Geological Society of South Africa

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news

Sulfur isotopes in diamonds
The study of mineral inclusions in diamond
Witwatersrand Goldfield Diamonds

CENTREFOLD:

Sea Point Contact Zone: annotated from GSSA Pamphlet, Sea Point Contact, Geology of a famous intrusive contact (site C1).
Photo by Stephen Davey.

GSSA
Geological Society of South Africa

contents

Front Cover:

A 65-carat parcel of alluvial diamonds from the Vaal River Waldeks diggings, Barkly West. The yellow octahedron is 9 carats. Diamonds courtesy of Victoria Diamonds, Kimberley. Bruce Cairncross photo.

Geological Society of South Africa

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from the editor's desk

Chris Hatton

The games people play. The last few months have seen some epic sporting performances. In tennis the gracious and graceful Roger Federer had match point at Wimbledon but lost to the relentless Novak Djokovic in the newly introduced tie break after 12 all. That same day pyjama cricket truly came of age when England somehow snatched the World Cup from New Zealand, then in Test cricket just six weeks later Ben Stokes kept the Ashes alive at Headingley in Leeds. Such is the attraction of real cricket that many listening could vividly recall a similar performance at Headingley thirty eight years earlier when Ian Botham rescued England after they were forced to follow on. Appropriately enough, these games were all played in England, the home of the books of rules which govern so many sporting games; and is too unkind to say that, typically, England twice needed judge's error to steal victory from upstart colonials? Probably not, as you realise when you drive through Kimberley and wonder how this town, geographically part of the Free State, differing only in its erstwhile abundance of diamonds, came to be included in the British-ruled Cape Colony.

Geology is also a game with its books of rules. Those concerning proper sporting behaviour are admirably set out in in the Professional Affairs Corner which has become a permanent feature of Geobulletin. At its core geology is a guessing game, but guessing how much gold a particular pile of rocks contains is not something to be left to the amateur or the charlatan. When someone invests their money in attempts to recover that gold they need to know that the estimates are based on measurements made by professionals and that the extrapolations from these measurements are made by someone who is experienced and qualified enough to know what they are doing.

Part of knowing what you are doing as a geologist comes from understanding how the earth works. Guessing how the earth works is a never-ending game. It starts with a map of what we can see at surface then continues to as far into the bowels of the earth as we can venture. Most of what we know about the deep earth comes from geophysical images, but the hard evidence is in the rocks themselves. The great attraction of diamonds is that they are samples from the deepest parts of the continents that we live on. And of course we are not talking about synthetic, man-made diamonds but real, Kimberley Process certified diamonds whose origins can be traced – those with a tale to tell. On pp. 27-31 of this issue Karen Smit makes accessible to readers of our magazine the results of research that has been through the rigours of review for the more formal scientific literature. Diamonds from the West African craton preserve evidence of having been through a subduction process, so supporting the argument that even the earliest continents have grown through plate tectonic processes not too dissimilar to present day continental growth. In his Mineral Scene, Bruce Cairncross provides his customary excellent images, illustrating what may be the first diamonds to reach the surface of the earth, the enigmatic green diamonds from the Wits. These too preserve evidence, previously presented by Katie Smart and co-workers, that the roots of the Kaapvaal Craton grew in the plate tectonic regime.

The initial supply of diamonds to the academic community stems in large measure from the efforts of Barry Hawthorne whose obituary appears on pp. 37-38 of this issue. During his career at AngloAmerican and

De Beers Barry continued (and gradually repatriated) the tradition of supporting research that began with Sir Ernest Oppenheimer's role in creating at the University of Leeds the Research Institute of African Geology, whence came Clifford's rule, that diamonds are to be found in the ancient cratons. As recalled by Jeff Harris on pp. 34-36 of this issue the pain staking dating of the minute silicate inclusions extracted after examining thousands of diamonds confirmed that diamonds did indeed grow in the time when the ancient roots of the Kaapvaal Craton were forming.

