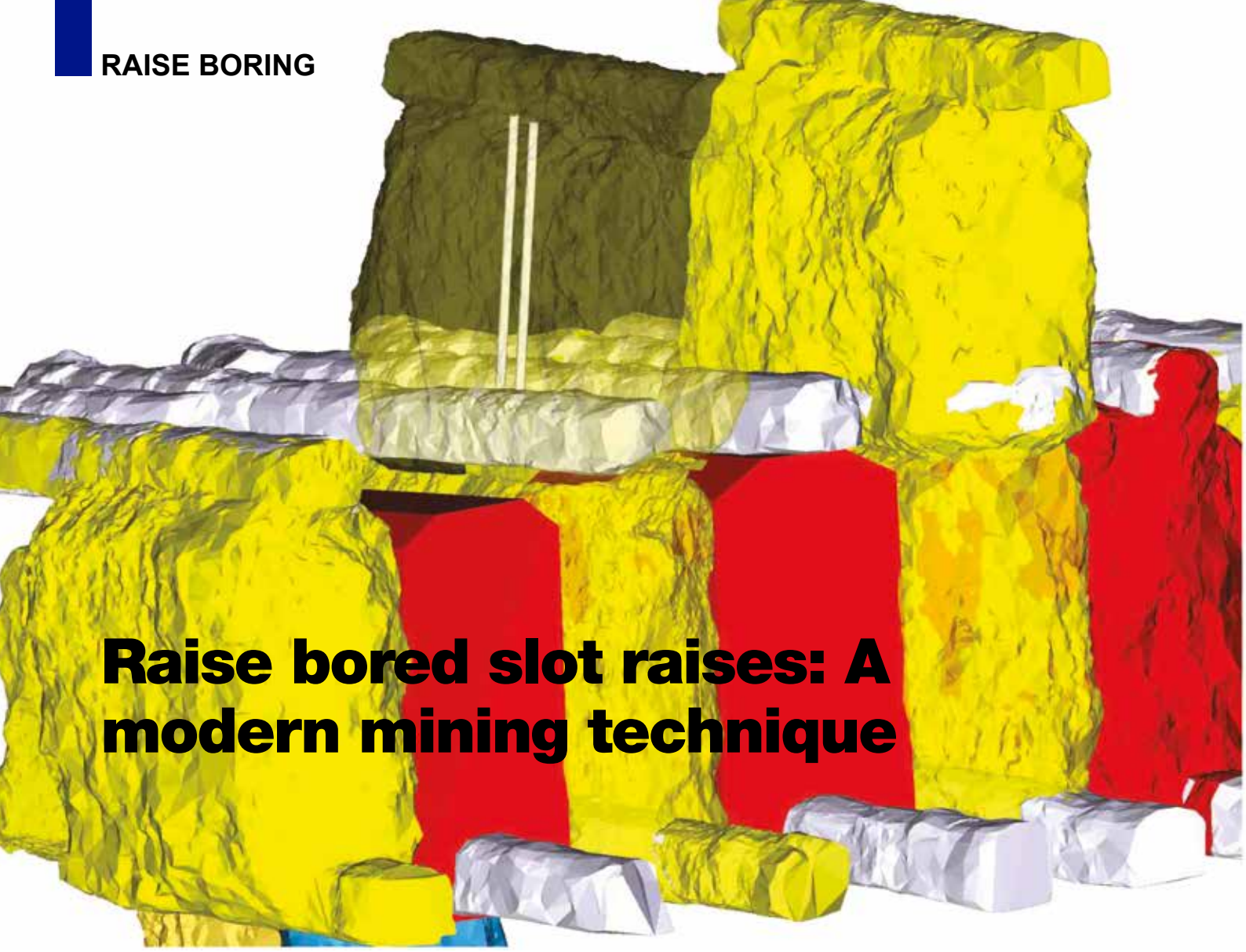

# Raise bored slot raises: A modern mining technique

**Figure 1**. Two slot raises in one stope.

**Slot raises refer to relief holes within a stope, intended to provide void space (or burn-cuts) for blasting, thereby allow "expansion" of the blasted rock and to improve fragmentation. The benefits of larger diameter slot raises to the mine productivity are well documented – but if only these slot holes could be produced safely, simply and cost effectively! Writes Jarko Salo, TRB-Raise Borers Oy**

Nowadays, there are several methods traditionally employed in mines to produce these slot raises: long-hole rigs, manual drilling methods, and even conventional raise boring to name but a few. But, regardless of the method, all of them share a common complaint: The complexity of the mining process involving multiple step operations, finally resulting reduced efficiency. There is a lot of room for improvement.

