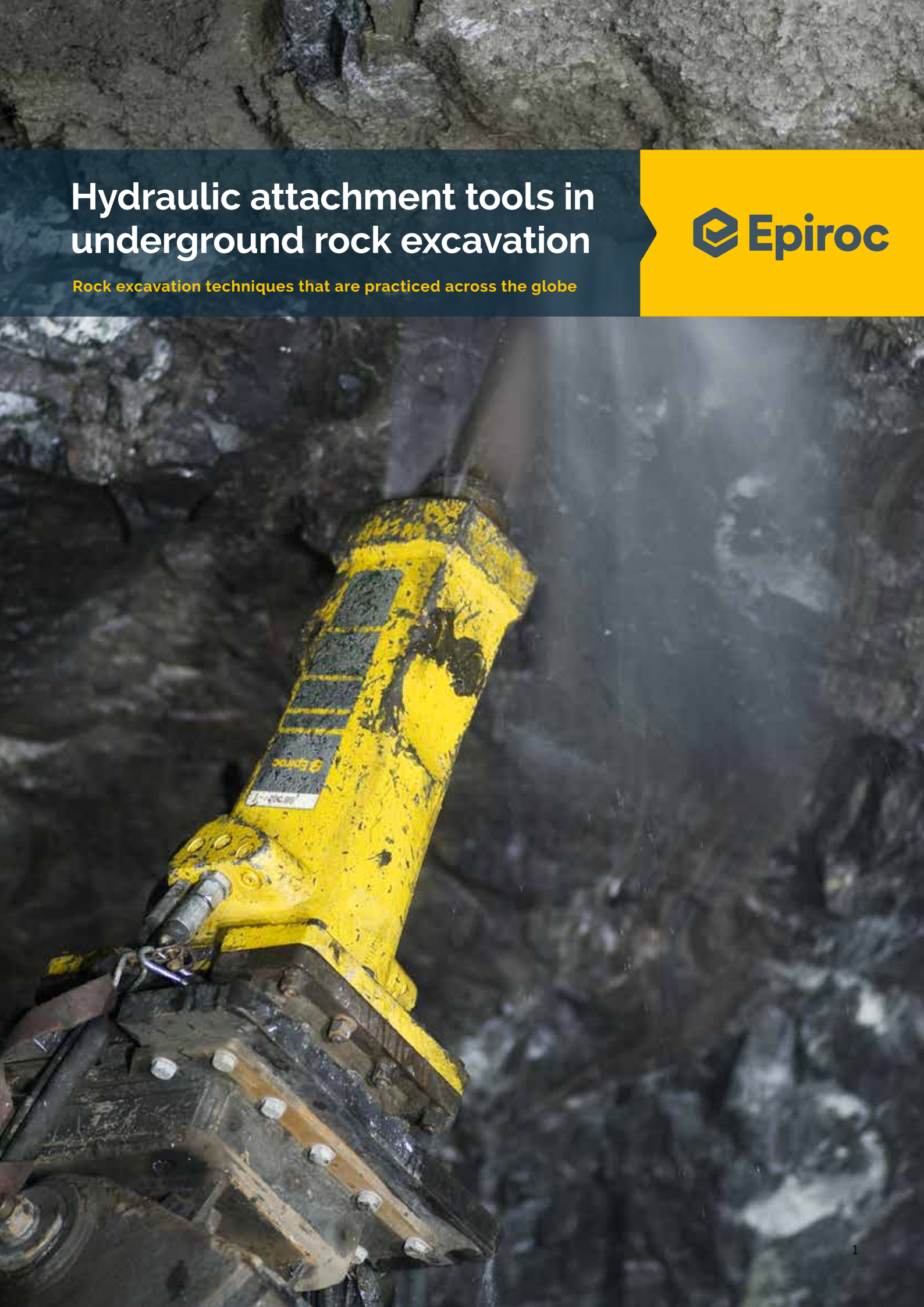
Hydraulic attachment tools in underground rock excavation

Rock excavation techniques that are practiced across the globe

Epiroc



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Foreword

As a leading supplier of rock excavation equipment for more than 140 years, we have gained considerable experience and knowledge in rock excavation techniques that are practiced across the globe.

This brochure has content on the Hydraulic Attachment Tools such as hydraulic breakers and drum cutters that are used in underground operations. The first hydraulic breaker was invented, and built in, in our factory in Essen in 1966, where we have continued to invest in development and innovation so enabling us to retain Epiroc's market leading position.

Some of the features of our breakers are solid body design for breakers up to 1100 kg, frequency switching, energy recovery, StartSelect, AutoControl, PowerAdapt and DustProtector.

The highlight of our tools is the patented IPS (Intelligent Protection System) for HB heavy breakers introduced end of 2017. This unique advance in technology effectively enables the breaker to think for itself, avoiding blank firing and resulting in higher productivity.

This publication will consider the use of hydraulic attachment tools in underground rock excavation applications - both in mineral extraction from underground mines and also developing tunnels, shafts, chambers and passageways.

Going underground is rapidly becoming the only viable option for meeting the infrastructure needs of the 21st century. The experts from UN expect that by 2050, two-thirds of the world population will be living in urban areas giving us a promising business opportunity.

