GSSA
Geological Society of South Africa

geobulletin

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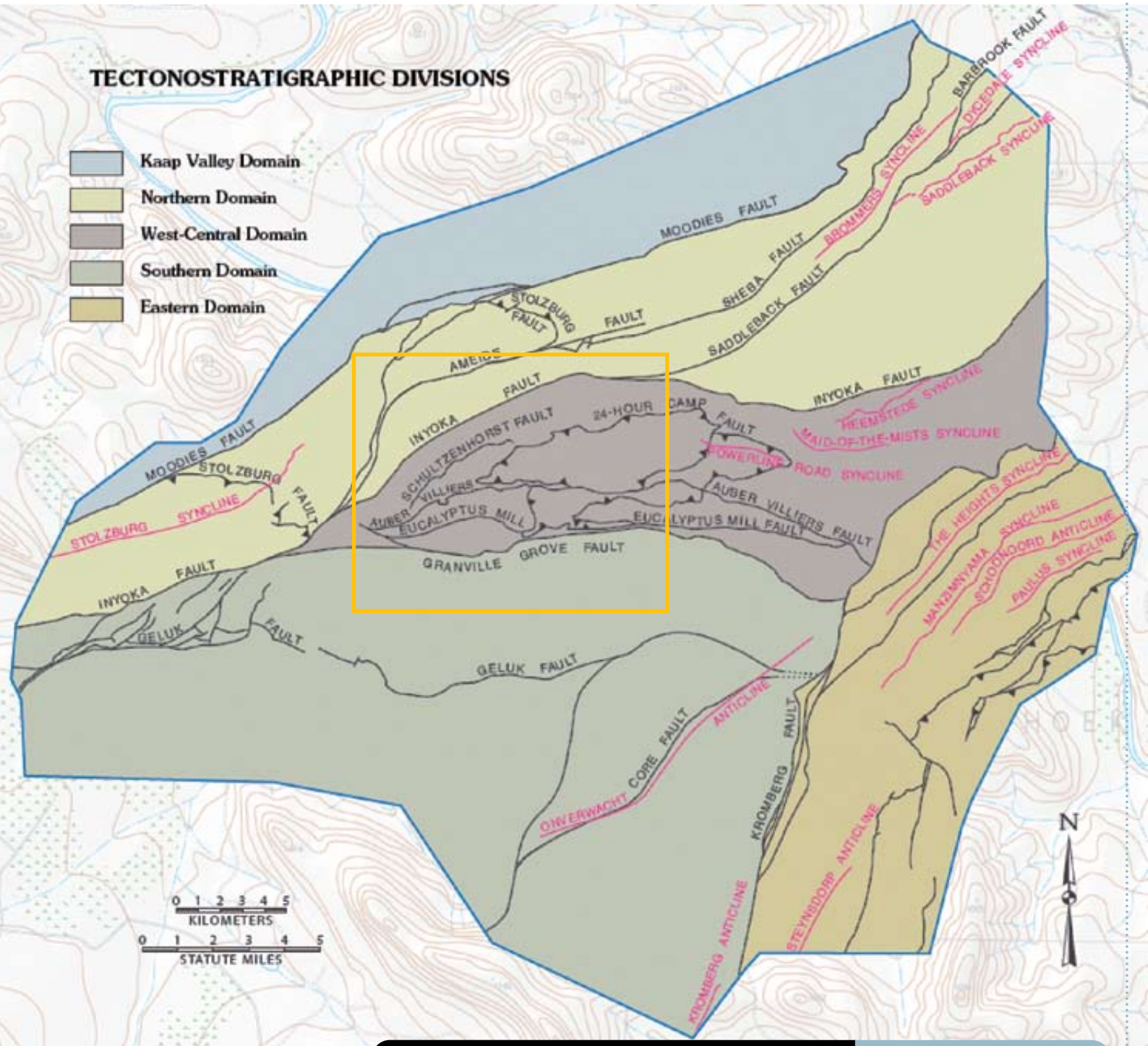

Barberton Greenstone Belt
George Harrison Park
CIMERA-KARIN

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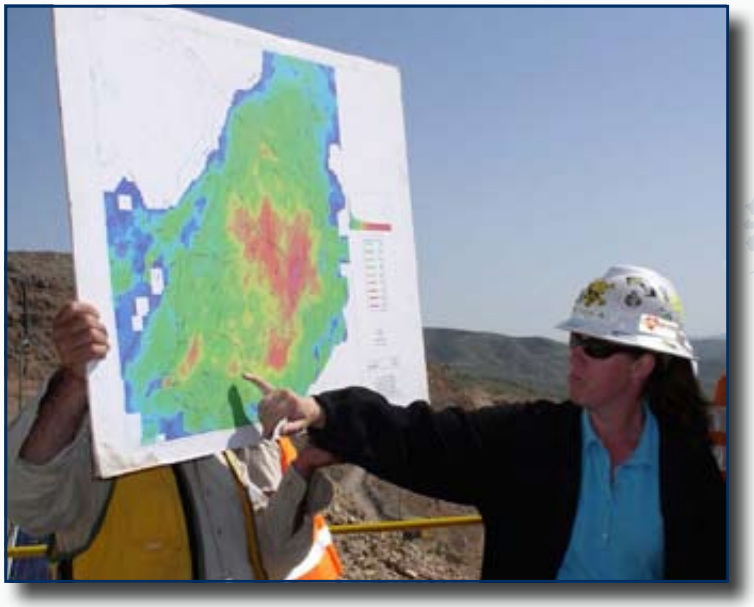

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Cover:

Domains recognised in the West-Central Barberton Greenstone Belt. The yellow rectangle shows the area extracted in the Centrefold

Centrefold:

The centrefold is an extract from the Geologic Map of the West-Central Barberton Greenstone Belt compiled by Donald R. Lowe, Gary R. Byerly, and Christoph Heubeck.This 1:25,000 map covers 500 square kilometers of Archean rocks in the Barberton Greenstone Belt(BGB) - the oldest, best-preserved sedimentary and volcanic sequence on Earth. Five major tectonic cycles are represented in the BGB's 3.55 –3.22 Ga history—komatiitic volcanism, forming lava plains, begins each cycle, and dacitic volcanism, likely related to an early style of subduction, ends each cycle. These cycles produce small yet stable protocontinental blocks that coalesce by magmatic and tectonic accretion. The BGB rocks provide direct information about the nature and evolution of early Earth and its biota. Carbonaceous cherts occur throughout the sequence, containing microfossils, microbial mats, and stromatolites. Evaporites represent shallow marine environments, whereas ferruginous chert and banded iron formation are indicators of deeper water settings. The BGB also contains a remarkable record of large asteroidal impacts, in eight distal impact layers, each more energetic than the K-T boundary event. The map is available from the Geological Society of America. https://rock.geosociety.org/Store/detail.aspx?id=MCH103F

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Geological Society of South Africa

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from the editor's desk

Chris Hatton

Robert Redford is more than just a pretty face. After establishing himself as an actor, he went on to be a really good director, most notably of the movie, A River Runs Through It. In this film, Redford doubles as the narrator, overlaying passages from Norman Maclean's book onto the story. Many of these passages resonate with earth scientists. *"Eventually, all things merge into one, and a river runs through it. The river was cut by the world's great flood and runs over rocks from the basement of time. On some of the rocks are timeless raindrops. Under the rocks are the words, and some of the words are theirs."* "Theirs" refers to the protagonist's family, his wife, his father - a Presbyterian priest, and his brother, played by another pretty boy, Brad Pitt. One of the elements of this tightly packed movie is the tragic inevitability of the brother's downward spiral to self-destruction. But along the way the brother attains perfection, life raised to art, as he lands the big fish. The film is also about attaining a state of grace. At the end of the movie we see the protagonist rhythmically fly-fishing. *"My father…. certainly believed God could count and that only by picking up God's rhythms were we able to regain power and beauty"*. In a moving tribute to Russell Shone on pp. 39-41 of this issue Peter Booth and John Bartels evoke the return of the birds Russell once fed to demonstrate that the spirit does not die with the man. As a result of Redford's movie, people return to the unspoilt rivers of Montana to imagine the ghost of Norman Maclean eternally fishing there.

Rivers however do not last forever. The changing paths that the rivers of South Africa have taken and the diamonds that these lost rivers have left behind will be visited in Mike de Wit's 35th IGC field trip to the diamond deposits between Lichtenburg and Kimberley. In this issue (pp, 17-22) Dave Reid gives a taste of what participants in the 35th IGC Orange River canoe excursion will experience in 2016.

As Africa rises, rivers cut back to create the Escarpment where progressively older rocks are brought to light. The best exposures of the very earliest rocks are in the Barberton Greenstone Belt where Don Lowe and Gary Byerly have spent much of their careers (pp. 31-33). Their map, featured on the cover and centrefold of this issue, is one of their primary legacies. They will be co-leaders, with Christoph Heubeck of a pre-Congress field excursion to explore the scientific wealth of Barberton. In the post-Congress Barberton excursion, Christoph Heubeck and local experts will include the mineral wealth of Barberton.

The faded mineral wealth of the Witwatersrand is meant to be preserved in the George Harrison Park but Gavin Whitfield argues (pp. 8-15) that this sad spectacle is under terminal attack from the new generation of gold miners. He advocates that to save some fragments from the wreckage, the only viable option is to cut out what remains of the Main Reef and Leader and retreat to a museum.

Hopes of new mineral wealth are now in the Karoo, where fracking, a mature technique elsewhere (pp. 42-43) but untried in the Karoo, is optimistically seen by some as a means of extracting wealth from the seemingly endless treasure chest below our feet. The initial signs that Michiel de Kock summarises on pp. 34-38 are not wildly encouraging, but this saga has barely begun. The enduring legacy of the fracking of the Karoo will be, as it is in Barberton, a deeper insight into the geological history of the Karoo. As David Kramer, the poet of the Cape and Karoo observes, in those rocks *"was daardie akkedis 'n vis"*. It doesn't rhyme as well in English, but the lizard scampering across the dry landscape of the Karoo evolved from fish which lived when the rocks below were deposited under water. To convincingly trace that evolution the rivers that once ran through the Karoo will have to be revealed in fine detail. Only mapping on the same scale that the West-Central Barberton Greenstone Belt has been mapped at can reveal that sort of detail. For the latest developments in these and other stories, visit Cape Town in August and September, 2016. Super Early Bird registration for the 35th International Geological Congress is now open. See you there.

GSSA
Geological Society **of South Africa**

executive managers corner

Craig Smith

The Annual General Meeting of the GSSA was staged on the 30th of July, and I'm pleased to report that it went well. The Annual Report has been given a facelift, and it is lodged on the GSSA website. Please have a look at it. Note also that all awards except the Jubilee Award (best paper in SAJG in 2014; under adjudication) are announced on pp 44-46 of the report. Congratulations to Steve Richardson of the University of Cape Town for winning the Draper Medal, and to Murray Hitzman of the Colorado School of Mines for winning the Des Pretorius award. This year the adjudicators had a serious challenge in deciding on the student awards – Best Fourth Year, Haughton Award (best Hons thesis) and the John Handley and Corstorphine awards (best MSc thesis). The difficulties were two-fold, and are the best kind of 'problems' to face. First, there were a larger than normal number of submissions. Second, they were all outstanding works of science. The adjudicators proposed dual awards in the Best Fourth Year and John Handley categories. This is not unprecedented – but it does not happen often. The Fellows Committee of the GSSA would also like to draw attention to the co-sponsorship of the John Handley award by the South African Council for Scientific and Natural Professions (SACNASP), along with the GSSA.

As is normal, the audited financial statements are bound into the report, and Thomas Molelengoane and

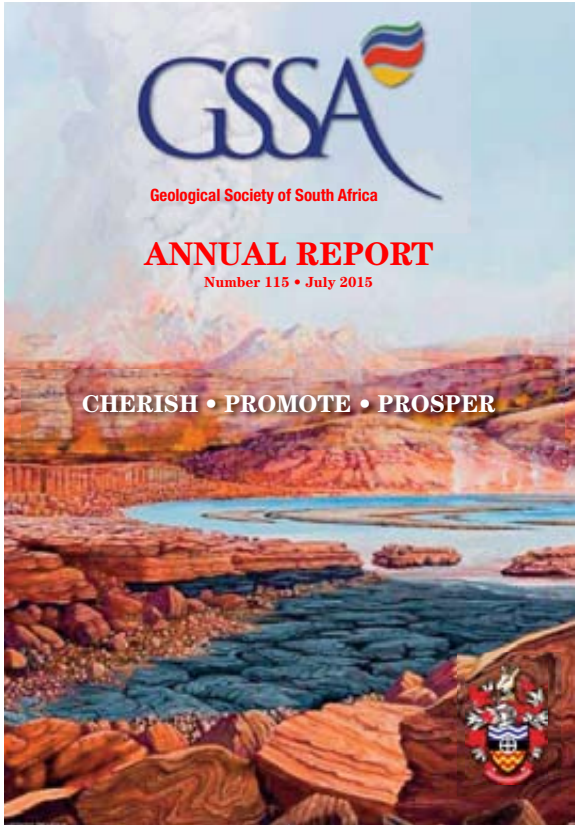
I are pleased to report that 2014 was a very good year financially for the Society. The GSSA is a not-for-profit voluntary association of members which is not expected to make a surplus, and we generally aim to break even in our budgeting process. In some years we get it wrong, and burn more cash than we bring in. This is compensated for in other years, when income exceeds expenses, and 2014 was happily one of those years. The main variances from budget arise from the unpredictability of meeting attendance, as well as the performance (or otherwise!) of the GSSA investment portfolios. As has been the case in recent years, the GSSA has been given a 'clean' audit, and this is in large part due to responsible and timely financial reporting by the branches and divisions. Thank you to all who are involved in that.

As any of you who compile documents with contributions sourced from a number of authors will know, attempting to persuade a dozen people to not swamp the office with late reports five days after the due date is, well, difficult. And sometimes futile. The office has established a reward system that lauds the VP with the first report submitted, but also 'recognizes' the last VP to submit. This year's clear winner is Jeannette McGill, our new President (who last year tied for last place). This year's Barking Dog winner (for last submission) was Sello Nzama (VP Membership). (These incentives work; I have it on good authority that one VP is already penning next year's report…..)

In the few days leading up to the penning of this column, there has been a flurry of communications initiated by a member of the public who attempted to take a number of school children to see the Wits discovery site in George Harrison Park in Johannesburg. Unfortunately, the Zama Zamas have moved in, neither the police or the City have made any effort to stop them, and the site has essentially been destroyed. The GSSA has been engaged with the City of Johannesburg for some time on the preservation of the park, but it seems there is no will to do anything about it, and no city or state agency is willing or able to protect it. However, there is clearly an interest from our membership as well as the public in geoheritage issues, and I think this will spur the establishment of a GSSA Geoheritage Division which could cater to interested members of the public as well as professionals. And the division would be a lobbying platform to assist protection of key sites while not sterilizing resource potential. Watch this space!

Prior to the Annual General Meeting we distributed the draft Continuing Professional Development (CPD) policy to the membership for comment. Many thanks to all those who have returned comment, all of which is very valuable. CPD has been in development for several years now, and is a direct result of the SACNASP mandate to put such a system in place. To remind all, registration with SACNASP is a legal requirement to practice as a geologist in South Africa, and establishment of a CPD system is part of that mandate. As the Voluntary Association for geologists within SACNASP, the GSSA is establishing a system suitable for our members – rather than being dictated to! It is very much a work in progress and will evolve over the next two to three years. Most of the comments received to date are quite positive; some are negative. We will address, and modify or respond accordingly.

Craig Smith



president's column

Jeannette McGill

All Geological Society of South Africa members and family and friends:

I consider it a significant honour and privilege to take over the reigns as President of the Society in the organization's 120th year. At the outset I do need to thank Avinash Bisnath for his guidance and leadership for the two previous years. I look forward to draw on his support at immediate past-president.

I looked back at what happened 120 years ago in 1895. In 1895 the first PhD in Science was conferred to a woman at a US University. This factoid resonated with me as I too was awarded my PhD from an American University: the Colorado School of Mines. I also understand that back in around 2000 I was the first female chairperson of a regional branch of the GSSA when I took over the leadership of the Free State branch that functioned in Welkom, from the Flamingo Yacht Club. Once I had finished my undergraduate studies at UPE and Rhodes as an Anglo Vaal Bursar I went and worked on the Target Brownfields exploration program and Target/Loraine gold mine. I completed my shifts for a blasting ticket at the first mechanized gold mine of its time: Target, then worked for AngloGold on the western margin of the Free State Goldfields. With a varied 12 year stint at the CSIR under my belt, which ultimately saw me leading the mining technology and research program, I am now responsible for the Technology and Innovation profile of AngloAmerican Platinum. At this juncture I wish to acknowledge and reflect my thanks to my employer who supports my role and tenure as the President of the GSSA.

The GSSA has been a natural professional home for me. After relocating back to South Africa after five years in the USA completing my Masters in Mineral Economics and my PhD in Economic Geology I struggled to resettle. Life in Gauteng had definitely changed in my absence. I took the decision to reconnect with the GSSA, attend a few meetings and get involved. Little did I know that within another five years that I would become president! When I look at

the photo-line up in the GSSA offices of all the previous presidents of this organization I am cognizant of the responsibility that I take on ensuring the custodianship of the Society continues. I am also reminded of the critical initiatives that my immediate predecessors Pamela Naidoo-Ameglio and Avinash Bisnath have delivered. From the critical update of the constitution that Pamela drove, to the focus on transformation of the society in terms of the overall demographics as well as the Journal undertaken by Avinash. My message for the coming year is not so much grounded in activities but an overarching tenant that will be taken up through Manco and Council alike.

The coming year is when "things are gonna get real" for the Society. With the focus on the upcoming 35th International Geological Congress (35IGC) the Society will occupy a far more public place in the global geological community as well as the larger associated and influenced community from a South African perspective. With the focus therefore on "getting real"

I want to share my thoughts on three critical "R's" which need to underpin the activities of the Society for the forthcoming year.

