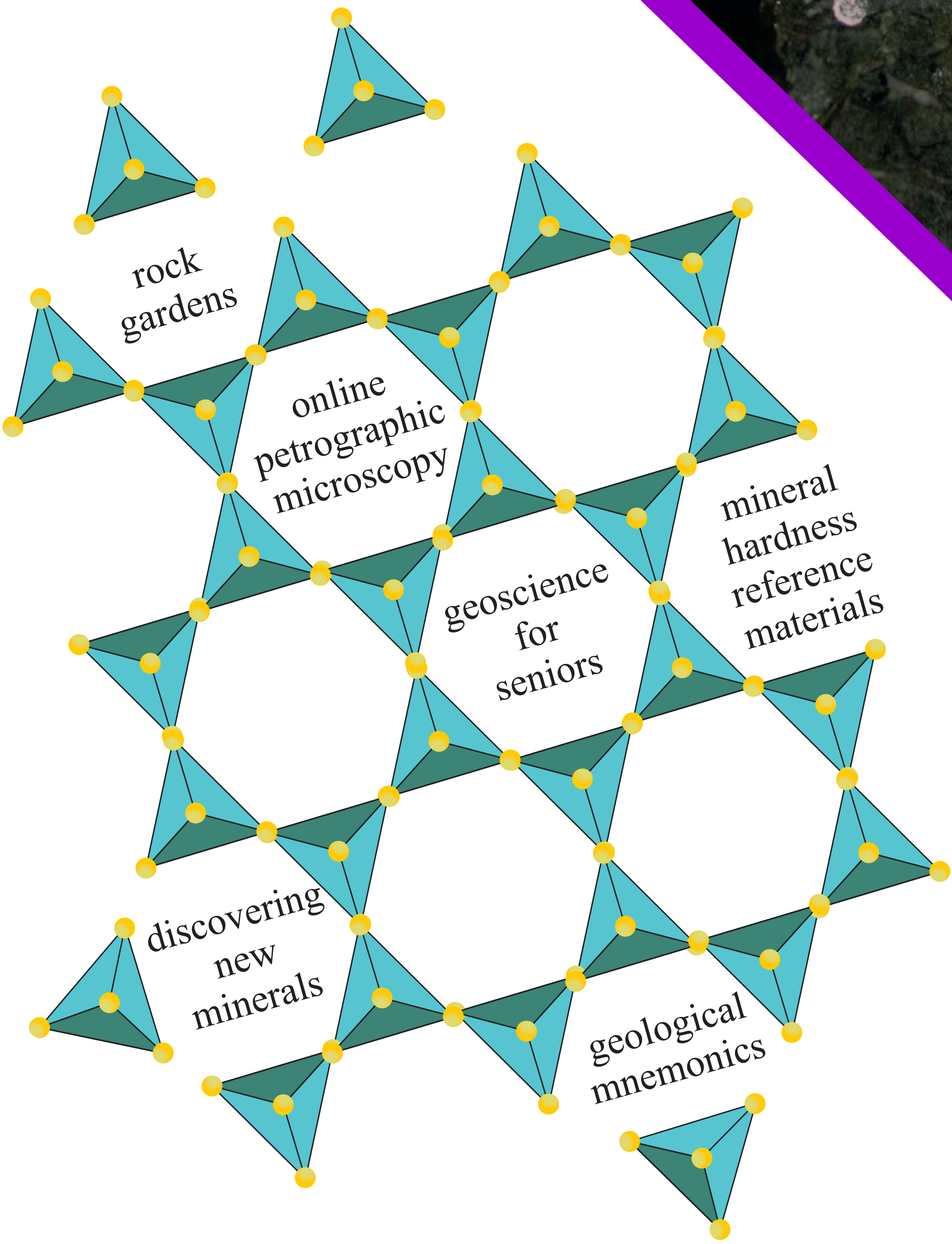
the Geode
the Geode

MINSA
Mineralogical Association of South Africa

Geological Pedagogy: teaching & learning of rocks & minerals



The GEODE

Minsa Newsletter
Volume 8
No. 1
March
2021

MINSA
Mineralogical Association of South Africa
A division of the GSSA
website: www.gssa.org.za/Minsa
e-mail: Minsa@gssa.org.za

the Geode
the Geode
NEWSLETTER
Volume 8 No. 1
March 2021

“the magazine you can share, virus-free”

Contents

Next issue theme:
Analytical methods for determining oxidation state of rocks & minerals

The Editor’s Site

In this issue, our feature section is on Mineralogical Pedagogics: how do we teach mineralogy, and its geological context? Accordingly, we present an contributions on Tukkie’s search for educational boulders with which to adorn their campus, and let’s face it, every campus looks better with geology added, as well as an article from Stuart Clague on acquiring reference materials for mineral hardness, Bjorn von der Heyden on online petrographic microscopy teaching, and Lesley Andrews on teaching geology to seniors. This is accompanied by some geological mnemonics I have acquired by trawling through the literature, providing a cross-section of the types of tools people have employed to help learn the fundamentals of the geological toolbox.

The Editor: “Haven’t the barbers reopened yet?”.

To further complement this, the Chair and the Editor have compiled a list of some undergraduate exam responses acquired over recent years, offering some insight into how effective our learning tools might be, in practice. I do notice that we didn't receive any articles on the teaching of my personal favourites as an undergraduate (and by favourites, I mean topics for future psychotherapy), Miller Indices, or Schreinemaker diagrams for metamorphic reactions and mineral stabilities. Why is that, I wonder.

In addition, we are informed that Grant Cawthorn (Wits U.) has been part of a research team that has recently identified a brand new mineral; think you've discovered a brand-new mineral? To avoid the kind of naming debacle that the palaeontological community got saddled with by Brontosaurus, and the astronomical community with Pluto, you need to talk to the Commission on New Minerals and Mineral Names (CNMNC). In "other gems", yours truly assesses the density considerations associated with Indiana Jones' efforts to purloin indigenous treasures in "Raiders of the Lost Ark" (also including some assessment relating to this issue's subtheme of stone boulders), and Bruce Cairncross features fluorescent minerals in this issue of "Bruce's Beauties": see common minerals in ways you've probably not seen them before, thanks to the magic of ultraviolet light. We finish with our crossword and the solution to last time's offering.

That's the perspective from the Editor's site.

Steve Prevec

From the Chair

This quarter's Chair's contribution is focussed on the proposed Educational Garden Route at the University of Pretoria, and has been relocated accordingly to accompany this article (see pages 8-10).

Look for the Chair's Challenge (and no, it's not like the ice-bucket challenge, but with rocks; read on!).

Igor Željko Tonžetić

Forthcoming Events & Attractions

A lot of these events are still missing dates as a consequence of lockdown logistics: Minsa will let you know! Watch for e-mailed announcements.

- Excursion to tile factory
- Joint Minsa-SAMS excursion to the Leeuwpoort Tin mine
- Wirsam Visit
- Phalaborwa visit – proposed for the end of winter or spring 2021.
- Night @ the Museum VI
- Participation in the GSSA "keeping Geocongress alive" online symposium in mid-year.
- 5th Annual Southern African Mineral Symposium – Saturday 20 November 2021.
- Annual theme talk 2021: 'International Year of Creative Economy for Sustainable Development ' – December 2021.

Articles

Discovering a New Mineral

So you think you've discovered a brand-new mineral? You need to talk to these people:

The International Mineralogical Association, Commission On New Minerals, Nomenclature And Classification (IMA-CNMNC)

The **Commission on New Minerals, Nomenclature and Classification** (CNMNC) of the **International Mineralogical Association** (IMA) was formed in July 2006 after the active **Commission on New Minerals and Mineral Names** (CNMMN) and the **Commission on Classification of Minerals** (CCM) merged at the request of both commissions.

The **Commission on New Minerals and Mineral Names** (CNMMN) was established in 1959 for the purpose of controlling the procedure on introduction and acceptance of new minerals and mineral names, and to maintain and rationalise mineral nomenclature.

The **Commission on Classification of Minerals** (CCM) was tasked to review existing systems of mineral classification and advice the mineralogical community on arising issues and relevant changes to the classification of minerals.

The CNMNC is headed by an executive committee consisting of a chairman, two vice-chairmen, a secretary and five chairmen emeriti. The commission members are representatives appointed by national mineralogical bodies across the globe, with 34 active members in total at present. New mineral proposals under review are assessed by the voting members once a month. In addition to the new mineral proposals, there may be proposals regarding nomenclature changes, discreditations, redefinitions, etc., under review. Over the past twenty-five years, the IMA-CNMMN has published official reports on its activities and publications in several mineralogical journals. They outline the rules and regulations about all aspects of the nomenclature of minerals and mineral groups. A comprehensive list of all valid mineral species is maintained and updated on regular basis by IMA-CNMNC and can be accessed on the IMA list of minerals page of the website (http://cnmnc.main.jp/). The IMA List of Minerals is intended as the primary and official source on minerals.

Have a new mineral??? Yes!? No?? Abstain?!?! For general criteria to defining mineral species with coherent guidelines and details regarding preparation and handling of new mineral proposals you may refer to the famous paper by Nickel and Grice (*The Canadian Mineralogist,* Vol. 36, p. 913-926, 1998), titled The *IMA Commission on New Minerals and Mineral Names: Procedures and Guidelines on Mineral Nomenclature.* A more recent reference on *How to define, redefine or discredit a mineral species* appeared in June 2017 Elements issue by the CNMNC executive committee at the time (Hatert *et al.,* 2017).

Contributed by Maria T. Atanasova
MTGeo Minerals Analysis Consulting

More on the IMA

Minsa, besides being an Association under the auspices of the GSSA, is also a member of the International Mineralogical Association, or IMA. The IMA was founded in 1958 to promote the science of mineralogy, and consists of 38 national mineralogical societies or groups as its members. Each of these societies participates through involvement of its individual members in meetings, commissions, working groups and other activities of the IMA. At IMA business meetings, each society may be represented and decide on outcomes through voting. Voting rights are in line with that society's own membership (*i.e.*, individuals) numbers. Minsa has two votes, given its membership size (just over 100 members), and is represented at the IMA by Desh Chetty.

The IMA currently hosts 6 commissions on specific themes within mineralogy. These commissions were established to further promote those themes through the organisation of various events for global participation:

The IMA Commission on New Minerals, Nomenclature and Classification (IMA-CNMNC) is the most active of the commissions, as it bears the responsibility of appraising submissions for new mineral definitions, mineral redefinition, or discrediting minerals. Maria Atanasova is Minsa's representative on this commission, and describes the important work done by this commission, elsewhere in the newsletter (see article on pg. 6-7).

The IMA Commission on Applied Mineralogy (IMA-CAM) is concerned with activities promoting process mineralogy, applied mineralogy of ceramics, cements and glasses, development and application of advanced materials, environmental mineralogy and health, analytical techniques, mineral surfaces and nanoparticles. Desh Chetty is Minsa's representative on this commission.