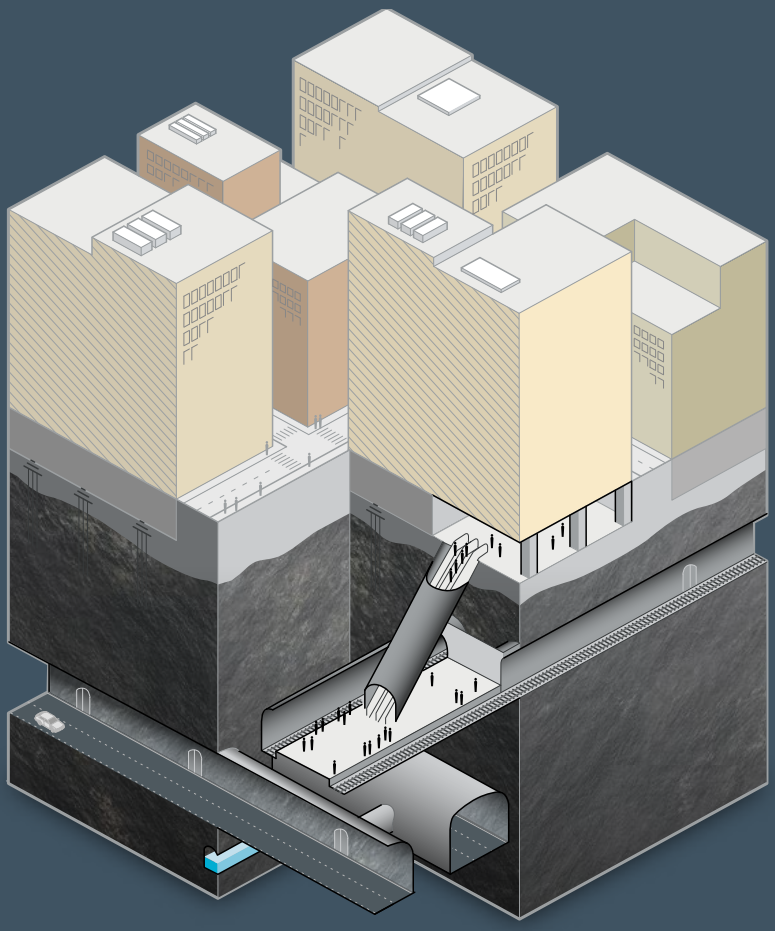

Glaskartunnelen

Classification and comparison of rock fragmentation methods

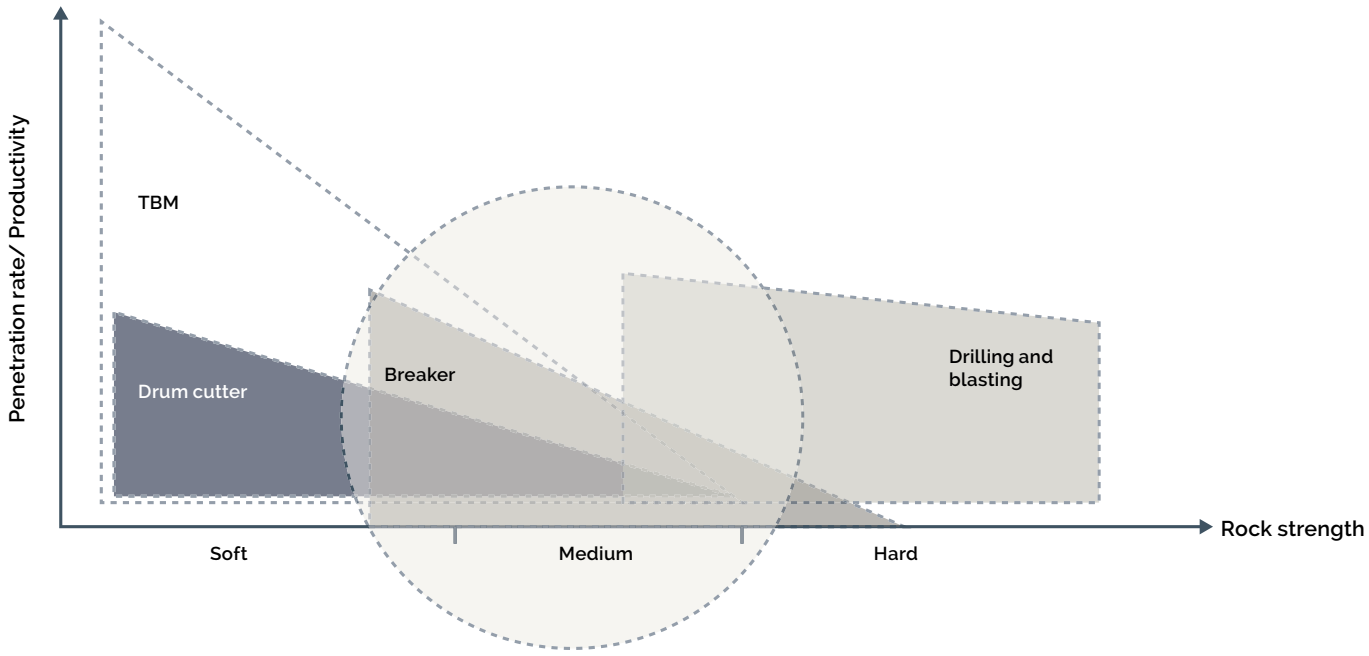
For a global insight into the tunneling industry and where it is headed, the type of excavation methods used is another important aspect. Currently there are two methods that dominate tunneling practices worldwide – drill and blast excavation and mechanical excavation.

Rock excavation methods in tunneling

Blasting (Conventional)	Non-blasting (Mechanical)
Drilling and blasting	**Cutting:**
	TBM (Tunnel boring machine)
	Roadheader with drum cutter
	Breaking:
	Excavator with hydraulic breaker



Mechanical excavation can be subdivided into full face Tunnel Boring Machines (TBM) and mechanical excavation using "roadheaders" or simply headers. Headers are specially designed machines or excavators with mounted hydraulic attachments like Drum Cutters or Hydraulic Breakers. A large share of TBM excavations are carried out in soft ground conditions and this is the most common method for developing subway tunnels in big cities.



Overlapping area where many other criteria can influence the selected method

Advantages of hydraulic breakers or drum cutters in tunneling compared to TBM

Flexibility: the tunnel cross section can be easily expanded to compensate for the convergences that will arise

More **capable** of dealing with unforeseen conditions

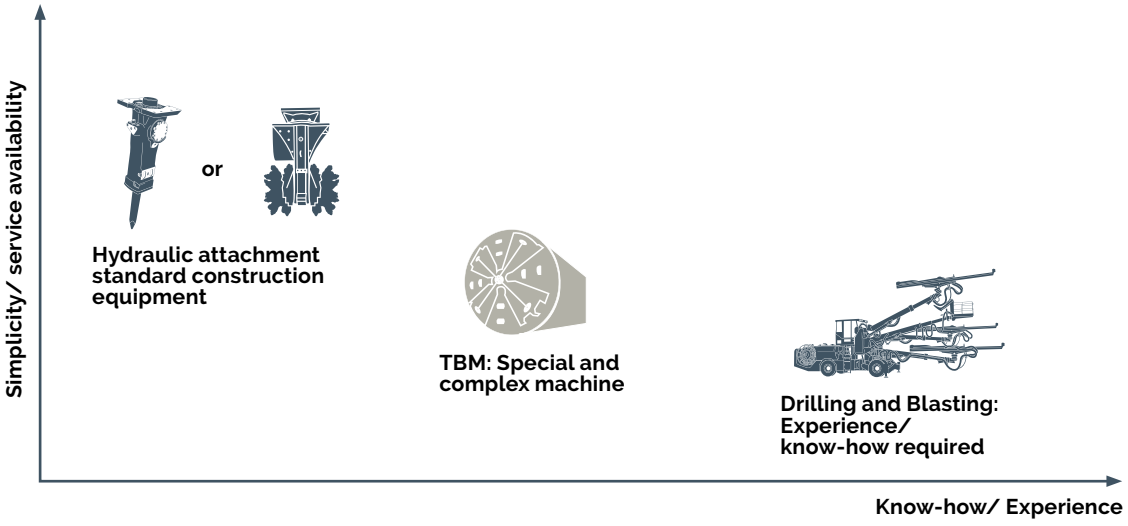
The tunnel face can be **stabilized by bolting in the direction** of excavation by use of long fiber strands that will be cut as the tunnel-face advances

Water-bearing and highly fractured ground can be sealed and stabilized by grouting and sometimes spilling or pipe roofing ahead of the tunnel face

Variable curve radius as well alteration in dimensions is possible all the time

Simplicity is the key factor

Many clients want to avoid blasting operations in built-up areas for a variety of reasons. Hydraulic breakers and drum cutters are robust and reliable tools mounted on the carriers - mostly it is an excavator. This is a well used technique that has been proven over decades. It means that standard construction service is available as well as the risk of machine downtimes is minimal. Summarizing breaking or cutting with hydraulic attachment tools is the easiest and simplest method compared to all other excavation methods.



Comparison of partial face breaking/cutting, drilling and blasting, full face TBM

Criteria	Partial face breaking / cutting hydraulic attachment	Drilling and blasting	Full face TBM
Initial machine investment	Middle	Middle	Very high
Costs of pre-investigation	Middle	Middle	Very high
Flexibility	High	High	Low
Mobility	High	High	Low
Selective excavation	Possible	Limited	Not possible
Staff qualification	Carrier operator	Expert	Specialized
Soft rock	Applicable	Not applicable	Applicable
Medium to medium hard rock	Applicable	Applicable	Applicable
Hard rock	Limited	Applicable	Limited

Reasons for choosing blast-free methods

Hydraulic breaker, drum cutter

Summary of factors influencing the choice of blast free mining and tuneling

Low production volumes requested
Use of hydraulic breaker or drum cutter is more economical than use of drilling equipment.

Rock structure (geology)
Heavily fissured rock sometimes makes it difficult to drill and blast.

Selective mining
To improve rock material quality and mineral purity the deposit layers can be excavated flexibly depending on desired rock material quality.

Legal regulations (Statutory or safety guidelines)
No blasting allowed or blasting to be subject to strict and costly regulations.

Environmental requirements
Reduction of blasting emissions for example noise (airblast overpressure), ground vibration, ground born noise, dust, flyrock, and fume emission because of deposit location close to nature reserve, water reservoir, residential areas, infrastructural facilities.

Geology for mining

A good understanding of the Earth's crust and the geology of a mineral deposit are key factors in knowing how to extract valuable material in the best way.

