

Mining in Chile

Chilean miners display resilience despite socio-political uncertainty

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Introduction

Social turmoil forces reconsideration of Pinochet era development model



The top copper producing country in the world continues to present enormous opportunities for copper and gold exploration and development. Photo of Cortadera, courtesy of Hot Chili.

Prior to October 2019, the pervasive view held amongst Chileans and outside analysts was that Chile was immune to political destabilization and social unrest. Although populism was spreading across Latin America and several other parts of the world, Chile was viewed as a consistently strong economic performer with relatively moderate politics. At the sustainable mining conference in Santiago in September, the most profound challenges facing the Chilean mining industry were outlined: weakness in the price of copper and lithium, water scarcity, declining ore grades, social license, high energy and labor

costs, to name a few. One concern absent from that list was internal stability. For the past three decades, investors have viewed Chile as a bastion of calm in an otherwise politically precarious region. Chile achieved its status as a leading mining jurisdiction not only because of its high quality and easy to exploit resource base, but also because its policies toward mining were regarded as best in class from an ease of doing business perspective.

In light of October's protests that have shocked the country, questions have been raised regarding Chile's ability to maintain its status as Latin America's most stable and successful country. The civil unrest was seemingly triggered by increased metro ticket prices, but at its core the disorder is fuelled by a gathering sense of economic inequality. Since 1990, the country's restored democracy has maintained the broad outline of free-market policies installed by Pinochet's dictatorship, which have enabled consistent economic success. The poverty rate has fallen from over 40% in 1990 to under 10% today, according to World Bank figures. The middle classes now form a majority, income inequality is below the Latin American average and Chile received the region's highest score on the United Nations Human Development Index, which is predicated on a blend of life expectancy, education and national income per capita.


In the context of the region, this performance is strong. However, compared to its OECD peers, Chile ranks highest in economic inequality. UN reporting found that the richest 1% of the population earns 33% of the nation's wealth. This fact is one of the principal reasons why there is such widespread anger. Poor and middle class people, who rely on public transport, feel that the burden of state funding is being unfairly placed on them at a time when middle class wages are stagnating and low skilled jobs are being replaced with technology.

Much of Chile's economic success has come on the back of a robust mining sector that has been and will continue to be the lifeblood of the economy. Chile is the world's top producer of copper, and exports of the metal account for approximately 10% of the nation's GDP. It also possesses the world's largest lithium reserves, based off of a U.S. Geologic Study (USGS) report.

It is unclear what, if any, backlash there will be long term on heavy industries such as mining. The protests have caused disruption to the typically efficient operational environment throughout the country, but strikes within the mines were limited to a few union groups and interruptions were minimal.

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According to Joaquín Villarino, President of Consejo Minero: "October and November have been very hard months for Chile. We believe that the social unrest is transitory. However, it will mean profound changes in certain public policies in the country in order to improve the quality of life of those Chileans who are suffering. We are optimistic that regulation of the mining industry will not change dramatically."

In Chile, mining is taxed at a rate of 40-43%, one of the highest percentages globally. Villarino continued, "There is not much room to raise taxes, but it is something we are anticipating."

It is not just those who have taken to the streets armed with clanking pots and pans that are disappointed in the pace of economic growth in 2019; mining companies also had high expectations going into the year. However, predictions of demand outpacing supply for copper and lithium have not materialized thus far. The demand shortfall for these commodities can be blamed on a variety of global economic factors, but the most salient are the China-U.S. trade war and economic stagnation in Europe. Adding to the pain was the fact that Chilean copper production fell 2.5% in the first half of 2019 on the back of declining copper grades, according to a study by the International Copper Study Group (ICSG).

Given these dynamics in the market, and protests that have crippled the nation's retail economy in October and November, it is a testament to the dynamism of the Chilean economy and sound management practices in its mining industry that the economy is still projected to grow at an annual rate of 1.4% for 2019. Although growth has been well below expectations, it is still far better than that of its regional

peers: Argentina, which is in recession, and Brazil, whose economy has stagnated.