Firstly: **Relevance.** At no previous time have the needs and expectations of the greater geological community been so diverse. What students, active professionals in public, private or academia as well as associated and retired members require of the Society is significantly different. We need to ensure that we can maintain our relevance in terms of such areas as training courses, publications and social media presence, and consider particular needs accordingly. These remain critical considerations for the communications, meetings and membership subcommittees.

Second: **Responsibility.** As members of the GSSA we have a responsibility to our peers, the Society, the Profession as well as ourselves. In the dynamic professional environment registration, professional compliance and ethics are key. The importance is for us to grow membership conversion from the free students and convert that cohort into fully subscribed members and to ensure all stakeholders continue to derive value from their respective membership class. These are topics for the professional affairs and membership subcommittees to pursue.

Third: **Resilience.** The natural resources environment and commodities markets remain cyclical. As we bottom out in another downturn we need to maintain our individual and professional resilience. In these downturns the Society needs to be a professional port of call in the economic headwinds. With the oversupply of geoscientists in the market how can the Society provide job assistance and/or mentorship opportunities? They are challenges that Manco and Council will take on going forward.

So I welcome the opportunity to lead the 120-year old Geological Society of South Africa. To use a fairly colloquial phrase: things are going to real over the next year. For us to prosper I challenge Manco, Council and the entire membership base to consider our relevance, our responsibility and ensure resilience for the year ahead. Thank you.

Dr. Jeannette E. McGill

letters to the editor

1

Dear Chris,

It was with considerable dismay that I read recently on The Heritage Portal website (www.heritageportal.co.za) that six potential sites in South Africa have been removed from UNESCO's Tentative World Heritage Site (WHS) listing. To quote directly from the article: "In what has come as a complete shock to many in the local heritage community, six local sites have quietly been removed from the country's tentative World Heritage Site list". This has recently come to light following an investigation by Jacque Stoltz of the Heritage Monitoring Project. Originally there were 13 sites on the South Africa's Tentative World Heritage Site listing, and one additional site has been added (Nelson Mandela Legacy Sites). But one should perhaps not be too surprised to see that the sites removed are all largely of geoscientific and/or of mining interest. The only two sites of geological or archaeological interest that remain are the Barberton Mountain Land and the Pleistocene Occupation Sites. The removed sites (apparently none of which have had any action) are:

1. Pilgrim's Rest Reduction Works (2004)
2. Kimberley Mines and associated Early Industries (2004)
3. Alexandria Coastal Dunefields (2009)
4. The Prince Edward Island (2009)
5. The Namaqualand Copper Mining Landscape (2009)
6. The Cape Arc of Meridian (2009)

This decision appears to have been finalised by the Department of Environmental Affairs (what role has Arts and Culture in this?) following a 2-year national review and a stakeholder workshop in 2014, and a wide range of reasons, at least some of which are reasonable, have been given for the de-listing of the above sites. Readers will be relieved to see that The Cape Winelands Cultural Landscape has survived (but what about including 'terroir', starting with the underlying geology?).

On a more serious note this appears to be another example of the general lack of knowledge and indifference within the local official heritage community of things technical, and their importance in the industrial and social development of South Africa. Indeed the biggest potential site of all, the Witwatersrand and its gold, has never ever been considered, as far as I know! It must be noted that UNESCO's WHS application is a 'bottom-up' process, driven by the local community. Indeed a WHS listing is perhaps not the best way to go (note the Vredefort Dome debacle) but it's time that the geological and mining industry took a firmer grip on their indelible South African heritage and got a sustainable geological heritage processes moving, and that local in-fighting and point-scoring should cease.

Sincerely.

Gavin Whitfield

7th August 2015

Comment from Tony Ferrar

The reality is that Geology and Natural Landscapes are required to go the Natural Heritage route and Mining will be required to go the Cultural/Historical Heritage route according to UNESCO's strict rules. Mix Geology with Mining Heritage and you will probably doom them both.

The difference in the processes involved in getting these two fundamentally 'chalk & cheese' categories of WHS accepted by UNESCO, is vast. The international agencies involved are IUCN and ICOMOS respectively. The former, the International Union for the Conservation of Nature is a scientific union with a long established reputation in global conservation and the natural sciences, primarily around biodiversity. The latter, the International Council on Monuments and Sites, offers advice to UNESCO on Cultural/Historical World

Heritage Sites. ICOMOS has to do a much tougher job finding its way through the political minefields.

Mining/geology lives across the divide between Cultural & Natural, and the 'Natural' component is odd because it is not biodiversity based; it is not 'live' and therefore responsive to ecological stresses. An additional aspect is that when GSSA talks about these issues they mostly just use the term "Heritage" on its own, without distinguishing between 'Cultural' or 'Natural'. And the reality is that most vaguely informed officials and general readers assume 'Cultural' relevance because the Conservation and Biodiversity professionals and officials don't often use "Heritage" as their up-front descriptor.

Consideration of the Wits gold mining example and the Vredefort debacle are both very instructive. Wits gold mining may only be possible to conserve and present to the public via the museum route, because of the lack of control of everything in urban GP – and all indications are that it can only get more complex and worse. Triage principle: save the best & abandon the worst.

Dear Sir

I teach geology and take geology outings for kids, adults, tourists etc.

Last week, Wednesday 4 August, I visited Harrison Park to find it being mined full scale by dozens of illegal miners. This is all happening in full daylight almost directly opposite the Langlaagte Police Station.

I have no doubt that the police, who know about it, are turning a Blind eye for the usual reasons.

If the side reef pillars are mined, the whole monument will collapse and be gone forever. If it is not too late already we have maybe only days to save it.

Hope something can be done.

Regards
Barry Bryant
082 331 8194 info@educationsupport.co.za

george harrison park -

Another National Geo-disgrace and a contrarian view.

(Why we should not waste further effort on maintaining this important heritage site as it is (a version of this article was distributed to the geological heritage community in September, 2014; Ed.)

The original black granite plaque at the entrance gate, erected in 1947, when the site became a national monument.

History

According to the memorial stones at the still-imposing stonework gateway, the park was officially opened to the public on 4th October 1947, on the 61st anniversary of the proclamation of the farm Langlaagte as a public digging. The park was created and named to commemorate the official discovery of the gold-rich Main Reef pebble conglomerate by itinerant Australian prospector George Harrison in early 1886. According

Vandalised ruins of the shelter that once housed the 10-stamp mill – now re-located to Hollard Street.

to the records the park forms part of two claims (a gold claim was a 150 x 400 Cape feet; 1 Cape foot = 1. 033 English foot) which were granted to George Harrison and his prospecting partner George Walker by G. C. Oosthuizen, owner of Portion A of Langlaagte farm, in terms of mining law at the time. The site became a National Monument in 1944 and in terms of current heritage legislation is now considered a Provincial Heritage Site. (As an aside Harrison soon sold his claim for £10 and disappeared).

The gateway was erected by the City Council of Johannesburg "in honour of the pioneers of the Witwatersrand goldfields". Also on site there was a 10-stamp mill (under a slate roof) that came from the Robinson Deep Mine. The woodwork to this was partly

Part of the "artistic" entrance at the gate on Main Reef Road, when Joburg was proud of its mining heritage

destroyed by vandals (for firewood) more than 10 years ago, but the machinery was renovated and re-erected in Hollard Street (now a pedestrian way) outside of the Chamber of Mines building. Black granite information plaques damaged by fire and should be relocated too. There was also other mining gear on site but this is long gone. Soon after the first Main Reef discovery the area became the site of one of the several Langlaagte gold mining syndicates that operated to the south of the line of the Main Reef.

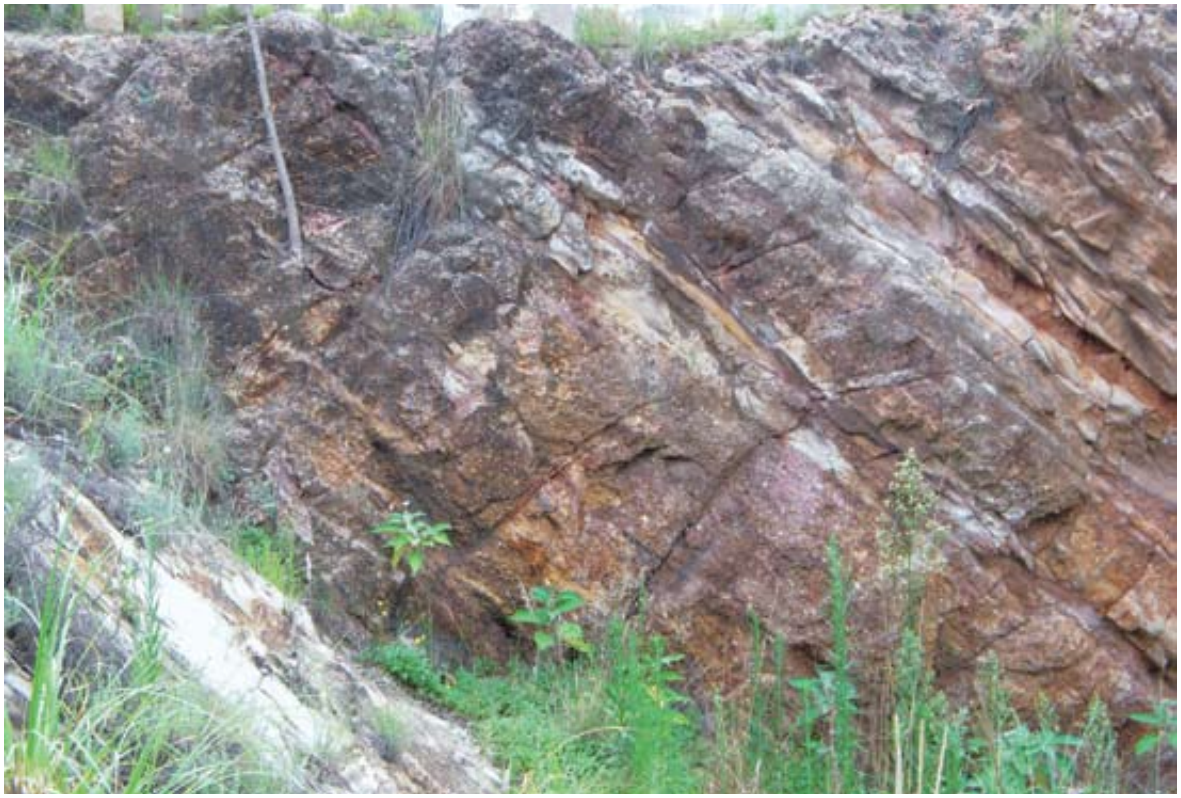
Ownership and development

Mining magnate J. B. Robinson was at the forefront, taking-up nearby claims (as mynpachts) and another group was the Paarl Syndicate which held the above claims area. In November 1886 the small township of Paarlshoop was laid out to the north of what is now Main Reef Road (at the same time as Johannesburg was being laid out). A variety of Langlaagte mining companies appear to have held the ground, and this in part became consolidated into the much larger Crown Mines area in 1909, ultimately part of the Rand Mines group. Surface rights were apparently donated by Langlaagte Estate G. M. and Crown Mines to the Historical Monuments Commission, later the now-defunct National Monuments Commission, before becoming the South African Heritage Resource Agency (SAHRA). The donated ground was later transferred to the City of Johannesburg and control now falls under management of Johannesburg City Parks. This iconic geosite was proclaimed a National Monument in 1944, as a memorial to the founding of Johannesburg and South Africa's phenomenal gold mining industry.

BUT TAKING THE EMOTION AND SENSE OF OUTRAGE OUT OF IT, LET US LOOK AT GEORGE HARRISON PARK'S GEOLOGICAL, HISTORICAL AND SOCIAL CREDENTIALS.

The Main Reef Group and the "reef remnant"

Here there existed a number of south-dipping, disconformity-bound, pyritic quartz pebble conglomerate "reefs", including the Main Reef (MR), the Main Reef Leader (MRL), the South Reef, and stratigraphically below the MR, the North Reef. They are laterally persistent and the MR and MRL were the main gold-producing reefs of the Central Witwatersrand Goldfield. As such they were the founding formation of the gold industry. These reefs, within beds of weathered quartzite, are very well exposed in the sidewalls of the old working, dipping south at about 35°. These exposures are now restricted to this immediate site,



A view of the Main reef (thick, to left side) and Main reef Leader (above it) separated by a thin sandstone layer.

The same sequence (as above,) on the western side where you can get close up to the rocks.

having been almost mined away on both sides and down dip (see pictures). Records show that the MRL was the most prolific, assaying at ounces per ton. It is an enigma why the GHP exposure was not mined, possibly remaining as a structural pillar next to the old incline shaft, or due to lower than normal gold content. As far as is known this is the only accessible, well-exposed example of in situ Main Reef that exists.

Wrong "address" and lack of local interest

George Harrison Park (GHP) has an important-sounding address along Main Reef Road, and must have been the creation of enthusiastic group people in the 1940s when there was little development in this area – although by then the main road was in existence. It lies between an unstable mined-out area to the south, exacerbated by an eyesore of more recent open-cast mining, and the arterial Main Reef Road (R41) to the

Detail of the oxidised, once pyritic quartz pebble conglomerate that is the Main Reef.

The new opencast workings immediately to the south of George Harrison Park, seen in bushy area on top right.

north. Old underground workings (inclined shaft) can be seen in the rubble on the right.

Further to the south is the working class suburb of Riverlea which no doubt has its own priorities; certainly not the conservation of an old mine working of little relevance and questionable value to them. The recent dust-making, open-cast mine working on their doorstep, would not have endeared them to the mining industry. To the north lies Paarlshoop, a small working class enclave and semi-industrial area, whose main occupier is the Abraham Kriel Orphanage. Likewise this community would have little interest in crossing an extremely busy Main Reef Road to use GHP. I would say that the immediate local community has never bought into the ideals of a National Monument here – it has little relevance to them. Indeed it is an unsavoury and tourist-unfriendly environment.

Lack of (geo)heritage education

It is generally acknowledged that this geological and historical site is one of South Africa's most important. Nevertheless promotion of the site is almost non-existent and its heritage value goes largely unnoticed. It is almost as if it is purposely being avoided by its custodian, the City of Johannesburg. Geoheritage promotion is sorely missing throughout South Africa, and it is only in some protected areas that limited education along these lines is promoted. I would venture to say that the site of the discovery of the Main Reef at GHP is certainly not in the school syllabus, nor do most of the people residing in the area know its history. I have never heard of a school bus tour stopping at GHP (while numerous schools visit the old Kromdraai gold mine near Sterkfontein). It's only the hardiest of tourists that are taken (by local geologist) to visit the site. Little mention, if any, is made of this geosite in local tourism literature.

Official neglect and Johannesburg Parks

In 2002, before the World Summit on Sustainable Development took place in Johannesburg, Eric Itzkin (then responsible for "fixed heritage" at the City of Johannesburg) arranged for GHP to be "put on the map" – and to become a tourist attraction. Together with local geologists (who spent considerable effort on this) descriptive 'black granite' rock plaques were created, a large specimen of conglomerate ore was obtained, cut and polished, and set in place in the covered stamp mill area. At that time it looked good and we were well-pleased with the work done. It was not long before the steel fencing in front of the old working was stolen – cut off at the base. A high concrete paling fence was erected around the entire park area, and the gates were kept locked for a time. Soon the large polished specimen of pyritic conglomerate disappeared, which must have taken several people and a truck to move. In

A view of the old workings looking westwards. Notice new rock dumps in the background.

2003 the stamp mill was partly destroyed and its shed left in ruins. Since then it's been a slow downward drift. But even 12 months ago it looked reasonable, if not a very attractive, but then the zama-zamas (illegal artisanal miners) arrived..

I think at best we can say is that GHP is not high on City Parks list of priorities and probably never will be, and for good reason. The park itself is an anomaly, with no defined users (except the occasional visiting geologist) and is essentially defenceless as it is. Never once have I ever seen it being used as a general park; I have on several occasions seen the grass being cut, and the weeds being removed. There is no security and it would not be viable to have any. Today all the wooden and steel railings have been removed, and the old mine working and the ruins of the stamp mill site is a potentially dangerous "nest" of zama-zamas, extracting what they can in the nearby open-cast, and possibly underground.

Recent mining activity and the zama-zamas

Recent opencast mining activity by Central Rand Gold has come within a few metres of the site, and it is

Same old working looking eastwards. The strata dip about 30 deg to the south.

probably only a matter of time before the old workings start to collapse into the recently created open-pit (see photos). The old workings are, in my opinion, in a structurally precarious position, with the possibility of sidewall collapse into the open-pit waiting to happen. Mining so close should never have been allowed, indeed no mining within say 100 m should have been carried out. This would probably have been the case if a proper environmental and heritage assessment had been carried out and strictly followed.

