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GBR GLOBAL BUSINESS REPORTS

Mining in Peru

The industry is on the march again

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This report was researched and prepared by Global Business Reports (www.gbreports.com) for Engineering & Mining Journal.

Editorial researched and written by Alfonso Tejerina, Lina Jafari, Sofia Messina, Sorina Dumitru, Julian Issa and Ben Cherrington. For more details, please contact info@gbreports.com.

Cover photo: Pucamarca gold mine at dusk (courtesy of Minsur)

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Putting Investment in front of Political Drama

The new government must prove that new mining projects can be developed under its watch

Quellaveco is the largest investment in Peru's immediate project pipeline. Photo courtesy of Anglo American.

The last months of Pedro Pablo Kuczynski's tenure as president of Peru were nothing but turbulent. When he narrowly avoided impeachment on December 21st, 2017, one might have thought that the stars aligned to save him on that summer solstice. However, when just three days later, he allowed the release of former president Alberto Fujimori, who had spent over a decade in prison, the public figured out the nature of the agreement that Kuczynski, also known as PPK, had forged with Alberto Fujimori's son, congressman Kenji Fujimori.

The efforts for a new start in 2018 were in vain. PPK's new cabinet, sworn in in January, barely lasted two months. On March 21st, one day after the autumnal equinox, the stars were far from aligned in PPK's interests. A series of revelations about murky political agreements and Kuczynski's private finances added to the already known links of PPK with Brazilian construction firm Odebrecht. Just one day before a second impeachment vote was to be held in Congress, Kuczynski resigned as president.

Interestingly enough, in parallel to all of this, the mining industry continued its recovery path, with solid commodity prices helping companies across the board reduce their debts and move their feasibility-stage projects towards a construction decision. Indeed, after three consecutive years of decline, total mining investment in Peru increased by 15.7% and reached US$4.92 billion in 2017. For 2018, the government expects an additional 20% growth.

When Martín Vizcarra took over as head of state, the sector not only welcomed the end of PPK's political agony, but also the new president's proactive approach towards mining development, following his successful work with Anglo American at the Quellaveco project when he was governor of the Moquegua region, between 2011 and 2014.

Luis Marchese, president, SNMPE; country manager, Anglo American.

Anthony Hawkshaw, president and CEO, Bear Creek Mining.

Luis Marchese, Anglo American's country manager, is the person who worked hand in hand with Martín Vizcarra during that process. Speaking as president of the SNMPE, the mining industry's main association, Marchese gave his impressions about Vizcarra's new cabinet: "This government is more pro-decentralization than the previous one. Both the new president and the new prime minister are former regional governors, which should help give impulse to mining activity, considering that mining is a decentralized industry."

Víctor Gobitz, CEO of Buenaventura, declared: "The political transition was abrupt, but acceptable, because it followed the existing legal framework." He also shared his opinion about the new president: "Martín Vizcarra may not have the same macroeconomic experience that Pedro Pablo Kuczynski had, but he has more experience at the micro level, overseeing the relationships between the mining companies and the communities. Quellaveco is a success case that should not be underestimated."

New year, new projects?

Before the political crisis, the Ministry of Energy and Mines, now led by former mining executive Francisco Ísmodes, defined five key objectives for 2018. These include making feasible the existing pipeline of projects, some of which have been pending for many years now. Speculation surrounding key potential investments continues to grow: there is expectation that projects like Mina Justa, Quellaveco, Pampa de Pongo and Corani will begin construction over the coming months.

Even though there has not been an official construction decision about Quellaveco yet, Anglo American already has around 3,000 people in the area doing substantial early works, such as the diversion of the Asana river. The recent sale of an additional 21.9% stake to Japanese partner Mitsubishi for US$600 million is a key milestone towards further de-risking the project. Meanwhile, Minsur made a significant step towards the financing of its US$1.6 billion Mina Justa copper project by selling 40% of the asset to Chile's Alxar Inversiones (part of the Angelini Group) for US$200 million. Finally, Chinalco, that had a very challenging ramp-up at Toromocho over the last years, also announced that a US$1.3 billion expansion at the copper mine in central Peru is under way.

In parallel to that, some triggers are yet to be pulled. As an example, Anthony Hawkshaw, president and CEO of Bear Creek Mining, remained cautious regarding Corani's potential construction schedule: "There is only one chance to build a project correctly. It is wiser to spend additional time and investment now on engineering than to rush ahead. We are being deliberate, thorough, and patient to minimize potential risks."

Corani, one of the largest undeveloped silver deposits in the world, has a significant zinc content. With the zinc price having reached an 11-year high earlier this year, one would assume there would be pressure to act. However, the project requires a capital expenditure of US$585 million, a large amount for a junior company, and Hawkshaw and Bear Creek's shareholders have seen a lot of failures over the years arise from rushing into construction. "When I was a lecturer, I used to tell my students: think first, write later. You can process much more when you are thinking rather than when acting, and I believe this is the right approach for us," he concluded.

Upcoming elections: the social aspect

Peru will be conducting regional and municipal elections on October 7th, and once again mining will be on the agenda. While the changing of authorities may produce added hurdles in terms of bureaucracy and relationships, the sector has been generally positive on the potential outcomes of the ballot. Indeed, many believe that there has been a change in how communities and politicians perceive the mining industry, especially in regions where anti-mining sentiment has been high. Luis Rivera, executive VP Americas at Gold Fields, the company running the Cerro Corona mine, declared: "We are used to working in Cajamarca. It is not the easiest environment, but since we started there has not been much opposition. We hope that, with the election, the political side of things will be more favorable to mining moving forward."

To ensure new mining projects can be developed in Peru, mining companies have adapted their engagement with the local populations and many are now doing more to build closer ties. Elsiario Antúnez de Mayolo, COO and general manager at Bear Creek, has made community relations a priority for the Corani project. "We have been developing skills and business ideas within the community to create long-term benefits. Mines are always temporary and cannot support the community forever, so it is important to guarantee the long-term future of the local populations," he said.

GDP growth in 2017 was only 2.5%, an insufficient figure for a country on its way to further development. Mining will continue to be the key driver of Peru's economy, and taking advantage of the high metal prices will be key to building momentum and unlocking a new wave of mining investment. As has been the case in the last two decades, mining projects may prove to be a significant catalyst for Peru to climb the ladder of economic development.

"Quellaveco is a model for consensus building"

Interview with Martín Vizcarra, President, Republic of Peru

Interview was held in March 2018 in Mr Vizcarra's quality of Peru's vice-president.

How can Peru establish the right conditions for the development of its mining project portfolio?

Over the last years, we have learnt that we need to find the right balance between economic activities, respect for the environment and an adequate relationship with the local populations. That balance cannot be achieved through a supreme decree; you can only get there through hard work and dialogue. In Peru, we already have several examples with very good results that serve as a model for project development. We also have projects trapped in difficulties because they have not been handled in the right manner by either the mining operator or the State itself. Therefore, we need to embark on a continuous improvement process.

As previous governor of Moquegua, what were the lessons learnt from the dialogue table for the development of Quellaveco?

The dialogue table of Quellaveco has been a model for consensus building that needs to be replicated in other projects. If Quellaveco finally goes ahead, it is going to be a very important project for Peru's economy, and even more important for a small region like Moquegua. There, a new challenge arises: the regional and local authorities need to be prepared to manage the tax money generated by the project. Those funds should not be used to build irrelevant infrastructure, but to substantially improve the lives of all Moqueguans. In the past, the money from the mining taxes has often been used to build large monuments or white elephants that do not bring progress for the population.

Critics blamed the decentralization process for these past mistakes. Do you think Peru should continue its decentralization efforts?

I am an advocate for decentralization. All decisions should be made closer to the populations that are going to be affected by them. During the decentralization process, we have had good examples and bad examples. Those who defend a return to centralization only highlight the bad examples. Decentralization has its challenges, but the solution is not to go back to centralism. We need to strengthen the regional structure, identify and correct the problems. Also, we need the population to be educated, empowered and vigilant, to ensure that their authorities use their resources properly.

"Decentralization has its challenges, but the solution is not to go back to centralism"

"This new cycle of global growth sees Peru in a great position to make the most of it"

Mining typically happens in remote areas. What is the role of the State in promoting the relevant infrastructure projects?

My view is that large projects such as railway investments to support mining operations should be mixed investments between the public and the private sectors. The private sector should contribute with the right percentage, according to the use that they are going to make of any particular infrastructure. There are some rail projects that are for social use for the whole community, and those should be fully funded and executed by the State. However, when you have a project that goes directly to a particular mine, that is a private project.

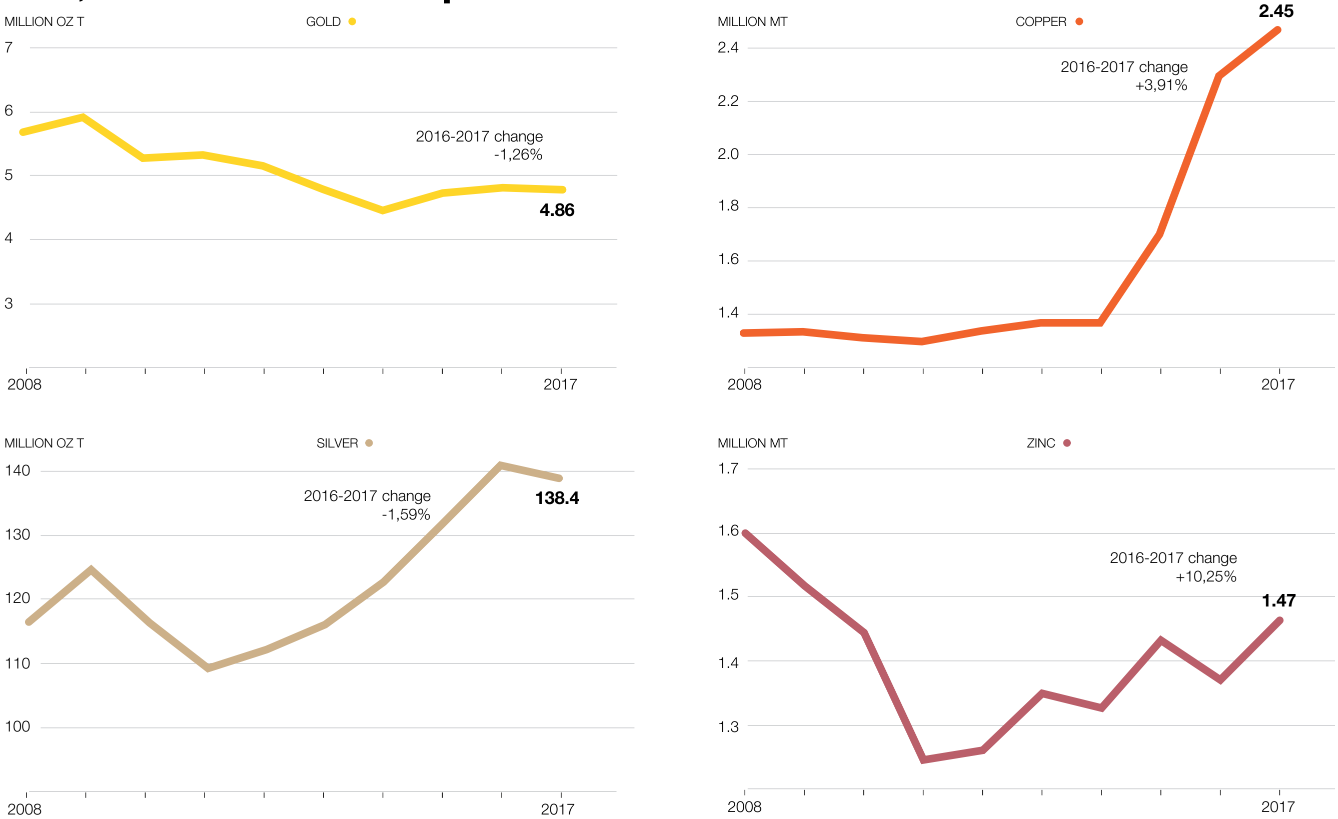
ProInversión recently awarded the Michiquillay project. Do you think Southern Copper will be able to solve the community issues there, as well as in Tía María?