Chile's history of churning out successfully run local businesses devoted to the mining industry is undoubtedly a positive driver of wealth creation. In describing the advantage Chilean companies have over large global enterprises, Ivan Rayo, general manager of Chilean engineering consulting firm JRI, said: "Being a Chilean company means that our clients benefit from increased flexibility. For example, many operations are struggling to stay profitable with a depreciated copper price. Local businesses excel in responding quickly to adjust costs and implement solutions."

Another locally run business, Perfo-Chile, has 35 years of experience as a provider of drilling services. General manager Osvaldo Carmona outlined his approach to weathering turbulent times: "We have focused on building our cash reserves over time in order to invest through good and bad economic and political climates."

Although mining is not experiencing its best year, companies continue to invest. Almost US\$66 billion has been earmarked for Chilean mining projects for the period between 2018 to 2027, and 43 mining projects will be built or will begin production by the end of 2023, according to the Ministry of the Economy. The biggest project is Teck Resources' Quebrada Blanca phase II, which involves US\$4.2 billion in investment over the next five years to extend the life of the copper mine in the Tarapacá region. Antofagasta Minerals, meanwhile, will invest US\$3.7 billion to expand its Centinela copper mine, with construction starting in 2021. The third biggest project is Nueva Unión, a joint venture between Teck and U.S.-based Newmont, which needs US\$3

billion over five years for construction of a copper-gold mine.

These new investments are needed to offset a potential decline in production from some of Chile's largest and most reliable sources of copper. After 104 years of production, Codelco's Chuquibambilla, the largest open pit mine in the world, closed its surface operation and commenced its underground phase, and there is uncertainty surrounding the mine's ability to maintain current production levels, particularly in the near term. Codelco is expected to invest US\$5.58 billion according to Consejo Minero in order to achieve a production level of 140,000 metric tons per day (mt/d) of ore, with a mine life of 45 years.

At the end of the day, it is important to keep in context the sheer size of opportunity that the Chilean market represents. It holds 22% of the world's copper reserves, 11% of the molybdenum reserves, 5% of the silver reserves, 7% of gold and 48% of the world's lithium reserves, according to Invest Chile. Furthermore, the quality of these reserves is often described as best in class.

In light of the civil unrest, political sensitivities have become a more important part of the discussion regarding mining in Chile, but given the role the mining industry can play in delivering a better future for Chileans, it is important that it prevails in the face of any populist backlash. Jorge Maldonado, general manager of Superex, a leading company in sonic and diamond drilling, summed this sentiment up: "Sometimes Chile forgets how vitally important a strong mining sector is to the health of its broader economy. We must not miss our opportunity to lead in mining."

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Chile's Project Development

Increasing necessity for new projects today to meet tomorrow's demand

Take a flight to the north of Chile and, as the plane descends, you may notice one of the many deep holes in the earth. Of the top 20 highest producing copper mines globally, seven are located in Chile: Escondida, Collahuasi, El Teniente, Los Bronces, Los Pelambres, Chuquibambilla and Radomiro Tomic are all stars in the global mining constellation. Maintaining high production from these large mines, along with additional new production, is essential as the world transitions to a new energy economy. Simply put, the green economy is far more metal intensive than the fossil fuel economy. So long as demand continues to rise for electric vehicles and solar and wind energy, demand for copper and lithium will rise synchronously.

Wind and solar energy requires three to 15 times as much copper per unit of output as fossil fuel generation, according to the *Financial Times*. Estimates are that copper consumption from electric vehicles, which was 0.9% of the global total in 2017, will rise to 8.2% of total copper demand in 2030. Given these dynamics, it is increasingly important that Chile continues to invest and innovate in order to offset production declines.



Baldo Prokuriča, Minister of Mining.

Although Chile is considered a mature mining jurisdiction, Timothy Beale, CEO of Revelo Resources, a prospect generator, described the quality of the country's mining assets: "World class means long life of mine and scalability of production, and Chile has several truly world class mines."

According to Mining Minister Baldo Prokuriča: "Chile has been mining since before the arrival of the Conquistadors and will be a mining country for much longer."

