GeoDrilling International

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Mineral-exploration companies are in need of new technologies to boost drilling efficiency and ease decision-making

Coal-bed methane drilling
Industry experts discuss the techniques and equipment used for coal-bed methane extraction

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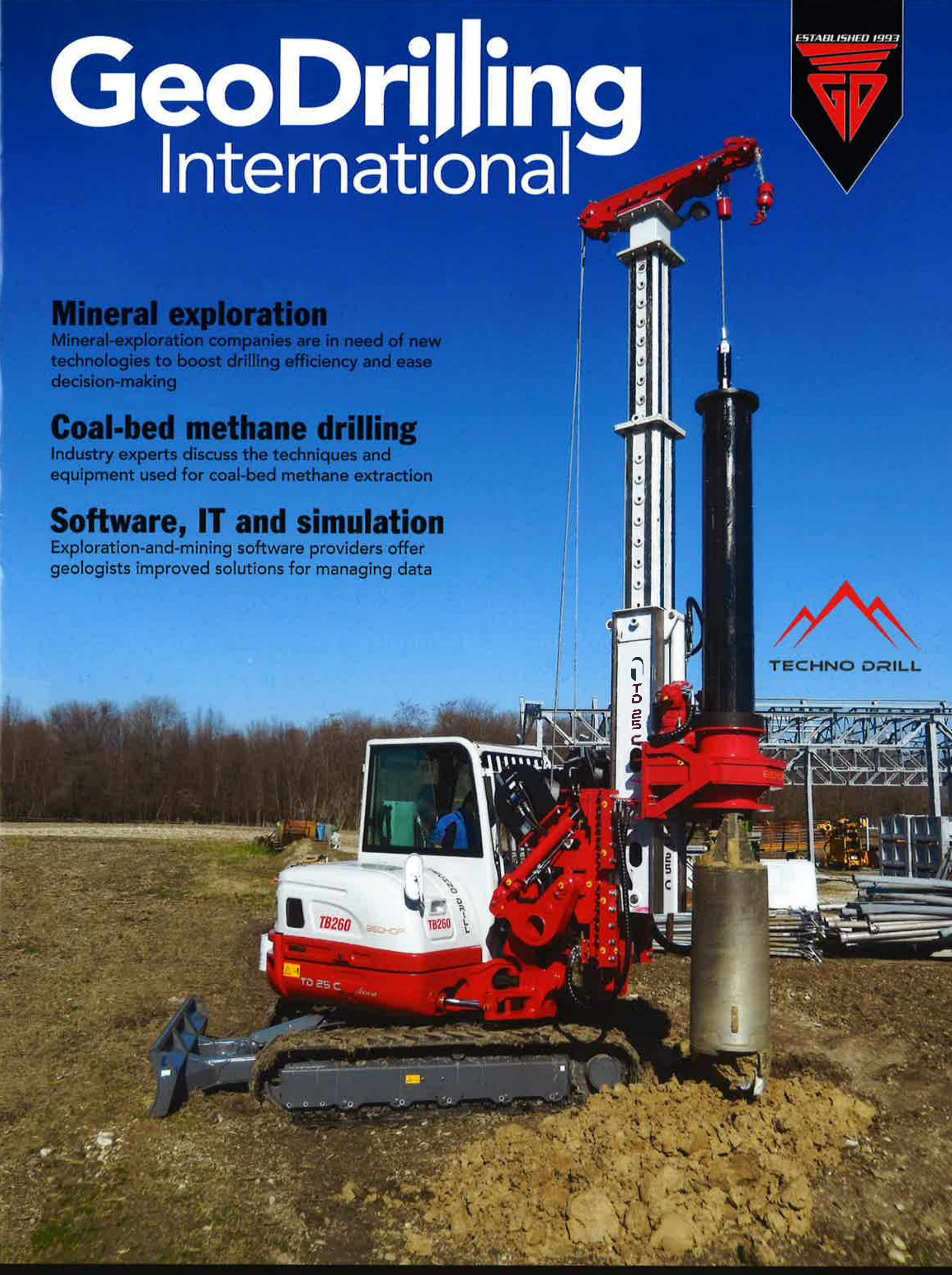

