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## CONFERENCE PROGRAMME

<b>Thursday 23 November 2017</b>	
09.30	<b>Registration &amp; tea &amp; coffee (Main foyer and Lower Library)</b>
<b>Theme 1: Future supply and demand</b>	
10.00	<b>KEYNOTE: Demand trends for mineral raw materials relevant to the energy transition</b> Peter Buchholz (DERA – German Mineral Resources Agency)
10.40	<b>Sustainable resource governance, the nexus and saturation levels</b> Raimund Bleischwitz (University College London)
11.00	<b>The shape of the industrial minerals sector in 2050</b> David Manning (Newcastle University)
11.20	<b>Tea, coffee and refreshments and posters (Lower Library)</b>
11.50	<b>The diversification of raw materials by new technologies</b> David Merriman (Roskill Information Services Ltd)
12.10	<b>Metals and minerals for the energy transition: Challenges for global governance</b> Sian Bradley (Chatham House)
12.30	<b>Lunch and posters (Lower Library)</b>
13.30	<b>Panel-led discussion: How confident can we be about future demand trends? How can we plan for an uncertain future?</b>
<b>Theme 2: Where will future resources come from?</b>	
14.30	<b>KEYNOTE: Sourcing metals for the future: The why, the where and the how</b> Richard Herrington (Natural History Museum)
15.10	<b>Developing new exploration models for rare earth elements and associated critical metals</b> Kathryn Goodenough (British Geological Survey)
15.30	<b>Tea, coffee and refreshments and posters (Lower Library)</b>
16.00	<b>New prospect or old rubbish? A geological perspective on secondary metal resources and the 'urban mine'</b> Andrew Bloodworth (British Geological Survey)
16.20	<b>Discovering the undiscovered: the role and value of industry-academia collaboration</b> Joshua Hughes (Durham University)
16.40	<b>Mineral exploration projects [title TBC]</b> Alex Lemon (Mkango Resources Ltd)
17.00	<b>Panel-led discussion: Does it make sense to think about 'running out' of mineral resources? What are the constraints on current and future resource availability?</b>
18.00 – 19.00	<b>Drinks reception and posters (Lower Library)</b>
<b>Friday 24 November 2017</b>	
08.30	<b>Registration, Tea &amp; coffee (Main foyer and Lower Library)</b>
<b>Theme 3: Meeting the resource challenge responsibly</b>	
09.00	<b>KEYNOTE: Reconsidering the role of minerals and matter in international development</b> Daniel Franks (United Nations Development Programme)

09.40	<b>Opportunities for mining companies to contribute to the UN Sustainable Development Goals in Sub-Saharan Africa</b> Natalia Yakovleva (Newcastle University)
10.00	<b>Social responsibility in the mining sector</b> Sarah Gordon (Satarla Ltd)
10.20	<b>Responsible sourcing of minerals</b> Frances Wall (Camborne School of Mines)
10.40	<b>Tea, coffee and refreshments and posters (Lower Library)</b>
11.10	<b>Rethinking the Narrative: Building A Case for Formalizing Artisanal and Small-Scale Mining in Sub-Saharan Africa</b> Gavin Hilson (University of Surrey)
11.30	<b>The Importance of water in project development, and how to reduce risk</b> Julia Dent (WSP Water Services)
11.50	<b>Panel-led discussion: How can we share the benefits and risks (economic, environmental and social) of mining more fairly? Can the resources needed for global development be sourced in an environmentally and socially acceptable way?</b>
12.50	<b>Lunch and posters (Lower Library)</b>
<b>Theme 4: Who should we engage in this effort, and how?</b>	
13.50	<b>KEYNOTE: Mobilising the European raw materials sector</b> Karen Hanghøj (EIT Raw Materials)
14.30	<b>The role of industry in meeting our mineral needs sustainably [title TBC]</b> Froydis Cameron-Johansson (Anglo American)
14.50	<b>The Great Battery Race and the New World of Resources</b> Henry Sanderson (Financial Times)
15.10	<b>Getting policymakers on board with the mineral resource challenge</b> Thomas Evans (Policy Connect)
15.30	<b>Tea, coffee and refreshments and posters (Lower Library)</b>
16.00	<b>Panel-led discussion: How can we build a roadmap for meeting future resource needs, an interdisciplinary community up for addressing this challenge, and the social and political capital to make it possible?</b>

**POSTER PROGRAMME**

**Ultimate off-shoring: Mineral Resources, UN 2030, Paris and Outer Space**

Mukesh Chiman Bhatt (Birkbeck College, University of London)

**Mining for the Future – Are Deep Sea Minerals really a viable option?**

Rob Langman (MarineSpace Ltd)

**Looking North for future gold resources: exploration and mining within the Nanortalik Gold Belt, South Greenland**

Denis M. Schlatter (Helvetica Exploration Services GmbH)

**A multidisciplinary approach to exploration of extinct seafloor massive sulphide (eSMS) deposits in the TAG Hydrothermal Field, Mid-Atlantic Ridge (26oN)**

Iain Stobbs (University of Southampton & National Oceanography Centre)

## ORAL ABSTRACTS (in programme order)

### **Demand trends for mineral raw materials relevant to the energy transition**

**Dr. Peter Buchholz**

*German Mineral Resources Agency (DERA) at the Federal Institute for Geosciences and Natural Resources (BGR), Wilhelmstr. 25-30, 13593 Berlin, Germany*

For the forthcoming two decades, wind and solar photovoltaic power generation is predicted to have the largest growth rates among renewable energy systems, including new and decentralized stationary energy storage systems such as redox flow or lithium-ion battery systems, which are almost none existent in current electricity networks. The dynamics of the energy transition will not purely depend on electricity price developments, but more on political action plans to reduce greenhouse gas emissions, regulatory measures of the sector especially in China, Europe and the United States of America, the economics of scale in the production of the new energy systems, and the overall financial strength of countries and societies to modernize national economies.

The required extension of the electric power infrastructure will demand more copper, aluminium, zinc, steel, ferroalloy metals, and other construction materials. Besides that, renewable energy technologies will significantly increase the demand for rare earth elements such as neodymium, dysprosium, praseodymium and terbium contained in permanent magnets of wind turbine generators, for lithium, cobalt, nickel, graphite and vanadium contained in batteries, and for silicon, indium, gallium, tellurium, and other base and minor metals as part of solar photovoltaic cells and other relevant technologies.

