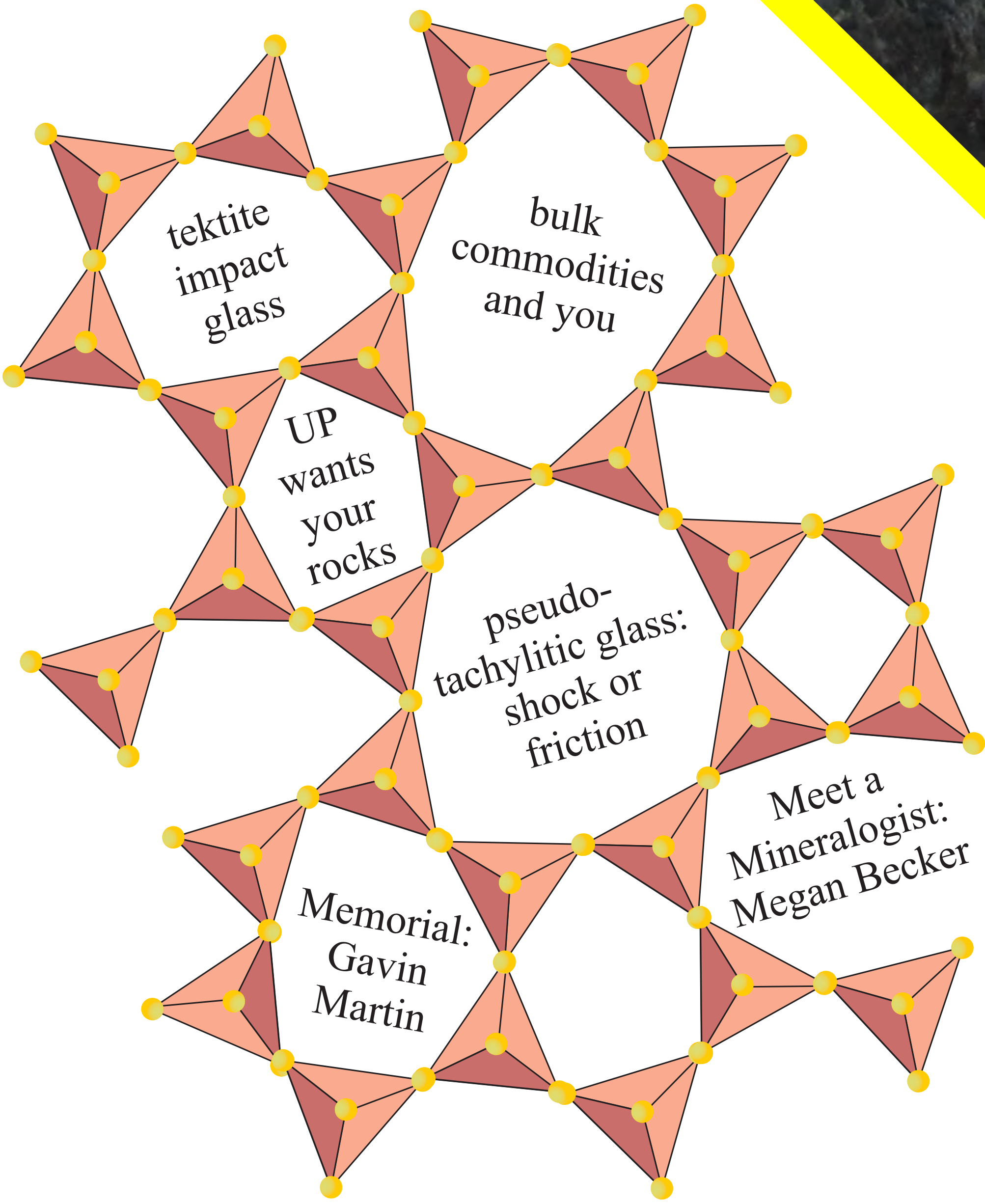
the Geode
the Geode

MINSA
Mineralogical Association of South Africa
A division of the GSSA

Glass in the geo-sciences; from shock metamorphic to lightning to laboratory.



The GEODE

Minsa Newsletter
Volume 9
No. 3
September
2022

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 9 No. 3
September 2022

2022: IMA's Year of Mineralogy

Contents

Next issue theme:

Clay minerals: what are they good for, and how do we analyse them?
(see also pg. 23)

Forthcoming Events & Attractions

Some events are still missing specific dates: Minsa will let you know! Watch for e-mailed announcements. All dates are 2022 unless otherwise stated.

- MEI (Minerals Engineering International):
  - Process Mineralogy – November 2-4 in Sitjes, Spain (online and in- person conference).
- R512 Dolomite Pub Crawl (19^{th} Nov., Lesedi Cultural Village, Lazy Lizard Brewhouse, L'Atmosphere Bistro, Nikita Restaurant Motel, Blue Night Revue Bar, Gem of the Bushveld Sportsbar).
- Minsa Night at the Museum, 2^{nd} December.
- Microscopy Society of South Africa (MSSA) annual meeting, Gold Reef City (JHB), December. For details, and membership info, see https://www.microscopy.co.za/.
- GSSA/IMSG combined meeting, January 2023 in Stellenbosch. See also their website at https://allevents.eventsair.com/geocongress/.
- 9^{th} International Platinum Symposium, 3-7 July 2023, Cardiff (U.K.).
- 5^{th} Southern African Minerals Symposium, 25^{th} Nov. 2023?

The Editor's Site

Welcome to the penultimate issue of the Minsa Geode for 2022. In this issue we are following the United Nations mandated focus on the Year of Glass, because that's the kind of responsive organisation that we are.

Accordingly, we feature articles on glass in geoscience contexts, both naturally occurring and analytical. These include features on impact-related glasses written by arguably the world experts on these topics, including tektites (from Christian Koeberl) and pseudotachylites (from Uwe Reimold, flying the flag of shock origin as distinct from a friction model), following an introduction to the topic by yours truly in which some of the various contexts in which glass is relevant to geoscientists are introduced; (I have omitted the glass ceiling, for example).

A tektite fragment, purchased by the Editor at this year's National Arts Festival.

In addition, Bruce Cairncross has photographed a selection of glass or glassy specimens especially for us, and our crossword this issue is glass-themed. Glass, glass, glass.

In this issue we continue with what we hope will become a more regular feature from now on, where a personal insight into practicing Mineralogists is provided, to inspire, educate and entertain prospective mineralogists and their colleagues. In this issue of "Meet a Mineralogist", Dr Megan Becker of the University of Cape Town is our featured guest.

We also remember Gavin Martin, who passed away earlier this year after an illustrious and long life and career in process mineralogy with Gold Fields – Lakefield – SGS.

I would also like to take this opportunity to thank the other Minsa members whose contributions of time and effort and make this publication possible, particularly Petra Dinham, without whose efforts to follow up on advertising and promised articles, and her keen editorial eye, this would be a significantly lesser quality product. All errors and omissions that slip through are mine.

And that's the Editor's site.

Steve Prevec

From the Chair

Time there was, when members of the association would, quite innocently, refer to me as "president" and I would have to correct them by insisting that I was in actual fact its chairman. Well, this will be my fourth tenure as chair of the association (the second longest serving tenure since the associations inception). I have served a presidential term…so in good humour, I will no longer be correcting those who refer to me as "president". Though it should be said, this will be my last tenure as "president". I'm growing long in the tooth and quite frankly am running out of ideas that I feel would come naturally to a younger, more fresh, more optimistic and more hopeful disposition.

Igor Tonžetić
Chair, 2022-23
Minsa Executive Committee

There has been one glaring and irritating failure in my dispensation (despite all the self-imposed mandates I feel I have achieved) …I have not been able to grow the association…and for the life of me, I don't understand why or how. I know we offer quality excursions, quality presentations, quality newsletters, quality workshops, and quality sessions at conferences. Admittedly, Covid (I would hazard to qualify that as "the political handling of Covid" rather) put a dampener (hydrothermal alteration?) on our activities, though I would suggest that we were still at least the second most active division or branch of the GSSA. I have suggested in a previous column (The Geode Vol. 5, No.4, Dec 2018) that there is no legitimate reason why Minsa cannot reached a membership of 250. And anecdotally I know this to be true. I see and have seen new faces at said excursions and presentations and yet know these people are not members of Minsa. And we humour them in good faith.

So…to those people who come to our presentations, who take part in our excursions and who read our newsletters (yes, I know you read our newsletters); I implore you…in the name of honour or integrity or virtue or honesty or principle or whatever you want to call it…please consider joining Minsa officially. It's the "barite" thing to do.

Igor Tonžetić

Minsa News

2022 Minsa Geode Advertising Rates	
	$^1/_8$ page = R120
	$^1/_4$ page = R290
	$^1/_2$ page = R575
	Full page = R1150

Odds and Ends

(I haven't yet contrived a cutesy mineralogically-derived name for this section of assorted Minsa-related news items from the past quarter. Submit your bright ideas to the Editor and win…something).

Desh Chetty infiltrates the IMA

Minsa is pleased to announce that our own (committee member, long time member, and past society President) Dr Deshenthree Chetty, has been elected to the Council if the International Mineralogical Association (IMA). We wish her well in her endeavours, and in the representation of our Association therein.

