EDISON

Niobium

The envy of the gods

Metals & mining

The growing recognition of niobium as a vital new-age metal with limited supply was reflected in Anglo American's recent sale of Catalão. The auction process was keenly competitive and resulted in Anglo selling Catalão for US$1.5bn, c 50% more than previous market forecasts. Two years earlier, in 2014, Magris Resources (owned 50% each by Cheung Kong and the Canadian Imperial Bank of Commerce) and Temasek acquired Niobec from IAMGOLD for c US$500m and, in 2011, Posco and Nippon jointly invested c US$2.0bn for a 15% interest in CBMM, followed by a Chinese consortium comprising CITIC, Baosteel and Shougang on similar terms, shortly afterwards.

Supply and demand

Niobium resources and production are concentrated in Brazil, which accounts for 92% of the world's supply, the majority of which (c 85%) is controlled by one company, CBMM. Niobium's principal use (c 89% of the market) is as a microalloy for high-strength low-alloy (HSLA) steels. In addition, its superconductivity also renders it important for high-power magnets, while its uniquely low thermal neutron capture cross-section makes it ideal for use in the nuclear industry. While, currently, about 10% of the steel produced globally contains niobium, that share is expected to rise to as much as 20% in the foreseeable future. Currently, the overall unit consumption of ferro-niobium in steel is around 51g/t of steel produced globally. In the most highly developed countries, however, this figure averages 100g/t, whereas in China and India it is c 20g/t. Significantly, the current intensity of use of ferro-niobium in China, in particular, is below trend given its GDP per head (see pages 10-11). Notwithstanding the current uncertainty in the global economy, in the longer term demand for HSLA steels will almost inevitably return to long-term growth, driven by the need to achieve weight reduction in both the automobile and construction sectors in particular. In addition, stainless steel could become a significant growth market in the event that continuing volatility in the nickel price results in a large-scale switch from austenitic to ferritic grades of stainless steel.

Pricing

Key characteristics of the niobium market are the important role played by bilateral, long-term contracts between buyers and sellers, which cover c 95% of total sales and have led to a highly stable pricing environment. As a result, while the rate of price increases slowed at the height of the global financial crisis in 2009, they did not reverse, but instead reached a peak in 2012-13, before moderating slightly in 2015. However, the price declines have been confined to a reasonable range by tight supply inter alia. While the narrow supply base could give the impression that the price rise from 2005 to 2013 was a consequence of price gouging by producers, a more likely explanation is that it represented a one-off adjustment to a persistently low prior pricing environment. Nevertheless, even at current prices, niobium inputs constitute only a very small portion of steelmaking input costs (eg c US$2.00 per tonne of steel produced), with the result that ferro-niobium prices, in particular, are expected to remain at approximately the same levels in the foreseeable future as in late 2008 and early 2009 (c US$35.16/kg) and will display only very limited volatility (cf an average import price in excess of US$41/kg in the period 2010-15).

11 August 2016

Companies in this report

Producers
Companhia Brasileira de Metalurgia e Mineração (CBMM)
Mineração Catalão
China Molybdenum
Magris Resources

Former producers
Anglo American
IAMGOLD

Developing producers
Cradle Resources
Alkane Resources

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This report was produced coincidentally with Edison's initiation report on Cradle Resources and the two reports should be read in conjunction with one another.

Niobium – Titanic by nature

History

Niobium, formerly columbium, is a transition metal in the vanadium family (Group 5, according to the new IUPAC system of classifying elements) with symbol Nb, located between vanadium (above) and tantalum (below). It was first named columbium (Cb) by the English chemist Charles Hatchett in 1801. Owing to its close chemical similarity with tantalum, however, the two were often confused, with many eminent chemists at the time claiming that they were the same element. In 1846, the German chemist Heinrich Rose recognised that tantalum ores also contained another metal, which he then named niobium (Niobe being the daughter of Tantalus in Greek mythology – worth a read). In 1864/5, it was demonstrated that columbium and niobium were one and the same element and for the next 84 years, the two names were used interchangeably – albeit columbium was more common in the United States, while niobium was more common in Europe. In order to standardise usage, niobium was adopted as the official name of the element in 1949, although the name columbium remains in use in the United States (eg coltan – see below). NB Adoption of the European name was a compromise in return for accepting the name tungsten instead of wolfram for element 74 in deference to North American usage.

Characteristics

Niobium is virtually identical in size to, and therefore has very similar chemical properties to, tantalum. Pure niobium is a comparatively soft and ductile metal, but impurities make it harder. Despite having a high melting point (2,468°C), it has a low density in comparison to other refractory metals. It is also corrosion-resistant, although not as corrosion-resistant as tantalum. In 1961, scientists at Bell Labs discovered that niobium-tin exhibits superconductivity at cryogenic temperatures, making it one of only three elemental Type II superconductors, along with vanadium and technetium (which, to all intents and purposes, does not exist in nature). Notably, at atmospheric pressure, it has the highest critical temperature of the elemental superconductors. Otherwise, it has the largest magnetic penetration depth of any element; it also has a low capture cross-section for thermal neutrons.

