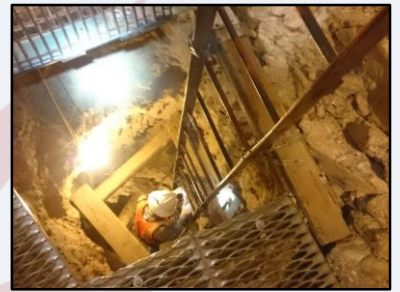


3rd Annual SEG Student Chapter Spring Meeting



*25th & 26th March, 2019
Old Council Chamber
Wills Memorial Building*



**Two days of
student and
industry talks
on all aspects
of economic
geology**



Litho Economics

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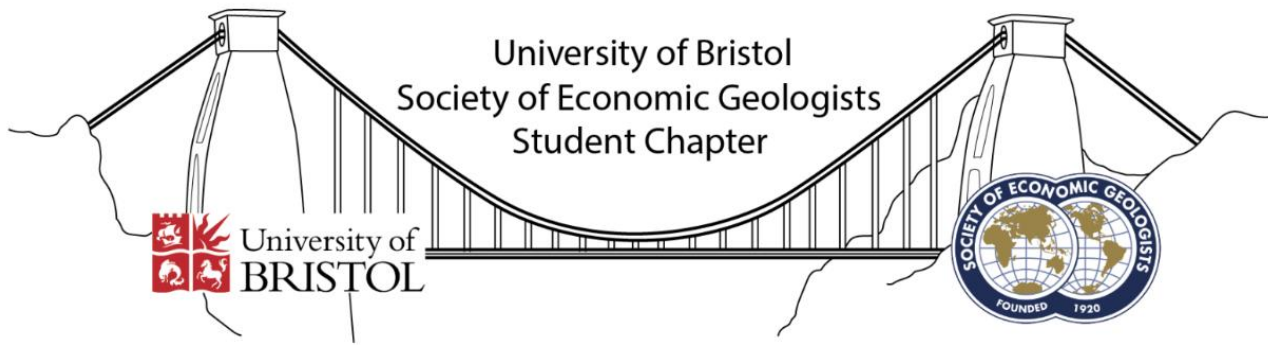


wood.

**W WOMEN
M IN MINING**



Cornish Lithium



3rd Annual SEG Student Chapter Spring Meeting

Bristol SEG are pleased to welcome you to the 3rd Annual Spring Meeting - an event which brings together students and mining professionals from across the UK and Europe, with a shared interest in economic geology. We would like to thank SEG and the Mineral Deposits Studies Group (MDSG) for financially supporting this event and the following companies for providing speakers: SRK Consulting, Cornish Lithium, Litho Economics and Wood Plc. We are also proud to have representatives of SEG and Women in Mining giving talks at this event and are pleased to be showcasing a broad variety of student research.



W WOMEN
M IN MINING



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Litho Economics

Icebreaker at the Lost & Found 19:00, Sunday 24th March

If you are arriving in Bristol over the weekend, we would like to invite you to an informal icebreaker at the Lost & Found pub, near to the University. We have a space booked and members of Bristol SEG will be there to welcome anybody who would like to join us over a beer.

Address: 85 Queens Road, BS8 1QS



The Spring Meeting Monday 25th & Tuesday 26th March

The Spring Meeting will be hosted in the Old Council Chamber, on the first floor of the Wills Memorial Building (shown on map above).

Address: Wills Memorial Building, Queens Road, BS8 1RJ

Spring Meeting Programme

Monday 25th March

- 09:00 Conference registration and refreshments outside the Old Council Chamber (1st floor of Wills Memorial Building)
- 09:30 Welcome to the Spring Meeting (Joseph Shaw, President of Bristol SEG and Dr Frances Cooper, Academic Sponsor for Bristol SEG)
- 09:45 Opening address + invited lecture. A career in economic geology – A great way to see the world and save the planet (Professor Paulick Holger, SEG Vice President for Europe and Head of Department for Raw Materials/Mineral Resources at the Geological Survey of Austria)
- 10:30 SEG Student Chapter activity summaries (~5 minutes per Chapter)
- 11:15 Refreshments
- 11:30 Artisanal miners: Activities and impacts on the formal mining sector (Mark Davis, Industry Sponsor for Cardiff SEG and Director/Geoscientist at Litho Economics)
- 12:05 Work experience in mining: Exploration in Eastern Europe (Ed Bunker, University of Bristol)
- 12:20 Starting out in exploration: Exploring with Rio Tinto in Serbia (Zafiri Theodorou, University of Bristol alumnus)
- 12:35 The Precious Metal Epithermal System at Tlamin, Serbia: A study of the Barje area (Lucy Blain, University of Leicester)
- 12:50 Lunch (room 1.5, opposite refreshments table on 1st floor landing. Lunch kindly sponsored by the Mineral Deposits Studies Group)
- 14:00 Nickel mineralization in the hydrothermally altered serpentinites (listwaenites) near the Stan Terg mine, Vardar zone, Kosovo (Szczepan Bal, University of Science and Technology, Krakow)
- 14:15 The behaviour of metals and volatiles during protracted magma differentiation from the deep to upper crust (Oliver Higgins, University of Geneva)
- 14:30 A new metal from an old mining area – Lithium exploration in SW England (Hester Claridge and Lucy Crane, Cornish Lithium and Women in Mining)
- 15:05 Refreshments
- 15:20 Rhenium - a little love for the lesser known commodity (Krzysztof Foltyn, University of Science and Technology, Krakow)

- 15:35 Spatial Variation and Mineral-Chemical Associations of Gold in the Tuvatu Deposit, Fiji (Alex Petts, University of Leicester)
- 15:50 Volcano deformation or atmospheric signals? Re-evaluating magma systems of Agung volcano, Indonesia, based on InSAR observations (Stanley Yip, University of Bristol)
- 16:05 The benefit of incorporating geological and structural data in mineral resource estimation (James Williams, SRK Consulting)
- 16:20 End of session/reminder of networking event and conference dinner

Break

- 17:30 SWIGS Networking event at the White Harte pub: 54-58 Park Row, BS1 5LH (Information overleaf)
- 19:30 Conference dinner at River Cottage Kitchen: St Johns Court, Whiteladies Road, BS8 2QY (Information overleaf)

