GSSA
Geological Society of South Africa

geobulletin

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35TH INTERNATIONAL GEOLOGICAL CONGRESS

XXXV GEOLOGORUM CONVENTUS · CAPE TOWN · 20 16 · SOUTH AFRICA · MENTE ET MALLEO

We are here at IGC!

giya ngomhlaba dance with earth

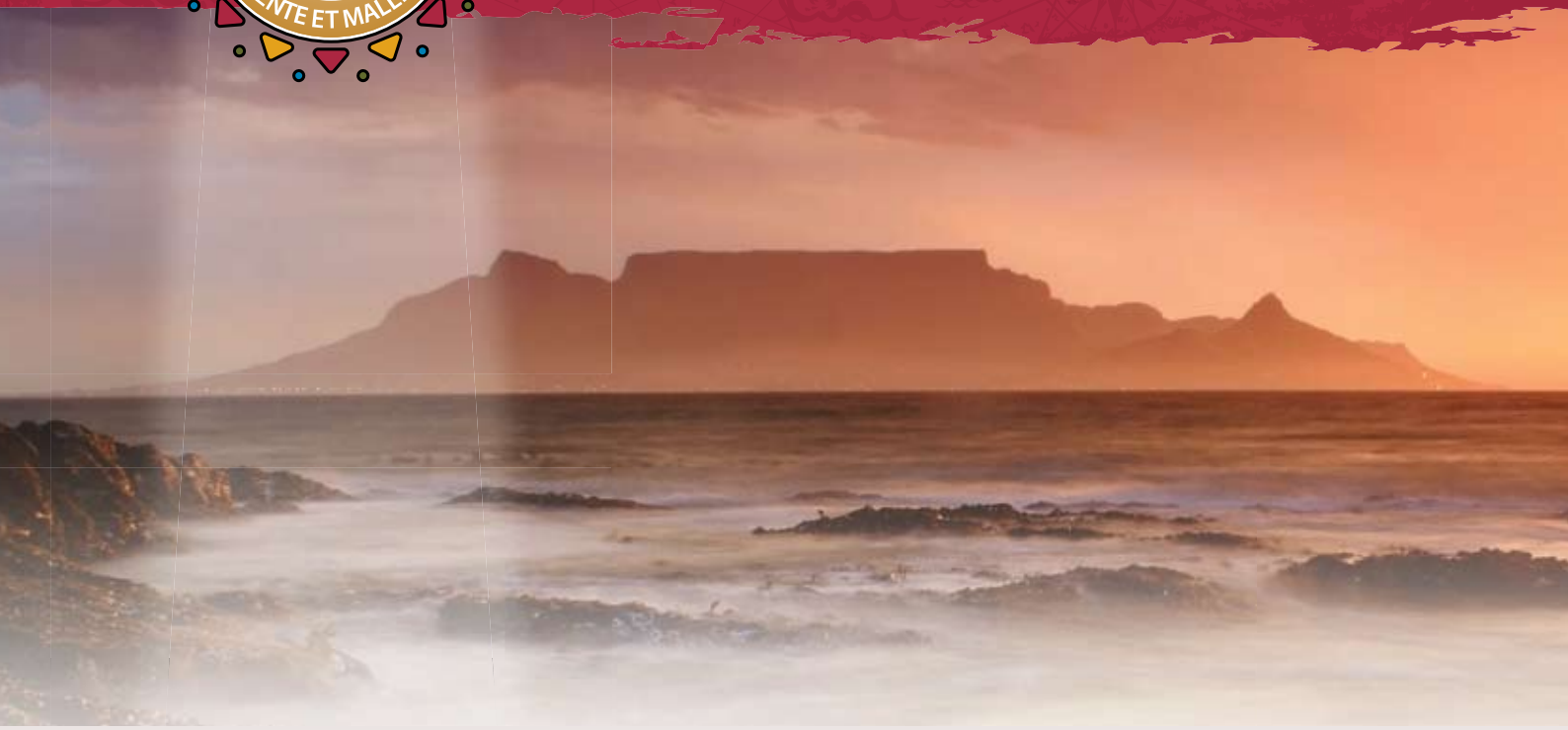
27 AUGUST - 4 SEPTEMBER 2016 I CAPE TOWN, SOUTH AFRICA

UCT du Toit lecture
Pre-IGC field trips
Mineral Scene

news

35TH INTERNATIONAL GEOLOGICAL CONGRESS

27 AUGUST - 4 SEPTEMBER 2016 | CAPE TOWN, SOUTH AFRICA



www.35igc.org

IUGS International Union of Geological Sciences

GSSA Geological Society of South Africa

Council for Geoscience

UNESCO United Nations Educational, Scientific and Cultural Organization

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GSSA
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

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from the editor's desk

Chris Hatton

The climate change debate doesn't seem to end. The relationship between carbon dioxide in the atmosphere and temperature is based on the measurements of carbon dioxide and hydrogen isotopes from the drill-core into the Vostok ice sheet. In this miraculous age of the internet anyone can look at the data themselves. Here you see a pattern which is unusually clear and unambiguous. When the carbon dioxide concentration in the trapped air bubbles goes from about two hundred ppm to three hundred ppm, the temperature goes up by about eight degrees. The fact that carbon dioxide is a greenhouse gas suggests that an increase in carbon dioxide caused an increase in temperature, rather than the other way around. The other unambiguous fact is that for the last 400 000 years the carbon dioxide in the air bubbles trapped in the Vostok ice sheet never went much higher than three hundred ppm. The exception is the last 100 years, when the concentration approached, and has now exceeded, four hundred ppm. The reasonable explanation for this is that burning of coal, starting with the industrial revolution, caused the increase. Because we humans burnt the coal, it is hard to deny that this recent increase in carbon dioxide can be attributed to human activity. Because increased carbon dioxide causes an increase in temperature, anthropogenic global warming must surely be real. It seems that we failed to pay proper attention when this issue was raised this issue in Geobulletin a few years ago. A few years on, and it appears to be time that we geologists should also accept what most other rational humans already have; burning fossil fuel is not a good way to generate energy.

But then there's the question of scale. The increases from two to three hundred ppm in carbon dioxide took place over ten thousand years. In geological terms this is virtually instantaneous, but on a human scale, this is too long to be of concern to the average citizen. Civilisations rise and fall over hundreds of years. On this relatively short time scale, the natural variations in solar intensity may be the responsible agent. Here at the 35th IGC, which is just getting underway at the time of writing, Bob Scholes related the rise and fall of Mapungubwe to the coming and going of rain cycles. Round about the time of Mapungubwe, English towns which are now kilometres from the sea had sturdy harbour walls. The iconoclastic sedimentologist, Roger Higgs, pointed out that the changes in sea level necessary to account for this must have proceeded at a rate which is five times faster than the IPCC uses in its forecasts. We may now be on the cusp of another rapid change. From this perspective it is the sun that is going to drive up temperature and sea-level is going to rise drastically in the next hundred years,

independently of carbon dioxide in the atmosphere. Humans can certainly do nothing about changes in solar intensity so if this is the main driving agent a miraculous application of human ingenuity will be needed to take us through the turmoil ahead.

Meetings like this 35th IGC are where ideas are exchanged and solutions are sought for an ever-expanding range of questions. In this issue we report on the pre-IGC field trips where delegates were able to examine at first hand the South African contribution to the rock record of geological processes and cycles. Chris Hawkesworth examined the longest of these cycles, that relating to the formation of the continental crust, in the du Toit lecture at UCT and again in a plenary lecture at the IGC. In the pre-IGC presentation of the du Toit lecture at UCT the re-opening of the Mantle Room was announced. Some of the xenoliths stored there were on display during the IGC. The opening of the Mantle Exhibition and other events from the cutting edge of science, which for this week is at the 35th IGC will be reported on in the next issue.

The South African Journal of Geology is about to become a print on demand journal. For a while at least Geobulletin will continue to appear on paper because it is a magazine which relies on its high-quality printed images. The spectacular images in Mineral Scene, which appears for the first time in this issue and will be a regular feature, are a welcome addition to Geobulletin.

Chris Hatton

executive managers corner

Craig Smith

Our esteemed editor has just informed me that he is going to press with the next issue – and he wants my column – yesterday. So I'm composing this at the GSSA exhibition stand in the Cape Town International Convention Centre a few hours before the opening of the conference.

Pardon the pun, but the GSSA exhibition stand is a stand-out! A glance around the exhibition hall floor is pretty impressive, given the variety of exhibitors as well as the obvious high standard of the stand builds. I can assure our membership that the GSSA effort compares favourably with the best of them. Congratulations to Lully and Sally in particular for the time and effort put into this; it shows. Well done to GL Events, the contractor who designed and built the stand.

We even have GSSA branded chocolates!

The pre-conference field excursions and workshops have gone well for the most part, and our pre-

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conference visitors have enjoyed some tremendous spring weather. The visitors who have travelled up the West Coast have seen a wild flower display that is reputedly the best in a number of years.

The technical program looks strong and the conference 'app' with the program details was finalized with a day or two to spare. This conference differs from previous Congresses in so far as we are moving further into the digital era, and away from the time of the 'printed brick'. Abstracts are posted on the website, www.35igc.org; printed programs with each day's proceedings will be available each morning, and the full program is available electronically to the downloadable app (links sent to each delegate).

As you can imagine, the last four to eight weeks have been hectic for members of the IGC organizing committee, as well as our contracted Professional Conference Organizer. There are a multitude of sub-contractors for this event, and I think the scale of the undertaking was well illustrated in the final pre-conference operations meeting held on the 25th of August. Last minute problems and issues were ironed out over the course of a full day, with 50 to 70 subcontractor representatives – and we did not see everyone. Some of these companies were working 24/7 for two to three weeks prior.

While the GSSA focus for the last couple of months has been on IGC, we have not entirely neglected other issues. A decision has been ratified by Council to move to a 'print on demand' model for SAJG, and we will write this into the 2017 membership fees structure to be circulated in September. The majority of our members now access SAJG electronically through Geoscience World. Printing and posting costs are environmentally unfriendly and have been cross subsidized for some time. It is not feasible to continue this practice. Further, many of our members have expressly asked for the Journal NOT to be shipped to them, and the postal system is unreliable. (I have just had complaints about two month mail delivery times – if it's delivered at all. You can still get a printed copy of SAJG if you need it, but this will be an additional cost option on your dues statement. It will be the same high quality print that you receive now if you select a print option. We will be printing some copies for archival purposes in any case.

Craig Smith

president's column

Jeannette McGill

I write this from the LOC war-room overlooking the bustling exhibition hall on the 4th day of the 35th International Geological Congress. The initial frantic pace has slowed and everyone is happily working on each area of responsibility. I am very proud of all that the team has achieved. As one of the largest Geosciences conferences that has ever taken place on African soil we should collectively be proud of our achievements.

A strong observation that has been raised in a few chats has been that while the conference is large it also extends us as geoscientists beyond our usual technical channels of practice. People who possibly thought they were the only person involved in a research channel have now discovered an entire network of peers. This underpins one of the important drivers for attending such events: network growth and the opportunity for cross-collaboration. These career investments will surely reap dividends in all our careers going forward. Start planning your trip to India for the 36th International Congress in 2020 now!

Dr. Jeannette E. McGill

GSSA stand at 35th IGC.

Lights on in Cape Town.

all the news fit to print

STELLENBOSCH

Earth Sciences

For this issue, we have many interesting and significant things to report.

Staffing Matters

After two years, the Faculty of Science finally caught up with Professor Alex Kisters and, on August 2nd, he delivered a typically lucid and fascinating inaugural lecture in front of an audience of friends, staff, students, former colleagues and government and industry associates. Alex's talk was entitled "What Lies Beneath Table Mountain or All Models are Wrong, but Some are Useful". Alex reviewed the various models for the development of the Malmesbury Group, concluding that it contains no really exotic terranes but instead represents an accretionary wedge, deformed initially in oblique, southeast-directed subduction. Alex reminded us that models are critical for understanding the geological development of a region but that we must always bear in mind the limitations of the models that we present. We all congratulate Alex on his full professorial appointment and wish him every success for his future at Stellenbosch. The photo above shows Alex (right) with Prof. Eugene Cloete (Vice Rector for Research, Innovation and Postgraduate Studies) and Prof. Louise Warnich (Dean of the Faculty of Science).