Michiquillay was awarded in February, and the level of participation shows the great interest that mining investors have in Peru. The advice we can give from the State is that the operator should engage in an empathic relationship with the communities. We certainly hope that any challenges will be overcome and that the project will be brought into production. With regard to Tía María, the project still presents some issues inherited from previous years, so it may take a bit longer, but with the right approach from the different parties, I am sure that any issues can be solved.

What is your message to investors that want to develop mining projects in Peru?

Peru offers enormous mineral wealth, and it is a country that opens its doors to foreign investors. We are a welcoming country, and the only thing we ask for in exchange is respect to our idiosyncrasy. I am very optimistic because this new cycle of global economic growth sees Peru in a great position to make the most of it, in particular thanks to our mining potential.

Peru, a diversified metals producer



Sources: Peru Ministry of Energy and Mines / GBR

Copper: Closing the Gap with Chile

Peru strengthened its copper output in 2017, reaching 2.45 million tonnes

Since 2012, Peru has increased its copper production every year and 2017 was no different. After the spectacular increase of 2016, driven by the expansion of Cerro Verde and the addition of MMG's Las Bambas, output increased by a moderate 3.9% last year, with a total output of 2.45 million metric tons (mt) of fine copper. Cerro Verde is still the largest producer of copper with 501,800 mt/y, followed closely by Las Bambas, which achieved its first year of full production with 454,000 mt/y, a 37.5% increase from its 2016 figures. Peru's third giant copper unit is Antamina, which yielded 439,200 mt/y.

Suresh Vadnagra, president of Minera Las Bambas, commented on the mine's performance on its first year of full commercial production: "Our C1 cost of US$0.99 positions us as one of the lowest cost producers. In 2017, we took some fairly aggressive steps to establish efficiency as the baseline of Las Bambas, which is something that does not normally happen in the first year of production."

Vadnagra anticipated that the copper operation, located in Apurimac, will yield between 410,000 and 420,000 mt of copper in 2018, at a C1 cost between US$1/lb and US$1.10/lb. "Our focus is very much on building on the success of 2017 into the future years," he continued. "Las Bambas has enormous potential for brownfield growth – this includes the development of further satellite pits and resource expansion. The Las Bambas tenement has 35,500 hectares, and so far we have explored less than 10% of it."

Other copper mines that produce more than 100,000 mt/y include Glencore's Antapaccay (206,500 mt/y), Chinalco's Toromocho (194,700 mt/y), Southern Copper's two units (Cuajone at 161,100 mt/y and Toquepala at 145,000 mt/y) and Hudbay Minerals' Constancia (121,800 mt/y).

Javier Del Rio, VP South America at Hudbay, explained how the company is introducing digitalization to integrate the mine with the process plant: "We have cameras at the apron feeder, and a particle size analyzer that provides real-time information on the particle size in microns going through the flotation circuit. Additionally, we have flotation cameras that measure the bubbles' formation, size, color and speed. All this needs to be integrated so we can respond to the ore coming from mother nature on real time. Once we have the material at the flotation cell, it is too late to react."

Hudbay expects the surrounding areas in Constancia to substantially extend mine-life. The company plans to put the Pampacancha satellite deposit into production next year, and has also acquired other properties nearby (Caballito, Kuriorcco and Maria Reyna). "The big picture is to have Constancia running for not just another 14 years, but for 30 years if possible. This is why we are focusing on brownfield exploration. Constancia was not the finish line for Hudbay in Peru, but the starting point," said Del Rio.

While the aforementioned mines account for the bigger chunk of Peru's copper production, there are also some interesting medium-

Javier Del Rio, VP South American Business Unit, Hudbay Minerals.

sized underground operations. With the ongoing expansion at the Marcapunta mine, for instance, Buenaventura's El Brocal operation narrowly beat Nexa Resources' Cerro Lindo as the country's largest underground copper producer (both are in the 45,000 mt/y range). Meanwhile, Condestable, operated by Southern Peaks Mining, yielded 22,000 mt of copper in 2017.

Víctor Gobitz, CEO of Buenaventura, was enthusiastic about El Brocal's future potential, as Buenaventura has eliminated the commercial restriction that El Brocal's arsenical copper used to have: "There is an opportunity to go from room and pillar to a different mining method that also extracts the ore from those pillars. If we are successful doing that, the Marcapunta mine could grow up to 20,000 mt/d," he affirmed. Marcapunta is already expanding from 8,000 mt/d to 13,000 mt/d by the end of this year.

Southern Peaks Mining has also introduced new mining methods as a way to improve both productivity and efficiency, with a focus on mechanization at Condestable, and is increasing its daily throughput from 7,000 mt/d to between 9,500 mt/d and 10,000 mt/d. Adolfo Vera, Southern Peaks Mining's CEO, said: "We started treating the previously known mantos as ore bodies and, for that, we needed to know the geometry in each particular ore block prior to mining. We then designed the drilling and blasting scope with the knowledge produced from the geology infill findings. That has given us incredible results as we have introduced long hole mining into 80% of our operation, and dilution has decreased by 75%."

The C1 cost at Condestable is US$1.55/lb and, with the expansion, it can be reduced to US$1.25/lb, according to Vera. Beyond productivity, one of Southern Peaks' main objectives last year was to double the reserve base and prepare for the company's future IPO. "The exploration is rendering great results as well, and we expect to be mining at Condestable for more than 20 years," Vera concluded.

Looking at the general picture, Peru's copper production continued to close the gap with Chile, that saw its red metal output decrease slightly to 5.5 million mt/y in 2017. The Peruvian government has set a goal of increasing copper production by 30% by 2021 to further cement Peru's position as the second largest producer of copper globally.

The expansion of Toromocho, operated by Chinalco, and the construction of the Quellaveco and Mina Justa greenfield projects are the main highlights in Peru's expanding copper production. Juan Luis Kruger, CEO of Minsur, owner of 60% of Mina Justa, explained the latest steps on what will be the company's first copper mine: "Last year we decided to do some early works and lock in the price and delivery times of the critical equipment. The idea is that, by the time we secure the full financing for the project, we are ready to go and we can shorten the time to market. Meanwhile, we have completed 70% of the detailed engineering to reduce the execution risk."

Kruger described what he sees as the main advantages of Mina Justa: "It is a world-class ore body in prime mining real estate, just next to the Pan American highway and close to the sea and power infrastructure. It is also going to be a sustainable project, that will only use seawater for its process."

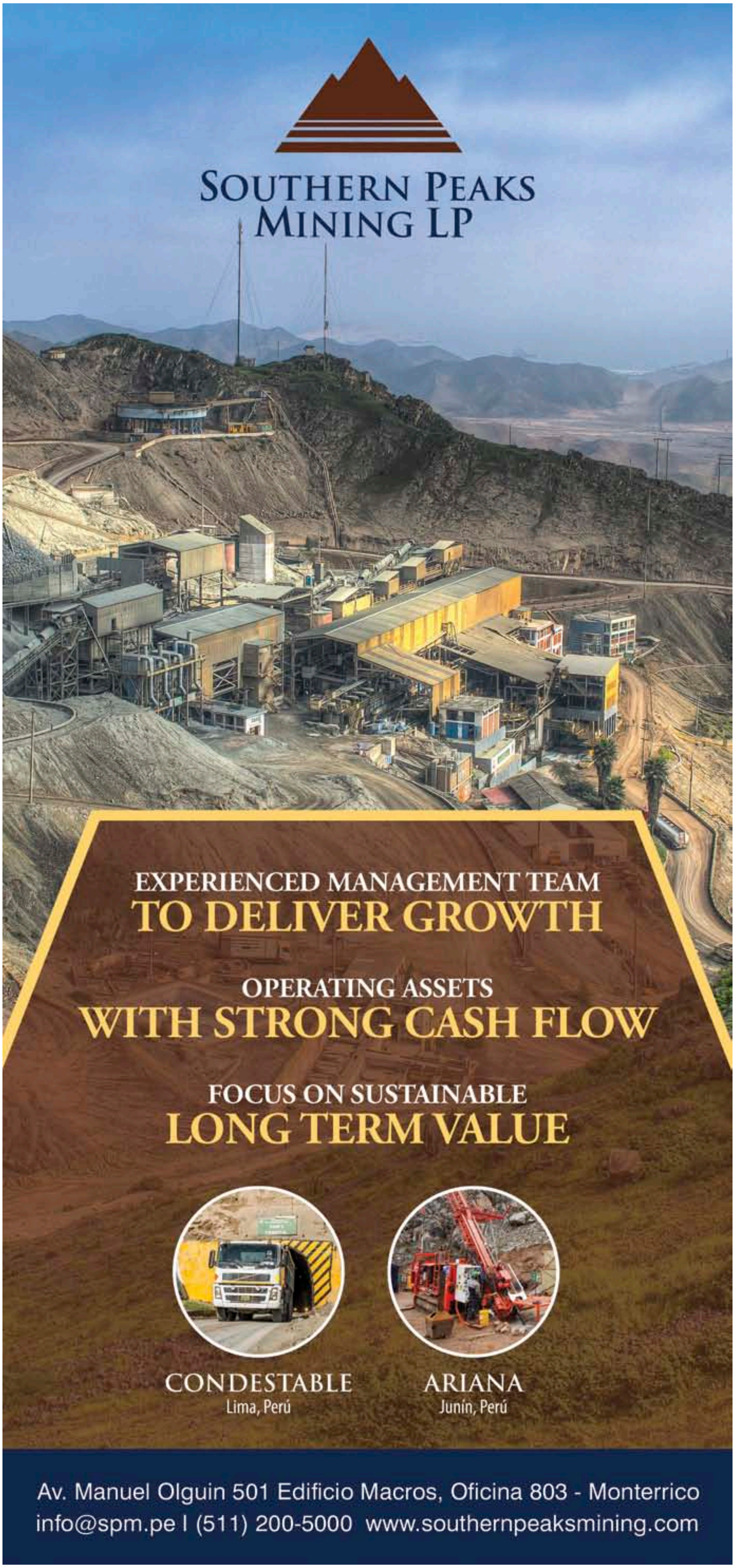
Mina Justa should be in production around 2020, with an average output in the range of 100,000 mt/y over the mine's life.

