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HALLGARTEN & COMPANY

Sector Review

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Rare Earths Review

Erbium:

The Secret Sauce in 5G Networks?

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The Secret Sauce in 5G Networks?

- + The rapid changes in mobile phone technology has brought 5G technologies to the forefront of political debate
- + 5G has become a red-hot political issue with the US resisting the putative dominance of Huawei in the space and other governments around the world pushing back against this dominance
- + Erbium is a crucial component in 5G technologies due to the role of Erbium-doped fibre as the plumbing of these new networks
- + This development propels Erbium from one of the more obscure Heavy Rare Earths into the forefront of a geopolitical tussle
- + China is facing an increasing shortage of Heavy Rare Earths, as is the West
- + Potential supply is constrained by tight financing having choked off development of new projects
- + The Rare Earth universe is stable without much prospect of new interlopers
- ✖ Erbium price movements and stockpiled materials remain essentially at the discretion of the Chinese
- ✖ Financing of projects remains very difficult and almost inevitably requires a committed offtaker

Erbium is the Word

In the beginning there were Rare Earths and they were confusing and somewhat monolithic. Rumour had it that they were in short supply and that they were all at the cutting edge of technology and also totally at the whim of the Chinese. That was 2009-12 and this is 2019. Times have changed. Pundits have become more informed even if investors have not. It is now realised that lanthanum and Cerium were massively overvalued during the REE boom of 2009-12 and yet some of the other Rare Earths may also have been overvalued but that there was intrinsic logic in them sustaining much higher values than had been seen in the long period of Chinese dominance from the 1970s to the early 2000s where loss-leading on price was the only consideration.

The prices of all Rare Earths plunged post-2011 but out of the primeval murk started to appear some sense. Those elements in the Lanthanide series linked to new technologies, whether they be EVs, alternative energy, or communications applications have started to be recognised and separated from the merely humdrum, like Lanthanum and Cerium.

Moreover it has become apparent that Chinese dominance of Heavy Rare Earths is waning faster than that in Light Rare Earths. Some chatter suggests that China is now a net importer of HREEs.

With 5G being a major buzzword in 2019 due to the tussle over the vulnerability of Western networks to Chinese military intervention if Huawei is adopted as the “cheap and cheerful” standard there has been little discussion of what makes up these networks and most particularly which metals and minerals are used in their fabrication.

Huawei may have lost the battle but China may end up winning the war unless the West gets itself its own sources of Erbium (Er), the hitherto obscure Rare Earth that is a key component in the fibre used in the newest networks.

In this review we shall look at Erbium, its uses, the vulnerability of the West and which wannabe Rar Earth miners might provide it going forward.

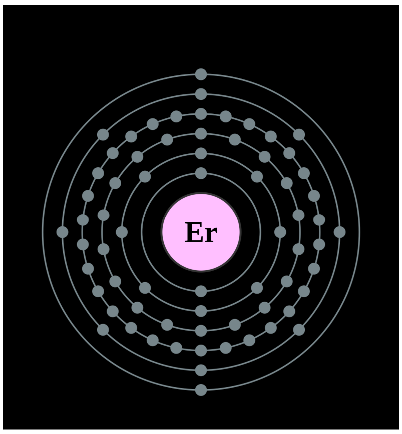
Some Background

The element Erbium was discovered by Carl Gustaf Mosander in 1843. He discovered that a sample of Gadolinite contained at least two metal oxides in addition to pure Yttria, which he named "Erbia" and "Terbia" after the village of Ytterby in Sweden where the Gadolinite had been found.

Fairly pure Er_2O_3 was independently isolated in 1905 by Georges Urbain and Charles James. Reasonably pure Erbium metal was not produced until 1934. It was only in the 1990s that the price for Chinese-derived Erbium oxide became low enough for Erbium to be considered for use as a colorant in art glass and other low-value applications.

Where to Find It

The concentration of Erbium in the Earth’s crust is about 2.8 mg/kg and in the sea water 0.9 ng/L. This concentration is enough to make Erbium about 45th in elemental abundance in the Earth's crust. So not scarce in absolute terms.