Science Highlights

1. THE VREDEFORT PSEUDOTACHYLYTES: A CENTENNIAL REAPPRAISAL

Almost precisely a century ago, venerable Stellenbosch University Professor S. J. Shand applied the term 'pseudotachylyte' to widespread, highly irregular, commonly clast-loaded, dark, flinty veins in granites and gneisses (Fig. 1A & C) within the Vredefort dome of South Africa (Shand, 1916). Following in his footsteps, Dr Martin B. Klausen (from the same Earth Science Department) has, together with a colleague from the Geological Survey of Denmark and Greenland (Garde and Klausen, 2016), introduced seismic shaking as a key process in the formation of its enigmatically voluminous pseudotachylytes within what is now known to be a circa 2.023 Ga meteorite impact structure.

The process of seismic shaking is well known from meteoritic impacts on the Moon (e.g. Fig. 1B) and asteroids, from terrestrial earthquakes and rock slides, as well as from nuclear tests, but has been largely overlooked in terrestrial cratering, except in the theoretical concept of acoustic fluidisation (Melosh, 1979). Previous struggles to convincingly explain Vredefort's large pseudotachylyte volumes through frictional, or instantaneous 'shock', melting/cataclasis, are now elegantly resolved by repeated comminution of blocks, initially loosened within a dendritic fracture system that was generated during the early, high-amplitude stage of seismic shaking (Fig. 1A). Continued high-frequency oscillations of these loosened blocks led to size reduction, rounding and further comminution (Fig. 1C), and eventually even frictional melting of K-feldspar and biotite in the comminuted mass. Most pseudotachylyte was thus not injected from elsewhere but produced in situ. Furthermore, microstructural analysis shows that most of the pseudotachylyte is actually finely comminuted material rather than former melt.

2. CONCENTRATION AND DISSOLUTION OF TRACE METALS FROM KNOWN DUST SOURCES IN NAMIBIA (HOW NAMIBIAN DESERTS FERTILIZE THE OCEAN FROM ABOVE)

Our Environmental Geochemistry Masters student, Ismael Kangueehi took part in a Summer-school program hosted at the University of Namibia's Sam Nujoma Campus and Marine Research Centre in Henties Bay, from the 2nd of May to 3rd of June 2016. The Regional Graduate Network in Oceanography (RGNO) for Southern Africa (in Namibia) offers research-driven

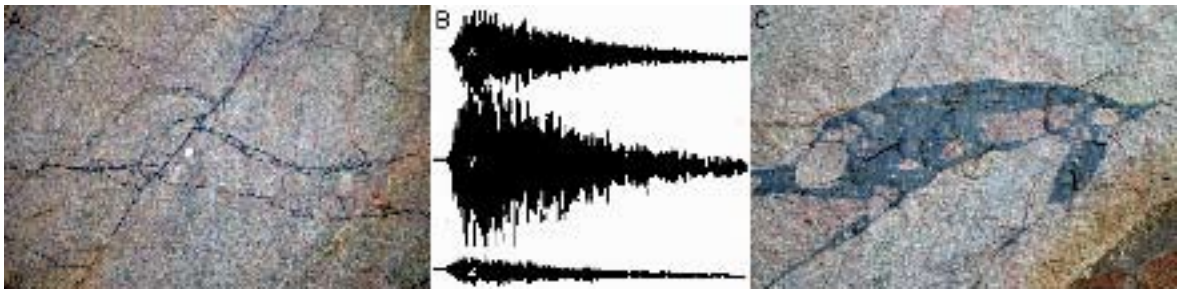

Figure 1: (A) Thin pseudotachylyte veins within a dendritic fracture system, generated by the initial shock waves from the c. 2.023 Ga Vredefort meteorite impact, as well as along a more regular, and presumed pre-existing, fracture/fault that cuts diagonally across the photo. (B) An approximately 90 min. three-component seismographic record of a Lunar meteorite impact (13 May 1972; modified from Nakamura et al., 1982) illustrating the amount of seismic shaking following initial impact. (C) A thicker, more voluminous, pseudotachylyte with characteristic rounded clasts, typically formed in situ through prolonged seismic shaking of loosened block corners (i.e. at intersections between fracture sets in A) and repeated comminution of dismembered clasts. Both field photos are from the Esperanza quarry and show approximately the same field of view, with a R5 coin for scale in (A).

Garde, A.A. and Klausen, M.B. 2016. A centennial reappraisal of the Vredefort pseudotachylytes: shaken, not stirred by meteorite impact. Journal of the Geological Society (London) in press. doi: 10.1144/jgs2015-147.

Melosh, H.J. 1979. Acoustic fluidization: a new geologic process? Journal of Geophysical Research 84: 7513-7520.

Nakamura, Y., Latham, G.V. and Dorman, J. 1982. Apollo lunar seismic experiments – final summary. Journal of Geophysical Research 87, A117-A123.

Shand, S.J. 1916. The pseudotachylyte of Parijs (Orange Free State) and its relation to 'trap-shotten gneiss' and 'flinty crush rock'. Quarterly Journal of the Geological Society of London 72: 198-217.

and practical learning opportunities for researchers in oceanography and integrated disciplines. Sailing on the Mirabilis Research Vessel for two weeks with RGNO, participants carry out research in the Namibian Ocean by collecting sediment cores and water samples. This course provided Ismael with an excellent opportunity to study the North-South flowing Benguela Current, which creates cells along the coast where cold, nutrient - and CO_2 - rich upwelling water leads to one of the world's most productive marine ecosystems.

The theoretical part of the program involved lecture sessions by various guest speakers and course instructors, on subjects ranging from physical and chemical oceanography, sedimentary organic and inorganic geochemistry to molecular biology and environmental geobiochemical modelling. Stellenbosch Earth Science department senior lecturer Dr Susanne Fietz was one of the guest lecturers, addressing the group on Fe fertilization and the use of the software package Ocean Data View (https://odv.awi.de/) in marine research and exploration. As a collaboration program with scientists from ETH Zurich, the University of Minnesota, the AGOURON Institute, the University of Namibia, the Scientific Committee of Oceanic Research (SCOR) and the Leibniz Institute for Baltic Sea Research, this course attracted students from across the globe.

Ismael Kangueehi handling a sediment core, with the assistance of (Daniel Montluçon, ETH Zurich) while Stephen Broccardo (North West University, South Africa) looks on.

Ismael's practical work on board the R/V Mirabilis included sampling of sediment cores along the Namibian coastline, and mapping and investigating the rock outcrops around Henties Bay. The practical work carried out during the RGNO course will form part of Ismael's thesis which focuses on the dissolution of dust particles that originate from Southern African sources.

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More Doings of Environmental Geochemistry Students

Four of our department's students attended the South African National Antarctic Programme (SANAP) meeting in Pretoria in July – Jean Loock (MSc; see below), Ryan Cloete (MSc), Ismael Kangueehi (MSc; see above) and Johan Viljoen (BSc Hons). The MSc students gave oral presentations, and the Honours student a poster.

Top National Awards for Stellenbosch Postgraduate Students

We are particularly pleased to report that two of our students received national awards, from the Geological Society of South Africa, for the best theses in Earth Sciences in 2015. These are:

Mr Jean Loock – Best Fourth-year Student Award

Jean's thesis examined climate change by studying bio-active trace metal concentrations in the Southern Ocean and defining the growth stress induced by low concentrations on marine phytoplankton. He graduated cum laude and is now working on his MSc at Stellenbosch, under the supervision of Prof. Alakendra Roychoudhury. He presented results from his thesis at a symposium of the South African National Antarctic Program (SANAP) at the end of July and again at the International Ocean Science Conference of the Scientific Committee on Antarctic Research (SCAR), in Malaysia, in August.

Mr Matthew Mayne – The John Handley Award for the best MSc thesis in Geology

As part of his thesis, Matt created a software tool, called Rcrust, which enables a new concept in modelling known as 'path dependence'. This allows researchers to investigate multi-step processes that are crucial to the formation of metamorphic rocks. Matt also graduated cum laude and is also registered at Stellenbosch and now working on his PhD, under the supervision of Prof. Gary Stevens. Based on his MSc work, he recently published an article in the Journal of Metamorphic Geology. In July he presented at the Workshop on the Origin and Evolution of Plate Tectonics in Locarno, Switzerland, and will also present in August at the International Geological Congress in Cape Town.

Prof. J. D. Clemens
(Departmental Communications Coordinator)

Some of the RGNO workshop participants after the two-week cruise along the Namibian coastline on the Research Vessel Mirabilis. From left: Daniel Montluçon (ETH Zurich, Switzerland), Ismael Kangueehi (University of Stellenbosch, South Africa), Phillip Eickenbusch (ETH Zurich, Switzerland), Blanca Ausin (ETH Zurich, Switzerland), Kurt Hanselmann (Course coordinator; ETH Zurich, Switzerland), Thomas Andreas (driver), Said Mohamed Hashim (University of Nairobi, Kenya), Zimkhita Gebe (University of Cape Town, South Africa), Leanne Grace Hancock (University of California, Riverside, USA) and Beth Wangui Waweru (Kenya Marine and Fisheries Research Institute).

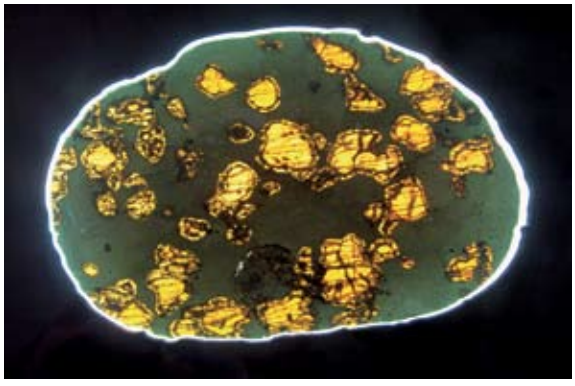
du Toit Lecture

UCT DU TOIT LECTURE

The Western Cape Branch hosted the first of three presentations of the 2016 du Toit lecture at the University of Cape Town, prior to the Plenary Lecture at the IGC and the post IGC presentation in Johannesburg. The evening began with the presentation of the 2014 Draper Medal to Steve Richardson. John Gurney, who has collaborated with Steve ever since their ground breaking work which demonstrated the ancient Archean age of diamonds, read a citation and presented the medal to Steve, who made a brief but heartfelt response thanking mentors, colleagues and friends. Jodie Miller then introduced Chris Hawkesworth, the presenter of the 2016 du Toit lecture. Chris has written or co-authored over 400 peer reviewed articles, a significant number based on African geology.

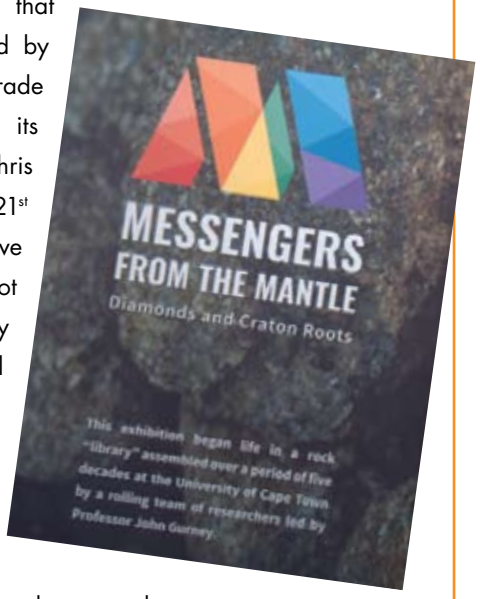
The lecture, "Geological Cycles and the Generation of the Continental Crust", addressed one of the enduring mysteries of global geology; why are there prominent peaks in the formation times of continental crust? Chris approached this from the assumption that the peaks do not record episodes of crustal generation but rather of preservation. He demonstrated the biased preservation of Archean crust with a study of a 300 km long river which drains.

