

Vanadium trends in exploration; markets and future demands

by A.D. Hammond

The drop in iron ore prices has claimed an unwitting casualty in vanadium. Vanadium is dominantly produced as a coproduct of steel production. The recent shutdown at EVRAZ's Mapochs steel-vanadium operations in South Africa has cut off 10 percent of the world's vanadium output. In February 2015, Australia's Atlantic Ltd. suspended operations at its Windimurra iron-vanadium complex after a fire caused severe damage at the plant. Since then, challenging market conditions has resulted in the permanent closure of this operation.

This decoupling of vanadium production from integrated iron ore producers presents an opportunity for vanadium exploration companies to target single-product deposits. This trend is manifested in the increasing number of pure-play vanadium ventures around the world.

The mine production of vanadium is dominated by three countries — China, South Africa and Russia, which collectively produce 96 percent of the world's vanadium. While the use of vanadium as an alloy in the steel industry remains the largest application for this metal, growth in demand is expected to come from the renewable energy industry in the form of batteries for energy storage.

This article summarizes the current state of vanadium exploration, briefly describes the vanadium market and lists sources of future demand for the metal.

Trend in vanadium exploration

The most active participants in the current vanadium exploration are pure-play vanadium ventures in Brazil, South Africa and Australia. These ventures are targeting deposits with higher vanadium grades than those typically mined in titaniferous magnetite operated by integrated steel-vanadium producers.

The 10 percent shortfall in vanadium production resulting from the shutdown at EVRAZ's Mapochs is expected to be partially compensated by Largo Resources' Maracás Menchen vanadium operation located in the



A view of the vanadium operation at Maracás in Brazil, controlled by Largo Resources.

state of Bahia in Brazil. It commenced operation in August 2014 and is expected to produce between 7.6 and 8.6 kt (8,421 and 9,523 st) of V_2O_5 in 2016 at a target production cost of \$3.71/lb (Largo Resources, 2016). This is the first primary vanadium operation to be placed in production in the Western Hemisphere in more than 35 years.

The Maracás Menchen Mine is a vanadium-bearing titaniferous magnetite deposit with an average reserve grade of 1.17 percent V_2O_5 , which is double the industry average. The vanadium content is associated with the magnetite of the Rio Jacaré mafic-ultramafic intrusion. The Maracás process plant comprises three stages of crushing, one stage of grinding, two stages of magnetic separation, magnetic concentrate roasting, vanadium leaching, ammonium metavanadate (AMV) precipitation, AMV filtration, and AMV calcining to V_2O_5 flake as final product. Largo Resources has a six-year, take-or-pay offtake agreement with Glencore for the entire vanadium production coming from the Maracás Menchen Mine.

In South Africa, Bushveld Minerals is conducting exploration at the Bushveld Vanadium project in Mokopane District, Limpopo province. The Bushveld Vanadium project comprises three adjacent and parallel magnetite layers. Total JORC-compliant resource amounts to 121 Mt (133 million st) with average grade of 36 percent Fe,

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Exploration

Figure 1

Vanadium estimated world production in 2015 (metric tons).



1.09 percent V_2O_5 , and 10.9 percent TiO_2 . In May 2016, Bushveld Minerals entered into a conditional agreement with EVRAZ to purchase the Vametco vanadium operation in South Africa (Bushveld Minerals).

In Australia, Australian Vanadium Ltd. is exploring its Gabanintha vanadium project located in the Murchison province approximately 43 km (26 miles) south of the mining town of Meekatharra in Western Australia. The Gabanintha deposit is a vanadium-bearing titaniferous magnetite deposit with reported JORC-compliant total resource amounting to 125.8 Mt (138.6 million st) at an average grade of 0.7 percent V_2O_5 . In June 2016, the company signed a contract to purchase a vanadium electrolyte pilot plant from C-Tech Innovation Ltd. and a dealership agreement with German vanadium battery manufacturer Gildemeister for the sale of its CellCube batteries in Australia. (Australian Vanadium Ltd.)

