Geological Society of South Africa

geobulletin

QUARTERLY NEWS BULLETIN ~ JUNE 2015

VOLUME 58 NO. 2

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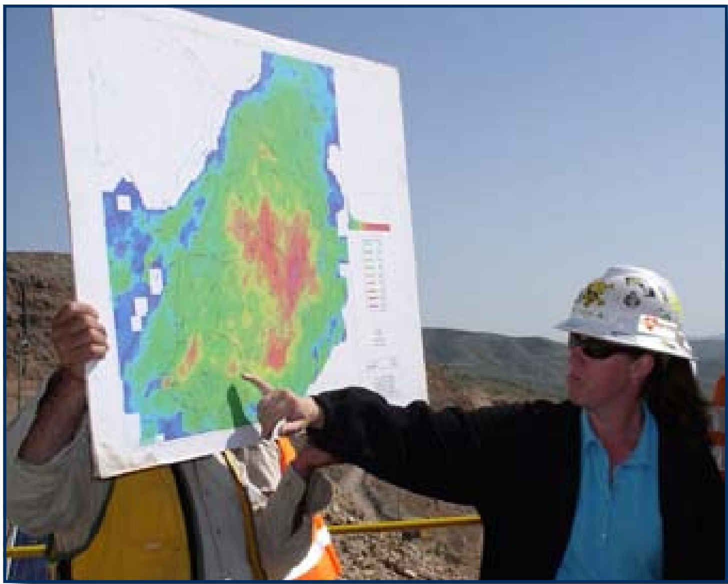

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contents

Geological Society of South Africa

CENTRE FOLD:

A composite reconstruction of the upper Elliot, Clarens, and earliest Drakensberg Formations, between ~200 and 183mya. In the foreground, reddish overbank mudstones of the Elliot support thriving ecosystems, while the Clarens dunes encroach in the distance. Flood basalts of the Drakensberg Formation send smoke and flames into the background. The gallery forest consists of yellowwoods, tree ferns, araucarias and gingkoes. Members of the latter two groups survive today as Norfolk Island pines and Gingko biloba*, respectively. The animal species are all known from fossils found in the Elliot and Clarens Formations. From front left: two* Megazostrodons *represent the earliest known mammals; the basal crocodylomorph* Protosuchus *escapes with a hatchling* Massospondylus *while its mother defends her nest from a hungry* Coelophysis*; more* Coelophysis *stalk the mammal-like* Tritylodon*; three* Heterodontosaurus *flee from a kill made by* Dracovenator*, who is in turn defending itself against a scavenging* Ceratosaur*. In the background,* Aardonyx *and other derived sauropodomorphs forage. (Painting: Maggie Lambert-Newman; Caption: Jonah Choiniere)*

COVER PHOTO:

Spectacular layering of lavas and ashes in the Njorowa Gorge. The yellowish colouration is typical of rhyolitic compositions. (Photo: Roger Scoon)

Geological Society of South Africa

GSSA
GB (GEOBULLETIN)
5TH FLOOR CHAMBER OF MINES
HOLLARD STREET
MARSHALLTOWN 2107
GAUTENG
SOUTH AFRICA

PO BOX 61809
MARSHALLTOWN 2107
SOUTH AFRICA

Tel: +27(11)492 3370
Fax: +27(11)492 3371
e-mail: info@gssa.org.za
Web: www.gssa.org.za

COMMITTEE

Convener & Editor: Chris Hatton 082 562 1517
Advertising: Jann Otto 082 568 0432

Design & Layout: Belinda Boyes-Varley 079 129 7748

Printing: Seriti Printing (Pty) Ltd 012 333 9757

All submissions to (in order of preference):
email attachments (in Word .doc) to: chatton@geoscience.org.za
disc/hard copy to: Chris Hatton
Postal Address: Council for Geoscience
Private Bag X112
Pretoria
South Africa 0001
Tel : + 27 (0) 12 841 1149
General Fax: 086 679 8591

Contributions for the next issue should be submitted by:
15 August, 2015.

Geobulletin is provided free to members of the GSSA. Non-member subscriptions per four issue volume are R150.00 for South Africa, R175.00 for the rest of Africa and US$ 45.00 overseas. The views expressed in this magazine are not necessarily those of the GSSA, its editor or the publishers.

ADVERTISING RATES (Excl. VAT & Agency Commission): Geobulletin is published by the Geological Society of South Africa (GSSA) and appears quarterly during March, June, September and December each year.

2015 RATES: Jann Otto 082 568 0432

For detailed prices, mechanical and digital submission requirements, please contact the GB advertising co-ordinator, editor (see Contents Page for contact information) to obtain an up-to-date Rates Card or other information.

DEADLINES FOR COPY AND ADVERTISING MATERIAL are 15 February (March 2015 issue), 15 May (June 2015 issue), 15 August (September 2015 issue) and 15 November (December 2015 issue).

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* Casual insertions • 4+ insertions

from the editor's desk

Chris Hatton

The things that you're liable To read in the bible It ain't necessarily so, goes the song. We geologists like to mock Archbishop Ussher's apparently naïve, biblically derived calculation that the world began in 4004 BC, priding ourselves that we can comprehend that the solar system actually started 4 567 million years ago.

The long lifespan that the Bible attributes to some of the characters used in Archbishop Ussher's calculation makes one wonder what a year means. Besides the fact that there is no ISO definition of a year before the beginning of the Christian era, we need to recognise that the everyday definition of a year is not the time that it takes for the earth to revolve around the sun, that is, the sidereal year of 365.25636 days. Rather, because spring is the ideal time to nourish the new-born, it is the time between spring equinoxes, the tropical year of 365.242189 days. Imperial Rome used the Julian calendar with a year of 365.25 days but this so messed up the time of Easter that it became necessary to try a new system, the Gregorian year of 365.245 days. This will work for the next thousand years or so and the Western world seems quite content with this useful approximation. Ancient societies appear to have been somewhat more discriminating. Although much of Maya culture was systematically destroyed {"We found a great number of books and since they contained nothing but superstitions and falsehoods of the devil we burned them, which they took most grievously, and which gave them great pain "(Friar Diego de Landa, 1566)} enough survives to recognise that the average length of the tropical Mayan year was probably 365.2422 days, a little better than our Gregorian calender. That such knowledge could have been accumulated by primitive societies is an affront to the splendid arrogance of the Archbishop, and indeed to those of us of British descent, who would like to believe that civilised life is hardly possible outside the English realm.

The Archbishop based his estimate on the Masoretic text, which was written down sometime around the 10th century. The older Septaguint, or Greek Orthodox version of the bible, translated into Greek from the Hebrew Bible some three centuries before the

beginning of the Christian era, provides a different set of numbers. If the Archbishop had applied his arithmetic to the Septaguint text he would have calculated that the world began about 5292 BC, similar to the Byzantine calendar which begins the world on 1st September, 5509 BC. The Archbishop found satisfaction in his derivation of the sacred and significant 4004 years since it chimes with the poetic truth that the world is perfect. By contrast ages around 5509 BC appear to be based on a real world event and are more in accord with the literal truth that the world is not perfect, unless we strive to make it so.

For a geological hypothesis for the beginning, or at least the rebirth of the world, we turn to William Ryan and Walter Pitman. In 1998 they published a book 'Noah's Flood' wherein they related the Biblical Flood to an influx of Mediterranean salt water into the Black Sea. In the original hypothesis the level of the Black Sea was 100m below the Mediterranean when the sea flooded in at 5600 BC. Things are never as simple as they first appear and the catastrophic nature of the flooding has been disputed, on the grounds that the difference in levels was not this great. However, even one of the most vocal of the critics, Yanko-Hornbach, presents data which show that Mediterranean ostracods were not present in the Black Sea before 5690 BC, but constituted more than 50% of the ostracod population at 5300 BC. The transition is abrupt and certainly suggests a catastrophic event. It appears that there was an outward flux of brackish water from the Black Sea to the Mediterranean when the ice melted at ~10 000 BC. At ~6000 BC a brief return to glacial conditions stemmed the flow, the Black Sea Lake shrank and was again isolated from the Mediterranean. At ~ 5600 BC, (dare we say 5509 BC?) the link to the Mediterranean was abruptly re-established.

The debate continues, but regardless of whether or not the Black Sea flooding event relates to the Biblical flood, the enduring message is that the transition from an isolated lake to a sea took place in a geological instant. This is particularly relevant to South African geology where many sedimentary basins show evidence for both lacustrine and marine depositional environments.

Under the influence of the prevailing paradigm of plate tectonics, the tendency is to lean toward the marine interpretation and disregard evidence for lacustrine conditions. The Black Sea example should encourage us to be more even-handed in our interpretations.

To conclude our discussion of the meaning of a year, the 35th IGC is only a year away, On pp. 24 - 30 Roger Scoon outlines an upcoming 35th IGC excursion which includes a visit to Oldupai Gorge and on pp. 20-22 Johann Neveling and Robert Gastaldo take us to the terrestrial mass extinction at the Permian-Triassic boundary. For those who would really like to peer into the heart of the matter, on pp. 18 - 19 John Gurney offers a visit to the Mantle Room, where visitors can handle rocks originating 200 km or more below us.

More in the next issue.......

executive managers corner

Craig Smith

Part of the GSSA's mandate, as a 'not-for-profit' association of members, is to interact with the public and not just our membership or other professional stakeholders. Arguably, one of our tasks should be to communicate the excitement of earth science to the public at large, and that includes primary and secondary school youngsters. Note that it is not the intention to recruit armies of people into geology – but we do want to get the message across to those with a high interest in science and particularly earth science. It is common cause that in most schools in South Africa, earth science instruction is sorely lacking (there are exceptions), and anything we can do to help alleviate the problem has to be a good thing. The public needs to know about the earth – and if it did, possibly we would see an improvement in the level of public debate around such topics as shale gas exploration, climate change, preservation of geoheritage sites, and possibly even an understanding of what it might mean to sterilize a resource because of inappropriate industrial action or poor investment decisions.

There are several 'hot button' topics that always draw queries to the office, and sometimes we scramble a

bit to find the right experts to provide public comment. And we see some howlers in other media (for example, Newsweek publishing an 'expert opinion' that the recent Nepal earthquakes resulted from climate change'). Earthquakes, volcanoes, dinosaurs (this issue!), fracking, climate change, geoheritage and geotourism issues, professional ethics issues, and tsunamis are topics that pretty reliably result in queries coming in to the office from the public and from news broadcasters wanting expert comment.

There is some assistance in educating the public that the GSSA can provide, such as running information rich 'advertorials' in Quest (which is circulated to thousands of students in South Africa annually). We can promote and communicate about interesting public sites and events (Barberton Geotrail, Fossil Park, Walter Sisulu Botanical Gardens), which the GSSA may or may not have direct involvement in. We support the Museum Association which is the oversight body for the geology section of the Museum Africa Geology in Newtown. We have very active geoheritage champions, and are assessing the establishment of a new Geoheritage division under the leadership of Genevieve Pearson. Some of our branches and regions are actively involved in geoheritage in their home regions (Western Cape Branch; Barberton Branch) and the question is how to roll out the benefits of regional efforts and non-GSSA efforts to a national audience.

And we can support science centres throughout the country. There are numerous science centres that are mostly underfunded, draw very high numbers of learners annually, and have varying degrees of earth science content. Most but probably not all belong to the South African Association of Science and Technology Centres (SAASTEC; see www.saastec.co.za), which is recognized by the Department of Science and Technology as championing science centres across the country.

The REI Fund of the GSSA is proud to have supported an initiative for the Cape Town Science Centre in upgrading the geology component of the centre, championed by Mike Venter. The GSSA sponsored the construction of a South African geology 'floor map', which takes the format of a giant jig saw puzzle. Visitors can overlay South African geology onto a South African map, and Julie Cleverdon, director of the Science Centre, tells us that even without the final signage in place, the display has been exceptionally popular – and cross generational. I'm not informed as to whether we've yet seen the Vredefort Dome re-located to Table Mountain, or the Bushveld Complex moved next to Graaff Reinet, but it all seems to be good fun – and a great learning experience. In my opinion, this is money well spent – and we will probably continue to support projects such as these.

The main geological 'happening' of the year is probably the Nepal earthquakes and aftershocks which have resulted in high loss of life. Our sympathies are extended to all affected. As geologists well know, this is one of the most tectonically active parts of the globe, and such events are not unexpected. The plan is to stage a public lecture about the Nepal events in early July; watch for notices to this effect.

Plans are progressing for staging the GSSA Annual General Meeting on July 30 in Johannesburg, at the Auckland Park campus of the Johannesburg Country Club. The AGM will take the format of a business meeting with a report-back to the membership and induction of the new Council, followed by a finger supper and networking. Requests for new nominations to Council have gone out, and should there be any additional nominations please forward to myself or info@gssa.org.za

By the time the Q3 issue of Geobulletin comes out, the GSSA will have a new President. Dr. Avinash Bisnath becomes Immediate Past President after serving a two year term. In the GSSA, the presidency is not only a ceremonial position, but also a very hands-on, strategic and operational role. Avinash and I are in constant contact, sometimes daily, about numerous issues and events that go on 'behind the scenes'. The incoming President is Dr. Jeannette McGill, who has been Vice President Meetings for the last two years. Another change to the Management Committee will be the addition of Mr. Sifiso Siwela as VP meetings. Please diarize the AGM date; it will be a great opportunity to catch up with the GSSA as well as colleagues and friends.

Plans for the International Geological Congress in Cape Town are proceeding well, and the pace is going to start accelerating about now! Our membership is urged to have a look at the second circular, which can be found on the website, www.igc35.org. Check out the technical program, which has been organized by Laurence Robb and his team. I think you will agree that it is a very strong program. There will be special early bird registration rates published a little later this year; see you in Cape Town next year!

Craig Smith

GSSA Geological Society of South Africa

president's column

Avinash
Bisnath

This is my farewell article as president to the GSSA membership. I will officially hand over to Dr Jeanette McGill on 30 July 2015 at the annual AGM and I would like to wish her and her MANCO all the best. As they begin their tenure a year before the 35th IGC, I am sure they going to have their hands full.

Being the first president to serve a 2 year team I wish to mention that there a few positives and this model should be maintained. 2 years allows one to set up and implement strategies and projects. The highlights of my term to mention a few have been:

1. Website development.

2. CPD testing phase.

3. Demographic tran sformation of MANCO and COUNCIL.

4. Increase of female participation in MANCO and COUNCIL.

5. Setting up of the Young Council members committee.

6.Appointment of new Chief Editor for SAJG and new submission process.

My largest disappoint has not been able to bridge the gap between our more senior members and younger members. I have expressed this issue and concern to both MANCO and COUNCIL. If allowed, I will continue to drive this effort.

Regarding GSSA business we continue with our efforts with CPD implementation and search for IGC funding and support. Please ensure that all scientific submissions to the SAJG must be run through the office of the GSSA. Please submit your manuscripts to Lully Govender (lully.govender@gssa.org.za) so that we can track the submission, review process and final adjudication. In time we hope to run the submission process via the website.

I wish to say thank you to the current MANCO and COUNCIL for all their support and hard work during my term. I also wish to express a special thanks to my wife (Bhavna) and Sodhie Naicker (business partner) for allowing me the time and freedom to attend long MANCO and COUNCIL meetings. Finally I urge the membership to communicate with the GSSA office, MANCO and COUNCIL so that we can address your complaints and welcome your compliments.

Avinash Bisnath

To All Advertisers and Sponsors in Geobulletin

Geological Society of South Africa

Late Publication of Quarter 1, 2015 Issue

I would like to apologize to current advertisers in the GSSA quarterly news journal, Geobulletin, for delayed publication of the first issue of 2015 (print version). It is happening, and should be in the post by early in the week of May 18.

The issue has been posted on the GSSA website as per normal practice, so you are getting digital exposure. See www.gssa.org.za.

Three issues have compounded to delay the print version, two of which were not in the control of the GSSA. In the first instance, we were late in getting this issue to the printer, and this can delay printing because of the schedule the printer needs to adhere to. The GSSA is not a sole customer!

Two other factors were at play. First, the printer encountered a substandard batch of paper, which then had to be re-ordered. Second, load shedding has affected printing scheduling – and unfortunately this disruption is likely to remain a factor that we need to allow for.

We will strive to get Geobulletin out on time, and for the last couple of years I think we have a pretty good track record except for periods affected by the postal strike. Geobulletin continues to thrive; it is very popular amongst the earth sciences community and we routinely receive requests for back orders. It turns out that publishing some of Maggie Newman's geo-art as an occasional centrefold or cover has generated much favourable content. Additionally, we have many contributors who regularly submit articles of interest and news items, which the community clearly sees and appreciates.

Please be assured that the editorial team are well aware of your need for 'eyes on pages', and despite the occasional problem we believe Geobulletin offers real value for your advertising and branding spend. Additionally, Geobulletin is published in both print and digital format.

Craig Smith (Executive Manager GSSA)
Chris Hatton (Editor Geobulletin)

May 15, 2015

Geological Society of South Africa

all the news fit to print

UJ

It's been a busy year so far for UJ's Geology department. On the staffing front, we have had unprecedented growth in our academic staff profile. Because UJ (together with Wits) was awarded the national centre of excellence (CIMERA), UJ management gave the department two new associate professorship posts. Dr Michiel de Kock successfully applied for one of these and was appointed as associated professor (previously senior lecturer). Dr Herman van Niekerk has been appointed as senior lecturer while at the same time Dr Bertus Smith has been promoted to senior lecturer and Dr Jeremie Lehmann joined the department in May as a senior lecturer. During early 2015, UJ's Academic Development and Innovation Division called for applications in the DHET's new incentive scheme nGAP (New Generation of Academics Programme), a thrust of the "Staffing South Africa's Universities Framework" initiative of the DHET. As a result, we were indeed awarded a new permanent lecture post in the department and this has been advertised as such. The one remaining associate professor post will be filled by Dr Sebastian Tappe who is moving from industry to take up this academic appointment. UJ has also established an initiative for young, black post-graduate PhD students to be appointed on 3-year contracts to assist with lecturing in the department. The assistant lectureship posts are awarded only after suitable motivation is submitted and then the proposal has still to be agreed upon by Management. Last year we were awarded one such position which Derek Rose, a PhD student of Fanus Viljoen, occupies. Earlier this year we were awarded a second assistant lectureship post and this went to Vincent Makhubela, a PhD student of Professor Jan Kramers.

Dr Geoff Grantham, formerly employed at the CGS has been appointed as Visiting Professor and will bring his expertise on Antarctic geology to the department (together with a R1 million NRF research grant). Professor Marlina Elburg already has a track record in Antarctic research, and Mike Knoper has undertaken several field seasons in the region. Their collective involvement in Antarctic geology research at UJ will add another thrust to department's research niches.

Professor Hassina Mouri has been selected to contribute to the Pan African University Institute of Earth and Life Sciences, University Of Ibadan in Nigeria as a guest lecturer ("course facilitator"). Hassina will be invited to Ibadan to spend 1-2 weeks lecturing to MSc students on "impacts of geological issues and material on health" (Medical Geology) as part of a module on "Environmental Impact Assessment / Evaluation".

Late last year we welcomed Associate Professor Nikki Wagner to the department. Nikki has been very active registering new post-graduate students who will research various aspects of coal petrography/ technology/geology under her supervision. Linked to this appointment was the purchase of a brand new R1.4 million state-of-the-art coal petrographic microscope and accompanying software, co-funded by UJ and the departments' PPM Centre. In addition, Nikki organized and hosted the 1st SA Coal Petrographers Meeting in the department during May (see separate report on this meeting below).