Four other commissions are as follows:

- The IMA commission on Gem Materials – IMA-CGM
- The IMA commission on Museums – IMA-CM
- The IMA commission on Ore Mineralogy – IMA-COM
- The IMA commission on the Physics of Minerals – IMA-CPM

Additionally, there is a working group on asbestos, asbestiform minerals, and other respirable minerals that pose potential negative health risks. *(cont. pg. 6)*

IMA 2022
MINERALOGY AND SPACE
Lyon, 18-22 July

Following the tradition of quadri-annual general meetings of the International Mineralogical Association organized by national societies, the French Society for Mineralogy and Crystallography will host the 23rd general meeting of the IMA in Lyon, France during 18-22 July 2022.

2022 is the year to celebrate mineralogy. It marks the bicentennial of the death of René Just Haüy (born 1743) who is a father of modern mineralogy and crystallography. Two centuries ago is also when Haüy's Traité de mineralogy and Traité de cristallographie were published. Back to our days, in 2022, the last two main Mars exploration programs, Perseverance (Mars2020) and Huoxing 1, will just have had enough time for science return and post-processing. With the return of Hayabusa 2, for the first time, fragments of a primitive carbonaceous asteroid will be analysed.

The 23rd meeting of the IMA will mark these celebrations. In Lyon, we want to paint IMA 2022 with the colours of space exploration. Alongside the more traditional mineralogist we want to inspire the new generation and make a step closer toward the final frontier. The meeting will bring together all the new facets of modern mineralogy; it will be the playground where mineralogy as we know it will meet exploratory planetology, and it will be the place to celebrate two centuries of mineralogy.

The overarching themes of the IMA2022 are:

* Mineral Systematics
* Physics and Chemistry of Minerals
* Ores and Ore Mineralogy
* Mineralogy and Petrology
* Planetary Mineralogy
* Planetary Interiors
* The Dynamical World Of Minerals

To stay updated visit regularly the official conference website: https://ima2022.fr and follow us on Facebook and twitter. The venue is the Lyon Convention Centre, a state-of-the-art, impressive convention centre featuring 25,000m² of innovative architecture and situated between the Rhône river and the Tête d'Or Park.

On behalf of the French Society for Mineralogy and Crystallography, the leading committee is formed of Razvan Caracas, Herve Cardon, and Cathy Quantin-Nataf.

We are looking forward to seeing you in Lyon in 2022!

More on the IMA *(continued from pg. 3)*

Minsa has no active representatives on these four commissions or the working group, and would like to nominate representatives to them. We would therefore like to invite our members to contact us (minsa@gssa.org.za) if they are interested in participating in the work of these commissions. More information on the commissions may be found at https://www.ima-mineralogy.org/.

The IMA medal is an annual award presented to an outstanding scientist for excellence in the mineralogical sciences. The 2020 IMA medallist is Georges Calas of Sorbonne University in Paris. Nominations for the IMA medallist may be submitted annually before 1 April, and are sent to the medal committee for consideration.

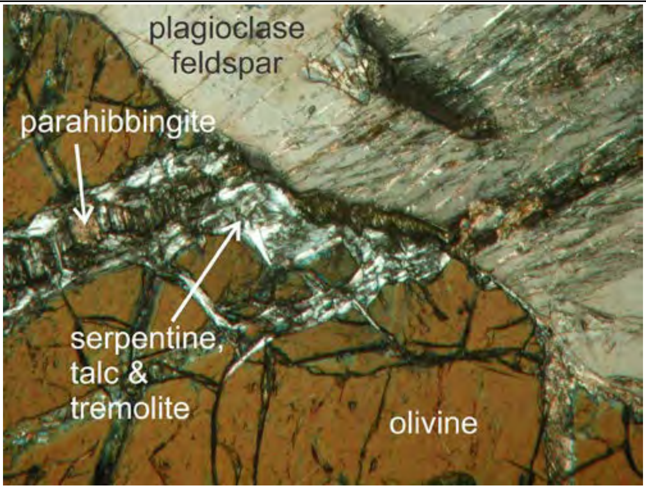
The flagship event of the IMA is its quadrennial conferences. South Africa was privileged to host the 21st meeting of the IMA in 2014, which was very well received. Next year, 2022, marks the 23rd meeting in Lyon, France. The meeting coincides with the IMA international Year of Mineralogy, which contributes to the UNESCO International Year of Basic Sciences for Sustainable Development 2022. Members are encouraged to submit session proposals for IMA 2022, for which the overarching theme is Minerals and Space. More information can be found in the advert elsewhere in the newsletter (pg. 5), and at https://www.ima2022.fr/.

Contributed by Desh Chetty

Parahibbingite – a new mineral found in South Africa

R. Grant Cawthorn
University of the Witwatersrand

The International Mineralogical Association Commission on New Minerals, Nomenclature and Classification has approved the recognition of a new mineral, parahibbingite, identified in samples from the Karee mine, just north of Marikana, operated by Lonplats (now Sibanye-Stillwater). The mineral is intergrown with talc, serpentine and tremolite that are replacing olivine along fractures, in the rocks of the Critical Zone, Bushveld Complex.



Parahibbingite

Ideal chemical formula: $Fe^{2+}_2(OH)_3Cl$
Crystal system: Trigonal

Space group: $R\bar{3}m$ (#166)
a = 6.94(5), c = 14.5(2) Å

The type material is in the collection of the Mineralogical Museum, Comenius University, Bratislava, Slovakia, catalogue number 7601. Visiting hours are 9 AM to 5 PM, although the museum has been closed to the public since 23 March 2020 due to coronavirus safety concerns. Book now to avoid disappointment.

This structure is different from hibbingite, but has the same composition. *(Hibbingite is named for Hibbing, Minnesota, from near its discovery site in the Duluth Complex in that state. Hibbingite is, of course, orthorhombic. Ed.)*

The background story:

In 2004 I was asked by then-Lonplats to help to understand the cause of the decomposition of borecore from close to the UG2 chromitite that resulted in a rusty and caustic surface in a short time after having been drilled. In 1995 I had been to a conference and field trip on mid-continental magmatism in Duluth, Minnesota. The excursion leader, James Miller, showed borecore that was crumbling, rusty and caustic to the touch due to a secondary alteration product identified as a new mineral, hibbingite. It took me some time to recollect this observation. We approached Mintek, and Archie Corfield prepared polished thin sections under oil (with great intuition, guessing hibbingite might dissolve or decompose in water) and found, in some very thin discontinuous fractures, a relationship of olivine being veined by serpentine which was itself replaced by a mat of finely intergrown material. (This description differs slightly from that found subsequently in the submission that was approved by IMA-CNMNC.) Probe analysis yielded a low total with less Cl than in stoichiometric hibbingite. Sadly, Mintek did not have a high-Cl standard and so the extrapolated value was imprecise. Lonplats gave us permission to publish our findings as "Suspected presence of hibbingite in olivine pyroxenite adjacent to the UG2 chromitite, Bushveld Complex, South Africa". Canadian Mineralogist, 47, 1075-1085. 2009.

A colleague, Peter Kodera, from Slovakia, asked for material to study the mineral further, and with an assortment of colleagues and with a battery of equipment proceeded to quantify the properties listed above, and obtained a higher Cl content consistent with the structural formula. They concluded that it is a polymorph of hibbingite. The prefix para, in Greek, means besides or beyond.

I hasten to add that the submission approved by IMA-CNMNC has seven authors, of which "yours truly" is number seven.

Kodera, P., Majzlan, J., Pollok, K., Kiefer, S., Šimko, F., Luptáková, J., and Cawthorn, G. (2021) Parahibbingite, IMA 2020-038a, in: CNMNC Newsletter 59, Eur. J. Mineral., 33, https://doi.org/10.5194/ejm-33-139-2021.

Finally, a big thank you to Lonplats (Sibanye-Stillwater).

Contributed by Grant Cawthorn
(with editorial adornments by S.P.)

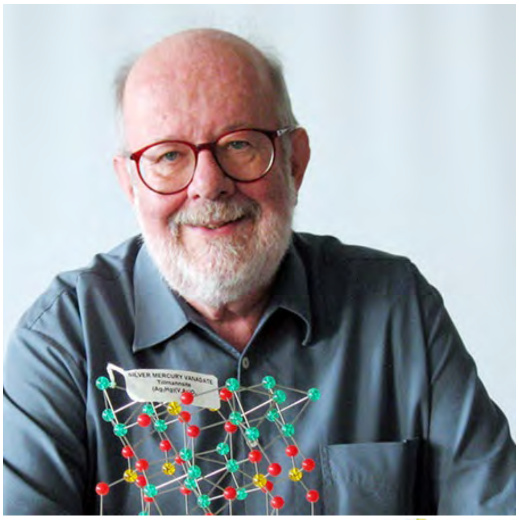
More recent work (submitted to American Mineralogist) by (some of) these authors reminds us that ferrous hydroxychloride is a chemical compound that can crystallise in three polymorphs: α, β and γ (Oswald and Feitknecht, 1964). Hence, parahibbingite is no longer a dimorph (with two stable forms only), as described in the official mineral announcement, but already has multiple siblings. Congratulations!

And as a postscript from Grant:

I have to admit to being less than ecstatic about identifying a new mineral. After fifty two years of research about rocks, to identify a mineral that is water soluble (in fact - disintegrates in moist air) is not what I would have wished for the culmination of my career.

Emeritus Prof. Dr. Ekkehart Tillmanns

It is with deep regret that we announce that Emeritus Prof. Dr. Ekkehart Tillmanns passed away unexpectedly in the night from 29 to 30 December just shortly before his 80th birthday. The international community has lost a colleague who will be remembered as both a human and scientific role model.



Ekkehart Tillmanns was born in Münster in 1941 and studied at the universities of Tübingen, Göttingen and Bochum. He worked at the University of Illinois in Chicago and the Universities of Bochum, Mainz and Würzburg, before moving to the University of Vienna as a full professor in 1991. He was head of the Institute of Mineralogy and Crystallography from 1991 until his retirement in 2009. He was an International Mineralogical Association (IMA) councillor from 2006 to 2010 and IMA president from 2010 to 2012.

We are publishing this note as Prof. Tillmanns was quite instrumental in encouraging MINSA to bid to hold the 21st Meeting of the IMA in South Africa, which as most of you know, was then held in Johannesburg in 2014.

As a member of several national and international mineralogical societies, Ekkehart Tillmanns had actively contributed to their development. In addition to numerous offices, he also did excellent scientific work, which is documented by more than 185 papers in scientific journals.

Contributed by Sabine Verryn
XRD Analytical & Consulting cc

The March Geode Theme:

Mineralogical Pedagogics

The theme invited thoughts on the teaching of geology, mnemonics, simplified learning, and other pedagogical underpinnings or learning paradigms.

- The value of rocks: the UP Educational Garden Route (I.Z. Tonžetić)
- Teaching reflected light microscopy using online teaching methods (B. v.d. Heyden)
- The hardness of forming rocks: practical teaching of mineral hardness (S. Clague)
- Mineralogical geragogics (L. Andrews)
- Geological mnemonics: an overview (S. Prevec)
- Teaching outcomes: mineralogical mirth (Tonžetić & Prevec)

Educational Garden Route at the University of Pretoria: Pedagogic value

Igor Željko Tonžetić
University of Pretoria

With regards to pedagogy, the University of Pretoria is currently attempting to construct an "Educational Garden Route" - "Concrete plinths will display info signs, rock specimens & surrounding plants in as far as possible a "natural environment" to educate passers-by on the botanical, ecological and geological history and relative importance to our daily lives. These plinth stops/stations will display the chronological creation of Earth's rocks and consequent environments (pers. comm. Jeannetta Dykstra & Minsa secretary, 2020). The garden should be "an educational, interactive display of rock displayed as far as possible in a natural environment and showing typical and major superlatives of economic, historic and stratigraphic importance of South Africa (Wladyslaw Altermann pers. comm. 2018).