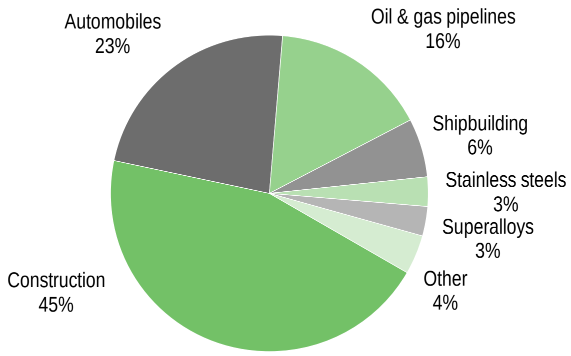
Manufacture and production

Niobium metal is produced by the aluminothermic reduction of high purity niobium oxide with aluminium, lime and fluorspar. Note that, once purified, the sensitivity of niobium to oxygen requires it to be processed in a vacuum or inert atmosphere, using techniques such as vacuum arc remelting (VAR) and electron beam melting (EBM), which significantly increases the cost and difficulty of production. Ferro-niobium is produced by the aluminothermic reduction of pyrochlore/columbite concentrates in the presence of iron oxide (hematite) to produce c 66% Fe-Nb matte.

Applications

Niobium's first use was as filaments in incandescent lamps, although it was quickly rendered obsolete by tungsten, which has a higher melting point. In the 1920s, however, it was discovered that niobium improves the strength of steel, and this application remains its predominant use, with c 89% of the market for niobium accounted for by ferro-niobium. Nevertheless, its superconductivity also renders it important for high-power magnets (as used in particle accelerators and particle detectors etc). Despite its lower corrosion resistance than tantalum, its lower price and greater abundance make it attractive for less demanding applications requiring this characteristic (eg linings in chemical plants). Its uniquely low thermal neutron capture cross-section makes it important for use in the nuclear industry.

Exhibit 1: Niobium use, by application (%)



Source: pallisadeglobal.com, palisade-research.com, NioCorp

Steel

In general, the properties of steel are a function of its chemical composition (especially with respect to carbon, manganese, phosphorus, silicon, alloying and microalloying elements) and processing conditions. In general terms, the easiest way to increase the strength of steel is to increase its carbon content. However, this adversely affects other desirable properties such as weldability, toughness and formability. Niobium has a high affinity for carbon, forming carbides and carbonitrides and it is often therefore added to steel and stainless steel in the form of ferro-niobium in order to maintain a balanced package of (secondary) properties, the carbon and niobium levels being carefully matched with processing conditions to achieve the desired properties. The result, known as microalloyed steel product, typically contains around 0.1% Nb by weight, often in conjunction with titanium and vanadium.

A number of factors influence the choice of steel composition. In low carbon, high strength low alloy (HSLA) steels (<0.1% carbon, by weight), for example, niobium is a more effective strengthening element than vanadium or titanium. As a result, HSLA steels with a niobium content up to 0.1% (by weight) are intensively used in both the automobile and pipeline manufacturing industries and widely used in the civil construction industry. NB Most modern HSLA steels fall into this 'low carbon' category. However, there are some circumstances in which it is acceptable to use vanadium and/or titanium. For example, cheaper titanium is used in much interstitial-free (IF) steel for 'unexposed' automobile parts, where a poorer surface quality is not important. NB These steels are described as interstitial free because interstitial elements (carbon and nitrogen) are fixed by the niobium and titanium. However, the best results are usually achieved with a combination of microalloys that exploit synergistic benefits. An example of this is the use of niobium and titanium together in 'exposed' interstitial-free steel automobile parts where the superior surface quality that results is important (NB synergy is much more significant for Nb-Ti than for Nb-V).

Civil construction

High-strength niobium microalloyed plate products are used in the construction of bridges (eg the Millau Valley bridge in France used 0.025% [ie 250g per tonne] Nb steel to reduce the necessary construction materials by up to 60%), viaducts, high-rise buildings etc. Heavy machinery, pressure vessels, etc, also represent additional applications of microalloyed plates. Structural sections (eg angles, beams, etc) are widely used in civil construction, railway wagons, transmission towers, etc, where niobium competes with vanadium. Similarly, steel reinforcing bar is used in large concrete structures to increase their resistance to tensile loads. Larger diameter high strength grades are produced via the addition of niobium and/or vanadium, although some modern steel mills also use water cooling, which negates the need for microalloying. Finally, niobium has also found application in high strength and wear resistant rails for railway tracks operating under high axle loads. An important producer in this respect is Nippon Steel.

Automotive

The major use of cold rolled strip is in the production of thin gauge car outer body panels. In this case, niobium is used as a strengthening element.

The application of cold rolled high strength microalloyed strip gained importance after the first oil crisis in 1973, when car manufacturers, especially in the US, needed to reduce car weight to save fuel consumption. Until the early 1980s, microalloying was only applied in the high strength grades, with somewhat limited formability. Since then, however, it has become feasible to produce interstitial free steels with extra low carbon content (less than 0.005% by weight), with excellent formability. The use of niobium and titanium as microalloys in interstitial free steel, in particular, has made possible the production of large integrated sheet panels on modern continuous annealing lines, and has thereby contributed to a reduction in the number of welds and parts and a consequent reduction in the weight of the part (akin to the German ‘pocket’ battleship innovation of the 1930s). Although developed in the US in the late 1960s, mass production on a large scale only began in Japan in the early 1980s. In the meantime, hot rolled strip (thickness 2-20mm) is used in the production of truck frames and wheels. Other uses of niobium microalloyed hot strip steel include crane booms, railway wagons, containers and off-road construction vehicles.

