The Redpath Group in a recent paper stated: “Through technology and innovation advancements, the opportunity to implement alternative excavation methods in the mining industry is becoming a reality. If a robust and well-managed feasibility review of alternative excavation methods is undertaken, we are able to pursue the various opportunities of mining through poor ground conditions and subsequently deliver economical solutions for resource development that may otherwise be unviable.” The company recommends that the following list of technical and performance factors should be considered before implementing any alternative excavation method:

- Is the method compliant with local legislation and standards?
- Does the method of excavation improve safety?
- What productivity can be achieved?
- Are the necessary skills available in the locality to implement the excavation method?
- Can a workforce be trained in the required skills to implement the alternative excavation method?

The company adds: “Once consideration is given to these technical and performance factors, the economics of the solution must be reviewed and whether the implementation of an alternative excavation method will deliver necessary the value to undertake the development of the resource. It is only through the willingness to explore alternatives to the norm that advancement can be made and innovation for the betterment of the industry implemented.”

**Alternative excavation methods**

Over the years, Redpath has undertaken a multitude of tunnelling and underground excavation projects for civil and mining clients both domestically and internationally. These projects have been undertaken through varying strata conditions with differing excavation methods in remote locations and in central business districts. With the recent turbulent nature of the global financial environment, project drivers have been challenged with the emphasis being placed on methods to gain early access to orebodies, rapid development techniques, lower capital costs and reduced labour requirements to name a few.

A number of mining companies seeking to achieve these objectives have commenced the journey to better understand the operational constraints, challenges and opportunities that may be available with the use of alternative excavation methods.

The development of safe and effective alternative excavation methods that comply with both domestic and international mining legislation and regulatory requirements is a challenge the industry needs to embrace. Given the current cost pressures being faced by the Australian mining industry particularly, some alternative excavation methods offer the potential for longer term sustainability and rapid development of resources.

More recently work has been undertaken on a project that challenged the norm and implemented an alternative excavation method with the use of an excavator with a rotating drum cutter head. Completed noteworthy projects that have included varying excavation methods in remote and challenging environments include:

- Ghagho diamond mine sand tunnel, Botswana – Gem Diamonds. Construction of a decline through the sands of the Kalahari desert in Botswana (see this month’s Operation Focus for more details)
- Ok Tedi Mine Drainage Tunnel, Papua New Guinea – Ok Tedi Mining Ltd (OTML). Construction of a 5.3 km tunnel for the purpose of dewatering the open pit mine. The main tunnel development was driven by a 5.6 m diameter tunnel boring machine (TBM)
- Kestrel Mine Extension, Australia – Kestrel Coal. Drift development using modified roadheaders supported by a sliding floor
- Carborough Downs Drift Development, Australia – Carborough Downs Coal Management: Construction of 3 drift entries through drill and blast excavation
- Mechanical excavation with TBM of both the conveyor drift and transport drift at Anglo American’s Grosvenor mine.

**Kestrel and Grosvenor**

The following summarises project details first published in the 12th AusIMM Underground Operator’s Conference proceedings and the 14th Coal Operators Conference proceedings.

The development of two drift access tunnels on the Kestrel Mine Extension (KME) project in Emerald, Queensland, Australia was completed...
The works package consisted of the construction of two drifts, a conveyor drift and transport drift, followed by the inseam development and subsequent panel development for a longwall coal mine. The drifts at KME are exclusive of each other, designed with different grades and close inseam interfaces at the German Creek coal seam. As a result of this, the drift portals are located a significant distance apart on the surface. Kestrel Mine is a Rio Tinto/Mitsui joint venture. The KME drift design provided by Kestrel Coal is generally described as follows:

- **Conveyor drift (Arch Profile) gradient 1 in 6,** nominally 6.5 m wide x 5.2 m high x 1,560 m slope distance from the start of the box cut to the inseam phase interface, and;
- **Transport drift (Arch Profile) gradient 1 in 8,** nominally 6.0 m wide x 4.9 m high x 1,870 m slope distance from the start of the box cut to the inseam phase interface.