On the research front, CIMERA continues to push forward. As part of publicizing the national centres of excellence, the NRF Science for Society Lectures Series was held at the University of Johannesburg on Thursday evening the 23rd April, 2015, in conjunction with the SABC's SAFm radio station. The Series "seeks to bridge the divide that exists between science and community issues in an effort to help society relate to how science, research and technology positively impact on our day-to-day lives and on future generations." The title of the lecture was "Economic Geology Research: What

NRF Science for Society guests of honour and speakers. Left to right: Professor Ihron Rensburg (Vice Chancellor UJ), Dr Linda Mtwisha, Professor Judith Kinnaird and Professor Nic Beukes in the University of Johannesburg Council Chamber.

makes South Africa the World's most valuable piece of Mineral Real Estate." The lecture was scheduled to have been broadcast live by SAfm, who are the NRF's media partners, but had to be recorded instead due to an unforeseen clash on the radio station. It was, however, broadcast on Tuesday evening the 28th April 2015 from 7pm to 9 pm in the Talk Shop slot hosted by Ms Naledi Moleo.

The programme was opened in the UJ Council Chambers by Mr Thabiso Nkone of the NRF. The guest of honour was UJ's Vice-Chancellor Professor Ihron Rensburg, who warmly welcomed all to UJ. Dr Linda Mtwisha of the NRF, who is the Acting Executive Director: Institutional Engagement and Partnership Development (IEPD), briefly outlined the purpose of the Science for Society Lecture Series. She noted that our Minister of Science and Technology, the Honourable Naledi Pandor, is fully supportive of science communication.

Ms Moleo introduced Professors Nic Beukes and Judith Kinnaird. Professor Beukes was first up and started by briefly outlining the aims of DST-NRF CIMERA. He explained why South Africa is blessed with so many valuable mineral commodities. Professor Kinnaird built on the theme by concisely outlining the important features of the Witwatersrand Basin gold deposits, the Bushveld Complex platinum group metal, chromium and vanadium deposits, and the diamond-bearing kimberlite pipes. Professor Beukes concluded the lecture with his views on the world-class manganese and iron deposits hosted in the Transvaal Basin. Questions were invited from the live audience and these were succinctly answered by the two speakers. The formal proceedings ended with a vote of thanks by Dr Mtwisha to Professors Beukes and Kinnaird, and all were invited to a light finger-supper in the function room.

On the publicity front, the geology department featured in an M-Net Carte Blanche world exclusive programme that revealed the Armageddon Cave to the public for the first time. Featured in this were Dr Herman van Niekerk, together with his MSc student Pedro Boshoff and the Speleological Exploration Club. As a result of the huge publicity generated from this, Herman and the team were contacted by numerous news agencies, radio and TV stations who wanted to know more about this extensive cave system in the Carletonville area.

Compiled by Bruce Cairncross

UJ, 1st meeting of South African coal petrographers

In May, the first meeting of active South African coal petrographers took place at the Geology Department, University of Johannesburg (UJ). It was established that there are currently at least 15 active coal petrographers

L-R: Patience Mavhengere (Wits), Jill Richards (Exxaro); Nandi Malumbazo (CGS); Vongani Chabalala (SABS); Grethe Naude (Exxaro); Manneka Mosisili (bhpbilliton); Maseda Mphaphuli (UJ); Willem Swanepoel (Bureau Veritas); Ndivhuho Nendouvhada (UJ); Nikki Wagner (UJ).

in the Gauteng region from nine different organisations spanning the industry, parastatal organisations and academia. This number excludes university students undertaking related projects or training in coal and carbon petrography who are not considered to be active coal petrographers at this stage. The main purpose of this inaugural meeting was to network and to establish contact with other South African coal petrographers, to discuss the different systems in use, to raise awareness about areas of speciality/focus, and to determine the requirements for future meetings. Eight coal petrographers and two MSc students, representing seven organisations, attended this meeting. This is believed to have been the first coal petrography meeting in the region, and certainly there are currently more people working in this field than ever before. In fact, globally, South Africa represents a significant number of active coal petrographers.

It was determined that the majority of attendees are accredited by the International Committee for Coal and Organic Petrology (ICCP) in terms of maceral and vitrinite reflectance analysis (SCAP). In addition, two petrographers have received accreditation in vitrinite reflectance of dispersed organic matter (DOMVr) and three petrographers have recently submitted results for the coal blend accreditation programme (BCAP). The ICCP accreditation is extremely important for petrographers to benchmark themselves globally and to ensure that their equipment is functioning correctly. In order to address more local issues, three coal samples were distributed at the meeting to form a South African round robin exercise on macerals and vitrinite reflectance (maximum and mean). A discussion about the ICCP resulted in a number of requests being tabled at the annual ICCP meeting, including the request for another petrographic training course in South Africa (specifically on DOM).

Coal petrography is the optical study of coal (and carbon materials) using specialised light microscopes to identify the maceral (organic) and mineral components making up coal. The study concerns the composition, structure and origin of coal from a geological perspective, and provides information pertaining to coal conversion/utilisation from an engineering perspective. Coal petrography also plays a role in mineral processing, and conversion products (for example, coke, chars and ash). Typically, the analysis is conducted on highly polished grain mounts under oil immersion using reflected light.

It was established that all petrographers in the region make use of either a Zeiss or a Leica microscope system (or both in some organisations), fitted with the Hilgers Fossil system for vitrinite reflectance (UJ, CGS, Bureau Veritas, Sasol), or the J&M Spectrolytic system for vitrinite reflectance (Exxaro, Sasol, Wits). The SABS still uses the Zeiss Universal photomultiplier system at this stage, and BHP Billiton has an automated system acquired from England for reflectance determination.

Looking forward, all in attendance agreed that the demand for coal and carbon petrography will remain an ongoing requirement in South Africa, assisting the export and local coal industries to work towards sustainable and cleaner solutions for energy supply, and alternative uses for coal. The shale gas industry is underdeveloped southern Africa, and petrographers and palynologists able to work in this specialised field are in short supply. Coke petrography remains very important for some organisations. Annual meetings will be scheduled in future, with specialist working group meetings taking place during the year for further discussion and training activities.

If you wish to participate in future petrographic events, please contact Dr Nikki Wagner (nwagner@uj.ac.za). We would welcome feedback from other scientists active, or interested, in the field of coal petrography.

Nikki Wagner

WITS UNIVERSITY

It has been a busy and fruitful few months at the School of Geosciences. After several years, the School is finally back to full strength, with the arrivals of Associate Profs Paul Nex and Robert Bolhar in 2014 and Dr Peter Horvath in February. Congratulations are due to Asinne Tshibubudze, who graduated with his PhD in April and has been confirmed as a Lecturer in the School, and Tamiru Abiye, who presented his Inaugural Lecture in March, following his promotion to Professor.

In March, the School opened its refurbished Petrology Teaching Lab, which is now equipped with 2 state-of-the-art petrographic and stereographic microscopes and a digital hand sample viewer linked via high resolution cameras to an interactive display screen and wall-mounted TV screens throughout the Lab.

Overall, this expansion and the use of high-tech teaching equipment enable seamless integration of theoretical and practical aspects of petrology, mineralogy and other disciplines such as structural geology. Ultimately, this upgrade is revolutionising the way in which mineralogy and petrology is being taught in the School.

In April, the School opened its new Reflection Seismic Research Centre under the leadership of Dr Musa Manzi. The Centre has been sponsored by a R600,000 donation from CGG over the past 2 years, but the injection of R5 M from Shell over the next 5 years has allowed a significant investment in high-end computer workstations to support the growing postgraduate

Various photos showing the microscopes and projection capabilities in the new Mineralogy and Petrology lab at the School of Geosciences, ably demonstrated by Dr Grant Bybee.

The new Reflection Seismic Research Centre in action!

student numbers (8 at last count). Projects currently underway include high-resolution mapping of South Africa's deep gold and platinum-bearing horizons, mapping and characterisation of southern African oil and gas reservoirs, and the development of new techniques that allow the detection of methane conduits in deep underground mines, thus mitigating the risks and hazards associated with methane explosions in mines. The Centre has received generous support for access to state-of-the-art software from Schlumberger, CGG, Kingdom (IHS), dGB Earth Sciences and Globe Claritas. The seismic datasets used in the Centre were provided by Shell, Gold Fields, Anglo Gold Ashanti, and Petroleum Agency.

The School successfully motivated for a new Cameca SXFive Field Emission microprobe – only the 4th in the world and the 1st on the African continent – that was installed in July 2014 and which is now running under the guidance of Dr Peter Horvath. The microprobe is equipped with 5 WDS spectrometers, and EDS, BSE, CL and SE detectors, enabling high resolution imaging. The new Cameca SXFive Field Emission microprobe at Wits will enable staff and students at the School of Geosciences to conduct in-house mineral compositional research on samples.

On 7th March, the 111th anniversary of the opening of the Department of Geology, the School hosted an

Celebrating the opening of the new Reflection Seismic Research Centre! From left to right (Jan Willem Eggink, Zamo Nkosi, Ansuya Naidoo, Musa Manzi, Marcello Molezzi, Mbali Xulu, Tawana Kupe, Matt Terracin, Siyanda Mngadi).

Alumni Event at the Wits Club that attracted over 100 alumni, staff and their families. Generous sponsorship by Theo Pegram & Associates, Red Dog and CoreStore helped keep costs to a minimum and allowed alumni to dip into their pockets to help launch the Geosciences Alumni Scholarship Fund, aimed at providing future assistance to needy students. An anonymous chocolate donor provided prizes and table gifts during the day! The third edition of the 20-week Rocks & Minerals Revealed Short Course, an initiative by staff to provide the general public with an introduction to geoscience, has been running since February, with over 30 attendees. Another major outreach activity is the School's participation in the annual Yebo Gogga event that was held 13-17 May. Matt Kitching designed a highly popular display around the theme 'Year of Light and Light-based Technologies'.

Honorary Professor Trond Torsvik visited the School in February-March, to continue collaborations with Lew Ashwal and Susan Webb on Iceland and palaeomagnetic research.

Susan Webb visited various universities in China between March-April, with the AGU Board of Directors. It is hoped that this visit will potentially lead to collaborations between the School and various universities in China. Paul Nex followed up on a visit last year by Judith Kinnaird to Akita University to further strengthen applied economic geology research.

In May, the RocSoc Students Society hosted its annual Careers Day that is now a fixture in the Gauteng calendar, with over 200 students from UJ, UP and Wits attending. Despite the gloomy national financial outlook, this was the best-supported event to date, both in terms of student numbers and company participation. Ten companies participated in the day, which involved a set of talks and Q&A sessions, followed by an opportunity for students to speak to the companies directly. Sponsorship from SRK Consulting, Sasol, the MSA Group, GSSA and AngloGold Ashanti ensured that no-one went home hungry!

The 6th Platreef Workshop organised by Judith Kinnaird and her team in May, was also the largest ever, with over 100 geologists in attendance from across South Africa, UK and Canada. Judith Kinnaird, Allan Wilson, Rais Latypov, Marina Yudovskaya, Hannah Hughes and MSc students Matthew McCreesh and Florian

Ostrich outside the Grasvally core shed during the 2015 Platreef workshop.

The new Cameca SXFive Field Emission microprobe at Wits

Postdoctoral fellow, Melissa Plail, during fieldwork in Argentina.

Huthmann, all delivered talks during the workshop.

Several new post-doctoral researchers have arrived in the School in recent months. These include both Hannah Hughes and Ben Hayes, hosted by Judith Kinnaird, Grant Bybee and Lew Ashwal, and Emma Hunt and Ria Mukahjee, hosted by Rais Latypov. All will be working on the Bushveld Complex. Post-doctoral researcher Melissa Plail recently completed a 4-week field season investigating deep arc crust in Argentina with Grant Bybee.

MSc student, Prince Maila won the best student presentation at the 8th Igneous and Metamorphic Studies Group (IMSG) held at the University of Pretoria in January, for his talk on the origin of magnetite layers in the Bushveld Complex. Melissa Plail won second best talk. Congratulations to Siyanda Mngadi who was awarded an SEG Foundation Travel Grant to attend the SEG/ExxonMobil Student Exchange Program at the International Geosciences Student Conference (IGSC) in Prague, Czech Republic. Kebonang Mogaadile has been awarded an Erasmus Mundus Action 2 INSPIRE Scholarship to attend postgraduate courses for 5 months at Ghent University, from September.

Ben Hayes

Lew Ashwal teaching Wits students in the new Mineralogy & Petrology lab

UCT

Short Course on the Geology of Gold Deposits, University of Cape Town, South Africa

The SEG Short Course on the Geology of Gold Deposits was held for the third year at the University of Cape Town, South Africa on the 7th and 8th of February prior to the annual Mining Indaba meeting. Thirty-three course participants included mainly industry professionals and some South African graduate students. Internationally recognized gold deposit geologists Richard Goldfarb, Hartwig Frimmel, Stuart Simmons, and Brian Rusk presented several sessions on the genesis, mineralisation models, characteristics and exploration criteria of orogenic, placer, epithermal, and iron-oxide-copper-gold (IOCG) gold deposits.

Sessions commenced with an introduction to gold deposit models, geological characteristics and genetic models of orogenic gold deposits by Richard Goldfarb. Deposit case studies included examples that ranged from the Archaean to Phanerozoic. The genesis and characteristics of Carlin-type deposits and intrusion related gold were also examined. This was followed by a summary of the geological setting, characteristics, and secular evolution of Witwatersrand-type gold and the implications for exploration by Hartwig Frimmel.

Discussions during session tea-breaks at the Department of Geological Sciences.

Stuart Simmons discussed the geological characteristics of epithermal and porphyry gold deposits on the second day. This session focussed on modern-day analogies and hydrothermal systems in terms of metal transport and deposition. The interpretation of hydrothermal mineral assemblages during exploration for epithermal and porphyry deposits was highlighted. The concluding session by Brian Rusk included the classification of IOCG deposits in terms of zonation, mineralization styles, ore genesis, and tectonic settings. Numerous case studies were used to illustrate the various deposit styles, and participants gained insight into the complexities and characteristics of these deposits.

Lynnette Greyling

Discussions during session tea-breaks at the Department of Geological Sciences.

Participants of the SEG Gold short course at Upper Campus of the University of Cape Town.

UFS

2014 was a busy year as usual with undergraduate and honours students embarking on numerous field trips across the country and with staff members travelling significantly both locally and abroad. Staff members and students presented their work at several conferences including the 12th International Platinum Symposium (Yekaterinburg, Russia), the 21st General Meeting of the International Mineralogical Association (Sandton Convention Centre), the Igneous and Metamorphic Studies Group Meeting (Rhodes University) and the European Geosciences Union General Assembly (Vienna). Marian Tredoux, Christoph Gauert and Freddie Roelofse also attended a workshop organised by the International Continental Scientific Drilling Programme to discuss matters related to a potential drilling project on the Bushveld Complex.

Last year also saw the birth of the Kovsie Geotalks series, a series of talks aimed at i) increasing academic discourse within the department, ii) exposing students to the work of non-Kovsie researchers, academics and industry professionals and iii) allowing the broader public access to the wonders of geology. Speakers included Mr Felix Yebo Amoako (Friedrich-Schiller University), Prof Duncan Miller (affiliated professor of the department), Prof Jan Kramers (University of Johannesburg) and Dr Gerrie van Aswegen (Institute of Mine Seismology). The department also played host to Prof Nic Beukes (University of Johannesburg) for the delivery of the 33rd Alex du Toit Memorial Lecture presented under the auspices of the Geological Society of South Africa. The year also saw the establishment of the Geological Student Association, which organised several social and academic events over the course of the year.

Christoph Gauert was awarded sabbatical leave between April and July 2014 to further his research on gold fingerprinting and the PGE mineralogy of the chromitite layers of the eastern Bushveld Complex, which he spent at the Museum für Naturkunde (Berlin). He also organised and led a pre-conference fieldtrip for the 21st General Meeting of the International Mineralogical Association to the eastern Bushveld and Uitkomst Complexes. Johann Claassen represented the department and the Faculty of Natural and Agricultural Sciences at the 3P Mining Lekgotla held at Gallagher Estate in August 2014. An exchange student from the Martin Luther University Halle-Wittenberg, Melanie Krüger, visited the department for several months in 2014 to conduct research on the metamorphic contact aureole of the Uitkomst Complex.

UFS core storage facility

An M.Sc. student of Freddie Roelofse, Mpho Mangwegape, was appointed a pre-doctoral fellow of the Carnegie Institution for Science and spent several weeks in the Department of Terrestrial Magnetism performing LA-ICP-MS Sr-isotopic determinations on plagioclase of the Bushveld Complex. Jarlen Beukes (M.Sc. student of Christoph Gauert) returned from a 7 month Erasmus Mundus funded stay at the Karl-Frantzens University of Graz, Austria. Freddie Roelofse was elected a Fellow of the Gemmological Association of Great Britain following the successful completion of the association's Diploma in Gemmology and was appointed a visiting investigator at the Carnegie Institution for Science. He was also appointed as chair of the Palaeoproterozoic Task Group of the South African Committee for Stratigraphy and to the editorial board of "Die Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie".

The department once again hosted the Free State leg of the Minquiz National Science Competition that was held on 15 May 2014. A total of 26 schools (mostly from the Free State) each represented by 3 learners, took part in the competition. The learners were also afforded the opportunity of visiting the departments of Chemistry, Physics and Geology in order to showcase what these departments have on offer for prospective students. The department was also involved in numerous other outreach activities including the UFS Astrofair, the National Science Week launch and the Eskom Expo for young scientists.

Until next time.

