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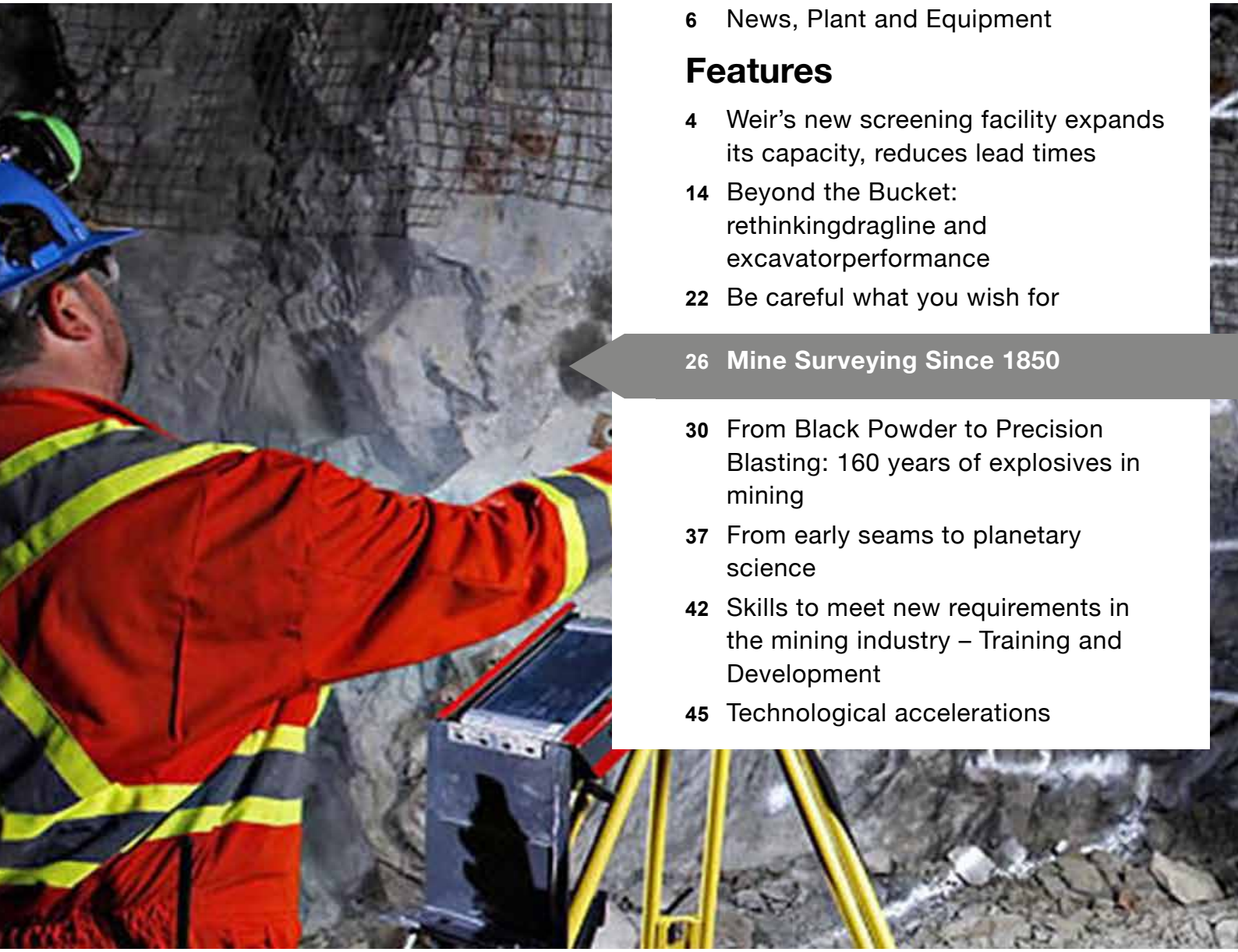

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Weir's new screening facility expands its capacity, reduces lead times

A fully assembled ENDURON Elite double-deck banana screen, designed to deliver higher throughputs from lower-grade ores.

The global demand for the metals needed for the renewable energy transition is driving many mining companies worldwide to expand mineral extraction at existing mines. At the same time, the rate at which new mines are coming online has slowed. According to S&P Global, the 'average lead time for mines continues to rise, reaching 17.8 years for those that became operational between 2020 and 2024. This duration is nearly three times longer than the lead time for mines that began operations from 1990 to 1999.'

From a minerals processing perspective, there is pressure on mining companies to make maximum use of their resource. In many instances, they are now processing lower grade material that they would have overlooked, say, twenty years ago. But they no longer have that luxury.

As a result, many mining companies are increasing their throughputs to meet this demand, which is driving a trend towards larger, higher capacity equipment. This was one of the reasons Weir expanded its range of ENDURON® screens.

Notably, its ENDURON® Elite screen is a large, double deck banana screen, available in a range of sizes with the largest weighing in at close to 50 tonnes and a deck measuring 4.3m x 8.5m.

Since its release in late 2024, demand for the screens has meant that Weir has now also upgraded its screen manufacturing facility in Alrode, South Africa. The expansion adds a further 1,600m² of dedicated, under-roof production space; the facility is equipped with two 63-ton gantry cranes operating at a clearance height of 18.5m.

Large industrial manufacturing environments are high-risk settings, particularly at this scale. Weir has prioritised safety as part of the upgrade. There are no mobile cranes and, because the facility has been purpose-built, there isn't any unnecessary handling required throughout the assembly process.

For instance, when the screen is ready to be shipped, there is enough clearance for the truck to drive into the facility, the screen is then lifted from the test back onto the back of the truck in a single lift, it's secured and the truck drives out.

There are also two hydraulically operated scissor lifts that streamline assembly and help ensure the cross beams, which can be up to 4.3m long, are correctly aligned during assembly.

There is sometimes a misapprehension that screens are put together without any accuracy or finesse, but that couldn't be any further from the truth, particularly when it comes to the largest screens on the market.

In reality, these are enormous machines with very tight tolerances. Because screens vibrate from the moment they're turned on, OEMs must have strict assembly guidelines and processes.

Weir's upgraded facility has significantly strengthened its screen manufacturing and assembly capabilities, allowing it to reduce lead times and expand its capacity.

Since Weir was awarded a £53 million contract to provide a transformational flowsheet for Barrick Gold's Reko Diq copper-gold project in Baluchistan Province, Pakistan, which includes twelve 4.27 m x 8.54 m double deck ENDURON® Elite banana screens, there has been growing interest in how these machines can help miners deliver their critical products for large greenfield and brownfield expansion projects.

Indeed, there has even been interest, particularly from EPCs, about the possibility of manufacturing larger, higher capacity banana screens than are currently available. This is part of Weir's technology roadmap and the Alrode facility has been designed with this in mind.

One of the reasons that Weir's ENDURON® Elite screens have been so well received by the market has to do with their exciter design. Unlike other screens of comparable size on the market, the ENDURON® Elite screens are driven by just two exciters, whereas all other OEM screens require three.

This simplifies the mechanical design and reduces the number of components requiring maintenance. The ETX exciters are mounted close to the side-plates to minimise deflection. Crucially, Weir's design eliminates the point load in the middle of the beam, which lowers the stress on the side-plate interface.

This exciter design extends the screens' service life and reduces structural complexity, which means lower maintenance costs, fewer spare parts and improved equipment availability. Take Reko Diq's twelve ENDURON® Elite screens as a case in point. Its maintenance personnel have to maintain, service and manage the inventory for 24 exciters, but if it had competitor screens installed it would be 36 exciters.

Reducing the number of exciters is an effective way of lowering operating costs. At a time when input costs are rising – inflationary pressures, higher fuel and electricity prices, labour shortages, etc. – many operators are looking to improve the efficiency of their operations without compromising the production of metals required for the energy transition. And large, high capacity screens are playing an increasingly important part in overcoming these challenges.

AUTHOR
Corné Kleyn
Weir, Global Product Manager – Vibrating Equipment

The ENDURON Elite's two-exciter drive design reduces mechanical complexity, maintenance demands and operating costs.

Large-format ENDURON Elite screen at Weir's expanded Alrode facility, supporting faster delivery of high-capacity screening equipment.

ENDURON Elite screen during assembly, engineered for durability, precision and long service life in demanding mining applications.

Fortescue campaign aims to cap diesel tax handouts for mining majors

Fortescue is launching a national advertising campaign calling for a reform of the Australian government's diesel tax handout, which is "delivering excessive benefits to a small number of large mining companies at the expense of a fairer and more secure energy system for Australians".

The campaign would roll out in Australia in April 2026.

Fortescue, itself being one of the largest recipients of fuel tax credits, is calling for the introduction of a $50-million yearly cap for each company, arguing that reform is both fair and economically responsible.

Fortescue metals and operations CEO Dino Otranto notes that the current system had drifted far from its original intent.

"We have made our position clear directly to government, but this issue goes beyond industry – it affects every Australian taxpayer.

"That's why we are taking this campaign to the public. Australians deserve to understand that billions of dollars are being paid out each year in a diesel tax handout to a small number of very large companies," Otranto says.

This campaign highlights the imbalance at the heart of the current policy, contrasting the cost-of-living pressures faced by everyday Australians with the "billion of dollars" in tax credits flowing to Australia's mining industry.

The advertisements are centred on a nurse struggling to pay her household bills, drawing a direct comparison between suffering Australians and large companies receiving billions in diesel tax credits.

Further, the campaign focuses on Australia's largest mining companies, which receive a significant share of an estimated $11-billion returned to businesses each year under the Australian Fuel Tax Credit Act, effectively subsidising the use of imported diesel.

Otranto says that the diesel tax handout should primarily focus on supporting essential industries as opposed to delivering outsized benefits to large mining companies.

At present, he says that this money could be well used to lower energy costs for households and businesses.

"At a time when families are cutting back and small businesses are doing it tough, it is reasonable to ask whether this is the best use of taxpayer money. Instead, it is being handed back to a small number of large companies to keep diesel cheap," Otranto says.

Meanwhile, households and small businesses will return to paying fuel excise in full when the government's temporary halving of the excise ends on June 30.

Analysis by think-tank Climate Energy Finance reveals the 18 largest mining companies received $3-billion in fuel tax credits in 2024/25. However, a $50-million market cap would have delivered estimated budget savings of $2-billion – with savings expected to grow significantly over time.

Otranto also notes that Australia has made itself dangerously reliant on imported diesel, leaving its economy exposed to global shocks and supply disruptions.

He says that while the Australian government has adopted several good policies that support energy security, they have also inherited a deficient policy that will get worse the longer it is left unchecked.

This leaves Australia more dependent on overseas fuel amid the current geopolitical tensions.

"It makes no sense to keep subsidising that dependence. Capping that diesel tax handout is a practical step toward restoring energy security and building a fairer, more resilient, self-reliant system," Otranto states.

Fortescue is urging the Australian government to consider the reform as part of the upcoming May budget, with savings rather being redirected toward lowering energy costs, easing cost-of-living pressures, essential services and investment in Australia's future energy systems.

USA Rare Earth to acquire Brazilian rare earths miner Serra Verde for $2.8bn

USA Rare Earth will acquire Brazilian rare earths miner Serra Verde for $2.8-billion in cash and shares, the two companies said recently.

The US company will pay $300-million in cash and 126.9-million newly issued shares of its stock for the transaction, which is expected to close in the third quarter of 2026, a statement said.

The Serra Verde project in Minaçu, Brazil, produces neodymium, praseodymium, dysprosium and terbium, which are essential for electric vehicle motors and wind turbines.

As a key, sustainable ionic clay deposit outside Asia, it began production in 2024 with a 25-year mine life and aims to reach 6 500 t/y of oxide production by 2027.

Volt Carbon secures third US patent for dry graphite separation tech

Canada-based science and technology company Volt Carbon Technologies has received a notice of allowance from the US Patent and Trademark Office for a US patent application.

This represents the third patent allowance arising from the company's original filing, establishing a growing patent portfolio that protects Volt Carbon's proprietary dry separation technology and its application across graphite processing and advanced carbon materials.

The continued expansion of Volt Carbon's US patent portfolio strengthens its position as it advances toward the commercial deployment of its dry separation platform, including the development of a scalable demonstration facility designed to validate the technology under commercial conditions.

The patent is expected to be issued following the completion of customary administrative procedures and payment of final fees.

"This third patent allowance strengthens our ability to scale a platform that preserves material value at the source and supports multiple downstream pathways, including high-value applications such as expandable graphite and graphene," Volt Carbon Technologies CEO V-Bond Lee says.

Volt Carbon's dry separation process preserves the crystalline structure of graphite at source, which is considered a critical distinction, given that conventional wet processing can damage the crystalline structure, thereby lowering yield and increasing downstream processing requirements.

By maintaining crystallinity, Volt Carbon's process enables efficient conversion into battery materials, expandable graphite, and graphene, while supporting reduced processing intensity and environmental impact.

Moreover, the water– and chemical-free nature of this process also reduces materials handling and processing time within the facility, supporting improved throughput and operational efficiency.

With this milestone, Volt Carbon continues to establish a defensible foundation for its dry separation platform as it advances toward commercial deployment.

"Our objective is straightforward: demonstrate, commercialise, and move toward cash flow generation," Lee says.

Notably, Lee is the first inventor of all of Volt Carbon's air classifier patent filings and has more than 38 years of product development and engineering management experience, with multiple inventions having been implemented in commercial applications, including granted patents across the automotive and aerospace sectors.

BHP locks in China iron ore pact

After months of negotiations and market uncertainty, BHP has finally locked in a major iron ore supply agreement with the China Mineral Resources Group (CMRG).

The deal secures a crucial pathway into its biggest export market with CMRG who represents 80% of China's steel mills.

Prolonged discussions didn't seem to affect BHP, with it's realised iron ore prices increasing by 2% to $84.91 per wet metric tonnes (wmt) in the March quarter, supported by a strategic shift in product mix towards higher-value ores from Mining Area C and increased lump sales.

"We have concluded iron ore sales contract negotiations with the China Mineral Resources Group," BHP said.

The agreement comes after senior BHP leadership travelled to China for high-level talks, with market data indicating prices for some previously pressured products have since rebounded to multi-month highs.

While the deal takes centre stage, it coincides with strong operational performance in Western Australia. BHP's Western Australia Iron Ore (WAIO) operations produced a record 191 million tonnes (Mt) for the nine months to March.

Output was underpinned by record material mined, improved rail efficiencies and stronger port performance, including gains from the Car Dumper 3 rebuild and optimisation of the rail network.

BHP has maintained its 2025-26 financial year (FY26) production guidance of 251–262Mt (284-296Mt on a 100% basis), with its Pilbara operations continuing to anchor earnings.

The agreement with CMRG reinforces the importance of iron ore to BHP's portfolio, particularly as the division continues to fund growth across various commodities.

Innovation meets implementation at GRX26

Global mining trends are rapidly changing, focusing in on critical minerals, decarbonisation and supply chain resilience, with the sector increasingly turning to ways innovation can create measurable outcomes.

Through helping to deploy artificial intelligence (AI) in exploration to deliver net-zero operations and securing global market access, conversations are shifting to what can be done and implemented at scale.

The Global Resources Innovation Expo (GRX26) will put that shift at the centre of discussion when it returns from May 5–7. Hosted by peak bodies AusIMM and Austmine and endorsed by the Minerals Council of Australia (MCA), the Perth event will bring together leaders from across mining, government, investment and research.

The program sets a clear theme for the three days – competing globally in the critical era – with the line-up reflecting that breadth of ambition.

Former Federal Foreign Minister Julie Bishop will examine the new rules of resource diplomacy in an era defined by critical minerals and strategic competition.

Austrade chief executive officer (CEO) Paul Grimes will address international market access for mining equipment, technology and services (METS) companies, highlighting how companies across the Pacific can benefit from this renewed focus and pivot towards greater collaboration.

These speakers are joined by a cross-section of respected voices, including MCA CEO Tania Constable and Perenti chair Diane Smith-Gander, underscoring the event's intent to bridge policy, technology and operational leadership.

GRX26 features a deliberate bias for action. Collaborative conversations are structured to define practical solutions and make public commitments. Fireside chats invert traditional speaking formats, placing the audience in the driver's seat.

GRX provides an opportunity for mining and METS collaboration. Image: GRX

The GRX Global Open Innovation Colab will see technology developers pitch live, with delegates voting for winning solutions in real-time and partnership discussions unfolding on the floor.

"Innovation is critical to the continued performance and competitiveness of the mining sector," Austmine interim CEO Vanessa Haberland said. "GRX brings together mining and METS companies to showcase technologies and services that are already making an impact in operations today, while also exploring the ideas and partnerships that will shape the next generation of mining solutions.

"Importantly, it provides a forum where the industry can see technology in action, share real operational experiences, and gain a clearer view of what is genuinely delivering value."

This sentiment was echoed by AusIMM CEO Stephen Durkin, who said the event showcases "game-changing leadership, groundbreaking innovations and collaborative thinking needed to supercharge the sector and lay the foundation for growth in a complex, globally competitive environment".

GRX26 focuses on the importance of international collaboration, with delegations arriving from Canada, the Philippines, India, Israel, Peru, Chile and Scandinavia.

"By connecting global markets with Australia's innovation ecosystem, GRX helps strengthen the partnerships needed to advance mining performance and sustainability worldwide," Austmine director international business Dr Robert Trzebski said. "Australia's METS sector plays a critical role in optimising mining operations around the world through technology, best practices and innovation."

That global outlook sets the tone for the event's broader ambition.

"Australia has long been recognised for its mining capability. The next phase of our competitive advantage will be defined by how quickly we translate innovation into scalable outcomes and strengthen our global partnerships," Haberland said.

"GRX26 brings industry together at a time when strategic alignment and decisive action matter more than ever."

Hitachi battery truck trial powers towards 2027 rollout

Hitachi Construction Machinery has advanced its push into mine electrification, showcasing a full battery-powered haul truck at a major African copper operation as it eyes commercial deployment later this decade.

The Hitachi Construction Machinery hosted its "Battery Truck & Electrification Showcase" on April 15 at First Quantum Minerals' Kansanshi copper mine in Zambia, providing customers with a live demonstration of its Full Battery Dump Truck in operation.

The event followed a technological feasibility trial conducted at the same site from June 2024 to August 2025, where the truck operated using overhead trolley lines and existing infrastructure. Close to 30 mining customers from around 25 companies attended the showcase, observing both the truck's performance and charging capabilities, while also inspecting the machine's design.

According to Hitachi Construction Machinery, the Full Battery Dump Truck maintained manoeuvrability and stability without changes to gross vehicle weight or centre of gravity when loaded, with attendees expressing strong expectations around its potential to support both productivity and decarbonisation outcomes.

The feasibility trial, undertaken in partnership with First Quantum, leveraged the miner's experience with trolley truck operations. Zambia's energy mix – with 92% of power sourced from hydropower – provided favourable conditions for testing, enabling the truck to achieve zero CO2 emissions during operations.

Over the course of the trial, the truck travelled more than 4000km along haul roads and transported in excess of 30,000t of material. Hitachi Construction Machinery said the unit also demonstrated improved acceleration and reduced noise levels, while delivering performance in line with its development concept.

The company said the real-world operating data collected at Kansanshi will play a critical role in supporting the truck's commercialisation, which is targeted for the 2027 financial year.

The showcase also highlighted a broader suite of Hitachi Construction Machinery Group technologies, including electric excavators, trolley-enabled diesel trucks and ground engaging tools, alongside digital solutions such as fleet management and analytics platforms.

Hitachi Construction Machinery executive officer and vice president of the mining business unit Hiroshi Kanezawa said the trial marked an important milestone for the company's electrification strategy.