IMA seeks likeminded webmaster

The IMA webmaster, Wolfgang Zirbs, is retiring, and a substitute is being sought. Also, the server hosting the website will no longer be in Austria; a new host location is needed. If any Minsa members are keen to assist with the new IMA website, they should contact Deshenthree Chetty (at deshc@mintek.co.za).

The Canadian Mineralogist, under Minsa control

From April 2022, your editor, Dr/Prof. Steve Prevec, commenced service as one of two co-Editors of the international mineralogical research journal, The Canadian Mineralogist, along with Dr/Prof. Andrew McDonald of Laurentian University (Canada). The journal, which is the research arm of the Mineralogical Association of Canada (MAC), publishes research on mineralogically-oriented geoscience and applied geoscience, including new mineral announcements, for which a streamlined quick-review process is provided. The journal features short papers with strong mineralogical inclination on a wide breadth of geoscience topics. Both of the editors are also Minsa members (as well as MAC members).

Minsa events

The Geometallurgy of Bulk Commodities, by Tricia Scott

Given the consistent interest in geometallurgy, Minsa hosted a long-awaited talk on the geometallurgy of bulk commodities, on 26 July 2022. The talk was presented by Tricia Scott of Anglo American, and focused on Fe ore and coal. This first attempt at a hybrid event was a resounding success, with about 25 people attending in person, and 40 online. Tricia delivered an engaging presentation that covered the entire value chain of Fe ore, from blasting and mining to processing, to its complementary meeting with coal in the blast furnace smelting for the production of steel.

Involving the audience, both in person and online, via the Slido app (slido.com), a CSI-type crime scene was presented by Tricia. In this scenario, the 'crime' was decrepitation of the ore in the furnace, which led to fines production forming an impermeable cap in the furnace, thereby blocking smooth airflow and preventing optimum smelting. Four 'suspects' were rounded up for questioning: 1. The blast furnace operating conditions; 2. Charge chemistry; 3. Ore texture and 4. Mineralogy. As the hotshot detectives, the members of the audience were asked to narrow down the suspects in trying to solve the case of sub-optimal smelting in the furnace. This they duly did, by punching in the prime suspect in the Slido app. It was great fun seeing how many different responses were received for 'prime suspect'. Tricia then provided information that the blast furnace operations were as normal; no deviations were noted from regular monitoring, so that struck suspect 1 from the list. The charge chemistry was well within the acceptable range, so suspect 2 could not be guilty. Ore texture was finely laminated, as previously the case with smelted ore, so it was not a suspect either. This left mineralogy as the last suspect. Hotshot detectives were once again engaged via Slido, from which it emerged that there was indeed a ‘rogue’ mineral in the assemblage – goethite. At temperatures around 700° C, goethite loses water, which incurs a volume change through physical cracking, thus leading to the decrepitation that caused the sub-optimum smelting.

The ‘CSI crime scene’ interaction effectively showed the importance of knowing your ore before each step in the process, and led nicely into the next part of the presentation, which covered the predictive power of modelling of such data as mineralogy, chemistry, particle size distribution, density, magnetic susceptibility, hardness, decrepitation index and marketing. The number of different variables can be mind-boggling, and increasingly sophisticated modelling programmes (like Datamine and RMS – Resource Modelling Solutions) are being used to handle these. In plotting variables like overall reducibility of an ore against the proportion of a specific ore type, for example, the relationship is non-linear. Together with high data dimensionality, this makes geometallurgical modelling highly complex, but also immensely powerful in predicting ore variability and handling it appropriately to ensure optimal operations, use of waste and return on the investment.

The talk was a great success, with a fun interaction that brought home the importance of a geometallurgical approach in the mining and processing of bulk commodities, in this case, Fe ore. Thanks to Tricia for giving up her time to present to Minsa. Thanks also to Petra Dinham, Bertus Smith and Igor Tonžetić for the planning and organisation of the event. We look forward to further presentations in the continuing series of quarterly Minsa talks, in what looks to be a highly successful hybrid format.

Contributed by Desh Chetty

Educational Garden Route at the University of Pretoria: An Update

The University of Pretoria is continuing with their “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. 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. Minsa have already collected: (a) a Wits conglomerate from just outside George Harrison park (the 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, (b) the collection of carbonatite from our trip to Phalaborwa and (c) Pretoria group quartzite. Minsa still intends to incorporate Bushveld chromitite, Waterberg conglomerate, and Dwyka tillite, for future recce's.

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.

UP's professional planning department is finalising the first plaques that will display the names of the organisations/companies who sponsored the specimens. UP is also considering an unique QR code and landing page for the garden that will take visitors on a virtual tour. The landing page will name and fame donors of specimens and serve as a free marketing tool for those who chose to contribute.

Rock description

- Komatiite from the Barberton Greenstone Belt, Onverwacht Formation (solidified komatiitic lava)
- Banded iron formation (BIF) from the Barberton Greenstone Belt, Fig Tree Formation
- Microbial mats in sandstones from the Barberton Greenstone Belt, Moodies Formation
- Banded iron formation (BIF) from Thabazimbi/ Prieska with Crocidolite
- Hekpoort lava
- Rooiberg lava/Ignimbrite/Volcaniclastic breccias
- Magnetitite from the Bushveld Igneous Complex
- Conglomerate with intercalated sandstone from the Waterberg Group
- Tillite from the Dwyka Group
- Dolerite from the Karoo Basin
- Coal seam in quartzite from the Ecca Group, Karoo Basin
- Sand River Gneiss
- Kimberlite/Griquaite ultramafic nodules
- Pegmatite (coarse-grained)
- Jaspilite from the Northern Cape
- Cape Granite, with large feldspar phenocrysts

Contributed by Igor Željko Tonžetić & Jeanette Dykstra University of Pretoria

Obituary
Gavin Martin

Gavin Martin, Fellow of the Geological Society of South Africa (GSSA), mineralogist, process mineralogist, sportsman Manchester United supporter, family man and all-round good guy; well-respected by geologists and metallurgists both in South Africa and internationally, Gavin will be sadly mised following his sudden and unexpected death in July from a massive heart attack.

Gavin was born and educated in Krugersdorp, and later graduated from the University of the Witwatersrand, before eventually joining the Gold Fields Mining Company. Somehow, in amongst all that he managed to fit in a spell as a fast bowler for Transvaal (for whom he once managed to claim the scalp of Graeme Pollock, one of South Africa's greatest batsmen). He remained at Gold Fields for many years and gained considerable experience in exploration and process mineralogy on a wide range of commodities, but particularly in gold and PGMs, uranium, diamonds, base metals, heavy mineral sands, ferrous metals and Sn-Nb-W ores. He also developed into a knowledgeable and respected technical consultant in various aspects of process mineralogy and geometallurgy, and mentored many mineralogists and geologists in that time.

In 1999, Gold Fields sold its laboratory facilities in Southdale, Johannesburg, to Lakefield of Canada, and it became known for a short time as Lakefield Africa before joining with SGS to become, first of all, Lakefield/SGS, and then finally SGS. Over this period, the labs went from a relatively small operation employing 20 people full time to a company of over 200 employees. Unbelievably, Gavin was initially only contracted to the company, but soon proved indispensable as the process mineralogist necessary for the growth of not only the mineralogical investigation of various types of ore, but also the metallurgical side of the company. As a result, he played a significant role in the growth and development of what became a major independent analytical facility for the mining industry, not only in South Africa but throughout Africa and the world. During this time he mentored many mineralogists and metallurgists, not only at Southdale but also at the other Lakefield and SGS sites in Canada. It is a sign of his indispensability that at the age of seventy five he was still retained as a respected consultant.

Gavin must have been one of the few people in this industry that over his long working life had the companies change around him, and not his place of work! He more or less retained the same office at Southdale for almost all of his working life, only relocating to Bryanston in recent years when SGS Mineralogy moved from Southdale.

A memorial service celebrating his life was held at the Ruimsig Golf Club in Roodepoort (where he was a long-time member and office bearer) on the 4th of August, with eulogies from Doug Forsyth (Minister), his lifelong friend John Baxter, SGS colleague Benne Nel, eldest grandson Cameron Martin, and Gavin and Barbara's three sons, Gareth, Roger and Jono. It was an indication of his influence on the local mining and sporting fraternity that more than 200 people attended his memorial service. He will be sadly missed by the South African geological and mineralogical community.

Contributed by Jill Richards

Minsa Feature:

Meet a Mineralogist

Name: Associate Professor Megan Becker

Affiliation: *Centre for Minerals Research, Department of Chemical Engineering, University of Cape Town.*

Megan Becker is an Associate Professor in the Centre for Minerals Research in the Department of Chemical Engineering at the University of Cape Town. Megan has degrees in both geological sciences (BSc Hons 2001, MSc 2005 – University of Cape Town) and metallurgical engineering (PhD 2009 – University of Pretoria). These have more than equipped her for research in the cross-disciplinary field of applied and process mineralogy.

The central focus of her research and teaching activities is the application of mineralogical knowledge for the understanding, optimisation and prediction of key unit processes within the mining industry from both techno-economic and environmental aspects. Through this research, she has developed numerous academic and industrial collaborations on projects in geometallurgy, process mineralogy, flotation and comminution, hydrometallurgy, and environmental mineralogy.