Zinc

With respect to zinc, Antamina regained top spot in production with a 69% increase in output, representing 442,500 mt/y of zinc. The spectacular change is probably explained by the erratic nature of the geology in skarn deposits, as well as a conscious decision by the company to boost zinc output and take advantage of the current high prices. Antamina's exceptional performance helped Peru's overall zinc production increase by more than 10%, to a total of 1.47 million mt/y.

Antamina is 33.75% owned by Glencore, that also recently took over a controlling stake in Volcan, Peru's second largest zinc producer with around 288,600 mt produced last year. Finally, Nexa Resources of Brazil (formerly Milpo-Votorantim Metais) produced 229,600 mt/y, the majority of which came from Cerro Lindo, Peru's largest underground operation.

Ricardo Porto, CEO of Nexa Resources, highlighted the importance of Cerro Lindo as the only operational mine in Peru currently using seawater for its process: "Cerro Lindo can be seen as a reference for how Nexa intends to



mine, utilizing dry stack tailings and seawater that is completely re-circulated during the mining process. The long-term benefits of this are undeniable, not just for the environment, but also to create a parameter for future projects."

Porto added that extending mine-life at Cerro Lindo is the company's current focus, as the integration of the Atacocha and El Porvenir mines continues to drive efficiency at the Pasco complex. Looking ahead, although Nexa lost the public tender process for the Michiquillay copper project to Southern Copper, the Brazilian company has a significant pipeline in Peru. The most advanced projects are Shalipayco (zinc), expected to be operational from 2021, and the Magistral and Pukaqaqa copper deposits, planned for 2022 and 2023, respectively.

More base metals

In other base metals, Peru's lead production decreased by 2.4% to 306,800 mt, and tin production from Minsur, the country's only producer, also decreased by 5.3% (total output was 17,800 mt/y), a trend that should be reversed by the company's US$200 million B2 project to reprocess the tailings of San Rafael's operation. "B2 will add 5,000 mt/y of refined tin at a very high margin. It will increase our production profile by 20 to 30% through 2028 or 2029," said Juan Luis Kruger of Minsur.

Meanwhile, Peru's production of molybdenum increased to 28,100 mt/y in 2017. According to the United States Geological Survey (USGS), Peru ranks as the world's second largest zinc producer, the fourth largest lead producer and the fourth largest molybdenum producer globally. Finally, iron ore production saw a 15% increase to 8.8 million mt, driven mainly by Shougang's ongoing expansion at Marcona, while Shouxin, a joint venture company between Baiyin and Shougang, produced 138,000 mt of iron ore through the reprocessing of Shougang's tailings, yielding some copper as well.

Ricardo Porto, CEO, Nexa Resources.

Precious Metals: The Challenge of Keeping Volumes Up

Peru's main gold mines are maturing, and production will increasingly come from medium-sized operations

Peruvian mines offer extremely competitive margins. Pucamarca (pictured) had costs of less than $350/oz in 2017. Photo courtesy of Minsur.

Peru maintains a key position in precious metals mining and development. In 2017, it remained the world's sixth largest gold producer (and the largest in Latin America), while it was also the world's second largest silver producer, only after Mexico. Peru's gold production remained relatively stable and only recorded a 1.2% decrease year-on-year. Total output reached 4.86 million troy ounces, with Yanacocha contributing 535,700 oz. This still places the operation, located in Cajamarca, as the country's largest gold mine despite its continuous decline. The guidance for this year is around the half a million-ounce mark and, with the Quecher Main project, its life should be extended until 2027. Quecher Main, a US$250 million to US$300 million venture, will add new output from oxides starting next year, with expected production of 200,000 oz/y between 2020 and 2025.

Yanacocha is a joint venture between Newmont, that operates the mine, Buenaventura, and Sumitomo, that recently acquired a 5% stake. On top of its share of production at Yanacocha (43.65% of the total, or 233,400 oz), Buenaventura also had an additional attributable production of


Víctor Gobitz, CEO, Buenaventura.


Luis Rivera, executive VP Americas, Gold Fields.


Manuel Fumagalli, executive director, Barrick Peru.

383,200 ounces from the other gold mines it operates, namely Tambomayo, Orcopampa, La Zanja and Tantahuatay.

Víctor Gobitz, CEO of Buenaventura, anticipated higher production figures this year from Tambomayo, which reached commercial production last year, and at Coimolache, where the company is processing the oxide stockpiles acquired from neighboring Cerro Corona. He also provided more details about the three-year debottlenecking project at the company's main underground mines: "In Orcopampa, the deeper side of the mine offers high grade but we have not developed a shaft, so with the ramp we are extracting less volumes at higher costs, including additional ventilation costs. In other mines, we are implementing better ventilation or dewatering solutions to extend the mine cycles. We also want to move our backfill around as slurry, with pumps, rather than having to use trucks and scoops."

Gobitz explained that allocating funds to improve efficiency presents less technical risk and a quicker return on investment than developing a greenfield project. Having said that, Buenaventura also has some precious metals projects in the pipeline, including the San Gabriel gold project and the Yumpaq satellite silver deposit at Uchucchacua.

Beyond Newmont and Buenaventura, the other large gold producers include Barrick, that recorded 508,700 ounces between Lagunas Norte and Pierina; Tahoe Resources, that produced 275,000 oz at its La Arena and Shahuindo mines; and Gold Fields, that had production of 166,000 oz of gold at Cerro Corona, a medium-sized mine in Cajamarca that also provides important copper volumes (gold equivalent production is 314,000 oz).

Stretching mine-life

In 2017, Barrick's Lagunas Norte produced 387,000 oz at an all-in sustaining cost (AISC) below US$500/oz, while there is an expected decline to between 230,000 and 270,000 oz this year, related to the depletion of the oxide ores. One of the main developments in 2018 is the building of a dry screener, while the company continues working on the refractory ore project (PMR in Spanish). Lagunas Norte has around 4 million ounces in reserves, most of which is sulphides.

According to the company's executive director in Peru, Manuel Fumagalli, a transitional phase for mine-life extension would involve a mill and carbon-in-leach recovery circuit to process the medium-to-high carbonaceous oxide material in the stockpiles for a total output of 600,000 oz between 2021 and 2026. Then, the PMR project would require a flotation and autoclave process for the sulphides and, if approved, would produce 2.2 million ounces starting in 2026.

Meanwhile, Gold Fields has also pushed to add mine-life at its Cerro Corona mine, with a seven-year extension to this operation, now expected to be running until 2030. Luis Rivera, executive vice-president of Gold Fields for the Americas, explained: "Mining is like a credit card, it has an expiration date. At the beginning of 2017, Cerro Corona was scheduled to shut down in 2023. That meant that, from 2018, we would have had to start closure activities, reducing our footprint and our workforce. We made it an urgency to extend the mine life."

Considering the space limitations Cerro Corona faces in Cajamarca, achieving this took its share of engineering and creativity. Alberto Cárdenas, vice-president of operations at Gold Fields, commented: "The beauty of the solution is that we are not extending the superficial footprint. We are challenging the density of the tailings to accommodate more volume within the same facility. Also, at the end of the day, the pit is also an asset, so we are looking at placing some tailings within the pit after the operation."

Also in Cajamarca, Tahoe Resources continues to ramp up its operation at Shahuindo, where it is commissioning a crushing and agglomeration (C&A) plant to improve recoveries from the fines of the ore body (production of 79,000 ounces in 2017 came from run-of-mine ore). Once the plant is commissioned, Tahoe will embark on the expansion of Shahuindo from 12,000 mt/d to 36,000 mt/d. "Our other Shahuindo projects, such as resourcing water, constructing pads and building a transmission line, are also key. Near-mine and satellite geological deposits in the north corridor of Shahuindo provide us potential targets to extend and maximize value at this operation," said Phil Dalke, until recently vice-president and managing director of Tahoe Peru.

Peruvian companies account for significant gold production as well. These include Poderosa (254,000 oz/y), Horizonte (253,000 oz/y), and Hochschild Mining, traditionally a primary silver producer, that has been increasingly leaning towards gold production with the impulse of the Inmaculada mine. Hochschild produced 203,600 oz of gold in Peru last year, and 165,000 of those ounces came from this flagship asset.

With respect to Poderosa, the company is currently expanding its processing capacity from the combined 1,400 mt/d in between its Marañón and Santa María plants, to 1,600 mt/d by the end of this year. One of the main items of the expansion in terms of the capex are the tailings dams, explained Marcelo Santillana, general manager of Poderosa: "With the investments in the Livias and Hualanga facilities, the tailings dams will now have a life of 22 years. Moreover, we filter the tailings, so we do not deal with pulp anymore."

Poderosa expects to produce 270,000 ounces of gold this year and continues to look at formulas to optimize production and extend mine-life.

Elsewhere in La Libertad, Corporación del Centro (CDC Gold) is advancing the El Toro

Ignacio Bustamante, CEO, Hochschild Mining.