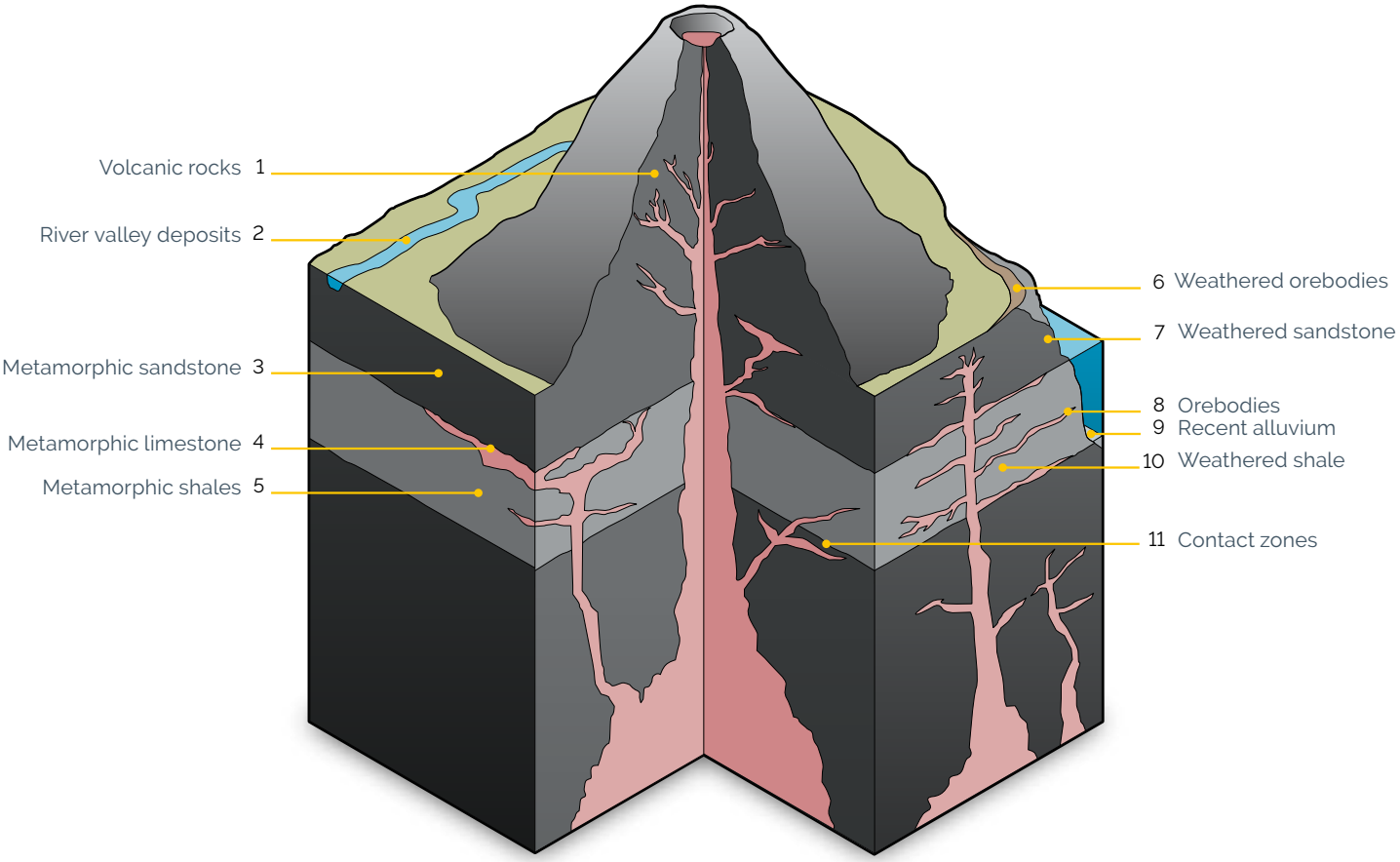
Selecting the excavation method, choosing the equipment, designing the rock support system and a dozen other key decisions affect the success of an underground rock excavation project, and are all directly related to the geology of the deposit. Without a thorough knowledge of the geological conditions at the site, the wrong decisions can prove to be disastrous. Rock is formed with a variety of properties and usually consists of one or more minerals ranging from single chemical elements to complex compounds. There are more than 3000 different known minerals in existence.

Rocks are classified into three main groups based on their origin and the way in which they were formed.

Typical formation and placement of mineral - and ore forming zones:

1. **Volcanic rocks -** fine-grained minerals including feldspar, quartz, olivine, hornblende, magnetite and mica
2. **River valley deposits -** may include gold, platinum, diamonds, cassiterite or magnetite, as well as clays and sands
3. **Metamorphic sandstone -** high proportion of quartz
4. **Metamorphic limestone such as marble. etc. -** calcite and dolomite
5. **Metamorphic shales such as slates, schists, etc. -** with garnet, mica, feldspar
6. **Weathered orebodies -** producing azurite, malachite, cuprite, etc.
7. **Weathered sandstone -** having high quartz content
8. **Orebodies.** Containing galena, sphalerite and chalcopyrite
9. **Recent alluvium,** lake and seabed deposits
10. **Weathered shale,** perhaps forming bauxite
11. **Contact zones:** garnet, hornblende, sulphides

Typical formation and placement of mineral and ore forming zones:



Igneous or magmatic rocks - formed from solidified lava or "magma" i.e. granite

Sedimentary rocks - formed by deposition of broken material or by chemical precipitation i.e. sandstone

Metamorphic rocks - formed by the transformation of igneous or sedimentary rocks, in most cases by an increase in pressure and heat i.e. gneiss

Prospects for breaking and cutting

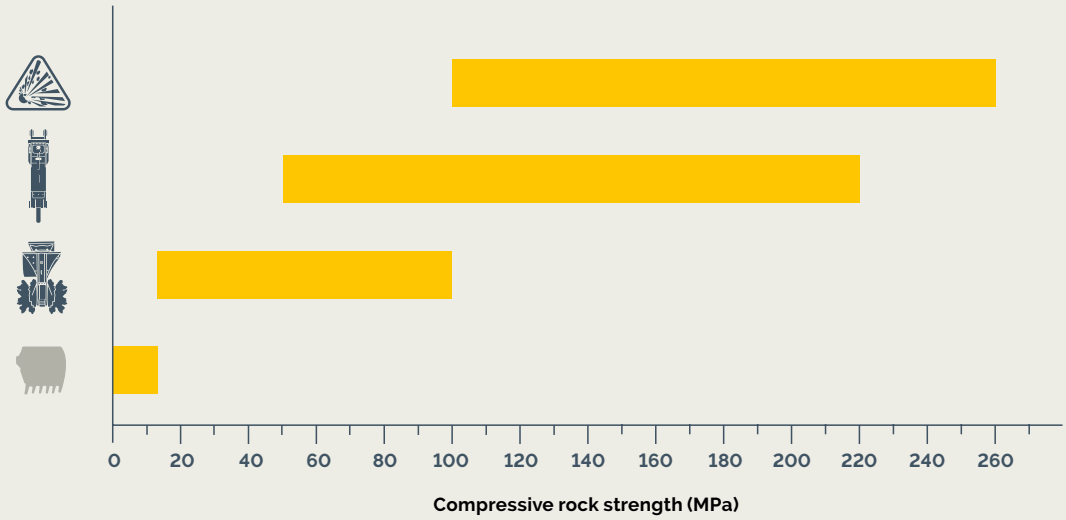
The ease of excavating depends on many properties of the rock material and rock mass. In some circumstances, certain mineral characteristics directly influence the mining method. Many salts, for example, are especially elastic and can absorb the shock from blasting. The rock may not only combine the properties of the minerals, but also exhibit properties resulting from the way in which the rocks were formed or subsequently altered by heat, pressure and other forces in the Earth's crust. It is comparatively rare to find a homogeneous rock mass and the discontinuities such as faults filled with crushed material, major jointing and bedding non-conformities are hard to predict.

Discontinuities are very important (often denoted by joints); these are horizontal and vertical as well. We can divide the rock based on our experience in

- Highly fragmented with spacing <0.4 m (15 in),
- Fragmented (blocky) 0.4-1.0 m (15-40 in) and
- Compact (massive) > 1 m (40 in).

Cutting ability in case of drum cutters depends on many properties of the rock material and rock mass. However, the most important properties are hardness (compressive strength) and rock structure. The quartz content is of a crucial significance to cutting. Abrasive rocks with higher quartz content result in higher wear of picks, pick boxes and the cutter drum.