Engineering bar can also benefit from microalloying as it removes the need for relatively expensive quenching and tempering heat treatments and thereby reduces processing costs. Engineering bar is widely used in the production of forged components for the automobile industry (eg, crankshafts, connecting rods, etc).

Similarly, wire rod, used to produce nuts, bolts, fasteners, springs, etc, has found an application in some high strength fasteners used in the automobile industry, where microalloying technology allows the elimination of intermediate processing (spheroidize annealing), quenching and tempering of the final part. Niobium, with vanadium, has also become a common additive in spring steels – the higher strength gained from microalloying allowing weight reduction in the finished part.

More than 30 major steel companies around the world are engaged in a project to develop the Ultra Light Steel Autobody (ULSAB). Porsche has built a demonstration prototype and, if this project comes to fruition, a large percentage of steels used will contain niobium.

Pipelines

Large diameter linepipe for the transmission of oil and gas is the most important item produced from steel plate.

Gas transmission linepipe requires a high level of strength to contain the high-pressure gas as well as acceptable toughness to prevent the propagation of a long fracture in the event of damage (this is especially important for ‘rich’ gas). Good weldability is also needed for easy fabrication, so the addition of niobium is effectively mandatory for producing linepipe steel. In addition, the plate hot rolling process must be specially optimised to maximise strength and toughness and minimise costs. Japanese plants achieve this using high power rolling mills and/or water spray quenching techniques to minimise the addition of niobium and other alloying elements. By contrast, in the US, less severe rolling regimes result in a greater reliance on niobium for strengthening and toughening rather than on the application of special rolling techniques. European plate producers use both techniques.

Similarly, hot rolled strip, produced in a continuous strip mill, is used for the fabrication of spirally welded (ERW – longitudinal electric resistance weld), smaller diameter (eg <550mm) pipes.

Shipbuilding

Plate for shipbuilding and offshore platforms constitutes another important application for niobium microalloys and many of the companies that produce plate for linepipe also produce ship-plate. In this application, plate in excess of 50mm thickness is common.

Stainless and heat resistant steels

Ferritic (nickel free) stainless steels can account for up to 10% of the world's consumption of niobium, the major application being in car exhaust systems, where the use of stainless steel (which has replaced carbon steel) is a consequence of higher working temperatures, the introduction of catalytic converters and the guarantee of a longer life for the component.

Centrifugally cast, heat resistant steels are also used in the petrochemical and power industries.

Other

Long products (eg bars, sections or wire rod) are produced in mini mills and can also be produced in higher strength grades using niobium.

Superalloys

Appreciable amounts of niobium (either in its pure form or in the form of high-purity ferro-niobium and nickel niobium) are used in nickel-, cobalt-, and iron-based superalloys used in the manufacture of jet engine components, gas turbines, rocket subassemblies, turbo charger systems, and heat resistant and combustion equipment. It therefore has widespread applications in the space industry. Typically, alloys such as these contain up to 6.5% niobium. In the alloy used for liquid rocket thruster nozzles, such as in the main engine of the Apollo Lunar Modules, however (known as niobium alloy C-103, the 103rd experimental composition that had the best combination of formability and high-temperature properties of the C-series alloys), the niobium content is 89%, with hafnium (10%) and titanium (1%) making up the balance. Another alloy is Inconel 718, which contains approximately 5% niobium and is used in advanced air frame systems.

Superconducting magnets

Niobium-germanium, niobium-tin and niobium-titanium alloys are used as a type II superconductor wire for superconducting magnets used in applications such as nuclear magnetic resonance imaging (as used in MRI scanners by the healthcare industry) as well as particle accelerators. The Large Hadron Collider, for example, uses 600t of superconducting strands, while the International Thermonuclear Experimental Reactor is estimated to use 600t of niobium-tin strands and 250t of niobium-titanium strands. By contrast, pure niobium is used in the 30km linear particle accelerator of the International Linear Collider and at Fermilab.

Materials with temperature-dependent electrical resistance are used in the manufacture of bolometers, which measure the power of incident electromagnetic radiation. The high sensitivity of superconducting niobium nitride bolometers, in particular, make them ideal detectors for electromagnetic radiation in the THz frequency band and have been used at the Heinrich Hertz Submillimeter Telescope, the South Pole Telescope, the Receiver Lab Telescope, APEX and the HIFI instrument on board the Herschel Space Observatory (among others).

Electronics

Lithium niobate and lithium tantalite are chemical compounds with unique optical, piezoelectric and pyroelectric properties. As a result, they are ideal for use in the manufacture of electronic components, such as capacitors, surface acoustic wave filters (employed in mobile telephones), motion detectors, laser switching devices (employed in range finding equipment) and circuit boards for cell phones, laptops, games consoles, etc, as well as touchscreen technologies.

Other uses

Electroceramics

Lithium niobate, which is ferroelectric, is used extensively in mobile telephones and optical modulators and niobium capacitors are available as an alternative to tantalum capacitors.