Many of the mineral raw materials relevant to renewable energy technologies are currently sourced in markets that are politically and economically rated critical, similar to the situation that applies to the oil and gas markets. In comparison to the politically complex crude oil market with a moderate market concentration, many mineral raw material markets relevant to renewable energy systems currently have a much higher market concentration with less suppliers around the globe. Under these circumstances, a growth in demand for the relevant mineral raw materials may also lead to new international trade conflicts and increase price and supply risks. Various relevant WTO trade dispute cases for mineral raw materials have already been fought in the past years. Strong price peaks occurred recently for lithium and cobalt affecting the value chains. For example, high expectations from the battery sector strongly influenced prices for lithium carbonate in 2016/2017, which doubled from 6,600 US\$/tons in January 2016 to 13,000 US\$/tons in March 2017, and for cobalt, which doubled from 23,000 US\$/tons to 52,000 US\$/tons in the same period.

As the energy transition will broadly be implemented most probably in industrialized countries and China at first, their transition process and economic growth will have the highest effect on the demand of the relevant raw materials. It also seems that renewable energy is important for economic growth and likewise economic growth encourages the use of more renewable energy sources. In total, 173 states have formulated strategic plans to develop the renewable energy market in their countries which could speed up the demand in various markets. For the past ten years, the global financial investment volume in renewable energies has already risen from 73 billion USD per year to over USD 286 billion a year in 2015. This trend will continue supporting an increased growth in demand also for specific mineral raw materials.

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## **Sustainable resource governance, the nexus and saturation levels**

**Raimund Bleischwitz**

*University College London*

The presentation looks at uncertainties of market trends and what we call 'new scarcities', i.e. environmental challenges related to mining interlinkages with water, energy, land, and downstream pressures on materials. Those interlinkages are explained as 'resource nexus'. The presentation elaborates on why it is relevant to overcome silo thinking for the Paris Agreement on climate change and the SDGs, and on the governance challenges related to those interlinkages. Some market uncertainties relate to downstream demand trends, especially from emerging economies, and implications of expected growth for minerals' demand. Contrary to some scenarios, we present recent findings on the saturation effect for steel, cement, copper, and aluminum consumption across countries over a time period of a century. Those findings demonstrate a peak in the demand for materials in developed countries, and suggest saturation levels in China soon to come. Macro-economic implications are briefly discussed, using the model UCL ENGAGE. The outlook addresses resource governance on multi levels, including new business models for the mining sector.

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## **NOTES**

## The shape of the industrial minerals sector in 2050

### David A. C. Manning

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Excluding fossil fuels, the value of minerals extracted in the UK is around £5billion, over 95% of which is as mineral raw materials for a wide range of industries. Globally, this sector of natural resource exploitation is growing as GDP grows, whereas the proportion of metal consumption remains constant. Policy changes have major implications for the industrial mineral sector. For example, if removal of CO<sub>2</sub> from flue gases to meet the UK's legally-binding targets was to rely entirely on silica based-products, the amount of sand mined in the UK to produce these would have to increase by a factor of 1000. Similarly, the UK's decision to move away from petroleum-driven vehicles by 2040 creates an enormous need for lithium. More widely, the pressure on soil resources arising from population growth, especially in Africa, creates a considerable need for novel fertilizers, especially potassium. The scale of what is required is staggering.

In order to meet these challenges, combined with the additional challenges and opportunities offered by Brexit, the industrial minerals sector will look very different in 2050. It will have to grow, given that the world's population requires accommodation, food, transport and consumer goods. It will have to become more efficient, ideally selling everything that is mined. Despite societal demand for its products and the employment and wealth it creates, mining is not popular. To achieve the required growth, great care will be needed to ensure that the industry works increasingly effectively with the public so that it is granted consent for mining activity.



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## The diversification of raw materials by new technologies

### David Merriman

*Roskill Information Services Ltd*



The use of raw materials throughout history has changed significantly with the developments of technologies reliant upon the specific properties of an increasingly large set of elements and materials. As new technologies emerge and become widespread, the draw on required raw materials continues to widen, which often places a strain on industries which are ill-prepared for significant demand growth. The recent and forecast growth in electric vehicles, energy generation and portable technologies is expected to place significant strain on a range of industries which supply raw materials for electronics, batteries, motors and light-weight metal alloys. This presentation will highlight the industries most impacted by this growth in demand, including their ability to scale-up production, the migration and regionalisation of industries, the potential for substitution of raw materials and indicate at which markets could be impacted by future technological developments.

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## **Metals and minerals for the energy transition: Challenges for global governance**

**Sian Bradley**

*Chatham House*

This presentation will explore the implications of the shift to a decarbonised economy for the mining and metals industries. Drawing on wider trends in resource production, trade and consumption, it will consider the extent to which the demand implications of low carbon transition represent a departure from 'business as usual'. What are the potential political, economic and environmental challenges associated with the delivery of metals and minerals for a low carbon future? How well prepared for these challenges are current governance structures around the mining and metals sectors? What are the key uncertainties around key technologies and business models, and what role can supply and demand scenarios play in preparing governments, industry and investors in this context?

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## Sourcing metals for the future: The why, the where and the how

### Professor Richard Herrington

*The Natural History Museum*

Despite advances in recycling, the world is demanding increasing amounts of mined non-renewable natural resources. Development in the emerging economies of Asia, South America and Africa and the trend for global urbanisation, spanning the world, demands continued growth in the extraction of the major infrastructural metals. The concurrent green revolution has ironically shifted demands from fossil-fuel based energy generation to renewable technologies using mined metal-based products. In addition, the industry of the e-connected world demands a complex cocktail of minor metals and elements from across the periodic table. The supply of major metals may be straightforward to forecast but understanding minor metal supply is complicated by the reality that their recovery comes largely as by-products from major metal mining.

