GSSA
Geological Society of South Africa

# geobulletin

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VOLUME 61 NO. 1

Groundwater
Geobotany
Reviving and transforming SA's minerals industry

news

**COVER PHOTO:**

The Goboboseb "dog". A bizarre shaped cluster of quartz with hematite inclusions and amethyst. The head of the dog is a sceptre, 5.5 cm.

Bruce Cairncross collection and photo.

**CENTREFOLD:**

Theewaterskloof Dam, February 2018. Nick Norman photo.

For an image of Theewaterkloof Dam in July 2014 visit the Daily Maverick website.

Picture Greg Gordan Allafricapix

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# from the editor's desk

Chris Hatton

It is interesting to investigate what people think is of academic interest. The front cover of this issue of Geobulletin illustrates a curious crystal which is beautiful but not necessarily vital to the continuation of our everyday lives. By contrast the centrefold illustrates the drying up of the water supply to Cape Town, threatening major disruptions to Western Cape lifestyle. Here the difference appears clear; crystallography is a branch of academic science providing food only to the brain while hydrology is a practical science, directly relevant to the provision of food to the stomach. When considering the needs of society hydrology could be considered to be more important than crystallography and a decreasing emphasis in the teaching of crystallography might appear justifiable.

The conflict between practical and academic science has long dogged the Geological Society of South Africa. A few years ago Geocongress, formerly the most important gathering of South African geologists, ceased to be held. The perception was that the meeting had become too strongly focussed on issues of interest to the mining community and the universities felt that their interests were being neglected. The reason for the shift in focus was that he who pays the piper calls the tune so the themes were selected to appeal to those best able to sponsor the meeting. The apparent shift away from issues regarded as academic resulted in the gradual withdrawal of the universities, who had provided the organising capacity essential to run the conference, and with their withdrawal came the eventual collapse of Geocongress.

While mining itself is clearly a practical science, mining embraces economic geology which itself encompasses almost all branches of geology. Within economic geology the field where knowledge of crystallography might appear most useful is diamond mining, since diamond is simply a beautiful arrangement of carbon atoms in a tetrahedral structure which could potentially stretch to infinity. Because carbon dioxide is considered by some to be responsible for the change of climate, carbon may be implicated in the drying up of Cape Town dams. While much of the carbon dioxide is released by burning coal, there is also a contribution, which at present may be insignificant, from the deep mantle.

The deep mantle is something we will never see. The only way to find out what is down there is to look at crystals we know and imagine what crystals would be stable at these great depths. The most abundant crystal on earth is bridgmanite, thought to be the principal mineral in the lower mantle. Until recently this arrangement of magnesium, silicon and oxygen atoms had not be seen in nature so was not allowed a proper name, being hitherto referred to as magnesium perovskite because the arrangement of atoms is thought to be the same as that of calcium, titanium and oxygen in the mineral perovskite. With the discovery of this mineral in a meteorite this curious anomaly was resolved and deep magnesium silicate now has a name. However, the crystal which carries carbon in the deep mantle may never receive a name. Crystallographers speculate that the carbon is contained in a deep magnesium carbonate and carbonate is much less likely to survive in a meteorite than is a silicate. Depending on which crystal structure this carbonate has and which computer code is used to calculate its stability field this carbonate could come from various depths in the lower mantle. Survival of this crystal in the upper mantle at depths around 670 km is unlikely and the breakdown of this mineral may be responsible for at least some of the carbon dioxide which is perturbing the climate and making life so inconvenient for the citizens of Cape Town.

Before proceeding further, qualification of the phrase 'at least some' is probably in order. Humans are currently releasing carbon dioxide at a rate that is estimated to be a thousand times greater than volcanic emissions. Considerably uncertainty attaches to these estimates and it is even conceivable that they are incorrect by an order of magnitude so 'at least some' could be one-hundredth of the human-released carbon. To put it another way, if natural fluctuations in carbon dioxide wiped out a

certain number species every million years then our current efforts would wipe out the same number of species every thousand years, but it could be as long as ten thousand years. The difference may be of academic interest only – the underlying fact is that fluctuations in the carbon dioxide of the atmosphere threaten life on earth.

While the flux of carbon dioxide from the deep mantle pales by comparison with our suicidal release of carbon dioxide from fossil fuel, Venus presents a picture of what an atmosphere full of carbon dioxide can do to a planet. There the surface temperature is hot enough to boil lead, yet some scenarios speculate that this planet was once habitable. If so the atmosphere would be unlikely to have then consisted of more than ninety percent carbon dioxide. The increase to this current level could well be result of the natural release of carbon dioxide from the deep mantle. If the example of Venus is relevant, the flow of carbon dioxide from deep magnesium carbonate to the atmosphere is not a matter of academic interest only.

At the end of the day the separation of academic and practical science makes as much sense as the separation of the brain and the stomach; neither can survive without the other. As the announcements in this issue make clear, all branches of geological science will be welcome at the upcoming Geocongress. Geologists of all persuasions should make an effort to attend.

**Chris Hatton**

# executive managers corner

Craig Smith

GSSA Geological Society of South Africa

Cape Town is in crisis mode, with water supply at great risk because of prolonged drought. This is well illustrated by the state of the Theewaterskloof Dam (centrefold), one of the key water sources for the city. As of writing, Day Zero (the day the taps go dry) is now pushed back from April to sometime in June thanks to release into the city reservoir system by the agricultural sector. Residents seem to be focused on the cut-off date, and not the probability that the taps will have to stay dry for an unknown period of time, even given 'normal' winter rainfalls – and there is no guarantee that this year will be 'normal'. Maybe half the historical mean annual rainfall might become the new 'normal'.

There is a general consensus in the engineering and scientific sectors that the Western Cape (and South Africa in general) is going to become drier in coming decades. But that is probably not a unanimous view, and predictions of this nature are more like working hypotheses than established fact. Nevertheless, the technical community has expected the current Western Cape drought for some years. 2015 was a low rainfall year. The political community – responsible for planning and development decisions – have either not seen it coming, did not listen to the warnings ('politics trumps science'), or perhaps the technical community has not presented enough of a clear and audible warning. The politicians are engaged publicly almost daily in the 'blame game' – and this is not helpful. Every once in a while we see an informative article or response from an informed stakeholder (such as the South African Weather Service). We need more of that – and less hot air. The SET community needs to take more responsibility for communicating science to the public.

Is this disaster the result of climate change? Maybe it is, and maybe it is just weather. We are not going to get a clear answer at this point in time. But, required reading for any earth scientist is the recently released Climate Science Special Report (CSSR) which can be found at http://bit.ly/climate-report-2017. It was prepared by the United States Global Change Research Program (USGCRP), a collection of 13 US Federal research

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agencies, and while focused on the United States, the conclusions have global application. The conclusions are also sobering.

The GSSA is pleased to announce the launch of the Geoheritage Division and the re-start of the Egoli Branch. If interested in participating in either or both, please contact info@gssa.org.za.

Planning for Geocongress 2018 (July 18-20) is well underway, and the proposed technical program is very strong. To stage the event at the low prices committed to, we need sponsorship. If you or your company would like to support in return for marketing and branding exposure, please contact craig.smith@gssa.org.za. We are particularly looking for funding to support student participation and the social events. For those wanting to present at the event, abstract submission is open, and will close in mid-April. See http://www.gssaconferences.co.za/, the conference website.

Two other major events the GSSA is involved in are the Geometallurgy 2018 meeting (August 6-8; http://www.saimm.co.za/saimm-events/upcoming-events/geometallurgy-conference-2018) and the AAPG ICE meeting (November 4-7; http://capetown2018.iceevent.org/) . Both are in Cape Town. (Delegates will not be expected to arrive with their own water supply.)

By the time this issue goes to print, Mining Indaba in Cape Town will be over. At the time of writing, South Africa's political and economic future is not finalized, but the result of the ANC Congress in December has instilled a sense of optimism and renewed confidence in South Africa's future – and that includes the resource sector – which will result in investment and growth. In the last issue I suggested that South Africa was at another high or low fork in the road ahead. I am optimistic that we have taken the high road.

*The full citation for the CSSR is: USGCRP, 2017, Climate Science Special Report: Fourth National Climate Assessment, Volume I (Wuebbels, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds). US Global Change Research Program, Washington, DC, USA 470 pp.*

**Craig Smith**

GSSA
Geological Society of South Africa

# president's column

Ed Swindell

We have now commenced countdown for Geocongress 2018 in July and the Local Organising Committee under Bertus Smith at UJ is in high gear. The holding of Geocongress this year represents a return to one of your society's fundamental reasons for its existence, namely the sharing of knowledge of South Africa's geology amongst the community of geologists living and working in the country. The theme of this conference is "Bringing the Geosciences Together", with the aim to provide a platform for Southern Africa-based geoscientists to present their latest research. The conference aims to cover a broad spectrum of geoscience topics that will include, but not be restricted to: economic geology; environmental geology; exploration geology; geochemistry; geochronology; geohydrology; geophysics; igneous petrology; metamorphic petrology; mineralogy; mining; sedimentary geology; and structural geology. Some, if not all of your passions should find air sometime at Geocongress.

Your Meetings Committee has worked incredibly hard to find ways and means of keeping the fee for the event at all-time lows. It would be virtually impossible to find a cheaper three day meeting in these times. A full fee is little more expensive than a smart restaurant meal for a family. So forego that

next indulgent outing and come and attend. Please come and present your research and participate fully. Your attendance is the fundamental reason all these good folks have been working so hard. We sincerely thank the Local Organizing Commitee and the team at the University of Johannesburg for stepping up and taking on this challenge and making it all possible.

In his letter in this issue Craig addresses the need for sponsorship to ensure that this meeting and meetings like it take place. I would like to endorse that call for sponsorship and do ask all of those who are in a position to do so to consider sponsorship for GSSA events or activities, or to consider and propose ways of raising sponsorship. Your membership fee covers the fixed and running costs of the Society and not much else. Your membership fee ensures that the Society exists and runs as efficiently as our limited resources allow. In order to run our events or to publish our various offerings we need continuously to raise funds either by charging event or publications fees or by finding sponsorship. Sponsorship has proven to be increasingly difficult to raise in these hard times given the awful state of a declining mining and exploration industry in South Africa. Many of the contacts and people whom we could rely on for sponsorship in the past are no longer around or are just not able to provide sponsorship. Having said that, we gratefully acknowledge all those regular sponsors who still, despite these hard times, come to the fore and we will continue to strive to ensure that you get value for money. If anyone has any ideas or comments about how we might attract and provide sponsors with value for money please feel free to contact me.

I am pleased to report that the new and reinvigorated Egoli Branch has set a date for their first meeting at the Mining Precinct in Johannesburg. Paul Nex has stepped up to bat and will deliver the first talk of 2018. Please watch the Newsletter for details of further talks and events and come and join in. The CSIR Mining Precinct on Carlow Road, Melville where the GSSA is now located is close to both Wits and UJ, is close to bus routes and there is parking. GSSA Past-President Matt Mullins and the current Chairman of the SamCodes Standards Committee has returned from West Australia and has stepped up and is offering a number of new and exciting Professional Development training opportunities for the membership. He will be running one day workshops this year covering topics such as Brownfields Exploration, Decision Analysis for Mining Investment, and Economic Analysis for Mining Investment. When added to the Introduction to Samrec / Samval Compliance course in Cape Town and the Workshop on Samrec / Samval Compliance and JSE reporting for CP/CV's our Professional Development program for 2018 is shaping up very nicely.

The Basic Skills program targeted upon recent graduates this year includes a 3 day workshop on the Foundations for a Geological Career and Colin Rice's annual Drilling Methods Techniques in Resource Exploration.

We urge all members to attend and to spread the word. We need to ensure high attendance numbers for all of these events. Please book early because for every event there is a cut off time (zero hour) when the Committee have to make the decision, based upon projected course enrolment numbers to hold the event or to cancel it. Last minute registration is not helpful as we cannot hold loss making events.

I believe that your Council, Management Committee, Portfolio Committees and Editors have set the path for a very fine 2018 with lots of great offerings. I thank every one of the staff and volunteers for all their effort and urge, you the members, to come and participate.

**Ed Swindell**

# all the news fit to print

*John Clemens*

## University of Stellenbosch

**Stellenbosch undergoes "regime change".**

Since we last reported, we have had two very significant staff-related changes in the department. The first is that we have a new Head of Department. Alex Kisters was anointed as our new leader from Oct 1 2017. Alex has been with the department as Associate and then full Professor since 1999, and we all wish him the very best in his new station.

*Alex Kisters*

Now, with the minor stuff out of the way, we can announce the really significant news that we also have a new departmental administrative officer – Mrs Gillian Strydom, who comes to us from Accounting and took up this key position on January 1 2018. Gillian is settling in well and beginning to understand the peculiarities of Earth Sciences staff and how to handle them.

*G. Strydom*

In addition, John Clemens, who joined the department, first as Executive Head in October 2007 and, since 2012, as an ordinary Professor, will retire at the end of the year. In the wake of this change, there will be two additional appointments, one a hydrologist/geohydrologist, in 2019. John will continue to have a presence in the department as Professor Emeritus, continuing with various research collaborations and student supervision.

**John Clemens**

# THE PROFESSIONAL (AFFAIRS) CORNER

Welcome to the first in a series of articles on Professionalism in the Geosciences. Over the forthcoming months, this column will endeavour to provide information on how various aspects of professionalism apply to geoscientists in general, and especially to members of the GSSA.

**An Introduction to Professionalism in the Geosciences**

Professionalism in the Geosciences rests on three pillars, namely registration, continuing professional development and professional norms and behaviours.

**Registration**

In South Africa, statutory registration in the geosciences is controlled by the Natural Scientific Professions Act 2003 (Act No 27 of 2003). The purpose of this act is to provide for a credible professional registration and regulatory body for natural scientists to establish, direct, sustain and ensure a high level of professionalism and ethical conscience in the natural scientific professions sector; and also, to improve standards of services rendered by professionals, maintain their integrity, enhance their status and manage liabilities attendant to the practice of natural science professions.

The body responsible for statutory registration for geoscientists[1] in South Africa is SACNASP (South African Council for Natural Scientific Professions). The Geological Society of South Africa (GSSA) is the voluntary association (VA) for the geosciences[2]. Registration is required by a geoscientist practicing in


*[1]Other statutory councils in South Africa that deal with mining professions include, inter alia, ECSA (Engineering Council of South Africa) and SAGC (South African Geomatics Council). Since SACNASP is the body most relevant to geoscientists, these other bodies will not be discussed further in this note. Interested readers are directed to the relevant websites (www.ecsa.co.za and www.sagc.org) for further details.*

*[2]Schedule 1 of the SACNASP Act lists 25 fields of practice covered by the Act – some six of these are related to the geosciences.*

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a consulting capacity (clause 20 of Act 27 of 2003). Such registration includes the verification of educational requirements and relevant work experience (attested to by two referees with personal knowledge of the applicant).

The Geological Society of South Africa (GSSA) is both a Learned and a Professional society – admission uses the same criteria as SACNASP registration. Any Member whose application for Membership has been accepted shall be bound by the Constitution, By-Laws, code of ethics and rules of the Society.

**Continuing Professional Development (CPD)**

Registration attests to the qualifications and experience of a Member at the time of application. One author noted that "The half-life of one's scientific knowledge has been estimated as being eight years. In other words, half of what you know today will not be correct, useful, or remembered after eight years. The answers to the problems keep changing, which means that the professional must be committed to expanding and improving his or her knowledge." (Sonnenberg, 2003).

As a result, it is essential for the professional geoscientist to continue their professional development (in both hard/technical and soft skills) throughout their careers. It is imperative to remember that the purpose of CPD is not simply to collect points, but it is to enhance one's personal skills over time. Currently, CPD log keeping within the GSSA system is not mandatory, however, since CPD is about one's own development, it behoves the individual to keep a lifelong personal log.

Both the GSSA and SACNASP have CPD systems in place. The SACNASP system, of necessity, is a more generic system that has to cater for the requirements of a wide range of natural scientific professions. By, contrast, the GSSA system has been developed on the back of numerous existing CPD systems in the international geoscience community. It was agreed that for a registered geoscientist to keep account through both the SACNASP and GSSA systems, it would be both time-consuming and unnecessary. Consequently, as at November 2017, the GSSA signed an MOU with SACNASP which allows GSSA Members to comply with the GSSA system only, to be accredited with SACNASP.

**Professional Norms and Behaviours**

A professional can be defined as a person who engages in an activity with great competence[3]. In turn, competence combines skills, knowledge and attitudes/ behaviours that demonstrate a person's overall ability to fulfil a given set of circumstances.

Skills can include both hard and soft skills. While most undergraduate education and training programmes concentrate on hard skills (technical skills and knowledge), it has been suggested through research conducted by Harvard University, the Carnegie Foundation, and Stanford Research Centre that some 85% of job success comes from well-developed soft skills and people skills (Mann, 1918). Increasing conceptual knowledge and applied skills increases an individual's proficiency from "basic" to "expert", but does not, in itself, equate to competence.

Professional behaviours, attitudes, norms and ethics[4] are increasingly recognised as desirable traits in all geoscience practitioners. To this end the GSSA has a well-developed Code of Ethics - adherence to which is obligatory for all GSSA Members. Alleged breaches of, and/or non-adherence to the Code of Ethics, the GSSA Constitution or to any related Code of Practice (e.g. SAMCODES) are dealt with through the Society's Complaints and Disciplinary Procedures which operate independently of each other, thereby enabling complaints to be handled without an implication of

*[3]American Heritage Dictionary of the English Language. 5th Edition. Houghton Miffin Harcourt Publishing Company.*

*[4]By contrast, SACNASP has a Code of Conduct. Both a Code of Ethics and a Code of Conduct are similar as they are used in an attempt to encourage specific forms of behaviour by employees. Ethics guidelines attempt to provide guidance about values and choices to influence decision making. Conduct regulations assert that some specific actions are appropriate, others inappropriate. In both cases, the organization's desire is to obtain a narrow range of acceptable behaviours from employees. (www.whistleblowerssecurity.com)*

unethical behaviour, and ethical complaints to be handled without a perception of bias.