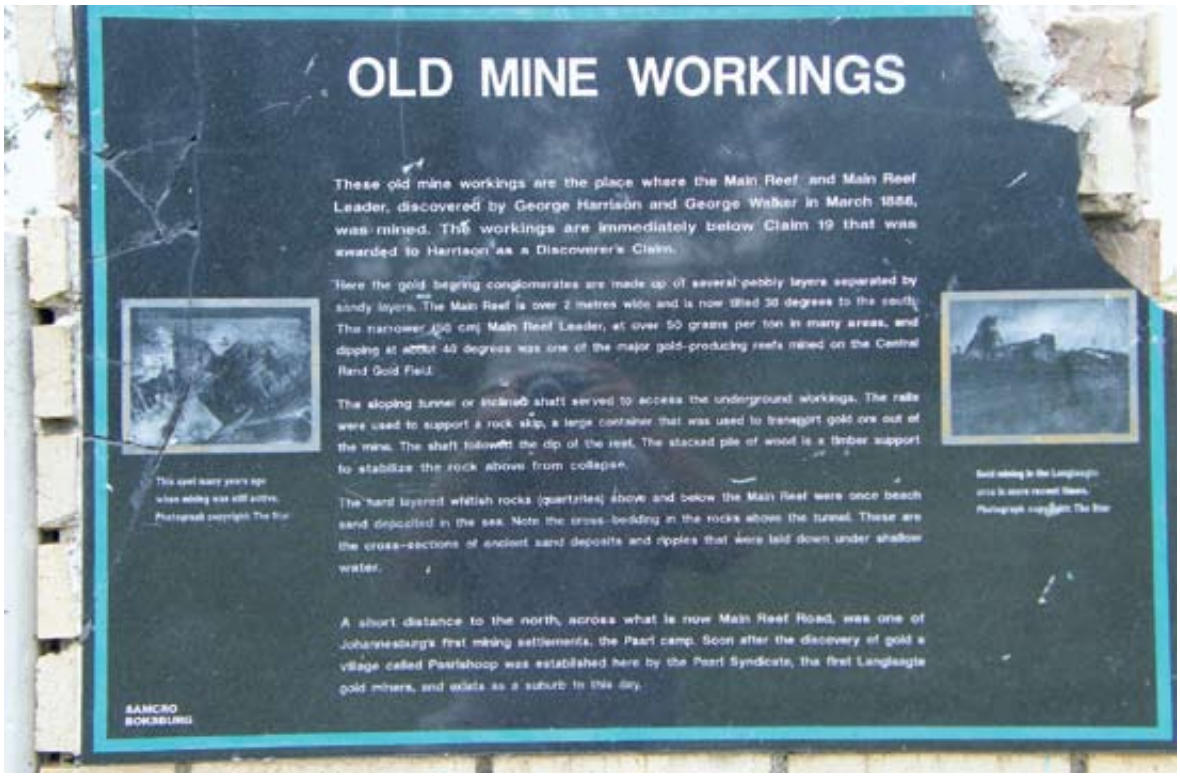
The concluding reality and a solution

There are probably few people in Johannesburg, other than geoscientists and historians, who have much of an idea what the park is about. While it is arguably one of South Africa's most important geological sites, I do not believe that there is a realistic case for preserving the site as it is. Let us not get emotional about this; progress and development happens, mistakes are made and geosites get destroyed. Nevertheless an innovative and safe solution is required to conserve this incredible geological heritage, and that does not only have to be on-site. I want to plant a seed as what may be a feasible two-fold solution:

1. A large size part of the rock strata (the MR, MRL and adjacent weathered quartzite beds) are cut and carefully removed, and sent to some suitable place for conservation, display and explanation. This could be the CoJ's Geological Museum, or an open-air display in Hollard/Main Street, maybe even a special display at Gold Reef City (where the tourists really go to). A mock-up of part of the existing workings could be created. This would be a delicate job, and a professional quarry-type company should be consulted and employed. At the same time this would leave a newly exposed face and floor still within the old working. The technology and expertise no doubt exists and can be sorted later.

2. The old workings and the newly exposed reefs would continue to exist and be protected in a manner that the CoJ can effectively manage. Having said that I do not hold out for a long-term future for the site. The park (which is next to useless, see above) could be "de-proclaimed" and the entire site re-developed – it must be valuable land. The condition on the new lessee (or owner) would

A general view of the fence in area of the national monument, looking eastwards. New mining (not seen) lies directly to the right.



Vandalised information sign at the entrance steps to the old workings. Even black granite is a target for the vandals.

be that they conserve only the old mine working and allow controlled access to the geosite. The rest of the park is an unnecessary burden.

3. The stonework gateway (erected in 1947 and hardly maintained thereafter) with its engraved stone explanations, in both English and Afrikaans, could be moved or they could stay in place, for the new occupier. If the latter then at least one should be copied for the proposed new location. The choice of that "person" needs to be carefully considered and managed. If possible the engraved stone plaques now mounted in the ruins of the "crusher shed" should be removed and go with the large specimen, for display and explanation (or copies made).

Gavin Whitfield

Part of the recent mining activity as seen from the monument site. Notice that they virtually reach the monument area (and which predictably will collapse in future).

theoretical geology

A proposed discipline to provide theory to geology.

SUMMARY

This is a summary of an article published earlier (Mikeš 2013).

Geology started as a descriptive science and developed into an empirical science. It is argued here that on its evolution it has skipped the necessary stage of theoretic science. As a result there exist numerous methods to describe geology geometrically and qualitatively on the one hand and numerous methods to describe geology mathematically and quantitatively on the other.

There has been a considerable effort in geosciences toward analytical, numerical and analogue modelling. However, it is argued here that most of these efforts still rely on inductive empirical reasoning rather than on deductive theoretical reasoning. This might cause problems if the input-output pairs are not unique (Fig below). If similar outputs can be reached by different inputs or different outputs from similar inputs than the solution is not unique and even if a model fits the data it might not be the only model that does.

The paper uses a number of thought experiments to highlight the implications of these ideas. The intention of this paper is by no means to criticise all previous works. On the contrary, they have contributed to the advancement of knowledge. The intention is to evaluate where existing knowledge might need re-consideration. It is argued that there is a need to provide a theoretical foundation across geosciences by means of a deductive reasoning from first principles. To that end the formal discipline of theoretical geology should be established.

D. Mikeš

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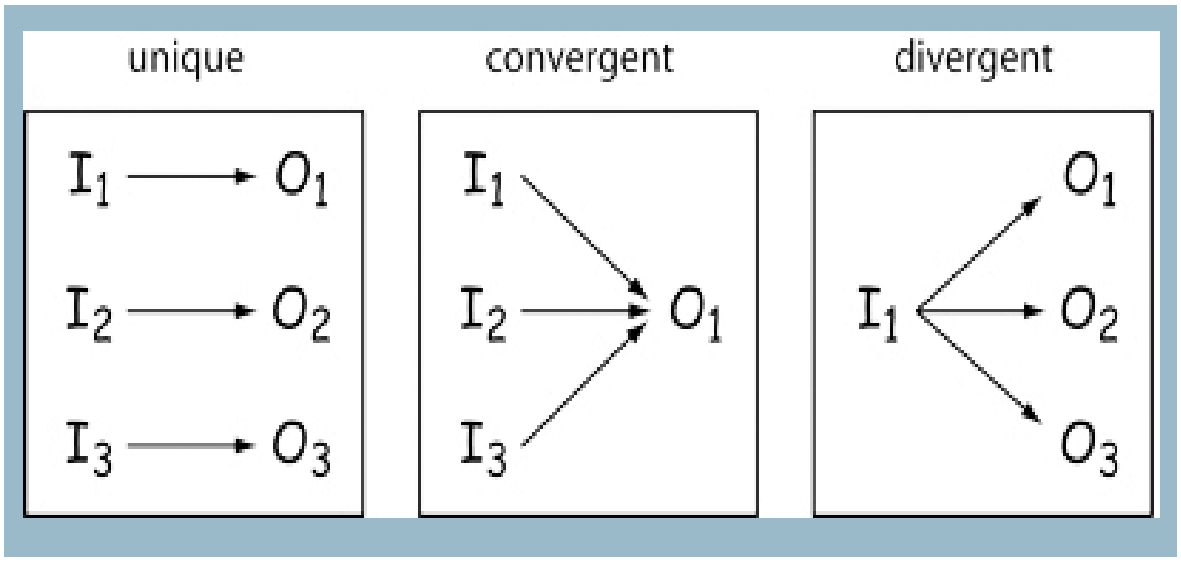
For the full article see the link.

https://www.researchgate.net/publication/280933262_THEORETICAL_GEOLOGY_THE_GAP_BETWEEN_EMPIRICAL_AND_MATHEMATICAL_GEOLOGY



Possible deductive input-to-output paths; unique: each input has one output; divergent: each input has several outputs; convergent: several inputs have one output. Input refers to a set of ambient conditions and output refers to a set of sedimentary features. Only for the unique case one output-to-input path is conclusive. For both convergent and divergent case one inductive output-to-input path is non-conclusive.

IGC 2016 field excursion:

Lower Orange River and the Richtersveld.

One of the planned pre-conference field excursions is a canoe trip through the canyon of the lower Orange River that provides an opportunity to experience at first hand the spectacular mountain desert scenery and complex geology of the Richtersveld. This account forms a condensed version of the excursion guidebook, in order to promote the trip and highlight some of the localities to be visited. Much of the canyon through the Richtersveld is inaccessible by vehicle, but the paddling, swimming and hiking in this world heritage and trans-frontier nature reserve is what makes life worth living!

Geologically, the Richtersveld area is located in the region of the Namaqua Highlands. The oldest rocks belong to the ***Orange River Group*** of volcanics and associated sediments, which were erupted and deposited about 2000 million years ago during the ***Proterozoic Era***, long before complex life forms had evolved on Earth. Consequently the ***Orange River Group*** contains no fossils and has been quite severely deformed and recrystallised during its long residence in the Earth's Crust. While the dark fractured lavas cover many a mountain slope, a very conspicuous pale grey layer of recrystallised sandstone, the ***Rosyntjieberg Quartzite***, is very resistant to erosion and builds a formidable mountain ridge (hence the name) that dominates the topography of the northern Richtersveld.

While the ancient volcanoes are long extinct and eroded away, their frozen magma chambers of granite are still preserved in the mountains that follow the Orange River Canyon. At many localities along the river the canyon walls are built of granite, such as at the Vioolsdrif border post, where the main highway crosses the river. Consequently geologists have used the name ***Vioolsdrif Granite*** when describing these coarse-grained plutonic rocks. The last intrusion of ***Vioolsdrif Granite*** occurred about 1900 million years ago.

Many features of the ***Orange River Group*** and ***Vioolsdrif Granite*** suggest that they were formed in an environment very similar to that currently prevailing in the Pacific "Rim of Fire", characterised by constant earthquakes, volcanic eruptions and other violent natural events (tsunamis, landslides, mudflows, floods). So the Orange River region was much like modern-day Japan or the Andes during the Early Proterozoic.

The zone of earthquakes and volcanoes migrated away from the Orange River region, but returned about a billion years later, about 830 million years ago, with the formation of another chain of volcanoes, the eroded roots of which build a broad ridge of granite and syenite called the ***Richtersveld Suite***. Many of these plutonic bodies are roughly circular, but are cut by a myriad of dark linear fractures called ***dykes***, where magma broke through the previously frozen deposits en route to the volcanic vents. Despite the striking contrast in colour and intrusive form between the Richtersveld granites and syenites on the one hand, and the black dykes on the other, their compositions are identical, and differ simply in the speed at which the magma froze.

Both the 2000 and 830 million year old volcanic chains had been eroded down to a flat, featureless plain close to sea level by about 750 million years ago. This coastal plain and neighbouring submarine shelf was covered with sediments of the ***Gariep Group***, comprising a thick sequence of conglomerates, sandstones and limestones. The sandstone layers have been tilted and erosion has fashioned them into the great north-south ***Stinkfontein Escarpment***, which splits the Richtersveld into two geographic domains.

The tranquil shelf seas into which the ***Gariep Group*** was deposited was disturbed about 550 million years ago by an intense belt of earthquakes from which a vast mountain chain rose and stretched all the way from the Cape to Namibia. Accelerated erosion of these Gariep mountains washed vast layers of sand and silt into the continental interior, now preserved in the horizontal sedimentary layers of the ***Nama Group***. The great load of sandstone strata depressed the

Dark limestone strata of the 540 million year old Nama Group build an escarpment above the Orange River at Noordoewer, Namibia.

Earth's Crust below sea level and allowed widespread reefs of limestone to form, containing fossil remains of the algal precursors to primitive corals (stromatolites), as well as the first marine invertebrates. The transition from sandstone to limestone in the ***Nama Group*** corresponds to the ***Cambrian Era***, which represents the time of initial expansion of life forms on Earth, which is thought to have taken place about 540 millions years ago. Continued mountain building fed more sand and silt into the ***Nama Basin***, covering the carbonate reefs and thus preserving their early life forms in the fossil record. The ***Nama Group*** is world famous for its record of the first appearance of abundant fossil remains.

The Orange River region about 500 million years ago must have been a flat featureless plain covered by the Nama strata, situated far from the sea within a huge supercontinent called ***Pangaea***. A modern analogue could be the Kalahari Plateau in Botswana or the Gobi Desert in Central Asia. This relatively quiet continental setting was interrupted by a another chain of volcanoes that erupted between 500 and 490 million years ago, again being marked by the eroded roots of granite and syenite, which build the massive ***Kuboos*** and ***Tatasberg*** Mountains in the northern Richtersveld and stretch for nearly 300 kilometres in a north-easterly direction from the Atlantic coast at Swartbank, across the Orange River Canyon at Grootpenseiland, into Namibia past Bremen and Garub in the Groot Karas Mountains.
The great Cambrian supercontinent ***Pangaea*** split into two smaller landmasses, ***Laurasia*** and ***Gondwanaland***, and the ***Carboniferous Period*** about 300 million years ago saw the latter drifting over the South Pole, with the inevitable development of vast ice sheets and mobile glaciers. For over 20 million years ***Gondwanaland*** was caught in this ***Ice Age***, with active glacial erosion of bedrock which in places removed everything down to the ancient Proterozoic basement of the ***Orange River Group***. As the ice sheets retreated, the rocky moraines and meltwater silts were left as extensive sedimentary deposits resting on the striated pavements, forming the famous ***Dwyka Tillite***.

Continued deposition of sands, silts and muds by braided river systems (like the Okavango today) covered the glacial remains with a thick sedimentary sequence called the ***Karoo Supergroup***, which continued from the ***Permian*** through to the ***Jurassic Period***. This vast ***Karoo Basin*** probably covered most of Southern Africa, and preserves an incredible array of land-based fossils, with one of the best ***Dinosaur*** records in the world. Only the ***Dwyka Tillite*** is preserved in the Orange River region, but spectacular exposures of glacial striations, facetted boulders and dropstones abound. It is probably the biggest paradox that in the Orange River region today one can stand next to the remains of ancient glaciers in an area that now records the country's hottest temperatures!

During the ***Jurassic*** to ***Cretaceous Periods***, between 180 and 130 million years ago, Gondwanaland split still further into smaller continental masses, which culminated in yet another great chain of volcanoes, which spewed forth vast volumes of dark basalt lava that also probably covered the entire landscape of Southern Africa, making it look a little like Hawaii or Iceland. While best preserved in the ***Drakensberg*** of Lesotho and Kwazulu-Natal, the roots of these volcanoes

Sunlight shines off the glacially polished surfaces on outcrops of the 300 million year old Dwyka Formation, Karoo Supergroup, Kotzedrif, Namibia.

are still preserved in the Orange River region as sheets of ***dolerite*** intruded into the ***Dwyka Tillite***, and eroded into the conspicuous ***Tandjiesberg*** that overlooks the ***Aussenkehr Plains***.

Since the ***Cretaceous Period*** Southern Africa has been uplifted into a vast high plateau, that has been eroded by scarp retreat from the coast inland. The Orange River Canyon represents the dissection of the great Escarpment, commencing at the Augrabies Falls and opening out onto a broad coastal plain at Sendelingsdrif. Downcutting of the Orange River below Augrabies and lateral dissection by its tributaries have created the spectacular mountain canyon. Differential erosion of hard and soft rocks results in the intense topographic relief, the near vertical canyon sidewalls and the many rapids throughout the sinuous course of the Orange River.

The serrated peaks of the Tandjiesberg are built of 180 million year old dolerite that intruded the horizontal sedimentary strata of the Dwyka Formation,. Aussenkehr.

The vertical wall of dark limestone that rises directly from the water at Echo Krantzes.

THE RIVER BY CANOE

The route begins at the river caps Noordoewer and follows the Orange River through to Aussenkehr, the site of a huge irrigated plantation producing grapes and vegetables for export.

Many landmarks down the Orange River have been given informal names by the river guides. The geological background to these landmarks follows.

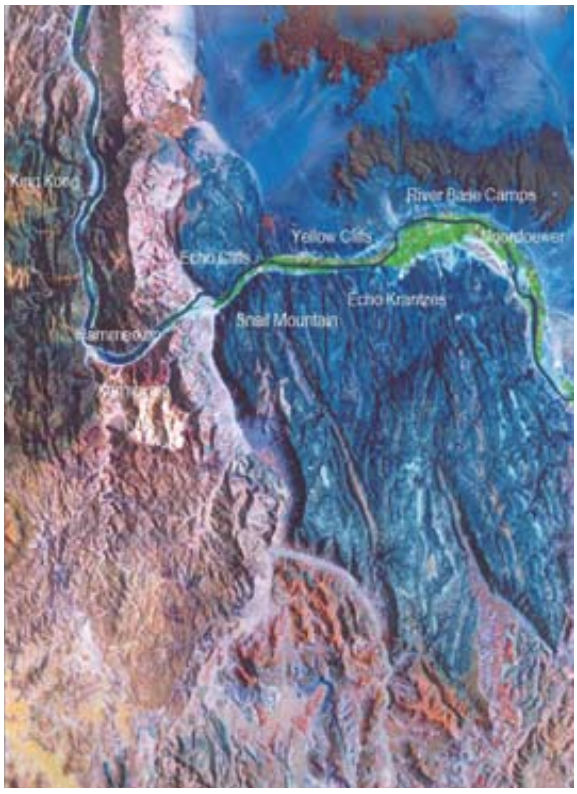
Yellow Cliffs:

The cliffs of yellow-weathering strata upon which the river camps are situated are of sedimentary origin and belong to the Dwyka Tillite Formation of the Karoo Supergroup. They are approximately 300 million years old. They continue to outcrop past the first weir and change to black near river level as the river makes a broad left bend of rapid water. Look out for large dropstones within the black tillite exposures.

If ones takes the opportunity for a closer inspection by walking from the camps to the outcrops, you will see many striated surfaces, loads of dropstones weathering out of the tillite, which themselves have pronounced facetted surfaces and linear scratches. Another feature of these glacial deposits is the development of carbonate concretions, which take on flattened spherical form, sausage shapes and often contain remarkable "cone-in-cone" internal structures. These concretions have

Satellite image of the Orange River canyon between Noordoewer and Sjambok Kloof.