Your Chair at work, with Jaco Delport, providing "continental lift".

Requirements for the dimensions and forms of the rocks are currently being debated but simplistically speaking should not exceed two tonnes, which of course means that most rocks will be on the order of 50 cm x 50 cm x 50 cm in volume. That is, of course, if the rocks are macro specimens (by no means a prerequisite).

Other options proposed for demonstrating the rock types are: 1.) Drill core (number indeterminate) mounted and polished to display the rocks or 2.) rock fragments in tubular gabions (which is obvious for some of the specimens being solicited). As should be seen, the requirements for these specimens are flexible and higher order thinking should direct the donations, namely answering the questions of the mandates of demonstrating superlative educational, economic, historic and stratigraphic value.

Whilst Minsa is not officially sanctioning the collection of these specimens, we are helping out in an unofficial capacity. We have already collected a Wits conglomerate from just outside George Harrison park (state of which can be discussed in future geoheritage editions perhaps) at 30 cm x 40 cm x 70 cm (probably coming in at ~220 kg) simply with two people and a bakkie. With that in mind, I'd like to propose a "Chairman's Challenge" to all in industry and those with available means to help us reach the goal of a world class educational garden route. I challenge those in industry (and those with available means) to collect a larger sample than was collected by two people and a bakkie or provide drill core of approximately 1m length or provide large fragments that cumulatively weigh more than 220 kg (from the list below). Obviously, please obtain requisite permissions from authorities where applicable.

LIST OF SOUGHT-AFTER SAMPLES

1	Komatiite from the Barberton Greenstone Belt, Onverwacht Formation (solidified komatiitic lava)
2	Banded iron formation (BIF) from the Barberton Greenstone Belt, Fig Tree Fm.
3	Microbial mats in sandstones from the Barberton Greenstone Belt, Moodies Fm.
4	Conglomerate from the Witwatersrand Supergroup (largest goldfield that led to the founding of the City of Johannesburg)
5	Stromatolitic dolomite from the Malmani/Campbellrand Group (Sudwala/Thabazimbi)
6	Banded iron formation (BIF) from Thabazimbi/Prieska with Crocidolite
7	Hekpoort lava
8	Quartzite from the Pretoria Group and a contact metamorphosed variety from the Bushveld Igneous Complex/Magaliesberg
9	Rooiberg lava/Ignimbrite/Volcaniclastic breccias
10	Magnetitite from the Bushveld Igneous Complex
11	Chromite and anorthosite from the Bushveld Igneous Complex
12	Gabbro from the Bushveld Igneous Complex
13	Conglomerate with intercalated sandstone from the Waterberg Group
14	Tillite from the Dwyka Group
15	Coal seam in quartzite from the Ecca Group, Karoo Basin
16	Dolerite from the Karoo Basin
17	Carbonatite from the Phalaborwa Complex (Phoscorite)
18	Sand River Gneiss*
19	Kimberlite/Griquaite ultramafic nodules
20	Pegmatite
21	Jaspilite from the Northern Cape
22	Cape Granite containing large feldspar phenocrysts

**editor's note: the Sand River Gneiss was once thought to be the oldest rock unit in southern Africa, at more than 3.6 Ga (older than Barberton or the Swazi Gneisses), based on early Rb-Sr ages. More recent geochronology has shown it to be ca. 3.3 Ga, comparable to its neighbours in the Limpopo Belt. But nonetheless a fine-looking rock. With a good back-story.*

For our part, Minsa intends to incorporate the collection of carbonatite from our trip to Phalaborwa (possibly) later in the year. Bushveld chromite, Pretoria group quartzite, Waterberg conglomerate, and Dwyka tillite are on the cards for future recces. And I'm going to attempt a pub crawl recce on the R512 to collect some Malmani dolomite…thereby by combining a geologist's two favourite pastimes…rocks and drinking…responsibly of course.

An alternative rock display format: sliced & mounted diamond drill core.

And of course, donators will have their names, company logo and/or marketing image displayed on the plaques.

Teaching reflected light microscopy using online teaching methods

Bjorn von der Heyden
University of Stellenbosch

According to the World Health Organisation (WHO), some of the symptoms of the COVID-19 virus include fever, dry cough, diarrhea and loss of taste and smell. In rare cases, notably in Honours level Earth Science students, the pandemic can also induce a need to learn ore microscopy using online methodologies. This is a relatively dire symptom, given that ore microscopy is best learnt as a 'hands-on' or practical course, with students spending appreciable time in front of the microscope. In 2020 however, this was not possible, both because of social distancing and lock-down measures and because by-and-large anything to do with hands was taboo (and no-one has ever heard of 'elbows-on' microscope training).

At Stellenbosch University, the 2020 Honour's level ore microscopy was taught using a combination of self-study, online resources and in-house created educational videos. These videos were recorded using video camera footage mounted on a Zeiss microscope and showed the field of view observed by the microscope-operator-cum-videographer-cum-flailing-lecturer. Each video showed a different polished mount (from a different ore deposit) and lasted about 30 seconds to a minute. Generally, the first 10-15 seconds were used to pan around the polished mount under low magnification (5x lens) and provided an overview of the textures, the number of different minerals and an idea of their modal proportions. The remainder of the video was used to zoom into pre-selected sites of interest where the magnification was increased by using the 20x or 40x lens. Here, the video recorded specific mineral phases under plane-polarised light whilst slowly rotating the stage (to test for mineral property bi-reflectance), and under crossed polars whilst rotating the stage (to test for anisotropy and the presence of internal reflections).

Advantages of the video format were that the videos could be played back several times (including in slow-motion) and that they could be paused at any frame for detailed inspections (Fig. 1a-c). Each video was augmented with a sequence of high-resolution still photographs which highlighted minerals, textures or features of interest and were usually labelled (Fig. 1d). The learning interactions were further extended to 'contact' sessions between the lecturer and the student cohort using the MS-Teams platform. The course was graded by student performances in mineral identification quizzes and in a capstone assignment (mineral and textural identification of an ore paragenesis) - both of which relied on pre-recorded ore microscopy video material. At the end of the course, nineteen students voluntarily completed an online survey in which questions were generally open-ended or used a Likert-type scale.

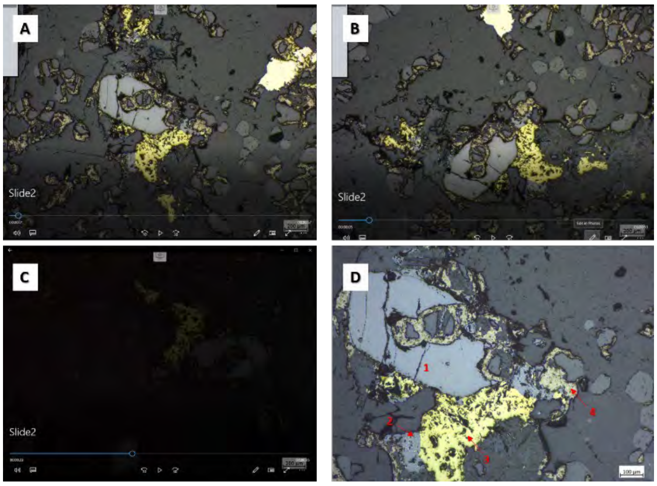


*Figure **1a-c:** a selection of freeze frames from an online video of an ore paragenesis. 1a: low magnification field of view; **1b:** image grab taken mid rotation whilst testing for bi-reflectance; **1c:** image grab taken under 90% crossed polars and whilst rotating to test for anisotropy. **1d**: High magnification and high resolution still photo. In the quiz or capstone assignment students would be asked to identify minerals 1-4.*

From the results of the survey, 90% of the students enjoyed the course whereas only 63% of the students stated that they 'agreed' or 'strongly agreed' that they developed a sufficient degree of proficiency in ore microscopy through taking the course. When asked which mineral properties were easiest to identify using the online material, students suggested that colour and habit were generally the most easy to identify, whereas the properties that required observation of change under rotation (e.g. bi-reflectance and anisotropy) were the most difficult to identify (Fig. 2).

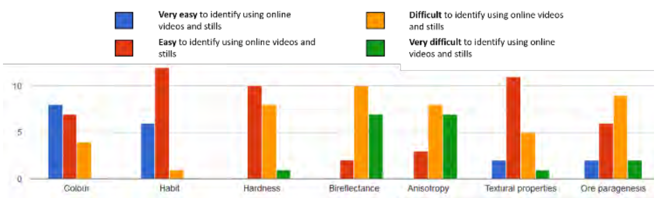


Figure 2: Summary of student feedback responses indicating which mineral optical properties were most easily identified from the pre-recorded video material.

Linked to this, the minerals that required observation of either bi-reflectance or anisotropy were some of the most difficult for the students to identify. For example, pyrite, chalcopyrite and bornite all have relatively distinctive colours and the students deemed these to be some of the easiest minerals to identify from video material. In contrast, students generally found it 'difficult' or 'very difficult' to identify pyrrhotite which has a pale colour yet noteworthy anisotropy.

Figure 3 summarises the student feedback related to which learning interactions were the most beneficial towards their mastery of ore microscopy. Face-to-face interactions (perhaps a misnomer here, since these interactions were all contact sessions using MSTeams) received mixed feedback (Fig. 3: on average deemed 1st, 3rd and 6th best learning interactions), and this perhaps relates to the lecture content or to the lecturers performance on the day.

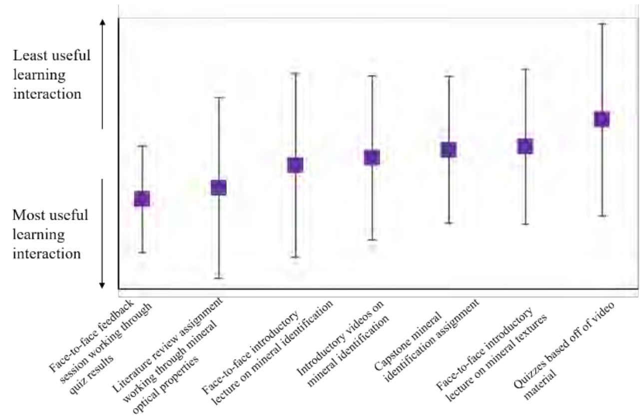


Figure 3: Summary of student responses in which they were asked to rate the teaching interventions that provided them with the best learning value. Responses have been ordered from those that were perceived to be most beneficial to those perceive as least beneficial. Error bars give an indication of the variability among student responses (n = 19).

The guided self-study exercise, in which students were asked to collate mineral optical properties from suggested online resources (Table 1), was on average the second most favourable learning intervention. The high error bars however, indicate that there was significant variability among the student responses, with some students benefitting greatly from the exercise whereas others found it much less useful. Interestingly, the mineral identification quizzes which relied heavily on the developed video and still photo material (Fig. 1) were deemed to be the least useful learning interactions. The subsequent feedback session, however, was generally found to be most beneficial learning interaction, thus stressing the importance of feedback as a critical part of student learning.