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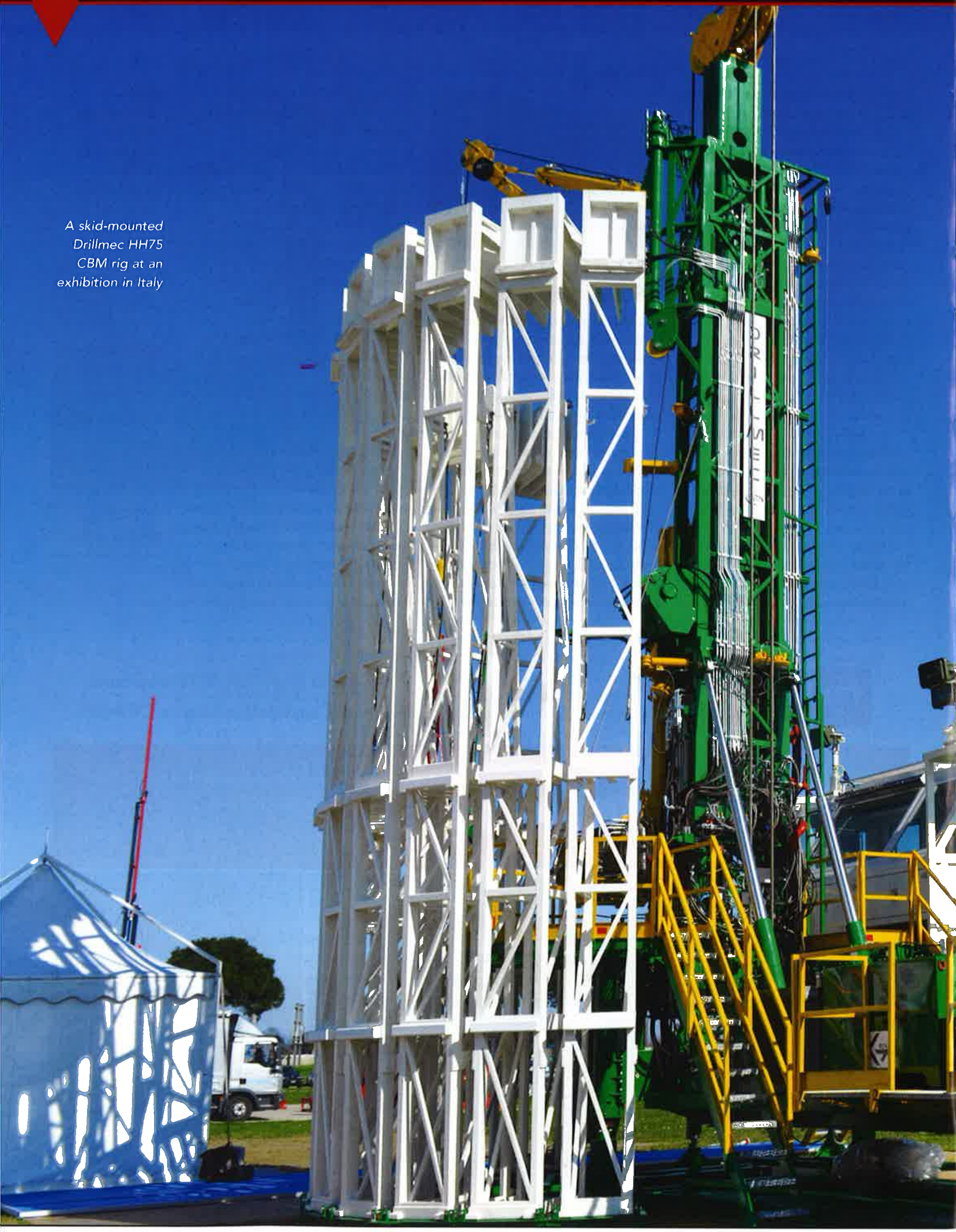