On 25th August the Western Cape the Archean Yilgarn Craton and the Proterozoic Albany-Fraser belt in Western Australia. By the time the river reaches the sea the Archean rocks in the sediments are under-represented by a factor of five. This is in accord with the general under-representation of Archean rocks that other field-based and isotopic studies reveal, and helps to account for the discrepancy between the great volumes of Archean crust that were generated, and the small amounts that are preserved. The peaks in the crustal record are the product of mixing between crust of 'type A', which was generated in large amounts in the early Archean, but is poorly preserved, and younger 'type B' crust, which is of smaller volume, but is disproportionately well-preserved.



Eclogite on display at the Mantle Exhibition.

In 1989 Paul Hoffman, presenter of the 2004 Alex du Toit lecture, eloquently summarised the expectation that 19th century views of global orogenic periodicity would not survive the 20th century plate tectonic paradigm of continuous sea-floor spreading and plate recycling: "Many expected that the long-term episodicity displayed by mineral age frequencies would degrade as the data base expanded and its reliability improved. It did not." Chris Hawkesworth has provided the 21st century explanation; the peaks survive but they are not real - they do not reflect global orogenic episodicity but rather record the preferential preservation of siliceous post-3 Ga continental crust at the expense of pre-3Ga mafic crust.



After the lecture Phil Janney announced the re-opening of the mantle room where John Gurney, the 1989 Alex du Toit lecturer, has overseen the preservation of the precious pieces of peridotite that kimberlites carry from the mantle through the crust. Phil also urged visitors to view the mantle exhibition on display at the IGC. During the beer and snacks Phil escorted several groups through the recently renovated mantle room collection.

Chris Hatton & Phil Janney

Pre-IGC field trips

Craton Traverse:
A TRANSECT THROUGH 2.7 BILLION YEARS OF SOUTH AFRICAN GEOLOGICAL HISTORY

35th International Geological Congress Pre Conference field trip 8

Bushmanland

This extensive field trip started in Johannesburg on the 17th of August 2016 and ended in the City of Cape Town on the 27th of August 2017. 16 International delegates came from New Zealand, Australia, Great Britain, Austria, Germany, Norway, the United States of America and China to participate in this trip that covered just over 3200 kilometres. A substantial part of the geology of South Africa, all the way from the Neoarchean Witwatersrand Supergroup near Johannesburg in the north, to the Bushmanland and Richtersveld terranes in the west, to the Palaeozoic to Early Mesozoic Cape and Karoo supergroups, close to Cape Town, in the south was seen. Some of the most spectacular scenery of South Africa, somewhat off the beaten track, was experienced, including Bushmanland, the Richtersveld, Namaqualand, and the Tankwa Karoo.

Alluvial diamond mining and environmental rehabilitation with William Macdonald from De Beers (left).

Delagates looking at Cloudina fossils in the Nama Group near Vioolsdrif.

Along the way, the delegates under the guidance of Dr Herman van Niekerk from the Geology Department of the University of Johannesburg explored and slowly pieced together, mostly in geochronological order, the structural evolution of the geology of the western part of South Africa and the geological successions that make up southern Africa as we see it today.

In addition to this, other aspects such as the provenance of the sedimentary successions that cover the different terranes and the various tectonic models for the assembly of the geology of southern Africa were investigated and explored. Another important aspect that was continuously discussed was how landscape evolution had affected this part of the African continent

The field trip often traveled far off the normal tourist route

Investigating core at the Vedanta mines in Aggeneyes

since the breakup of Gondwana and how this evolution had affected and controlled the distribution of iron, manganese, and alluvial diamond deposits in South Africa. Some of the main mineral deposits in South Africa, as well as their origin, were explored. These included the ASSMANG Khumani mine, the Vedanta Black Mountain Mine and the De Beers alluvial diamond operations along the west coast of South Africa. Several controversial geological problems, such as the timing of the formation of the Limpopo belt, as well as new information on the timing of the Great Oxidation Event were also discussed in the field.

Along the way great friendships were forged and new contacts were made. The delegates ended an exciting and often tiring field trip with a lunch on a wine farm outside Cape Town, after which they started preparing themselves for the main event, the 35th International Geological Conference.

Herman van Niekerk

Plate boundary celebrations

Craton Traverse:
A TRANSECT THROUGH 2.7 BILLION YEARS OF SOUTH AFRICAN GEOLOGICAL HISTORY

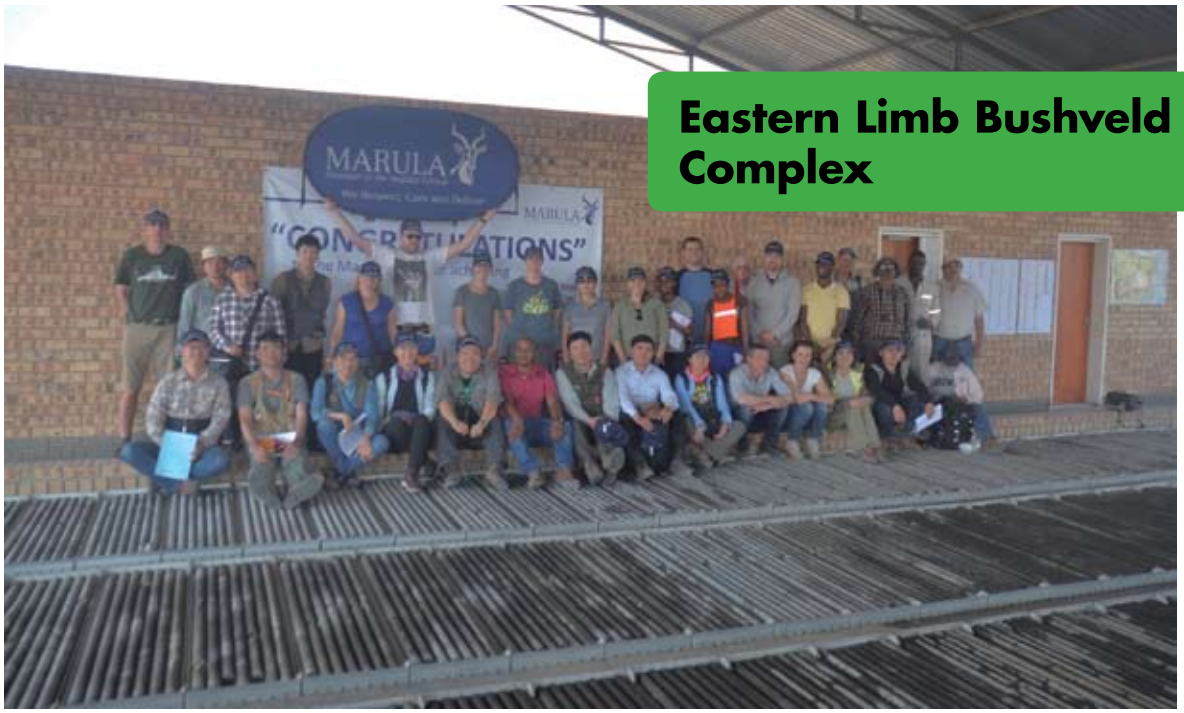
Lunch in the Tankwa Karoo

Eastern Limb Bushveld Complex

The group of 33 geologists representing approximately a dozen countries and six continents commenced the six-day field excursion to the Eastern Limb of the Bushveld Complex on 22nd August. Despite blustery conditions and a dust-laden sky for the first two days, the remainder of the trip experienced almost perfect field conditions. All five zones of the Rustenburg Layered Suite were examined together with the floor and roof rocks and Bushveld sills. Highlights were visits into the De Grooteboom open pit (Boulder Group) where the MG chromitite layers are superbly exposed and an underground visit to historical declines on the Merensky Reef at Winnaarshoek (Marula Mine of Impala Platinum) developed by Lydenburg Platinum under the guidance of Hans Merensky in 1925. The internal details of the Merensky Reef including two thin chromitite layers were examined with the assistance of assay grades from channels cut at 5 m spacing. Other

In the De Grooteboom open pit

Eastern Limb Bushveld Complex



Core shed at Marula Platinum Mine

highlights included the glory hole at the Onverwacht dunitic pipe where the reticulate pattern of secondary magnesite veins and dyke-like protuberance of platinum-rich hortonolite dunite remain intact. The favourite lunch stop was, predictably, the Dwarsrivier locality where the group spent several hours examining the intricate relationship between the UG2 chromitite layers and footwall anorthosite. The overwhelming consensus was that the Bushveld is far more complex than reported in textbooks and overviews.

Daudi Chrirwa

Cape Granites

The trip had 35 international participants and was led by Profs. Gary Stevens and John Clemens, ably assisted by Ms Erin Hilmer, Dr Jeanne Taylor and Mr Matt Mayne. The key localities visited (on the Cape Peninsula and along the West Coast) exemplify important features of the geology of the Cambrian Cape Granite Suite and associated volcanic rocks, with an emphasis on the S-type rocks. Localities visited and associated activities included:

- the Sea Point injection complex – the sheeted contact between the Proterozoic Malmesbury Group

Seemingly oblivious to the activity and noise of the nearby blowhole, a rapt participant scrutinises geochemical data provided for this part of the Peninsula pluton at Llandudno.

The group listens while Prof. Stevens points out some features of the Sea Point contact and the more homogeneous granitic rocks of the Peninsula pluton.

metasediments and the Peninsula pluton; magmatic layering and related structures in the Peninsula pluton at Llandudno;

- sheet-like intrusions of finer-grained granitic rocks at Miller's Point;
- a lunch at the Blue Marlin at Miller's Point, with spectacular views over False Bay and overnight accommodation at 2 hotels in Langebaan;
- the contact between the Hoodjiespunt granite and the overlying pyroclastic rocks at Trekoskraal, including spectacular fields of daisies in yellows, oranges and white;
- a more compressed and complex but similar contact between the granitic rocks and the fragmental volcanic sequence at Bomgat on the Saldanha naval base;
- and a marathon, 10-course lunch at the Strandloper restaurant near Langebaan, including local specialties (4 kinds of local sea fish, 2

Following the lamb stew course at the Strandloper, and suitable libations from a local provider, Prof. Stevens explains the geology and petrogenesis of the restaurant area (and beyond) to two of his assistants on the trip (Matt Mayne and Erin Hilmer) while, after several failed attempts, another participant demonstrates the correct way to inhale a brew through the right nostril (don't try this at home!).

Cape Granites

Outcrops of Peninsula granite with graded, magmatic, mineralogical layering are lapped by the sparkling sea at Llandudno (near Camps Bay) and overlooked by the unconformably overlying quartzitic metasandstones of the Cape Supergroup in the Oudekraal Nature Reserve.

mussel dishes, plaasbrood, fruit conserves, lamb stew, roosterkoek, West-coast Spiny Lobster and koeksisters (which we did not stay for)).

John Clemens

Barberton Greenstone Belt

Field Trip Pre-16 took place August 22 (arrival) to August 28 (departure) and focused on the geology of the Barberton Mountain Land. The field trip was led by Profs. Don Lowe (Stanford University, USA), Christoph Heubeck (Jena University, Germany), and Gary Byerly (Louisiana State University, USA). Eighteen participants from China, Japan, Italy, Brazil, Belgium, the UK, and the US learned about early life, the growth of continents, ultramafic magmatism, historical and active gold mining and the many unusual factors that shaped the surface conditions of the early Earth.

Day-to-day organization of the trip lay in the capable hands of Astrid Christianson of Barberton Community Tourism who had assembled seven bakkies and staffed them with experienced local drivers, all of them active members of the community and involved either in the tourism industry or in mining / geology. This proved ideal for both sides: The international guests, all of them newcomers to greenstone belt geology, not only learnt about geology from the three field trip leaders but also about local history, botany, wildlife and culture from their drivers; the drivers, in turn, experienced first-hand what attracts worldwide scientific attention to their region and also improved their own understanding of their home mountain range.

