Steep Wall Open Pit Mining at Zhelezny

The Zhelezny open pit mine at Kovdor operates Atlas Copco and Russian drill rigs, Russian electric shovels and Belaz, Caterpillar and Komatsu haul trucks. The in-pit crushing station is on the upper right of the picture.

Super-deep mining

Kovdorsky GOK, one of two mining companies in the Kola Peninsula supplying two of Russia's major phosphate fertilizer manufacturers, has decided to utilize super-deep mining at the Zhelezny open pit until reserves are exhausted in 2049. The technique relies heavily on precision drilling with equipment supplied by Atlas Copco.

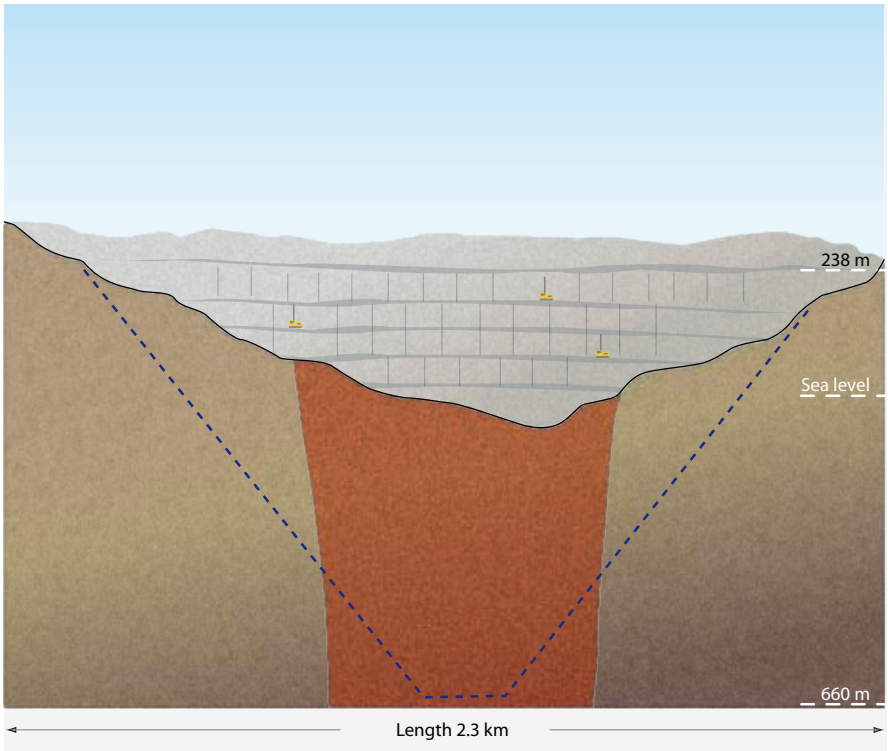
Treasure Trove

Discovered in 1933, the ore deposit at Kovdor in Russia's Murmansk Oblast (67° 33' N, 30° 30'E) is unusual, probably unique. The discrete, deep and more or less downwardly conical carbonatite deposit hosts 45 recorded minerals and is the type locality for five of these. It is also one of the Kola Peninsula's two major sources of Apatite for fertilizer production, one of the world's few reserves of Baddeleyite (containing zirconia), and a substantial supplier of Magnetite.

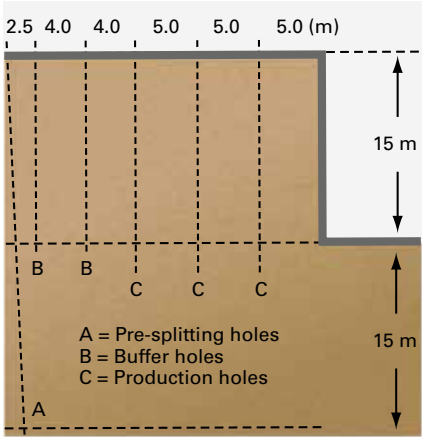
The mining method developed for the Zhelezny open pit is a bit special too. Described as a breakthrough technique in Russia, super-deep mining requires extraordinary control of drilling and blasting on near vertical benches. Kovdorsky GOK, which is part of the Eurochem fertilizer group, wants to minimize ore dilution while maintaining production rates – although bench areas will decrease as the mine deepens. The rim of the pit is approximately 200 meters (m) above sea level and is 2.3 kilometers (km) in length, 1.7 km wide and presently 170 m deep. Whereas mining was scheduled to cease in 2015 Kovdorsky GOK now intends to mine down to 660 m below sea level, thereby accessing an additional 330-400 million tonnes of ore and enabling Zhelezny to produce 23 million tonnes per year (Mt/y) until 2032. Output will then decline until closure around 2049.

