Going Underground at Kemi Mine

Intelligent Mining

The large chromite deposit being mined by AvestaPolarit at Kemi, Finland has a lower than average Cr_2O_3 content of about 26%, so chromite and ferrochrome production technology has had to be continuously upgraded to remain competitive.

The Intelligent Mine Implementation Technology Programme of 14 projects achieved real time control of mine production in precise coordination with the needs of the mineral processing plant and the ferrochrome smelter. The system utilizes a fast, mine-wide information system that can help optimize financial results for the whole operation. Needless to say, accurate coring with Craelius, computerized drilling with Boomers, and reliable rock reinforcement with Swellex form a major part of the mine strategy. The result is cost-efficient, integrated production, on a model which may form the basis of the next generation of mining techniques.

Introduction

AvestaPolarit is the world's second largest stainless steel producer, accounting for about 8% of global stainless slab output, and a similar share of cold rolled production. These are hugely significant proportions of a market that has risen by an average of 5.5% per annum over the last 20 years, and is currently enjoying 7.5% growth.

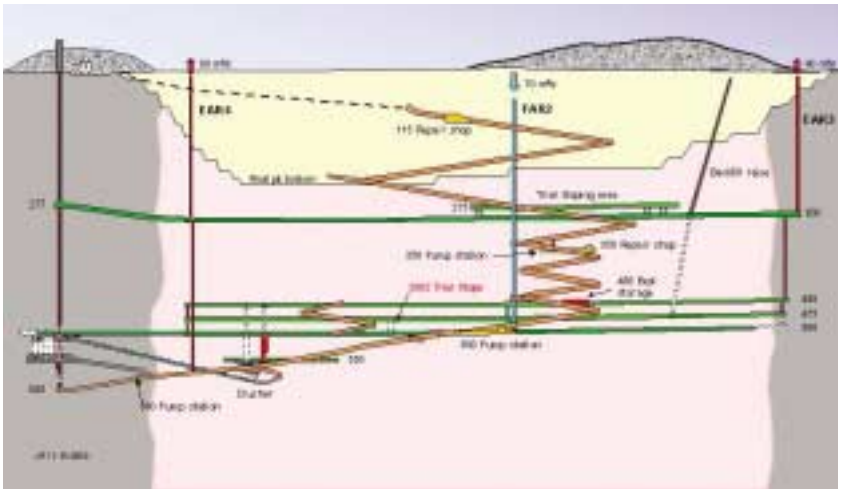
Mainstay of the AvestaPolarit strategy is its highly cost-efficient fully integrated mine-to-mill production chain in the Kemi-Tornio area of northern Finland. An ongoing investment programme of €770 million will expand annual slab capacity from 1.75 million t to 2.75 million t, and coil rolling capacity from 1.2 million t to 1.9 million t.

Ore reserves at Kemi chrome mine are abundant, and the efficiency of the Tornio smelter is enhanced by its proximity to both the mine and harbour facilities. The plan is to progressively switch from surface to underground mining at Kemi, where intensive use will be made of information technology to optimize the overall mining and processing operation. Underground mining starts in 2003 at 150,000 t/y, and production will increase to the planned level of 1.2 million t/y by 2008.

Aerial view of Kemi mine, located close to Finland's border with Sweden.

Open Pit

The Kemi deposit is hosted by a 2.4 billion year old mafic-ultramafic layered intrusion extending for some 15 km northeast of the town itself. The chromite-rich horizon appears 50-200 m above the bottom of the intrusion, and has an average dip of 70 degrees northwest. The main immediate host rock is weak talc-carbonate, so pit



Kemi underground mine simplified long section.

POWER AND INTELLIGENCE

The Rocket Boomer L3 Series

The Rocket Boomer L3 series combines power with intelligence – the power of Atlas Copco rock drilling equipment and the latest in advanced computer technology. Select the level of intelligence that best suits your needs.

You choose between three different boom console configurations. The Rocket Boomer WL3 C with a maximum width of 17.8 m for highway tunnels and underground caverns, the Rocket Boomer XL3 C with the high reaching Eagle console for railway tunnels with heights up to 12.8 m, and the Rocket Boomer L3 C for standard tunnels of up to 106 m^2.

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slope stability must be carefully monitored. Furthermore, although the hanging wall contact is clearly defined, at the footwall the chromite and host rock is interlayered, and must be mined selectively. However, there is strong granite some 80 m below the footwall.