A number of important factors needed to be considered during the tender period for this works given some of the constraints imposed on the works. These constraints included no cross passages included in the design; construction through multiple coal seams; and compliance with the Coal Mining Safety and Health Act and Regulations.

It was established that to deliver the requirements of the scope of work and contract, a method that would deliver completed drift as the face advanced was what was required. The basic construction principle carried forward was to provide a completed drift cross section within 30 m of the advancing drift excavation heading. This would ensure no delays to subsequent work activities once the drifts were complete.

The final drift construction methodology proceeded with the major excavation equipment comprising of a Mitsui S200MA roadheader, combined with an integrated ground support system. It was further concluded that to achieve the desired outcome systems that minimise delays to the face advance needed to be developed. The systems identified as integral to the success of the chosen method included:

- **Machine capable of excavation and supporting to eliminate place changing at the face**
- **A continuous material handling system**
- **Method of extending the ventilation with minimal disruption to the works**
- **Pavement installation method that would work concurrent to the face advance.**

The equipment selection and design for the works required due consideration of industry regulations, codes of practice and project specific requirements and general constraints associated with the nature and environment of the work. A significant influencing factor in the equipment selection and design was the requirements of the CMSHR. The CMSHR along with the recognised standards stipulate the controls that must be placed on equipment operating in an underground coal mine. The stipulated requirements meant that the majority of the underground equipment planned to be used to construct the drifts would require significant modifications prior to the works commencing.

To comply with the CMSHR for explosion risk zones (State of Queensland, 2011), it was necessary to ensure that any piece of equipment that operated in-bye of the last installed ventilation duct complied with the requirements of an Explosion Risk Zone 1 (ERZ1). Equipment operating on the out-bye side of the ventilation duct was to comply with the Negligible Explosion Risk Zone (NERZ) requirements.

A critical aspect was to achieve a construction methodology that minimised the time taken to change from one activity to another. The ability to have drift construction activities carried out concurrently provided the real advantage of the system to the project.

The Mitsui S200MA was fitted with a shotcrete boom and a roof bolting boom which satisfied the excavation and ground support design requirements. A benefit of the modified Mitsui S200MA is its capability to excavate, bolt...
and fibrecrete the drift heading without the introduction of supplementary equipment.

As part of the nominated support requirement, fibrecrete needed to be installed for most support types for the length of the drift. Fibrecrete was sprayed using a specifically designed spray arm assembly which was mounted onto the S200MA roadheader. Fibrecrete was delivered to the roadheader via a Jacon Midjet which was connected via a series of steel pipes and rubber hoses. Fibrecrete was transported underground to the roadheader via Jacon transit mixers.

The last aspect of the equipment system is the ventilation duct extension and installation arrangements which are fixed to the sliding floor. The system provides for the installation of 6 m long 1.8 m or 1.4 m diameter spiral wound steel ducts to extend the vent system as mining progresses. A telescopic vent duct section located on the inbye end of the sliding floor provides for the ventilation extension between the installed static duct and the moving/advancing duct located on the sliding floor. Additionally the vent duct system extends to within 3 m of the excavated face to maintain the zone boundary between NERZ and ERZ1.

As discussed in IM July 2014, last year work commenced on a project that is challenging the norm and implementing an alternative excavation method into the Australian coal mining industry with the use of a Robbins TBM that is mechanically excavating both the conveyor drift and transport drift at Anglo American's Grosvenor mine in Moranbah, Queensland.

The project is the development of a single longwall operation at Grosvenor, producing up to a maximum of 7.5 Mt/y ROM coal with the average ROM being 6.5 Mt/y. Coal will be transported to the existing Moranbah North Mine (MNM) via an overland conveyor and processed through an upgraded MNM Coal Preparation Plant. Product coal will be loaded out via the Moranbah North rail facility.

The underground development scope consists of the construction of a 762 m long 1:6 gradient conveyor drift, a 993 m long 1:8 gradient transport drift, development of the pit bottom area roadways (nominally 2,520 m of driveage), and the development of the first longwall tailgate (nominally 10,550 m of driveage) The contract to undertake the underground development works was awarded to Redpath Australia in 2012 with excavation of the drifts beginning in the 4th quarter of 2013.