"We are delighted to have successfully completed the technological feasibility trial in partnership with First Quantum and to have showcased the results to many customers," he said.

"The real-world operating data obtained from this technological feasibility trial demonstrates the Full Battery Dump Truck's capability for continuous operation in actual mine sites, enabling us to propose optimal operational plans and trolley line designs.

"We will continue to refine this innovative technology and solutions with a view to commercial deployment in FY2027, contributing to sustainable mining operations by leveraging diverse power sources while achieving zero emissions and greater energy efficiency."

Hitachi Construction Machinery said it will continue to develop the technology through collaboration with partners, positioning battery-electric haulage as a key pathway toward reducing emissions from mining fleets.

Goldman Sachs maintains 2026 copper price, surplus forecasts

Goldman Sachs recently maintained its forecast for the copper price to average $12 650 per metric ton this year and its estimate of a 490,000-ton 2026 surplus for the metal.

However, the bank flagged risks to copper supply from potential sulphuric acid shortages should disruption to shipping through the Strait of Hormuz continue.

The bank said the disruption, combined with China's decision to ban sulphuric acid exports from May 1, could tighten a market critical for copper production.

Sulphur and sulphuric acid are key inputs for solvent extraction and electrowinning, a process that accounts for 17% of global copper supply.

Goldman said the Democratic Republic of the Congo and Chile were the most exposed to disruptions in sulphur flows.

The US-Israel war on Iran has hit the supply of energy goods and other materials, as Iran has effectively blocked the key Strait of Hormuz shipping artery.

President Donald Trump said recently he did not want to extend the current ceasefire and the US military was "raring to go" if negotiations were not successful.

Companies in the DRC still hold two to three months of inventory, but if supply-chain delays extend beyond late May through June, Goldman estimates the country could curtail about 125,000 tons of production in 2026.

That curtailment would be offset by 140,000 tons of lower copper demand from weaker global growth in the bank's adverse scenario.

Separately, China's ban on sulphuric acid exports lasting through the year would put 200,000 tons of Chilean production at risk, equivalent to 1% of global supply, as the country sourced roughly a third of its acid from China in 2025, the bank added.

MMD and CiDi partner to deliver autonomous material handling within the TraxIQ platform

MMD Group Limited ("MMD") has signed a Memorandum of Agreement with CiDi Inc. ("CiDi") to integrate advanced autonomous driving technology within the TraxIQ platform, enabling a new approach to material handling.

Under the agreement, MMD will continue to lead the global commercialisation and deployment of the TraxIQ system. CiDi will provide the autonomous driving hardware and software, including the sensing and compute systems that forms part of the TraxIQ platform. The agreement includes the provision of retrofit kits designed to make compatible mining equipment autonomous.

The partnership marks a shift toward an integrated, system-level approach to material movement, allowing mining operations to move beyond the constraints of traditional equipment-led models. The TraxIQ system brings together modular equipment, advanced energy strategies, and autonomous control systems to create a more flexible, scalable, and efficient approach to mining operations.

The companies will initially focus on the further validation of the technology in global mining environments. This will build on the existing operational experience from deployments across China, while continuing to advance the development of the TraxIQ autonomous material handling system.

"TraxIQ represents a new approach to material movement. By combining MMD's materials handling expertise with CiDi's advanced autonomy technology, we are enabling the deployment of autonomous handling systems that improve operational efficiency, reduce energy consumption, and support the transition to more scalable and efficient operations," said Martin Vorster, Group Managing Director of MMD Group.

"We are delighted to announce this agreement. Together we are developing an intelligent system that integrates autonomy with the physical flow of material through the mine," said Dr. Ma Wei, Co-Founder of CiDi. "The agreement establishes a framework for long-term collaboration as the TraxIQ platform progresses toward deployment and commercialisation across global mining markets."

Cummins celebrates 100 years powering the mining industry

Cummins is kicking off a global celebration in 2026 to mark 100 years of powering the mining industry, citing a century of innovation and partnerships in some of the world's toughest operating environments.

From early applications in the 1920s powering rope shovels and excavators to today's high-horsepower engines and integrated power solutions, Cummins says it has helped shape modern mining by enabling operators to move more material, work more efficiently and improve productivity.

Over the past century, the company has introduced new technologies, from early diesel adoption and fuel-system breakthroughs to turbocharging, electronically controlled engines and digitally connected solutions designed to maximize uptime and reduce total cost of ownership.

Cummins said the anniversary is also a look ahead to what it calls a cleaner, smarter and more connected future for mining.

"Reaching 100 years in mining is a milestone for Cummins and a testament to our partnerships with customers around the world," said Cummins Asia-Pacific mining director Ben Clark said.

"For a century, we've focused on solving real challenges for miners and delivering power solutions that improve reliability and productivity while reducing total cost of ownership in demanding conditions," Clark said.

Cummins said it has built a reputation for delivering dependable solutions that support mining operations.

The company said each decade has brought new developments as it has updated its technology to meet changing industry needs, including more powerful engines, improved efficiency, a global service network and technical support.

Cummins said partnerships with mining companies and original equipment manufacturers have been central to that work, helping it design solutions aimed at real-world operating challenges.

"Mining is one of the most demanding industries in the world, and it has always pushed technology to its limits. Cummins has been there every step of the way," Clark said.

"Our role has been to innovate and adapt, delivering solutions that keep our customers moving day in and day out."

Cummins said the next century will be defined by transformation and that it is investing in new technologies.

With investments in advanced engine platforms, alternative fuels, hybrid technologies and integrated power solutions, Cummins said it is helping mining customers reduce emissions while preparing for future energy systems.

The company said digital connectivity and smart technologies are improving efficiency, increasing uptime and providing operational insight, changing how mines operate at scale.

"The future of mining is about more than power. It's about smarter, more sustainable performance," Clark said.

"We're working alongside our customers to deliver practical solutions that support decarbonisation without compromising productivity. That's the challenge, and that's where Cummins thrive."

Throughout 2026, Cummins will mark its 100th year in the industry with global and regional activities to recognise the people, partnerships and innovations it says have helped power mining.

The company said the anniversary will recognise employees who develop and support its technology and customers who rely on its power systems.

"This is more than a milestone; it's a launchpad for what comes next," Clark said.

Next-generation partnership for Hastings Deering and Caterpillar

What started as a simple question of refreshing a fleet of trucks turned into a next-generation rollout of Caterpillar 793 trucks by Hastings Deering at the South Walker Creek mine.

A multi-million-tonne coal operation requires the best-of-the-best machinery to ensure operators are firing on all cylinders.

Stanmore Resources' South Walker Creek mine in Queensland's Bowen Basin produces more than six million tonnes per annum of high-quality low-volatile pulverised injection coal for steelmaking using truck-and-shovel methods.

Having the right trucks for the job, for Stanmore, was non-negotiable. What started as a strategy review resulted in a rollout of 31 Caterpillar (Cat) 793 trucks across central Queensland – the largest fleet on the east coast of Australia.

The Cat 793 Next-Gen mining truck has a target of 264 tonnes. This capacity provides Stanmore with an efficient pass match across its 400- and 600-tonne digger fleet, enabling highly flexible production planning.

In addition, superior fuel efficiency can be achieved because the truck's low empty weight and high efficiency from the mechanical drivetrain results in a low-cost-per-tonne option. A redesigned cab also allows for 34% increased space, enhancing comfort and boosting operator productivity.

Add to that cutting-edge connectivity through optimised electronics architecture, dual mode product link radio and faster data transfers specific for an operator-focus environment.

Initially planned for rollout by April 2026, the Hastings Deering team was able to beat the baseline project plan and ensure the rollout of trucks finished in March. This extended a previous plan of having 16 trucks arriving by Christmas, with 20 on-site on January 1.

A culture of open dialogue between parties is behind the success of the rollout.

"We've got constant communication between Stanmore and Hastings Deering representatives, and the product delivery team has all but joined the Stanmore team in terms of project execution," project manager at South Walker Creek Brendan Paton said.

Hastings Deering delivered the project ahead of time earlier this year.

The 793 trucks, described as the "jewel" in Hastings Deering's crown, show what is possible through trusted partnerships and bespoke solutions to keep mine sites across Australia on track to produce minerals for the future.

"We're lucky enough to have 31 of them here at Stanmore," Hastings Deering resource industries account manager Sean Ryan said. "It really is a step change, upgrading the 793 to make the best better."

This sentiment is echoed by the wider team at South Walker Creek.

"It's a world-leading truck in terms of its technology," South Walker Creek general manager Jason Greig said. "There's an uplift in payload, performance, bank cubic metres per hour, and the ABS braking technology increases safety performance."

From Stanmore's perspective, the outcomes were almost immediate.

"The feedback we got from the operators was almost instantaneously positive," Greig said. "It was, 'Wow, we absolutely love them'.

"They're comfortable, they're productive, they're quiet, and you see operators driving round in the cabin with a smile on their face.

For Stanmore, the upgrades represent a clear step in the direction towards greater improvements. Not only are the trucks class-leading in terms of payload capacity, but with the support of Hastings Deering and Cat, they also represent a low risk operational option.

"This is an integral part of South Walker Creek's growth strategy," Greig said. We're trying to get bigger; we want to do more with less and being able to increase our payload, increase our speeds and increase our safety performance fits extremely nicely with Stanmore's overall business objectives."

The rollout of Next-Gen Cat 793 haul trucks highlights the role strategic partnerships play in implementing tailored solutions that support long-term operational performance.

Yancoal, Whitehaven moves signal coal strength

Coal continues to assert its importance within Australia's mining industry, with a series of recent developments underscoring its resilience amid shifting market, policy and investment dynamics.

One of the clearest signals of coal's ongoing role is the scale of investment flowing into the sector. Yancoal's proposed acquisition of the Kestrel coal mine for up to $US2.4 billion ($3.36 billion) highlights the strategic value attached to high-quality assets. The deal secures an 80% stake in what is described as Australia's largest producing underground coal mine, with 164 million tonnes of reserves and a 25-year mine life.

This move reflects a deliberate shift by Yancoal towards premium metallurgical coal, which remains essential for steelmaking. By strengthening its presence in Queensland's Bowen Basin, Yancoal is consolidating its position in a commodity segment that continues to attract global demand. The transaction also sits within a broader trend of consolidation across the coal sector, where scale and asset quality are increasingly critical.

While Chinese customers bought 31% of Yancoal's export volumes last year, 4% of Kestrel's coal was delivered to China, with Japan, India, Korea and Taiwan Kestrel's key markets.

Similarly, financing activity suggests that coal remains bankable.

Whitehaven's recent funding boost demonstrates that capital markets are supporting coal producers, particularly as energy security concerns reshape investment priorities. In fact, recent deals indicate lenders are reassessing earlier environmental, social and governance (ESG)-driven restrictions as geopolitical pressures and supply concerns elevate the importance of reliable energy sources.

Government policy is also reinforcing coal's ongoing role, particularly in Queensland and New South Wales.

Policy settings aimed at supporting mine extensions and sustaining employment highlight the balancing act between energy transition goals and economic realities. Coal remains a major employer in regional Australia, and governments continue to emphasise its contribution to jobs, royalties and regional development.

The Queensland Government's positioning further illustrates this dynamic. Official statements point to a continued commitment to supporting the resources sector, including coal, as part of a broader economic and energy framework. While diversification into critical minerals is gaining traction, coal is still recognised as a cornerstone of the state's export economy and energy mix.

Queensland Minister for Natural Resources and Mines Dale Last said Yancoal's acquisition of the Kestrel mine represents a vote of confidence in Queensland's world-class assets.

"Queensland is home to some of the world's best coal mines and it makes sense that Yancoal is looking to expand its portfolio in our backyard," Last said.

"I have made it clear to the sector and the investment community that we are open for business, we have a stable operating environment, and we will throw our support behind those companies who want to do business here."

Market conditions are another key factor underpinning coal's resilience.

Recent price rallies have not only improved project economics but also triggered flow-on effects across the workforce. Reports of a FIFO (fly-in, fly-out) boom linked to rising coal prices indicate that labour demand remains strong, reinforcing coal's position as a driver of employment and regional activity.

Such developments point to a coal sector that is evolving. Investment is becoming more targeted, focusing on high-quality, long-life assets. Financing is increasingly tied to energy security considerations. Government policy is balancing transition ambitions with economic stability. And market conditions continue to provide strong incentives for production.

Australia's coal industry is adapting to new conditions, with a focus on efficiency, asset quality and strategic positioning. The recent wave of acquisitions, funding deals and policy support demonstrates that coal continues to play a significant role in Australia's mining industry – one that is likely to continue.

Beyond the Bucket: rethinking dragline and excavator performance

In the evolving landscape of surface mining, few pieces of equipment embody the scale, ambition, and engineering prowess of draglines and excavators. These machines are more than tools of extraction – they are strategic assets that shape productivity, cost efficiency, and the long-term sustainability of mining operations. As the industry navigates rising demand, deeper deposits, and increasing scrutiny around environmental performance, understanding the complementary roles of draglines and excavators has never been more important.

Draglines, with their unparalleled reach and low operating cost per tonne, continue to anchor some of the world's largest overburden removal programmes. Excavators, meanwhile, offer the precision, mobility, and versatility required for modern, data-driven mining fleets. Together, they form a powerful combination: one defined by scale, the other by adaptability.

Gordon Barratt of Mining & Quarry World explores how operators are leveraging both technologies – individually and in tandem – to unlock efficiency, reduce emissions, and future-proof their operations. From advances in automation and digital monitoring to the practical realities of fleet optimisation, we examine why draglines and excavators remain central to the industry's performance today and its transformation tomorrow.

A HISTORICAL REVIEW OF DRAGLINES AND EXCAVATORS: EARLIEST DRAGLINES USED IN MINING

The earliest draglines emerged in the early 20th century, coinciding with the rapid expansion of surface mining – particularly coal mining – in the United States. The very first dragline was built in 1904 by Page & Schnable, originally for the Chicago Drainage Canal project, but its success quickly led to adoption in mining applications.

By 1912, Page Engineering Company had fully committed to dragline manufacturing, recognising that the machines were more profitable and more widely applicable than their original

Monighan 200-W Dragline

Ruston & Hornsby Crawler Mounted Dragline

contracting work. At this stage, draglines were still stationary or track-mounted, limiting their mobility in large open-cut mines.

A major breakthrough came in 1913, when an engineer at the Monighan Machine Company introduced the first practical walking mechanism. This innovation – two large shoes mounted on either side of the revolving frame – created the Model 1-T, the world's first walking dragline. This design solved the mobility problem and made draglines far more suitable for strip-mining operations, where they needed to reposition frequently as pits advanced.

By the 1920s and 1930s, manufacturers such as Bucyrus-Erie, Marion, and Page were producing increasingly large draglines specifically for mining. These early machines laid the foundation for the massive walking draglines that would dominate mid-century coal mining.

The development of draglines and excavators is inseparable from the rise of modern surface mining. These machines, now central to overburden removal and large-scale earthmoving, emerged from more than a century of engineering refinement, industrial ambition, and the relentless pursuit of greater productivity.

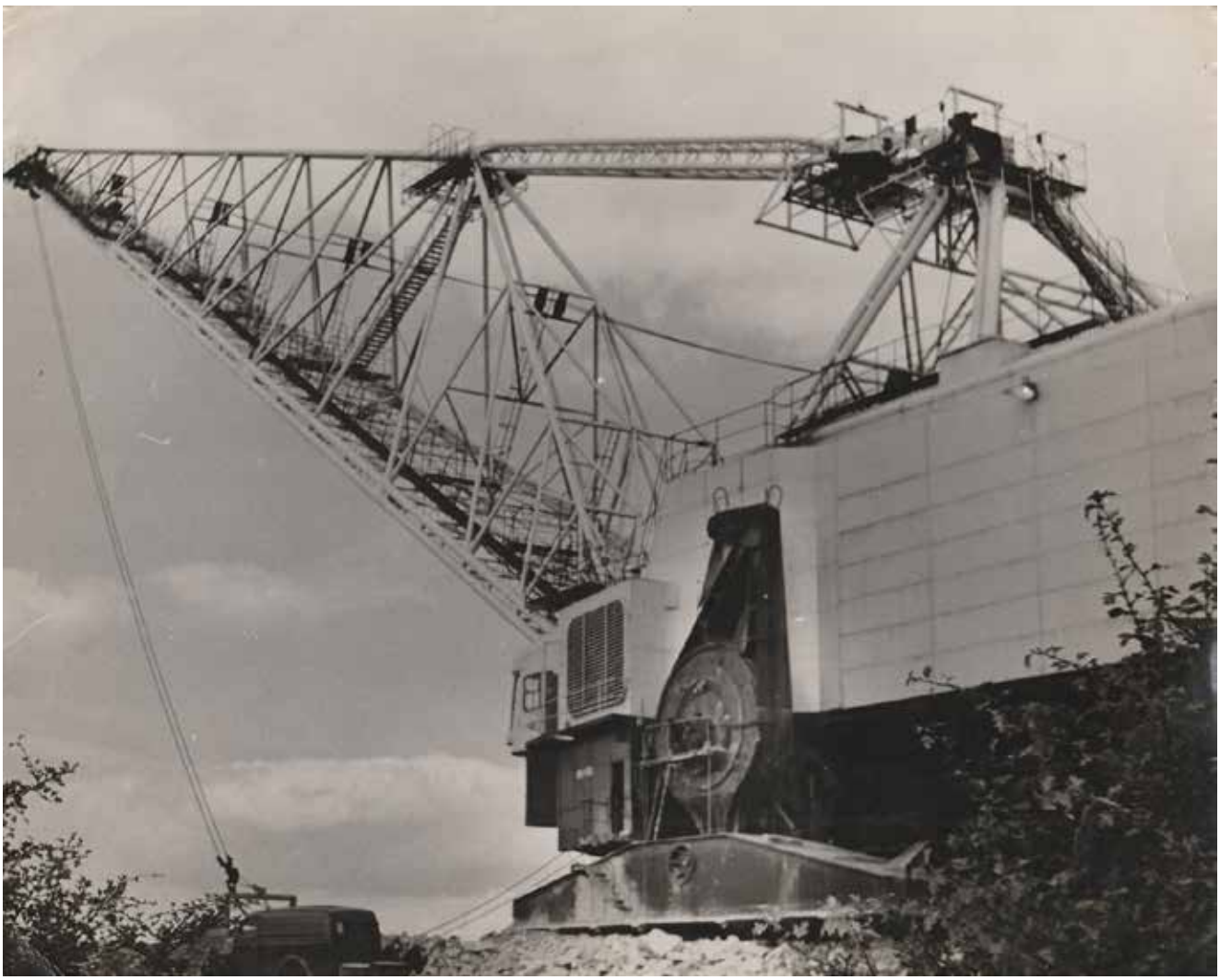
The origins of mechanical excavation can be traced to the mid-nineteenth century, when early steam-powered shovels began replacing manual labour in canal construction and railway expansion. These first-generation machines were crude by modern standards, but they introduced the fundamental principles of mechanised digging and material handling. Their success quickly attracted the attention of the mining industry, which recognised the potential to accelerate production and reduce reliance on large workforces.

By the early twentieth century, the transition from steam to electric power marked a turning point. Electric motors offered greater reliability, smoother operation, and significantly higher lifting capacity. It was during this period that the first true dragline excavators appeared in the United States, initially supporting coal mining operations. Their long booms and suspended buckets allowed operators to remove overburden from a safe distance, dramatically improving both efficiency and safety in open-cut mines.