Since joining the Centre for Minerals Research in 2005 (then the Mineral Processing Research Unit), she has successfully integrated process mineralogy into the research activities of the Centre and other research groupings within the Dept of Chemical Engineering. She has close to 90 peer-reviewed publications. In 2018, she was nominated as one of the top 100 Global Inspirational Women in Mining.

Question 1: What is your favourite mineral and why?

Surprisingly, this is a somewhat difficult question! From an academic perspective, pyrrhotite is probably one of the most interesting minerals due to its non-stoichiometry. Even though this was the area of my PhD research, there are still many unanswered questions about the behaviour of the different pyrrhotite superstructures (e.g. Fe_7S_8, Fe_9S_{10}, $Fe_{11}S_{12}$) and the international academic community is still focused on understanding the complexities of pyrrhotite although in many varying applications, e.g.

flotation, acid rock drainage, paper industry, cement manufacture and cemented paste backfill.

From an aesthetic perspective, sapphire (blue gem quality corundum) is my favourite, most likely because of the richness of its colours and because blue is my favourite colour!

Question 2: What is your most funny or memorable fieldwork/lab experience?

Travelling to other African countries has probably been some of the most memorable experiences for me, especially being exposed to varied climates, cultures, cuisine, and wildlife. Two experiences that stand out would be arriving in rural Zambia during a thunderstorm and stepping off the plane in white trousers to a landscape of red mud, needless to say, the white trousers were never quite so white afterwards! Then also coming face-to-face with some very large and ugly marabou storks in Tanzania that wouldn't move for you when you need to walk past en route to the plant.

Question 3: What is the most exciting aspect of mineralogy for you?

I've always had a fascination with rocks and minerals and thoroughly enjoy the opportunity to work on them every day. Although many associate mining with a host of negative connotations given its legacy, we also know that minerals and mining can contribute to sustainability[1]. This means that I get to work on projects that are relevant to both society and industry. The continual development of new techniques allowing us to characterise minerals and elements at ever-increasing scales, resolution, speed, and number of dimensions further adds to the excitement of mineralogy.

1. *World Economic Forum, 2016. Mapping mining to the sustainable development goals: An Atlas, 12pp.*

Question 4: What motivates you to go to work every day?

I thoroughly enjoy my work environment which continually provides me with stimulation working on relevant and exciting new projects that stretch one's abilities, as well as the opportunity to engage and develop both undergraduate and postgraduate students. I'm also fortunate enough to work in an environment where continual learning takes place. Given the cross-disciplinary nature of my work, I get to work with other researchers from within my university and globally. Working as part of a team is always more interesting than doing it all by yourself.

Question 5: What is the most exciting project you have worked on?

That's not an easy question to answer since most of my projects are exciting! The most rewarding projects, however, are those where there is a strong interdisciplinary academic team, and we have an industry champion working with us on the project. Ultimately, it's about the people we work with and the teams we work in that bring the most reward.

Question 6: What advice would you give your younger self, when you were just starting out in the industry?

Don't discount the value of the first few years in any new junior role as you learn the ropes. This is often the most important foundation of your career.

Question 7: What route did you take to become a mineralogist?

After completing an MSc in geology, I joined the Centre for Minerals Research (then known as the Mineral Processing Research Unit) in the Department of Chemical Engineering in a new role tasked with integrating process mineralogy into the research activities of the group. I was fortunate enough to be given plenty of mentorship, encouragement, and support from my colleagues to establish a foundation in mineral processing thereafter leading to the initiation of these process mineralogy activities. A year after I joined the research group, I started my PhD on a part-time basis at the University of Pretoria, working under the very capable supervision of Prof Johan de Villiers (one of SA's finest mineralogists), and the late Prof Dee Bradshaw (a true legend in her own right for her exuberance and passion to develop young people). Since then, it's been a road of continual learning, as we become exposed to more and more commodities, complex mineralogy, and exotic minerals with the changing demands of industry and society.

Contributed by Bavisha Koovarjee

The OLYMPUS BX53P for Mineralogy - A New Standard for Polarized Light Observation

The Olympus BX53-P polarizing microscope provides superb performance in polarized light applications such as mineralogy, using a combination of UIS2 infinity-corrected optics and a distinctive optical design. An extended line of compatible compensators make the BX53-P microscope versatile enough to handle observation and measuring applications in virtually any field.

UIS2 Optics Provide Outstanding Expandability

Maximizing the advantages of infinity correction, the UIS2 optical system helps prevent the deterioration of optical microscope performance and eliminates magnification factors, even when polarizing elements, like analyzers, tint plates, or compensators, are introduced into the light path. The BX53-P microscope also accepts intermediate attachments available for BX3 series microscopes, as well as cameras and imaging systems.

Bertrand Lens for Conoscopic and Orthoscopic Observations

With a conoscopic observation attachment, switching between orthoscopic and conoscopic observation is simple. It is focusable for viewing of clear back focal plane interference patterns. The Bertrand lens is focusable for clear viewing back focal plane interference patterns. The field stop makes it possible to consistently obtain sharp conoscopic images.

An Extensive Range of Compensators and Wave Plates

Six different compensators are available for measurements of birefringence in rock and mineral thin sections. Measurement retardation level ranges from 0 to 20λ. For easier measurement and high image contrast, Berek and Senarmont compensators can be used, which change the retardation level in the entire field of view.

Minimal Strain Optics

Our polarized light objectives reduce internal strain to a minimum. This means a higher EF value, resulting in excellent image contrast.

Robust and Accurate Rotating Stage

The rotating-centering mechanism attached to the rotary stage enables smooth rotation of a specimen. In addition, there is a click-stop mechanism at each 45 degrees for precise measurement. With the optional dual-mechanical stage, discreet X-Y movement is possible.

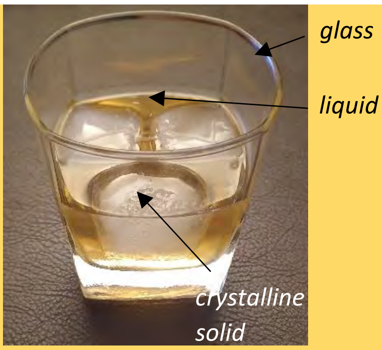
Articles

The September issue theme: Glass: what's it good for, and how do we analyse it?

Glass: how to tell your glass from your elbow

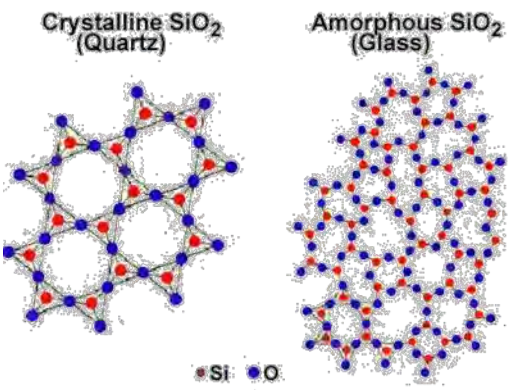
S.A. Prevec
Dept of Geology, Rhodes University, Makhanda, RSA
s.prevec@ru.ac.za

At first glance, glass is a relatively peripheral concept from the perspective of a mineralogist, and of a geologist. After all, glass is by definition not a mineral, and in most rocks, glass doesn't stay glass for long, devitrifying to an assemblage of fine-grained minerals over time. So what is glass, and why should we care?



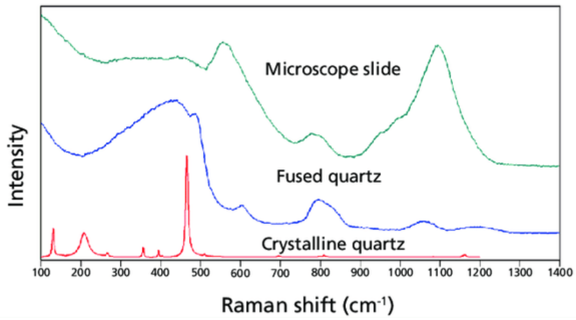
Glass, a disordered solid, shares some of its physical properties with both crystalline solids and with liquids (in this case, Glen-morangie).

Glass is defined as an amorphous solid, meaning that it does not possess long-range periodicity of its atomic structure.

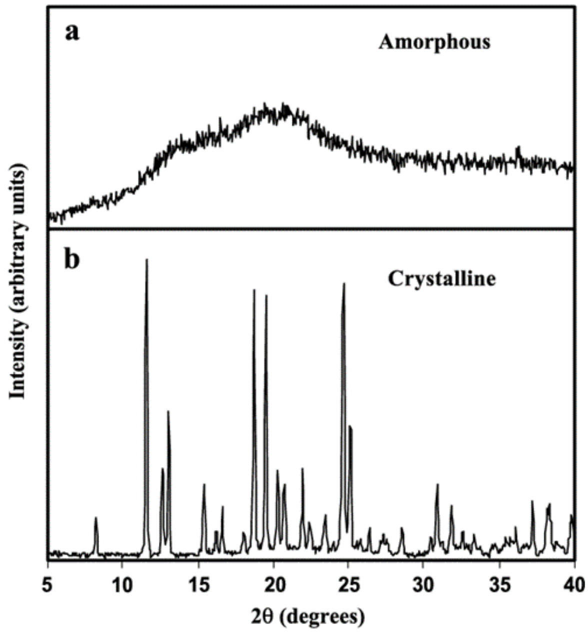


This illustration shows the distinction between an amorphous structure and an ordered crystalline solid using the example of SiO_2 (Ortiz, 2007).