Further, enshrined in the GSSA Constitution Code of Conduct is the provision that every member of the GSSA shall observe and be bound by certain specified codes of practice, such as the SAMCODES (South African Mineral and Oil & Gas Reporting Codes), which are developed and promoted by the SAMCODES Standards Committee (SSC). These Codes comprise the SAMREC, SAMVAL and SAMOG Codes, and associated Guidelines. Governance of the Codes is effected through membership of Professional Bodies, through Statutory Registration of Geoscientists and Engineers, and through the Johannesburg Securities Exchange (the JSE) Reader's Panel.

The Chairmanship of SAMCODES rotates between the two Patrons, the Southern African Institute of Mining and Metallurgy (SAIMM) and the Geological Society of South Africa (GSSA), every two years. We are pleased to inform you that as from February 2018 Matt Mullins has been appointed as Chair of the SSC, as the SAIMM representative. Matt has been involved in Resource and Reserve Reporting since 1992. He was a member of the Committee which delivered the first SAMREC Code, in 2000. He subsequently chaired both the SAMREC and the SAMVAL Codes, delivering the SAMREC Code Update in 2007, and the first SAMVAL Code in 2008. Prior to moving to Australia in 2009 he was Vice-Chair of the SSC. As Global Vice President for Mineral Resource development for BHP Billiton, Matt was closely involved with developments in reporting in Australia, and globally.

On behalf of the GSSA we are happy to welcome Matt as Chair of the SSC, and we look forward to interacting with as many of the global Professional organisations as we can over the next few years.

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Mann, C. R. (1918). A Study of Engineering Education. New York City: The Carnegie Foundation for the Advancement of Teaching (Harvard University).

Sonnenberg, S. A. (2003, January/February). Professionalism in Geology. The Professional Geologist, pp. 27-30.

**Tania Marshall**

# groundwater

**The "G", the "M" and the TMG.**

Exploitable Groundwater mainly occurs in two main types of hydrogeological environments in the Cape Town area: in the shallow, alluvial aquifer of the Cape Flats and in deeper formations (mainly sandstone) of the Table Mountain Group (TMG) Aquifer.

And right here the hysteria started: you are going to drill how many holes in our beloved mountain?!

No. The Table Mountain Group Aquifer and THE Table Mountain is not the same spot. We are not going to punch the mountain full of holes (sigh of relief from the audience).

In 1580 Sir Francis Drake rounded the Cape and described it as "the fairest Cape we saw in the whole circumference of the earth". And still today, whether you are approaching Cape Town from the ocean, the air or the highway, Table Mountain welcomes you with its impressive stature.

The detailed geology of the Cape Town area is well documented. Instead of repeating the current knowledge as gathered, mapped, inferred or assumed by both acknowledged geologists and zealous travellers, this article will touch on the path of the development of a geological understanding of the most southern part of South Africa. The focus however, will be on that part of a geological environment where the real magic

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happens: those awkward spaces between the rocks.

**A brisk walk through the geological history**

The first clear outline of the geology of the Cape Colony was given by Andrew Geddes Bain (1856) in two papers submitted to the Geological Society of London in 1845 and 1852 respectively (Loock). Bain, a road-maker by profession and a "selftaught individual", carried out his observations in the western, southern and eastern parts of the Cape Colony, in part in an "uncivilized and dangerous region".

In 1859 Andrew Wyley published the results of his investigations during his journey across the Cape Colony. He encountered the Table Mountain, Bokkeveld and Witteberg Groups and confirmed Bain's generalized order of the succession. The contact zone where the Malmesbury Group was intruded by molten granite can be seen at the Sea Point Contact and was made famous by Charles Darwin during his voyage of scientific discovery on H.M.S. Beagle in 1836. Here, beds of dark coloured Malmesbury rock, altered by intense heat are intermingled and folded with the light coloured intrusive granite. In 1888 Dr. A. Schenck introduced the term "Cape Formation" to include the three groups of the Cape Supergroup. He also applied the term "Karroo Formation" to what is now known as the Karoo Supergroup.

**SIMPLIFIED STRATIGRAPHY TABLE**

Three main rock types are exposed in the Cape Town area: metamorphic rocks of the Malmesbury Group, igneous rocks of the Cape Granie Suite (including young dolerite dyke intrusions) and sedimentary rocks of the Table Mountain Group (including much younger deposits of wind-blown, or aeolian, sand deposits along the coast) (Anhaeusser & Viljoen, eds.,2016).

The sedimentary rocks of the Table Mountain Group were deposited on the eroded surface of Malmesbury and granite basement rock. The spectacular Chapman's Peak roadway was constructed along the contact unconformity between granite and the overlying Table Mountain Group sequence. The sand, silt and mud deposits of the Table Mountain Group were lithified by pressure and then folded in the Cape Fold Belt,

**Geology and Geohydrology of the TMG (Barrow, 2010).**

| Lithostratigraphy | | | Lithology | Hydrostratigraphy | | |
|---|---|---|---|---|---|---|
| Group | Subgroup | Formation | | Subunit | Unit | Super Unit |
| Table Mountain Group | Nardouw | Rietvlei | Feldspathic sandstone, minor shale at base | Rietvlei Subaquifer | Nardouw Aquifer | Table Mountain Supergroup |
| | | | | Verlorenvalley Mini-aquitard | | |
| | | Skurweberg | Thickly bedded quartzitic sandstone | Skurweberg subaquifer | | |
| | | Goudini | Reddish brown quartzitic sandstone and siltstone | Goudini meso-aquitard | Winterhoek Mega-aquitard | |
| | | Cedarberg | Dark grey shale and siltstone | Cedarberg meso-aquitard | | |
| | | Pakhuis | Diamictite and quartz sandstone | Pakhuis Mini-aquitard | | |
| | | Peninsula | Quartzitic sandstone, finer towards base | Platteklip subaquifer | Peninsula Aquifer | |
| | | | | Leeukop subaquifer | | |
| | | Graafwater | Siltstone ad shale | Graafwater meso-aquitard | | |
| | | Piekenierskloof | Conglomerate, sandstone and minor shale | Piekenierskloof subaquifer | | |

*Barrow, D. 2010. Ground water Dependence of Ecological Sites Located in the Table Mountain Group. Thesis submitted in fulfilment of the requirements for the degree Magister Scientiae in the Faculty of Natural and Agricultural Sciences (Institute for Ground water Studies), University of the Free State, Bloemfontein, South Africa.*

extending 800 km along the southern coast to Port Elizabeth and 300 km to the north as the Cederberg Mountains (Compton, 2004).

The basal Graafwater Formation (80-100m thick) consists of interlayered pale brown sandstone, laminated pink siltstone and dark maroon coloured mudstone. It is best seen in road cuttings on the slopes of Table Mountain and along Chapmans Peak drive.

The overlying Peninsula Formation (800-1500 m thick) consists of hard, light grey quartz arenite sandstone and dominates the steep mountain cliffs. Current bedding and pebble layers suggest that it was originally deposited as migrating sand bars in broad river channels.

Faults cut across and displace the rock layers. These more easily eroded zones are marked by ravines, for instance, cross-cutting faults separate multiple peaks of the Twelve Apostles. Some fault zones of crushed rock (breccia) are re-cemented by dark brown coloured iron and manganese oxide minerals and the Hout Bay museum displays samples of the rich manganese ore that was mined there last century.

The present landscape is due to prolonged erosion which carved out deep valleys, removing parts of the once continuous Table Mountain Group sandstone cover from the Cape Flats and leaving high residual mountain ridges.

Almost 50% of the Cape Peninsula and Cape Flats area is blanketed by a thin veneer of aeolian and marine sands. Sea-levels fluctuated between -120 to +25 m from present mean sea level during the Pliocene and subsequent Pleistocene ice-age between 2.6 million and 18,000 years ago. At times the sea covered the Cape Flats and Noordhoek valley and the Cape Peninsula was then a group of islands.

**That awkward spaces between the rocks**

Water arrives in Cape Town in the same manner as anywhere else in the world: through rainfall (even though in the current drought situation the perception is that it arrives in interlink carriers). The rain soaks into the soil/sand or runs off the surface into streams to return to the ocean. The actual pathway of the water is more complicated than just this because of its interaction with the vegetation, soil and the underlying rocks. The water that flows off Table Mountain is acidic (pH levels of around 4) because it picks up carbon dioxide ($CO_2$) from the organic-rich fynbos soils through which it seeps and because Table Mountain rocks lacks feldspar or carbonate minerals that can react with and neutralize the acidic waters. These waters also leach soluble organic compounds from the fynbos soils to give mountain streams a distinct yellow to brown colour.

GROUNDWATER: Water found in the subsurface in the saturated zone below the water table.
AQUIFER: A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to store and transmit water; and to yield economical quantities of water to boreholes or springs.

**Historical assessments of groundwater resources in the Western Cape**

So is the discovery of these potentially high-yielding aquifers a recent phenomenon? Definitely not. Hydrogeologists have been studying these main aquifer systems for decades. Numerous postgraduate studies, large private- and/or public research projects as well as small individual consultancies began in the early 1980's.

**But let's start from the early beginnings…**

In the early days (then) Department of Mines conducted various Geological Surveys throughout the entire country. In 1933 H.F. Frommurze published a chapter on Underground Water Resources as part of the Explanation Sheet of a Geological Survey done for "Cape Town and Adjoining Country".

The following is a summary of the findings based on various drilling programmes in the late 1920's:

| GEOLOGY | Average yield encountered (ℓ/s) | Average depth of boreholes (m) |
|---|---|---|
| Malmesbury beds | 22 | 42 |
| Granites | 14 | 48 |
| Table Mountain Sandstone | No drilling, mountainous area. Plenty of springs. | |
| Cape Flats Area | Great number of shallow wells. | |

Probably one of the most intensely studied aquifers in the country; the Cape Flats Aquifer, has shown some development promise from the late 1900's already. Various studies were conducted and it seems that an agreement has been reached regarding the potential yield of the aquifer system, as summarised in the table below:

**STUDY**

| AQUIFER | Potential Yield (million $m^3$/year) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Henzen, 1973 | CSIR, 1980 | DWAF 1985 (based on clusters of 10 boreholes) | Vandoolaegle, 1990 | Ninham Shand, 1994 | CSIR, 1995 | Maclear, 1995 |
| **Cape Flats** | **28** | **18** | **5** | **20** | **18** | **15** | **18** |

**INTERESTING FACT**

According to Maclear (1995) the cost to install a complete wellpoint was between R600 and R2000, which included all fittings and the pump.

**So what is happening on the groundwater scene in the Western Cape?**

The current drought situation in the Cape Town and broader Western Cape areas leaves National and Local Government no option but to invest in alternative water supply sources. Therefore, the City is planning to abstract 80 million $m^3$ from the Cape Flats aquifer, 30 million $m^3$ from the Atlantis aquifer and 40 million $m^3$ from the TMG aquifer before the end of this year. The shallow Cape Flats and Atlantis aquifers will come on stream first and this groundwater will be treated and added into our bulk supplies. The TMG, a huge aquifer which underlies the mountain ranges of the Western Cape into the Eastern Cape, has the potential to deliver more than the initial amount into bulk water and development of this large aquifer will continue for a few years. The TMG well fields are mainly outside the metropolitan area near Grabouw. Drilling in the Cape Flats aquifer has commenced, with initial results indicating very good yields.

The Western Cape Government (through the Department of Transport and Public Works (DTPW)) has put plans in place to ensure that essential facilities continue to function in the event that municipal water becomes severely constrained.

The plans include both demand management and supply-side interventions. The first priority for the Western Cape Government is to make the hospitals water secure and a programme of drilling boreholes at the facilities has already started to augment municipal water supply. The drilling programme is followed by pumping tests to properly assess the performance of a borehole, the borehole yield, the zone of influence of the borehole and to determine the aquifer characteristics. The water

supplied by the boreholes is seamlessly integrated into the existing water supply of the hospitals, including Grootte Schuur and Tygerberg Hospital.

The Premier of the Western Cape, Me. Helen Zille, has also initiated a project to ensure that schools have access to alternative water resources and are not crippled by the likely arrival of Day Zero. Approximately one third of schools in the province already have an existing borehole. A process is underway to test, potentially treat and reticulate available ground water. This funding is being provided by the Western Cape Education Department (WCED).

Various private hydrogeological consultants, drillers and academics are involved in these (almost) orchestrated efforts. On the ground, experts and field personnel are collaborating and extending support to each other. Still, these groundwater resource development efforts are a reaction to the water crisis, and not an implementation of previously recommended plans to augment the city's water supply with groundwater.

In general, the need to become less reliant on National Government for water supply seems to be increasing exponentially. Current groundwater exploration indicates that large industries, factories, businesses, farmers as well as the individual house owner are actively investigating and developing groundwater resources to meet their water demand.

## Challenges and opportunities: so where is the "G" going from here?

***So based on our geological knowledge, can we "predict" where to drill for the most viable groundwater resources?***

*Definitely. Together with geophysical exploration and local hydrogeological knowledge, we are able to identify optimal positions.*

***How much more research do we need before we can start developing these waters?***

*The CoCT is talking about groundwater, but moving too slowly. We need to drill. We need the information that only drilling can provide.*

***How do we ensure that we do not over-exploit the groundwater resources?***

*This will be our biggest challenge from today. Only with diligent implementation of a monitoring network, which includes authorisation of use, can we manage and ensure long term utilisation of the groundwater resources. The inclusion of hydrogeologists improve higher level decision-making structures.*

## Nice surprises and discoveries along the groundwater flow paths...

The groundwater science continues to amaze and surprise even its practitioners. These are some of the encounters reported by local (some grey) hydrogeologists and also curious bystanders in the last few months:

- The Malmesbury Group within the TMG is an excellent aquifer (once you drill it properly!) and even more surprising is the good water quality associated with it.
- It is possible for a local Municipality, Water User Association, business or factory to become solely dependent on groundwater for water supply.

Groundwater development is happening at an incredible (somewhat alarming) rate in the Western Cape. This is however an excellent opportunity to develop a good, well-referenced hydrogeological database for the province. With the cooperation of the different groundwater users, it can be a remarkable display of sound groundwater monitoring and management that will lead us well into a water-secure future.

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THE GEOLOGY of CAPE TOWN AND ADJOINING COUNTRY.

An Explanation of Sheet No. 247 (Capetown)

BY S. H.

HAUGHTON, B.A., D.Sc., F.G.S.

WITH A CHAPTER ON UNDERGROUND WATER RESOURCES BY H. F. FROMMURZE, B.Sc.

Published by Authority of the Honourable the Minister of Mines

THE GOVERNMENT PRINTER, PRETORIA. 1933

**Marlese Nel**

# geobotany

Exploration for buried mineral deposits remains a costly and risky enterprise. For centuries prospectors have used all kinds of methods to locate mineral deposits that do not have a surface outcrop. Some methods are based on good observation skills, a bit of luck, experience and connecting the ques. The premise of Geobotanical exploration is that certain plants will grow preferentially in soils overlying certain mineral deposit types. The first written accounts of geobotanical exploration date from 18th century Italy. The application of geobotanical indicator plant species or assemblages is based on the principle of limits of tolerance. The method assumes that only specialized species can withstand high metal contents in contaminated soils. In practice it has been found that plant responses are more complex. The responses may rather be due to low availability of essential nutrients than to the high presence of toxic minerals or elements. This makes use of such indicator plants as a standalone method unreliable. In modern applications, geobotanical explroation includes the collection and chemical analysis of plant materials or soil layers, specifically humus, in which metal ions may accumulate. Geobotanical exploration is currently used as a supplementary rather than a primary prospecting method.

The most famous geobotanical exploration case study is that of *Ocimum centraliafricanum*, known as the "copper plant" or "copper flower". It was formerly referred to as Becium homblei and is only found on copper and nickel containing soils in central to southern Africa. Shoot material of *Phacelia sericca, Oxytropis campestris,* and *Sedum lanceolatum* are used for gold exploration. The plant material is tested using neutron activation analysis and the presence of gold and arsenic reported in parts per billion (ppb). The loss of gold after dry ashing

*Ocimum centrali-africanum*

*Phacelia sericea*

*Oxytropis campestris*

of the plant material is then established. The same method can be applied for the exploration of uranium deposits. In this case plant material dry ash is analysed directly for the determination of uranium content. The uranium content of the ash of plants growing above non-mineralized formations should generally be less than 1 part per million (ppm), whereas plants rooted in ore bodies contain several parts per million. Certain Astragalus (Fabaceae) species have been found to accumulate selenium. *Astragalus pattersoni* thrives on the direct intake of selenium from ore bodies and was identified as one of the indicator plants for sandstone hosted uranium deposits. A range of other plant species have been extensively investigated from the 1950's as indicator plants for other elements.

The higher occurrence of metalliferous elements in top soils can also affect the physiology and flowering appearance of plants. Most gardeners are familiar with the trick of adding iron or aluminium to red hydrangeas to turn them blue. Anthocyanins, the natural plant pigments which impart red, blue, and purple colors to flowers, leaves, fruits, and some vegetables form complexes with iron, aluminium, chromium and uranium. Varying amounts of these metals could therefore produce a blue tint in flowers that are normally red or pink. This a useful field indicator when prospecting

*Sedum lanceolatum*

for metals. The flowers of Aloe's in the vicinity of the Mapochs Magnetite Mine have a more intense shade of red relative to other Aloe's of the same species that grow further away from the sub-outcrop area.

The presence of toxic elements result in abnormal plant growths, including: unusual size, increase branching and early or second blooming. An example is a specific set of abnormalities exhibited by plants as a result of the presence of bitumens in the soil.