Niobium is also added to glass in order to attain a higher refractive index – a property of use to the optical industry in making thinner corrective glasses.

Hypoallergenic applications

Niobium and some niobium alloys are physiologically inert and thus hypoallergenic. For this reason, niobium is found in many medical devices such as pacemakers. Niobium treated with sodium hydroxide forms a porous layer that aids osseointegration (the connection between living bone and the surface of a load-bearing artificial implant).

Jewellery

Along with titanium, tantalum, and aluminium, niobium can be electrically heated and anodized, resulting in a wide array of colours (eg blue, green, brown, purple, violet and yellow) as a result of the diffraction of light by a thin oxide layer. The fact that niobium is hypoallergenic is also variously beneficial for its use as jewellery (eg body piercings).

Numismatics

Niobium is used as a precious metal in commemorative coins, often in combination with silver and/or gold. For example, Austria produced a series of silver niobium euro coins in 2003, and in 2011 the Royal Canadian Mint started production of a C$5 sterling silver and niobium coin named Hunter's Moon in which the niobium was selectively oxidized, thus creating unique finishes where no two coins are alike.

Other

Other applications of niobium metal and its alloys include:

- Platinized niobium anode wires for the cathodic (corrosion) protection of large offshore platforms, reinforced concrete structures and some water tanks
- Pure niobium foil used in the production of synthetic diamonds
- Niobium carbide is a heavy, brown-grey metallic powder containing c 87% niobium. It is an extremely hard (8.5-9.0 Mohs), refractory ceramic substance that is often used in high stress, high temperature operations. Carbide coatings, in particular, increase strength and improve wear-resistance, increasing the life of tool cutting edges. Added to tungsten carbide (in the form TaNbC and/or WTiTaNbC), it is used in the manufacture of industrial, high speed cutting tools, teeth for excavator buckets and drill bits for the mining industry. Carbides are formed by sintering a mixture of finely ground niobium powder with an excess of carbon and heating to around 1,800°C. It is also used as a refractory coating in nuclear reactors and furnaces.
- Niobium-titanium non-sparking components used by mining companies (especially gold mining operations)
- Niobium metal for sputtering targets used in the architectural glass industry, for razor blades and in the electronic industry
- Niobium-titanium alloys recently developed for use in surgical implants.

The arc-tube seals of high-pressure sodium vapour lamps are made from niobium (or niobium with 1% zirconium), because niobium has a very similar coefficient of thermal expansion to the sintered alumina arc tube ceramic. It is also used in arc welding rods for some stabilised grades of stainless steel.

Distribution

Niobium is estimated to be the 34th most common element in the Earth's crust (cf its atomic number of 41), with a relatively low abundance of eight parts per million. The free element is not found in nature. Minerals that contain niobium include pyrochlore (a niobate and the main commercial source for niobium), columbite and columbite–tantalite (coltan). Compared to other metallic elements, such as the light rare earths, niobium is rather depleted, which can be attributed to the fact that much of the continental crust was formed at convergent margins above subduction zones and that magmas formed in this zone are typically depleted in both niobium and tantalum.

Mineral deposits containing niobium are commonly associated with igneous rocks, including granites, pegmatites, syenites and carbonatites. Secondary deposits are invariably found located in close association with their primary sources.

Primary deposits can be divided into three main types:

- Carbonatites and associated rocks,
- Alkaline to peralkaline granites and syenites (although there are no niobium mines operating in alkaline granite and syenite complexes), and
- Granites and pegmatites of the LCT family (eg coltan).

Whereas the columbite-tantalite mineral group is the most common group of niobium-bearing minerals, the enrichment of tantalum is greater than that of niobium, with the result that pyrochlore is the more significant economic source of niobium.

Exhibit 2: Pyrochlore and col-tan mineral characteristics

Mineral name	Mineral group	Formula	Nb_2O_5 content range (%)
Pyrochlore	Pyrochlore	$(Na,Ca)_2Nb_2O_6(O,OH,F)$	25-76
Columbite	Columbite-tantalite (coltan)	$(Fe,Mn)(Nb,Ta)_2O_6$	25-79

Source: BGS

Carbonatites and associated

Carbonatites are igneous rocks that comprise more than 50% primary carbonate minerals. They are almost exclusively found in areas of continental extension and rifting and their source magmas are thought to be derived directly from the mantle with very little crustal influence. Carbonatites are most commonly found as dykes, sills or small plugs. They rarely occur in isolation and are commonly associated with alkaline silicate rocks, igneous rocks or mafic to ultramafic alkaline rocks. Many carbonatite bodies are surrounded by a metasomatised or 'fenitised' zone that is typically rich in sodium and/or potassium, formed through alteration of the country rocks by fluids derived from the carbonatite. Carbonatites are typically enriched in a range of elements, including niobium, which is preferentially enriched over tantalum in carbon dioxide-rich melts. Common niobium-bearing minerals found in carbonatites include members of the pyrochlore and perovskite mineral groups, as well as niobium-rich silicates, such as titanite. In general, the bulk rock niobium content of carbonatite bodies is moderately high (eg up to 1.0%). However, niobium-bearing minerals such as pyrochlore may then be concentrated by magmatic differentiation processes, such as crystal settling. Weathering processes may also concentrate these minerals in the shallow subsurface. Late-stage veins and areas of metasomatism, formed through carbohydrothermal activity, are then a third potential sources of niobium mineralisation.

