How to evaluate a rare earths opportunity

The race is on for rare earths investment, but what should you look for?

So where do we go from here? That is, what are the criteria investors should consider when they are looking for rare earth/zirconium investment opportunities?

At this early stage of developing a domestic critical minerals supply chain, and as mentioned previously, one of the most important criteria for investors to consider with rare earths is whether the resource offers potential to recover other commonly associated critical minerals such as zirconium/hafnium and scandium, that are also largely controlled by China. These may offer better opportunities than rare earths for quickly finding domestic market outlets for the processed forms of these elements.

The rare earth elements neodymium, praseodymium and dysprosium are well known for application in high strength permanent magnets, now in increasing demand for electronics, wind turbines and electric vehicle motors. There are also opportunities in aircraft construction, where aluminum and titanium have been the traditional metals of choice. Zirconium and hafnium can be used in various combinations to make certain titanium and aluminum alloys that are perfectly suited for the high-temperature regions of jet engines. Similarly, scandium is in increasing demand as an additive to aluminum alloys to increase their strength and reduce their weight. When all of these elements are recoverable from the same resource, it becomes a much more attractive investment opportunity.

A couple of North American rare earth projects that meet most of these criteria, are Avalon Advanced Materials' Nechalacho Basal Zone Heavy Rare Earth project in the Northwest Territories and Imperial Mining's Crater Lake Scandium project in northern Quebec. The Nechalacho resource contains the critical elements zirconium/hafnium as well as both the light and heavy rare earth elements. The Crater Lake Project is a rare earth resource with exceptional scandium enrichment and is now being looked at mainly as a scandium project. It also contains concentrations of zircon as well as the rare earths.

Another factor to keep in mind is the balance between the Light Rare Earths (Lanthanum through Samarium) and the Heavy Rare Earths (Gadolinium through Lutetium), plus Yttrium. Most rare earth resources are dominated by the light rare earths, but having recoverable heavy rare earths as well can further enhance the overall value proposition as demand for these will grow as new supply becomes available.

Once the investor has identified a rare earth project that also contains other critical elements like zirconium and scandium, the next step is to assess whether they occur in minerals that are amenable to economic processing and recovery. The feasibility study (FS), Pre-feasibility Study (PFS) or Preliminary Economic Assessment (PEA) are the best sources of this type of information. Many early stage projects are focused on defining the largest potential size and grade of resource without focusing on whether the elements of interest occur in minerals that are amenable to economic recovery. These projects should not be considered as attractive investment opportunities until an appropriate economic extraction process has been identified. The next step is to be certain that the recovered products will meet the specifications required by the consumer.

Other important points to consider when considering new rare earth project investment opportunities is the content of radioactive elements uranium and thorium which often occur with rare earths. High levels of uranium and thorium can be problematic from an environmental regulatory standpoint. Some jurisdictions are more challenging than others. Personal experience has shown that regulations in Canada are better than in the U.S. by providing an appropriate level of environmental regulation while not causing any unnecessary burden on industry.

Rare Earths

Finally, regardless of the balance of critical elements contained in a rare earth resource, the operation will need a well-qualified team to perform the development and product marketing work. So, the most important requirement at this early stage of creating a new supply chain is finding the people with both the appropriate skill sets and experience. Companies with these assets will have a greater chance of success.

In summary, an investor looking for a rare earth project with the best prospects of success should be one that has the following attributes:

1) a resource that also contains significant recoverable quantities of zirconium/hafnium, scandium or heavy rare earth;

2) contains low level of radioactive elements or is located in a region that has less-burdensome environmental regulations;

3) has a defined a viable extraction process flowsheet; and,

4) has the appropriate, key people available for the early stage of development.

Now the trick is to find them.

Zirconium and establishing a domestic rare earths supply chain

A clear path forward required for reducing our reliance on China

Despite its relative obscurity, zirconium remains a critical material with significant supply risk. China controls most of the industrial production capacity to process zirconium mineral concentrates into the basic starting compounds needed for downstream zirconium products. In fact, **China controls 95% of the world's production of the key zirconium compound** Zirconium Oxychloride ("ZOC"), which is the starting material required for downstream manufacturing into various commercial products including nuclear-powered naval vessels. Currently, 100% of the ZOC used outside China must be purchased from producers in China. A second basic zirconium compound required by industry is Zirconium Basic Carbonate (ZBC). The ZBC is derived from ZOC. The current North American annual demand for ZOC is approximately 50,000 tonnes. Worldwide demand outside of China is approximately 150,000 tonnes per year.

To reduce reliance on China for a domestic supply of critical zirconium starting compounds such as ZOC, a North American production facility for zirconium compounds must be established. And, with zirconium minerals often found associated with rare earth minerals, developing a rare earth supply chain could create an opportunity to establish a new primary supply of zirconium minerals at the same time.