This disorder is manifested as a failure to demonstrate reproducible optical properties using a polarizing petrographic microscope, for example (no optic sign or birefringence), and no well-defined peaks in X-ray diffraction patterns.



A comparison of glass vs crystalline equivalents based on Raman spectroscopy, from Tuschel (2017).



A comparison of the XRD spectra of glassy versus crystalline sucrose, from Nunes et al. (2005).

However, in addition, the solid must demonstrate the phenomenon of the glass transition to qualify as a glass; simply being amorphous is insufficient (amorphous solids exist which do not qualify as glass). The glass transition is the property by which during heating (or cooling) through a critical temperature range referred to as Tg (the glass transition temperature, helpfully), physical properties including the specific heat and the coefficient of thermal expansion, as well as the density and viscosity, are found to change significantly in a smooth stepwise manner. This is not a phase transition, however, and this change in physical properties occurs below the melting temperature of the material. It represents a transitional temperature range from physical properties largely corresponding to those of the equivalent crystalline solid for a given composition at temperatures below Tg, to those corresponding to that of a supercooled liquid above it. A supercooled, or undercooled liquid is one which exists at temperatures at which crystallization ought to have commenced, but has not, typically for lack of nucleation sites from which crystalline solids can grow. This circumstance arises as a result of rapid cooling in a stagnant environment from a crystal-free starting state. In naturally-occurring glasses, and in industrial and laboratory conditions this is facilitated by quenching of liquids, which involves rapid cooling driven by a steep thermal gradient, such as by magmas erupting into air or water. The speed of cooling is the critical parameter in the production of glass. A wide range of glass compositions can be produced, from the silicate glasses which are most prominent in geological and mineralogical disciplines, to metallic glasses such as the chalcogenide compounds (O-free amorphous solids made of chalcogenic elements such as S, Se, Ge, Te and others) from which CD and DVDs are made.

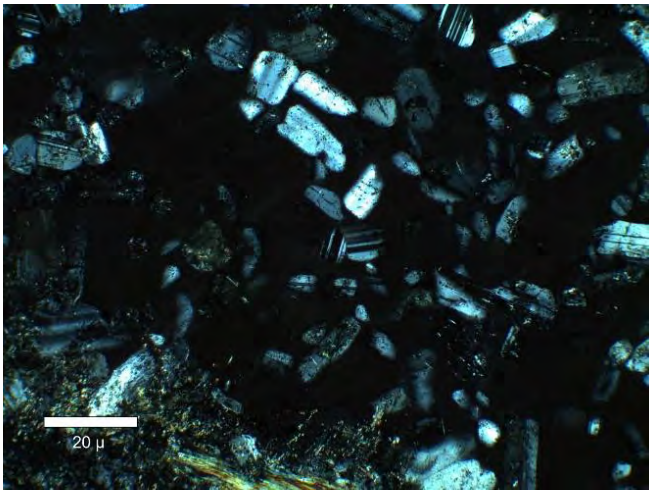
Natural glasses can occur from rapid cooling of volcanic rocks, such as basalts, and obsidians from more silicic eruptions. Other naturally occurring glasses can form as the result of bolide impact events which create locally ephemerally high temperatures and pressures, producing impact glasses (tektites) as well as impact diamonds.

Fulgurites, courtesy Stephen Tooth (U. Aberystwyth).

Lightning can produce fulgurite glass locally from melting of quartz sand. In addition, glass can be generated by frictional melting and (probably) by shock melting along fractures, creating pseudotachylites. Articles on impact glass and on impact pseudotachylites appear elsewhere in this issue, following this introduction. In addition, rapidly cooled partial melts of existing rocks can also generate glass under the right circumstances. Images of a range of glass-forming environments related to large terrestrial impact craters are shown here.

Plastically-deformed impact glass from the Nördlinger Ries crater fallback deposit (Germany) in outcrop (above), and in building-stone (below) derived from the resultant suevite rock that contains sintered molten fragments.

Above, a metres-wide (ca. 45-cm long hammer for scale at right) pseudotachylite in the granitic footwall of the Sudbury impact structure (Canada). All photos S. Prevec.



A photomicrograph of isotropic sanidine-composition melt with partially consumed plagioclase feldspar laths from the basal impact melt norites at Sudbury. (S. Prevec photo & interpretation).

In addition to the naturally occurring geological glasses, glass features prominently in analytical geoscience. In particular, rock samples are reduced to powder and mixed with flux and fused into glass beads for major element analysis by X-ray fluorescence spectroscopy on the basis that the sample is melted and homogenised and then quenched in the process (see also Geode v.9 no. 1 for more on this). The more refractory the elements of interest, the more difficult it is to efficiently melt and homogenise them, and to prevent them from crystallising again during cooling. Extensive research on how best to homogenise often refractory materials for the production of non-crystalline glass fusions for XRF analysis has been conducted (e.g., Loubser, 2009), with fusing and then recrushing and refusing the beads being one common practice to optimize homogeneity and effective quenching. Obtaining a proper glass routinely is key to reliable analysis.

Bibliography & References

Bragg, W. (2002) The Glassy State. In Structural Chemistry of Glasses. Elsevier. p. 13-76.

Loubser, M. (2009) Chemical and physical aspects of lithium borate fusion. Unpublished M.Sc. thesis, University of Pretoria, 139 pp.

Nunes, C., Mahendrasingam, A. & Suryanarayanan, R. (2005) Quantification of Crystallinity in Substantially Amorphous Materials by Synchrotron X-ray Powder Diffractometry. Pharmaceutical Research 22, 10.1007/s11095-005-7626-9.

Ortiz, C. (2007) Spectroscopy of terbium doped sol-gel glasses. Unpublished B.Sc. Honours thesis, Davidson College, N.C., U.S.A. 103 pp.

Tuschel, D. (2017) Why Are the Raman Spectra of Crystalline and Amorphous Solids Different? Spectroscopy 32, 26-33.

Tektites and other Impact Glasses – Characteristics and Importance

Christian Koeberl

Department of Lithospheric Research, University of Vienna, Althanstrasse 14, 1090 Vienna, Austria (christian.koeberl@univie.ac.at)

Impact cratering is a high-energy event that occurs at more or less irregular intervals (although over long periods of time, an average cratering rate can be established). Part of the problem regarding recognition of the remnants of impact events is the fact that terrestrial processes (weathering, plate tectonics, etc.) either cover or erase the surface expression of impact structures on Earth. Many impact structures are covered by younger (i.e., post-impact) sediments and are not visible on the surface. Others were mostly destroyed by erosion. In some cases, the ejecta have been found far from any possible impact structure. The study of these ejecta led, in turn, to the discovery of some impact craters.

The affected (target) rocks are important witnesses for the characteristics of the impact process. Crater structures are filled with melted, shocked, and brecciated rocks. Some of these are in situ, others have been transported, in some cases over considerable distances from the source crater. The latter are called ejecta. Some of that material can fall back directly into the crater, and most of the ejecta end up close to the crater (<5 crater radii; these are called proximal ejecta), but a small fraction may travel much greater distances and are then called distal ejecta. Distal ejecta can only be recognized as such if they include either shocked minerals or rock fragments, and/or meteoritic components. Tektites and microtektites are natural glasses that an important group of distal ejecta. In general, glass formed by impact is the result of the high temperatures (and pressures) during an impact event, and the glass usually forms by melting (whole-rock or mineral melting, such as in the case of lechatelierite from quartz), but there are also a few cases in which minerals are transformed to an amorphous (glassy) state as a result of just high pressure, such as in the case of maskelynite (e.g., Jaret *et al.*, 2015). However, not every glass found in a geological context, possibly in the vicinity of some circular structure of unknown origin, is indeed of impact origin; for glass to be identified as "impact-derived", more detailed considerations are necessary. This applies in particular to glasses possibly formed during airburst events (cf. Cavosie and Koeberl, 2019).

Tektites are natural glasses on Earth of up to a few cm in size that occur mostly in four geographically extended (but well-defined) strewn fields: the North American strewn field of 35.5 Ma age (associated with the Chesapeake Bay impact structure; cf. Poag *et al.*, 2004); the Central European strewn field of ca. 14.8 Ma age (associated with the Ries crater in southern Germany); the Ivory Coast tektite strewn field of 1.1 Ma (derived from the Bosumtwi impact structure in Ghana); and the 0.79 Ma Australasian strewn field (for which no undisputed source crater has been identified so far). For details on these strewn fields and the chemistry and origin of the tektites, see the reviews in, e.g., Koeberl (1994, 2014). It is well established that the chemical and the isotopic composition of tektites in general are identical to those of the upper terrestrial continental crust (see reviews in e.g., Koeberl, 1994, 2014, and references therein).