Slot raises have larger diameters. Therefore, it would seem fitting to utilise raise boring technology to produce them. In raise boring the risk of rock falls or the handling of explosives is eliminated as the rock excavation process is mechanised. Raise boring was originally developed to replace hazardous manual shaft construction where miners had to work under newly blasted rock.

Raise boring is not only a safer method, but it is also a much more productive one: shaft construction is quicker; and the outcome is a perfectly round profiled hole. The round shape is also robust. It requires minimal additional rock support. Furthermore, produced without the use of explosives – and therefore without the time required to ventilate-out blast fumes, bar down and install either temporary or permanent support – shafts can be finished safely and quickly.

So, raise boring should fit perfectly within the requirements of mine production drilling. The method itself is safe, potentially very productive and simple in its basic principles. What more could anybody want?

Despite the attractions for using raise boring for production work, it is still not being employed for this purpose very

**Figure 2.** Slot raise drilled by Rhino 100.

often. This article discusses the recent developments in raise boring and the effects that these may have on future underground mining. The idea of raise boring application in mine production may not be brand new, but recent results may initiate a revolution in thinking, and possibly create a new mining standard.

Raise boring utilises brute strength to break the rock. The cutting action is accomplished by applying more than enough thrust and torque against the rock through cutters installed on a reaming head. The various parts of the raise borer are heavy and bulky, and are therefore designed to be transported individually from one drill site to another.

Unfortunately, a typical raise borer cannot simply be carried from one site to the next. Instead, the new site requires preparation and planning. The construction starts typically with drilling and blasting as the raise borers often require higher than normal overhead space. Then, a concrete pad needs to be poured over firm rock although non-concrete solutions have recently become more common.

The raise borer set-up includes one or two power packs, a control system, the raise borer itself, a base plate system providing attachment to the ground, many smaller tools and utility items, and all the drill string items. Naturally, the components form a functioning raise borer only after proper connections are made with hydraulic hoses, electric and control cables. In the past the number of connections was almost overwhelming, and include heavy hydraulic hoses with difficult to handle couplings. Luckily, the latest and most modern technology in hydraulic, electric, and control system design simplifies connection and control solutions.


**Figure 3.** Conventional raise boring system (without operator's station).

Finally, basic supplies such as electricity are necessary for a successful raise boring operation and need to be installed and available prior to the arrival of the raise borer. Less obvious supplies on the drill site include proper lighting to allow safe working practices around the raise borer. Sufficient water must also be provided for pilot drilling. A typical method is to construct a dam nearby, and pump returning water (with cuttings) to the dam. After the cuttings have settled, the water can be recirculated and re-used for flushing the pilot hole.

A good raise boring operation also includes safe and effective rod handling practices. Apart from the time taken for the raise borer's transport, drill string handling and rod changing are the greatest non-productive aspects of raise boring, and have also traditionally been the most hazardous.

While the erection of the modern raise borer can be achieved in just a couple of hours, nevertheless, the whole process can still be a very long and complex process. In underground mines, the issue of transportation (even when using the most up-to-date raise borers) of so many different items may prove to be a huge challenge due to roadway congestion with all the manpower and equipment scheduling. Even in the most favorable scenario, the process takes time.

Typical raise boring projects, such as ventilation shafts are large in diameter and hundreds of meters long. The projects easily take several weeks or even months to complete, as such the set-up time is insignificant even if it took a whole week or ten days. However, the slot raises to be drilled in mine production are of relative short lengths, and there are many of them in different areas of the mine, sometimes far away from each other. Any extra time or manpower required in transportation, setup, or site preparation will be detrimental to the success in production drilling function. If the productivity suffers, the other methods simply take over.

Considering the above, it is no surprise why traditional raise boring concept has struggled to maintain presence in the past. Setup is non-productive time, and the longer it takes the less there is interest in applying raise boring as a production method. Despite its many potential benefits, its lack of mobility makes raise boring an unattractive alternative for production drilling (particularly when considering drilling short lengths). Indeed, for typical production, it is impossible to justify the time and cost of traditional raise borer transportation and set-up times.