Also in Australia, TNG Ltd. is conducting studies for the development of its Mount Peake

titanium-vanadium-iron project situated in the Northern Territory. Production is projected to be on the order of 17.5 kt (19,300 st) V_2O_5 for a 17-year project life. Total JORC-compliant resource is 160 Mt (176 million st) at an average grade of 0.28 percent V_2O_5 (TNG Ltd.). TNG Ltd. plans the construction of a hydrometallurgical processing plant to be built in Darwin for the recovery of vanadium pentoxide from magnetite concentrate. TNG signed an offtake agreement with Woojin Metals (South Korea) for the purchase of its vanadium production.

In North America, American Vanadium Corp. and Stina Resources are pure-play vanadium exploration companies with properties in central Nevada. The depressed vanadium prices, coupled with unfavorable sentiment affecting the resource space forced American Vanadium Corp. to discontinue the development of its Gibellini project. Stina Resources is awaiting more favorable market conditions to pursue vanadium exploration efforts at its Bisoni Mackay property. Both, the Gibellini and Bisoni Mackay properties are vanadium-bearing metalliferous organic shale deposits contained in the Woodruff formation of central Nevada.

Finally, Canada's Vanadiumcorp Resources completed a NI 43-101 study for its flagship Lac Dore vanadium project in Quebec. In May 2016, the company signed a memorandum of understanding with Schmid Energy Systems GmbH to collaborate in the production of vanadium electrolyte by direct processing of ore from its Lac Dore mineral claims.

Vanadium market

The global supply of vanadium comes from three different sources, namely primary production, coproduction and secondary production. Coproduction from steelmaking slag accounts for approximately 65 percent of the global supply. Vanadium produced from primary sources accounts for 25 percent and secondary production derived from the processing of vanadium-bearing fly-ash, petroleum residues, pig iron slag and spent catalysts account for the remaining 10 percent.

In 2015, no vanadium was produced from primary or coproduction sources in the United States (USGS, 2015). The small vanadium production in the previous years came from the mining and processing of uraniferous sandstones deposits in the Colorado Plateau. The United States imported 3.3 kt (3,638 st) of ferrovanadium (FeV), 3.5 kt (3,858 st) of vanadium pentoxide (V_2O_5). The United States imports of vanadium in 2015 decreased by 31 percent relative to 2014. This was due to

Figure 2

Projected vanadium supply/demand balance. Source: Roskill (2014).



the sharp drop in imports of vanadium-bearing ash and residues. Exports decreased by 55 percent from those of the previous year. This decrease was seen across all materials. Reported vanadium consumption in the United States was 3.6 kt (3,968 st) of contained vanadium, a decrease of 470 t (518 st) from 2014. All U.S. demand is currently met by foreign sources, the majority coming from South Africa (40 percent), Russia (35 percent) and China (18 percent). In 2015, estimated worldwide production of vanadium was 79.4 kt (87,523 st), a decrease of 3.3 kt (3,638 st) relative to 2014 (Fig. 1).

Steel applications account for approximately 91 percent of the total world consumption of vanadium. High-strength low-alloy (HSLA) steels are by far the largest market for vanadium and accounted for 46 percent of vanadium consumption in steel in 2014. Consumption of vanadium in this application has benefited from the enactment of stringent building codes, particularly in China, which has resulted in the use of larger quantities of vanadium-bearing rebar. Catalysts for the production of sulfuric acid represented the leading nonmetallurgical use of vanadium.

The price of vanadium in its two marketable products, ferrovandium and vanadium pentoxide, is currently at a 10-year low. The price for vanadium pentoxide is \$3/lb and for ferrovandium is in the range of \$15/kg.

Vanadium demand

Because more than 90 percent of vanadium is used in steel production, its demand is highly correlated to gross crude steel production. From 2006-2014, the production of crude steel increased at a rate of 3.6 percent compound annual growth rate (CAGR). However, the intensity of use of vanadium grew at an 8 percent CAGR over the same period. Intensity of use is defined as the ratio of materials use to value added. This is mostly a reflection of the increased use of vanadium in the manufacture of rebar in China and emerging markets as these countries adopt western standards in the fabrication of high-strength rebar in new construction. Vanadium has the property to increase the tensile strength of steel and its high strength-to-weight ratio supports fuel efficiency mandates in the automotive and aerospace industries.