A skid-mounted Drillmec HH75 CBM rig at an exhibition in Italy

Drilling down into the coal bed

GeoDrilling International talks to industry experts about coal-bed methane development, as well as the methods and equipment used for its extraction

Coal-bed methane (CBM) is often grouped together with tight gas and shale gas under the umbrella term of unconventional gas sources.

This refers to the fact that conventional gas usually resides in permeable reservoirs and can be extracted fairly easily by traditional well-drilling methods. CBM, on the other hand, is a gas contained within coal seams and held in an adsorbed state within the molecular framework of the coal; whereas shale gas and tight gas exist in sedimentary rock with low permeability.

CBM is generated through a process called coalification – either a biological (microbial action) or thermal process (increasing temperature and pressure) – which produces large amounts of methane. The gas is then stored in natural fractures called cleats, which are usually filled with water.

Jack Pashin, professor and Devon chair of basin research at Boone Pickens School of Geology, Oklahoma State University, describes in what circumstances CBM can be recovered: "Adsorption capacity increases with reservoir pressure, and so the objective of CBM production is to lower reservoir pressure below the saturation point of the coal. This is accomplished by dewatering the coal.

"And to facilitate commercial flow rates of gas and water, the coal must contain abundant open cleats. Accordingly, two fundamental ingredients of a commercial CBM reservoir are high gas content and a sufficiently permeable cleat system to support commercial flow rates.

"Although coal is present throughout much of the world, it requires careful prospecting to identify the areas with these fundamental ingredients."

Commercial CBM production has been realised around the world and from all ranks of coal – from subbituminous coal seams in the Powder River Basin, US, to anthracite seams in China, and Australia is known as a pioneering country in extracting CBM.

Jonathan Kelafant, a senior vice-president with Advanced Resource Enterprises, clarifies: "While there is some difference in nomenclature between countries, CBM production is generally considered the production of methane contained within unmined virgin coal seams.

"When methane in the coal seam is produced in conjunction with mining operations, it is generally referred to as coal-mine methane (CMM). CMM can be produced in a number of ways depending on the type of mine and local geologic conditions. Production methods include gob wells, in-mine horizontal wells and cross-measure boreholes." ►

EXTRACTION METHODS

Initially, CBM was developed and recovered by mining methods, but since then drilling technology has become a reliable method for its extraction. There are two main methods for extracting CBM: vertical, hydraulically stimulated wells and directionally drilled in-mine boreholes.

Kelafant explains that for vertical wells the technology is essentially the same as conventional gas extraction, with the main difference being in the production operations, as optimum CBM production requires that reservoir pressure is lowered to near atmospheric pressure, which requires the use of artificial lift to remove the water in the coal seam.

This is in contrast to conventional gas production where reservoir pressure is kept high to maintain production. This gives rise to different production profiles for CBM and conventional gas: in conventional extraction the production rate starts at a maximum and initially there is little to no water production. In CBM extraction, initially mostly water is produced and the gas production rate increases over time before reaching a decline stage.

"Most CBM operations are built around water production and management, since many commercial reservoirs produce around 1 barrel (119L) of water per 1,000 standard cubic feet (1MMBtu) of gas. Vertical well construction differs from most other reservoirs in that water is produced through a tubing string (2⅜in/60mm in the US), and gas is produced through the annulus between tubing and casing (generally 5-8in (127-203mm) casing).

"Most wells are fractured hydraulically, with fluids ranging from slickwater to nitrogen foam and with a sand proppant. Where multiple seams are present, such as in the Appalachian region, wells are hydrofractured in multiple stages depending on where and how coal seams are clustered," adds Pashin.