This perspective is especially welcome in a year when several of Chile's top producers have struggled to boost production and earnings. Chilean state-run Codelco, the world's largest copper producer, saw year-on-year

profits plunge over 70% from US\$1.235 billion in June of 2018 to US\$318 million in June of 2019, according to their earnings statement. This drop in earnings is not expected to continue, but it illustrates the impact weak copper prices coupled with the high cost of investing in future production can have on profitability.

Before the wave of protests and riots began in October, Codelco was already facing the difficult task of having to invest billions just to maintain production levels and keep costs from rising. Now, as the government faces a long list of spending demands to appease protesters, the challenge is more formidable. The government announced US\$5.5 billion of additional government spending in December, and Codelco will be expected to help fund a larger welfare system in the country. The company can also anticipate a much more tightfisted response from the state in its allocation of funds to meet Codelco's need for financing.

On the spending side, Codelco is now looking to shrink its project budget through 2028 by US\$8 billion, or 20%. According to the company's Q3 2019 reporting, there are no plans to suspend any planned projects. At the same time, the company is looking to generate an additional US\$1 billion in gross earnings from 2021. According to CEO Octavio Aráneda, Codelco is making a "great effort" to help generate the cash Chile needs to address social demands. To achieve the capex savings, Codelco will simplify project design, and reinforce operations maintenance and supply. "Codelco's future depends on finishing structural projects on time and at lower costs. Without them, our production will fall significantly and we will stop contributing to the country," Aráneda said.

Meanwhile, the story at BHP's Escondida, the highest producing copper mine in the world, was more optimistic, yet still below expectations. Copper production at Escondida in FY 2019 decreased by 6% to 1,135 million mt/y as a consequence of a 12% decline in copper grades. Revenue from Escondida also fell by US\$1.5 billion to US\$6.9 billion overall for the year. According to BHP's end of fiscal year 2019 (Australian) conference call on June 30th, 2019, it is believed that Escondida will continue to be a very good cash returner for the next decade despite the down year. Results amongst the majors operating in Chile vary, however, and 2019 has generally proven to be a difficult year with profit margins being squeezed by low commodity prices and high production costs. Driving the high cost of production in 2019

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Octavio Araneda, CEO, Codelco.

were falling ore grades, collective bargaining issues and increased water costs.

Given the current dynamics of the market in Chile, there are relatively few greenfield projects being pushed forward today. In a conversation with Claudio Martínez, commercial director at Worley, he confirmed this trend: "There are a lot of greenfield projects, but they are currently dormant due to grades and prices. The mining industry in Chile is thus mostly seeing brownfield expansion at this time."

Projects like Chuquicamata underground and the second phase of Quebrada Blanca, commonly referred to as QB2, dominate the

headlines when it comes to investments in the future of mining in Chile. However, these should not overshadow the progress some of the mid-tier and junior mining companies are making in developing assets that could soon become strong producers.

One such company is Los Andes Copper. Its Vizcachitas project, located in the Rio Rocin Valley of central Chile, is one of the largest advanced copper projects in the Americas not held by a major. The project is currently well positioned to continue its development as it is now in the permitting process for its pre-feasibility study. According to executive chairman Fernando Porcile: "The Vizcachitas project not only has a large resource, but also has some qualities that make it more competitive than many new greenfield projects and even some of the brownfield expansions in Chile."

Other important copper projects being advanced by juniors and mid-tier miners are Mantos Copper's Mantos Blancos, Pucobre's El Espino, Sprott Resource Holdings' Minera Tres Valles, Coro Mining's Marimaca, Hot Chili's Cortadera and Aethon Minerals' Arcas. Each of these companies has had to weather a volatile few years, and, given their ability to survive the downturn up to this point, they would all be positioned for success given any uptick in the copper market.

Financing has not come easily for juniors in recent years. In 2018, juniors accounted for only 4.5% of the total exploration budget in Chile, while majors accounted for 88.8% according to Cochilco. There are a few reasons for this, but foremost among them is the difficulty juniors are experiencing to raise capital. David O'Connor, chief geologist at Aethon Minerals, said: "There is a lack of investment in junior companies resulting in a lack of activities from them. It has become increasingly difficult for juniors to raise financing on the stock markets. There has also been a slowdown in exploration activity from the majors, making it hard to do joint ventures."