The two largest deposits of pyrochlore were found in the 1950s in Brazil and Canada, and both countries are still the major producers of niobium mineral concentrates. In Brazil, the main niobium deposits occur in alkaline ultramafic-carbonatite complexes of the Late Cretaceous Alto Paranaiba province, intruded into Neoproterozoic, metasedimentary rocks. The largest deposit is hosted within a carbonatite intrusion at Araxá, Minas Gerais Brazil, owned by CBMM (Companhia Brasileira de Metalurgia e Mineração). The central part of the intrusion has been weathered under tropical conditions to form a thick (>200m), lateritic cover in which pyrochlore has become concentrated at a reported mean grade of 2.5% Nb_2O_5, which is then exploited by open pit mining (ie it is a lateritic regolith above a carbonatite intrusion). The other deposit is located in Goiás and owned by China Molybdenum (formerly Anglo American, via its subsidiary Mineração Catalão). While it is also hosted within a carbonatite intrusion, the Catalão deposit is unusual in that it is hosted in intrusions comprising carbonatite- and phoscorite-series rocks with no associated syenites. As at Araxá, the mined deposit is in the weathered lateritic zone above the centre of the complex. The mine comprises three open pits and a processing facility. Together, these two Brazilian mines produce around 92% of official world supply.

The third largest producer of niobium is the Niobec Mine in the southern region of the Saint-Honoré carbonatite complex in Quebec, which is owned by Magris Resources (formerly IAMGOLD) and produces around 7% of world supply. Again, pyrochlore is the main niobium mineral in the complex. It is disseminated throughout the carbonatite, but is particularly abundant in mineralised lenses that are 50-150m wide, up to c 750m long and at depths of over 100m, with grades of 0.44-0.51% Nb_2O_5 (hence Niobec is the only underground niobium mine in the world).

Exhibit 3: Principle niobium deposit types and characteristics

Deposit type	Description	Typical grade & tonnage	Examples
Carbonatite-hosted primary deposit	Niobium deposits found within carbonatitic igneous rocks in alkaline igneous provinces.	Niobec: 23.5Mt of proven & probable reserves at 0.59% Nb_2O_5.	Niobec, Canada.
Carbonatite-sourced secondary deposits	Zones of intense weathering or sedimentary successions above carbonatite intrusions in which niobium ore minerals are concentrated.	>1,000Mt at 0.1-1.0% Nb_2O_5 in lateritic deposits. Up to 12% Nb_2O_5 at Tomtor in Siberia (tonnage unknown).	Araxá and Catalão, Brazil; Tomtor, Siberia; Lueshe, Congo (DR).

Source: British Geological Survey

Granites and pegmatites of the LCT family

Columbite-tantalite (coltan)

Columbite-tantalite minerals are most usually found as accessory minerals in pegmatite intrusions, and in alkaline intrusive rocks. An example of this type of mineralisation is a zone of Neoproterozoic-age tantalum-mineralised pegmatites that cuts through the Mesoproterozoic Kibaran belt which extends through Burundi, Rwanda and the Democratic Republic of the Congo (DRC). In the DRC in particular, small-scale, unregulated mining of columbite-tantalite minerals occurs on deeply weathered pegmatites and from secondary placer deposits derived from the pegmatites in Katanga, Maniema, North Kivu, Orientale and South Kivu.

Supply

Official

Over 93% of official, global niobium resources occur in Brazil, with the balance being in Canada. Numerous other carbonatite-hosted niobium deposits are known across the world, the most significant being the Tomtor deposit in Siberia and the Morro dos Seis Lagos deposit also in Brazil. Other countries with unquantified niobium resources include Egypt, Malawi and Greenland.

As with its resources, niobium production is concentrated in Brazil, which accounts for 92% of the world's supply, the majority of which (c 85%) is controlled by one company, CBMM. The balance of the world's supply is produced in Canada (8%). As a result, Brazil is also the world's leading producer of ferro-niobium (containing 60-70% niobium). Nevertheless, there are also a number of developing producers around the world, including Cradle Resources' Panda Hill project in Tanzania and Alkane Resources' Dubbo Zirconium Project (DZP) in New South Wales.

From 1995 until 2011, the USGS estimates that global output of ferro-niobium increased at an average compound growth rate of 8.2% per year, before stabilising in 2012. Resources available to support existing production from official sources are as follows:

Exhibit 4: Resources available to support current supply

Entity	Ore type/category	Tonnage (Mt)	Grade (%)	Contained Nb_2O_5 (Mt)	Capacity (tpa)	Years of capacity	Comments
CBMM	Weathered ore	440	2.75	12.1	110,000	110	2017 expansion to 150ktpa planned
	Fresh ore	700	1.5	10.5	110,000	95	
Niobec	Measured & indicated	636	0.42	2.7	8,300	322	No plans for expansion
	Inferred	84	0.31	0.3	8,300	31	
Goiás	Measured & indicated	31.1	0.97	0.3	10,000	30	Expansion recently completed
	Inferred	53	1.12	0.6	10,000	59	
	Tailings	14.5	0.69	0.1	10,000	10	
Total		1,958.6	1.35	26.5	128,300	207	