☞

*Astragalus pattersonii*

Lines of plants have also historically been used to find groundwater by water diviners. The occurrence of plants, especially trees and scrubs in grasslands grow preferentially along fault lines or lithological contacts between aquifers and aquitards. In dolomitic areas trees have a tendency to grow in sinkholes, even if partially covered. This can give geotechnical engineers and city and town planners an idea of the surface distribution of sinkholes and karst land features, based on aerial photos.

*Camelthorntree*

The distribution of plants can also aid in delineating the contract of lithological units during regional geological mapping. Vegetation assemblages aid in distinguishing lithology, salinity conditions and geologic age. Camelthorn trees *(Vachellia erioloba)* are located on the margin of the Kalahari Desert in the so-called Green Kalahari. The Camelthorntrees preferentially grow in deep sandy soils with clay content below 15%. The distribution of the Camelthorntrees is used to determine the boundary of the Gordonia formation, a Quaternary deposit consisting of Aeolian sand dominating most of the northwestern part of

*Ceratonia siliqua* seeds.

South Africa. In Hungary mushrooms were applied to geological mapping. It was found that *Boletus edulis* and *Leccinum aurantiacum* have an affinity for siliciclastic and magmatic formations while the occurrence of *Calocybe gambosa* is correlated with limestone substrate.

Plants even had an influence in the valuation of diamonds. The carat measurement is based on the mass of a Carob seed. It was believed that the seeds of the Carob *(Ceratonia siliqua)* had very little variation in terms of its size and mass. In 1871 the British established the Old English Weights and Measures. Seeds of the Carob were collected from both sides of the Mediterranean, the seeds weightd on average 0.204304 grams. This resulted in the current use of 200 milligrams being equal to one carat.

During the exploration of abandoned prospects and mines it was found that the presence of exotic plants, fruit trees and flowering plants are good indicators of the remains of pospector gardens. Bougainvillea's appeared to have been a popular choice among pioneering Western prospectors in Africa in the early 20th century. The bright flowers can be seen in the otherwise green and brown surrounding. Brownfields exploration of historic site has proven this to be a good indicator of old mining areas, especially during spring.

An off-shoot of geobotany is Agro-mining or Phyto-mining. Agro-mining involves the use of plants to absorb valuable metals from soils that have high metal concentrations. At the same time mined-out areas are also partially rehabilitated. Agro-mining involves the harvesting, drying and incineration of the biomass to deliver metal ore. In Australia there is currently research being undertaken to plant various species in mined out nickel belt areas to absorb the remaining nickel in the soil that is beyond current modern metallurgical capability. Eucalyptus trees are planted to absorb gold in mined-out parts of the gold rush area of Kalgoorlie, in Western Australia. The Eucalyptus trees have the ability preferentially to concentrate gold in the leaves and bark in high concentrations.

In South Africa, research is currently underway by MINTEK to harvest gold from wheat crops grown on old mine dumps. The gold is absorbed by all parts of the wheat plant except the seeds, allowing for subsequent planting of theses seeds and enabling harvesting of the cereal as a traditional food crop. It also has the added benefit of reducing the exposure of near-dump communities to hazardous high levels of chemicals such as mercury that are often associated with some of these dumps.

**Nicolaas C. Steenkamp**

# reviving & transforming

## REVIVING AND TRANSFORMING SOUTH AFRICA'S MINERALS INDUSTRY

### Introduction

South Africa's minerals and mining industry faces severe headwinds. The Republic hosts a treasure trove of geology and minerals, valued at about $2.5 trillion, but without modern exploration, prospecting, and new local and foreign investment, these resources will not be developed for the benefit of the Country and its people.

Challenges facing the industry include, amongst others, ineffective, uncertain and outdated minerals policy, a dysfunctional DMR, widespread industry corruption, labor challenges including poor productivity, substandard education and training, disinvestment, aggressive international competition for capital, old ore bodies, high grading, lack of exploration, an absent Junior sector, paucity of modern geological information, and absence of new projects and replacement resources, vested interests, illegal mining, and grossly inadequate transformation and black ownership.

The people, skills, and goodwill exist to address these challenges. Enabling mineral policy interventions, restructuring, and modernization of the minerals industry are required to renew investment in exploration and new mines, drive transformation, revive growth and longevity, and reverse unemployment.

A pipeline of new discoveries and projects is required to replace ageing mines and address legacies which the ANC Government inherited in 1994. Industry challenges cannot be solved in the law courts; new leadership, partnerships, and Stakeholder engagements are essential to find and implement solutions. Recent political changes and the election of a new President on 15 February 2018 offers hope for positive change in the industry. With the Chamber of Mines (COM) having withdrawn legal challenges against the DMR, the possibility of change is improved.

However, a patchwork quick-fix approach to existing policy and Charters will achieve little. The existing Sunset mining industry has major structural issues, and requires far reaching policy revision, modernization and transformation to compete for investment Dollars, and begin a renewal process.

### Sunset Industry?

The year 2017 represented the 150th anniversary of South Africa's diamond industry, after a young boy discovered a diamond in 1867 on the banks of the Orange River at De Kalk between Hopetown and Douglas. The Witwatersrand basin was discovered by a farmer about 20 years later in 1886 at Langlagte and is thus had about 130 years of mining. The Bushveld Igneous Complex and its treasure trove of PGM's and base metals was discovered by a farmer in 1924 and is also an aging asset.

By virtue of their vintage and related declining grades, increasing depth of mining, fractured labour dynamics and poor productivity, cost increases (including rampant inflation of electrical power costs due to mismanagement at ESKOM), paucity of new capital investment, and loss of skills, the majority of existing ore bodies are approaching pensionable age. These challenges, combined with Government policy which lacks certainty, a dysfunctional and corrupt DMR, have lead an industry that was once to world leader to a Sunset stage.

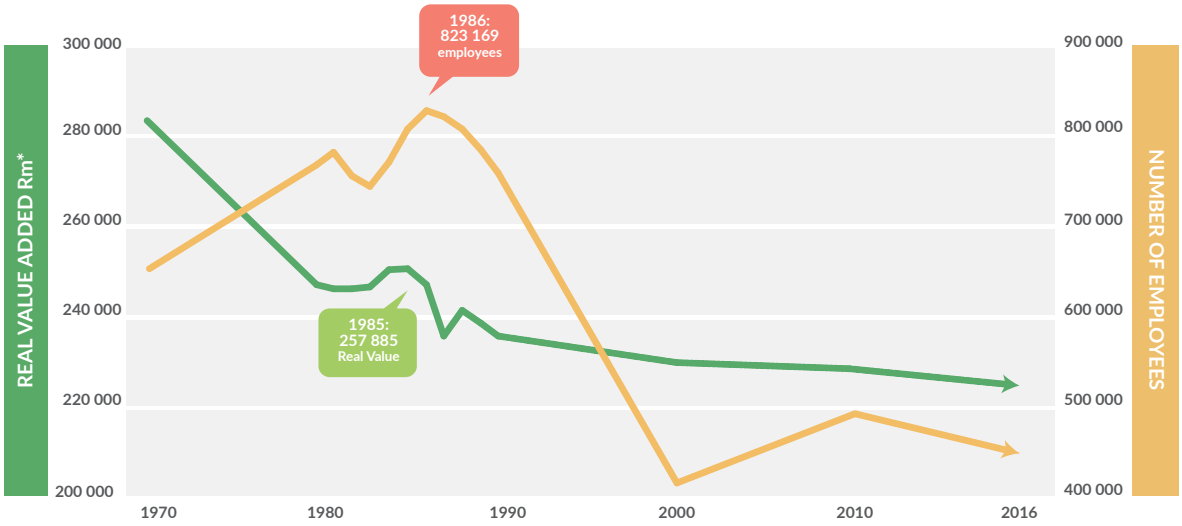
The consequences of the numerous industry challenges are drastic in respect of job losses and unemployment, a shrinking contribution to the fiscus and economy

as royalties, taxes, and GDP contributions decrease, disinvestment by mining companies and investors, and rapid contraction of the number of listed and private mining operations, including small scale operations. Shrinking employment numbers, declining contribution to GDP, and contraction of small or junior private diamond mining operators are depicted in Figures 1 and 2 below.

Aside from reasons noted above for the demise of our industry, there are other related misconceptions that add to the industry woes. These include, but are not

## Total Mining Contribution to GDP & Employment

Mining & Quarrying - South Africa

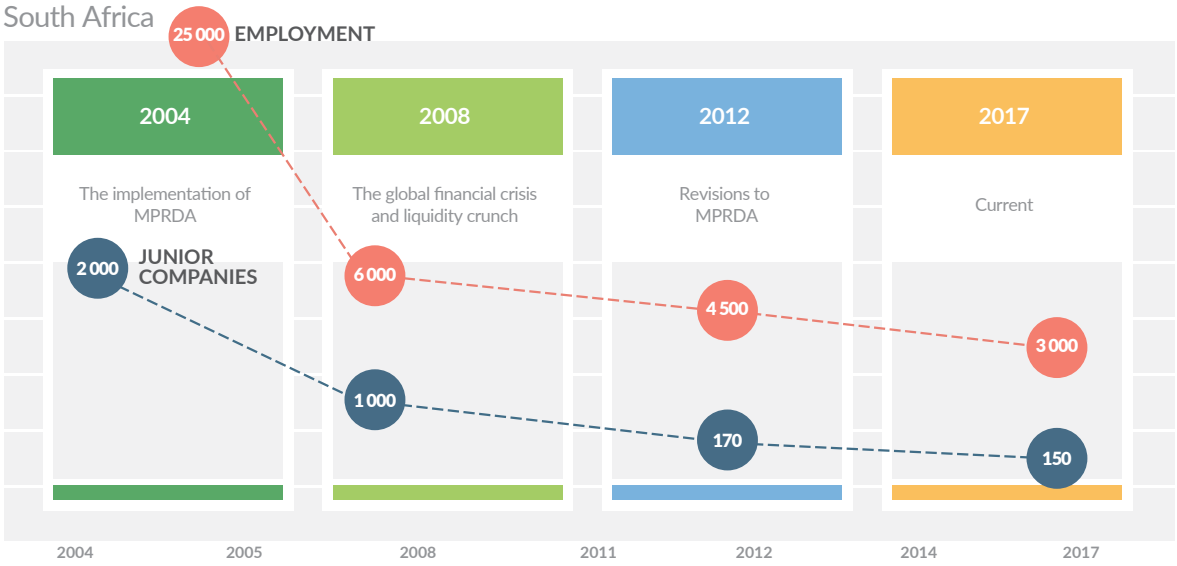



* Based on 2010 prices

**Sources:** Quantec Research | Global Diamond Network

## The Plight of the Self-funded Junior Alluvial Diamond Mining Sector

South Africa




**Sources:** JM Farrell, MSc, 2012 (UFS) | SADPO | Global Diamond Network

limited to the following:

- South Africa is over explored, and 'we have found all the mineral deposits that there are to be found'
- All exploration projects will become mines,
- Mining creates quick and easy wealth
- All kimberlites contain diamonds and diamonds make you rich.

These views about exploration and mining reflect the greater challenges faced by the local industry and the essential need for education. World class mineral discoveries do create wealth, for example the Jwaneng diamond mine in Botswana, but require diligent long term exploration and stable fiscal and minerals policy to drive high exploration, discovery, and development. In well managed jurisdictions, discoveries such as these can contribute significantly to the wealth of countries, communities, employees and shareholders, provided there is an equitable distribution of royalties, taxes, expenditure, and shareholder dividends. But the missing thread in South Africa is that such deposits are only discovered if investors are prepared to make significant long term investments in the first place.

Black economic empowerment (BEE) and transformation have added an additional dynamic to the old 'white' dominated mining industry. The early 'first round' of BEE transactions saw the previous owners of 'white dominated' companies hand out 26% slices of very large and established mining companies to a small group of new entrants. This process of empowering a few politically connected black businessmen/women and politicians, who ended up being enriched rather than empowered, and became instant millionaires and billionaires never achieved its intended objectives. What followed typically resulted in many cases of failed ventures, value destruction, and considerable frustration for the majority, including workers and communities who did not share in the cake.

Reality is that few of the numerous past BEE mining deals have created new mines and jobs, new and sustainable businesses, new value, and the major benefactors have typically been legal firms and banks who structured and funded vendor financing and debt mechanisms. The Ponhalo empowerment deal undertaken by De Beers, almost bankrupted this once world leader, and only served to create some very wealthy black businessmen. Equally, none of the early politically connected empowered new mine owners have maintained an active presence in the industry, taken leadership positions, and engaged in policy development. A possible exception is Patrice Motsepe who has built a large diversified mining group across southern Africa, though a scan of the websites of many of the businesses that followed from the early empowerment process still shows a predominance of white senior management.

Lack of broad and real transformation in the South African mining sector is unforgiveable. Particularly so given the massive informal business sector driven by Stokvels, Spaza shops, township businesses, the Taxi industry, illegal tobacco dealers, illegal miners and poaching syndicates (witness the massive Rhino horn and illegal Perlemoen smuggling). Like it or not, these activities employ millions of innovative, creative and successful entrepreneurs. Why has the minerals sector not changed, transformed and assisted their entry into the formal minerals and mining sector?

Transformation and creation of real black ownership is essential, but smarter ways exist to create genuine black ownership and control of sustainable mineral businesses. Equally unless the industry is able to re-engineer itself and reverse its demise, opportunities for further transformation and job creation will continue to contract.

**Finding the Sunrise – the role of Entrepreneurs**

To understanding how a successful minerals industry should work, it is pertinent to review how business models typically work, be they IT, pharmaceuticals, or mineral exploitation. The majority of successful and unsuccessful new business ventures typically start with 'idea' by an entrepreneur which is turned into a potential small business venture. The small private

business then either grows through hard work (the "10 000" hour rule), persistence, and luck, into a successful venture, or fails.

Of the few business that end up being sustainable, some will remain small and private, some may become successful mid-tier business, and only a few will become large international companies through growth, expansion, diversification, new investment, public listings, M+A, or buyouts. As in every single 'idea' and type of business the risk profile of 'start-ups' is huge, and the failure rate massive.

The construction of the Model-T Ford by Henry Ford, and the subsequent development of the auto-business is a classic example of a successful entrepreneur turning an idea into a business empire. The advent of the I-phone (Steve Jobs), Microsoft (Bill Gates), and Facebook (Mark Zuckerberg) are more recent examples. All of these examples started as an idea in a garage or coffee shop, and today they represent amongst the world's largest and most successful companies.

The modern drug and pharmaceutical business is similar to exploration and mining – most people are familiar with a few big brand pharmaceutical companies such as Johnson and Johnson, Roche, Pfizer, Novartis, Bayer, SANEF and Merck. But behind these mega-companies are, or were, hundreds and thousands of "incubator' or small or Junior companies, run by smart biochemists and related professionals, who did the clever R+D work pioneering new drugs and medical cures.

Many incubator companies have relationships with large companies. Once a new drug is developed, the 'rights' to these new products are typically acquired by the large brand names who have the financial muscle to undertake the costly and time consuming trials and testing, accreditation, manufacturing, marketing, and eventual distribution, which may take many years, as in building a large new mine.

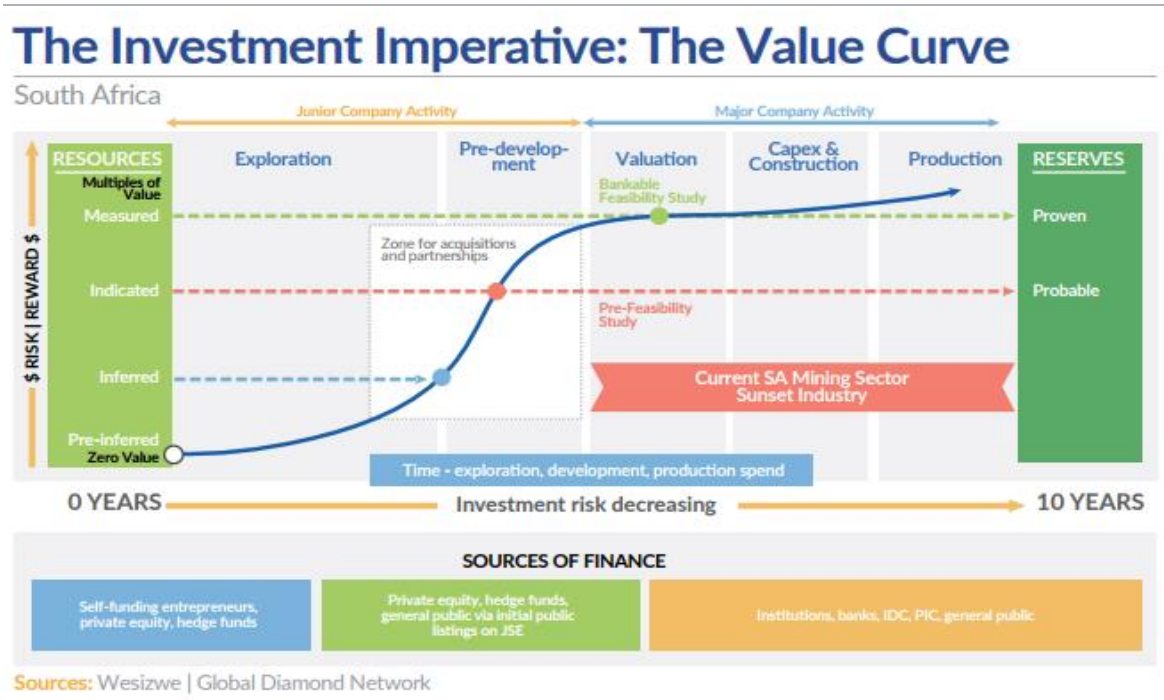
In the case of the South African mining industry, the giant De Beers diamond business was created by an entrepreneur, Cecil John Rhodes. He had the foresight, passion, and acumen to create what was to become the world's premier diamond exploration, mining, and marketing company, and was assisted early in the process by Barney Barnato, a raconteur, boxer, and stage-show promoter. Love him or hate him, Rhodes was an intrepid and driven entrepreneur with a vision and passion. He began his career in the Kimberley and Vaal River diamond fields as a contractor providing water and then pumps to remove water from flooded mining concessions on the diamond bearing kimberlite pipes. With entrepreneurial foresight, strong self-belief, and clever leveraging of the initial capital acquired from his water pump business, he was able to pursue the consolidation of hundreds of individual mining claims with Barney Barnato.