The results from this pilot intervention highlight that if the 2021 academic year is also predominantly online, then the microscope-operator-cum-videographer-and predominantly-cum-flailing-and-failing-lecturer needs to continue revising and improving the online ore microscopy teaching offerings. A not-too-far off end goal, should the video material become adequately professionalized and improved, is for such teaching material to be made available online to a broader community. This will be particularly useful for students from less endowed universities (e.g., in other parts of Africa and elsewhere) who wish to obtain an introduction to reflected light microscopy as an important ore geology skill, but who may not have access to reflected light microscopes (*i.e.*, teaching microscopes can cost in excess of R100K).

Table 1: List of useful websites for learning about optical properties of ore minerals

1. http://www.rachitparihar.com/search/label/Blumbachite
2. https://www.virtualmicroscope.org/content/metalliferous-ores
3. http://www.atlas-of-ore-minerals.com/
4. https://www.unige.ch/sciences/terre/research/Groups/mineral_resources/opaques/opaques_systematic.php
5. https://www.unige.ch/sciences/terre/research/Groups/mineral_resources/opaques/opaques_slides.php

The Hardness of Forming Rocks

Stuart W. Clague
SW CLAGUE Geological Consulting

A few years ago, I was given the challenge of making up Mohs hardness testing kits for use by students in the field and classroom. It would have been easy enough to produce a little bag containing a copper coin, piece of glass, nail and broken bit of hacksaw blade; we had been taught these "home remedies" in 1976 during classes in the first comprehensive school in Britain to offer geology at O-Level (our Headmaster was a Fellow of the Geological Society). However, I felt that providing a specimen of each of the original minerals decided upon by Friedrich Mohs in 1812, would be a much more impactful teaching tool.

I quickly found a supply of well-formed quartz (H7) crystals; some double ended. I then purchased a quantity of large cleavage pieces of near optical-quality Iceland spar, calcite (H3) (Fig. 1). (Here I turn to look towards my microscope collection where I have an early-20th-century Italian Officine Galileo with original Nicol prisms).

Figure 1 – Calcite $CaCO_3$, Iceland Spar variety, showing double refraction of the ruler through the cleavage rhomb.

For Gypsum (H2) I could only find polished, wands or hearts of satin spar from a "crystal healing" supplier, which I smashed and sawed into pieces for my specimen boxes. Desert roses from the Namibian coastal pans had been suggested but I know these have incorporated sand, which would make them effectively hardness 7. I have subsequently sourced a good supply of satin spar from Morocco but am trying to secure some tabular selenite crystals and am looking towards Europe as plenty of gypsum was precipitated in the Permian Zechstein Sea there. These will be better for the purpose as they have flat surfaces, which show scratches easier than fibrous satin spar.

I found Fluorite (H4) in big, green lumps, perhaps from Okorusu in Namibia? There was another supply of cleavage octahedral, possibly hand-cleaved by child labour but I do not have an effective blockchain in place at this stage to be able to determine this.

I could only find apatite (H5) in small green fragments from an unknown source; I was told it did not resemble that from Phalaborwa and is probably from outside South Africa. Subsequently, I managed to secure a supply of decent-sized pieces from Madagascar in an unusual and beautiful blue.

It was difficult to find orthoclase (H6), despite its abundance on Earth. I found a supply of labradorite however; a more-attractive, iridescent feldspar with identical hardness to orthoclase. I collected some large pieces of alkali feldspar from the pegmatites intruding the Damara Belt in Namibia but they are perthitic with albite, albeit again with identical hardness. Eventually though, I sourced pure crystallised orthoclase from Norway. After all, orthoclase was the actual feldspar that was defined by Mohs for his scale of hardness.

Topaz (H8) was found in a mineral shop as small crystals or the “rolled” variety, which has been abraded by desert sand over recent epochs, probably from Namibian pegmatites. I was concerned about the small size until, through a friend of a friend, I procured a modest stock of larger specimens from a Namibian gem miner.

Corundum (H9) was sourced from India as non-gem-quality rubies and blue sapphires; occurring as basally-parted hexagonal prisms.

Talc (H1) was difficult to procure initially so I used engineers’ chalk, which is talc although not the purest. I now have a fair stock of pure, soft talc from Egypt.

Diamond (H10) was not as problematic as one would think. Ownership of uncut stones is illegal in southern Africa and also, even a poor-quality bort would disproportionally raise the price of a boxed set of Mohs hardness-scale minerals. Most commercially marketed Mohs collections only contain examples of hardness 1 to 9. However, diamond cutting-tool edges are composed of microdiamonds in a soft base-metal matrix. Pieces of these were sandblasted to expose the microdiamonds and they work effectively as hardness testers; easily scratching corundum.

The plastic boxes have folded and glued card partitions with labels. A glossy card insert provides a key to the partitions with the chemical formula and mode of occurrence of each mineral (Fig. 2). The reverse side gives the history of Mohs scale, a comparison with the Vickers scale and instructions for use. Further information is also provided on the sticker inside the lid.

Figure 2 – Boxed set of Mohs Hardness testing minerals, with glossy information card insert.

With a positive response to the quality of the boxed sets from university staff, students, professionals and hobbyists, I am making up similar boxes of the ten, major, igneous and volcanic rock-forming minerals and have now acquired stocks of all the minerals required, again from various places around the world. For these sets, the card insert depicts a modification of Bowen’s reaction series to show the order of crystallisation but has more overlaps than Bowen’s continuous branch of calcic to sodic plagioclase to indicate, in general, which minerals can occur simultaneously in a magma.

Figure 3 – Olivine: Mg_2, $Fe_2^{2+}SiO4$, as dunite (Norway), composed almost entirely of olivine.

The minerals olivine (as pure dunite) (Fig. 3), pyroxene (diopside), amphibole (hornblende) (Fig. 4), biotite, plagioclase (labradorite), muscovite (Norway), orthoclase, quartz, garnet and calcite are provided. The olivine, hornblende, muscovite and orthoclase are from Norway and the biotite is from Pakistan.

Figure 4 – Hornblende: $Ca_2(Fe^{2+}{}_4,Al)(AlSi_7O_{22})(OH)_2$ (Norway), in a monoclinic crystal aggregate.

A future project is a set of metamorphic minerals based on George Barrow's 19th century recognition of facies and zoning with regional metamorphism of argillites and his designation of six index minerals (Barrow, 1893). These are, in increasing metamorphic intensity; chlorite, biotite, garnet (Fig. 5), staurolite (Fig. 6), kyanite (Fig. 7) and sillimanite (the quartz/feldspar and muscovite zones are not indexed as they are ubiquitous in many rocks and cannot be used to determine the metamorphic facies).

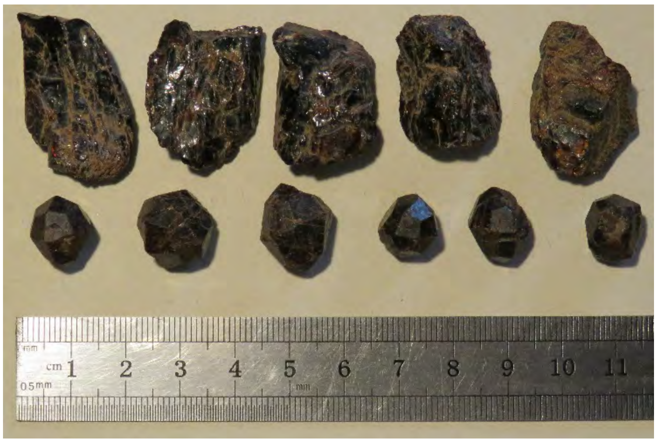


Figure 5 – Almandine garnet: $Fe_3^{2+}Al_2(SiO_4)_3$, as cubic trapezohedra and rough-crystalline forms.

Figure 6 – Staurolite (Fe^{2+}, $Mg,Zn)_2Al_9$ $(Si,Al)_4O_{22}$ $(OH)_2$ (Russia) in cruciform, monoclinic twinned crystals.

Figure 7 – Kyanite Al_2SiO_5, as bladed, triclinic crystals.

Also provided will be the minerals formed during contact metamorphism of argillites, in increasing metamorphic intensity; graphite, andalusite (including the variety chiastolite) and cordierite. The latter suite of minerals takes me back to a camping weekend at Carrock Fell in the English Lake District around 1978. Here the early-Devonian, Skiddaw Granite (398±8 Ma) intrudes slates of the Ordivician, Skiddaw-Group argillites. Approaching the contact, segregations of carbon (graphite) appear in the "spotted slates". These give way to porphyroblasts of chiastolite in the slate and then cordierite porphyroblasts in hornfels occur in the inner zone. Metamorphic overprinting has occurred here as the granite pluton was emplaced between the regional D1 and D2 deformation phases that mark the closure of the Iapetus Ocean at the northwest Avalonia margin.

The collection of these sets of metamorphic minerals is a greater challenge than the previous mineral sets due to the relative rarity of macro-specimens of some of the minerals. I found stocks of kyanite and chiastolite, sourced chlorite (in schist) from Scotland, garnet from Norway and a supply of cordierite hornfels from the locality in English Lake District that I mentioned earlier. Lump graphite is also available from the nearby in the same area, one of only two large volcanic-hosted occurrences in the World, the other being in Spain. This would perhaps not be entirely honest in a metamorphic collection though and good pieces of graphite are available from China. I imported some beautiful, cruciform-twinned staurolite crystals from Russia. Andalusite is readily available in the Bushveld Complex aureole but sillimanite in appreciable quantity is scarce worldwide, only being mined in India but was mined historically near Pofadder in this country in the past (Frick & Coetzee, 1974). I suppose I will be making a trip there before long.

References:

Barrow G. (1893) On an Intrusion of Muscovite-biotite Gneiss in the South-eastern Highlands of Scotland, and its accompanying Metamorphism. George Barrow. Quarterly Journal of the Geological Society, 49, 330-358.

Frick, C., Coetzee, C.B. (1974) The mineralogy and the petrology of the sillimanite deposits west of Pofadder, Namaqualand. Trans. Geol. Soc. S. Afr., 77, 169-183.

Mineralogical Geragogics

Lesley Andrews

The term "Geragogy" was coined by J. Lebel in 1978 and is used interchangeably with "Educational Gerontology" (Maderer & Skiba, 2006). Lebel felt there was a need to focus an educational theory on the needs of older adults.

Over the last thirty years, a plethora of Geragogy-related articles has appeared in educational publications, especially in Europe and the USA. Definitions of the age of older adults vary from one country to the next as well as between organisations. Although people in their fifties sometimes qualify, the usual age group targeted is the over-sixties, who are commonly (but not always) retired.

Studies invariably show that the education of seniors boosts their quality of life, and that there is a demand for opportunities to learn something new, or to further existing knowledge. Learning should be a life-long process, and in the elderly there are added advantages such as increasing cognitive ability and social interactions (Escuder-Mollon *et al.*, 2014; Herscu-Kluska *et al.*, 2018).

