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the Applied Mineralogist

OF THE MINERALOGICAL SOCIETY

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From our editors...

Welcome to the December edition of the Applied Mineralogist! In this edition we explore some fascinating advances and introduce some exciting upcoming events. Test your mineral knowledge with the new crossword puzzle and discover the winner of #thinSectionThursday.

Within this issue, Andressa de Araujo Silva summarises their experience of attending a workshop on orogenic gold during SEG-2023 courtesy of an AMG bursary. Following this, Rachel Purvis provides an interesting summary of her recent masters thesis exploring magmatic Ni mineralisation in southern Finland.

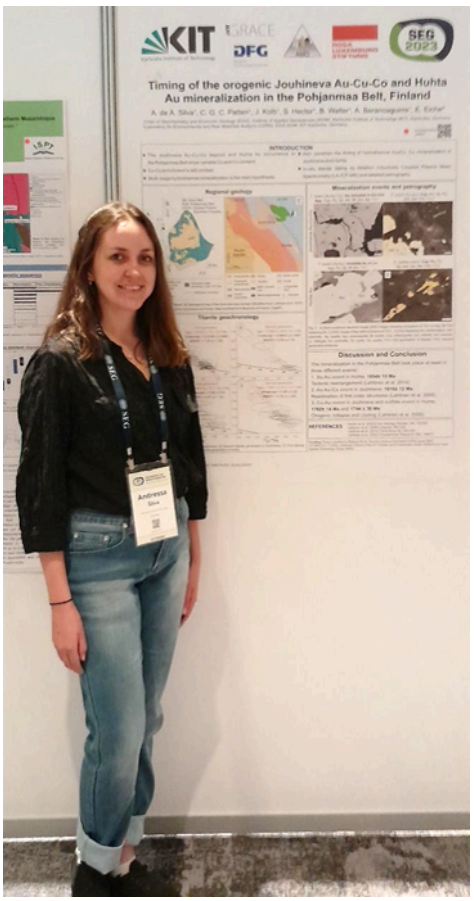
Thanks to all those who contributed to this issue. We hope you enjoy this month's publication.

AMG BURSARY REPORT

Andressa de Araujo Silva

Structure and Diversity of Orogenic Gold Deposits, SEG 2023.

From August 25-26, 2023, I had the opportunity to participate in the workshop "Structure and Diversity of Orogenic Gold Deposits" held at the Hilton London Metropole from August 25-26, 2023. It was part of the SEG Conference: Resourcing the Green Transition and attracted approximately 60 participants, including industry professionals and students. The workshop was led by prominent experts on gold deposits Dave Rhys, Stephen Cox, Richard Goldfarb, and François Robert. Attending the workshop was highly beneficial for my research on atypical Orogenic Co-Cu-Au deposits in the Pohjanmaa Belt, western Finland, because the theme closely aligned with my area of study.



Highlights

Edited by:
Christian Bishop
Rachel Purvis

Richard Goldfarb delivered a comprehensive overview of Orogenic Gold Deposits, emphasizing their critical role in global gold production. He outlined the key characteristics of these deposits, highlighting their strong structural controls, their association with metamorphic rocks (mostly greenschist facies), and the importance of geochemical traps in their formation. Furthermore, it was emphasized that Orogenic Gold Deposits are hydrothermal in origin, in contrast to those who suggest magmatic or magmatic-hydrothermal origins. He explained how these deposits are prevalent in Precambrian and Phanerozoic metamorphic belts, making them some of the most significant sources of gold. Specific examples were drawn from Phanerozoic deposits, particularly within the Cordilleran orogen, with a focus on Alaska, and the Western Pacific. François Robert followed, focusing on the diversity of gold deposit styles and settings within Precambrian metamorphic belts. François highlighted the key features of prolific gold belts and their evolutionary and structural developments. He presented three models for gold deposits: Orogenic quartz-carbonate vein, epizonal intrusion-associated, and volcanic-related deposits. He also illustrated how Precambrian and Phanerozoic belts differ in terms of deposit formation and geochemical characteristics. Case studies, such as gold deposits within the Abitibi Greenstone belt (Canada) provided practical insights into exploration criteria, including key lithological and structural associations.

