The Top 10 trends and Innovations in Underground Mining

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INTRODUCTION

The case for innovation in the mining industry has never been more compelling. The world of mining is still going through difficult times.

To turn the page on these difficult times, mining companies will need to realize important transformations in their business system: rapid and accurate characterization of ore bodies, faster development of mines and speed of extraction, improved recovery rates and mine planning as well as increased use of automation. This eBook will inform about some of the latest developments in the underground mining world.

YOU WILL LEARN:

• The top trends in the underground mining industry, such as the need to cut costs and the necessity to achieve speed to market and get things right the first time.
• Expandable rock bolts, the computerization of the design of roof support technologies and IPKON’s silicate capsules as the top innovations.

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1. The leading 4 trends in the underground mining industry
2. Six leading innovations in the underground mining industry

From its experience in the mining industry The Institute for the study of complex mineral development IPKON has identified 10 leading trends and innovations in the mining industry.

More particularly, we have identified the following 4 leading trends:

1.  Mining productivity has hit new lows;
2.  In these difficult economic times for the mining industry, there is a greater need to increase the efficiency of mining operations and to cut costs;
3.  Mines are getting deeper; what are the implications?
4.  Increased automation of drilling and installation of rock bolts and capsules;
We have also identified the following 6 innovations:

1. Expandable rock bolts;
2. Tensionable cable bolts;
3. Automated drill rigs;
4. RFID tags used to track ore grade for mill optimization;
5. Mining simulators;
6. IPKON’s silicate capsules.

4 LEADING TRENDS

TREND # 1 MINING PRODUCTIVITY HAS HIT NEW LOWS

According to a recent report by Deloitte\(^1\), in 2013 we hit new lows in terms of mines productivity.

These two graphics illustrate well the loss of productivity in the mining sector from 2007 to 2012.

On the left you have a graphic that shows the cost to build one ton of iron ore in US Dollars. In Green in Australia the cost went from 100$US dollars in 2007 to 195$US in 2012. In blue, you have the cost to build one ton of iron ore in the rest of the world". It went from 96$ in 2007 to 150$ in 2012.

On the right you have a graphic that shows the cost to build one ton of thermal coal. In green, you can see that in Australia the cost went from 61 US$ in 2007 to 176 US$ in 2012. In blue, in the rest of the world, the cost went from 73US$ in 2007 to 106US$ in 2012.

Despite commodity price weakness, input and production costs – everything from labour and energy to equipment and supplies – remain stubbornly high—despite the fact that metallurgical coal prices dropped from $330 per tonne in 2011 to $150 per tonne in September 2013, while thermal coal commodity prices fell to under $80 per tonne for the first time since October 2009.²

Uncovering hidden costs

Mining lower-grade deposits also gives rise to a host of hidden costs. Between 2001 and 2012, the weighted average head grade for copper fell by almost 30%.³ Nickel, zinc and gold grades also plummeted. Some gold projects yield less than one gram per tonne.⁴ With 75% of new base metal discoveries hidden at depths in excess of 300 metres, this practice is pushing up strip ratios – reducing the economic sustainability of mining lower grades. As mining companies work to rectify their cost imbalances, many will need to refocus on return on capital employed (ROCE) by making a business case for producing fewer ounces or tonnes at higher grades.

In these circumstances, even a small change that can increase productivity incrementally can make a positive difference and should be adopted. IPKON’s silicate capsules can constitute such a change.

TREND # 2 THE NEED FOR GREATER EFFICIENCY⁵

In an increasingly volatile global market, what can mining companies do to improve operations, become cost efficient and agile, and maximize value across their business?

As the uncertainty in the global economy continues to impact the demand for metals and mining products and their prices, mining companies are under pressure to achieve speed to market and get things right the first time. For companies trying to improve business performance in an ever-volatile environment, the challenge lies in rethinking and addressing a range of issues across the business with an eye toward maximizing value.

For mining companies, waiting and watching while markets become less volatile is no longer an option.

² Mining. Com, September 15, 2013, Frik Els, “Mongolia opens new door to world’s richest coking coal fields”.
³ Mining.com, July 23, 2013, Ana Komnenic, “Copper costs up, grades down: Metals Economics Group”.
⁴ The Globe and Mail, August 12, 2013, Tim Kiladze, “Gold producers squeezed by rising costs and sliding prices”.
Instead, mining companies can improve their ability to respond to market conditions and increase value in an ever-volatile environment by considering two actions to take: focus on core operations and optimize core operations. Those that take positive steps now to be cost efficient and agile stand to create a foundation for sustained high performance.

