The city of Kiruna is located in the extreme north of Sweden (67°50’34” N, 20°25’10” E), above the Arctic circle. The city has grown up with mining, which began more than a century ago. The ore body is 4 km long and around 80 m wide. It lies roughly in a north-south direction, dipping some 60 degrees to the east, and extending to a depth of at least 2 km.

The so-called Kiruna Type of iron ore is a phosphorous containing iron ore with magnetite as the ore mineral. Scientists remain divided on its origins. In the past, it was thought to have been formed by magmatic differentiation processes and to have reached its present position through a magmatic-intrusive emplacement, but many researchers now support a marine synsedimentary origin.

A high-phosphorous apatite-rich ore, called D ore, makes up some 20% of the ore body. It has an average phosphorous level of 2% although this varies widely. The remaining 80% is a low phosphorous, iron ore, called B ore, with an average of...
0.025% phosphorous, and 68% iron. Distinct boundaries separate both the ore types, and the ore and surrounding bedrock at the hanging wall and footwall contacts. D ore is usually found near the hanging wall, although it occasionally occurs in the centre or even along the footwall. The two ore grades are kept apart during mining operations, as is the barren bedrock.

Mining method

Kiruna ore was originally mined in open pits on the surface of the mountain, and has subsequently been pursued underground. Sublevel caving is currently used, which is both suited to this sort of ore, and also allows different operations to be carried out independently in various parts in the mine. The ore body is divided into main levels to facilitate haulage and access to the ore. On sublevels between these haulage levels, drifts are made across the ore body from the footwall to the hanging wall. This involves transversal sublevel caving, although longitudinal sublevel caving is sometimes also used depending of the geometry of the ore body.

Drifts, 7 m wide and 5 m high, are made at 25 m horizontal intervals in a vertical zigzag pattern with 28.5 m vertical spacing. In sublevel drifts, production drilling starts at the hanging wall with rings of long holes drilled in a fan-like pattern, and rings spaced at 3 to 3.5 m. They are then charged and blasted, again beginning at the hanging wall and subsequently retreating towards the footwall. Each production ring contains around 10 000 tons of ore. The blasted ore is loaded on the level below and carried to ore passes by electric load-haul-dump (LHD) units.

The ore passes themselves are built along the sublevels to the main haulage level below. All haulage is currently carried out at the 1045 m level. The mine is divided into ten production blocks, each with both its own ventilation shafts, and ore passes situated at the block centre. Each block is around 400 to 500 m long. Sublevels are interconnected both with each other, and the main haulage levels, using a system of ramps; this allows equipment to be moved, and gives maintenance and support staff access to the various parts of the mine. Over 400 km of maintained underground roads have been built.

Mining begins at the top sublevel and proceeds sequentially downwards. At the main haulage levels, ore is transported by train from the ore passes to vertical bins where crushers lead the ore to loading bays at the bottom of the hoisting shafts. Skips bring the ore to the surface where it is further processed into fines and pellets. The finished products are transported by rail to the ports of Narvik, Norway and Luleå in the Gulf of Bothnia.

Production at Kiruna in 2002, including the nearby Svappavaara pellet plant, amounted to 13 million tons of finished products - 10 million tons of which were pellets - derived from 20.7 million tons of crude ore. The same year, 12.800 km of drifts were constructed.
Remote control

The substantial chain, from drifting to port delivery, offers good opportunities for planning and optimization, including mechanisation.

As production drilling in sublevels is performed uniformly at several drifts simultaneously, this repetitive process is amenable to remote control. Fibre optic cables connect key positions in the mine via feeder cables to other blocks where mining is done. Each block is fitted with a base station for wireless communication. This enables control and monitoring of different machines in the mine.

Communication must be fast enough to let remote control operators obtain information and have sufficient time to make proper corrections. This was achieved in 1997 with wireless transmission of sound, images and data. The Atlas Copco drilling rigs; all fitted with Wassara drilling machines operated with water rather than compressed air - are remote-controlled from a centre situated at 775 m depth - thousands of metres from where drilling actually takes place.

Drilling is remote controlled, with a remote operator drilling via a joystick. Newer drilling rigs have facilitated this as they have a high-degree of inbuilt automation. A computer-based system provides operators and maintenance technicians with the information they need to monitor drill-rig status, including maintenance history as well as parameters of its current condition.