The principal commercial sources of Erbium are from the minerals Xenotime and Euxenite, and most recently, the ion adsorption clays of southern China. Due to its resources of the latter, China managed to become the principal global supplier of this element. However, it should be recalled that due to the rapacious exploitation of these resources and the associated environmental disaster, the clays are widely regarded as mined out.

In the high-Yttrium versions of these ore concentrates, Yttrium is about two-thirds of the total by weight, and Erbia is about 4–5%. When the concentrate is dissolved in acid, the erbia liberates enough Erbium ion to impart a distinct and characteristic pink colour to the solution. This colour behaviour is similar to what Mosander and the other early workers in the lanthanides would have seen in their extracts from the gadolinite minerals of Ytterby.

What's It Used For

Erbium's everyday uses are varied. It is commonly used as a photographic filter and because of its resilience it is useful as a metallurgical additive. Amongst other uses are in lasers and optics (this is where the 5G linkage arises).

It also has a large variety of medical applications (i.e. dermatology, dentistry) for instance in laser surgery, and the efficient production of steam for laser enamel ablation in dentistry.

When added to Vanadium as an alloy, Erbium lowers hardness and improves workability. An Erbium-nickel alloy Er_3Ni has an unusually high specific heat capacity at liquid-helium temperatures and is used in cryocoolers.

Erbium oxide has a pink colour, and is sometimes used as a colorant for glass, cubic zirconia and porcelain. The glass is often used in sunglasses and cheap jewellery.

Meanwhile in the nuclear industry, Erbium is used in neutron-absorbing control rods.

The Evolution of 5G

The crucial new application that is likely to unbalance things in this quiet corner of the Rare Earth space is communications networks. With the rapid changes in mobile technology, wireless technology has evolved from 1G to 4G over a short period of time. Seamless integration of cellular networks such as GSM and 3G, WLAN and Bluetooth was the main focus of 4G systems but now that 4G technology is reaching maturity.

Currently researchers are working on defining the next generation of wireless communication. The first 5G networks will initially operate in conjunction with existing 4G networks, but what makes 5G desirable is its ability to operate at frequencies above those currently in use by 4G networks. Now, 4G networks operate in the spectrum of frequencies below 6 GHz.

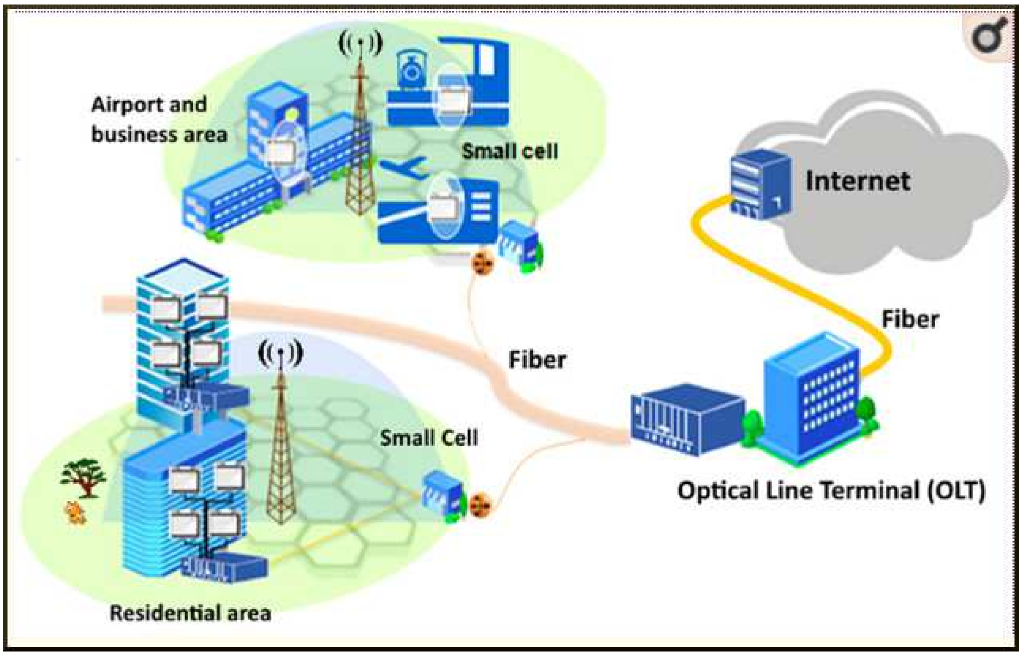
However, as of today, networks strain under current demand in this range and therefore 5G networks will help alleviate this crowding by operating in two different bands: a lower frequency below 6 GHz (for long-distance links), and a higher millimetre wave 20–100 GHz region (for super-fast communication in cities).

