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The Crucible

Drakelands Tungsten Mine - Enter Wolf Minerals

By-Product Status: Implications for Reserve Estimates

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Membership Subscription Fees Held for 2016

MMTA Members will have noticed that for the 6th year, we have held the rate at £1200.

In that time we've gone from strength to strength as an Association:

- Increased engagement in issues affecting the industry has meant that we've gone from 1 employee in 2010/11 to a staff of 3 today;
- We undertake activities to raise the profile of the Association, promote the activities of the Membership and the importance of minor metals;
- The association has a much wider and more international Membership, including contra agreements with other supporting organisations, such as the CRM Alliance and the International Magnesium Association
- The Crucible has developed from a quarterly newsletter to a magazine with a global distribution, and from January 2016 will be produced monthly;
- We've moved to vastly superior premises that allow Members to hold meetings in a central London space at no cost.

It will not come as a surprise to you that over the past 5 years our operational costs have risen, and in order to drive forward with developing the Association for the benefit of the Membership, we posted a small deficit last year. Based on our current income, this trend is likely to continue. However, given the current economic climate, the Directors decided at their last meeting that this is not the right time to increase subscription fees, and that we should support the Membership in these difficult times by absorbing the deficit in 2016 and delay any increase in fees until 2017.

With best wishes for the New Year on behalf of the MMTA Board and the Executive Team,

Yours sincerely

Maria Cox,

General Manager

NEW MMTA MEMBER

GLENCORE

Glencore is one of the world's largest global diversified natural resource companies and a major producer and marketer of more than 90 commodities. The Group's operations comprise of over 150 mining and metallurgical sites, oil production assets and agricultural facilities.

With a strong footprint in both established and emerging regions for natural resources, Glencore's industrial and marketing activities are supported by a global network of more than 90 offices located in over 50 countries.

Glencore's customers are industrial consumers, such as those in the automotive, steel, power generation, oil and food processing sectors. We also provide financing, logistics and other services to producers and consumers of commodities. Glencore's companies employ around 181,000 people, including contractors.

Glencore is proud to be a member of the Voluntary Principles on Security and Human Rights and the International Council on Mining and Metals. We are an active participant in the Extractive Industries Transparency Initiative.

Primary contact: David Brocas

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Phone: +41 41 709 2000

NEW MMTA MEMBER

Environmetals LLC

The MMTA is delighted to welcome Environmetals LLC, based in Simsbury, CT, USA as a new Member.

Environmetals is a trader and processor of zirconium and hafnium metals.

Primary contact: Bill Sharkey

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Phone: +1 860 214 6529

INSIDE THIS ISSUE

Cover Picture: Shaking Table, Drakelands Tungsten Mine, Hemerdon, UK

The MMTA promotes essential elements that add quality, safety and enjoyment to our lives.

The MMTA is the world's leading minor metals industry organisation.

mmta
Minor Metals trade association

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THE MMTA'S INTERNATIONAL MINOR METALS CONFERENCE 2016

TAKING PLACE AT NH GRAND HOTEL KRASNAPOLSKY, AMSTERDAM, THE NETHERLANDS, 17-19 APRIL 2016

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We are delighted that C. Steinweg Handelsveem BV is hosting a reception for all delegates on board the Het Wapen van Amsterdam on Monday April 18.

Be sure to take advantage of the excellent value Early Bird Rates:

MMTA Members £895 (+21% VAT) for registrations received from 15th January 2016

Non-members £995 (+21%VAT) for registrations received from 15th January 2016

To register or for more information please visit www.metalevents.com or www.mmta.co.uk alternatively email sales@metalevents.com

What attendees had to say about our 2015 Conference:

"A great opportunity to meet with customers, suppliers and colleagues. The key factors for us attending the conference are the wealth of information provided by the speakers and a convenient method to interface with the key individuals in our in businesses.."

Matt Danish, Telex Metals , USA

"The Conference is well-organized, industry attendance is excellent, and the presentations are relevant and interesting. From a trader's perspective, it not only provides insight into new business opportunities but also delivers a platform where you can meet the partners necessary to embark on a new project."

Melvin Hill, Aminco Resources , USA

" We get to meet up with all the suppliers of our strategic materials in first class surroundings at a well organised topical conference."

Wavell Coulson, Rolls-Royce Plc, UK

"There is a large gathering of our clients within one location giving the opportunity to meet with and or be available to our clients within a specified time frame...the opportunity to meet with potential new clients also at the same time and learn about their businesses."

Paul Chew, Alfred H. Knight, UK

IN BRIEF

Introducing.....

Lewis Winters,Account Executive
Purity Certification Services @
EAG Labs, Inc.

Vast skills and abilities that span more than seventeen years in technical sales focusing on the establishment of long-term customer relationships, advanced technology product knowledge, and superior client services. Interpersonal and articulate, able to pursue initiatives that capitalize on strengths and opportunities, and a proven track record of effectively building and leading sales teams to attain/exceed imposed goals and objectives. Lewis resides in Austin, Texas and he supports the Evans Analytical Group (EAG Labs, Inc.) Materials Characterization Division's Purity Survey Services.

High-purity metals and alloys find applications in automobiles, semiconductor devices, aerospace materials, sputter targets, evaporation sources, magnetic media, and many other products. Accurate and precise determination of their chemical composition ensures that end users have the right materials for their specific applications. EAG can verify the purity of these materials and certify the results under ISO/IEC 17025 Accreditation.

U.S GAO interviews the MMTA

As many of the North American Members will already be aware, the MMTA was recently interviewed by the U.S. Government Accountability Office (GAO) on the potential creation of a 'Critical Raw Materials (CRM)' list for the U.S.A. similar to the EU CRM list which has existed since 2010. GAO is looking broadly at U.S. federal government efforts to identify and strategically plan to address critical materials supply issues at the request of the Senate Committee on Energy and Natural Resources. For the purpose of this review, "critical materials" are not limited to rare earth materials and could include a variety of other non-fuel raw and semi-finished materials used in the production of advanced technologies.

The MMTA was asked about some of the lessons that could be learnt from the EU list, whether a long-term or a short-term approach should be taken by the government, what such a list could be used for, as well as the quality of data and understanding of the minor metals industry and supply chain.

The MMTA has asked to be kept informed of the progress of this project, and we will then disseminate any updates or opportunities to participate further to Members.

Pioneering Shipbroker Changes the Landscape to Help Charterers & Ship-Owners

Last year, Rotterdam based shipbroking firm Blue Ocean Brokers, a subsidiary of MMTA-Member Odin Warehousing & Logistics (OWL), launched a revolutionary idea to charge a flat brokerage fee of EUR 750 per fixture, instead of a percentage of the seafreight. The aim is to close more fixtures, as the ship-owners would have to take less money into account in their voyage calculation, reducing the seafreight level the charterer has to pay. "It is a win-win-win situation", says MD, Alain Grotenhuis.

According to Grotenhuis the new concept adheres to the strategy and philosophy of the Odin Group, as it adds value to our customers' supply chain by decreasing logistics costs without compromising on the service level.

"By maintaining low overhead costs, investing in ICT facilities and choosing the right location, we are able to offer our clients a value proposition which means reduced costs on their supply chain, but still offer a dedicated service with the famous single point of contact principle."

The same applies to our concept in shipbroking. "In our opinion, it is simply unfair that we, as an intermediary, gain more money when the seafreight is higher, although the workload remains the same. Moreover, as an intermediary, the risk of money loss is only in a commission which is not to be paid by the ship-owner. Whereas both the charterer and the ship-owner invested in assets—the ship and cargo - and thus run a higher risk of loss of capital. Therefore, we think the majority of the benefit should lie with those running the real risk of capital loss," says Grotenhuis.