Like Barry Hawthorne, the late Arthur Fuller (pp. 39-40) was also a proficient athlete in his youth and in his retirement he devoted much of his time to the sport of golf. The indefatigable Alfred Kroner (pp. 40-43) never really retired. For this fortunate man the boundary between profession and hobby was permeable and to the end of his life he continued to play this glorious game of geology, governed not by the arbitrary rules of man but by the mysterious yet adamantine rules of nature.

Chris Hatton

executive managers corner

Craig Smith

The GSSA is pleased to announce that Geocongress 2020 will be staged at the University of Stellenbosch from June 29 to July 1 next year. 2020 is the 125th anniversary of the GSSA, as well as the 125th anniversary of the Department of Geology at Stellenbosch, so we have a couple of events to celebrate. A formal call for themes and sessions will be sent out in September, through the normal channels. Watch for the monthly newsletters, in particular. The Chairman of the Organizing Committee is Dr. Bjorn Von der Heyden, suggestions for session themes in advance of the formal call can be forwarded to info@gssa.org.za. The 2018 Geocongress was successful in part because of student participation, and we intend to maintain a focus on student participation in 2020. This requires that registration fees be as low as possible, and that we obtain sponsorship for student support and general meeting support. Please contact info@gssa.org.za if you would like to sponsor.

In the last issue of Geobulletin, attention was given in the Presidents Column to the effects of Plan S on the publication of the South African Journal of Geology (SAJG). In brief, Plan S is a European political initiative to move scientific publication to open access platforms to counter the high subscription costs imposed by the major publishers. It is a complex issue, and there are significant challenges particularly for scientific journals published by professional societies – such as the SAJG. The SAJG is currently part of the Geoscience World (GSW) stable, with the GSSA receiving a small share of the GSW revenue stream, which in turn partially covers publication costs. This allows the SAJG to publish without imposing Article Processing Charges (APC), which are very high for some of the major journals – and which I expect will increase if and when Plan S goes into effect. There are other effects of open access publishing, such as the proliferation of on-line journals that will publish anything for a fee and the establishment of dubious archival web services that have no regard for copyright ownership. Various bits of legislation concerning intellectual property rights – including in South Africa – are not necessarily aligned with each other or publishing practice. The waters are very muddy (!), and one consequence is that 'fake science' is proliferating and sometimes hard to recognize. To us earth scientists, the 'conclusion' that the moon formed from material ejected by the Morokweng impact 145 million years ago is beyond fanciful. To a 'citizen scientist' (or a politician), supporting arguments can be made plausible. (This is a real example!)

The GSSA would like to reassure its members that the SAJG will retain its independence, and its track record of publishing high quality, properly peer reviewed science. The GSSA will retain ownership of SAJG, in contrast to some societies which have transferred ownership of flagship journals to major publishing houses. There is an open access option for SAJG if that is required. The SAJG mandate accepted by Council is published elsewhere in this issue of Geobulletin, and we continue to monitor the progress and implications of the trend to open access publication.

Of interest is the current list of most read and most cited papers in SAGJ, as reported by GSW:

Top 5 Read:

T Pearton and M Viljoen (2017), Gold on the Kaapvaal Craton, outside the Witwatersrand Basin, South Africa, 120(1), 101-132

A Mitchell, J Henckel and A Mason-Apps (2019), The Upper Critical Zone of the Rustenburg Layered Suite in the Swartklip Sector, north-western Bushveld Complex, on the farm Wilgerspruit 2JQ: I. Stratigraphy and PGE mineralization patterns, 122(2), 117-142

C Anhaeusser (2019), The geology and tectonic evolution of the northwest part of the Barberton Greenstone Belt, South Africa: A review, June 1 digital publication

J Johnson, S Webb, C Condit, N Beukes, and W Fischer (2019), Effects of metamorphism and metasomatism on manganese mineralogy: Examples from the Transvaal Supergroup, June 1 digital publication