In May 2014, the 8 m diameter Robbins Hybrid Single Shield/EPB TBM completed the first of the two tunnels, having made a successful run in challenging ground conditions that included sand, clay, and coal seams. The machine maintained an average production of 40 m per week with a top production of nearly 90 m per week. As stated, once both tunnels are finished at grades of 1:6 and 1:8, they will be used for mine access to new coal seams.

The hybrid machine is tackling mixed ground conditions ranging from softer ground to varying types of sedimentary hard rock up to 120 MPa UCS. Methane gas is expected to be present throughout the tunnel, so the machine has been designed as Explosion Proof Compliant to ERZ-1.

"The machine essentially uses its EPB technology to deal with methane gas safely," said Doug Harding, Robbins Vice President. If any methane leakage is detected, an evacuation system draws methane out of the end of the screw conveyor and directly into the ventilation system.

"The TBM tunneling method delivers advances in safety, higher quality drifts, and faster project development," said Glenn Tonkin, Grosvenor Project Director for Anglo-American.

As both TBM tunnels are blind headings, the machine must be retracted quickly back up the slope in a concrete segment-lined tunnel of just 7 m finished diameter. In order to accomplish the process, Robbins developed a unique Quick Removal System to enable swift retraction, which was implemented in July 2014. At the end of the heading, cutterhead pieces were unbolted and the TBM “inner core” components were moved back up the grade using specially designed transport dollies. The outer shields were grouted.
in place to provide life of mine roof support in the final section of tunnel. Back at the surface, the TBM was transported to its new launch site 2 km away where a new outer shield waited to be assembled with the machine.

For Adam Foulstone, Underground Construction Manager at the Grosvenor Decline, the use of a TBM makes sense in these conditions over more traditional methods using roadheaders: “Our experience with roadheaders has been in much different conditions, mostly bare rock, but with the TBM we are able to easily make 50 m per week. A roadheader has far slower production, about 2 to 5 m per week. The risks to personnel are also less in a fully enclosed TBM that is operating inside a concrete tunnel, as the operators are not working while exposed to the tunnel.” The machine is scheduled to start its second tunnel in November 2014, finishing up in the first quarter of next year.

Murchison, Qakimajurq and Freeport
Silver Lake’s Murchison project is situated in the Murchison Goldfield and is located between the gold producing areas of Mount Magnet and Cue, 600 km north-east of Perth. The Murchison project comprises numerous gold deposits on several historically successful mining leases which include Tuckabianna, Comet and Moyagee.

The focus here is on the excavation method adopted for the commencement of development of the Causton’s decline and Vent decline at the Tuckabianna mine. The Tuckabianna project is situated approximately 25 km east of Cue in the Murchison Province of the Archaean Yilgarn Block. The decline development from the Causton’s open pit commenced in predominately moderately weathered, strongly bedded sedimentary rock. As the decline progressed the rock mass changed, moving through a ‘transitional zone’ from weathered to fresh rocks which were more strongly jointed and have an increased susceptibility to unravelling failures.

This observation of the rock mass resulted in the requirement for shorter rounds in development to be taken to minimise the risk of fall out and rock falls post blasting and prior to installation of the final ground support.

The decline development work for the project commenced with the development of two declines that were nominated to be 5.8 m (H) × 5.5 m (W). On award of the contract, the planned excavation method was the use of standard development jumbos to bore and develop the required declines. This method was to be commenced from the Causton’s open pit and would be supported by a number of underground loaders, trucks and ancillary equipment.

Due to a late change in the decline location, which was prompted to reduce the number of metres through the transition zone, the ground conditions that were to be excavated for the initial decline development would be similar to those contemplated from the original location. After approximately 70 m of development, the ground conditions changed unexpectedly and jumbo development at the planned cut lengths was no longer possible.