To maximize value in a volatile environment, mining companies must:

**Focus on core operations:** To realize value in weak markets, companies need to evaluate and determine core activities and functions and outsource non-core ones to a business partner, increasing its ability to focus on core competencies, speed up time to market and reduce costs.

**Optimize core operations:** Miners can pull various levers—such as mature analytical planning and management technology solutions, centralizing data-primary activities through the control room, using fly in, fly out options to maximize labor efficiencies, and so on—to optimize core operations and create greater value. IPKON’s silicate capsules can help in this regard by increasing the productivity of a mine and allowing to cut costs.

### TREND # 3 MINES ARE GETTING DEEPER; WHAT ARE THE IMPLICATIONS?

The deeper the mine, the higher the stress level exerted on the surrounding rock, and the need for reinforcement increases significantly.

As mines get deeper, there are challenges associated with providing sufficient load-transfer capability in primary and secondary roof-support systems. Having bolting products that can cope with increased stress loading, squeezing and dynamic loading capability is becoming increasingly important.

The Geothermal gradient is the rate of increasing temperature with respect to increasing depth in the Earth's interior. Away from tectonic plate boundaries, on average, it is about 25°C per km of depth.

In some places in South Africa it is as low as 9 degrees per km of depth. That may partly explain why South Africa has the deepest mines in the world.

As mines get deeper, the temperature of the face rises a great deal. IPKON’s silicate capsules have a great advantage over resin capsules in this regard. They can be used at temperatures up to 50° C. Resin capsules auto-ignite at 31°C.

For example, The TauTona Mine or Western Deep No.3
Shaft is a gold mine in South Africa. At 3.9 kilometers (2.4 mi) deep it is currently home to the world's deepest mining operations. The mine today has some 800 km (500 mi) of tunnels and employs some 5,600 miners. The mine is so deep that temperatures in the mine can rise to life-threatening levels. Air conditioning equipment is used to cool the mine from 55 °C (131 °F) down to a more tolerable 28 °C.

Nowhere else do mines go so deep as in South Africa, and lessons learned there from attempts to extend the life spans of mines will be applicable globally, not just for gold but for extracting other minerals underground. The Mponeng mine in South Africa, owned by Anglo Gold has plans to dig to 16 500 feet (5 km).

The trend toward deeper mines increases the trend toward automation and mechanization. For example, Anglo Gold has given assurances that all mining below 13,200 feet (4km) will be fully mechanized, with few mineworkers involved, in order to minimize the danger and that no jobs will be affected by this.

**TREND #4 GREATER AUTOMATION**

Artificial ground support has developed into a refined science over the past 20 years. From reactive support systems such as timber props and steel supports, to active systems such as roof bolts and cable anchors, ground support technology has now developed efficient systems that work well in many instances.

Steve Mackaway, marketing manager for DSI's Asia-Pacific division, explains: “Australian mining in particular is such a safety-conscious industry; change only takes place in incremental steps. We are seeing a move to more remote-operated mining equipment with fewer people present at the face. This means that manual handling,
respiratory hazards, crush hazards, eye and hearing protection remain key priorities in new product development.\(^6\)

Meanwhile, the high cost of labour in some markets and the drive to improve safety by reducing the number of personnel exposed to risk is fuelling innovations in bolting automation.

Ground-support systems can be installed mechanically or manually, and varying degrees of automation are available with certain machines:

- mechanized bolting involves operator supervision at every stage. The operator performs the bolt installation using mechanic/hydraulic means controlled with levers and joysticks. Bolting rigs can be fully or semi-mechanized, where part of the bolting sequence, or the full sequence, is performed using the rig;
- automated bolting is fully mechanized and does not require operator supervision. Many manufacturers offer rigs that can be partially or fully automated. Fully automated rigs would be pre-programmed to drill holes and install bolts in accordance with a digital mine plan;
- manual installation (where the operator uses a hand-held drill and installs the bolts with a wrench or dolly) is still the most common technique in underground hard-rock mines, mainly because it is more productive than using mechanized rock bolters. However, the use of semi- and full mechanization for bolting is increasing rapidly as mines strive to improve safety records. Manual bolting is both labor-intensive and hazardous due to the risk of falling objects, and the benefits of enclosing the operator in a cabin or enabling bolting from a remote location are significant.