Nonetheless, 2019 has seen some positive developments as each of the aforementioned juniors has received the needed financing and is continuing to progress through the permitting and approvals process.

Reaching long-term production goals

Cochilco has stated that the goal for Chile over the next 10 years is to raise copper production from 5.8 million mt/y in 2018 to 7 million mt/y over the next decade. "Some projects are going to increase their production, but development will not be as easy and fast as companies have planned. Mining projects are taking an increasingly long





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time to develop due to social, environmental and technical challenges,” said Juan Pablo González, president of the Institute of Mining Engineers of Chile (IIMCH).

One of the reasons it takes so long to develop a project in Chile is that the number of permits required to operate is very high. Codelco's Ministro Hales project obtained 645 permits before starting its operation. Another reason the permitting process is so extensive is that communities are now becoming more involved and mining companies are finding it harder to earn and maintain their social license to operate. There have been a number of high-profile court cases that have succeeded in delaying or halting projects, and a lack of wealth and development in mining areas has awakened communities to try to maximize their benefits from mining activity. Chile does not directly reinvest its mineral tax revenue in producing regions, so communities feel the need to apply pressure in order to get their fair share.

When asked about the main issue facing the mining industry in Chile, Cochilco vice president Jorge Cantallop responded: “Improving the level of engagement between the mining industry and the community is critical. We believe that previous relationships between mining companies and communities have been more transactional rather than

developmental. The mining industry should be more involved in the development of local communities, so we are studying how to improve these relations... The entire permitting process can take up to a decade, which is way too long and also too expensive. This scares investors, and it is necessary for Chile to streamline the process to attract more investment. Because the permitting process is timely and expensive, the Chilean mining market is dominated by major mining companies and there are too few juniors operating in Chile.”

Lithium

Although Chile is known for its prowess in copper, lithium mining is a new frontier in which the country has great potential. In 2018, USGS figures show the country produced 16,000 mt/y of the mineral, second only to Australia. Given the global trend towards electrification of transportation, lithium production could be poised to become an increasingly important part of Chile's economy. This would be particularly true if demand ends up meeting expectations to triple by 2025.

Currently two major producers, SQM and Albemarle, dominate the Chilean market. Canadian-based companies Lithium Chile and Wealth Minerals are some of the most

well known juniors operating in the space, and Wealth Minerals in particular has attracted the attention of potential partners and financiers around the world. In October 2019, Uranium One, a subsidiary of Russia's state nuclear company Rosatom, bought a controlling stake in the firm in the wake of China's Tianqi Lithium acquiring a 24% stake in SQM.

The reason Chile is such an attractive jurisdiction for lithium production is largely because of the Atacama salar, which produces the most lithium of any salar in the world. Wealth Minerals has a 46,200-hectare concession in the Atacama salar, and the company's CEO, Henk Van Alphen, described why it is so compelling: “The Atacama salar is the world's highest grade and largest producing lithium brine deposit and currently produces approximately one third of global lithium output from two production facilities operated by SQM and Albemarle. It possesses a very high grade of both lithium and potassium and has a high rate of evaporation and extremely low annual rainfall.”

Gold

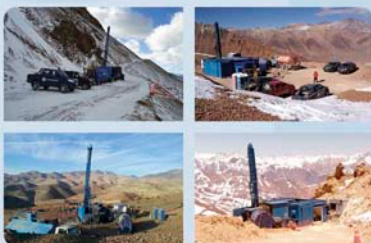
In contrast to copper and lithium, precious metals focused companies have not experienced the same level of difficulty in financing their operations. With gold trading at a five year high around US\$1,500 per oz and the majority of global central banks devaluing their currencies, there is optimism that gold prices will remain high for a prolonged period. Because of this thinking, the market for new exploration has been reinvigorated and projects are being advanced.

One example is Gold Fields Salares Norte Project. Discovered in 2011 and expected to begin operations in 2022. Salares Norte has completed its feasibility study and hosts a gold mineral resource of 3.9 million oz of gold and 44 million oz of silver while the reserves are 3.5 million oz of gold and 39 million oz of silver. Approximately 90% of the value and volume is in gold and 10% of the value and volume in silver. The initial life of mine is expected to be 11.5 years and the payback period is 2.5 years, given a US\$ 1,200/oz gold price. According to Max Combes, Gold Fields Chile country manager: “At today's gold price, the mine would be very profitable.”