A detailed discussion of tektite characteristics is given by Koeberl (2014). The important properties of tektites are: 1) they are glassy (amorphous); 2) they are fairly homogeneous rock (not mineral) melts; 3) they contain abundant lechatelierite; 4) they occur in geographically extended strewn fields (not just at one or two closely related locations); 5) they are distal ejecta and are not found in or around a source crater, or within typical impact lithologies (e.g., suevitic breccias, impact melt breccias); 6) they generally have low water contents and a very small extraterrestrial component; and 7) they are interpreted to have formed from the uppermost layer of the target surface, as is indicated by the ^{10}Be content of Australasian, Ivory Coast, and Central European tektites. This ^{10}Be was not produced by direct, in-situ irradiation with cosmic rays in space or on Earth but was inherited from sediments, where it was produced by neutron reactions on oxygen in the atmosphere; such ^{10}Be is often termed meteoric or garden variety. It is recommended that the term "tektite" should only be used for glasses that have (most) of the above characteristics listed; if not, or if the data are still ambiguous, the more general term "impact glass" should apply. There are a couple of cases where geographically distributed impact glasses, possible even tektites, were found rather recently, such as in Belize (see Koeberl *et al.*, 2022), but the specific sources and origins are still not entirely clear.

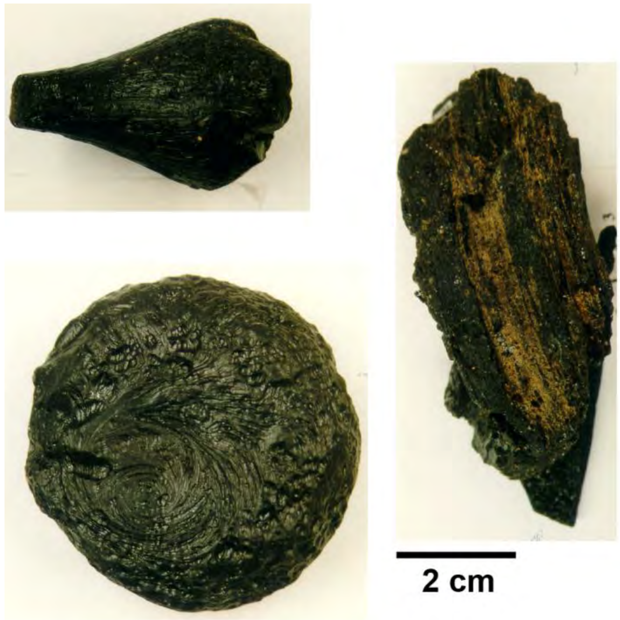


Figure 1: Three examples of tektites from the Australasian strewn field: bottom left a "normal" tektite, showing etching marks (from long-term water interaction), upper left, a droplet-shaped tektite, and right side, a Muong Nong-type (layered) indochinite (after Koeberl, 2014).

In addition to the "classical" tektites on land, microtektites from three of the four strewn fields have been found in deep-sea cores. They are generally less than 1 mm in diameter and show a somewhat wider variation in chemical composition than tektites on land but with an average composition that is very close to that of "normal" tektites. Microtektites have been very important for defining the extent of the strewn fields, as well as for constraining the stratigraphic age of tektites, and to provide evidence regarding the location of possible source craters. In colour they range from colourless and transparent to yellowish and pale brown. They often contain bubbles and lechatelierite inclusions. Microtektites occur in the stratigraphic layers of the deep-sea sediments that correspond in age to the radiometrically determined ages of the tektites found on land. Thus, they are distal ejecta and represent an impact marker. The geographical distribution of microtektite-bearing cores defines the extent of the respective strewn fields, as tektite occurrences on land are much more restricted. Furthermore, microtektites have been found together with melt fragments, high-pressure phases, and shocked minerals and, therefore, provide confirming evidence for the association of tektites with an impact event.

Tektites have very minor meteoritic components, as indicated, for example, from Os isotopic studies. As most tektites are homogeneous glass, they must have experienced extremely high formation temperatures. Recent work has shown that Zn, Cu, Sn and others are isotopically fractionated by volatilization in tektites (e.g., Moynier *et al.*, 2010; Creech *et al.*, 2019). The study of unconventional stable isotopes provides interesting clues regarding formation, differentiation, and deposition of tektites.

Tektites might be produced in the earliest stages of impact, which are poorly understood. The possibility that the glass was superheated was discussed, and there was a suggestion that tektites went through a plasma state and then recondensed in the form of coalescing droplets. However, such a model has problems to explain the close compositional similarity between the tektites and their source rocks and the presence of lechatelierite particles in tektites. The formation of tektites, in which up to 109 t of glassy material were distributed over distances of up to 12,000 km (or about 800 km from the proposed source region; in the case of the Australasian tektites) must be occur only under special conditions. Maybe low angle impact is important because of the asymmetric distribution of tektites within a strewn field. However, the question regarding tektite formation and distribution remains the subject of further research.

Tektites, along with some of the other types of impact glasses, somewhat resemble obsidian and can be easily misidentified. Obsidian is a naturally occurring volcanic glass, generally black in colour (as most known tektites) but it can also be brown, grey, or green. Obsidian typically exhibits layers, whereas tektites do not (with the exception of the Muong Nong-type layered tektites). Over the last 100 years, a number of glass samples were described as possible tektites and one of these glasses is the so-called “Cali glass”, which is found near the city of Cali (Colombia). This glass is assumed to be a type of obsidian by some authors, whereas others argued that it is a tektite. In a detailed recent study, Ferrière *et al.* (2021) found that both the petrographic characteristics of the studied samples, such as the presence of layering and microlites, as well as the chemical composition, with extremely low FeO content and high K2O + Na2O content, high water content, and also the high Nd and low Sr isotopic compositional values, typical for a mantle signature, clearly indicate that the Cali glass is not a tektite but a rhyolitic volcanic glass (obsidian). It is evident that it is not enough to find some unusual glass and immediately assume an impact-origin, but that several criteria need to be fulfilled as discussed in this contribution, and only detailed petrographic and geochemical investigations can provide a proper answer.

References

Cavosie A.J. and Koeberl C. (2019) Overestimation of threat from 100 Mt-class airbursts? High-pressure evidence from zircon in Libyan Desert Glass. Geology 47, 609-612, doi.org/10.1130 /G45974.1.

Creech J.B., Moynier F., and Koeberl C. (2019) Volatile loss under a diffusion-limited regime in tektites: Evidence from tin stable isotopes. Chemical Geology 528, paper no. 119279, doi.org/10.1016/j.chemgeo. 2019.119279.

Ferrière L., Crósta A.P., Wegner W., Libowitzky E., Iwashita F., and Koeberl C. (2021) Distinguishing volcanic from impact glasses – The case of the Cali glass (Colombia). Geology 49, 1421-1425, doi.org/10.1130/ G48925.1.

Jaret, S. J., Woerner, W. R., Phillips, B. L., Ehm, L., Nekvasil, H., Wright, S. P., and Glotch, T. D. (2015)

Maskelynite formation via solid-state transformation: Evidence of infrared and X-ray anisotropy. J. Geophys. Res. Planets, 120, 570–587. doi.org/10.1002/2014 JE004764.

Koeberl C. (1994) Tektite origin by hypervelocity asteroidal or cometary impact: Target rocks, source craters, and mechanisms. In: B. O. Dressler, R. A. F. Grieve and V. L. Sharpton (Eds.), Large Meteorite Impacts and Planetary Evolution, Boulder: Geological Society of America Special Paper 293, 133-151.

Koeberl C. (2014) The Geochemistry and Cosmochemistry of Impacts. In: Holland H.D. and Turekian K.K. (eds.) Treatise on Geochemistry, Second Edition, vol. 2 (Planets, Asteroids, Comets and The Solar System), pp. 73-118. Oxford: Elsevier.

Koeberl C., Glass B.P., Schulz T., Wegner W., Giuli G., Cicconi M.R., Trapananti A., Stabile P., Cestelli-Guidi M., Park J., Herzog G.F., and Caffee M.W. (2022) Tektites from Belize, Central America: Petrography, geochemistry, and search for a possible meteoritic component. Geochimica et Cosmochimica Acta 325, 232-257, doi.org/10.1016/j.gca.2022.02.021.

Moynier F., Koeberl C., Beck P., Jourdan F., and Telouk P. (2010) Isotopic fractionation of Cu in tektites. Geochimica et Cosmochimica Acta 74, 799-807.

Poag C.W., Koeberl C. and Reimold W.U. (2004) Chesapeake Bay Crater: Geology and Geophysics of a Late Eocene Submarine Impact Structure. Impact Studies, vol. 4, Springer Verlag, Heidelberg, 522 pp (+ CD-ROM).