Luckily, raise boring is evolving just as any other technology. Technical solutions and their applications are constantly being developed. Most definitively a couple of major raise boring concept categories have formed. Conventional raise boring is the category when setup time is insignificant in the grand scheme with large projects lasting weeks or months. The other category would consist of the various mobile raise borer concepts trying to expand the traditional raise boring scope of works with solutions that somehow allow shorter and smaller projects to be completed quickly and more cost effectively.

To increase production in an underground operation, any mobile raise borer must reduce the production complexities and simplify the mining process. Whilst the

**Figure 4.** Mobile Rhino 100 raise boring system operated by a single operator.

| Slot drilling operation | Conventional raise borer | Mobile raise borer[1] | Rhino 100[2] Highly mobile raise borer |
|---|---|---|---|
| Monthly production | up to 140m | 155 | 336 |
| Number of slots/month | 5 | 6-7 | 14-15 |

**Table 1**. Comparison of slot drilling productivity. The data comparing "Mobile raise borer" and "Rhino 100 highly mobile raise borer" are from the same mine in Western Australia since 2016. The data presents averages over several months in the same conditions. Conventional raise borer results are an achievement by an experienced crew in a typical mine.

potential is certainly there, the challenge is to truly create an appealing alternative for short hole lengths. How to utilise the benefits of conventional raise boring whilst also addressing the drawbacks?

The results with mobile raise borers have been mixed. There has definitively been improvement in transport speed when the lack of mobility has been solved with rubber wheels as there are also mobile solutions with tracks. The problem is that only mobility is then solved, none of the other issues have been addressed!

It is not enough to bring about a revolution in thinking with partial solution only. The new mobile solution must include several capabilities: a rapid machine set up; to effectively drill holes that are suitable for production; and to be suitable for swift dismantle/relocation/set-up. Such a unit would also not require a concrete pad, nor additional rock works, nor any special utilities or provisions other than the ones already established for the equipment operating in the same drifts. Additionally, the operation should be performed safely by a single operator without any additional resources or dedicated equipment for assisting the raise boring operation. This means all the necessary tools must be carried with the rig to simplify underground logistics.

TRB-Raise Borers' Rhino 100 is an entirely new type of highly mobile, self-contained raise borer for underground production drilling. The whole process is controlled by a single operator. No other resources are required. The strength of the concept is proven by the operating results from different mines in different continents. The highly mobile Rhino 100 rigs have been introduced in Australia, Africa, both South and North America in addition to few European installations. It can be easily concluded that any drawbacks in raise boring have been addressed. When comparing the results of Rhino 100 against conventional and other mobile raise borers, the difference is remarkable!

A mine in Western Australia's Goldfields has seen the whole development cycle in raise boring recently. The cycle may have turned into a revolution of sorts when Rhino 100 was commissioned there by Raising Australia who are a raise drilling contractor based in WA and owned by the Byrnecut Group. At the time of arrival, the mining plan in use was based on the achievement by a mobile raise borer[1]. The plan called for 5-8 meters' daily advance. Most that anybody had achieved in that mine ever in one shift was 10 meters. Already the first shifts during Rhino commissioning produced double the rate of advance. The mining plan was very quickly revised to keep the Rhino drilling. With Rhino 100 a typical shift would produce close to 20 meters of slot raise. It also became possible to complete one 25-meter slot raise in one day and be drilling the next one on the following day.

When the achievements are annualised, the differences in the approach are magnified even further. Mobile raise borer produced 100 raises and 2329 meters during 15 months in the WA mine site[1]. Rhino 100 production will be more than 5000 meters in that same mine in the same period[2].

**Figure 5.** Rhino 100 changing drill sites in Western Australia.

The case in WA mine site is not unique. Agnico Eagle Kittilä gold mine (Finland) is without a doubt a global pioneer and leader in utilizing raise boring in their production drilling. Their first Rhino 100 was introduced 2014. After two years of operation, they had drilled 302 slot raises and more than 7200 meters. Since then they have relied on raise bored slot raises and nowadays operate two Rhino 100 rigs on daily basis.