Rock excavation method according to compressive rock strength



Properties of the rock mass relating to the in place rock mass are:

- Discontinuity: any distinct break or interruption in the integrity of a rock mass. Discontinuities within a rock mass, reduce its strength and stability and reduce the energy required to excavate or erode it
- Structure
- Texture
- Shearing resistance
- Consolidation

Properties of the rock material are:

- Rock type and color
- Strength: the ability of a material to resist deformation induced by external forces
- Hardness: characterizes the strength properties of rock mass. It is the resistance of the material to scratching or indentation
- Density
- Particle size, mineral composition, shape of grains, texture, crystallinity, stratification, lamination influences the strength

Mining and tunneling

Talking about underground rock excavation, we have mining with the aim of extracting minerals from underground. At first, we excavate (non-valuable) waste rock in order to gain access to the mineral deposit.

In underground mines hydraulic breakers mounted on the pedestal booms near to grizzly crushers are used for breaking oversized rocks (secondary breaking). Another very common application is scaling (roof support) after drilling and blasting.

The Drum Cutters are used successfully as a primary excavation machine in Soft to Medium rock formations like gypsum or salt. Drum Cutters are a very good solution for scaling or profiling.

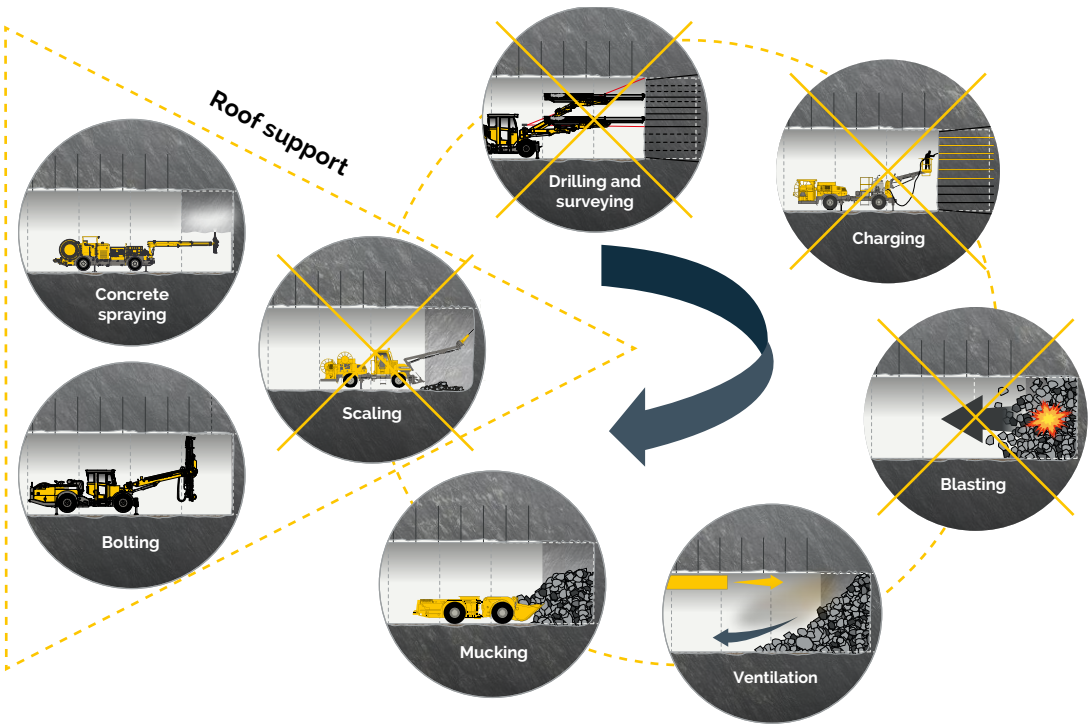
Another kind of underground rock excavation is construction (tunneling) where the main aim is to develop underground tunnels, shafts, chambers and passageways for civil engineering use. Depending on the rock properties Hydraulic Breakers or Drum Cutters can be used as a primary excavation method or in combination with Drilling and Blasting.

The combination is sometimes required when roof conditions don't allow blasting because of collapse risk of the surface area. A common practice as well is to use hydraulic attachment tools at the entrance area of a tunnel to protect surrounding rocks for better stability.

Potential for hydraulic attachment tools

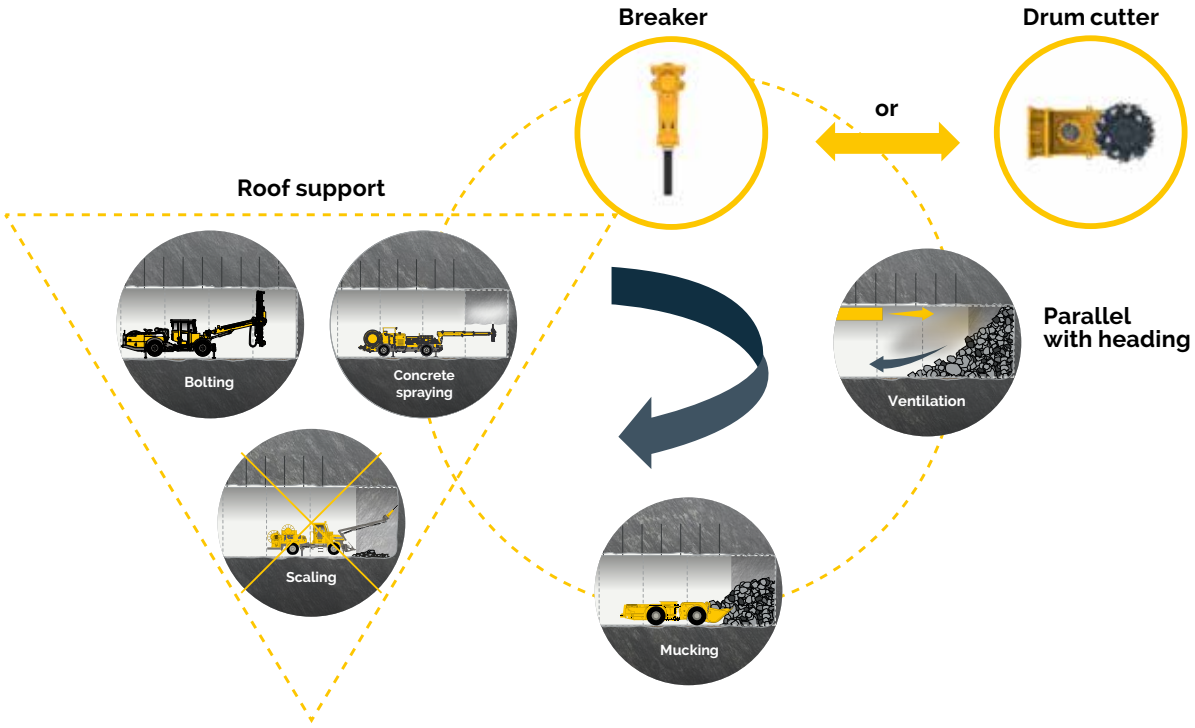
Hydraulic attachment tools will play a big role when changing from drilling and blasting to non-blasting methods

Tunneling and mining process



Underground operations using hydraulic attachment tools

Tunneling and mining process



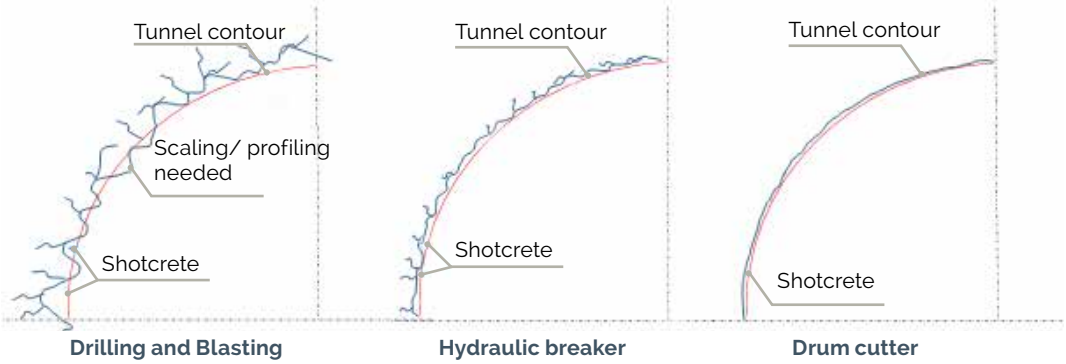
Rock support

Mining remains a challenging environment and rock fall still poses a serious threat if not taken care of in a professional way. The principles in rock reinforcement include some basic considerations:

- Carefully select the rock support system to meet all requirements of the mine environment, from bad rock and convergence to seismic conditions
- Always install rock reinforcement close to the face, immediately after excavation
- Investigate if the system can be divided into primary and secondary rock reinforcement
- In unstable rock mass, evaluate the need for forepoling or grouting
- Choose a rock support system that is adaptable to changing rock mass conditions
- Make sure that rock bolts and shotcrete interact well with the rock mass

Minimized overbreak will prevent the excavation of too much waste rock and a good contour preserves the structure of a drift and facilitates rock support. This means there is less waste rock to transport and in tunneling less shotcrete means saving costs.