James Bannantine, president and CEO, Great Panther Silver.

project, an epithermal gold deposit hosting around 1 million ounces, that is being developed as an open pit operation with heap leaching and a carbon-in-column plant. Initial production is estimated at 100,000 oz/y. Construction is already under way and mining operations should start before the end of the year. Jaime Polar, general manager of CDC Gold, gave more details: "Our stripping ratio is quite good, just 2:1 according to our mine plan, and we also have favorable hydrogeological studies that indicate that we will not have to dewater the pit. In its first phase, the capital investment to put El Toro into production amounts to around US$150 million."

Silver

Silver production in Peru also decreased by 1.6%, totaling 138.4 million ounces. Buenaventura is the country's largest silver producer with 23.3 million ounces in 2017, a figure that does not include the additional 4 million ounces coming from El Brocal, another company that it controls. The other main silver producers in the country are Antamina, with 20.8 million oz/y; Volcan, with 15.9 million oz/y; and Hochschild Mining, with 15.9 million oz/y.

The latter company had production costs of around US$12.5/oz silver equivalent last year, and those should increase slightly in 2018 to between US$13/oz and US$13.4/oz according to the corporate guidance. Part of this cost increase is the US$30-million investment in the Pablo development at the Pallancata mine in Peru. "In 2017, Pallancata was working at 1,400 metric tons per day (mt/d). Through incremental expansions, we will reach 2,800 mt/d by Q3 2018, and production will stabilize at that rate," explained Ignacio Bustamante, CEO of Hochschild Mining.

A new player in Peru is Great Panther Silver, a company with operations in Mexico, that is working to reopen the Coricancha mine in Peru after acquiring the asset from Nyrstar. The company has recently published a preliminary economic assessment (PEA) that anticipates future production from Coricancha will be 3.1 million oz/y, an internal rate of return (IRR) of 81% and a relatively low capex to get the mine restarted at US$8.8 million. The initial mine-life of four years comprises 28% of Coricancha's resource statement. Great Panther is now embarking on a 6,000 mt bulk sample program to test the mining method, recoveries and dilution rates. The company's objective is to have the mine fully up and running by the end of 2019.

"Our study anticipates using a combination of resue mining and captive cut and fill, which is a mechanized method with very small equipment," said James Bannantine, president and CEO of Great Panther Silver. "Nyrstar suffered from dilution, so our main focus is going to be dilution-control, which means lower volume and higher selectivity for narrow-vein mining, as well as having more mining faces," he concluded.

Finally, Bear Creek Mining continues advancing at Corani, a very large silver deposit with significant base metal content. Potentially moving into construction over the next year, and with expected production of 12 million oz/y during the first six years of operation, Corani is one of those 'company makers' that do not come in production very often in the industry.

Of course, such a large project brings significant risk with it. Through recent engineering, the company has reduced the estimated capex of the project to a US$585-million figure, which is still high for a junior player transitioning to become a mining company. Anthony Hawkshaw, president and CEO of Bear Creek, said: "There are areas to save money and initial engineering observations have identified possible capex reductions."

In May 2018, the company received its mine construction and water permits. Bear Creek will wait for a "compelling project financing structure" before taking a final construction decision.

Aerial view of Corani project in 2017. Photo courtesy of Bear Creek.

Juniors Gain Momentum

Peru offers enormous potential for both exploration and small-scale production

Both mining companies and juniors have increased their exploration activities. Photo courtesy of Nexa Resources.

Following the recovery of metal prices in 2017, financing for junior exploration companies has increased and with that, has exploration in general. In Peru, one of the Ministry's key objectives for 2018 is to promote new investment in exploration and increase Peru's share of the global exploration budget from 6% to 8% by 2021. A key observation from the number of junior exploration companies in Peru is the vast geographical scope they are active in. Spanning all corners, from the tip of Peru near Lake Titicaca, to near Huaraz in the Andean mountains, and the Sechura desert near the Ecuadorian border, exploration companies are seizing the opportunity to explore Peru's untapped mineral richness.

Copper

As Peru continues to cement itself as the second largest producer of copper in the world, a number of exploration projects gather pace across the country. Regulus Resources continues to focus on its AntaKori copper project in Cajamarca, northern Peru, located immediately next to the Tantahuatay gold-silver mine owned by


John Black, CEO, Regulus Resources.


David Kelley, president and CEO, Chakana Copper.

Coimolache, a joint venture of Southern Copper and Buenaventura. Coimolache and Regulus have actually signed an agreement to carry out collaborative exploration in the area, which will certainly benefit the advancement of AntaKori.

AntaKori has a 43-101 resource of 295 million mt at 0.48% copper, 0.36 g/mt of gold and a little more than 10 oz/mt of silver. Regulus' campaign for 2018 will be approximately 18,000 meters of drilling, and the company has already released the results of 12 holes. John Black, CEO of Regulus, said: "Drilling continues to go well at AntaKori with three drill rigs turning and plans to increase to five rigs shortly. Much of our initial drilling has focused on the southern margin of the previously known mineralization and results to date have significantly extended mineralization in this direction."

Regulus wants to use the current campaign to update the resource estimate, however John Black warned that it will take more time than that to realize AntaKori's full potential: "AntaKori is a very large project and we must be patient to fully capture the opportunity. Although it is difficult to predict what will happen with the price of gold, we do know that copper will be in shortage for the foreseeable future and demand will keep increasing. A benefit of higher metal prices is that more capital is available and this has allowed us to move exploration along more quickly."

Meanwhile, in the south of the country, Kaizen Discovery has continued to focus on its Pinaya project, located in between Arequipa and Puno. Pinaya, previously explored by AM Gold and Rokmaster Resources, sits in the same belt as Glencore's Tintaya deposit and presents typical skarn and porphyry copper-gold mineralization. After some delays created by the Peruvian government's *consulta previa* process (prior consultation with the local communities), Kaizen's drill program this year will have two primary components, according to Kaizen's president and CEO, Tom Peregoodoff: to extend the resource laterally and to explore the potential of some deeper areas. For this, the company will use Typhoon, a proprietary technology of HPX, Kaizen's major shareholder. "Typhoon enables the user to penetrate much deeper into the ground. This is especially important in areas where you have resistive cover. In the case of Pinaya, a primary focus of application of Typhoon is to identify and understand any significant depth potential," said Peregoodoff.

The company is also planning to drill one new target called Pedro 2000, which was identified through both existing geophysics and some ground mapping. The program has a total budget of US$5 million, jointly funded by Kaizen's partners, Itochu of Japan, who will be earning a 20% participation in the project. "We expect this drill campaign will lead both to a second phase of drilling and to an increase in the resource," said Peregoodoff.

Peru's dynamic junior sector and its positioning as the best upcoming destination for copper exploration has helped attract other companies in this space. Newly-arrived Chakana Copper, a company that started trading on the TSX-V end of January, is focusing on the Soledad project located in Ancash, following its agreement with Condor Resources. Interestingly enough, Chakana is not targeting yet another large open-pittable deposit at Soledad, but is focusing on defining the potential of its high-grade pipes instead. In the words of David Kelley, president and CEO of Chakana Copper: "The strategy of the previous operators was to find a porphyry deposit that is assumed to be related to the tourmaline breccia pipes. Our view is different. We think these high-grade breccia pipes can offer significant economic value because they are numerous, high-grade, vertically extensive from surface, and are relatively easy to explore."

Exploration team at AntaKori. Photo courtesy of Regulus Resources.

Luquman Shaheen, president and CEO, Panoro Minerals.

According to Kelley, it should take Chakana two years to go through all the pipes, but this year they could have an initial resource estimate already. He added: "Because Soledad does not have a large footprint, it does not present the environmental and social impacts of a huge low-grade deposit that takes years to drill out. It is a very compact project in a good mining area. We can move along quickly, which is very important in a cyclical industry like mining."

Meanwhile, Panoro Minerals continues its exploration efforts at its flagship Cotabambas project. On the M&A front, the company recently sold the Kusiorcco property to Hudbay Minerals for US$5 million plus a 2% net smelter royalty (NSR), and now it would also like to divest its Antilla project, for which an updated preliminary economic assessment (PEA) has been released.

Luquman Shaheen, president and CEO of Panoro, provided some highlights about Antilla: "As an investment option it is low-risk because the capital cost, at only US$250 million, is low. Moreover, the net present value of the project is higher than the capital cost, the capital intensity and the cash costs are low, the footprint is small, and no community relocations are required. 98% of the resource that is in the mine plan is already at the indicated category, therefore minimal infill drilling is required, so there is as a shorter runway to feasibility and development."

With regard to Cotabambas, the company is focused on testing satellite targets. "There is great potential for the project to see a significant increase in higher-grade resources and oxide resources [...] Following this, the next step will be the skarn mineralization located in Cluster 2," Shaheen concluded.

Finally, privately-owned Pembrook Copper continues advancing its Pecoy copper project in southern Peru, with a current resource of 644 million mt at 0.334% Cu, using a 0.25% Cu cut-off grade. Pembrook owns 51% of the project and can get to 80% ownership by completing a feasibility study and making a cash payment. The company is currently focusing on the engineering studies at a preliminary economic assessment level.

"We hired several engineering companies to complete a power line study, a road study for access to the coast, a water well study that has provided positive results for a pumping station from the gravels, and a tailings and waste dump study. What is remaining is the pit scheduling, which will be done over the next months," explained Brian Booth, president and CEO of Pembrook Copper. In parallel to this, the company is also exploring a second porphyry copper project in the same area, called Tororume, which is 100%-owned by Pembrook.

Zinc

In the zinc space, Tinka Resources updated its NI 43-101 resource estimate for Ayawilca, its flagship project in the department of Pasco, central Peru, which provided a 130% increase in the zinc resource. The new resource consists of 42.7 million mt with 5.6 billion lb of zinc content (2.5 million mt zinc) as well as some indium, silver and lead. In 2018, Tinka is set to complete a 15,000-meter drilling campaign and will

Graham Carman, president and CEO, Tinka Resources.

Brian Maher, president and CEO, PPX Mining.

target new areas, including Zone 3 and Chaucha, as well as an extension of Central, South and West Ayawilca. Graham Carman, president and CEO at Tinka Resources, said: "This drilling campaign will aim to add more high-grade resources to our portfolio and further improve the economics of the project. We will have a resource upgrade by June or July. In parallel, a detailed metallurgical study will occur in Q2 2018 and then we will complete our preliminary economic assessment (PEA) over the second half of the year."

