be plotted to their coordinates in the mine, showing a two dimensional map of the drilling characteristics at different areas in the mine, indicating variations of the mechanical properties of the rock.

Aitik's drilling contractor uses two Atlas Copco drill rigs, a ROC 936 and a ROC L8. The mine has a target of annual total of 90,000 meters drilling. Downhole drilling is the method used.

The contractor carries out both bench preparation and pre-splitting. Tight alternate rows of 6-inch and 5-inch diameter holes are drilled in 5 x 5 m and 4 x 4 m sections respectively. This contractor has its own equipment workshop and carries out all servicing with five drillers keeping the two drill rigs constantly in operation during the demanding work schedule. Both rigs operate well in temperatures down to -40℃ and penetration in the hard rock is 60 cm/min. The ROC L8 is also equipped with a water mist system to aid hole stabilisation.

The blasting in Aitik is done with emulsion explosives. The average density of the emulsions in the holes is about 1150 kg/m3 and the velocity of detonation, VOD, is about 5700 m/s. Over the years there has been a trend to decrease the powder factor in the mine, due to increasing scale of the mining equipment.

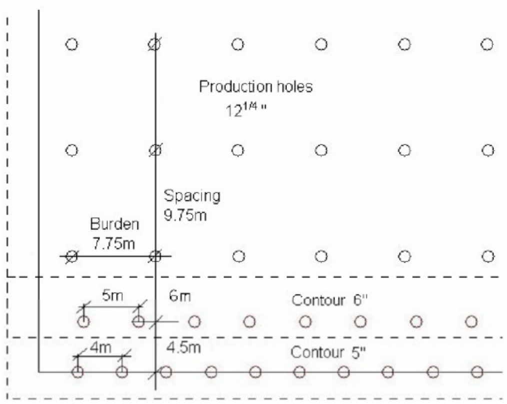

Figure 76: Geometry of the blasting holes

After the holes are charged they are plugged with about 6.5 meters of crushed and screened stemming material, 11-25 mm. Oricas Nonel ignition system is used for the ignition of the blasts with 176 ms delay between the rows and 42 ms between the holes in the rows. The direction of the blast is to the foliation of the ore body. The ignition of the blasts normally takes place at the outermost holes of the blasts, like in conventional bench blasting. When the blast has reached a couple of rows into the blast the confinement from the blasted material is so big that the swelling mainly goes in axial direction of the holes, like crater blasting. This makes a selective loading of the different ore qualities, high/low grade, possible. Each round is on average about 450 000 tons.

- **Loading and Hauling**

In 1989 Boliden switched from electric rope shovels and diesel-electric drive trucks to hydraulic shovels (two Demag H485s) and Caterpillar mechanical drive trucks, including 789, 789B and later 793B and 797 models. More recently Aitik has reintroduced large electric rope shovels (Bucyrus, P&H), with new rotary and DTH drills, all equipment that was obtained from the closed Los Frailes mine in Spain. Supplementary drilling and clean up around the main shovels is contracted out.

Four shovels, with varying bucket size from 17 m^3 to 43 m^3, are used for loading the ore and waste rock in the mine. A Caterpillar 994 wheel loader, 16 m^3 bucket, completes the loading fleet. 25 trucks haul the ore and the waste rock to the crusher or to the waste dumps. To optimise the production, all trucks and the shovels are equipped with the MineStar system, which schedules and assigns the trucks to the different shovels and dumps.

- **Crushing and storage**

The main part of the primary crushing is done at the crusher station in the pit, at 165 m level. The crusher station consists of two parallel gyratory crushers, model Allis Superior 60-109. Two older crushers on the surface are still in use but only during periods of maintenance and break downs of the crusher station in the pit. The opening of the main crushers is 152 cm and the diameter at the lower part of the mantel is 277 cm. The closed side setting, 16 - 18 cm, determines the crusher product. The coarsest rocks after the crusher varies from 35 cm to 40 cm with variations depending on the characteristics of the ores. A belt conveyor transports the crushed ore to two stockpiles. The total stockpile capacity is about 50 000 t.

6.8.5 Ore Processing

The Boliden mine is polymetallic, i.e. the ore contain different metals. From a technical and financial point it is not possible to smelt these ores directly. The different minerals and metals have to be separated.

The crushed ore is concentrated by flotation. The copper concentrate thus obtained is the dewatered by filtration and drying. The residue, the tailings, is deposited in the tailings disposal facility, where the tailings are dewatered. The water is then pumped to an adjacent pond and re-used in the mill, thereby reducing the need for external fresh water from the River Vassara älv.