Although currently there is a slight surplus in the supply of vanadium relative to market demand, Roskill projects a 3-percent CAGR increase in demand for the period 2015-2025 (Fig. 2).

The bulk of the demand is expected to come from the production of HSLA steels, particularly for automotive and aerospace uses, at an average rate 6.81 percent CAGR. Aircraft usages currently account for 7 percent of the vanadium market. The increase in usage of HSLA steel is mostly driven by fuel efficiency and emissions regulations.

Future demand for vanadium is expected to come from the renewable energy industry in the form of vanadium flow batteries for storage of energy generated from renewable sources. Vanadium flow batteries are used in power grid balance and off-grid energy storage solutions.

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Final V₂O₅ flake product produced from Largo Resources' Maracas project.

Currently, only a small fraction (1 kt or 1,100 st) of vanadium consumption is attributed to batteries. Various manufacturers of vanadium flow batteries are already deploying their products in multiple applications around the world. Among them Sumitomo Electric (Japan), Gildemeister (Germany), Rongke Power (China), Redt Energy (United Kingdom) and United Technologies, UniEnergy Technologies, Imergy Power Systems and Vionx Energy in the United States are the leaders in the industry. The upward trend in the implementation of

renewable energy solutions ensures an increase in demand for vanadium as the technology of flow batteries is perfected and the cost per MWh becomes more competitive.

Conclusion

The recent drop in iron ore prices has resulted in the closure of important vanadium producers. Consequently, a decoupling of vanadium production from integrated steel producers may be on the horizon. This presents an opportunity for pure-play vanadium exploration companies to establish a position in the vanadium market in anticipation of further shortfalls and increase in demand for this metal in its traditional use in the steel industry and, potentially, in its future use in the energy storage space as the technology of vanadium redox batteries is perfected.

Under this scenario, future vanadium production is likely to come as primary product extracted from single-product deposits, with preference to those amenable to vanadium recovery by hydrometallurgical methods. ■

BHP Billiton to spend \$900 million on copper and oil exploration in the coming year

BHP BILLITON continues to show its commitment to the copper sector, as it recently announced that it plans to spend \$900 million on exploration in the coming year. While some of the money will be dedicated to the search for untapped copper deposits, some of the money will also be used for oil exploration. The announcement from BHP comes after it announced that it also plans to up its investment in copper projects.

The Australian reported that the \$900 million the company has earmarked for exploration represents a 30-percent decline from 2013, but is more than the \$816 million expense recorded in the 2015 financial year.

Exploration will total 18 percent of the miner's overall capex budget, up from 10 percent in the 2016 financial year and 7.4 percent the year prior.

BHP Billiton's geoscience leader, Laura Tyler, said the focus would be

on oil and copper through the next 12 months, with crude targets in Central America and off the coast of Western Australia of particular interest.

"Over the last four years we have developed a new approach to petroleum exploration that is much more focused," Tyler said.

"We have commenced drilling in Trinidad and Tobago and have secured an additional rig that will soon commence drilling in a prospective block north of our Shenzi operations in the Gulf of Mexico."

BHP's copper targets span South America, North America and Australia, with the firm eyeing new partnerships to boost its growth pipeline.

"We execute our copper exploration both directly and through investment in joint venture opportunities and we continue to seek partnerships with junior explorers," Tyler said.

The commentary follows BHP chief executive officer Andrew Mackenzie's insistence that BHP was an industry leader in exploration through the downcycle, with the firm expressing confidence in the medium-term outlook for oil and copper prices.

"We have been surprised by the extent of cost cutting across the industry," Mackenzie said.

"We are increasing our exploration activity to take advantage of falling costs as others pull back."

Tyler said the bottom-line figures of a decline through the past four years were deceiving, as it is now a lot less expensive to test new finds, while the firm has noticeably lifted the share of capital expenditure it directs toward exploration over the past two years.

"We have reduced exploration operating costs by 70 percent since 2013, and this year we have increased the targets tested by 44 percent," she said. ■