On the first day, Gary Byerly introduced the participants to the world of ultramafic magmatism by presenting komatiites, pyroxenites, and peridotites from the Sawmill and Pioneer Ultramafic Complexes west of Barberton. Many fine-grained interbeds, formerly

Fine-grained mafic ash in a unit of the Piuoneer Ultramafic Complex, Weltevreden Formation, Onverwacht Group (ca. 3300 Ma) showing cross-bedding stratification.

thought to be shear zones, are actually (partially aquatically reworked) mafic and ultramafic ash beds, some of them with unambiguous sedimentary structures. Together with the spinifex-textured komatiites and coarse-grained cumulates, these units drew a clear picture of high-volume, high-temperature, low-viscosity Archean magmatism and its interaction with oceans and the atmosphere.

Tubercled Gecko (Chondrodactylus sp.) found under a rock at the Pioneer Complex.

Leucospermum sp., member of the Protea family, in early bloom. Winter in the Barberton Mountains is coming to an end.

The second day brought the field trip to the Buck Reef Chert, basal chert of the Kromberg Formation in the Onverwacht Group. Don Lowe presented the regional geology of the Onverwacht Anticline and then led the group through a deepening-upward section of this unit, in places up to 300 m thick and thought to be the thickest Archean chert. He presented clear evidence of initial evaporitic deposition in shallow lagoons on a large volcanic plateau, overlain by abundant microbially-laminated cherty sediment (some of the earliest microbial body fossils) which graded in ferruginous chert. The group examined evidence for the Quaternary (not Archean) nature of iron-oxide precipitation near the top of the unit before returning to Barberton.

Silicified crossbedded and wave-rippled sandstone overlain by chert-slab conglomerate; Buck Reef Chert (Kromberg Formation), central Barberton Mountain Land.

Meteorite impacts and sedimentary barite sedimentation stood in the centre of attention of the third day. A series of large but distant meteorite impacts had generated melt droplets which had rained out from near-Earth orbits as decimetre-thick fallout deposits, blanketing the sea floor and preserved in strata of the basal Fig Tree Group. Don Lowe explained the multifold consequences of these nonuniformitarian events to the early Earth, including shattering of the sea floor, partial evaporation of the oceans, reworking by tsunamis and partial extinction of life.

Christoph Heubeck presented the geology of the central BGB along the transect of the R40, a scenic paved road across the range from Barberton to the Josefsdal/Bulembu border post. This road, known as

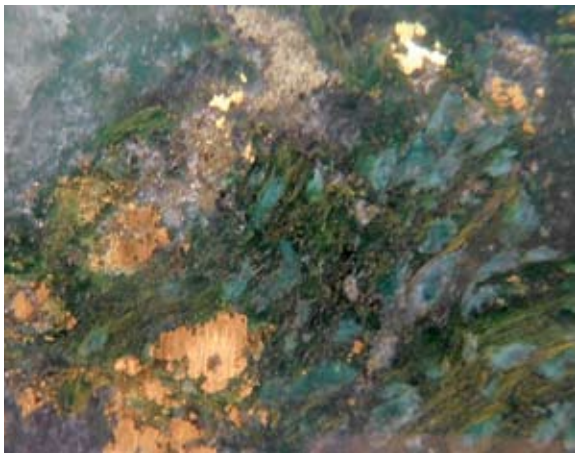
Research student Nadja Drabon (right) is interviewed at the rock outcrop by a Nelspruit-based SABC TV crew. Emlembe, highest peak of Swaziland (1862m), is visible in the center background.

Microbial laminations interspersed with sandstone and overlying conglomerate of a fluvial-supratidal sandplain, exposed in the Moodies Group of the Saddleback Syncline, central Barberton Greenstone Belt. Angular green clast is composed of altered ultramafic rock.

the Barberton-Makhonjwa Geotrail, features about a dozen parking lay-bys with well-designed panels explaining geological perspectives of early Earth. A second focus of the day lay on the depositional environment and ecological niches of abundant widespread photosynthetic microbial mats in high-energy tidal zones of the Moodies Group, ca. 3220 Ma, clearly demonstrating how early life had adapted to cope already with challenging environments.

The program of the fifth and last day led participants along the northern margin of the greenstone belt east of Barberton. The field trip examined the large "gneiss dome" of the Kaap Valley tonalite and, in several stops, its complex contact and structural relationships with adjacent coeval and younger strata. The afternoon was dedicated to historical and active gold mining, during which the group visited illegal alluvial gold mining activities in Fig Tree Creek, the stupendous

Geotrail panel at the Lebombo Overview stop of the Geotrail, the R40 between Barberton and Bulembu. The panel is one of a series explaining the natural history of the Makhonjwa Range, visible in the background.



Flakes of visible gold in sheared cherty ultramafic rock from Sheba Mine.

underground hole of the Golden Quarry of 1885, historical modern extraction and refining techniques at Sheba Mine, and the museum integrated into its Geology office, all enthusiastically presented by Chris Rippon of PanAfrican Resources. An evening farewell party concluded the field trip, and the participants departed the next morning to Cape Town to take part in the icebreaker program that evening.

Participants showed themselves impressed by the level of detailed investigation which the excellent preservation of greenstone belt geology made possible, and expressed their satisfaction at the depth and breadth of information they had received through the three field trip leaders and the guidebook. Field trip leaders, in turn, praised the curiosity and the inquisitive questions of the visitors and emphasized that the success of the field trip was to in no small part due to the professional hospitality of the members of the Barbertonians who organized an evening at the local MOTH club, sent a national TV crew to join us in the field, proudly presented their town on impromptu sightseeing tours and always had cold drinks handy. Many thanks to all involved – Barberton presented itself very well!

Christoph Heubeck

Barberton Tourism marketing manager, Astrid Christianson, and staff member Daphne serving hot lunch to field trip participants near the Old Sheba cementary

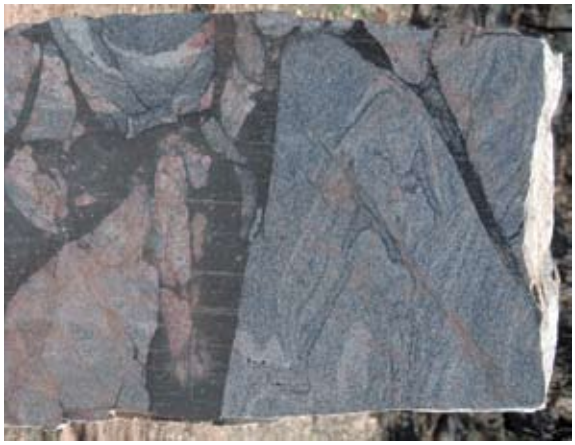
Field trip participants climb a scree slope in Golden Quarry of Sheba Mine.

Barberton Greenstone Belt

Vredefort Impact Structure

Field trip leader Roger Gibson in front of Salvamento Quarry wall of large variably-rounded blocks of trondhjemitic gneiss cemented by pseudotachylitic breccia.

44 participants from around the world, more than half from China, came to South Africa to see the world's oldest and possibly largest impact structure. Some were seasoned workers in this field, some were just curious, but everybody came to learn from the man who knows the Vredefort Impact Structure better than anybody else, field trip leader Roger Gibson, professor at the University of Witwatersrand. As summed up by Wouter Bleeker, an expert on the equally famous Sudbury impact crater, "Great field trip – high *impact* and *shockingly* beautiful, a trip that *injects* new ideas, helps to *overturn* static geological paradims, and makes erroneous hypotheses go *extinct*."



Polished slab (~2 m wide) of pseudotachylitic breccia dike with angular fragments of migmatite and granite, all of which have further veins and veinlets of pseudotachylitic breccia ranging from 10 cm to less than 1 mm.

In addition to being big and old, Vredefort also may be the most deeply eroded impact crater on Earth, thus allowing participants to see the roots of a system beneath the stereotypical image of a large crater. It is hard to say which of the sights were the most spectacular – the large country-rock blocks cemented by pseudotachylitic breccias, pseudotachylitic breccia veins and dikes that came in all shapes, sizes, and complexities, or the impact melt radial dikes that locally are adorned with petroglyphs carved by Bushmen thousands of years ago.

Many of the field textures such as anastomosing and crosscutting pseudotachylitic breccia veins inspired spirited discussions about how they formed. One has to stretch one's mind to envision processes that don't (and probably can't) happen under normal geological conditions. This is one field trip where the old axiom

Continued on p 24

Bushmanland

Petroglyph of black rhinoceros engraved onto surface of impact melt radial dike.

"the present is the key to the past" does not simply apply. I thought I knew something about impact craters and processes, but the more I saw of some of the Vredefort outcrops, the less I understood what I thought I knew! Something as grand and glorious and puzzling as Vredefort inspires return visits and we can only hope that future field trips will be planned.

Larry Meinert
U.S. Geological Survey

Very fluid-looking dike of pseudotachylitic breccia with offshoots into granodiorite gneiss. Dike walls range from planar to irregularly curved with inclusions of wall rock fragments and crystals.

Vredefort Impact Structure

media monitor

MINING AND EXPLORATION NEWS

Copper

Ivanhoe Mines is conducting a 25 000 m infill and exploration drilling programme, using up to nine rigs, at the Kakula discovery on the Kamoa copper mining licence in the DRC. Kakula, which is about 10 km southwest of the planned initial mining area at Kamoa, is flat-lying stratiform copper discovery that contains shallow resources at grades materially higher than the average grades at Kamoa, and which potentially could be incorporated into Kamoa's phase one feasibility study, now under way. Intersections from drilling in 2015 included 13.14 m of 5.26% copper and 14.94 m of 5.33% copper, both at a 2% cut-off.

Gold

Orion Gold has begun drilling at its Marydale gold project, situated in the Areachap Belt in South Africa's Northern Cape Province. The programme is aimed at testing the geological model for the mineralisation, which is presumed to be epithermal in origin, by infilling historical drilling. The historical work returned intercepts that included 50.4 m at 2.68 g/t gold and 37.1 m at 2.72 g/t. Drilling is also under way targeting near-surface mineralisation at the historical Prieska Copper Mine zinc-copper project, and Orion has commenced field work at its recently optioned Masiqhame prospecting right, 80 km north of Prieska, which covers the Kantienpan zinc-copper deposit and other similar occurrences. The company recently expanded its exploration portfolio by acquiring the right to earn an 80% interest in the Jacomynspan nickel-copper-PGE project, also in the Areachap Belt.

Resolute Mining is going ahead with the development of a 2.4 Mt/a underground operation at its 80%-owned Syama gold mine in Mali, having completed a positive definitive Feasibility Study. Excavation of the decline will begin in the September quarter, with the first development ore delivered at the year-end, and stoping is expected to start in December 2017. Syama's total production will grow to 250 000 ounces per annum, with an operating life of more than 12 years based on current underground Probable Reserves of 23.9 Mt at 2.8 g/t. The pre-production capital cost is estimated to be US$95 million. Resolute also completed a Feasibility Study to re-establish underground mining at Bibiani in Ghana. The mine plan envisages an operating life of 5 years with production of approximately 100 000 ounces per annum from initial Probable Reserves of 5.4 Mt at 3.7 g/t.

Industrial minerals

Armadale Capital agreed to acquire the Mahenge Liandu graphite project in Tanzania. The project is adjacent to Kibaran Resources' Epanko project and Black Rock Mining's Mahenge project. A mineralised trend about 1.6 km in strike length and up to 500 m wide has been identified, and results of exploration drilling completed in December 2015 include 10 m at 6.54% total graphitic carbon (TGC), 24 m at 12.9% TGC ,and 5 m at 21.5% TGC. Armadale is targeting a maiden resource estimate in late 2016.