In light of this unexpected change in ground conditions, the chosen method of excavation was the use of a modified excavator that would be small enough to fit within the nominated portal and have sufficient size and installed power (hydraulic) to excavate and/or cut the rock material using a rotary cutter head.

The chosen solution was a 13 t Komatsu PC138 excavator with a modified boom (shortened) which was mobilised to the mine to excavate the initial sections of the declines. The excavator was equipped with a Simex TF600 DDRC twin drum rotary cutter. The Simex TF600 was selected as the preferred cutter head due to its low noise and vibration level, accurate cutting profile and general reliability. The success of the rotary cutters is due to the high reliability of these attachments which is in part due to the hydraulic piston motor which delivers improved efficiency and contains a limited number of moving parts.

This then reduces possibility of wear and breakdown on the cutter head compared to attachments operating with gearing cascade systems.

The implementation of the modified excavator was completed successfully with the ensuing production performance of the excavator providing a cost effective solution.

Given the change in the ground conditions, and had a roadheader been necessary, the initial mobilisation and establishment costs together with the operating costs, hire charges and potential for the roadheader to become bogged would have made it an uneconomical solution. The quick mobilisation of a small modified excavator that fitted within the existing
development headings proved to be a more appropriate solution.

JS Redpath, the Canadian Redpath Group company, has several rapid development projects currently ongoing. At the Qakmajurq project in northern Quebec, it has achieved a lateral development total of 11,973 m (1,892 m in 2012, 5,200 m in 2013, 4,881 m to date in 2014) using rapid development mining methods. This has involved 1,065,766 t of haulage; 1,190 m of Alimak raising (nine raises); 112 m of drop raising; and 104 other underground construction items. Innovations included having a second MacLean bolder and operator available on each shift when several faces are available; converting the ventilation system to an exhaust one (push-pull) as soon as the distance from the portal exceeds 500 m to ensure a re-entry time not exceeding 30 minutes after blasting regardless of the length of the ramp; larger LHDs to save on mucking time from the face to the remuck and longer feeds on the jumbo to maximize round lengths.

Othersimilar current Projects in Canada include the Red Lake to Cochenour tram drift at Red Lake, Ontario and the Lalor Main Access Decline (now complete) at Snow Lake in Manitoba

In Asia, PT Redpath Indonesia is a mining service provider with over 30 years of providing mining development at PT Freeport Indonesia in West Papua, Indonesia. Redpath’s current scope of work covers the development of all main accesses, levels, fix facilities, ventilation drills and ore flow system for the Grasberg Block Cave Mine and Deep Mill Ore Zone Mine, (GBC & DMLZ). The target production for both mines is 160,000 t/d for GBC and 80,000 t/d for DMLZ. With over 1,000 employees, Redpath delivers annually 50km of tunneling, mass excavation development and 5km each of raiseboring and mechanised raise development.

Lateral development heading sizes can go up to 7 m wide x 7 m high, while larger dimensions are considered mass excavation development. Most of these mass excavations belong to the ore flow system and fixed facilities; they are comprised of lateral development, chamber excavation and vertical development. These mass excavations are critical for the handling and treatment of the crushed ore to deliver it to the mill.

Underground handheld drills

The new Atlas Copco HRD100 hydraulic underground handheld rock drill-system is one of the most powerful underground handheld rock drills on the market, according to the company. The smart power pack monitors all vital functions and can compensate for pressure changes automatically.

“The crucial benefit of the HRD100 has an outstanding drill rate and considerable energy efficiency compared to conventional pneumatic or electrical rock drills. Besides being one of the most powerful tools on the market, the HRD100 rock drill is silenced. Measured noise is approximately 50% lower than that of a pneumatic drill.”

The polyurethane cover shields noise and makes the unit shockproof. The unit can handle a drop from two metres. HRD system consists of the rock drill (RD100), the power pack (PP100) and a selection of water pusher legs. All hoses and cables are included.

Quality rock drilling means using just enough water for flushing. The HRD100 features a five-step water adjustment to help the operator use the right amount of water for each step. And when the drilling stops, the flow stops automatically. There is still the ability to force in water to flush out the drill if jammed.