Remote control of loading and hauling poses another technical challenge - how does one navigate a 14 metre long, 100 ton loader inside the mine? The solution is a system based on a revolving laser on top of the loader, with reflectors located on the walls of the drifts. Loading, hauling and dumping on the sublevels are now fully remote-controlled from the control centre in the main office building on the surface. As a result, one operator can run three LHD loaders simultaneously, having to intervene only during loading, while the loaders can be operated continuously.

Loading out the ore at the face is very efficient. When one face is being mucked clean, the loader is moved to a nearby drift heading to continue loading. Remote control also means that the machines operate for longer hours; there is no need to wait until dispersion of blasting gases after detonations, for example, and the machines need no coffee breaks.

The first remote-controlled trains came into operation in the Kiruna mine as early as 1970. Today, six trains are each loaded with 500 tons of ore at the 1045 m level. Each train has one locomotive, powered by four 150 kW AC-motors, and 24 cars. A train cycle takes around one hour. Trains run 365 days a year. Crushing, weighing, skip loading and hoisting have been automatic for decades.

Production control centres have recently been introduced to help run operations smoothly and to avoid bottlenecks from arising. The centre for mining operations, which houses operators, is situated in the main office of LKAB in Kiruna. From here, the entire process is monitored and controlled, with some 15,000 measurement points covering everything from underground operations to ship loading in port. Operators can at any time compare actual performance with production plans.
Drill rig Atlas Copco BVK.
Foreuse Atlas Copco BVK.
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Environmentally friendly mining

The ore mined in Kiruna is non-hazardous magnetite, but LKAB, nonetheless takes environmental issues very seriously. An environmental management system, including environmental policy and reporting, is an important part of its total quality management system. The company is continually improving the internal and external environment as a means of contributing to sustainable and profitable development. Environmental issues are taken into account when making new investments, and occupational health, environmental protection and energy efficiency are always considered when introducing new technology.

The challenge of underground mining

The LKAB Group sells its iron ore products on the international market, where prices are in practice set by the dominant producers operating in Brazil and Western Australia, where deposits are mined in huge open cast operations. In contrast, LKAB’s mines in Kiruna and Malmberget are both underground operations run at depths of some 1 km.

Open-cast mining avoids many of the complications of underground mining. Drilling, loading and hauling can also be done at a larger-scale as they can make use of equipment much larger than would fit into an underground mine. Streamlining of the entire underground mining operation is needed if it is to compete with the giants on the international scene.

LKAB invests heavily in diverse research and development to keep a competitive-edge. In product development, for example, LKAB operates its own research blast furnace in Luleå. Every bit as important, however, is research on the upstream processes and the logistics. Advances here double up in contributing to the total quality management system needed to ensure that the product delivered meets the specifications ordered, and keeps customers happy.

Moving the remote control centre from the mine to the main office will offer further flexibility. Modern telecommunications provide the company with the freedom to operate the mine from almost anywhere. Indeed, the mine has been operated from the Technological University of Luleå some 340 km away.

As well as streamlining mining operations, automation and remote control also contribute to better working conditions for staff, as there is no need for people to be in the zones where mining operation takes place. The mine can be operated at night without a single person being down the mine.

Remote control and automation

In 2003, the mine produced 11 Mt of pellets, and 2.3 Mt of sinter fines, and employs 1800 people, 400 of whom work underground.
The Kiruna iron ore mine

It is located at latitude 68° in northern Sweden, far north of the Arctic Circle. The magnetite ore body is 4 km long and 80 m wide. It has been mined for over a century, yielding some 950 million tones over this period. This amounts to around just one third of the original ore body, according to current knowledge of the deposit’s size.

A third pellet plant is located at nearby Svappavaara. Products are transported by rail to the ports of Narvik in Norway and Luleå in the Gulf of Bothnia. Most business is with European Union countries. The mine produced 11 million tones of pellets, and 2.3 million tones of sinter fines, in 2003. It employs around 1800 people, 400 of whom work underground.

A vast mine like Kiruna with a 4 km long ore body drains water from a large area. In 2003 more than 5.3 million m³ of drainage water was pumped from the mine at an average rate of 25 m³ per minute. Water brought to the surface is diverted to the processing plants, and used in ore sorting, concentrating and pelletting, before being cleaned and pumped to a settling pond. Water quality is continuously monitored. Water used in the mine for purposes such as washing equipment, and for operations in the repair shop at the 775 m level, is treated to separate out oil before being pumped to the surface.

People living in the city of Kiruna are affected by mining activities in various ways. Blasting, for instance, create ground vibrations, which are monitored by the company to ensure they remain at low levels and within set limits.

Remote controlled loader Toro 2500.
Chargeuse télécommandée Toro 2500.
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