Opposite Figure. Satellite image of the Orange River canyon between Sjambok Kloof and Grootpens Eiland.



probably grown by precipitation from percolating waters when the sediments were still unconsolidated, nucleating around small stone fragments. In view of the frigid conditions prevailing at the time, it is unlikely that these concretions grew around small fossil remains, as is the case with similar concretions elsewhere (eg. the famous ammonite concretions in Zululand or Southern England).

Echo Krantzes:

Not to be confused with the Echo Cliffs, which come later, soon after leaving the camps a series of sheer grey limestone cliffs rise over the left bank of the river. These limestones belong to the Nama Group and were deposited in shallow seas from about 540 million years ago. Today the modern setting would be similar to the tropical coral reefs of the Caribbean, but back then the only life forms would have been primitive algae that precipitated the carbonate as planar to wavy mats. Look carefully at the thick limestone beds and you will notice that they are built of numerous thin laminae, each of which would represent annual seasonal accumulation, much like the growth rings of trees. Counting up these thin laminae would allow you to establish how many years it took to deposit the entire cliff thickness. It probably took several thousands of years!

From a distance the thick limestone layers show a broad wavy pattern described as open folds. Squeezing of the strata as if in a vice has caused the originally flat-lying beds to buckle, much in the same way as folding a magazine. Sound is bounced back from these cliffs in a dramatic fashion, the time for the echo depending on the distance. Try shouting or smacking the river with your paddle.

Echo Krantzes to Echo Cliffs:

The grey to black Nama limestone persists for the entire distance, with the cliffs periodically retreating from the river bank, and rising on both banks. Note also the irrigation fields developed where the river banks are terraced and covered with fertile alluvium. After two further weirs, the entrance to the Echo Cliffs section is marked by a reef that extends out from the right bank, where you will see a distinctive box edge fold in the Nama beds. The strata are bent at right angles and the nature of the fold has brought some of the more resistant sandstone layers that are buried beneath the softer limestones to the level of the river, hence the reef

Echo Cliffs are built of massive bedded limestones that tower over the Orange River. An ancient earthquake caused the displacement of the beds along a fault.

jutting out into the main channel.

Echo Cliffs:

After the box fold in the strata on the right bank, the Nama limestones rise out of the river into a stupendous sheer wall that dwarfs even the Echo Krantzes. Irrigated fields line the left bank, backed by rocky ridges stretching way into the southern distance. About halfway along Echo Cliffs you can see a vertical crack in the rock layers, where displacement has occurred. This vertical crack is called a fault, probably produced during an ancient earthquake that heralded the breakup of Gondwanaland about 130 million years ago. Many of these faults contributed to the splitting of the continent and the ultimate drifting away of South America from Africa. All the major rift faults along the coast are now obscured by the ocean, so we have to look elsewhere for their smaller associated breaks, which you can see extended quite a distance inland.

Snail Mountain:

Also called the "Thumbprint" or the "Swiss Roll", the rocky ridges running behind the left bank develop some really wild patterns, as if not to be outdone by the imposing Echo Cliffs opposite. The same grey limestone beds that build the faulted cliffs have been bent into a series of folds. Unlike the highly angular box edge fold encountered earlier, the Snail represents a more smooth fold structure, caused by the buckling under pressure that was exerted during the rifting of Gondwanaland. Very soon along the river the Nama beds disappear from the canyon altogether along a major fault boundary, so the folds represented by the Snail are part of this contorted zone heralding the margin.

In geological parlance, the faults in Echo Cliffs and accompanying Snail folds have all developed along the edge of a graben within which the Nama Group have been preserved. The other edge of the graben is at Vioolsdrif near where the highway crosses the Orange River. There the Nama beds rise in another series of massive cliffs that tower over the Orange River opposite Noordoewer.

David L. Reid
Department of Geological Sciences,
University of Cape Town

Snail Mountain resembles the growth pattern of that animals shell, but represents a fold in the Nama limestone beds, brought about by compression of the strata during ancient Earth movements.

Earth Stewardship Science Research Institute

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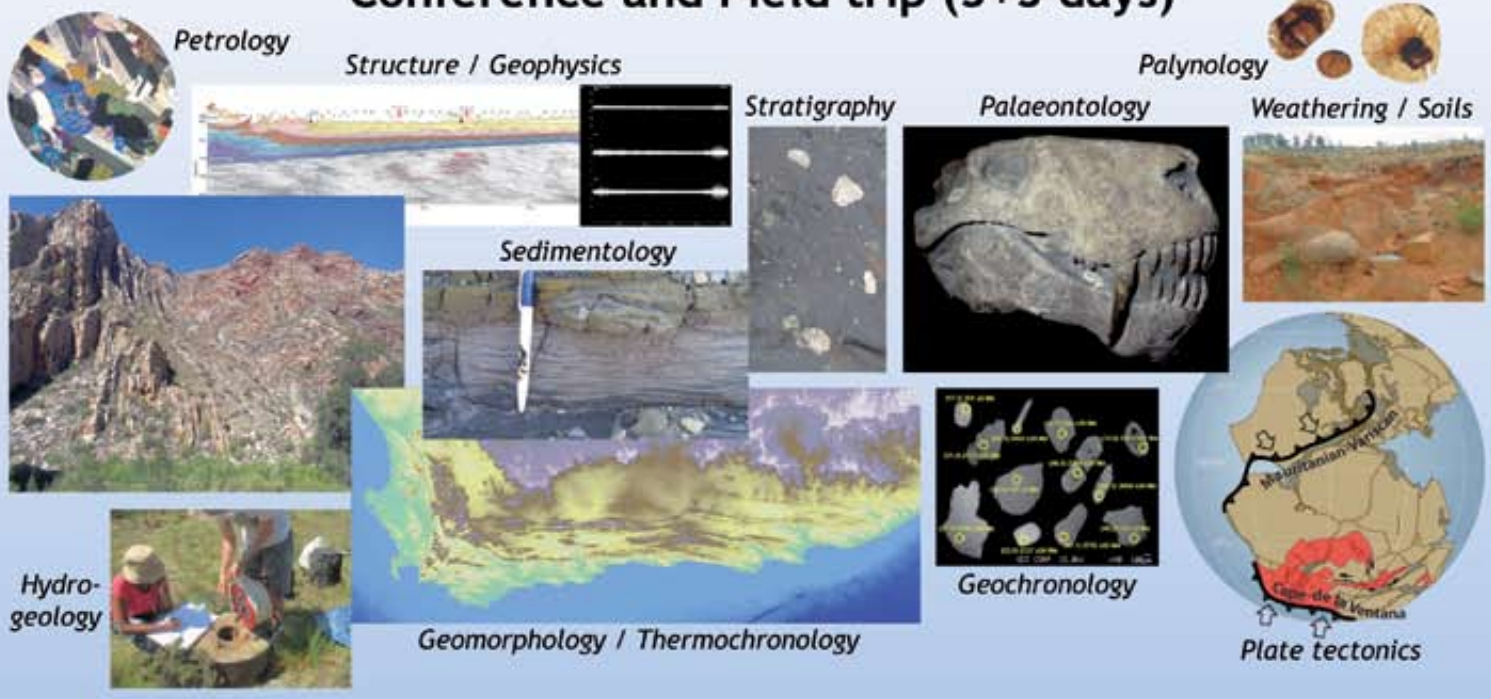
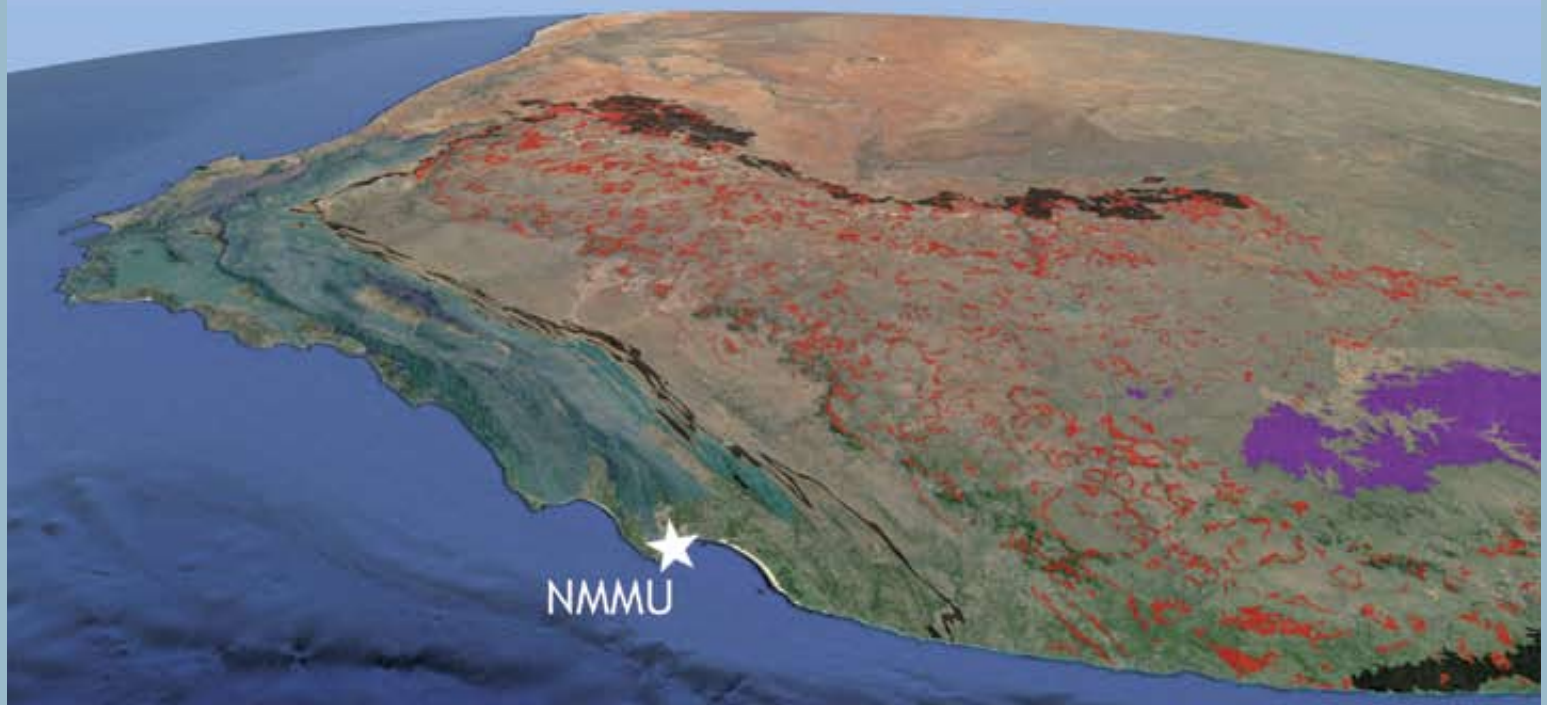
for tomorrow

'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

a geological walking tour

of Robben Island

Aerial perspective

In this 35th IGC field trip we begin our walk from the harbour to the entrance of the Political Prison, where the best sign is situated, engraved in a fine example

Sign of Political Precinct. Good example of load structures in turbidites of the Tygerberg Formation Photo: John Rogers

of deep-marine siltstone from the Malmesbury Group's Tygerberg Formation, the oldest rocks (560 million years old) on the island.

•

We then head south along the tarred perimeter road to the intersection with the road to the Lime Quarry, where we turn east to reach the rocky shoreline, just south of the beach. Here the siltstone bedrock of the island is folded and the originally horizontal beds are now vertical.

•

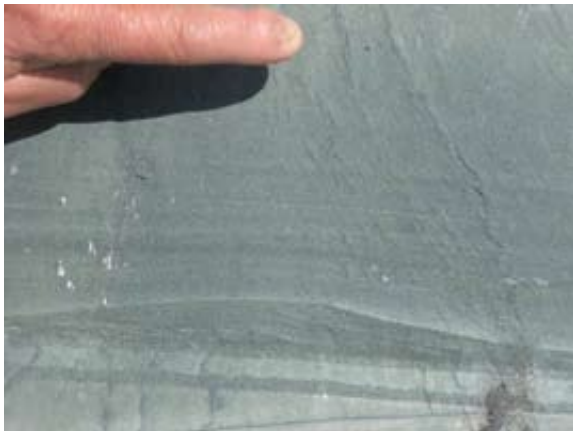
Returning to the perimeter road, we continue through the village to Alpha on the SE corner of the island, to show the well-developed shingle (gravel) beaches there.

•

After a pit-stop and a visit to the newly renovated snack-shop at Alpha, we head west along the perimeter road to the Robben Island sign between the road and the coastline with a fine view of Table Mountain, whose sandstones have long been removed from Robben Island by erosion. Here there is an outcrop of the dolerite dyke of the False Bay Dolerite Dyke Swarm, which is easier to see at Langbaai.

•

We cross the road to explore the magnificent exposures of the Tygerberg Formation in the Jan van Riebeeck Quarry, working from east to west.



Formset, proving palaeocurrent towards NW, in Tygerberg Formation (Jan van Riebeeck Quarry).

•

In the NW corner, is a Late Pleistocene lime-cemented raised beach (< 1 million years old), on top of the much older bedrock.

•

Back on the road, we head west to the SW corner of the island to show the geologically younger, uncemented, Latest Pleistocene raised beach of wave-rounded cobbles, along the landward edge of the perimeter road, out of reach of the waves of the modern, lower, coastline, which has only been at that level for less than 10 000 years.

•

Next stop is Langbaai, north of the SW corner of the

View of Table Mountain.

Differential weathering of Early Cretaceous dolerite dyke to form Langbaai on SW coast of Robben Island. Photo: John Rogers.

island, where, ideally at spring low tide, we examine the dolerite dyke there. This intruded the siltstones of the Tygerberg Formation about 130 million years ago, as the supercontinent Gondwana split up, giving birth to our geologically young South Atlantic Ocean. We stop for a packed lunch at Langbaai.

•

After lunch, we head inland, eastwards, just south of the tar road back to the village, for a better outcrop of the lime-cemented Late Pleistocene raised boulder beach, a few hundred thousand years old, first seen in the quarry. This is on the western side of the dirt road, west of the lighthouse that currently leads to a small rubbish dump.

•

Returning to the road from Langbaai to the village, we walk eastwards across Minto Hill past the huge naval guns and the lighthouse.

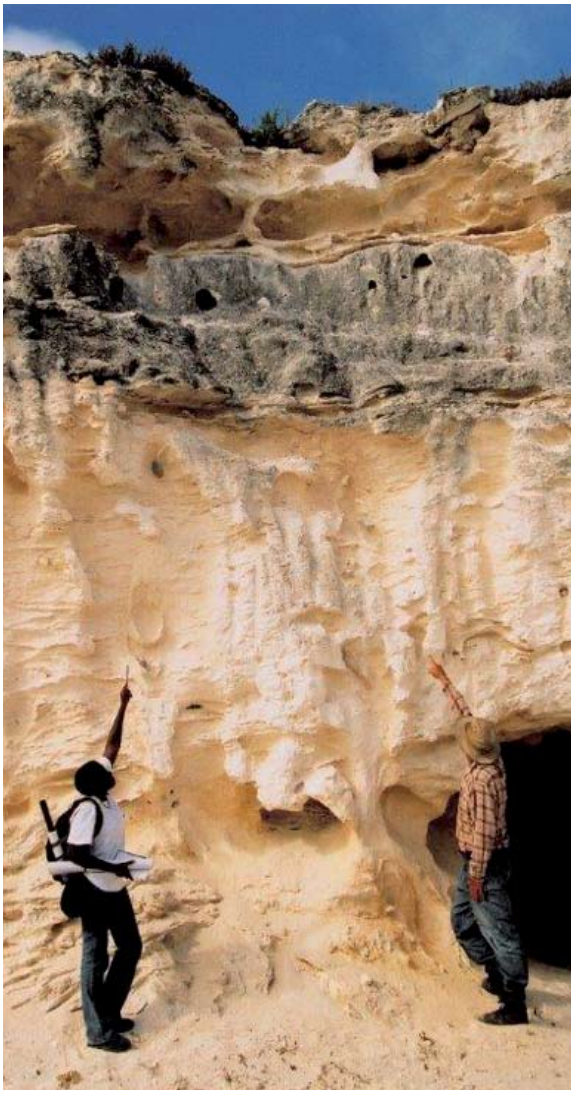
•

On reaching the perimeter road, back in The Village, we turn left (north) and walk to the intersection to turn west towards the Lime Quarry for a fine outcrop of calcrete-capped dune-rock.

•

Finally, we return eastwards to the perimeter road and turn left (north) to return to the harbour to catch the ferry back across Table Bay to the Waterfront.

John Rogers



Lighthouse on Minto Hill. Photo: John Rogers

John Rogers and his UCT Honours Student, Ms Phumzile Mkhize, pointing to the thick calcrete overlying Late Pleistocene aeolianites in the Lime Quarry, beside the excavated tool-shed used by political prisoners, including the late President Nelson Mandela. Photo: John Compton.

maggie newman -

an under-valued geological artist

Maggie has had a long professional career working on detailed fossil and geological displays for museums in the UK and South Africa, and for a number of years she has been applying her artistic talent to our geological heritage. She is now working as a freelance artist and I believe that it is high time that she received more recognition from the geological fraternity. Under the technical guidance of different geologists she is one of the few people that have the artistic ability to make a specific geological event or time period "come alive". In my opinion Maggie a largely under-valued geological asset and her technical artwork deserves both more exposure and credit.

Going back to around 1978 I have a comprehensive booklet written and illustrated by her on the Victoria Falls and published by The Victoria Falls Publicity Association when she was Secretary to that organization. Clearly her latent talent of geological illustration was then in its early stages but her intuitive grasp of geological processes, and of related natural history, comes through strongly.

Probably Maggie's most well-known geological work is the "kimberlite" series that she did for De Beers Consolidated Mines and which is now on display at the Big Hole tourist attraction in Kimberley. I understand that De Beers holds the copyright. One of her most evocative but lesser known works in this series, of a post-eruption kimberlite crater, which has a very telling Late Cretaceous story, is attached.

More recently her covers to Geobulletin are further examples of her art, under the direction (mostly I believe) of Morris Viljoen.