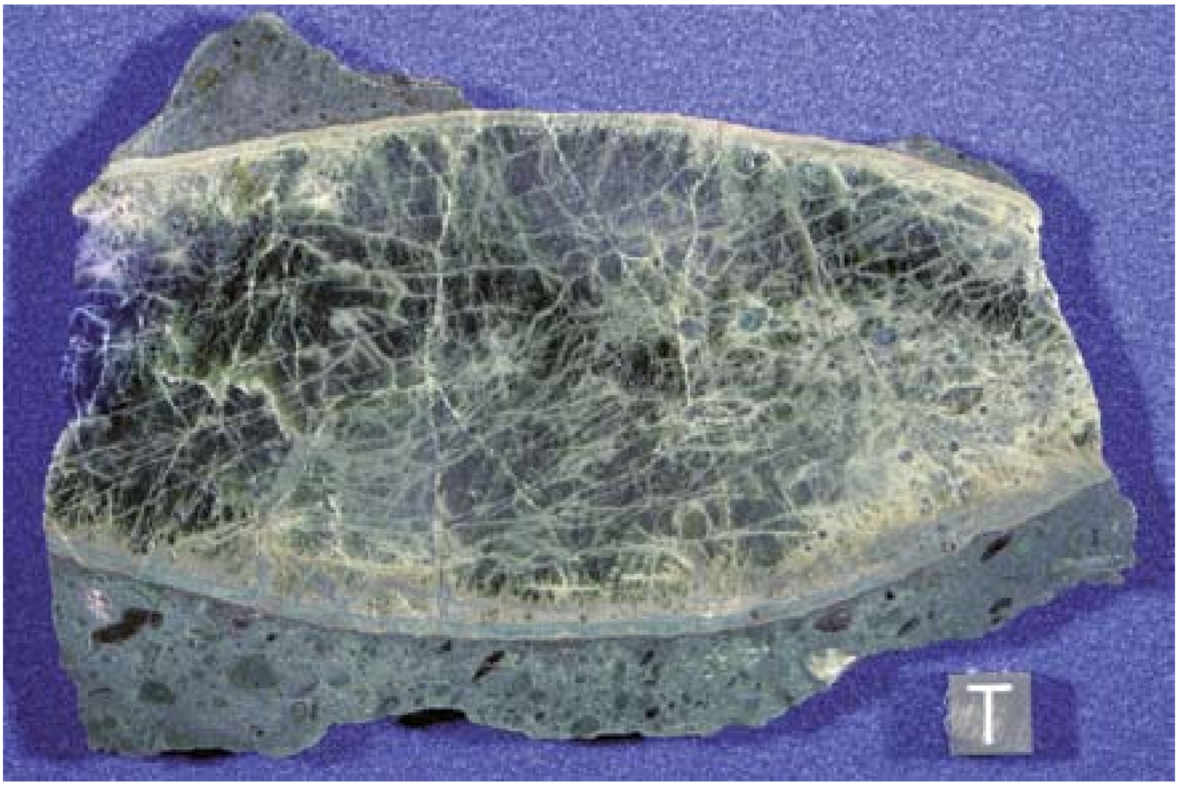
craton roots & diamonds

Messengers from the Earth's Mantle:
Craton Roots and Diamonds

This 35th IGC tour offers visitors the opportunity to visit a unique collection of mantle rocks brought to the surface in kimberlites, that have allowed researchers to piece together the nearly four billion year history of the Earth's continents. Complementing the museum-style exhibit Messengers from the Mantle: Craton Roots and Diamonds on display at the Congress, the tour will allow participants to visit the world-famous Mantle Room research collection at the University of Cape Town, which is a most extensive collection of deep Earth samples from southern Africa. It contains over 14,000 mantle and deep crustal xenolith specimens from more than a hundred kimberlites from southern Africa and across the globe. The Mantle Room has been and remains a destination for mantle researchers worldwide. They have used these specimens to provide insight about the timing and processes involved in the generation of the earliest continental nuclei, the Earth's Archaean cratons. The Mantle Room visit is intended to make interested researchers aware of the depth of the collection and its availability for collaborative research purposes.

Also key to the story behind *Messengers from the Mantle* are diamonds brought to the surface in kimberlites. This mineral acts as a time capsule uniquely preserving evidence of ancient processes, as well as providing information on the timing and nature of diamond formation itself. Participants will travel to the Mineral Services Group in Ndabeni, a leading mineral exploration consultancy, to view a private collection of diamond related mantle rocks. UCT scientists and experts in the field including diamond specialist Prof. John Gurney, Prof. Steve Richardson and Dr. Philip

Mantle Room collection at UCT.



Clinopyroxene megacryst from the Monastery Mine.

Janney, will guide daily tours. Each tour will begin at the Messengers from the Mantle exhibition in the CTICC. Spectacular rocks and minerals from the world-famous UCT collection of upper mantle and kimberlite samples archive this display.

The tour will last approximately five hours in total duration. Transportation from the CTICC to UCT, Mineral Services and back to CTICC will be provided. A light lunch will be served to give delegates the chance to interact with tour guides. The tour will be run once per day over the five days of the Congress. The cost is R1000 for delegates and R500 for students. Advanced booking is recommended, as space is limited.

Provisional Tour Schedule:
- 8h00-8h30: meet at exhibit in CTICC
- 8h30-9h00: transportation from CTICC to UCT
- 9h00-10h00: UCT Mantle Room
- 10h00-10h30: transportation to Mineral Services
- 10h30-12h00: Mineral Services tour
- 12h00-13h00: luncheon with researchers
- 13h00-13h30: transport back to CTICC

Wendy Taylor

Garnet lherzolite from Kimberley.

Kyanite eclogite from Roberts Victor Mine.

karoo basin

Permian–Triassic Boundary Interval, Karoo Basin.

Bethulie section

FIELD TRIP LEADERS: Johann Neveling (jneveling@geoscience.org.za) and Robert Gastaldo

DATES: 20 – 25 August 2016

START – END: Cape Town – Cape Town.

NUMBER OF PARTICIPANTS: 18 – 28, including 4 guides and drivers

TRANSPORT: 2 x 22 seater buses

BROCHURE: A comprehensive field-guide will be issued to each participant.

The end-Permian mass-extinction is generally considered to represent the largest ecological catastrophe to have befallen life on earth, with biodiversity losses estimated to have exceeded 85%. The cause of this event is still debated by the scientific community, but a climate change model has been gaining favour in recent years. As a result this so-called "Mother of Mass Extinctions" is often used as a model for ecosystem response to severe perturbation and is considered a possible scenario for how Earth Systems may react to current rapid global warming trends and climate extremes.

Extinction models are largely based on research in marine sequences which also contain the only chronometric data for this event, with the most recent, accurate date (from the Meishan section in China) placing the Permo-Triassic mass-extinction at 251.94-251.88 Ma. By comparison there are only a small number of terrestrial sections known in the world that encompass this interval and as a result the terrestrial ecosystem response to this mass-extinction is poorly understood. The Karoo Basin in South Africa is one of only a small number of continental sequences that contains the Permo-Triassic Boundary and research conducted in the Karoo made an important contribution to the global extinction literature.

At present the Permo-Triassic Boundary in the Karoo is closely associated with a biozone boundary between the Dicynodon and Lystrosaurus assemblage zones. Many workers consider this horizon to be coeval with the extinction in the marine realm. The litho-facies described from this interval form the basis of correlation between different sections in the Karoo and have been used to establish a model that attribute phased end-Permian vertebrate biodiversity loss to catastrophic climate change; yet there has been significant debate on the validity of these interpretations.

Late Permian Dicynodon

The majority of Permian-Triassic Boundary sections in the Karoo occur in inaccessible locations in the sparsely populated Karoo region of South Africa. As a result, very few scientists have been able to visit and scrutinize these localities, except for the few researchers involved in active research. This trip offers a unique opportunity to interested scientists to visit at least six of the main Permian-Triassic Boundary localities reported in the literature. The field trip will focus on currently published models for the response of terrestrial ecosystems to the crisis, as well as recently acquired stratigraphic, sedimentologic, geochronometric, palaeomagnetic, and palaeontological data used to test hypotheses about this critical time in Earth history.

ITINERARY

DAY 1:

Travel Day: Cape Town to Middelburg, Eastern Cape Province (770km).

- Depart Cape Town and drive to the Karoo National Park, Beaufort West. Lunch at the park restaurant, with an overview of the fossil vertebrate display.
- Depart Beaufort West for overnight accommodation near Middelburg.

DAY 2:

Middelburg to Aliwal North (300km). Visit the Bethulie locality.

- Depart accommodation at Middelburg and drive to Bethel Farm (Bethulie section; 220 km).
- Transport to the outcrop and spend 3.5 - 4 hours at the Bethulie locality.
- Depart Bethulie locality @ 15:30–16:00, drive to Aliwal North (80 km) for dinner and accommodation.

DAY 3:

Aliwal North to Ganora Guest Farm, Nieu Bethesda (375 km). Visit the Carlton Heights and Lootsberg Pass localities.

- Depart Aliwal North and drive to the Carlton Heights locality (270 km). Stop at Carlton Heights for field lunch and examination of the Lower Triassic (Induan) Katberg Formation exposures.
- Drive to Lootsberg Pass on the N9 (80 km). Stop at the top of Lootsberg Pass to examine Katberg Formation exposures. Walk down-section to the base of the Katberg Formation and, possibly, the reported Permo-Triassic boundary interval (1.5 hours).
- Depart Lootsberg Pass for Nieu Bethesda and accommodation and dinner at Ganora Guest Farm (25 km).

DAY 4:

Circular trip returning to Ganora Guest Farm (50 km). Visit the Old Lootsberg Pass locality.

- Depart Ganora for Old Lootsberg Pass section. Spend full day at this pivotal boundary locality where sedimentology, stratigraphy, and palaeontology will be featured, along with explanation and examination of palaeomagnetic sampling sites. New data will be presented and examined.
- Return to Ganora for accommodation and dinner.

DAY 5:

Ganora Guest Farm to Cradock (220 km). Visit the New Wapadsberg Pass and Commandodrift sections.

- Depart Ganora and stop at Wapadsberg Pass. Examine the Wapadsberg Pass locality where stratigraphic, stable isotopic, palaeontologic, and sedimentologic data on the reported pre- and post-boundary stratigraphy will be presented.
- Depart Wapadsberg Pass for Cradock (80 km) for lunch.
- Depart Cradock for Commandodrift section (50 km).
- Examination of stratigraphic section and presentation of new data for Commandodrift locality
- Depart locality for Cradock for accommodation and dinner

DAY 6:

Travel Day: Cradock to Cape Town (800 km).

- Depart Cradock early morning for return to Cape Town; arrive Cape Town ~18:00.

Johann Neveling

Late Permian Glossopteris fossils

Lystrosaurus, dominant

The Bethulie

AEON

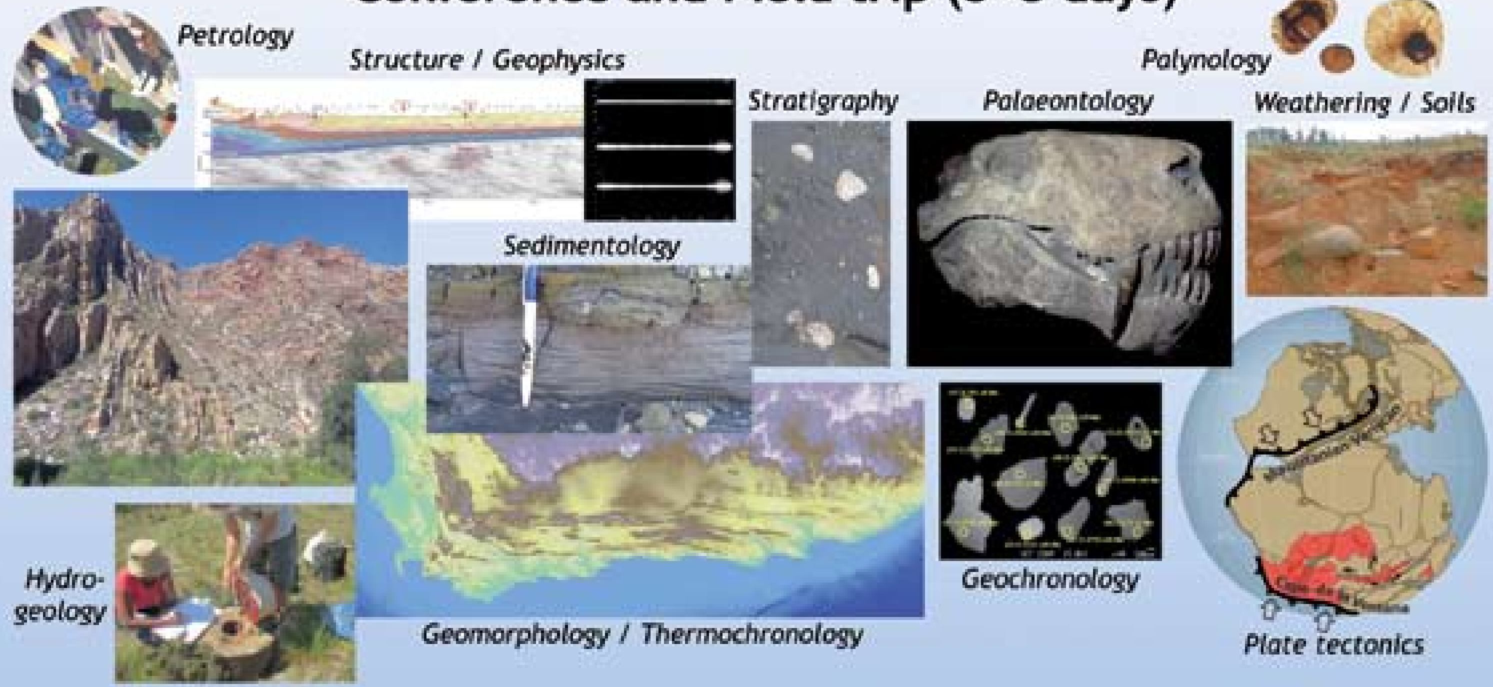
Earth Stewardship Science Research Institute

Nelson Mandela Metropolitan University

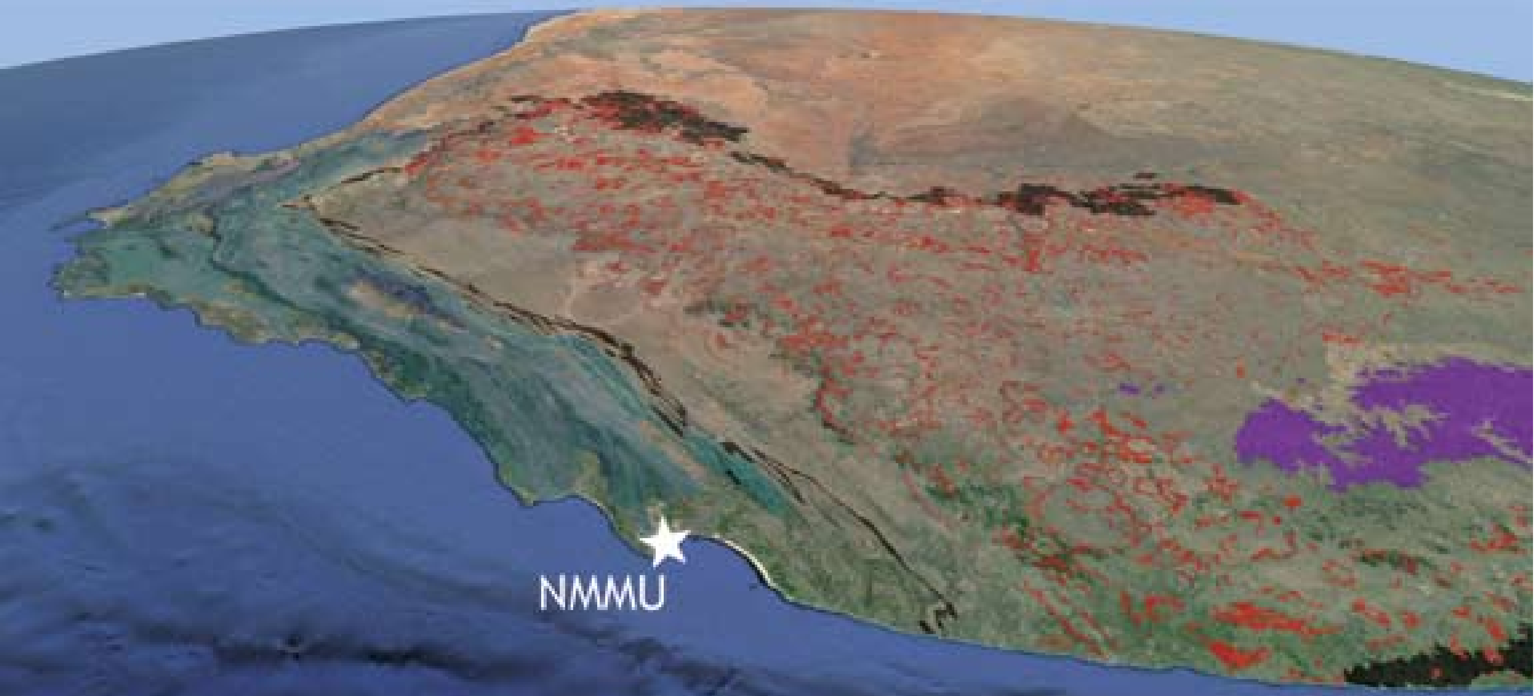
for tomorrow

'Imbizo'

Conference and Field trip (3+3 days)



Origin and Evolution of the Cape Mountains and Karoo Basin



from 25th to 30th Nov. 2015

Nelson Mandela Metropolitan University

Port Elizabeth, South Africa

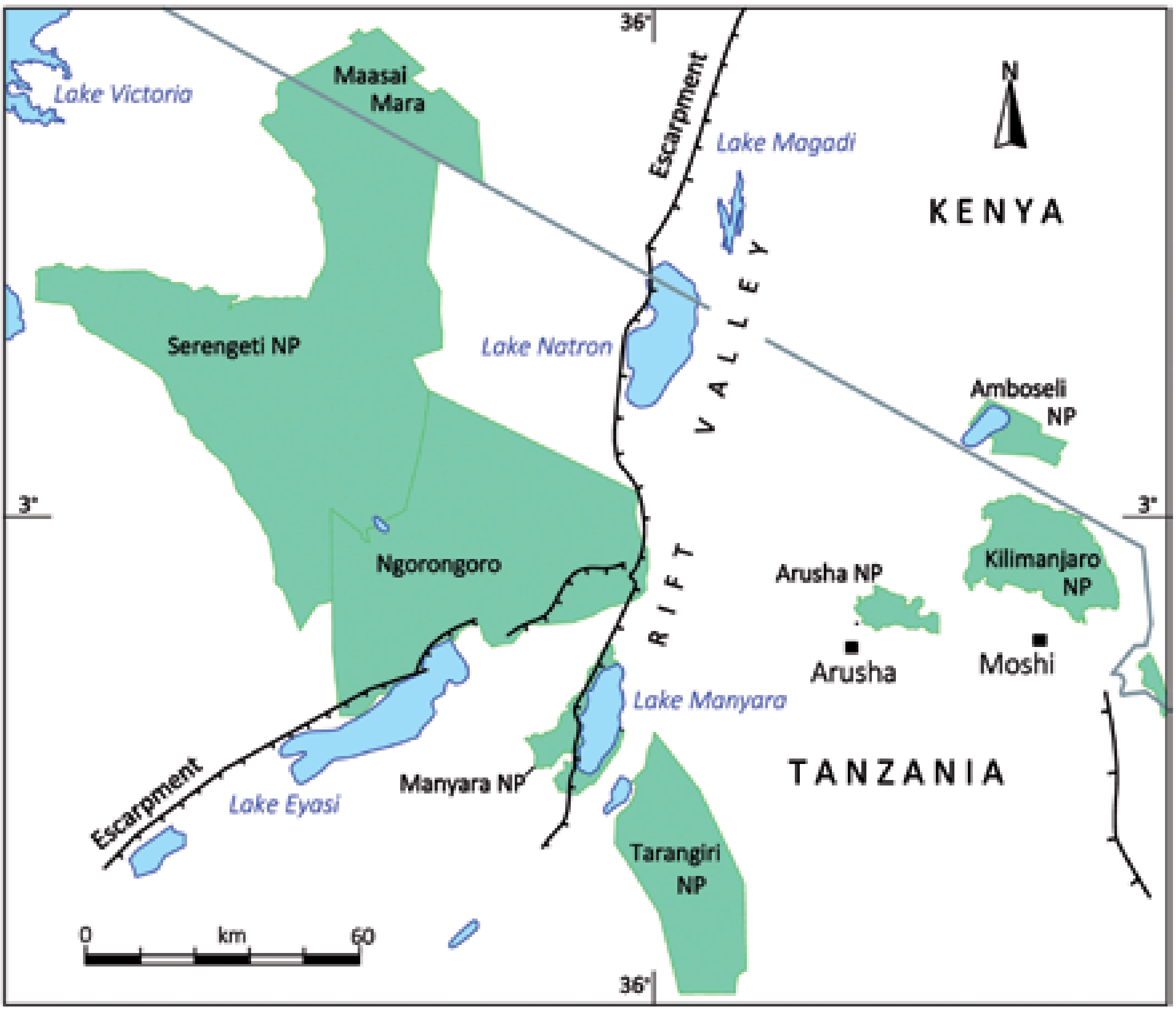
Information + Registration: http://aeon.org.za/capekaroo

contact Bastien Linol for querries: Bastien.aeon@gmail.com

ARTICLES

northern tanzania:

Rift Valley and Neogene-Holocene Volcanism.