Located at an altitude of 4,500 m the estimated investment in Salares Norte is around US\$850 million in capital investment and a further US\$450 million in sustaining capital over the life of mine. “Gold Fields will create a peak of 2,700 jobs during construction of the mine, and an average of 900 workers during the operational phase,” Combes said.



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The Services Sector

Building resilient businesses for tough times



Efficiency in comminution and material handling remains essential for profitability in Chile's aging mines. Photo courtesy of Metso.

Copper runs through the veins of Chile, and cities such as Antofagasta and Calama have risen out of the desert fuelled by exports of the red metal. Underlying Chile's success as a leading metals producer is a robust ecosystem of service providers. Drilling contractors, engineering firms, mineral processing specialists and consultancies all play an equally important role in contributing to the country's high level of production. Consejo Minero estimates show 6,300 companies in Chile qualify as mining suppliers, with 25% headquartered in mining regions outside of Santiago. That inevitably means regional economic success is highly correlated with the price of copper and the performance of the industry's service businesses. In Antofagasta, mining contributes 54% of GDP, Tarapacá 37% and Atacama 38%, based off Chile's Central Bank data.

Unfortunately, when commodity cycles are in a down phase, service providers are susceptible to tightened margins, falling utilization rates and less ambitious planning for greenfield projects.



Ivan Rayo, general manager, JRI Ingeniería.

According to Stephanie Ashton, CFO of Griffith Drilling, a diamond drilling company capable of operating at 2,300 meter depths: "There has been little capital for greenfield exploration nor any appetite for it from a timeline and permitting perspective.... The current trend is for companies to do expansions of their existing operations. One of the ways in which the industry is confronting the problem of permitting and not being able to develop new projects is by drilling deeper at their existing operations."

On the engineering side, Ivan Rayo, general manager of JRI Ingeniería, observed: "Nowadays we have a lower copper price and demand for engineering services has shrunk. There are less opportunities to expand the business, and many engineering companies have been forced to take austerity measures to increase efficiency. It has also meant fiercer competition."

That is not to say that opportunities aren't present for service companies. Both a growing lithium industry and an increasing push into underground mining will continue to keep service providers busy for years to come. Furthermore, the mining industry is becoming much more focused on sustainability, so there will be a host of new opportunities and challenges associated with reducing water usage and lowering carbon emissions.

One of the primary demands on service providers in today's market is to lower costs, and that often means careful planning. Claudio Martinez, commercial director at Worley, highlighted his company's success in this area: "Worley has expertise in the designing and reviewing of capex and opex estimates. We have been able to support customers with

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Jorge Maldonado, general manager, Superex.

significant reductions (approximately 20%) in their capex investment in brownfield projects.”

There are also opportunities for Chile's service providers to grow their exports. Despite its reputation as an export-oriented country, only 5.6% of local Chilean mining suppliers are currently exporting their products and technologies, according to Prochile.

One of the biggest complaints among service providers is that regulations are too tight, and that cuts into profits. According to Jorge Maldonado, general manager of Superex: “The rules are not clear. We do not have big communities in the north, but a few people are creating big problems for business. In Dominga they have not been able to begin because of environmental regulations and community issues. If government is granting permits, then the rules should be clear.”

Ashton of Griffith Drilling also pointed to policy issues complicating operations: “From a cost efficiency perspective, we have to comply with a significant number of standards, which has increased our operational costs over time. The same amount of work that we used to perform with three crews now requires four to meet the current labor regulations.”

Opportunities Underground

Given Chuquicamata's US\$5.6 billion switch to underground cave mining from open pit and El Teniente's new level proposal requiring an additional US\$5.5 billion of investment, underground mining is one of the more promising areas for service companies.

JRI Ingeniería has a division specifically devoted to providing efficient and innovative designs in underground mining. Throughout the downturn in copper prices, JRI has been able to increase market share and, since 2017, has experienced 20% per annum growth. A large contributor to this growth came from underground mine engineering and design. According to Yamana Gold vice president of finance for Chile and Argentina



Stephanie Ashton, CFO, Griffith Drilling.