The interwar and post-war decades saw rapid expansion in dragline design. Manufacturers such as Bucyrus-Erie, Marion, and Page introduced larger machines with longer booms, stronger hoist systems, and improved bucket designs. These innovations enabled mines to work deeper seams and move unprecedented volumes of material. By

Marion Walking Dragline

Page Walking Dragline



the 1960s and 1970s, the era of the “super-dragline” had arrived. Machines like Big Muskie in Ohio and the massive Australian draglines of the Bowen Basin demonstrated the scale that surface mining had achieved, with individual units capable of shifting hundreds of thousands of tonnes per day.

Parallel to the rise of draglines, hydraulic excavators were undergoing their own transformation. Early cable-operated shovels gradually gave way to hydraulic systems, which offered superior control, faster cycle times, and greater versatility. By the late twentieth century, hydraulic excavators had become the dominant tool for smaller-scale mining, quarrying, and construction, while draglines retained their position as the preferred choice for high-volume overburden removal in large open-cut operations.

Advances in materials science, digital monitoring, and automation have continued to shape both machine types. Modern draglines incorporate high-strength steels, sophisticated electrical systems, and condition-monitoring technologies that extend service life and reduce downtime. Hydraulic excavators now feature precision controls, telematics, and semi-autonomous capabilities that enhance safety and productivity. Across both categories, the integration of data analytics and predictive maintenance has become a defining feature of twenty-first-century mining equipment.

Today, draglines and excavators remain essential to global mining operations, each occupying a distinct but complementary role. Draglines dominate where long reach and low cost per tonne are paramount, while hydraulic excavators provide the flexibility and precision required for selective mining and complex geological conditions. Their parallel evolution reflects the broader trajectory of the mining industry itself: a continuous drive toward greater efficiency, improved safety, and more sustainable resource extraction.

From steam-powered beginnings to electrically driven giants and digitally optimised fleets, the history of draglines and excavators is a story of engineering ingenuity and industrial transformation. Their development has not only reshaped the physical landscapes of mining regions but has also defined the operational capabilities of modern surface mining.

Dragline excavators have become a defining feature of large-scale earthmoving, valued for their ability to dig deeply and rapidly with a level of precision that has reshaped both construction and mining practice. Often described as power shovels, these machines are deployed across an array of demanding environments, from trenching and pit development to land reclamation, demolition, and major excavation works.

Their origins can be traced to the early twentieth century, when the first draglines were introduced to support coal

mining operations in the United States. Since then, the technology has undergone continuous refinement. Modern draglines are vastly more capable than their early predecessors, having grown in size, strength, and mechanical sophistication. Today's largest models can reach depths exceeding 50 metres and move as much as 6,000 tonnes of material in a single day, a testament to the engineering ambition that has driven their evolution.

Some of the world's most iconic draglines – such as Bagger 288, Big Muskie, Marina Barrage, and Marrong – stand as engineering landmarks in their own right. Each represents a significant leap in lifting capacity, structural design, and operational efficiency, illustrating the scale at which modern earthmoving technology now operates.

This article examines the development of dragline excavators, their expanding role in contemporary construction and mining, and the characteristics that distinguish the major types in use today.

Draglines have long been central to road construction, where their ability to remove large volumes of overburden quickly enables the creation of stable, level surfaces. Their reach and bucket capacity also make them indispensable in mining, where they are used to open deep pits and expose mineral deposits efficiently. In land reclamation, draglines are deployed to reshape terrain and recover usable ground for agricultural, residential, or commercial development. Their precision and reach also lend themselves to demolition work, where operators can remove concrete, foundations, and structural elements with controlled force. In deep excavation projects – such as pipeline installation or foundation development – their ability to work at depths approaching 200 feet makes them a preferred choice for contractors managing complex subsurface environments.

Over time, several distinct dragline designs have emerged to meet the varied demands of industry. Wire rope draglines remain the most widely used, relying on a rope-and-bucket system powered by electric or diesel drives. Their versatility makes them suitable for everything from mining to demolition. Heavy-duty draglines, built with larger hoists, motors, and structural components, are engineered for the most demanding large-scale operations, particularly in mining and major construction. Bucketwheel draglines, equipped with a rotating wheel fitted with multiple buckets, are designed for high-volume material movement and are typically found in operations where continuous excavation is required.

Understanding the differences between these machine types – and the materials and conditions they are best suited to – is essential when selecting equipment for a project. Hard, compact materials such as rock or reinforced concrete are often best handled by wire rope draglines, while softer soils or large-scale overburden removal may call for heavy-duty or bucketwheel systems.

The appeal of dragline excavators lies not only in their capability but also in their economic and environmental advantages. Their fuel efficiency and long reach reduce the need for additional machinery, lowering operating costs and minimising site congestion. Advanced control systems and sensors enhance accuracy, reducing rework and improving safety outcomes. Many modern draglines are also designed with sustainability in mind, incorporating recyclable components and operating with lower emissions than traditional excavation methods.

Selecting the appropriate dragline for a project requires careful consideration of power requirements, excavation depth, material characteristics, and overall project scale. Larger machines may demand higher upfront investment, but their productivity often delivers long-term cost benefits. Conversely, smaller models may be more suitable for confined or specialised applications where manoeuvrability and precision outweigh raw capacity.

With the right machine in place, dragline operations can be executed with remarkable speed, safety, and efficiency – qualities that have cemented their role as indispensable assets in both the construction and mining sectors.

Walking dragline excavators – often referred to simply as mobile draglines – represent the most widely used class of dragline machinery. Designed to move independently across

Crawler Draglines

Early Electric Dragline Excavator

Diesel Powered Dragline

a worksite, they are fitted with either tracks or wheels that provide the mobility needed for large open-pit mines and major earthmoving operations. Their versatility, efficiency, and ability to handle a broad spectrum of materials have made them a mainstay of modern surface mining.

Crawler dragline excavators share many of the same mobility advantages but are generally larger and more powerful. Mounted on crawler tracks, they offer exceptional stability and weight distribution, qualities that make them particularly valuable in deep mining applications and in environments where heavy digging and lifting are required. Their robust construction allows them to operate effectively in challenging terrain and under adverse conditions.

Backhoe dragline excavators combine the capabilities of a traditional dragline with those of a backhoe. Featuring a front-mounted bucket in addition to a long boom with a suspended dragline bucket, these machines can perform both digging and dragging operations with equal proficiency. Their dual functionality makes them especially useful in construction and mining projects that demand a wide range of excavation techniques.

Front shovel dragline excavators are purpose-built for specific types of material handling. Instead of a conventional dragline bucket, they are equipped with a shovel attachment at the end of the boom, enabling them to dig and load loose materials such as sand and gravel with high efficiency. This specialised configuration makes them well suited to mining operations focused on unconsolidated deposits.

Electric dragline excavators have emerged as an environmentally conscious alternative to diesel-powered models. Powered entirely by electricity, they reduce emissions and offer lower operating costs while maintaining the high energy efficiency required for large-scale excavation. Their adoption is often driven by sustainability targets and the need to minimise carbon footprints in modern mining operations.

Diesel dragline excavators, by contrast, remain valued for their mobility and independence from fixed electrical infrastructure. Although they produce more emissions, they are indispensable in remote regions where grid power is unavailable. Their durability and reliability continue to make them a practical choice for demanding field conditions.

Complementing these various machine types are the dragline buckets themselves, which are engineered in multiple configurations to suit different materials and excavation strategies. Clamshell buckets are designed for grabbing and handling loose material, while drag buckets excel at scraping and scooping from the ground surface. Hybrid clamshell-dragline buckets offer a combination of these capabilities, and rock buckets are reinforced to withstand the stresses of working in hard, rocky environments.

Together, these dragline types and bucket configurations illustrate the breadth of engineering solutions available to meet the diverse excavation challenges encountered in mining and construction.

THE WORLD'S LARGEST DRAGLINE EXCAVATORS

The scale of today's largest dragline excavators underscores the extraordinary engineering ambition that defines modern surface mining. These machines demand immense structural design, vast material inputs, and highly skilled crews to operate them safely and efficiently. A closer look at several of the most notable examples illustrates just how far dragline technology has advanced.

Big Muskie & Marion Draglines

Germany's Bagger 288 remains one of the most recognisable earthmoving machines ever built. Although technically a bucketwheel excavator rather than a traditional dragline, its sheer scale places it firmly within the conversation about the world's largest land-based mining machines. Since entering service in 1978, it has stood as a benchmark for mega-scale excavation, rising 315 feet high, stretching 721 feet in length, and weighing approximately 45,500 tonnes. Its continuous digging system enables it to move up to 240,000 tonnes of material in a single day.

For decades, the Big Muskie in Ohio held the title of the world's largest dragline excavator. Operating from 1969 until its retirement in 1991, it matched the Bagger 288 in height at 315 feet but weighed a comparatively lean 13,500 tonnes. Its bucket – one of the largest ever constructed – allowed it to shift up to 240,000 tonnes of material per day, making it a defining machine of its era.

Singapore's Marina Barrage dragline represents the largest dipper-type dragline excavator built to date. Commissioned in 2006, it stands 270 feet tall and is capable of moving around 150,000 tonnes of material daily. Its scale and performance place it among the most significant dragline installations in the world.

Australia's Marion dragline, constructed in 2001, is another standout example. Rising to 330 feet, it is often cited as the largest traditional dragline excavator in operation. With a digging depth of roughly 250 feet and a radius exceeding 1,000 feet, it can move around 120,000 tonnes of material per day, making it a central asset in large-scale overburden removal.

Together, these machines demonstrate the remarkable evolution of dragline technology. Their size, capability, and operational demands reflect decades of innovation aimed at improving productivity, reducing cost per tonne, and enabling mining operations to tackle ever-larger deposits. As the mining industry continues to pursue efficiency and scale, the legacy of these giants underscores the enduring importance of dragline excavators in shaping modern surface mining.

WALKING DRAGLINES: A HISTORICAL AND ENGINEERING PERSPECTIVE

As mining operations expanded and the need for frequent relocation grew, engineers confronted the limitations of conventional mobility systems. Moving such massive equipment over uneven terrain proved impractical, prompting the development of the walking mechanism in the mid-century period. This innovation allowed draglines to lift their entire superstructure using cam-shaped shoes, shift forward, and settle into a new position. Although their movement is slow – often only a few metres per hour – mobility is secondary to stability, reach, and productivity.

At the heart of a walking dragline is the revolving frame, which supports the operator's cab, machinery deck, and the boom assembly. Booms typically range from 60 to 120 metres in length and are constructed from lattice steel structures tensioned by an intricate system of cables. Suspended from the boom is the bucket, controlled by hoist and drag ropes. During operation, the bucket is cast forward, dragged across the ground to collect material, then hoisted and swung to a dump point. This horizontal scraping action is exceptionally efficient for large-scale overburden removal, which is why draglines remain the preferred tool for stripping operations rather than vertical excavation.

The machine's lower structure, known as the tub, provides the foundation for both stability and mobility. It rests on massive steel plates and walking feet designed to distribute the dragline's enormous weight – often several thousand tonnes – over a broad surface area. When movement is required, hydraulic or mechanical jacks lift the tub slightly while the curved walking shoes pivot forward on cam mechanisms. Each step demands precise control to avoid structural stress, maintain balance, and prevent excessive ground disturbance. This low ground-pressure design allows draglines to traverse soils that would be unsuitable for wheeled or tracked equipment.

One of the defining advantages of dragline excavation is its energy efficiency. By dragging a suspended bucket across the surface rather than lifting material vertically, draglines exploit mechanical leverage to reduce resistance and power demand. Although their cycle times are slower than those of hydraulic shovels, the sheer volume of material moved per cycle compensates for this, enabling draglines to achieve exceptional productivity in continuous stripping operations. This makes them indispensable in open-cut coal mines where overburden must be removed across vast areas.

Powering these machines requires a dedicated electrical supply, typically delivered through trailing cables connected to the mine's grid. Electric drive systems are

favoured due to the immense energy requirements, which would be impractical for diesel engines alone. Electric motors control hoisting, dragging, swinging, and walking functions, while modern control systems incorporate computer-assisted operation, automated cycle monitoring, and real-time load analysis to optimise performance and reduce mechanical stress.

Constructing a walking dragline is a major engineering undertaking. Because they are far too large to transport fully assembled, components are shipped to the mine and erected over several months using specialised lifting equipment and highly skilled assembly teams. Aligning the boom, calibrating the hoist and drag systems, and commissioning the walking mechanism require meticulous precision. The investment in a single dragline can reach hundreds of millions of dollars, justified only in long-life mines where sustained productivity gains offset the capital cost.

Maintenance is equally demanding. Most servicing must occur on site, often with the machine partially assembled. Engineers routinely inspect boom structures for fatigue, monitor cable wear, lubricate critical bearings, and replace bucket teeth subjected to constant abrasion. The walking cams, despite being manufactured from hardened steel, require periodic refurbishment to maintain smooth, stable movement. Environmental exposure adds further challenges, including corrosion, dust ingress, and thermal expansion. Because unplanned downtime can result in significant production losses, preventive maintenance regimes are rigorously enforced.

The operational impact of walking draglines has been transformative. Their ability to move vast quantities of overburden with minimal reliance on truck fleets reduces haul road construction, lowers diesel consumption, and decreases overall site emissions. Their walking capability eliminates the need for disassembly and heavy transport when relocating within a mine, allowing them to follow advancing pit boundaries with relative ease. In many jurisdictions, draglines also contribute to progressive rehabilitation by shaping spoil piles into stable landforms suitable for revegetation.

Operator proficiency remains a critical factor in dragline performance. Managing the simultaneous motions of swinging, dragging, and hoisting requires exceptional spatial awareness and coordination. Experienced operators develop highly efficient digging patterns that maximise bucket fill and minimise wasted motion. Modern training programmes increasingly rely on advanced simulators, enabling new operators to gain experience in realistic scenarios without risk to equipment.

Despite their advantages, walking draglines are not universally applicable. Very deep pits often favour truck-and-shovel systems, and the high capital cost restricts dragline deployment to long-life operations. Relocating a dragline between mines is rare due to the logistical complexity, though not impossible; such moves can require months of planning and specialised engineering support.

Looking ahead, the evolution of walking draglines is likely to blend traditional mechanical engineering with emerging digital technologies. Advances in high-strength materials may enable lighter booms and larger buckets, while machine-learning algorithms could optimise digging cycles and predict component wear. Improvements in electrical systems, including variable-frequency drives, promise greater efficiency and reduced mechanical stress. Remote and semi-autonomous operation is also on the horizon, potentially enhancing safety by removing operators from hazardous environments.

Walking draglines remain enduring symbols of mining engineering achievement. Their ability to move thousands of tonnes of machinery across rugged terrain while excavating millions of cubic metres of earth has reshaped the economics of surface mining. As the industry continues to pursue efficiency, sustainability, and technological innovation, these remarkable machines will continue to play a central role – slow, deliberate, and immensely powerful, yet indispensable to the future of large-scale resource extraction.

Dragline excavators offer a range of advantages that have cemented their place in large-scale mining and earthmoving operations. Their ability to handle vast quantities of material with exceptional efficiency makes them indispensable in environments where high production rates are essential. Automated and semi-automated operating systems further reduce labour requirements, allowing a single machine to achieve what would otherwise demand a sizeable fleet of equipment. For major excavation tasks, draglines consistently deliver strong cost-effectiveness, particularly when measured over the long operational life typical of open-cut mines.

Despite these strengths, dragline excavators are not without limitations. Their mobility is restricted compared with other types of excavators, making them best suited to operations where they can remain in a defined working area for extended periods. The initial capital investment is substantial, reflecting the scale and engineering complexity of these machines. Their size also introduces maintenance challenges, as servicing components on a dragline often requires specialised equipment, extended downtime planning, and highly skilled personnel.

Maintenance and safety considerations are central to sustaining dragline performance. Regular inspections, structural monitoring, and timely component replacement are essential to ensure reliability and extend service life. Given the scale of the equipment and the forces involved in operation, strict adherence to safety protocols is vital to protect operators and maintenance teams. Comprehensive training, clear communication systems, and rigorous procedural controls form the backbone of safe dragline operation.

Looking ahead, the future of dragline excavators is shaped by ongoing technological innovation. Advances in digital monitoring, automation, and energy efficiency are expected to enhance their mobility, productivity, and safety. As mining operations increasingly prioritise sustainability and operational optimisation, draglines are likely to evolve with improved control systems, lighter and stronger structural materials, and more environmentally conscious power solutions.

In conclusion, dragline excavators remain a cornerstone of modern mining and large-scale construction. Their unmatched capacity for bulk earthmoving, combined with their robust mechanical design and broad application range, ensures their continued relevance in the heavy equipment sector. As technology progresses, these machines will only become more capable, more efficient, and more integral to the future of surface mining.

BE CAREFUL WHAT YOU WISH FOR

When planning to replace a rubber conveyor belt, the process of specifying, obtaining and then evaluating quotations from potential suppliers, whether they are a manufacturer, trader, service company or procurement company is full of hidden and very costly pitfalls. Requests for quotations regularly contain specifications that effectively put the buyer and their company at a big disadvantage. In this special feature, conveyor belt specialist Bob Nelson provides his best advice to help in the selection of belts that are not only the technically most suitable but equally, the best value for money.

AVOID 'NON-STANDARD' SPECIFICATIONS WHENEVER POSSIBLE

There are two common types of specification errors – over specification (including unnecessary demands) and specifications that require special, 'non-standard' production. As with all manufacturers, intermediaries and retailers, good stock management is essential in achieving a viable return on investment. In this case, costly rolls of slow-moving spec belts held in stock for prolonged periods is not good business. Conversely, long production runs of fast moving, popular specifications such as, for example, abrasion resistant 400/3 4+2 DIN Y (ISO 14890 L), is the most cost-efficient approach for both manufacturer and end-user.

The dilemma facing manufacturers is that the range of permutations of different tensile strengths; number of

plies; cover type (abrasion, oil, fire resistant etc); cover thicknesses and belt widths is very long so it needs to be strictly controlled according to popular demand, leaving all other specifications requiring special (bespoke) production.

BEST ADVICE: My best advice is that wherever possible, avoid non-standard specifications by asking the manufacturer/supplier to provide a list of their standard stock items and available widths.

UNDERSTANDING MASS PRODUCTION

To optimise cost-efficiency and minimise waste and environmental impact, manufacturers also need to make belts as wide as possible (around 2000mm wide). Four of the most commonly used widths are 650mm, 800mm, 1000mm and 1200mm. This means that belt can be produced at 2000mm wide and then cut (slit) into, for example, one roll of 800mm and one roll of 1200mm or two rolls of 1000mm wide etc. It is important to understand that, regardless of the roll length, there is very little difference in production line set-up costs. This is why producing a 100m roll is significantly more costly per meter than producing, for example, a 400m roll.

BEST ADVICE: If buying a non-standard specification is unavoidable, always try to order a full roll (usually at least 200 meters) or a multiple of the required length to a total length that is economic for special production to minimise the cost per meter. Belt that is surplus to immediate requirements can be used to provide inserts for damage repair or, better still, act as a spare if emergency replacement is necessary.

CHOOSING THE OUTER COVERS

The biggest influence on the performance and longevity of a conveyor belt is the quality and resilience of its rubber covers. In quarrying and mining, the key rubber properties are usually resistance to abrasive wear, cutting, gouging and ripping & tearing. The wear properties of ALL abrasion resistant conveyor belts should be at least DIN Y standard (ISO 4649 / DIN 53516 test maximum 150 mm3 loss) to achieve reasonable economic longevity (lowest lifetime cost). If sharp, abrasive materials are being conveyed then higher-grade DIN X covers (maximum rubber loss under testing of 120 mm³] may be more suitable due to a higher resistance to cutting and gouging.