Dave Rhys discussed the structural framework essential for understanding the spatial distribution of Orogenic gold within metamorphic belts. Rhys detailed the Porcupine Camp, also located in the Archean Abitibi Greenstone Belt - Canada, as an example. The gold mineralization in this deposit occurred after a major fold-thrust event (D2) during a sinistral transpression (D3). His sessions focused on how different structural configurations influence deposit types and how understanding these differences can lead to more effective exploration strategies.

Stephen Cox introduced concepts related to fluid flow and permeability, which are critical to understanding how Orogenic Gold Deposits form under dynamic geological conditions. He also covered the relationships between stress fields, fracture geometries (extension, shear, and hybrid extensional shear fractures), and fault slip direction in veins. Additionally, the main structural controls on location and geometry of high flux sites in faults were presented. These structures are, for example, jogs, relay ramps, fault bends, fault termination zones, fault branches and intersections. An important point highlighted by Cox is that although these structures can show high permeability, they must be hydraulically connected with the fluid source. His focus on high fluid flux regime and injection-driven swarm seismicity offered participants insights into the theories that link seismic events with ore genesis.

The workshop proved to be highly valuable for my research, as it reinforced my understanding of the fundamentals and structural evolution of Orogenic Au deposits. Much of the content from the lectures connected directly to my own research, allowing me to relate many ideas on the deformation and hydrothermal evolution to my study area in the Pohjanmaa Belt.

SPECIAL FEATURE

A geological characterisation of intrusions in southern Finland to assess the prospectivity of magmatic Ni mineralisation.

Rachel Purvis
MSc Exploration Geology, Camborne School of Mines, Univeristy of Exeter.

For my MSc Exploration Geology thesis, I investigated the prospectivity of Ni-sulfide mineralisation associated with a series of intrusions across a region of southern Finland, with help from RioTinto (AER). The primary aim was to classify the intrusions in the target area to understand their formation and assess the mineralisation potential associated with the potential conduit system. The project was simple: 1. Outline the aims and objectives; 2. Research background information and conduct a literature review; 3. Conduct 2 weeks of fieldwork to understand the area and collect samples; 4. Examine thin sections of the samples under the microscope and with and SEM-EDS; 5. Analyse the geochemistry; 6. Interpret the results. This feature synthesises the use of petrography and geochemistry for understanding the relationships of minor intrusions.

In order to answer the key questions and determine the prospectivity of the region, I travelled out with the team to study the mineralogy, structure and relationships of intrusions and host rocks. The lithology of the area comprises host gneiss with various intrusives metamorphosed to typically amphibolite grades. The area is composed of a suite of small intrusions in proximity to a couple of larger bodies, analogous to conduit systems i.e. Jinchuan, China. Figure 1 shows an adapted model used to understand the key elements for a deposit to form. The lithology of both the intrusions and prospects varied significantly creating a dynamic region and posing a number of controls on mineralisation. Modelling of whole-rock geochemistry across rock samples showed the greatest Ni and S concentrations to be associated with olivine websterite and pyroxenite lithologies and least prospective being the gneisses and diorites, thus providing a good basis for knowing where to explore across the intrusions.