Map showing the National Parks of northern Tanzania.

LEADER: Roger Scoon (rnscoon@iafica.com)

A 10 day post-conference field excursion starting and finishing in Johannesburg: 5 - 14 September 2016

- Monday: Fly ORT-Arusha (lodge)
- Tuesday: Arusha NP, caldera of Mount Meru (mountain huts)
- Wednesday: Lake Manyara NP (soda lake, hot springs); Ngorongoro Highlands (lodge)
- Thursday: Ngorongoro and Empakaai calderas (lodge or camp)
- Friday: Gregory Rift and Lake Natron (Tented Safari camp).
- Saturday: Oldoinyo Lengai or Lake Natron and Western Escarpment (Tented Safari camp).
- Sunday: Serengeti NP (lodge)
- Monday: Serengeti NP (lodge)
- Tuesday: Oldupai Gorge; fly Ndutu-Arusha (Lodge)
- Wednesday: Fly to ORT

Highlights

- Unique opportunity to visit some of Africa's most famous National Parks
- Hike at over 8000 feet in the caldera of Mount Meru, an active stratovolcano
- Unique splendour of the extinct Ngorongoro Caldera

- Visit the Gregory Rift and a chance to climb Oldoinyo Lengai the world's only active carbonatite volcano
- If timing is good see migration in the Serengeti
- Examine rock sequences that host some of the world's most important hominid finds at Oldupai Gorge

Note: The itinerary and costs are dependent on number of participants, so early booking will assist greatly. Costs are estimated at US$6-8,000. There will be opportunities to add on private trips to visit, for example, primates (gorilla, chimpanzee) in Uganda and Rwanda, or the volcanic areas of southern Kenya.

Geological Overview

The Gregory Rift, the easterly branch of the East African Rift System, is part of one of the most recognizable geological features on Earth. The first geologist to examine this area was Joseph Thomson, but it is John Walter Gregory who, in 1894 defined the concept of a rift valley as a series of linear faults. Rifting triggered abundant Neogene-age volcanism and includes active centres.

This part of northern Tanzania contains some famous national parks and conservation areas, as shown on the attached map. The excursion will visit the Arusha, Manyara, Ngorongoro, and Serengeti parks, as well as the wilderness area around Lake Natron. The airport is located near the regional town of Arusha so logistics restrict us to examining some young volcanic centres prior to the rift itself. The excursion will also provide an opportunity to see the Archean basement, to climb the active volcano of Oldoinyo Lengai, and visit Oldupai Gorge, the famous paleoanthropological site. Some days will be spent at altitudes of 8,000 feet and the temperate nature of the climate (with chilly nights) is surprising in an area so close to the Equator.

Geological Structure

The petering out and splitting of the rift south of Lake Natron into three branches, Eyasi, Manyara, and Pangani, is a consequence of the southward-propagating faults refracting off the Tanzania Craton. The Natron-Manyara branch is bordered to the west by a subgraben that hosts the Ngorongoro Volcanic Complex, an extinct complex of shield volcanoes. Individual cones occur in the rift, notably near Lake Natron, and a cluster of huge stratovolcanoes,

The barren escarpment of the Gregory Rift near Lake Natron.

The spectacular cone of Oldoinyo Lengai rises 2000 m above the floor of the Gregory Rift near Lake Natron.

including Meru and Kilimanjaro, occur on the eastern platform.

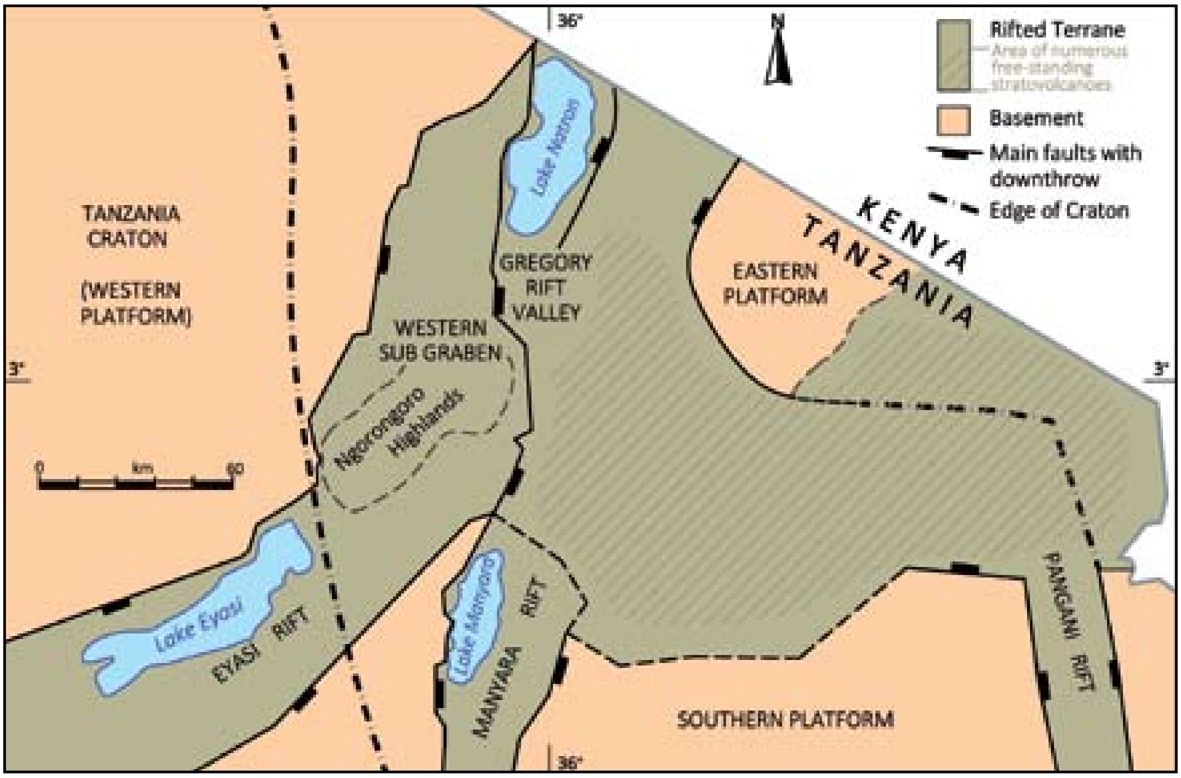
The partial separation and extension of the African Plate into Nubian (west) and Somali (east) Plates has probably been driven by a thermal plume located in the upper Mantle. The general drift northward of the Nubian Plate is complicated by the eastward drift of the Somali Plate. There has been 130 km of extension at the northern tip of East Africa during the last 40 Ma. The Gregory Rift differs from the Western Rift in that it contains small, mostly alkaline lakes, and volcanism within the rift and on the eastern platform is very extensive.

Rifting, which commenced in the Miocene in Ethiopia reached northern Tanzania in the Pliocene (3-1.8 Ma). The currently active faulting commenced at 1.2 Ma. The two ages of faulting correlate approximately with two ages of volcanism, known as the older (Pliocene and Lower Pleistocene) and younger (Upper Pleistocene-Holocene) groups.

Mount Meru

With a height of 4562 m and diameter of 25 km, Mount Meru is a giant stratovolcano. The annular ring of forest on the lower slopes is a characteristic of most high peaks in East Africa. The main geological features are a rocky summit ridge, a giant horseshoe-shaped caldera with near-vertical internal cliffs, and undulating topography with small lakes and marshes on the lower eastern slopes. Meru is regarded as active as there was minor activity in the last century.

The ash cone and upper slopes of the Mount Meru caldera.



Simplified structural map of northern Tanzania.

The excursion will include a visit to the subsidiary volcano of Ngurdoto that includes a discrete summit crater that has been preserved as a "park-within-a park". The highlight will be a hike with an armed ranger (the park has large herds of elephant and buffalo) into the caldera at over 8,000 feet with views of the internal walls. (Unfortunately time will not permit an ascent of the summit: this requires four days.) The main cone at Meru was built up in the period 200,000-80,000 BP. The partial disintegration of the cone and formation of the caldera is dated at approximately 7,000 BP. Formation of the caldera may be compared with the 1980 eruption of Mount St Helens as massive debris avalanches travelling up to 35 km were created. We will visit the Momella lakes that were created from hollows associated with the avalanche deposits. The most recent at Meru activity is formation of the giant Ash Cone.

Alkaline Lakes

Alkaline lakes are important components of the ecology of northern Tanzania. They are restricted to the rifts and larger calderas and may be associated with thick sequences of Neogene-age sediments. The Manyara NP is well known, partly for pioneering studies of elephant behaviour but also for large concentrations of water birds. Lake Natron is the main breeding ground of flamingo in East Africa, a consequence of the high proportion of dissolved sodium carbonate derived from the natrocarbonatite volcanoes. The brines are so poisonous that the flamingo could not survive if their filtration systems were not so efficient. The extent of Lake Magadi, the largest lake in the Ngorongoro Caldera has varied since the Pleistocene.

Forested slopes and lake-filled depression of the Empakaai Caldera.

Ngorongoro Volcanic Complex

The extinct cones and calderas of the Ngorongoro Highlands, an area some 100 km north-south and 80 km west-east, is associated with the older phase of volcanism. Cones and shoulders of calderas rise over 2000 m above the valley. Eight discrete centres are recognized, but it is Ngorongoro (2.25-2.01 Ma) with one of the largest and best preserved calderas on Earth that is the most well known. With an internal diameter of some 20 km, internal walls 350 m in height, and with only localized areas of collapse and debris flow, the caldera is justifiably famous. We will visit the Lerai section which has been studied in some detail: geochemical trends are consistent with a stratified magma chamber of which the silicic top and basaltic

The forested escarpment and Lake Manyara.

base was inverted by sequential eruptions. Two flows of rhyolite ignimbrites located toward the top of the section are associated with the caldera event.

Escarpments

The escarpments are observed as near-vertical walls, and at Lake Natron we will examine the huge thicknesses of volcanic ash and lava associated with the western wall of the Gregory Rift.

Oldoinyo Lengai

The natrocarbonatite volcanism in this area is restricted to the younger activity. Oldoinyo Lengai is the most widely studied of these centres and includes a near symmetrical cone (2,880 m) typical of active volcanoes that have undergone minimal erosion. The high sodium content causes the lava to react rapidly with meteoric water so that despite being erupted as dark-coloured flows the lavas oxidize to light-coloured secondary minerals within a few days. The primary mineral (sodium calcium carbonate or nyerereite), was identified by J B Dawson from examining newly erupted flows; after a few days the sodium in the nyerereite is replaced by calcite.

Recent eruptions occur every 15-25 years. The first event to be observed was in 1904. Eruptions in 1966-7 were unusually violent and excavated a summit crater with a depth of 150 m and diameter of 400 m. The ashfall reached as far as the Serengeti Plains, 150 km to the west. For the fit – the ascent is very strenuous – the opportunity to climb the cone and walk into an active crater is an opportunity not to be missed. During a visit in May 1995, numerous ash and spatter cones were active and shiny white, smooth-topped pahoehoe flows (from the 1992 eruption), although severely oxidized, were still intact.

Serengeti

Large areas of the Serengeti NP are underlain by the 2.8-2.5 Ga old Tanzania Craton. The eastern plains include distinctive koppies of coarsely-crystalline granite-gneiss. The greenstones form bushy ridges in the central and southern parts of the park. The prevailing easterly winds have spread ash from the rift-hosted volcanoes onto the Serengeti Plains. This movement of ash may have influenced the famous migration. The ash has affected the water table by development of a near-surface layer of hard pan to form an ecological area known as the "short grass plains". This is distinct from the "long grass plains" where Basement rocks occur and the water table is deeper.

The "Shifting Sands" on the eastern plains of the Serengeti, near Oldupai Gorge, are isolated dunes composed of black ash derived from Oldoinyo Lengai. The largest of the dunes reveals a classic crescent-shape and is 9 m in height and 100 m in length. It is

Part of the active northern crater, Oldoinyo Lengai.

migrating west at the rate of approximately 17 m/year. The track left behind the dune is visible and includes a trail of different species of fossilized dune beetles. Movement of sand particles by wind and bouncing of grains off the ground, a process known as saltation, is thought to cause a negative charge, thus creating an electrical field which suppresses dispersion of individual grains.

Oldupai Gorge

Oldupai Gorge (formerly known as Olduvai) has revealed highly significant discoveries, including Homo habilis (1.9-1.6 Ma), Paranthropus boisei (1.8-1.2 Ma) and Homo erectus (1.2-0.70 Ma). Fossil evidence suggests Homo sapiens arrived at Oldupai around 17,000 BP. Many animal fossils have also been found at Oldupai, including numerous extinct species. The gorge is some 48 km in length, and forms a steep-sided incision into the Serengeti plains. The drainage pattern of the Serengeti is generally toward Lake Victoria; Oldupai is part of an old river system related to a paleo-basin on the margins of the rift that drains eastward. The geology of the gorge was studied in great detail by Richard Hay, over a period of more than 40 years. The Oldupai sequence is divided into seven beds. Most of the important finds were made in sequences of volcanic ash (from Ngorongoro and Olmoti) and clay within Beds I (2.1-1.7 Ma) and II (1.7-1.1 Ma). Bed III (700,000 BP) consists of a 10 m-thick sandstone, but the clay-rich Bed IV (300,000 BP) has yielded abundant Hominin fossils. Beds V-VII consists of windblown ash from Kerimasi and Oldoinyo Lengai, the latter having been dated at 17,000 BP.

CONCLUDING REMARKS

The volume and pervasiveness of the volcanism in the Gregory Rift of northern Tanzania is almost without parallel. The fall-out of radioactive ash associated with

Isolated sand dune of black volcanic ash (derived from Oldoinyo Lengai), eastern plains of the Serengeti.

Oldupai Gorge showing the basal lava (black) which is overlain by fossil-rich Beds I and II of the Oldupai sequence.

the younger, nephelinite and carbonatite volcanism, it has been suggested, may account for rapid speciation of both cichlid fish (e.g., in Lake Victoria) and of Great Apes and Hominids.

Photographs from visits in 1995, 1998, and 2005.

graphite petrography

Introduction

Industrial minerals such as graphite have recently become the focus of attention for many listed exploration companies, particularly due to developments in battery technologies and new product opportunities such as graphene. Consequently the race has been on to report larger tonnage exploration targets and resources, with certain projects being described, for example, as world class or highest grade.

Although resource tonnes and graphitic carbon content (grade) are important metrics, the evaluation of graphite projects (as with other industrial minerals) is more complex; key attributes in addition to deposit size and grade, are product flake size distribution and purity (Scogings, 2014; Scogings and Chesters, 2014).

Graphite purity is particularly important for the higher value end uses like lithium-ion batteries and is a key determinant in saleability of the product. Producing high purity graphite may also adversely affect the cost of production, as additional processing to make the product saleable will increase the operating cost.

Graphite flake size distribution is one of the more debated project factors. However a number of facts about flake size are currently true; firstly, the larger the flake the higher the purity of the graphite product is likely to be and secondly, the larger and purer the flake size the higher is the selling the price.

Graphite prices related to flake size and purity

Graphite type	Purity (% Carbon)	Size (mesh)	Size (Microns)	Low (US$, CIF)	High (US$, CIF)
Flake	94 to 97	+80	+180	1,050	1,150
Flake	94 to 97	+100 -80	+150 -180	900	1,000
Flake	94 to 97	-100	-150 + 200	750	800
Flake	90	+80	+180	750	850
Flake	90	+100 -80	+150 -180	700	800
Flake	90	-100	-150 + 200	600	650
Flake	85 to 87	+100 -80	+150 -180	550	600
Amorphous	80 to 85	-200	-75	430	480
Amorphous	70 to 75			500 (ex-works)	550

SOURCE: Industrial Minerals Magazine 30th April 2015 www.indmin.com

SAMREC 2009 Table 1, Section 5.5 Treatment / Processing

ASSESSMENT CRITERION: T 5.5 Treatment / Processing
EXPLORATION RESULTS (A)
(i) Describe any obvious processing factors that could have a significant effect on the prospects of any possible exploration target or deposit
MINERAL RESOURCES (B)
(i) Discuss the level of study, possible processing methods and any processing factors that could have a material effect on the likelihood of eventual economic extraction.
(ii) The basis for assumptions or predictions regarding metallurgical amenability and any preliminary metallurgical test work should already be carried out.
(iii) It may not be possible to make assumptions regarding metallurgical processes and parameters when reporting Mineral Resources. Where no assumptions have been made, this should be explained.

Source: The SAMREC Code 2007, as amended July 2009

The current edition of the SAMREC Code for public reporting of Exploration Results, Mineral Resources and Ore Reserves includes Table 1 which is a high-level checklist of assessment and reporting criteria. Although not prescriptive, it is important for the Competent Person ("CP") to "report all matters that might materially affect a reader's understanding or interpretation of the results or estimates being reported" (SAMREC, page 28). The Code goes further and states that the CP has the responsibility to consider all criteria listed and which additional criteria should apply to the particular project.

The author's intention is to address some of the criteria listed under 'Treatment / Processing' of Section 5.5 of SAMREC Table 1 and to provide examples from graphite exploration projects related to the issue of flake size and liberation characteristics. These criteria include the description of any "obvious processing factors that could have a significant effect on the prospects of any possible exploration target or deposit" and "the basis for assumptions or predictions regarding metallurgical amenability and any preliminary metallurgical test work".

Given that industrial minerals such as graphite are normally produced and sold according to size, purity and / or performance specifications, the responsibility falls on the CP to ensure that samples are tested for appropriate parameters such as flake size and purity, in addition to basic assay tests for graphitic carbon content. In this regard, the question is often raised about how to test graphite flake size across a deposit; given that relatively costly and time-consuming lab flotation procedures are usually required to separate graphite from gangue minerals.

The author suggests that petrographic examination of polished thin sections is a relatively affordable and quick option to estimate the *in-situ* graphite flake size distribution and likely liberation characteristics.

Back to basics – take a look at the rocks

The microscopic investigation of rocks in transmitted and reflected light is one of the classic mineralogical methods of analysis. Polarized-light microscopy provides a non-destructive way to identify minerals, as they can be studied within their textural framework. This method provides clues to the history of formation of the material, using specific textural characteristics such as structural fabric, mineral assemblages and relationships and has distinct advantages over bulk-analytical methods that use sample powders for mineral identification or chemical composition such as XRD and XRF. It is recommended that polarized-light microscopy, complemented by methods such as SEM (Scanning Electron Microscope), QEMSCAN (Quantitative Evaluation of Minerals by Scanning Electron Microscopy) and MLA (Mineral Liberation

Maggie Lambert-Newman
Dinosaurs

Analyser, or automated SEM) should be used when evaluating a graphite project.

Graphite explorers are encouraged to 'get back to basics' and use thin section petrography as a primary tool to evaluate and compare prospective targets (Scogings, 2015). Thin section petrography helps with the geometallurgical domaining of graphite deposits and selection of composites for metallurgical testing, in addition to explaining subsequent metallurgical test results.