Realising that the claims he acquired were located on kimberlite pipes which continued to depth, Rhodes used his intuition to recruit an American mining engineer from the Barberton goldfields, Alpheus Williams, to develop underground diamond mines, and his business skills to persuade the Rothschild's banking group (an early foreign investor) out of the US, to help build a diamond empire.

**The Value Creation Curve**

The examples of the success of entrepreneurs, incubators, prospectors/explorers outlined above are represented in a simple value curve in Figure 3 below. In this case the Value Curve has been constructed for a typical minerals industry scenario, and includes the various activities, stages, and risk and reward profiles found within the minerals industry, including exploration, pre-development, valuation, construction, and production (mining) segments.

The South African mining industry is locked into the right hand half of this diagram (Figure 3) where the segments are represented by valuation and feasibility studies of new brownfield projects and mine extensions, capex spend and construction of mines, production, and leveraging of cash flows from mining operations.




Sources: Wesizwe | Global Diamond Network

Critically, in the South African situation, the left hand side of the Value Curve is missing. In a sustainable scenario, as is in practically every other successful and expanding minerals development and mining jurisdiction, the full extent of the Value Curve shown in Figure 3 is always in play.

Hence in the ideal Value Curve scenario entrepreneurs or 'explorers' will start with an idea at Zero Value on the far left side of the diagram. By acquiring mineral rights (rented from the State), the explorer will conduct exploration and development of these rights, and subject to the successful discovery of a mineral anomaly, proceed with the delineation, evaluation, and feasibility study of this anomaly. Given the right geology and mineral content, this feasibility study may turn out to be a potential mine?

The explorer has migrated up the value curve, and a potentially high value mineral resource, and possibly even a mine with multiples of Dollar value, as is depicted in the middle and upper parts of the Value curve may end up yielding substantial financial upside to the explorer and developer.

Various options exist for the explorer as he/she progress the value add process – including self-funding and development, a merger, or acquisition by another company. Importantly once the feasibility study returns positive results, the development costs kick in at millions of Rands/Dollars, and so a large company balance sheet, banks, of Investor(s) with access to significant funds are required to underwrite the mine development.

**Underexplored and Undeveloped**

In the case of South Africa, the current Sunset mining industry reflects a skewed and incomplete Value Curve. The left hand of the Curve is missing, there is no exploration leading to new discoveries which should be replacing old and depleted ore bodies. The industry is trapped in a zero sum game of trying to extend and leverage old and declining assets which are increasingly challenging to mine.

There has been no rigorous modern greenfield minerals exploration for the past +30 years. The last world class minerals deposit, the Venetia diamond

mine, was discovered in 1980. The importance of entrepreneurs and Junior companies, the application of modern exploration techniques and procedures have been neglected. International research by the likes of Richard Schodde also shows that many new ore body discoveries, are only made after multiple exploration campaigns, an observation mostly ignored by the local mining industry.

Locally there have been new brownfield extensions found on some of the countries existing ore bodies. The Waterberg Platinum deposit at the far end of the northern limb of the BIC, and extensions to the iron ore and manganese deposits of the Northern Cape are examples of this. However new mine projects, particularly the platinum projects are still in development, and will only partly help to replace old depleted assets, rather that drive expansion and new growth.

Reality is that the left hand side/block of the Value Curve in Figure 3 has been missing for 30 or more years. Given that licence grants, exploration work, discovery, new mine permitting, and development may take all of 10 to 15 years, it is almost too late to revive the local mining industry. Reasons for this are many, but the most obvious are the arrogance of statements made to the effect that 'all there is to be found has been discovered', an unhealthy preoccupation with mining and big companies, lack of transparency and incompetent management of mineral and mining rights, and the absence of enabling minerals development policy. Lack of appreciation of how a healthy minerals business should function, excessive barriers to entry for local entrepreneurs, and the overriding absence of real transformation are further impediments.

The importance of minerals exploration has been documented and interpreted from extensive studies of exploration spend, spend-rate, company type, new discoveries, and new mine development, largely for the western world by Richard Schodde of Minex Consulting in Australia. His intensively researched work has been conducted over several years and is included in presentations and publications available on his website MinExConsulting.com. Local policy makers, regulators, mining company executives, geologists, mining engineers and labour officials would be well advised to interrogate findings published by Schodde. Notable findings in respect of exploration and the role of Juniors presented in Recent Trends and Outlook for Global Exploration (PDAC 2017, 6 March 2017, Toronto) are as follows:

- In the past 20 years Junior Companies have accounted for 70% of all mineral deposit discoveries (by number) and 50% of the value created in the Western World
- Major and moderate (mid-tier) producers found 18% of new projects by number, and 35% by value.

**Successful Exploration and Mining Jurisdictions**

We have undertaken an extensive review of international and African exploration and mining jurisdictions to ascertain the factors that sustain a successful long term Value Curve. Our research has included Australia, Canada, Chile, Peru, West African countries, and our neighbours Botswana, Mozambique and Namibia; this work is ongoing. We also have first-hand experience of the minerals and mining sectors in Brazil, India, Russia, the USA, DRC and Tanzani which provide useful reference points for these studies. Key points that emerge from this work are as follows.

**Australia** – This is the world's leading exploration and mining jurisdiction. It is home to several of the world's largest mining companies including BHP and Rio Tinto, and largest and most technologically advanced mining operations covering iron ore in the Pilbara, gold, uranium and base metals at Olympic Dam, and diamonds at Argyle. Its strength lies in a large and diverse array of Junior explorers, developers and miners who are active in Australia, Africa, and South America, and internationally, practical and enabling minerals policy, ready access to information, robust Government support both at Federal and State level, and a business environment supportive of entrepreneurs.

Recently the Federal Government announced a A$100 million tax incentive for Junior explorers to stimulate the industry which is a key driver of the Australian economy (Turnbull announces A$100m tax incentive for junior exploration; Mining Weekly, 4 September 2017).

Key facets of the Australian minerals sector are the following:

- There are about 550 listed exploration and mining companies on the ASX, with a predominance of entrepreneurial Junior explorers and developers
- 5 mining companies with market caps > $10 billion (including BHP and Rio Tinto)
- Since the Global Financial crash of 2009, investors in the Australian market have supported over 270 new junior resource floats since 2009.
- Further useful information on the ASX Top-100 listed companies is presented in www.asx.com.au/documents/products/asx-metals-and-mining-sector-profile.PDF

**Canada** – in terms of the number of listed companies, Canada ranks second to Australia. It too has a horde of aggressive juniors who are active in Canada, and practically every other favourable minerals jurisdiction around the world. Exploration and mining play a crucial role in Canada's economy, and Central and Provincial government work closely with organizations such as MAC (Mining Association of Canada), the PDAC (Prospector and Developers Association of Canada), and related advocacy groups supportive of the Junior sector, labour, indigenous communities, and minerals education to ensure that enabling policies encourage responsible exploration and mining, both in Canada, and abroad. Key facets of the Canadian industry are:

- About 230 TSX listed exploration and mining companies, with a majority of Junior explorers and developers
- 8 mining companies with Market caps > $10 million

**Chile** – like Australia and Canada, Chile is a favoured jurisdiction for exploration and mining companies, though interestingly this country has a predominance of large mining companies, and smaller number of explorers.

**Peru** – this is a particularly interesting country for comparison with South Africa's situation. Peru, like RSA, has a lengthy history of Colonial legacies, poverty, and disadvantaged indigenous peoples. With assistance from the World Bank fiscal discipline and user friendly mineral policy interventions have helped it become a favored international exploration and mining jurisdiction, with consequent economic growth and poverty reduction. Local policy makers would be advised to investigate the reasons for Peru's progress.

**Botswana, Mozambique, Namibia** – These countries are all African, and three of them are our neighbours. They are amongst the shining lights in terms of enabling minerals policy and overall leave much to be desired when compared to South African minerals policy. Characteristic of our neighbours has been their consistency of policy, access to information (less so for Mozambique given it comes off a low base), and efficient and transparent minerals tenure management systems.

**West African jurisdictions** - With their rich endowment of gold deposits, most West African countries, with increasing few exceptions have shown obvious benefit from investor friendly minerals codes and policies. Countries such as Mali and Ivory Coast have experienced considerable investment in their economies through consistent application of enabling minerals policy, and 'peer pressure' continues to drive improvement in minerals and mining codes amongst countries that have lagged behind the rest.

**Government Policy and the Minerals Industry**

The general impression of many local and international explorers, miners, and investors, is that the South African politicians and regulators do not fully understand nor have the will to develop a sustainable long term exploration and mining industry. Instead the reality or perception is that the mining industry is a cash cow for empowerment of politically connected individuals, which has been a huge deterrent to investment in the industry. Though exploration and mining are effectively two different industries requiring different cultures and

skills sets, a successful mining country or company is 100% dependent on exploration. Without exploration, the mining industry will inevitably die. Unfortunately South Africa's complex and inefficient license application process encourages neither exploration nor the development of successful juniors, and is onerous for mining operations.

The exploration industry should be nurtured and embraced in order to attract much needed investment and the development of new mines. As we have noted elsewhere education is key, including Government officials who because of historical reasons have never had full and proper exposure to this key element of the minerals business. Exploration requires a different mind-set and the construction and implementation of appropriate policy. It is the basis for new long term growth and employment, and poverty alleviation.

Exploration is a high risk, low return industry usually funded by hedge funds and other complex financial vehicles which operate worldwide and look for the best investment opportunities. South African companies have to compete worldwide for these funds. Furthermore, these exploration companies spend cash, they do not generate cash. This leads to the question of how can high risk exploration projects support BEE, and how should real transformation and black ownership be achieved, a challenge that requires new solutions.

Solutions to Revive the Minerals Industry

Based on an extensive review of international minerals and mining jurisdictions (successful and challenged), our own lifetime of experiences in exploration, project evaluation, and mining in our backyard, and numerous discussions with local and international role players we propose the following as key to the revival and modernization of the South African minerals industry.

Modernization of the Department of Minerals Resources – implementation of transparent minerals rights management, and 'use or lose' policy:

- Implement a modern real-time, transparent mineral right management system, and 'use or lose' mineral policy
- The ability to access mineral rights quickly and transparently provides a competitive edge for development of new projects and mines, and encourages capital investment as demonstrated by successful jurisdictions such as Botswana, Mozambique, Namibia, West African countries, Argentina, Canada, Chile, Australia, Peru, and many others
- The SAMRAD system needs a complete revamp, or preferably replacement by a modern real-time management system (consideration should be given to acquisition of the internationally recognized mineral tenure management system developed by the Spatial Dimension Group in Pinelands, Cape Town).

Renew Focus on Exploration – facilitate Junior exploration and development companies:

- RSA is grossly under explored – there has been minimal "Greenfields" exploration utilizing modern exploration methodologies, technologies, data processing, and interrogation of "big data" sets, since the 1970's/early 80's
- The last world-class exploration discovery was Venetia diamond mine in 1980; existing and ageing mineral deposits were discovered by farmers, prospectors, and entrepreneurs in the late 1800's and early 1900's
- A strong Junior exploration and development sector will provide opportunities to create real black ownership, drive exploration, make new discoveries, and create black owned mining companies
- Successful international minerals development jurisdictions such as Australia, Canada, Peru, Chile and West African countries have a robust mix of Junior and Senior companies; this situation does not exist in RSA
- South Africa has many unique small and mid-tier mineral opportunities in rural areas e.g. alluvial diamonds, industrial minerals, and semi-precious stones, in the N Cape and NW Province; poor minerals policy is hampering development of these opportunities.

**Transformation of the Industry** – to create genuine black ownership:

- Existing mineral and mining policies and BEE Charter(s) are in need of modernization to revive the industry, and drive transformation which is non-negotiable
- Ease of access to mineral rights (as noted above) and transparency will assist black entrepreneurs, explorers and developers to establish meaningful ownership in the industry
- A State and Industry backed Minerals Development Fund (MDF) which supports black entrepreneurs, and Junior explorers and developers, on a preferential and matching Rand for Rand basis up to Feasibility Study will assist in developing real black ownership
- Funding for the MDF would be from a levy applied to established small to mid-tier mining and quarrying operations, with matching funds from the State; other innovative options should be explored e.g. the newly announced R5bn Aluwani Capital fund for Junior miners.

**Provision of Modern Geological information and technical support:**

- Successful exploration, development and mining requires access to modern real time information; 'big data' is crucial
- Valuable old geological information exists in State archives (e.g. CGS), and extensive modern info exists in numerous public domains (e.g. listed company CPR's); this requires urgent capture to assist explorers
- Service providers such as the CGS, MINTEK, CSIR Mining Group, and related structures, should be restructured and modernized, and partnerships established with University Geology Departments to undertake critical mapping
- Incentives for R+D to aid exploration, generate discoveries, facilitate technology driven robotic mining in challenging underground mines, and enhance health and safety are essential to future development and growth
- The Department of Science and Technology should establish a number of new specialist University positions to focus on new technology innovations to modernize the industry.

**Financial incentives to restart exploration and development:**

- Innovative tax and financial interventions should be considered by Government as per our competitors (e.g. flow-through shares, matching exploration funds) to drive exploration, and thereby revive the existing mining industry and stem job losses
- A Minerals Development Fund (as in section 3) will facilitate transformation and black ownership, and ensure exploration and new discoveries
- Exploration, new discoveries, and new mine development will create new ownership, jobs, and critically additional royalties, taxes and revenues, and renewed economic development.

**Implementation of modern enabling Policy and Regulations**

- The existing MPRDA, Charters, and BEE policies require repeal and modernization, with the caveat that policy consistency and certainty of tenure, limitation of discretionary powers, transparency, and communication between role players are paramount; transformation is non-negotiable
- Minerals policy should be rewritten with the objectives of reviving and transforming the industry, and ensuring new investment; a patchwork approach to fix existing policy will be counter productive
- Local and foreign explorers and investors, recognize the treasure trove of geology and minerals, and the quality of people and skills in RSA, but are reluctant to commit new long term investment given poor and uncertain mineral policy, ownership/BEE complexity, lack of transparency, and corruption.

**Education and Training:**

- South Africa faces immense challenges with primary and tertiary education, and the resultant poorly educated unemployable black youth, added to which the previous and recent governments, and every related structure associated with the industry, including the Chamber of Mines (COM), failed to adequately inform, expose and educate the greater population as to the needs and benefits of minerals and mining

- For 95% of the population, mining is a dangerous occupation that once provided jobs for a many South African citizens, and migrant workers. This applies equally to Township dwellers and Sandton housewives
- An immediate challenge is education to develop skills and change the negative perception of the industry, and highlight the role of modern technology in exploration and mining; belatedly the COM has initiated an educational process, but this may be too little too late
- Intervention is required across the broader industry, including Government Departments, service providers, and our geology and mining departments at Universities, to educate and expose policy makers, bureaucrats, technocrats, researchers, and employees about the principles of minerals exploration, development and mining, and demonstrate that these activities are mutually related and essential to sustaining a successful mineral industry
- Equally there is an urgent need to change the perceptions of local and foreign investors and show the attributes of its immense mineral wealth, and the ability to regulate in a manner attractive to investors, local and foreign.

**Conclusions**

South Africa's current, stand-alone 'Sunset' mining industry is locked in an old paradigm, it is contracting rapidly, and shedding jobs. Existing minerals policy is ineffectual to address legacies and challenges, and skewed to 'benefit' large mining companies which can afford big legal, environmental, mineral right, H+S, and allied service departments.

Current minerals policy should be re-written, and Charter #3 replaced with sustainable transformation mechanisms, thereby encouraging entrepreneurs, junior explorers, and developers. Present policy is detrimental to the existing mining industry, unsupportive of exploration, discovery, and new mine development, and negative to new investment.

Without healthy synergy between Junior explorers and developers who can identify new deposits, and large mining companies who can develop big capital intensive mine projects, South Africa's exceptional mineral wealth will not be realized and unlocked.

Exploration and mining requires large on-going capital investment, consistent and enabling minerals policy, transparent real time use or lose mineral rights management systems, an effective and un-corrupt mineral regulator, and properly educated and flexible work force to ensure efficiencies in mining and ore processing, and the ability to adapt to rapidly changing technology driven exploration and mining methods, and compete for international for investment monies.

The role that the mining industry has itself played in creating the current climate of distrust, legal challenges, lack of exploration, paucity of new discoveries and development, and job losses also requires introspection. Past legacies have caused ingrained fractures that will require repair, and the attitudes and vested interests that still exist in many key mining organizations and structures present challenges in terms of driving modernization and transformation. Missing from the side of the mining industry, including key structures and role players such as the COM and GSSA are clearly articulated strategies, policies, solutions, and a roadmap to transform and revitalize the minerals industry.

Political will, foresight, and leadership, are required to modernize and transform this essential industry, drive job creation, and revive economic development.

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# GEO CONGRESS

18 - 20 July 2018

University of Johannesburg | South Africa

BRINGING THE GEOSCIENCES TOGETHER

**The Local Organizing Committee (LOC), the University of Johannesburg (UJ) and the Geological Society of South Africa (GSSA)** would like to invite you to attend Geocongress 2018 to be held 18 to 20 July 2018 at the University of Johannesburg's Auckland Park Kingsway Campus, South Africa. The theme of this conference is **"Bringing the Geosciences Together",** with the aim to provide a platform for southern Africa-based and –associated geoscientists to present their latest research.