Recent returns to Malthusian fears of peak metals are perhaps unwarranted, but there are clear pressures to the timely supply of the metals we need. Worries that discovery rates have recently declined and evidence that new resources are now taking longer to turn from discoveries to mines, suggests the exploration business needs to adapt to keep the pipeline of need filled. Exploration investment needs to be sustained (increased?) and there is a need to get smarter at both discovering and mining, particularly the ability to do both under deepening cover. A fuller audit of deposit types for the suite of recoverable minor metals is warranted and many 'unfashionable' deposit styles with minor metal credits may again find favour as a result. New frontiers are opening for future exploration whilst others may close off for a range of reasons. The public should remember that industrial Europe was built on the mineral wealth of Europe and it is clear that although neglected, much may remain to be discovered or even recovered from what was left behind. For this we need to better educate the consumer on why these metals need to be mined. Finally, for all of this, we need to invest in the technologies and the correctly skilled people to allow us to develop the kinds of 21<sup>st</sup> and 22<sup>nd</sup> century mines that we shall certainly need.

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## Developing new exploration models for rare earth elements and associated critical metals

Kathryn Goodenough<sup>1</sup>, Frances Wall<sup>2</sup> and Martin Smith<sup>3</sup>

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The rare earth elements (REE) have been the headline of the critical metals agenda for several years. They are essential ingredients in decarbonising the global economy, and with the current interest in both electric vehicles and renewable energy, demand for REE is projected to continue increasing. However, global REE production is dominated by China, and opening REE mines elsewhere in the world has proved challenging in recent years. REE exploration briefly boomed after 2010, but then declined significantly, and is now picking up again. Our ongoing research projects, SoS RARE ([www.sosrare.org](http://www.sosrare.org)) and HiTech AlkCarb ([www.carbonatites.eu](http://www.carbonatites.eu)), are investigating some of the main primary deposit types for REE and other critical metals, with the aim of developing enhanced deposit models to improve future exploration targeting and lower the environmental footprint of production.

The HiTech AlkCarb project, funded by the EU's Horizon 2020 programme, aims to create new geo-models for the alkaline and carbonatite igneous complexes that host many deposits of the REE and other critical metals such as niobium. This research is being delivered through the study of a number of 'natural laboratories' around the world; datasets from these localities will be drawn together to develop conceptual geomodels. One 'natural lab' that has been studied in detail is the Kaiserstuhl alkaline-carbonatite complex in the Rhine Graben, Germany. This was selected because it offers exposures and borehole data that extend from the volcanic superstructure, into the shallow-level intrusions below. Extensive geophysical work by project partners at Terratec, and mineralogical/ geochemical work undertaken at the University of Tübingen, will allow us to build up a more detailed 3D model of the Kaiserstuhl as an analogue for similar rift-related complexes worldwide. In contrast, data from localities as diverse as Italy, Turkey, Mongolia and NW Scotland will all contribute to developing a more generic model for alkaline complexes and mineralisation in post-collisional settings.

The SoS RARE project is part of the NERC Security of Supply of Minerals programme. It has two main research strands, one focusing on hard-rock REE mineralisation and a second strand investigating ion-adsorption deposits. Ion-adsorption deposits are formed by tropical weathering, and such deposits in southern China currently provide almost all of the world's heavy REE. These deposits are low grade, but typically have low levels of radioactivity, the balance of REE needed by manufacturers, and potentially simple processing routes. However, to-date there has been little research onto what controls REE grade in ion-adsorption clays, or into the most environmentally friendly ways of mining them. The SoS RARE project is studying a deposit in Madagascar and comparing it with the Chinese deposits, with the aim of developing better models for targeting this type of REE deposit.

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## **New prospect or old rubbish?**

### **A geological perspective on secondary metal resources and the 'urban mine'**

**Andrew Bloodworth**, Gus Gunn and Evi Petavratzi

*British Geological Survey, Environmental Science Centre, Keyworth, Nottingham NG12 5GG, UK*

Over the last 100 years the global mining industry has achieved major technological innovation and economies of scale. Despite significant environmental and social impacts, these developments have led to the growth of an efficient and reliable international system for the supply of metals at relatively low economic cost.

Although it has potential to make a major contribution to a more environmentally-sustainable system of supply, the recovery of metals from secondary resources in the human environment contrasts sharply with the primary mining sector. From a geological perspective, secondary 'mining' or recycling of metals appears to be a relatively immature activity. Resources in the 'urban mine' are complex and poorly understood. Knowledge of metal transport and concentration processes in the human environment is incomplete. Measurement and quantification of secondary resources and reserves is poor and/ or inconsistent. Physical access to secondary resources, and the extraction and processing of anthropogenic 'ores' are often problematic, as is the separation and refining of individual metals from the resultant concentrates.

As a result of these challenges, the volume and variety of metals currently supplied from the urban mine is small and restricted in comparison to primary mining. For example, only 12 per cent of aluminium metal produced globally currently comes from end of life scrap. Of platinum-group metals produced, only 30 per cent currently comes from end of life scrap. This is despite recycling rates for both aluminium and for platinum-group metals being relatively high compared to most metals.

This presentation considers these problems and how they might be overcome, in part by learning lessons from economic geology and the primary mining sector. Sustainable resourcing of future generations with a wide palette of metals requires a paradigm shift in the way in which we utilise the urban mine. Major improvements in efficiency, scale and scope of the recycling industry are required. A long-term goal might be the efficient management of all metal resources through increased integration of primary and secondary sectors. This would help maximise the circular flow of metals through our economy and reduce the environmental footprint of metal extraction and processing.

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## Discovering the undiscovered: the role and value of industry-academia collaboration

Joshua W. Hughes<sup>1\*</sup>, Hannah S. R. Hughes<sup>2</sup>, Denis M. Schlatter<sup>3</sup>, Nicolas J. Saintilan<sup>1</sup>, Jochen Kolb<sup>4</sup>, Kathryn M. Goodenough<sup>5</sup>, Robin-Marie Bell<sup>6</sup>, Richard A. Spikings<sup>7</sup>, Glenn Bark<sup>8</sup>, David Selby<sup>1</sup>, David Corrigan<sup>9</sup>, Adrian Finch<sup>10</sup>, Kevin Murphy<sup>11</sup> and Jan Štembera<sup>12</sup>

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In this contribution we highlight the value of collaboration between academia and the junior exploration sector in furthering exploration efforts through case studies from recent advances in Greenlandic gold exploration. The gold prospectivity of Greenland was first recognised as early as the Viking era as documented within the Icelandic sagas (Schlatter *et al.*, 2015). Orogenic gold occurrences have been located throughout the island in Archaean, Palaeoproterozoic and Palaeozoic terranes (e.g. Kolb, 2015; Kolb *et al.*, 2016; Schlatter *et al.*, this meeting and references therein). However, to date most exploration has been unsystematic and the genesis of known deposits remains poorly understood, resulting in a lack of identified gold resources. Despite the clear potential, only one gold deposit (Nalunaq) has commercially produced gold.