Emphasizing on small cell concepts, network speed and capacity enhancement and introducing new communications technologies are among the most important announcements about future 5G. Ideally, 5G will lead to higher data rates, lower latency and increased connectivity for improved performance for potentially billions of wireless devices.

Wireless access network (WAN) at millimetre wave bands (30–300 GHz) has large bandwidth which offers an alternative for high speed indoor/hotspot communication to be utilized for 5G. To support the combination of small cells and mm-wave radio for future 5G access, fibre-optic communication plays an important role in both the backhaul and front haul networks.

Erbium & 5G

The key thing to note is that Erbium-doped optical silica-glass fibres are the active element in Erbium-doped fibre amplifiers (EDFAs), which are widely used in optical communications. The same fibres can be used to create fibre lasers.

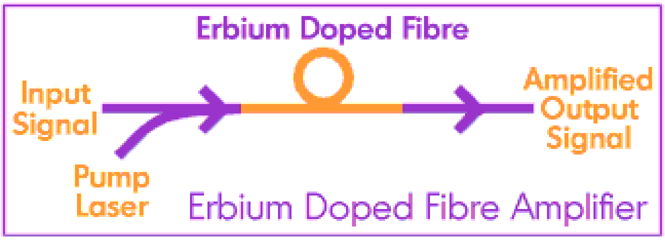


Source: Alavi & Amiri

An erbium-doped fibre amplifier (EDFA) is an electronic that opens up an optical fibre signal. It is utilized as a part of the broadcast communications field and in different research areas. “Doping” alludes to the manner of utilizing components to encourage comes about through the control of electrons.

An Erbium-doped fibre amplifier (EDFA) consists of a few meters of optical fibre doped with a few parts per million of Erbium. In order to work efficiently, Erbium-doped fibre is usually co-doped with glass modifiers/homogenizers, often aluminium or phosphorus. These dopants help prevent clustering of Er ions and transfer the energy more efficiently between the Er ions and the signal. Co-doping of optical fibre with Er and Yb is used in high-power Er/Yb fibre lasers. Erbium can also be used in erbium-doped waveguide amplifiers.

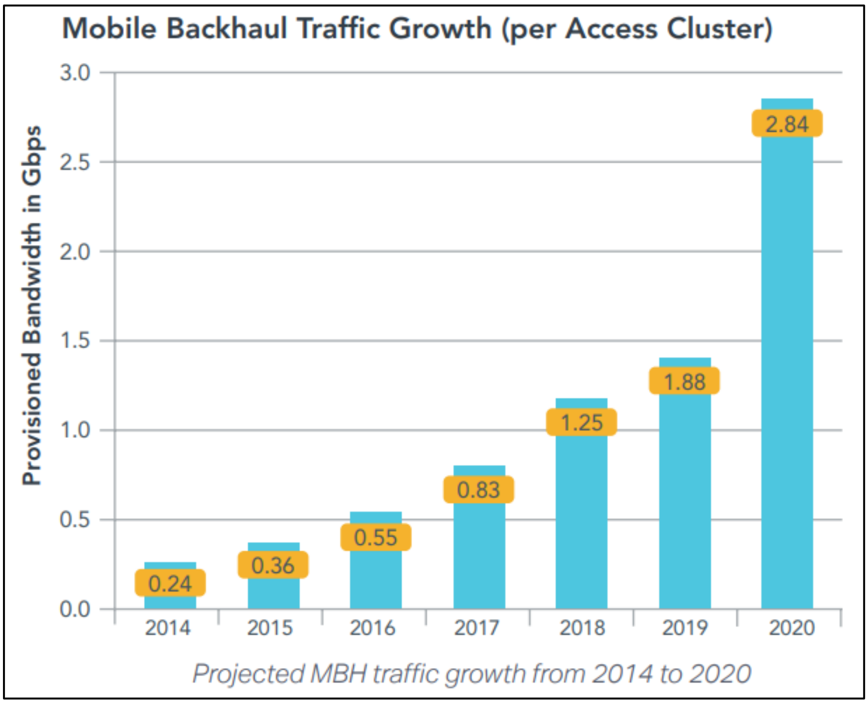
The optical signal is injected into this fibre, along with the light from a special “pump” laser that is designed to excite the Erbium ions.