Contour conditions using different excavation methods



Scaling with hydraulic attachment tools

Scaling of the face, roof and walls is the only process in the drifting sequence that might be somewhat difficult to optimize in advance. This depends on the rock conditions. In good rock conditions, the roof and walls will not yield any falling rock, and the need for scaling will be minimal. In poor conditions, all surfaces will require scaling, which is much more time-consuming.

Scaling can be done with different size of breakers and drum cutters depending on the rock type and its properties. The size of hydraulic attachment tools is limited to the excavator size and available space.

New range of SB Tunnel version

Based on our long experience from previous dedicated SB Scaler breakers, Epiroc has introduced a completely new range of SB tunnel breakers.

With longer lifetime of press-fit bushing and piston, the new SB comes with a solid body design where simplicity, compactness and less parts are it's main advantages.

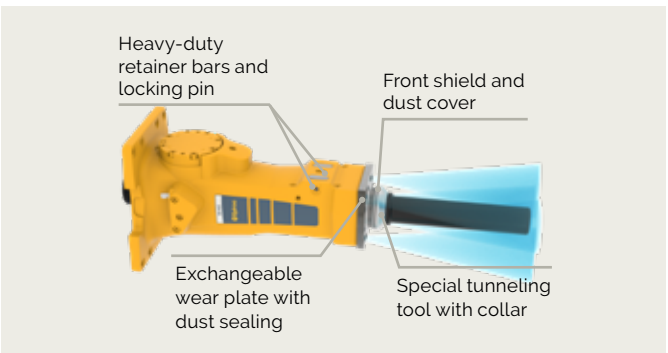
To protect the breaker, special collared tools have been introduced, and exchangeable wear plates with dust sealing have been added. Integrated water line and nozzles helps to bust the dust. Two restrictor variants are supplied: a scaling restrictor which is fitted in the breaker, and a second tuneling restrictor which can be fitted if higher impact energy is required.

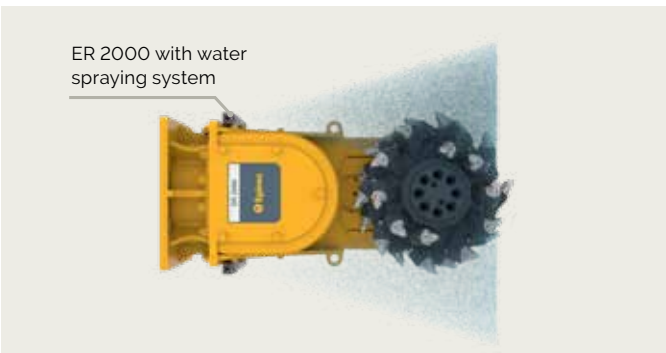
Tunnel with water spraying system for dust minimization

Taking care about safety and health of people working underground the water nozzles and integrated water channel in SB breakers were introduced almost 20 years ago.

Drum cutters have optional water spraying bars which can be added to the cutter body.

Dust supression system for SB Tunnel versions and ER drum cutters





Scaling in mining operation with the scaling rig

SB 302 Tunnel with water spraying system for dust minimization

Breaking oversized rock

(Pedestal booms)

While it is true that boulders are created by insufficient blasting or blasting difficulties due to hole deviation, they are a reality and must be broken up into smaller, more manageable pieces through haulage or crushing. There are only two ways of dealing with these unwanted boulders. They can either be drilled and blasted or broken down using hydraulic breakers.

The standard excavator can also be used with a hydraulic breaker if there is space available and there is no need for continuous operation.

Example for underground pedestal boom system

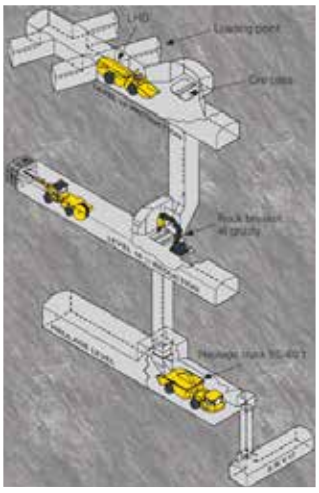
Hydraulic breakers

Selecting the breaker on a pedestal boom based on boulder size and rock hardness. From a practical point of view the selection criteria for the size of the breaker is dependent on the available space underground.

Secondary rock breaking on rock breaking systems

Rock hardness	Soft to medium (<80 MPa)			Hard (80-160 MPa)			Very hard (>160 MPa)		
Boulder size	< 1 m^3	< 1-2 m^3	< 2-4 m^3	< 1 m^3	< 1-2 m^3	< 2-4 m^3	< 1 m^3	< 1-2 m^3	< 2-4 m^{3a}
	< 35 ft^3	< 35-70 ft^3	< 70-140 ft^3	< 35 ft^3	< 35-70 ft^3	< 70-140 ft^3	< 35 ft^3	< 35-70 ft^3	< 70-140 ft^3
SB 202	•								
SB 302	•								
SB 452	•	•							
SB 552	•	•		•					
SB 702	•	•		•					
MB 750		•	•	•					
MB 1000		•	•	•	•		•		
SB 1102			•	•	•		•		
MB 1200			•	•	•		•		
MB 1500			•		•	•	•	•	
MB 1650					•	•	•	•	
HB 2000						•		•	•
HB 2500						•		•	•
HB 3100									•
HB 3600									•

•=Suitable
Final breaker selection based on pedestal boom system size & type and number of boulders per hour



Secondary breaking in ore mine at grizzly (crusher)

Tunneling with hydraulic breakers and drum cutters

Tunneling with hydraulic breakers or drum cutters is a common method when drilling and blasting is forbidden, restricted or economically unviable for example, for short tunnels.

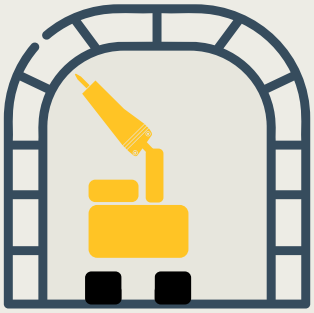
Another example is a combination of using a breaker in the starting phase of the tunnel when the roof conditions are too weak and then switching to drilling and blasting once the roof is more stable. Depending on the size of the tunnel and the mobile equipment that can be driven in one-step as a full face or sequential as partial face.

For working in low roofed tunnels, there are special excavators equipped with front linkage.

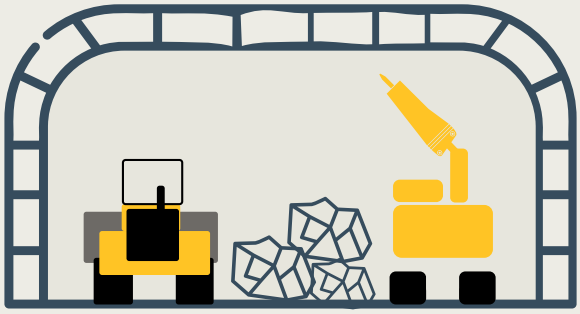
When the rock is hard or difficult to excavate with a breaker, the work is assisted with pre-drilled holes.