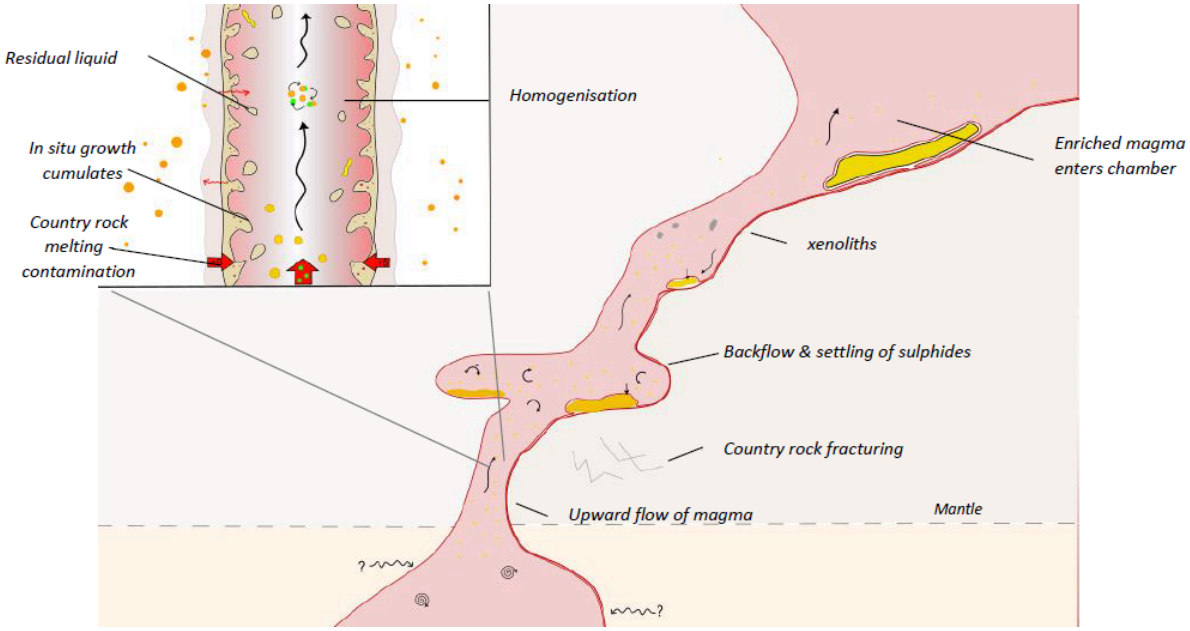


Figure 1. A schematic of a magmatic conduit system (adapted from Latypov, 2015) used to show the fundamentals of mineralisation within Ni-sulfide bearing systems.

The differences in lithology observed both between the prospects and within the intrusions themselves reflects the evolution of magma within the system. Other factors, such as multiple magma pulses and different levels of crustal contamination and alteration, cause the mineralisation variation. Many of the units display taxitic and variable textures, and autobrecciation typically reflecting a dynamic open system. Due to the lack of outcrop, any clear large-scale structures in the units are hard to observe. On the microscale, key structures within the intrusion provide insight to the dynamic nature of formation. Xenoliths support the conduit theory with wall rocks being introduced due to decompression fracturing and wall rock interaction (Figure 2). Additionally, enclaves of differential composition suggest phases of magma generation with contrasting properties. Minor late-stage veins and pegmatites observed across the region are typically composed of quartz, plagioclase and carbonate. These reflect recrystallisation due to hydrothermal fluids moving through the rocks. In places these minor veinlets contain remobilised sulfides. Secondary basaltic intrusions crosscut a number of the intrusions indicating the prolonged history of magmatism.

