Deep mining for tomorrow's minerals

As the numbers of orebodies that can be mined using conventional methods are becoming increasingly scarce, the mining industry is preparing for an inhospitable environment. Seismicity and heat are two of the challenges as miners venture deeper toward the centre of the Earth.

When miners approach the limit of an orebody at the lowest level of excavation, they are usually confronted with two options. They can either abandon the site or look for mineralized areas elsewhere, which is the traditional approach, or they can venture deeper into the Earth's core.

In countries with rich mineral reserves, such as South Africa, it is true that some mines can sustain running operations for up to a hundred years. This, however, is a rare occurrence and most companies today are working hard to secure an operational lifespan of 15–20 years at various mining sites.

Although our planet's mineral resources remain vast, fewer orebodies that lie relatively near the surface are being discovered, and the number of conventional mines established each year are diminishing. This has led to deeper workings at existing mines as an increasingly popular alternative.

So, what qualifies as deep mining? The answer is any operation that extends down beyond 1,000 m via shafts and openings. This limit is generally considered the breaking point for geological and tectonic stresses where manpower and equipment are more likely to be put at risk.

The basic principle is that the deeper you go the more extreme the environment becomes, with increased heat, pressure, and rock instability. The deepest mine in the world today, the TauTona Mine in South Africa, extends to nearly 4 000 m, having employed a number of special techniques.

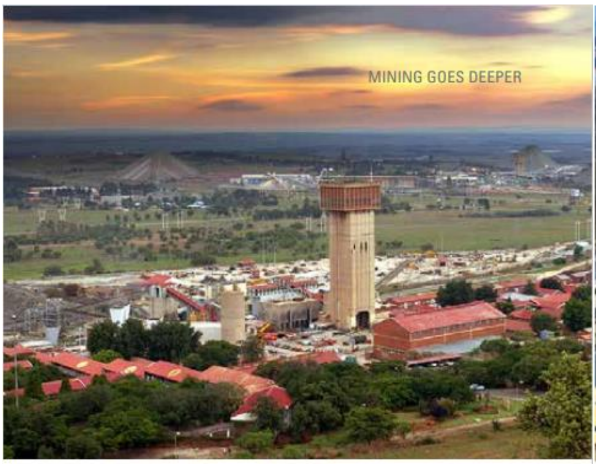
Typical challenges of deep mining operations include:

- Higher ambient temperatures
- Seismicity and potential wall convergence
- Increased risk of rock burst

As the preconditions change drastically in deep drifts, safe and productive mining is not an easy task. But with new technology and advanced mining methods, these obstacles can be overcome in the quest to secure long-term production.

Savings on infrastructure

While it is primarily the scarcity of viable orebodies at accessible levels that is driving the mining industry deeper underground, there are also cost saving benefits associated with this developing practice. To make the shift to a deep mining operation requires its fair share of investment, but it is often significantly lower than what is required to develop new infrastructures at new sites. Nevertheless, the added complexity involved should not be underestimated. While efforts to stabilize the rock may be successful, rock bursts at deep levels are unpredictable and potentially life threatening.



The surface installations at TauTona, South Africa, the world's deepest mine with operations at nearly 4 000 m below ground.

The tailings management division at KGHM's Rudna Mine in Poland.

A list of basic criteria must include advanced extra measures including:

- Specially modified equipment
- High-capacity ventilation and cooling systems
- Increased ground support
- Monitoring of rock stability
- Monitoring of mining induced seismicity
- Monitoring of air quality
- Emergency planning

To ensure safe and sustained production in a highly constrained and sensitive environment, equipment used at extreme depths must be modified in various ways. Drill rigs should be equipped with reinforced cabins, advanced communication, and monitoring systems, as well as high-capacity cooling systems.

Articulated design, especially when it comes to truck haulage, may also play a key role in helping operators to navigate through narrow drifts and tunnels without damaging walls, which could jeopardize the mine's stability as well as the safety of personnel and equipment. There will also be an increased demand for maximum automation of mining processes.