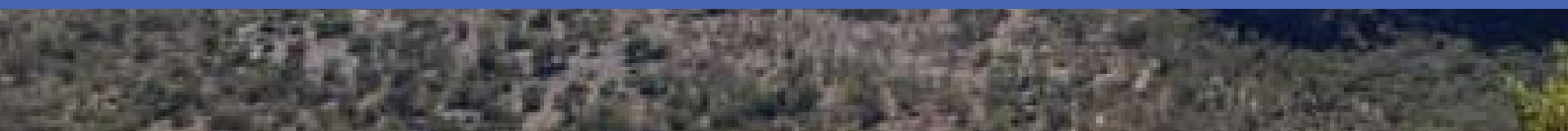
The conference aims to cover a broad spectrum of geoscience topics that will include, but not be restricted to:

- economic geology;
- exploration geology;
- geochronology;
- geophysics;
- metamorphic petrology;
- mining;
- and structural geology.
- environmental geology;
- geochemistry;
- geohydrology;
- igneous petrology;
- mineralogy;
- sedimentary geology;

Since announcing the call for sessions at the end of 2017, the reaction has been very positive, with numerous session proposals focusing on both academia and industry already submitted. The conference will also be combined with workshops preceding the conference and one and two day excursions in the region surrounding Johannesburg.

**We look forward to seeing you at the University of Johannesburg 18 to 20 July 2018!**

18 - 20 JULY 2018 | UNIVERSITY OF JOHANNESBURG



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| ACADEMIC REGISTRATION | |
|---|---|
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| STUDENT REGISTRATION | |
|---|---|
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# silver mining legends

**Silver Mining Legends of the Old Cape**

Visitors to the Cape might have noticed the Silvermine Nature Reserve off Ou Kaapse Weg and wondered what the history behind the name was. Legends of silver mineralisation abound during the early years of the Cape of Good Hope. Most of the speculation was that silver could be found in the Steenberg (Steinberg) area. Despite numerous efforts from 1675 to 1685, no silver was ever discovered.

Three silver mines are recorded as having been sunk during the time of Simon van der Stel as governor of the Cape. The most famous of these is the old Zilvermyn alongside Ou Kaapse Weg on the Steenberg, the others being on either side of the Silvermine River in the valley below. Zilvermyn was established in 1687 as part of Simon van der Stel's ambition to discover and exploit the Cape's mineral wealth for the Dutch East India Company (Vereenigde Oostindische Compagnie - VOC) and make the Colony economically viable.

The story of silver mining in the Cape started in 1686 when Governor Simon van der Stel's Chief Miner, Frederick von Werlinckhoff, claimed to have found silver on van der Stel's farm Witteboomen. With the help of two miners he sank a sixteen fathom (approximately 29 metre) deep shaft in what is now Cecelia Forest Station. A dispute arose and the miners asked the Governor for a transfer. van der Stel grew suspicious and asked another Chief Miner, Gabriel Moller, to investigate. Moller undertook an investigation and reported to van der Stel that there was no silver. Van der Stel immediately had von Werlinckhoff arrested and sent to Sumatra for wasting the Company's money. Moller remained in the Cape and started work in the Steenberg the following year.

A Company diary entry indicates that on the 15th of November 1687, van der Stel on his way to what


*Silvermine Walks*


*Silvermine Reservoir Trail*

would be later called Simon's Town, met the three employees of the Company that was supposed to guard the Steenberg Zilvermyn on the beach, claiming to be looking for a runaway slave. Four months later a Johann Vogel visited the "Steinberg" and found the mines abandoned and inaccessible. He wrote (*translated from Dutch) ""*I examined the mine, finding beside the shaft a considerable quantity of ore obtained from this, which was asserted to be copper ore but was in fact nothing but a coarse iron glance mixed with copper dust. It was not possible to visit the shaft, since it had fallen in, and also the cross beams and shores, together with most of the ladders in it were broken and crushed together. By the side of the shaft I saw some remains of a smelting furnace, in which the Mine Overseer, Gabriel Moller, had smelted the ore, but obtained nothing but cobalt ore*". In this instance "cobalt" referred to an infusible ore and not the element cobalt. No silver was ever discovered and historic evidence would seem to suggest these mines were not salted, but rather that other minerals were mistaken for silver. The mines were never offered up for sale and remained the property of the Dutch East India Company.

The most famous instance of salting in the Cape is the case of the Simonsberg silver mine, in Groot Drakenstein outside Franschoek. A certain Frans Diederik Muller in 1740, claimed to have discovered a rich deposit of silver on the eastern slopes of the Simonsberg mountain.

In 1743 a silver mine, *Octroojeerde Society der Mynwerken aan de Simonsberg*, was started with the backing of reputable local businessperson Olaf de Wet. Also on board the directorship were some local burgers and prominent VOC officials Hendrik Swellengrebel, Rijk Tulbagh, Jan Louwrens Bestbier, Jacob Cloete and Jan Phillip Giebbelaar with Nicolaus van Dessin as treasurer and Johannes Louw Pieters as deputy cashier. By late 1746 a total of 18 slaves, two masons, two carpenters along with six more laborers arrived to work on the mines.

The company began digging long tunnels into the side of the Simonsberg at different levels and sinking shafts measuring between 15 and 30 meters to connect those tunnels. For the next several years, "mining" activities continued on Simonsberg without producing any ore.

*Silvermine Reserve Cape Town*

*Silvermine Dam*


Muller continued to demand more capital to finance the "mining" operation, assuring the company's investors that rich veins of silver and, later, copper and even gold, always lay just ahead of the current workings. Finally the company directors became suspicious of Muller's claims and ordered a sample of ore from the mine to be sent to Amsterdam for analysis. The assay revealed no silver, copper or gold content in the sample.

Frans Diederik Muller was ultimately exposed as a fraudster that scammed his investors out of large sums of money. The Dutch East India Company was embarrassed by the exposure of the scam as it was one of the main backers of the project. The VOC officials banished Muller to the Dutch colony of Batavia, in the East as punishment.

Although the site has been abandoned for more than 270 years, the Simonsberg silver mine remains intact on the farm Goede Hoop, in the Banghoek Valley. The ruins of various structures that are believed to have once been part of that mining operation can still be seen and visited today.

Reference:
Trevor Vaughan Jones, Old Cape Mines – The Zilvermyn on Steenberg.
(http://ctminsoc.org.za/articles/old-cape-town-mines)

Dwarsrivier Valley Tourism
(http://dwarsriviertourism.org.za/tours-activities/heritage-attractions/)

**Nicolaas C. Steenkamp**

# MINSA field trip

**MINSA field trip to the Barberton Mountainlands**

Perhaps the days are gone when MINSA could organise week long or even fortnight long field trips all over the country… or even to faraway places like the island of Reunion or our neighbouring countries (sometimes at the expense and leave of companies the old timers supposedly worked for… talk about continuous professional development!). As I often say, we seem to be busier than we've ever been before getting less stuff done, due to the pressures of modern living, the rise of technology etc. But that doesn't seem to be (at least for me) a big enough excuse not to try or at least not to do away with field trips all together. With this in mind, MINSA, at the suggestion of one of its committee members, organised a weekend field trip to the Barberton Mountainlands and vicinity from Friday the 3rd to Sunday the 5th November, 2017.

Dave Mourant was to be our most pleasant host (along with his lovely wife, Anne) and guide for the excursion, taking us especially on the Barberton "Makhonjwa" Geotrail (and lesser known fossicking locales) on the Saturday and the associated komatiite heritage river traverse on the Sunday. The Friday afternoon was meant to be spent sightseeing the Golden Quarry at Sheba Mine and the Eureka City "Ghost Town". Unfortunately, violent strikes (and the what-has-become-ubiquitous presence of Zama-Zama's) put a stop to these plans. Instead a pleasant braai was had whereby introductions were made, pleasantries exchanged and plans for the morrow were discussed.

*Tidal deposits of the Fig Tree Group exposed by roadworks.*

Dave's Aloe Ridge Guesthouse was used as a base of operations (especially because all of us had booked into it). After a delicious English breakfast (served by our hosts), we left for the 38km long Makhonjwa Geotrail (of mostly the Fig Tree and Moodies stratigraphic Groups). The stops included:

- A felsic/mafic contact
- Preserved tidal flats (exposed thanks to recent road workings)
- Boulder conglomerate
- Sheba Fault Zone
- Oldest Algal Mats in the world preserved in situ
- Banded ferruginous/manganiferous formations (with folding)
- Tsunami conglomerate
- Fuchsite/verdite exposures
- Worked barite mine
- Ash/lapilli tuffites

The group was allowed to collect some samples, as long as they were not directly on the points of interest on the trail itself (fuchsite and barite) and had to be collected from scree/talus deposits…No geological picks were allowed, in line with current geoheritage statutes of the GSSA (currently being drafted). The day ended with a few cold ones at the pub Digger's Retreat and a hot braai to warm up the limbs after a particularly cool and misty day.

Sunday again saw us depart from our Aloe Ridge base

*Well preserved tidal foresets of "herringbone" cross-bedding.*

Continued on p 36

*Algal mat geoheritage point-of-interest. Moodies Group.*

of operations to mostly explore a river traverse consisting of komatiites and pillow basalts from the Overwacht Group. Our first stop was the compulsory geologists-exploring-road-cutting-exposure visit, being of a rather peculiar "siliceous dolerite". Upon investigation, this peculiarity appeared to be possible because of a non-equilibrium contact between a dolerite intrusion and surrounding felsic rocks.

The second stop was of the most spectacular migmatites associated with the basement granites. The association and structural geology of the greenstone belts around these basement granites have been proposed as suggesting a different mechanism of crustal formation (Van Kranendonk, 2011), namely partial convective overturn, colloquially referred to as "sag-duction" resulting in the granitic domes and greenstone keels that we currently see in the Barberton Greenstone Belt.

*Investigating the ubiquitous white horizons terminating the banded manganiferous bedding planes.*

*Ash/lapilli tuffite. Note unusual black quartz veining.*

The third stop gave us an overview of the area to be explored, being the water reservoir hill of Tjakastad. It also allowed for us to collect some of the oldest in situ sediments (now phyllitic) of the planet, for our collections.

The fourth stop (and the highlight of the entire trip) was the "Hoogenoeg River Traverse" which is being incorporated as an associated feature for the Makhonjwa Geoheritage Trail (it is envisioned that self-guiding pamphlets will be available to tourists, from

*Pillow lava outcrop on the "Hoogenoeg River Traverse".*

the Heritage Centre, if and when vicinity is granted UNESCO world heritage status). Filled with spectacular pillow basalts and both randomly-oriented spinifex textured komatiites and parallel-oriented spinifex komatiites, it made for a wonderful morning's hike.

Geological fieldtrips and excursions never cease to humble me. For all the eloquent theories and hypotheses we come up with as a community, it only takes a visit to "out-there-in-the-wild" to appreciate the magnitude and difficulty of explaining field relationships of rock outcrops when half the time, the scales are overwhelming, both in time and distance. For every question answered, the scientific hydra invariably grows two more questions in their place. This certainly illumines the hard work that researchers put into their beloved science.

But this at least of this trip certainly remains…that the Barberton Makhonjwa Geotrail is by far the gold standard when it comes to the preserving and relaying of geoheritage. Do yourself a favour…go see it for yourself.

P.S. Thanks go to Doug Phillips and Robert Schouwstra for some of the pics. A million thanks to David Mourant for his hospitality. Be sure to stay at his guesthouse when you finally do make it to the geotrail (website below).

Youtube information on the Geotrail:
https://www.youtube.com/watch?v=VWKOOMZ1Mi0

Official Barberton Tourism Website of the Geotrail:
https://geotrail.co.za

Dave & Anne Mourants' Guesthouse Website"
http://www.aloeridgeguestfarm.com

**References:**

Van Kranendonk, M.J. (2011); Cool greenstone drips and the role of partial convective overturn in Barberton greenstone belt evolution; Journal of African Earth Sciences Vol. 60; pp 346–352

**Igor Tonžetić**

*The tour group from left: Linda Iaccheri, Robert Schouwstra, Marinda Schouwstra, Igor Tonžetić, David Mourant (Host & Tour Guide), William Black. Photographer: Doug Phillips.*

# night @ the museum

**MINSA "Night @ The Museum"**

For the past three years, MINSA has run an annual "Night @ The Museum" Excursion at the Ditsong Museum of Natural History (formerly the Transvaal Museum of Natural History). The excursion is specifically meant to cater for members of MINSA (and the greater GSSA family) with kids (although the occasional amorous couple have taken advantage of the varied opportunities offered by this very different type of a date). This year's event took place over the Friday the 24th of November to Saturday the 25th.

This year's event saw 37 participants from 7 families take part: 16 adult chaperones/parents with a bumper group of 21 kids. From the Minaar Street Gate entrance (which provides secure parking for all those taking part), participants arrived at the museum to set things up (sleeping places, food storage, dinner etc.) inside the Ditsong Museum of Natural History.

Our guide and master-of-ceremonies for the evening, Tersia, conducted us to the traditional first stop of the activity: the Austin Robert's Bird Hall to view 875 stuffed birds and other ornithological interests. This is traditionally where the activities and proceedings of the evening are explained but also (to those paying attention) where most of the clues are given for the treasure hunt activity (the last activity that happens before the movie screening). Firstly, each of the halls would be visited (barring the Geoscience Centre and Discovery Centre which would be seen early the next day) for educational reasons but mostly to pick the best place to sleep (softest carpeting, coolest area, furthest space away from the most life-like mannequin you-have-ever-seen milking the cow in the Mammals Hall etc.). Priceless quips from the children are a standard feature of the excursion and this time around the Bird Hall provided another one. Upon discussing the Queen Crane (Balearica regulorum), Tersia was asked, "But if there's a Queen Crane…where's the King?"

The next stop involved the "Genesis of Life" (part I) exhibit, being basically the arthropods, bugs and amphibians hall…the gooey and sometimes disgusting hall, as it were. As evidenced when Tersia pointed out a soccerball sized exhibit with flatworms and explained that they had been collected? harvested? (I struggle for the right word here) from a single two year old boy…promptly upon which one of the two year old boys in the party started crying. Science is not for the faint-hearted. On a previous Night @ The Museum activity, it was here, during one of the palaeontology discussions when a previous guide pointed to a large Megaladon skeleton and asked the kids what fossil it was, to which one of the youngin's replied, "Godzilla".

"Genesis of Life" (part II) followed, being essentially the Hall of Mammals. Here many anecdotes were mentioned. For instance, the fact that the oldest dinosaur eggs in existence were found in South Africa (Massospondylus), the preserved elephant in the Big Five (Entrance) Hall was stuffed in 1914 (making it over 100 years old) and that the stuffed gorilla in the exhibit actually hailed from the Hartebeespoort Zoo/Reptile Park in Schoemansville. Dinner was subsequently had, with many opting for fast food brought along. Thereafter, a treasure hunt occurred in a slightly different format to previous years (much preferred by the parents) where the children were divided into age groups with single chaperones…it meant that some of us could continue drinking. The evening finally ended (most appropriately since this was MINSA's third "Night @ The Museum") with a screening of the blockbuster "Night At The Museum 3" movie starring Ben Stiller.

Saturday saw us enter the Ditsong Technology and Discovery centre for a hands on appreciation of science and engineering. Similar to the Sci-Bono Discovery Centre in Newtown, the centre is meant to encourage a hands-on approach to the appreciation of science. Having been here twice before, it was the first time I'd actually heard of and discovered the Tooth Fairy/Mouse House which was a surprise (little treasures abound in the museum). Tersia then led us out into the Museum's front yard to talk about the bone exhibits and for a group picture. It was here that we then discovered that the whale in the front is in fact NOT a blue whale but in fact the finback whale which is the second largest animal in the world (this, after coming to the museum for 3 years straight!). Thereafter, the geological exhibit (which is actually under the auspices of the Council for Geoscience) was opened to all to explore.

Overall, a fun and exhilarating sleepover was had by all (as always) and requests have already been made to repeat the event in 2018 (at around the same time). We are having many repeat offenders, some of which have come up with novel ways of keeping track of their kids over the years. Credit to the "Love's" for their "soundoff" technique, whereupon when David Love shouts "soundoff" and all the Love children fire back "one", "two", "three", "four", "five" and "six". Informal discussions have already started around which movies to show in the future (archaeologically themed Indiana Jones or the Mummy?). Keep a look out for MINSA notifications concerning the event. Please don't be shy! We're looking for new offenders. Don't miss out!

*MINSA is always looking for excursion ideas or leaders. If you have a great idea but are not in a position to lead an excursion let us know anyway and we'll try to make it happen. Contact the author. MINSA also has an archive of previous excursion tour/field guides that can help with logistical preparation. These are freely available to anyone who requests them.*

**Igor Tonžetic'**
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MINSA
Mineralogical Association of South Africa

# book review

**Green Mining:** Beyond the Myth
Perspectives on the Future of Mining
**Editors:** Caroline Digby, Dee Bradshaw, Hanri Mostert and Brian Chicksen


*Prof Dee Bradshaw, Director, Minerals-to-Metals Initiative, University of Cape Town and the South African Research Chair in Mineral Beneficiation, University of Cape Town*
*Photo: YoungPreneur Media, Prolinx*

The desire expressed globally to move away from 'resource finite', 'destructive' and 'environmentally compromising' industries such as mining cannot be a reality simultaneous with the establishment of a green economy from which minerals and metals are inextricable.[1] "The apparent paradox of 'Green Mining' captures the contradiction of the invasive mining process and the colour green, which symbolises life, renewal and sustainability. Green mining depicts the provision of minerals and metals in a way that is not only techno-economically viable but also environmentally responsible, and that contributes to social inclusion and benefitting communities. While it does not necessarily describe the mining industry as we currently know it, it is one we can imagine, aspire to and seek to create."[2]

These words encapsulate some of the exciting thinking behind the recent launch of the book "Green Mining: Beyond the Myth" held at the Two Oceans Aquarium in Cape Town on the 4th of February, ahead of the Annual Mining Indaba. Guest speakers at the event were Dr Max Price (Vice Chancellor, University of Cape Town - UCT), Sipho Pityana (Chairman of UCT Council, Independent Non-Executive Chairman, AngloGold Ashanti), and Jeff Radebe (Minister in the Presidency for Planning, Monitoring and Evaluation, RSA). The book is inspired from a one day interactive Symposium in August 2017 organised by the interdisciplinary Minerals-to-Metals (MtM) Initiative and Mineral Law in Africa (MLiA) at UCT in partnership with AngloGold Ashanti. This workshop drew on leading Sustainable Development thinkers and practitioners from academia, the private sector, government and civil society which is reflected in the publication that covers such areas as: the role of technological research and innovation in improving performance and efficiency, the role of engagement and collaboration, and the role of mining companies in contributing to the achievement of the UN's 17 Sustainable Development Goals.