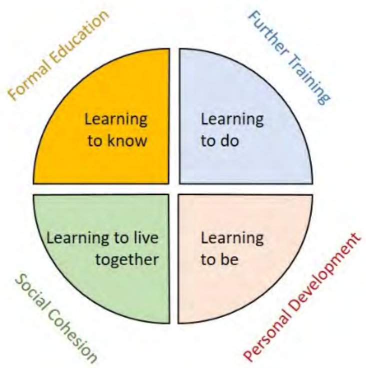


Figure 1: The ELLI Framework. The lower quadrants generally apply to senior learners.

A schematic representation of the ELLI (European Lifelong Learning Indicators) framework is shown in Figure 1. This cycle and its applications apply to all forms of education and illustrate the changing requirements with life stage. These are explained in detail in the literature (*e.g.,* Saisana, 2010; Hrebeňárová, 2018).

Geragogic principles

The application of such principles to science and technology does not feature in the literature to a great extent, but the guidelines are the same. Any senior teaching scheme must take account of the following:

- Student age range and distribution
- Previous knowledge or experience
- The number of students (should not be large, 10 is ideal, 20 at a stretch)
- The mobility of students (especially if any outings or visits are involved)
- The budget available (usually 0 – most senior teaching is voluntary)

The time, frequency and venue for a senior teaching class must also be established. Students will prefer to attend classes during the daylight hours, and they will not want to be involved in peak hour traffic. Class should be limited to one day and time, be it weekly or monthly. The venue should be accessible and suitable seating provided.

When teaching the elderly it is important to proceed at a slower pace than when teaching younger persons, and to limit the subject matter to what can be absorbed. Always revisit previous lessons before launching into the next session. Talk slowly and clearly and keep your lectures short. Depending on their age, senior learners may be subject to short attention span, poor eyesight and some degree of deafness. A bit of practical study and some moving around keeps everyone motivated.

The social side of the teaching is particularly important. Tea and coffee, even biscuits, should be produced at the end of the lesson and the students should be encouraged to "chat", *verbally* that is! The advantages (to both teacher and student) of senior coursework are that there are no assignments, tests or exams, and that talks can be customised to accommodate the students' preferred subject matter where this is practical.

Geragogy and Mineralogy

When teaching Mineralogy or Mineral Science there is bound to be some overlap with other geosciences such as Geology, Gemmology, Palaeontology, Geochemistry, and so on. Material of this kind can be included to give background and to add interest. Terminology in the geosciences can be like a foreign language to new learners – take time to go over this or write up a small glossary for distribution.

Course content

As mentioned earlier, this depends largely on the level of experience or understanding of the subject and can be customised to suit individual interests. Some idea of coursework for basic and more advanced students over 10-12 sessions is given in Table 1. The more advanced students can be on their second time around or have a history of working with minerals. It is common for senior learners to "repeat", often purely for the social aspect, so it is a good idea to introduce a different slant or to use new examples to retain interest.

Table 1: Examples of mineralogical course content for senior learners.

	Basic	*More Advanced*
Introduction	Rocks and Minerals Minerals *vs.* Crystals	Rock Types and Related Minerals
Structural Properties	Crystal Shapes Crystal Planes *vs.* Facets	Crystal Systems Crystal Twins Isomorphs and Polymorphs
Physical Properties	Hardness, Density Colour, Lustre	Hardness, Density, Cleavage, Magnetism Colour, Lustre, Opacity, R.I.
Optical Properties	Coloured Varieties	Coloured Varieties and Origin
Composition	Chemical Composition Mineral Identification	Chemical Composition, Allotropes Classification and Identification

Practical Sessions

Approximately half of each lesson should consist of practical exercises. If possible, samples relating to the same-day talk should be made available, as well as any reference books, but nothing should be removed from the classroom. Local libraries usually keep mineral and gem-related books in the non-fiction section, and these can be taken out by the students themselves. Those who have access to computers and the internet can learn more at home.

Outings

Any outing undertaken should be local, physically undemanding, and feature a visit to a coffee shop or tearoom. A walk along the beach will serve to identify minerals in local rocks, and pebbles of more distant origin. A visit to a stone mason's shop is preferable to scrambling around a quarry, and so on. Many National Museums have displays of minerals and gemstones, lifts, seats for visitors and, invariably, a tearoom!

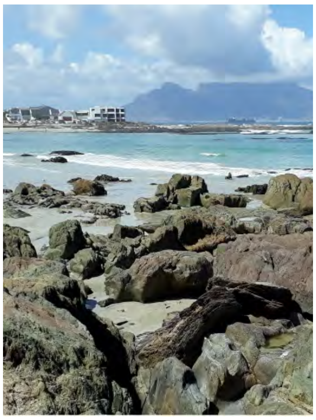


Figure 2: A short outing to the beach is ideal for the examination of rocks and minerals in situ and in transported pebbles.

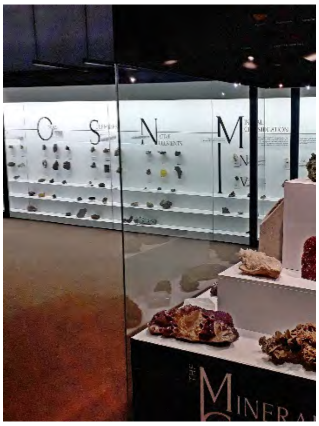


Figure 3: An example of an informative museum display on minerals. This one is in the Iziko South African Museum in Cape Town.

To end on a personal note: I have taught mineralogy sporadically to people aged from eight to (over) eighty, and I find teaching senior people is both relaxing and fun. No doubt some of my enjoyment springs from being a senior learner myself!

References

Escuder-Mollon, P., Esteller-Curto, R., Issakainen, Lubkina,V. and Lozanova, S. (2014). *Procedia – Social and Behavioural Sciences,* **116**, 3152-3159.

Herscu-Kluska, R., Pe'er, S. and Shafir, S. (2018). *Proc. 9th Conference of the ESREA Research Network on the Education and Learning of Older Adults,* Univ. of the Algarve, 157-168.

Hrebeňárová, L. & Kulla, A. (2018). *Proc. 9th Conference of the ESREA Research Network on the Education and Learning of Older Adults,* Univ. of the Algarve, 200-213.

Lebel, J. (1978). *Lifelong Learning: The Adult Years,* **1**(9), 16-25.

Maderer, P. & Skiba, A. (2006). *Educational Gerontology,* **32**, issue 2, 125-146.

Saisana, M. (2010). *European Commission. JRC Report* EUR24529EN, 53pp.

More on Mineralogy

Minsa readers interested in serious analysis of and insights into mineralogy teaching are also directed to the following article:

The mineralogy concept inventory: A statistically validated assessment to measure learning gains in undergraduate mineralogy courses, by Emily D. Scribner and Sara E. Harris, in the Journal of Geoscience Education in 2020 (Vol. 68, No. 3, 186–198) at https://doi.org/10.1080/10899995.2019.1662929.

Minsa readers interested in the frivolous aspects of mineralogy and geology teaching are invited to read on:

The Moh's Hardness Scale

and this was how my classmate and I all related to that (there was a lot of slapping & simulated eye-poking involved; good for reinforcing concepts):

Hard-ness	Archetypal mineral	A	B	C	D*
1	*Talc*	The	The	To	Toronto
2	*Gypsum*	Girls	Green	Get	Girls
3	*Calcite*	Can	Clawed	Candy	Can
4	*Fluorite*	Fight	Ferocious	From	Flirt
5	*Apatite*	And	Aardvark	Aunt	And
6	*Orthoclase/Feldspar*	Order	Ordered	Fanny	Only
7	*Quartz*	Queens	Quick	Quit	Quit
8	*Topaz*	To	Tasty	Teasing	To
9	*Corundum/Sapphire*	Sacrifice	Chinese	Cousin	Chase
10	*Diamond*	Diamonds	Dinners	Danny	Dwarves

Sources:

A. *https://geoetc.com/how-hard-is-mineral-hardness/*
B. *https://www.cliffsnotes.com/study-guides/geology/the-earths-components/mineral-properties*
C. *https://slideplayer.com/slide/8960585/ (Mineral Identification by Valentine Casey)*
D. *https://en.wikipedia.org/wiki/List_of_mnemonics#Geology**

*This one is from Wikipedia, but as a native-born Torontonian, it doesn't really ring any bells!

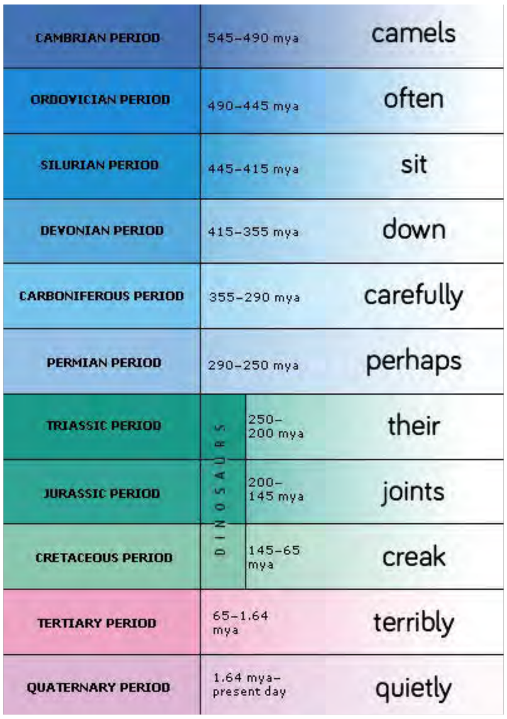
An additional problem I have encountered in teaching mineral hardness in South Africa is with the reference materials. We mostly do not use a copper coin, but rather alloys of copper and other metals for our coinage, so the good 'ol copper penny (discontinued in Canada since 2013, as 1¢ is increasing good for nothing) is not actually available as a reference hardness for H3. The U.S. penny (2.5 % copper plating; 97.5 % zinc) and the Canadian (4.5 % copper plating; 95.5 % steel + nickel). Our tiny 10¢ coin is actually also copper-plated steel, but the more manageable 20 and 50¢ coins are bronze-coated steel, where the copper is alloyed with other, harder metals.

H3 reference materials, from my sock drawer: from left to right: A U.S. penny, a Canadian penny, a S.A. 10, 20 and 50 cent piece, and a Namibian dollar coin. The two more reddish coins are most copper-plated; note that the Canadian penny is turning green on the edges, evidence of copper oxidation.

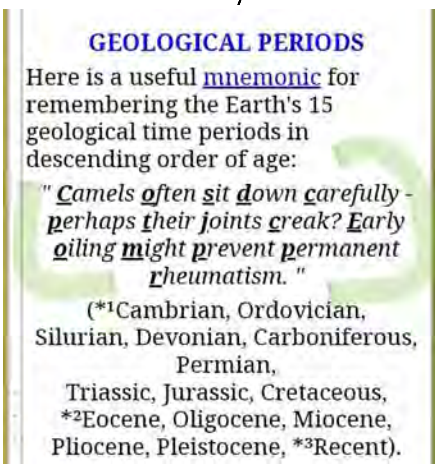
Providing a steel nail also tends to invite destruction of specimens; I mean, it does come with a built-in pointy end, and these are first-years, so…

Moving on, we can leave Mineralogy *per se* behind and venture out into the wider world of geology for some time period mnemonics, next.