"Initially, CBM was developed and recovered by mining methods, but since then drilling technology has become a reliable method for extraction"

A variety of directional and horizontal drilling technologies have been deployed by the CBM industry in areas that are not immediately prospective for coal mining. Pashin tells *GDI* that the most innovative of these technologies is the pinnate horizontal well, which was developed by CDX Gas to produce permeable coal seams.

"The wells have a central horizontal trunk and numerous branches that facilitate recovery of up to 85% of the original gas in

A front view of the Drillmec HH75 rig working with the blowout preventer (BOP) installed

Comparison: conventional v unconventional

Greka Drilling explains the differences in extraction methods:

Conventional gas
Deep wells are drilled to depth of conventional gas reservoirs that may be at 4,000-5,000m below ground level.
Due to the greater depths, the well design, completion design and production strategy may be complex.
Dewatering of gas reservoir is undesirable (water coning) and, if it occurs, is a downhole production problem.
Hydrofracturing is used as a secondary recovery method.
Drilling, if performed with uncontrolled bottomhole pressure, might result in gas influx in wellbore. Hence, well control is mandatory to prevent blowouts, including primary control by drilling fluids, secondary control by circulating out undesirable gas kicks, and tertiary control by closing and sealing the annulus via BOP rams.

place. These types of wells have been extremely successful in the Pocahontas no. 3 seam of the Appalachian Basin in Virginia, US, where low permeability limits the ability to produce from vertical wells," he says.

"Horizontal wells with long lateral displacement are often used to expose long seams. Although popular, horizontal wells demand much higher budgets and are more technically challenging, especially in an undulating seam," adds Ian Hatchell, vice-president of operations at Radial Drilling Services.

EQUIPMENT AND TECHNOLOGY

Equipment involved in the drilling of wells for the development of CBM is similar to that utilised in conventional oil and gas development. "Almost any type of rig or bit can be used," Pashin explains. "Ideally, air rigs are preferred in many basins because wells can be drilled rapidly and because they minimise formation damage. To me, this is a critical concern in CBM development, because drilling can generate abundant coal fines that can plug cleats if fluid moves into the formation.

"For this reason, many developers deploy underbalanced drilling technologies so that the amount of fluid carrying fines into the formation is minimised or, preferably, fluid will flow out of the formation during drilling."

While CBM and oilfield equipment are essentially the same, how it is deployed is often different. One of the main differences is the fact that CBM wells are usually drilled using air or air/mist systems, whereas conventional gas wells often need to employ a mud system to control blowouts encountered in overpressured zones. Unconventional gas-drilling company Greta Drilling, however, uses drilling fluid – polymer with water – to prevent subsurface mud loss.

"Rigs using compressed air typically require a compressor package consisting of a rig compressor, auxiliary compressor and a booster. The sizing of the compressor package depends on the rate of circulation needed to clean the hole while drilling and the type of rig," says Kelafant.

He adds that another difference is hydraulic fracturing; due to the low permeability of coal seams, virtually all CBM wells require stimulation, generally hydraulic stimulation, in contrast to many conventional reservoirs that have high permeability.

And a third area where CBM wells differ from conventional wells is artificial lift. Most CBM wells are placed on artificial lift soon after they are completed in order to remove the water from the coal seams. Conversely, conventional gas wells generally do not install artificial lift until late in the productive life as gas rates drop and the wells 'water out'.

"The dewatering and artificial lift aspects of CBM wells can be the most challenging part of CBM development, as the equipment needs to be able to handle the initially high volumes of water production, along with the production of coal fines and sand," Kelafant clarifies.