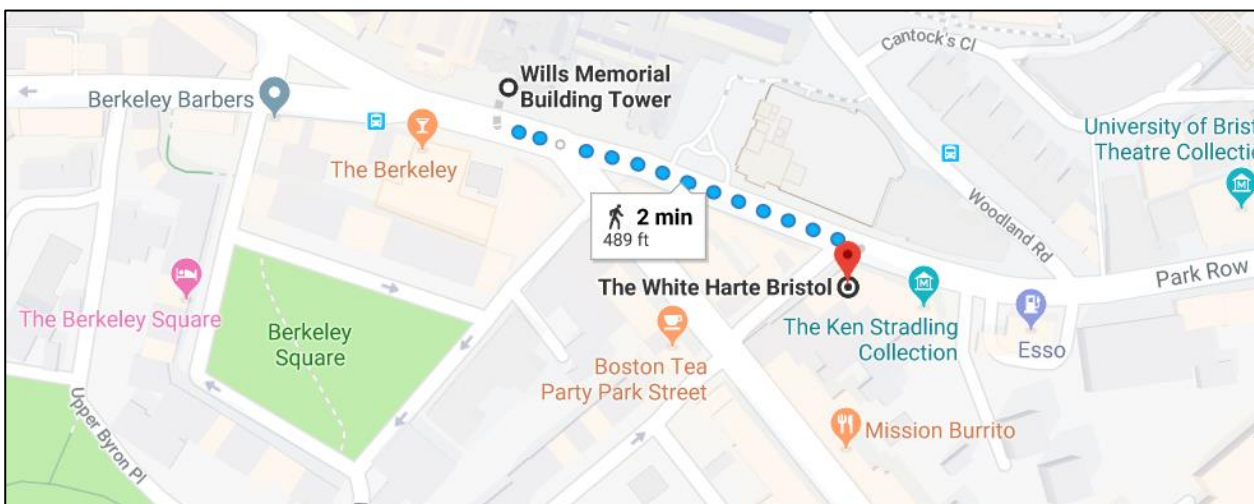
SWIGS networking event @ The White Harte

17:30-20:00, Monday 25th March

Following the talks on Monday there will be a networking event organised by Bristol SEG and the South Wales Industrial Geoscience Sundowner (SWIGS) group. The Sundowner will be hosted in the upstairs room of the White Harte, over the road from the Wills Memorial Building. Attendees of the Spring Meeting will be joined by geoscience professionals from across the southwest for an informal networking event.

There will be a 10% discount on drinks for conference participants!

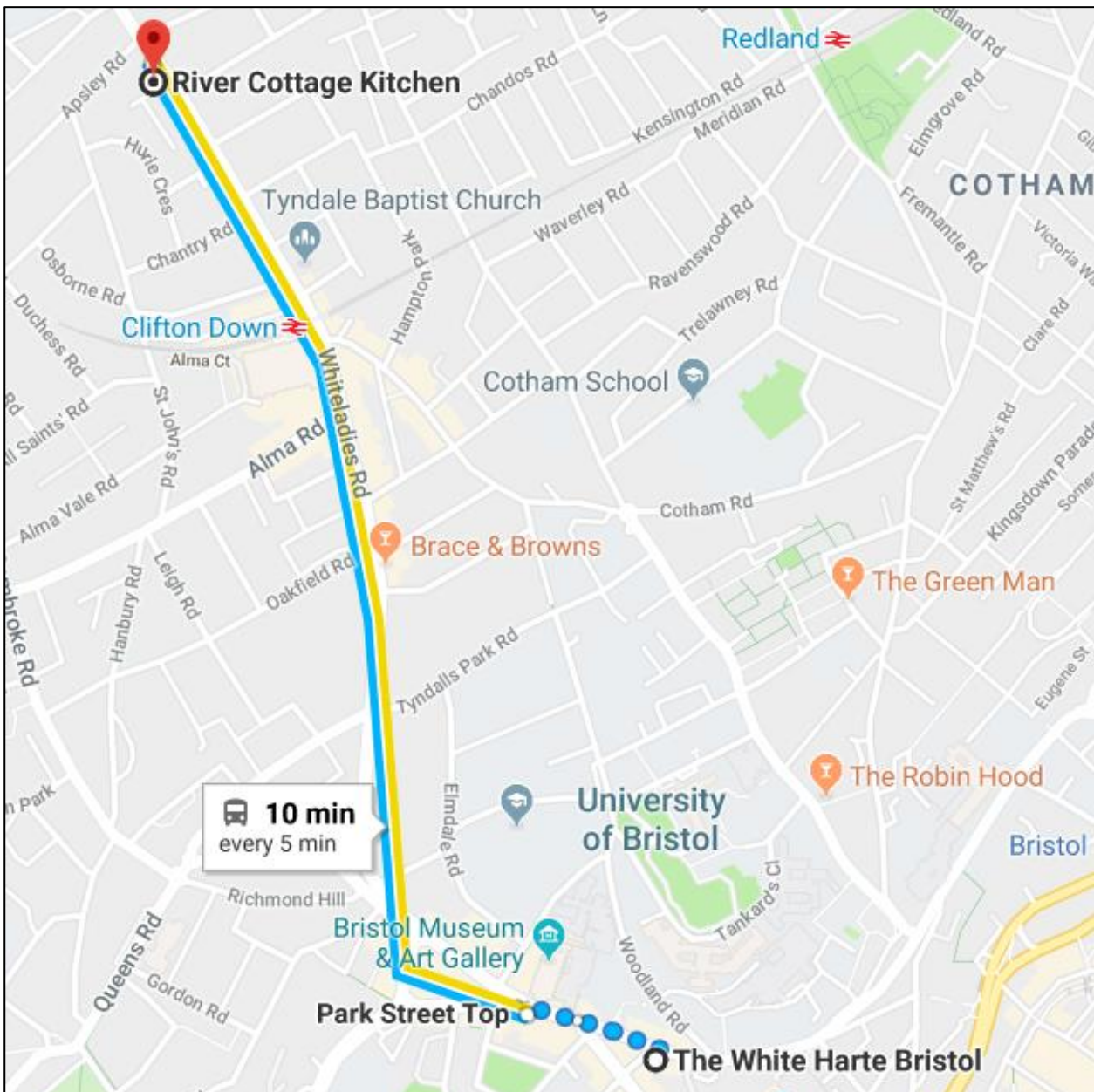
Address: 54-58 Park Row, BS1 5LH



Conference dinner @ River Cottage Kitchen 19:30, Monday 25th March

The conference dinner will be held at River Cottage Kitchen on Whiteladies Road. To get from the Sundowner to the dinner is a 10 minute bus journey (number 1 or 2) or a 20 minute walk (map below). The SWIGS networking event will continue at the White Harte for anyone not attending the dinner.