H van Niekerk and N Beukes (2019), Revised definition/outline of the Kheis Terrane along the western margin of the Kaapvaal Craton and lithostratigraphy of the newly proposed Keis Supergroup, 122(2), 187-220

Top 5 Cited:

B Rubidge (2005), 27th Du Toit Memorial Lecture: Re-uniting lost continents – Fossil reptiles from the ancient Karoo and their wanderlust, 108(1), 135-172

L Chevallier and A Woodford (1999), Morpho-tectonics and mechanism of emplacement of the dolerite rings and sills of the western Karoo, South Africa, 102(1), 43-54

B Eglington and R Armstrong (2004), The Kaapvaal Craton and adjacent orogens, southern Africa: a geochronological database and overview of the geological development of the craton, 107(1-2), 13-32

A Moore and P Larkin (2001), Drainage evolution in south-central Africa since the breakup of Gondwana, 104(1), 47-68

M Fouch, D James, J VanDecar, S van der Lee, Kaapvaal Seismic Group (2004), Mantle seismic structure beneath the Kaapvaal and Zimbabwe Cratons, 107 (1-2), 33-44

I warn against over-analyzing these lists, and rankings undoubtedly change over time. The SAJG is a high quality, highly respected scientific journal – and we intend to maintain that reputation. Thanks to the editing team, the contributors and reviewers for the effort required of them. It is a significant workload.

Craig Smith

Geological Society of South Africa

SAJG

SAJG Publication Mandate

The South African Journal of Geology (SAJG) is a peer reviewed, scientific journal that has been continuously published as the Transactions of the Geological Society of South Africa (GSSA) since 1895. The GSSA is proud of this heritage and intends to maintain the journal as a high-quality scientific publication that is the 'journal of record' for African geology.

The journal is edited on a volunteer basis, by a Scientific Editor assisted by a Managing and a Technical Editor, who are all recognised and leading academic geoscientists, as well as senior members or fellows of the GSSA, together with the assistance of an international editorial panel.

Recently, SAJG moved to distributing digital copies in preference to print copies. The SAJG is available online to GSSA members at no cost and subscribers to Geoscience World (GSW; paid subscription) through the Geoscience World portal, to which many institutions have access. Print copies can still be supplied by the GSSA by arrangement at additional cost.

The cost of publishing is paid for by means of GSSA membership fees and subscription fees. In addition, the cost of the journal is covered by a share of the GSW income paid to participating journals. Author charges are not levied, and the SAJG receives no public funding.

A secure website has been created where digital subscribers can electronically access SAJG as well as other GSSA publications such as Geobulletin and the monthly newsletter.

Articles in the SAJG may be published as Open Access papers via the GSW portal upon request by the author. This will be funded by "Article Processing Charges" (APC), set annually, and to be paid by the author or the author's research funding organisation. As such, the journal is a "hybrid publication".

The GSSA exists to support the needs of its members and the broader community of geologists within South Africa. It believes that the best way to achieve this is by publishing the SAJG as a hybrid publication whereby it provides a publication service paid for out of its membership and subscription fees and by offering authors an OA option.

The GSSA intends to maintain the SAJG as a fully-owned and published scientific journal of high scientific integrity that only peer review can provide. The journal will continue to focus on the geology and earth science of Africa, and earth processes that are related to the geological evolution of the African continent. As the Open Access publishing landscape evolves, the means of financing publication may change, but the core values of independence and quality will remain.

president's column

Sifiso Siwela

The theme for my tenure is "***relevance***", based on the foundation laid by Ed Swindell, who indeed took the GSSA "back to basics". The theme going forward is also linked to one of the four historical objectives of the GSSA, being to "promote the best interests and relevance of the earth sciences, the earth science professions, and earth scientists". My inauguration and AGM was aptly held on International Mandela Day, which is relevant to the theme going forward, as in the words of Madiba, everyone has the ability and responsibility to change the world for the better and a movement for change begins with small actions. The membership has some of the smartest brains and can definitely add value to the respective industries, however geoscientists are striving to stay relevant relative to other disciplines. With the advent of the 4th Industrial Revolution and Future of Work, geoscientists need to stay relevant. There is also the predicament of the unemployed geology graduate that we are dealing with.