Pashin comments: "Many types of drilling setups are used to make ►

"The dewatering and artificial lift aspects of CBM wells can be the most challenging part of development"

Unconventional gas
Shallow wells are drilled to coal beds that may be at a maximum depth of 2,000m.
Due to shallow depths, the well design, completion design and production strategy are simpler.
Dewatering of coal seam is a primary recovery process (well activation) for CBM production.
Hydrofracturing is a primary recovery method.
Well control is a precautionary measure to divert pressured subsurface fluid out of the wellbore.

A long-hole directional drill used for in-mine CMM development
Photo: REI Drilling

horizontal and pinnate wells, many of which are not cased at reservoir depth. Two critical concerns exist when drilling these types of wells: keeping the bit in the coal seam and avoiding borehole collapse. Measurement-while-drilling (MWD) technology helps ensure that wells stay in zone. To avoid borehole collapse and the associated problems, the coal must have good mechanical integrity – this is why not every coal seam is prospective for directional drilling."

"Due to the shallow depths of CBM wells, a lower rig capacity is needed than for conventional land rigs"

Due to the shallow depths of CBM wells, a lower rig capacity is needed than for conventional land rigs, and they should be of sufficient hook-load capacity to overcome downhole issues in coal seams (such as stuck-pipe due to fluid loss and coal collapse).

Greka Drilling has a fleet of GD75 rigs, which provide a hook-load capacity of 75t, while having a minimal footprint on ground. These rigs are purpose-built in Italy by Greka Drilling's partner Drillmec, which works alongside the company's own engineers to ensure that the equipment meets the expected high standards. The rigs are designed to overcome downhole issues occurring due to coal complexity and can drill up to 1,700m vertical depths or 2,200m in lateral wells.

According to Greka, automated rigs reduce man hours and time consumed in various drilling activities. The unconventional GD75 rig allows Greka to use conventional a bottom-hole assembly (BHA) for CBM drilling. In general, tri-cone and PDC bits are used in CBM extraction methods.

The sale of 25 CBM rigs to Greka Drilling in 2011 was a remarkable record for Drillmec, which offers a series of machines for CBM. They range from 55t to 100t (450hp to 600hp).

Stefano Angeli, vice-president of sales for Drillmec, explains that the rigs usually have low rig-floor height to enable the installation of an entry blowout preventer and simple pipe-handling system to minimise the cost and rig moving time. "Great attention is paid to the control system and the data management. Our rigs are also available in fully cyber-digital control with remote access to view the parameters from any location," he adds.

When it comes to complex and unstable coal-bed formations, specialised downhole directional drilling equipment is required, and Greka says it offers its custom-made directional services to cater to the needs of CBM operators.

The company uses its in-house rotating-magnet ranging systems (RMRS) technology in lined faulted brittle coal (LiFaBriC) well intersects. Greka's MWD/LWD technologies can help the directional driller to stay in the zone while being aware of the formations being encountered and their behaviour.

Radial Drilling Services says it performs all its services in an existing well, using its radial drilling technology. "This well can be vertical – no need for an expensive horizontal well. The RDS deflector is run into the existing well bore on production tubing. We then run inside the production tubing with a downhole motor and a mill bit and make a hole in the casing. After this, we pull out of the tubing, change the BHA from the motor and mill bit to a rotary nozzle and run back through the tubing to the hole and make a 100mx50mm hole into the coal," explains Hatchell.

The company has completed several CBM projects around the world, where it has entered vertically drilled wells that penetrate several coal seams at different depths. It has then utilised the RDS technology to place multiple 50mm OD laterals into the coal seam of 100m in length.

The sequence is normally two or four 100m laterals on one horizon (or in one seam), with upwards of 50 laterals in one vertical well. Multi-lateral projects have been completed for BG/Queensland Gas in Australia, BP in the US and Trisula in Indonesia.

FACING CHALLENGES

Some of the main challenges related to CBM drilling include geological and operational issues such as formation damage and water management.

Coal seams are very susceptible to damage because their cleat systems can be invaded by mud, which reduces the in-situ permeability of the coal and lowers productivity. To minimise this, many operators drill their wells using air for circulation.