Rock bolting attachments, special bolting rigs and semi-automated units for the installation of conventional rock reinforcement systems, such as friction stabilizers or cable bolts, have been successfully introduced to the market in the past decades. However the increasing demand for fast and safe one-step rock bolting procedures resulted in significant changes in the design of bolting automation units. The main issues are the integrated view on the rock bolt itself, the installation mode and the required machinery. A rock bolt automation unit for self-drilling rock reinforcement systems must feature a reliable and easy-to-handle interconnection with the associated supporting machinery as well as a tough and lightweight design. In addition the integration of the automated handling into the drilling procedure requires measures on synchronization and optimization of corresponding working procedures.

We have also identified 6 leading innovations.

**INNOVATION #1 EXPANDABLE ROCK BOLTS**

Sandvik® supplies the RX300 ERB (expandable rock bolt) series of friction bolts, which come in different sizes and lengths to suit underground, hard-rock mines or civil tunnelling applications.  

The bolt is folded into a U shape to be installed in holes slightly wider than its diameter. Once inserted into the hole, the bolt is inflated with high-pressure water, causing it to expand and fill the hole perfectly. The contact between the bolt body and the rock creates the friction required to prevent rock movement and deformation. The ERB is made of high-quality, hollow, steel pipe and is sealed at both ends by special fittings. A valve at one end allows the pressurised water to be pumped in for inflation.

The bolts can be installed with face plates of various dimensions, allowing them to be combined with mesh where necessary. Special coatings make them highly resistant to corrosion, and they are quick and easy to install in all rock types.

The ERBs' limitations are their smaller resistance to rock shearing compared to plain rebar bolts and a shorter lifespan compared to fully-encapsulated rock bolts.

The most well-known expandable rock bolt is the Swellex model, produced by Atlas Copco. It is Available in three versions, Swellex Premium line, Swellex Manganese line and Swellex Spartan line.  

Here is a summary of Swellex features:

- It provides immediate full-column rock reinforcement.
- It is offered in a variety of dimensions and steel types for stiffness or resilience.
- It reaches full load-bearing before large rock movements occur.
- It can accommodate a wide variety of rock mass types and conditions.
- It has a high tolerance to variations in drill hole diameter.
- It adapts to hole irregularities and grips along their entire length.
- The bolt is insensitive to blast vibrations.
- Its standard length is up to 6 meters.
- It is simple to install for all bolt lengths/types.
- The Swellex can easily be installed using manual, semi or fully mechanised equipment.

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• The Swellex is available for special applications; such as a connectable version for deep anchoring or in confined areas.

And a hanger version also exists for supporting equipment.

JENMAR produces the PYTHON expandable rock bolt

PYTHON® expandable rock bolts offer superior quality that responds to the most demanding roof support applications. PYTHON’s high load capacity along with excellent elongation properties ensure safer working conditions and faster excavation cycles, effectively reducing costs and increasing production.

1. When inserted into drill hole, the PYTHON bolt has an Original shape. Water is pumped into the bolt, expanding the PYTHON.
2. The bolt is then pressed against the rock, which provides high load friction capacity. The water pressure is then removed.

DSI makes the Omega bolt. The DSI OMEGA-BOLT® is an expandable rock bolt with excellent elongation properties designed to accommodate ground movement. The OMEGA-BOLT® is a folded steel tube with a welded ferrule on each end. The OMEGA-BOLT® is safe and easy to install. The OMEGA-BOLT® is inserted into the drilled hole and inflated using high pressure water. The OMEGA-BOLT® is inflated to the exact shape of the drilled hole and can tolerate a large variation in hole diameter.

Dywidag Systems International Omega® Bolt
INNOVATION #2 TENSIONABLE CABLE BOLTS

Minova’s patented Tensionable Cable Bolt (TCB) System offers an advanced support with all the installation versatility of the traditional cable bolts while providing the ability to tension the cable during the normal roof bolting cycle. The TCB System provides compression into the roof and ensures “top-to-bottom” tension of the cable, which places the anchorage higher in the roof structure to eliminate “anchorage shock” during loading.