Government-industry-academic alliances provide valuable platforms for jointing-up thinking and idea sharing in exploration. A Mineral Resource Assessment Workshop held in 2014, co-hosted by the Geological Survey of Denmark and Greenland, and the Government of Greenland, brought together an expert panel of academics and exploration professionals to assess the potential for undiscovered orogenic gold deposits in Greenland through reviewing all existing geological, geochemical and geophysical data. The Tartoq Gold Province was ranked as the most prospective tract, followed by the Paamiut Gold Province and the Nanortalik Gold Belt (Kolb, 2015; Schlatter *et al.*, this meeting). As a result of the workshop the Tartoq (specifically the Nuuluk and Ilerlak gold occurrences) and Paamiut Gold Provinces are now being explored by Alopex Gold Inc. and Greenland Gold s.r.o., respectively. An ongoing initiative by the Universities of Durham and Geneva aims to determine the absolute timing of mineralisation and the hydrothermal system at Nuuluk using <sup>187</sup>Re-<sup>187</sup>Os and <sup>40</sup>Ar/<sup>39</sup>Ar geochronology of coeval arsenopyrite and fuchsite, respectively.

In 2014, following the collaboration of a group of geologists working on the North Atlantic Craton, the first “North Atlantic Craton (NAC) Conference” (held in St Andrews) was formulated. A key objective of these meetings is to provide a forum promoting engagement between academics and those in industry, geological surveys, regulatory agencies and government regarding mineral deposits associated with the NAC and its adjoining mobile belts. This format was successfully repeated in 2016 (held in Edinburgh) with plans for future meetings beyond. Both NAC conferences hosted ca. 80 international delegates representing the aforementioned sectors, approximately 40% of which were from industry, government and geological surveys.

Craton-specific or region-specific meetings such as the NAC Conferences and Mineral Resource Assessment Workshops are a chance to discuss the most up-to-date developments in the geological understanding of a particular region. By focussing discussion on a craton and its surrounding mobile belts, a trans-Atlantic translation of observations across disparate segments of the same crustal block may be brought together in a holistic manner, allowing for new correlations and crossovers to be highlighted in an open dialogue. The latest ideas about correlations between disrupted parts of the previously assembled supercontinents can be coupled with detailed information from a collective wealth of experience about how exploration can be carried out in an efficient and successful way by predicting the types of deposits spatially. In the case of the NAC, models established in 'well-studied' areas (e.g., Eastern Canada, Scotland and Scandinavia) enable us to extrapolate into areas that are less explored. One such output of the NAC Conference with broad implications for the exploration sector is the proposed correlation between the 1.8 Ga Nanortalik Gold Belt of South Greenland (which hosts the Nalunaq gold mine) and the 1.8 Ga Lycksele-Storuman Gold Belt of northern Sweden (which hosts the Svartliden gold mine; 2.97 Mt @ 4.3 g/t Au) prior to the breakup of the Palaeoproterozoic Columbia (Nuna) supercontinent (e.g. Bark and Weihed, 2012; Schlatter *et al.*, 2016; Schlatter and Hughes, 2014). Furthermore recent structural, petrological and geochemical studies have better constrained the controls on gold mineralisation within the Nalunaq deposit (Bell *et al.*, 2017a,b) and supported renewed efforts by Alopex Gold Inc. to locate additional gold resources within the former mine.

In summary, such orchestrated efforts aim to lead to future discoveries of mineral deposits in remote parts of the Greenland, the NAC and the surrounding belts, assisting economic development in isolated communities, and promoting independence and self-governance.

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**NOTES**

## Reconsidering the role of minerals and matter in international development

### Daniel M. Franks

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Minerals matter in our efforts to achieve the ambitious United Nations Sustainable Development Goals, because they are literally the matter that underpins much of global development. International development actors have traditionally focused their support for governments and the private sector on globally traded 'high value' metals and energy minerals due to their potential to generate foreign currency and taxation. However, there are significant issues that need to be carefully navigated when pursuing export-led, raw commodity-based development. The literature on the resource curse and Dutch disease (Sachs and Warner, 1995; Tilton, 1995; Ross, 1999), conflict minerals (Le Billon, 2001), the flyover effect (Storey, 2001; Rolfe, 2013), and dependency theory (Moran, 1974) all convey cautionary tales. The challenges described in this literature have prompted a suite of policy approaches, from the Extractive Industries Transparency Initiative and Natural Resource Charter, to the Kimberley Process Certification Scheme, and the Voluntary Principles on Security and Human Rights (for a history of these initiatives see Franks, 2015).

International institutions, regional economic commissions and developing country governments, have recently begun to reconsider the role of minerals and matter in international development. This has been prompted by the realization that metals and energy minerals make up a minority of the global mining sector (Nötstaller, 1988; USGS, 2017). Eight of the top ten produced commodities are industrial (non-metallic) minerals or construction materials, which total more than 80% of global mineral production (Peduzzi, 2014; USGS, 2017). But despite their potential to impact livelihoods, both positively and negatively, industrial minerals and construction materials have been neglected in development debates. Economic geologists call these non-metallic and non-energy minerals, 'Low Value Minerals and Materials,' due to their low price as a function of their weight, and their relatively low value to international commodity markets (O'Driscoll, 2006). 'Low value' commodities are contrasted with 'high value' minerals, like gold and diamonds, which are mostly exported from mineral-rich developing countries to the developed world. But from a development perspective 'low value' commodities are anything but 'low value'. Their value is in their local and domestic use, rather than the price that they command on global markets, and as inputs for domestic economic development and broad-based national development (Nötstaller, 1988). Instead of the term 'Low Value Minerals and Materials,' Franks et al. (2016) defined these minerals as 'Development Minerals', i.e. minerals and materials that are mined, processed, manufactured and used domestically in industries such as construction, manufacturing, infrastructure and agriculture. Development Minerals are economically important close to the location where the commodity is mined. In comparison to the metals sector, they have closer links with the local economy with a more direct impact on poverty reduction.