The Kemi chrome deposit comprises 11 mineralizations within a 4.5 km-long zone varying from 5-105 m in width, with average thickness of 40 m. Mineral resources are over 150 million t of 28.6% Cr_2O_3, with 5 million t proven reserves in the open pit and 47 million t proven reserves underground. The orebody continues at depth, probably to 1,000 m, with 750 m having been reached by the deepest exploratory hole. The 1.5 km-long x 500 m-wide main pit is now 170 m deep, with final planned depth being 220 m.

At the open pit, AvestaPolarit directly employs 25 people to cover drilling, blasting, surveying and geological investigation. Four main contractors employ another 40-45 people, who carry out ore and waste loading and transport, dewatering, wall support and smooth blasting, and explosives supply direct to the hole.

A two shift/day, five day/week pattern is worked in the mine, from which about 1.2 million t/y of ore grading 24-26% Cr_2O_3 is processed continuously by the concentrator. The yield is 220,000 t/y of 12-100 mm lumpy concentrate with 35.5% Cr_2O_3, and 420,000 t/y metallurgical grade concentrate at 44% Cr_2O_3. Around 4.5 million t of barren rock is removed to achieve this production. Over the years, some 26 million t of ore has been produced, resulting in 115 million t in the waste heaps.

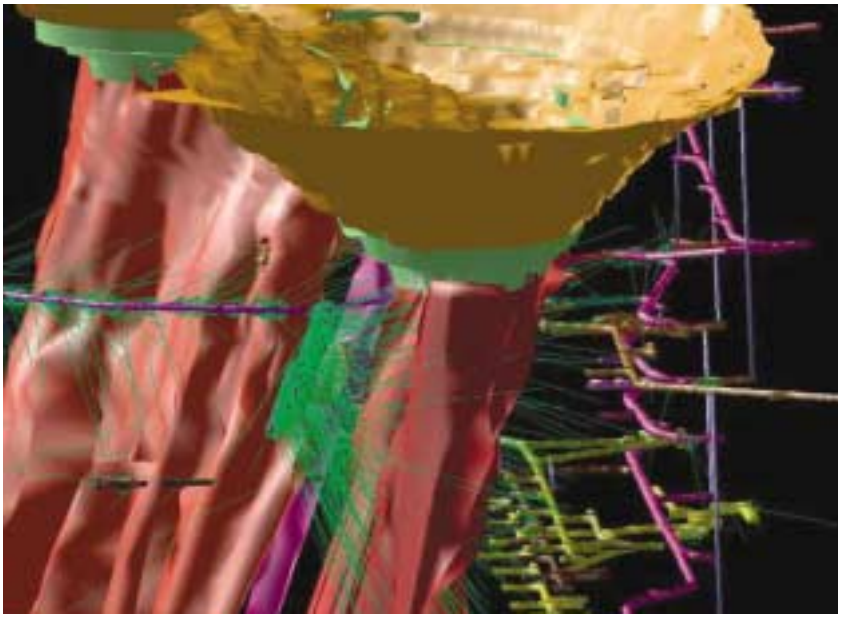
A tracked Atlas Copco Craelius Diamec 252, which returns 20-25 m/shift, carries out diamond drilling in the open pit. The 12 m benches are production drilled with 14 m-long x 102-115 mm diameter holes by three track drills, which have a combined output of 600 m/shift. Blasting is by Kemiitti 510 emulsion loaded at 130 kg/hole and Nonel detonators. 60,000 t of rock requires 10,000 kg of explosives. Production in the open pit will be phased out over the next few years as the underground mine comes on stream, and closure should take place in 2007.

Ore Grade Control

Ore grade control in both the open pit and the underground mine involves intensive wireline diamond core drilling, to determine boundaries and qualities of specific ore types. In addition, all blast holes in the open pit are sampled. Technical innovations for ore characterization and quantification include OMS-logg downhole logging, and automated image analysis for establishing grain size distribution.

Basic production data about mineralogical and process histories is logged for each ore stope on a daily basis, and this is merged and compared with daily and blast-specific production histories from the database.

Each ore blast is treated selectively at the concentrator, in order to minimize feed variation and maximize process stability.



Isometric of Kemi operation shows core drill hole density.

Atlas Copco Craelius Diamec 264 APC at work underground.

Atlas Copco Rocket Boomer L2 C is used for development.

In the concentrator, total chromite recovery is around 80%, depending on the proportion of lumpy ore. Metallurgical grade concentrate contains about 44.3% Cr_2O_3 of 0.2 mm grain size, while upgraded lumpy ore is about 35.5% Cr_2O_3 with 12-100 mm size. The former is pelletised at Tornio, and then mixed with upgraded lumpy ore before smelting to produce ferrochrome.