Ayawilca also hosts a tin resource, which increased in the latest 43-101 report of November 2017 to a total of 10.5 million mt containing 145 million lb tin. "The tin lies deeper than the zinc so it will probably not be mined from the start, yet we would like to include the tin in our upcoming PEA as its realization is very high in terms of value. We will need to do more metallurgy and see what we can incorporate this year," Carman said.

Another junior involved in zinc exploration and development is Zinc One, whose primary focus is to reactivate zinc production at the Bongará mine, following the company's acquisition of Forrester Metals in 2017. The company has been drilling in the area to bring the historical resource from previous mining operators to 43-101 standard. The mine was exploited most recently by Cementos Pacasmayo, and the company's plan is to be back in production by 2020.

Bongará's zinc mineralization is high grade and heavily oxidized, hence Zinc One's strategy to set up a Waelz kiln on-site running on anthracite coal. Bill Williams, COO of Zinc One, gave more details: "The Waelz kiln provides an efficient process with low capital costs, and eliminates waste management expenditure. Thanks to the pyrometallurgical process, there are none of the typical tailings that mines have to deal with. The waste will be a slag, which is chemically inert and can be recycled and used for road aggregate."

Precious metals

There are no large junior-held projects in the pipeline, and most of the exploration activity is related to early stage projects or small mining operations by juniors that decided to move into production.

One such is PPX Mining, that has an extensive bulk sampling program ongoing from the Callanquitas structure at the Igor project in La Libertad. Over the last year, the company has mined 25,000 mt of bulk sample, which has been processed at a nearby toll milling facility. "This has given us reams of hugely valuable data, such as information on recovery, grade distribution, and ore control underground. In addition, we have received geotechnical and engineering information from the working faces at the mine – what stope designs and orientations to use, which size ramps work the best, and at what cost", declared Brian Maher, president and CEO of PPX Mining.

Maher said that so far, bulk samples have averaged a grade close to 8.5 g/mt, and that that all the data gathered will help the company make an informed decision to go into production, via the pre-feasibility process (PFS). The PFS will evaluate the economics of a 350 mt/d underground mine, using a heap leaching process to recover gold and silver. The company expects to receive its permit to build the facility in Q4 2018.

Beyond Callanquitas, other areas of interest in the Igor project are the Portachuelos discovery and Tesoros. According to Maher, the company has identified five parallel breccia zones at Portachuelos, with grades near the surface of up to 2.7 g/mt gold equivalent. "While this is 'lower grade,' from a bulk and surface mining standpoint, it is actually quite spectacular," he assured.

Following a similar model, Lupaka Gold has been focusing its efforts on Invicta, a gold-copper polymetallic underground project. The company's plan is to start mine development, use a contract miner and then


Exploration work amounted to $556 million in Peru last year. Photo courtesy of AK Drilling.

send the ore to a toll milling facility for processing, generating cash flow for investors. Commercial production is expected in the third quarter of 2018. Will Ansley, CEO of Lupaka Gold, gave more details about the company's plans: "We intend to operate at an initial 350 mt/d. We have an initial mine plan which outlines a six-year mine life. By 2019, we will have another updated resource with an expanded concept of between 500 and 1,000 mt/d. Investing in our own plant on-site would allow us to double or triple production."

Meanwhile, in the Ancash region, Eloro Resources is completing its second phase of drilling at La Victoria, consisting of 4,000 meters. Tom Larsen, chairman and CEO of Eloro Resources, said: "At Phase I, we defined a significant low-sulphidation epithermal system at the Rufina sector of La Victoria. Phase II will focus on newly discovered gold-bearing structures and how these are related in the different sectors."

When first visiting La Victoria, the Eloro team was surprised by the fact that no modern exploration had been done in the area, even though there was intense informal mining activity. A similar situation applies to another known gold region, the Puno orogenic gold belt in south-eastern Peru, where Palamina has staked a significant land package, with an initial focus in the Coasa and Gaban projects. "There is a modern day gold rush underway in south-eastern Peru by informal miners that everybody is aware of, yet little to no modern day systematic exploration is under way," affirmed Andrew Thomson, president and CEO of Palamina. "No one truly knows how much gold is being produced as large quantities cross the border and are sold to Bolivia."

Thomson is confident that, albeit grassroots, the Coasa and Gaban projects can be advanced fairly quickly, thanks to the team's experience in this belt, consisting of some former Minera IRL geologists who defined the Ollachea deposit in the area. Thomson continued: "At Gaban we have already identified slate shear zones very similar to the mineralized shear zones at Ollachea, where gold occurs in quartz and the metallurgy is very straightforward. Much of the gold in the belt is associated with pyrrhotite and can be located through magnetic survey, so we are planning to fly the Gaban project area to identify the best targets."

Finally, Miramont Resources, a company formed last year, has two main projects of focus: Cerro Hermoso, a gold, copper and poly-metallic breccia type prospect in Puno, where the company is undertaking an initial 5,000-meter drill program this year; and Lukkacha, a porphyry copper project situated in Tacna, 55 km from Southern Copper's Toquepala mine. Being a foreign company, for the latter project Miramont requires a special approval from the central government due to the fact that Lukkacha sits within 50 km of the Chilean border.

Bill Pincus, president and CEO of Miramont, gave his impressions about the current state of the exploration market: "In the last decade, a lot of larger companies overpaid for projects and the cycle went down, which in turn caused companies to become very conservative. The effects of this can still be seen; certainly in the copper space there is a dearth of good exploration and new development projects for the large producers. The known deposits are already being mined and, in some cases, running out of reserves. I believe there will be a scramble for more gold projects as well."

Money for grassroots

Pucara Resources, a company formed in 2013 with the exploration team and early-stage projects of the former Esperanza Resources, had to survive the worst of the downturn in a market that did not have any money to offer for grassroots explorers. For that reason, Pucara relied partly on the prospect generator model, acquiring joint venture partners to fund exploration.

Steve Zuker, CEO, Pucara Resources.

Today, the company counts Nexa Resources and Iamgold as partners, while it has recently closed significant financing with the support of Resource Capital Fund and Sandstorm that should allow Pucara to engage in substantial drilling campaigns. The team has set aside around C$3 million for its Lourdes and Pacaska gold projects this year. "During the downturn there was a lot of ground available and very few companies were picking up exploration opportunities," said Steve Zuker, CEO of Pucara Resources. "Today, we control more than 300 square km, mostly in central and southern Peru, in Ayacucho and Cusco. We are one of the few juniors doing grassroots exploration."

Laurence Stefan, president and COO, Plateau Energy Metals.

Pucara is focused on high-sulphidation, bulk-minable gold projects, so it is open for joint ventures on its base metals projects. Zuker is happy to see that the market is picking up: "We are seeing interest from mid-tier and major companies that are becoming more aggressive – this is new in the market. The BHP's and Rio Tinto's are still in Peru but they definitely prefer projects that are more advanced."

Another company with a similar focus on project generation, and who also plans its own drilling campaigns this year is Condor Resources. Beyond its agreements with Chakana Copper and local mining companies, Condor wants to advance its Pucamayo, Andrea and Huiñac Punta projects. "Pucamayo is our more advanced project, both from a technical and a permitting perspective," declared Ever Márquez, VP Exploration at Condor. "It is an epithermal gold project, and next to it we have identified a porphyry copper-gold area."

A year ago, Condor did a hybrid financing with Sandstorm involving both shares and royalties at Condor's early stage properties. "Certainly, institutional investment is coming back, but the retail side has not picked up yet," related Lyle Davis, president and CEO of Condor. "In any case, today two thirds of the financing for junior exploration is coming from bigger, established mining companies, so the model seems to be that the majors are using the juniors as their exploration teams."

Uranium and lithium

2017 was a transformational year for Plateau Uranium, now rebranded as Plateau Energy Metals. While exploring in one of its areas in the Macusani plateau, the company made the Falchani discovery, containing uranium but also high lithium grades of 3,500 parts per million (ppm). "The deposit is at least 100 meters thick and two square kilometers in area. We are quite confident that this will be among the top lithium resources in the world. It is a totally new style of rock: you can process it easily and it is within 200 meters of the surface, so it is open-pittable," said Ted O'Connor, until recently CEO of Plateau Energy Metals.

The Falchani discovery adds to the sizeable resource the company had already defined in the area of 124 million lb of uranium and 176,000 mt of equivalent lithium oxide. "As we move west towards the Falchani area, the focus is increasingly on the lithium," explained Laurence Stefan, president and COO of Plateau Energy Metals. "Having said this, the uranium at Falchani is double the grade of our uranium to the east, so we will end up as well with a significantly expanded uranium resource on the surface."

Now, the company needs to define the size of its lithium resource and confirm that the extraction will be straightforward and economic. O'Connor gave more details: "In this rock that has 3,500 ppm lithium, we get 80% of the lithium out by using warm sulphuric acid. Our solutions have 2,500-2,700 ppm lithium in them, as opposed to 250 ppm in a normal brine."

Fertilizers

Despite the poor forecast for global phosphate prices, the Sechura basin has become a hotbed for juniors due to its strategic location next to the ocean, its mineral richness that includes highly reactive phosphate rock, and a very large mine already in operation, initially developed by Vale and recently acquired by Mosaic.

One of the juniors in the area is Crops Inc. (previously Focus Ventures) with the Bayovar 12 project. The company carried out recent beneficiation tests that showed a minimum of 30% P_2O_5 content in their rock. With these results, the company has been able to sign MOUs with two phosphate rock merchants based in Switzerland, defining specific export destinations for the traditional phosphate fertilizer industry.

The shorter-term view for Crops Inc., however, is different. Its president, Gordon Tainton, has been looking at different methods to add value to the Bayovar 12 product given the low global phosphate prices: "We believe we have a genuine opportunity to produce elemental phosphorus (P4). P4 is one of the main materials used to make the Roundup weed killer. We investigated the North American and European markets and found out that

Last year, Peru received 7% of the world's dollars for non-ferrous exploration. Photo: Ariana project, courtesy of Southern Peaks.

all P4 demand for North America, Eastern and Western Europe is covered by imports from China and North Vietnam," explained Tainton. He suggested that a second added value for the product can be achieved by coating the phosphate rock with a special polymer, further enhancing the nutrient release.