Geometallurgy is multi-disciplinary approach that combines geology and mineralogy with extractive metallurgy, to create a predictive model that assists with selecting appropriate mineral processing for a deposit. It is used to reduce risk during mineral processing plant design and can also assist with production scheduling. Mining and processing based solely on grade (e.g. graphite content) may not be sufficient, as seemingly low grade mineralisation may result in a high quality concentrate if processed appropriately.

There are several steps that may be used in developing a geometallurgical model for a graphite deposit, including:

- Petrographic studies to define geological domains (e.g. lithologies, mineralogy and textural characteristics);
- Selection of samples according to geological domains, for metallurgical testwork;
- Laboratory-scale test work to determine the response to mineral processing methods;

In order to define geometallurgical domains, a suite of samples may be prepared, representing the main lithologies from which two thin sections can be made for each sample, one perpendicular to the graphite flakes and a second approximately parallel to the flakes. In the case of RC chips, these can be cast into resin and made into polished thin sections in which case the sample orientation is random.

Graphite populations

An example of how thin section microscopy can help understand metallurgical results is where graphite recoveries are lower than anticipated. Thin section examination highlighted that there were two graphite populations, with the majority as coarse flakes but with a second population of very small flakes within large crystals (porphyroblasts) of K feldspar. The small flakes

Core samples representative of rock types on a specific project. Approximate graphite contents indicated as percentages.

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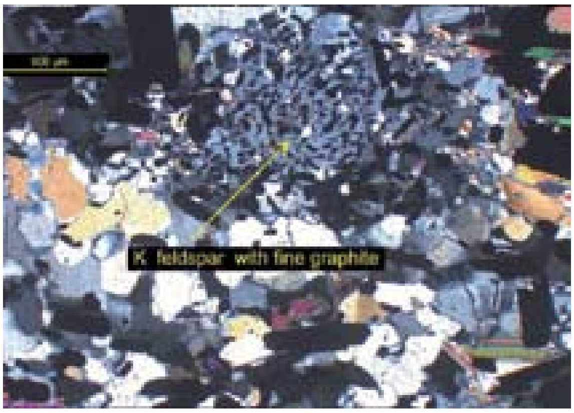
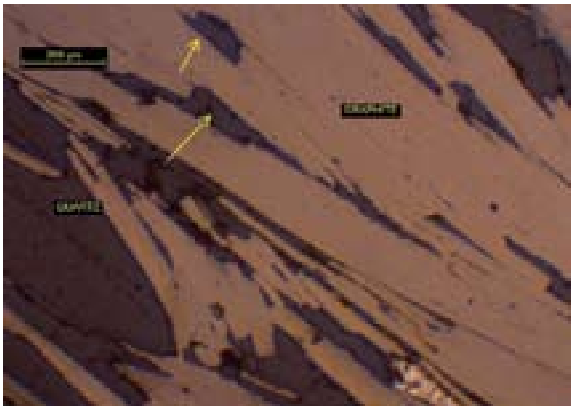
Polished thin sections made from core or outcrop (two samples on the left) and RC chips (two samples on the right)



Photomicrograph illustrating two graphite populations within one sample: large flakes in the general rock matrix, compared with fine flakes within K feldspar

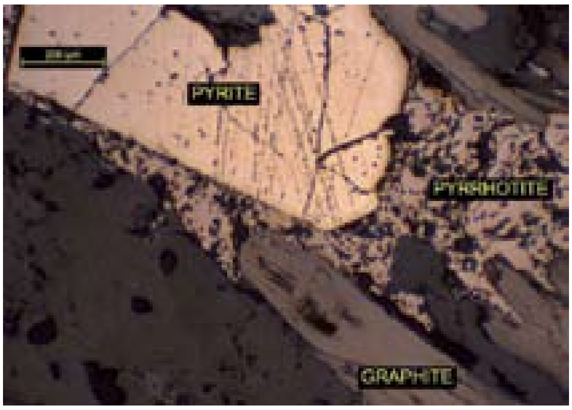


Photomicrograph of large 'clean' graphite flakes with one minor sulphide inclusion

were not being liberated at the coarse crushing size used to liberate large flakes, hence were not being recovered.

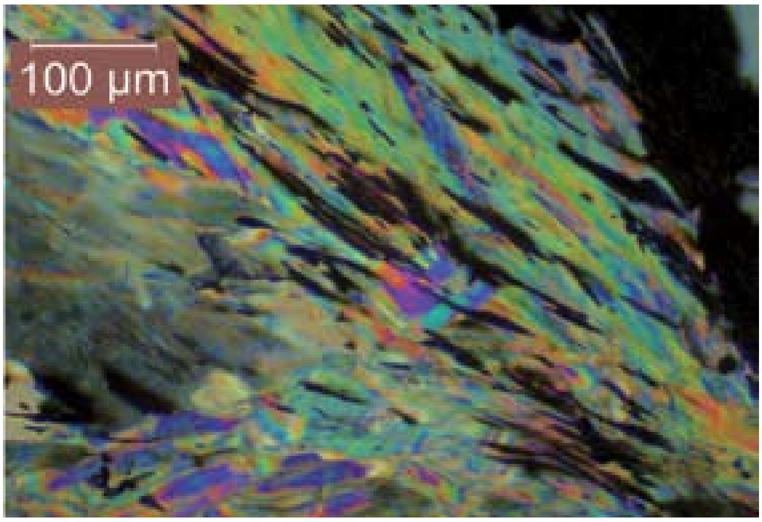
Mineral impurities

Sulphide minerals such as pyrite and pyrrhotite are common impurities in graphite deposits and thin section petrography can help define areas or specific lithologies where sulphides may be absent, present as discrete grains or interleaved within graphite flakes and thus more difficult to liberate.

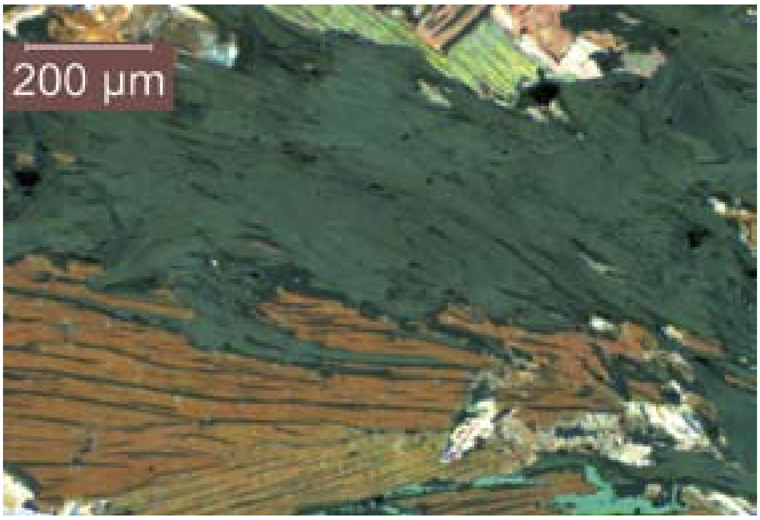


Photomicrograph of graphite flakes with discrete pyrite crystals and pyrrhotite blebs

Photomicrograph of pyrrhotite interleaved along cleavage planes in graphite



Photomicrograph of small graphite flakes generally less than 75 microns in length, intergrown with sericite



Photomicrograph of coarse graphite flake more than 1mm in length, associated with biotite

Flake size

A second example of the benefits of thin section petrography may be where flake size varies across an individual deposit, or between prospects within a region and where the explorer wishes to select an appropriate target. In this particular case, the explorer identified one target as having a population of very small flakes in a retrograde sericitic assemblage and a second target as containing coarse flakes in a medium to high grade metamorphic assemblage and elected to follow up on the second target.

Conclusions and recommendations

- Graphite explorers are urged to 'get back to basics' and use thin section petrography as a basic tool to help address treatment / processing aspects of industrial mineral resources according to SAMREC 2009 requirements.

- It is suggested that petrographic examination of polished thin sections be done early on in the project and during the subsequent resource drilling phase. Polished thin sections are relatively inexpensive and can be used to estimate the size and shape of *in-situ* graphite flake populations, relationships with other minerals including contaminants such as sulphide minerals, and for estimating likely liberation size. However it should be borne in mind that *in situ* flake size estimations don't necessarily translate directly to flake sizes produced by metallurgical processes such as gravity separation or froth flotation.

- Core drilling is the preferred technique for graphite exploration, as this provides undisturbed samples for thin sections and for metallurgical tests. Reverse Circulation (RC) drill chips may also be used to make thin sections; however RC chips are not suitable for metallurgical tests due to the grinding action of the drill bit, which reduces flake size. Caution should be exercised when selecting RC chips, as there may have been preferential grinding of softer (possibly graphite-rich) rocks.

- Once appropriate metallurgical samples have been selected, some cost-effective and fairly quick tests such as i) assay by size and ii) heavy liquid separation

(SG 2.3) may be considered as precursors to more detailed flotation tests.

- Knowing this type of information means being smarter early on in the project and can guide to more intelligent and informed selection of composite drill samples for metallurgical testing, in addition to benefitting mine planning and metallurgical processing further down the line.

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Acknowledgements

Sincere thanks are extended to CSA Global Pty Ltd for their support in publishing this review.

Andrew Scogings

PhD, MAIG, MAusIMM, MGSSA, RP Geo. (Industrial Minerals)
Principal Consultant, CSA Global Pty Ltd
Industrial Minerals Magazine Consultant
Perth,
Australia.

density

Industrial Minerals - Why measure Bulk Density?

Introduction

Bulk density is often a relatively neglected parameter during industrial mineral exploration and generally doesn't receive the attention devoted to other measures such as i) sample width in borehole intersections, ii) chemical analysis and iii) product performance testing (Scogings, 2015b).

As noted by Lipton and Horton (2014, p.97) "There are three fundamental inputs to any Mineral Resource estimate: grade, volume and bulk density"; they also state that "The estimation of density commonly receives less attention than is paid to geochemical data and may be based on fewer data points derived from less controlled measurement practices".

Geological resources are generally modelled as volumes in three-dimensional space, after which the estimated volume must be converted to mass using density value/s, thus the measurement of density should be an integral part of the resource estimation process.

The author's intention is to address certain aspects concerning bulk density listed in Section 2.4 of the SAMREC code Table 1. The first part of this review describes bulk density and some of the methods most commonly used for measuring the density of rocks and materials; this is supported by case studies from Minerals Technologies Inc. ("MTI") mines in Australia and South Africa, where the author was previously involved.

The current edition of the SAMREC code for public reporting of Exploration Results, Mineral Resources and Ore Reserves includes Table 1 which is a high-level checklist of assessment and reporting criteria (Table 1). Although not prescriptive, it is important for the Competent Person ("CP") to "report all matters

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SAMREC 2009 Table 1, Section 2.4 Specific gravity and bulk tonnage data

ASSESSMENT CRITERION: T 2.4 Specific gravity and bulk tonnage data
EXPLORATION RESULTS (A)
(i) If target tonnage ranges are reported then the preliminary estimates or basis of assumptions made for bulk density or specific gravity(s) must be stated. (ii) Specific gravity samples must be representative of the material for which a grade rage is reported.
MINERAL RESOURCES (B)
(i) Describe the method of bulk-density / specific-gravity determination with reference to the frequency of measurements, the size, nature and representativeness of the samples.
(ii) The bulk density must have been measured by methods that adequately account for void spaces (vugs, porosity, etc), moisture and differences between rock and alteration zones within the deposit.
(iii) Direct assumptions for bulk density estimates used in the evaluation process of the different materials.
Source: The SAMREC Code 2007, as amended July 2009

that might materially affect a reader's understanding or interpretation of the results or estimates being reported" (SAMREC, page 28). The Code goes further and states that the CP has the responsibility to consider all criteria listed and which additional criteria should apply to the particular project.

The author's intention is to address some of the criteria listed under Section 2.4 'Specific gravity and bulk tonnage data' of SAMREC Table 1 and to provide examples from industrial mineral exploration and mining projects related to the issue of drill core, stockpile and product density. These criteria include the description of "the method of bulk-density / specific-gravity determination with reference to the frequency of measurements, the size, nature and representativeness of the samples" and that "the bulk density must have been measured by methods that adequately account for void spaces (vugs, porosity, etc), moisture and differences between rock and alteration zones within the deposit".

What is Bulk Density?

Bulk density is a measure of mass per unit volume of rock and in South Africa it is generally expressed as metric tonnes per cubic metre. Density is determined by measuring the mass of a sample and dividing this by its volume. Generally the dry mass is obtained by drying the sample and then weighing it, which is the easy part. The challenging bit happens when trying to determine the volume of a rock sample especially when specimens have irregular shapes, are friable, soft and / or porous.

Density may be defined in a number of ways (Table 2) and it is important to ensure that the appropriate density measurement is used for any specific project. Assays for constituents such as Cr_2O_3 (in a chromitite seam), MgO (in magnesite or dolomite) or Graphitic Carbon (in a graphite schist) are normally reported on a dry weight basis and therefore in such cases the 'dry bulk density' (DBD) is applicable. Lipton and Horton (2014) define DBD as the mass per unit volume, including pore spaces but excluding natural water content.

The 'in situ bulk density' (ISBD) includes natural water content and according to Lipton and Horton (2014) should be applied when estimating tonnages of material to be mined. The use of ISBD would apply to a commodity such as bentonite, which may contain 25 to 35% moisture before being mined and core should therefore be sealed immediately after drilling to preserve in situ moisture content.

Specific Gravity (SG) is commonly used to describe density but caution should be exercised, as SG (also known as Relative Density) is often measured using pulverised samples in equipment known as a pycnometer. This method does not take into account porosity or natural water content, which is a limitation of the method for use in geological resource estimation.

Table 2 Description of some commonly used density terms (adapted from Lipton & Horton, 2014)

Term	Units	Definition
Specific Gravity		Relative density: the ratio of the density of the material to the density of water at 4°C
Density	t/m^3	Mass per unit volume
In situ bulk density (ISBD)	t/m^3	Density of the material at natural moisture content
Dry bulk density (DBD)	t/m^3	Density of the material after all free moisture content has been removed

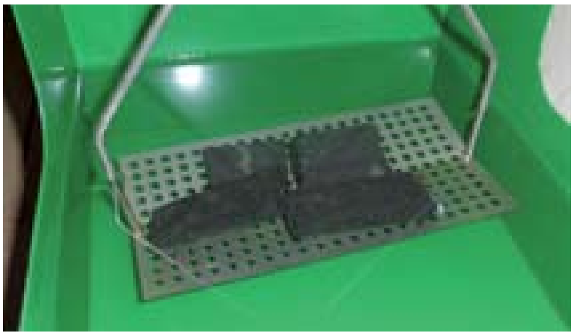
Bentonite core sealed inside plastic to preserve in situ moisture content. Source: MTI

Determining bulk density from small samples

The geologist frequently has only drill core samples to use for density measurement and there are several practical methods available, essentially based around the issue of measuring volume. Each density method has its own potential source of error and it is useful to verify the results of one method against a second if at all possible. It is important to ensure that rock / mineralised samples are representative and that a particular type of rock is not sampled preferentially, e.g. hard material relative to soft material (Lipton and Horton, 2014).

Water displacement method: there are several methods which rely on displacement of water to estimate sample volume and are described in detail by Lipton and Horton (2014, pages 99-101) who list six water displacement methods. One of the most common methods for exploration samples is based on the Archimedes principle in which the sample is first weighed in air, after which it is weighed in water. The density is calculated as the mass of the sample in air, divided by the volume (difference between the sample mass in air and in water). Samples should be competent and not absorb water; if porous they should be waterproofed with substances such as paraffin wax or beeswax which melt at ~60°C, spray lacquer or hairspray, vacuum packed in plastic or wrapped in 'cling wrap' film to help prevent ingress of water.

2 Paraffin wax coated friable chromitite sample being weighed in air. Source: MTI



3 Archimedes (water displacement) equipment. Competent, non-porous chromitite core sample being weighed in water. Source: MTI

Calliper method: this is applicable for drill core samples that can be trimmed at right angles to form a regular cylinder. A pair of callipers is used to measure the core diameter at several points to estimate an average result, while the core length is determined using a tape

4 Paraffin wax blocks. Source: Protea Chemicals, Wadeville

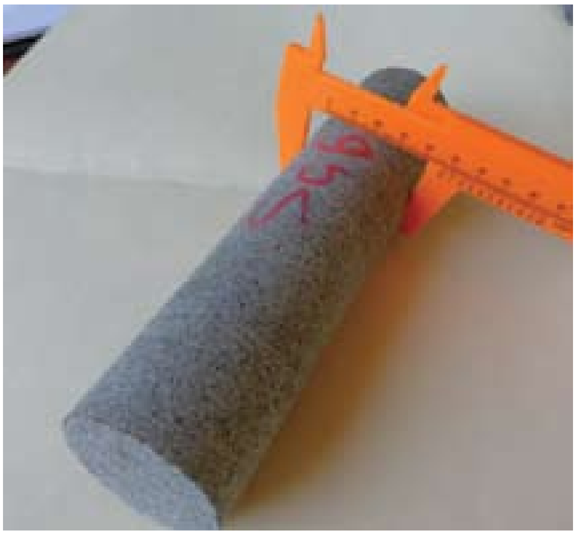
Coating a friable chromitite core sample with molten paraffin wax. Source: MTI

Vacuum-packed pyroxenite core. Source: MTI

measure or ruler. The core is weighed and the density determined simply by using the formula of weight / volume. The calliper method has the advantage of

Pyroxenite core covered with cling wrap, illustrating water ingress. Source: MTI

simplicity, but it is cautioned that using small diameter core or short core lengths may result in unreliable results (Lipton and Horton, 2014). The calliper method may also be used on half core samples, such as might be encountered when evaluating an older project with previously cut core, or where core has been sampled prior to measuring density. Errors will arise if the core was not aligned correctly when cutting and this should be verified before proceeding with this method. The



Pyroxenite core sample being measured using a calliper. Source: MTI

following parameters should be measured on half core namely i) core length; ii) core segment width and; iii) core segment height (Lipton and Horton, 2014).

Pulp sample method: density of competent rocks that have very low porosity and low natural water content may be measured using a gas pycnometer and rock pulp samples (finely milled rock) but this method is not suitable for porous rocks, as the fabric is destroyed by the milling process. The gas pycnometer method determines volume within the sample chamber from which the gas is excluded. The pycnometer will accurately give volumes for samples weighed into plastic vials which are in turn dropped into the sample chamber. Best precision is obtained from the largest possible volume of sample which is typically around 30 grams. SG data derived from a gas pycnometer may form a useful part of the density database and in the author's experience such SG data can be a valuable QC tool.

Stoichiometric method: there may be an obvious correlation between SG or bulk density and rock chemistry, such as with relatively simple mineral assemblages such as some barite and chromite ores. Assuming that a barite ore consists of discrete barite ($BaSO_4$) and quartz (SiO_2) or that chromitite ore consists essentially of chromite and pyroxene minerals, it should be possible to estimate bulk density based on XRF 'whole rock' analyses. An example is barite ore in which pure barite has a density of ~4.5 g/ml compared with quartz which has a much lower density of ~2.7 g/ml.

Gas pycnometer. Source: Intertek, Perth

Seeing that density is expressed in terms of volume and that XRF whole-rock analyses are expressed on a weight percentage basis, the calculated density must be based on mineral volumes in order to maintain a constant volume. The relationship between whole-rock chemistry and density is non-linear, which is especially obvious when there is a marked difference in density between the different mineral phases (Lipton and Horton, 2014).