Pre-drilling makes it easier to keep the tunnel heading in the right direction and minimizes the amount of excavated rock material.

Tunneling and rock excavation with breakers is a cost efficient method because it produces the required size of boulders without secondary reduction or problems on a crusher feeding. Normally there is no need for separate scaling after excavation, which reduces the need for carriers and special machines.

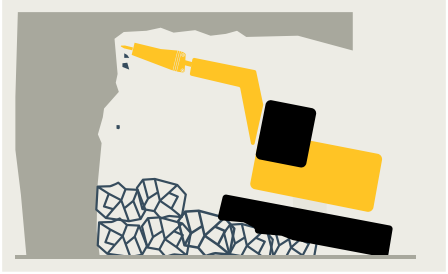


Tunneling with single excavator 30-70m²



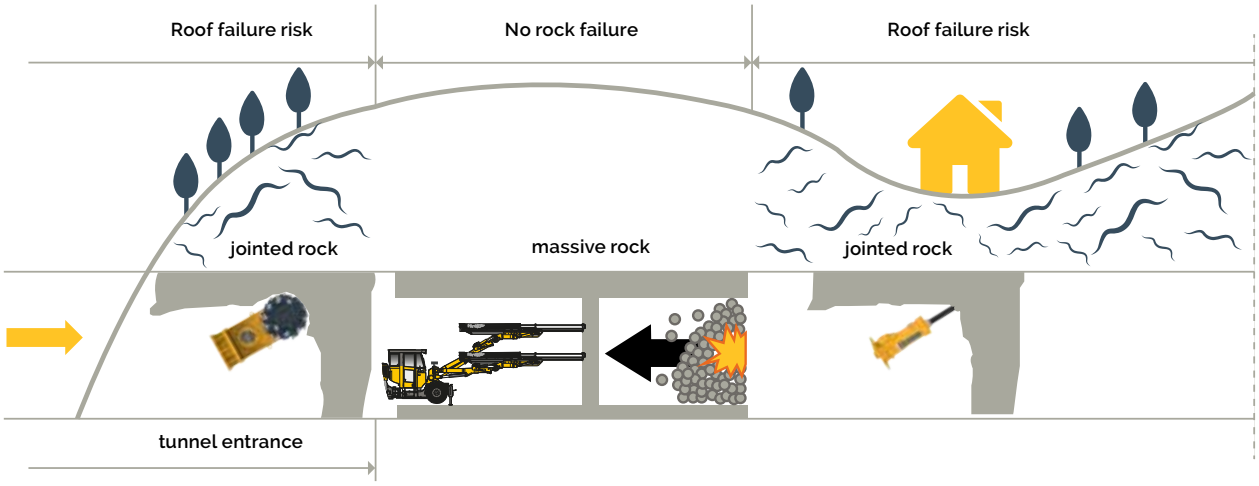
Tunneling with single excavator and parallel mucking >70m²

Breaking steps in case of high cross section



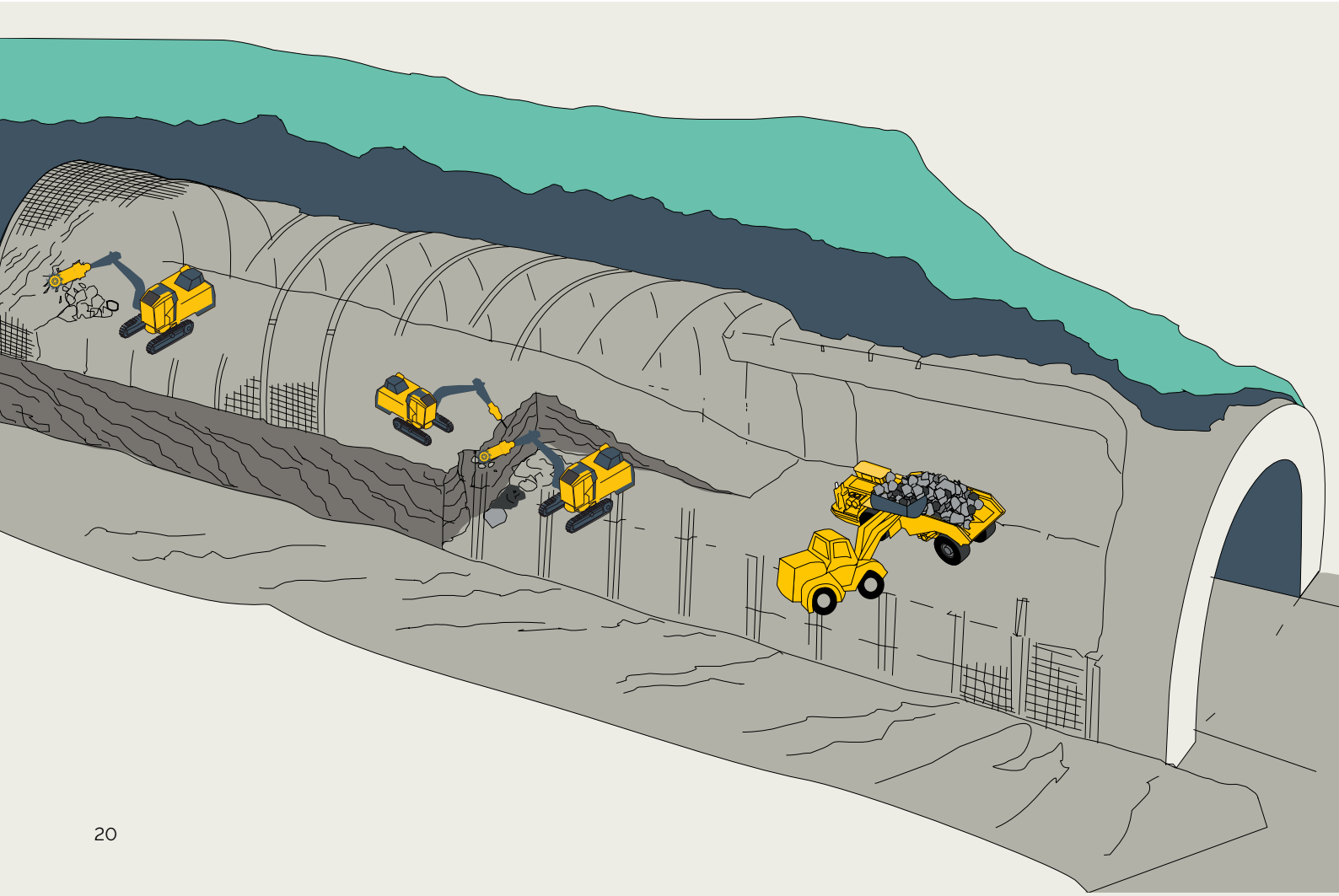
Tunneling with HB 2500 Dust with parallel mucking (Genova)

Combination = Flexibility



Tunneling combining drilling and blasting with non-blasting methods: drum cutters and/or hydraulic breakers. Because of weak roof condition and/or surface protection requirement

Sequential excavation method



Tunneling with MB 1500 Dust on special excavator in Norway

In this method depending on the tunnel diameter and geology, the tunnel is driven simultaneously in two stages:

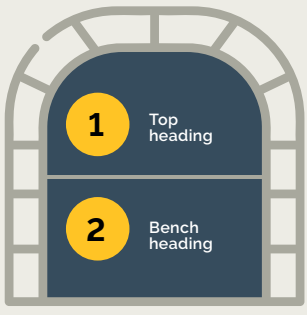
- Top heading
- Bench heading

Top heading opens and stabilizes the roof. Excavation methods like drilling and blasting are selected depending on the ground and rock conditions, and in less compact rocks tunnel excavators with hydraulic breakers or drum cutters are the preferred choice.