Auroch Minerals has acquired the Hombolo lithium project in Tanzania. The 1700 km^2 project area, approximately 40 km northeast of the Tanzanian capital Dodoma, is adjacent to the Mohanga lithium-tantalum project, where Liontown Resources recently announced grades up to 5.2% Li_2O and 0.11% Ta in pegmatites intruding the regional metamorphic basement rocks.

Australian company GB Energy signed an option to farm in to 70% of a lithium clay project in Namibia. The Bitterwasser project, located in the Mariental district, consists of five large salt pans with a total area of about 58 km^2 that contain highly anomalously concentrations of lithium, potassium, and boron in smectite clays. The company is carrying out sediment sampling to validate existing data. Based on preliminary observations, the mineralisation at Bitterwasser appears similar to the Nevada (formerly King's Valley) project being

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developed by Lithium Americas, which is one of the largest lithium resources in North America.

Platinum group elements

Eastern Platinum agreed to sell the Crocodile River mine, which was placed on care and maintenance in mid-2013, to private Chinese company Hebei Zhongheng Tianda Platinum (HZT) for US$50 million. Eastplats retains ownership of its other projects, which include Mareesburg, Spitzkop, and Kennedy's Vale on the eastern limb of the Bushveld Complex. HZT is not connected with Hebei Zhongbo Platinum, the company that had a previous arrangement to acquire all of Eastplats' South African assets.

Tantalum and niobium

Cradle Resources completed a definitive Feasibility Study for its 50%-owned Panda Hill niobium project in Tanzania. The study, based on 35.3 Mt of resources, identified the potential for a 1.3 Mt/a operation, expanding to 2.6 Mt/a in year five, that would produce an average of 5.4 kt/a niobium as ferroniobium over a 30-year life of mine for an initial capital cost of US$165 million. Panda Hill is expected to be the first new niobium producer in 40 years and the only new producer of this rare metal in the foreseeable future. A decision to proceed is expected by the end of 2016.

Uranium

GoviEx Uranium and Denison Mines have merged their African uranium interests in a C$5 million share transaction. GoviEx's new, combined asset portfolio now includes two permitted uranium development projects – the flagship Madaouela project in Niger and the Mutanga project in Zambia. It also includes the Falea project, an advanced exploration-stage project in Mali, and the exploration-stage Dome project in Namibia. GoviEx now controls one of the largest uranium resource bases among publicly listed companies, with combined NI 43-101 Measured and Indicated resources of 124.29 million pounds of U_3O_8, plus 73.11 million pounds in Inferred resources.

Zinc

Nevsun Resources completed the new zinc flotation plant at its Bisha Mine in Eritrea, and the company expects to reach commercial production by September. The plant adds to the existing copper flotation circuit, and Bisha will average over 100 kt (225 million pounds) of zinc and 20 kt (45 million pounds) of copper per year for the next nine years, while having excess capacity to absorb feed that might come from other deposits without defined mineral reserves to date.

OTHER GEOSCIENCE NEWS

Geoscientists from Oxford and Durham universities, working with Norwegian company Helium One, have discovered a world-class helium gas field in the Rukwa Basin in Tanzania. This is the first discovery of commercial quantities of helium by systematic exploration – all previous finds have been made fortuitously during petroleum exploration. The team sampled several helium-rich gas seeps with helium concentrations ranging from 2.7% to 10.6%. Using an understanding of helium geochemistry combined with seismic images of trap structures, independent experts Netherland Sewell and Associates estimated an 'Unrisked Prospective Recoverable Helium Resource' (P50) of 54.2 billion standard cubic feet (BCf) – enough for over 1.2 million medical MRI scanners. In comparison, the US Federal Helium Reserve, the world's largest supplier, has a current reserve of 24.2 BCf. Global consumption of helium is about 8 BCf per year, largely in cryogenic applications where it is used to cool superconducting magnets. The research, which was presented at the Goldschmidt geochemistry conference in Yokohama, Japan, indicates that radiogenically produced ^4He accumulates in ancient crust during quiescent periods and is released during periods of active tectonism. The high helium concentrations in the region are likely related to the heating and fracturing of the Archean Tanzanian Craton and Proterozoic Mozambique Belt by the younger arms of the East African Rift System. The distribution of high-helium seeps along active faults shows increased communication between the shallow and deep crust, while high $^4He/^{20}Ne$ values indicate that local hydrothermal systems may play an important role in gas transport.

The CarbFix Project, a collaborative venture between Reykjavik Energy, the University of Iceland, CNRS in Toulouse, and the Earth Institute at Columbia University, has demonstrated for the first time that CO_2 can be safely and permanently sequestered as environmentally benign carbonate minerals in basaltic rocks. The results

of the study, which was carried out at the Hellisheidi geothermal power plant in Iceland, were published in the 10 June issue of the journal Science [DOI: 10.1126/science.aad8132]. In two experiments, 175 t of pure CO_2 and 73 t of CO2-25%H_2S gas mixture from the power plant were re-injected into basalt and hyaloclastites at a depth between 400 and 800 m, using a novel injection system that dissolves the gases into downflowing water in the well. To avoid potential degassing, the CO_2 concentration in the injected fluids was kept below its solubility at reservoir conditions. Once dissolved in water, CO_2 is no longer buoyant and immediately starts to react with the Ca-Mg-Fe-rich reservoir rocks. The fate of the injected gas was monitored with a suite of chemical and isotopic tracers, and by analysis of mineral precipitates collected from a submersible pump in a monitoring well. The results showed found that over 95% of the CO_2 injected was converted to carbonate minerals in less than two years. This contrasts with the common view that the immobilization of CO_2 as carbonate minerals within geological reservoirs takes several hundreds to thousands of years. In conventional carbon capture and storage (CCS) the CO_2 is stored as a supercritical fluid in deep saline aquifers and depleted oil and gas reservoirs in sedimentary basins, which could potentially leak, although none have done so to date. Basaltic carbon storage eliminates the leakage risk, since natural aqueous fluids in basalts tend to be at or close to equilibrium with respect to calcite, limiting its redissolution.

Antony Cowey

The CarbFix CO2 injection site near the Hellisheidi geothermal power plant in southwestern Iceland (Photograph: Juerg Matter/Science)

obituary:

Andrew Osmund Thompson †

Andrew Osmund Thompson 1920-2016

Veronica van Zyl, with contributions from Tim Broderick, Pat Stidolph and Peter Fey

Born in Bizana, Pondoland, South Africa on 16th February 1920, Andrew was the 11th child in a family of 12 born to his mother, Lizzie Lundie, and his father, Dr George Batchin Thompson, District Surgeon.

Andrew and his siblings were brought up in the strict Presbyterian way of their ancestors. Schooling started at home before Andrew attended the local one-room school in Bizana, followed by boarding at school in Kokstad. He followed several of his older siblings to attend university in Pietermaritzburg, where he attained his Bachelor's degree in 1939, followed by his Master's degree on the coastal dune terraces of Pondoland in 1940 under the supervision of Dr Lester C. King. His studies towards a PhD were terminated in February 1942 when he volunteered for the Union Defence Force and was assigned to the Engineering Corp. With the rank of Lieutenant he was dispatched to the Middle East in January 1944 within the 43rd Water Treatment Section, a multinational group that included Louis Dubertret of the Free French. He was fondly referred to as "Papa Louis" by Andrew, their task being to assess water resources with an eye to these being sufficient to sustain an Allied invasion through the Middle East into Europe.

When he was demobilized in January 1946 Andrew, with civilian clothing and £30 in his pocket, joined the Hydraulic Branch of the Public Works Department in Nairobi, Kenya. He transferred to the Mines and Geological Department in Nairobi in March 1950 where he was mostly engaged in regional geological mapping published as the Malindi (1954), Derkali-Melka Murri (1958), Bur Mayo-Tarabaj (1960) and Naivasha (1963) sheets. For the last three of these he was assisted by R.G. Dodson. In 1964 the geological map of the Kijabe area east of Naivasha was published. During his long leave in 1957 Andrew accompanied his mentor, Lester King, on a trip through South West Africa (Namibia). Before leaving Kenya he joined a group of friends that included Piet Joubert (later professor at UCT) to climb snow-topped Mount Kilimanjaro in his geologist's boots, a hand knitted sweater and, to break the wind, his wife's plastic raincoat! They made men tough in those days.

In January 1959 Andrew became the Deputy Director to the Northern Rhodesia Geological Survey in Lusaka. There he met up with his old friend, Dr Louis Dubertret*, who was the geological consultant to consulting engineers Gibb, Coyne & Sogei during the entire construction period of Kariba Dam.

Andrew left the Northern Rhodesian Geological Survey in October 1964 to join the South African Geological Survey, being based in Bloemfontein through to 1969. During this period he was seconded with A. C. Forbes to undertake geological mapping of the Mokhotlong area in Basutoland where he took his caravan to the top of the Sani Pass. Beyond there the survey

transportation was by Basuto pony, a painful process for a bony man. Subsequently he wrote an internal report on the geology of part of the Rouxville area in the Free State.

Andrew then joined the Rhodesia Geological Survey on 7th January 1970 and was based in Bulawayo until his retirement on 31st May 1980. From there Andrew was to cover 6825 km^2 of reconnaissance geological mapping of Karoo sediments and lavas during the 1971 and 1972 field seasons. This effort resulted in the publication in 1975 of a Short Report and three 1:100 000-scale maps covering the expanse of country between the Tuli Circle and the Bubye River. Following compilation of this report in 1973 Andrew reconnoitred a further 1200 km^2 of ground in the Mateke Hills region. He then switched to assisting the Industrial Development Corporation (IDC) with geological mapping and the logging of drill core from across the Lubimbi, Dahlia and Hankano coal areas between the Gwaai and Shangani rivers. This effort related to IDC's quest to establish an oil-from-coal facility under sanction conditions between 1974 and 1978, the edited work being published as a bulletin of the Zimbabwe Geological Survey in 1981. An intervening distraction was Andrew's logging of what became the 853 metre-deep Insuza borehole, drilled following a divined assumption that oil might be found. The core provided a 429-metre record of Karoo stratigraphy above an unexpected interception of Proterozoic-aged Lomagundi dolomite, giving an important insight to the extent of this sequence. During 1978 and 1979, at the height of the Bush War, Andrew reviewed all available information on the 13 known coal localities within the Wankie and Sebungwe regions of the mid-Zambezi Valley, which were published informally as "Records of Rhodesian Coalfields" and included a confidential summary of Rio Tinto's exploration of the Sengwa Coalfield. His work on the Western Areas and Entuba coal localities near Hwange was subsequently reviewed and published in 1982.

Andrew married Diana "Billy" Wilkins in Johannesburg on 30th June 1945 and together they had three children, Derrick, Veronica and Donna, all of whom were born in Nairobi. Billy died in July 1981, following which Andrew married Barbara Mitchell in July 1982. On retirement Billy and Andrew moved to Shelly Beach on the Natal South Coast, where Andrew remained until 2003 when he and Barbara moved to the Margate Retirement Village. Never a man to keep still Andrew became involved in the Gardening Club, serving as secretary for many years. He joined a group of walkers with whom he visited and camped at many of the areas in the Transkei that he had surveyed for his Master's thesis. To keep his hands busy Andrew discovered a love of weaving, and he joined the Weaver's Guild. He continued to weave until the time of the fall that led to his death on 28th June 2016. A scientist through and through, he kept records of rainfall, temperature and wind direction during the entire 36 years of his retirement, also made copious notes in his Robert's Books of South African Birds, and he gave his body to medical science.

Pat Stidolph, a colleague of Andrew's in Bulawayo, and his wife Marie remember him as one of nature's true gentlemen. "There are many nice people in this world, but every now and then one comes along who rises above the norm – Andrew was one of those. He was kind and caring and welcomed us into his home when we moved to the Bulawayo office of the Geological Survey. He was always interested in our lives and keen to know what he had been up to. One can't imagine he had any enemies because he was always approachable, interested and involved in so many different aspects of life. We were fortunate to remain friends well after we all left the Survey. We had interests in common, including ornithology and the outdoors, and we would often compare the garden birds found respectively in Australia and South Africa. His really was a life well lived, and one which seemed to go on forever. We will miss his Christmas letters and we will miss his presence".