A common memory problem is the revision of the basic Geological time Periods. A widely shared online mnemonic involves rheumatic camels (an African connection, clearly):



(from https://blogs.ncl.ac.uk/stem/2017/01/20/top-revision-tips-memory-techniques/).
Some more ambitious schemes incorporate the epochs of the former Tertiary Period:

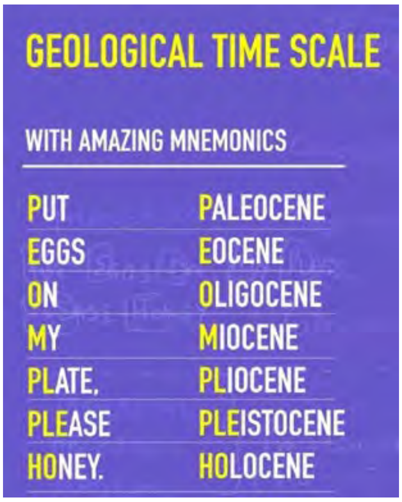

GEOLOGICAL PERIODS

Here is a useful mnemonic for remembering the Earth's 15 geological time periods in descending order of age:

" *Camels often sit down carefully - perhaps their joints creak? Early oiling might prevent permanent rheumatism.* "

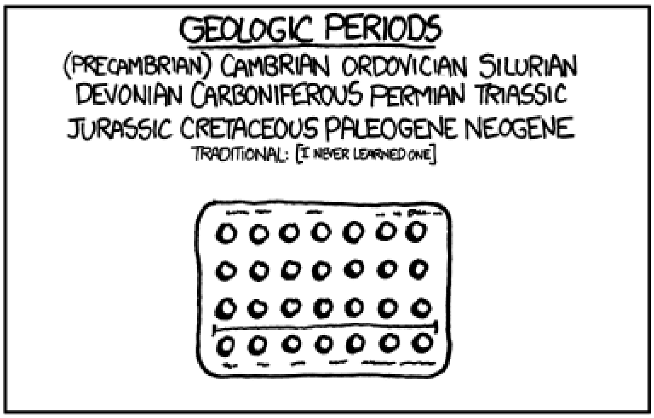
(*¹Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, *²Eocene, Oligocene, Miocene, Pliocene, Pleistocene, *³Recent).

from https://leilabattison.wordpress.com/2012/01/29/camels-in-the-cambrian-a-geology-mnemonic/, and



from Samajho Learning, Sep 17, 2018 (YouTube).

Since the abandonment of the Tertiary and Quaternary, additional revision has been required. A novel option that addresses this, among other things, can be found at https://xkcd.com/992/:



POLYCYSTIC OVARIAN SYNDROME DOES CAUSE PROBLEMS THAT JUDICIOUS CONTRACEPTIVES PARTIALLY NEGATE.

Moving back up to the larger, less troublesome time periods, such as the Eras, we find , for the sequence Precambrian, Paleozoic, Mesozoic, Cenozoic, the mnemonic “Please Pay My Children!” offered by https://www.homeschoolwithlove.com/2019/09/02/mnemonics-for-geological-periods/.

And what about the Geological Æons (Eons)?

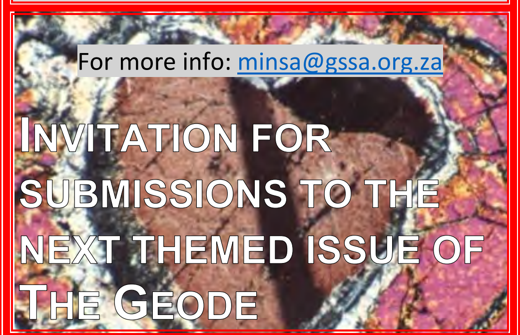
Æon	Mineralogist	Agriculturalist	Florist	Marxist
Hadæan	Halite	Harvest	Hibiscus’	Harness
Archæan	Always	And	Are	All
Proterozoic	Precipitates	Plant,	Predominantly	Proletarian
Phanerozoic	Prediagenetically	Perennially	Pink	Production

Yes; let’s bring back the dipthong; it’s Alt-145 (lower case) and Alt-146 (upper case)! My usual problem is remembering which time periods are eons and which are eras, but that’s another matter. Let’s face it, if you struggle to remember four eon names, geological mnemonics are probably the least of your worries. You’ll probably be needing this one, too, in the mornings: Uncle Sam Plants Squash Slowly (for the North Americans: underwear, socks, pants, shirt, shoes) or for the UK, “Princess Stinks, Tabloids Still Say” (pants, socks, trousers, shirt, shoes), or alternatively, “Palace Six, Tottenham Score Seven”. And/or “Pangolin (or) Bat Disease” (pants, bra, dress). Opposite order at bed-time, folks. (I realise that not everyone dresses themselves in this sequence; it’s a general guide. If you want to replace pants/trousers with a skirt, then it’s a mess of “s”’s, so we’re not addressing that option; sorry.)

Contributed by S. Prevec

Minsa invites its members to contribute submissions for our next issue of the Geode, on the theme of “determining the oxidation state of rocks” (see below), for June 2021.

Submissions can be sent to minsa@gssa.org.za and should reach us by 31st May 2021.



Submissions dealing with analytical methods for determining the oxidation state of rocks are solicited. Some examples include the traditional, but seemingly relatively rarely conducted titration/wet chemical method, the use of Nuclear Magnetic Resonance(NMR) spectroscopy, and inferring oxidation states from inferred site occupancies from mineral chemical analyses (by EPMA or SEM-EDS). Or simply using a correction factor based on whole rock geochemistry. Or just writing FeO* and hoping nobody notices.

Minsa Mirth, or "Is our children learning?"; How effective are all those learning devices, anyway?

Here are a few excerpts from (mostly) first year student submissions over the past few years, as collected by I. Tonžetić and S. Prevec *(and in case you think we are simply making fun of confused students here, think again; all of these errors are clues as to how students link unfamiliar new information against their existing reference knowledge database, which is probably different from yours; these are windows into student thinking and core knowledge, which the teacher can access constructively, potentially)*:

Q. Name the three types of solid solution:

A. Substitutional (tick)

Interstitial (tick)

OSMOSION (the solid solution that occurs through OSMOSIS?!)

In an essay question on diamonds:

"In 1905 the worlds largest diamond, the Cullinan, weighing about 1,37 TONS (that's one big diamond!?!?!) was found in the Premier Mine. When found at the surface, it was an ALTERNATIVE (wonder what Kurt Cobain would say about that?!?!?!) product.

Q. Define "Association" in the mineralogical context (as related to mineral occurrences).

A. "Association is a group of minerals with the same MOTIVE." (To assassinate someone?!?!?!)

A lecturer marking an essay on fracking:

"Just marked an essay about "Franking" in the Karoo. I assumed it was just a typo in her title, but she uses this word very consistently throughout the essay. (Franking is actually what the post office does when it stamps your mail, to confirm that the correct postage has been paid. If we stop franking in the Karoo, none of the farmers will get their mail!)

Answer returned on the systematic classification of goethite:

Goethite is part of the "DIASPORA" group (imagine an orthorhombic crystal sporting Hasidic dreads wandering in the desert! Or an orthorhombic crystal with a thick South African accent in the outback!).

From a first-year essay on fracking:

"Fracking is a clever process in accessing the trapped gases in our Earth's CORE" (That's some serious fracking!).

Did you know??:

The concept of continental drift was introduced by Polar Welner?

(presumably the offspring of Alfred Wegener and Polar Wander...)

The student further theorized that it is not possible for similar fossils to be found on different continents, since the continents are separated by oceans and fossils cannot fly!

The process that explains why the inner core is liquid is called the Geomophysics.

(this must be the equivalent of alchemy to geophysicists, particularly as the inner core is in fact believed to be solid, although very recently, new seismic evidence suggests the existence of a liquid inner-inner core! But that only came out after this course was taught.)

An example, admittedly "made up" (according to the student), of an absolute age time scale, used in an exam as an example of absolute dating (but they had been taught the real dates):

800-900 BC: Dinosaurs
900 BC: Birds
901-901 BC: Dinosaur extinction
1500 AD: Humans
1875: The first car

I also had a student state that as an example of an age relationship, Prof. is 61 years older than the students. What the hell? They think I'm 80! (From a lecturer in his mid-50's).

Compiled by Tonžetić & Prevec

Other Gems

Great moments in mineral density calculation

Indiana Jones and the Raiders of the Lost Ark

In the opening scenes of Steven Spielberg's 1981 classic film "Raiders of the Lost Ark", our protagonist, Indiana Jones, a Professor of Archaeology in his day-job, attempts to liberate a golden fertility idol from its roost by quickly switching it for a substitute of equal weight, so as not to trigger the various protective devices set up to prevent its theft. Dr Jones uses a bag of what appears to be sand, of approximately equal volume to the idol, as a replacement. Prior to the switch, we see him evaluating the volume of the idol and pouring out a small amount of sand from the bag, as though refining (downwards) his weight estimate of the idol.

So, let us assess this plan from a mineral density perspective. The density (specific weight, if you prefer) of gold is around 19.3 g/cm^3, one of the densest elements around. An idol with the volume of a cylinder about (conservatively) 20 cm high and say 12 cm wide, on average, would have a volume equal to $\pi r^2 h$, which is around 2260 cm^3 (or 2.3 litres, if you prefer). For solid gold, this would correspond to a not inconsiderable weight of just over 44 kg. A corresponding-sized (well, let's make it a bit bigger, for the sake of argument, at 20x15 cm) sack of sand, consisting of grains of quartz (density of 2.65 g/cm^3) and intergrain spaces filled with, well, air, would have a density of around 1.6 g/cm^3 (I looked it up; with wet sand, you can get up to 2.0 g/cm^3, but Indy's sand was clearly dry), for a weight of around 5.7 kg. We are ignoring the weight contribution of the bag, which should be negligible. At first glance, then, it is no surprise that thirty seconds later he is racing through a hail of poisoned darts and running from a huge stone boulder.

Can we reconcile this apparent mismatch any other way? Surely when Indy picked up the idol, he would have quickly noticed that it weighed a lot more than his sandbag and reacted with a little discomfort and/or anticipation, instead of nervous smugness. Maybe he wasn't using plain old beach sand, but rather something much denser. Chromite, for example, with a density of around 5 g/cm^3, produces a very nice fine sand, as many people attempting to collect and transport hand specimens of the LG6 chromitite layer from the Bushveld can attest. The density of chromite sand is around 2.6 g/cm^3, though, which still only gives us a sack weighing about 9 kg. Also, when Indy pours out the sand during his evaluative phase, it is clearly not black chromite sand, but white. Are there any other possible candidates? Pure lead has a density of 11.3 g/cm^3, but galena (PbS) is only 7.6 g/cm^3, and a galena sand would presumably again be around half of that (and it would look silvery and cubic). Lead-halogen salts have relatively high densities; lead iodide (6.2 g/cm^3) is bright yellow, but both lead bromide (6.6 g/cm^3, a byproduct of leaded petrol of yester-year) and lead chloride (5.9 g/cm^3, and a key ingredient in lead-based white paints of similar vintage) are both white powders, albeit toxic to humans. If Indy had a sack of lead salts 30 cm by 22 cm, then he'd have his 40 kg. And, given the toxic properties of the sand he'd been cavalierly pouring through his fingers, we'd have an explanation for his happy-go-lucky approach to risk-taking, relationships, and museum ethics. However, he is not carrying a big sack of bright white lead salts the size of his head, and let's face it, even gold sand is not going to provide a corresponding weight to a solid gold idol unless he was carrying a sack of it twice the size of the idol.