Determining bulk density from larger samples

Bulk samples may be obtained if trial mining or production is already in progress at a site. The *in-situ* volume of bulk samples can be estimated by surveying an excavated void (for example an extracted bentonite or chromitite seam) or by surveying a stockpile before and after removal. The sample mass may be determined by directly measuring truckloads across a weighbridge; however sub- samples will have to be taken to determine moisture content as it is impractical to measure the moisture of an entire stockpile or run of mine material. Reconciliation of tonnage mined against the mineral resource or ore reserve is also a good check, not only of the three-dimensional geological model, but also of bulk density.

Operating mines generally measure raw material stockpile volumes for audit and reconciliation purposes, but the question arises of selecting an appropriate bulk density for conversion of volume to mass. Bulk density (BD) values for free-flowing powders and granular materials can vary significantly according to particle size distribution and on how closely the particles are packed. Since powders and granular materials are composed of particles and voids, the volume of a given mass of particles depends on how closely they are packed. In practical terms, the bulk density of a powder tends to increase the more it is subjected to tapping, vibration or other action which causes particles to become better packed, with less void space between larger particles; this is known as the 'tapped bulk density'. Bulk density of free-flowing powders or granular materials can be determined by filling a container of known volume, at which stage the material is weighed and the 'loose bulk density' can be estimated. The container is then tapped and refilled until the material stops settling, at which stage the tapped bulk density can be estimated.

QAQC

QAQC methods commonly applied to other factors in an exploration program such as equipment calibration, duplicates, standards and external laboratory tests should also apply to density measurements.

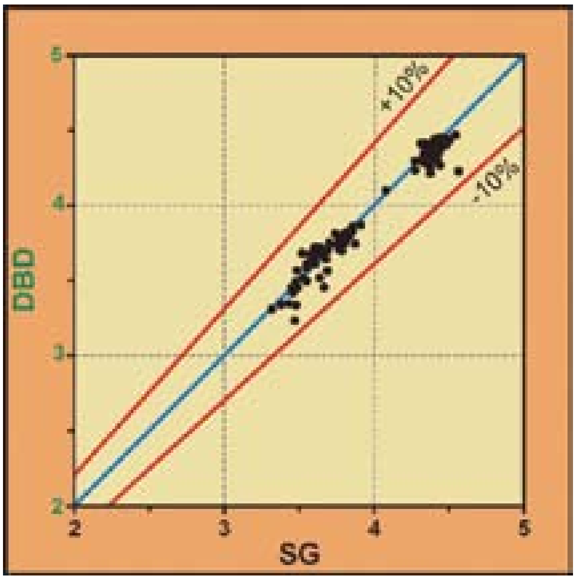
Case study – chromitite in South Africa

The main aim of this paper is to give practical examples of density measurement and the first example is of drill core from the Batlhako mine at Ruighoek; this MTI operation produces a range of premium-grade chromite sands for foundry, chemical, metallurgical and refractory applications.

In the first example the LG6 chromitite is 'fresh' or un-weathered competent rock consisting predominantly of chromite and pyroxene, hence the Archimedes water

Calibration of a density balance using standard weights. Source: MTI displacement method was deemed suitable. Given that the chromitite seams in this particular example were unweathered, non-porous and competent, a set of milled samples was also analysed by gas pycnometer as a check; this data set demonstrated acceptable correlation between methods.

A further example from Ruighoek concerns pyroxenite drill core from the chromitite hangingwall, which the mine planners wished to evaluate for an open pit situation. In this case the pyroxenite ranged from weathered (friable and porous) to fresh (competent and non-porous) hence there were several options, including water displacement of sealed samples and the calliper method. An un-weathered pyroxenite core sample 'SG6' was chosen as a control and density was estimated using the calliper and various water displacement methods (**Table 3**). The calliper method yielded comparable results to the Archimedes method (uncoated, vacuum packed and paraffin wax). However the 'cling wrap' method proved to be unreliable as it entrained air (reducing the density) and was not waterproof. The author has observed significant differences when using cling wrap on other industrial mineral projects and recommends avoiding this method.



Scatterplot comparing SG (pycnometer) with DBD (Archimedes method) for chromitite and chromiferous pyroxenite. Source: MTI

The density of a second sample of un-weathered pyroxenite core 'SG10' was measured by various methods, after which the core was cut approximately in half and the calliper method used to determine volume. This yielded similar results to the various immersion methods (**Table 4**).

Following the initial tests on control sample SG6, a range of pyroxenites and friable chromitites were tested, which illustrated that densities were generally within 1 to 3% of the calliper method. The significantly lower DBD of weathered material (e.g. sample SG2) highlighted the need to test density across a range of weathering domains within a mineral deposit.

It was concluded that for competent, non-porous core samples at the chromite mine the following methods were suitable: i) calliper; ii) water immersion and iii) gas pycnometer, while porous core sample densities are best measured using: i) calliper and ii) wax-coated, spray lacquered or vacuum-packed water displacement methods.

Case study – bentonite in Australia

Measuring the ISBD of sodium bentonite presents a whole set of challenges related to the fact that such material absorbs water and swells; therefore direct immersion in water cannot be used with much confidence.

MTI's sodium bentonite mine is located approximately 350km inland of Brisbane in Queensland, eastern Australia. The bentonite beds were deposited within a high energy fluvial/lacustrine environment of Upper Jurassic to Lower Cretaceous age. Several bentonite beds have been identified on the property; these range up to ~ 4m in thickness and consist of dioctahedral smectite (montmorillonite) with accessory minerals including feldspar, kaolinite, quartz and zeolite. The beds are capped by volcaniclastic rocks identified petrographically as either tuff or ignimbrite in addition to volcanogenic sandstone which is often cross-bedded. Silicified fossil wood is fairly common in sandstones and conglomerates above the bentonite.

In the case of the Australian bentonite example, all exploration drilling was carried out by an open hole method known as Rotary Air Blast (RAB) using a bladed bit, which results in small drill chips unsuitable for water immersion or the calliper method. An alternative drilling method was considered in order to measure ISBD and after discussion with the contractor, the RAB rig was modified to drill core (without water) at several strategic locations. On reclaiming the cores, all samples were sealed in plastic bags to retain in-situ moisture

ARTICLES

Table 3 Chromitite and pyroxenite drill core DBD estimated by various methods. Source: MTI

Method	Diameter cm	Length cm	Volume cm^3	Mass in air g	Mass in water g	Sealant mass g	Sealant density g/cm^3	Sealant volume cm^3	Density g/cm^3	Difference vs. Calliper
SG2 oxidised pyroxenite										
Calliper	6.3	11.35	353.95	880.25					**2.49**	
Vacuum pack				887.85	530.75	7.6	0.9	8.26	**2.52**	1.5%
Paraffin Wax				887.35	536.9	7.1	0.9	7.89	**2.57**	3.3%
SG6 competent pyroxenite										
Calliper	4.76	19.6	348.93	1145.85					**3.28**	
Archimedes				1145.85	801.05				**3.32**	1.2%
Cling Wrap				1147.95	786.1	2.1	0.9	2.28	**3.19**	-3.0%
Vacuum pack				1153.5	796.4	7.65	0.9	8.32	**3.29**	0.0%
Paraffin Wax				1154.85	800.2	9	0.9	10	**3.32**	1.2%
11R0007 22.1-22.8m (LG6 chromitite, friable)										
Paraffin wax (1/2 core)				175.8	132.65	1.55	0.9	1.72	**4.21**	
Spray Lacquer (1/4 core)				94.45	71.85	0.4	0.9	0.44	**4.24**	

Table 4 Fresh pyroxenite 'half' core BD estimated using the calliper method. Source: MTI

Sample ID SG10B ('half' core)	Width cm	Height cm	Length cm	Radius cm	Area cm^2	Volume cm^3	Mass in Air g	Density g/cm^3
SG10B fresh pyroxenite ('half' core)								
Calliper	4.72	2.255	18.3	2.36	8.26	151.15	487.55	**3.23**
Archimedes							487.55	3.37
SG10 fresh pyroxenite ('whole' core)								
	Diameter							
Calliper	4.793		18.3	2.40	18.05	330.32	1064.1	**3.22**
Archimedes							1064.1	3.35

before estimating density. The core samples were then trimmed with a hacksaw to yield regular cylindrical shapes from which volumes could be estimated using the calliper method, and moisture content derived from the 'shavings'. Density values of between 1.72 and 1.84 t/m3 were obtained (Table 5) and it was elected to use 1.8 t/m3 for estimation of *in-situ* 'wet' bentonite resources.

Once a mine is in operation, it is advisable to verify densities that were estimated during the exploration phase of the project. This can be achieved by surveying the volume of an excavated void, for example an extracted bentonite seam in an opencast

RAB drill chips at the Australian bentonite mine. Source: MTI

10 Bentonite core trimmed for calliper method. The core 'shavings' were used for moisture analysis. Source: MTI

pit and using this in conjunction with truckloads of mined material measured on a weighbridge (Table 6). This procedure was adopted at the Australian mine and verified that an ISBD range of 1.74 to 1.8 t/m3 is probably applicable to this type of bentonite (~27% moisture; ~ 80% montmorillonite). It is to be expected that ISBD would vary across such a deposit according to mineralogical composition, degree of weathering, moisture content and overburden thickness. A further benefit of reconciling actual volume and tonnes mined against the estimated mineral resource volume and tonnes is to verify the geology model. In this

Table 5 Bentonite ISBD estimated using the calliper method. Source: MTI

Bentonite	Length cm	Diameter cm	Volume cm^3	Mass g	Moisture %	ISBD tonnes /m^3
5D	4.6	6.4	148.0	254.6	27.3	**1.72**
5D	2.3	6.4	74.0	135.9	27.0	**1.84**

particular case the surveyed volume was within 3% of the modelled volume, indicating that the exploration and modelling methods were applicable for this style of bedded mineralisation.

Another example from the Australian mine addresses the estimation of bulk density of sun-dried (granular) bentonite stockpiles. As with surveying the volume of bentonite mined from a pit, an option for stockpiles is to measure the stockpile before and after shipment and estimate the volume removed. An alternative is to extract some material from the stockpile and fill a container of known volume, which can then be weighed. This latter procedure was adopted at the Australian bentonite mine and it was estimated from filling a box of one cubic metre volume that; i) loose (untapped) density was ~1.3 t/m3 and ; ii) that tapped density is ~1.4 t/m3 (**Table 7**).

Table 6 Bentonite ISBD estimated from a surveyed open pit, Australia. Source: MTI

Description	Bentonite	Tonnes hauled (over weighbridge)	Volume m^3 (surveyed)	Volume m^3 (geology model)	Difference in volume	ISBD (calculated t/m3)
NP Block 3	5D	10,017	5,773	5,947	3%	**1.74**

Case study - Barite

Given the recent trend towards the use of lower SG barite for oil drilling applications, this study evaluated the stoichiometric method of estimating density using a series of barite-silicate blends. The American Petroleum Institute standard for oil drilling barite was SG 4.2 until 2010, a new lower SG 4.1 product was accepted as an alternative standard. Over the past few years some experts in the oil industry expressed reservations that, as lower SG is related to dilution of barite by abrasive contaminants such as 'silica' (quartz or chert); this

'Dried and crushed' bentonite about to be tipped into cubic metre box. Source: MTI (above and below)

Table 7 Bentonite stockpile BD measured using a cubic metre box. Source: MTI

Bentonite	Location	Untapped Mass (tonnes)	Tapped Mass (tonnes)	Volume (m^3)	Moisture (%)	Density Untapped t/m^3	Density Tapped t/m^3
5B OP	Dry Stockpile	1.253	1.41	1	10.4	**1.25**	**1.41**
5D OPW	Dry Stockpile	1.306	1.43	1	11.9	**1.31**	**1.43**

would result in increased mill wear, increased tonnage required to be milled and more abrasive drilling mud. The consensus was that going to an even lower 4.0 SG standard would release more barite into the market, but could cause problems and increased costs for drilling fluids and waste management (Scogings, 2015a).

The author has calculated SG for a theoretical series of barite-quartz compositions between SG 2.7 and SG 4.5 in an attempt to quantify the effect of dilution by 'silica contaminants'. In addition, a series of barite-quartz dilutions (by mass) were prepared and measured by gas pycnometer at Intertek in Perth, Australia. The pycnometer results appear to verify i) the non-linear relationship between whole-rock chemistry and density and; ii) that a barite product with density of 4.1 could have as much as 23% silicate mineral by volume, rising to ~30% when SG is decreased to 4.0. This latter value for mineral impurities at SG 4.0 is higher than when assuming a straight-line relationship between chemistry and SG (**Table 8**).

Conclusions

- Mineral resource estimations rely on three main inputs: i) grade, ii) volume and iii) bulk density, of which the latter is often relatively neglected during mineral exploration

- The SAMREC 2009 code requires that the methods and assumptions of estimating bulk density be described when reporting Mineral Resources and Reserves

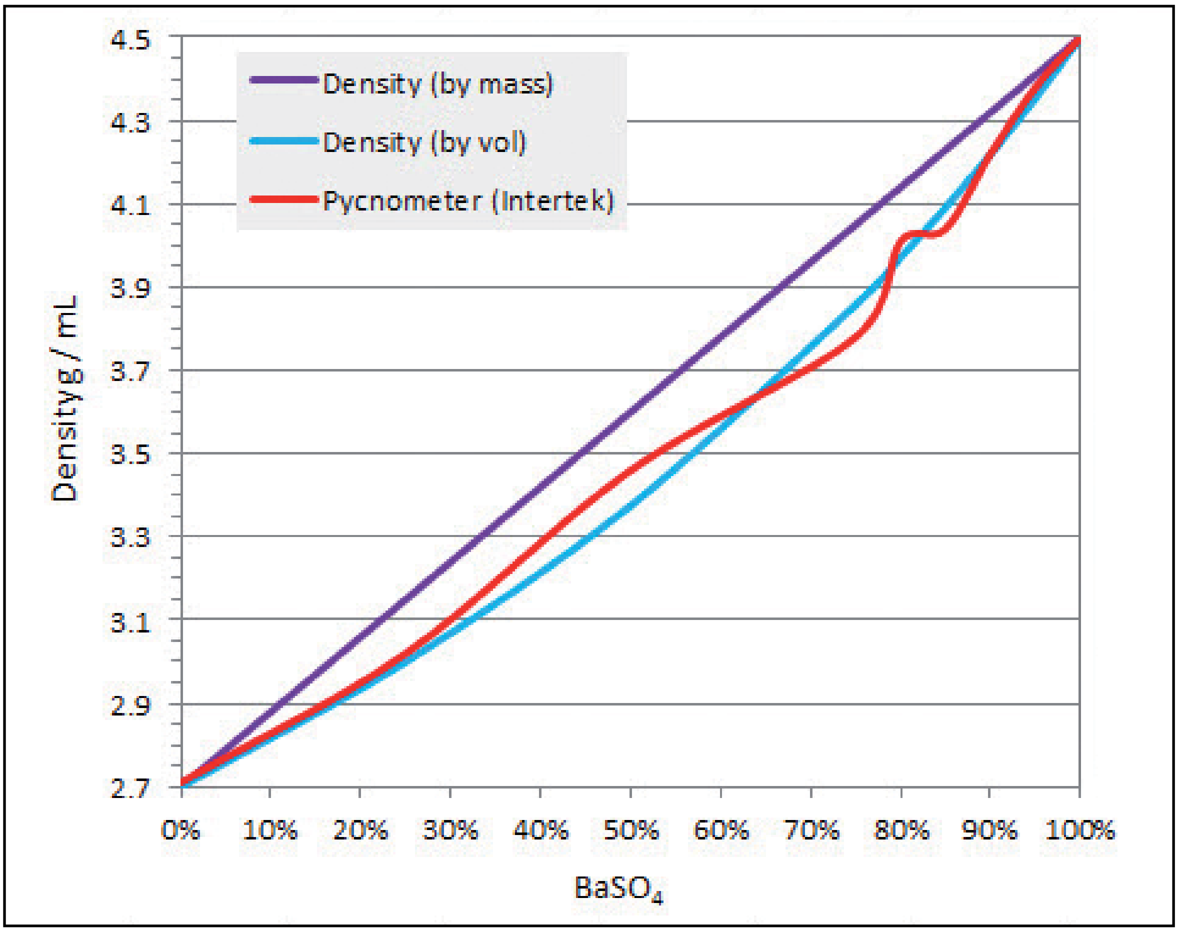
- Poor quality bulk density measurements result in unreliable tonnage estimates and impact negatively on mine scheduling and reconciliation of mineral production against reserves

- Determination of sample mass is the 'easy part' of estimating density. The difficult step generally lies in trying to determine the volume of a sample

- There are several methods for estimating the volume of rocks and materials, each of which has practical limitations and it is suggested that more than one method be used, as an internal check

Table 8 Barite product:
SG related to dilution by SiO_2 impurities

$BaSO_4$ (% by mass)	SiO_2 (% by mass)	SG (calculated) (g/mL by mass)	Barite (calculated) (% by volume)	Silicate (calculated) (% by volume)	SG (calculated) (g/mL by volume)	SG (pycnometer) (g/mL lab. blend)
100	0	4.50	100	0	4.50	4.50
95	5	4.41	92	8	4.35	4.38
90	10	4.32	84	16	4.22	4.22
85	15	4.23	77	23	4.09	4.04
80	20	4.14	71	29	3.97	4.01
75	25	4.05	64	36	3.86	3.78
50	50	3.60	38	63	3.38	3.46
25	75	3.15	17	83	3.00	3.02
0	100	2.70	0	100	2.70	2.71



Stoichiometric density estimates for barite-quartz blends. Source: Industrial Minerals Research, Intertek Perth

- The use of 'cling wrap' film to seal samples should be avoided, as entrapped air can lead to significantly low density results compared with other methods

- The method/s chosen should take into account physical and chemical variations across the deposit such as weathering, porosity, mineralogy and moisture content

- QAQC methods commonly applied to other factors in an exploration program should also apply to density measurements.

Acknowledgements
The author sincerely thanks Mineral Technologies Inc. for permission to use exploration data from its mines in Australia and South Africa. The assistance of Frazer Fallens and Ann Evers at Intertek Minerals Australia in Perth is gratefully acknowledged, as is the support provided by CSA Global Pty Ltd.

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Andrew Scogings
Principal Consultant, CSA Global Pty Ltd
Industrial Minerals Magazine Consultant
Perth, Australia

obituary:

David Grant Hutchins 1948 - 2015

David Hutchins was born in Torquay, Devon, England on 21 July 1948 and he died in Windhoek, Namibia on 30 April 2015.

He completed his schooling at Newton Abbot Grammar School in 1967 before entering the University of Southampton, England where he completed a BSc (Honours, Geology) in 1970. He then joined the Ministry of Overseas Development as a Natural Resources Student and attended the University of Birmingham, where he was awarded an MSc (Applied Geophysics) in 1971. His southern African connection started when he was posted to the Geological Survey, Botswana as a geophysicist. Here he joined Colin Reeves who had just completed a gravity survey of the Okavango Delta.

As this time Regional geophysical studies were playing an important role in the geological exploration of Botswana, particularly in the 80% of the country falling within the Kalahari where the bedrock geology is totally concealed by Tertiary to Recent Kalahari sediments. During the 1970s David was involved in a variety of major geophysical projects including the first national gravity survey of the country (1971-74) and a reconnaissance airborne magnetic survey of the Kalahari followed by ground truth drilling and geological exploration (1976). Subsequently David planned and supervised an airborne magnetic and radiometric survey of eastern Botswana to complete the reconnaissance coverage of the country.