The TCB System can be used for primary support and as secondary support in applications where traditional cable bolts are used and enhanced beam building is needed. Common application areas include: tail gates, bleeder, recovery room, set-up room, head gates, intersections and other mine areas where longevity and additional support is required.

Minova Tensionable cable bolt main advantages:

It uses existing bolting equipment.

It provides enhanced beam building with tension up to 15,000 lbs (7 tonnes).

Innovation #3 AUTOMATED DRILL RIGS

Sandvik underground drill rigs come in five product families: mining jumbos, production drill rigs, rock support drill rigs, secondary breaking drill rigs, and tunneling jumbos. Each is specifically designed to suit the particular application in question. Equipped with high-performance hydraulic rock drills, ergonomic controls, and various levels of automatic drilling systems, they are highly productive, extremely reliable, and economical to use. In addition, Sandvik underground drill rigs are characterised by ease of operation and maintenance.


Sandvik rock support drill rigs are designed to install rock bolts of various types in a safe and efficient way after blasting. Available in high-capacity standard models as well as low profile (LP) and extra low-profile (XLP) models for use in low reefs and seams, they both drill the holes and install the bolts in rapid sequence. Equipped with a telescopic boom, an efficient hydraulic rock drill and a universal bolting head, they have advanced ergonomic controls with many automatic functions and built-in safeguards to ensure maximum safety.

The award-winning Autorock drill range offered by Minova\textsuperscript{13} has been designed for the safe and effective drilling and installation of rock bolts. The portable rigs can be operated by one man and can be safely operated from up to 5 m away. Today more than 3,000 units are operated in South Africa.

\footnotesize{\textsuperscript{13} Minova Autorock drill, http://www.minovainternational.com/minova-south-africa-offers-autorock-drill-rig-for-safer-drilling.7081.html}

These semi-mechanised support drill rigs have been designed for the safe and effective drilling and installation of rock bolts while, at the same time, offering built-in temporary support jacks and remote drilling.

The Autorock uses a standard pneumatic mining rock drill which is housed between two telescopic legs which form the clamping frame and the third cylinder thrusts the drill. Other rock drill options include either electric or hydro-powered units.
The rigs are portable - the smallest weighs only 45kg - and can be operated by one man. The operator can control the rig from up to 5m away from the safety of permanent support, thus reducing the potential for "fall-of-ground" accidents, which are responsible for the majority of the fatalities and injuries in mines. The operator is exposed to reduced noise owing to the remote operation and is also not exposed to the severe hand vibrations experienced with hand-held jack hammers.

Built-in clamping rods secure the Autorock between hanging and footwall of the stope during drilling, which enhances drilling accuracy. When making use of resin bolts for support, the Autorock rig can also be used to spin the resin bolts home, which provides an active support system within minutes of the installation. Support holes can be drilled between 70 degrees and 90 degrees in stoping widths varying from as low as 800mm with the smaller rigs up to 4,5m with the larger units.

INNOVATION #4 RFID TAGS USED TO TRACK ORE GRADE FOR MILL OPTIMIZATION

An innovative material tracking system being piloted at Vale Inco's Frood-Stobie Complex in Sudbury could keep millions of dollars worth of nickel and other metals from being disposed of in tailings. Once fully implemented, the tracking system will provide technicians at the company's Strathcona Mill with ore grade information for material in transit, allowing them to schedule deliveries, blend material from different sources, optimize the mill process and increase recoveries.

The tracking system employs RFID (Radio Frequency Identification) technology and software from Montreal-based Ship2Save Inc. to track ore from the muckpile underground to rail car loading facilities on surface. Ore tracking will "optimize the milling process because the mill runs different strengths of reagents and adjusts the holding times in the tanks, depending on the grade."

Picture of Mine Site Technologies RFID Tags

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The process begins at the face, where a geologist tosses three or four specially designed ultra high frequency, passive RFID tags into a muck pile. The geologist associates each tag with the ore grade and location, enters the data into a handheld computer and uploads it on surface to a central database. The tags are scooped up along with the muck, dumped into an ore pass and introduced into a crusher before being shipped to surface. Though built to take abuse, some of the tags get chewed up along the way. That’s why they throw in more than one per muck pile.