"With this strategy, it is important to think about how the landscape has changed over the years. Traditionally, in the past, brokers could create a comparative advantage by having a large network of ship owners and charterers and the ability to quickly mix and match the cargo position to a ship position. This was in the days of telexes and, earlier, in cafés like the Baltic Exchange where brokers met ship-owners to 'sell' a cargo", Grotenhuis claims.

In Grotenhuis' opinion, this traditional way of mixing and matching has vanished. He continues, "with the evolution of the internet, the shipping market has become open to everyone. Charterers can be much more easily approached directly by a ship-owner and vice versa. By creating an automatic address list, with the click of one button, you can inform ship-owners about your open cargo position. In short, both the workload and communication expenses of the broker have decreased. This should be accounted in the earnings of the broker, which is his brokerage."

In a broader sense Grotenhuis thinks the role of a shipbroker in general is on the line. In his opinion, it is just a matter of time before the broker becomes redundant. "Just look at the financial market or the housing markets. A house owner can now sell his house via the internet without the use of realtor. In financial markets, banks are not allowed to charge a percentage on the value of the mortgage, only a flat fee," says Grotenhuis.

Although the concept is revolutionary and is proven to reduce seafreight levels, some charterers are skeptical of the concept, as they are afraid there are hidden costs which arise only later. "Sometimes it is a struggle to convince a client," Grotenhuis says. "But this concept is even more transparent than a commission and is supported by a charter party, clearly stating the money we earn, and countersigned by both parties."

With the claim by some charterers that they do not benefit from a reduced seafreight, Grotenhuis is brief. "It is simple, the owner makes a calculation on all the costs of the voyage. Besides bunker costs and daily operation costs, the commission paid to the shipbroker is also accounted for. So if a voyage costs EUR 100,000 on seafreight with 3.75% on brokerage, EUR 3,750 is included. We charge a flat fee of EUR 750—EUR 3,000 cheaper, and thus instead of EUR 100,000, the seafreight is now EUR 97,000. If the charterer ships 3,000mtns, this means his supply chain costs are reduced by EUR 1.00 per mtns. Multiply by your year's tonnage, you know how much you save."

Drakelands Tungsten Mine - Could this be the most popular mine in the world?

Who would be a miner?

If your name happens to be Glencore, Anglo, BHP, Vedanta, Rio, you might be wondering what kind of model made you think mining was a good business.

Years ago, I was lucky enough to meet the mining prospector who discovered the *Cyprus Anvil* mine in Canada. At that time it was one of the largest zinc-lead resources on earth. He described how he was dropped by helicopter onto the snowy sub-zero wastes of the Canadian Yukon and left with just his tent, food, ice-picks, shovels, and a shot-gun to ward off the grizzlies. His only means of exit was a rendez-vous at agreed map co-ordinates six weeks later.

Discovering that deposit was, in fact, the easy bit. Funding, developing, and managing, a mining resource like Cyprus for the long-term or, in the case of, say, Rio Tinto's Bingham Canyon, 152 years (and counting), requires persistence. In mining, one thing is a dead cert – odds on failure are higher than anything else. It is one thing mining high in the Yukon or down in the deserts of Utah, in locations where populations are small. But what mining house would make the job even harder and go digging in populous and regulated Britain?

It would appear there is one. Enter, Wolf Minerals.

My visit to Britain's newest mine, in South Devon, on the last day of November 2015 is under the guidance of Health and Safety Officer, Andy Harry, on the day that first run-throughs of wolfram ore are being trialled. I stand at the top of a wind and rain-swept Hemerdon Hill and survey a panorama of outlying farms with sheep, 22,000 saplings planted by the mine owners, a solar panel farm and, at the centre, the 850 metre by 450 metre and 260 metre deep open-cast mine taking shape.

Across my line of vision I can see the mine waste facility being built up and am shown how it will gradually move across the landscape as the years go by. I see also the catch-pits, into which run-off water is directed in a series of connected pools, which act as filters to stop dirty water leaving the site. Meanwhile, earth-moving equipment lumbers across the landscape like yellow-painted dinosaurs. After all, we are not far from the Jurassic coast.

Strange as it may seem (and despite the lowest prices for tungsten in a generation) Wolf's chances are not bad.

First off, Wolf does not represent 'big mining'. Drakelands is Wolf's only asset. Where big digging (and even bigger debt) is regarded by some as beautiful, Wolf sees mining beauty elsewhere. Listed in Australia, where mining is understood, this windswept reserve with a ten-year renewable mining licence is, in mining terms, a tiny project that required just £123 mln of investment.

Second, Wolf has been clever choosing their asset. Rather than picking virgin terrain, Wolf has taken a second look at something that was already proven. At the MMTA we hear all too often from junior miners marketing an asset to raise funds based on an extrapolation of value for an element that at time of funding remains strictly in the ground – and unproven.

Drakelands is rather different. The site had been identified and mined for tungsten in Victorian times and, in the early 1970s, mining giant, Amax, spent £10 mln on pre-feasibility. But Amax never developed the asset because, by the time the work had been done, prices were poor. Wolf hopes, of course, that history will not repeat itself, and there are good reasons for optimism.

Using www.measuringworth.com, the £10 mln Amax spent is worth more than £100 mln in today's money. In other words, Amax spent the same as Wolf, but Wolf's money has gone on the more positive sides of digging – equipment, process, labour, health and safety, and product.

As a result, Wolf's cash costs are relatively low. Measured in prices for APT (Ammonium Paratungstate), which is the benchmark for the market, break-even is about $108 per dmtu, according to Wolf's brochure. Taken together with debt servicing, realised prices after the discounts to the APT price that Wolf receives for its wolfram ore to allow for conversion costs, the mine will not be wildly profitable right now. But with prices steadying at time of writing at $170-185 per dmtu for APT (Source: MB 16.12.2015), WO_3 at $10-11 per kg WO_3, ferro tungsten at $21.50-$22.25 per kg W (Source: MB 16.12.15) Wolf will hang on in there.

The background factors cannot be changed and are beyond Wolf's power: the ultra-dominance of a weakened China (forced to continue making and selling tungsten to keep people in work), the ascendancy of Vietnam as a competing producer, lower industrial activity both in China and elsewhere, reduced demand for Tungsten Carbide and EU laws banning tungsten filament and incandescent light-bulbs.

But, if prices and demand improve even slightly, Wolf and its customers are set to reap the benefit of eight years' work since taking this project on in 2007 and now have a completed mine to show for it and the prospect of 35.7 mln tons of proven ore grading at 0.18% tungsten (about 60,000mt or half the annual world demand of tungsten). Essentially, this is why I am here in South Devon being shown round a working mine and process facility and not just a glossy consultancy report.

A few days after my visit, by chance, I meet surveyor, mine and quarry owner, William Voaden, who tells me some of the history. While metal mining in UK was allowed to wither and die, quarrying was not.

The area in which Drakelands sits is surrounded by reserves of English China Clay similar to the exhausted Cornish works adopted by Sir Tim Smit and turned into The Eden Project.

Clay works, unlike other forms of mining, are relatively easily reclaimed by nature and actually become a magnet for wild life, like a sunken oil platform attracting fish and coral.

The history of mining in the West Country is long and deep. From the pre-biblical Cornish tin trade with the Phoenicians and Cyprus, exchanging tin for the bronze artefacts made from it, through to the Zinc mining of the Romans in the Mendips near my home in Somerset, the West Country instinctively sees mining as its friend. A mining job is a better form of farming when it comes to pay. In fact when Wolf agreed to re-build the road leading to the mine, the locals were won over instantly. It was more than Devon Council had done - and the sheep farmers were happy.

It is true that on one level Wolf's fate does not lie in its own hands but with prices and customers – and the thing that will actually make or break Drakelands is customers. Those customers are largely Global Tungsten & Powders and Wolfram Bergbau und Hütten , in the USA and Austria. Eighty percent of Drakelands' output is split on long-term formula sales to these two with the balance to be sold on the spot market.