GrowMax Resources' asset, the Bayovar property, is also located in the same region in northern Peru. The company's initial proposal was to develop a potassium chloride operation out of potash brine. Further studies have concluded that the asset was more suited to become a sulphate of potash (SOP) project. Furthermore, the company discovered approximately 500 million mt of fairly high-grade near-surface phosphate. For this year, GrowMax is focused on generating cash-flow and has decided to invest its time and resources in the development of specialty fertilizer assets in the Latin American region.

Stephen Keith, president and CEO of GrowMax, sees huge potential in the region with Peru's agricultural exports looking to double by 2021. The SOP project, however, needs to improve its numbers: "The initial results of the EPC study were not as good as we were predicting; the after tax IRR was not so attractive. The capex was set at US$20 million for a 5,000 mt/y SOP operation. We are now optimizing the project with the view of taking a production decision during 2018, while we are in discussions with potential partners to develop or finance the project."


Stephen Keith, president and CEO, GrowMax Resources.

With respect to the phosphate deposit, Keith referred to it as an "unbelievable asset" with a great location on the coast, next to Mosaic's Miski Mayo operation. "However," Keith continued, "global phosphate prices have not been in our favor. I believe this will be a critical project for global phosphates but it would not be prudent to build it at present."


Core shack at Cerro Lindo. Photo courtesy of Nexa.

Sharpening up Projects

An overview of the latest industry trends for the main consultancy houses and contractors

Engineering firms are seeing increased levels of activity. Photo: Constancia copper mine, courtesy of Hudbay Minerals.

During the downcycle, engineering firms had to downsize and alter the approach that had brought much reward during the boom years. In order to survive, firms created synergies between different offices across the Americas, focused more on operations and environmental work, diversified into new sub-sectors and modified their rates to be competitive in the marketplace.

Now, however, the mining sector is back on a growth path, as noted by SRK Consulting's director Antonio Samaniego, who suggested that the new positive cycle should translate into higher levels of work across the board. Particularly in geology, he emphasized SRK's effort to develop its structural geology group with the support of SRK's offices in Canada and the U.K.

"All mineral deposits occur through the geological faults, and structural geology looks at finding the mineral enrichment zones. It is an interpretation of how the deposits were formed. Before, this methodology was used for geotechnical work, but we are now applying it to exploration, especially in the narrow-vein mines we have in Peru," Samaniego said.

The return of the positive cycle does not mean that consultancy firms can relax their focus on tailoring their proposals for the sake of efficiency and cost reduction. In the words of Eduardo Ruiz, general manager of Amphos21, a firm specialized in the water cycle: “A hydrogeological study can cost US$50,000 or US$2 million; at the end of the day, you need to do a study that serves your client’s purpose, and often consulting companies are not good at understanding that.”

The return of EPCM projects

Indeed, poor performance in engineering, procurement and construction management (EPCM) projects during the supercycle led to cost overruns and lengthy delays to reach commercial production. This, coupled with the sudden fall in commodity prices, prompted mining operators to look for cheaper alternatives to carry out their investment projects. In the words of Alexandra Almenara, general manager of SNC-Lavalin: “The downturn in mineral prices in the last few years has taught us lessons as we have had to struggle with less resources to deliver projects.”

For a while, smaller EPCs became fashionable, but the savings of that model were often offset by the lack of integration between the different modules of the project, causing –again– delays, inefficiencies, and higher costs than originally budgeted. Denys Parra, general manager of Anddes, one of the largest Peruvian engineering firms with a team of 250 people, sees future projects returning to the traditional EPCM approach: “In general, I see the EPCM model coming back, however, low cost will continue to be an obligation moving forward. The only way this will change is if there is a multiplicity of projects that would generate a shortage of engineering capacity.”


Alexandra Almenara, general manager, SNC-Lavalin.

With this in mind, the traditional EPCM players keep their eyes open for potential opportunities as Peru unlocks its investment pipeline over the next couple of years. SNC-Lavalin, a company celebrating its 25th anniversary in the country, expects to grab an EPCM opportunity following a few years where they had to gear more towards environmental, social studies and permitting work. Alexandra Almenara said: “Depending on the specific requirements for the project, we try to find the right experts in SNC-Lavalin from around the world. For copper we can bring resources from Chile, for gold from Australia or Canada, and for material handling usually from Brazil.”

Australian company Ausenco, that handled the EPCM at Hudbay’s Constancia and is in charge of the upcoming Mina Justa project, is now one of the strongest international engineering players in Lima, with around 400 people. Niresh Deonarain, VP Peru at Ausenco, summarized some of the main factors to be considered for successful project execution: “The only way to understand if there are technical risks is to perform sufficient test work and site investigations. That takes time and costs money, but if done thoroughly you will understand the ore deposit very well.”

Synergy and M&A

Working with synergies became a key concept in the downturn as companies and of-

Eduardo Ruiz, general manager, Amphos21.

fices brought together their diverse range of expertise in a bid to not only survive, but grow. Companies merged, and regional offices began to collaborate more. Hatch not only pushed for synergy between its Chile and Peru offices, but also acquired Indisa in Colombia. Meanwhile, WSP entered the South American market aggressively with three important acquisitions: Schlumberger Water Services, Poch (Chile) and ConCol (Colombia). Also, last year SNC-Lavalin completed the acquisition of Atkins, an 18,000-people strong consultancy firm with a reputation for its digital engineering innovation capabilities.

On a smaller scale, SRK Consulting is now using the team from the former Mine Ventilation Services (MVS), a company it acquired in California, to carry out all the work related to ventilation in Peru's underground mines. "We are bringing a lot of expertise from this company," said Antonio Samaniego of SRK. "In Peru, you have some small ventilation companies, but through MVS we have exposure to much deeper mines from Canada and South Africa."

Water and tailings

Water is often looked at for its socio-environmental implications but the truth is that, beyond these key components, water sourcing costs can make projects uneconomic. According to Eduardo Ruiz, general manager of Amphos21, the first thing companies should understand is the way the whole water cycle works in the operation: "The water resource is increasingly scarce, so you need to look at opportunities to be more efficient: how you can use less water, how you can reuse more water, how you can stop polluting water."

"Often, you see companies that treat the effluent water after the operation and then dispose of it, while at the same time they pay their water rights to extract fresh water. In those cases, it would be easier, and certainly cheaper, to recirculate the water in the operation instead," added Ruiz.

With regard to tailings, Denys Parra of Anddes pointed out that, while Peru has not had any major dam disaster like the one in Samarco in 2015, the industry needs to raise the bar: "A tailings dam failure is always terrible news, no matter if it is a small leak. The effect on the mining industry's reputation is very important. We have recently seen dam failures in Australia and Canada, countries meant to have the highest standards. This is not acceptable," he said.

One of the challenges presented by tailings management is the large volumes that need to be handled. New environmentally-friendly technologies are yet to prove an economic case for the larger operators. According to Gustavo Bravo, Latin America leader for Mine Waste at Golder: "In the future, filtered tailings will be the solution for the issue of mining waste in larger operations, but globally there is still not a great deal of experience in processing and filtering large volumes. I think there will be a natural process of maturity for the technology to reach the point in which it is a more viable solution."

Contractors-in-waiting

Similar to what happened in the engineering spectrum, a number of contractors diversified their portfolio of services during the crisis, while also focusing on reducing operating expenses to improve cash flow.

OHL, which arrived in the mining sector in 2012, has expanded its range of action. "In the past, the market probably saw OHL as a company focused on earthmoving, but we can do much more than that. For example, we are currently executing three tailings dams' contracts, none of which are for earthmoving," said Martín Fernández, mining manager Latin America at OHL.

The company's mining clients in Peru include Antamina, Las Bambas, Tahoe Resources and Anglo American. Ricardo Vega, president of OHL in Peru, highlighted that mining generated 77% of OHL's construction revenue in the country last year. As an example of OHL's capabilities in value-added services, the company recently completed an EPC project for the crushing, agglomeration and transportation facility for Tahoe Resources' Shahuindo project in Cajamarca. "Thanks to OHL's procurement capabilities, we can adapt the crushing systems, conveyor belts and grasshoppers very well to the needs of the client. It is a tailor-made solution," said Vega.

STRACON, until recently part of the Graña y Montero Group, has started a new phase under new shareholders, namely Ashmore Group and Steve Dixon, the company's CEO. Dixon affirmed that the recent transac-


Steve Dixon, CEO, STRACON.


Diego Morales, general manager, Mas Errazuriz.


Mario Matuk, general manager, AESA.

tion will allow STRACON to enter new business areas: "We will remain focused on our core business, which is contract mining and bulk earthworks in Latin America. However, we now have an opportunity to broaden our service offering and implement further geographical diversification."

As an example of STRACON's capabilities, Dixon spoke of their work at Cobre Panama: "There, we already provide a number of services outside of our core activities, including the construction of the transmission line, a tunnel and mechanical and piping installation for both the power station and the concentrator."

In Peru, the company handles the contract mining operation at Tahoe's mines and is also doing construction for the tailings facility at Constancia. STRACON has a goal to replicate the US$460 million it had in sales in 2014 by 2020, and for that it is open to sign joint ventures and acquire new companies in the region as well.

The underground opportunity

Moving forward, both OHL and STRACON want to increase their participation in underground mining: "We have very strong expertise in tunneling for civil works, but we have never applied that expertise to an underground mining operation," said Martín Fernández of OHL.

Meanwhile, STRACON is already present in underground mining in Colombia, at Red Eagle's San Ramón gold operation. Underground mining, however, still represents less than 10% of STRACON's business.

The issue for large contractors looking to enter the underground space is that most of the current underground mines in Peru are in the small to medium size range. The country's largest underground operation is Cerro Lindo, with a daily processing capacity of 20,000 mt/d. The expected large underground projects will probably come from aging open pits, like Yanacocha or, eventually, Antamina. Another interesting underground project is Glencore's Coroccohuayco, where development work has already started.

In light of these developments, different players are already taking positions. Chilean company Mas Errazuriz, for instance, expects the Peruvian market to replicate the conditions of Chile's large underground mines soon. Diego Morales, general manager of Mas Errazuriz in Peru, said: "In Chile, mining companies look for a full-service contractor. Luckily, in Peru we start to see a move towards that model, with one single contractor that has strong financial capacity and higher safety standards." Mas Errazuriz is executing the diversion of the Asana river at Quellaveco, while also working in Fruta del Norte in Ecuador for Lundin.