The publication widely acknowledges that 'business as usual' is no longer possible when it comes to mining. "What is needed now is a new paradigm with a laser-like focus on implementation … resulting in inclusive and equitable development."[3]

This publication assists in mapping the direction towards a new mining and minerals beneficiation vision.

For further details please see:
http://www.mineralstometals.uct.ac.za/

**References**

[1]Sue Harrison, 2018
[2,3]Dee Bradshaw & Caroline Digby, 2018

Article by **Conchita Kamanzi** & **Theophilus Dzingai**, University of Cape Town

# GSSA calendar 2018

Geological Society of South Africa

| DATE | EVENT |
|---|---|
| Postponed till later in 2018<br>2 February | Introduction to SAMREC/SAMVAL Compliance – Cape Town |
| 21 – 23 February | Drilling Methods and Techniques in Resource Exploration |
| 8-10 March | Foundations for a Geological Career |
| 24 - 25 May | Economic Analysis for Mining Investments |
| 26 - 28 June | Workshop on SAMREC/SAMVAL Compliance and JSE Reporting for CP/CVs |
| 18 – 20 July | Geocongress |
| 26 July | AGM |
| Date TBC<br>31 August | Excursion to Hartebeesthoek Radio Astronomy Observatory |
| 26 - 28 September | Drilling Methods and Techniques in Resource Exploration |
| 4 - 7 November | AAPG ICE Meeting – Cape Town |
| 15 November<br>Date TBC | Fellows Dinner (tbc) |
| 15 - 16 November<br>Date TBC | Technology Day and African Exploration Showcase |

# obituary



## Ian Christopher Slatem †

**IAN CHRISTOPHER SLATEM B.Sc. HONS, MBA.**
10th January 1957-1st January 2018.

Ian Slatem died tragically on New Year's Day of 2018 in a climbing accident, while leading two tourists from Hong Kong on the precipitous Arrow Final ascent on Table Mountain.

An informed source described how Ian, an experienced climber and registered guide, was leading the climb, well secured by 3 solid anchor points, when a large block of sandstone was dislodged, causing him to fall. Below him, his belayer was struck by the rock and killed instantly. Without a belayer, Ian suffered a long fall and was killed. Fortunately the third climber in the party was in a good position, out of the line of falling rock and was unharmed.

Ian Slatem was one of the Cape's best known mountain climbing guides and yachtsmen, as well as being an experienced independent contract geologist, having worked full time in the mining industry in his earlier years. Born and schooled in Johannesburg, Ian obtained a B.Sc. degree majoring in Geology and Chemistry at The University of the Witwatersrand in 1983 and completed a B.Sc. Honours degree in Geochemistry at the University of Cape Town in 1984. Already in these early undergraduate years, mountaineering featured strongly in his extramural activities.

After graduating from UCT, Ian joined Anglovaal Limited in Johannesburg in 1985 and for the next nine years, he served a stint as a mine geologist at the Loraine Gold Mine and was later involved in exploration projects in Ghana, Namibia, Zimbabwe, Zambia and South Africa in the search for base metal, gold, heavy mineral sands, uranium and platinum deposits. During this period, he achieved the rank of Senior Exploration Geologist. By 1992, Ian was engaged in extramural

studies for an MBA degree at The University of the Witwatersrand, which he obtained in 1994.

At this point, Ian's restless spirit moved him to leave Anglovaal to join African Explosives Limited, where he spent the next eleven years in various capacities, ultimately achieving the position of Business Partnership Manager in the Mining Services Division of AEL.

During 2003, Ian participated in a climbing expedition to the Peruvian Andes. On one ascent, Ian experienced an accidental fall into a glacier crevasse, resulting in severe injuries to his legs. Fortunately, another climbing team arrived on the scene and managed to extract Ian from the crevasse. The Peruvian Alpinist rescue team was alerted and eventually, with great difficulty, Ian was carried to a lower elevation, where a helicopter airlifted him to a pick-up point for an ambulance to convey him to a hospital in Lima. Due to the severity of his injuries, Ian was airlifted back to South Africa and hospitalised in Pretoria, where it was ultimately necessary to surgically fuse both his ankles. This resulted in limited flexibility in his ankles and an awkward gait, but his passion for climbing was undimmed. In due course, his considerable grit and determination enabled him to return to full participation in the sport of mountaineering.

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In 2006, Ian relocated to Cape Town to facilitate pursuit of his twin passions of yachting and mountaineering. He started a company known as Jewel Marine, which supplied advanced sailing equipment to the yachting fraternity, trading until November 2016. During this time, Ian developed his considerable yachting skills and astro-navigational expertise and was involved in the chartering and ferry delivery of yachts to many destinations, as well as racing Warlock, his own L26 class yacht. He was also involved in the activities of the Mountain Club of South Africa and the Royal Cape Yacht Club, acting as scrutineer for the Lipton Cup races for a number of years.

In 2016, Ian achieved the AQN International Certificate in trad multipitch rock climbing and the National Mountain Guide qualification, conducting his first guiding venture in October 2016. At this time, Ian embarked on a new endeavour as a registered mountaineering guide, launching his own company known as ClimbTableMountain. Ian's passion and commitment resulted in ClimbTableMountain winning the Lilizela Provincial Adventure Tourist Guiding award for 2017 and qualifying as a finalist in the National competition. As Ian commented at the time – "Finally found work that I love. Table Mountain is now my office and I'm happy".

A Memorial Service was held for Ian at the Cape Town premises of the Mountain Club of South Africa on what would have been Ian's 61st birthday, Wednesday 10th of January 2018. A kilted piper paid homage to Ian's Scottish heritage by playing Flower of Scotland, followed by the hymn Amazing Grace. The service was well attended by Ian's family and friends, some of whom related anecdotes of his sailing and climbing adventures.

It is a somewhat daunting task to summarize Ian's multifaceted persona and do justice to his undoubted extraordinary gifts. Perhaps a random sampling of the words and phrases used by his many friends and colleagues in their tributes to him on social media bear witness to his exceptional qualities. Among them, the following expressions were common – good friend, patient and encouraging, mentor, good companion and colleague, gentle, kind, always smiling and willing to share his passion, thorough, intrepid, bold, innovative, caring – so many words that describe who he was and what he meant to so many people. He will be sorely missed by all who knew him.

Ian is survived by two sisters, Alice and Trish; his son Stefan Michaelis, and his partner Jennifer Burger.

**Jan Mostert,** With the help of so many.

# obituary

## Hugh Jenner-Clarke †

**HUGH CLIFFORD DAVID JENNER-CLARKE**
8th December 1929 (Sutton, Surrey, UK) – 31st March 2016 (Cape Town, South Africa)

Born as the eldest son of George and Vera Jenner-Clarke, Hugh and his younger brother, also named David, grew up in a home called "Roselea". George was a general dealer who sold groceries and fresh produce from a typical "English corner shop" in High Street, Sutton.

*Wedding day, 20 February, 1981*

Hugh attended a local Grammar School where he obtained his A-Levels. His BSc degree in geology followed four years of study at the Chelsea Polytechnic, a Division of London University.

His career in geology commenced soon afterwards, with his appointment as junior geologist with Anglo-American Corporation of South Africa, seconded to the Consolidated Diamond Mines of South West Africa (CDM, currently known as NAMDEB) at Oranjemund. At the age of 24 he boarded the RMS Pretoria Castle in Southampton, arriving in Cape Town in September 1954 and proceeding almost immediately to Oranjemund. The contrast between the green fields of his hometown and the SW tip of the Namib Desert, must have astounded him.

It is certainly true to say that most people exposed for the first time - especially during those early days - to this isolated region of South-western Africa with its dramatic desert mountain scenery would depart greatly impressed and awed. The young son of the shopkeeper of Sutton was no exception and it left an indelible impression on his mind.

At CDM Hugh worked under two of the stalwarts of the West Coast diamond industry, viz. Darryl Hallam and the 2-i-c, Dr Charles Stocken.

During October 1954, soon after his initial introduction to CDM's style of diamond exploration at Oranjemund (mostly at the so called G Area), Hugh was attached to a geological mapping programme – the first since before 1914 – covering the barren, very isolated area east and north of Oranjemund up to the Sperrgebiet boundary. This area included the infamous Obib Dune Field, part of the area that was later on named "The Namib Sand Sea" by geographers. This programme did not last long as the geologist in charge was beginning to show signs of a nervous breakdown, and told Management at Oranjemund: "There are troublesome lions in the area and I'm not going back to work there again!". In later years it became well known that the deep umph-umph! sounds made by a male ostrich patrolling his territory at night, are almost identical to those made by a male lion patrolling his territory.

*Sutton (Google Earth, 2017)*

*Oranjemund (Google Earth, 2017)*

Unperturbed by the challenges offered by this harsh part of the world, Hugh steadily became more attached to its natural beauty and unique features.

The mapping programme having been shut down, Hugh was spared from enduring endless months of fruitless work and returned to Oranjemund. His duties were to map and record the geology of the prospecting trenches at Kerbehuk and Affenrucken. He remained working on raised beach deposits until March 1956 when he was seconded to an exploration programme for uranium in the southern interior of South West Africa (now Namibia). This programme soon developed into a search for kimberlites, targeting the drainage areas of the Konkiep and southern Fish Rivers. Hugh enjoyed this period immensely; while the work was largely stereotyped and sterile he was in the company of several young and enthusiastic, lively colleagues living a rugged but carefree camp life, so much different from the claustrophobic, rigidly confined and overly regulated Diamond Area No. 1.

However his marine alluvial capabilities were needed at Oranjemund where he returned at the end of June that year. This time he was given charge of prospecting the high level beach deposits at Kerbehuk north of the main (at that time) mining blocks of G-Area, Uubvley

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and Mittag. Here at least, CDM provided well-made though small transportable living quarters for its field staff. Hugh spent a considerable period of time there, largely in the company of his fondly remembered and devoted Ovambo personal servant and cook, Festus. Weekends were spent at Oranjemund, providing social stimulus as well as geological discussions and collaborations with colleagues at base. Hugh was reserved and a reluctant party-goer, and so he remained throughout his life.

Having lived and worked in remote areas myself, I know the value of good friendships under trying and challenging conditions. Hugh was blessed with two such friendships that started in those early days in Oranjemund, and continued to support him for the rest of his life. R Baxter-Brown arrived in Oranjemund early in 1956 after graduating from Rhodes University in Grahamstown the previous year. Their friendship was immediate and empathy of personal interests developed. In my mind it was a case of two complete strangers meeting, but both of them true gentlemen and acute earth scientists and the bonding of a lifelong friendship was inevitable. They discussed theories of diamond transportation and concentration and visualised a time when they would be free and able to launch their own diamond exploration ideas. In the comfort of their secure surroundings it all seemed so effortless and geologically obvious, but many years were yet to pass before it would materialize.

More or less the same time Hugh met Cynthia Laubscher, described by Baxter-Brown as "a remarkable outgoing and lively personality, an original thinker and teacher as well as a talented artist". A lifelong platonic friendship developed.

In April 1957 Hugh was transferred to the De Beers Kleinzee Mine at the mouth of the Buffels River, accompanied by a mining engineer, Gary Browne and his wife, both friends of Hugh's. Not long afterwards Baxter was transferred to Lichtenburg to prospect the farm Pypklip for De Beers, Kimberley, and the two thereafter kept in touch with the occasional letter.

At Kleinzee Hugh began to plan his departure from De Beers in order to seek out a financial "backer" to grubstake his plans to "discover the source of the Kleinzee diamonds in the headwaters of the Buffels River". The Bushmanland plateau was the obvious starting point for testing the theory and Hugh consumed all the then known literature documenting the earlier exploration work done on the plateau, in particular that of Dr E Reuning in the 1920's. Hugh's field research was initially hampered by the ban on diamond exploration on State Land in Namaqualand during 1927 to 1963.

During 1958 Hugh bade the town of Kleinzee and De Beers goodbye and paid a brief visit to his family in England. Returning to Namaqualand he based himself in Springbok and soon thereafter met the remarkable Gertjie Niemoller of Pofadder, a multi-millionaire sillimanite miner and very successful farmer. Hugh convinced Gertjie of the merits of kimberlite exploration in the Bushmanland and a deal was struck that gave Hugh a minimal budget, sufficient for obtaining option agreements from farm owners (in those days, the property owner still had the first right to apply for an exploration/mining authorisation on his property, which right became the basis of an agreement with the mining companies). The agreement with Gertjie Niemoller also provided Hugh with the funds to run a small exploration team.

With the aid of aerial photographs and meticulous field mapping, Hugh soon recognised upwards of 200 meta-kimberlite pipes in the Bushmanland. Those were the days before Clifford's Rule and the seminal work done on kimberlite mineralogy by John Gurney and others, and a flurry of excitement filled the Bushmanland air. The mining companies did not want to be left behind, and the "Bushmanland kimberlite" race was on. Alwyn Cornelissen (Newmont's O'okiep Copper Company), Roderick Baker and others (De Beers) and Keith Whitelock (Rand Mines) were the main players. The confidence in the Bushmanland Project combined with the enthusiasm of Hugh Jenner-Clarke and Niemoller, paved the way for the recruitment of Baxter-Brown to the project. Baxter had then just completed the prospecting

of Pypklip and its proclamation as an Alluvial Diggings for the benefit of the local digger community, and resigned from De Beers with the intention of further studies at Imperial College in London. Before leaving South Africa he agreed to join Hugh and Niemoller on his return from London.

Baxter returned via an unconventional route that took him through Egypt, the Red Sea, overland from Mombasa to Kitwe, then Salisbury and home in the Eastern Cape. In the meantime Hugh had been frantically trying in vain to reach him to say that he should not return here, since it has been shown that the two "diamonds" found in one of the Bushmanland pipes turned out to be highly resorbed crystals of clear, brilliant yellow zircon.

Hugh then continued his Bushmanland work on a reduced scale and Baxter was given the task of exploring the lower Sout River north of Vanrhynsdorp. Diamonds of excellent quality were found, but small and after a while Niemoller quit diamond exploration.

Soon thereafter Hugh and Baxter decided to become diamond consultants with emphasis on alluvial exploration. Thus the company Asam Minerals was born, headquartered in Springbok. Building a client base was a slow and difficult process but consultancies took them to many exploration sites in Namaqualand, the Kimberley region, the Middle Orange (where they found the first diamonds on Niewejaarskraal between the historical diggings of Saxendrift and the town of Prieska), Botswana and even as far afield as Brazil.

While writing this obituary, I was lying awake early one morning. Suddenly I was in another place, at another time. I saw nothing, but I heard Hugh saying: "Having ignored You for most of my life, it dawned upon me that it was futile living without You, but I dare not die without You. I have nothing to offer, I can only plead for mercy" and a quiet, authoritative voice replied: "Mercy is what My plan of Salvation is built upon. Because I knew that no one will ever be able to earn it, I made it a gift of unmerited favour. In the parable of the servants hired at different times of the day I made it clear that it does not matter at what time of the day you accept My Gift, as long as you do it before the end of your day".

Shalom Hugh, we'll meet again!

**Assie Van der Westhuizen**

**ADDENDUM** to Obituary of Hugh Clifford David Jenner-Clarke

Following their successful interpretation of the Miocene deposits on the farm Bontekoe in 1965, Asam became better known, and were contracted to manage the exploration programmes at Sendelingsdrif (the Octha operations, later called the Reuning Mine) where the first diamonds were found in September 1966 and later at Bloeddrif. Hugh then correctly interpreted the geology at Baken with the first diamonds recovered in 1967.

The financial collapse of the overseas backers of Baken Diamante after 1972 saw a very unhappy Jenner-Clarke losing control of this magnificent deposit and the asset was sold to Trans Hex. In July 2001 this author had the privilege of interviewing Lenny Judaken who did the deal with Trans Hex, in Los Angeles. Considering all the facts (having worked for Trans Hex for 22 years as from April 1982) led to the conclusion that Baken was a classical example of a deposit that was discovered too soon, since it was only since 1982, when the Rand first slipped below the US$, that this deposit with its high stripping ratio in places could be worked economically. Baxter recalls that this disappointment was to lead to the separation of both himself and Hugh and gradually thereafter they each went their separate ways.

Despite this blow Hugh never lost faith in the potential for diamond and other mineral deposits in his much loved Namaqualand. Recently Baken celebrated its 35th anniversary of continuous production.

Hugh loved to pass on interesting finds from his diggings in Namaqualand to the SA Museum in Cape Town, who honoured him by naming a spore after him.

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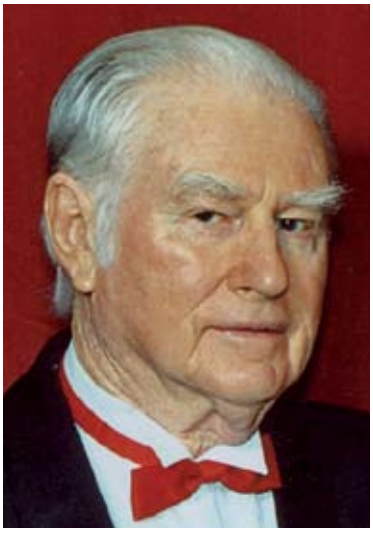
Hugh being a reserved and dedicated earth scientist married fairly late in life. He met Christine Melidonis in 1980 through a mutual friend. Born in Cape Town from Greek parents Christine was a teacher at the time. They were married on 20 February 1981 and their only child, Louise, was born in January 1983. Shortly thereafter they moved to Constantia where they enjoyed a country life in the city. Christine says Hugh was always a geologist and even found a Stone Age tool in their garden. Louise, a Nutritionist lives in London with her husband Peter and two year old son James. She composed the epitaph on Hugh's tombstone: "Geologist, husband, Father. We return you to the earth you devoted your life exploring".