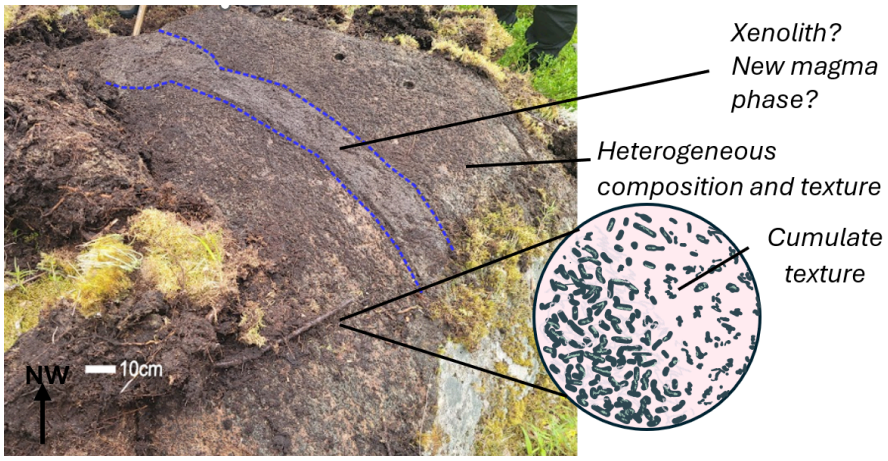


Figure 2. potenital xenolith (blue) within the cumulate leucogabbro.

Macro-scale structural interpretation was driven by geophysical modelling due to the lack of exposure. Numerous crosscutting structures are located within many of the prospects giving them favourable conditions for magmatic deposits. However observations of numerous refolding events and shearing provide some insight to the dynamics of the area. Reconstructing the orientation of folding events is complicated by the overprinting structures, such as Figure 3. Within the country rock we observe a foliation suggesting a dominant compressional strain direction SE-NW. In this outcrop (Figure 3), multiple phases of deformation and intrusions are observed. The base of the outcrop shows the foliation (78/200°) which in the upper layers has been sharply and irregularly folded in place with a felsic pegmatite intrusion. Pyroxenite boudins (possible xenoliths within the pegmatite?) are offset by the tight fold in the centre of the image. Within one of these inclusions is a tight folded earlier pegmatitic vein.

Sulfide mineralisation is observed throughout the intrusions very finely disseminated within the rocks. Due to the common dominance of biotite within the samples, the vitreous nature made it hard to identify and quantify the sulfides thus SEM-EDS was critical for identifying the assemblages present. Modelling of a PCA plot highlighted a number of trace element assemblages controlling the sulfide geochemistry. Dominant trends are Te-Cu-S and Ni-Cr.