A 980nm pump excites the Erbium ions into a much higher state than the 1480nm pump. However, the ions only stay in that higher state for a very short period of time (maybe nanoseconds) before moving down to the next state. Once there, they stick around for several milliseconds, which is much longer than ions excited by the 1480nm pump. The longer they remain in the excited state, the more likely it is that the signal will come along and cause stimulated emission. This also reduces the unwanted spontaneous emission that adds to the noise in the system. Therefore 980nm pumps give greater amplification efficiency and are the preferred pump method for EDFAs.

Applications & Limits

EDFAs are commonly used in submarine systems where signals often have to travel thousands of miles under the world's oceans. They can be made in compact, water-tight packages that will be placed every 50 miles or so along the length of the system. For such applications reliability is essential, and so submarine EDFAs tend to be of very simple design. Land-based EDFAs are becoming more popular now, as optical networks spread over wider distances on dry land.



Source: Ciena

All is not rosy as implementation of 5G will depend upon capacity installed and Erbium-doped fibre is a key consideration.

Although current networks may suffice for 4G today, the promised access speeds of 5G are likely going to overload existing MBH networks quite quickly.

The chart at the left shows the expected steep in recent times and the near future.

EDFAs are typically restricted to close to 10 spans covering the most distance of around 800 kms. Longer separations require a transitional line repeater to retime and reshape the signal and channel gathered from different light scattering shapes from twists in the optical fibre. Attributable to build application fibre optic communication for commercialization and organization of 5G technology is one the critical factor in the swift adoption of erbium-doped fibre amplifier around the world.

The pace of introduction is heating up. For example, recently Verizon announced that the company’s fibre deployment now encompasses more than 60 cities outside of the company’s Incumbent Local Exchange Carrier (ILEC) footprint, and it laid about 1,400 route miles of fibre per month on average in its second quarter 2019. The 1,400 route miles is a sizeable increment from the 1,000 route miles per month Verizon averaged in its first quarter 2019.

It’s worth noting that Erbium-doped fibre amplifiers can be utilized as a part of various applications as hardware testing and long spans of passive fibre networks to improve a long distance signal. The rising trend of use of fibre optic communication in media transmission, research and military and defense industry is expected to fuel the growth of the erbium-doped fibre amplifier market in coming years.

Erbium - Who Does Produce It?

Projections of the actual state of the Rare Earth production and consumption are very vague and have a high component of “tail of frog and eye of newt” in their calculation. Below one can see the projection by the respected consultant, IMCOA, of the demand and the supply of the principal Rare Earths.

Rare Earth	Demand		Supply/Production	
	Tonnes	Share in Total Demand	Tonnes	Share in Total Production
Cerium (Ce)	72,175	36%	76,950	34.20%
Lanthanum (La)	49,425	25%	60,750	27%
Neodymium (Nd)	46,100	23%	42,975	19.10%
Praseodymium (Pr)	15,175	8%	13,725	6.10%
Yttrium (Y)	9,675	5%	13,275	5.90%
Gadolinium (Gd)	3,675	2%	5,400	2.40%
Dysprosium (Dy)	1,850	1%	3,150	1.40%
Samarium (Sm)	1,600	1%	4,725	2.10%
Erbium (Er)	900	0%	900	0.40%
Terbium (Tb)	400	0%	675	0.30%
Europium (Eu)	250	0%	675	0.30%
Ho-Tm-Yb-Lu	275	0%	1,800	0.80%
Total	**201,500**	**99.80%**	**225,000**	**100%**