One of the drivers in Kittilä mine's approach was a 30% higher annual production target. Kittilä mine uses the sub-level stoping mining method. The average stope height is 25 meters but can be as high as 40 meters. The original long-hole open stoping method required 21 drill holes for opening a drop raise in each stope, using the same conventional long-hole rigs as that were used for drilling blast holes. The drop raises required 5 to 6 workdays (10–12 shifts) to construct, including all the drilling, blasting and hauling stages, and necessitated the use of two drill rigs and several members of a drilling/mining crew. Using long-hole drilling for the drop raises not only doubled the number of holes required (due to their smaller diameter) but also made it necessary to blast the drop raise in five-meter breaks, which requires a lot of space as well as multiple work stages.

There was also a safety consideration involved in this process. Due to the challenging rock conditions presented by the sulphide-rich mineralization, the method also required re-drilling after each blast to open closed holes. Re-drilling holes after blasting is inherently risky due to the potential for encountering live detonators that could explode during re-drilling. Addressing this bottleneck (and reducing the operational complexity) was necessary if the mine was to achieve its original production target of more than 140 stopes per year. The target has been since upgraded to about 200 stopes per year.

The new process at Kittilä mine started from scratch. None of the raise borer operators had any previous experience with raise boring. Yet, they soon drilled an incredible campaign of 18 slot raises, total of 478,6 meters in one month. Now, with a Rhino 100 raise borer, all work stages and complications could be replaced with a single machine, a single operator, and a single work-order. The new method also eliminates the safety concerns associated with live detonators and explosives, because raise boring slot holes makes it unnecessary to blast at all before the actual production blasts.

The long-hole top-hammer drill rigs drilling drop raises were assigned to other tasks after the 21 holes required for opening a drop raise in each stope were replaced by a larger raise bored slot hole. No dedicated loaders, supplementary equipment, or utilities were assigned for the raise boring process. Simplified and reorganised production resulted significantly shorter stope cycle time. This also freed up the long-hole rigs for drilling the actual blast holes instead of opening up the drop raises. This job previously required 30% of the long-hole drilling capacity without adding anything to the tonnage.

Not only does Rhino 100 offer a much more productive solution with reduced number of steps in the process, but in this case simplicity also means safety. Rhino 100 raise borer includes a comfortable, vibration free, quiet and ergonomic operating cabin which is far away from the drilling action. To further assist the operator, the most advanced controls are installed: Rhino SMART operating system is a dedicated raise boring management software offering various features for operator, manager, maintenance personnel, and mine planner to improve production efficiency, optimise maintenance schedules, and maximise uptime. Additionally, almost unlimited number of cameras can be added to remotely follow the operation, if needed. Cameras are included in heavy lifting of raise boring drill string components too. The job is safe with remote operation, and standardised handling system over all different components does not require any special arrangements while operating.

The rig itself is an articulated, highly mobile unit capable of carrying all the equipment necessary to drill a typical slot raise. This means the operation and set-up follows much the same principles as with any mining jumbo or long-hole rig operation, (ie the same connections are used, and the raise borer utilises laser-assisted positioning after electric and water connections have been made). This design integrates dust suppression and a muck guide to not only create a dust free drill site, but also to take the cuttings away from the rig.

In conclusion, the success of this new process has offered some significant benefits for the mining operations. The quick and easy solution for drilling slot raises can now actually maximise output and minimise risks, without compromising productivity or safety. Clearly, raise boring can be a productive mining method. The raise boring fundamentals provide a safe and simple process which is very fitting to underground conditions.

Raise bored slot raises are nowhere near a new mining standard yet, however, the technique has caused a revolution already. New raise boring solutions have given people a reason to start questioning older methods. Even slightly more mobile solution than the conventional raise boring solution has the potential to expose bottlenecks in underground operations, but are unfortunately not powerful enough to do anything about it. The results show they are just slightly more productive than a well-organised conventional raise boring operation.

The real potential lies with highly mobile raise borers such as Rhino 100. The solution is addressing all the drawbacks in raise boring, and is capable of immediately moving bottlenecks in underground production. The pace in production with this highly mobile concept is incredible. A typical problem of complexity in production drilling is fixed with a single rig, and a single operator. As proven by experience in many mines already, a single work order with Rhino 100 can turn a typical mining operation around so that horizontal development becomes the bottleneck.

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