Source: Company sources, MDN, Edison Investment Research

Unregulated

While probably only accounting for less than 1% of global supply and a relatively greater source of tantalum than niobium, coltan nevertheless accounts for the majority of global trade in niobium concentrates and is the main source of supply for the non-steel processing sector. In the DRC, in particular, small-scale mining of coltan, from either alluvial or pegmatite sources, is labour intensive and unregulated and it is estimated that rebel groups in the DRC made in excess of US$1bn through trade in conflict minerals in 2009. As a result, illegally traded coltan may be shipped to Asia for processing, after which it is effectively impossible to determine the source of the original ore. From there, the processed material may then be shipped to the Western World for use in electrical components, before being shipped back to Asia for inclusion in electronic goods such as mobile phones and laptop computers. While many large electronics companies are refusing to use conflict minerals in their components, because they are indistinguishable beyond the processing stage (and the fact that the success of these schemes also depends upon the ability of the DRC to police its exports effectively), it is likely to prove difficult to completely avoid the use of these materials in finished consumer goods.

Recycling

Niobium can be recovered from waste metals and scrap, which accounts for up to 20% of total supply.

Substitution

Niobium is difficult to substitute. Specifically in instances in which strength at high temperature is required, metals such as molybdenum and vanadium may be substituted. As alloying elements in stainless and high-strength steels, tantalum and titanium may be used. In ceramics, molybdenum and tantalum may be used and tungsten in high-temperature applications. In general, however, substitutes tend to be more expensive and/or to entail performance deficiencies.

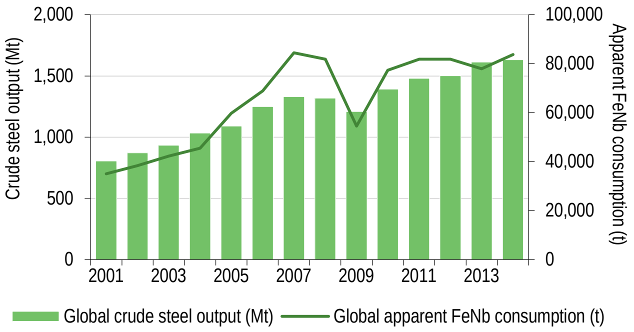
Demand

Since 2001, global apparent ferro-niobium demand has increased at a compound average growth rate of 6.9% per year, notwithstanding a material contraction at the time of the global financial crisis in 2009. While, currently, about 10% of the steel produced globally contains niobium, that share is expected to rise to as much as 20% in future.

By application

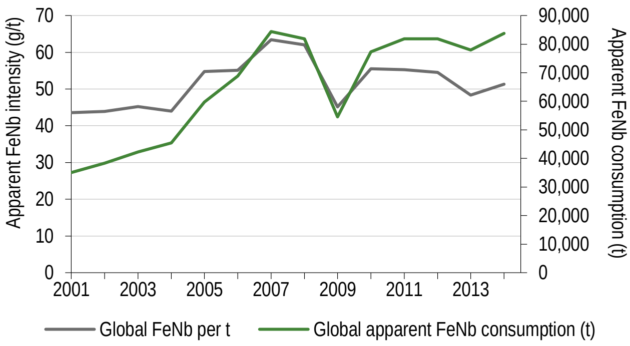
Unsurprisingly, given its application as a steel strengthening agent, global apparent ferro-niobium demand is closely correlated with both crude steel output and the intensity of ferro-niobium use in steelmaking, although the correlation is statistically closer for the former than the latter.

Exhibit 5: Global apparent FeNb consumption (t) vs global crude steel output (Mtpa)



Source: MDN, Worldsteel Association, Camet, Edison Investment Research

Exhibit 6: Global apparent FeNb consumption (t) vs apparent FeNb intensity (g/t steel)



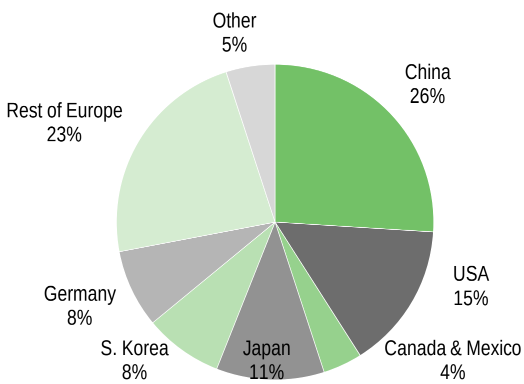
Source: MDN, Worldsteel Association, Camet, Edison Investment Research

Notwithstanding the current uncertainty in the global economy, in the longer term, demand for HSLA steels will almost inevitably return to long-term growth (at the expense of mild steels), driven by the need to achieve weight reduction in both the automobile and construction sectors in particular. In addition, ferritic (nickel-free) stainless steel – as used in car exhaust systems – could become a significant growth market for niobium in the event that continuing volatility in the nickel price results in an eventual large-scale and permanent switch from austenitic to ferritic stainless grades of steel. Finally, demand for natural gas linepipe will continue to be supported by global demand for energy, with the possibility that the supply disruptions that have been experienced in Europe in recent years could result in the construction of entirely new transmission networks in the future.