Arguably her recent work, the Dwyka-Ecca coal centrefold for the December 2014 edition, in one of her geologically most ambitious. What makes this work more attractive is (a) the size of the picture (A3) and (b) the accompanying geo-environmental explanation by Morris Viljoen and Marion Bamford. It would have been good if similar size pictures and more comprehensive explanations where available for previous works of geological art. As a 1960s vintage student I am sure that I would have been a lot more aware of the evolving geological environment had I seen and appreciated paintings such as these. Probably the same goes for today's young geology students.

Gavin Whitfield

MAGGIE NEWMAN
GEOLOGICAL/PALAEONTOLOGICAL ART-WORK

1. PENGELLY CAVE RESEARCH CENTRE, DEVON, U.K.
Reconstructed scene showing fauna and flora of the area during a Pleistocene interglacial.
Property of Natural History Museum, London.

2. VICTORIA FALLS.
Illustrated guide book to the geology, flora, fauna and history of Victoria Falls.
Property of Victoria Falls Publicity Association.

3. PORT ELIZABETH MUSEUM.
Series of display panels illustrating dinosaur evolution. On display in Evolution Gallery.
Property of P.E. Museum

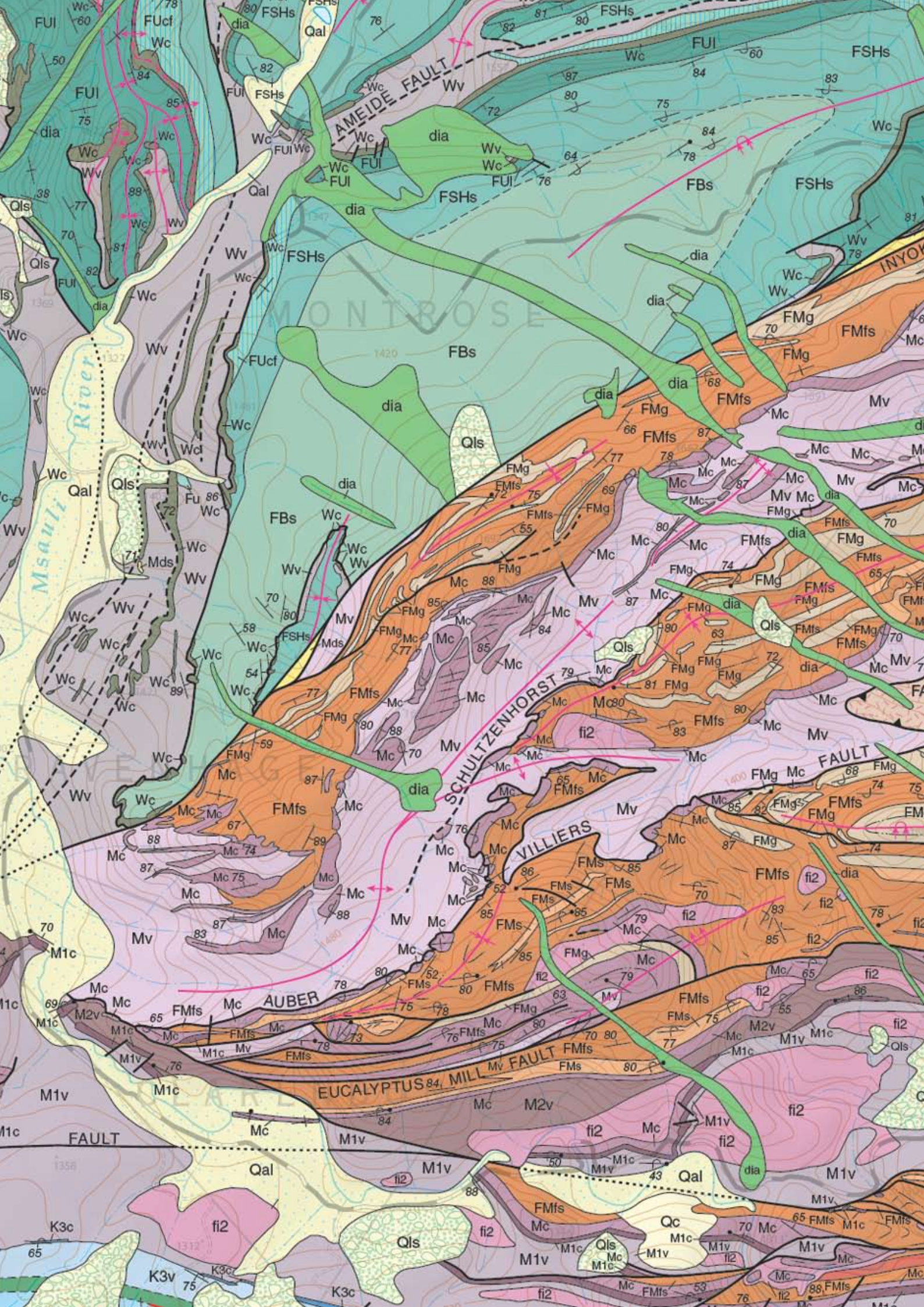
4. IZIKO MUSEUM, CAPE TOWN.
Painting of Karoo Beaufort scene with flora and fauna. On display with Lex Bremner Collection, Graaff – Reinet Museum.
Property of Iziko (?)

5. BAVIAANSKLOOF NATURE RESERVE, EASTERN CAPE.

Series of paintings showing geological history and influence of geology on drainage patterns, flora and fauna.
Displayed in Baviaanskloof N.R. visitor information centre.
Property of Eastern Cape Dept. of Environmental

Life and death in a kimberlite crater.


M. NEWMAN
2000


AMEIDE FAULT
MONTROSE
SCHULTZENHORST FAULT
VILLIERS
AUBER
EUCALYPTUS MILL FAULT
FAULT
Msauli River
INYOK
FUl
FUcf
Wc
Wv
FSHs
Qal
dia
Qls
FBs
FMg
FMfs
Mc
Mv
fi2
FMs
M1c
M2v
M1v
Qc
K3c
K3v
Mds
Fu


SADDLEBACK FAULT
24-HOUR CAMP FAULT
24-HOUR CAMP FAULT
EUCALYPTUS MILL FAULT
GRANVILLE GROVE FAULT
SCHULTZENHOF
FSHs
FUl
Wc
Wv
dia
FMfs
FMs
FMg
FMbf
FMj
Mds
Mc
Mv
FAs
FAg
FAv
Qls
Qc
Mvs
M1c
M1v
M2v
fi2

Affairs and Tourism.

6. CANGO CAVES.

Series of paintings showing geological history of the caves and typical features of karst scenery and cave formations. Displayed in restaurant area of visitor centre.
Property of Graaff-Reinet Municipality.

7. JOHAN HATTINGH'S PhD Thesis.

Series of three paintings illustrating the formation of the Sundays River Valley.
Property of Johan Hattingh.

8. KAROO NATIONAL PARK.

Two paintings, one showing the geology, flora and fauna of the park and the second, a reconstructed Beaufort scene including flora and fauna.
Displayed in visitor information area.
Property of SANparks.

9. CAMDEBOO NATIONAL PARK, GRAAF-REINET.

Series of diagrams illustrating geological history of the area.
Displayed in visitor information area Valley of Desolation.
Property of SANparks.

10. VICTORIA WEST MUSEUM.

Three paintings showing geology, flora and fauna of a typical Karoo koppie.
Property of McGregor Museum, Kimberley.

11. MCGREGOR MUSEUM, KIMBERLEY.

Diorama background paintings showing past N.Cape landscapes and associated human habitation for Ancestors Gallery.
Property of McGregor Museum.

12. De BEERS, KIMBERLEY.

Series of paintings illustrating the origin and emplacement of diamonds, with particular reference to the Kimberley area.
Displayed in De Beers Head Office, Johannesburg.
Property of De Beers.

13. De BEERS, CULLINAN.

Series of paintings (as above) but applied to Cullinan Mine.
Were to have been displayed in visitor information area but this was not done. One painting is in the board-room at the mine, but the whereabouts of the others is uncertain.
Present ownership uncertain, but originally paid for by De Beers.

14. De BEERS, VENETIA MINE.

One painting showing section of kimberlite pipe at time of eruption.
Whereabouts unknown.
Property of De Beers (?)

15. NATIONAL MUSEUM, BLOEMFONTEIN.

Poster illustrating vertebrate evolution for Jennifer Botha-Brink. These were distributed to schools in the Bloemfontein area.
Original paintings owned by the National Museum, Bloemfontein.

16. KRUGER NATIONAL PARK.

Series of fourteen diagrams with two reconstructed scenes for book by Morris Viljoen and SANparks ecologist on the geology and ecology of the Kruger Park and environs. These have since been made into posters for display at several of the camps in the park.
Property of SANparks.

17. GEOLOGICAL SOCIETY OF SOUTH AFRICA.

Five paintings for a set of posters illustrating iconic geological events in South African history, beginning with the Barberton Greenstones. The series is incomplete. Barberton, Wits gold fields, Rooiberg felsites, Transvaal dolomites, Ecca coal forests, Clarens/Elliot dinosaurs, Langebaanweg Pliocene
Original Barberton painting with Morris Viljoen, remaining four with artist.
Property of G.S.S.A.

lowe & byerly -

a Barberton Greenstone Belt Odyssey

The 2016 IGC field trip to the Barberton Greenstone Belt provides us an unusual opportunity to take an international group of scientists through what has become over the last 40 years our geologic home and favourite geologic work area.

Our study in the Barberton Belt commenced in 1975 when Don first visited the Barberton area hoping to learn a bit about the sedimentology of these ancient rocks and what they told us about life and environments on the early Earth. His interest had been piqued by a colleague at Louisiana State University, Prof. Paul Knauth, a stable isotope geochemist, who wanted to come over the greenstone belt to analyse the oxygen isotope composition of chert as a geothermometer for the Earth's surface. Don's contact in South Africa on that first trip was the now deceased Dr. Thomas Reimer. After spending a few days in Johannesburg, Don, Tom, Tom's wife Barbara all loaded into the trustworthy field vehicle, a VW Beetle rented at the airport, and headed off for Barberton. Tom was very kind in taking the time to accompany Don into the field and introduced him to many of the localities that became the focus of our study over time: the Conglomerate Quarry, Dolomite Gorge, the Barite Syncline, the Middle Marker, and many others. After Tom and Barbara returned to Johannesburg, Don was sitting out in the field in his sturdy VW and realized that he had never read the instructions for the snakebite kit that he had bought earlier in Joburg. He opened the kit, took out the folded instruction sheet, and was presented with an approximately 1 m by 1 m flow chart that looked more like the organizational schematic for a major international company. He carefully folded it back up, put it in the container, and never opened it again. So much for snakes!

Gary first came out in 1980 after we each received grants from the National Science Foundation to study the unusual mix of volcanic rocks and inter-bedded sediments in Barberton. Our basic equipment was hammer, hand lens, circa 1950 1:10,000 aerial photos, and circa 1970 1:50,000 topographic maps. For nearly twenty years of working in the greenstone belt little changed until the early 2000's when GPS and Google Earth gave us access to remarkably accurate and up-to-date satellite images and locations.

In 1981 we brought three students to begin PhD projects in the Mountainland. We had gotten a bit more sophisticated by then and rented two VW Combis for the fieldwork. Most of our research for the first few years was focused in the southern part of the belt, along the Komati River and up the long ridge to the north in the Komati, Hooggenoeg, and Kromberg Formations: areas made famous by the mapping of Morris and Richard Viljoen in the 1960's. We camped at that time, which was before the "city" of Tjakastad came into existence and there were only a couple of native rondavels in the entire valley. We were fortunate that there were some local folks because we had to get them and a team of oxen to pull one of our combis out of a gully where it had been stuck for three days after a heavy rain.

Gary (left) and Don (right) examine a satellite image during mapping

By 1982 we had a field group of eight, now using several large army tents and camping equipment generously

loaned to us by WITS geology folks, especially Mitch Miles. We were learning by trial and (many) errors how to camp and work in the bush. Two stories from this time are favourites. The tents were without floors, the ground rough, and so we cut the abundant tall grass, laid it down as a mattress, and covered it with a tarp. After a week at our first campsite one of the students lifted his old wooden suitcase and the bottom fell away. Lesson number one was termites never rest, and they will eat anything. Over the next eight weeks we occupied a number of campsites. Our second lesson was in the selection of campsites: that very cold air moves down into valley bottoms, where we unfortunately sited our tents at what became known as Ice Camp; that rodents persist in old mealie fields and welcome human visitors, Mice Camp; and that a site on the sheltered side of a ridge makes a Nice Camp.

Lunch on a chert ridge somewhere in the Barberton belt. Love that peanut butter and jelly.

At this time we also worked in the Msauli River Valley on Granville Grove and adjacent farms, where our PhD students had map and research areas. Although mapping and measuring stratigraphic sections were key parts of this study, we had largely restricted our work to the southern areas until a major period of rain in the early 1980's made it difficult to do much hiking and section measuring and we were left to drive forest roads in the combis. As a result, we extended our mapping up into Montrose and areas toward the Moodies Hills. Eventually, our map, published in 2012, covered the bulk of the Barberton Belt from the central part of the Stolzburg Syncline to the Barberton-Bulembu Road and from the Kaap Valley tonalite to the Komati Formation.

Gary would spend the 1983-84 academic year as a visiting professor in the Department of Geochemistry at University of Cape Town. The late Tony Erlank hosted the visit, and with the help of many folks at UCT, Gary learned XRF geochemistry and the value of trace elements – both opening a new perspective on how igneous rocks could be studied. Gary and wife Maud would have their first child in Cape Town.

In the mid-1980's a new group of BGB workers began an effort to discredit the stratigraphic and structural interpretations of a generation of past workers. Notably, an ophiolite model was proposed and the thick BGB stratigraphic sequence of previous studies was regarded as single thin sequence of subducted oceanic crust repeated numerous times by thrust faulting. Our early efforts seemed to best fit the older and more complex history of the BGB. We developed collaboration with Alfred Kroner that for the first time provided a basic geochronology of the BGB. This work demonstrated that the BGB rocks and stratigraphy had indeed developed over a 300 million year period by magmatic and tectonic accretion of progressively younger stratigraphic units from south to north.

Over the years we have had over 30 students at Stanford and LSU complete MS and PhD theses on the BGB rocks. Another dozen American students spent a summer as field assistants, including a number who would eventually go on to receive doctoral degrees. In 2003 we would lead a group of 28 NASA Astrobiology colleagues in a 10-day field trip and workshop, emphasizing Archean surface environments, early life, large asteroidal impacts, and the general nature of early Archean volcanism and tectonics.

Perhaps our most like-minded student and now a long-time colleague, Christoph Heubeck, has mapped much of the central BGB on either side of the Barberton-Bulembu Road and co-authored our 2012 GSA map of the greenstone belt. Christoph is now introducing a third generation of students to the remarkable rocks of the BGB. Several other former students are now also introducing a new generation of geologists to the new problems we discover each year as we continue our studies of the BGB.

End of Day. Christoph Heubeck, Gary Byerly, Roelf Le Roux, Don Lowe, and Chris Rippon talk about the day's work.

Today, most of our work does not involve regional mapping but the study of selected smaller areas aimed at trying to answer some of the many remaining issues of greenstone belt geology and early Archean crustal and biological evolution. We hope that future generations of geologists will understand the importance of field work -- the appropriate identification of lithologies, the creation of stratigraphic and structural context, and only then the application of the array of geochemical techniques that have so much potential to answer future questions about the early Earth. We would argue that many important problems are resolved or significantly ameliorated by careful field work done early in scientific work.

Since about 1985, some of our most exciting research has been the discovery and study of layers of spherical particles formed by the condensation of rock vapour clouds produced by large asteroid impacts. We have now discovered 7 or 8 of these layers and concluded that they reflect a much more prolonged Late Heavy Bombardment than is conventionally thought to have ended at about 3.8 Ga based on lunar studies. These discoveries have perhaps yielded our most widespread news coverage on multiple occasions. For young scientists a lesson from this comes from the initial negative reception of these ideas. Nearly ten years elapsed before the end of papers challenging our work. If you are confident of the work you have done, tested hypotheses in multiple ways, looked carefully at criticism, then you should persist with the work, adding new observations that support your models or disprove the models presented by others.

Barberton has truly been a life-altering experience for us. Having the privilege of studying such ancient rocks, of looking back through the window of time to observe and interpret the events on the Earth when it was young, is an opportunity that few geologists have. We have camped, shared experiences, and made the acquaintance of some of some wonderful folks, many now life-long friends. We are supremely grateful to the many geologists, scientists, mining folks, forestry persons, game park personnel, and others who have generously shared their knowledge and made available their land and facilities. These studies would not have been possible without their help. While we are not sure that 2016 will be our last field research year in Barberton, we both feel that we are likely to continue to study the treasury of rocks that we have accumulated over the years for long after our scampering around the Barberton hills has finished. It has been a hoot and we are very grateful that the opportunity to take this incredible odyssey came our way.