Autogenous and ball mill grinding is followed by conventional flotation, the system design being typically 'Boliden'. It has been enhanced by the installation of Microcel flotation columns. The plant's capacity is around 250,000t/y and the whole plant is managed by an ABB distributed process control system, optimised using Svedala CISA software.

Pressure filtered concentrate is transported 400km in purpose-designed containers to Boliden's Ronnskär smelter at Skellefteham on the Baltic coast. The Rönnskär smelter has been processing Aitik's concentrates since the mine began operations in 1968.

A new rail link from the mining area to the main line may be used to ship out crushed mine waste rock for aggregates, as well as eliminating the previous truck haul to Gallivare.

The grinding circuit (shown in the next figure) consists of primary crushing, autogenous grinding. Pebbles are extracted to the secondary pebble mill. The primary and secondary mills are running in a closed circuit with a spiral classifier where coarse material returns to the primary mill.

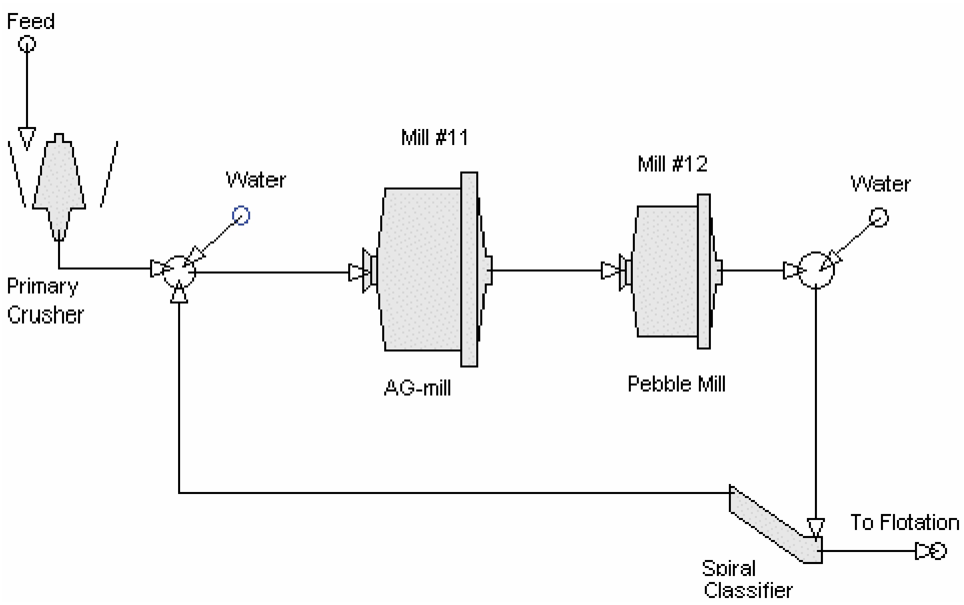

Figure 77: Grinding circuit

Flotation Process

At the flotation stage, various types of minerals are separated by inducing them to float to the surface as foam, assuming the mineral particles have been separated from each other through grinding. Water is added in the grinding process, and the ore is grinded to fine sand in large rotating mills. The water/sand-mixture (pulp) is then led to flotation cells consisting of open flow-through tanks equipped with agitators and air distributors. The various surface-chemical properties of minerals are used to separate the minerals and remove the low-grade waste materials. By adding special chemicals and blowing air into the pulp, the value minerals adhere to the air bubbles that float to the surface with the foam formed at the surface. The additives are combined to induce flotation within each individual mineral type and in different steps.

The residual product after enrichment, the tailings, is pumped with the process water to tailings ponds. The mineral concentrate is dewatered through filtration and drying. The concentrate is then ready for shipment to smelters for further refining.

Tailings

The waste rock is deposited on dumps on both sides of the pit. The mill tailings are pumped to the tailings pond, situated in a shallow valley nearby. The overall length of the tailings pond area is 8 km. The depth of the tailings is at present about 30 meters. The tailings are limited by a downstream dyke, at which a small pond of water is maintained to secure settling of the fines. Downstream of the tailings is a separate settling pond with an area of 4 square kilometers, built to ensure an efficient sedimentation of ultra fine particles. From the settling pond, process water is diverted back to the mill through a spillway and channel system. On an annual basis only about 20% of the water passing the tailings pond system is discharged into the Lina River.