Concentrator operation is optimized by accurate calibration of the feed slurry analyzers, and control of product quality from each unit process, both by compensating for changes in feed type, and measuring product quality on-line. Manual input can be used, as well as on-line information.

A Craelius Diamec 264 APC drillrig carries out 12 km of coring each year. Drill sections are established every 10 m and downhole survey is standard procedure, using a Maxibore system. Based on the drill hole data, a 3D model of the orebody is created and used as a basis for production planning.

Tying all these streams of collected data and planning outputs together requires an extremely fast communications network, interfacing with a single master database.

The cabin and the computer control system with double joystick operation helps the operator to achieve high productivity.

Underground Infrastructure

The main decline starts at a portal in the footwall side of the pit, at about 100 m below the rim. The decline is mostly 8 m-wide x 5.5 m-high, to accommodate passing vehicles. It descends at 1:7 to a depth of 600 m at the base of the hoisting shaft, and connects with several intermediate sublevels. The decline is asphalted throughout most of its length.

There is also a 5,000 cu m repair shop for open pit equipment at the 115 m level, and a larger 14,000 cu m workshop at the 350 m level for the underground mobile equipment fleet. A huge 23,000 cu m main workshop is planned for the 500 m level. The 350 m level workshops are enclosed by megadoors, which keep in the heat so that an ambient 18 degrees C can be maintained. The service bay is equipped with a 10 t travelling gantry and 16 m-long inspection pit. The washing bay is equipped with two Wallman hydraulically controlled washing cages, so there is no need for operatives to climb onto the mobile equipment.

The main pumping station is located at the 350 m level, and has pumping capacity of 2 x 250 cu m/h. The slurry-type pumps, with mechanical seals, pump the unsettled mine water to the surface with a total head of 360 m. Two other dewatering pumping stations are located at the 500 m and 580 m levels.

The crusher station at the 560 m level is being equipped with a 1,000 t/h Nordberg gyratory crusher. This will be fed from two sides by vibrating feeders from separate 8 m-diameter main ore passes from the 500 m level, and from one side by a plate feeder, to which the ore can be dumped from the 550 m level. A 40 t travelling gantry crane services the entire crusher house. Crushed ore will gravitate onto a conveyor in a tunnel below the crusher for transport to the shaft loading pockets 500 m away.

Shafts

Some 1.5 km of raise boring was required for ventilation purposes, with intake at 4 m-diameter and exhausts at 3.5 m-diameter. In summer, fresh air will be drawn into the workings down the main decline and through the intake, and exit through the exhaust shafts located at the extremities of the ore body. In winter, the central ventilation shaft becomes the only intake, and air will be heated on its way into the mine. It will then be exhausted both up the decline, and through the exhaust shafts. Contractor NCC raise bored the first backfill raise.

The main shaft was sunk in two stages, from surface to the 300 m level, and then on to final depth at the 600 m level. Drillcon Raise AB core drilled the pilot hole at 76 mm, and then reamed in three stages to 280 mm using DTH hammers. A raise borer then back reamed the hole to 2.44 m diameter, following which crews from contractor YIT slashed the shaft to 5.5 m diameter in 4 m lifts. Ten 2.2 m x 20 mm cement grouted rebars were installed to support each metre of shaft, with 8 cm of steel fibre reinforced shotcrete and a 2 cm protective layer of shotcrete without fibres. The shaft is being furnished with skip and man riding cage, counterweight, and a separate service cage.

The 70 m-high x 11 m-wide x 11.4 m-long main shaft head frame, with ABB friction winder, is scheduled to commence ore production on 1st September, 2003.

Underground Production

Trial stopes in three areas accessed from the 275 m and 300 m levels were mined to determine the parameters of the bench cut-and-fill technique to be used. These had a width of 15 m, and were 30-40 m-long, with 25,000-30,000 t of ore apiece. Both uphole and downhole drilling methods have been tested, and 51 mm-diameter downholes have been selected as being the safest.

For production purposes, 25 m-high transverse stopes are planned, with cable bolt, shotcrete or wiremesh to minimize dilution. Primary stopes will be 15 m-wide, and secondary stopes 20 m-wide. Cemented fill, using furnace slag from an iron ore smelter and fly ash from local power stations, will be placed in the primary stopes, while the secondary stopes will be backfilled with mine waste rock. The primary stopes will be extracted one or two levels above the secondary stopes, and maintained *en echelon*.