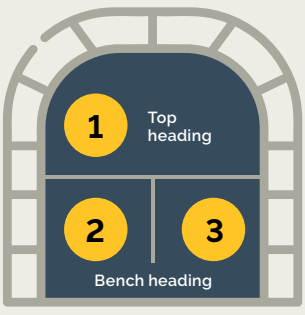
After the tunnel rocks or soil are mucked out, the tunnel arch is supported by shotcrete, mesh, anchors and steel arches as required. In some bad conditions, the roof needs to support in the longitudinal direction at an earlier stage using different techniques like grouting, freezing or fore poling.

Bench heading follows top heading and is driven in each site separately or in one single step over the total tunnel width. Shotcrete, mesh or anchors as required support the site walls.

Inner lining is the last step in the construction of a tunnel. This includes final concrete roof, cable ducts and carriage ways. The tunnel arch is sealed against ground water using waterproofing membrane. The final inner lining of mined tunnels is of concrete and this is done using mobile steel framework.



Sequential tunneling with two steps



Sequential tunneling with two steps in bench heading

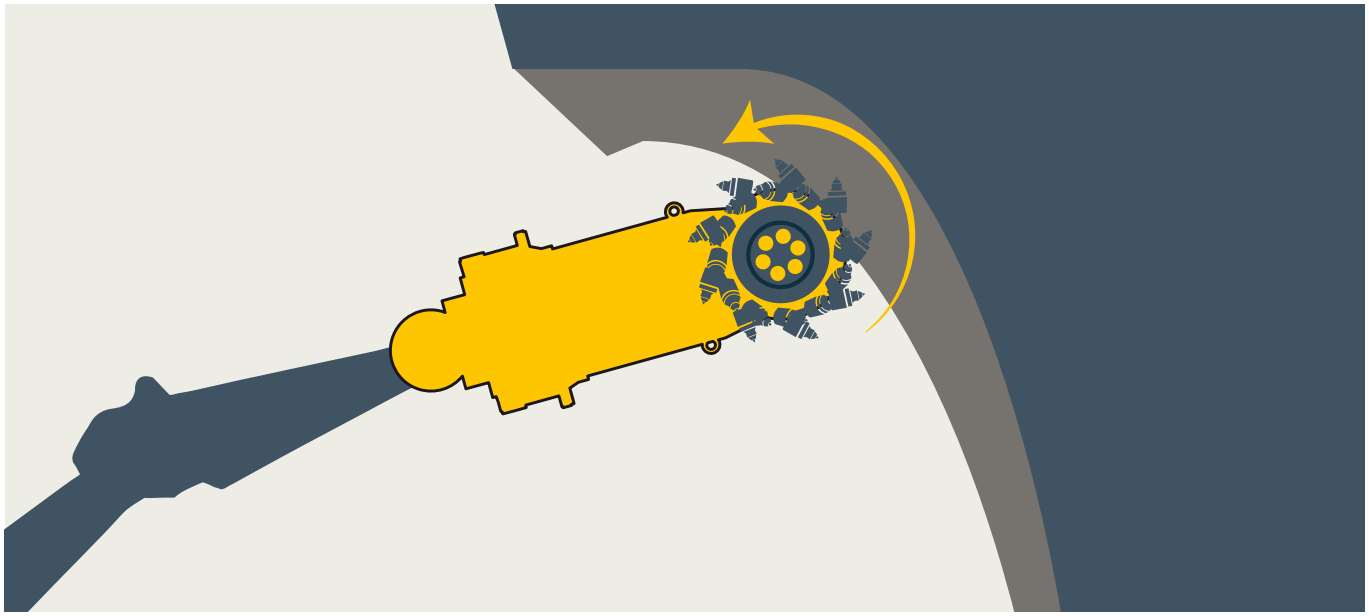
Steps in tunneling after drifting/heading

1. Stabilization anchors, shotcrete lining and steel mesh or ring support
2. Waterproofing membrane
3. Final lining

Optimum cutting direction for tunneling and wall scaling

A similar tunneling process can be conducted using drum cutters instead of breakers.

Compared to using breakers, drum cutters produce much smaller rocks which are easier to handle. However cutting also produces more dust, so it is highly recommended that water spraying is used to minimize the dust on site.



Breaker in primary rock excavation of slate

An interesting example in the dimensional stone industry is the underground rock excavation of slate using the room and pillar method where the pillars are 5m wide and the rooms 20-25m wide, depending on the geology. To achieve the blocks underground, the face of the room is cut in horizontal and vertical lines using a cut-off saw on the carrier.

Next, an SB 202 hydraulic breaker removes the bottom row of blocks, reducing the stress in the rock. Then the row above is broken out of the rock mass, and so on, step by step or block by block.

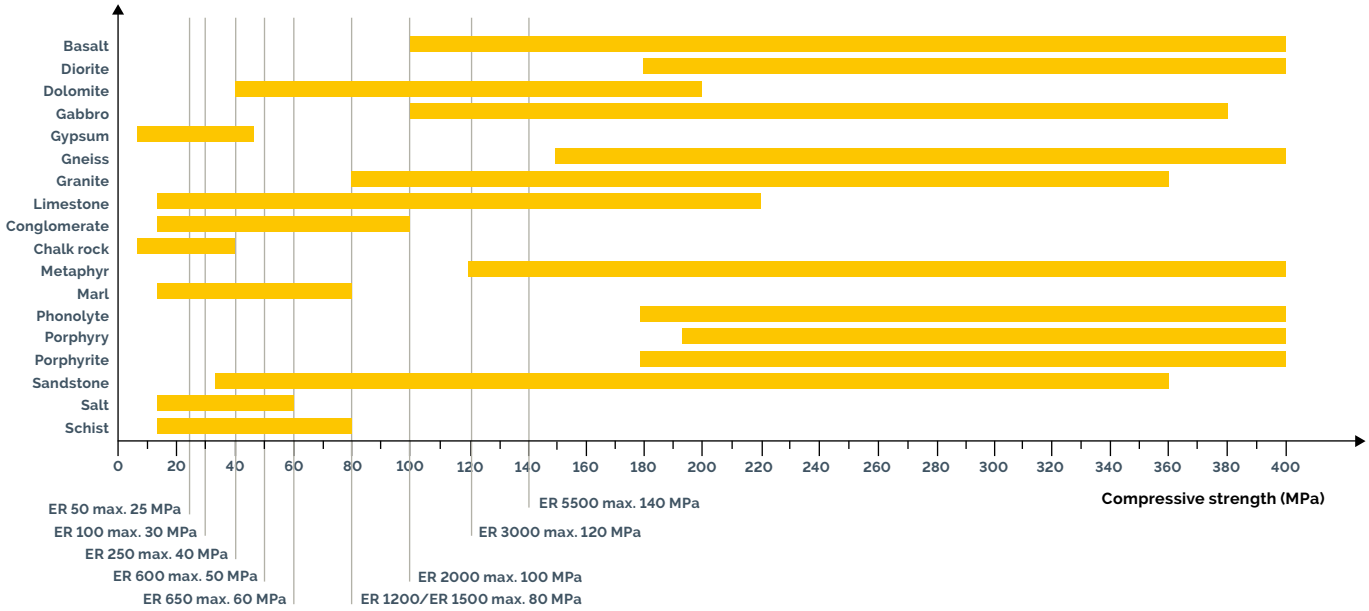
Breaking out the slate blocks with the breaker SB 202