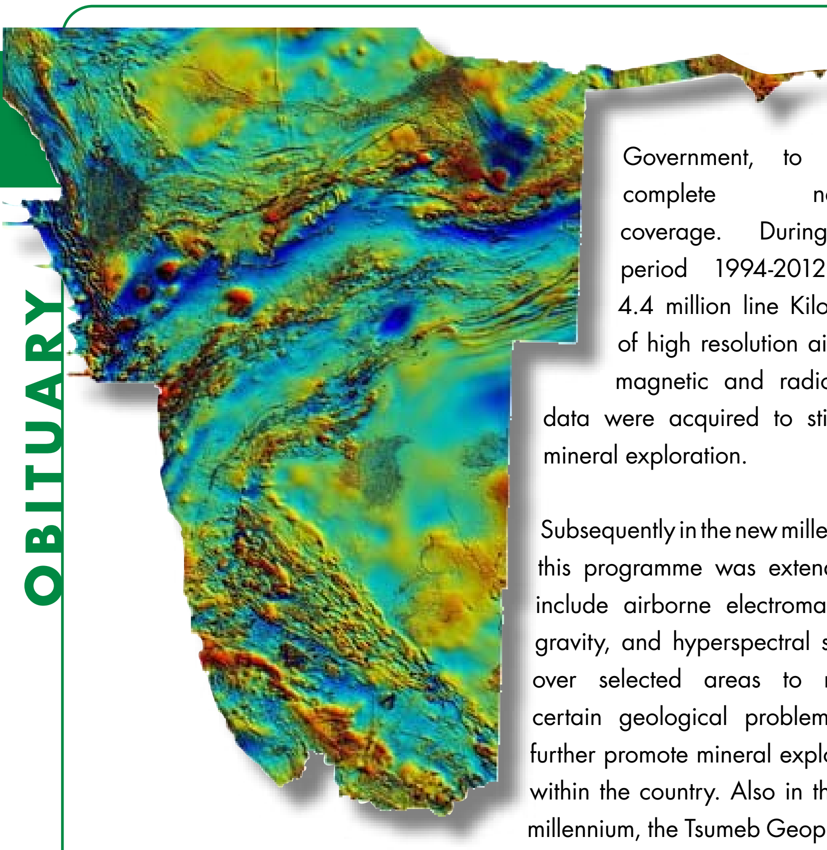
During 1972 David was also involved in a seismic refraction survey of the Okavango Delta in northwest Botswana and a study (with Christopher Scholz and Ted Koczynski) of microearthquakes in northern Botswana, September to December 1974, indicated that this region is tectonically active. Microearthquakes were found to occur primarily in a zone striking north-east from Lake Ngami through the Okavango delta to the Zambezi River (associated with an en echelon set of north-easterly striking normal faults of Quaternary to Recent age. These appear to be continuous with the activity at Lake Kariba and continuing further north along the Luangwa valley to the main rift zone south-east of Lake Tanganyika).

During his time in Botswana, David also undertook geophysical studies associated with rural drought relief and for the development water supplies for the then proposed Jwaneng Diamond Mine and the Morupule Coal Field. By the time he left Botswana he was Principal Geophysicist heading an embryonic geophysics division within the Botswana Geological Survey.

In 1986 David joined the Geological Survey of SWA/ Namibia as their sole geophysicist initially as Principal, and since 1988, as Chief Geophysicist. Prior to the independence of Namibia he planned and supervised four regional airborne magnetic surveys (78 000 line kms) and motivated the acquisition of the first hardware and software for the Geological Survey.

On Independence of the country, David organized the transfer to the Namibian government of the Windhoek Seismological Station and the Tsumeb Magnetic Observatory, respectively, from the Geological Survey of South Africa and the CSIR. He also became increasingly involved with the development of hydrocarbon exploration, the drafting of petroleum legislation and the interpretation of offshore seismic data prior to Namibia's first licensing round.

Post Independence, David became involved in many international and national projects including the compilation of Namibia's regional airborne magnetic and radiometric surveys in cooperation with the German Funded Mineral Promotion Project. This project (1992 -2002) also provided for the training of previously disadvantaged Namibians as geotechnicians and geophysicists. During this time he also planned and supervised high resolution (200m line spacing) geophysical surveys, initially funded by the European Union's SYSMIN fund and later funded by the Namibian



Government, to obtain complete national coverage. During the period 1994-2012 over 4.4 million line Kilometres of high resolution airborne magnetic and radiometric data were acquired to stimulate mineral exploration.

Subsequently in the new millennium, this programme was extended to include airborne electromagnetic, gravity, and hyperspectral surveys over selected areas to resolve certain geological problems and further promote mineral exploration within the country. Also in the new millennium, the Tsumeb Geophysical Station was renovated and a seismological and Infrasound monitoring station was established on behalf of the Comprehensive Nuclear Test Ban Treaty Organisation (CTBTO). This led to the establishment of a national seismological network consisting of 10 stations which by 2013 was nearing completion.

Whilst at the Geological Survey of Namibia, David served on numerous government and ministerial boards and committees including the Continental Shelf Submission of Namibia to UNCLOS; the Minerals Development Fund of Namibia Control Board; the Minerals Bill Committee; the Mineral (Prospecting and Mining) Rights Committee; and several Technical Advisory Committees (Oil Exploration). His professional affiliations have included: Society of Exploration Geophysicists, (District Representative for Africa and Middle East, 1984 – 1987); Australian Society of Exploration Geophysicists; Botswana Geoscientists Association (Founder member, Editor of Lentswe 1981 – 1982, Life member1985); South African Geophysical Association; and the Geological Society of Namibia. Numerous articles and papers have been published in scientific journals and papers have been presented at International geological, geophysical and investment conferences.

Dave's commitment to Namibia was illustrated by his becoming a Namibian citizen in February 1994.

Dave was also an avid Lawn Bowler who joined the Windhoek Bowling Club in 1987. From 1990 – 2005, Dave served on the Management Committee as President, Vice President (Competitions), Vice President (Club Affairs). Dave also served as President of the Namibian Bowling Association for 12 years.

Unashamedly, Dave used his contacts with the Mining Community to sponsor tournaments, equipment purchase, and even club renovations. His laconic style made his requests difficult to refuse. Among many fund raising efforts, Dave initiated and raised funding for Namibian Junior Bowls development, as well as travel funding for the Namibian team to World Championships. Recently, Dave represented Namibia in the Men's Veterans competition against South Africa.

This understated man leaves behind a rich legacy in geophysical excellence. Dave will be missed by his extended family, the geophysical community in southern Africa, Namibian bowlers and all those whose lives he touched.

Johan de Beer and Rainer Wackerle

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media monitor

MINING AND EXPLORATION NEWS

COPPER

Palabora Copper (formerly Palabora Mining Company) has approved the development of a R9.3 billion underground block cave operation extending 450 m below the current underground mine. Some R2 billion has been spent to date on the feasibility study, a twin decline system, and supporting engineering infrastructure. The project, known as Lift II, will extend the life of the mine until 2033.

Regal Resources completed a scoping study for fast-tracking the development of the Kalongwe joint venture in the DRC by the initial production of high-grade copper-cobalt concentrate using heavy media separation. The company is also evaluating the transition to a heap leach and potential stage 2 solvent extraction-electrowinning operation that would extend the mine life and more effectively exploit the current resource of 302 000 t contained copper and 42 000 t contained cobalt. Kalongwe is located towards the western end of the Katanga Copperbelt, approximately 20 km south of Ivanhoe Mines' Kamoa project, and Regal has an agreement with Ivanhoe to earn a 90% interest in a number of exploration permits surrounding Kalongwe.

INDUSTRIAL MINERALS

Israel Chemicals Ltd (ICL) has entered into an arrangement agreement to buy the 84% of TSX-listed Allana Potash that it does not already own for C$137 million. The deal gives ICL control of the Danakhil project in the Afar region of Ethiopia, which according to the 2013 feasibility study could produce up to 1 Mt of muriate of potash (KCl) per annum for 25 years, from 93 Mt of Proven and Probable sylvinite reserves at 28.5% KCl, using solution mining. Allana recently completed a preliminary economic assessment for the separate production of 1 Mt/a of sulphate pf potash production from the kainite resources, with a project life of 77 years.

In neighboring Eritrea, South Boulder Mines completed a preliminary feasibility study for its 50%-owned Colluli potash joint venture with the Eritrean National Mining Company (ENAMCO). Colluli is expected to become one of the world's most significant and lowest cost potassium sulphate (SOP) operations, with an expected production of 425 kt/a SOP, increasing to 850 kt/a from year five, and with a mine life of 30 years. However, the large 1289 Mt resource could accommodate substantial expansions. Mining will be by open pit using conventional truck and shovel operation. A definitive feasibility study will be completed in the third quarter of 2015, with first production planned for 2018.

IRON ORE

Shandong Iron and Steel Group has acquired the remaining 75% per cent stake in the Tonkolili iron ore mine in Sierra Leone from African Minerals for over $170 million. The group will also own the associated infrastructure company African Port and Railway Services. Shandong said it intended to return the mine to full production, and will fund the phase 2 expansion that will lift production to 25 Mt/a. African Minerals placed Tonkolili on care and maintenance in December 2014 due to insufficient working capital, and appointed administrators in March after failing to reach an agreement with Shandong, its secured lender and partner in the project.

NICKEL

Botswana Metals declared a maiden Inferred primary sulphide resource of 2.38 Mt at 0.72% Ni, o.21% Cu, and 0.63 g/t 4PGE+Au) for its Maibele North joint venture with BCL Ltd in Botswana. Maibele North, which is about 55 km to the northeast of BCL's nickel mine and smelter Selebi-Phikwe, is one of three known mineralised areas that make up the joint venture, in which BCL is spending A$4 million to earn an initial 40% interest.

PLATINUM GROUP ELEMENTS

Impala Platinum has deferred its Afplats project for four years in order to conserve cash. The company acquired its interest in the project, which is about 10 km west of Brits on the western limb of the Bushveld Complex, through the acquisition of African Platinum plc in 2007. Shaft sinking operations were begun in 2011 and have progressed to a depth of 1 025 m below surface. The minerals resources as at June 2014 are 160 Mt at 5.11 g/t 4E (26.4 million ounces), all within the UG2 Reef. Impala said that Afplats remains a quality resource, with significant potential to develop a low-cost mechanised mine.

RARE EARTHS

Rainbow Rare Earths Ltd, part of Africa-focused natural resource and energy group Pella Resources, has secured up to US$12 million from Pala Investments to fund the development of its high-grade Gakara rare earth project in Burundi through to full production. The deposit, located within the north-eastern Kibaran belt in western Burundi, comprises bastnaesite and monazite mineralisation in veins and stockworks. Rainbow has established a NI 43-101 compliant mineral inventory of 256 kt of ore at an in-situ grade of 54.3% total REO (141.8 kt contained REO) to a depth of 25 m, with over 50% of the value contained in the 'critical' rare earths (Nd, Tb, Dy, Eu, Y) and Pr, and with very low uranium and thorium levels. Rainbow is fast-tracking the project into production and aims to produce a high-grade (67%) concentrate using simple mining and density-based beneficiation techniques, for a capital cost of just US$5 million. A ten-year offtake agreement has been signed with ThyssenKrupp Metallurgical Products for 5 000 t/a concentrate or downstream products.

TITANIUM AND NIOBIUM

Cradle Resources increased the Measured and Indicated mineral resource in primary carbonatite at its Panda Hill niobium project in Tanzania to 68.8 Mt at 0.53% Nb_2O_5 (362 000 t of Nb_2O_5), with only one-third of the outcrop drill-tested to date. The preliminary feasibility study, completed prior to the update, outlined an open pit operation producing and 2 Mt/a processing plant producing 6800 t of ferroniobium per annum over 30 year life of mine for capital cost of US$158 million. The definitive feasibility study, which is now in progress, is scoped for a more capital-efficient start-up that will target 5000 t/a ferroniobium production – about 5% of world consumption.

URANIUM

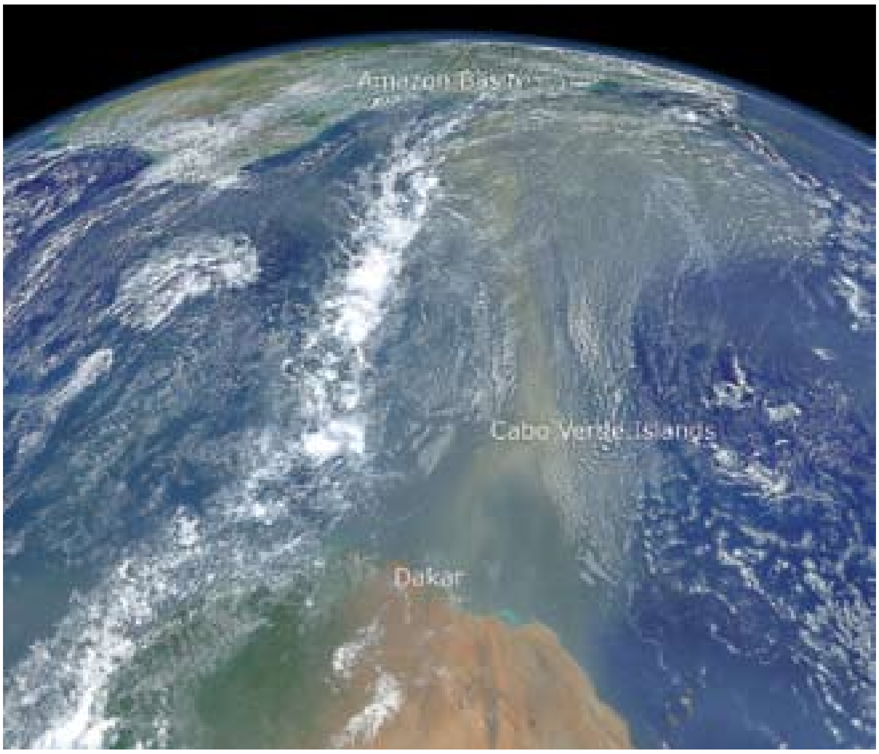
Forsys Metals announced the results of a feasibility study on its Norasa uranium project, comprising the Valencia and Namibplaas deposits, in Namibia. The production schedule has been modified to include an increased processing rate of 11.2 Mt/a, with an average production of 5.2 million pounds of U3O8 per annum over the 15-year life or mine. The capital cost is estimated at US$432.8 million, with average operating costs of US$34.72 per pound. Forsys is looking to attract strategic partners and investors for the next phase of Norasa's development.

OTHER GEOSCIENCE NEWS

Porphyry copper deposits, which supply 75% of the world's copper, are typically associated with magma intrusions in the crust above subduction zones. However, it is not clear how a single, copper-rich magmatic fluid could cause both copper enrichment and the precipitation of sulphide ore minerals within a zone of hydrothermally altered rock. In a paper published in Nature Geoscience [doi: 10.1038/ngeo2351], a team of researchers from the University of Bristol proposed a two-stage model for porphyry copper formation, involving brine enrichment followed by gas-induced precipitation. Based on observations of volcanism in modern subduction zones, they suggest that initially, copper-rich magmatic brines are exsolved from large dacitic intrusions and accumulate in the crust at a depth of a few kilometres. At a later stage, sulphides are precipitated by the interaction of the accumulated brines with sulphur-rich gases ascending from underlying mafic magmas in the same volcanic system, which react explosively with the brines to form sulphide minerals. High-temperature and high-pressure laboratory experiments simulating such gas-brine interactions yielded copper-iron sulphide minerals and hydrogen chloride gas at magmatic temperatures of 700–800°C and pressures of about 180 MPa, with textural and chemical characteristics resembling those in porphyry copper deposits. Lead author Professor Jon Blundy of the University of Bristol said that the findings could have far-reaching implications for the search for new copper deposits.

Every year, millions of tons of dust from the Sahara Desert are blown 2500 km across the Atlantic Ocean to South America. Now, for the first time, geoscientists have quantified the rate of dust transport, and shown its important role in supplying nutrients to the Amazon Basin. The findings are published in the February 24 issue of Geophysical Research Letters [doi: 10.1002/2015GL063040]. Using 3D aerosol measurements over 2007–2013 from NASA's Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) satellite, the team, led by atmospheric scientist Hongbin Yu at the University of Maryland, calculated that of the average 182 Mt of dust carried each year past the western edge of the Sahara at longitude 15°W, 27.7 Mt falls over the Amazon basin. About 43 Mt of dust is carried onward to settle out over the Caribbean. The actual pattern is highly variable, with the annual variation being negatively correlated with the previous year's rainfall in the Sahel. The fallout over the Amazon supplies about 22 000 t of phosphorus per year, equivalent to 23 g per hectare, to fertilize the Amazon rainforest. This is comparable to the hydrological loss of phosphorus from the basin, suggesting an important role for African dust in preventing phosphorus depletion on time scales of decades to centuries.

Antony Cowey



This composite image, from data from the Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi NPP satellite, shows dust from West Africa heading toward South America and the Gulf of Mexico, along a track roughly parallel to the intertropical convergence zone (Photo courtesy NASA Earth Observatory

media monitor

Longonot & Hell's Gate, Kenya

THE GEOTRAVELLER

By Roger Scoon

LONGONOT AND HELL'S GATE, KENYA: Active Volcanism in the Rift Valley

The Mount Longonot and Hell's Gate localities are located in the Rift Valley of southern Kenya. This, the eastern branch or Gregory Rift hosts numerous volcanic cones in a harsh, relatively dry and hot area of scrub-covered plains. In contrast, the climate of the rift platforms, which are forested or open savannas, is far more temperate. The rift in southern Kenya has an average height of approximately 1600-1800 m is bounded by steep walls on the eastern and western sides; the uplifted blocks locally reveal altitudes of over 3000 m.

A generalized map of the central part of Kenya depicts the north-south alignment of the Gregory Rift. The rift includes large, finger-shaped lakes that are mostly alkaline. Rifting commenced in the Cenozoic but the most prominent volcanoes are Quaternary in age. Many are still active. Volcanoes are notably prominent in the rift between Lakes Turkana and Natron. Barrier volcano constitutes a natural partition between Lake Turkana and the southern part of the rift that includes the active volcano of Oldoinyo Lengai in northern Tanzania.

Rift-related volcanic lavas and ashes extend tens of km either side of the rift. They overlie much older terrains, either granite-gneiss of the Tanzania Craton or metamorphic rocks of Proterozoic-age mobile belts. Other features of note are the Kisumu Graben, a branch of the rift that includes an arm of Lake Victoria, and Mount Elgon, a huge stratovolcano that straddles the border with Uganda.