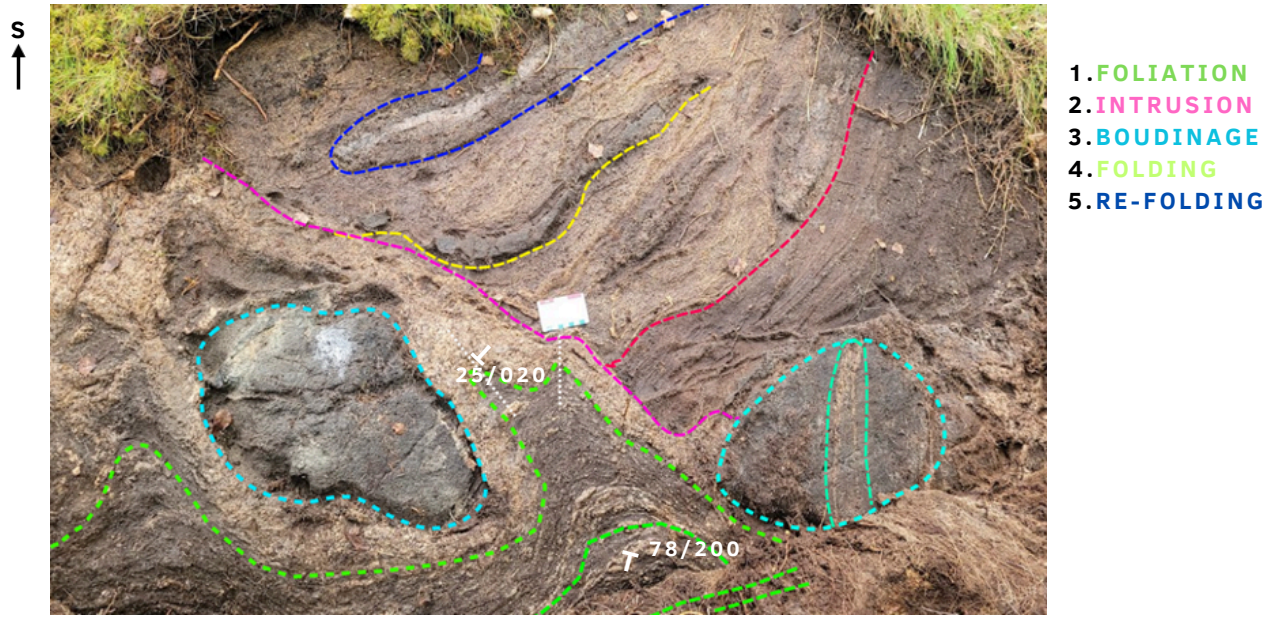


Figure 3. Field annotation of complex deformation history observed in the host rocks. Overprinting foliation, intrusions, boudinage, and episdal folding complicate the reconstruction.

Alteration assemblages and intensity varied across the intrusions. Biotitisation dominates the alteration of most intrusions, replacing primary mafic minerals and amphiboles during regional metamorphism. More intense alteration affected the texture leading to a weak schistosity. Surface oxidation of sulfides was particularly prevalent across the region indicating the influences of hydrothermal leaching producing rusty red goethite and hematite on rock surfaces. Further chlorite and serpentine alteration provide insight into the interaction of hydrothermal fluids and metamorphism in the region. Serpentinisation of ultramafic rocks, as shown in Figure 3, is often associated with nickel and PGE mineralisation and thus can be a useful indicator for prospectivity.