Drum Cutters as a primary excavation machine

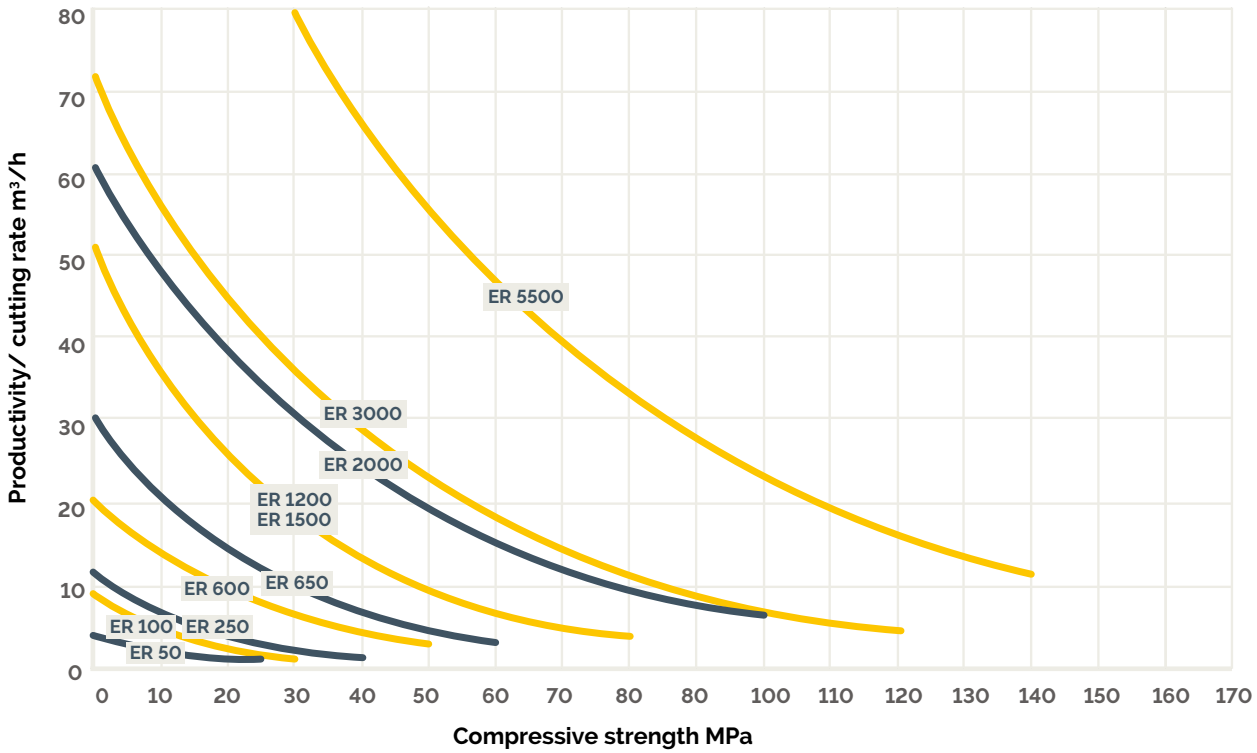
In soft to medium hard rock types like gypsum, salt or some kinds of limestone the drum cutters are used as a primary excavation machine. The advantage of this is an exact and smooth profile without the need of any additional scaling.

ERC 3000X in primary excavation of gypsum in France

Choosing the drum cutter model according to the rock type and compressive strength



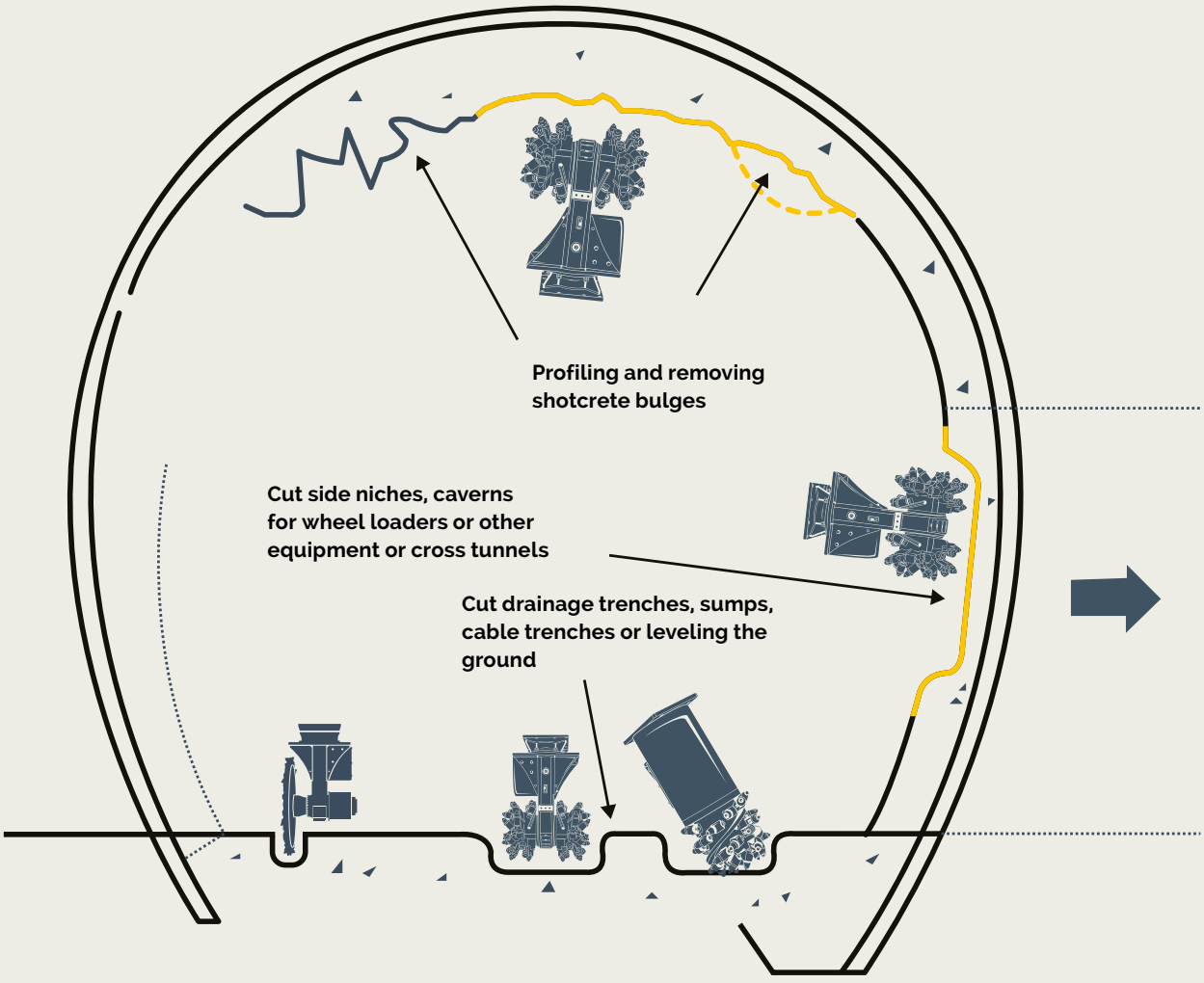
Cutting rate m³/h of the rock mass (not broken material)



Cutting cross passage in the Albaufstiegtunnel between two main tunnel lines

Microtunneling with drum cutter ER 250L

Common works in tunneling or underground mining using drum cutters



Breaker and drum cutter modifications for underground rock excavation

Working underground in horizontal or overhead positions leads to cuttings and dust getting inside the breaker. There are some basic rules to follow to do the job correctly:

- Connect external compressed air supply to force ventilation of the percussion chamber
- Use the DustProtector II Version
- Clean the DustProtector regularly depending on the site conditions. Once per shift checking and cleaning is recommended to keep it fully functional
- Frequently check the wear of the tool and bushing, because of one side wear due to work in horizontal position
- Regularly check the lubrication because compressed air removes the grease more quickly than in normal operation

Feeding external compressed air to percussion mechanism is mandatory to keep out the dust from the breaker and it is a standard feature on all Epiroc SB, MB and HB breakers.

The air is supplied from the hydraulic driven compressor installed on the carrier. Water spraying channels for dust reduction are standard in SB breakers.

Active DustProtector

Consists of two-stage sealing-system with coarse and fine stripper. Wear on the bushes and the working tool is reduced as they have less contact with abrasive material. Floating bush can be replaced without dismantling the breaker. Another advantage is lower grease consumption, because DustProtector keeps the lubricant longer in wear bush area and prevents penetration of dust into lower breaker part.

Dust suppression systems for drum cutters

To reduce the dust, wet suppression systems are used. In this system water is forced under pressure through small nozzles to create a fog. The installation of the nozzles directly at the attachment is the most effective way compared to the spray canons, because of the distance to the dust source. The number of nozzles to cover the working area depends on the size of the drum cutter.

Hydraulic driven compressor installed on the tunneling excavator

DustProtector lower parts for tunneling application with guide ring, steel floating ring and grooved counter ring

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