“We really made an effort to provide high drill rates at low operational cost. But it is equally important to create a system that save the operators energy by being light and reliable”, says Oleg Korobotchkine, Product Line Manager.

User-centric design is at the core of the HRD-system. “One example is the soft start function that makes collaring especially easy. Another is the replaceable rotation chuck, which saves service time. Working underground is hard work, but thanks to one-handed operation and carrying handles, the HRD-system makes it easier.”

The stackable PP100 power pack basically manages itself. Smart functions monitor oil flow and oil temperature. Water-cooling and automatic heat protection means safety and reliability are at its core. The system also monitors oil volume and compensates for pressure differences. That allows you to work with the PP100 at a 45° angle, without power loss. Simple tools make it easy to top-up hydraulic oil in the mine.

To minimise waste, the water used for cooling and flushing also powers the pusher legs. The legs are suited for narrow mining and are made for rough use. The teeth are made from tungsten carbide steel, which is much stronger and harder than steel.
include either one tunnel plan or several different plans,” he says.

Pule adds that a tunnel plan, in turn, combines a curve table, tunnel profiles, drill plans, lasers and data collection files, all of which can be controlled separately. iSure uses information relating to explosive power and explosive charging requirements for the different parts of the tunnel cross-section to be entered into the system. It also requires information relating to weight and power of explosives, as well as the depth of fracture, to enable users to visualise the outcome during the preparation of the pattern.

Users have access to four modules which includes iSure Tunnel for drill and blast design, drilling pattern design, long hole pattern, tunnel line and project files. iSure Bolting provides designs of up to five bolting fans, hole placement and direction, tools for hole generation and fan management, while iSure Report provides the necessary drilling management and process developments required on site. iSure Analysis is used more holistically for measures of drilling data collection and analysis of rock structures and characteristics.

“Currently, we have introduced iSure into our 400-series mining jumbos including the DD421-60C drill rig, which provides operators with data relating to their own tunnel developments. It also allows them to view blasting outcomes and make adjustments as required to ensure the best possible pull out. It has already been released in South Korea, Switzerland and Sweden and results prove that marked improvements in tunnelling performance are being achieved.”

Sandvik believes that the new technology marks a distinct leap from manual procedures to effectively need to step outside of their comfort-zones and move away from known practices.

“For this reason we are facilitating change management throughout the industry to facilitate acceptance of technology among managers and miners at the mine face. In fact, we are already working to identify technical individuals to undergo operational training on the new software (as well as the DD421 60C). We are also working more closely with drillmasters and blasting engineers wherever the technology is being adopted and have already sent five technical personnel from local mines to Finland for training to gain experience and master the iSure system. Technology like this truly has the ability to transform the industry and we believe it is our duty to ensure local mines adopt and embrace technology in order to remain competitive on the global stage.”

Boxholes and shafts

Moving on to news on vertical developments, Mancala’s need for a more efficient and a safer method of boxhole excavation led to the development of the first Mechanised Vertical Miner (MVM1100), which was covered in the IM July 2014 issue. The prototype, built in conjunction with specialist tunnel boring manufacturer Herrenknecht, was first commissioned at Cadia East and fulfilled its benchmark aim of completing 16 m x 1.1 m slots in under 24 hours on a consistent basis. Since then it has also performed well as two subsequent customer sites, namely to the Perilya zinc/lead/silver mine at Broken Hill then to the Frog’s Leg gold mine near Kalgoorlie.

Detailed analysis of operational and maintenance parameters from the first 100 holes was used to specify design changes for the next two second generation MVM1100s in Mancala’s fleet. The improvements have focused on fine tuning the machine’s mobility and reducing the need for manual handling. Redesigning the rig tilting cylinders and adding a 20 m trailing cable to the power pack has also led to reduced operator handling and shorter rigging times. Upgrading the track frame and installing more rollers has better distributed the machine’s weight reducing tramming times. There is increased crawler stability and ground clearance at the front and the rear of the unit. Other major modifications from the prototype include automation of the coupling of the jacking pipes eliminated the need for personnel access via platforms. Controls and maintenance points on the thrust frame and the crawler were moved so they could be accessed from ground level, while the umbilical controls have been replaced with wireless controls. Over 100 changes were implemented to improve maintenance management and daily servicing and a higher level of electronic control and monitoring introduced as a step towards full automation in future machines. Finally, a new cutter head with centrally placed conical cutters and targeted water flushing has improved cutter clearance, reduced wear and lowers consumable cost per metre.

