

Applied Mineralogist

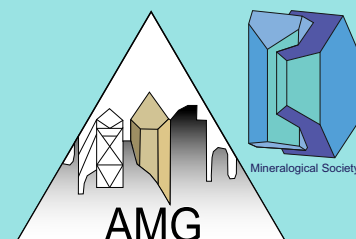
The bulletin of the **A**ppplied **M**ineralogy **G**roup

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From the AMG committee

Hello and welcome to the March edition of *Applied Mineralogist*! This edition contains a fantastic special feature on the use of microbes in the mining and processing of rare earth element deposits by Megan Barnett, Barbara Palumbo-Roe and Simon Gregory of the British Geological Survey. In addition, we have a student bursary report by Emily Fallon about her seafloor massive sulphides work. We also have a short roundup of what happened at MDSG 2017/18, plus dates of future conferences and events that are not to be missed. And last but by no means least we have our **#AppliedMineralogy** winner and some interesting facts to mull over with a cup of coffee.

AMG Committee Changes

Before you peruse this AM edition, we would like to draw your attention to some changes to the AMG committee. George Guice and Andrew Dobrzanski will be stepping aside to focus on finishing their PhDs - good luck chaps! Their work over the past couple of years has been exemplary, both running the AM bulletin and keen contributors to the @Amg_min Twitter. John Bowles will be stepping aside as Treasurer, but will remain an ordinary member of the committee and is passing the role onto Alicja Lacinska. New additions to the AMG committee include Richard Shaw (BGS), elected as an ordinary member, plus new student representatives William Smith (Cardiff University) and Eva Marquis (University of Brighton).

Would you like to become more involved in the AMG?

See how on page 4.

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AMG bursary report: *Emily Fallon*

The student bursary awarded by the AMG would have allowed me to attend the Mineral Deposits Studies Group (MDSG) conference in Brighton this January. Much to my dismay, I was too sick to attend, so my desire for ore related discussions will have to wait for another year! My talk was entitled '*The fate of SMS deposits, insights from natural and accelerated oxidation and implications for future mining activity*' and aimed to highlight the key findings of my PhD. With exploitation of seafloor massive sulphides (SMS) becoming a reality, it is important we fully understand both natural oxidation of deposits and how this affects their economic worth as well as any anthropogenically-enhanced oxidation and toxicity that may occur during mining.

Throughout my PhD I have analysed SMS deposits from a wide range of tectonic settings (high temperature vent, ultra-mafic hosted, back-arc rift, hot spot) and at various stages of evolution and oxidation to both assess toxicity potential and highlight the fate of metals throughout natural oxidation.

Cont. page 3



Ivanic (2002) Honours Thesis.

#AppliedMineralogy @ArchaeanGeo

This edition's winner of the #AppliedMineralogy tweet is by Dr Tim Ivanic (@ArchaeanGeo) about these beautiful garnets with double coronae from South Harris in the Outer Hebrides of Scotland.

"Here are some double coronae around garnets in the lovely meta-anorthosite of Roneval, South Harris, Outer Hebrides from my Hons mapping project for this #ThinSectionThursday [hornblende-play symplectite followed by retrograde zoisite in the inner coronae]"

To be in with a chance of seeing your tweet here use the **#ThinSectionTuesday** or **#MineralMonday** and you may be our next #AppliedMineralogy feature.

Special Feature: MicroMiners - the future potential of biomining.