* The URL will lead you to an obituary on the life of Dr Louis Dubertret who was consulting engineering geologist during the design and construction phases of Kariba Dam.

ftp://rock.geosociety.org/pub/Memorials/v15/Dubertret-L.pdf

mineral scene

Gatehouseite from the Kalahari Manganese Field,South Africa

Bruce Cairncross[1] and Maria Atanasova[2]

[1]Department of Geology, University of Johannesburg
[2]Head of Mineralogy, Council for Geoscience, Pretoria

Four bundles of gatehouseite on a matrix comprising mainly grey, colourless baryte. There is minor pink rhodochrosite at the top of the specimen with some very small orange shigaite crystals. The field of view is 2.2 cm.

The Kalahari Manganese Field is well known as being the largest land-based resource of manganese in the world (Cairncross *et al.*, 1997; Cairncross and Beukes, 2013) In addition, it is home to 170 mineral species, 24 of which are type-locality species (http://www.mindat.org/loc-14466.html) From time to time, unusual and rare species are found and gatehouseite, recently quantitatively identified, is one such mineral.

Gatehouseite $Mn_5^{2+}(PO_4)_2(OH)_4$ is a (very) rare manganese hydroxyl phosphate that, to date, was only known from one other locality, the Iron Monarch open cut located in the Eyre Peninsula in South Australia. Here, it occurs as tiny (100 μm) crystals associated baryte, shigaite, manganoan ferroan calcite, hausmannite and hematite (Pring and Birch, 1993). Up until this year (2016), the Australian specimens were the only ones known and they are micro-crystals.

The South African gatehouseite occurrence originates from N'Chwaning I mine in the Kalahari Manganese Field and was collected in June 2006 by Paul Balayer who had a contract at that time to mine for minerals at N'Chwaning mine. He was exploiting a zone that was known to produce world-class shigaite specimens. One of us (BC) obtained specimens from him and these were subsequently catalogued and stored for future investigation. How the N'Chwaning gatehouseite came to be recognized is an interesting story.

In August 2015, Bruce was invited to be a keynote speaker at the Dallas Mineral Symposium which is held annually in Dallas, Texas in the USA. While at this meeting, Thomas Campbell, a geological

consultant and mineral collector from Rapid city, South Dakota, asked whether we were aware that gatehouseite had been discovered from the Kalahari Manganese Field. He explained that he had obtained a specimen of shigaite associated with rhodochrosite and baryte from N'Chwaning I mine and noticed some tiny yellow acicular crystals on the specimen. Not knowing what these were, he sent the sample to Frank Hawthorne who holds the Canada Research Chair in crystallography and mineralogy at the University of Manitoba. Hawthorne analyzed Campbell's specimen and positively identified it as gatehouseite. Campbell promised to send a photograph of his specimen to Bruce after the symposium, which he subsequently did. Bruce then looked at all of his N'Chwaning I specimens to see if any of these enigmatic yellow crystals were present but could find none. He also contacted Dr Ludi von Bezing in Kimberley, an expert on the Kalahari minerals to ask whether he had any such specimens in his colelction and he did not. It appeared that Campbell's specimen was, at that time, a one-of-a-kind. Then in early 2016 while photographing some Kalahari Manganese Field specimens, Bruce happened to look on the *reverse* side of one his shigaite/baryte specimens he had just photographed and noticed some tiny yellow acicular crystals. It appeared that these might be the elusive gatehouseite but could equally be some other more common mineral. To verify this, the sample was given to Maria Atanasova at the CGS who quantitatively identified the crystals to indeed be gatehouseite. This is therefore the second known world occurrence. It is interesting to note that the mineral assemblage of associated species is somewhat similar to the gatehouseite from Australia, namely shigaite, rhodochrosite and baryte. Despite looking very carefully at all his specimens again and the reverse sides as well, no more examples of gatehouseite have been found. That is not to say it is not lurking in some other collection, because many specimens of the shigaite / rhodochrosite / baryte have been acquired by collectors both locally and abroad.

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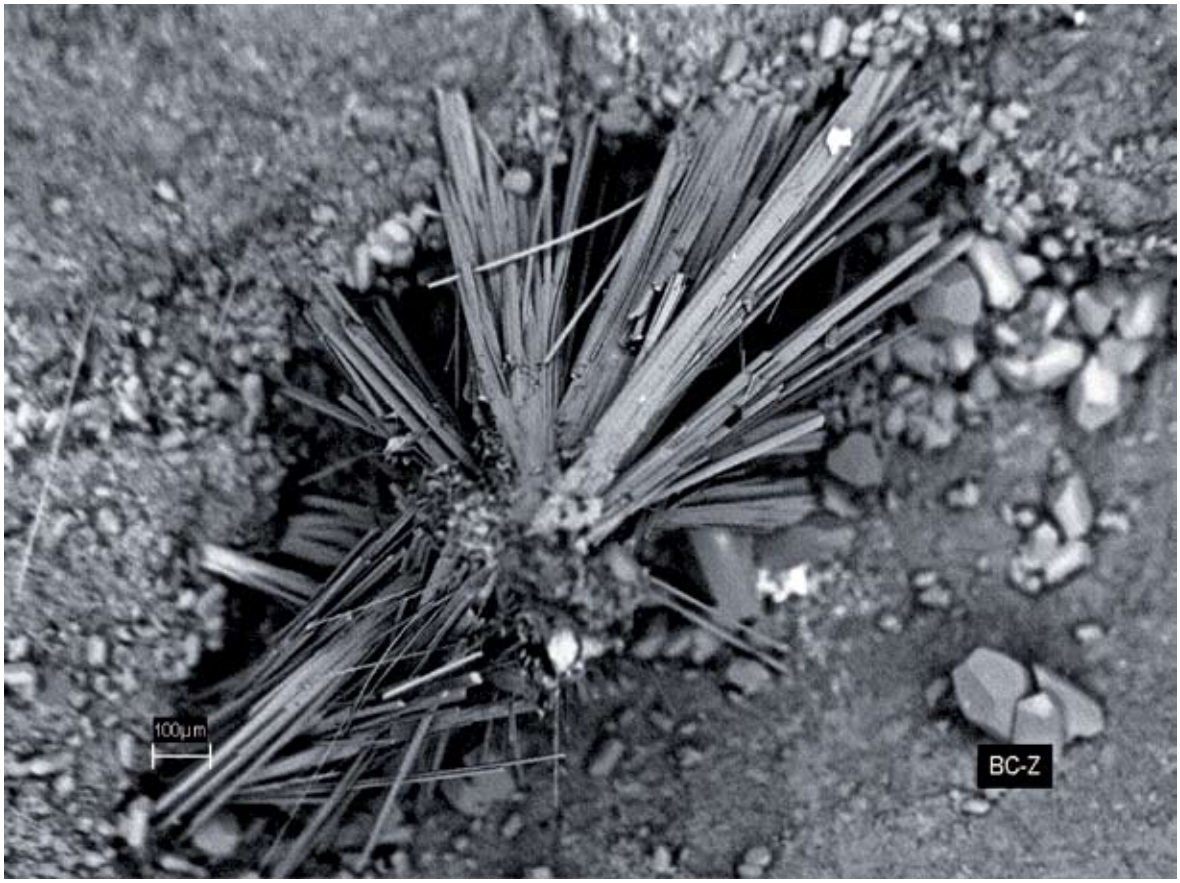


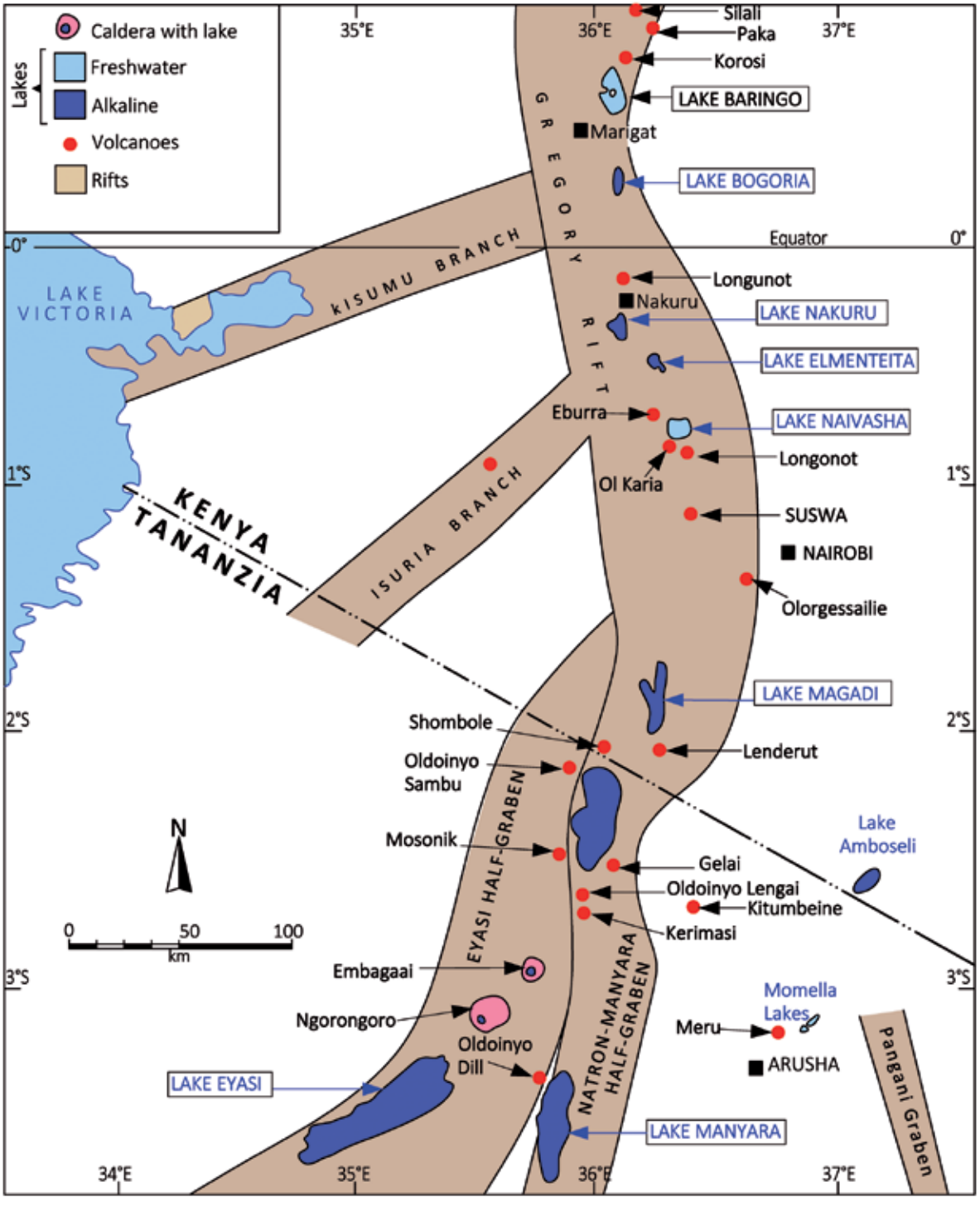
Scanning electron microscope image of one of the gatehousite aggregates present on the specimen.