Address: St Johns Court, Whiteladies Road, BS8 2QY



Tuesday 26th March

- 09:00 Refreshments outside the Old Council Chamber
- 09:30 Geometallurgy: The Importance of Discipline Integration in Mineral Projects (Matthew Field, Wood Plc)
- 10:00 Structural evolution of the Northumberland Trough during the Lower Carboniferous and implications for lead-zinc mineralization potential (Alex Jenkins, University of Bristol)
- 10:15 Pb-Zn-Sb mineralization in the Kizhnica-Janjevo area, central Kosovo (Sławomir Mederski, University of Science and Technology, Krakow)
- 10:30 Refreshments
- 10:45 Potential economic by-products in copper porphyries: Silver in the Ascutita Cu-porphyry, Romania (Adam Eskdale, University of Leicester)
- 11:00 Volcanic-magmatic breccias (Richard Turley, University of Bristol)
- 11:15 Water table movement and supergene enrichment at Spence porphyry copper deposit, northern Chile (Joseph Shaw, University of Bristol)
- 11:30 Refreshments
- 11:45 Invited lecture: Gold exploration in Africa (Dr Bob Foster, past SEG President and Director of Bob Foster & Associates Ltd)
- 12:35 Closing address (Dr Bob Foster)
- 12:45 End of Spring Meeting (Joseph Shaw)
- 12:50 Lunch (kindly sponsored by the Mineral Deposits Studies Group).
Conference participants to travel on their own schedules
- 13:00 **OPTIONAL SCHOOL SEMINAR**
Sediment Control on Subduction Plate Speeds (Professor Whitney Behr, ETH Zurich)
- 14:00 **OPTIONAL SEG STUDENT CHAPTER PLANNING MEETING**
Discussion forum for future collaborative field trips and activities

Abstracts

The following pages contain abstracts for all of the student talks...

The Precious Metal Epithermal System at Tlamino, Serbia; a study of the Barje area.

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In recent years Eastern Europe has become increasingly accessible to geological exploration by international companies, such as Medgold Resources Corporation, revealing new metalliferous prospects across the region. Serbia, a landlocked country neighbouring Romania, Bulgaria and Albania, sits within the Serbo-Macedonian Massif (SMM), a metalliferous composite of highly metamorphosed crystalline terranes^[1] constituting a portion of the Alpine-Balkan-Carpathian-Dinaride Province (ABCD)^[2]. The ABCD hosts a large proportion of Europe's gold and copper deposits ± Pb-Zn-Ag^[2], associated with strong deformation from both Variscan and Alpine orogenies^[1].

Serbia is currently under investigation by numerous companies including Medgold Resources Corp. Medgold's prospects include several areas of gold mineralisation, suspected to be epithermal in nature. At Barje, mineralisation is associated with shallow-angle faulting in units of, Cambrian aged Vlasina Schist^[1]. Mineralisation includes sphalerite (sph), galena (gl), pyrite (py), arsenopyrite (asp) and minor chalcopyrite (cpy), with precious metals being associated with arsenopyrite and pyrite according to Laser-Ablation^[3].

The strongest concentrations of gold at Barje have been located within horizons of intense hydrothermal brecciation associated with faulting cutting the host Vlasina Schist. Angular schist clasts are sparse, with sulphide mineralisation present within a dark-sulphide rich matrix. Gold and base metals are enriched in mineralised veins above ore horizons, with little gold present in schist units below the breccias.

Due to the abundant faulting in the area, including the Crnook detachment^[3], it was theorised that the brecciation zone may represent a fault plane, which has transported strong mineralisation and massive sulphide clasts from depth. However, chemical and petrographic studies have shown a strong relationship between the schists above and below the hydrothermal breccia ore horizon, therefore faulting provided the pathway for fluid rather than relocating mineralisation.

The varying ratios of base and precious metals within the epithermal area, suggests a complex evolution of fluids. Comparisons of gold to base metals, and petrographic relationships, have suggested a minimum of two stages of mineralisation: (1) gl and sph mineralisation occurring first, shown by a stage of deformation in gl, followed by (2) py, asp and then minor cpy replacing earlier phases. Previous laser-ablation^[4] studies suggested an association of gold to asp and py which has not been confirmed in this study using SEM, however there appears to be a strong correlation between arsenic and gold concentrations within hydrothermal breccia samples.

References

- ^[1] Antić, M.D., Kounov, A., Trivić, B., Spikings, R. and Wetzel, A., (2017). International Journal of Earth Sciences, 106, p1665-1692.
- ^[2] Heinrich and Neubauer, (2002). Mineralium Deposita, Volume 37, Issue 6–7, p 533–540.
- ^[3] Walding, S., (2018). Unpublished masters project, University of Leicester.
- ^[4] Sillitoe R., (2016). Report prepared for Medgold Resources.

Nickel mineralization in the hydrothermally altered serpentinites (listwaenites) near the Stan Terg mine, Vardar zone, Kosovo

Bal, S., Pršek, J.¹, Adrianna Wojnarowska, A.¹, Asllani, B.¹

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Kosovo is characterized by rich occurrences of polymetallic deposits with economic importance. The most important one are hydrothermal type of Zn-Pb deposits with addition of Au-Ag (Cu, Bi, Te, Sb). The aim of my research is to characterize nickel mineralization in the broad Stan Terg mine-area in Vardar Zone.