*At daughter's 21st, Jan 2004*

Hugh was able to meet his grandson before he passed away, an event that brought him much joy.

Finally a part of the eulogy by Baxter Brown that was read at Hugh's memorial service, reveals another facet of this remarkable colleague's character: "Tribute to Hugh, a close acquaintance for the past 60 years and a friend, who despite the ups and downs of business, had one singular trait: Hugh, your outstanding singularity was first loved Namaqualand. Your quiet, unsung contribution to the economic benefit of this unique region ranks high and places you among the 'great and unforgettableand foremost a desire to promote the welfare of your be characters' of Springbok. Neither will your contribution to, nor your concern for the less privileged members of this community be forgotten".

**Assie Van der Westhuizen,**
ALEXANDER BAY. 1 MAY 2017/11 OCTOBER 2017.



# mineral scene

**Quartz from the Goboboseb Mountains, Namibia.**

**Bruce Cairncross**
**Department of Geology, University of Johannesburg**

The Goboboseb Mountains located west of the Brandberg are well researched regarding the geological setting and evolution of this volcanic succession. The Goboboseb Mountains cover an area approximately 1,100 km2 (Milner and Ewart, 1989) and consist of interbedded basalts and quartz latites, that forms part of the Etendeka Group (Ewart et al., 1998a). The regional geology of the Goboboseb Mountains is subdivided into three geological members. The oldest at the base is the 250 metre-thick Tafelkop Basalt Member composed of multiple basalt flows that vary between 5-30 m thick. Some of the flows are characterised by amygdaloidal flow tops. Amygdales vary in size from a few millimetres to geodes over 1 metre. It is this formation that plays host to the quartz (and other minerals) that are the feature of this "Mineral Scene" column. Apart from quartz, and its varieties, other species are well known from this region (Cook, 1999).

Quartz occurs in vugs in the lavas and is found most commonly as clear, colourless crystals. However, the desirable specimens are amethyst and smoky quartz, and these two colour variants offer occur in the same crystal (Cairncross and Bahmann, 2006). In addition to the different varieties, quartz can contain fluid inclusions (bubbles) and solid secondary mineral inclusions such as hematite, as shown in the specimen and facetted stone illustrated here. The hematite occurs as bright red transparent flakes.

In addition to quartz and amethyst, brown clay is also found as inclusions and this quartz variety is referred to as "venster" quartz, because the brown inclusions are often confined to specific faces of the crystal forming brown "windows". Sequential growth of quartz has

*A 4.5 cm quartz with inclusions of red hematite and pale amethyst core. The colourless crystals attached on the left side are analcime and the hematite-included faceted stone is 8.45 carats.*
*Bruce Cairncross collection and photo.*

produced internal zoning, known as phantoms, where successive layers of clear quartz alternating with smoky and amethyst layers produce attractive internal zonation. In addition, the Goboboseb region has produced world-class sceptred crystals, some over 20 cm in length where a colourless quartz crystal forms the base of sceptres that both can be amethystine and smoky, or both. Finally, some of the specimens from Goboboseb occur as clusters of crystals. These can form bizarre shapes such as the one shown on the front cover of this issue of Geobulletin.

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*The Goboboseb "dog". A bizarre shaped cluster of quartz with hematite inclusions and amethyst. The head of the dog is a sceptre, 5.5 cm.*
*Bruce Cairncross collection and photo.*

# media monitor

## MINING AND EXPLORATION NEWS

### Copper and cobalt

Celsius Resources completed a 17 000 m resource drilling programme at its 95%-owned Opuwo cobalt-copper project in northwestern Namibia. Highlights from the assay results so far include 17 m at 0.14% Co and 0.42% Cu, 10 m at 0.12% Co and 0.59% Cu, and 7.7 m at 0.11% Co and 0.52% Cu. The remaining assays are expected shortly, to be followed by completion of interpretation, geological modelling, resource estimation, and reporting of a maiden JORC Mineral Resource. Significantly, two deep diamond drill-holes intersected semi-massive sulphides at vertical depths of approximately 380 m, extending the mineralisation well beyond current exploration target depth of 200 m and supporting the theory that a feeder zone, or zones, may exist for the extensive mineralisation at Opuwo.

Toronto-listed Namibia Rare Earths has agreed to acquire a majority interest in seven projects, ranging from exploration opportunities to near-term feasibility stage, in Namibia. The acquisition broadens the company's single commodity focus from heavy rare earths at the Lofdal project into a broader portfolio of critical metals and minerals, including cobalt, lithium, graphite, tantalum, niobium, and gold. The initial focus will be on the Kunene cobalt project, following discovery of stratabound cobalt-copper mineralization at Celsius Resources' neighbouring Opuwo project. The other targets include graphite (Black Range), lithium (Warmbad area), the Epembe and Otjiwarongo carbonatites (tantalum-niobium), nickel-cobalt in a large buried mafic-ultramafic intrusive complex (Grootfontein area), and gold in the Erongo region.

### Gold

B2Gold Corp. announced that the Fekola gold mine in Mali achieved commercial production in November, 2017, one month ahead of schedule. In 2018, the first full year of production, the company is projecting a production of approximately 400 000 to 410 000 ounces of gold, increasing its consolidated gold production to between 925 000 and 975 000 ounces.

### Lithium

Prospect Resources has further increased in the mineral resource estimate at its flagship Arcadia lithium deposit in Zimbabwe to 72.7 Mt at 1.11% $Li_2O$ (0.2% $Li_2O$ cut-off), with the conversion of all the Inferred Resource from the conceptual pit design into Indicated and Measured categories. The confirms Arcadia's status as the largest JORC-reported lithium resource in Africa and the sixth largest globally, with an overall mineral resource comprising about 808 kt of contained lithium oxide, equivalent to 2 Mt contained lithium carbonate equivalent. The deposit, which is about 38 km east of Harare, is hosted within a series of stacked, sub-parallel petalite-spodumene bearing pegmatites, extending 3.5 km along strike, which intrude the Archaean Harare Harare Greenstone Belt. A pre-feasibility study completed in 2017 outlined a 1.2 Mt/a mining and processing operation producing an average of 75 kt/a spodumene and 155 kt/a petalite concentrates, based on a Probable ore reserve estimate of 15.8 Mt grading at 1.34 % $Li_2O$ and 125 ppm $Ta_2O_5$, for a capital expenditure of US$52 million. Prospect is also evaluating the construction of an on-site plant to produce battery-grade lithium carbonate.

### Nickel

Mkango Resources has been granted an Exclusive Prospecting Licence covering the Chimimbe Hill nickel-cobalt deposit and other targets in Mchinji district, central Malawi. The 98.48 $km^2$ licence area features

laterite- and saprolite-hosted nickel, cobalt, chrome and other mineralisation, and has undergone significant historical exploration, including pitting, drilling, and metallurgical test work. Mkango is undertaking a full review of the historical data for Chimimbe Hill, including an evaluation of the exploration potential in the context of geophysical data from the recent World Bank airborne geophysical survey of Malawi, and is considering potential synergies with the its Songwe Hill rare earths project and Thambani uranium-tantalum-niobium project.

## PLATINUM GROUP ELEMENTS

Sibanye-Stillwater and Lonmin have agreed on a recommended offer by Sibanye-Stillwater to acquire the entire share capital of Lonmin by way of a £285 million all-share transaction. The deal will increase Sibanye-Stillwater's PGE reserves by 31.7 million ounces (3PGE + Au), and its resources by 180.6 million ounces, and is expected to boost the group's 4E production to 2.80 million ounces per annum. The combination gives Sibanye-Stillwater access to its own processing facilities in South Africa and creates a larger and more resilient company, with greater geographical and commodity diversification, that is better able to withstand short-term commodity price and foreign exchange volatility. Sibanye-Stillwater has followed a strategy of growing its precious metals business by completing three other separate, similar transactions in the past two years, specifically by acquisitions of the assets of Anglo America Platinum's Rustenburg Operations and Aquarius Platinum in 2016, and Stillwater in 2017.

### Rare Earths

Rift Valley Resources has received preliminary results from a scoping study on its 70%-owned Longonjo carbonatite project in Angola. The company said that the results, which are based on the weathered zone portion of the mineral resource estimate, justify the further evaluation of the project, which will include additional resource drilling, metallurgical test work, and more detailed cost and engineering studies. The weathered zone contains an Inferred mineral resource of 11.6 Mt at 4.30% rare earth oxides for 499 kt of contained REO at a 1% cut-off. Longonjo, which is located 200 km east of the port at Benguela, contains a total mineral resource (weathered plus fresh mineralisation) of 44.7 Mt at 2.50% REO. Only a 650 x 350m area of the total 2.3 x 1.3 km prospective carbonatite core has been drill-tested to date and the mineralisation remains open in all directions.

### Tin

Canadian company Alphamin Resources has secured a credit facility of US$80 million for the construction of the Bisie underground tin mine in the North Kivu Province of the Democratic Republic of the Congo. The project, which is likely to become one of the most significant tin mines in the world, is expected to begin production in in the third quarter of 2018. Bisie is one of the world's largest tin deposits and among the most advanced, with a Measured resource of 0.46 Mt at 4.31% Sn plus 4.14 Mt at 4.55% Indicated, both at a 0.5% cut-off grade, for a total of 208 kt contained tin. The mine is anticipated to produce 10.7 kt of tin in concentrate per year over a life of almost 12 years, with cash costs of production of US$7396 per ton tin, for a projected capital cost of US$151 million.

### Zinc

Orion minerals established a maiden global mineral resource, based on about 58 000 m of drilling, of 24.2 Mt at 3.47% Zn and 1.23% Cu at the Prieska project in South Affrica's Northern Cape Province. The target massive sulphide body remains open both on strike and dip, and further drilling will be carried out during the first half of 2018 to extend the mineralisation and upgrade the confidence classification of a substantial portion of the resource. Engineering studies and metallurgical work are under way in preparation for a feasibility study.

ASX-listed Tanga Resources has secured an option

to acquire up to a 90% interest in the Joumbira zinc project in the Otjiwarongo district of Namibia. Joumbira is considered to have potential to host a large, high-grade zinc-lead-silver skarn orebody, with historical drilling results from the 1970s including 14 m at 9.5% Zn, 8.2% Pb, and 79.8 g/t Ag and 23 m at 5/86% Zn and 6.30% Pb. None of the historical samples were assayed for elements such as gold, tin, tungsten, copper, or cobalt, which commonly occur in felsic intrusive-related exoskarns like Joumbira. Tanga intends to drill at least five diamond-drill holes as twins of the high-grade historical intercepts , and conduct a programme of detailed multi-element assaying and metallurgical test work.

## OTHER GEOSCIENCE NEWS

Geocientists have predicted a possible significant increase in the number of major earthquakes over the next few years, following a slowing down of the Earth's speed of rotation. The link was highlighted in a paper by Roger Bilham of the University of Colorado and Rebecca Bendick of the University of Montana, presented at the 2017 annual meeting of the Geological Society of America [doi: 10.1130/abs/2017AM-300667]. Bilham and Bendick looked at earthquakes of magnitude 7 and greater that had occurred since 1900, and found that on five occasions in the past century a 25-30% increase in the annual number of magnitude 7 earthquakes had followed a slowing in the mean rotational velocity of the Earth. Such fluctuations, which are caused by the exchange of angular momentum between the solid and fluid Earth (atmosphere, oceans and outer core) are small – changing the length of the day by about a millisecond, which can be measured very accurately by atomic clocks. The latest deceleration episode commenced in 2011, suggesting that the world is now entering a period of enhanced global seismic activity with a duration of several years. Two possible mechanisms have been proposed to account for the link between seismicity and length of day – decreased oblateness of the globe that attends a slowing of rotation, and lithospheric overshoot, a process whereby the equatorial lithosphere sluggishly overrides the decelerating underlying mantle westward.

Analyses on a small pebble from south-west Egypt have cast significant questions on a widely-held view about the primitive pre-solar dust cloud that our Sun, Earth, and other planets were formed from. Professor Jan Kramers and Dr Georgy Belyanin from the PPM Research Centre at the Department of Geology, University of Johannesburg have found exotic micro-mineral compounds in the 'Hypatia' stone that are not known to occur on Earth, elsewhere in our solar system, or in meteorites or comets.

In 2013, Kramers and his co-authors announced that the Hypatia pebble, found in south-west Egypt by geologist Aly Barakat in 1996, was definitely not from Earth. By 2015, other research teams had concluded that the stone was not part of any known types of meteorite or comet, based on noble gas and nuclear probe analyses. The latest study, published in Geochimica et Cosmochimica Acta [https://doi.org/10.1016/j.gca.2017.12.020], has provided evidence runs counter to conventional views of the material out of which our solar system was formed.

The Hypatia matrix contains a massive amount of carbon and an unusually low level of silicon, the reverse of what is seen in chondritic meteorites, as well as a high amount of polyaromatic hydrocarbons (PAH), a major component of interstellar dust. Most (but not all) of the PAH have been transformed into diamonds smaller than 1 μm, probably as a result of the shock of impact with the Earth's atmosphere or surface. The inclusions in the matrix comprise pure metallic aluminium, silver iodine phosphide, and moissanite (silicon carbide) grains, as well as grains of a compound consisting of mainly nickel and phosphorus, with very little iron; a mineral composition never observed before on Earth or in meteorites. Taken together, the inclusions suggest that Hypatia is an assemblage of pre-solar material – that which existed in before the solar system was formed; or if not, that the early solar nebula was highly heterogeneous, which runs counter to the generally accepted view of the formation of the solar system.

'What we do know is that Hypatia was formed in a cold environment, probably at temperatures below that

*The Hypatia stone was found in the Lybian Desert Glass Field, a 6500 km² area in south-west Egypt strewn with fragments of highly pure, silica-rich natural glass, most likely formed by the high temperature impact of an extraterrestrial body into a sand or sandstone layer. The stone is named after Hypatia of Alexandria, the fourth-century woman philosopher and mathematician. Photo: Dr Mario Di Martino/ INAF Osservatorio Astrofisico di Torino.*

of liquid nitrogen on Earth (-196°C)', says Kramers.' In our solar system it would have been way further out than the asteroid belt, where most meteorites come from. Comets come mainly from the Kuiper Belt, beyond the orbit of Neptune and about 40 times as far away from the Sun as we are. Some come from the Oort Cloud, even further out. We know very little about the chemical compositions of space objects out there. So our next question will dig further into where Hypatia came from.'

**Antony Cowey**

*Hypatia Stone*

Gulf of Corinth and Zakynthos

# THE GEOTRAVELLER

**By Roger Scoon**

## GULF OF CORINTH AND ZAKYNTHOS, GREECE:
*Active Tectonism and Ancient Cultures.*

*The antiquity of Acrocorinth is located on a limestone (Mesozoic) plateau south of the modern city of Corinth. Source: By elveoflight - Own work, CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=1133863.*

*The Gulf of Corinth is a narrow, 120 km-long east-west trending indentation in the coastline of western Greece. The eastern limit of the gulf terminates near the Corinth Canal which links the Aegean and Ionian Seas. The western extremity of the Gulf is demarcated by the narrow straits of Rion and Andírrion (also known as the "Little Dardanelles") which passes into the Gulf of Patras. The area is characterised by narrow coastal strips located beneath high, mountainous terranes. The island of Zakynthos, the southernmost of the seven Ionian Islands, occurs 12 km to the west of the mainland. Zakynthos is known for the wooded interior, sandy beaches and rocky coastline. The Gulf of Corinth and the island of Zakynthos occur in one of the most tectonically active regions on Earth.*

*The settlements of Corinth and Patras (the latter is Greece's third largest city) are located on the coastal strip which delimits the southern shoreline of the Gulfs of Corinth and Patras. This area of fertile soils, which is extensively farmed, contrasts with the rugged nature of most of the Peloponnese. The town of Zakynthos is the only large settlement on an island known historically for extensive cultivation, in part due to the relatively high annual rainfall. The island is now one of the most popular tourist destinations in Europe, with a million visitors annually.*

*Many early civilisations, including the Mycenaean's (1600-1100BC), Arcadians (1100-800BC) and ancient Greeks (800-300BC) preferentially settled coastal areas and islands of the eastern Mediterranean. Famous sites include the ancient city of Corinth, to the south of the modern town, and Delphi which is located on the lower slopes of the Parnassus Mountains, on the northern shores of the Gulf of Corinth.*

*The ancient Corinthians were reputed to be hard-living folk who had little in common with the modern usage of this term for ethical sporting prowess. The earliest inhabitants of the island of Zakynthos owe their allegiance to the Arcadians, including Odysseus as related by Homer. The island has a long history of civilisation and is the home of many respected Greek and Italian poets. Many of the*


*The location of the Isthmus of Corinth with the modern canal shown in light blue. Modified with some additions after EcoChap - Own work, https://commons.wikimedia.org/w/index.php?curid=17550835).*

*sites of antiquity in western Greece have experienced major seismic events over the past few thousand years.*

*Sedimentation patterns and sea level changes have persistently reshaped the geology of western Greece during the Holocene. The greatest changes, however, can be ascribed to tectonism. The active extension of the continental crust is associated with convergence of the African and Eurasian Plates (e.g., Robertson and Mountrakis, 2006). The Hellenic subduction zone is consuming the remains of the ancient Tethys Ocean. Deformation is also associated with the western limit of the North Anatolian Fault. Extension occurs in an approximately N-S direction which includes the WNW-ESE striking Gulf of Corinth. Active volcanism (including Methana Volcano) is restricted to the Saronic Gulf on the eastern shores of the Peloponnese.*