A quality manufacturer's DIN Y can often be more durable and more wear resistant than another manufacturer's DIN X or even DIN W.

Faced with continual surface wear and damage problems, increasing the cover specification may seem logical but not necessarily the best solution. One manufacturer's DIN Y (ISO 14890 L) can often be far more durable and wear resistant than another manufacturer's DIN X (ISO 14890 H) or even DIN W (ISO 14890 D), which are usually reserved for extreme duty applications. Laboratory testing regularly exposes instances of belts at the lower end of the price/quality spectrum claimed to be DIN X or DIN W, but which are actually below the DIN Y standard.

As previously mentioned, rubber quality is key. A highly experienced application engineer friend of mine recently proved the truth of this when he was inspecting a belt supplied by Fenner Dunlop in The Netherlands that was running on a particularly aggressive application in Finland. *"The top cover thickness was measured using an ultrasonic thickness gauge. Amazingly, only 7%, about 0.5mm, of the cover had worn away in 2 years and 3 months service".*

BEST ADVICE: Rather than blindly increasing the cover grade specification, simply change to a manufacturer with a tradition for high quality instead of manufacturers that produce belts designed to achieve a low selling price rather than a high standard of performance.

COVER TYPES

When experiencing repeated stoppages for cover surface repairs, rip and tear damage and ultimately, premature replacement, a common practice is to fit belts with thicker covers and heavier carcasses. This is almost invariably a costly mistake because simply using more of the same material is not the answer. The same applies to fitting low-priced 'sacrificial' belts.

The most economical solution all round is to fit a conveyor belt that has been specifically engineered for the purpose. The best one's are proven to last up to 400% (or more) longer than conventional multi-ply belts because they have a combination of top-quality, highly resilient rubber and highly specialised inner-ply fabrics with up to five times

Specially designed super-tough belts often last up to 400% longer than conventional belts.

Sealed edges are usually perfectly adequate

the resistance to rips and tears compared to conventional multi-ply belts. The initial buying price will be higher, but the cost will be many times lower over the working life of the belt, with the added benefits of far lower 'below the line' costs for repairs and downtime.

BEST ADVICE: Always choose belts that are specifically engineered for the conditions they need to cope with, especially on conveyors prone to rip, tear and impact damage.

SPECIFYING THE CORRECT TYPE OF BELT EDGE

In my experience, unnecessarily specifying belts with moulded edges is probably the most common over-specification and one that has a significant impact on belt costs, repairs, maintenance, lost production and lead times. Originally, (more than 40 years ago) moulded edges were necessary because cotton was used as the reinforcing fabric in multi-ply belts. A moulded edge (fully covered in rubber) was therefore essential to prevent moisture penetrating the cotton fabric and causing it to rot. Apart from steel cord and steel-reinforced belts, the introduction of synthetic ply fabrics using polyester and polyamide means that this problem barely exists. Despite this, many conveyor operators (and their buying departments and procurement companies) continue to specify moulded edges, even though they do not provide any structural advantage and can be prone to damage if the belt wanders off-track.

The first signs – small cracks appear on the surface of the rubber.

Nowadays, the most commonly used type is the 'cut & sealed' edge or simply 'sealed edge', which prevents moisture being drawn into the carcass by capillary forces. Although the synthetic fibre plies are barely affected, moisture can potentially cause vulcanising problems when making splice joints. For this reason, never order a belt with a raw edge. Provided that the belt is also resistant to ozone & ultraviolet, a sealed edge also enables a belt to be used in very wet conditions and better suited for long-term storage outdoors.

The importance of not over-specifying the type of belt edge comes back to the need to manufacture belts at the optimum width and length. This is why the vast majority of rubber multi-ply belting held in stock by manufacturers and other suppliers has sealed edges. Moulded edges can only be created when a belt is manufactured to an exact width so if, for example, a belt that is 1000mm wide is specified with moulded edges then the manufacturer cannot achieve optimum production efficiency, which must therefore be reflected in the selling price.

BEST ADVICE: Rather than specifying the edge type, always choose the most economical the supplier can offer, being either moulded edge or cut and sealed edge.

OZONE AND ULTRAVIOLET RESISTANCE.

Finally, resistance to the damaging effects of ozone and ultraviolet light is something that should, without exception, be part of any specification. At low altitude ozone (O3) becomes a pollutant that attacks the molecular structure of rubber, causing a seriously damaging reaction known as ozonolysis The first visible sign is when cracks start to appear in the surface of the rubber. Further attacks then occur inside the freshly exposed cracks, which continue to grow steadily until they complete a 'circuit' and the rubber starts to fail.

Ultraviolet light from sunlight and fluorescent lighting has a similar effect because it produces photochemical reactions that cause oxidation of the rubber surface resulting in a loss in mechanical strength and wear resistance. This is known as 'UV degradation'. The combination of ozone and UV seriously reduces the operational lifetime of a rubber belt. Although easy to prevent, surveys show that some 90% of belts sold in Europe, the Middle East and Africa are not protected. This is because the necessary anti-ozonants have been omitted because of cost.

BEST ADVICE: Never order a conveyor belt without first obtaining written confirmation from the supplier/ manufacturer that the belt being supplied is fully resistant to ozone and UV according to EN ISO 1431/1 procedure B testing over a 96 hour period.

CONCLUSION

Old habits die hard as they say. But simply ordering the same specification that you have ordered before without thinking of the possible implications can waste a lot of time and money.

AUTHOR

Bob Nelson

Mining and Quarry World

Hillhead

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MINING & QUARRY WORLD

Hillhead 2026

Mine Surveying Since 1850

Note from the Author – Trevor Barratt

Mine surveying has played a foundational role in the development of modern mining. Since 1850 surveying professionals have shaped have the planning, safety, regulation and expansion of mining operations across generations. Mining is an industry defined by precision and accountability. The documentation of its history deserves the same standards. By recording the developments of mine surveying from early mechanical methods to modern digital systems- My work contributes to preserving industrial knowledge for future professionals, research and organisations.

FOREWORD- FROM THEODOLITES TO SATELLITES

If surveyors are like countries and the happier for being without histories, the mine surveyor must have led an enviable existence during the first 20 years or so of the period under review, for nothing startling either in instruments or in technique came to ruffle his inarticulate calm.

The beginnings of the mining history date back to ancient times, up to the second century B.C. One field closely related to mining activities is mine surveying. Mine surveying and mapping are disciplines that deal with the surveying and displaying of underground works and mining claims, in which their spatial relationships are determined against the surface.

This article reflects the early methods of surveying through to today's technology advances with a strong reference to the Uk and the worlds coal industry from 1850-Today

The decade previous to the founding of the Uk's Colliery Guardian (1858) had been more eventful; an act of 1850, dealing primarily with the inspection of mines in the UK, had made it compulsory to keep plans of collieries, and in 1855 an amending act gave the inspector power to insist upon them being drafted to a scale of not less than two chains to the inch. These examples of parliamentary vigour had followed close on the heels of the invention by Gravatt of the dumpy level in 1848. and by John Headley, two years after of swinging sights carried on trunnions lying along the E.-W. line of the box of a miners dial. Both were important improvements that have stood the test of time. Incidentally, the latter is the only major alteration of design affecting the colliery surveys favourite instrument that comes directly from the coal mine side, accepting this, the Cornish surveyors and makers were responsible for the gradual development of the dial, until by 1860, vernier dials of high finish and considerable precision were turned out by Wilton of St Day and others.

At the time the most up to date treatise of mine surveying was W. Rickard's Miners Manual (1859); it deals competently with dumpy levelling and with fast needle dialling or 'racking'-for, as a legacy from early Theodolites, the dial of the period had a rack and pinion for the movement of the vernier over its circle.

Mr John Davis founder of Messrs. John Davis and Son was associated with the inventor in introducing the first Headley dials, so that, by 1860, the firm had nearly ten years' experience of their construction. The early Headley dials were provided with a rack and with a detachable, graduated vertical side arc, giving the angle of inclination and the percentage correction for lines measured on the slope. The vernier was inside the box.

In 1861. Casartelli, of Manchester, produced a dial with swinging sights and having a semi-circular graduated arc attached to the compass box by pivots a prolongation on the N.-S. diameter, thus enabling the arc to be raised in position for the measurement of vertical angles and swung down flat when such readings were not required.

The quiet score of years after 1860 were, we may thus gather, a time of assimilation: the dialler was learning

Early miners dial

to use and to depend more and more on fast needle traversing and on rather more elaborate dials, and he was replacing the old Y- level by the handier and more robust dumpy of the railway engineer. But even then, there were voices crying in the wilderness.

Arther Beanlands, a surveyor of great experience in the Northern coalfields of the UK, used the transit instrument for shaft connection before 1856, and continued to apply it with a degree of success which, for that method has never been surpassed. He was a consistent advocate of the theodolite for underground surveys and a disciple of Butler Williams- who first described three-stand traversing in 1842-in regard to the advantages of three tripods. The North of England Institute of Mining Engineers contains several papers on mine surveying. Beanlands writes of shaft connection and other matters. WF Howard urged upon an audience powerful to promote amendments, 'that all plans of mine workings should be contoured, and adduced reasons that are even more cogent today than they were then; from J.A. Ramsay we glean the information that, in the enlightened Northern Coalfield-however it may have been in more benighted regions- underground levels were at the time connected fairly often with the ordinance datum; and R.S. Newell suggested using a magnetometer for precise work. H.D. Hoskold, mining engineer and able designer, constructed a mining theodolite before 1863- and an excellent instrument it was-and described it, and theodolite operations, in his book of that date. Though his practise was wholly abroad, his influence was considerable in the UK and his instruments held in high esteem.

More than 145 years ago – in 1881, to be exact – a young man named Bennett Hooper Brough, having just taken the Associateship of the Royal School of Mines set out to study mine surveying under the famous Borches at the Royal Prussian Mining Academy, Clausthal. A year later he returned to England as assistant to Sir Warrington Smythe, and in 1886, was appointed instructor in mine surveying at the Royal School of Mines in South Kensington. He moulded the subject into a systematic course, and its reputation and value were indicated by the fact that several associates returned to the school to take it. I cannot think of no better way of bringing out the changes in mine surveying that have taken place during the last half century than to compare the instruments and methods Broughs yellowing notes describe those of the present day.

The 1880s saw something of a renaissance in mine surveying. The need of accurate surveys and plans was being more fully realised. The subject was receiving attention serious of those who were, in Howards happy phrase ' powerful to promote amendments 'It was this demand that Brough set himself to meet; and by far the most significant event in the circumscribed world of mine surveying during the eighties was the building up, in London of a course that was soon to equal the best the Continent could provide. Both he and Lewis H. Cooke improved the quality of surveying in every mining field in the UK and abroad to which many students proceeded.

Cooke was appointed to the lectureship vacated by Brough in 1896 and held it to his death in 1929. A German scholar, like his predecessor he found much of his early inspirations in the writings of such authorities as Breithaupt, Weisbach, Borchers and Brathuhn; He critically analysed and tried out their methods; and it is, indeed owing to his advocacy that some of those methods- the shaft -connection processes of Weisbach and Weiss, for example- are now part in the stock-in-trade of the British mine surveyor. No history of the period would be anything but imperfect without an acknowledgement of the signal services of Lewis H. Cooke.

Broughs notes indicated how little the fundamental operations of surveying have changed-or for that matter, how little they can change. The properties of the triangle, for instance, stand for all time, and methods of reduction that share that rely on those properties must share in their immutability. In matters of practical detail, however, one is struck with the contrast between the seeming modernity of some of his descriptions and the naïve archaicness of others. Much attention was given to the calculation of

co-ordinates; yet there were several expressions of doubt as to the sustainable ability of the theodolite for underground work at all, the chief objection being its size and weight. There is a truth in the epigram that, in surveying there are three cardinal points- accuracy, speed, and clarity- and of these, the greatest is charity

The concluding decade of the 19th century witnessed a good many developments in mine surveying instruments. USA mining engineers, finding sighting down steep openings to be impossible with an ordinary theodolite, provided themselves, as long ago as 1855 or1856 with auxiliary telescopes attachable sometimes over the top and sometimes at the side of the instrument and, though less esteemed on this side of the Atlantic, the auxiliary telescope appeared regularly in the catalogues of UK and German makers at the period reached. It was however, at the instance of another distinguished American engineer, Dunbar D. Scott that the auxiliary was brought int line with modern ideas.

Looking back in time at mine surveying and the equipment used as I hope I have done, gives a historical insight into what was then in comparison to What is Now. But it is a fact that more modern theodolites are still used in surveying today, although their role has shifted as more advanced instruments like total stations, GNSS receivers, and 3D scanners have become standard. They remain relevant because they provide precise angular measurement, are mechanically reliable, and are useful in environments where electronic instruments are impractical.

Even with modern digital tools, theodolites continue to serve important functions:

- High precision angle measurement – Theodolites are designed specifically for measuring horizontal and

Early Theodolite These instruments played a crucial role in the early mining industry, helping surveyors and engineers navigate and plan mining operations effectively.

vertical angles with very high accuracy, sometimes down to seconds of arc.
- Reliability in harsh conditions – Optical theodolites do not rely on electronics or batteries, making them dependable in remote or extreme environments where power or sensitive electronics may fail.

DIGITAL INSTRUMENTS AND THE RISE OF TOTAL STATIONS

The most profound shift from the early 20th century onward was the replacement of purely optical instruments with electronic distance measurement (EDM) and, later, total stations. These instruments combined the functions of the theodolite with electronic distance measurement, enabling surveyors to capture angles, distances, and coordinates from a single setup.

This development fundamentally changed underground and surface surveying by:

- reducing the need for long, labour intensive tape measurements

- improving accuracy and repeatability
- enabling rapid traversing in confined or hazardous environments
- allowing data to be stored electronically rather than transcribed manually

- Total stations remain the backbone of many mine surveying operations today, especially in underground workings where GNSS signals cannot penetrate.
- Digital Instruments and the Rise of Total Stations

GNSS and Global Positioning in Surface Mining

The introduction of Global Navigation Satellite Systems (GNSS) – GPS, GLONASS, Galileo, BeiDou – brought a revolution in surface mine surveying. GNSS enabled:

- real time positioning of machinery
- rapid establishment of control networks
- automated guidance for drilling, blasting, and haulage
- continuous monitoring of pit walls and infrastructure

GNSS has become indispensable in open pit mines, where large, unobstructed skies allow for high precision satellite positioning.

LASER SCANNING AND 3D SPATIAL CAPTURE

The modern equivalent of the miners' dial and theodolite is the 3D laser scanner, capable of capturing millions of points per second. These instruments produce dense point clouds that accurately represent:

- underground roadways

- stopes and voids
- pit walls
- stockpiles
- conveyor systems and plant infrastructure

Laser scanning has transformed mine surveying by enabling:

- precise volume calculations
- deformation and subsidence monitoring
- safer mapping of inaccessible or unstable areas
- integration with digital mine models and BIM systems
- Cavity Monitoring Systems (CMS) extend this capability into areas too dangerous for personnel.

UAVS AND AERIAL PHOTOGRAMMETRY

The last decade has seen the widespread adoption of unmanned aerial vehicles (UAVs) for mine mapping. Drones equipped with cameras or LiDAR sensors provide:

- rapid, high resolution mapping of large areas
- accurate stockpile volumes
- change detection for safety and compliance
- reduced exposure of surveyors to hazardous terrain
- UAVs have become a standard tool in surface mining, complementing ground based instruments.

GEOPHYSICAL AND SUBSURFACE IMAGING

Where 19th century surveyors relied on geometry, plumb lines, and magnetic needles, modern surveyors can draw on advanced geophysical methods to understand the subsurface. These include:

- seismic reflection and refraction
- ground penetrating radar (GPR)
- electromagnetic and magnetic surveys
- gravity and microgravity techniques

These tools are used to detect voids, faults, abandoned workings, and ore bodies – tasks that were once impossible with mechanical instruments alone.

Digital Workflows and Integrated Mine Models

Perhaps the most significant change is not a single instrument but the digital ecosystem that now surrounds mine surveying. Modern workflows integrate:

- total station and GNSS data
- LiDAR and photogrammetry
- geological models
- mine planning software
- real time monitoring systems

This creates a digital twin of the mine – an evolving, three dimensional representation that supports planning, safety, and operational decision making.

Surveying has shifted from periodic measurement to continuous spatial intelligence.

CONCLUSION

The Continuity of Principles in a Changing Discipline

Looking back across the long arc of mine surveying – from the miners' dial and dumpy level, through the refinements of Brough and Cooke, to the precision theodolites of the late nineteenth century – it becomes clear that the discipline has been shaped less by sudden revolutions than by a steady, determined pursuit of accuracy, reliability, and clarity. Each generation of surveyors inherited the tools of the last, questioned their limitations, and sought improvements that would better serve the safety and efficiency of mining operations. The mechanical ingenuity of the Victorian period laid the foundations for the scientific rigour that followed, and the principles established then remain recognisable in the profession today.

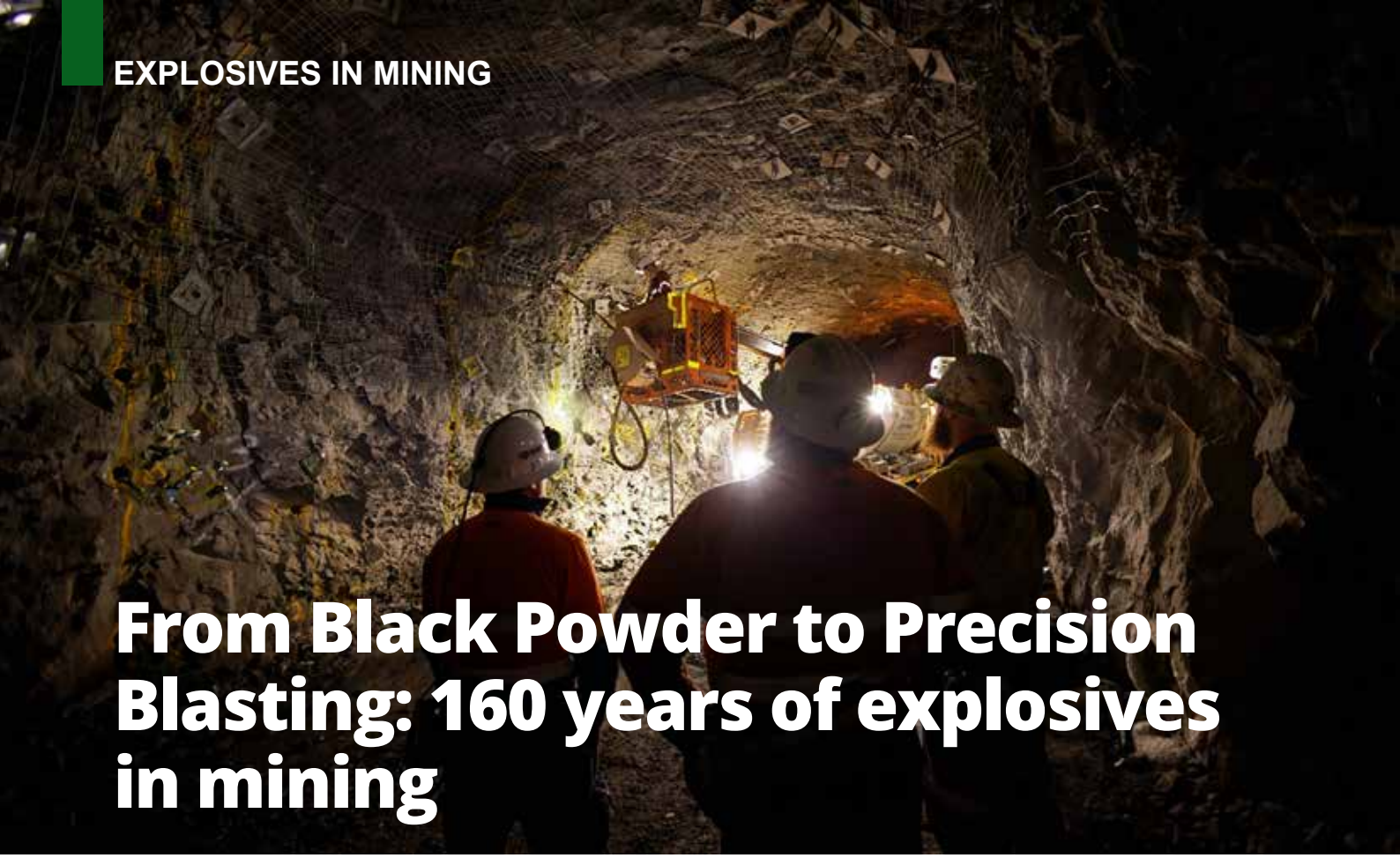
Modern mine surveying, for all its digital sophistication, is still governed by the same imperatives that guided the early pioneers. The total station, GNSS receiver, laser scanner, and UAV are simply the latest expressions of a long tradition of measurement and verification. Where the nineteenth century surveyor relied on geometry, plumb lines, and magnetic needles, the twenty first century practitioner draws on satellites, lasers, and real time computation. Yet the underlying task – determining position, direction, and elevation with the greatest possible certainty – has not changed. Nor has the responsibility: to produce plans and data on which the safety of miners and the viability of operations depend.