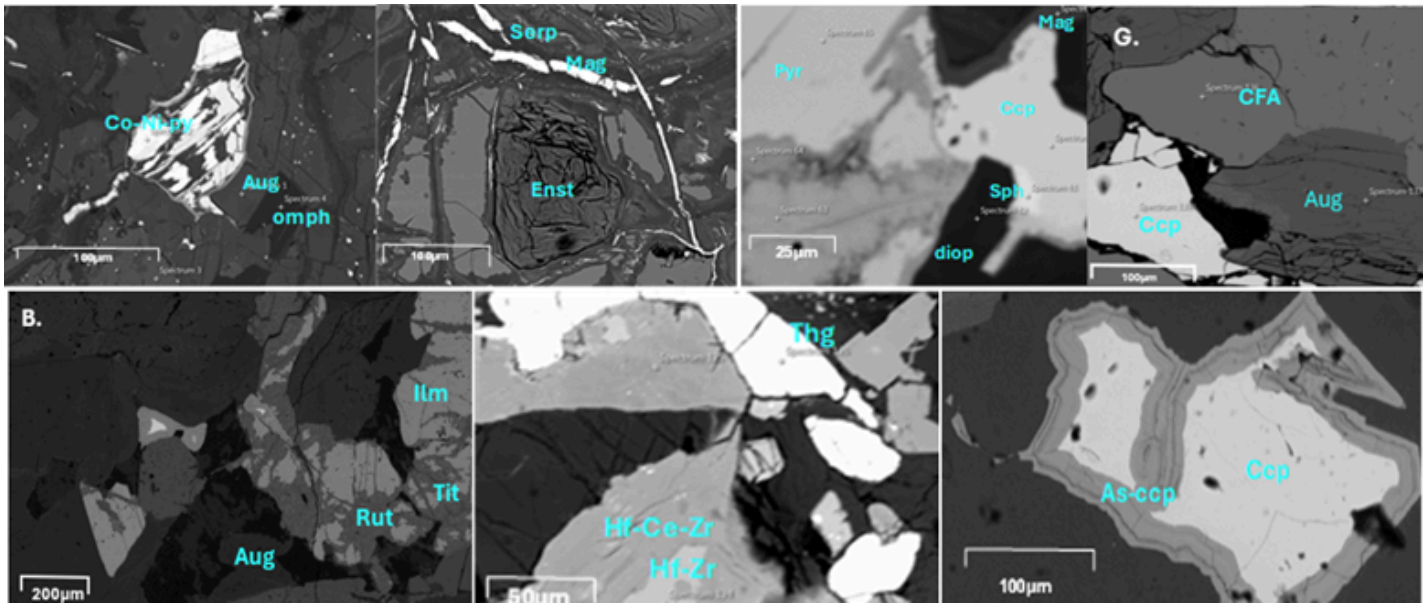


Figure 4. SEM-EDS images of sections taken from across the intrusions with minerals labelled: Ccp=Chalcopyrite, Py=Pyrite, Aug=Augite, Omph=Omphacite, Thg=Thorogummite, Zr=Zircon, Pyr=Pyrrhotite, Mag=Magnetite, Sph=Sphalerite, Diop=Diopside, Enst=Enstatite, Serp=Serpentine, CFA=Chlorofluoroapatite, Rut=Rutile, Ilm=Ilmenite.

Using geophysics we identifed larger intrusions crosscutting the stratigraphy, contrasting to the other intrusions with typically narrower morphologies, conformable to the host strata. One intrusion showed a similar geochemical trend to a larger body, both indicative of a depleted mantle source. It could be expected that the smaller conduit-like intrusion was feeding the larger one. These depleted mantle intrusions were potentially intruded during the regional extensional phase early in the magmatic episodes. Chlorofluoroapatite was present in a number of intrusions (Figure 4) indicative of a volatile-rich magma and potential Ni-Cu-PGE system. Intrusions with large MgO and Ni content, along with elevated Cr and Cu levels, are good indicators of conduit-related nickel sulfide mineralisation. These signatures suggest a magmatic origin characterised by high degrees of partial melting and mantle derivation, followed by sulfide saturation and segregation in a dynamic magmatic conduit system. Sulfides are probably primary with secondary hydrothermal interaction modifying the assemblage. Further research is needed to understand the dominant source and quantify the contamination and hydrothermal introduction of sulfur. Some of the intrusions show petrographic similarities with the Kevitsa deposit, particularly those with mineralisation assemblages of pyrrhotite, chalcopyrite, titanite and apatite.

The project was very rewarding, with great practical exposure to the geology of conduit-style magmatic systems. It provided a great insight to working with an exploration team and applying ESG practices in the field.