Vardar Zone is elongated belt extending from Bosnia through Kosovo, Macedonia and Greece to Turkey in the NNW-SSE direction. It is interpreted to be a transitional zone between Serbian-Macedonian massif from the east and Dinaric Alps from the west. It was formed during the late Cretaceous closure of Neo-thetys ocean basin, as a result of the Adria and Eurasia craton collision. Vardar Zone mainly consists of marine and continental sedimentary rocks which are characterized by different grade of metamorphic and tectonic deformation. Additionally as a result of continental collision, younger acid rocks intruded into the sequence. Age of this volcanic rocks is between late Cretaceous period and Miocene [1]. This structure consist of fragment of Paleozoic crystalline rocks discordantly lying on the Triassic clastic rocks and upper Triassic carbonates. Jurassic rocks are mainly consist of ophiolite sequence. Cretaceous strata is represented by clastic series. During the Oligocene and Miocene period, huge volcanic activity took place. This rocks were intruded in the old sequences and they often exhibit different chemical composition. In the areas where igneous andesite/latite rocks intruded into serpentinites, listwaenite were formed [2]. In Kosovo part of Vardar Zone Trepca Mineral Belt as the main metallogenic unit was recognized. This belt is one of the most important area with Zn-Pb ores in Europe. His length is above 80 km and start in the northern part of Kosovo[3].

Samples for research were collected close to the Melenica village, 5 km on the north from the famous Stan Terg mine. On the outcropping listwaenite type of mineralization, small thin veinlets with Pb-Zn mineralization as well as barite occurs. Hydrothermal mineralization occur in hydrothermally altered serpentinites on the contact with volcanic rocks. The zone is more than 50 m thick and more than 2 km long. The main filling of hydrothermally altered zone are highly silicified rocks with greenish Cr bearing micas, carbonates, disseminated sulphides and sulpharsenides. Ore mineralization occur in form of thin veinlets up to 1 cm thick together with carbonates, quartz and barite. Our research was focused on the microscopic examination in the reflected light. Our research gives us information about composition, structures, textures, relationship between ore minerals and the gangue minerals. We identified following minerals in our samples: pyrite, galena, chalcopyrite, niccolite, gersdorffite, millerite, pentlandite, sphalerite, Pb-Sb sulfosalts, hematite, Cr-bearing spinels and quartz, carbonates and Cr-bearing micas. Mineralization is usually disseminated, sometimes thin sulphides veinlets occur. Ore mineralization in listwaenites was formed in two stages. The older stage (Ni stage) is is represented by sulphides and arsenides of Fe-Ni: millerite, gersdorffite, niccolite and piryte/marcasite. The younger phase is typical by presence of galena, sphalerite, chalcopyrite as well as Pb-Sb sulphosalts. Ore minerals usually occur as small individual grains of different size – from 50 up to 500 µm. Some of the minerals could not be precisely identified only at the base of microscopic study, for the better identification we will be used EDS or EMPA analyses. On the base of microprobe data we will be able to identified minerals from the different groups, check their chemical composition and changes in the microlements content as well as check the solid-solution in some minerals which is typical for the hydrothermal deposits.

References:

[1] Zelic et al., (2010)

[2] Hyseni et al., (2010)

[3] Kolodziejczyk et al., (2012)

The behaviour of metals and volatiles during protracted magma differentiation from the deep to upper crust

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The processes of cooling, crystallising and degassing during the differentiation of a silicate melt at a subduction zone produce four magmatic phases: residual melt, silicate crystals, aqueous fluids and solid sulphides. The formation of a porphyry copper deposit (PCD) relies on the enrichment of Cu, Cl and S, key ore-forming ingredients, within the residual melt and aqueous fluid phases during differentiation [1]. However, the ideal magma differentiation history for the generation of a Cu-fertile system in a subduction zone setting remains elusive [2].

Here I use Monte Carlo style numerical modelling to show that the formation of a PCD is contributed to by both a favourable source chemistry and optimised processes during differentiation. The effects of pressure, temperature, and initial quantity of Cu, Cl and S are explored. The new parameterisation of Cl partitioning between aqueous fluid and silicate melt is tested using an incremental degassing model [3].

This study effectively links deep (lower crustal) differentiation with the chemistry of exsolving fluids in the upper crust. Cl largely modulates the extraction efficiency of a given melt meaning that even melts with moderate Cu have the potential to release relatively Cu-rich fluids should they contain high Cl-concentrations. The role of S is characterised, an element often neglected from other numerical models of PCDs. Numerical model results can reproduce the liquid line of descent for Cu from a wide variety of global arcs [4].

These findings reinforce the conclusion from ref 3 that melt chemistry at the onset of fluid saturation, largely controlled by deep crustal processes, is fundamental for determining ore-fertility in exsolving fluids.

References:

- [1] Richards, J. P. (2011) *Ore Geology Reviews* 40.1: 1-26
- [2] Chiaradia and Caricchi (2017) *Scientific reports* 7: 44523.
- [3] Tattitch et al., in review
- [4] Chiaradia, M (2014) *Nature Geoscience* 7.1: 43.

Cornish Lithium: A New Metal From An Old Mining Area – Lithium exploration in SW England Crane, L.¹, Claridge, H.¹ Matthews, A.¹

¹Cornish Lithium. l.crane@cornishlithium.com Tremough Innovation Centre, Penryn, Cornwall, TR10 9TA

Cornwall was a major European producer of tin and copper from the Bronze age, but the remaining mines closed shortly after 1985 due to the international tin market crash – rather than a lack of ore. By using modern, sustainable, exploration techniques, Cornish Lithium are recognising new opportunities within the county.

The progress of some deep mines in Cornwall, such as United Mines (500m below the surface), was impeded as deep levels were inundated by hot water (up to 50°C) flowing from permeable faults and dykes. Geochemical analysis of these fluids has identified lithium present in elevated concentrations (50 – 220mg/l Li) in many hot springs throughout Cornwall. The fluid compositions are also similar over a large geographic area, indicating that fluid production is likely a regional phenomenon.

Cornish Lithium believes that this source of lithium can contribute to both global supply and European resource security. As the world transitions towards a low carbon future powered by renewable and green energy and driven significantly by the increasing demand for electric cars, the global demand for lithium is predicted to increase to 785,000 t Lithium Carbonate Equivalent (LCE) by 2025 (Roskill), from 217,000t LCE in 2017 (Reuters).