It is striking that even as technology has advanced, the older instruments have not been rendered obsolete in spirit. The theodolite, whose weight and complexity once provoked debate among underground surveyors, survives today in digital form and remains indispensable where electronic systems falter. Its continued use is a reminder that the essential craft of observation endures beneath the layers of automation. The surveyor's judgement, patience, and understanding of error remain as vital now as they were in the days of Brough and Cooke.

What has changed most profoundly is the speed and scale at which information can be gathered and interpreted. Modern mines operate within digital ecosystems where surface and underground data flow continuously into integrated models. Laser scanning captures millions of points in seconds; drones map entire pits in a single flight; GNSS guides machinery with centimetre precision. Surveying has expanded from a periodic task to a real time service, supporting planning, monitoring, and decision making across the whole life of a mine. The surveyor is no longer merely a measurer of lines but a custodian of spatial intelligence.

And yet, for all this progress, the discipline remains rooted in the same values that shaped its early development: accuracy, safety, clarity, and accountability. These principles guided the work of the Victorian dialler, the early theodolite makers, the educators of the Royal School of Mines, and the generations that followed. They continue to guide the profession today, even as its tools evolve at a pace unimaginable to the surveyors of the nineteenth century.

In tracing the journey from the miners' dial to the digital twin, one sees not a series of disconnected innovations but a continuous thread of improvement. Mine surveying has always adapted to the needs of its time, and it will continue to do so as mines become deeper, more complex, and more automated. The story is far from finished, but its foundations – laid more than a century and a half ago – remain firm.



From Black Powder to Precision Blasting: 160 years of explosives in mining

About the Author – Trevor Barratt

Trevor Barratt has spent decades shaping mining communication through his wholly owned journals Coal International and Mining & Quarry World. His expertise spans technical editing, historical integration, and industry outreach. He is recognised for turning complex mining topics into accessible, engaging narratives that support training, marketing, and heritage preservation.

*This article is a **must read** reference for drill and blast professionals.*

Built on: Original 19th century archives from the Colliery Guardian (now Coal International)

Modern technical insights from today's blasting and explosives industry. Editorial authority from two globally recognised mining journals.

ABSTRACT

As I look back across more than a century and a half of explosive development, I'm reminded that progress in mining has never been accidental. It has always been driven by necessity – the need to protect miners, to improve productivity, and to understand the forces we work with beneath the earth. From the unstable nitroglycerine of the 1860s to today's digitally modelled blasts and precision electronic detonators, every generation has pushed the industry forward with ingenuity and determination.

Coal mining worldwide, in particular, has shaped this journey more than any other sector. The hazards of firedamp and coal dust forced early researchers, manufacturers, and regulators to confront the realities of underground work long before modern safety culture existed. The standards forged in the coalfields – permissible explosives, testing galleries, shot firer training, and rigorous regulation – became the foundation upon which blasting practice in mines and quarries worldwide was built.

FOREWORD

Today's mining explosives market is experiencing significant advancements driven by the need for safer, more efficient, and more environmentally responsible blasting operations. I will highlight these modern developments later in this article. First, it is essential to understand the historical journey that brought us here – a journey in which the coal industry worldwide played a defining role.

To do that, we turn to the *Colliery Guardian (now Coal International)* Commemoration Number of 1935, published to mark the journal's 75th anniversary as the leading publication for the UK industry and later as Coal International (1995) becoming a leading worldwide journal.

The edition in 1935 provided an authoritative account of the evolution of explosives in British coal mines.

1860-1935: A PERIOD OF TRANSFORMATION

Between 1860 and 1935, coal mining underwent a profound transformation in how explosives were manufactured,

regulated, and applied underground. This era spans the shift from unstable nitroglycerine-based products to scientifically engineered "permissible" explosives designed to reduce the risk of igniting firedamp and coal dust – hazards tragically illustrated by the major disasters of the period.

BETTER SAFE THAN SORRY

The disastrous explosions which occurred in the UK coal mines about the beginning of the period under review, because of their very nature, directed attention to the dangers associated with coal operations. Explosions had always promoted public interest in the hazards of the miners calling. During the 70years 1863-1932 the decennial average death rate per 1,000 persons employed underground in the UK decreased from 0.88 to 0.6. The lowest death rate from this cause.0.02 was recorded in 1917.

Excluding the year 1926, in which there was a long stoppage the direct result of a deep and escalating conflict between coal miners, mine owners, and the government, several intertwined factors pushed the industry into crisis, ultimately triggering the nine day General Strike and a much longer miners' lockout.

The reduction in the death rate can undoubtedly be attributed to the realisation that coal dust itself could have been the cause of the disastrous nature of colliery explosions worldwide.

With a view to eliminating the danger of explosions consequent upon the use of gun powder, many devices were invented and used to a small extent, but it was not until the so-called 'flameless' explosives were devised, and subsequently improved, that reasonable safety in shot firing operations was ensured. Before the adoption of coal dusting making, it innocuous, the application of water had been practiced.

Safer methods of firing explosives evolved over the years. The electrical initiation detonators and fuses in mining was first suggested by Abel in1883 and went on to provide the safest means of firing shots in safety lamp mines, also the use of sand-clay stemming showed to be very efficacious.

The first explosion at Cambrian Colliery UK in 1905 with the loss of 31 lives followed later by a second one shattered the peace of more than one Welsh valley, took away the breadwinner from a score of families, brought pain and sorrow to several local townships and mining communities, and added yet another disaster to the already list of such tragic events in the annuls of coal mining in the UK. Although the pit explosion is happily much less familiar to us all today than it was a century ago, this explosion brought a grim reminder to the country of at least one of the great potential perils of the miner's calling.

Explosions in coal mines were a worldwide problem and the Cambrian incident was followed within two or three weeks, by an explosion at Dhori Colliery in the state of Bihar, India with a loss of 375 lives; by one at Kyushi Colliery in Japan, with a loss of 237 lives; by another at Kakan Colliery in central Yugoslavia, with a loss of 125 lives and by still another smaller explosion at Rudabanya Colliery in Northern Hungary, with a loss of five lives: this was perhaps both unexpected and quite fortuitous.

It was universally accepted at the time that British mines were amongst the safest in the world, nevertheless these happenings in five different countries at once brought home very forcibly not only the fact that that the days of the disastrous explosions was not over, even in the best regulated countries.

Fast forward to today, recent explosions would have one believing through TV, radio and the press that explosions constitute the greatest cause of accidents and death, so often to grip the public imagination. It is unfortunate that this sort of publicity tends to distort the true focus of the accident problems in mines worldwide. Ask any miner what the greatest single source of accidents is and they will all say roof fall followed by haulage and transport. This does not distract from the fact that the explosion hazard as a potential source of a serious accident has received over many years the earnest attention of engineers, chemists, scientists and research workers to make the use of high explosives safer and more efficient.

HOW IT ALL BEGAN

In 1860, the only explosive available for use in coal mines was black powder. It remained a useful explosive for breaking up coal and rock deposits until the early 20th century, when it was gradually replaced by dynamite for most mining purposes.

It may never be known with certainty who invented the first explosive, black powder, which is a mixture of saltpetre (potassium nitrate), sulphur, and charcoal (carbon). The consensus is that it originated in China in the 10th century for its use in fireworks.

By 1935, black powder had disappeared entirely from gassy mines in the UK and other countries. In its place stood a new generation of high explosives – vastly more efficient, more controllable, and safer when handled with proper precautions.

The era of high explosives in coal mining began with three pivotal developments:

Nitroglycerine Explosives – Nitroglycerine was discovered by Sobrero in 1846, and the first ammonium nitrate explosives were patented by Ohlsson and Norrbin in 1867. but it was Alfred Bernhard Nobel a Swedish chemist, inventor, engineer, and businessman who became the most well-known for inventing dynamite and making it usable in mining operations.

He coined the name from the Greek *dynamis*, "power." The basis for the invention was his discovery that kieselguhr, a porous siliceous earth, would absorb large quantities of nitroglycerine, giving a product that was much safer to handle and easier to use than nitroglycerine alone. Dynamite No. 1, as Nobel called it, was 75% nitroglycerine and 25% guhr.

His invention of the use of nitroglycerine explosive with diatomite as a absorbent and then developing a gelatinous nitroglycerine explosive led to a new generation of mining explosives. Later, various powdery explosives with ammonium nitrate as the main component emerged one after another. He would later bequeath his fortune made in explosives development to establish the now famous Nobel Prizes. His life blended scientific brilliance, personal introspection, and a late life desire to leave a legacy of peace and progress.

The Arrival of High Explosives

He shaped modern industry in ways far deeper than "inventing dynamite." His influence runs through mining, construction, manufacturing, global trade, and even the culture of scientific innovation. What he created wasn't just a product – it was an entire industrial ecosystem.

Nobel's inventions forced the mining industry to adopt:

- Training standards
- Safety procedures
- Blast design principles
- Regulatory frameworks
- Specialist roles (shotfirers, explosive engineers)
- He didn't just change the tools – he changed the culture.

The life and times of Alfred Nobel are well documented on various websites the most respected being:

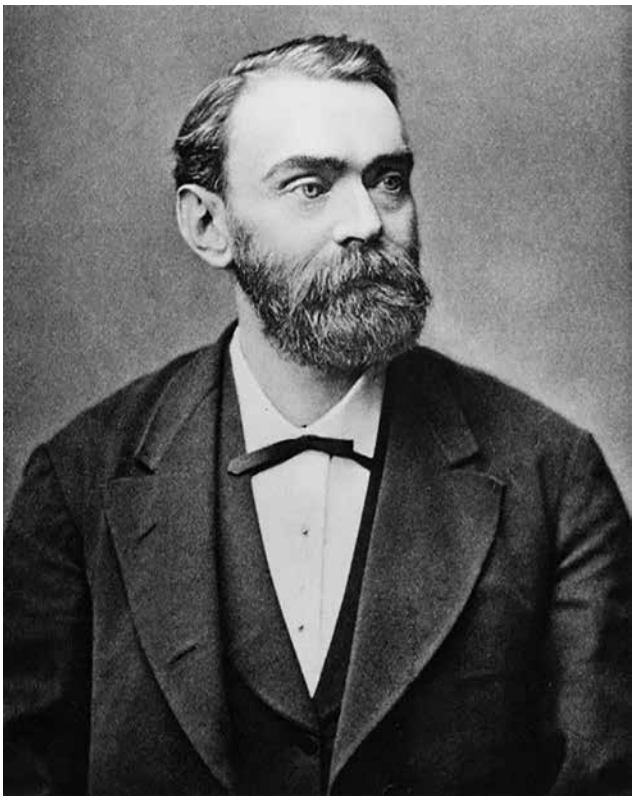
www.nobelprize.org/alfred-nobel

ANOTHER NOTEWORTHY STEP

THE MERCURY FULMINATE DETONATOR (NOBEL, 1867)

Mercury fulminate had been known since 1800, and metal detonator caps containing it appeared around 1814–1815. But Nobel's adoption of the detonator for industrial blasting was transformative. It provided the reliable initiation needed to detonate high explosives safely and consistently. Together, these innovations laid the foundation for modern blasting practice. Though mercury fulminate, like nitroglycerine and ammonium nitrate had been known for many years before their introduction into industry.

Early nitroglycerine was powerful but dangerously unstable, difficult to handle, and prone to freezing – which made it even more hazardous. Though a powerful explosive when used alone, the liquid nitroglycerine first used for blasting had many disadvantages It was inconvenient to use in any, but vertical and firm shot holes. It was dangerous to handle, and it readily froze becoming then less efficient



Alfred Bernard Nobel

on the one hand and still more dangerous on the other. Three distinct advances in nitroglycerine explosives enabled these drawbacks to be overcome, firstly the use of absorbent material such as Kieselguhr or wood meal.

ABSORBENT MATERIALS (KIESELGUHR, WOOD MEAL)

Absorbing nitroglycerine into kieselguhr or wood meal created the first dynamites. Wood meal became particularly favoured because its partial oxidation utilised the excess oxygen in nitroglycerine, improving performance. The use of wood meal was also favoured since the slight excess oxygen of the nitroglycerine could be utilised by oxidation of the wood. More wood meal that could be thus oxidised was usually added, so that a further oxygen carrier, usually an inorganic nitrate, was added at the same time. In this way the composite modern explosives were made up of several constituents mixed together.

GELATINISATION WITH NITROCELLULOSE

The discovery that liquid nitroglycerine could be converted into a gelatinous solid by dissolving in it some 6 or 7% of collodion or nitrocotten was made by Nobel in 1875. Gelatinisation yielded a denser and more powerful explosive that became safer to handle. The modern blasting gelatine at the time consisted of nitroglycerine gelatinised with 8% upwards of nitrocotton, together with a small proportion of a stabiliser to retard decomposition in storage. This became too violent in its actions for many purposes; hence the gelignite's were developed to be made milder in their actions by the addition of potassium nitrate and wood meal. Adding a small proportion of nitrocellulose produced blasting gelatine – more stable, more powerful, and more water resistant than earlier dynamites.

LOW FREEZING EXPLOSIVES

One of the persistent challenges with early nitroglycerine explosives was their tendency to freeze at relatively mild temperatures. Frozen nitroglycerine not only lost efficiency but became markedly more sensitive to shock – a dangerous combination in the cold, damp conditions typical of many mining operations worldwide.

Nitroglycerine freezes at 13 degrees centigrade (55 degrees Fahrenheit). It crystallises very slowly but, during storage in cold weather, all explosives containing it freeze to a hard mass, which became unsuitable for use because of its hardness and insensitiveness. It is somewhat paradoxical that frozen nitroglycerine should be insensitive, for the danger in handling frozen nitroglycerine explosives suggests a much greater sensitivity.

The probable explanation at the time was that liquid nitroglycerine separates from explosives during freezing or, more likely, during partial thawing after freezing. Repeated accidents from this cause occurred over the years, so a lot of attention was made to the methods of rendering nitroglycerine less readily frozen.

The principal of lowering the freezing point of one substance by the addition of another became well known. Examples being spreading salt to make snow melt and the addition of glycerine to prevent freezing in car radiators.

Tetranitrodiglycerene was used in the first low freezing permitted explosives later being replaced by nitroglycol.

The explosive properties of nitroglycol were submitted to a thorough examination in the USA and was found to be more sensitive than nitroglycerine and safer to handle. Its explosive power was slightly superior. It had the disadvantage of being slightly more volatile and thus gave rise to headaches during the process of manufacturer.

The excellent results that ensured from the use of low freezing explosives had the effect that no fatal accidents were reported from mines and quarries in the UK for several years. These additives allowed explosives to remain pliable and reliable even in winter conditions or in deep, poorly ventilated workings where temperatures fluctuated dramatically.

Low freezing explosives represented a major step forward in operational reliability. They reduced misfires, improved consistency in shot performance, and – crucially – lowered the risk of accidental detonation during handling. By the early 20th century, low freezing dynamites had become standard in many mines worldwide particularly where cold conditions were a constant operational concern.

LOW DENSITY EXPLOSIVES

The properties of a blasting explosive may be varied within wide limits by alteration in its composition. The importance of density as a factor in deciding the action of an explosive had been known for a long time, and repeated efforts had been made to find means of reducing it, but it was not until 1927 that the first true low-density explosive was approved for coal mining. The new explosive being first introduced in the USA following the previous use of black powder as in many other countries. The first UK low density explosive was approved in January 1932. There were eleven on the permitted list at the time all proving of great value for coal purposes, over 20% of the weight of explosives used in 1933 being of this type.

By proper methods of working, it was found the permissible explosives were just as effective as black powder in many workings whilst they provided less fumes and smoke and were easier to handle and less liable to be accidentally fired. The advantages then became offset by the introduction of pellet powder as the USA would refer to it that was similar to the black powder pellets in the UK. In 1931 nearly half the black powder used in the USA was in the form of pellet powder. It would be seen that even in 1931 there was a greater quantity of black powder used than of all high explosives, permissible and otherwise. The advantage of black powder being the absence of a shattering effect when it is used, so that it produced less fine coal and a greater size of lump. Many attempts were made to increase the yield of lump coal, the most important being known as 'cushion blasting,' the purpose of which is to spread the explosive effect over a greater surface of borehole.

The difficulties of cushion blasting with the older type of explosive were overcome by the introduction of the low-density explosive, in which the cushioning is, in a sense incorporated in the cartridge. In other words, by decreasing the density by the same weight of explosive occupies a greater length of borehole so that its direct explosive effect acts on a greater length of material and thus, by being distributed over a greater area, has a smaller shattering effect on the coal.

Loading a drill hole underground

Surface drilling rig

Herein lies the main driving force for the developments of the low-density explosive in America, but other advantages also became apparent namely the use of different cartridges.

There were perhaps two main reasons for the introduction of low-density explosives in the UK, first was the higher price obtained in many districts for the larger grades of coal. The second was for finding a substitute for Bobbonite, an explosive which had for some time been kept on the permitted list, on sufferance only, because of its utility as a coal getter.

Four methods were tried in the period for the reduction of density of explosives, namely, loose packing, alteration in the granular state of the ammonium nitrate, impregnation of wood meal, and the use of substitutes for wood meal. Loose packing is not a practical method because it decreases the sensitivity of the explosive and the explosive materials pack more closely during transport. The other three methods had been used singly or together, but bulky substitutes for wood meal perhaps yielded the best results. The substances that were patented for this purpose in the USA included bagasse (pith and fibre of sugar cane), boiled bagasse, balsa wood, oat husks, maize stalks, ground popcorn and sphagnum (peat) moss. Wood disintegrated by saturation with high pressure steam, followed by rapid cooling, was also tried. The use of bulky plant material formed the basis of the first true low-density explosives in the USA which were introduced in 1927 by the Du Pont Co.

EXPLOSIVES OF LOW BALLISTIC STRENGTH

The spreading action of a low-density explosive was attained by distributing the explosive constituents over a greater volume of cartridge. The same effect was obtained by mixing with the explosive a greater quantity of its non-explosive constituents such as sodium chloride. The objection to this was the inevitable loss of sensitivity of the explosive, which was overcome by the then manufactures. As a result, the initial blow of the explosive and, consequently, the shattering effect was considerably reduced.