Rudna's deep-seated and narrow vein orebodies require specially adapted equipment to keep dilution low and ore recovery high.

Seismicity and rock bursts

It is not uncommon for mining operations to affect the natural stress fields of rock mass. But the impact is far greater at 1000 m and beyond where seismic activity is more frequent and more severe.

For all deep mining operations, a comprehensive ground support system is essential to avoid injuries, damages to equipment and loss of infrastructure. But knowing where and how to implement ground control in an optimum way requires advanced technology and considerable expertise. When stress gets accumulated in sections of rock mass, extremely hazardous rock bursts can occur. Rock bursts are not only difficult to predict but can easily be triggered at the mining area where face bursts are frequent dangers.

Low profile drifts are expected to become more common as existing mines increase their operational depths.

Using advanced monitoring and seismic systems, coupled with previous experience of seismic activity, engineers are able to predict where rock bursts are most likely to occur. A more difficult task, however, is to answer the question of when, and this requires a careful study of the frequency, location, and magnitude of rock bursts. Based on this activity, seismic engineers can decide when it is time to close an area until the activity decreases again.

The technique is based on measuring the velocity of seismic waves travelling through the rock mass which are picked up by geophones distributed throughout the mine. These waves will determine all forms of seismic events, big or small, that can be expected. The location of seismic events can be calculated by combining the signals from several geophones. All results, however, should be crosschecked and compared with findings in the study of rock burst events in the area.

Exploration in 3D

More and more studies of deep deposits are conducted today using 3D scanning technology that enables detailed mapping of rock structure. It is a method that is expected to grow rapidly in the years to come. By taking full advantage of 3D geological modelling, mining companies will be able to improve their predictions for safe operation and obtain knowledge about surrounding areas in order to determine a viable path for development. Most systems and software offered today combine 3D subsurface visualization with a wide range of possibilities for rock data storage.

Heat and ventilation in deep mining operations, temperatures will typically increase by 10–20°C every kilometre and some deep mines experience ambient temperatures as high as 50°C. This means that creating a deep mine atmosphere that can sustain workers and equipment is a complex task for ventilation engineers. Similar to ground support efforts, ventilation and cooling represent a significant investment that must be given top priority. The task of removing noxious fumes, diesel emissions, blasting dust and methane gases that emerge from excavated rock is crucial for all mines, but the requirements are far more rigorous at greater depths.

Normally, the first step is to set up a health and safety scheme using computer aided design (CAD systems). Once the required levels of air flow and cooling are defined through computer simulation, engineers can propose a system to match the mine’s ventilation demands.

For deep level mines it is highly recommended that a modern, on-demand ventilation system is employed, which enables the air flow to be fully adapted to the areas in use. It is significantly more economical in the long run, as tremendous amounts of energy are saved when ventilation is reduced to a minimum in non-operational areas.

It is also recommended to install modern heat sensors on pillars or walls at strategic locations in the mine. These can communicate wirelessly and measure any temperature changes that may jeopardize the well-being of mine personnel and machinery. Once a ventilation system is in place, working in unison with a required setup of air-cooling units (ACU), it is important for engineers to regularly inspect the fans and air ducts, ventilation seals and gas drainage systems, as well as measure the overall quality of air circulation.

Deep mining workforce

Increased air flow and cooling are fundamental components of any health and safety plan, but the potential risk of exposure to heat stress means that deep mining is not suited for regular personnel.

As harsh conditions are to be expected, each person involved must be evaluated thoroughly against to safety parameters such as age, health condition and stress tolerance. Special training is also a prerequisite and should include everything from safe operation of modified equipment to communications routines and contingency plans.

The deep workings we see today are just the beginning of a new phase in the mining industry in which increased monitoring in all its forms will be essential. Recruiting young and dedicated personnel with high technological skills is a key element in order to achieve a successful transition and meet the demand for base metals in a safe and productive way.