This presentation will re-consider the relationship between minerals and global development, presenting empirical data collected from country-level studies of Development Minerals in Jamaica, Fiji, Uganda, Guinea-Conakry, Cameroon and Zambia. The presentation will highlight the points of intersection between minerals, materials and the Sustainable Development Goals and offer new perspectives on how international development actors can support sustainable and equitable development.

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**NOTES**



## Opportunities for mining companies to contribute to the UN Sustainable Development Goals in Sub-Saharan Africa

**Natalia Yakovleva**

*Newcastle University*



The United Nations Sustainable Development Goals (SDGs) set targets for all nations in the most important areas of human development, as well as environmental protection and climate change for the period 2015–2030. This viewpoint discusses how mining companies can contribute to the implementation of SDGs through developing region-specific approaches to sustainable development. It argues that investment and cross-sector collaboration for the provision of collective goods such as health, education and infrastructure should be the main focus of the sustainable development policies of the mining companies operating in developing countries. We believe that academics and practitioners could further develop indicators to measure the progress of industry towards the SDGs and devise innovative solutions that link these to mining sector operations. Further research into mineral production at the national level can extend the understanding about the implications of sustainable development for mineral commodities, mines and mineral enterprises.

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### **NOTES**

## Social Responsibility in the Mining Sector

Dr Sarah Gordon<sup>1</sup> & Catriona Cahill<sup>2</sup>

<sup>1</sup>Secretary for External Relations & Foreign Affairs, Geological Society; Managing Director Satarla Risk Management. [sarah@satarla.com](mailto:sarah@satarla.com); <sup>2</sup>Satarla Risk Management. [Catriona@satarla.com](mailto:Catriona@satarla.com)

Social responsibility is “doing good, not just doing well” [1]. For industries that are geologically bound to the minerals with which they work, this often means operating in locations of higher than average risk. These geographies can be remote, environmentally fragile, and home to people who have rarely encountered heavy industry previously.

No longer is it acceptable to mine in an area without the consent of the local population. Guidance on how to create and maintain this social contract is well publicised and understood; from the United Nation’s 17 Sustainable Development Goals, to the sharing of practical methodologies such as the Anglo American Socio-Economic Assessment Toolbox (SEAT) [2]. Further-education courses in sustainability have also helped to develop the skills necessary to implement these tools. Despite advancements, almost every mining project is or will be disrupted by unanticipated social responsibility issues.

The nature of these sustainable development risks, while consistent at their core, change in context as a mine progresses through its life cycle. For example:

- **Exploration (finding the minerals)** – Exploration teams, often led by a geologist, not only have to be technically excellent, they also have to lay the foundations for a strong relationship with the community if the project is to progress. Legacies from poorly led exploration teams can prevent mining occurring in an area for generations.
- **Project (planning for construction & operation)** – Acquiring the necessary permits for a mine from government or regional municipality will take far longer than shareholders expect. Also, go/no-go company decisions for a project continue to be weighted towards the anticipated short-term financial return rather than the more holistic sustainability context.
- **Construction (building the mine)** – Thousands of temporary construction workers arrive in a small community and have to be managed appropriately.
- **Operations (running the mine)** – The Life of Mine will likely be decades long, resulting in the expansion of existing and building of new communities.
- **Closure (closing the mine)** – Both environmental and social closure. How do you permanently close what has often become the heart of a community?

This presentation will explore the social responsibility faced and addressed by mining companies at each stage of the lifecycle of a mining operation.

[1] Butler, T (2017) ‘Here’s how Mining can reinvent itself for the modern age’ International Council on Mining and Metals (<https://www.icmm.com/en-gb/our-stories/here-s-how-mining-can-reinvent-itself-for-the-modern-age>)

[2] Anglo American (2017) SEAT TOOLBOX Version 3, An Overview. [www.angloamerican.com/sustainability/communities](http://www.angloamerican.com/sustainability/communities)

**NOTES**

## Responsible sourcing of minerals

**Frances Wall**, Rob Pell, Ed Loye

*Camborne School of Mines, University of Exeter, Penryn, TR10 9FE*

Many of us buy fair trade coffee, tea or bananas, but how many of us think about the origin of the raw materials in our manufactured goods? We may look for a forestry stewardship council tag on wooden furniture but are less likely to enquire about complex products such as cars or computers, which may have thousands of components, most with long supply chains. Responsible sourcing of these goods is equally important.

There certainly are responsible sourcing schemes for minerals. Gemstones and gold in jewellery are the mineral commodities closest to tea and coffee. They are still easily recognisable and only a few steps away from their source. Well-known responsible sourcing schemes include the Responsible Jewellery Council, Oro Verde from Colombia, and the Fairmined scheme. Companies use responsible sourcing as part of their brand image.

The long supply chains of specialist and technology metals make this kind of recognition much harder. The public become concerned by high profile single issues rather than the overall concept of responsible sourcing. Conflict minerals such as 'blood diamonds and 'coltan' are the best examples of this. Child labour in the production of cobalt from the DRC has recently become a high profile issue in battery manufacture.

We will consider three approaches to responsible sourcing of minerals.

1. The most quantitative comparison is via life cycle assessment techniques. This is a 'world of its own' which is constantly evolving and growing in use in the mining sector. The method requires painstaking data collection and some subjective decisions when calculating scores so that they can be compared. It is most useful to the specialists in manufacturing supply chains.
2. Responsible sourcing schemes for raw materials are increasing in number and vary from the International Council on Mining and Metals (ICMM) with its best practice guidelines and toolkits, to schemes such as Initiative for Responsible Mining Assurance (IRMA), specific schemes for conflict minerals, and national schemes such as that being implemented in Finland.
3. Clear, simple and fun techniques are needed to communicate the concept to young people. We have been developing a 'Top Trumps-style' game to compare rare earth deposits, allowing non-specialists to consider and understand geological aspects of responsible sourcing.

Acknowledgement: Funding was received from NERC grant NE/M011429/1, [www.sosrare.org](http://www.sosrare.org). Geobus, University of St Andrews, helped with the 'Top Trumps style' game cards.