Designing the RFID tags to pass through a crusher and survive the punishing underground environment was the biggest challenge faced by Ship2Save in adapting its technology for the mining industry. The tags are 3 x 5 inches (7.5 X 12.5 cm) in size, flat and enclosed in a durable plastic casing.

Data captured from RFID readers on conveyor belts at loading facilities could then be correlated with tags on the railcars to provide mill operators with precise information on ore grades for every car.

The system can also be used to provide more precise tracking of ore volumes shipped to the mill.

Frood-Stobie loads between 12,000 to 16,000 railcars per month and every single one is recorded by hand, so it’s a tedious job, and some are missed, he explained. With RFID tagging, the railcars would be tracked automatically.

While the tracking system does a bit of policing, the main goal is ore blending and mill optimization.

**INNOVATION #5 MINING SIMULATORS**

The main idea behind mining simulators is to reproduce a mining environment as closely as possible for training purposes. The 2 main mining simulator producers are CAE, a Canadian company based in Montreal and Thoroughtec Technologies, creator of the Cybermine Simulator.

**The CAE Terra Mining Simulator**

CAE has been perfecting the science of simulation for close to 65 years. Leveraging the experience of developing more than 1,300 simulators for land vehicles and aircraft, CAE Terra simulators provide the highest fidelity experience available to the mining industry. What does this mean? In practice the training environment is highly realistic, closely resembling site conditions and operating responses including rock and soil dynamics for digging and drilling equipment. Sophisticated millisecond response integrating operator inputs, high definition graphics and machine movement mean the incidence of motion sickness is vastly reduced, allowing complex

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training tasks to be conducted and facilitating greater utilization of the simulator.

**The CYBERMINE Mining simulator**

At the heart of each CYBERMINE mining simulator is a simulated cab, a highly realistic replica of the actual mining equipment, with fully functional simulated instruments and controls. The replicated cab is mounted on a motion platform capable of imparting up to six degrees of freedom and is surrounded by a 270° or full 360° panoramic, high-resolution projection display system with surround sound audio. Control of all aspects of training and evaluation is exercised in real time from a feature rich instructor station and displayed on two High Definition widescreen displays. The entire mining simulator system is housed in a well-appointed, self-contained ISO standard container, which also facilitates ease of transport. CYBERMINE mining simulators offer a controlled environment which is highly conducive to the professional training, re-training and evaluation of student operators.

Each CYBERMINE mining simulator provides training and facilitates objective evaluation in the following areas:

- Training and evaluating novices in the proficient operation of heavy equipment
- Providing a new-recruit screening system.
- Providing effective refresher training for experienced operators.
- Instilling the theory and practical aspects of economical mining.
- Providing training in emergency situations not possible on the real mining equipment.
- Entrenching safety procedures.

Operators are logged onto the CYBERMINE mining simulator using a unique password. As the operator controls the heavy equipment, all aspects of operation are electronically monitored and digitally presented, including adherence to operating and safety procedures and student’s economic performance. Exercise results are stored in a comprehensive database for viewing and printing by the instructor. The entire mine operator training exercise is recorded for after-action-review.

CYBERMINE mining simulators immerse the operator in a highly realistic operating environment within a 3D virtual training world. Instruments and controls are either sourced from original equipment manufacturers or accurately replicated to function as they do in the real mining equipment. The operation of sub-systems such as engines, braking systems, hydraulics and drilling heads is mathematically modelled to original manufacturer specifications.

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specifications so as to provide accurate, realistic feedback to the student. Other simulated equipment and vehicles interoperate with the student to test and enhance his skill levels. Accurate 3D surround sound reproduction and composite visual effects such as reflections, dust, rain and shadows complete the picture to ensure a high fidelity training experience.

**INNOVATION # 6  IPKON'S SILICATE CAPSULES**

The last but not least innovation we will speak about is IPKON’s silicate capsules.

We will speak briefly about cement capsules and resin capsules because IPKON’s silicate capsules advantages are best shown in comparison to these competing products.

**CAPSULES**

As you probably know, Capsules are installed at the bottom of a borehole and allow to permanently fix a rock bolt in a borehole. Three types of capsules are currently available depending on their content: 1. Cement capsules; 2. Resin capsules; and 3. Silicate capsules.