6.8.6 Production, Reserves & Ressources

Total ore throughput in 2005 was 16.67Mt of ore grading 0.44% copper, 0.22g/t gold and 3.61g/t silver. Mill production of 28% copper concentrate was 237,197t. The metal content in 2005 and (2004) was 65,619t (64,498t) of copper, 41,297kg (44,948kg) of silver and 1,840kg (1,985kg) of gold. The ore output in 2007 was 18,2 Mt of ore grading 0,32 % Cu, 0,14 g/t Au 3,7 g/t Ag. In the following table the Production Facts 2007 are listed.

Concentrator	Milled thousand tonnes	Concentrate prodution			Metal contents				
		Copper tonnes	Lead tonnes	Zinc tonnes	Copper tonnes	Lead tonnes	Zinc tonnes	Silver kg	Gold kg
Aitik	18 481	240 054	---	---	66 133	---	---	35 730	2 342

Table 16: Production Facts 2007

Since 1968, more than 400 million tons (2007: 21,5Mt) of waste rock have been removed. A large part of the removed waste rock may become a commercial product in the future to be used in the construction of roads and as ballast material in cement.

Since the production start in 1968 Aitik has produced:

- concentrated 470 Mt of ore
- Delivered 6 Mt copper concentrate to Rönnskär smelter

- Extracted 1,7 Mt copper
- Extracted 49 500 kg gold
- Extracted 1 260 000 kg silver

When Aitik began production in 1968, the total mineral resource was estimated at ca. 50 Mt. Today's figure is > 1,000 Mt.

RESERVES	Mt	Cu [%]	Au [g/t]	Ag [g/t]	Mo [g/t]
Proven	389	0,29	0,2	3	32
Probable	221	0,28	0,1	3	36
RESOURCES					
Measured	445	0,2	0,1	1	22
Indicated	523	0,2	0,1	1	23
Inferred	80	0,2	0,1	1	24

Table 17: Ore reserves & resources

Exploration

In the year 2000 Aitik drilled 4000 m boreholes for exploration and it is planed to drill in the year 2008 26000 m of exploration boreholes and 8000m core drilled exploration boreholes. With the intensive exploration program there was a tripling of ore reserves from ca. 200 Mt to just over 600 Mt possible.

6.8.7 Mine Expansion

A total of SEK 5.2 billion in new investments between 2007 and 2011 and the mine expansion, announced in November 2006, will extend the mine's life from 2016 to until 2025. The investments include, amongst other things, a new concentrator, facilities for crushers and inward freight, along with other infrastructure such as roads and buildings. A decision was also taken to invest in ore conveyor belts between the crusher stations and the concentrator, thereby minimising the need for truck-based transports. The higher investment cost for the 7 kilometer long conveyor belt transport solution is compensated by improved operational reliability and operating costs that are considerably lower than those for truck transportation.

The Concentrator will built in new location with a gold leaching plant and a molybdenum extraction plant. It was necessary to build a new Crushing and conveying system.

Construction of the new concentrator is scheduled for completion at the end of 2009, with production scheduled to start in 2010, provided that the necessary permits have been

obtained. The capacity will initially be 33 million tons, but this is expected to increase gradually, reaching full production of 36 million tons by 2014. Aitik will be able to produce at full capacity (18 million tons) during the investment phase (2007-2010), in accordance with previous production plans.
At full production, the new copper metal production capacity is expected to average approximately 100,000 t per annum. Gold production will double from existing levels of approximately 2 t as a result of increased capacity and the metal recovery offered by the new facility. Boliden will also start processing molybdenum, a metal which is greatly in demand in the steel industry where it is used as a metal alloy.
The average copper level will be 0.29 %. Aitik will continue to be a low-level mineralization but will, as before, compensate for this through high levels of productivity. Aitik is already high on the list of the world's most productive copper mines, with 43 tons/man hour in comparison with a global average of 15 tons/man hour. The expansion will increase the mine's productivity to 55 tons/man hour, making Aitik one of the most efficient copper mines in the world.
The previous production plan for Aitik ran until early 2016. The expansion plan now approved will extend the mine's lifespan to at least 2025.
The investment will yield a substantial increase in the ore reserve from its previous level of approximately 200 million tons to just over 600 million tons. The investment will ensure that almost 60 per cent of Aitik's total mineral reserve can now be mined, thereby extending the mine's lifespan by 10 years. The remaining mineral reserve coupled with the increased exploitation potential, creates the potential for a further expansion of the mine in the future.
With the new facility it is possible to increase copper, gold and silver production and start with production of molybdenum.