Kelafant notes: "One must also be careful to minimise formation damage during cementing operations. For cementing operations, operators generally use a lightweight cement pumped in two stages to minimise the weight of the cement column against the coal seam.

"In cases where drilling fluid and cement do infiltrate the coal cleat system and cause formation damage, the subsequent hydraulic fracturing operations typically reverse the formation damage."

From an operational standpoint, dewatering and pumping operations usually present the biggest challenges. Sand flowback from the hydraulic fracturing operations and coal fines are the biggest problems faced during the start-up of dewatering, because they can clog or destroy downhole pumps. Therefore, operators will run the pumps at relatively slow speeds initially to prevent the migration of sand and coal fines.

Pashin adds: "For most operations, I would say that produced-water management is the principal challenge. Where subsurface disposal of produced water is possible, these concerns are minimal, provided the disposal zone has adequate capacity and the cost of drilling and operating disposal wells is controlled.

"In the Powder River Basin of Wyoming and the Black Warrior Basin of Alabama, however, no adequate subsurface disposal zones have been identified, and so the produced water is disposed of in streams. In these cases, producers need to operate significant water-processing facilities to minimise the environmental impact of water disposal.

"The industry has, in my opinion, managed in-stream disposal well through the years. For example, operators in the Black Warrior Basin maintained a river-monitoring system for many years that demonstrated that chloride concentration never approached the allowables defined by toxicity testing."

CBM wells also produce a lower gas rate than conventional gas reservoirs. "In general times of crisis, as we are now, the focus is to have reliable machines that move fast from one well to another. Several wells can be drilled in the same location to make the project economical and viable," Angeli argues.

ENVIRONMENT AND SAFETY

The environmental and safety concerns related to CBM drilling are largely the same as for any other drilling project. CBM operators have to follow the same kind of water and air guidelines and regulations that apply to any typical oil and gas production operation.

Potential environmental impacts from CBM drilling could come from construction of roads and pad sites and production operations. "The impacts related to construction generate the most visible environmental impacts," mentions Kelafant. ►

Greka Drilling has a fleet of purpose-built GD75 rigs

A Drillmec HH75 ► CBM rig in use in Indonesia

"Construction activities can affect the aesthetics of a given environment through the clear cutting of vegetation, exhaust from heavy machinery and drilling rigs and noise. The majority of these environmental concerns are relatively short-lived as they are mostly confined to the 1-2 week period during the drilling of the well."

"Perhaps one of the biggest environmental concerns associated with CBM production is the water generated by the operation"

Perhaps one of the biggest environmental concerns associated with CBM production is the water generated by the operation. It is important to take care of this valuable resource by utilising it again, treating it properly or evaporating it.

"The impacts can be mitigated in a number of ways, depending on the quality of the produced water. If the water is relatively fresh, it can be disposed of in rivers or other surface bodies of water after minimal treatment.

"If the water is not suitable for surface discharge, a number of options exist for its disposal including underground injection, evaporation and reverse osmosis. The produced water can even be reused for various purposes such as hydraulic fracturing or agriculture once treated," Kelafant continues.

"On the environmental side, methane is a potent greenhouse gas that has 23 times the global-warming potential of carbon dioxide. Methane released by coal mining contributes 8-10% of anthropogenic methane emissions worldwide.

"As the coal-mining sector looks to reduce its environmental impact, CBM/CMM recovery and utilisation offers a cost-effective way to reduce the amount of methane released to the atmosphere during mining that would otherwise be vented to the atmosphere."

Greka Drilling possesses specialised mud-engineering systems to avoid surface spillage and seepage losses. The company has a lithium battery disposal policy of its own and, to prevent unexpected blowouts, GD75 rigs are installed with rotating diverters, which work as the well-control system.

Working with drilling rigs naturally involves many safety concerns for the crew. However, the GD75 offers a completely automated system that minimises the need for manual operations, thereby reducing the risk of work-related incidents.