An example of how the industry is favoring large, integrated underground contractors is AESA, part of the Breca group, probably the largest player in this segment with around 2,000 people working across seven projects. The company has grown by around 20% annually for nearly a decade: "The industry trend is towards consolidation," affirmed Mario Matuk, general manager of AESA. "We take care of a wide range of services, so mining companies can focus their resources on the long-term planning of the operation, rather than having to deal with many different contractors. Productivity also increases when you have an integrated solution."

Increasing standards

JRC Ingeniería y Construcción, a Peruvian underground contractor, has grown over the years to provide integrated underground services. As part of this evolution, the company obtained the triple certification two years ago, and today has six running contracts around the country. Wilder Ruiz Conejo, president of JRC, explained that the company's strategy is also related to potential diversification, considering that JRC's history actually started in construction work: "Looking at the long term, we want to consolidate our growth through integrated underground contracts, based on our experience in this field over the last 10 years. Moreover, we are developing related business opportunities, with construction services. This way, we hope to restart doing earthmoving and infrastructure work, as well as other projects in tunnel excavation for roads and hydropower plants."

Another underground contractor that has set foot in the country is Byrnecut, through its partnership with local firm San Martín. The Australian company's business plan is to target underground mines that will require production faces of five meters by five meters, therefore large volumes, for which it plans to introduce the latest technologies, such as real-time 3D scanning technology to minimize shotcrete wastage, and mechanical fan hanging devices to improve safety, according to Greg Jackson, managing director of Byrnecut Offshore.

AESA, in partnership with GE, has also been investing in new underground technologies, particularly in the development of electrical scoops. "We are one of the first companies to introduce such equipment into mining operations," said Mario Matuk. "It will take time to reduce the size of the batteries and increase their power and duration, but we are already on that path. Battery-operated machinery do not lose power at high altitude, which is a particular advantage in Peru."

Beyond that, Matuk also described AESA's pilot project for a paperless reporting system, the usage of data analytics to improve maintenance performance and other initiatives related to safety, such as virtual reality training and identification technologies via smartphones to track each worker's training levels and authorizations to operate equipment. "Optimizing productivity for the mining industry will be crucial in the near future as the upcycle heats up and human resources becomes an issue," said Matuk.

Rómulo Mucho, general manager, Pevoex.

Ruiz Conejo of JRC agreed on the need for further mechanization and digitalization: "From our perspective, the only way to bet on the upcoming opportunities is to incorporate the latest technologies across all processes to execute massive exploitation methods. Related to this is the need to train all our people to be able to manage large-scale operations," he said.

Safety aspects

The aforementioned trends for larger underground mining also provide for a safer working environment. While achieving economies of scale and incorporating the latest technologies may imply a bigger initial investment, this will pay off in the long run, said Morales of Mas Errazuriz: "Many see safety as an expenditure, but safety is an investment. With a safe environment, productivity rates will increase. If the industry continues moving towards the integrated contract model, not only productivity will increase, but also the overall safety records in the country."

Local contractor Pevoex is also closely involved with the safety aspects of mining operations as the core business of the company is drilling and blasting services. Its general manager, Rómulo Mucho, raised a problem that is costing a lot of time and money to contractors: "In Peru we have not standardized the induction procedure to go to the different mines. There is a whole system around it which involves a lot of medical providers and a lot of money. Chile has already solved this issue, but we have not," he said.

Mucho assured that the implications of this reach the training programs of young people across the industry: "This lack of standardization also prevents students to do internships in the mines, because the induction process takes more than a month and it is simply not feasible for them."

Beyond drilling and blasting, Pevoex has also expanded its service range to provide general earthmoving works, including tailings dam expansions, as well as construction of explosive storage facilities. Mucho was critical when asked about the main challenges for mining investment in Peru: “The main enemy of Peru’s development is the State itself. Considering all the permits needed to make an investment, we need to solve the issue of moving licenses in a timely manner –otherwise, it is impossible for the country to move forward,” he said.

Cristopher Varas, general manager, Grupo Vivargo.

A level-playing field

If corruption has proven to be a deep problem for contractors when trying to win projects for public institutions, Peru’s very open market for private investment pushed competition to the limits during the downcycle, when outsiders were desperate to win their first contract in the country, and clients were looking for the lowest costs possible.

Cristopher Varas, general manager of Grupo Vivargo, a local lifting and installation specialist, saw a number of its construction clients affected by the Lava Jato scandal, and also had to face very aggressive competition from outsiders. He related: “When the rates go below the average, you know that something is wrong. In Chile, companies really make sure that no-one offers a price that would result in safety issues later –in Chilean tenders you have bottom-line prices below which you cannot even participate.” Varas said that during the crisis he saw providers offering a 50% discount on the market average, especially foreign companies that just wanted to enter the Peruvian market. “At the end of the day, Peruvian companies that invest locally and obtain financing through the local bank lose an opportunity.”

Luckily, there seems to be light at the end of the tunnel, thanks to the reactivation of mining investment which has allowed Grupo Vivargo to have a 90% occupation rate in its equipment rental fleet. “We are doing quite a lot of maintenance projects and we are also seeing good levels of activity in Chile, which creates synergies and allows us to move the equipment between the two countries depending on the demand”, said Varas.

Beyond its lifting and installation equipment, Grupo Vivargo also offers project logistics with heavy and oversized cargo services, while a third business line is related to warehouse and inventory management in the mines.

Underground niches

Beyond the potential for large-scale underground mines discussed above, Peru already has a rich history in underground mining, with a wide variety of operations from the very small narrow-vein mines to highly mechanized medium-sized operations.

Robocon, one of the key contractors offering rock support through shotcrete application, is currently focused on narrower tunnel development, as per its clients’ demands. “Typically, our clients have faces of four by four meters, but now they want to advance in tunnels of three by three meters [...] Through Tecnomecánica, our technological arm, we are developing new machines in collaboration with other manufacturers in Peru and abroad that already have some technologies for narrow-vein operations,” said Enrique Sattler, managing director at Robocon.

Robocon has been working for Volcan (now Glencore) since 2005 and for Pan American Silver’s Huarón and Morococha mines since 2012. When discussing Robocon’s most recent activity, Sattler commented: “We started operations in Tambomayo and Uchucchacua for Buenaventura, and we began working in Yanacocha in 2017, in collaboration with AESA. Our most recent client is Sociedad Minera Austria Duvaz, where we are transitioning from a dry shotcrete operation to a mechanized, wet shotcrete operation, in narrow tunnels.”

Meanwhile Tumi, a raise boring contractor, has increased its involvement in production drilling thanks to the development of the SBM 400 SR machine. While raise boring has traditionally been used for ventilation needs, Marc Blattner, Tumi’s general manager, explained the usage of the SR machine: “What we do is a burn hole: a hole in the center of the blast zone, which provides a cavity for the blast area to collapse into. The SR model is not only an upgrade of our traditional raise boring machine, but it is actually a new method of production which did not exist before.” In 2017, Tumi grew from 11 to 15 crews, three of which are dedicated to production activities, and is also expanding into Chile, where the company expects to grab boxhole contracts with Codelco at El Teniente. As a company that engineers and develops its own machines, increased mining activity worldwide may result in more revenues coming from the outright sale of equipment to miners, commented Blattner: “We will see Tumi’s growth coming not just from contracting, but also selling machines into the Peruvian market, which so far we have tried not to do. It seems that the mines are going back to the mentality of the 1970s inasmuch as they want to buy their own equipment again. We are flexible enough to offer to run the equipment ourselves with a contract, or provide all the maintenance, and also to train our clients’ operators if required.”

A World of Innovation

Technology and service providers keep incorporating new concepts to improve productivity and safety

With high altitudes and both open pit and underground mines, Peru is fertile ground to test new technologies. Photo courtesy of Nexa Resources.

The mining industry is constantly evolving. If the last downcycle was fertile ground to look for new ideas that would bring more efficiency to production processes, the current upswing in commodity prices may offer the perfect opportunity to properly test those new technologies. At the end of the day, there is more cash available in the market, and final users may be a bit more flexible with their budgets to give the latest gadgets a try.

For the global original equipment manufacturers (OEMs), innovation is a long-term pillar with a clear strategy. Epiroc, the new company formed when Atlas Copco spun off its mining business, has defined four areas of interest for innovation: electrification and the use of battery-powered equipment; automation related to the possibility of having remote operations; interoperability with all machines compiling big data that will allow for fast decision-making; and technologies for rock excavation, with the idea of potentially replacing drill-and-blast methods with continuous mining techniques.

Gonzalo Díaz Pró, general manager of Ferreyros, the Caterpillar distributor in Peru, explained the impact that continuous mining could have on the industry: "Foregoing the need for blasting is the dream of all miners, because blasting drives the whole extraction process: you need to clean up, prepare, evacuate, blast and go back." Over the years, especially since Caterpillar's DBT acquisition, the brand has been investing in this field, and it is already testing a continuous mining prototype for hard rock in Chile.

Ángel Tobar, general manager for the Andean region at Epiroc, developed on the advantages that battery-powered equipment can bring to the mines, especially as underground operations move deeper and health, safety and environment (HSE) regulations worldwide become more stringent: "At this moment, the initial cost of a battery-powered machine is higher, but if you look at the total cost of operation, you can obtain significant savings in areas such as mine ventilation, by having smaller tunnel sections, and also you would avoid the operational delays related to fumes underground," he explained.

Caterpillar also has a significant presence underground with its family of load-haul-dump machines (LHDs). Díaz Pró of Ferreyros related: "Caterpillar bought Elphinstone in the early 2000s, a brand of underground equipment with traditional configurations and, little by little, Caterpillar has incorporated technologies such as sensors, payload systems and rear view cameras, for productivity and safety."

Speaking of battery-powered equipment, Díaz Pró added that Caterpillar will only launch this technology at a commercial level once it is able to perform as well as diesel engines.

Komatsu Mining Corp., the company created from the merger of Komatsu and Joy Global, is also in a good position to push its technological developments across a wide variety of machines involved in mining, from the Komatsu trucks and construction equipment to the P&H shovels, Joy underground equipment and Montabert drills. Carlos Fonseca, general manager of Komatsu Mining Corp. in Peru, gave more details about the SR (Switched Reluctance) technology included in the P&H wheel loaders and the larger Joy underground loaders: "It consists of the ability to recapture energy when you put the brakes on, like in hybrid vehicles, or when you lower the bucket. This energy can be applied to propel the wheels. The feedback we have received is that it is very fuel-efficient and low on maintenance. This technology is targeted to be included in other Komatsu products in the future."