Evolution

The mining and processing operations at Kovdor started in 1959-62, initially recovering only the magnetite from 6 Mt/y of ore, explained Igor Melik-Gaikazov and Mikhail B Togunov, respectively Technical Director and Chief Mining Expert at Kovdorsky GOK. Super-deep mining is not the operation's first technical breakthrough, they pointed out. During the 1970s the staff developed a process for separating the apatite and baddeleyite as well as the magnetite, with optimal processing achieved early in the 1980s. The iron ore is extracted by magnetic separation, then the pulp undergoes flotation to recover the apatite and, finally, gravity techniques separate the baddeleyite. In the same period the mineable area



The Zhelezny open pit is 2.3 km long, 1.7 km wide and its current depth is approximately 170 m. The diagram shows the vertical orebody and the planned angle of the slopes at the projected depth of 900 m (dotted line). Kordovsky GOK aims to accomplish this with no significant expansion of the pit rim.



A typical drilling pattern for drilling and blasting the Zhelezny benches.

**The Kovdor property also includes deposits of apatite-shtaffelite (AShR) and apatite-calcite ores. During the period 2000 – 2006 engineers developed an AShR open pit mining plan with 12 m high benches. The apatite-calcite part of the deposit below the AShR is regarded as a long-term strategic phosphate reserve.*

was extended by draining part of Lake Kovdoro and diverting the High Kovdora River to access all of the primary orebody. The pit has since been progressively deepened, with necessary changes to the material transportation systems and equipment fleet. Particularly interesting are the Cyclical Line Technology (CPT) in-pit crushing and conveyor systems used to haul ore and waste.

Privatization in the early 1990s – as Kovdorsky Gorno-obogatitelnyi Kombinat (Kovdorsky Mining and Processing Combine, Kovdorsky GOK) – was followed by a difficult period. But in 1998 management started exploiting baddeleyite-apatite-containing waste from magnetite-only processing stored in sedimentation ponds*. This enabled Kovdorsky GOK to compensate reductions in mine apatite and baddeleyite output made in response to low iron ore demand until 2005.

In 2001 EuroChem Mining and Chemical Company JSC (EuroChem), reputedly Russia's largest integrated fertilizer producer, acquired the Kovdor facilities. A report for Kovdor's 40th anniversary in 2002 commented that 1997-2001 had been a period of stabilization for the operation and for Kovdor city.

During 2003 the Kovdorsky team introduced (and later modified) a Strategic Development Programme suited to EuroChem's phosphate feedstock requirements that covered the period until 2015. Commenting on progress in the period 2003 – 2006, senior personnel[1] pointed out that the mine succeeded in restoring ore production to the desired long-term 16 Mt/y target. The planned apatite concentrate recovery from open pit ore in 2010 would be about twice the amount achieved in 2001.

Super-deep mine planning

The mining licence for Kovdor allows mineral extraction from the primary orebody to a depth of two kilometer and a major mine redesign to exploit the lower levels started early this century.

The start of super-deep mining was preceded by several years of advanced and extensive studies using some of the most sophisticated methods of testing, calculation and data processing in the industry. In view of general trends and advances in rock mechanics Kovdorsky GOK decided to continue development of the Zhelezny pit to lower levels rather than switch to underground mining. To avoid widening the surface pit rim and creating large volumes of waste rock the project team focused on super-deep mining of benches with vertical or near vertical highwalls.

Initial geomechanical studies enabled expert organizations to produce parameters for the engineering geologists and a 3D geological-structural map of the Kovdor deposit for use in forecasting potential slope failures. Five engineering-geological sectors of the pit were defined and for each one the bench slope angles, bench heights and widths of safety berms were calculated.

This information was used to develop specifications for super-deep excavation using methods such as presplit drilling and blasting. These specifications are used in conjunction with techniques for the relief of water pressure in the benches; stabilization of weak rock masses by, for instance, rock bolting and cement mortar injection; and thorough slope stability monitoring for which Kovdorsky is using three methods: visual observation, surveying with electronic and optical instruments

including laser scanning, and seismic monitoring in high risk areas.

Once the deep mining concept was approved by EuroChem, the Giproruda institute started work on the mine redevelopment plan in 2004 and two years later completed the project – "Reconstruction of the open cut for restoration of the project capacity of Kovdorsky GOK by means of the use of steeper constant open-pit benching and in-crease of the open pit depth and duration of open-pit mining". Two pit design versions were used for techno-economic evaluation. Stage One of forward development will hold open pit output at 15-16 Mt/y of baddeleyite-apatite-magnetite ore and 7 Mt/y of low-iron apatite ore until 2032, thereafter production will decrease gradually until closure.

Drill and blast design

Blasting at Zhelezny was thoroughly modernized from the late 1990s to 2005. The mine introduced non-electric initiation with Nonel and Primadet systems and from 2000 progressively switched to EVV emulsion explosives – VET emulites. Consequently, in 2006 as compared with 2001 (figures in brackets), 99.1% of blasting was with EVV, using 21,500 t (9,400 t) of explosive, and yielded 15.25 Mm^3 (7.5 Mm^3) of blasted rock; 200t (2,400t) of conventional explosives blasted 0.23 Mm^3 (2.59 Mm^3) of rock. VET explosive is mixed by the Russian company Eastern Mining Services Ltd, a subsidiary of Maxam, delivered to the holes and charged using SZM mixing-charging machines. The new technology significantly reduced the number of misfires.