Both GTP (the group formed by the merger of Plansee of Austria with Sylvania Osram) and Wolfram Bergbau (of the Sandvik group) have similar but separate reasons for wanting to keep this non-Chinese resource of tungsten afloat. Synonymous with tungsten, Wolfram Bergbau, whose *Mittersill* mine in Austria is a strategic asset, has a demand for low radioactivity ore - a grade that Drakelands can easily supply. While Wolfram Bergbau's mine, discovered in 1967, is not exhausted, nevertheless the company fears depletion and would want to lengthen its life as an asset. GTP, meanwhile, does not own a mine, but is one of the premier companies making all manner of down-stream products out of tungsten, for industries such as aerospace and, as such, are vulnerable to the uncertainties associated with dependency on China.

You would have to ask, in all seriousness, whether these two groups would want to allow this new operation to expire? And what would be their interest in letting Drakelands fail?

Out of the 120,000 tpy world market for tungsten, although Drakeland's 3/5,000 tpy output represents less than 5% of world supply, when you look at what this represents as a percentage of supply, excluding China, this rises to more than 25%. In the power-play with China this little corner of Britain may contain a counter-balance which has huge strategic significance to this close-knit industry.

The first thing in the mine's favour, it seems to me, is price – but in a different sense to the one you might imagine. The memory of Ammonium Paratungstate (APT) prices at $350 per dmtu in 2008, when China had the tungsten market to itself, might be the spur to make GTP and Wolfram Bergbau think twice. To allow Drakelands to fail, would simply return control of the tungsten market to China and return prices to damagingly high levels. Would this be better or worse for the two off-takers? As consumers and makers of downstream products of tungsten, it could be argued that supporting Drakelands in hard times will provide the balancing factor of local security of supply should prices rise sharply in the future.

Secondly, Drakelands does not reside in a conflict zone (unless it happens to be a night when the local Football team, Plymouth Argyle, has lost to Portsmouth) and tungsten mining is regulated under the Dodd-Frank agreement. All tungsten from Drakelands is by definition 'conflict-free', it is therefore certifiable for content in consumer goods for use by consumers worldwide who need to know for certain that their products do not contain conflict minerals damaging to their reputation.

Thirdly, as mentioned, Drakelands' output will be low in 'uranium-plus-thorium' contents (less than 10ppm) which is appreciated by Sandvik/Wolfram Bergbau who generally demand the lowest radioactivity available.

Fourthly, the EU has defined tungsten as a critical raw material. In other words it encourages tungsten production in Europe as a strategic counter-balance to China on fears that the largest producer might hold back supply.

But more than the foregoing, there could be one other over-arching factor that will ensure Drakeland's success and survival. As I leave Hemerdon, having been shown through the process, I am struck by one factor above all - doing things right, from health and safety, to high standards in process, means 'efficiency' – and that very efficiency (not cutting corners) equals 'low cost'.

Yes, choosing Britain in which to mine, must have caused some head-rubbing. UK has exacting standards; every emission is monitored, health and safety is paramount, wages are European, the Environmental Agency is stringent, and mining licences can be withdrawn. But – and I am commenting here as a UK citizen more than a merchant – isn't it good to see mining done to high standards? We know it can be done, and yet so often, out of sight and out of the glare of London, in developing countries, corners are cut and standards are low; justified by the mania to keep costs down, but usually at the cost of the environment or people.

It would be my hope that Wolf will prove that doing right is good for both profit and survival.

Perhaps, then, Drakelands could indeed be the most popular mine in the world - and Plymouth Argyle Football Club, top of League Two of the English League at time of writing, will get promotion?

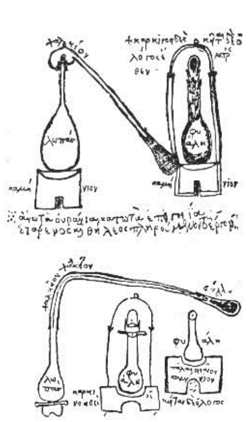
Michael Foot, its MP, post-war, in 1945 during the Attlee Government, and later leader of the Labour Party, who once said he would only die after Plymouth Argyle reached the Premiership, would be proud.

Anthony Lipmann, Lipmann Walton & Co Ltd

View live streaming at the Drakelands mine: http://www.wolfminerals.com.au/irm/content/live-streaming-video.aspx?RID=326
www.wolfminerals.com.au

Discovering the Elements

In his book, The Last Sorcerers, Richard Morris charts the path from alchemy to the periodic table. He describes how scientists and philosophers have tried for well over two thousand years to understand the nature of the universe, as well as its composition. According to the ancient Greek philosopher, Thales, there was only one fundamental elements—water. Although this seems ridiculous today, when one considers that when heated, water evaporates into mist, and when frozen it becomes solid, as well as having the ability to sustain life, it isn't impossible to see why this idea seemed plausible. This theory then developed into one that was held to be true for over two thousand years—namely, that the four 'roots of all', or elements were earth, air, fire and water. Aristotle also added a fifth, which was supposed to be the substance from which heavenly bodies were made.



Ancient Greek alchemical drawing

Alchemy was a fusion of Greek and Egyptian thinking. Egyptians had practiced many chemical processes, including metallurgy, for centuries, and had created many 'recipes' for chemical transformations, for example when cinnabar (mercury ore) was heated and was 'transformed' into a pool of liquid metal. The Egyptians knew of seven metallic elements: gold, silver, copper, tin, iron, lead and mercury, but the Greeks were unable to see them as distinct elements, choosing instead to categorise them as mixtures of the traditional four elements, earth, air, fire and water. These changes in the state of elements seemed to confirm to the ancient philosophers (scientists did not exist at that time) that transformation from one element to another was a possibility.

Jabir ibn Hayyan

It was in the years between 640 and 720 that the Muslim scholars had Greek and Syrian texts translated into Arabic and so learned of the ideas of ancient philosophers, and also of alchemy, the name they gave to the collections of chemical recipes and techniques handed down from the Egyptian alchemists. It is in Arabic alchemy that the concept of the Philosopher's Stone—a substance believed to turn base metals into gold—first appeared.

Arabic alchemy was only discovered in Europe in the 11th Century when texts were translated from Arabic into Latin. One Arabic alchemist in particular, Jabir ibn Hayyan (known as Geber) introduced a theory that all metals were simply mixtures of sulphur, mercury and arsenic (except gold which was just sulphur and mercury). Jabir's theory was that gold contained the most mercury and the least sulphur, so other metals could be transformed into gold if ways were found to increase their mercury content.

Geber-Waterbath 1678 woodcut

Following the translations of the older Arabic texts into Latin, European alchemy began to grow in the 11th and 12th Centuries, and although was equally unsuccessful in finding the Philosopher's Stone, did make the important discoveries of how to make strong sulphuric and nitric acids in the early 14th Century, and so they were able to dissolve most metals. Some alchemists became completely obsessed with their quest for the Philosopher's Stone and devoted their lives to discovering how to turn base metals into gold, spending family fortunes in the process.

The Swiss-German physician and alchemist, Paracelsus, who was born in 1493 was the first to use the term 'chemistry'. Despite many long-lasting myths suggesting he had discovered the secret of immortality and was a servant of the devil, he engaged in serious experimentation in order to learn new cures for illnesses and was the first to focus on the purity and quantities of the chemical compounds he created. He also made an attempt to classify different chemical substances based on the reactions they produced. In fact he was the first to clinically describe syphilis and put forward small quantities of mercury as a treatment for the disease, which remained the standard treatment until 1909.

Robert Boyle, the 17th Century English scientist, was the founder of modern chemistry, as distinct from the work of alchemists, dye makers and metallurgists, and by the time of his death in 1691, chemistry had grown out of natural philosophy into a science. He challenged, although was unable to disprove, the long-held theory of the four elements.