AMMONIUM NITRATE EXPLOSIVES (FAVIER, C. 1884)

Although ammonium nitrate explosives were first patented by Ohlsson and Norrbin in 1867, it was Frenchman P.A. Favier's work in the 1880s that made them practical. These mixtures would later become the foundation of safer, cooler burning explosives for gassy mines. They were easier and cheaper to manufacture and safer to handle. They required a hydrocarbon sensitiser to ensure detonation, trinitrotoluene being used for this purpose in the UK, while a small proportion (at least 4%) of nitroglycerine became compulsory in Germany. They have a lower sensitivity than nitroglycerine explosives and absorb moisture rather easily, but the latter disadvantage was overcome by waxing the paper wrapper of the cartridges used or by cartridging in metal containers. In 1933, 12,087,032 lb. of nitroglycerine explosives were used in UK coal mines and 4,460,186 lb. of ammonium nitrate explosives containing no nitroglycerine, but it must be remembered that, with a few exceptions, all nitroglycerine explosives contained ammonium nitrate. The use of ammonium nitrate also had certain advantages in reducing the flame temperature of an explosive and had an important influence in the development of permitted coal mining explosives.

In the 1950s, ammonium nitrate fuel oil mixture (ANFO) and slurry explosive were invented successively. In the 1970s, emulsion explosive was developed. Liquid oxygen has also been used as an explosive in some mines

CARDOX

The introduction of Cardox in the UK became one of the outstanding advances over the period, because of the complete departure from ordinary explosive techniques. The Cardox blasting device consisted of a strong steel shell that contained a charge of liquid carbon dioxide and a heating device. By means of this heating device, the liquid carbon dioxide is converted almost immediately into gas at high pressure. The pressure produced was sufficient to shear a disc at one end of the cartridge, when the gas escapes and exerts a disruptive effect on the surrounding strata.

The advantages claimed for the Cardox device were:

1. The increased safety in the presence of firedamp and in handling.
2. Increased yield of lump coal and easy recovery of misfires.
3. little disturbing effect on roof and supports near the shot hole and absence of fumes.

THE RISE OF PERMISSIBLE EXPLOSIVES

As understanding of firedamp and coal dust hazards deepened, it became increasingly clear that even improved nitroglycerine explosives posed unacceptable risks in gassy mines. The flame temperature and violent detonation characteristics of early high explosives could ignite methane or raise coal dust into an explosive suspension.

This led to the development of “permissible explosives” – formulations engineered specifically to minimise flame, reduce detonation temperature, and limit the risk of igniting flammable atmospheres.

KEY CHARACTERISTICS

- Lower flame temperature
- Reduced after flame duration
- Cooler detonation products
- Inclusion of flame suppressing salts
- Controlled energy release tailored to coal cutting needs
- These explosives were not simply “safer dynamites”; they were purpose designed for the unique hazards of mining. Their introduction marked the beginning of a scientific approach to blasting safety.
- **Testing Stations and Scientific Evaluation**
- The late 19th and early 20th centuries saw the establishment of formal testing stations, where explosives were evaluated under controlled conditions. These facilities – including the famous testing galleries – allowed researchers to measure:
- Flame length
- Ignition probability in methane air mixtures
- Detonation pressure
- Fume characteristics
- Cartridge behaviour under confinement
- Explosives were graded and approved based on their performance, and only those meeting strict criteria were permitted for use in gassy mines. This was a revolutionary shift: for the first time, explosives were not judged solely on power, but on safety performance under realistic mining conditions.
- The testing stations also drove innovation. Manufacturers competed to produce explosives that met or exceeded permissible standards, leading to rapid improvements in formulation, consistency, and reliability.
- **Regulation and Standardisation (1900–1935)**
- By the early 20th century, the UK had developed one of the most advanced regulatory frameworks for explosives in mining.
- Key developments included:
- **Approved Lists of Explosives**
- Only explosives that passed official testing could be used in designated mines. This created a clear distinction between:
- **Permissible explosives** (approved for gassy mines)
- **Non permissible explosives** (restricted to non gassy conditions)
- **Shot Firer Certification**
- Blasting operations could only be carried out by trained, certified shot firers. This professionalisation reduced accidents caused by poor handling or incorrect charging.
- **Rules for Storage and Transport**

Explosives had to be:

- Stored in approved magazines
- Transported in locked, spark proof containers
- Issued in controlled quantities
- Accounted for after each shift
- **Charging and Firing Regulations**
- Restrictions on cartridge size and number
- Mandatory stemming requirements
- Prohibition of certain explosives in specific seams
- Introduction of electrical firing systems to replace fuse based ignition
- By 1935, the combination of improved explosive formulations, scientific testing, and strict regulation had dramatically reduced the risk of ignition during blasting. While coal mining remained inherently hazardous, the industry had taken major strides toward controlling one of its most unpredictable dangers.

TRANSITION TOWARD MODERN EXPLOSIVES

By the mid 1930s, the direction of travel was clear:

- Nitroglycerine based dynamites were declining in coal mines.
- Ammonium nitrate mixtures were becoming dominant due to their cooler flame and lower sensitivity.
- Research into water based gels and slurry precursors was underway.
- The concept of tailoring explosives to specific geological conditions was firmly established.
- The groundwork had been laid for the post war evolution of emulsions, ANFO, and the highly engineered blasting agents used today.

FROM 1935 TO THE PRESENT: THE EVOLUTION TOWARD MODERN BLASTING

By 1935, the foundations of modern blasting practice were firmly in place. The industry had moved from black powder to nitroglycerine based dynamites, then to ammonium nitrate mixtures and scientifically tested permissible explosives. The decades that followed would build on this legacy, transforming explosives from simple chemical mixtures into highly engineered blasting agents designed for precision, safety, and environmental responsibility.

THE POST WAR SHIFT: ANFO AND BULK EXPLOSIVES

The most significant development after the 1930s was the introduction of **ANFO (Ammonium Nitrate–Fuel Oil)** in the 1950s. Simple, inexpensive, and remarkably effective.

The post war period introduced systems-level thinking in blasting. Advances in drilling technology produced deeper and more uniform blast holes requiring explosives with predictable detonation velocities. Electric detonators and millisecond delays allowed engineers to shape blast outcomes. This era marked the beginning of fragmentation engineering where blast results were measured, analysed and optimised.

ANFO rapidly became the dominant blasting agent in mining and quarrying. Its advantages were clear:

– Low cost and easy manufacture
– High stability and low sensitivity
– Suitability for bulk loading
– Predictable performance in dry conditions

Although ANFO was less suited to wet or water logged environments, it marked the beginning of a new era: bulk explosives delivered directly into the borehole, reducing handling risks and improving productivity.

WATER BASED EXPLOSIVES: SLURRIES AND EMULSIONS 1960S

From the 1960s onward, research focused on overcoming ANFO’s limitations. This led to the development of slurry explosives and later emulsion explosives, both of which offered:

- Excellent water resistance
- High energy density

- Greater control over detonation velocity
- Improved safety in storage and transport

Emulsions, in particular, became the backbone of modern underground blasting. Their ability to be sensitised on site – often moments before loading – dramatically reduced the risk of accidental initiation during transport or handling.

1970S-1980S: NON-ELECTRIC INITIATION AND RELIABILITY

The development of non-electric initiation systems (such as shock tube technology) greatly improved safety and reliability. From a technological standpoint this reduced systematic risk and allowed blasting operations to integrate more with modern, electrified mine sites.

1990S- COMPUTATIONAL MODELLING AND BLAST SIMULATION

With the rise of computing, blasting entered the digital planning era.

– Engineers began using software to model:
– Rock mass properties
– Detonation timing features
– Stress wave propagation
– Fragment size distribution

This transformed blasting from a rule of thumb practise into a data driven engineering discipline. Explosives were increasingly selected and deployed based on modelled outcomes rather than experience alone.

2000S-2010S

ELECTRONIC DETONATORS AND PRECISION BLASTING

Electronic detonators represented a major technical leap providing millisecond to microsecond accuracy. This precision enabled

- Improved ore recovery
- Lower energy losses
- Better crushing efficiency
- Reduced vibration and flyrock
- Improved fragmentation and wall control

This precision allowed mines to design blasts that were not only safer but also optimised for downstream processes such as loading, hauling, and crushing. Blasting became integrated into the entire mining value chain from drilling to milling.

TODAY

DIGITAL INTEGRATION AND AUTOMATION

Today, explosives are part of a fully integrated digital ecosystem. Modern blasting incorporates:

- GPS-linked blast design
- 3D geological modelling
- Drone based survey data
- Wireless detonator programming
- Cloud-based analytics
- Borehole deviation measurement
- Real time blast simulation
- Autonomous charging and initiating systems
- Automated loading

The result is a level of control unimaginable to the miners of the 1860s – or even the 1930s. Blasts can be designed to minimise vibration, reduce overbreak, control dust, and improve fragmentation, all while maximising safety.

ENVIRONMENTAL AND SAFETY PRIORITIES

Contemporary explosives development is shaped by global expectations around sustainability and worker protection.

Key trends include:

- Reduced NOx emissions
- Lower toxicity formulations
- Recyclable packaging
- Reduced explosive fumes in confined spaces
- Automated or remote loading to remove personnel from hazardous zones

These innovations reflect the same driving force that shaped the industry in the late 19th and early 20th centuries: the need to protect miners while improving productivity.

A CENTURY AND A HALF OF PROGRESS

From the unstable nitroglycerine of the 1860s to today's digitally controlled, water resistant emulsions and precision detonators, the evolution of mining explosives has been one of the most remarkable technological journeys in industrial history.

The story of explosives is ultimately a story of people – miners, blasting engineers, chemists, manufactures and innovators – all striving to make the industry safer and more efficient. Their work continues, and so does ours: to record, to inform, and to ensure that the lessons of the past guide the progress of the future. For companies working in the explosives industry, **this history** matters. It explains why your products exist, how the industry got here, and where innovation is heading next.

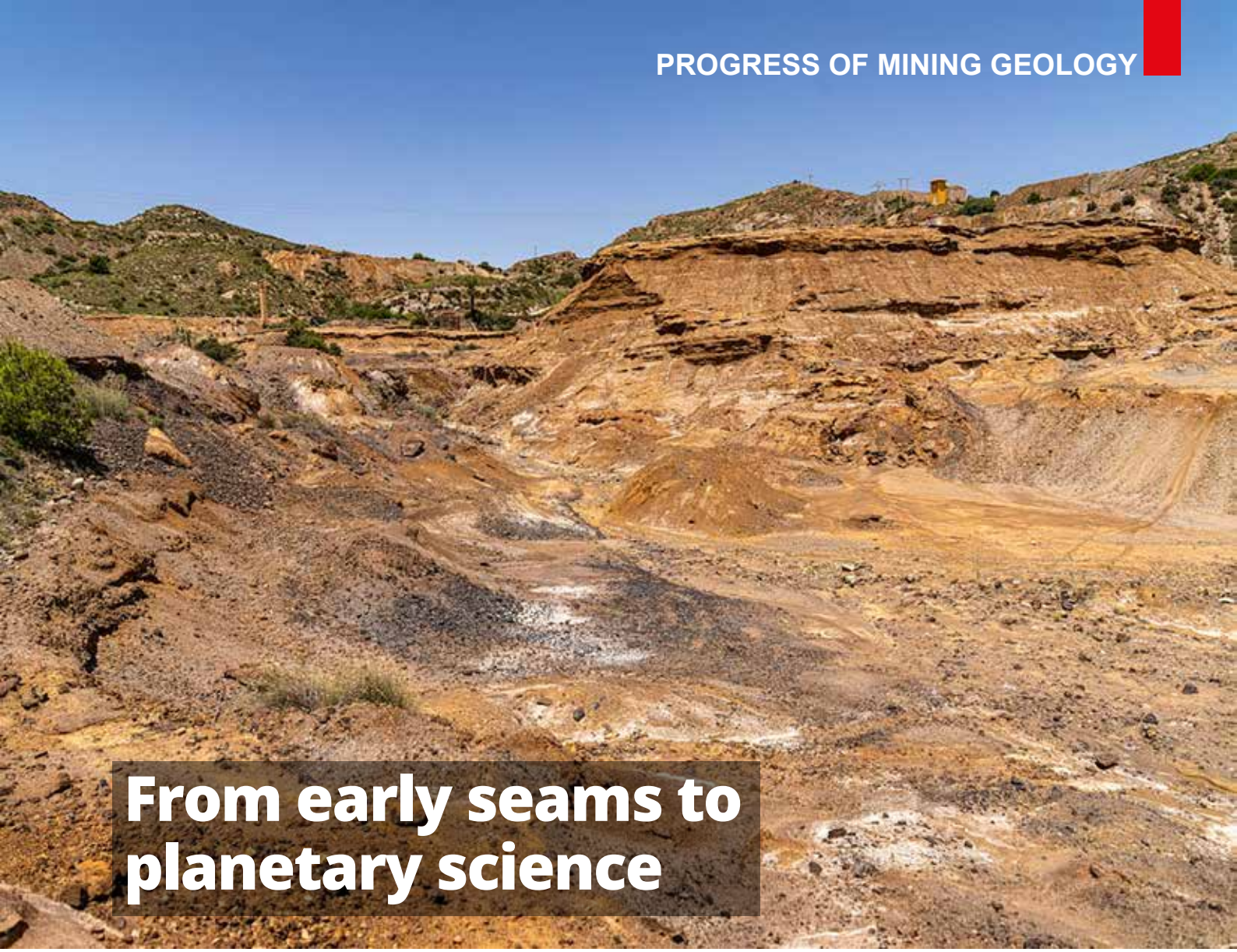
WHY IT MATTERS

As mines go deeper and sustainability pressures intensify, the industry faces a familiar challenge: How do we deliver more energy, more precisely, with less environmental impact?

The answer lies in the same principles that have guided 160 years of innovation:

- Engineered formulations
- Reliable initiation
- Scientific testing
- Data driven design
- Continuous improvement

The past isn't just history. It's a roadmap.



From early seams to planetary science

Perhaps it is more than a simple coincidence that the 1860s became the most rapid period of development that the science of geology has ever known. Fifty years earlier the subject had scarcely shaken itself free from the welter of barren argumentation contained in the many" Theories of the Earth" produced by the writers of the 17th and 18th centuries. It is true that by that time the sedimentary origin of most of the stratified rocks was at last admitted, and the whole history of the earth's crust was being explained., all to simply, on this basis by Werner of Freiberg and his enthusiastic disciples. Hutton's evidence of the warping and dislocation of the rocks, and of the intrusion of molten rock from the interior, was scarcely heeded. It was still the current view that the whole history of the earth might be compromised within a few thousands of years.

In 1835 a complete revolution in geological thought had been accomplished. The way was prepared by the growing attention of the fossil remains found in the rocks. When, during the latter part of the 18th century, it became universally recognised that these were in fact the remains of creatures, which had once lived in the seas or on the ancient lands, comparisons of the fossils with living forms was inevitable, and an increasingly deep impression was made by the discovery that no living forms could be found which were identical to the fossils. The latter were the relics of an extinct creation. Several workers made the further discovery that different strata contained different fossil remains.

In the UK coal industry, another development was coming from the early attempts to trace the distribution of rocks in different areas. Maps of small districts had been prepared. But it was left to William Smith, the civil engineer and road surveyor, to combine these advances; to show that the same strata always contained the same fossil remains; that by this means the strata could be recognised in distant places; and to construct with the aid of this powerful weapon, the first complete geological map of a large area. In 1815 he completed 25 years work on these lines and published the first geological map of England and Wales. This map may be justly regarded as the starting point of modern geology. It revealed with a clarity which no general descriptions could give the long succession of stratified rocks and the many changes of fauna and flora that had occurred in the past. The whole scale on which the past history of the earth had been viewed was immeasurably enlarged.

The enlarged vision of Earth's past did more than satisfy scientific curiosity; it transformed the practical business of extracting minerals and fuel. As the Industrial Revolution gathered pace, the demand for coal, ironstone, limestone, and metallic ores increased beyond anything previously imagined. Mines were driven deeper, workings became more extensive, and the risks multiplied. It was no longer sufficient for the miner to rely solely on inherited local knowledge or the rule of thumb traditions of earlier

generations. The new understanding of stratigraphy offered a means of prediction – a way to foresee what lay beneath the surface before a shaft was sunk or a drift was driven.

By the 1830s and 1840s, the principles established by Smith and his contemporaries were being applied directly to the coalfields of Britain. The recognition that each coal seam occupied a definite position in the stratified sequence, and that this position could be traced across counties and even national boundaries, revolutionised coal exploration. Geological mapping became an indispensable tool of the colliery viewer, enabling him to anticipate faults, anticipate thinning or splitting of seams, and avoid costly miscalculations. The miner's world, once confined to the dim light of the pit lamp, was now connected to the broad sweep of geological time.

At the same time, the science itself was advancing with unprecedented speed. Sedgwick, Murchison, Lyell, and others extended the geological column into ever more ancient periods, each marked by its own characteristic fossils and rock types. Lyell's insistence on slow, continuous processes acting over immense spans of time provided a framework within which the structure of ore bodies, the formation of coal measures, and the metamorphism of rocks could be more clearly understood. The earth was no longer seen as a static stage for human activity but as a dynamic system, constantly reshaped by forces still active today.

Mining geology emerged from this ferment as a distinct branch of the science. Its practitioners combined the observational rigour of the field geologist with the practical demands of engineering and mineral economics. They learned to read the underground world with increasing precision: the folding and faulting of strata, the migration of mineralising fluids, the relationship between rock type and ore deposition. Each new colliery, quarry, or metalliferous mine became both a workplace and a laboratory, revealing structures and sequences that could not be observed at the surface.

By the 1860s, the cumulative effect of these developments was unmistakable. Geology had become a mature science, grounded in evidence, guided by mapping, and enriched by the discoveries of palaeontology and chemistry. Mining, in turn, had become more systematic, more predictable, and more closely tied to geological understanding. The partnership between the two disciplines – forged in the coalfields and refined in the metalliferous districts – laid the foundations for the mining geology of the modern world.

BROADENING THE GEOLOGICAL HORIZON

As the 19th century progressed, the coalfields of Britain, Europe, and North America became the proving grounds for geological method. The careful tracing of seams, the recognition of structural disturbances, and the mapping of stratigraphic sequences gave mining geology its first systematic tools. But coal, for all its importance, represented only a fraction of the Earth's mineral wealth. Once the principles of stratigraphy, palaeontology, and structural geology were established, it became inevitable that they would be applied far beyond the Carboniferous basins.

Three forces drove this expansion:

- **Industrial demand** for metals such as copper, lead, zinc, tin, and later nickel and aluminium.
- **Imperial and commercial exploration**, which opened new territories to geological survey.
- **Scientific curiosity**, which sought to understand ore formation, metamorphism, and the deep structure of the crust.

The miner's world, once centred on the coal seam and the ironstone band, now extended to mountain belts, volcanic provinces, and ancient crystalline shields.

THE RISE OF METALLIFEROUS GEOLOGY

By the mid 19th century, mining districts such as Cornwall, the Harz, the Urals, and the American West became laboratories for a new kind of geological thinking. Unlike coal, which lay in predictable stratified sequences, metallic ores were often found in veins, lodes, and irregular bodies controlled by faults, intrusions, and hydrothermal activity. This demanded a deeper understanding of:

- **igneous processes,**
- **mineralising fluids,**
- **structural deformation, and**
- **metamorphic environments.**

Geologists learned to read the signs of mineralisation: alteration halos, vein textures, breccias, and the relationship between intrusive rocks and ore bodies. The science became more interpretive, more three dimensional, and more global in its outlook.