The super-deep mining system required further improvements to blasting practice. Firstly, it was essential to reduce fragment size as even sizeable increases in the amount of explosive used in the 250 mm production blast holes did not fragment the rock to dimensions sufficiently small to improve performance of the CPT systems, truck haulage, or comminution. Secondly, the drill-blast system used in the zones near the pit rim must maintain the stability of the benches and steep highwalls and not disturb the rock mass outside the mine walls. Thirdly, because the proportion of wet blast holes is expected to increase, waterproof explosives would be required.

Contractor Technobur has four Atlas Copco Drilling Solutions DML rigs working for Kovdorsky GOK. Three are low pressure (LP) rigs for rotary drilling, and one is a high pressure (HP) rig for DTH drilling or rotary drilling.

Blastability studies led to the definition of five categories and for each one the burden, hole distance and height of explosive charge are calculated in relation to hole diameters, bench height, grade of emulsion charge and row position in the blasting sequence (see illustration page 110). Typically, the inner blocks of the bench are drilled with smaller diameter bits, transitional blocks are drilled with the smaller holes on the inner part but with larger holes further away, and outer production blocks are entirely drilled with the larger diameter holes. Using emulsion explosives reduces impact on the environment, especially the urban area close to the mine as they emit less gas and dust pollutants and the vibration effects are easier to control. For routine planning mine surveyors and drill-blast engineers use the GIS GEOMIX information system developed by Kovdorsky and the VIOGEM FSUE organization and introduced in 2004. They report that this has improved blast preparation and stabilized the quality of ore feed to the process plant. System development continues.

Upgrading the drilling fleet

For more than 30 years Zhelezny relied on Russian-built electric powered rotary drilling rigs to drill 250 mm and 270 mm diameter holes. But, as Mikhail Togunov pointed out, a fleet able to drill a wider range of hole diameters with optimum efficiency would be crucial for super-deep mining.

Accordingly, in 2004 Kovdorsky GOK acquired one imported rig for

A major player in Kovdovsky's Super Deep Mining programme: Atlas Copco' s DM45 HP (high pressure) rig on the pit's upper, 12 m high benches.

drilling 171.4 mm diameter holes. Two Atlas Copco ROC L8 down hole drilling (DTH) rigs were added in 2005 in order to drill 140 mm pre-split holes and also 165 mm buffer hole rows close to the margin of the benches. The new rigs demonstrated the advantages of using smaller holes that match the physico-mechanical properties of the rock.

These results and the bench configurations required for super-deep mining persuaded Kovdorsky GOK to use diesel-powered as well as electric drilling. The diesel rigs could drill the required smaller hole sizes and also work efficiently where long tramming distances are a disadvantage for rigs with power cables. Nevertheless, the old electric rigs achieve high performance indices and Rig Numbers 15 and 16 have respectively completed 500 and 600 drill km since they went into operation. So Kovdorsky GOK has retained five SBSh electric rotary rigs plus the two ROC L8 and one other DTH machines. Management also looked for an external drilling partner.

These efforts led to the deployment, starting in 2007, of a second drilling fleet comprising Atlas Copco large blasthole rigs operated by a Russian contractor, Technobur. This company, based in Moscow, was formed in October 2004 by an experienced team specifically to carry out mine drilling. Prior to the contract at Zhelezny, Technobur had started work at Olcon's Olenogorsk iron ore mine north of Kovdor and has a Pit Viper 275 there. The company also tested a DM 45 against SBSh rigs at Olenogorsk, finding the diesel machine was 30% faster. Presently Technobur operates an Atlas Copco fleet at Kovdor comprising three DML LP rigs (1600 and 1200), one Pit Viper 275 LP, one DML HP 1250 and two DM 45 HP machines. This fleet usually does more than 70% of the meters drilled at the mine, over 40,000 m of a total of 55,000 m in a month being typical.

All the rigs are set up for multi-pass drilling. To a depth of 70 m above sea level benches are 12m high but below this level they are generally 15 m high with 3 m sub-drill. Production holes are normally 14-20 m in depth. Presently the slope angles range 35-40° from vertical but the long term aim is to make them as near vertical as possible. The rotary rigs use Russian tricone bits while the down hole production drilling is done with Atlas Copco Secoroc COP64 hammers and 165 or 200 mm bits. The DML and DM 45 high pressure rigs can be used either for down hole drilling or for rotary, in which case the pressure and engine power are reduced. They are fitted with inclination angle indicators for use when tramming. Technobur services the rigs with help from Atlas Copco, explained the company's site manager Evgeny Perevozchikov.

The project has been progressing according to plan and Kovdorsky GOK expects to reach its first stage targets in 2011.

Reference

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Acknowledgements

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