By geography

As with most other metals, the major industrial nations represent the largest market for ferro-niobium (and therefore, by extension, niobium), with the exception of China, which is the world's largest consumer.

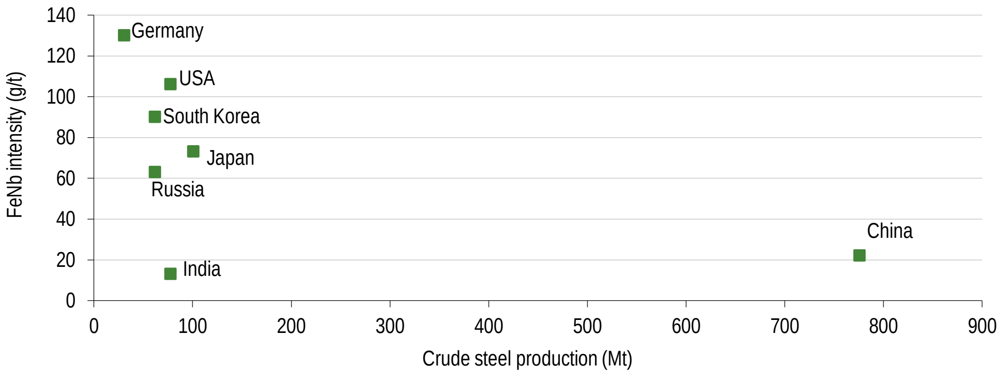
Exhibit 7: Global ferro-niobium consumption, by country



Source: Cradle Resources, Roskill, Edison Investment Research

In 2014 the overall unit consumption of ferro-niobium in steel was around 51g/t of steel produced. In the most highly developed countries, however, this figure averages 100g/t, whereas in China and India, for example, it is below 20g/t (simple average); see Exhibit 8.

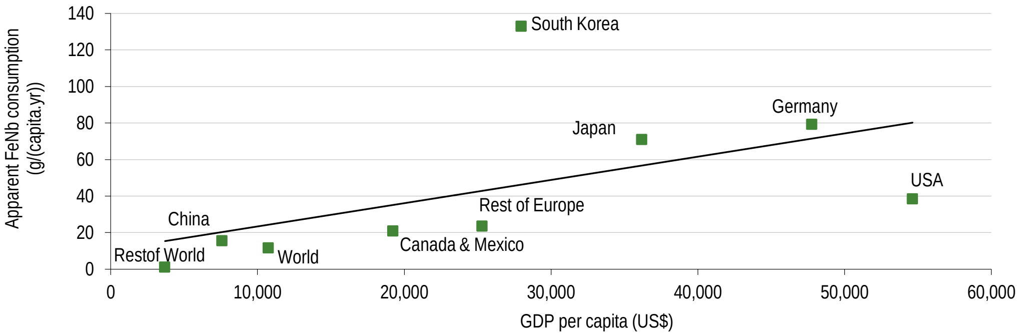
Exhibit 8: FeNb intensity of use (g/t) vs crude steel production, by country



Source: Cradle Resources, Camet, Roskill, Edison Investment Research

However, there is also a perceived relationship between a nation's GDP per head and its intensity of FeNb use (in grams per capita per year), the logical extrapolation of which clearly implies greater unit FeNb consumption with wealth (see Exhibit 9, below).

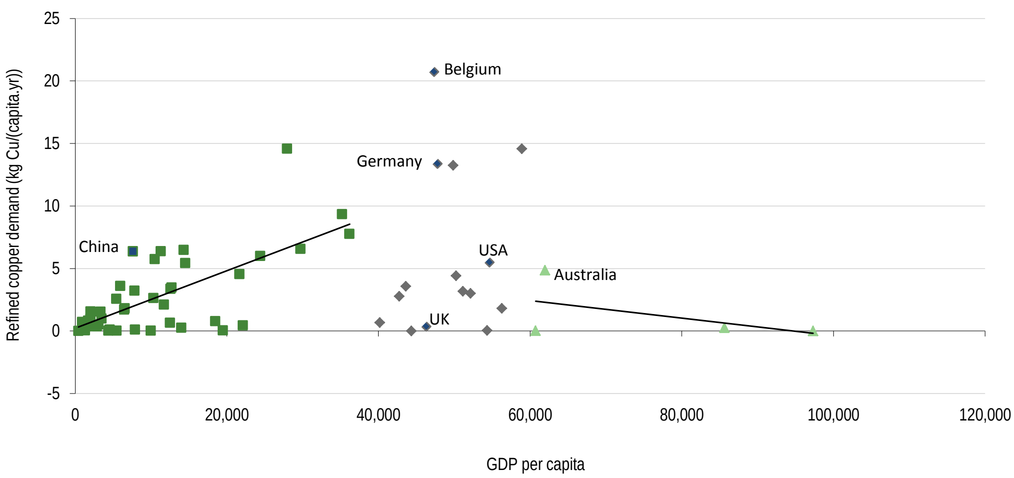
Exhibit 9: Apparent FeNb consumption per capita per year vs GDP per capita, selected countries



Source: Edison Investment Research, Camet, Cradle Resources

Moreover, in the case of ferro-niobium (and therefore, by extension, niobium), the current intensity of use in China, in particular, is below trend given its GDP per head, whereas for other metals (eg copper, see below) it is typically well above trend.