At the start of the 17th Century, there were 13 known elements, of which 9 (carbon, sulphur, iron, copper, silver, gold, tin, lead and mercury) had been known since classical times, while arsenic, antimony, bismuth and zinc were discovered between 1250 and 1500. Most of these known elements were relatively low melting-point metals, perhaps discovered through fires. In 1650, however, all the known elements were still believed to be mixtures of earth, air, fire and water, except for tin, which was thought to be a mixture of silver and lead.

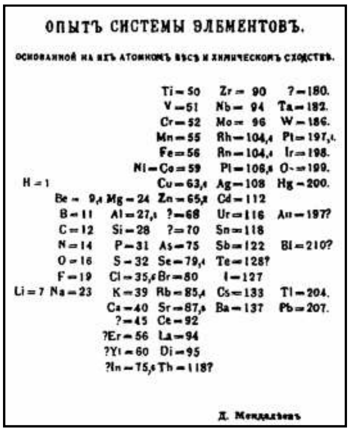
The first new element to be discovered since 1500 was phosphorous, discovered by an alchemist attempting to make gold from urine. This discovery eventually led chemists to realise that if one new element had been found, there may perhaps be still more. The next element, 66 years later, was cobalt—first used to colour glass, and from which the metal was first extracted in 1735.

There followed a period of rapid discovery, with a total of 78 elements being discovered during the 18th and 19th Centuries.

By 1900, the question that was puzzling chemists was why there were so many elements.

It was, of course, Dimitri Mendeleev who discovered the periodic law—it couldn't explain why there were so many elements, but did allow him to group together elements with similar properties, as well as predict the existence of elements that had not yet been discovered, along with their atomic weight and chemical and physical properties. There was at that time, 1865, no comprehensive textbook of chemistry in Russian, so he decided to write one. During the course of this work, he gave much thought to the fact that there was no guiding principle of chemistry. He felt that there must be an order to the 63 elements that were known at the time.

As he wrote, it seemed natural to him to group the elements together into those with similar properties. To help him do this, he created a card for each element, including its atomic weight and most significant properties, such as melting point, density and malleability. He ordered the cards according to their atomic weight, beginning with hydrogen, the lightest, and ending with uranium, the heaviest known at the time.



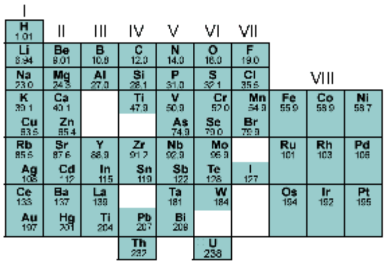
ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

			Ti=50	Zr=90	?=180.
			V=51	Nb=94	Ta=182.
			Cr=52	Mo=96	W=186.
			Mn=55	Rh=104,4	Pt=197,4.
			Fe=56	Rn=104,4	Ir=198.
			Ni=Co=59	Pl=106,6	O-=199.
H=1			Cu=63,4	Ag=108	Hg=200.
	Be=9,4	Mg=24	Zn=65,2	Cd=112	
	B=11	Al=27,4	?=68	Ur=116	Au=197?
	C=12	Si=28	?=70	Sn=118	
	N=14	P=31	As=75	Sb=122	Bi=210?
	O=16	S=32	Se=79,4	Te=128?	
	F=19	Cl=35,5	Br=80	I=127	
Li=7	Na=23	K=39	Rb=85,4	Cs=133	Tl=204.
		Ca=40	Sr=87,6	Ba=137	Pb=207.
		?=45	Ce=92		
		?Er=56	La=94		
		?Yt=60	Di=95		
		?In=75,6	Th=118?		

Д. Менделѣевъ

By pinning the cards on the wall, he noticed that the properties of the elements "were periodic functions of their atomic weights." The same properties could be seen after every seven elements. Several of the elements, however, simply didn't fit into his scheme—beryllium was thought to have an atomic weight of 14 at the time, which would have put it in a group with nitrogen and phosphorus, so he took a leap of faith and changed the atomic weight to 9, which put it into the magnesium family, where it seemed to fit. He did the same with tellurium, moving it from 128 to somewhere between 123 and 126, and doubling the atomic weight of uranium, making it 240 (the modern figure is 238, so he wasn't far off).



I	II	III	IV	V	VI	VII	VIII		
H 1.01									
Li 6.94	Be 9.01	B 10.8	C 12.0	N 14.0	O 16.0	F 19.0			
Na 23.0	Mg 24.3	Al 27.0	Si 28.1	P 31.0	S 32.1	Cl 35.5			
K 39.1	Ca 40.1		Ti 47.9	V 50.9	Cr 52.0	Mn 54.9	Fe 55.9	Co 58.9	Ni 58.7
Cu 63.5	Zn 65.4			As 74.9	Se 79.0	Br 79.9			
Rb 85.5	Sr 87.6	Y 88.9	Zr 91.2	Nb 92.9	Mo 95.9		Ru 101	Rh 103	Pd 106
Ag 108	Cd 112	In 115	Sn 119	Sb 122	Te 128	I 127			
Ce 133	Ba 137	La 139		Ta 181	W 184		Os 194	Ir 192	Pt 195
Au 197	Hg 201	Ti 204	Pb 207	Bi 209					
			Th 232		U 238				

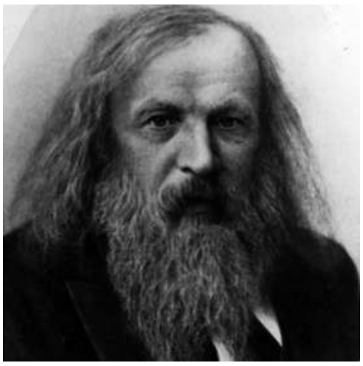
This image and above: early versions of Mendeleev's Periodic Table

He was so confident in his system that he was sure the changes had to be correct.

Mendeleev also used his system to predict the weights and properties of 'missing', undiscovered elements which would fill the empty spaces in his table. There were elements under boron, aluminium and silicon which he knew must have similar properties. He called them eka- (the number 1 in Sanskrit) boron, eka-aluminium and eka-silicon.

When he first published his work in 1869, there wasn't much interest, until he published a revised table two years later. He had revised the table, listing elements vertically rather than in horizontal rows. This work was then translated and received a great deal of interest from both Russian and foreign scientists.

In 1875, eka-aluminium was discovered and named gallium (after the ancient name for France). Scandium's discovery in 1879 filled the eka-boron slot and eka-silicon was filled by germanium in 1886. Mendeleev's predicted atomic weights and properties were largely accurate.



Dimitri Mendeleev

In honour of Mendeleev's contribution, an artificial element was discovered at the University of California at Berkeley. It was produced one atom at a time, with a total of 17 atoms being produced in total. The scientists named it Mendelevium, and it was added to the periodic table as element 101.

Images: www.wikipedia.org, www.alchemywebsite.com, www.kullabs.com, www.chemwiki.ukdavis.edu, www.springer.com

Source: **Morris, Richard, The Last Sorcerers**— *The Path From Alchemy to the Periodic Table*, Joseph Henry Press, Washington D.C, Copyright, National Academy of Sciences.

Periodic Table News

Officials from the International Union of Pure and Applied Chemistry have confirmed the discovery of as-yet-unnamed elements 113, 115, 117 and 118, completing the 7th row of the Periodic Table.

More in February's Crucible.

By-product Metal Recovery in an Uncertain Market

DG GROWTH's recent by-product metal recovery conference in Brussels was host to widely diverse views on the technology and policy challenges of increasing the availability of a range of materials essential to the EU's supply chain security, which are summarised here.

Firstly, the current pricing structure for metals does not incentivise producers to recover their by-products. There is hope that prices and/or demand will increase to incentivise greater recovery than is currently being undertaken. The longer-term question is whether the EU has sustainable access to these currently unrecovered metals, as they are undervalued in the market.