Pseudotachylite, Pseudotachylitic Breccia, and Impact Melt Rock

Wolf Uwe Reimold

Institute for Geosciences, University of Brasilia, Brasilia, Brazil, wolf.uwer@gmail.com

Folks, in addition to *tektites* and *impact glass* that have been dealt with by Christian Koeberl, there are several other types of impact-generated melt rock (yes, and that does include glassy varieties!) types found in impact structures. For starters, there is *pseudotachylite (PT)* - a rock type known to you from numerous tectonic occurrences worldwide. It occurs mostly as thin veins or sometimes in zones of multiple thin veins and pods (so-called network breccias), usually occurring in fault or shear zones. These occurrences can be meter wide zones with such networks of thin veins, or veinlets restricted to just millimeter to centimeter width. Only rarely have substantial melt occurrences in such settings been described (e.g., a prominent occurrence from the Insubrian Line in Italy). Definitions of pseudotachylite in Structural Geology read somewhat like this: "Pseudotachylite is a glassy or very fine-grained material formed on principal slip surfaces. It may also occur in veins and pods. Pseudotachylite is typically dark in color and glassy in appearance. It received its name because it resembles tachylyte, a basaltic volcanic glass. It may also contain quench crystals after melt. Pseudotachylites are also found in rocks from impact structures [in fact, the name was first coined - spelled pseudotachylyte - by Shand, 2016 for such breccias in the Vredefort Dome - WUR]. It is widely held that such material is the result of fast frictional sliding, such as rapid fault movement, associated with seismic events" (modified after Brandes and Tanner, 2020). In the impact cratering research community this preference of friction-derived melting is also widely supported – but rightfully?

A block of metaquartzite from the northeastern collar of the Vredefort Dome. The fine, millimeters-wide veinlets in the upper half of the block are glassy pseudotachylitic breccia of the shock vein-type. Pen for scale is some 13 cm long.

Well, in impact structures things are not so simple. The impact cratering process is ultradynamic with unprecedented strain rates. It has been estimated that the largest known impact structure on our home planet, the Vredefort impact structure of originally 250-300 km diameter, was formed in just 15 minutes. At Vredefort, there exist at least two types of pseudotachylite-like breccias, which in the past have been variably called S (shock)- or E (endogenic)-type, or by others, A- and B-type pseudotachylite. The S (A)-type of veins of generally < 5 mm width has recently also been discussed as *shock veins*, in analogy to high-pressure mineral polymorph-bearing veinlets in meteorites. In the two largest terrestrial impact structures, Vredefort (South Africa) and Sudbury (Canada), pseudotachylite-like material occurs in mind-boggling volumes of hundred meters to kilometers in extent. At Vredefort we have a number of occurrences of massive melt breccia of tens of meters extent and, in some instances, up to hundreds of meters length. Significant melt breccia of this type, although by far not so massive, has also been described from Manicouagan (another large Canadian impact structure of 80-90 km diameter). There has been a lively debate for several decades how these massive melt breccias would have formed. The preferred mechanisms have been frictional melting or – especially for the massive occurrences - decompression melting related to rapid uplift during the impact modification stage of the initially strongly shock compressed target crust. Since 1998, yours truly has, thus, promoted to refer to the Vredefort (and other, equivalent) melt breccias seemingly formed from more than one process (friction melting, early shock compression/decompression, late decompression melting) as *pseudotachylitic breccia (PTB)* until the true genetic process has been identified.

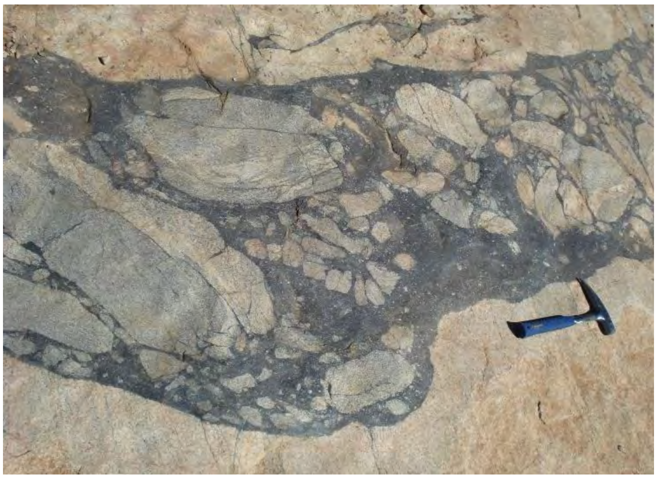
As if this debate were the only problem with these impact structures and impact melt breccias. Let us look at the Araguainha impact structure in Brazil, which has numerous occurrences of melt rock veins or pods of mostly < 10 cm width but occasionally with a presence of up to a meter, and in one case known to me personally of > 10 m extent. It seems that all these breccias have the exact same chemical composition of the alkali granite host rock that forms the core of the central uplift there. And not very surprising, these melt rocks have been referred in the scientific literature as either "pseudotachylite, pseudotachylitic breccia, or *impact melt rock*". Another complicated case relates to South Africa´s other large impact structure, Morokweng in the Northern Cape of 70 km diameter. It has been shown that there are veins of pseudotachylite/pseudotachylitic breccia-like material, which were, however, identified through detailed petrographic and geochemical study to represent impact melt rock that was intruded into the crater floor.

Impact melt is formed in that part of the shock-compressed target rock volume where the shock pressure is high enough to result - after transition of the shock front generated by the impact – in post-shock temperatures sufficiently high to cause part or wholesale melting of target rock. Impact melt may accumulate in impact structures to form large, coherent, mostly sheet-like melt bodies, or it may intrude into fractures within the crater floor. Some of this melt may also be ejected and incorporated into proximal (< 5 crater radii from the impact structure) ejecta deposits. Thus, we have several types of melt rock that may occur in (and around) an impact structure and confound the geoscientist interested in getting to grips with their genesis. Impact melt rocks and pseudotachylitic breccias are extremely important for impact cratering research, as these lithologies may allow dating an impact event, and the former may also contain chemical traces of the meteoritic impactor. If this is the case, application of Highly Siderophile Element and/or Re-Os or Cr isotope analysis may allow identification of the projectile type.

Why, the heck, are we examining these "exotic" rocks here in this Glass-themed issue? Well, we have these shock veins and they, indeed, may carry glass – even at ripe Archean ages: White (1993) confirmed the presence of glass by TEM work on thin veinlets formed in the Vredefort impact event at 2020 Ma ago. At Vredefort, these veinlets carry coesite and stishovite high-pressure polymorphs after quartz. Shock veins from the Steen River and Manicouagan impact structures also carry a host of different high-pressure polymorphs, all of which constitute evidence that shock veins formed as a result of very high shock pressures in the early compression stage of cratering. Shock veins in meteorites may also be treasure-troves for high-pressure polymorph detectives. There are also reports of glass occurrence from tectonic (even Archean) pseudotachylite (e.g., Ermanovics *et al.*, 1972). However, no high-pressure polymorphs have ever been reported from impact or non-impact generated friction melt. In Structural Geology the term "pseudotachylite" is indeed reserved for friction melt. There has been debate (of course!) about the formation process for these generally aphanitic materials – i.e., whether fusion of fault gouge or fine-grained cataclastic material is indeed required for pseudotachylite formation or whether the process only involves (ultra)cataclasis. The aphanitic matrices of many so-called pseudotachylites do not allow, at optical or scanning electron microscopic scales, resolution of the true nature of these groundmasses. In quite a few impact structures, thin veinlets have been observed but the strongly altered nature of their groundmasses no longer allows the identification of the true nature of the vein fill. Slower cooled, more massive PTB occurrences are characterized by partial or complete crystallization of their matrices (i.e., presence of microlites). Chemical compositions of pseudotachylites/pseudotachylitic breccias are dependent on chemistry of their precursor rocks, but where more than one lithology is implicated, compositions may be mixtures and not directly indicative of mode of origin. Impact melt rock, when occurring in a massive melt sheet or dike, will, in all likelihood, be holocrystalline (frequently with small crystal sizes, and often in granophyric texture). However, in thin veinlets in the crater floor quenched, glassy variety may still exist. Impact melt rock may carry shocked clasts possibly sampled in all parts of the transient cavity and, thus, representing a broad spectrum of shock stages. The composition of impact melt depends predominantly on target composition but if only few samples are available, they may not be representative and compositions may even have been affected by fractionation of the main melt body (such as the so-called Sudbury Igneous Complex).

What about friction melt in impact structures? Obviously, nobody would deny the possibility that friction/fault movements/ultrarapid shear movement could take place at any stage during the cratering process, with deformation at ultrahigh strain rates and block movement at all stages from shock compression to the end of crater modification. Mineral and lithic clasts in Vredefort PTB may show shock metamorphism, just like the wall rock from which the clasts would normally be derived. This does, however, not necessarily indicate a PTB formation during the shock compression/decompression stage, as early shock deformation in clasts and wall rock may predate PTB formation during a later stage of cratering (uplift-related decompression).

Geochemical analysis may assist in determining whether such a melt rock is of local origin or may have intruded from elsewhere. However, the nature of the target must be well-understood in any case, and a mono-lithological target (or host rock environment, as at Araguainha) may represent a serious obstruction. Thus, it is generally premature to assign a formation process for a melt rock in the field, and besides geological context, detailed petrographic and geochemical evidence is invariably required to assist with process interpretation for melt rock in an impact environment. Nomenclature in the literature has turned, in part, into a mine-field where two impact workers studying the same lithology may end up reaching widely different conclusions.



A two-meter-wide section of an exposure of more massive pseudotachylitic breccia at Salvamento Quarry located north of the town of Parys in the crystalline basement core of the Vredefort Dome. Material from such massive exposures has typically quite well crystallized matrix. In this case, where the protolith was a felsic gneiss, the matrix contains mineral clasts that are mostly quartz and feldspar microlites, besides some biotite, amphibole, and magnetite crystallites.