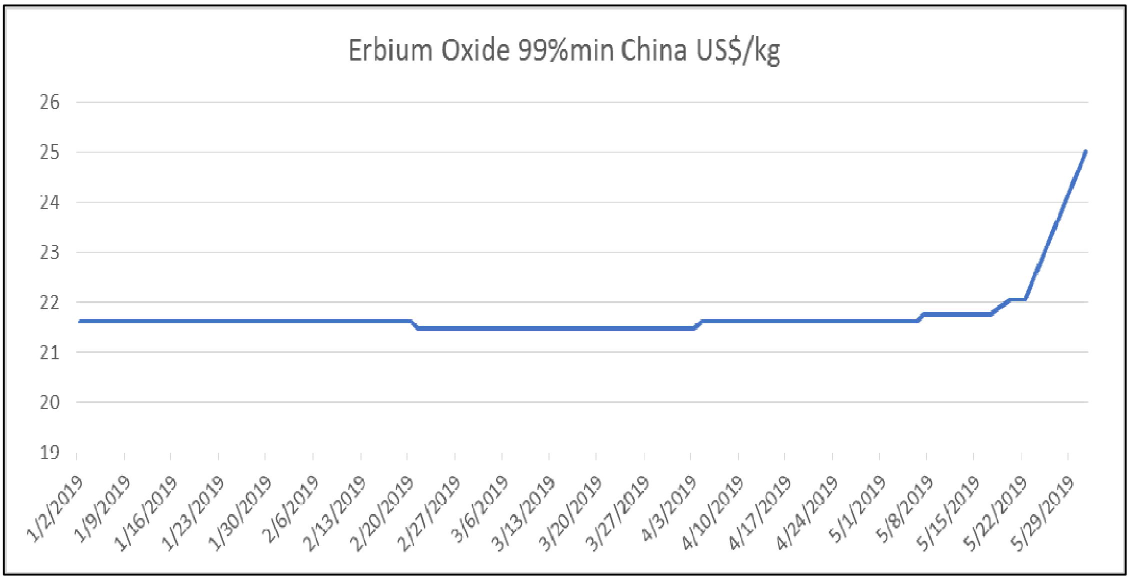
Source: IMCOA

The problem is that, despite a brief flurry in the midst of the REE boom, most of the focus has been on Light Rare Earth deposits and thus of the three publicly listed entities to reach production both Lynas (LYC.ax) and Rainbow Rare Earths (RBR.L) are LREE-oriented and only Northern Minerals is HREE-focussed.

China has squandered its advantage in Rare Earths. Now it is an importer of Heavy Rare Earths and these are mainly from tenuous suppliers in conflict zones, like Burma and the like. Firm sources of non-Chinese supply are a narrow subset which principally consists of Northern Minerals in Australia. The two majors, Lynas and Molycorp were always skewed towards the lightest of the lights, Cerium and Lanthanum. Reports indicate Mountain Pass is now just a shipper of ore to China.

Prices

These are also opaque to say the least in the Erbium category with trades, at best, being by appointment. Erbium's has started to uptick in recent months as shown in the chart below.



Source: Argus Metals

Erbium - Who Might Produce It?

The brutal, and necessary, culling has left us with a small rump of REE developers that, by our calculations, number less than 15 companies. The group of survivors are geographically diverse and now tend to be classified by their stage of development rather than the old discriminators of light vs heavy or bastnaesite vs monazite vs eudialyte vs Xenotime. Early stage no longer exists with virtually all players at least having a PEA, or better, a FS, to their name no matter how old, bloated or inaccurate it might be.

From this small universe we can glean which of the players have the strongest position in Heavy Rare Earths and thus Erbium.