GEOLOGICAL SURVEYS AND THE GLOBAL SEARCH FOR MINERALS

The second half of the 19th century saw the establishment of national geological surveys across the world. These institutions mapped vast regions, catalogued mineral occurrences, and provided the first systematic assessments of national resources. Their work extended far beyond coalfields to include:

- goldfields in California, Australia, and South Africa,
- copper belts in central Africa and the Americas,
- tin and tungsten provinces in Southeast Asia,
- iron ore basins in India, Brazil, and Scandinavia.

The geological map – pioneered by William Smith – became a global instrument of economic development.

THE TECHNOLOGICAL SHIFT

As mining moved into deeper, harder, and more complex environments, geology had to evolve again. The late 19th and early 20th centuries introduced:

- **microscopy**, revealing mineral textures and paragenesis;
- **chemical analysis**, enabling precise ore characterisation;
- **geophysics**, detecting concealed structures and ore bodies;
- **geochemistry**, tracing subtle signatures of mineralisation.

These tools allowed geologists to explore terrains where surface clues were sparse or absent. Coal geology remained important, but it was now one branch of a much larger discipline.

A GLOBAL INDUSTRY BUILT ON GEOLOGICAL UNDERSTANDING

By the early 20th century, mining geology had become international in scope. Geologists travelled from continent to continent, applying the same principles to radically different geological settings. The profession expanded from colliery viewers and district surveyors to include:

- exploration geologists,
- structural specialists,
- economic geologists,
- petrologists,
- and later, geophysicists and geochemists.

The shift from coal to global minerals was not a replacement but an enlargement – a recognition that the Earth's crust held a diversity of resources shaped by processes for older and more varied than the Carboniferous swamps.

THE EMERGENCE OF MODERN ECONOMIC GEOLOGY

By the opening decades of the 20th century, geology had matured into a science capable of explaining not only the arrangement of strata, but the origins of ore deposit themselves. The work of Lindgren, Emmons, and the early economic geologists in the United States provided a systematic classification of mineral deposits based on temperature, pressure, and geological environment. Their studies of porphyry copper systems, epithermal veins, and contact metamorphic deposits created a framework that could be applied anywhere on Earth.

This new understanding coincided with a period of rapid industrial expansion. Steelmaking demanded vast quantities of iron ore and manganese; electrification required copper on an unprecedented scale; the chemical industries sought sulphur, phosphates, and potash; and the emerging technologies of the age – from aluminium smelting to petroleum refining – depended on minerals that had scarcely been exploited before. The world's appetite for resources had outgrown the traditional mining districts of Europe.

GLOBAL EXPLORATION AND THE OPENING OF NEW FRONTIERS

The search for minerals now ranged across continents. Geological surveys, prospecting companies, and private syndicates pushed into regions that had previously been only lightly explored. Several developments defined this era:

- **The discovery of the Witwatersrand goldfields**, which transformed South Africa into one of the world's great mining centres.
- **The rise of the copper belts** in the American Southwest, Chile, and central Africa, each revealing ore bodies of a scale unimaginable in earlier centuries.
- **The exploitation of bauxite**, leading to the global aluminium industry and opening new mining frontiers in the Caribbean, West Africa, and Australia.
- **The recognition of vast iron ore provinces**, from the Mesabi Range to the Pilbara, which reshaped global steel production.

These discoveries were not accidental. They were the direct result of applying geological principles – stratigraphy, structural analysis, petrology, and mineralogy – to terrains far removed from the familiar coal measures of Europe.

SCIENTIFIC TOOLS THAT TRANSFORMED EXPLORATION

The mid 20th century brought a revolution in the tools available to the mining geologist. Techniques that had once been confined to academic laboratories became essential components of mineral exploration.

- **Petrographic microscopy** revealed the textures and histories of rocks and ores.
- **Chemical assays** provided precise measurements of metal content and alteration patterns.
- **Geophysical methods** – magnetic, gravity, electrical, and later seismic – allowed geologists to "see" beneath the surface.

- **Geochemistry** traced subtle halos of mineralisation, guiding exploration even where no outcrop existed.

- **Aerial photography and satellite imagery** opened vast regions to rapid reconnaissance.

These innovations allowed exploration to move into deserts, jungles, tundra, and mountain belts where surface clues were sparse or absent. The geologist became not merely a mapper of rocks but an interpreter of hidden structures and deep processes.

A GLOBAL INDUSTRY BUILT ON GEOLOGICAL INSIGHT

By the latter half of the 20th century, mining geology had become a truly international profession. Geologists travelled from continent to continent, applying universal principles to local conditions. The discipline expanded to include:

- **Plate tectonics**, which explained the distribution of mineral belts across the globe;

- **Ore genesis models**, linking mineral deposits to specific tectonic and magmatic environments;

- **Resource estimation**, combining geology with mathematics and statistics;

- **Environmental geology**, recognising the need for responsible stewardship of land and water.

The shift from coal to global minerals was not simply a change in commodity. It was a transformation in scale, method, and ambition. Mining geology evolved from a regional craft into a worldwide scientific endeavour, capable of supporting the technological and economic systems of the modern world.

DIGITAL TOOLS THAT RESHAPED EXPLORATION

The late 20th and early 21st centuries mark the point where mining geology became not only global, but digital, predictive, and deeply intertwined with questions of sustainability and resource security. The discipline that began with William Smith's hand coloured maps now operates in three dimensions, across continents, and at depths and scales unimaginable to earlier generations.

The arrival of computers, remote sensing, and advanced analytical methods transformed the geologist's craft. What had once been a field notebook and a compass became an integrated system of data capture, modelling, and interpretation.

Key developments included:

- **Geographic Information Systems (GIS)**, allowing geological, geophysical, geochemical, and topographic data to be layered, analysed, and visualised with precision.

- **3D geological modelling**, enabling geologists to reconstruct subsurface structures, ore bodies, and alteration systems in ways that guided drilling and reduced exploration risk.

- **Remote sensing**, using satellites and airborne sensors to detect mineral signatures, structural trends, and alteration zones across vast terrains.

- **High resolution geophysics**, capable of imaging deep crustal structures and concealed mineral systems.

- **Automated geochemical analysis**, providing rapid, accurate data from drill cores and surface samples.

These tools allowed exploration to move into regions where traditional mapping was difficult or impossible – dense forests, arid deserts, polar environments, and deeply weathered terrains.

THE RISE OF GLOBAL MINERAL SYSTEMS THINKING

Plate tectonics, accepted by the scientific community in the 1960s and 1970s, provided the unifying framework that modern mining geology still relies on. Mineral deposits were no longer seen as isolated curiosities but as products of large scale geological processes.

This shift enabled geologists to:

- predict where certain deposit types should occur based on tectonic setting;

- understand the relationship between magmatism, crustal evolution, and mineralisation;

- recognise global belts of mineral wealth – copper in the Andes, gold in the Yilgarn, diamonds in the cratons, nickel in the komatiites, rare earths in carbonatites.

Exploration became more strategic, guided by models of ore genesis rather than chance discovery.

NEW COMMODITIES FOR A CHANGING WORLD

As the 20th century progressed, the mineral demands of society shifted dramatically. Coal remained important, but new technologies required new materials.

Several trends reshaped the industry:

- The rise of base metals (copper, nickel, zinc) to support electrification and industrial growth.

- The expansion of bulk commodities (iron ore, bauxite, phosphates) to feed global manufacturing and agriculture.

- The emergence of critical minerals – lithium, cobalt, rare earth elements, graphite – essential for batteries, electronics, and renewable energy systems.

- The growth of industrial minerals such as potash, gypsum, and silica, vital to construction, fertilisers, and glassmaking.

Mining geology broadened again, now encompassing everything from deep sea nodules to evaporite basins and volcanic arcs.

ENVIRONMENTAL RESPONSIBILITY AND THE MODERN GEOLOGIST

By the late 20th century, geology's role expanded beyond discovery and extraction. The environmental

consequences of mining – land disturbance, water use, waste management, and long term rehabilitation – became central concerns.

This led to new branches of practice:

- **environmental geology**, assessing impacts and guiding responsible development;
- **hydrogeology**, understanding groundwater systems and protecting water resources;
- **geotechnical engineering**, ensuring the stability of slopes, tailings, and underground workings;
- **mine closure planning**, integrating geology with ecology and community needs.

THE MODERN MINING GEOLOGIST BECAME BOTH A DISCOVERER AND A STEWARD

The 21st century transformation: data, automation, and critical minerals

Today's mining geology operates at the intersection of technology, sustainability, and global resource strategy. Several forces define the current era:

- **Machine learning and artificial intelligence**, analysing vast datasets to identify subtle patterns of mineralisation.
- **Automated drilling and core logging**, increasing accuracy and reducing risk.
- **Real time data acquisition**, allowing decisions to be made as drilling progresses.
- **Global competition for critical minerals**, driven by renewable energy, electric vehicles, and digital infrastructure.
- **A renewed focus on recycling, circular economy principles, and reducing the environmental footprint of mining**.

The geologist of today must understand not only rocks and structures but data science, environmental regulation, community engagement, and the geopolitics of mineral supply.

SPACE TECHNOLOGY

Space technology marks the newest frontier in the long evolution of mining geology. After centuries spent moving from coal seams to global mineral belts, the discipline now extends beyond the Earth itself. What began with William Smith's map has grown into a planetary – and increasingly interplanetary – science.

Key advances included:

- **Satellite multispectral and hyperspectral imaging**, detecting alteration minerals, iron oxides, clays, carbonates, and even subtle geochemical halos.
- **Radar and LiDAR**, penetrating vegetation and shallow cover to expose structural trends and lithological boundaries.
- **Global positioning systems**, enabling precise mapping and integration of field data with digital models.
- **Earth-observing constellations**, providing continuous monitoring of remote terrains, climate impacts, and environmental change.

These tools allowed geologists to map entire mineral provinces in days rather than years, and to target exploration drilling with unprecedented accuracy.

THE FUTURE: A UNIFIED SCIENCE OF PLANETARY RESOURCES

Mining geology is now entering a phase where Earth and space are part of a single continuum. The same questions apply whether studying a copper belt in Chile or a crater on the Moon:

- What processes formed the deposit?
- What structures control its distribution?
- What technologies can detect and extract it?
- How can it be done responsibly and sustainably?

The next generation of geologists may work not only in the Pilbara or the Andes, but in lunar lava tubes, Martian sedimentary basins, or the rubble piles of near Earth asteroids.

Mining geology now sits at the intersection of science, society, and sustainability. Future practitioners must be able to balance resource development with environmental and community considerations.

The next generation of mining geologists will work in a world where Earth based geology, planetary science, digital technology, and sustainability are inseparable. Their skillset will be broader than anything required in the coalfields, the metalliferous districts, or even the great exploration booms of the 20th century. What follows extends your historical narrative into a forward looking, structured account of the capabilities tomorrow's geologists must master

Key competencies include:

- **environmental geology**, predicting and mitigating impacts on land, water, and ecosystems;
- **hydrogeology**, essential for managing groundwater in arid and sensitive regions;
- **geotechnical awareness**, ensuring the stability of slopes, tailings, and underground workings;
- **mine closure and rehabilitation planning**, integrating geology with ecology and long term land use;
- **community engagement**, communicating geological concepts clearly and building trust with stakeholders.

The geologist becomes a steward of land as well as a discoverer of resources.

Skills to meet new requirements in the mining industry – Training and Development

By **Trevor Barratt MD**
Coal International and Mining and Quarry World

I want this article to have but two virtues: brevity and fundamental relevance. I want it to be brief since over-elaboration draws attention away from central issues. relevant to the extent that it isolates these central issues from the temptingly easy detail and concerns itself more with the 'what' rather than the' how' of training and development.

I have spent more than five decades immersed in the mining industry, beginning my career as an apprentice electrician in 1965 in the UK. under the then National Coal Board, a system that demanded commitment but gave far more in return. It was a wonderful period, rich with learning, mentorship, and the kind of camaraderie that only mining can produce. The NCB didn't just train apprentices; it shaped them. It taught discipline, respect for the craft, pride in doing things properly, and the quiet confidence that comes from earning your place underground. Those years were not simply preparation for a career; they were an education in life, work, and community.

The five-year apprenticeship before qualification provided a foundation of skill and character that shaped the rest of my mining career long before moving into publishing.

ONWARDS

Today's mining industry is shifting faster than at any point since mechanisation arrived in the 1960s – automation, digitalisation, ESG pressures, and new safety expectations are reshaping what "skilled" means underground and at the surface. Training and development aren't just HR tick boxes anymore; they're strategic survival tools. First then, do we fully recognise the extent of the change taking place? Those who live through a period of radical change and are active participants in it often cannot see the extent of change as clearly as the bystander- ask any occasionally visiting grandparent!

Have we as professionals and as people yet come to terms with the change and are we fully equipped by education, training, development and experience to respond to the

opportunity and the challenges now presented. Are we equipped and in the right frame of mind to attack the future rather than-as for so many years- to defend ourselves against it. That must be the fundamental question asked when treating the subject of this article.

In this article, I will argue that training and development must evolve from administrative obligations into strategic assets. My call is simple: keep it brief, keep it relevant, and focus on the fundamentals.

RECOGNISING THE NEW SKILL LANDSCAPE

If we accept that the industry is changing, we must then define the skills that matter most in this new environment. The temptation is to produce long lists – competencies, frameworks, matrices – but these often obscure more than they reveal. What matters is clarity around the domains of capability that determine whether a workforce can thrive in a modern mine.

Four stand out as fundamental.

1. **Digital Fluency, Not Digital Specialism**
   Mining no longer needs every worker to be a data scientist, but it does require a workforce that is comfortable with data enabled decision making. Sensors, dashboards, autonomous systems, and predictive maintenance tools are now part of daily operations. The essential skill is not coding; it is the ability to interpret information, trust it, and act on it.

2. **Systems Thinking Over Task Thinking**
   Modern mines are integrated ecosystems. A change in one area – ventilation, haulage, scheduling, energy use – ripples across the whole operation. Workers who understand how their role fits into the wider system make better decisions, reduce downtime, and improve safety. This is a shift from “my job” to “our process”.

3. **Adaptability as a Core Competence**
   For decades, mining rewarded mastery of a stable craft. Today, the craft evolves continuously. Equipment updates, regulatory shifts, ESG expectations, and automation cycles demand a workforce that can learn, unlearn, and relearn. Adaptability is no longer a personality trait; it is a professional requirement.

4. **A Modern Safety Mindset**
   Safety has moved from compliance to culture. The new skill is not simply following rules but recognising risk, communicating it, and intervening early. Psychological safety – speaking up without fear – has become as important as physical safety. Mines that fail to cultivate this mindset will struggle to meet both regulatory and societal expectations.

THE REAL QUESTION: ARE WE PREPARING PEOPLE FOR THIS?

If these are the skills the industry now requires, the uncomfortable question becomes unavoidable: **are our training and development systems aligned with them?** Too often, training remains reactive, compliance driven, or anchored in yesterday’s job descriptions. Development programmes still assume a static industry rather than a dynamic one.

The challenge is not simply to update courses or buy new simulators. It is to reshape the mindset of the organisation so that learning becomes continuous, strategic, and valued. The mines that succeed will be those that treat training not as a cost but as an investment in resilience.

WHAT A FUTURE READY TRAINING STRATEGY MUST LOOK LIKE

If the industry is to meet its new skill requirements, training and development must shift from event based instruction to a continuous, strategic capability. Three principles define this shift.

1. **Training Must Be Integrated, Not Isolated**
   For too long, training has been treated as a separate activity – scheduled, delivered, signed off, and forgotten. Modern mining demands the opposite. Learning must be embedded into daily operations:

   - real time feedback from digital systems,
   - on shift coaching,
   - simulation based practice before equipment changes,
   - and structured reflection after incidents or near misses.

Training becomes effective when it is part of the workflow, not an interruption to it.

2. **Development Must Be Forward Looking, Not Backward Facing**
   Traditional development models reward tenure and past performance. The new environment rewards potential, adaptability, and the willingness to learn. Mines must identify and nurture people who can grow into new roles – automation technicians, data enabled supervisors, ESG coordinators, remote operations specialists.

   The question is no longer “What can this person do today?” but “What could this person become with the right development?”

3. **Leadership Must Champion Learning as a Strategic Asset**
   No training programme succeeds without leadership commitment. Supervisors and managers must model the behaviours they expect curiosity, openness to change, and a willingness to admit when they need to learn something new.

   A mine that encourages questions, experimentation, and constructive challenge will outperform one that clings to hierarchy and habit. Culture, not curriculum, is the decisive factor.

THE COST OF INACTION

It is tempting to believe that the industry can adapt gradually, that incremental improvements will be enough. They will not. Mines that fail to modernise their training and development approach will face:

- widening skills gaps,
- reduced productivity,
- increased safety risks,
- and difficulty attracting the next generation of workers.

The industry is already competing with technology, energy, and engineering sectors for talent. Without a compelling development pathway, mining will lose that competition.

CONCLUSION: PREPARING PEOPLE TO SHAPE THE FUTURE, NOT SURVIVE IT

The mining industry stands at a point of inflection. Technology, regulation, and societal expectations are rewriting the definition of a skilled workforce. The question is not whether we can keep up with this change, but whether we can get ahead of it.

Training and development must therefore be treated not as administrative necessities but as strategic investments – investments in resilience, innovation, and long term competitiveness.

If we equip our people with the right skills, mindset, and confidence, they will not merely adapt to the future of mining. They will shape it.

Technological accelerations

The mining industry stands at a pivotal moment, where technological acceleration, shifting societal expectations, and the global push for sustainability are reshaping what it means to work in this sector. As automation, digital systems, and low-carbon processes move from aspiration to operational reality, the workforce is undergoing a profound transition – not a decline, but a transformation. Roles are evolving, new skills are emerging, and organisations are being challenged to rethink how they attract, develop, and retain talent in an increasingly competitive landscape. This transition is not simply about adapting to new tools; it is about redefining the culture, capabilities, and identity of the mining workforce for the decades ahead.

THE MODERNISATION IMPERATIVE

Despite ambitious decarbonisation targets and sustained investment in digitalisation, sustainability, and ESG performance, mining leaders continue to confront a stubborn challenge: the industry's public image has not kept pace with its transformation. For many external stakeholders – and even for potential recruits – the sector is still associated with environmental degradation, slow innovation cycles, and a historically homogenous workforce. These legacy perceptions persist even as modern operations deploy advanced automation, renewable energy systems, and increasingly diverse teams.

Recent findings conducted across several markets in the last 3 or 4 years, confirm that the mining industry continues to face entrenched negative public perceptions. Many respondents still associate mining with environmental damage, community disruption, and legacy social issues. Despite significant progress in operational standards, rehabilitation practices, and sustainability initiatives, these outdated perceptions remain a major barrier to industry reputation and stakeholder trust.

Internally, leaders recognise that the industry must reposition itself as a technologically sophisticated, socially responsible, and future-focused sector. This means shifting the narrative from one of environmental strain and operational monoculture to one defined by innovation, inclusivity, and climate accountability. The stakes are high. Workforce expectations are evolving at unprecedented speed, with younger talent seeking purpose-driven careers, flexible work models, and employers who demonstrate genuine commitment to sustainability. Investors are scrutinising ESG performance with greater intensity, influencing capital allocation and long-term project viability. Meanwhile, geopolitical volatility is reshaping supply chains, commodity strategies, and national resource policies. Together, these forces create one of the most complex and consequential operating environments mining has ever faced.