To understand the distribution of lithium enriched geothermal fluids, Cornish Lithium is using a range of modern exploration techniques and digital modelling to build a 3D fracture network of Cornwall to map the potential lithium bearing fluids. The industry must discover new sources of lithium to satisfy demand, and so understanding the distribution of these lithium bearing geothermal fluids, and the structural features that control them in 3D, is vital for Cornish Lithium's exploration success.

Rhenium – a little love for the lesser known commodity

Foltyn, K.¹

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Although rhenium is one of the rarest and most dispersed elements in the Earth's upper crust with an average concentration below 2 ppb [1], it plays a huge role in ore geology as rhenium–osmium (Re–Os) chronometer is a powerful method for dating ore minerals directly. For a long time, it was believed that rhenium does not form its own minerals but occur only as a substitution in sulphides, until the first rhenium mineral rheniite (ReS₂) was found and described in the 1994 [2].

An annual production of this metal, used mainly for jet engines superalloys and for catalyst in petrochemistry, do not exceed 50 tons and is almost exclusively a by-product of a copper mining. The most important sources of rhenium are Cu-Mo porphyry deposits, responsible for around 80% of the primary production [3]. Rhenium occurs mainly as a substitution in molybdenite (MoS₂) which in the case of porphyry copper deposits usually contain 100-3000 ppms of Re. In some cases, even higher concentrations up to 4.7 wt% of Re were noted [4] and in my studies, molybdenite samples from the Maronia Cu-Mo porphyry deposit in Northern Greece show 0.8 wt% of Re on average.

Remaining 20% of primary rhenium production is extracted from sandstone-type sediment hosted copper deposits in Kazakhstan and from reduced-facies (Kupferschiefer)-type sediment hosted copper-silver deposits in Poland [1]. Little is known about rhenium occurrence in these deposits, host minerals and processes responsible for rhenium enrichment remains poorly understood. The black Upper Permian Kupferschiefer hosts the largest copper and silver deposits in Europe which occur along the southern margin of the Zechstein basin (Lubin-Sieroszowice deposits in Poland) and are stratigraphically positioned between the underlying siliciclastic red beds (Rotliegende) and the Zechstein limestones. Sandstone-type strata-bound copper deposits in the northern Chu-Sarysu basin in central Kazakhstan also contain significant concentrations of rhenium. They consist of copper sulphides forming intergranular cement and replacing detrital grains in sandstone and conglomerate within a Carboniferous red-bed sequence. Box [5] presented the most comprehensive description of these deposits, including data regarding rhenium concentrations and spatial distributions, although the mineralogy of rhenium there is still poorly understood.

There are several proposals which phases are the main host of rhenium in sediment-hosted deposits. Kucha [6] declared that molybdenum bearing minerals (mainly castaingite) are the principal host of rhenium in the Kupferschiefer but he didn't back his claim with substantial data. Banaś [7] also emphasize rhenium substitution in molybdenum sulfides but he points out that minor amounts of total Re are hosted by kerogen and metalorganic complexes. According to his study, average content in the deposit is 0.5-1 ppm while in the footwall of the copper shale locally increases to 10-32 ppm. Dzhezkazganite, rhenium bearing mineral has been reported in the deposits in Kazakhstan but it has not been officially recognized by the International Mineralogical Association yet. Significant amounts of rhenium may be present in copper-iron sulfide minerals and our results show that chalcocite from the Kupferschiefer deposit contains... ppm of Re.

References:

- [1] John DA et al. (2017) Rhenium, chap. P, USGS Professional Paper 1802, <https://doi.org/10.3133/pp1802P>.
- [2] Korzhinsky MA et al. (1994) *Nature* 369(6475): 51
- [3] Ober JA (2017) Mineral commodity summaries 2017. USGS: 136-137
- [4] Melfos V et al. (2001) *Bull Geol Soc Greece* 34:1015-1022
- [5] Box SE et al (2012) *Econ Geol Spec Pub* 16:303-328
- [6] Kucha H (1990) *Geologische Rundschau* 79(2):387-399.
- [7] Banaś M et al. (1997) *Monografia KGHM Polska Miedź SA*: 258-271.

Spatial Variation and Mineral-Chemical Associations of Gold in the Tuvatu Deposit, Fiji

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¹ School of Geography, Geology and the Environment, University of Leicester, Leicester, LE1 7RH
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A common source of gold and tellurium is epithermal deposits, hosted in alkaline and calc-alkaline rocks (e.g. Cripple Creek); these deposits are often enriched in key elements such as Bi, Pb, Te, Pt as well as extensive amounts of Au. Along a 250km lineament, Fiji hosts a suite of mines including the world class Vatukoula (a.k.a. Emperor) deposit on Viti Levu. This deposit has been well studied, but a neighbouring deposit, Tuvatu, has remained untouched with little information being known about it until the last decade.

It's estimated that there is 13 t of Au [1] hosted within the monzonitic rocks and volcanic Nadele Breccia around the Tuvatu caldera, with enrichments in Te, Bi, Ag and Au. This gives rise to the possibility of gold and silver tellurides as well as the opportunity for bismuth tellurides as new sources of gold and tellurium for the global markets. By understanding the relationship between Au, Ag and Te and the processes behind it that have caused these enrichments it is hoped that this can be applied to other geological settings around the planet.

Lion One Metals, the current operators of the Tuvatu gold deposit in Fiji, have provided a dataset of drill core samples, along with detailed analysis and logging results. This detailed dataset in conjunction with a subset of samples collected from individual drill cores is being used to create a three-dimensional model of the ore deposit and this result will be presented in a GIS type format using Micromine. By creating this three-dimensional model, it allows for the examination of spatial and possibly temporal controls on ore grade, associations of grade, the chemistry and structure and will ultimately determine any opportunities to expand the footprint of the deposit and mining efforts.

Current research suggests that there is a relationship between As and Au with gold being hosted as inclusions and possibly in solid solution within pyrite. SEM analysis shows that calaverite often occurs as an inclusion on the inner margin of pyrite, whilst Au-Ag alloys (electrum) seems to be situated within quartz veins. By using Micromine, spatial correlations can be visualised, showing areas of higher gold and tellurium concentrations, and by knowing what its setting is we can apply the most effective extraction techniques.