Inside the 350 m-level workshop at Kemi.

Mining sublevels with 5 m x 5 m cross sections have been established by NCC at 25 m vertical intervals, using two Atlas Copco Rocket Boomer L2 C drillrigs equipped with 1838 ME rock drills. Rounds of 60-80 holes took about 2 hours to drill, charge and prime. A new emulsion charging truck with elevating platform and Atlas Copco GA15 compressor provided fast and efficient explosives delivery. Pipe charges were initially used for the profile holes, but were progressively replaced by measured amounts of slurry. Some 600 m/month of sublevels were mined, and contractors have completed 22 km of tunnels. The footwall granite is very competent, but lots of rock reinforcement is required in the weaker host rock, where all drives are systematically rockbolted and secured with steel fibre reinforced shotcrete.

A number of electro-hydraulic drillrigs, six large LHDs, and a variety of trucks and ancillary vehicles will be purchased for production, which starts from the 500 m level in late 2003 and will proceed upwards to the open pit bottom. The Atlas Copco Rocket Boomer will be equipped with Rig Remote Access (RRA) option to work in real-connection with the mine communications network, facilitated by the Rig Control System (RCS). RRA also allows Atlas Copco to monitor and evaluate the drillrig systems from its HQ in Orebro, and assist with troubleshooting.

The mine will work two shifts/day, five days/week. The planned nominal capacity is 2.7 million t/y of ore, which allows for

With the Boltec LC and Swellex Mn12 rockbolts operators at Kemi mine are installing some 80-90 bolts per shift.

increased ferro-chrome production at Tornio when AvestaPolarit decides to expand the smelting operation. Budgeted cost for mine development is about €70 million.

Rock Reinforcement

Swellex Mn12 2.4 m-long bolts are used for support in ore contact formations. These are being installed at a rate of 80-90 bolts/shift using a new Atlas Copco Boltec LC rig, which is returning average penetration rates of 2.5-3.0 m/min. The CAN-bus controlled LC rig mounts the latest Swellex HC1 pump, for bolt inflation at 300 bar pressure, and reports progress on the operator's screen.

When Swellex was first introduced at Kemi, the mine and Atlas Copco got together over proving trials. The Swedish Corrosion Institute was employed to evaluate the potential for corrosion, and came to the conclusion that the application of shotcrete was beneficial to bolt life.

Then Swellex Mn12 2.4 m-long bolts were installed in a damaged crosscut at the Kemi to study their efficiency in specific conditions, while the performance of the Boltec LC bolting rig was seen during a visit to the Zinkgruvan mine. At the same time, Atlas Copco was developing an intelligent pump to ensure the perfect installation of Swellex bolts. The new HC1 hydraulic pump is robust, simple, and with low maintenance cost. Coupled to an intelligent system, it reaches the 300 bar pressure level quickly, and maintains it for the minimum time for perfect installation. Combined with the rig's CAN-bus system, the pump can confirm the number of bolts successfully installed and warn of any problems with inflation. The new HC1 pump has now installed more than 10,000 Swellex Mn12 bolts without a single problem.

A series of slip-pull tests carried out throughout the mine proved the strong anchorage capacity of Swellex Mn12. In all of the three rock formations: the orebody, the softer talccarbonate zone and in the mylonite zone.

Contractor's Report

NCC's contract at Kemi included 15 km of drifts and other facilities totalling 500,000 cu m of excavation. Face sizes varied from 16 sq m to 60 sq m, and were mainly 20-30 sq m. The best month produced 775 m of drift, and the average has been about 600 m. Some 75% of drifts have been in competent footwall granite, and 25% in the weak talc-carbonate of the ore zone. Contract duration was May, 2000 to December, 2002. NCC employed about 23 miners working 3 shifts/day, and local subcontractor Tapojärvi Oy about 18 men on loading and hauling. The main ramp has been developed down to the 600 m level, along with main sublevels at 450 m, 475 m, 500 m, and 550 m levels. Site-mixed ANFO, Kemix-pipe charges and emulite capsules, detonated by Nonel LP were used. Drilling was carried out by two Atlas Copco Rocket Boomer L2 C twin boom rigs equipped with 5.5 m feeds and COP 1838 ME rock drills. Hole depth is 5 m and diameter 48 mm, with 102 mm cut holes. Around 1.1 million metres have been drilled, and 15,000 cu m of shotcrete placed. ■

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