Megan Barnett, Barbara Palumbo-Roe and Simon Gregory (British Geological Survey, Keyworth)

The human race has made use of the microbes around them since practices such as cheese making and brewing began. The discovery of the microbial world in the 1800s led to greater understanding and development of these processes and the era of classical biotechnology began. Biotechnology is the use of microbes and microbial products for the benefit of mankind, and modern biotechnology is of huge importance not only in medical industries, but also to produce fuels and remediate contaminated land. The main uses of microbes in the mining industry (biomining) are twofold: mobilising the metal of interest (bioleaching) or removing of the sulphide matrix leaving the metal of interest behind, such as iron in gold ores (biooxidation). Commercial copper sulphide biomining operations rely on the actions of acid-loving micro-organisms (acidophiles) to oxidise the ore. The most commonly studied acidophile is *Acidithiobacillus ferrooxidans*. All life needs an electron donor, an electron acceptor and a source of carbon. Bacteria have greater metabolic flexibility than us, so while *A. ferrooxidans* also uses oxygen as an electron acceptor, they do not need organic carbon to live. Instead they use carbon dioxide as a carbon source and a range of elements and minerals as electron donors. Of particular interest to bioleaching of sulphidic ores is ferrous iron and sulphur. The activity of the acidophiles maintains a low pH environment as they reduce sulphides to sulphate forming sulphuric acid. The low pH improves the solubility of copper and ferric and ferrous iron. More importantly, microbial activity accelerates the oxidation of ferrous to ferric iron. The rate of this oxidation would be otherwise very low at the acid pH level typically used in non-microbial sulphide leaching. Although bioleaching systems are continually being refined to improve the efficiency of leaching, in real terms

these microorganisms only need air to provide carbon dioxide and oxygen to leach. Therefore, the cost of biomining is lower than many other techniques facilitating commercially viable recovery from low grade ore.

Current commercial bioleaching focusses on sulphidic ores, however, ongoing research is expanding the potential ore body targets for biomining. One of these alternative processes is dubbed 'biomining in reverse gear' where microbes are used to leach oxidised ores such as nickel laterites [1]. The flexibility of microbes is highlighted by the fact that *A. ferrooxidans* can also grow without oxygen and can be used in this reverse process. Due to the lack of oxygen, a different electron acceptor is needed by the microbes, as thus sulphur is often added to the ore to facilitate this. Another bioleaching approach is to use microbially produced acids. These can either be inorganic acids such as sulphuric acid produced by *A. ferrooxidans* or organic acids. In contrast to the organisms mentioned so far, organic acids are produced as a metabolic by-product of microbes that use organic carbon as both a carbon source and electron donor. Microbial organic acid production is exploited commercially for the production of citric acid by *Aspergillus* fungi, and the use of waste material has been proposed as an organic carbon source for bioleaching processes. Both inorganic and organic acids have the

potential to mobilise metals by dissolution of the matrix. In addition, organic ligands can stabilise certain species in solution enabling recovery.

Here, at the British Geological Survey, we are looking into alternative sources of rare earth elements (REE), and the potential of biomining and bioprocessing as part of the NERC funded SoSRARE project (<https://www.bgs.ac.uk/sosRare/home.html>). Current REE supply relies heavily on Chinese imports, and there is a growing interest in diversifying the sources of REE and processing techniques. The potential for bioleaching of REE is dominated by organic acid processing and has been applied to red muds, ion adsorption deposits (IAD) and monazite sands [2]. Ion adsorption deposits have a portion of their REE sorbed to their surface, these can be easily leached by salt solutions, which exchange for REE at the surface of the IAD. Salt leaching is currently used in commercial operations in China. Our investigations into bioleaching of REE from laterites have shown similar leaching efficiencies to an ammonium sulphate salt solution. However, the higher cost of the leaching fluid (i.e. organic matter) compared to salt solutions and time required to produce a suitable leaching solution, means that bioleaching of laterites may only be suitable in niche situations where a waste organic carbon source (as a feedstock for microbes) is in plentiful supply. We