Narrow-vein mining

The improvement of the market has clearly been felt across the underground spectrum. Indeed, higher base metal prices have drastically improved the economics of many mines, encouraging operators to engage in more dynamic budgeting after years of severe cuts in investment.

The lack of mechanization in narrow-vein operations opened up a business niche that the very large OEMs probably did not find to be large enough for them. Yet, it is a significant market worldwide. Resemin, a Peruvian manufacturer of underground equipment, has specialized in this segment, and is achieving excellent growth rates (50% in 2017).

Gonzalo Díaz Pró, general manager, Ferreyros.


Detonating cord. Photo courtesy of Exsa.

Resemin produced 92 units last year, and the company has expectations to reach the 150-unit/year mark soon. “Our most successful product lines are the roof bolters and the Muki,” said James Valenzuela, CEO and chairman of Resemin. “There is now greater demand for equipment for smaller tunnels of three by three meters. The Muki is constantly described as a game-changer, because it has four applications: drilling, scaling, roof bolting and cut-and-fill mining. It can quadruple productivity compared to a manual drill.”

Another important milestone for Resemin’s corporate growth was its purchase of Schopf, a Stuttgart-based manufacturer of underground loaders. With this acquisition Resemin received all the engineering capability of Schopf as well as the brand, and it will begin manufacturing Schopf loaders in Peru – initially the 3.5-mt payload model, then will progressively move up the product range to the 18-mt payload loaders. Valenzuela said: “We have a complete line of products for underground mining, and the loader market is three times the size of the market for drilling rigs. It is an enormous growth opportunity for us.”

Automation and drives

Another important component in mobile machines and industrial equipment is the drives. Bosch Rexroth, a German company with a leading position in hydraulic drives, has been expanding its service capability in Peru over the last years through the acquisition of a local distributor and the setting up of a new service shop. Now operating as a new legal entity in Peru, the company will continue capitalizing on the after-market opportunities (many mining machines arrive in Peru with Bosch Rexroth components already installed), but will also push for the introduction of new solutions locally.

Kai Rothgiesser, general manager of Bosch Rexroth, explained that the company sees a lot of opportunity in Industry 4.0: “By recording all the parameters of the different machines and components, you can make sure that the operation is running at an optimal level and that you can anticipate maintenance. These sensors, and the wiring and software associated to them, are not a big investment for the client if you compare it with the benefits you can obtain.”

Mining already represents 50% of Bosch Rexroth’s business in Peru. While Peru’s large fleets of mining machines will continue to present significant opportunity for the company’s hydraulic drive business, it is in the processing plants that the company sees greater room for development in the automation area: “Mobile machines are closed systems. The plants, however, include many components from different brands. The feeders and conveyors, for example, are huge investments that use a big amount of drives, so there is an opportunity for us to come in,” concluded Rothgiesser.

Jorge Granda, general manager, AK Drilling International.

Gustavo Gómez Sánchez, general manager, Exsa.

Benedikt Kirchgässler, CEO and founder, CyanoGuard.

Drilling services

Exploration was probably the segment that suffered the most during the crisis because the level of activity was drastically reduced or, in some cases, stopped altogether.

Jorge Granda, general manager of AK Drilling International, a contractor with a fleet of 25 machines in Peru and operations in seven countries, explained that the low volume of work available and high pressure on drilling rates made the downturn a difficult period to adapt to: "During the crisis, the procurement specialists within the mining companies were empowered to take many decisions about which contractors to use. This always happens during the low cycles. Seeing the drilling service as a commodity means that you will only pay attention to the final price, and this is shooting yourself in the foot."

Geotec, another drilling contractor, has seen a positive trend in the market and doubled its sales in 2017. Recent drilling campaigns by the larger mining operators are prompting contractors to invest in automation and new technologies related to safety. Geotec's general manager, Miguel Ángel Arenas, said: "We increasingly see clients ready to pay more for safety and new technology. In Las Bambas, we incorporated seven hands-free rod handlers, so the whole drilling campaign was hands-free. This year we won a contract to introduce intelligent machines for rod handling in underground mining. It is the first hands-free diamond drilling campaign for underground mining in Peru."

Arenas highlighted that some mining companies are willing to engage in long-term drilling contracts, like the three-year assignment Geotec has at Yanacocha, because they know the drilling rates will increase very soon. Asked about the investment required to incorporate the hands-free rod handlers, he explained: "If you include the training required, a hands-free rod handler for a surface drilling rig can cost US$450,000, while a brand-new drilling machine costs US$600,000. Not all clients are willing to pay substantially more for their drilling, but for us this amount needs to be seen as a long-term investment where we are also improving productivity, efficiency, and safety."

Granda of AK Drilling affirmed that the introduction of these new technologies, however, should not be seen as a 'one-size-fits-all': "At AK Drilling we were one of the first contractors to use these technologies for an oil and gas project in Colombia. In the oil and gas industry, you spend months on the platform and each pipe weighs half a ton. In mining exploration, the rods weigh 35 kilograms, and you are on a platform for just a couple of weeks. In mining, you need an agile setup and competitive costs [...] At the end of the day, it is the end user who needs to decide what is best for each particular project."

New blasting technologies

If 2017 could be seen as light at the end of the tunnel for exploration-related companies, the blasting market remained tight with the arrival of new competitors and a continued focus on cost reductions and productivity. For Exsa, one of Peru's main rock fragmentation companies, innovation was instrumental to ensure the company's strong positioning in the open pit segment, where it has a 45% participation. Through the introduction of the Quantex technology, clients obtained cost reductions of 30% in the blasting process and 80% reductions in CO_2 emissions, according to Gustavo Gómez Sánchez, the firm's general manager.

Gómez Sánchez highlighted that the second half of 2017 allowed for an increase of work volumes but that the higher price of ammonium nitrate presented some challenges as well. Moving forward, Exsa will continue expanding its scope, offering specialized blasting

Claudia Marchini, country manager, Ixom.

Miners keep incorporating new solutions for higher efficiency. Photo courtesy of Minsur.

services for construction and non-production activities, and leveraging its brand-new initiation systems plant in Peru: "This is the only new plant built in the region for more than 20 years, so the gulf in technology is vast. We will reduce our environmental footprint, as the plant will not use lead and is far more efficient. We are specializing in non-electric detonators, detonating cords, boosters, shock tubes, PETN and we are in the process of manufacturing end products as well," he said.

Innovation is also a key pillar for global blasting players like Maxam and Orica. Orica participates in Peru's mining industry through both blasting solutions and the provision of cyanide for gold mines. The company is introducing a wireless detonation system called Webgen that consists of a wireless primer and supporting equipment. Webgen is already being used in underground mines in Canada and Australia, and it should be tested in Peru this year. Gustavo Costa, general manager of Orica in Peru, provided more details: "As there is no need for wiring, Webgen allows our customer to have fewer people exposed to risks and for less time. Moreover, we are capable of significantly reducing the blasting time cycle [...] For example, in mines that usually have thunderstorms, the wireless process will allow work to carry on for longer and will reduce the stoppage time."

Finally, Spanish-based multinational Maxam is targeting growth in Peru through its Rioflex hydrogel technology, already in operation in Chile's large open-pit mining segment. According to Maxam's general manager in Peru, José Luis Alonso, the Rioflex technology offers 25% more energy than equivalent emulsion blends through a wider range of available densities.

Asked about how much the final price weighs on mining companies' tenders for blasting solutions, Alonso said: "In Peru we see that our customers are requesting value-added propositions to optimize the total cost of their operations beyond the cost of drill and blast. This holistic view is what has enabled us to be successful around the world, and we see the industry in Peru moving towards this more sophisticated and smarter approach."

Cyanide control

Peru's mining industry uses large amounts of cyanide, which is one of the main cost drivers for gold producers. In this context, making sure companies use the right amount is key from both an efficiency and from an environmental perspective. CyanoGuard, a Swiss company with a new technology for instant cyanide detection, has entered the Peruvian market with the idea of changing the way mining operators manage their cyanide usage. "If you do not use enough cyanide you lose gold, but if you use too much you incur in high costs to eliminate the excess cyanide, on top of what you already paid for cyanide you did not need," explained Benedikt Kirchgässler, CEO of CyanoGuard, who also affirmed that the cyanide elimination costs can be three times as high as the price of cyanide.

CyanoGuard offers a solution that allows cyanide detection in just 90 seconds, foregoing the need to take a sample to a laboratory, while all the information compiled can be sent to the cloud in real time. Mathias Cherbuin, CTO of CyanoGuard, provided more details: "Our solution provides mobile lab-grade cyanide measurements stored in the CyanoChain blockchain. This is easily integrated in already existing process management software and aims to become the gold standard for cyanide monitoring in the 21st century."

With modern mine closure plans becoming more common in the years to come, and with an increasing push for more transparency in environmental monitoring, the company expects to achieve significant growth in the precious metals industry in the years to come.

Chemical supplies

Quimtia, a chemicals provider, has seen specialties increasingly overshadowing the more traditional business of commodity trades, where the company provides copper sulfate, sodium cyanide and activated carbon.

It was on the environmental front that Quimtia started its diversification: "Due to the numerous gold and silver mines that have to deal with cyanide contamination in discharge streams, there was a strong opportunity to implement related solutions in the Peruvian market," said Eduardo Galdo, sales manager of mining at Quimtia. Today, advanced oxidation technology, like the hydrogen peroxide used for cyanide destruction, contributes to 30% of Quimtia's business, while other niche products used to improve recoveries in both leaching and flotation processes already make up 20% of revenue.

Ixom, a company created from the divestment of Orica's chemicals division in 2015, is also increasingly focusing on regular supply relationships for mining clients rather than spot commodity trades. The company's mining business grew by 30% last year, triggered by contracts in water treatment and flotation with large copper producers.

Claudia Marchini, country manager of Ixom, declared: "Our chemicals business was mainly based on commodities, which allowed us to start relationships with large customers and increase our volumes in the past. After that, the fall of copper and other mineral prices represented an opportunity for us to offer specialty chemicals for mineral processing."

Ixom develops emulsifiers for explosives and has a plant in Chile where it produces flotation agents. Marchini gave more details: "We have specific products and applications to improve productivity in oxides or sulfides of copper, zinc, lead and precious metals. In copper concentration, we develop customized collectors according to each specific ore mineralogy," she concluded.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