Andres Guzman: “As underground mines go deeper, costs per ton increase, so managing costs such as energy consumption and ventilation of underground mining operations is a big challenge the industry faces.”

Sustainability

With Chile chosen to host COP 25 in December of 2019, the country was set to showcase its efforts to become a leading sustainable mining jurisdiction globally. Ultimately, the event was moved because of protests and instability. However, that does not diminish the progress made in implementation of renewable energy, investment in desalination plants and adoption of more resourceful water resource management tactics.

In October of 2019, BHP announced four new renewable power agreements to meet power demand for its Escondida and Spence operations in Chile. BHP proclaimed its aim to supply Escondida and Spence's energy requirements with 100% renewable energy sources from the mid-2020s onward.

Of course these decisions are not made solely out of good will. There is a strong economic case to be made for the ramp up in renewable energy investments. The cost of energy in Chile is one of the highest in Latin America and higher than the OECD average. In addition, access to water is an ongoing challenge in the arid north, where most of the country's copper mines are located. To resolve the issue of water scarcity, mining companies have been building desalination plants, but the high cost of energy required to transport water up to the mine sites increases the overall mining cost. At the same time, declining ore grades require more water to be used in processing, and ore grades in Chile have fallen significantly from 1.13% in 2002 to 0.65% in 2017, according to Cochilco. Energy consumption is expected to increase by 80% in the coming decade, and the cost of energy represents about 20% of copper production costs according to Consejo Minero.



Max Combes, country manager, Gold Fields.



Jim Spenceley, senior vice president of mining, Black & Veatch.



Juan Castaño CEO, Amphos 21.

For Black & Veatch, a full service provider of energy and water solutions to the mining industry, the transition to more renewable energy and more sustainable water use operations holds great prospects. The company engineered the desalination plant at BHP's Escondida and has several other projects throughout Chile, particularly in the area of studies around ways to capture water that will otherwise be lost to evaporation. "Many of the mines in Chile are at 3,000-4,000 meters of elevation and around 100-200 kilometres from the sea, so transporting water via pipeline requires a lot of energy. These systems must be designed the right way, particularly because they are operating at high pressures, so the design can be very sophisticated. There is significant permitting that comes with this process and mistakes can be very costly," said Jim Spenceley senior vice president of mining at Black & Veatch.

Companies are looking to improve in areas of water reuse and recycling. Yamana Gold, for example, has stated that its focus at El Peñón is on "increasing reuse and recycle rates and minimizing overall raw water consumption." To that end, the company has implemented a dry-stack method of tailings storage at the mine, which allows 80% of the water contained in the tailings to be recovered.

At Gold Field's Salares Norte mine, according to country manager, Max Combes: "A lot of effort and money was invested into creating a sustainable design that ensures water use is kept to a minimum. In terms of tailings, we have an environmentally stable design. We have introduced filtered tailings that will allow us to recover most of the water and produce a dry tailing that will be moved with trucks to be compacted."

Environmental consultancies such as Amphos 21, which provides sustainable reuse and feasibility analysis of water resources, are well positioned to be the beneficiaries of the increased focus on sustainability in Chile. "Companies need help and supervision in the construction of new underground wells, and they need defined conceptual models of how groundwater behaves at a mining site and to develop and implement numerical models that allow them to predict groundwater flow and groundwater chemical behavior. Our purpose is to create a sustainable operation that minimizes its impact on groundwater balance," said Juan Castaño CEO of Amphos 21.

Conclusion

There is no denying that Chile's mining service industry is one of the most dynamic in the world. The sector is full of entrepreneurial local businesses competing with well established global firms for contracts. The service workforce is well educated and qualified and, for these reasons, Chile has been able to reach record production levels, despite the maturity of its market. 2019 has been a year that began with great optimism that new investments would be pushed

forward and suppliers would benefit from higher margins. However, uncertainty around the global macroeconomic climate and political chaos at home caused projects to dry up. As a result, the market for services remains extremely competitive, with companies lowering their hourly rates and operating on low margins in order to keep from shedding staff.