Maria Cox presenting on the role of the MMTA and importance of minor metals to the EU By-product Metal Recovery Conference

So how is it possible to persuade a plant manager to recover by-products?

There are 4 key factors to be considered:

Environmental

There is a growing need to treat huge stacks of 'waste' material and also to try not to increase them further;

Currently, by-product recovery processes are not very efficient; More cooperation with potential users of by-products is needed, to address environmental issues and thereby avoid further burdening our environment.

At the same time, there is increasing environmental regulation and greater focus on the environmental impact of the metals and mining sector.

Technical

There is only minimal interest from major producers in developing new technological processes to recover by-products. Hydro-metallurgy is currently the dominant way of extracting by-product metals, although some recovery is through pyro-metallurgy. A more efficient and selective means of extraction, for example using solvents or ion exchange, needs to be found. Modern Chinese smelters are producing 15-17 by-products, but older less technologically advanced smelters can only recover 2 -3. These all need modernising.

However, the process to recover by-products should not affect the production of the main metal, as that is where the economic value is derived. The reality is that the by-product does not exceed 2-5% of the value of the main metal. There is a significant capital investment required to recover by-product metal, so focussing on this activity is not currently attractive to primary metal producers. Despite the fact that from a Critical Raw Material perspective there is high value in by-product metals, this value is not reflected in the price.

Market

This is the most challenging aspect, as the metals' markets are currently not functioning; The inability of the market to resolve these issues came out as a key point over the course of the conference. Minor metals are more important for users than for producers. They are important for smelters and refiners, but for most are not the key focus of their production. Will mines/smelters focus more on by-products in future? Yes, but their main focus will understandably continue to be on core business. Some will want to diversify income streams, so will be more receptive. However, this is all against the short-term picture of troubled markets with low prices. Platinum, for example, is described as an example of market failure, where the industry cannot function in a context where 70% of producers are operating at below the cost of production.

There is a balance to be struck. Prices need to incentivise production, but if they rise too much it's a disincentive for consumers.

Producers won't invest in by-product recovery unless they think they can make money, so how can the market be convinced to invest and to take a risk? There is not one straightforward answer to this question, the reason being that it is not a straightforward question. Namely, the market is one thing, and security of supply is something completely different – we need to be clear which we want.

If what we want is for this to be left to the market, prices won't move just because we say we need to incentivise producers. It is also important to point out that not all are following the same set of rules, for example, the Chinese government has a high ability to influence the market, so in this context, the market cannot compete.

Security of Supply

Security of supply cannot be achieved by following market rules, so if we want security of supply, we have to operate to a different set of rules than traditional market rules.

If the aim is for increased by-product metal recovery to be a core element of European security of supply, something needs to be developed, and some have suggested policy instruments along the lines of the Common Agricultural Policy. It was set up to allow a big influence to be exercised on a particular industry, on a market that has to be supported, but the CAP consumes a large part of the EU budget, and it would be an understatement to say that it is not universally popular; however, it does support agriculture. The problem is that the raw materials' market is global, not European, so it can't be controlled by Europe.

The primary goal of such a policy would be to maintain prices at a high enough level to ensure the viability of by-product metal recovery.

Alternatively, is there a place for a stockpile? They exist, for example in China and the USA, and have the role of stabilising prices for minor metals that don't reflect supply and demand. There has been an EU project to explore the possibility of stockpiling in Europe, but the study found it was not needed by the big companies, although it might have been useful for SMEs.

Whatever the success of any intervention, prices will still face fluctuations due to regulations and export restrictions, for example.

But the EU is trying to level the playing field.

It applies trade measures such as anti-dumping controls, in an attempt to help protect the EU market. There are other mechanisms that the EU and other markets can apply where disputes occur, for example through the WTO

The introduction of conflict minerals regulation in the US and currently being discussed within the EU, requires industry to do due diligence. The argument was made that there needs to be a balance

between free trade and measures offering some degree of protection to a particular market. In this modern era of globalisation, we are all interdependent – no one country is self-sufficient in all its resource needs, so an approach needs to be found where all can co-exist and do business.

Finally, to return to the environment - there is a moral obligation to use the planet's resources as efficiently as possible, for the benefit of us all. Can such an obligation be left to the market? It does not respect the environment (that is not its role), so if we want to protect the environment, we cannot just leave the future to the market.

Round Table Participants:

Peter Craven, Mintek, South Africa

Rein Nieland, of the EU Commission's DG TRADE

Ioannis Paspaliaris, National Technical University of Athens, Greece

Christophe Petit, Eramet, France

Don Smale, International Metals Study Groups, Portugal

Chair: Mattia Pellegrini, Head of Unit C2, Resource Efficiency & Raw Materials, DG GROWTH

Maria Cox, MMTA

LAST OPPORTUNITY TO BOOK FOR THE MMTA'S NEW YORK DINNER

Thursday 21st January 2016 from 6—10pm New York Yacht Club, W44th Street, NY, USA

Start 2016 strong and capture business opportunities in Q1!

Share networking drinks & canapes with business colleagues and friends

Speaker: David Abraham, Director of the Technology, Rare & Electronics Materials Center and author of *The Elements of Power*. For more information on David and his work, go to www.davidsabraham.com.

Followed by a locally sourced 3-course meal, and at the historic New York Yacht Club, in the Commodore's Room overlooking the spectacular Model Room.

We have been able to hold the cost of the New York Dinner, offering great value to kick off the new year:

Cost: MMTA Members: $150 (GBP100) **Non-members: $200 (GBP130)**

The evening is kindly sponsored by Exotech Inc.

REGULATORY UPDATES

Conflict Minerals

Chinese Chamber of Commerce for Metals, Minerals and Chemicals Implements OECD Responsible Mineral Sourcing

The OECD and the Chinese Chamber of Commerce of Minerals, Metals and Chemicals Exporters (CCCMC) have recently launched the Chinese Due Diligence Guidelines for Responsible Mineral Supply Chains. These Guidelines are of importance, as many manufacturers globally use components sourced from companies based in China. These Guidelines will now align with the OECD Due Diligence Guidance for Responsible Mineral Sourcing from Conflict Affected and High Risk Areas and were developed in collaboration between the two organizations.

The Guidelines are designed to align Chinese company due diligence with international standards and allow for mutual recognition with existing international initiatives and legislation. Companies are required to comply with all applicable laws and regulations, and the implementation of these Guidelines cannot act as a substitute for such legal or regulatory compliance.

The Guidelines provide guidance and support to companies which are extracting and/or using mineral resources and their related products and are engaged at any point in the supply chain of minerals to identify, prevent and mitigate their risks of directly or indirectly contributing to conflict, serious human rights abuses and risks of serious misconduct. These companies are also encouraged to use the Guidelines as a reference.

The implementation of the Guidelines will initially be voluntary.

For the full copy of the Guidelines see: http://mneguidelines.oecd.org/chinese-due-diligence-guidelines-for-responsible-mineral-supply-chains.htm

Background

The extraction and trading of natural resources can create a beneficial relationship between local communities and companies, with growth and prosperity for all. As widely seen, however, natural resources can also be exploited to fund armed conflict, with the recent focus being on 3TG (tin, tantalum, tungsten and gold). The international community has focused on breaking the link between business and the violation of human rights over the past decade. Measures range from UN Resolutions to initiatives such as the "Kimberley Process" (for the traceability of diamonds) from which global standards, laws and regulations have been implemented. In 2011, the UN Human Rights Council unanimously endorsed the "United Nations Guiding Principles on Business and Human Rights" which is the first corporate human rights responsibility framework supported globally.

The hope is that the approach taken internationally will put pressure on mineral smelters to gain certification for their output. Once a critical mass is certified, it will help manufacturers upstream to meet their obligations. It is estimated that there are approximately 370 smelters in the 3TG supply chain, of which round half are now certified.