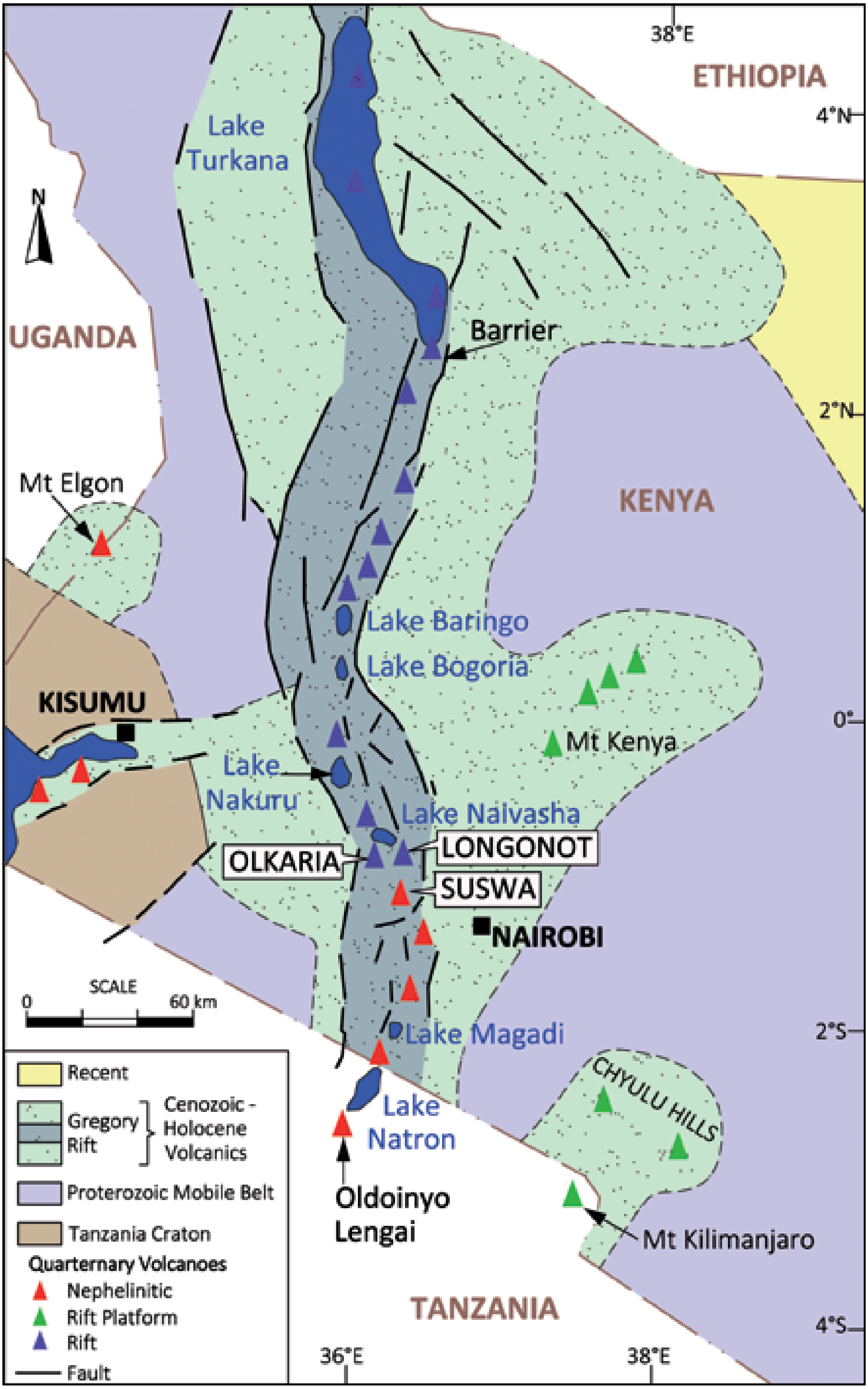
Longonot and Hell's Gate occur in the vicinity of Lake Naivasha, one of the few fresh water lakes in the rift. This area is almost exclusively volcanic. The prominent cone of Longonot occurs to the east of the lake and Olkaria Volcanic Complex (formerly known as Naivasha Complex) occurs to the south. The geology of the rift in this area was first described by Joseph Thomson, in 1885. Thomson is well remembered in Kenya for both his pioneering travels and negotiations with some of the nomadic people. Longonot and Hell's Gate (part of the Olkaria Volcanic Complex) were incorporated into national parks in 1984. The proximity to Nairobi results in the parks being visited by large numbers of tourists, many of whom undertake hiking trails in the volcanic terrains. They are important migration corridors and host several endangered species, but the geology is their most important feature, and it is for this reason that Hell's Gate was awarded UNESCO Heritage status in 2010.

The Longonot volcano is located in the centre of the rift, approximately 60 km from Nairobi. It includes a central cone with a near circular summit crater. The name "Longonot" is derived from the Maasai language describing a mountain of many steep ridges: these correlate with recent lava flows that have flowed down the cone to peter out on the plains. Longonot last erupted around 1860. Hell's Gate is so named because of the narrow break in the volcanic cliffs that wall in the lower parts of the Njorowa Valley. More than eighty centres have been identified in the Olkaria Complex, with the most recent flow dated at approximately 190 BP.

Longonot

The main tourist feature of the Longonot National Park is a 13.5 km hiking trail that provides the opportunity to climb an active volcano. This includes a circle of the summit crater. The trail starts at the gate on the northern slopes, at an altitude of 2,150 m and climbs to 2,780 m. Parts of the trail are very steep as recent ash deposits are severely eroded. The highest point of the rim constitutes a distinctive peak on the northwestern flanks. The summit crater has a diameter of 1.8 km. The floor is thickly forested and is difficult to access because of the near vertical internal walls that are up to 350 m high. A prominent satellite crater occurs on the northeastern flanks. In 2009, an intense bush fire caused considerable damage and photographs of Longonot may depict a barren scene, whereas, typically, the slopes of the cone are well wooded.

The Longonot volcano has an area of 3,500 square km, but ashfall covers an area of up to 30,000 square km.



Generalized map showing the Gregory Rift and Quaternary volcanoes, Kenya. Volcanoes of alkali basalt occur both within the rift and on the rift platform. The nephelinite (and carbonatite) volcanoes are restricted to the rift. (Map simplified from a presentation by Mariita.)

Part of the forested summit crater at Mount Longonot.

View of the central cone, Mount Longonot from the northern slopes. Longonot is an active volcano located in the rift valley.

Ash from Longonot is locally intercalated with products of the Olkaria Volcanic Complex at Hell's Gate. Volcanism at Longonot commenced around 400,000 BP. The central cone and summit crater, however, are much younger, having formed around 3,500 BP. The most recent lava flows occur on the flanks and within the crater. The fronts to some of the flank flows may be 40 m in height. The central cone and crater are enclosed within a large caldera, some 12 by 8 km in diameter. Multiple caldera events have been identified over a period between 21,000 BP and 6,000 BP. Parts of the outer perimeter of the caldera form steep cliffs amid the rugged scenery south of the cone. The view of these features from the track

View from rim of summit crater at Mount Longonot looking south over rugged terrain associated with the edge of the caldera.

that circles the summit crater includes the much larger Suswa volcano. Geophysical data has suggested there may be older calderas outside of the main perimeter at Longonot.

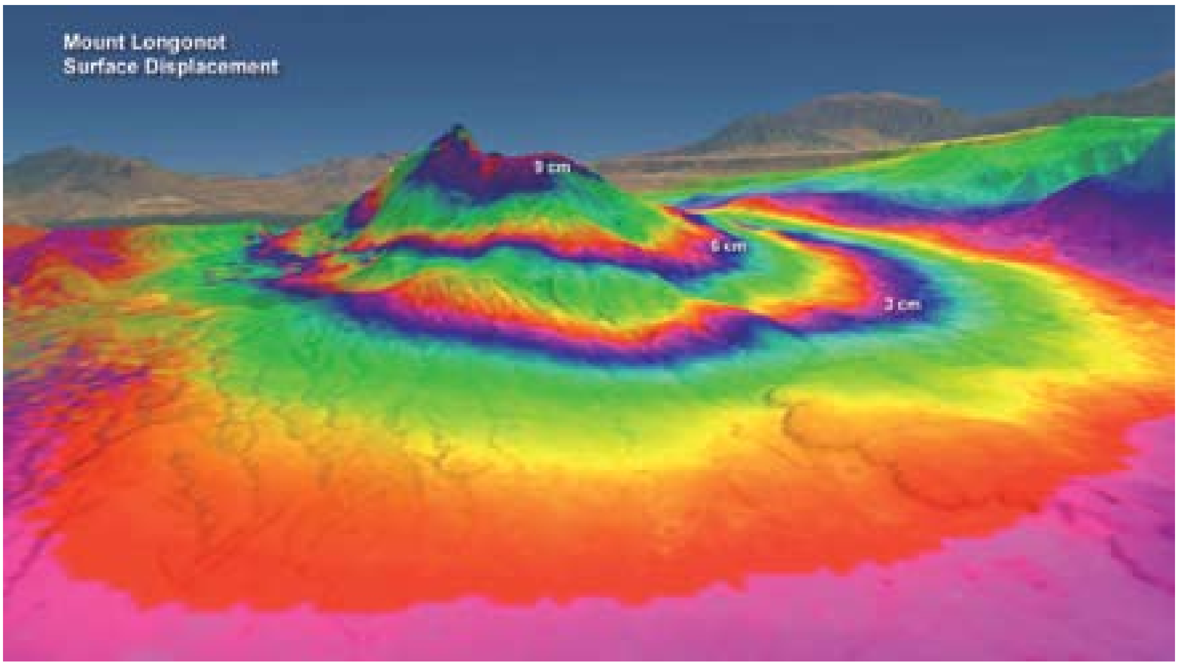
Longonot is dominated by lavas and pyroclastics with compositions of trachyitic basalt. The caldera event triggered huge outpourings of both lavas and ignimbrites. Seven major periods of activity have been recognized, these include the early activity, repeated caldera events, building of the cone and summit crater, and the most recent flows. The greater part of the lavas and ashes erupted are not represented in the exposed material so that calculating the average compositions is problematic. On the basis of detailed studies of tephra from Longonot and the adjacent Suswa volcano it has been suggested that the calderas at both localities formed, not from depletion of individual chambers, but from a regional event. This is supported by the presence of a large dome within the rift responsible for all of the volcanic centres in the vicinity of Lake Naivasha. This uplifted terrain is cut by a series of NNW-SSE lineaments associated with crustal extension (the rift is estimated to be spreading at the rate of 3.2 mm/annum). The caldera events at Longonot and Suswa may have been driven directly by rifting and the ensuing rapid decompression of shallow magma chambers.

Geodatic activity recorded at Longonot suggests the presence of an active magma chamber at a shallow depth. Changes in the land surface recorded by satellite imagery show the surface has bulged upwards a few tens of cm over the last ten years. There are few significant, near-surface geothermal features at Longonot due to the thickness of the young pile of pyroclastics. Those that have been identified occur either in the summit crater or high on the flanks of the cone. Small fumeroles and sulphur vents can be observed from the main track.

Light coloured pyroclastic with abundant lithic fragments, Mount Longonot.

Hell's Gate

The average elevation of the Hell's Gate NP is 1900 m. The park is relatively small, with a total area of only 68 square km. The site of abundant plains animals grazing in a relatively barren volcanic landscape is fascinating. One of the main features is a 2-3 hour hike along the



Landsat 7 ETM+ image mosaic of Mount Longonot looking northwest over Lake Naivasha to the Mau Escarpment (western wall of rift). Overlaid with interferometric radar (InSAR), European Space Agency' (ESA) Envisat. Surface displacement is for June 2004 - May 2006 with uplift at 3, 6 and 9 cm. Image provided by Planetary Visions (joint project with University of Bristol and ESA).

The cliff faces near the Elsa gate of the Hell's Gate National Park. Thick layer of columnar jointed ignimbrite at the base of the cliff is one of the youngest products of Olkaria Volcanic Complex.

upper parts of the Njorowa Gorge. This is locally up to 200 m deep and in places very narrow. The gorge reveals sections of the volcanic pile and includes fumaroles and hot springs. Njorowa Gorge has been the setting of a number of well known films, including Tomb Raider and Mountains of the Moon. Possibly the most iconic feature of the park are rock pinnacles, including the Fishers and Central Towers. These are not volcanic plugs, as may be thought, but relicts of retreating cliff faces that include a prominent layer of columnar jointed ignimbrite. Several caves with abundant obsidian are an additional feature. The park has a Joy Adamson educational centre, which together with the Elsa Gate is named in memory of this famous conservationist.

The multi-centred Olkaria Complex covers an area of some 240 square km. The oldest date obtained is 45,000 BP. The complex is active and there are numerous fumaroles. The relatively shallow magma chamber is the source of an extensive geothermal feature. The lavas and pyroclastics at Olkaria have a wide compositional range, including basalt, trachyte, and peralkaline rhyolite. Numerous centres are identified and there is no single large cone. The lavas generally occur as small, steep-sided domes and short flows. The largest dome, Olkaria Hill has a diameter of 2 km and height of 400 m. Drilling for the geothermal resource (see below) has revealed the volcanic pile persists to a depth of at least 2,500 m. The oldest rock layer on surface at Hell's Gate is the Maiella pumice formation. This is the product (ash and lapilli tuff) of a catastrophic Plinian eruption. The layer of pumice is overlain by the Olkaria trachytic lavas. These in turn are partially covered by one of the youngest products of the complex, a thick layer of ignimbrite. This rock is readily identified: it is pale grey and includes welded lithic fragments. This ignimbrite, the product of an extensive

The 25 m high Fishers Tower at Hell's Gate is an erosion relict.

LEFT: The hike through the narrow, upper part of the Njorowa Gorge, Hell's Gate includes scrambling with escape routes established after a recent serious flood event. Thick vein of obsidian in the background. The dark colour of the river gravel is due to obsidian or volcanic glass.

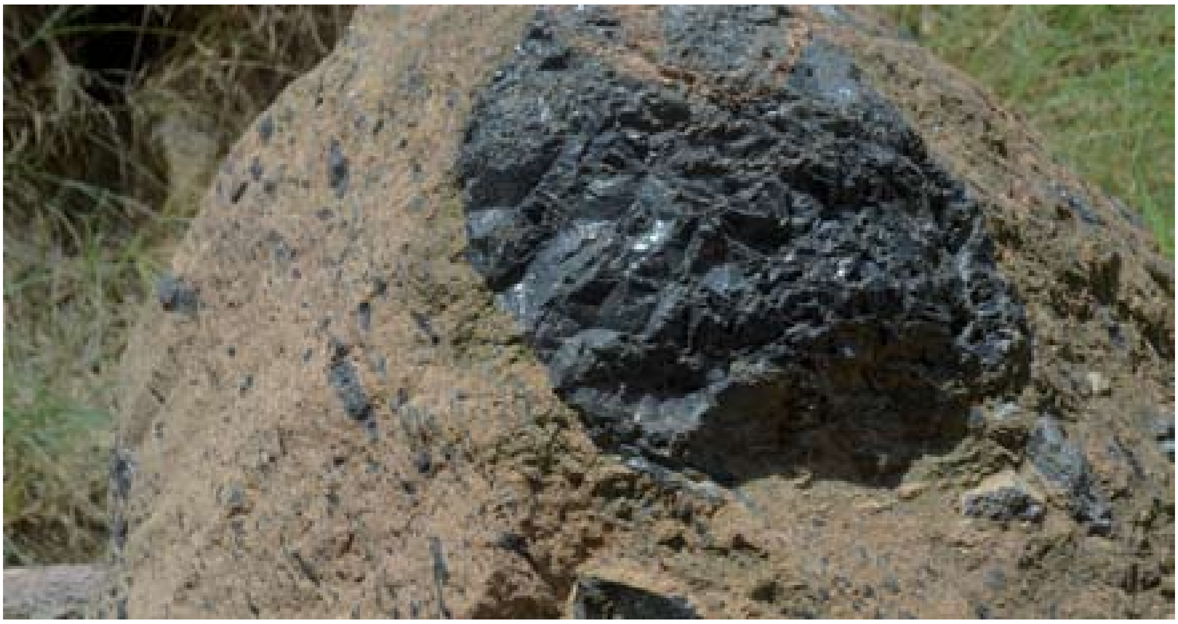
RIGHT: Spectacular layering of lavas and ashes in the Njorowa Gorge. The yellowish colouration is typical of rhyolitic compositions.

pyroclastic flow, one of the most devastating products of this style of volcanism, forms the most prominent of the layers in the cliffs near the Elsa Gate, as noted above.

The Njorowa Gorge was formed by waters draining into a much larger paleo-lake during Pleistocene when lakes Naivasha, Elmenteita and Nakuru were connected. Eruptions at the Olkaria Complex were mostly beneath this lake. Sidewalls in the upper part of the Njorowa Gorge are made up of layer upon layer of lava, ash, and pyroclastics. They include finely bedded ash deposits indicative of a subaqueous origin. Flow banding and pipe vesicles can be observed in some sections. Fumeroles and hot springs are demarcated by multi-coloured algae, the colour being determined by temperature (red-orange colours reflect a high temperature; yellow intermediate, and green-blue cooler).

Many features of the Njorowa Gorge can be compared with Yellowstone, Wyoming, including the colour of the cliffs, active fumaroles and the occurrence of obsidian, or volcanic glass. At Hells gate, obsidian occurs both

Finely layered ashes indicative of a subaqueous origin, Njorowa Gorge.



Samples of massive obsidian are readily obtained in the Njorowa Gorge

in the gorge and in several caves, the latter including lava tunnels that may reveal lava drips from the roofs. A vein in the gorge, which is approximately a metre in thickness, is associated with a prominent joint or fault. The obsidian occurs within the vein as both a massive filling and as thin veinlets where banded with the earlier formed sidewalls of lava and ash. Erosion has littered the floor of the gorge with samples that range in size from boulders or pebbles to gravel. The jet black, glassy obsidian has the typical conchoidal fracture. Obsidian was commonly used by ancient cultures for stone tools and the larger samples at Hells Gate shatter readily into knife-sharp shards. Obsidian forms when the mobility of ions within a highly siliceous or rhyolitic melt is prevented from achieving an ordered crystalline pattern. Typically this is due to very rapid heat loss. Obsidian is associated with lava flows that have a lower viscosity than their rhyolite host, thus the banded texture. Typically, this occurs as one of the final eruptive phases of siliceous, volcanoes, after the bulk of the gas and pumice has been vented.

The Olkaria geothermal field is situated in one part of the Hell's Gate National Park. The view of a series of well heads venting off steam under pressures too great to be piped is of interest. This is a world class power generation site with a high enthalpy field. Wells are drilled to a depth of around 2,500 m where they source temperatures up to 300 degrees C. The potential of the rift valley for geothermal energy has long been known and many of

Multi coloured algae associated with hot springs, Njorowa Gorge (Scale provided by Mohammed Billow).

View of well heads venting steam, Olkaria Geothermal Field.

the Quaternary volcanoes located within the Gregory Rift of Kenya have substantial sources of geothermal energy. The operator, KENGEN, drilled the first set of wells at Olkaria in 1976. A fourth steam turbine-driven generating station has recently been commissioned. The field currently produces some 600MW of geothermal power. The hydrothermal waters are relatively siliceous and, together with other impurities may block wells and turbines. Trapping of some contained metals has resulted in production of high quality silicon as a by-product. By far the largest economic activity in vicinity of Lake Naivasha is, however, the growing and export of cut flowers: this is a huge earner of foreign exchange for Kenya. This enterprise is greatly assisted by the nutrient-rich volcanic soils that extend from the western slopes of Longonot to the shores of Lake Naivasha.

Acknowledgements:

The National Park guides are highly recommended for their local knowledge of areas where there is danger from wildlife, flash floods etc.

Photographs by the author

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EXPLORATION GEOLOGIST
SOUTH AFRICA

Allan E Saad
Msc Pr Sci Nat
FGSSA
CONSULTING
EXPLORATION
GEOLOGIST

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CONSULTING GEOLOGIST

David de Carcenac
B Sc (Hons) FGSSA Pr Sci Nat

Consulting Geologist

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Bsc (Hons) Msc (Wits) Pr.Sci.Nat, MGSSA

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