With the results of the geochemical analysis, reflected light, petrography and SEM imagery it is possible to characterise a paragenesis and vein history for the area and from there utilise this information for a better extraction method to be employed. Not only does this aid the Tuvatu project but by understanding this relationship between alkaline volcanic rocks and the relative enrichments in critical elements, similar geological settings can be located worldwide to help increase supply of gold and tellurium, resolving part of the gold issue but more importantly allowing humanity to carry on its transition to renewable energy by using CdTe photovoltaic cells.

References:

[1] Scherbarth N and Spry P (2006) *Econ Geol* 101: 135-158

Volcano deformation or atmospheric signals? Re-evaluating magma systems of Agung volcano, Indonesia, based on InSAR observations.

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²Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET), School of Earth Sciences, University of Bristol, Bristol, BS8 1RJ, UK

The 1963 eruption of Agung volcano, Indonesia, is one of the most devastating eruption in the 20th century. To understand the volcanic systems of Agung volcano, we used Interferometric Synthetic Aperture Radar (InSAR) and atmospheric correction technique. We re-evaluated previous observations^{1,2} by using ALOS satellite data from 2007-2009 and show that the displacement signals observed within this time period is characterised by atmospheric artefacts, suggesting Agung volcano is not deforming during the period of observation. Here we propose a few magma recharge models for Agung volcano prior to the 2017 eruption³.

References:

[1] Chaussard, E., & Amelung, F. (2012). *Geophysical Research Letters*, 39(21).

[2] Chaussard, E., Amelung, F., & Aoki, Y. (2013). *Journal of Geophysical Research: Solid Earth*, 118(8), 3957-3969.

[3] Albino, F., Biggs, J., & Syahbana, D. K. (2019). *Nature Communications*, 10(1), 748.

Structural evolution of the Northumberland Trough during the Lower Carboniferous and implications for lead-zinc mineralization potential

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Lower Carboniferous rocks in the Irish Midlands host world-class lead-zinc mineralization in orebodies referred to as 'Irish-type' [1]. Lateral equivalents of these rocks, exposed in the Northumberland-Solway Basin in northern England, are not known to be associated with Irish-type mineralization. However, the two areas have similar geological histories during the Carboniferous and Pb-Zn deposits of Early Permian age are present in northern England [2,3]. Together, these points raise the possibility of Carboniferous Irish-type mineralization at depth within the Northumberland-Solway Basin.

A series of 2D seismic lines located over the Northumberland Trough are analysed to build a regional 2.5D fault evolution model in order to assess the suitability of the structures and the associated syn-rift lithologies for hosting Irish-type deposits. Deposition of both calcareous and siliciclastic syn-rift sediments was controlled by the Lower Carboniferous kilometre-scale growth faulting along the north-dipping Stublick Fault, and possibly along a few other lesser faults. Active faulting continued until at least the Asbian, with subsequent Carboniferous sedimentation mainly controlled by post-rift thermal subsidence and compaction-assisted subsidence. The Stublick Fault is of similar scale, orientation and timing to faults which control mineralization in Ireland. An east-northeast trending array of intrabasinal faults may also display suitable geometries and timings. We suggest a model where the known vein-style Early Permian mineralization in Northumberland may reflect remobilisation of older, Carboniferous Irish-type mineralization associated with the faults at depth. Whilst the results are positive from a structural geology viewpoint, other factors necessary for formation of an Irish-type deposit in Northumberland remain to be tested.

References:

[1] Wilkinson J J and Hitzman M W (2015) in Piercey A, Irish Ass. Econ. Geol. 59-72

[2] Jones D G et al. (1994) in Fontbote L and Boni M, Spec. Pub. Soc. Geol. App. Min. Dep. 10: 198-218

[3] Dunham K C (1990) Econ. Mem. Geol. Surv. 300pp

Pb-Zn-Sb mineralization in the Kizhnica-Janjevo area, central Kosovo

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The study area is located in the central part of the Kosovo, 9 km southeast of Prishtina. The Kizhnica Pb-Zn deposit is located in the Hajvalia-Badovc-Kizhnica ore field within the Trepça Mineral Belt, part of the tectonic Vardar Zone [1]. The study area is dominated by Paleozoic and Mesozoic magmatic, metamorphic (serpentinites, gneisses) and sedimentary rocks (flysch), Neogene volcanic rocks (two generations of andesites), and Pliocene sediments [2]. The polymetallic mineralization occurs as lenses, irregular veins, and stockwork-impregnations at the contact between the Jurassic serpentinites and the Cretaceous flysch series, orebodies occurs typically close to the andesites [3]. Polymetallic mineralization are genetically related to the youngest generation of andesite. The mineral assemblage in the deposit consist of sphalerite, galena, pyrrhotite, sulfosalts with carbonates and quartz [2]. The Pb-Zn deposit was exploited during the 20th century as an open pit. However, the relics of previous mining activities are observed in the hills between Janjevo and Kizhnica. In the massif there are numerous polymetallic mineral occurrences which indicate the large scale mineral zonation.

Ore samples were collected from the old dumps, approximately 1 km to the south from the open pit. The ore samples consisting of massive sulphides, sulfosalts and Fe-Mn carbonates were selected for EDS and microscopic examination in the reflected light. Additionally, listwaenite ore (rich in galena and gersdorffite) was examined. Most of the ore polished section contain a well-developed growth zoning of Pb-Zn sulfides, sulfosalts, carbonates and marcasite. Three mineralization stages were distinguished. First stage is made by sulphides (sphalerite, galena, chalcopyrite, stibnite and pyrrhotite), sulfosalts (boulangerite and members of the benavidesite-jamesonite series), Fe-Mn carbonates and quartz. Sphalerite is the first sulphide in the ore and typically has galena overgrowths. Several generations of sulfosalts are observed. Boulangerite is the most widespread sulfosalt in the samples and occurs as big autonomous aggregates or as overgrowth with sphalerite and galena. Zones composed of idiomorphic crystals of benavidesite-jamesonite series are also observed. Second stage is represented by zones of idiomorphic prismatic marcasite crystals and Fe-Mn carbonates. Third – breccia – stage are made of carbonates, quartz, pyrite and older angular sulfide and sulfosalt fragments. The listwaenite-type ore are enriched in galena veinlets and dispersed pyrite - gersdorffite mineralization. Numerous intergrowths in galena are observed: pyrite, tetrahedrite and pyrrhotite. Gersdorffite occurs as idiomorphic zonal crystals, commonly around dissolved pyrite aggregates. Additionally native gold grains were observed in the quartz-sphalerite breccia.