This HREE group is shown in the table that follows:

Erbium Projects Comparatives

Project	Project Jurisdiction	Stage	Developer	Ticker	Erbium Resource (t)	Erbium Grade	Production ErO (tpa)
Browns Range	Australia	Production	Northern Minerals	NTU.ax	3,371	0.037%	39.3
Kvanefjeld	Greenland	FS Complete	Greenland Minerals	GGG.ax			
BioLantanidos	Chile	FS Complete	Mineria Activa			22 ppm	
Kipawa	Canada	FS Complete	Matamec Explorations	MAT.v	1,996	1.01 ppm	95
Lofdal	Namibia	PEA Complete	Namibia Critical Metals	NMI.v		1.089%	
Dubbo	Australia	FS Complete	Alkane Resources	ALK.ax			75
Ashram	Canada	PEA Complete	Commerce Resources	CCR.v	1,201	41 ppm	45

Preparing this table has been nothing short of hellacious. The cluelessness of managements in reporting minor Rare Earth presences could charitably be attributed to the fact that Erbium was not a consideration five or eight years ago. That does not excuse the almost total absence of mention of a Lanthanide component in many resource statements. Do the TSX and ASX have exemptions for managements of reporting members of the Lanthanide series that don't management's criteria for inclusion in the *promote du jour*?

Of the companies in our table, Northern Minerals, as mentioned, is now in production and we would not be surprised to see the Chilean project of BioLantanidos also advance to production.

Risks

The potential risks are:

- That REE prices remain in the doldrums
- Ongoing tough financing conditions
- Significant substitution efforts if the metal went too steeply higher in price, or became too scarce
- Supply imbalance from too many players coming on-stream

REE prices are still captive to Chinese whims. There seems to be a perception that at least in the more strategic REEs (i.e. not Lanthanum and Cerium) that the Chinese would prefer to see higher prices but they do not want to trigger a rush of wannabes into the space that would threaten their dominance. The REE space has shrunk to a sufficiently small number of players that the Chinese can permit some price increases without triggering a rush of new entrants.

The danger of prices going lower is negligible.

Financing will be available if prices start to rise. Already sentiment in the space has improved without prices having shown a meaningful improvement. This would be accentuated if the positive vibes start to expand.

Substitution of Erbium is not likely. Use of inferior alternatives may be forced upon Western users if they cannot secure supplies.

The danger of too many players coming on-stream is unlikely at this stage with only Northern Minerals having been added to the ranks of producers since 2012. To bring one of the other contenders to production would require at least a two-year lead time and only then if the financing issue could be resolved.

Conclusion

The US government seemingly thinks that by blocking Huawei it has liberated itself from Chinese dominance of 5G networks. However, our thesis is that if the US does not have non-Chinese sources of Erbium then it is still a prisoner of Chinese machinations in the Rare Earth space and struggling with Huawei is mere tilting at windmills if it does not grapple with securing itself a non-Chinese supply of this obscure mineral.

Erbium and its supply have suffered at the hands of the promoters of the Rare Earth boom of 2009-11. The Rare Earth space has been an example of Darwinian principles in action. A species burgeons and eats all the available food and then prompts a massive die-off that leaves a few survivors that are more cautious beasts and forage within the limits of the new environment in which they find themselves.

The first Rare Earth boom (REE 1.0) had been coloured by a Green Energy tinge with wind turbines featuring prominently with background music on EVs. We would posit that the second go-around for Rare Earths will be driven principally by communications issues (Erbium, Terbium) the crystallising EV surge (Dysprosium, Neodymium and Praseodymium). Heavy Rare Earths will be needed in vastly greater quantities to feed the demand for Erbium, Terbium and Dysprosium. If prices do not spike to crazy levels then substitution need not be a realistic threat for Dysprosium whereas with Erbium, in particular, there is a suggestion that substitution is well-nigh impossible.

We sense that China's Rare Earth advantage has been made vulnerable due to massive overexploitation over the last 30 years and the ONLY remedy is to cut back exports and start stockpiling material before the country becomes as dependent upon fickle outside forces in REEs as it is in Cobalt. This potentially sets the scene for a supply crunch outside China and no amount of WTO whining and appeals will stop the Chinese halting exports if it is deemed to be in the national interest.

We have previously called the Great Dysprosium Crisis of 2020, and now we add the Great Erbium Dilemma of 2021-24. These linked supply crunches will come as a "surprise" to the powers that be, both in China and outside. And yet the warning signs are there for everyone to see. The Adamas report on Dysprosium was a red flag, and now the more *sotto voce* alarm bells of Erbium are largely going unheeded as well. For those countries wanting to be players, or at least control their destiny, in 5G the hunt for Erbium must now be powered up.

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