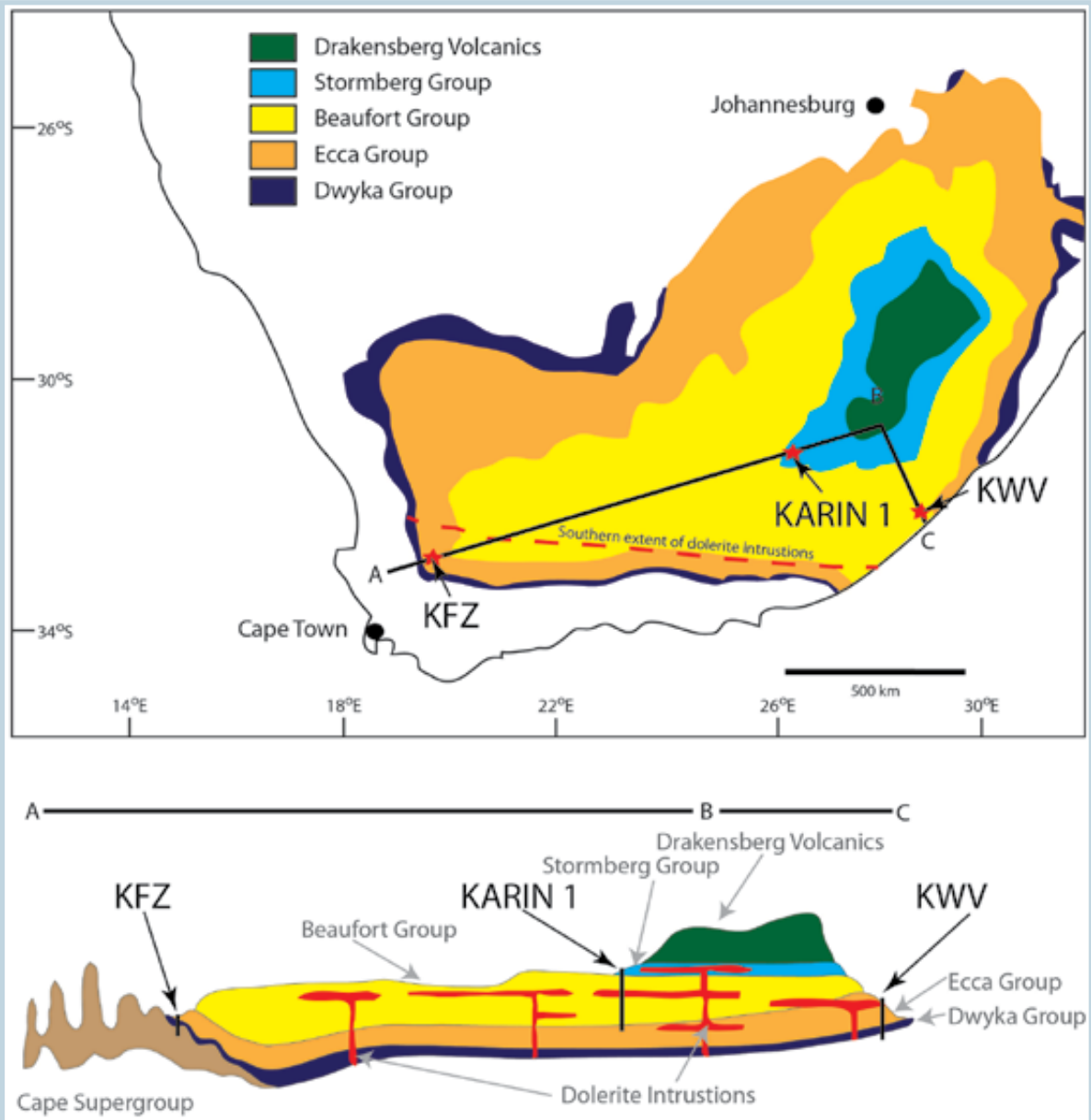
Don Lowe
Gary Byerly

Recent visitors to the Geotrail. Dave Mourant leading a group of 'geocachers' from Gauteng up the Barberton Geotrail on Saturday 8 August. Marcia van Aswegen comments; the public is getting good value and much enjoyment from the picnic spots as well as the top class presentations along this geotrail. It is a job well done.

cimera-karin

First core retrieved by Karoo Research Initiative

KARIN aims to explore the southern Karoo Basin through the extraction of deep drill cores. Drillcore will allow for reconstructing the depositional history of the Karoo Basin, determining the physical and petrochemical character of the rock succession, and unravelling the deep structure of the basin and dolerite intrusions.



Not to scale schematic representation of a cross-section through the Karoo Supergroup along section A-B in the figure above. Note the positions and depth of the boreholes are indicated only to show the geology that is expected to be intersected and is not a true reflection of their geographical location.

Figure 1: Simplified geological map and cross section of the Karoo Basin of South Africa with the position of planned CIMERA-KARIN boreholes

Figure 2: CIMERA-KARIN Project Zandfontein 89 drill site

Borehole KFZ, Zandfontein (Ceres district)

Borehole KFZ (Fig. 2) was chosen south of the so-called dolerite line near the lower contact of the Ecca Group with the Dwyka Group and within the syntaxis zone of the Cape Fold Belt (Fig 3).

Starting in the Tierberg Formation with dark grey shale with very thin and sporadic occurrences of upward fining sandstone beds, this hole progressed fairly well to intersect the carbonaceous black shales of the Whitehill Formation at ~420m (Fig. 3). The hole has intersected several fault zones and possibly a small fold structure as well. At the time of writing of this article the depth of the hole was at 485m and progressing into the Prince Albert Formation. It is the aim that this hole is completed by the 15th of August 2015.

Borehole KWV, Willowvale

The second borehole of the CIMERA-KARIN project is planend near Willowvale in the Eastern Cape Province given the dearth in knowledge about the Karoo Basin in this area (Fig 1). Borehole KWV will be a deep borehole starting just above the lower contact of the Beaufort Group with the Ecca Group (Fig 4), and is planned to be stopped within the Dwyka Group. Several intersections with dolerite intrusions are expected.

Permission was received from the Roads Department at Bisho to drill in an abandoned burrow pit on 30 July 2015, and a permit to use water from the nearby river was granted shortly after that. A separate environmental management plan will be compiled by AGES (Potchefstroom). Nick Mogridge of Geoserve visited the site, and arranged for accommodation for drilling team very close to the site.

Borehole KARIN1 near Molteno

This hole (Fig 5) is planned for the future (pending the outcome of the first two holes). The borehole is intended to be accompanied by a seismic line and aeromagnetic survey to understand geometry and distribution of numerous dolerite sills, in addition the planned borehole would intersect important biostratigraphic boundaries such as the Triassic-Jurassic boundary interval and Permian-Triassic boundary interval.

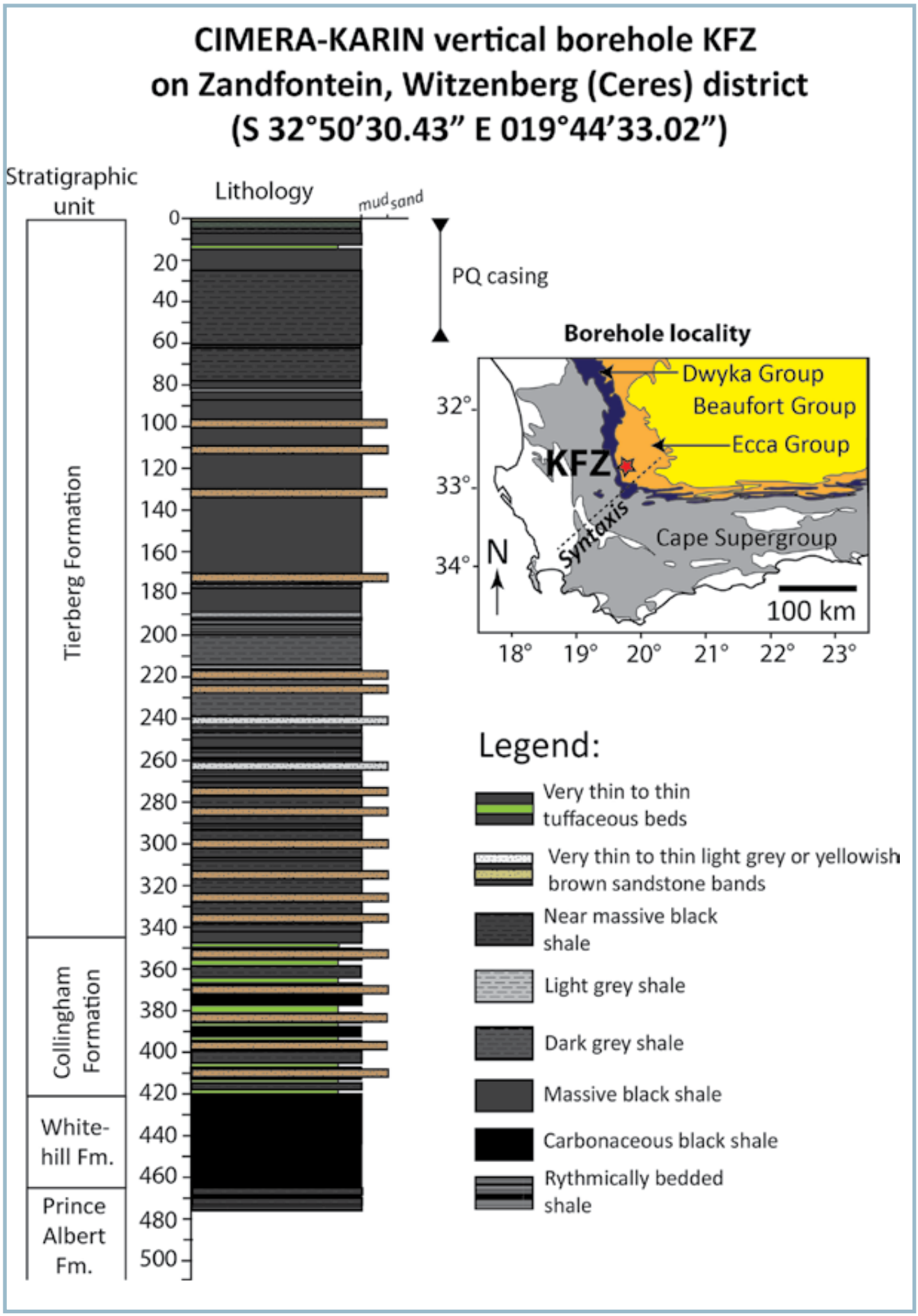


Figure 3: Simplified graphic log of retrieved core from borehole KFZ.

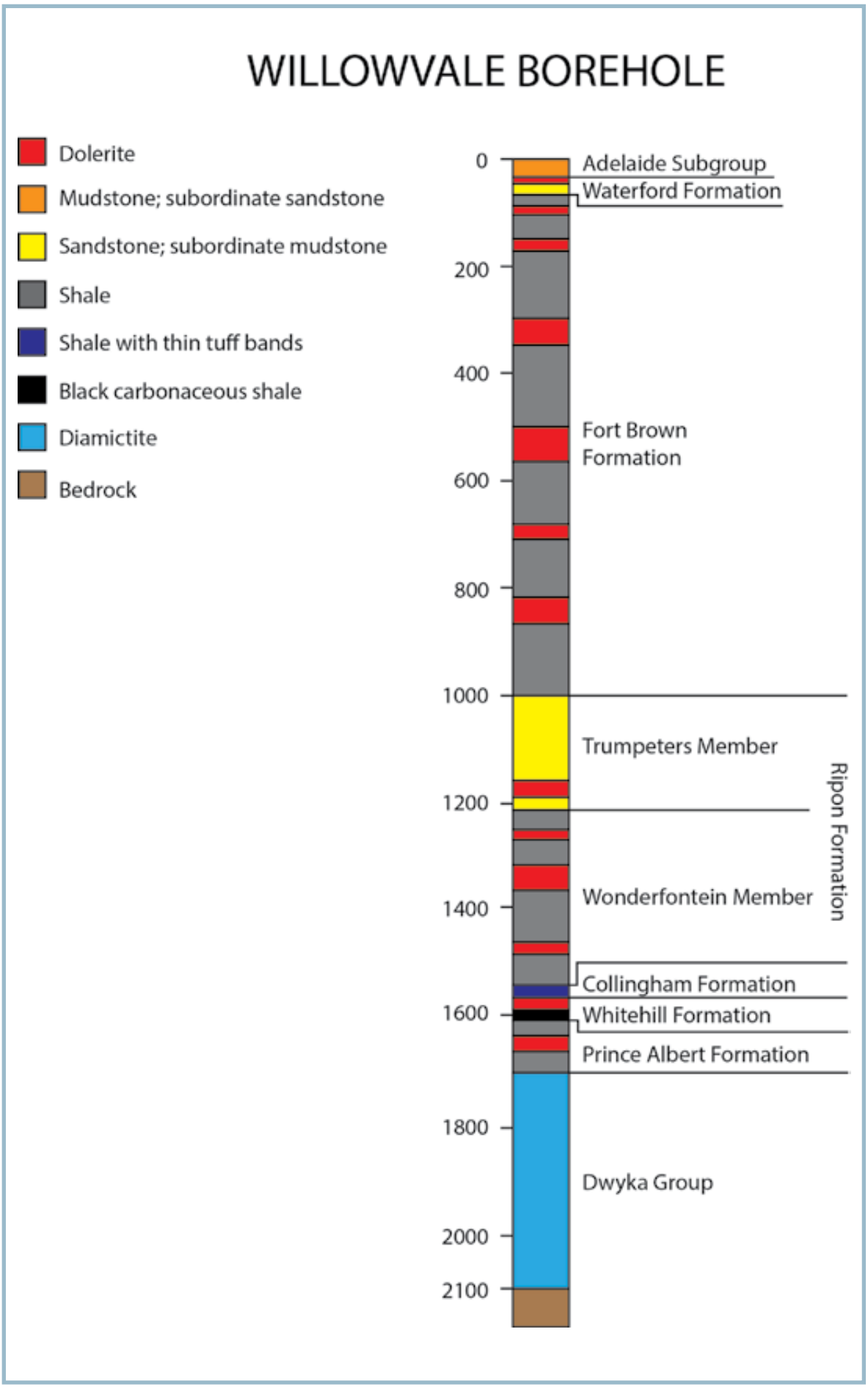


Figure 4: Predicted intersection of units by the CIMERA-KARIN project KWV (Willowvale) borehole

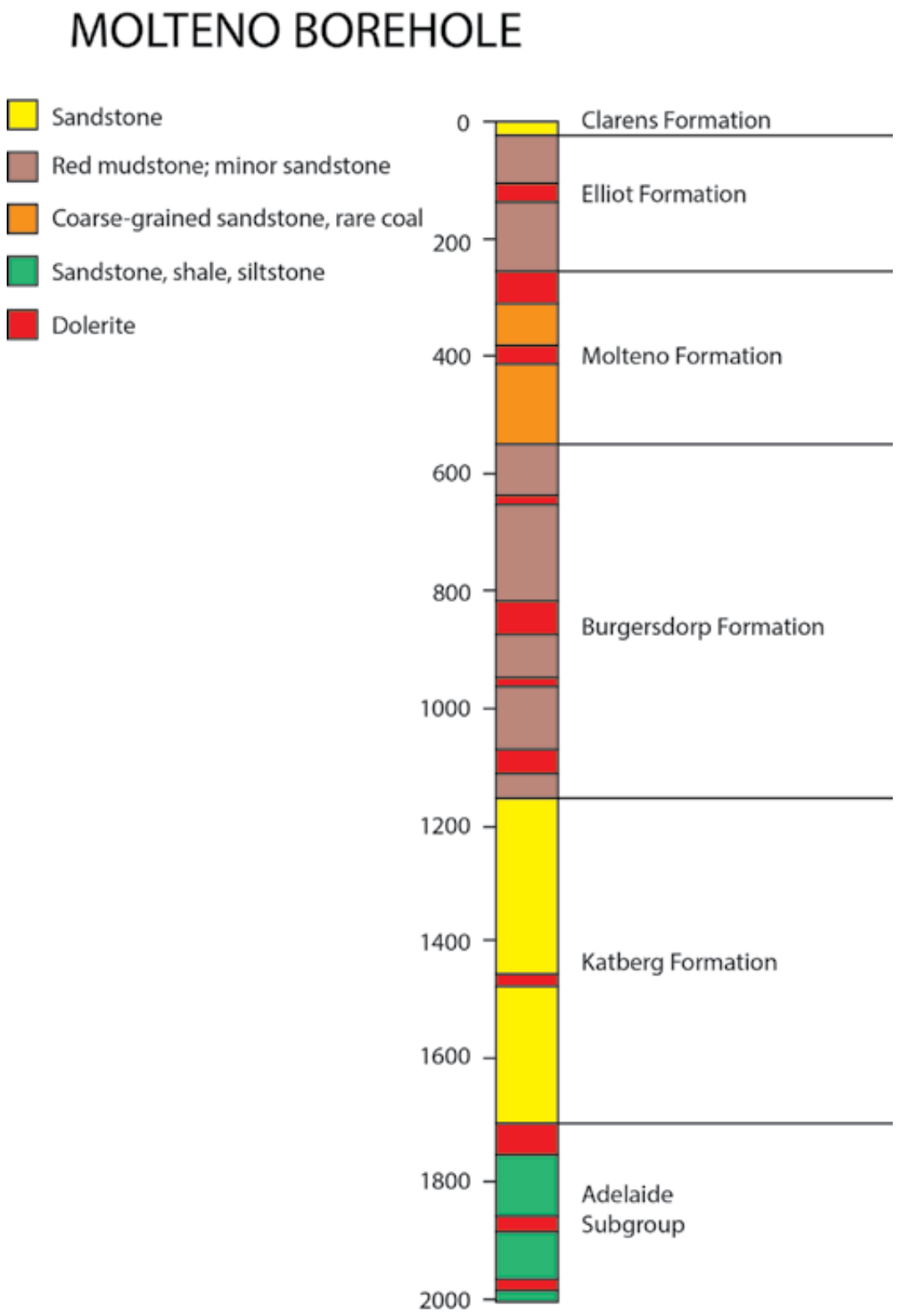


Figure 5:
Expected intersection of stratigraphic units by the CIMERA-KARIN borehole KARIN 1 near Molteno.

obituary:

Russell Wynton Shone 1944 - 2015

Professor Russell Shone passed away in Port Elizabeth on the 19th of July 2015, after bravely fighting against deteriorating health for the past 10 years. "Russ" is survived by his wife Jennifer, and two sons, Antony and Barnaby, and their families.

Russell Shone was born in Harare, Zimbabwe, on the 4th of September, 1944. He was an only child who grew up on his parents' cattle and tobacco growing farm just south of Harare. Although he had a strict and disciplined upbringing, he did experience a great deal of freedom generally associated with a farming life. Imagine having a wild Bushpig as one's favourite pet! "Pig" accompanied him on his errands which included taking morning coffee to the supervisors who were too intent on completing their tasks at hand to take a break, until welcome relief was provided by the "delivery boy". He was permitted to drive the farm Land Rover whilst still in his early teenage years and, of course, his most frequent companion was Pig, who always sat on the passenger seat!