In spite of this year's struggles, much optimism remains surrounding opportunities in desalination, water reuse, the paradigm shift to underground mining, the focus on tailings dam safety, and generally any solution that improves operational efficiency. Furthermore, there are still billions of dollars of investments coming online in the next few years that will keep demand for services strong. Regardless of fluctuations in markets and politics, Chile's mining service providers have proven their resilience and are built to weather turbulent market conditions.

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Innovation that Offsets

Disruptive technologies are compensating for declining ore grades



Robotics continue to display their potential for Chile's mining future. Photo Courtesy of HighService Corp.

Thanks to George Lucas and his Star Wars franchise, as a society, our most popular image of a robot is R2D2. For a small number of visionary thinkers, however, robots are more than science fiction; they are a critical enabler for a safer and more productive mining future.

Marco Ruiz, general manager of ENAEX Robotics, is one of the thinkers attempting to bring disruptive change to the mining industry. He said: "We recognized that as ore grades decline, there is a need to facilitate access in difficult to reach deposits while protecting the safety of operating personnel."

Within the mining industry, robotics may be considered niche and unready to immediately replace traditional methods, but their development and presence is indicative of a broader trend in which companies

are investing heavily in technology. According to a KPMG survey, the highest level of investment in the mining technology space is occurring in data and analytics tools, autonomous vehicles and robotic process automation.


One local Chilean company that is growing its presence as a regional leader in automation for mining is MIRS, a subsidiary of HighService Corp. Its president, Hugo Salamanca, characterized industry enthusiasm for robotics saying: "We believe that the industry is more receptive to technology today than it has been in the past, and that presents a big opportunity. The mining industry is facing many challenges and the importance of robotics in mining is now widely understood. We need technology, in Chile especially, because productivity is low and

production costs are high. Robotics can help boost competitiveness, improve productivity and reduce costs."

The company develops robotic applications in the concentrate sampling process and in the plugging of flash furnaces. Its robots are active at Codelco's El Salvador operation and in the smelters at Chuquibambilla.

Autonomous Mining and Teleoperation

It is no longer an uncommon sight to see a mine truck cabin empty as it is being operated remotely or fully autonomously. Trucks that drive themselves can spend more time working because software does not need to stop for shift changes or to take a lunch break.




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One of the added benefits of investment in autonomous solutions is that it encourages innovation from suppliers. For example, there are several new autonomous trucks being introduced to the market today. Companies such as American Air, which supplies air conditioning, are then incentivized to tailor innovations to complement new fleets. According to Joel Araujo Strul, commercial manager at American Air: "The challenge (of automation) is that there are not enough qualified people in the industry who are prepared for this rapid change. We are developing the most automated AC unit on the market, and it will require minimum work on installation and maintenance."

Additionally, American Air is developing a predictive maintenance system for air conditioning units to be launched in 2020.

Beyond vehicles, there are also autonomous solutions for other segments of the mining process. Technosteel subsidiary Polimet, for example, has developed a technology that can transmit information to a remote operator, which eliminates the need for inefficient manual inspections. Their other subsidiary, Safedrill, developed a 100% hands-free rod handling operation in drilling. Technologies such as these will have big implications for increasing safety in the mines.

Data and Analytics

Coupled with development in autonomous mining, data analytics is also quickly becoming an essential tool for operators. Predictive maintenance solutions that address problems before they occur are one of the biggest benefits that digital technologies can offer the mining industry. Maintenance in mining often occurs on a time-based schedule, rather than as needed, leading to a lot of wasted time and money.



Hugo Salamanca, president, HighService Corp.

In Chile, there are several companies that specialize in helping customers leverage their use of data through software. Although data and analytics tools are still in their infancy in Chile, they represent a significant opportunity because data has the potential to unlock value in nearly every aspect of the mining process.

EY for example, has been working closely with the large mining companies in Chile on ways in which they can better use the vast amounts of data they collect. In one case, the company provided advice that increased recovery in the flotation plant simply by using data analytics to understand the optimal settings on different pieces of equipment. These subtle changes boosted copper recovery by 3%, which translates into significant cost savings.