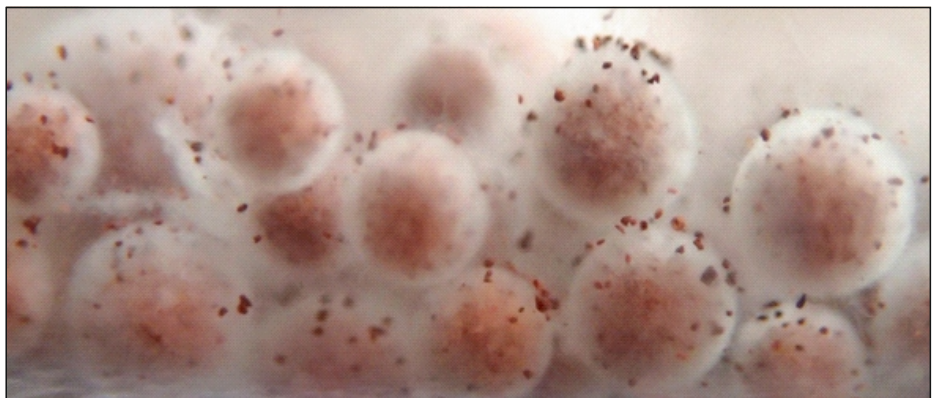


Figure 1. *Aspergillus* spheres growing in the presence of powdered bauxite for 5 days, spheres are 3-4mm diameter.

have recently shifted our attention to material where, due to association of REE within mineral structures, salt leaching is not effective. Figure 1 shows the growth of *Aspergillus* in the presence of powdered bauxite after 5 days. The advantage of using material such as bauxite for bioleaching is the potential to add value to a material already destined for alumina extraction via the Bayer process.

Commercial biomining operations use a relatively small number of microbial species. The diversity of microbes and microbial processes provide a wealth of potential novel mechanisms by which microbes could contribute to mining operations for leaching, processing and remediation. The potential for microbial processing is being explored through research but issues such as scaling and

industrial acceptance are needed to explore its full potential.

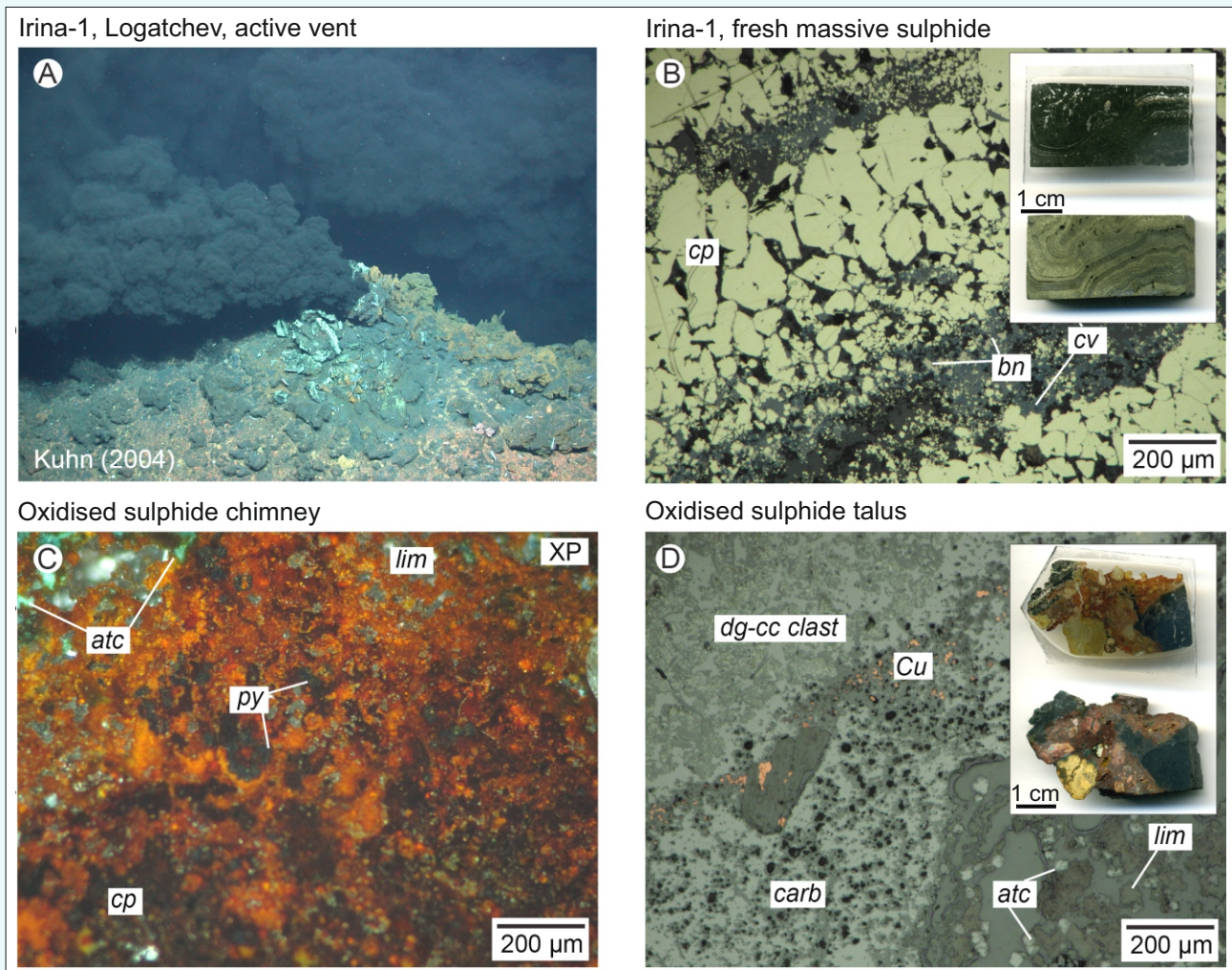
References:

- [1] Johnson, D. B. and Du Plessis, C. A., 2015. Biomining in reverse gear: Using bacteria to extract metals from oxidised ores. *Minerals Engineering*, **75**, 2–5. doi:10.1016/j.mineng.2014.09.024
- [2] Barmettler, F., Castelberg, C., Fabbri, C. and Brandl, H., 2016. Microbial mobilization of rare earth elements (REE) from mineral solids - A mini review. *AIMS Microbiology*, **2**(2), 190 - 204. doi:10.3934/microbiol.2016.2.190.

AMG Bursary Report: Emily Fallon cont.

Following this, experiments designed to simulate the mining process were undertaken with a selection of these natural samples, allowing assessment of accelerated oxidation and metal release. Toxicity was evaluated by comparing experimental concentrations to tolerance levels of species at active vent sites.

The results of my analyses and experiments highlight Zn, Cu, and Cd to be the metals of most concern in terms of toxicity. Leaching experiments indicate that the potential for localised toxicity is significant and requires thoughtful consideration prior to mining activity in the future.



Figures A-D. A series of photographs highlighting the natural oxidation of seafloor massive sulphides observed at the Logatchev-1 hydrothermal vent site along the Mid-Atlantic Ridge: **A)** Seafloor photo of the Irina-1 active vent observed at Logatchev-1; **B)** Fresh massive chalcopyrite observed at Irina-1; **C)** Oxidised sulphide chimney found in the north-west of the Logatchev-1 field where relict chalcopyrite and pyrite are observed in the core of the chimney within a matrix of limonite and atacamite [cross-polarised (XP) reflected light image]; **D)** Oxidised sulphide talus found in the east of the Logatchev-1 field, where sulphide and limonite clasts are sat in a matrix of carbonate. Sulphide clasts are composed of predominantly secondary copper sulphides and atacamite is commonly observed in pore spaces, along rims and within fractures. Native copper is observed along chemical boundaries where grains of sulphide are dissolving (reduced areas) and are exposed to oxygenated seawater, forming limonite and carbonate. *Mineral abbreviations include: atc* (atacamite), *bn* (bornite), *carb* (carbonate), *cc* (chalcocite), *cp* (chalcopyrite), *cv* (covellite), *dg* (digenite), and *lim* (limonite).