The nomenclature problem that has permeated the literature is significant and has even affected the widely accepted impactite nomenclature by Stöffler *et al.* (2018; based on the original work by Stöffler and Grieve, 2007). Stöffler *et al.* wrote "… melt veins and melt pockets described here [i.e., melt veins, pockets, so-called shock veins…all lumped together – WUR] are formed in situ as documented by their composition….they result from localized melting of the constituent minerals of the rock sample in question in contrast to so-called pseudotachylites, which are macroscopic features and predominantly formed by the intrusion of impact melt into the basement of impact craters…they do not contain high-pressure phases formed simultaneously with the melt. However, coesite and stishovite occur in the wall rocks of rather thin pseudotachylite veins in very large impact craters such as the Vredefort Dome….” (p. 19). This is a statement by authors that have never worked on pseudotachylitic breccias from Vredefort and obviously mix them up with impact melt rock. At Vredefort, the so-called *Vredefort Granophyre* contains a projectile-derived meteoritic component, besides shocked clasts, and doubtlessly represents the impact melt rock generated in this gigantic impact event. Nobody with first-hand knowledge of the Vredefort Granophyre and the massive PTB from this structure will be fooled by the obvious differences between these two lithologies – in particular, their very different chemical characteristics.

Selected References

Brandes and Tanner (2019) Understanding Faults – Detecting, Dating and Modeling. Elsevier, Amsterdam, ISBN: 9780128159859.

Ermanovics, I.F., Helmstaedt, H., and Plant, A.G. (1972) An occurrence of Archean pseudotachylite from southeastern Manitoba. Canadian Journal of Earth Sciences 9, 257-265.

Montheil, L., Toy, V.G., Scott, J.M., Mitchell, T.M. and Dobson, D.P. (2020) Impact of coseismic frictional melting on particle size, shape distribution and chemistry of experimentally-generated pseudo-tachylite. Frontiers in Earth Science 8, 506116.

Reimold, W.U. (1998) Exogenic and endogenic breccias? A discussion of major problematics. Earth- Science Reviews 43, 25-47.

Reimold, W.U., Hauser, N., Hansen, B.T., Thirlwall, M. and Hoffmann, M. (2017) The impact pseudotachylitic breccia controversy: Insights from first isotope analysis of Vredefort impact-generated melt rocks. Geochimica et Cosmochimica Acta 214, 266-281.

Shand, E.J. (1916) The pseudotachylyte of Parijs (Orange Free State) and its relation to the “trap-shotten gneiss” and “flinty crush-rock”. Quarterly Journal of the Geological Society of London 72, 198-221.

Spray, J.G. and Biren, M.B. (2021) Distinguishing friction- from shock-generated melt products in hypervelocity impact structures. In: Reimold, W.U. and Koeberl, C. (eds.), Large Meteorite Impacts and Planetary Evolution VI. Geological Society of America Special Paper 550, pp. 147-170.

Spray, J.G. and Boonsue, S. (2018) Quartz-coesite-stishovite relations in shocked metaquartzites from the Vredefort impact structure, South Africa. Meteoritics and Planetary Science 53, 93-109.

Stöffler, D. and Grieve, R.A.F. (2007) Impactites. In: Metamorphic rocks: A classification and glossary of terms, recommendations of the International Union of Geological Sciences, Fettes, D. and Desmons, J. (eds.). Cambridge University Press, Cambridge, pp. 82-91, 111-125, and 126-242.

Stöffler, D., Hamann, C. and Metzler, K. (2018) Shock metamorphism of planetary silicate rocks and sediments: Proposal for an updated classification system. Meteoritics and Planetary Science, 535, 5-49.

Walton, E.L., Sharp, T.G., and Hu, J. (2016) Frictional melting processes and the generation of shock veins in terrestrial impact structures? Evidence from the Steen River impact structure, Alberta, Canada. Geochimica et Cosmochimica Acta 180, 256-270.

Wenk, H.R. (1978) Are pseudotachylites products of fracture or fusion? Geology 6, 507-511.

White, J.C. (1993) Shock-induced melting and silica polymorph formation, Vredefort Structure, South Africa. In Defects and Processes in the Solid State? Geoscience applications, Boland, J.N. and FitzGerald, J.D. (eds.). Elsevier, Amsterdam, pp. 69-84.

Bruce's Beauties: "Glassy" Minerals!

In keeping with the theme of this issue of Geode, several "glassy" minerals are featured. A degree of latitude has been used in deciding what to feature, but most would seem to fit into this category.

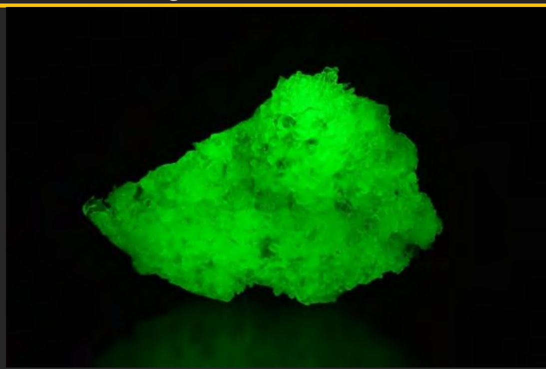
Black obsidian from an unspecified locality in East Africa, 8.7 cm. Specimen is from the Geology Department, University of Johannesburg. Bruce Cairncross photo ©.

Botryoidal quartz (variety chalcedony) lining a vug in carbonatite matrix; field of view is 2.1 cm. Self-collected in the Palabora open pit in 1986.

A teardrop-shaped tektite from China, 4.6 cm.

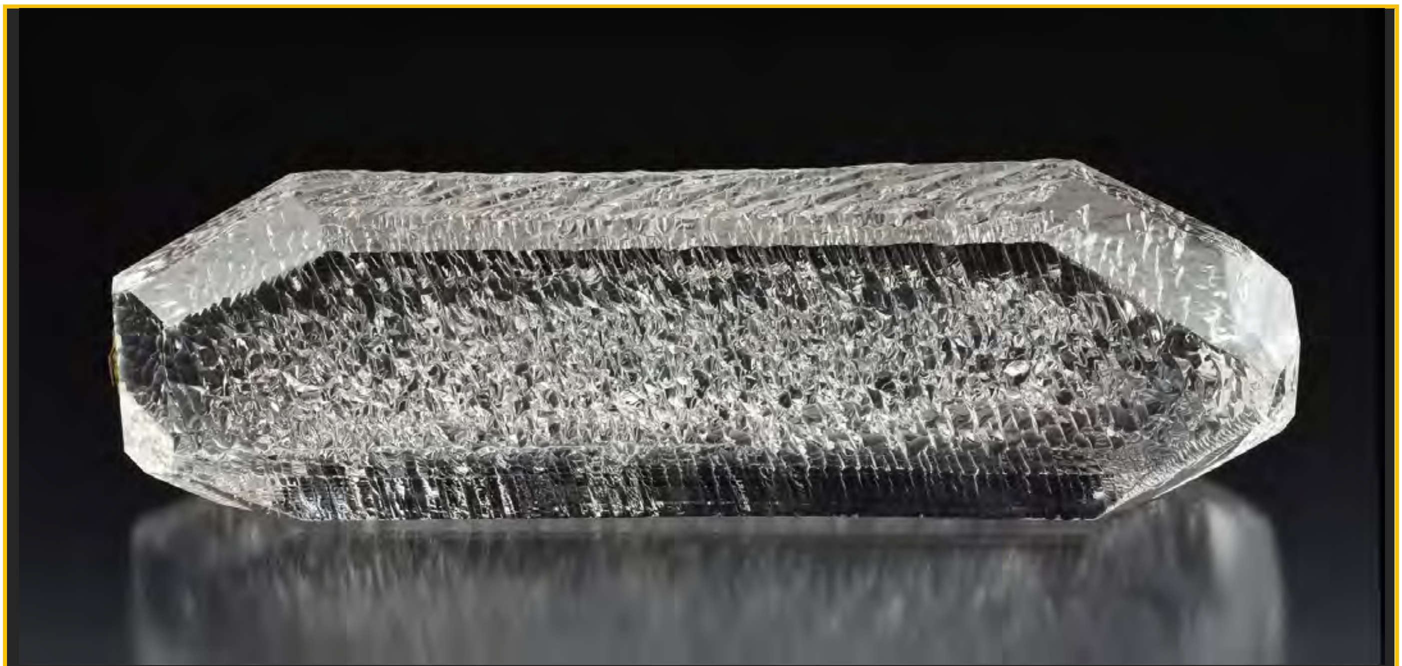
"Snowflake" obsidian. A small 3.2 cm tumbled and polished specimen. The "snowflakes" are cristobalite, formed during the partial crystallization of the volcanic glass – see https://www.mindat.org/min-8520.html Black Spring, Black Rock Desert, Millard County, Utah, USA.

Glass-like opal-AN, 3.6 cm from the Valeč Hyalite occurrences, Valeč, Karlovy Vary District, Karlovy Vary Region, Czech Republic. It fluoresces green under 365 nm long wave ultraviolet light. This variety of opal is collected from loose boulders of leucitic tephrite surrounded by clay. See https://www.mindat.org/loc-764.html.