There are several examples in North America of primary rare earth resources that also contain zirconium minerals. This is commonly the case with rare earth deposits that occur in alkaline igneous intrusive rocks. These rocks may contain resources of a number of critical minerals as well as some more familiar metallic commodities such as copper and iron ore. In some cases, where such resources were mined for base metals, the tailings may contain significant quantities of recoverable critical minerals. An appropriate rare earth / zirconium resource could supply the ZOC compound for the zirconium production industry as well as the refined rare earth products to downstream users.

Zirconium dioxide is a white crystalline oxide of zirconium. Its most naturally occurring form is the mineral baddeleyite.

Zirconium is usually found in the silicate mineral zircon (ZrSiO4) which always contains another rare element, hafnium, averaging a low 2% concentration. Hafnium can be a valuable by-product of zirconium recovery from a zircon resource. One interesting application for hafnium is its addition to nickelbased superalloys used in gas turbines. The other zirconium ore mineral occasionally found in a type of alkaline intrusive rock called carbonatite is baddeleyite, a pure ZrO_2 mineral that offers a simpler processing solution to produce ZOC, if it can be found in sufficient concentrations to justify recovery.

Unlike the rare earth industry’s lack of domestic, downstream-refining and manufacturing capacity to make the needed derivative products such as magnet alloys, **the zirconium industry does have downstream manufacturers for all the current products needed in industry**. Because the downstream manufacturing capacity of zirconium products is available, it could be argued that an attractive development option for a combined rare earth / zirconium resource would be to start by selling ZOC and stockpile the rare earths until downstream rare earth consumers can come on line. There is also a potential role for government to purchase the rare earths for a government managed stockpile of critical minerals until the downstream components of the supply chain are established.

The critical importance of zirconium alone could be sufficient to justify the need for bringing a combined rare earth zirconia resource into production. Significantly, there are many applications that require both a rare earth and zirconium to develop the necessary properties for the application. One example is the use of yttria-stabilized zirconia in hydrogen fuel cell technology.

Zirconium needs to be considered part of the solution for establishing a rare earths supply chain, along with other critical minerals such as scandium, that often occur together with rare earths in the same resource. Developing these resources in alkaline igneous rocks, of which there are a number of examples in North America, offers a clear path forward for reducing our reliance on China for a basket of critical materials.

The future looks bright for zirconium

The most important metal you never heard of

"Zirconium is yet another example of an obscure critical material with great potential in new technology where China controls the supply chain." – Donald Bubar, President & CEO at Avalon Advanced Materials Inc.

Zirconium is a relatively obscure but important element that is finding increasing application in a range of new technologies. It is most commonly found in zircon ($ZrSiO_4$), an industrial mineral used directly in many high-temperature applications. Zirconium in its many forms is now an essential part of cell phones, nuclear plants, dialysis machines, paint, ceramics and catalytic converters.

Zirconium was discovered in 1789 but it took 35 years to isolate the element. It took another 100 years before a pure zirconium metal was produced. With a high specific gravity, zircon is commonly found with other heavy minerals in deposits of prehistoric beach sands. It is usually a byproduct of mining these sands for titanium. Heavy mineral sand resources are found in several parts of the world with much of the historical production coming from South Africa and Australia. There is another rarer zirconium ore mineral called baddeleyite (Zr02) presently only recovered from an iron ore mine in Russia. As with many technology metals, the challenge of zirconium is in the economic processing of the mineral concentrates, not in mining the resource. Much of this processing is currently being done in China.

The ceramic pigment market was the main early driver for the development and production of zirconium chemicals of various types. After World War II, the ceramic/refractory industry became interested in zircon and zirconium oxide while the Department of Defense focused on the pure metal of zirconium. The driver behind the need to produce a pure zirconium metal on an industrial scale was to supply the military with alloys of magnesium and zirconium. The second major military market development for pure zirconium metal was for cladding fuel rods for both the nuclear navy reactor as well as for civilian nuclear power stations.

There are at least three things that use zirconium in this photo – the ceramic mug, the cellphone and the wall paint.

Today some of the many applications for different zirconium compounds include kidney dialysis, coated paper (frozen food packaging), pigment coating (Ti02), paint driers, and thixotropic paints (paints that are free-flowing and easy to apply while being brushed on, but quickly reset into a gel). As industry has gained a better understanding of the chemistry, it has been able to move into the growing market of advanced ceramic/oxide applications. Some applications of zirconium ceramics are piezo electrics (spark ignitors, sonar devices, and ultrasonics), thermal barrier coatings (turbine blades), solid electrolytes (oxygen sensors, fuel cells), and catalysts (cracking of petroleum, catalytic convertors).

Demand for zirconium and the appeal of producers will continue to grow, and because of its unique physical and chemical properties it will find application in many new growth technologies, including more efficient and environmentally-friendly clean technologies. It won’t take long before its critical importance is appreciated.