Southern Kenya/ Northern Tanzania

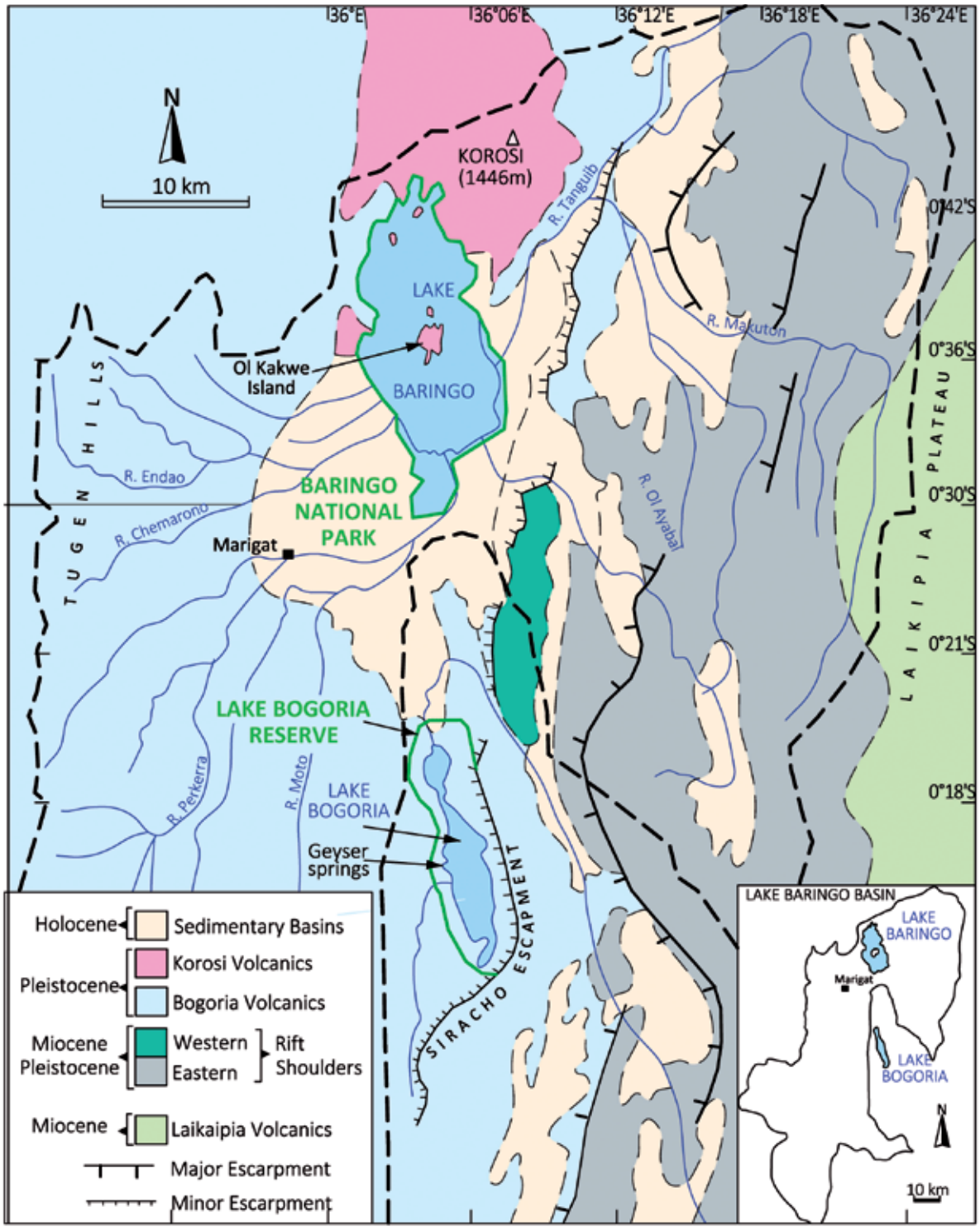
THE GEOTRAVELLER

By Roger Scoon

FINGER LAKES OF THE GREGORY RIFT VALLEY:
Oases in arid areas of Southern Kenya/Northern Tanzania



Simplified geological map of the Gregory Rift in southern/central Kenya and northern Tanzania. The finger-shaped lakes are typically alkaline and saline; the more rounded lakes are freshwater. Small lakes occur outside of the rift in calderas, hollows made by debris avalanches, and palaeo-basins. Lake Victoria occurs in a shallow warp located between the Gregory and Albertine Rifts.



Map of the Lake Baringo and Bogoria Basins (based on Google Earth image with geology simplified from published maps).

The finger-lakes of the Gregory Rift Valley in southern Kenya and northern Tanzania are mostly shallow and occur in small basins with limited catchment. Typically, evaporation exceeds inflow resulting in high levels of alkalinity and salinity. Lakes Bogoria, Nakuru, Elmenteita, Manyara, and Eyasi are typical in this regard. Lakes Magadi and Natron are so extraordinarily toxic that animal remains are fossilized by sodium carbonate-rich salts. Lakes Baringo and Naivasha are unusual as they are the only large freshwater lakes in the region. Most basins are enclosed by volcanic terranes and in several localities geysers and hot springs discharge sulphurous brines into lakes. Many of the lakes occur in spectacular landscapes that are protected in National Parks and conservation areas.

Lake basins in the Rift Valley are affected by rifting and volcanism. Rifting is ongoing and the Gregory or eastern

Basaltic lava, Ol Kokwe Island, Lake Baringo.

branch of the East African Rift System has numerous dormant and active volcanoes (e.g., Baker, 1987; Dawson, 2008; Woolley, 2001). The differential rise of rift platforms may channel water into distal basins whilst bypassing nearby lakes. Considerable fluctuations occur and the size, depth, alkalinity, and salinity are subject to climatic cycles. During the wetter periods of the Holocene epoch, most lakes that are currently alkaline were fresh. Moreover, juxtaposed lakes were joined into much larger palaeo-lakes.

Lake Baringo, the most northerly of the lakes described here is protected in a National Park served by the regional town of Marigat. The lake occurs in a relatively low-lying (970 m) section of the Rift at the base of the Laikipia Escarpment. The lake has a surface area of 130 km^2 and is located in a basin fed by a myriad of rivers. The absence of outlets causes the depth to vary and the lake rose over 5 m in recent years, probably due to increased rainfall. The lake supports fishing for both the local population and tourists (several endemic species occur). The lake is mostly underlain by the Pleistocene-age Korosi (0.38-0.10 Ma) volcano, which rises some 500 m above the valley floor and covers an area of 260 km^2 to the north of the Park. The composition is dominated by basalt and trachyte. The Ol Kokwe Island – which includes a luxury tourist lodge - is formed by coalescence of basaltic scoria cones (northern part) and trachytic lava flows (southern part). Sulphur-rich fumaroles, hot springs, and gossans (hydrothermally-altered rocks with oxidized sulphides) are a notable feature. Discharge into the lake causes small bays to concentrate the sulphurous waters.

The Baringo Basin is dominated by volcanic terranes and a Holocene sedimentary basin. Miocene-age volcanics occur on the Laikipia Plateau, Pliocene to Pleistocene-age volcanics dominate the eastern and western shoulders, and younger volcanics occur in the centre of the valley.

Hydrothermal alteration, Ol Kokwe Island, Lake Baringo.

View of Lake Bogoria including the Bogoria Volcanics (foreground) and Siracho Escarpment (background).

Extinct volcanic cones to the north of the lake include Silali and Paka. The uplifted fault block of the Tugen Hills has revealed important hominid fossils, some of which are exhibited in the Smithsonian Museum (Wood, 1999). The unusual shape of the basin is ascribed to detachment blocks on the edge of the Gregory Rift which include the Aberdare Mountains (to the east) and Elgeyo Block (to the west). Two examples illustrate how rifting has affected drainage. The Molo River drains part of the Mau Escarpment near Lake Natron and yet flows northward and skirts Bogoria prior to feeding Baringo. Conversely, several rivers that rise near Lake Baringo channel water either northward into Lake Turkana or southward into Lake Natron.

The Lake Bogoria National Reserve was established in 1973 to protect a wilderness area described by J W Gregory as having the "most beautiful view in Africa".

The Siracho Escarpment rises some 600 m above the lake on the eastern side. The dimensions (length of 35 km and width of 3.5 km), shallow nature (maximum depth of 10 m), and alkalinity (pH of 10.5) are characteristic of the finger lakes. Most water is sourced from the Waseges (or Sandai) River, which rises on the lower slopes of the Aberdare Mountains, but several hundred hot (alkaline) springs feed the lake with high concentrations of Na^{+}, HCO_3^{-} and CO_3^{2-} (Renaut and Tiercelin, 1993; 1994). There are no outlets and the lake retains a palaeo-stratification: less dense surface waters overlie denser and more saline basal waters. Drill-cores of the underlying sediments have shown the lake to have varied from alkaline to freshwater in the Holocene and to have locally overflowed into Lake Baringo.

Access roads within the reserve have been submerged since 2013 and the level remains anomalously high. The

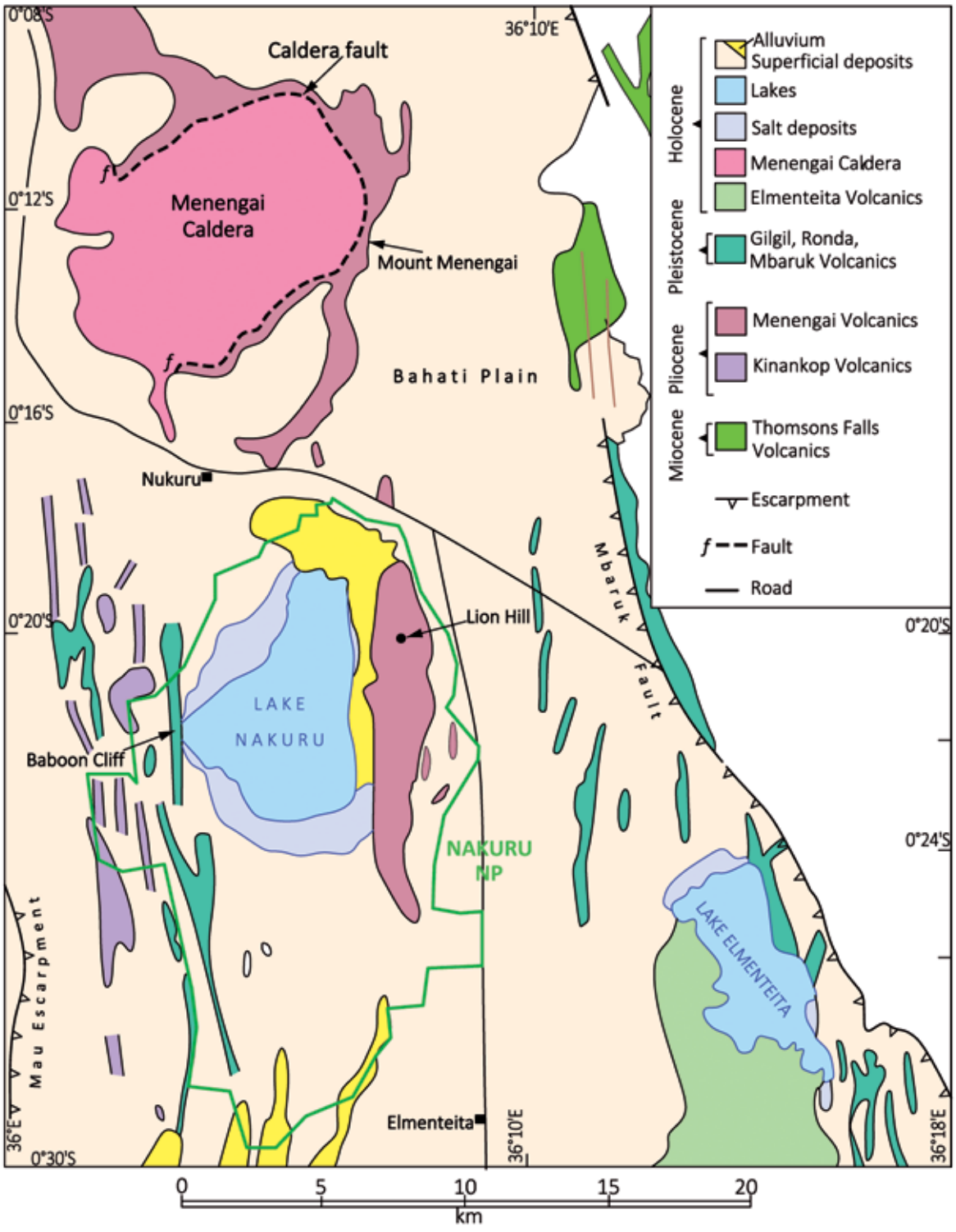
Hot springs and hydrothermally-altered volcanics on the foreshore of Lake Bogoria.