Molybdenum – the new Aitik product:
The massive Aitik project includes exploiting the molybdenum present in the copper concentrate. The molybdenum concentrate is extracted by means of flotation of the concentrate and conventional dewatering of the specific molybdenum concentrate.
The product will then be sent to steelworks. Molybdenum is a silvery-white metal that is almost as hard as tungsten, but more pliable. It is a very valuable alloy metal that is used, among other things, to improve the strength of steel at high temperatures.

Investments in the mine:

- Three crushing stations, incl. one in the open pit: semi-mobile crushers, 8,000 t/h
- New conveyor belt system with a total length of 7 kms, 3.5 kms of which is underground.

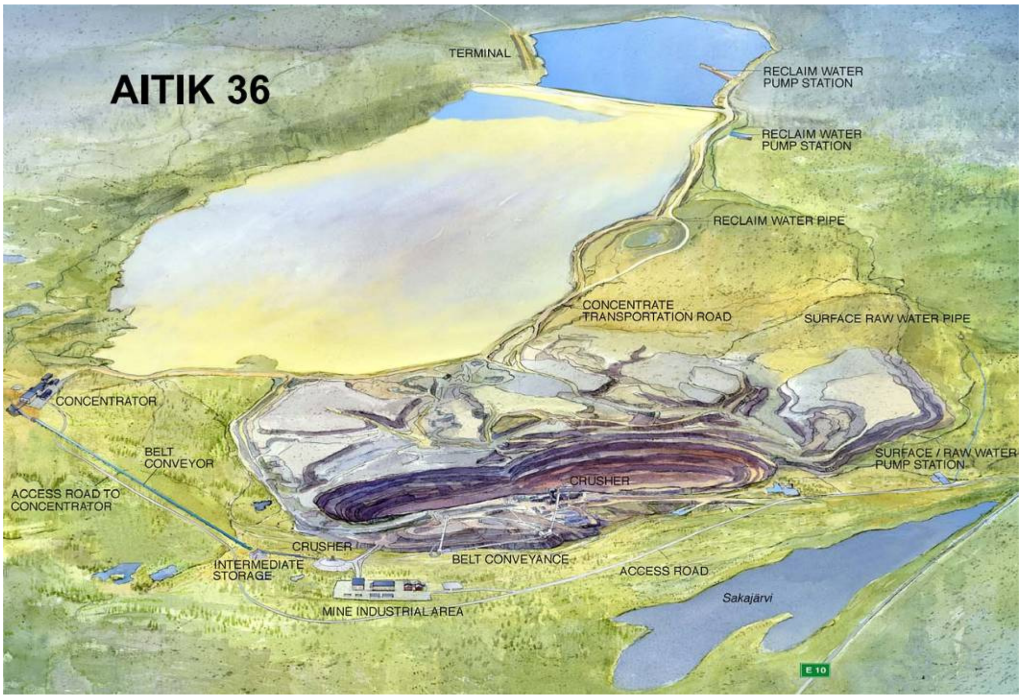

Figure 78: View over the planned new Boliden mine

A facility is planed which based on the best available technology and the biggest tested scale and it contains the following equipment:

- Two milling lines, nominal feed 2,200 t/hr
- Primary mills: 11.6 m x 13.7 m 22,5 MW gearless drives
- Secondary mills: 9,1 m x 11,3 m 10 MW variable speed drives
- 26 x 160 m^3 flotation cells
- Depyritisation
- Three pressure filters

Molybdenum flotation and gold leaching

7 Appendix

7.1 Pictures

7.2 Figures

7.3 Table

7.4 References

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PICTURES

- **TU Helsinki**



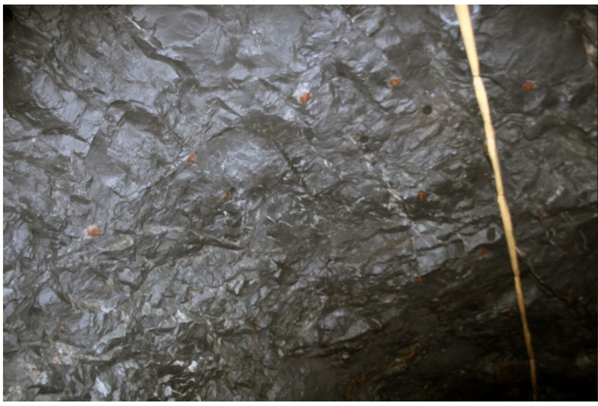



• Outokumpu Chrome Oy (Cr)

• **Geological Survey**

• **Agnico-Eagle Oy (Au)**

• **LKAB (Fe)**



• **Boliden (Cu)**