**NOTES**

## **Rethinking the Narrative: Building A Case for Formalizing Artisanal and Small-Scale Mining in Sub-Saharan Africa**

**Gavin Hilson**

*Surrey Business School, University of Surrey, Guildford, United Kingdom*

This presentation builds a case for formalizing artisanal and small-scale mining (ASM) – low-tech labour-intensive mineral extraction and processing – in sub-Saharan Africa, drawing attention to its often-overlooked positive attributes. It calls on donors and policymakers to shift their focus away from the sector's negative impacts, in particular, its sizable environmental footprint and health and safety concerns. Despite dominating most headlines about ASM, these problems, it is explained, are, in the case of sub-Saharan Africa, due to most of the sector's activities being found in informal 'spaces', which confines operators to their current unpopular and heavily-scrutinized development trajectory. The barriers to formalizing ASM in sub-Saharan Africa are highlighted, and ways in which to bring the sector's activities into the legal domain and the benefits with doing so are identified.

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### **NOTES**

## The importance of water in project development, and how to reduce risk

**Julia Dent**, Martin Boland, Peter Baur, Angelo Papaioannou

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Water can often be of critical importance to project development. Lists of the top 10 risks facing miners often include access to water, or social or environmental risks from pollution of local water sources. Whether it's too much water, or too little water, it has the potential to stall a project and potentially make it unviable. Mining companies need to think of water locally as a resource in a distinctly different way from the mineral resource. The need to think sustainably about water in a mining context is increasingly important, and should be focused on by using water resources that other water users are unable to use, now or during mine life, and on sharing resources equitably such that livelihoods are enhanced and not derogated. This approach will be likely to be in line with governing and funding bodies where local and regional development goals tie in requirements for aquatic protection and universal access to clean water, along side sustainable economic and employment growth.

Potentially the biggest risk to mine project development is conflicts in water demand with current users, and subsequent repercussions on not only the physical and operating performance of a mine but the social acceptability of a project to the local and regional population. Implementing early investigation into a robust water balance for the mine, investigating alternative water resources in the area and engagement with current community stakeholders can reduce this risk and allow the development of a catchment based approach and solutions for the local water resource. Environmental risks, such as flooding or pollution, are also a key issue when understanding the importance of water in project development. Initiation of reliable analysis of pollution risk, such as acid rock drainage and metal leaching studies, and feedback into mine design during the planning stages can reduce future water treatment requirements as well as facilitating permitting with local authorities and reducing the legacy of the mine following closure. Baseline studies involving community based and stakeholder monitoring can raise awareness of current, non-mining, water pollution or flooding issues, and provide information and education as to the cause of future incidents as well as developing mitigation measures to reduce the impact of any current or future events. Mine dewatering can also cause an increased risk of subsidence or slope instability, given the right geological conditions, and investigation and modelling of the soil water balance or pore pressures in relation to changes in groundwater during operations and following closure can allow a management plan to be developed and implemented, reducing the risk. This presentation will look at a number of global examples of key water issues in project development, and the steps implemented to reduce risk and maintain project development progression and operation.

**NOTES**



## Mobilising the European raw materials sector.

**Karen Hanghøj**

EIT Raw Materials

The Raw Materials Initiative is the EU raw materials policy strategy. This is supported by the European Innovation Partnership on Raw Materials, which brings together the entire raw materials community, and by the H2020 actions on raw materials.

EIT RawMaterials is a *Knowledge and Innovation Community* under the European Institute on Innovation and Technology and is part of the H2020 framework. The strategic objectives of EIT RawMaterials are, *1. Securing raw materials supply, 2. Designing solutions for sustainable use of raw materials, and 3. Closing material loops*. To achieve these goals, and secure an economically viable and sustainable raw materials supply, a range of options must be developed. Environmentally responsible and sustainable mining must be strengthened in Europe including in the Arctic and from the seabed as well as in other regions in the world. Raw materials supply from secondary and tertiary sources must be increased through innovations in substitution, recycling, extraction from industrial residues, tailings, urban and landfill mining. The activities carried out by EIT RawMaterials include *Matchmaking and Networking, Education, Validation and Acceleration and Business creation and Support*, and cover six main knowledge and innovation themes along the raw materials value chain:

- 1) Exploration and raw materials resource assessment
- 2) Mining in challenging environments
- 3) Increased resource efficiency in mineral and metallurgical processes
- 4) Recycling and material chain optimisation for End-of-Life products
- 5) Substitution of critical and toxic materials in products and for optimised performance
- 6) Design of products and services for the circular economy

EIT RawMaterials are working actively with stakeholders in Europe and abroad to in all activities and addressing all themes. This will help ensure long-term sustainable impact on the industry and on the raw material supply.

**NOTES**

## Getting policymakers on board with the mineral resource challenge

**Thomas Evans**

*Policy Connect*

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How can we generate action on the challenge of meeting our future mineral needs sustainably? Drawing on case studies from the work of Policy Connect – a cross-party think tank that works with politicians, civil society, the business community and academia to find common ground policy solutions to sustainability problems – this talk will outline how it is possible to impact the policymaking process, and share reflections on how a conversation among politicians about sustainable mineral use might get started.

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### **NOTES**

**POSTER ABSTRACTS**  
**(in alphabetical order)**

**Ultimate off-shoring: Mineral Resources, UN 2030, Paris and Outer Space**

**Mukesh Chimam Bhatt**

[m.bhatt@physics.org](mailto:m.bhatt@physics.org)

*School of Law, Birkbeck College, University of London, Bloomsbury, London, WC1E 7HX*

It is 60 years since the Outer Space Treaty came into force. Its successor treaties and UN resolutions and covered questions of extraterrestrial resources, terrestrial environmental concerns and the benefits of outer space to developing countries. Recent years have seen the enactment of legislation by the USA and Luxembourg allowing the mining of mineral and other resources in space, the publication the sustainable goals by the UN, and the Paris agreement. Apart from their applicability in Outer Space, how do these various documents interact, overlap or otherwise effect each other? What conflicts arise between application of Outer Space international law, national legislation, UN 2030 goals and the Paris agreement? Can any resolution be found, or is further legislation needed?