Pig

His early years on the farm set him up for an open-air life as a geologist. So, equipped with a good education that he obtained from Prince Edward High School in Harare, he then furthered his education at Rhodes University, graduating with a B Sc (Hons) degree in Geology (1967). After graduation he took on employment with a firm of Swiss oil exploration consultants (Harry Wassal and Associates). Exploration was initially focused on the Cretaceous Algoa Basin, in the vicinity of PE, but later expanded to include similar deposits outcropping along the southern coastal region of South Africa. Over a period of some five years Russ and his co-worker John Knapton, through regional and detailed field-work, were able to obtain an in-depth perspective of the oil bearing potential of the Uitenhage Group. This required a sedimentological study of all outcrops, coupled with a 3-D interpretation of the subsurface strata and structural data related to Gondwana faulting. Russ wrote up his part of the work as an MSc thesis (submitted to UPE) and his work still stands as a logical and robust interpretation of the history of geological events in the Algoa Basin. Geologists subsequently working on Cretaceous deposits in the area have found his maps exceptionally useful as a basis for understanding the configuration of the Algoa Basin. After seven years of exploring for oil and base metals, his firm decided to terminate exploration activities in South Africa. At that time a lecturing post in sedimentology was on offer at UPE which Russell filled, until his retirement in 2009.

Sardinia Bay-2005

Russell obtained his PhD in 1984, basing his studies on the sedimentology of the Sardinia Bay Formation (lowermost Table Mountain Group). This product of scientific observations, coupled with brilliant artistic diagrams drawn in freehand, is probably the most detailed study of Cape Supergroup rocks done to date. It was always a fascinating and pleasurable experience for all who listened to his interpretation of the origin of these Palaeozoic inter-tidal and storm surge deposits.

Russell played a major role in saving the old Geology Department of UPE from closure in 1990, when the government of the day announced that Geology was no longer to be taught at the university. An appeal was sent out from the lecturers to the greater geological fraternity to advise the Rector of the university whether this was a sensible directive, or not. Some 90% of the respondents informed the Rector that it would not be wise to close down the department mainly because local geological expertise was serving the public well. Since then the Geosciences Department has been able to continue with teaching and research, focusing mainly on the sedimentology and structural geology of the Cape Fold Belt.

Balalaika

Russ will be remembered as a unique character who seemed oblivious to the state of his attire, drove his car very slowly, and had a penchant for holding on to old possessions (as testified by the presence of his many old vehicles in the backyard). He was good at sport, and, as a student, he participated in athletics, boxing and tennis - the latter he played until late in his life. He was also a qualified Professional Tennis coach. Whilst at Rhodes University he won an earlier version of what was known as the "50 mile walk". He also completed 3 gruelling Comrades Marathons, but aching knees forced him to give up on subsequent long distance events. Russ was very musical, even making a perfect balalaika in his retirement. He also played his banjo by ear. He coached tennis and athletics, paying particular attention to every athlete, encouraging each one to attain their personal best times in their events.

One of his many talents was his photographic memory, as one of us (PB) would recall how during our student days, his compatriots were very envious of this talent which enabled him to pass exams with seemingly minimum effort, while the rest of us had to put in so much extra sweat to achieve the same result. Another talent that really stood out was the way he could express his many enthusiastic ideas, often accompanied by wonderful artistic drawings. His caricature drawings, in particular, were outstanding - something along the lines of a modern Zapiro, and mostly they were created to raise a laugh.

Naturally he was able to apply at least some of his

talents in his job as a university lecturer, and many of his students realized they were being taught by someone special who could portray the normally "heavy going" subjects like Palaeontology in such an interesting fashion. With just a few lines on the board there would appear a Stegosaurus, Brontosaurus, Trilobite or a Lepidopteris fern, each drawn to perfection, accompanied by an explanation of how these animals and plants lived. Not only was he an excellent lecturer, but he went to great effort to advise students on how to prepare themselves for their examinations, and even for their first job. This advice came from the wealth of experience he gained, mainly as a roving exploration geologist, prior to joining the university in the 1970's. Russell held the HOD position for seven years, until the merger of UPE, Technikon, Vista and George Campuses to form the comprehensive "Nelson Mandela Metropolitan University" (NMMU) in 2005.

It was obvious that he was a caring person, especially where family needs were concerned. His role in nurturing his sons so that they could achieve academically, and on the sports-field, are legendary. There were many proud moments when his eldest son, Antony, excelled at tennis and Barnaby at athletics (the latter obtaining Springbok colours, specializing in the 800 metre event).

One mark of his character was to consistently search for, and expose, "The Truth". His deep sense of right and wrong, and speaking out when unfair situations manifested themselves, reflected a strict and disciplined upbringing in Zimbabwe. It was a matter of great concern to him when he heard of, or read accounts of, unscrupulous financial wizards who had cheated people out of their money, or inept politicians who were not doing their job, or were engaged in "up to no good" tricks. It really was amazing how he could recall all the finer details of so many of those cases he had read about in the newspapers.

Russ was a great storyteller, many times bending the facts somewhat to make the story worthwhile, but his friends accepted this because it was all designed to give us a good laugh. Whenever he expounded on conspiracy theories his story-telling abilities made these well worth listening to.

One attribute Russell possessed, which often put him at loggerheads with some people, was his ability to confront those who, through their own self-importance, had found themselves promoted to higher stations. He could not resist it, being a self- confessed iconoclast, he liked nothing better than to knock these people off their pedestals. It goes without saying that this did not go down well in many cases. However, one had to secretly admire his tenacity and courage in the sense that he stood up for what he saw was the right thing to do.

Russell was very kind to animals and birds. He was particularly attentive to his dogs, and cats (he built additional steps from the front garden to his bedroom for the sole purpose of assisting an ailing 18 year old cat to have easier access into his house). In his backyard are carefully carved wooden crosses bearing the names of deceased animals that had previously graced the Shone household, each with the name of the animal on it, bearing testimony to his caring nature for animals. He nursed many injured birds back to health.

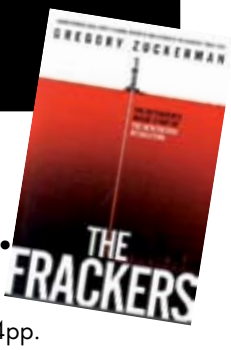
On the afternoon he died one of us (JB) walked out into the backyard of the Shone home and noticed a large number of birds (mainly pigeons and doves) settling on the roof above the kitchen. More and more birds arrived – all coming for the grain that Russell had faithfully fed them for years. What a tribute it was to Russell's caring love for Nature's creatures.

The message we take with us on the departure of a dear friend is, firstly, let us seek out and defend the truth wherever we find injustices in our society, and secondly, let us be kind to animals and birds, playing our part in preserving our heritage for future generations.

Peter Booth and
John Bartels

book review:

The Frackers



The Frackers by Gregory Zuckerman,
Portfolio Penguin. London (2013) 404pp.
ISBN 978-0-670-92367-0
List price: £14.99 www.penguin.com

'THE FRACKERS is written by the Wall Street journalist, Gregory Zuckerman and was published as a 412-page paperback by Penguin in 2014. Although no mention is made of the potential for shale-gas in South Africa, it is nevertheless an interesting book for South African geologists to read. The geological detail, however is sparse and the author concentrates on following the fortunes of several wildcatters, drilling all over the United States of America with hugely varying fortunes as time goes on. To mention time is relevant, because the time-frame of the book is the first decade and a half of the 21st Century, during which the USA became far less dependent on Middle East oil, while, thanks to ISIS, that area became even more politically volatile than usual. The roller-coaster tales of the wildcatters are cleverly interwoven throughout the book and Zuckerman's grounding in Wall Street allows him to cope with the billions of dollars involved in the telling of this fascinating story. A comprehensive review by Dick Selley follows below.

John Rogers

The Frackers' is, as it says on the cover, 'The outrageous inside story of the new energy revolution'. It is a rollicking good tale that reads as if Bart Simpson had written the TV series 'Dallas'.

Gregory Zuckerman lives in New Jersey and writes for the Wall Street Journal. To research 'The Frackers' he has ventured outside his own comfort zone into unknown territory, both geographically and technically. The book tells the story of the shale gas revolution, tracing the renaissance of an old-established Appalachian cottage industry into the boom in shale gas and oil brought about by the combination of hydraulic fracturing and horizontal drilling. He describes the birth of artificial fracturing using exploding gunpowder. This technique developed by John Wilkes Booth who later applied his skill with explosives to shooting Abraham Lincoln. There was another early cottage industry method of hydraulic fracturing, so-called 'River fractures' in which rivers were the source of both water and sand (how green is that?). The tale continues with the advent of gel-fracks and then how, almost by accident, by diluting the gel with more water, the slick-water fracks finally enabled the gas to be produced at economic flow rates. Parallel with this tale the book describes the evolution of horizontal drilling by Sun Oil and its spinoff company, Oryx.

There is a useful account of the etymology of fracking/fraccing. This includes the little known fact that the word was first used as a swear word in the late 1970's TV series 'Battle Star Galactica'.

The science and technology in this book is presented higgledy piggledy, with geoboobs that will make geologists wince. But what really makes the book come alive is the account of the characters that made the breakthroughs in the shale gas revolution. First and foremost is the late George Mitchell. He drilled 200 wells in the 'tombstone' rock of the Barnett shale before his company perfected the combination of drilling and fracturing that made the tombstone give up its gas. Many other characters, winners and losers, in the shale gas revolution are described along the way with colourful descriptions of their physical characteristics, sporting and business prowess and sexual proclivities. The book concludes with a brief 'Afterword' that dismisses the environmental opposition to fracking. There is a bibliography of sorts, but it lists references to newspaper articles rather than to learned journals.

Zuckerman credits George Mitchell's geologist James Henry with identifying the productive potential of the Barnett shale but does not include the paper in the bibliography (Probably Gregory, 1981 - See below). Gregory's paper was spotted by the USGS who used it in subsequent reports on the gas potential of the Barnett. The book shows every sign of being written in haste and is poorly edited. The list of contents has a series of headings, with accompanying page numbers, but the book itself is divided into chapters which are not listed in the contents. The book contains extensive amounts of dialogue, much of which if not created by the author must be hearsay, as the author was not present during the conversations. The imaginative nature of the dialogue and poor editing are shown by the insertion of inverted commas denoting the termination of dialogue half way through sentences. These criticisms should not detract from the reader wanting an exciting account of the shale gas revolution.

'The Frackers' is not a book to read for a careful study of the renaissance of the US shale gas (and oil) industry. 'The Frackers' is, however, a perfect read, in tone and length, for a flight between London and Dallas-Fort Worth airports.

REFERENCE

Henry, J.D., 1982, Stratigraphy of the Barnett Shale (Mississippian) and associated reefs in the northern Fort Worth Basin, in Martin, C.A., ed., Petroleum geology of the Fort Worth Basin and Bend Arch area: Dallas Geological Society, Dallas, Texas, p. 157-177.

Reviewed by Dick Selley

media monitor

MINING AND EXPLORATION NEWS

COPPER

Ivanhoe Mines and China's Zijin Mining Group signed a landmark agreement to co-develop the world-scale Kamoa copper discovery in the Democratic Republic of Congo. Zijin will buy 49.5% of Ivanhoe's 95% stake in Kamoa for a total cash consideration of US$412 million, with the option to acquire a further 1% upon successfully arranging project financing for 65% of the first phase of the development costs, which the preliminary economic assessment estimated at approximately US$1.4 billion.

GOLD

Aureus Mining's New Liberty project in Liberia completed its first gold pour and is on track to reach full-scale steady-state production in the third quarter of 2015. New Liberty, Liberia's first commercial gold mine, is expected to produce 119 000 ounces per annum over the first six years of an 8-year mine life.

Auroch Minerals is selling its Manica mining concession in Mozambique to Xtract Resources for US$11 million in cash and shares. Auroch recently completed a preliminary economic assessment on the Fair Bride deposit within the concession, which outlined a 7-year open pit and shallow underground operation producing an estimated 46 700 ounces per annum, with a start-up capital requirement of US$28.4 million. Xtract Resources, which is listed on the London AIM, owns the Chépica gold and copper mine in Chile and has acquired the O'Kiep and Carolusberg copper sulphide dump projects in South Africa.

INDUSTRIAL MINERALS

Circum Minerals' Danakil potash project in Ethiopia could become one of the world's largest and lowest cost producers, according to the outcome of the definitive feasibility study. Based on Proven and Probable reserves of 107.8 Mt of KCl equivalent, the project has an expected annual production of 2 Mt of muriate of potash (KCl) and 750 kt of sulphate of potash over a 26-year mine life for phase 1. The Measured and Indicated resources total

2800 Mt of potash salts. The deposit is easily amenable to low-cost solution mining, and the project is forecast to have one of the lowest capital intensities per annual ton of production of any major potash project in the world. The DFS estimates the development capital for phase I at US$2.58 billion, or US$940 per ton of annual production, compared with US$2000 per ton for recently completed or planned projects in Canada and Belarus.

South Boulder Mines declared a maiden ore reserve of 1100 Mt, comprising 287 Mt Proved plus 820 Mt Probable, at 10% K_2O equivalent for its Colluli potash project in Eritrea. The equivalent contained K_2SO_4 (sulphate of potash) is approximately 205 Mt, which would support a mine life of more than 200 years at the production rate modelled in the prefeasibility study. A definitive feasibility study is due to be completed in the third quarter of 2015.

Elemental Minerals has appointed Hatch Goba to conduct the bankable feasibility study at its Kola sylvinite project in the Republic of Congo, together with a prefeasibility study for the Dougo carnallite project. Kola is a large sylvinite deposit, for which the pre-feasibility study defined Proven and Probable Reserves of 152 Mt of at an average grade of 31.7% KCl. The Kola BFS will be for a conventional underground mine with phased development, planned to reach full scale (2 Mt/a KCl) by 2024. The Dougou deposit, 15 km southwest of Kola, is a very large carnallite deposit with a Measured and Indicated resource of 1100 Mt grading 20.6% KCl. The Dougou PFS will be for an initial 400 kt/a KCl solution mining operation, scaleable to 800 kt/a and then to 1.2 Mt/a.

Syrah Resources finalized the feasibility study for its Balama graphite project in Mozambique's Cabo Delgado province. The maiden ore reserve of 81 Mt at 16.2% total graphitic carbon (13.2 Mt contained graphite) is sufficient to support operations for over 40 years, with an average annual production of 356 kt of concentrate during the first 10 years. The ore reserve includes 13.2 Mt of contained flake graphite making Balama the world's largest reserve of flake graphite. The initial capital cost is estimated at US$138 million, with cash operating costs of approximately US$ 286 per ton product FOB from the port of Nacala and a payback period of less than 2 years from commercial production. Syrah separately announced a fully underwritten capital raising of A$211 million, which will be predominantly used to finance the development of Balama, and expects to begin ramp-up of production 18 months after completion of financing.

IRON ORE

Ferrum Crescent plans to sell a 39% stake in its Moonlight magnetite project in South Africa's Limpopo Province to Principle Monarchy Investments for R124 million (US$12 million). The proceeds will be used towards the bankable feasibility study. The Moonlight deposit contains a JORC-compliant Measured and Indicated resource of 135 Mt at around 29% Fe. The project concept involves mining and beneficiating at Moonlight, transporting the concentrate via slurry pipeline to area close to railhead, and the manufacture of 6 Mt/a of blast-furnace and direct-reduction grade pellets for export and domestic sale.

Equatorial Resources has agreed to sell its Mayoko-Moussondji iron ore project in the Republic of Congo to Midus Global, a subsidiary of European trading company Interalloys Trading, for A$5 million plus a 2% royalty on all production. Interalloys intends to develop Mayoko-Moussondji with a view to starting small-scale production in 2016. Equatorial retains 100% ownership of the potentially large-scale Badondo project in the northwest region of the country.

PLATINUM GROUP ELEMENTS

Ivanhoe Mines began work on a feasibility study for the first phase of development at the Platreef project on the northern limb the Bushveld Complex. The study will build upon the findings of the pre-feasibility study completed in January 2015 that included construction of an underground mine and an initial 4 Mt/a concentrator to produce an estimated 433 000 ounces of platinum, palladium, rhodium, and gold (3PE+Au), plus 19 million pounds of nickel and 12 million pounds of copper per year.

Platinum Group Metals Ltd increased the mineral resource at the Waterberg Joint Venture to 38.25 million

ounces 3E (platinum, palladium, and gold), including 12.61 million ounces in the Indicated category. Drilling is continuing with 10 rigs, and the deposit is still open for expansion. Drilling and engineering work is being funded by the Japan Oil, Gas and Metals National Corporation (JOGMEC) under a US$20 million commitment.

RARE EARTHS

Frontier Rare Earths completed a positive pre-feasibility study on the Zandkopsdrift rare earth element project in South Africa's Northern Cape Province. The economic evaluation shows an internal rate of return of 30%, and a net present value of US$2.98 billion at an 8% discount rate. Frontier is planning to produce 8000 t/a of high-purity, separated total rare earth oxides for the first four years of operation, with an expansion to 16 000 t/a from year five onwards. A saleable manganese sulphate by-product will also be produced at a rate of 48 kt/a during phase 1, doubling to 96 kt/a for phase 2. The Proven and Probable reserves of 41.12 Mt at 1.92% total rare earth oxides (788 kt of TREO) are sufficient for a 45-year life of mine. Frontier is developing Zandkopsdrift in partnership with Korea Resources Corporation, the mining and natural resource investment arm of the South Korean Government, which owns a 10% interest in the project.