Companies are advised that they will need to set up auditable processes and practices and make sure they keep track of developments.

The primary responsibility of companies that they do not intentionally or unintentionally cause, contribute to, or benefit from human rights abuses or armed conflict, and respect the human rights of all whom their business activities might impact. Responsible companies, therefore, must conduct ongoing comprehensive due diligence on all aspects of their business, including risks that may be present in the supply chains through which they source natural resources. The recognized international framework to conduct supply chain due diligence in the natural resource sector is the "OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas", which serves as the basis for most industry programs on responsible mineral supply chains in many countries.

IN BRIEF

South Korea:

K-REACH — Lead Registrants have been published for 121 of the 510 priority existing chemical substances.

Cadmium in Artists' Paints:

In a previous Crucible we reported on a proposal from Sweden to ban the placing on the market and use of cadmium and its compounds in artists' paints. The European Commission has now rejected this proposal.

LETTER FROM NORTH AMERICA

Dear Members

Well, it's the shortest day of the year soon; winter – supposedly. But it was already some 62°F at 05.45 this morning. Another record? Let's see how Paris will now help.

Retirement often means little in minor metals when it comes to the continued presence of the retiree in the somewhat rarified world in which we move. I understand from Maria Cox that, only the other day, she met up with Tom Graedel of Yale at the recent EU By-Product Metals Recovery Conference in Brussels. After 18 years at the School of Forestry & Environmental Studies, Professor Graedel 'retired' in June. However, he remains more than active in the field. (You may remember that the professor is the prime mover behind Yale's Criticality Consortium, the spring meeting of which I wrote about in a couple of issues of The Crucible earlier this year.)

Another notable announcement of 'retirement' (effective on 5th January next year) has been that of the doyen of rare earths here in the U.S., Karl Geschneidner. Professor Geschneidner truly can be described as 'Mr. Rare Earth'. Amongst other things, he is the Chief Scientist of the Critical Metal Institute – a U.S. Department of Energy Innovation Hub, a Senior Metallurgist at the Ames Laboratory (the '*government-owned, contractor-operated national laboratory of the U.S. Department of Energy*'), and the distinguished Professor of Materials Science and Engineering at Iowa State University.

Even though he may have celebrated his 85th birthday in November, the professor intends to continue working and will continue to occupy the same office he's had since 1963! His situation seems most enviable. As Professor Geschneidner described it in a piece published recently by the Ames Laboratory: "*The biggest difference in being 'retired' will be that I don't have to be here for meetings! I can just concentrate on the research.*" I think this can only constitute a very just reward after over 60 years in the world of metals! I can but wish him all the very best in his 'retirement'.

Finally, on the subject of metals research, I can thoroughly recommend the following paper (published in April in **Environmental Science & Technology**): *"Mining Critical Metals and Elements from Seawater: Opportunities and Challenges"*. It is fascinating.

I'm sure that, back in 2011, and sporadically thereafter, many of you will have seen various articles in the press about Japan (and other countries) and undersea mining. This research piece takes a different view and says, 'Don't look at undersea mining, look at what is in, and could be extracted from, seawater'. If nothing else, extracting it from seawater could have considerably fewer environmental impacts, for example, chemical pollution and habitat removal and/or disturbance.

There certainly seem to be a ton of metals in the oceans' waters. These include not only loads of ferro-manganese, but also "*large amounts of dissolved ions (~30-45 g/L) including hydrated ions of critical metals/elements such as Li, Mo, Ni, Zn, V, and Au*". There are, in addition, quantities of Co, Nb, Ag and U: who would have thought?

Needless to say, the trouble is extracting them – economically, or at all! As Hamlet (amongst others) would say: "*…there's the rub*". Not least, as the paper points out: "*…the availability of high capacity and selective separation materials remains a major and unresolved challenge"*. So, whilst providing an interesting prospect, I don't think we should hold our breath.

And, on that note, from an unseasonably warm New York, I remain, with best wishes for the holiday season (by now probably past) to MMTA Members everywhere.

Tom Butcher, December 15th, 2015

Not metal, but….

A new hi-tech material has been developed by an Oxford University lab, with a cost per gram of…wait for it….£100m. Unfortunately for us, the material is not a metal but is a 'cage of carbon atoms containing nitrogen atoms.'

The material is being used to make a small, portable atomic clock which will be the most accurate timekeeping system in the world, enabling improvement in GPS positioning accurate to 1mm.

BY-PRODUCT STATUS: IMPLICATIONS FOR RESERVE ESTIMATES

C P Broadbent (Wardell Armstrong), R Seltmann (Natural History Museum), J Drielsma (Euromines),

W Reimer (Geokompetenzzentrum Freiberg), M Cox (MMTA)

Because there is no exploration and little process technology development for metals when their by-production fully satisfies demand, by-product resources and reserves are consistently underestimated. Assessment methods that take resource or reserve estimates as inputs tend therefore to exaggerate supply risks associated with by-products. For the same reason, claims as to whether current by-products will ever be economically mined as a main product could be highly speculative[1].

DEFINITION OF RESOURCES AND RESERVES—JORC

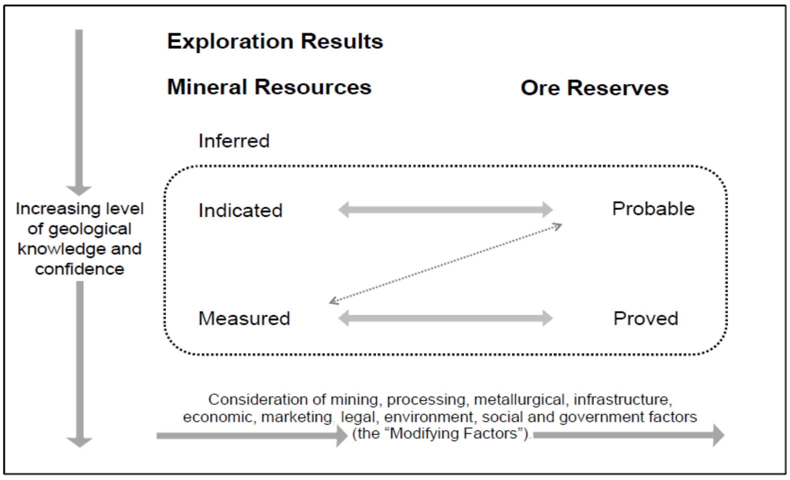


Figure 1: General Relationship between Exploration Results, Mineral Resources and Ore Reserves[1]

A mineral resource is a concentration of material that has reasonable prospects of economic recovery. A mineral reserve implies technical feasibility and economic viability and ALL modifying factors have been considered (Fig. 1). To quote a resource and / or reserve, considerable work has to have been done. In the case of most by-products, they may (or may not) be known in the deposit, but rarely has any detailed metallurgical processing work (modifying factor) been done—hence, they will never appear in reserve and only occasionally in resource statements. This may limit the promotion of the reserve for investments or will indicate higher investment costs and / or requires longer to reach a break-even position.

MAJOR METALS—e.g. copper (Cu)

For major metals, resources and reserves are reasonably well described, but as some elements are produced mostly as by-products from production of a major commodity, their appearance in resource and reserve statements is much more problematic. Copper ores provide a good example. Many important elements are produced as by-products from copper production (Fig. 2). Over 80% of total world production of rhenium (Re), selenium (Se) and tellurium (Te) is produced as a by-product from primary copper production. Most, if not all, of these by-product (elements) will not have featured at all in reserve statements prepared at the relevant feasibility studies required pre-mine start up. Whilst the major metals are reasonably well known, it is a different story for minor metals. Resource, reserve and even basic production data can be scarce or not available.