References:

- [1] Durmishaj B et al. (2015) *Int J Geol Agric Environ Sci* 3(3): 1-4
- [2] Dangić A (1985) *Econ Geol* 80: 180-183
- [3] Kołodziejczyk J et al. (2016) *Minerals* 6(2): 42

Potential economic by-products in copper porphyries: Silver in the Ascutita Cu-porphyry, Romania

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Typical porphyry deposits host one or two main economic metals, usually Cu, Mo or Sn, in low-grade but large tonnage quantities [1]. Standard by-products vary between deposits but typically include Ag, W, Zn, Pb and Bi [1]. A lot of potential by-products end up left in waste rock as they are either not hosted in the target minerals or not spatially associated to the sought metal. Ag is a known by-product in Cu-porphyries, usually mineralised with chalcophile elements, in electrum or hosted in argentiferous galena through substitution of Pb. Although known for being hosted in galena, Ag is also a potentially distinct trace component in primary Cu-sulphides such as chalcopyrite and bornite. If this is the case, in galena-poor Cu-porphyries Ag could still be extracted as a by-product along with the Cu. Deeper investigation into a deposits geochemistry and mineralogy could therefore avoid wasted by-products pre-extraction, boosting a deposits potential profit.

This could be the situation in the Ascutita Cu-Mo porphyry deposit in SW Romania. The deposit is situated in the Poiana Rusca Mountains, just North of the Carpathian Mountains which trend N-S through Romania and into SE Europe. The region is well known for Tertiary skarn-porphyry-epithermal mineral deposits, explored and mined through government-funded work over the last few decades. The Ascutita deposit is 110Mt grading at 0.15% Cu with 2-3ppm of Ag, currently under investigation by the Romanian exploration company Belevion. There is a correlative trend between Ag and Pb down-hole but minimal galena mineralisation in the core. This indicates that argentiferous galena may not be the main host for Ag. Cu also has a clear, unique correlation with Ag against depth seen throughout each of 14 drill holes from the deposit. This relationship may indicate that the Cu-sulphides are the main host for Ag within this porphyry. Understanding whether this is the case or not could lead to the Ag being extracted as a by-product with the Cu-sulphides.

To investigate this association, 13 samples were taken from throughout the drill core and studied under Reflective Light and SEM. Chalcopyrite is the main Cu-sulphide with very minor chalcocite replacement and minor bornite. It is associated to pyrite with galena and sphalerite mineralised intermittently downhole. The major lithology is granodiorite with skarn present due to the granitic intrusion through the local sandstone-limestone protolith. A geochemical database was interrogated, taken from ICP and Aqua Regia data from half-core samples of each drill hole. The Cu-Ag association is at its highest when correlating with higher K/Na ratios, indicating an association to high-temperature potassic alteration. Ag is also associated down-hole with Zn and various chalcophile elements such as Sb, Se, Te, As and very minor Au. The lack of Au and the lack of major sphalerite indicates Ag may not be hosted in electrum or with sphalerite either.

To determine if the Cu-sulphides host Ag, LA-ICP-MS was used. The results of this will quantify how much Ag is directly within the chalcopyrite and whether it is hosted in solid solution or as micro-inclusions with other elements. The implications for major base metal sulphides to host economic levels of trace metals is significant. It will further the metallurgical characterisation and understanding of not only the Ascutita deposit, but encourage other deposits with similar elemental associations to be considered for further investigation. With only minor changes to mineral processing post-extraction, a potentially important economic gain can be made from the same rock.

References

[1] Sinclair, W.D (2007), Porphyry deposits, in Goodfellow, W.D., ed., Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods: Geological Association of Canada, Mineral Deposits Division, Special Publication No. 5: 223-243.

Volcanic-magmatic breccias

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Sillitoe 1985 [1] classified 5 types of breccias that form critical components of many large mineral deposits such as porphyry copper deposits (PCD). These include: magmatic-hydrothermal breccias formed by release of fluids from a cooling magma body, hydromagmatic breccias related to the interactions between an external water source and a magma body, and magmatic breccias, encompassing anything related to the fragmentation and eruption of magma. Significantly for ore deposit studies, brecciation generates a large volume of pore space [2], which can host later mineralisation and, due to high permeability, may be important in the focusing of fluids.

Processes of brecciation are similarly prevalent at active volcanic systems. Volcanoes are thought to be the surficial representation of vertically extensive porphyry copper systems, but due to the erosion that takes place during the exhumation that exposes a PCD, physical evidence of the eruptive history and edifice structure is removed [3], [4]. Examination and comparison of processes of brecciation in both settings may therefore help us to better understand the structure and processes occurring in the subvolcanic environment and the relationship between PCDs and volcanoes.

In this project, the genesis and role of breccias in PCD formation will be explored through a case study of the Spence mine, northern Chile. Two mineralised porphyry lithologies have been described at the Spence deposit: QFP1 and the later QFP2. Associated with QFP2 are substantial (>50m thick) sections of highly variable magmatic and hydrothermal breccia. In contrast to the QFP1 bodies, the QFP2 unit is mapped as a vertical intrusion or pipe-like body. It has a highly variable range of textures, from an igneous texture of interlocking crystals through to crystals suspended in a rock-flour matrix. Distinct to QFP2 is the abundance of xenoliths of QFP1, country rock and earlier QFP2 phases. The texture and clast compositions imply a violent origin for QFP2, potentially by explosive subvolcanic events.

Unzen volcano, Japan, has been chosen as a case study of an active volcanic system. Unzen exhibits periodic vulcanian and dome-style eruptions with long periods of repose[5] and has a well documented history of past eruptions and plethora of geophysical data. Drilling through the conduit of the 1990-95 eruption revealed that large volumes of the volcano are composed of breccia, which has been rapidly and extensively altered by a pervasive hydrothermal system [6]. The rocks of this well-constrained system provide an interesting analogy to investigate the similarities and differences with the brecciation encountered at the Spence deposit.