So maybe it was not a solid gold idol, then. Let's assume it does have some substantive weight to it, though, probably consistent with the 6 kg sack of beach sand we used as our default premise. A minute later Indy is coerced into tossing the idol to his last surviving porter, and the item clearly has some heft to it. In alternative existences, his porter goes on to become the similarly imprudent mayor of a small provincial French village (in "Chocolat"), and soon after that, Doc Octopus, who would have had no trouble making his escape with the idol, but here he survives only a few seconds more, dropping the idol again in the process of getting impaled on a spring-loaded spiky-trellis trap.

Could it be an alloy of gold and another metal, rather than 24 carat (pure) gold? 18 carat gold consists of 75 % gold combined with various other metals, typically mostly copper, accessory (a few percent) silver or other alternatives. 12 carat gold is only 50% gold, but even a 12 carat gold-copper alloy (known as red gold, thanks to the colour contribution from the copper) would have a density of over 14 g/cm^3, for an idol weight of 32 kg. So a plausible metal alloy, in which the gold is not so diluted as to disrespect the idol, is probably not the answer.

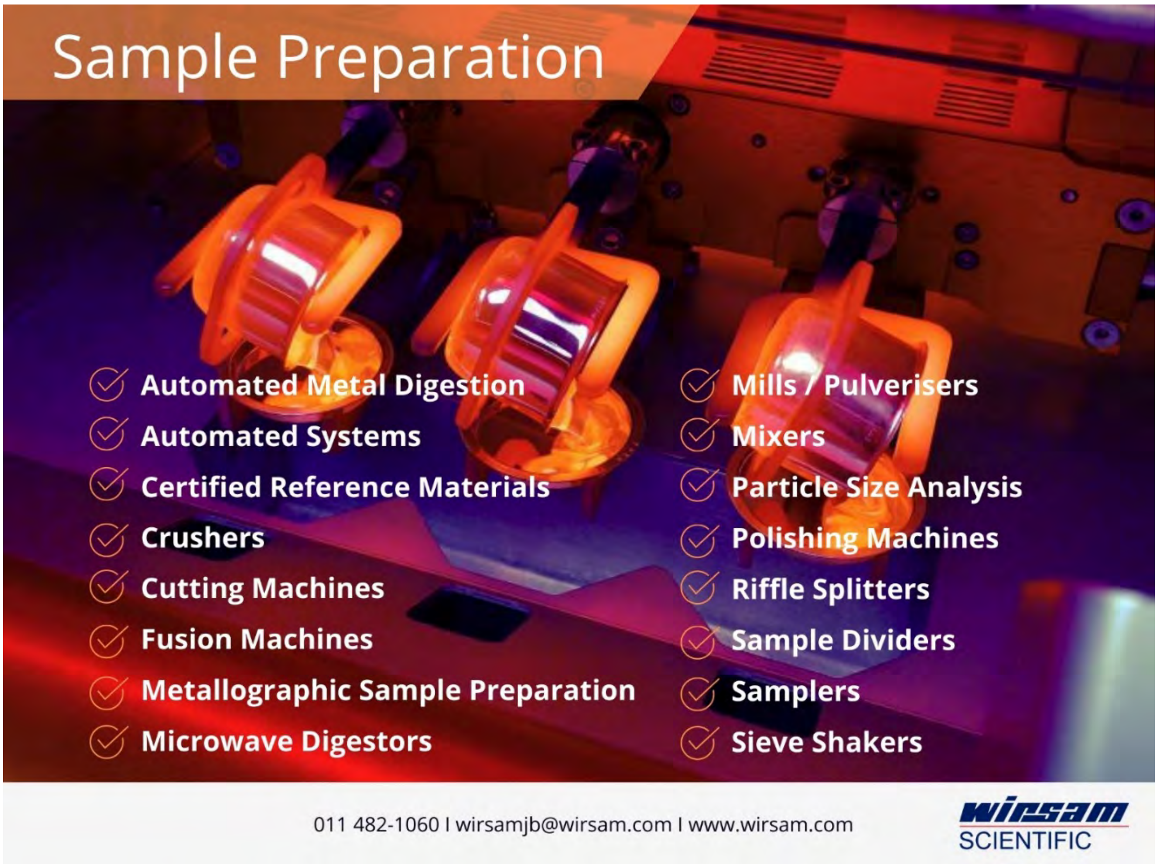
The eight-hundred year old golden rhino of Mapungubwe (located in modern-day Limpopo Province, South Africa), is made of wood, plated with gold sheet. There are various woods native to South America (which we are informed is the setting of Dr Jones' current activities) which have densities on the order of 1 g/cm^3, which is about as dense as wood gets, including the Lignum vitae (the guayacan), and the greenwood. An idol of our prescribed dimensions made of wood could weigh 3.5 kg, leaving the remaining 2 kg or so to attribute to gold plating. This would correspond to a sheet of gold of 1 mm thickness (not atypical commercially today) wrapped around the wooden idol four times, and then worked to its current artistic format. The density of the wood is thus effectively irrelevant to this calculation, since we could just use more gold, but usually the idea is to make your gold go as far as possible as an economic principle, so we'll stick to nice dense wood. I would suggest then that this is the most plausible explanation here. Apparently the carving which inspired this movie prop was a Peruvian fertility symbol carved from a block of "greenstone" (hence, mostly serpentinite of some description), which would have itself had a weight of 7-10 kg based on our modelling dimensions.

Dr Jones then goes on to outrun and evade a boulder rolling down a ramp designed to take out any intruders who have evaded the other potentially lethal traps. Since we're here anyway (and yes, I do have an imminent manuscript deadline, a Faculty Board meeting, and teaching to prepare; why do you think I'm doing this instead?), a 2 m-diameter granitic boulder (density around 2.7 g/cm^3) would have a volume of 4000 litres, and weigh just over eleven tonnes. If we use a dolomite boulder, arguably a little easier to shape for such a trap, it has a density of 2.8 g/cm^3, but ultimately this doesn't really make much difference.

If we assume, based on a quick squizz at the movie footage, that the boulder starts from a height of 2.5 m and drops to about waist-height (say 1 m) within 5 m of distance (or 2.5 boulder rotations, if you like), and then carries on from there on a flatter ramp for 10 m until it hits ground level, this corresponds to an initial acceleration up to a speed of about 15 km/hr over 1.5 seconds, then picking up speed on the lower ramp to reach a speed of about 27 km/hr after 15 m of rolling over about 7 seconds (I didn't do *this* math from scratch; I used a physics website). This seems very broadly consistent with the movie time. If you shorten up the distances, the acceleration increases and so does the speed. Usain Bolt has averaged just under 40 km/hr over 100 m, and he peaks at speeds greater than this, but not in the first few tens of metres. Athletes can run 20 m from a standing start in less than three seconds, apparently, corresponding to speeds of better than 6 m/s (about 22 km/hr). This is slower than the boulder at the end of that ramp, so it's touch and go as whether Indy, laden with his idol and field gear and work boots, albeit with a bit of a muscle warm-up and a head start perhaps, and a great adrenaline surge, could have made it to the end. The boulder had to whack its way through some roots and stalagmites along the way, slowing it down a little. So maybe.

Contributed by S. Prevec
Rhodes University Geology

.


Sample Preparation
Automated Metal Digestion
Automated Systems
Certified Reference Materials
Crushers
Cutting Machines
Fusion Machines
Metallographic Sample Preparation
Microwave Digestors
Mills / Pulverisers
Mixers
Particle Size Analysis
Polishing Machines
Riffle Splitters
Sample Dividers
Samplers
Sieve Shakers
011 482-1060 I wirsamjb@wirsam.com I www.wirsam.com
wirsam SCIENTIFIC

Be the mentor you wish you had!

Bridge the Gap Geosciences Guidance Program (BTG), is a student run organization that focuses on mentorship between undergraduate and postgraduate students as well as students and industry professionals. In addition BTG hosts a number of informative talks, workshops and field trips to expose students and graduates to opportunities and expectations in the work environment.

Earn CPD points through mentoring!

Be the mentor you wish you had and assist in giving some guidance to geology undergraduate and postgraduate students by signing up to be a mentor through BTG. We invite all geosciences/ mining related companies, industry professionals and academics to 'bridge the gap' between university and industry, and to act as positive role models by joining the BTG program as a mentor, sponsor or motivational speaker.

If you are interested in getting involved please complete the Google form by clicking on the following link: https://forms.gle/Sf5tMciuSStAQuFL8

BridgeTheGap
GeosciencesGuidanceProgram
EMPOWER || INSPIRE

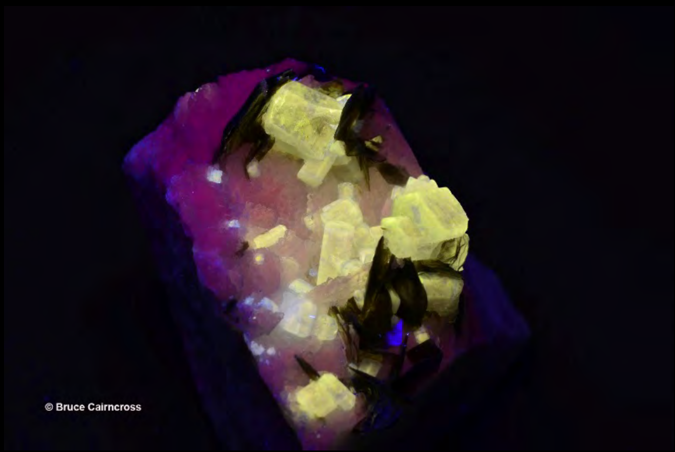
Your influence can go a long way in encouraging and shaping aspiring geologists to become future leaders. We believe that each of us can inspire and empower students by being 'the mentor you wish you had'

The program will start in February/March 2021

Bruce's Beauties: Fluorescence

The selections of minerals for this issues feature are some local southern African specimens that display fluorescence, often in different colour to what the specimen displays under normal daylight.

In all the images below, the specimen on the left has been photographed under normal daylight, while the image on the right is seen under 365 nm long wave ultraviolet light. Photographing under UV light is challenging, as exposures often run into many seconds and vibrations of the camera tripod have to be kept to an absolute minimum. As does the platform the specimens stand on. Some photographers who live close to busy highways have problems with vibrations from passing traffic causing blurry images!