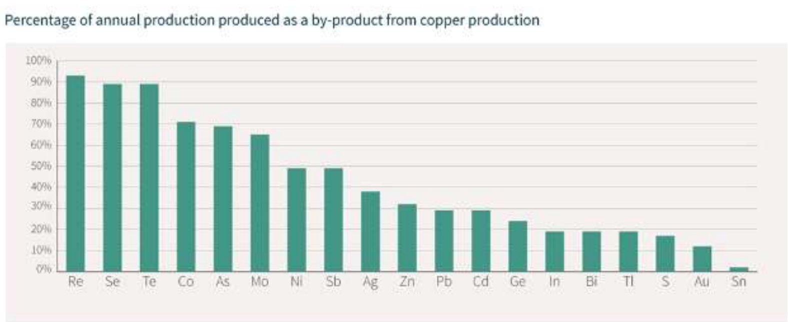


Figure 2: By-product Elements Associated with Copper Productions[2]

The BGS and the USGS publish World Mineral Production statistics (most recently available for 2012 and 2014 respectively). However, reserves data are dynamic and will change with time. In essence reserves may be considered a working inventory of a mining company's supply of an economically extractable mineral commodity. The USGS has now discontinued the publication of its reserve base data.[3]

Reserves will only ever be a relatively small proportion of the known resources. Future supplies of minerals will, in the very short term, be derived from reserves. In the mid to long term, however, they will be derived from currently undiscovered resources, in deposits that will be discovered in the future and material recycled from current in-use stocks, or minerals in waste disposal sites. This situation leads to seemingly anomalous results. For example, in 1970, identified and undiscovered world copper resources were estimated to contain 1.6 billion tons of copper, with reserves of about 280 million tons of copper. Between 1970 and 2011 about 400 million tons of copper have been produced worldwide, but world copper reserves in 2011 were estimated to be 690 million tons—more than double those of 1970.

Production statistics are generally more reliable than 'reserve' data. The BGS now publishes data on 73 commodities (Ref: World Mineral Production 2008-2012 Centenary edition[4]) compared with 39 commodities in the original data set. Many of the commodities that have been added might be termed 'technology metals' and are critical to new technologies, such as use in clean energy production, modern communications and computing—but it is incorrect to regard the commodities themselves as being 'new'. The BGS data are available for some metals commonly produced as a by-product of a major metal commodity, but in some cases are absent, for example, indium data consist of refined metal production data only, and no data are given for mined ore production, and even with these data, most are presented as estimated values only.

MINOR METALS—e.g. tin (Sn), tungsten (W), indium (In)

Given this background, it is not surprising that some of the best available data for reserves and resources are those produced by companies involved with the mining, processing or refining of these by-product elements.

Data are provided below for world deposits containing indium (Fig. 3)[5] and tin (Fig. 4)[5].

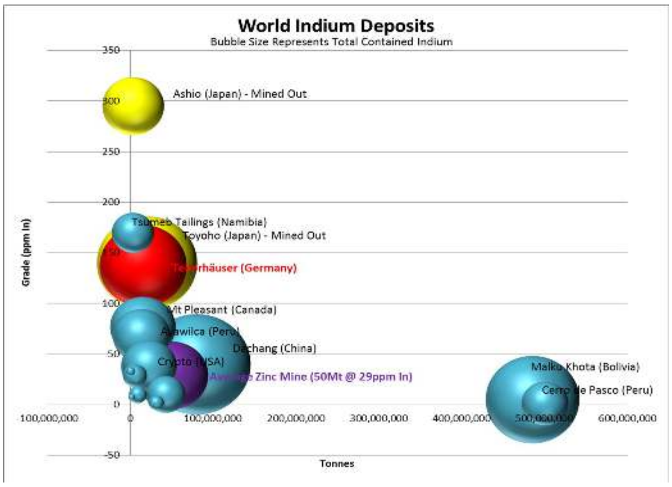


Figure 3: World Indium Deposits[5]

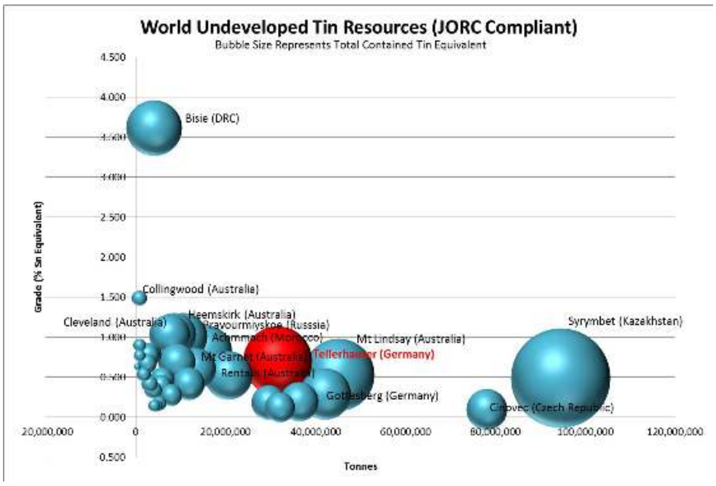


Figure 4: World Tin Deposits[6]

These ore data originate from Anglo Saxony Mining[5,6], and the indium resources will only represent those that are known (i.e., predominantly Sn deposits in which chemical analysis for In was carried out). They do not represent, in any way, world resources (or reserves) for indium.

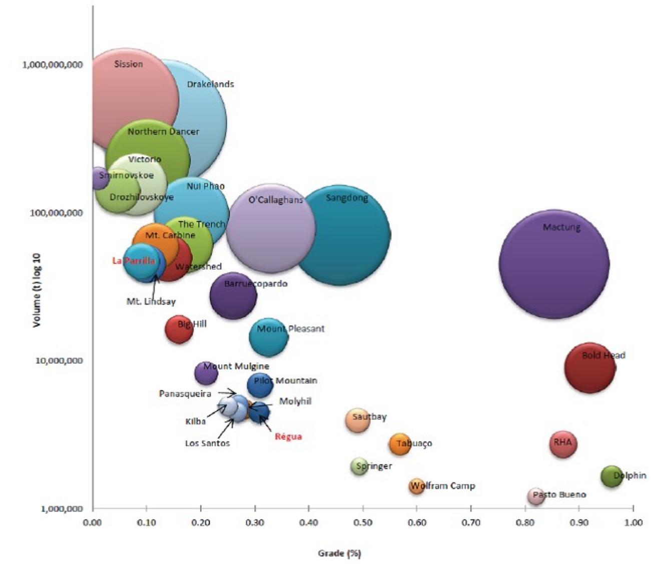


Figure 5: Comparison global W deposits —High Grade Resource[7]

Figure 6: Tonnage-Grade diagram for Sn; Kasbah Resources[8]

Similar bubble diagrams (Figs. 5-6) are commonly presented for main commodities such as WO_3[7] and Sn[8] which tend to be a major component of the ore, however, almost certainly these will also appear as by-products in other ores and will certainly be under-represented in both resource and reserve data.

Once again these bubble diagrams for WO_3 and Sn were created by mining companies, based on their in-house archives and probably reflect the best available data. Metals such as indium (In) and tungsten (W) are included on the list of 20 Critical Raw Materials, and care has to be taken when evaluating the resource and reserve base for these commodities. Premier African Mineral (PAM) who produced the bubble diagram for W (Fig. 5) has not investigated the presence of co-existing by-product metals such as Sc, In, Ga, Ge, etc. at all. Indeed, these have been rarely, if at all, analysed for by PAM. Hence, there may be significant unreported inventories of these by-products associated with the deposits quoted in the diagram. A very obvious example is that of Sn and W hosting considerable by-products. The geological setting of Sn and W, in particular, means that a range of other by-product metals / elements could be present, and often these potential by-products are not included in Reserve Statements and hence cannot show in financial evaluations.