- [1] R. H. Sillitoe, "Ore-related breccias in volcanoplutonic arcs.," *Econ. Geol.*, vol. 80, no. 6, pp. 1467–1514, 1985.
- [2] C. W. Burnham, "Energy release in subvolcanic environments: implications for breccia formation.," *Econ. Geol.*, vol. 80, no. 6, pp. 1515–1522, 1985.
- [3] R. H. Sillitoe, "Porphyry copper systems," *Econ. Geol.*, vol. 105, no. 1, pp. 3–41, 2010.
- [4] R. H. Sillitoe, "The Tops and Bottoms of Porphyry Copper Deposits," *Economic Geology Vol.*, vol. 68. pp. 799–815, 1973.
- [5] H. Hoshizumi, K. Uto, and K. Watanabe, "Geology and eruptive history of Unzen volcano, Shimabara Peninsula, Kyushu, SW Japan," 1999.
- [6] Y. Goto, S. Nakada, M. Kurokawa, T. Shimano, T. Sugimoto, S. Sakuma, H. Hoshizumi, M. Yoshimoto, and K. Uto, "Character and origin of lithofacies in the conduit of Unzen volcano, Japan," *J. Volcanol. Geotherm. Res.*, vol. 175, no. 1–2, pp. 45–59, 2008.

Water table movement and supergene enrichment at Spence porphyry copper deposit, northern Chile

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Supergene enrichment has been fundamental in producing the economically extractable metal grades of exhumed porphyry copper deposits (PCDs) in the Central Andes of northern Chile [1]. Enrichment occurs when exhumed PCDs undergo oxidative weathering in the near-surface environment. Dissolution of sulphides (principally pyrite [FeS₂]) by meteoric water produces sulphuric acid, which leaches Cu (e.g. from chalcopyrite [CuFeS₂]) and transports it downward in solution. Under reducing conditions beneath the water table, Cu is reprecipitated through ion-exchange reactions, forming a supergene blanket enriched in secondary sulphides (e.g. chalcocite [Cu₂S]) [2]. The water table forms the boundary between oxidising and reducing conditions and determines the depth to which leaching and enrichment can occur [3]. Supergene enrichment through aqueous redistribution of metals requires meteoric water, however northern Chile is currently one of the driest regions on Earth. Previous work suggests supergene enrichment of PCDs in northern Chile ceased in the middle Miocene, possibly due to an increase in aridity [1,4,5], although conditions may have been dry for much longer [6].

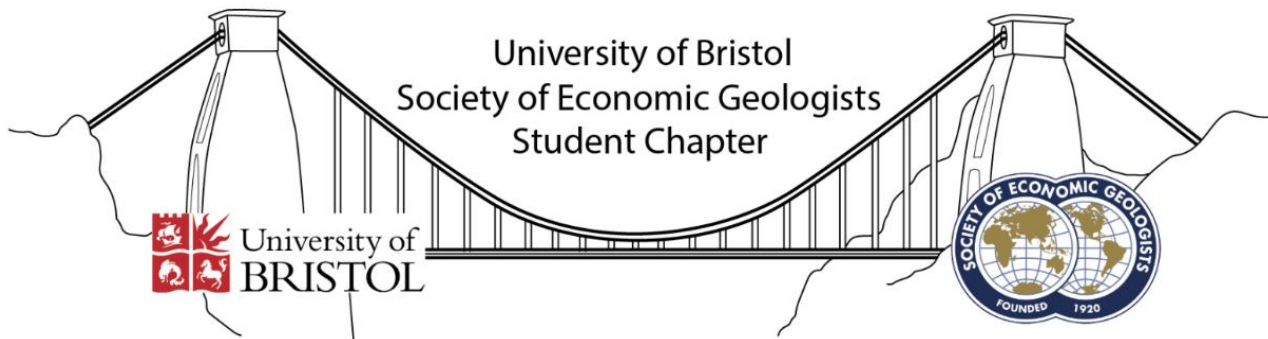
We aim to understand the relationship between Cu leaching and water table movement at Spence PCD, by dating supergene alteration and weathering minerals in the leached cap of the deposit. Published supergene chronologies for PCDs in Chile are based on ages of supergene alunite [KAl₃(SO₄)₂(OH)₆] [2], formed through sulphide weathering. Ages of hematite [Fe₂O₃], which only forms under oxidising conditions above the water table, constrain water table depth through time [5]. Alunite ages for Spence suggest enrichment occurred from 44-20 Ma [7] although a preliminary suite of hematite (U-Th)/He dates suggest the water table dropped from the base of the post-mineral cover to its lowest position at the top of the chalcocite enrichment zone between 11 and 2 Ma.

In many samples from Spence however, veins of supergene alunite (confirmed through textural observations and S isotopic analysis) cross cut hematite veins, meaning the existing chronologies of the two minerals provide an incomplete account of weathering and supergene enrichment at Spence. Unless the hematite ages already obtained do not capture a much earlier water table-dropping event, cross cutting alunite veins must be younger than 11 Ma, dramatically extending the duration of acid weathering and associated Cu enrichment within the deposit.

We will use ⁴⁰Ar/³⁹Ar dating of alunite and (U-Th)/He dating of texturally associated hematite to constrain the timing of Cu enrichment and water table movement at Spence. Understanding this interplay and how supergene processes relate to current knowledge of palaeoclimate and tectonic activity in the region will be a valuable addition to Cu exploration models targeting enriched PCDs.

References:

- [1] Sillitoe R H and McKee E H (1996) *Econ Geol* 91 (1): 164-179
- [2] Sillitoe R H (2005) *Econ Geol* 100th Anniversary Vol: 723-768
- [3] Ague J J and Brimhall G H (1989) *Econ Geol* 84: 506-528
- [4] Alpers C N and Brimhall G H (1988) *GSA Bull* 100 (10): 1640-1656
- [5] Cooper F J et al. (2016) *Geol* 44 (8): 675-678
- [6] Clarke J D A (2006) *Geomorph* 73: 101-114
- [7] Rowland M G (2001) Mining report for Rio Algom



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