Other news in brief

MDSG round-up

The Mineral Deposits Studies Group AGM in January hosted over 180 attendees. The quality of student presentations was, as always, exceptionally good. Student prizes included Laura Ward for her MGeol thesis on the use of magnetite as a geochemical indicator in the exploration of magmatic Ni-Cu-PGE sulphide deposits (see publication in Journal of Geochemical Exploration, volume 188). The student oral presentation prize was split this year between Daryl Blanks and Laura Ward (both of the University of Leicester) for their presentations on the sulphide mineralisation of the Munali magmatic megabreccia, and magnetite as a indicator mineral, respectively. Also two best student poster prizes were awarded to Hannah Stephenson from Cardiff University for her work on mineralisation in the Platreef at Turfspruit, Bushveld Complex, South Africa; and Lisa Hart from Imperial College London (also previous recipient of the AMG Student Bursary in 2017) for her work using titanite U-Pb petrochronology to distinguish between multiple episodes of alteration at the Oyu Tolgoi porphyry Cu-Au district in Mongolia. We thank the Martin Smith and his Brighton conference committee for organising such a successful MDSG.

Prizes and Awards in the AMG community

Congratulations to our very own AMG Chair, Dr Hannah Hughes, who has been awarded the 2018 William Smith Fund from the Geological Society of London in recognition of her research excellence.

Notices

Get Involved

If you would like to become more involve in the AMG please consider becoming a committee member.

Coffee break small-talk

- The smallest known metallic asteroid that is an “accessible near-Earth” object has 40 times as much metal as all the metal mined in Earth’s history.
- Antimatter is the most expensive substance in the world, with NASA pricing it at \$62.5 trillion per gram in 1993 (or \$91.83 trillion in today’s money), as a high-energy particle collision facility (such as CERN) dedicated to their production could only produce 1 billionth of a gram per year.
- A typical smart phone contains approximately 0.014 g of gold.

About Us: Founded in 1963 by Norman F.M. Henry, the AMG is a special interest group of the Mineralogical Society of Great Britain and Ireland. We encourage and promote the study and research of mineralogy applied to ores and related industrial mineral materials. This encompasses: ore microscopy, fluid inclusions, nuclear minerals, coals, refractories, slags, ceramics, building materials, nuclear waste disposal, carbon capture and storage, down-hole borehole alteration, and mineral-related health hazards.

Elections are held yearly at the AGM. In particular, spaces for Student Representatives come up regularly. If you would like to be considered for a committee spot please email Eimear Deady (amgminsoc@gmail.com).

AMG Postgraduate Bursaries

The AMG provides bursaries for postgraduate students in the disciplines of *Applied Mineralogy, Crystallography, and Petrology and Geochemistry*. Bursaries are intended to support conference attendance and associated travel costs, although other activities may be considered. Further details and the application form for the bursary can be found on the AMG website at <https://www.minersoc.org/amg-bursaries.html>

Please note there are two bursary application deadlines each year: 1st March and 1st September. Requests for funding must be received at least 8 weeks in advance of the event to allow for consideration by the committee.

Funding

We welcome applications from both individuals or organisations for funding in support of events covered in the AMG remit. Further guidelines on how to apply for this funding can be found on the AMG website at <https://www.minersoc.org/amg-funding.html>

Editorial

Thank you to all those who have contributed to this issue of Applied Mineralogist. Please forward any articles, comments or notices of events, conferences and workshops to amgminsoc@gmail.com before the 31st May so they may be included in the next bulletin. All previous issues of Applied Mineralogist are available to download from <https://www.minersoc.org/amg-applied-mineralogist.html>

Calendar

- APR '18**
8 - 13 European Geosciences Union General Assembly 2018, Vienna, Austria.
- JUN '18**
16 - 21 Resourcing Future Generations, Vancouver, Canada.
- JUL '18**
30 - 6 Platinum Symposium and Layered Intrusion workshop, Mokopane, South Africa.
- JUL '18**
10 - 13 Granulites and Granulites 2018, Ullapool, UK
- AUG '18**
13 - 17 XXII Meeting of the International Mineralogical Association, Melbourne, Australia.



Interested in joining the Mineralogical Society and Applied Mineralogy Group? Go to: <http://www.minersoc.org/> for membership details.