CASE STUDY

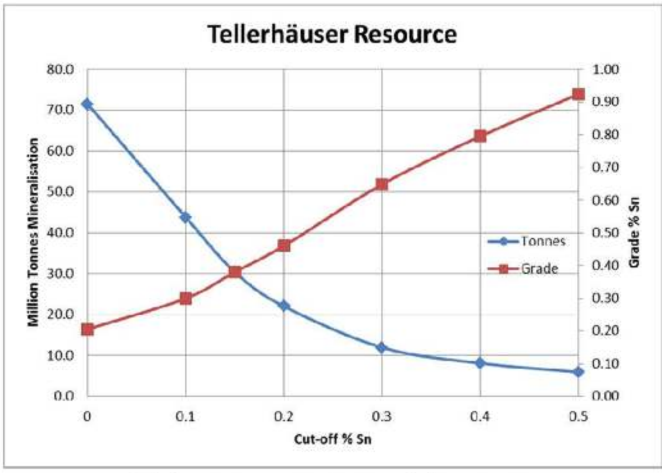
The Tellerhäuser Tin Project is located in Germany and being evaluated by Anglo Saxony Mining. A resource (Sn) estimate was prepared in 2015 by Simon Tear of H&S Consultants out of Brisbane, Australia.

It is interesting to note that the resource estimate grade / tonnage curve produced in Figure 7[5] only takes into account Sn. The economics may be significantly different, thereby allowing lower cut off grades, if by-products (especially indium) were taken into account. The resource (and subsequent reserves) will be totally different if all valuable by-products are included. However, to do this, it is likely that new processing techniques will be required, especially innovative mineral processing technologies to separate the different mineralogical (chemical) constituents of the ore. Process flow sheets for by-products must be economically viable in their own right and 'contribute' to mining minor metals, but not vice versa. This still requires extensive R&I work.

European R&I into mineral processing has been generally lacking in the last 20 years, due in part to the reduced size of the European mining sector and decline of mining / mineral processing taught at universities and colleges. For example, in the UK, 30 years ago mineral processing was taught at the Royal School of Mines (RSM—London Imperial College), Camborne School of Mines (CSM, Cornwall), Birmingham University, Leeds University, Nottingham University and Cardiff University. Whereas only really CSM (now as part of the University of Exeter) retains significant mineral processing teaching capability.

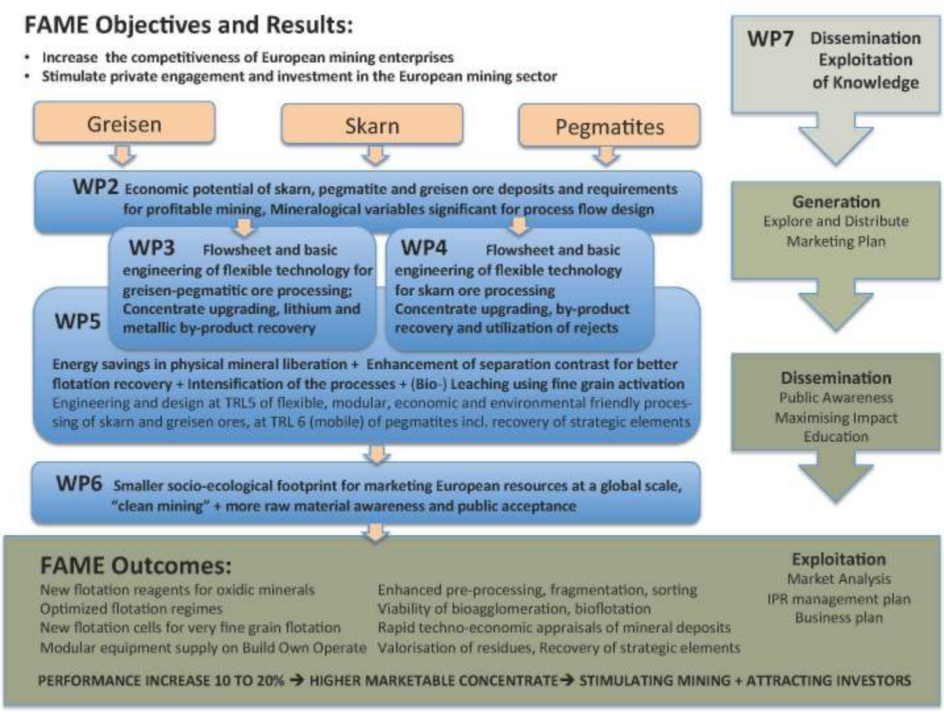
Cut-off % Sn	Million Tonnes	Grade % Sn	Tin Tonnes
0	71.4	0.21	146,800
0.1	43.8	0.30	131,400
0.15	30.4	0.38	115,700
0.2	22.1	0.46	101,500
0.3	12.0	0.65	77,500
0.4	8.1	0.80	64,500
0.5	5.9	0.92	54,900

Tellerhauser resource estimate at different cut-off grades



Tellerhauser resource estimate grade/tonnage curve

Figure 7: Tellerhäuser case study [5]



The EU call topic SC5-11-2015: *New Solutions for Sustainable Production for Raw Materials, Flexible Processing* attempted to re-address this situation, and one of the successful projects attracting EU funding was FAME (Figs. 8-9)[9].

An objective of FAME is to help maintain skills, especially mineral processing expertise, within Europe to enable exploitation of complex ores. These skills are exactly what will be needed to enable exploitation of all valuable components (i.e., by-product recovery) from ores in a sustainable mining context.

Figure 8: FAME Objectives

Figure 9: FAME Consortium Activities

CONCLUSIONS

Reasonably robust resource / reserve estimates exist for the major metals, e.g. Cu. However, many of these 'major' metal producers are also significant producers of minor metal by-products. Whether these by-products are shown in reserve statements is dependent upon a number of factors, especially whether they are actively explored for and whether viable process flow sheets exist so that the economically viable recovery of the minor element can be proven. If by-production fully satisfies demand, there is no active exploration, and resources and reserves are simply not discovered and reported at rates comparable to those of major metals[10]. Similarly, if no viable process flow sheet exists, a reserve (and in some instances a resource) can not be quoted to an international standard such as JORC.

For ore deposits where there is no dominant major metal, the position is slightly different to that of the majors. The grade/tonnage relationship and life of mine relationship is far more complex, and it is often much more difficult to demonstrate economic viability and hence, quote reserves.

Whilst utilisation of all components in ores represents the most sustainable approach to mining, it is clear that without other incentives (for example a change in government policies), many of the minor metals (by-products) will not appear in reserve estimations, as their financial and technical viabilities are often not proven. Furthermore novel, or innovative, process flow sheets are often required to recover all the potential metals of value (i.e. enable recovery of all potential by-products). Until enhanced, flexible mineral processing options have been developed, as well as in some instances improved refining techniques (especially with respect to smelting technology), many potential sources of by-products will not be realised. Without improvements to the process at both the mineral processing (beneficiation) as well as the metal extraction (smelting and refining) stage, to ensure effective recovery, by-products are unlikely to appear in reserve estimates. This situation may become crucial in attracting investors if prices of by-product metals continue to rise, or by-product metals will become even more strategic.

There are current EU initiatives in the Horizon 2020 programme designed to address some of the (mineral) processing and metallurgical challenges but, perhaps, different financial / policy scenarios will be required before resource and reserve estimates reflect accurately the actual availability of many by-product metals. Currently estimates must therefore be treated with caution and will under-estimate resources and reserves of these metals.

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6: Internal presentation by Anglo Saxony Mining
7: Premier African Minerals (www.premierafricanminerals.com)
8: Kasbah Resources Presentation, ITRI Conference Shanghai 2015
9: FAME (www.fame-project.eu)
10: Drielsma J, Russell-Vaccari A, Drnek T, Brady T, Weihed P, Mistry M, Perez Simbor L (2015) Mineral Resources in Life Cycle Impact Assessment – Defining the Path Forward. Int J Life Cycle Assess (DOI 10.1007/s11367-015-0991-7)