GEO-BIO INTERFACES

The Mineralogical Society of the UK and Ireland + Cambridge University Press

https://www.cambridge.org/core/journals/geo-bio-interfaces

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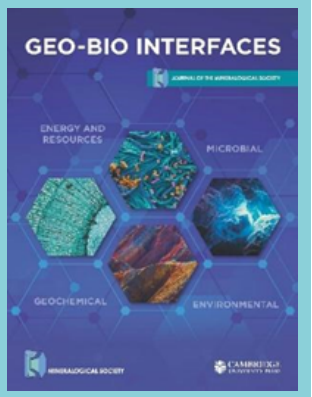
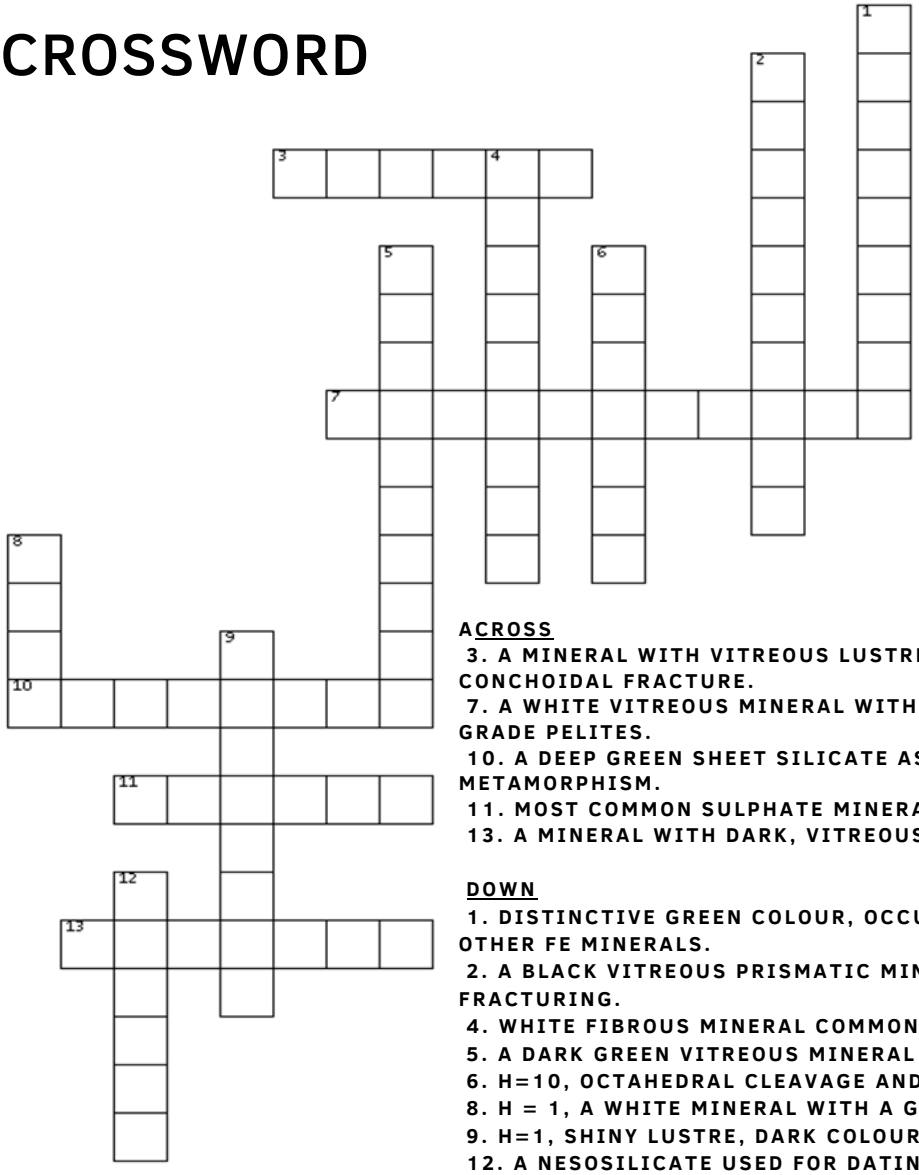


CROSSWORD



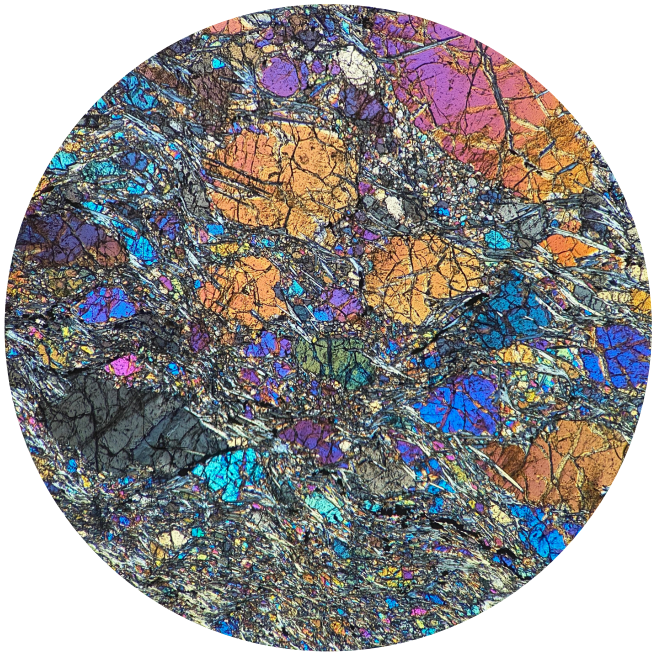
ACROSS

3. A MINERAL WITH VITREOUS LUSTRE, H=7, LACK OF CLEAVAGE, AND CONCHOIDAL FRACTURE.
7. A WHITE VITREOUS MINERAL WITH FINE NEEDLES COMMON IN HIGH-GRADE PELITES.
10. A DEEP GREEN SHEET SILICATE ASSOCIATED WITH LOW-GRADE METAMORPHISM.
11. MOST COMMON SULPHATE MINERAL, TRANSLUCENT, H=2.
13. A MINERAL WITH DARK, VITREOUS LUSTRE AND MICACEOUS HABIT.