While environmental concerns dominate public sentiment, the survey also shows that people recognise mining's essential economic role. Respondents acknowledged the sector's contribution to job creation, regional development, and national economic growth. However, these positive impacts are often overshadowed by concerns about environmental performance and social responsibility. The challenge for the industry is not the absence of economic value – it is the lack of visibility and understanding of the modern mining reality.

The ICMM report reinforces the importance of trust as a strategic asset for the mining industry. Building trust requires more than operational improvements – it demands consistent, open communication about environmental performance, social outcomes, and long-term sustainability commitments. Mining companies must be proactive in sharing data, reporting progress, and demonstrating how modern practices differ from outdated perceptions. Trust grows when stakeholders can see, understand, and verify the industry's efforts.

DIGITAL TRANSFORMATION ACCELERATED

The rapid shift toward a digitally enabled workforce – accelerated dramatically by the COVID-19 pandemic –

has intensified the urgency for operational transformation. Technologies once considered optional or experimental are now central to competitiveness. Artificial intelligence, autonomous haulage, predictive maintenance, digital twins, and real-time analytics are no longer future concepts; they are becoming foundational to productivity, safety, and strategic decision-making.

Yet the digital evolution is unfolding alongside rising expectations around ESG performance and the global transition to low-carbon systems. Mining organisations must therefore redesign operating models to close widening skill gaps, strengthen workforce engagement, and embed sustainability into every layer of the business – from exploration and extraction to processing, planning, and community partnerships. This is not simply a technological shift; it is a workforce transition that demands new capabilities, new mindsets, and a new social contract between mining companies and the people who power them.

WORKFORCE TRANSITIONS: REDEFINING CAPABILITY AND CULTURE

As mining organisations accelerate modernisation, the workforce transition has become both a strategic priority and a defining test of leadership. The industry is shifting from labour-intensive, equipment-centric operations to digitally integrated, data-driven ecosystems. This evolution is reshaping job profiles across the value chain. Traditional roles – such as equipment operators, maintenance technicians, and geologists – are being augmented or redefined by automation, remote operations, and advanced analytics, while entirely new roles are emerging in fields such as data science, robotics, cybersecurity, decarbonisation engineering, and renewable energy integration.

Yet the challenge extends far beyond acquiring new technical skills. Mining companies must cultivate a workforce that is adaptable, multidisciplinary, and comfortable operating in environments where human expertise and digital intelligence intersect. This requires a fundamental shift in how capability development, career pathways, and organisational culture are approached.

BUILDING THE TALENT PIPELINE OF THE FUTURE

The competition for talent is intensifying, and mining is no longer competing solely with other heavy industries. It now finds itself up against technology firms, renewable energy companies, and advanced manufacturing sectors that often carry greater contemporary appeal. Younger generations are evaluating employers through a different lens – seeking purpose-driven careers, flexible work models, and organisations that demonstrate genuine commitment to sustainability and social impact.

To attract and retain the next generation of talent, mining organisations must reframe the industry narrative to highlight innovation, climate solutions, and the essential role mining plays in enabling renewable technologies and electrification. They need to invest in future-focused training that builds digital literacy, systems thinking, and cross-disciplinary problem-solving. Career pathways must become more visible and flexible, enabling employees to move fluidly between operational, technical, and digital roles. Stronger partnerships with universities, technical colleges, and Indigenous and local communities will be essential to building inclusive, long-term talent pipelines. Above all, diversity, equity, and inclusion must become core organisational values rather than compliance obligations.

These shifts are critical not only for attracting talent but also for building a resilient workforce capable of navigating the volatility and complexity that define modern mining.

CULTURAL TRANSFORMATION AS A STRATEGIC ENABLER

Technology alone cannot deliver the full value of modernisation. The cultural transformation required is

equally significant. Mining organisations must foster environments where innovation is encouraged, continuous improvement is expected, and employees feel empowered to challenge legacy practices.

This cultural shift involves moving away from hierarchical decision-making toward collaborative, data-informed problem-solving. It requires a mindset that embraces experimentation and learning, recognising that digital transformation is iterative rather than linear. Strengthening psychological safety is essential, ensuring that all voices – particularly those from underrepresented groups – are heard and valued. Leadership behaviours must evolve as well, with greater emphasis on transparency, empathy, and purpose-driven decision-making.

Ultimately, the workforce transition is not a peripheral initiative; it is the foundation upon which operational excellence, ESG performance, and long-term competitiveness will depend.

A SECTOR POISED FOR REINVENTION

The mining industry is navigating one of the most consequential periods of change in its history. Digital transformation, ESG expectations, and shifting workforce demographics are no longer parallel trends – they are deeply interconnected forces reshaping how mining companies operate, compete, and define value. The organisations that succeed will be those that recognise this convergence and respond with clarity, ambition, and a willingness to rethink long-standing assumptions.

Workforce transformation sits at the centre of this reinvention. As operations become more automated and data-driven, the industry must cultivate a workforce capable of managing complex digital systems while also advancing sustainability outcomes. This requires not only new technical capabilities but also a cultural shift toward collaboration, adaptability, and continuous learning. The companies that invest early in these capabilities will be better positioned to unlock the full potential of modern mining technologies and meet the expectations of investors, communities, and employees.

THE PATH FORWARD: INTEGRATING PEOPLE, TECHNOLOGY, AND PURPOSE

The future of mining will be defined by how effectively organisations integrate people, technology, and purpose.

Digital tools will continue to enhance safety, productivity, and decision-making, but their impact will depend on a workforce that is empowered, skilled, and aligned with the organisation's strategic direction. ESG commitments will shape investment flows and community trust, but they will only be credible when supported by transparent reporting, measurable progress, and a workforce that understands and contributes to sustainability goals.

This integration requires leadership that is both visionary and grounded – leaders who can navigate operational realities while championing innovation, inclusivity, and environmental responsibility. It also requires a renewed focus on workforce engagement, ensuring that employees feel connected to the organisation's mission and equipped to contribute to its evolution.

INSIGHTS FROM INDUSTRY LEADERS

Our engagement with experts and thought leaders across the mining and resources sector underscores a shared recognition: the industry has made meaningful progress, but the pace of change must accelerate. Leaders emphasised the importance of modernising talent strategies, strengthening digital capability, and embedding ESG into everyday decision-making. They also highlighted the need for more agile operating models, improved communication across dispersed teams, and a stronger commitment to diversity and inclusion.

These insights reinforce a clear message: mining's transformation is not a distant aspiration – it is an active, ongoing process that requires sustained focus and investment.

A FUTURE BUILT ON CAPABILITY AND COMMITMENT

The mining industry's role in enabling global decarbonisation and technological advancement has never been more critical. But fulfilling this role depends on the sector's ability to evolve. Companies must build flexible, digitally fluent workforces; create cultures that support innovation and belonging; and deliver ESG outcomes that meet the expectations of investors, communities, and future generations.

The path forward is challenging, but it is also an opportunity – an opportunity to redefine mining as a modern, responsible, and future-ready industry. Those who embrace this moment with purpose and conviction will not only strengthen their own organisations but also help shape the future of a sector essential to the world's progress.

A NEW WORKFORCE AND ESG REALITY

To remain competitive, mining companies will need to prioritise diversity, equity, and inclusion, while also accelerating efforts to reduce emissions and environmental impact. These priorities are no longer optional – they are central to attracting talent, securing investment, and maintaining social licence.

LEADERSHIP FOR A TRANSFORMING INDUSTRY

Mining remains a critical driver of global development, but its future depends on how effectively leaders respond to these converging pressures. The sector must cultivate a workforce equipped for digital operations, foster a culture that supports innovation and inclusivity, and implement strategies that deliver measurable ESG progress.

To better understand the needs of today's mining workforce and the actions required to accelerate industry transformation, engagement with experts and thought

leaders across the mining and resources sector is crucial. Their insights highlight both the progress made and the steps still needed for mining to thrive in an increasingly progressive and technology-driven world.

FLEXIBILITY

Modern work has shifted decisively toward flexibility, with remote and hybrid models now embedded across most industries. Mining, despite its operational complexity, is not exempt from this shift. For a sector dominated by “deskless” workers who operate far from traditional office environments, flexibility has become a strategic requirement rather than an optional benefit. To support this evolution, mining organisations must invest in technologies and systems that enable seamless communication across vast and dispersed worksites. This includes building the facilities, digital infrastructure and policies that make flexible work both practical and equitable for all employees.

SKILLS GAP AND MANAGEMENT

At the same time, the industry must elevate its approach to talent management. Addressing the skills gap requires structured learning systems, targeted development programs and competency-based training that reach both operational and corporate teams. Mentoring, upskilling pathways and opportunities for cross-functional collaboration are essential to building a workforce capable of supporting increasingly digital operations. Flexible learning models – accessible on demand and across locations – will be central to maximising workforce development and ensuring that employees can grow alongside the technologies transforming the sector.

CULTIVATING CULTURE

However, technology and training alone are not enough. Sustainable transformation depends on cultivating the right organisational mindset. Mining is fundamentally a people-driven industry, and the success of any new system or process hinges on effective change management. Clear communication, structured frameworks, and visible leadership support are critical to ensuring that workers understand the purpose behind change and feel equipped to adopt new ways of working. Without this alignment, even the most advanced technologies will fall short of their potential.

ESG

As the industry modernises, ESG considerations must be embedded into every strategic decision rather than treated as an afterthought. Investors, communities, and governments are raising expectations, and mining companies must respond by addressing the root causes of environmental, social and governance risks. Strong governance, transparent policies, and an engaged workforce are essential to delivering meaningful ESG outcomes and maintaining social licence in an increasingly scrutinised operating environment.

DIVERSITY, EQUITY, AND INCLUSION

Diversity, equity, and inclusion also play a central role in shaping the future of mining. Ensuring fair treatment, equal opportunity and safe working conditions is fundamental to attracting and retaining talent. This includes addressing issues such as sexual harassment, implementing inclusive policies for workers from diverse backgrounds and adopting gender-neutral processes. Leaders must develop the cultural awareness and sensitivity required to manage a workforce that is increasingly varied in both geography and demographics.

Together, these shifts signal a profound transformation in how mining organisations must operate. Flexibility, talent development, cultural readiness, ESG integration and genuine inclusion are no longer peripheral considerations – they are core leadership responsibilities. The companies that embrace these priorities will be best positioned to build a resilient, future-ready workforce and sustain long-term competitiveness in a rapidly evolving industry.

Only a few years ago, the idea of implementing remote or hybrid work in industries reliant on physical operations –

mining included – seemed unrealistic. The arrival of the global pandemic in 2020 fundamentally altered that assumption. Flexible working arrangements shifted from a theoretical concept to an operational necessity, and organisations discovered that remote work could be effective not only for office-based staff but also, in certain contexts, for hourly and deskless employees. In many cases, productivity increased rather than declined, challenging long-held beliefs about where and how work must be performed.

As attitudes toward workplace environments evolve, mining leaders must determine how best to support a workforce whose expectations have changed. While many roles – particularly shift-based and site-critical positions – will always require physical presence, the industry can no longer treat digital enablement and flexible arrangements as exceptions. Embracing new technologies, redesigning workflows and modernising communication systems are now essential to meeting the needs of a diverse and distributed workforce.

Encouragingly, mining organisations are already responding to this shift. Leaders across the sector recognise that flexibility is becoming a core component of workforce strategy, not a temporary accommodation. One industry survey found that approximately 68% of mining companies now view flexible working arrangements as essential for workforce success. This reflects a broader understanding that empowering employees – whether they are deskless or desk-bound – supports not only productivity but also retention, engagement, and long-term organisational resilience.

Mining is a deeply established industry, and with that legacy often comes a natural resistance to change. Yet in a world that is evolving at unprecedented speed, even the most entrenched systems must adapt. The sector can no longer rely solely on traditional processes; it must be prepared to respond to new expectations, new technologies and a workforce whose needs are shifting rapidly.

CHANGE MANAGEMENT.

Change management has therefore become a critical component of mining performance and resource strategy. Creating the right environment for large-scale transformation is challenging, but it is essential. Leaders must recognise that mining is fundamentally a people-driven industry. Culture plays a central role in helping both office-based and deskless workers feel empowered, informed and aligned as the organisation evolves. A strong culture provides autonomy while also acting as a stabilising guide rail during periods of transition.

This requires a shift away from the traditional top-down communication model that has long defined mining operations. Deskless and hourly workers, in particular, often have limited access to conventional communication channels, making one-way directives far less effective. Two-way communication – timely, transparent, and accessible – is essential to ensuring that all employees understand the purpose behind change and feel included in the journey.

With the right employee experience solutions, mining leaders can bridge the gap between corporate and operational environments. Modern digital tools make it possible to engage workers wherever they are, strengthen alignment across teams and improve the overall employee experience. When workers feel connected, informed, and supported, they are far more likely to embrace new technologies, adopt new processes and contribute to sustainable organisational progress.

The importance of ESG in today's mining landscape is impossible to ignore. Investors and shareholders are applying increasing pressure on companies to accelerate decarbonisation and demonstrate genuine commitment to environmental responsibility. Recent data shows that more than six in ten mining and metals investors are reluctant to invest in organisations that fail to meet their decarbonisation targets or show insufficient progress toward them. This shift in investor sentiment has prompted mining leaders to strengthen their sustainability strategies, establish dedicated committees and enhance the depth and transparency of their reporting.

Despite these efforts, the industry continues to grapple with a persistent stigma. Mining is often viewed through the lens of its historical environmental impact, even as it plays a critical role in enabling the global green transition by supplying the raw materials essential for renewable technologies. This disconnect underscores the need for clearer, more consistent communication. Workers, communities, and stakeholders must understand not only what actions are being taken, but why they matter and how they contribute to broader climate goals.

Environmental progress alone, however, is not enough. The social and governance dimensions of ESG are equally important. Prioritising health and safety, strengthening corporate policies and ensuring that workers' needs are met are fundamental to building trust and maintaining a resilient workforce. When employees feel protected, informed, and valued, they are more likely to support and advance the organisation's ESG objectives.

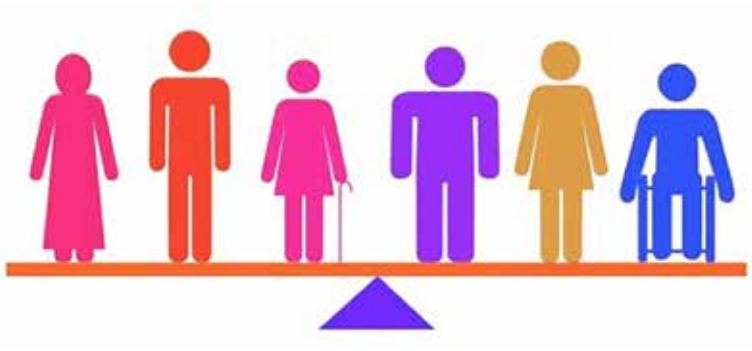
Ultimately, an effective ESG strategy cannot be built in isolation from the workforce. Progress depends on engaging employees at every level, ensuring they understand the organisation's commitments and empowering them to contribute to meaningful change. By aligning environmental ambition with strong social practices and robust governance, mining companies can strengthen their ESG performance and reinforce their role in a sustainable future.

Here is a polished, executive-level essay version of your text, aligned with the tone and structure of the rest of your article:

EQUAL OPPORTUNITIES

For many decades, mining was widely regarded as a man's world – an industry where women faced significant barriers to entry, from hostile working cultures to the risk of sexual harassment and a lack of inclusive policies. These challenges made it difficult for women, and for many under-represented groups, to build long-term careers in the sector. Over time, however, the industry has begun to shift. A stronger emphasis on diversity, equity and inclusion (DEI) is reshaping expectations and opening doors that were once firmly closed.

DEI is now recognised as essential to the future of mining. Ensuring that workers – regardless of gender, ethnicity, or background – are treated fairly and given equal opportunity is not only a moral imperative but a business one. A growing body of research shows that diverse workforces outperform their less diverse counterparts. Companies with above-average diversity generate significantly



more innovation-related revenue – 45% compared with 26% – a difference that translates directly into stronger financial performance. In an industry where innovation is increasingly tied to digital transformation, operational efficiency and sustainability, this advantage is particularly meaningful.

MODERN WORKFORCE MANAGEMENT

Modern workforce management therefore requires more than simply hiring diversely. It demands policies and processes that meet the needs of all employees, wherever they work and whatever their background. By adopting management approaches that are inclusive and adaptable, mining organisations can create environments where people from different cultures, identities and locations collaborate effectively. This not only strengthens team performance but also enhances problem-solving, creativity and organisational resilience.

As mining continues to evolve, embracing DEI is no longer optional. It is a strategic necessity – one that supports workforce attraction and retention, strengthens organisational culture, and positions the industry to thrive in a world that increasingly values fairness, representation, and innovation.

SIGNIFICANT CHALLENGES

While mining has made meaningful progress in improving its appeal as both a career path and a socially responsible industry, the reality is that significant challenges remain. Despite rapid growth in technical capability across the sector, a severe talent shortage continues to threaten long-term competitiveness. The issue is particularly acute in regions such as Australia, where tertiary enrolments in mining engineering have fallen by 63% since 2014, even as demand for new workers is projected to rise by approximately 24,400 by 2026. Addressing this labour gap is now a matter of urgency.

To respond effectively, industry leaders must focus on attracting new talent while simultaneously reskilling and upskilling the existing workforce. This is especially critical for hourly and deskless workers, who often have fewer opportunities for structured development. Implementing robust learning management systems and targeted talent programs can help bridge this gap by providing accessible pathways for growth. Mentoring, technical training, upskilling initiatives, and networking opportunities all play a vital role in building a workforce capable of supporting the industry's digital and operational evolution. Flexible learning models – designed to accommodate varied schedules, locations, and job types – are essential to ensuring that development is both practical and inclusive.

By creating an environment where continuous learning is encouraged and supported, mining companies can strengthen organisational capability and improve long-term strategic positioning. This investment in people not only helps address immediate labour shortages but also reinforces mining's role as a central contributor to societal development. As the industry becomes more progressive, technologically advanced, and worker-focused, it will be better equipped to attract the next generation of talent and sustain its relevance in a rapidly changing world.

It is increasingly evident that the modern workforce requires management approaches that differ dramatically from those of the past. Today's mining organisations must rely on smart, data-driven communication systems that use real-time insights, advanced analytics, and automation to create personalised workflow experiences and support greater adaptability across all roles. These capabilities are no longer optional; they are fundamental to building a workforce that can operate efficiently in a rapidly evolving environment.

At the same time, mining is not solely defined by its systems and processes – it is defined by its people. For the industry to achieve the outcomes it seeks, all workers, whether deskless or office-based, must have access to the same level of shift flexibility, attendance accuracy, learning opportunities and workflow optimisation. Equity in these areas is essential to ensuring that every employee can contribute effectively and feel supported in their role.

Encouragingly, leaders across the mining and resources sector recognise that a significant shift has taken place. Many have already begun adjusting their thinking and investing in more progressive approaches to workforce engagement and management. We are seeing deliberate efforts to extend flexibility to deskless workers through modern tools and communication platforms that connect teams across sites, regions, and communities. Diversity and inclusivity are also gaining traction, with organisations working to build cultures where ESG priorities are embedded and employees feel both supported and challenged.

Transformation, however, is a long-term journey. The industry still has work to do to reshape perceptions and fully realise the benefits of a modern, people-centred operating model. But if leaders remain focused on strengthening workplace culture through effective change management, advancing ESG and DEI commitments, and developing and attracting the right talent, mining will be well positioned to enter its next phase of evolution. By unlocking the full potential of its workforce, the sector can continue to play a central role in global development while becoming more progressive, resilient, and future-ready.

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