IPKON perceived the following limitations in the existing capsules[^17].

### Comparison of roof support technologies

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<td>Allowable ambient temperature range, °C</td>
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CEMENT CAPSULES

Cement capsules have a short shell-life of 6 months because the shell of the capsules is made with a water permeable material. During their storage the capsule is affected by any humidity in the ambient air. They need to be soaked in water before being installed. Once installed in the borehole, they take 3 to 5 minutes to stiffen. They allow for a difference in diameter between the rock bolt and the borehole of about 4 to 8 mm.

RESIN CAPSULES

Resin capsules are notably composed of styrene, a highly toxic material. According to the US Environmental Protection Agency, if inhaled, styrene vapors can cause damage to the gastrointestinal tract, to the kidneys, and to the respiratory system. The U.S. National Toxicology Program has described styrene as reasonably anticipated to be a human carcinogen.

Unless a mine has a very good ventilation system, after installation of resin capsules, a mine usually has to be evacuated of all its workers for 2 to 3 hours to allow for a proper ventilation and an evacuation of the toxic vapors emanating from the said resin capsules. This can have a significant impact on the productivity of a mine.

Resin capsules have a short shelf-life of 6 months, because after this period of storage the resin contained in the capsules hardens. They should be stored at temperatures below 20 C and can only be used at temperatures between 10 and 25 C. At temperatures lower than 10 C, the resin gets hard and does not react properly with the fixing agent. At temperatures above 25 C it loses its chemical characteristics and its bearing capacity. These are not re-established even if they are stored at lower temperatures later. They constitute a fire hazard and can auto ignite at temperatures above 31 C.

Resin allow for a difference in diameter between the rock bolt and the borehole of 4 to 6 mm. Each resin capsule is in fact composed of 2 capsules one inside the other. The inside capsule contains the fixing agent. The diameter of this inside capsule is 4-5 mm. With resin capsules there is a high risk that the inside capsule will not break when the rock bolt is installed in the borehole.

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18 EPA settles case against Phoenix company for toxic chemical reporting violations. EPA Website, http://yosemite.epa.gov/opa/admpress.nsf/6427a6b7538955c585257359003f0230/09b1cf3cd58139228852570d005e16031OpenDocument
IPKON'S SILICATE CAPSULES

IPKON invented a new fixing agent for silicate capsules in order to create a product that presented the advantages of cement capsules and resin capsules without their drawbacks. IPKON holds a patent for its new fixing agent and silicate capsules in Kazakhstan and Russia. A patent is pending in virtue of the Patent Cooperation Treaty. Its silicate capsules are entirely composed of inorganic, non-toxic, non-flammable materials.

Being non-toxic, the installation of silicate capsules does not require the evacuation of a mine to avoid intoxication by styrene vapors. The stiffening time of the mixture of the silicate capsules is only 1 minute. The shelf-life of the capsules is 3 years. They can be stored at any temperature below 50 C. They allow for a difference in diameter between the rock bolt and the borehole of up to 12mm, permitting savings on the rock bolts of up to 30%.

With IPKON's silicate capsules, the fixing agent is inside another capsule of a diameter of 17 mm (In comparison, in resin capsules, the inside capsule has a diameter of 4 to 5 mm). In Silicate capsules the diameter of 17 mm of the inside capsule ensures that this inside capsule will be broken and the fixing agent will be released and will mix with the hardener.

The savings estimate of 30% on the cost of rock bolts is based on a comparison of IPKON silicate capsules and resin capsules. This is because in IPKON's silicate capsules, the diameter of the inside capsule of 17 mm allows for a greater difference between the diameter of the rock bolt and the diameter of the borehole. With IPKON's silicate capsules, for a given borehole diameter, you can use rock bolts of a smaller diameter, compared to cement capsules and resin capsules, allowing you to save up to 30% on the cost of rock bolts.

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20 IPKON's silicate capsules http://ipkon.org/technology/
Furthermore, on average the volume of the contents of silicate capsules grows by 2 to 3 % after its installation, allowing for a tighter installation of the rock bolt. On average the volume of the content of a resin capsule shrinks after installation.

IPKON's silicate capsules offer permanent roof support usually for the whole life of an operating mine. They are easy to install and provide an effective protection against corrosion. They can be installed even in a very humid environment.