*The plate boundary follows an east-west trend in the Aegean Sea (south of Greece), albeit notably curvilinear, but swings northward in the Ionian Sea (west of Greece). The displacement in the Ionian Sea on the Kephalonia Fault brings the Hellenic Trench close to the Ionian Islands. Compression associated with these structures affects large parts of north and western Greece, including the Gulf of Corinth and the Ionian Islands. The channels between the islands, as well as between Zakynthos and the Peloponnese, are relatively shallow, but southwest of Zakynthos the sea floor drops rapidly into the Hellenic Trough. Seismicity of the region means that the Gulf of Corinth, in particular, is very susceptible to tsunamis.*

*The Arcadian Mountains on the southern shore of the Gulf of Corinth, as well as the Parnassus Mountains on the northern shore are part of the Ionian-Peloponnese Tectonic Zone. This region is dominated by resistant limestone of Jurassic through Cretaceous-age. Pliocene and younger sediments, mostly relatively soft marl and sandstone, are developed on the coastal plains. Both formations can be examined from the new highway*

*The southern flanks of the Gulf of Corinth reveal high cliffs of grey limestone (Mesozoic) with lighter marl and sandstone (Pliocene and younger) forming extensive badlands.*

*connecting Athens with Patras, as well as from the narrow gauge Diakofto railway. The latter, which was built in the latter part of the 19$^{th}$C for tourists to access the interior mountains, cuts through the near-vertical limestone cliffs by a remarkable series of tunnels and undercuts. The younger sediments are associated with extensive areas of badlands, necessitating avalanche shelters and tunnels on the coastal highway.*

*The Pliocene and younger strata have also caused problems for the 2.9 km long Rion- Andírrion Bridge, opened in 2004, which crosses the narrows near Patras. The bridge required unique engineering solutions to overcome problems including pillar support for suspended cableways, the risk of tsunamis, and seismic activity. Expansion of the distance between the pillars (estimated at 30 mm/year) has been a key issue. The bridge has achieved iconic status in Greece and is widely photographed.*

*The cliffs near the highway between Corinth and Patras are comprised of thick sequences of pale grey and white Pliocene-Pleistocene sediments deposited on the flanks of the graben.*

*View looking north of part of the Rion-Andírrion Bridge which crosses the narrows at the entrance to the Gulf of Corinth.*

*Jackson (1999) observed that the area associated with the Gulf of Corinth has narrowed through time; it occupied a much broader part of central Greece during the Plio-Pleistocene. Faults were progressively abandoned with localisation of the structure into a 30 km-wide zone. Rifting may have commenced in the Miocene (Bull, 2009), although recent estimates suggest the Gulf formed during the previous 3-4 Ma (Roberts et al., 2011). The total subsidence is estimated at 3 km. Extension is occurring at 10mm/yr. There have been eleven earthquakes with magnitude >6 in the last 100 years. During the low stands of the Late Pleistocene Ice ages, the Gulf of Corinth is sufficiently shallow at the join with the Gulf of Patras (average of 60 m) as to convert into a lake.*

*The structure of the Gulf of Corinth is an asymmetric half-graben. The most active faulting is currently concentrated on the southern shores. Uplift is dramatic; Plio-Pleistocene sediments occur at elevations of up to 1,200 m. The asymmetry has resulted in a relatively linear coastline on the southern side, with a far more*

*Cliffs under the old road bridge in the centre of the Corinth Canal are part of a horst located on the margin of the graben. View looking south towards the new road and railway bridges shows the Late Pliocene age sediments (pale coloured marl and brownish sandstone) in the centre of the horst.*


*Cliffs under the railway bridge close to the entrance of the canal in the Saronic Gulf are capped by dark Pleistocene age sediments. They unconformably overlie the lighter coloured Pliocene strata.*

*sinuous coastline on the northern side. The differential rise of blocks has preserved marine terraces on the narrow coastal strips.*

*Ancient Corinth is built on a terrace of Pleistocene sandy limestone aligned approximately parallel with the Gulf of Corinth (Higgins and Higgins, 1996). An old fortress, the Acrocorinth, stands on a high plateau (575 m) of Jurassic limestone to the south of the ancient city. Major earthquakes occur in the vicinity of Corinth approximately every 300 years (the old city was severely damaged by two large earthquakes in the 6$^{th}$C AD), and after the major 1858 event the location of the city was moved to its current position. Three major events in 1981 included a magnitude 6.6 tremor which caused severe damage and loss of life. Patras also experiences major earthquakes, with the most recent occurring in 2008 (magnitude of 6.6).*

*Lechaion, the ancient harbour for Acrocorinth, located west of modern day Corinth, has a long history of both Greek and Roman civilisations, including being the main base for the famous Macedonian fleet of Philip V (200 BC). Excavations of the historical site include evidence of historical tectonism. Terraces have been correlated with specific historical periods (Roberts et al., 2011). The Ancient Corinth Terrace, for example, shows an elevation change from 60 m near Acrocorinth to 360 m near Xylokastro (approximately 7 km west of the Corinth Canal). Average uplift is estimated at 1.5mm/year.*

*The Corinth Canal connects the Gulf of Corinth and the Saronic Gulf which are separated by the narrow Isthmus of Corinth. Despite being less than 6 km in length, the canal saves a 700 km voyage around the Peloponnese peninsula. The narrowness of the canal (25 m), however, means few modern ships can use it, although there is considerable tourist activity. There are several fixed bridges across the canal, as well as floating bridges at the southeastern (Isthmia) and northwestern (Posidhonia) extremities. The near-vertical side walls, over 70 m at the high-level bridges are a notable feature.*

*Construction of the modern canal started in 1881 but was only completed in 1893. Geological problems were encountered due to slips of the relatively soft rocks from the high, steep sides. An additional problem is the different state of the tides in the two gulfs (there are no locks), and a current of 5.5 km/h can flow either way (Heikell, 2002). The canal was first conceptualised by Periander in the 7$^{th}$C BC. The project was soon abandoned and a stone carriageway, the Diolkos, along which boats could be towed, was constructed (Fowler and Stillwell, 1935). Relicts of the Diolkos can be seen at Posidhonia as a pavement constructed of large square blocks (measuring 1.6 m by 1.1. m). Several Roman Emperors had similar*

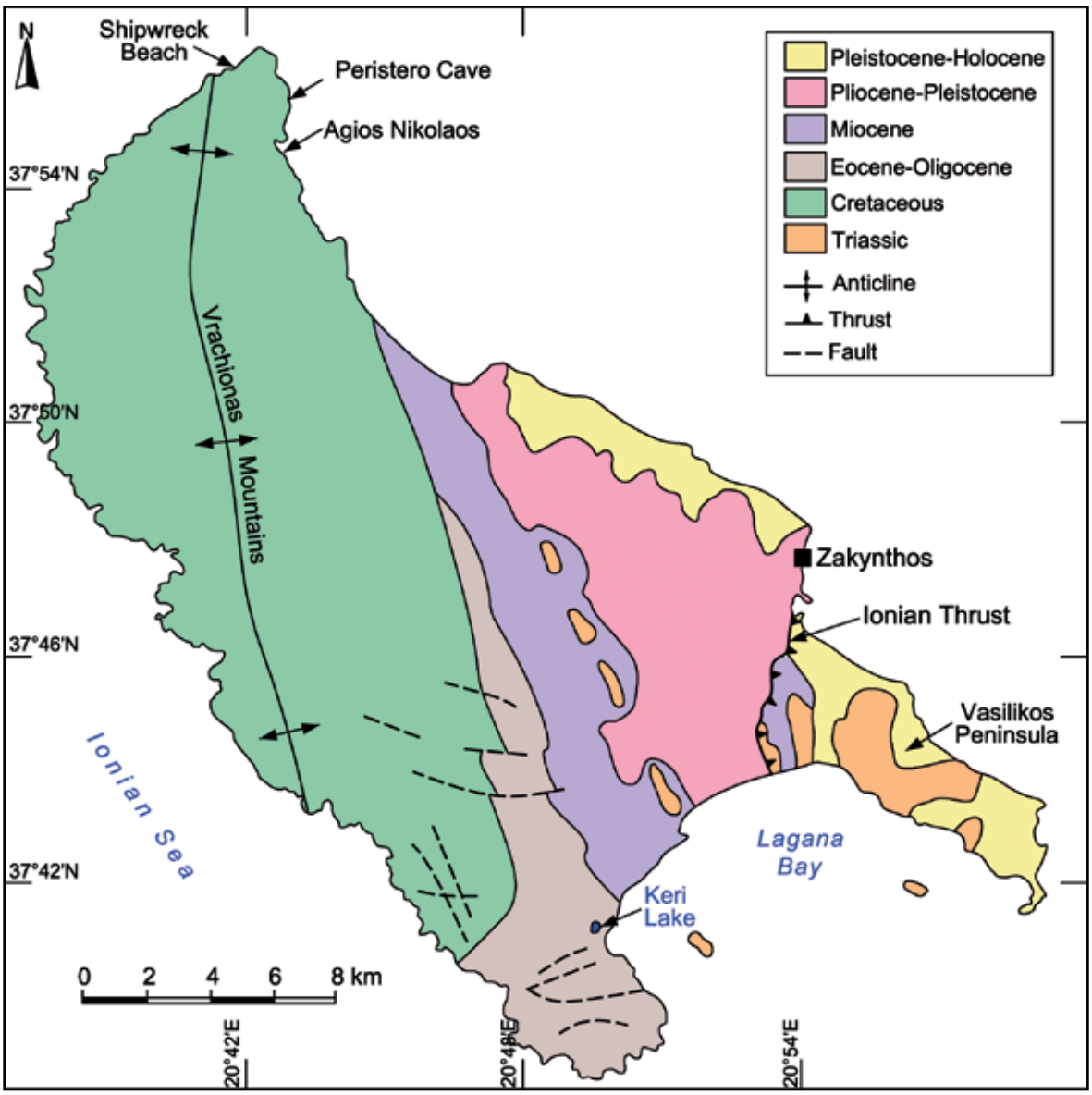

*The stone carriageway built in the 7th C BC (the Diolkos) near the Posidhonia Floating Bridge at the northern end of the Corinth Canal has been uplifted in recent years. The background includes cliffs of Jurassic limestone at the eastern extremity of the Gulf of Corinth.*

*plans of a canal, but the first excavations were initiated by Nero, in 67 AD. This continued after his death by digging 50 m-wide trenches, although they only managed a length of 700 m.*

*The isthmus transacted by the canal is a horst block on the flanks of the Corinth Graben (Mariolakis and Stiros, 1987; Higgins and Higgins, 1996). In the centre of the canal where the sidewalls are highest, a thick sequence of Pliocene age marls, sandstones, and conglomerates are exposed. The lower cliffs at the southern and northern ends of the canal are capped by Pleistocene conglomerate, sandstone, and limestone. Steeply inclined, normal faults, consistent with the persistent seismicity of the region occur in the sidewalls. Plio-Pleistocene sediments were deposited in a palaeo-lake when the Gulfs of Corinth and Patras were isolated from the Ionian Sea by the Zakynthos-Kephalonia barrier. This barrier was only broken at 250,000 BP. Uplift of the Plio-Pleistocene strata of the Isthmus horst is, therefore, relatively recent.*

*The youngest rocks exposed in the canal are Holocene age calcified sands and gravels ("beachrock"). They can be observed to postdate construction of the Diolkos as they cover sections of the pavement. This evidence suggests they accumulated in the previous 2,500 years after the Diolkos had been down faulted approximately 0.8 m (Higgins and Higgins (1996). The current position of both the Diolkos and the beach deposits is ascribed to relatively recent uplift (over 1 m). The beachrock deposits extend some 300 m inland near the canal, as compared*


*Outcrops of beach rock located above the stone carriageway were deposited during the previous 2,500 years when the Diolkos was submerged.*




*Simplified geological map of the island of Zakynthos. Redrawn from Avramidis et al. (2017a).*

*with only 15-20 m near Xylokastro. The beachrock is only poorly lithified and the inland deposits may have accumulated from tsunamis.*

*The island of Zakynthos (area of 406 km$^2$) is located approximately 10 km from the western shores of the Gulf of Patras. The geology was first remarked upon by Strickland (1840) who identified three principal features, older limestone forming the spine of the island, younger sediments, and mineral springs. The oldest rocks, Triassic age sediments in the Vasilikos peninsula have been thrust over the younger strata. The Vrachionas Mountains (756 m) consist of Cretaceous age limestone, draped either side of a large anticline. Limestones of Eocene through Miocene ages occur on the eastern flanks of this anticline. The eastern part of the island includes Plio-Pleistocene marls, sandstones, and gravels.*

*The geomorphology and sedimentation of Zakynthos have been affected by both compressional and extensional tectonism. Avramidis et al. (2017a) deduced that the island was separated before the middle Neolithic times (approximately 75,000 BP) into two parts: Vasilikos peninsula was isolated from the rest of the island by the Ionian Thrust. This division has consequences for both archaeological and geological studies.*

*Pale, thinly bedded Cretaceous limestones form high sea cliffs in the northern part of Zakynthos, including Shipwreck Beach. Xigia Beach is as equally scenic and includes sulphur-rich hot springs. Sea arches and caves, the latter known for the occurrence of clear, turquoise water (the "Blue Caves") occur near Agios Nikolaos. The Cretaceous limestone is quarried from sites in the Vrachionas Mountains.*

*Shipwreck Beach is overshadowed by steep cliffs of white Cretaceous limestone which characterise the northern coast of Zakynthos.*

*The town of Zakynthos, also known as Zante by its residents, indicative of the historical ties with Italy, is situated in the southeastern corner of the island i.e. close to the Ionian Thrust. The town includes a large harbour situated at the base of pale coloured cliffs comprised of Plio-Pleistocene sediments. These rocks erode to form extensive areas of badlands. They are capped to the north of the town by a thin layer of relatively hard conglomerate on which a Venetian castle is located (Higgins and Higgins, 1996).*

*The island of Zakynthos was subjected to four major seismic events in August 1953 associated with the Ionian Earthquake. The epicentre of the third event (7.3 on the Richter scale), which despite being located on the southern tip of the neighbouring island of Kephalonia, destroyed the town of Zakynthos. Only three or four buildings survived, including the recently built, solidly constructed St Dionysius Cathedral. The town has been entirely rebuilt. The location on poorly consolidated*

*The town of Zakynthos is situated at the base of prominent white cliffs of Pliocene-Pleistocene age sediments.*

*The location of the town of Zakynthos at the base of the eroded cliffs Pliocene-Pleistocene age sediments with older rocks of the Vasilikos peninsula visible in the background.*

*sands and gravels is far from ideal, and contrasts with older settlements which tend to be on the Mesozoic limestones. The area is still prone to earthquakes and significant tremors occurred recently, including a 5.9 event in 2006 and a 6.4 event in 2008. Damage was minimal as strict building guidelines, introduced after the 1953 event, are adhered to.*

*The beach resort of Keri, near Lagana Bay, includes an antiquity known as the Spring of Herodotus. The village is situated between the marshy Keri Lake and the high, limestone cliffs of Megali Myzithra. The lake has an area of 3 km$^2$ and is situated at an elevation of 1 m, being separated from the sea by a low sand barrier (Avramidis et al., 2017b). The primary limnic*

*The seepage of bitumen into Keri Lake on the island of Zakynthos was described by Herodotus.*

*environment has been interpreted as having evolved into a coastal fen within a small Neogene age tectonic depression. Seepages of bitumen into the fen were first described by Herodotus, a Greek historian (484-425BC), as the "pitch" was highly sort after for a number of uses, including caulking boats. The bitumen is derived from deeper-lying petroleum deposits in the Cretaceous age limestone. (A major offshore drilling programme centred near the resorts of Lagana Bay is planned for the near future.) During the previous 4,000 years, the ecosystem of Keri Lake changed from marsh to fen with accumulation of peat (prior to this the area was inundated by the sea) (Avramidis et al., 2017b). The fresh water originates from the older limestone of the catchment. A sanctuary for preserving loggerhead sea turtles (Caretta caretta) is located in part of Lagana Bay.*

*Permission by Michael Higgins to quote from the book he co-authored with his father is greatly appreciated. The descriptions in the book greatly facilitated the field visits.*

*Photographs are by the author except where otherwise acknowledged.*

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# Geometallurgy Conference 2018

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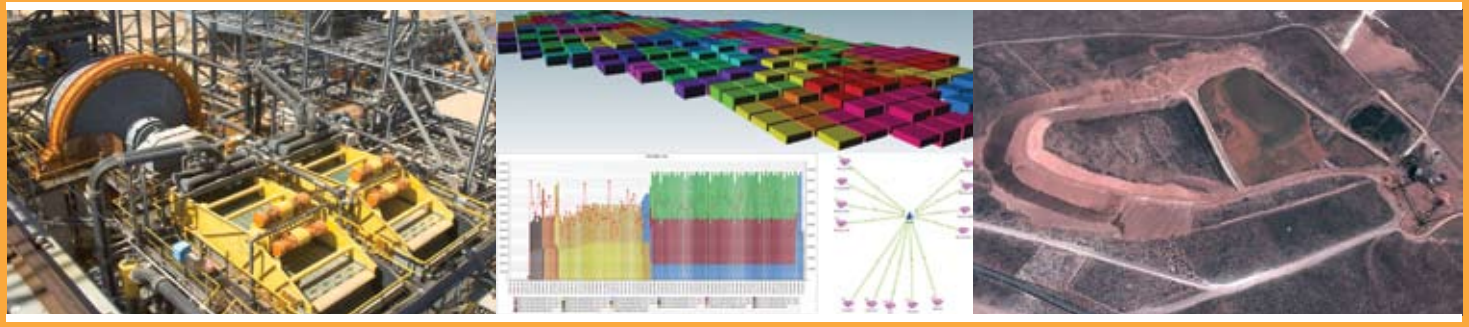

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