DOWN

1. DISTINCTIVE GREEN COLOUR, OCCURS AS SECONDARY MINERAL WITH OTHER FE MINERALS.
2. A BLACK VITREOUS PRISMATIC MINERAL WITH CONCHOIDAL FRACTURING.
4. WHITE FIBROUS MINERAL COMMON IN METACARBONATES.
5. A DARK GREEN VITREOUS MINERAL WITH BLADED HABIT.
6. H=10, OCTAHEDRAL CLEAVAGE AND TRANSPARENT.
8. H = 1, A WHITE MINERAL WITH A GREASY FEEL.
9. H=1, SHINY LUSTRE, DARK COLOUR AND STREAK, AND FOLIATED.
12. A NESOSILICATE USED FOR DATING ROCKS.

#THINSECTIONTHURSDAY



AND THE WINNER IS ....

@HIKARU_SAWADA

IMONO PERIDOTITE BODY, SANBAGAWA. A HIGH-P/T METAMORPHIC BELT ON SHIKOKU ISLAND, JAPAN.

GET INVOLVED.

If you would like to become more involved in the AMG, elections are held yearly at the AGM. Spaces for Student Representatives come up regularly. If you would like to be considered for a committee spot please email our chair Martin Smith: martin.smith@brighton.ac.uk.

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. Application guidelines can be found at:

www.minersoc.org/amg-bursaries

Please note there are two bursary application deadlines each year: 15th April and 15th October. Requests for funding must be received well 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 can be found at:

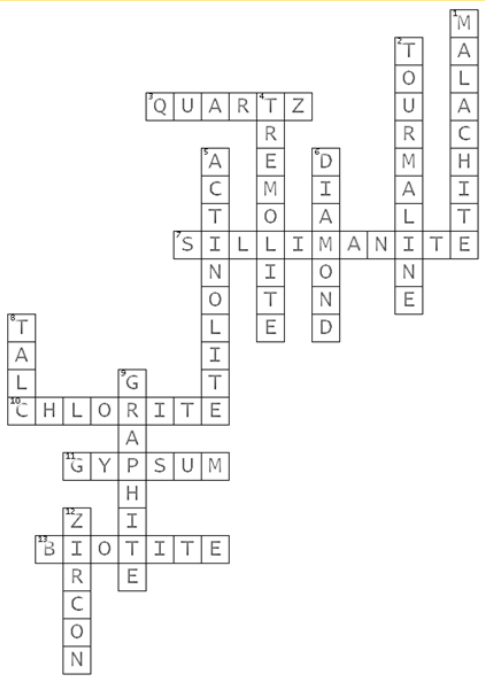
www.minersoc.org/amg-funding

Don't forget to keep posting with ***#ThinsectionThursdays, #FieldworkFridays, #MineralMondays,*** *and* ***#AppliedMineralogy*** *for your chance to be featured.*

Please forward any articles, comments or notices of events and conferences to amgminsoc@gmail.com.

Find all previous issues of the Applied Mineralogist at: www.minersoc.org/amg-applied-mineralogist

CROSSWORD ANSWERS



Interested in joining the Mineralogical Society and Applied Mineralogy Group?
https://www.minersoc.org/

Upcoming Events:

MDSG-VMSG: 6-8th January 2025

EGU: 27th-2nd May 2025

Goldschmidt: 6-11th July 2025

International Clay Conference: 18-23rd July 2025

SGA: 3-7th August 2025