All new machines have teething problems and Mancala admits that it underestimated the ferocity of the Western Australian salt. It initially played havoc with the sophisticated electrical upgrade and resulted in poor availability. When the machine was drilling it was breaking records, but low availability was the limiting factor.

Mancala has reengineered the protection of the electrics and now has good availability and excellent drilling times. The company has just completed a three month campaign at the Glencore Lady Loretta zinc mine in Queensland, which includes 26 holes for a total of 506 m. The...
The new machines represent a quantum leap in productivity and safety. The cost benefits run right through the stoping cycle, with less slot failures. Key issues of dilution and ore loss are reduced. The mine is no longer overcharging holes, and there is no foot wall or hanging wall damage at start of the stoping cycle.

Herrenknecht has developed a next generation of the rodless shaft enlargement machines that have been established on the market for decades as so-called V-Mole technology. Herrenknecht told *IM* that it worked closely together Thyssen Schachtbau and Murray & Roberts Cementation, to update and adapt the technology to current conditions and requirements. The result is the SBE (Shaft Boring Machine for Shaft Enlargement). It facilitates high sinking speeds and maximum working safety for shaft boring using the pilot borehole.

With the newly developed shaft enlargement machine, Herrenknecht offers a modern version of shaft boring machines that complies with the highest standards of efficiency, safety and reliability. With this new generation machine, shaft boring diameters of up to 9.5 m can be realised under optimum conditions in hard rock. The machine concept allows significantly higher sinking speeds compared to earlier shaft boring generations. It is robustly designed to handle the tough working conditions found in sinking of shafts. Qualified personnel can easily operate the system.

The SBE basically works like modern hard rock TBMs, but vertically. Advance and primary shaft lining are carried out simultaneously. With the help of laterally extendable hydraulic cylinders the 15 m high and 350 t machine braces itself before every drilling stroke in the shaft steadying the machine, allowing the thrust cylinders to push the rotating cutterhead against the borehole floor. Hydraulic cylinders ensure precise vertical alignment of the shaft boring machine to the target axis. This is constantly transmitted to the machine operator by a laser aiming device.

The rotating anchor platform is located on the drilling deck above the cutterhead. From there, anchors and steel mesh can be put in place by two powerful hydraulic drill rigs. If required, a shotcrete unit on the shaft boring machine secures the shaft wall immediately after exposure of the rock outcrop. The machine operator controls all operations safely and conveniently from the interior of the machine. The sinking of a shaft with the new SBE occurs in three phases.

First a pilot hole is created from the top downwards, which sets the vertical target axis. Once at the bottom, workers in the cavern replace the drill bit with a reamer, which then enlarges the pilot hole from bottom to top until the pilot borehole diameter is reached. The muck is continuously loaded at the foot of the borehole and transported away. Thereafter, the shaft boring machine enlarges the pilot borehole from top to bottom to the final diameter and installs the primary lining of the shaft in parallel. The shaft depth is only limited by the technically feasible length of the pilot borehole.

With the SBE shaft boring technology using the pilot borehole the shaft sinking time is reduced by 20% to 30% compared to conventional shaft sinking technology.

The high precision in terms of verticality and circular shape of the shaft cross-section as well as the virtually vibration-free ground treatment are further advantages of the shaft boring technology compared to the conventional shaft sinking method with drilling and blasting or, alternatively, in comparison to other mechanical methods. The sinking cycle runs continuously and is not interrupted by drill and blast times or dispersal of explosion gases. The new Shaft Boring Technology not only boasts high levels of efficiency but also that of greater levels of safety and ergonomic working conditions. *IM*