Somewhat similar to the Czech material but pale yellow under normal light and really bright yellow-green under 365 nm long wave ultraviolet light is this opal-AN specimen from the Erongo Mountains in Namibia.

Boulder opal from Quilpie, Quilpie Shire, Queensland, Australia, 10.1 cm. Unlike the other varieties of opal featured here, this is the famous gem variety found in Australia.



The final picture is of a glassy, synthetic quartz crystal. This is 22.1 cm long and was grown from a seed crystal in an autoclave at STC (Standard Telephone & Cable) located on the East Rand, Gauteng, under temperature conditions of 300-400 C° and pressures of 130-145 Mpa. These ultra pure crystals are used to manufacture silicon chips. See this link to see how they are manufactured: https://www.ndk.com/catalog/AN-SQC_GG_e.pdf.

For more info: minsa@gssa.org.za

INVITATION FOR SUBMISSIONS TO THE NEXT THEMED ISSUE OF THE GEODE

Minsa invites its members to contribute submissions for our next issue of the Geode, on the theme of "*Clay minerals*" (see below), for December 2022.

Submissions can be sent to minsa@gssa.org.za and should reach us by 30st November 2022.

Clay minerals: they can hold water, radioactive waste, and other nasties; you can't make bricks, ceramics, or even paint or toothpaste without them, and you can even eat them or coat your face with them. What makes clay minerals so special that they have their own dedicated research journals?

Minsa Classifieds

Diopside seeks atom for Y (M1) octahedral crystallographic site. Should be between 6-9 nm diameter, +2 charge preferred but +1 and +3 may be considered; electronegativity around 1.5. No volatiles please.

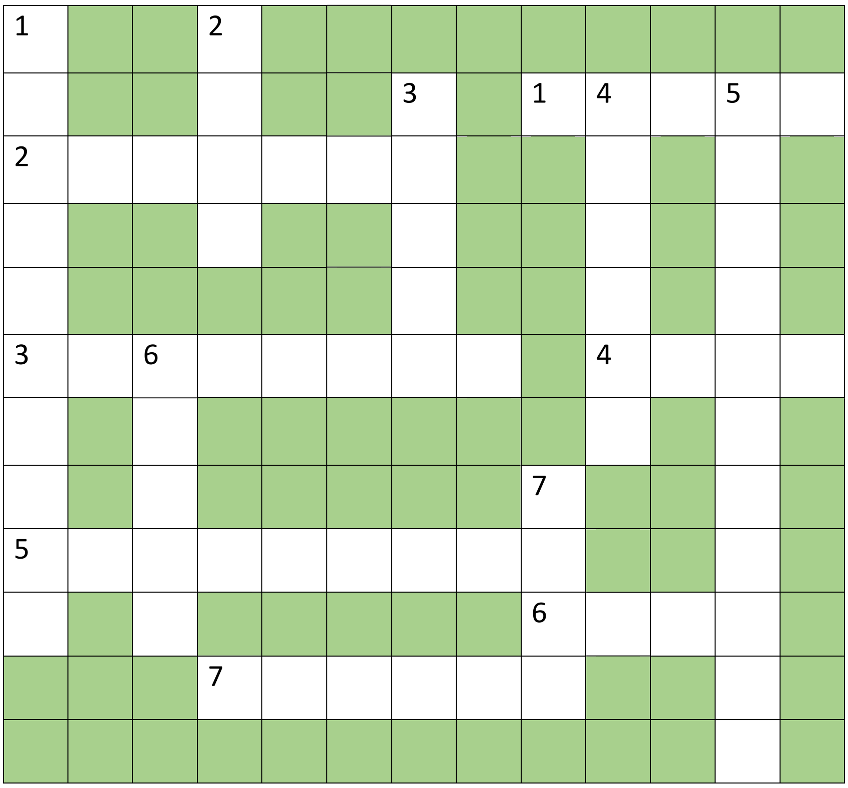
University Dept of Geology seeks mineralogist. Mineralogist in question was last seen existing department with laptop & copy of Deer, Howie & Zussman. Do not approach; may be tedious.

Atom seeks accommodation and covalent relationship; charge usually +5, atomic radius around 170; willing to share electrons.

Halogen seeks electron to complete outer valence shell.

Minsa Crossword for September 2022

The theme is glass. Yes, we're going to beat this to death.



ACROSS:

1. The smallest units (plural) of mass whose disordered organisation manifests as an amorphous structure.
2. The term for volcanic ejecta, typically glassy particles, between 2 and 64 mm in diameter. It is Latin for "little stones".
3. The second half of the formal name assigned to the well-preserved impact crater in Bavaria (Germany), deriving from the name of the pre-Roman tribe occupying the area, the Raetians (less helpful than you'd think). It is the site of a UNESCO Global Geopark. Suevite from this crater features elsewhere in this issue.
4. Silicic (typically >70 wt.% SiO_2) volcanic glass, usually black to dark brown in colour, found associated with rhyolitic volcanism.
5. Silica-poor volcanic glass, associated with basaltic volcanism, it is common to modern Icelandic and Hawaiian volcanism.
6. A mountain bisected by a volcanic fissure in southern Iceland, its eruption in *ca.* 1784 resulted in the death of more than half of Iceland's livestock, and subsequently a quarter of its human population, and caused global cooling and drought across the northern hemisphere.
7. The rock consisting of highly microvesicular volcanic glass, typically light in colour. Its former Latin name means "froth of the sea", where it is often found floating, as a product of submarine eruptions.

DOWN:

1. The common alteration product of basaltic volcanic glass reacting with water, often containing sideromelane glass as a principal constituent.
2. The descriptive suffix of the "body part" of the Hawaiian volcano goddess (see also 7 DOWN) used to describe masses of long strands of volcanic glass.
3. The blanket term for volcanic pyroclastic ejecta of any particle size, which includes both glassy materials as well as volcanic rock fragments.
4. Feldspathic (labradoritic plagioclase) glass found in some impact craters and meteorites, produced by shock melting and quenching.
5. The country in north Africa in which green tektite glass is found distributed, known as this nation's "desert glass". It consists mainly of the mineraloid lechatelierite, which was too long for my crossword, and which also constitutes most fulgurites.
6. The place, in the broadest sense, where impact bolides (meteorites & comets) originate prior to impact, as in "outer ___". Also, the category of symmetry group characteristically absent in glasses.
7. The name of the Hawaiian goddess of volcanoes and fire. Examples of 2 ACROSS are often referred to as her tears. Removing specimens from Hawaii and taking them home invokes her curse. Unless they're for research…presumably.

Minsa Crossword solution for June 2022

Last issue's theme was retrograde metamorphism; the replacement of one mineral by another, relatively isochemically equivalent one (or ones) as a consequence of decreasing pressure, temperature or both, and typically associated with increasing water content (and associated dissolved ions).

												1 C
			2 A		3 A							H
1 B	4 O	W	L	I	N	G	5 I	T	E			L
	L		M		T		D					O
	I				I		D			6 S		R
	V				G		I			E		I
	I				O		N			R		T
	N		2 C	H	R	Y	S	O	T	I	L	E
	3 E	7 H			I		I			C		
		4 B	I	O	T	I	T	E		I		
					E		E			T		
										5 E	N	

ACROSS:

1. A hydrated calcium iron oxide aluminous silicate mineral of the smectite group, now identified as part of the saponite mineral group, formed as part of the breakdown of olivine in the presence of water at low temperatures and pressure.
2. A fibrous serpentine mineral also known as white asbestos which occurs as fibrous crystals replacing the host olivine along fractures.
3. The chemical parameter used to describe the oxidation and reduction potential of a system; the higher the value, the more oxidising the system, as is typically the case in retrograde hydration reaction environments.
4. A K, Fe and Mg sheet silicate mineral group that forms as a result of the hydration and replacement of primary amphiboles and orthopyroxenes during cooling of mafic igneous rocks.
5. The abbreviation for the principal low-Ca pyroxene that forms in mafic igneous rocks at high temperatures, and, similarly to olivine, can alter to serpentine during deuteric alteration.

DOWN:

1. A sheet silicate mineral group that forms as the result of decompression metamorphism of garnets, and by cooling and hydration metamorphism of cordierite.
2. The abbreviation for the common garnet mineral species found in metamorphosed granitoid composition (*s.l.*) crustal rocks, which reverts to the mineral in 1 down with depressurisation.
3. "The other" (along with 2 across) main, non-fibrous structural variant of serpentine that forms from olivine breakdown during late magmatic hydration.
4. The Mg-Fe orthosilicate mineral associated with silica-poor igneous rocks, which readily reacts along its characteristic fractures to form an assortment of sheet silicate minerals, often as pseudomorphic replacements.
5. A microcrystalline rock (no longer considered a mineral) consisting of variably oxidised and hydrated versions of its protolith mineral, from 4 down, found in hypabyssal and extrusive (but not plutonic) rocks.
6. A fine-grained variant of muscovite that characterises the alteration of various tectosilicate minerals such as orthoclase, cordierite, and plagioclase feldspars.
7. The abbreviation for the amphibole mineral group that occurs as a replacement of primary calcic pyroxenes in mafic igneous rocks, either as rims, or eventually as pseudomorphic or wholesale replacements thereof.

Note: The recommended deadline for submissions for the next issue of the Geode is November 30, 2022.