## Mine Wastes of Critical Metals: Current Knowledge and Future Directions

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Mining is vital as it provides jobs, innovation, infrastructure, social benefits and wealth that drive the global economy. However, the extraction of metals and other commodities from ores results in the production of vast quantities of mine wastes that are found at or near mine sites in virtually every country in the world (Hudson-Edwards et al., 2011). These wastes often contain elements such as arsenic, cadmium, lead, mercury and uranium that can be toxic, corrosive or radioactive, or a combination of these (Lottermoser, 2010). Much research has been conducted on the geochemistry, mineralogy, microbiology and potential toxicity of these common mine waste contaminants. In recent years, however, increasing extraction of new commodities, known as Critical Metals, has introduced new types of mine wastes and 'emerging' contaminants. Critical metals are those essential to industrial and green technologies. Examples of these include Be, Co, Ga, Ge, In, Li, Nb, REE, PGE, Sb, Ta and W. Although their current annual global production is not large (c. 100s to 100s of thousands of tonnes) compared to that of metals such as Fe, Cu and Ni (millions to billions of tonnes), their extraction is increasing significantly. Some critical elements (e.g., Co, Se) are by-products of base metal mining that have well-known environmental issues such as acid and neutral mine drainage. The mining of other critical metals has contaminated soils, waters and dusts, leading to human health issues (e.g., Co in the Democratic Republic of Congo). Other critical metal deposits (e.g., REE) are associated with radioactive elements (U, Th) that also present health hazards. Overall, however, there is a severe lack of biogeochemical and toxicological data for the mine wastes of most critical metals. This presentation will outline the current state of knowledge of Critical Metal mine wastes, and future research needs.

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## **Mining for the Future – Are Deep Sea Minerals really a viable option?**

**Rob Langman**

*MarineSpace Ltd*

Rare-Earth Elements (REE) are a group of plentiful minerals that are not often found together in commercially viable ore deposits. These elements are used in aircraft components, advanced electronics, pigments, batteries and other industrial applications.

Since the 1950s, the demand on REEs has been increasing, with placer deposits in India and Brazil initially providing industry with the elements, before other deposits in South Africa and America were used to satisfy the growing demand. In recent years, China has played an increasing role in the production of REEs to the extent which 95% of all REE elements were produced by China in 2010.

Despite producing the majority of REE, China is estimated to only have around 37% of the worlds proven REE reserves, and therefore alternative sources are required to ensure a consistent supply of these minerals are brought to the market.

Land based production of REEs is typically destructive and polluting, with a mildly radioactive slurry waste being produced following removal of the REEs with toxic acids.

Deep Sea Mining (DSM) offers an alternative supply of these elements from various sources from the abyssal planes. Polymetallic Nodules (PMN) and Massive Sulphide Deposits (MSD) also contain REE within them along with other commercially viable elements helping the commercial viability stack up for investors.

However, DSM involves the extraction of mineral deposits from depth greater than has been attempted before for a commercial operation, and therefore certain technological and environmental challenges exist.

Technological advances are now ready to meet the challenge of mining and extracting mineral deposits from several kilometres below the sea surface and return them to the surface in a commercially viable way. Systems using modified traditional dredging/mining equipment has been proposed, along with some more radical designs and systems.

The environment also requires careful consideration. These deep-water habitats are typically only fed through the rain of detritus from the photic zone above, and therefore, the habitats encountered tend to be slow to evolve, long-lived and unused to disturbance. However, with almost no development having taking place in these regions in the past, analogous areas should be investigated to help to demonstrate the likely effects of the disturbance to these communities. A comparative cost-benefit-effect may also help to ensure that the authorities look objectively at DSM as a viable source of these minerals, whilst acknowledging the uncertainties associated with a new industry in a new environment.

This paper will attempt to highlight the known knowns, the known unknowns and the unknown unknowns relating to the extraction of minerals from deep sea environments.

**Looking North for future gold resources: exploration and mining within the Nanortalik Gold Belt, South Greenland**

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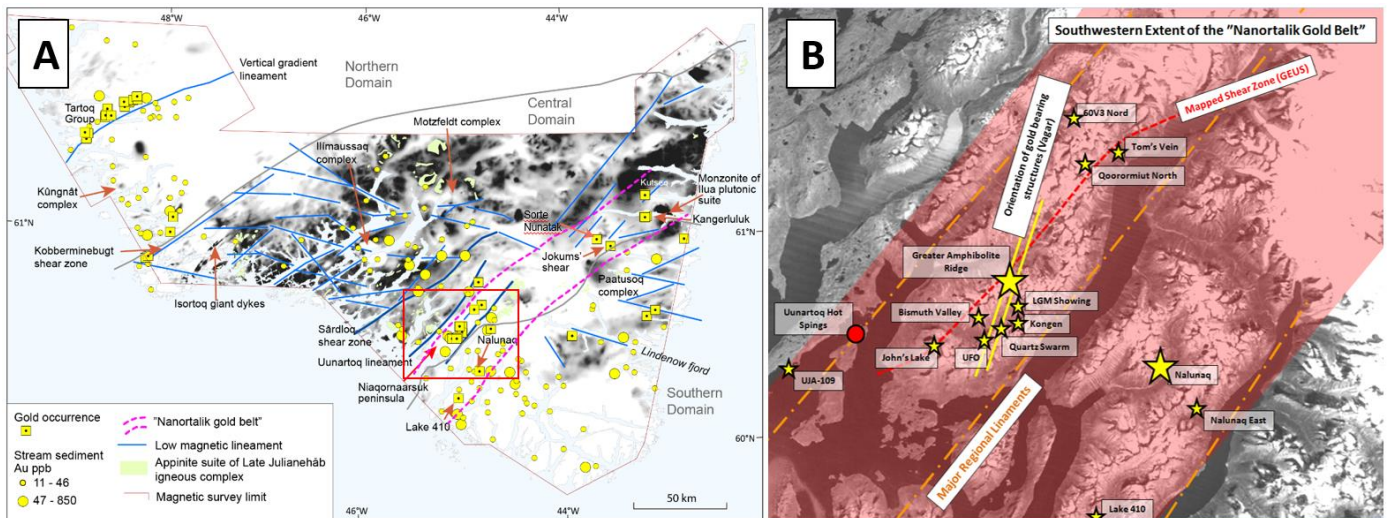
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Greenland's economy relies heavily upon fishing, hunting and tourism, but increasing emphasis is being placed upon the development of the country's mineral wealth. Mining has played an important role in the local economy of South Greenland for over a century including Nalunaq gold mine, 2004-2013; the Ivigtut cryolite mine, 1854-1987; the Amitsoq graphite mine, 1915-1924; the Josva copper mine, 1904-1915; and the King Frederik VII copper mine, 1851, and 1912 (e.g. Kolb *et al.*, 2016, 2017; Steenfelt *et al.*, 2016). One of the most densely populated parts of the country, South Greenland is located at a similar latitude (ca. 60°) to Oslo, Helsinki and Whitehorse. The region benefits from a well-developed infrastructure with an international airport (Narsarsuaq), as well as several heliports and harbours. The deep water fjords that bisect the region, generally remain ice-free throughout the winter months. The relatively mild climate would facilitate year-round mining operations.