All drill-floor operations are handled by the driller from within the driller's console, which means no crew member is working directly on the drill floor; this also reduces the risk of accidents.

NEXT STEP

According to Kelafant, two areas that the CBM industry is exploring to improve gas recovery are enhanced coal-bed methane recovery (ECBM) and improved hydraulic fracturing. When utilising ECBM, CO_2 or N_2 is injected into the CBM reservoir to help displace methane from the coal matrix. There have been several successful pilot projects in the US and international projects are under consideration in China and India. ECBM has the potential to increase CBM productivity, as well as the potential to sequester large volumes of CO_2.

"Improved hydraulic fracturing techniques have been a major emphasis in CBM development as well: for example, Range Resources in southwest Virginia has increased production 2-3 fold by redesigning its fracture treatments and pumping at higher rates," Kelafant adds.

"Further improvements in hydraulic fracture design and implementation may also open up previously avoided low-permeability coal fields such as the Pennsylvania anthracite fields, just as hydraulic fracturing opened up the ability to economically produce gas-shale formations."

CBM continues to broaden its reach around the world, and every new region presents a new set of challenges for development, which means operations have to be tailored to meet them.

Pashin comments: "Indeed, the conceptual models that drove early development in the San Juan and Black Warrior basins had to be modified substantially when the Powder River Basin came on line. The same has been true in Australia, where the composition and physical properties of the coal differ substantially from those in North America.

"I think a lot of technological advancement will come in our ability to drill and complete directional wells in coal. The precision of directional drilling is increasing greatly, and it is now possible to keep wells in coal seams approaching 1m in thickness.

"Development of technologies that can access multiple coal seams and increasingly thinner coal seams has the potential to add significantly to the world's CBM reserve base."

Greka Drilling says its research-and-development team is committed to overcoming industry issues such as capital expenditure, serious environmental challenges (hydrofracturing etc.) and complex geology. It is also dedicated to developing LiFaBriC technology and its implementation for different environments and requirements.

"LiFaBriC provides a reliable and economic solution to the development and commercialisation of the CBM assets. It is an adaptation of the horizontal drilling methods traditionally used for drilling in coal-seam reservoirs and is designed to provide a precise and high-quality completions technique," confirms Randeep Grewal, Greka Drilling's chief executive.

"We are confident that CBM will remain an interesting opportunity. Due to the low margin, we think the next step and challenge will be to increase the technological content as far as both the upstream and downstream sides are concerned. Doing so, oil companies can be able to reduce the initial investment and minimise the break-even barrier point," concludes Angeli. ▼

CBM project: West Bengal, India

Essar Oil is currently conducting a large CBM project in the East Raniganj coalfield, located in West Bengal, India. The project covers a 500km^2 area and is designed to exploit a CBM resource estimated to be 2.15 trillion cubic feet (2.2 quadrillion Btu).

The focus of the project is to extract high-quality CBM, perform any necessary processing, including compression for pipeline use, and then sell the gas to the recently built Matix fertiliser plant. The project initially began with planning followed by data acquisition, processing and interpretation.

The first phase of the project was the exploratory phase, consisting of 17 core holes and 15 production test wells. Based on the positive data obtained during the exploration phase, a pilot well-assessment phase consisting of 75 production wells was implemented. After the pilot assessment phase determined that the project was commercially viable, the project moved to the on-going development phase consisting of 500 wells.

The project employs vertical wells in combination with directionally drilled wells. Artificial lift systems consisting of progressive cavity pumps to maximise production are used for dewatering.

Recently, measures have been taken to enhance production. These measures include drilling multiple wells from a single well pad and upsizing pumps to accelerate dewatering.

Essar is also looking at the potential of incorporating new enhanced coal-bed methane recovery (ECBM) techniques by injecting CO_2 or N_2 to further increase CBM recovery.