Sulphurous waters pond on the edge of Lake Bogoria.

rocky, barren shores are dominated by flows of phonolite, part of the Pleistocene-age Bogoria volcanics. Access tracks recently cut through the mostly unvegetated lava flows enhance the feeling of a barren landscape. Geothermal activity on the shores of the lake includes geysers, hot springs, and steam jets (Renaut and Owen, 2005). Eighteen geysers have been documented (they once spouted to heights of 5 m), although activity has waned in recent years (due to the high water level?) and is currently restricted to small fountains and hot pools.

The Lake Nakuru National Park is located near the regional town of Nakuru. The alkaline lake, which occurs at an altitude of 1754 m, is located south of the Menengai volcano (0.18 Ma-8,000 BP) which includes one of the world's largest intact calderas (area of 12 by 8 km). The size of the lake is very variable (5-45 square km) and is rarely more than 3 m deep. In the early 1990's the lake almost dried up. The main water source is the Njoro River that flows eastward from the Mau Forest. Aquifers in the basin are composed of lacustrine deposits derived from

View of Lake Nakuru from Baboon Cliff.



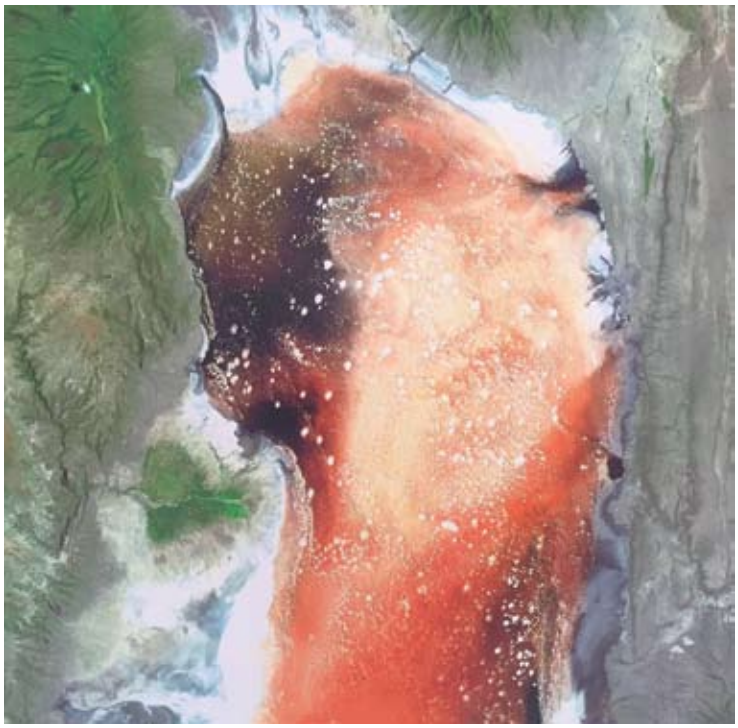
Map of Lake Nakuru (based on Google Earth image with geology simplified from the Nakuru Quarter Degree Sheet 43).

erosion and re-deposition of volcanic rocks. Views from Baboon Cliff, an eroded lava flow provide an excellent panorama. Hyrax Hill is an important archaeological site with Neolithic and Stone Age remains. The adjacent Lake Elmenteita is a shallow, alkaline lake located within a closed basin fed by water from the Mereroni River that drains the Bahati Highlands. Elmenteita may be connected with Nakuru via underground aquifers.

Located near a small town of the same name, Lake Naivasha is the highest of the finger lakes, occurring at an altitude of 1,884 m. The area is surrounded by dormant or active volcanoes and complexes. They include the Eburru Complex, Olkaria Complex (last eruption around 1800), and Mounts Longonot (1860) and Suswa (0.42-0.10 Ma). The large surface area of the lake (140 km^2) is enhanced by an extensive rim of swamps. The

Unusually high water levels in recent years have caused Lake Nakuru to flood large parts of the foreshore.

Lake Natron occurs in a dry, desolate section of the Rift Valley surrounded by huge volcanoes.



The unusual colour of Lake Natron in this Terra (EOS AM-1) 2003 satellite image is due to the abundance of cyanobacteria that have a red photosynthesising pigment (image provided by Philip Eales, Planetary Visions).

average depth (6 m) is variable and in 1945 reduced to only 0.6 m. The lake is fed by the perennial Malewa and Gilgil Rivers. There are no outlets, although the lake once drained into the Njorowa Gorge, an important feature of the Hells Gate National Park. The basin is comprised of Pleistocene-age volcanic and sedimentary rocks. The active volcanoes of Longonot and Olkaria occur to the south and east. Crescent Island is an exposed rim of an extinct volcanic crater located within an area of the lake that is unusually deep (30 m). Two small alkaline lakes occur southwest of the main lake, Lake Sonachi within a volcanic crater and the larger Lake Oloiden. Despite not being protected in a park, Lake Naivasha is well known for supporting large herds of game and aquatic birds, although in recent years the freshwater is also used to support one of the world's largest flower industries.

Lakes Magadi (southern Kenya) and Natron (northern Tanzania) occur in a particularly hot (temperatures are regularly over 40^{0}C) and arid section of the Gregory Rift. Vegetation is sparse - large areas of the valley floor are covered by volcanic ash and debris deposits

Lake Manyara occurs at the foot of a thickly forested escarpment. The highly saline and alkaline waters appear as a mirage stretching towards the horizon.

- and rainfall is erratic. Lake Magadi has a maximum surface area of 100 km^2, although during the dry season extensive salt flats (with characteristic hexagonal cracks) develop. Even in the wet season, parts of the lake are covered by a thin crust of brine. Lake Natron is larger, having a length of up to 57 km and maximum width of 22 km. Both lakes are shallow (maximum depth of 3 m) and strongly alkaline (the pH of 12 is high enough to burn the skin). Small pools on the margins of Magadi that are fed by saline springs report temperatures of up to 85°C. They are even more toxic.

The extremely alkalinity of Lakes Magadi and Natron is ascribed to high rates of evaporation and erosion of the numerous volcanic cones that enclose the lakes. The Lake Magadi plateau lavas (1.42-0.63 Ma) are among the youngest of the volcanics on the rift shoulders (Baker, 1958). Cones near Magadi include Lenderut (2.62-2.53 Ma), Olorgesailie (2.62-2.21 Ma), and Shombole (2 Ma). Shombole is a deeply eroded cone (1570 m) with a diameter of 9 km. Cones adjacent to Natron include the 2,043 m-high Oldoinyo Samba (2.02 Ma), the 1,702 m-high Mosonik (1.28 Ma), Gelai (0.99-0.96 Ma), Kerimasi (0.6-0.4 Ma) and Oldoinyo Lengai (the most active of the Holocene volcanoes in the region). Gelai was formerly thought to be extinct, but in 2007 small fissures opened on the lower slopes that have been related to a volcano-tectonic event at depth (Delvaux et al., 2008). Some of these volcanoes include natrocarbonatite lavas and ashes that react rapidly with meteoric waters to release huge quantities of sodium carbonate.

Lakes Magadi and Natron occur in small, closed catchment areas, although the latter is fed by both thermal springs and the Southern Ewaso Ng'iro River which rises in southern Kenya. Fossil evidence from lacustrine and volcaniclastic deposits have shown that between the late-Pleistocene and mid-Holocene, they were connected and filled with freshwater. The palaeo-lake Magadi contained species of fish that are now extinct. The current lake does, however, contain a unique species of cichlid fish that has evolved to cope even with the extreme alkalinity and temperatures (up to 45°C) within small pools.

The margins of Lake Magadi include layers of sodium carbonate salt up to 40 m thick that are quarried and used to produce soda ash. The salt has precipitated from brines that form a mix of two minerals, natron and trona (Eugster, 1970; 1980; Jones et al., 1977). (Natron = mix of sodium carbonate decahydrate [$Na_2CO_3.10H_2O$] and sodium bicarbonate [$NaHCO_3$]; Trona = sodium sesquicarbonate dihydrate [$Na_3CO_3.HCO_3.2H_2O$]). The

Flamingo formerly gathered in huge numbers on Lake Nakuru (Internet).

salts are intercalated with the unusual Magadi chert (micro-crystalline silica) that is derived from dissolution of magadiite, a sodium silicate (Behr, 2002). The chert also occurs as dyke-like bodies that were injected into the bedded deposits whilst the silica was soft enough to be deformed.

The Lake Manyara National Park includes a large alkaline lake that nestles below the steep, thickly forested western escarpment of the Rift Valley. The area is very scenic area and was described by Ernest Hemingway as "the loveliest lake in Africa". The eastern side of the valley is, however, a gently sloping plain as the rift in this area is a half-graben in which only the western boundary faults are developed. The extent (maximum of 230 square km), depth (average of 3.7 m), and alkalinity (pH of 9.5) of the lake vary considerably. Large areas of salt flats and mud banks are exposed during the dry seasons. The lake is fed by the Simba and Makayuni Rivers. The western shore is nurtured by underground springs replenished from the Ngorongoro Highlands. Hot springs and pools with multi-coloured algae occur near the western shoreline. The Kwakuchinja wildlife corridor, situated to the east of Manyara allows wildlife to migrate between Tarangiri, the Ngorongoro Highlands, and the Serengeti.

The seasonal, highly saline and alkaline Lake Eyasi is the southernmost of the finger lakes in the Gregory Rift. The lake occurs below a huge escarpment dominated by quartzite and mylonite of the neoProterozoic Mozambique mobile belt. The Neogene-age Ngorongoro Volcanic Complex caps the escarpment and includes the south-western flanks of the extinct Oldeani volcano. The main inflow to the lake is from the Sibiti River on the southern end. The lake may dry completely during the dry season and even during the wet season depths rarely exceed 1 m. The Mumba cave has yielded important archaeological findings.

Many of the alkaline lakes in the Gregory Rift are famous for one of the world's greatest spectacles: the concentration of lesser and greater flamingo. Flocks of several millions were formerly so numerous as to change the colour of the shoreline in aerial photographs, e.g., Lake Nakuru. Lake Natron is thought to be the principle breeding ground of flamingo for all of East Africa. The flamingo has evolved remarkably efficient filtration systems (lake brines are poisonous to most other species) that are capable of processing the cyanobacteria which flourish in the highly alkaline waters. At their peak, flamingo on Lake Nakuru consumed some 250,000 kg of algae per hectare of surface water annually. Some twenty years ago the number of flamingo decreased, either due to pollution from increased land usage in catchments or simply higher rainfall. High water levels since 2013 have exasperated the problem as decreased alkalinity inhibits algae growth. The loss of flamingo from Lake Nakuru was initially balanced by an incremental increase at Lake Bogoria, but recently the numbers have decreased here as well. Whether pollution or non-reversal climatic shifts are the cause is not known.

Most of the finger lakes of the Gregory Rift Valley have been afforded Ramsar status as they contain important wetlands and are sanctuaries for as many as 500 bird species. Lakes Baringo and Naivasha reveal great diversity of birds, and the associated areas include large mammals and reptiles. The Natron Basin is targeted for a hydroelectric scheme (in Kenya) and mining of sodium carbonate (in Tanzania), although the unique biodiversity has led the WWF to recognize the lake as an important halophytic ecosystem. The lakes described here are sensitive to climatic fluctuations and land use changes in the catchment. The climate of East Africa is dominated by the twice-yearly passage of the inter-tropical convergence zone. Two rainfall seasons (March–May and October–November) are experienced. Projections on global warming suggest an increase in precipitation for the region.

All photographs by the author (2004 and 2015) unless otherwise referenced.

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