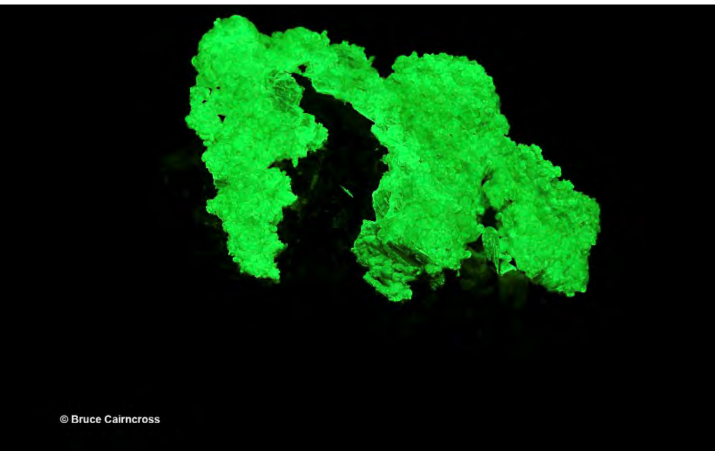


Above, transparent, glassy fluorapatite-(K), almost invisible under normal light, associated with quartz and muscovite from the Blesberg pegmatite, Northern Cape Province, 3.6 cm.

The apatite fluoresces bright yellow under UV light. Bruce Cairncross specimen and photos.

Above, a doubly terminated calcite crystal, associated with barite, 7 cm, from N'Chwaning II mine in the Kalahari manganese field.

Bruce Cairncross specimen and photos.



Above, black schorl and smoky quartz, partly coated by glassy, botryoidal quartz, variety hyalite, 6.4 cm. Erongo Mountains, Namibia.

The latter fluoresces brilliant yellow under the UV light. This hyalite is so fluorescent that it glows in bright sunlight.
Bruce Cairncross specimen and photos.

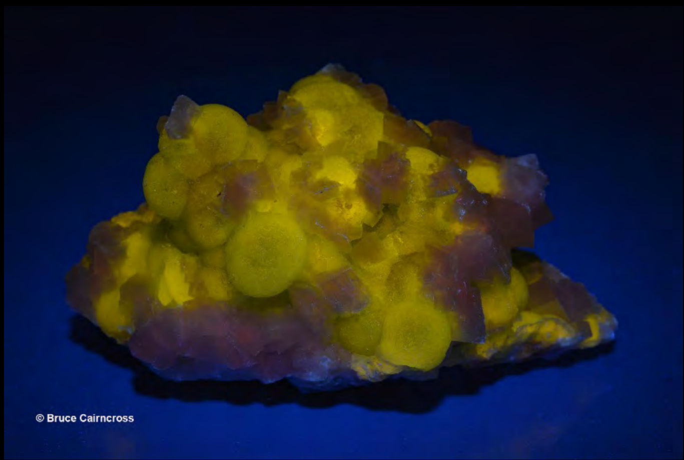
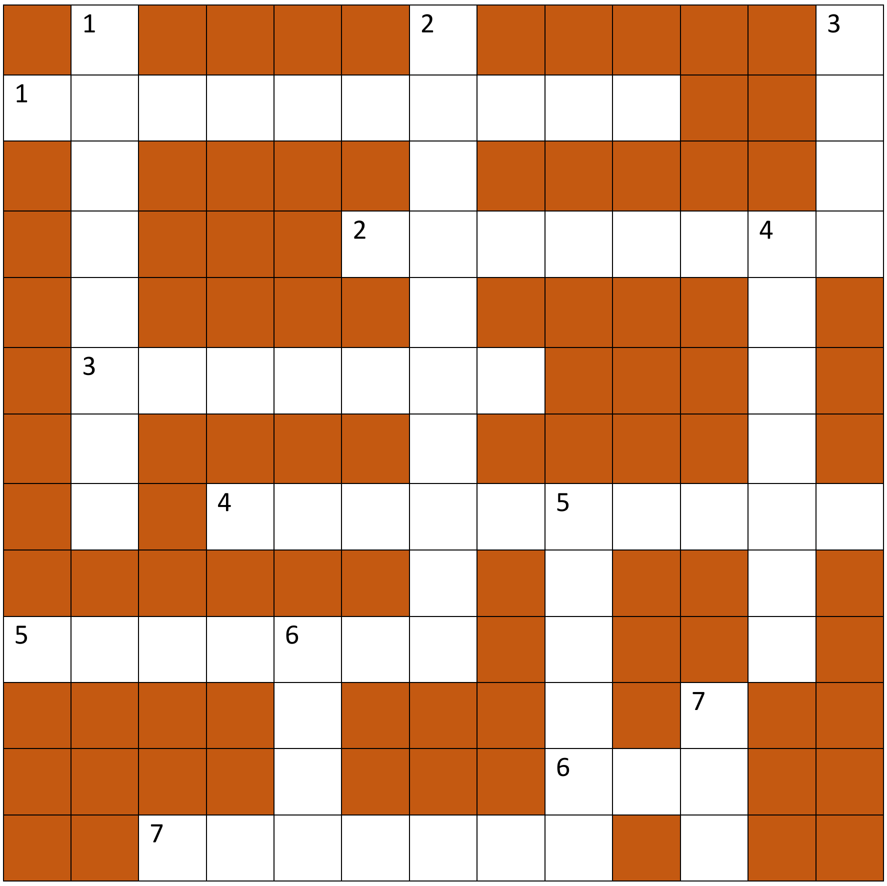


Figure 4. Blue willemite with white dolomite, 6.5 cm, from the Tsumeb mine, Namibia.

The willemite is yellow under UV light, versus its blue hue under normal light. Bruce Cairncross specimen and photos.

Minsa Crossword for March 2021

This issue's puzzle is in honour of Professor Anthony J. Naldrett (1933-June 2020), who wrote the book (twice!) on magmatic sulfides (*sic*), and made immense contributions to our understanding of Ni-Cu-PGE sulphide behaviour. Two journals are currently publishing special issues in his honour (Canadian Mineralogist & Economic Geology), and that's probably just the tip of the iceberg (or the gossan over the ore deposit, if you prefer). This is our bit.



ACROSS:

1. Naldrett's post-doc employer at the Geophysical Lab, from whence all those wonderfully complex ternary Ni-Fe-S and Cu-Fe-S phase diagrams originated; $NiSe_2$ is named for him.
2. The dominant mineral phase that proceeds from crystallization of immiscible sulphide liquid. Also, non-stoichiometric troilite.
3. _____-assay; The essential preconcentration stage for PGE+Au analysis, usually involving an oven, some powdered Pb or Ni, and S.
4. The city hosting Naldrett's academic home base for more than 30 years.
5. Frood-______ mine; During World War II, this mine accounted for a full 40 per cent of all the nickel used in Allied artillery production; the headframe was finally demolished in December 2020, after >100 years of mining.
6. The acronym for the Ir-associated PGE, compatible in sulphide solids (relative to sulphide liquids).
7. The acronym for the first solids to appear from cooling sulphide liquid, prior to ordering themselves into stoichiometric minerals.

DOWN:

1. The mineral (Pd,Ni)Sb, named for the mining camp at which Naldrett's career was linked for nearly half a century.
2. A sulphide of Pt, Pd and Ni discovered in the Bushveld Complex and named for the father & son who developed the x-ray techniques by which it was characterised.
3. The subject of Campbell & Naldrett's (1979) iconic paper in Economic Geology, providing a key to understanding partitioning behaviour of siderophile metals into sulphides in real magmatic systems. Normally written with a hyphen after the first letter (but not here).
4. The mining camp in Russia prominent in Naldrett's career, host to the largest known Ni-Cu-Pd ore deposit on Earth.
5. The chemical symbol for the main commodity mined at Sudbury (Canada).
6. The main Ru sulphide mineral, prominent as chromite-hosted grains in ophiolites and podiform chromitites.
7. A Cu-rich solid sulphide phase, exsolving at late magmatic temperatures from solids in 7 Down, forming mainly chalcopyrite.
8. NiS_2; the high temperature Ni phase associated with pentlandite ores.

Minsa Crossword Solution for December 2020

This puzzle's theme was South African-themed minerals; discovered here, named for South Africans, or prominently mined here.

	1 C					2 F				3 T		4 L
	A					O				R		I
1 W	I	L	L	E	M	S	E	I	T	E		E
	R					C				D		B
	N		2 J	A	C	O	B	S		3 O	R	E
	C					R				U		N
4 T	R	E	V	O	R	I	T	5 E		X		B
	O					T		G		I		E
	5 S	A	J	6 G		E		O		T		R
	S			A				L		E		G
	I			U				I				I
	T			T					7 A			T
	E		6 M	A	P	U	N	G	U	B	W	E

DOWN:

1. A Ni-Mg phyllosilicate mineral, $(Ni,Mg)_3Si_4O_{10}(OH)_2$, discovered in talc schists associated with the Barberton greenstone belt, named in the 1960s by Sybrand de Waal in honour of Prof. Johannes Willemse of the University of Pretoria (as was Prof. de Waal, only much more recently).
2. The family name of the farmer on whose farm, near Colesburg, in the Northern Cape, alluvial diamonds linked to kimberlites were first discovered in South Africa, by their son, Erasmus. Alluvial diamonds had been mined along the Vaal River over the preceding 60 years, but this 1867 discovery led indirectly to the identification of Kimberley's diamondiferous blue ground a year later.
3. The generic term for any mineral commodity which can be extracted from the ground and sold for economic gain.
4. $NiFe_2^{3+}O_4$, found in serpentinites from the Barberton area, and named (in 1921) for in honour of Major Tudor Gruffydd Trevor, mining inspector for the Pretoria District, Transvaal, South Africa. And no, it isn't "majorite" (which is in fact a shock metamorphic olivine)!
5. The acronym for the flagship journal of the Geological Society of South Africa.
6. The site of the capital of the 12th Century kingdom (of the same name), now part of the Limpopo Province, in which the earliest evidence of worked gold in South Africa was found.

ACROSS:

1. A phyllosilicate, $SrCa_3Na(Si_4O_{10})_2OH,H_2O*7$, found in manganese ore dumps of the Wessels Mine, Kalahari Manganese Field, South Africa, and named in 2016 in honour of Prof. Bruce Cairncross of the University of Johannesburg for his career contributions to mineralogy.
2. $NiSb_2O_6$ (nickel antimony oxide), found in Ni ores from the Barberton area, and named in honour of the (now) late Prof. Marian Tredoux in recognition of her career work on Ni and precious metal ore minerals at Wits University, UCT, and finally at the University of the Free State.
3. A phosphorus ore rock composed primarily of magnetite, apatite and olivine, associated with carbonatites, and named for its discovery site at the Phalaborwa mine, Mpumalanga, operated by Foskor (Pty) Ltd of South Africa. The spelling used here links to the company spelling, rather than that of the ore element, which is otherwise valid.
4. $(Ni,Mg)_2SiO_4$, a nickeliferous forsteritic olivine, found in ultramafic rocks in Barberton, speculatively derived from meteoritic sources (but don't bet the farm on it). Named (by Sybrand de Waal) in honour of William Liebenberg, Deputy Director-General of the National Institute of Mineralogy (now MINTEK).
5. The Sotho name for Johannesburg, meaning "place of gold".
6. The North Sotho word for the commodity most profitably mined in the Johannesburg area over the past century and a half. The South Sotho spelling begins with 'kh', according to my sources (and will not fit, here).
7. The chemical symbol for the South African-mined precious metal currently trading at just under $1900 U.S., and which "all that glitters" is not, necessarily.

Note: The recommended deadline for submissions for the next issue of the Geode is May 31, 2021.