Exhibit 10: Global refined copper demand (kg per capita per year) vs GDP per capita



Source: International Copper Study Group, World Bank, Edison Investment Research

Given that China's unit consumption of copper (6.38kg per capita per year) is more than one error of estimation (2.37kg per capita per year) from its predicted level (1.96kg per capita per year) given its GDP per capita, there must be justifiable uncertainty as to whether and to what extent any increase in its GDP per capita will translate into growth in copper demand. Statistically, China's GDP per capita would have to increase to US$26,929 per year before it can justify its existing demand for copper. For ferro-niobium, by contrast, any growth in GDP per capita could reasonably be expected to translate into an increase in the intensity of FeNb usage (and, by extension, aggregate FeNb demand in China). For this (and a number of other reasons) ferro-niobium intensity in HSLA steel is expected to grow from current levels to as much as 65g/t in 2020.

Strategic significance

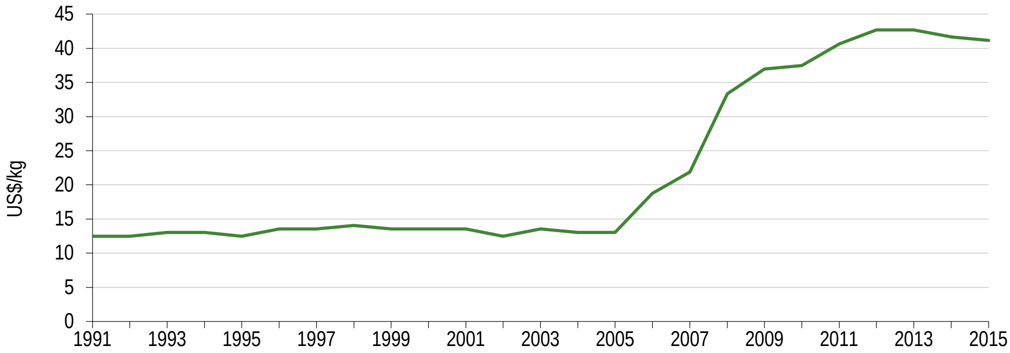
Niobium is considered "strategic" by the US and essential for national security and industry. Nevertheless, in 2008, the Defense National Stockpile Center (DNSC) announced that the US's stockpile of niobium had been depleted and that further sales from stockpile would be discontinued (NB before that time, sales from the stockpile were described as "significant"). In 2015, the Defense Logistics Agency Strategic Materials announced a 2015-18 maximum acquisition limit of 104.5t for ferro-niobium.

Similarly, the European Commission (EC) has identified niobium as a "critical" raw material, which means that the EC considers there to be a potential risk of supply shortage with an associated impact on the EU economy.

Pricing

Niobium materials are not openly traded on any metal exchange. Key characteristics of the niobium market therefore are the important role played by bilateral contracts between buyers and sellers, which now cover about 95% of total sales. Under these, FeNb is sold directly to steelmakers, with prices typically fixed for the year, bi-yearly or on a quarterly basis, which has led to a highly stable pricing environment.. Nevertheless, even at current prices, niobium inputs constitute only a very small portion of steelmaking input costs (eg circa US$2.00 per tonne of steel produced). Hence, between 1991 and 2005, the average export price for Brazilian ferro-niobium remained (almost exclusively) within the range of US$12.5-13.5/kg contained Nb. That changed in 2006. Average import prices for ferro-niobium reported by major importing countries in 2008 were more than double those achieved in 2005, despite CBMM doubling its niobium production capacity over the same period. In the case of Japan, the average price rose from about US$9.0/kg (gross weight) to over US$22.0/kg. What is more, while the rate of price increases slowed at the height of the global financial crisis in 2009, they did not reverse (indicating price inelasticity to demand), but instead reached a peak in 2012-13, before moderating very slightly in 2015.

Exhibit 11: Ferro-niobium price, 1991-2015 (US$/kg)



Source: Cradle Resources, Global Trade Atlas

While the narrow supply base could give the impression that the price rise from 2005 to 2013 was a consequence of price gouging by producers, a more likely explanation is that it represented a one-off adjustment to a persistently low prior pricing environment. In real terms, niobium prices had been falling for years, at the same time as demand was increasing and producers were expanding capacity. As a result, a structural adjustment to the benchmark price became inevitable.

In the meantime, the current weakness in the pricing environment for niobium can be attributed to weakness in global GDP growth and tepid demand from the electronic product industry, coupled with increasing inventories of niobium oxide in particular. However, the price declines have been confined to a reasonable range by tight supply and the rising environmental cost (among other things) of new plants. As a result, the requirement for access to high-quality ores has become more important to consumers in sourcing raw materials.

In conclusion, therefore, we (conservatively) expect niobium prices (and particularly ferro-niobium prices) to remain at approximately the same level as in late 2008 and early 2009 (c US$35.16/kg) and to display little volatility in the coming years (cf an average import price in excess of US$41/kg in the period 2010-15).

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