ECONOMIC TRENDS

Mineral exploration worldwide is in crisis, according to a new report, *Tackling the Crisis in Mineral Exploration* by The Boston Consulting Group (BCG). From 2010 through 2013 the annual number of discoveries (excluding bulk commodities) declined by more than half, despite significant increases in exploration spending. Since the end of the boom, most mining companies have shifted their focus to productivity and cut back sharply on exploration spending. Risk-averse companies are cutting back on greenfield exploration in favour of brownfield projects, but in doing so, they incur more risk than if they had balanced the two types of exploration in a portfolio approach. The report concludes that mining companies that shift their focus from productivity to an integrated approach that restores greenfield exploration will come out ahead. Similarly, EY, in its report *Business risks in mining and metals 2015–2016*, placed future growth at the top of the risk rankings, with productivity and access to capital in second and third place respectively. 'Given the long lead time to develop new supply, decisions to invest for future growth have to be made now or long-term returns will be lowered', the report stated. PwC, in its latest review of trends in the global mining industry, *Mine 2015*, notes the top 40 companies by market capitalization decreased their exploration spending to 'a miserly' $4.9 billion in 2014, compared with $6.3 billion in 2013 and $12 billion in 2012, while a further concern is that junior miners are finding it increasingly difficult to raise funds for greenfield exploration and find promising new prospects. The report warns that 'if reserve levels continue to decrease … it may further exacerbate the demand and supply volatility witnessed in recent years'.

Pamukkale & Hierapolis, Turkey

THE GEOTRAVELLER

By Roger Scoon

PAMUKKALE AND HIERAPOLIS, TURKEY:
Spectacular Travertine Terraces and an Ancient City

The wall of snow white terraces of travertine tower above the village of Pamukkale.

The snow white deposits of travertine that cap a plateau that towers above the village of Pamukkale are one of the most well known tourist attractions in south-western Turkey. Together with an ancient city, which was built on the travertine in part due to the availability of building stone and the associated hot springs and mud pools, the Hierapolis-Pamukkale site was awarded UNESCO World Heritage status in 1988.

Pamukkale (the English translation is "cotton castle") is situated to the north of the regional city of Denizli, within the Menderes Valley. This is a fertile, temperate region, typical of south-western Turkey. The temperate nature of the climate is in part due to proximity to the Aegean and Mediterranean Seas and the broad valleys and plains are in marked contrast to the mountainous, arid areas farther east. Numerous Greco-Roman (and Byzantine) archaeological sites occur in this part of Turkey, including Ephesus one of the largest and best preserved ancient cities in the world.

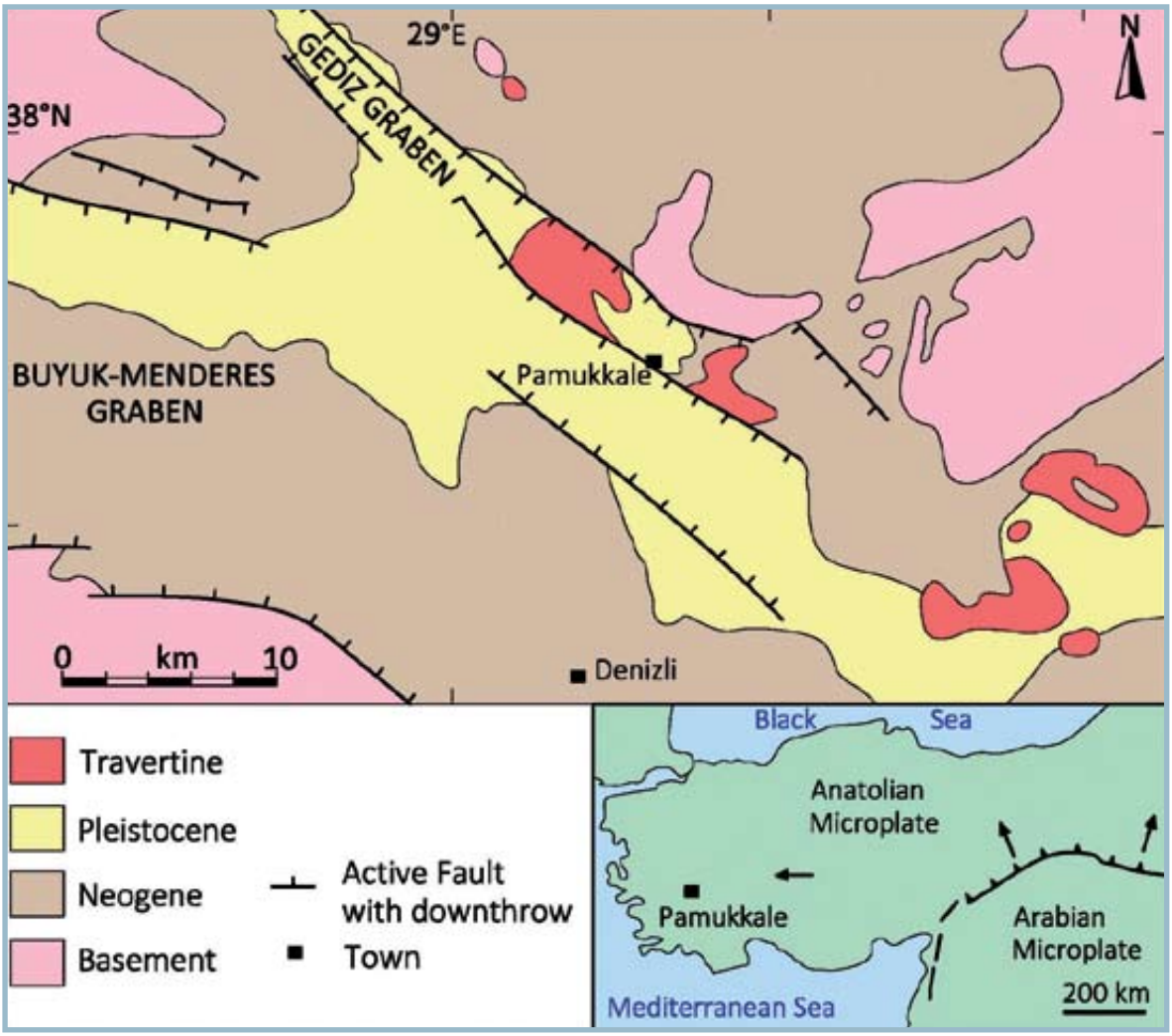
Visitors have bathed in the hot springs and travertine pools of the Hierapolis-Pamukkale site for thousands of years. In the mid-20th century, tourism became a problem as hotels and a road were built over part of the site causing considerable damage. After declaration of the World Heritage status, hotels were demolished and the road was replaced with artificial pools. The site is now well protected; the new hotels were moved to a nearby village and visitors are only allowed to walk and bathe in selected pools. The wearing of shoes on the terraces is prohibited and access is controlled by a system of walkways.

*The terraces at Pamukkale are made almost entirely of travertine, a hard, compact limestone deposited from springs or percolating waters. Travertine is a corruption of "**Tiburtinus**" (from the occurrence of extensive deposits of hard limestone at Tibur, near Rome) and is distinguished from softer, porous tufa. The travertine at Pamukkale is deposited from carbonate-rich waters flowing from hot springs. Some seventeen hot water springs have been documented in the area with temperatures in the range of 35 - 100 degrees C. Several of the springs feed a 300 m-long channel that provides hot water to a manmade pool near the edge of the plateau at Pamukkale. This channel is initially fed into a manmade bathing pool, partially lined with ancient stone tablets and blocks, prior to cascading over a section of the terraces. A chemical analysis of*

The travertine deposits and pools at Pamukkale are visited by huge numbers of tourists.

the water reports the concentrations of selected cations (calcium: 419 mg/l; magnesium: 106 mg/l; sodium: 6 mg/l) and anions (bicarbonate: 1080 mg/l; sulphate: 560 mg/l; chlorine: 14 mg/l; nitrate: 5 mg/l).

The travertine is deposited from upwelling hot water supersaturated in calcium carbonate. Precipitation is triggered by degassing of carbon dioxide, a process that continues until the carbon dioxide in the water is in equilibrium with the carbon dioxide in the air. The reaction can be quantified as $H_2O+CO_2+CaCO_3 = Ca(HCO_3)_2$*. The calcium carbonate is initially deposited as a soft jelly-like substance, but this rapidly hardens into hard, compact, travertine. Hardening is dictated by temperature (of water and air) and flow rate. The water sourced from the hot springs at Pamukkale typically*



Generalized map showing the structural setting of the Pamukkale travertine deposits (simplified from Altunel and Hancock).

Some of the fresh (white) travertine deposits of travertine at Pamukkale drape downward off the plateau of older travertine (grey).

reports atmospheric levels of 725 mg/l of carbon dioxide, but this decreases to 145 mg/l as the water flows across the terraces. The contained content of calcium carbonate similarly decreases, from approximately 1200 mg/l to 400 mg/l. Some 500 mg of calcium carbonate is deposited for each litre of water (assuming a constant flow rate of 465 l/s, this equates to 44 kg daily). It is estimated that the travertine can deposit a thin skin over an area of 13,500 square metres per day.

The active travertine deposits in the Denizli region - four main centres are recognized, of which the Pamukkale locality is the most well known - cover an area of about 10 square km. They typically crop out on parts of a regional plateau. The morphology and regional setting of the deposits has been described in some detail by Altunel and Hancock. Four lithological units are recognized: (i) Palaeozoic-age basement comprised of metamorphic rocks that are dominated by marble with subordinate schist; (ii) Neogene-age clastic sediments that include limestone; (iii) Pleistocene-age fluvial and colluvial deposits; and (iv) The travertine deposits. Contacts between the four lithological units are unconformable; many are fault-bounded.

From a study of historical sites, it has been deduced

Terraces of travertine are continuously forming as the calcium carbonate-rich hot waters drip down the flanks of pools.

Buff coloured travertine pools are a feature of Pamukkale.

that the travertine has been forming for at least 14,000 years. Preliminary isotopic data has yielded ages of over 400,000 BP, indicative of a long period of activity, although many of the deposits are younger than 60,000 BP and are currently active.

Travertine deposition has been influenced by neotectonics within an extensional terrain dominated by grabens. Grabens have developed in much of south-western Turkey in response to the westward movement of the Anatolian microplate triggered by collision with the northward-migrating Arabian microplate. The tectonically-active Denizli Basin is characterized by the intersection of two fault systems, the E-W trending Buyuk Menderes graben and the NW-SE Gediz graben. The preferential development of travertine at Pamukkale - rather than along the entire range of active faults - is ascribed to the predominance of limestone bedrock at the confluence of the two grabens where extensional fissures have created suitable conduits.

A number of varieties of travertine are recognized. The two most important types at Pamukkale are terrace-mound and fissure-ridge. The former build up around thermal springs, either as point sources or along faults. This includes the travertine depositing on the flanks of the plateau at Pamukkale: they include ornate forms that may be steeply, curving with overhanging pools. The scale of these terraces is from a few mm to several m. This variety of travertine reports a snow-white colour although it turns initially buff and then grey upon oxidation. Some of the active mound deposits that mantle steep slopes are 80 m in vertical height. They reveal a pseudo layering – gently inclined beds a few m

Botryoidal form of travertine is typical of the terrace-mound deposits.

in thickness – caused by channels that are covered by the terracing.

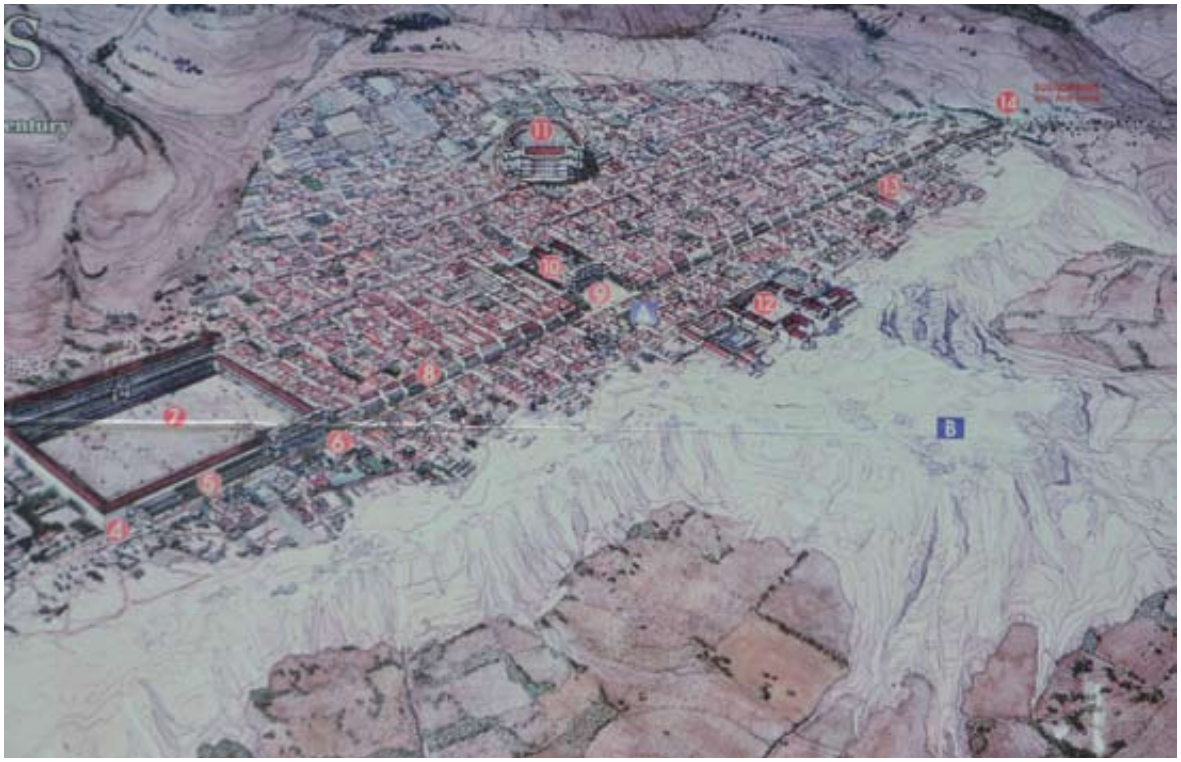
Fissure-ridge travertine, which is well known from Mammoth Springs in the Yellowstone National Park, Wyoming, is the most abundant form at Pamukkale. Some of these deposits have been extensively quarried and are well exposed. Typically a ridge is some 1.5 km long, 400 m wide and 20 m high. The high point of

Vermicular-texture travertine reveals how the layers build up incrementally cm by cm

ridges corresponds to localized areas of high water flow. The colour is typically pale orange or buff. Individual beds are 20-70 m thick and dip outward at angles of between 5 and 30 degrees. Ridges contain a central fissure some 2 cm to 5 m in width from which the water was, or is sourced. The travertine ridges are interpreted as the main linkage among brittle structures that affect circulation of hydrothermal fluids and location of thermal springs.

Altunel and Hancock identified three additional morphologies of travertine at Pamukkale: range-front, eroded-sheet and self-built channel. The former two types include massively bedded, inactive travertine, typically located near the base of ridges. Their relative age is attested to by the extensiveness of erosion. Some are ascribed to ancient Karst terrains that have been incised by present day streams. The channel deposits may distribute lime-rich waters away from the terraces, including for irrigation purposes.

The ancient city of Hierapolis (probably named after Hiera or Hiero the wife of Telephus the mythical ancestor of the Pergamenes) was inhabited since 1900 BC. In the second century BC a city was built by the Ancient Greeks which was subsequently incorporated into the Roman Empire. This city was affected by numerous earthquakes, many of which necessitated major rebuilding programs. The most severe earthquake was probably in 60 AD. Multi-coloured and banded ridge travertine was highly prized and large blocks are found in many of the historical sites. The bulk of the stone used to create the city is ridge-type travertine from nearby quarries. Many quarries are



Historical map of the Hierapolis-Pamukkale site. The travertine is depicted by area "B". Other sites of interest are: 1: Northern Necropolis; 7: Agora (Shopping Centre); 8: Frontinus Street; 11: Theatre; 14: Southern Gate.

The large theatre at Hierapolis, which was constructed in the 3rd Century AD is comprised of blocks of light grey marble and white travertine, the latter used for decorative purposes most notably in the gallery and stage.

observed as deep, vertical-sided trenches as they can be linked to extinct or active fissures. The rapidly-depositing mound travertine has covered many ancient buildings (thick deposits have accumulated in the last 2000 years), including some of the tombs in the necropolis.

At the ancient city and archaeological site of Kibyra (or Cibyra), near the modern town of Gölhisar, to the south of Denizli, a NE-SW trending, active fault zone ruptured during both the historical period, and recent times. Evidence described by Akyüz and Altunel from the ruins revealed the presence of sinistral faults that have offset rows of the stadium by up to 50 cm. Blocks and columns have also been broken and tilted. Field observations suggest much of the damage can be ascribed to the post-Roman earthquake of 417 AD which had an intensity of 9 on the MSK scale. The collapse by earthquake of many archaeological sites is a regional feature of south-western Turkey (and Greece). Moreover, Hancock and colleagues ascribe the destruction of some travertine deposits to earthquake activity.

Hot springs at Hierapolis have created localized concentrations of carbon dioxide and sulphur dioxide in a cave known as the Plutonium (place of the god Pluto). This cave was used for religious purposes by priests who deceived visitors by appearing to be immune to the suffocating gases. A similar strategy was used by the far more well known Oracle at Delphi, Greece.

The recognition that the Hierapolis-Pamukkale site is located on an active fault zone explains the occurrence

The principal street at Hierapolis, Frontinus Street (1st century AD) which connects the Agora and Northern Necropolis was covered with deposits of travertine some 2 m-thick prior to reconstruction.

Some of the burial chambers adjacent to Frontinus Street are partially covered by recent deposits of travertine.

of the huge travertine deposits: extension along the fault zone aids movement of hot waters. The maximum build up of travertine, as well as the hot springs and mud pools is proximal to the fault zone, on the downslope side. Recently conducted geophysical surveys, reported by Brogi and colleagues have indicated that the deposition of the banded and bedded travertines is contemporaneous with recent fault activity. An understanding of the travertine fissure-ridges may assist with reconstruction of palaeotectonic activity in the Denizli Basin.

Photographs by the author

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The Southern (Byzantine) Gate at Hierapolis is characterized by a monolithic arch of marble supported by walls comprised of large blocks of marble (light grey) with selective use of travertine (white).

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