**Figure 1:** (A) Location of the “Nanortalik Gold Belt” in South Greenland showing all know gold occurrences and stream sediment gold anomalies, adapted from Steenfelt *et al.*, 2016; (B) southwestern extent of the gold belt showing the location of gold occurrences on the Niaqornaarsuk Peninsula, as well as the location of Nalunaq gold mine. Note that the Greater Amphibolite Ridge area hosts the Vein I, Vein II, Femøren, Bella I/II, West Ridge, Crown, Kastrup, Ørestad, Øresund and Christianshavn gold occurrences.

At the current spot price the physical gold market accounts for 170 billion USD annually, with gold receiving more than half of the global mineral exploration expenditure. In this contribution we present recent exploration results from the highly-underexplored Nanortalik Gold Belt (NGB), a >150 km long and 50 km wide corridor of gold occurrences and anomalies with significant future gold resource potential. The NGB hosts Greenland's only commercially exploited gold deposit to date (Nalunaq gold mine; Kolb *et al.*, 2017; Hughes, J.W. *et al.*, this meeting). The alpine terrain of South Greenland offers a spectacularly well



exposed and essentially complete transect through a mid-crustal Palaeoproterozoic continental arc which was accreted along the southern margin of the West Greenland North Atlantic Craton (c.f. Hughes, H.S.R. *et al.*, this meeting) during the Ketilidian Orogeny. The multiphase Julianehåb Igneous Complex represents the plutonic component of the arc and covers more than half of the present exposure of the Ketilidian Orogeny. The NGB is located along the southern margin of Julianehåb Igneous Complex, with the overlying Southern Domain (previously divided into the Psammite and Pelite Zones), which represents a fore-arc basin with interbedded metasediments and metavolcanics (Fig. 1).

Previous explorers had neglected the gold potential of the granitoids of the Julianehåb Igneous Complex, notwithstanding the presence of unexplained gold anomalies. Their focus has been limited, directed by the geological setting of the 1.8 Ga Nalunaq deposit within hydrothermally altered metavolcanics of the Southern Domain. Recent exploration by the authors within granitoids on the Niaqornaarsuk Peninsula (the so-called "Vagar" area) has successfully located >18 individual targets with in-situ gold grades exceeding 10 g/t gold (Schlatter *et al.*, 2015; 2013). Sediment sampling defines several large, highly anomalous gold clusters. The >3 x 4 km Greater Amphibolite Ridge cluster hosts some of the strongest sediment gold anomalies in the whole of Greenland. Here orogenic gold mineralisation occurs as laminated quartz veins carrying up to 2533 g/t gold, hosted within hydrothermally altered granitoids, themselves mineralised up to 14 g/t gold. Channel sampling has returned up to 11 metres @ 80 g/t gold. Exploration within the southeastern extent of the NGB has resulted in a number of gold discoveries within Palaeoproterozoic plutonic and volcanic host rocks, e.g. Jokum's Shear, Sorte Nunatak and Kangerluluk (Schlatter and Hughes, 2014). Correlation of gold with As, Bi and Te is characteristic of the NGB.

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## **A multidisciplinary approach to exploration of extinct seafloor massive sulphide (eSMS) deposits in the TAG Hydrothermal Field, Mid-Atlantic Ridge (26oN)**

**Iain J. Stobbs**<sup>1,2</sup>, Berit Lehrmann<sup>2</sup>, Paul A.J. Lusty<sup>3</sup>, Sven Petersen<sup>4</sup> and Bramley J. Murton<sup>2</sup>

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It is widely thought that seafloor massive sulphide (SMS) deposits, the modern analogue of volcanogenic massive sulphide (VMS) deposits, present a potential global resource for base (Cu, Zn) and precious metals (Au, Ag). In addition, SMS deposits can be enriched in 'critical metals' including Ga, In, Tl, which are essential for many green- and high-technology applications. Globally over 340 high temperature hydrothermal sites have been identified in a range of oceanic spreading environments with significant massive sulphide deposit formation recorded at 165 of these sites<sup>1</sup>. Due to the elevated temperatures and unique biota at active deposits, extinct SMS (eSMS) deposits are the main focus of current exploration, but pose a more difficult target.

Recent technological advances in underwater exploration equipment enables mapping and surveying of these EC deposits in greater detail, which is required to assess their resource potential. The EC-funded (FP7) Blue Mining project (604500), is the first research programme to undertake a large scale multidisciplinary investigation of eSMS deposits.

New geological and geophysical data was obtained with the aim of characterising eSMS deposits in three dimensions. This included: high resolution bathymetry (obtained by autonomous underwater vehicle - AUV), seismic reflection and refraction, 3D controlled source electromagnetics, robotic underwater vehicle (RUV) surveys and samples, and sediment cores. A key challenge for resource assessment is understanding the internal structure and composition eSMS, therefore the British Geological Survey's robotic seafloor drilling rig (RD2) was deployed to obtain core samples from the deposits. This combination of RUV surveying, coring and interpretation the bathymetric data proved effective for exploration, and resulted in detailed surface geological maps of two deposits within the TAG field.

Surface observation and mapping of the mounds, particularly fault scarps that dissect the flanks of both mounds, revealed a superficial cover of carbonate and iron-oxyhydroxides sediments, directly overlying oxide-coated sulphide material. Drilling the mounds verified this stratigraphy, but also identified a coherent layer of silica-rich 'jasper', reaching up to ~3m thick, and overlying unoxidised massive sulphides. This 'jasper' cap, which would not have been identified without subseafloor drilling is potentially very significant from a resource perspective, as it may protect the majority of the sulphide deposit from seawater oxidation.

This presentation highlights the effectiveness of combined geological and geophysical exploration for eSMS and the employed methodologies will help inform future, large scale, multidisciplinary exploration of deep sea resources.

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Ground Floor Plan of the Geological Society, Burlington House, Piccadilly

ROYAL ACADEMY  
COURTYARD

MUSTER POINT  
(outside Royal  
Astronomical  
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