According to eBooting Co-founder Juan Vega, a company with expertise diagramming and integrating data flows: "We have access to a significant amount of data today, but it does not mean anything if there is a ton of data and no way of using it to become



Francisco Portilla, general manager, Plasma 4th.

more productive. We see opportunity in distilling and adding context to the vast swaths of data mining businesses collect. If they use these tools properly it will increase their bottom line."

Beyond Blasting

The market for blasting services is highly competitive in Chile, and this competition is producing some of the most cutting edge technology in the business. Maxam, Plasma 4th, Enaex, Technosteel and Orica all are all developing products that make blasting safer, more efficient and more environmentally friendly. By investing in the appropriate explosives, the way these explosives are positioned and stabilized, the accuracy of the blastholes drilled and the detonation procedure, companies can make a material difference to their bottom line.

While some companies are focused on optimizing the results of blasting, Plasma 4th, a subsidiary of Enaex, is focused on eliminating the need for blasting altogether by using advanced rock fracturing techniques. Fran-

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cisco Portilla, general manager of Plasma 4th, noted that the benefits of plasma are far reaching. Blasting is often unpopular with nearby communities and is also considered harmful to the environment. Portilla said: "To develop a project near a community, you need technologies that are minimally invasive. Blasting creates a lot of pollution, a lot of noise and a lot of vibration. Often this can lead to resistance from communities and the risk of a project being blocked."

In order for any new technology to be adopted, however, the product must be cost effective. Portilla noted that 1 kilogram of plasma is more expensive than 1 kilogram of explosives. However, there are other costs to consider. These include community resistance to blasting and the high cost of evacuating the mining site when blasts occur. With Plasma 4th technology, only those within a 150 m radius of the fracture are required to be evacuated. This guarantees operational continuity and limits downtime.

Sanhattan Valley?

With so much focus on technology development in mining, Santiago has become an important regional hub for many of the leading global technology firms. According to Pascual Veiga, president of APRIMIN: "Chile is being used as a laboratory for experiments with new technology because it offers great diversity and variation in style of operations, height of mines and rock types."

Another reason technology companies find Santiago appealing is because the city has some of the most well educated and well trained workers, an entrepreneurial culture and a good climate for investors – characteristics the city shares with other international



Tomás Buttazzoni, general manager, Technosteel.

hubs for the development of disruptive technology such as Silicon Valley.

Because Chile is a country where vast geological potential mixes with a well educated workforce, it is able to pilot and test cutting edge technologies in its mines. Companies with experience in Chile can then look to apply their knowledge to other less technologically advanced markets. One such company is Technosteel: "Chile is a mature mining market. Therefore, Chilean companies have an opportunity to contribute in introducing world class technologies into less experienced markets, like Bolivia for example. The technologies we introduce are new for them, but have often been in use for some time in Chile," said Tomás Buttazzoni general manager of Technosteel.

Conclusion

The reality in the Chilean mining industry is that as a result of being the leading copper producer globally for over 30 years, many of its most productive mines are mature. Therefore, in order to spur future growth and main-

tain production levels, technology must be implemented and used to its full capability. The potential to achieve big breakthroughs is now within the industry's reach and companies have begun to embrace digital and technological innovations that are transforming key aspects of the industry. Technologies that have long been in the works are now available and affordable enough to become operational at scale. This transformation is being experienced at varying degrees depending on the producer, but it is without a doubt happening in Chile. Codelco and Lundin Mining are incorporating autonomous fleets into their operations, Pucobre signed an agreement with Epiroc to digitize their operations in Chile and Antofagasta Minerals is investing US\$40 million to strengthen its technological platform in the country. As long as these investments prove that they are saving money for clients and making the industry safer, businesses will increasingly move to adopt technology at an even greater pace in order to replicate results.

The technological applications include building a more comprehensive understanding of the resource base, optimizing material and equipment flow, improving anticipation of failures, increasing mechanization through automation, and monitoring performance in real time. Alone, each of these opportunities has real potential. However together, they represent a fundamental shift in both potential safety outcomes and how value can be captured. 65% of large mining companies in Chile invest in improving what they have, while 21% invest in doing things differently and 14% in radical changes according to Deloitte. These numbers will need to shift if Chile intends to remain the world's leading producer of copper for another 30 years.



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