During the coming year, the GSSA will continue to emphasise relevance through the various portfolios. The Meetings Portfolio will continue to address CPD with emphasis on upskilling graduates and introducing digital offerings. Another Geocongress is planned for 2020 to coincide with the 125th year of the GSSA. Outreach and relevance to the public through Geoheritage Division, Geology Museum and other initiatives will also be a focus. The Professional Affairs Portfolio will continue to strengthen rapport with represented committees, such as at SACNASP and the SAMCODES Standards Committee (SSC). The Academic Affairs Portfolio will continue to keep a close eye and provide advocacy for the membership on potentially significant issues such as the Plan S and implications thereof on open access for research publications such as the SAJG. We will also continue to make the membership aware of, as well as provide commentary on pertinent issues and gazettes. Growth of GSSA Branches and Divisions will be a focus, with examples being the Komatiite Barberton Geoheritage trip in September organised by the Barberton and Egoli branches, as well as the planned relaunch of the Northern Cape Branch during the Deposits of the Northern Cape event in Kathu in October. We will continue to strengthen ties and reciprocity with affiliate societies, as well as outreach into the rest of the sub-continent with the respective geological societies.

We also intend to send out a few short surveys in order to assist to address some challenges and we therefore appeal to the membership to complete these. We also appeal to the retired to assist in mentoring graduates and get involved in Geoheritage initiatives, as a way of staying relevant themselves.

A vote of thanks goes to my predecessor Ed Swindell, who is the epitomy of professionalism and an example to all of us. His presence, leadership and wisdom manifests itself in the current state of affairs of the society. I am grateful to him for bestowing the faith in me. I know that he we still contribute his wisdom to the society.

A big thank you to Council, MANCO and Craig for their support and for dedicating their time, as well as Lully, Marliese and Sally from the GSSA office for their continuous support. I would also like to thank the membership as a proud servant for such a learned society. The GSSA has been a transformed society since the 90s at Council & MANCO level, not just by race but by gender and age. That also makes me proud to be associated. This diversity manifests itself in the membership and is also key for inclusiveness and staying relevant.

I look forward to an exciting year.

Sifiso Siwela

codes of practice

THE PROFESSIONAL (AFFAIRS) CORNER

The GSSA Complaints and Disciplinary/Ethics (C&D) process

Employees are generally subject to the policies, rules and regulations of their organisation. Academics are peer-reviewed regularly through their publications, through staff development and promotion committees and through student assessments of their teaching and of their courses. Depending on where an individual works, the codes/policies might vary and will certainly change when/if that individual changes employment or institutions.

The one constant is affiliation with the GSSA, which is applicable wherever the member might be employed – in academia, research, industry or government. As defined in the GSSA constitution, the Code of Ethics (Annexure 2 to the GSSA Constitution) is binding upon all members of the GSSA and membership with the GSSA implies that the member agrees to abide by them and be subject to them and the associated Complaints and Disciplinary processes described below (Annexure 3 to the GSSA Constitution).

The purpose of the Society's Code of Ethics is to maintain the professional esteem of the members throughout the wider community (*see June 2019 (Vol62, No2) Geobulletin for details of the GSSA's Code of Ethics*); it follows that anyone should be able to make a complaint against a member, in relation to an alleged breach of the Codes or Constitution of the Society. Complaints against members are handled as follows:

The overriding principles here are firstly that the reputation of a member must be protected while an alleged breach is assessed and secondly, that the process itself conforms to the principles of natural justice. The requirements of the process are:

a. That confidentiality is paramount.
b. That the process must minimise the opportunity for false implications from accusations and complaints.
c. That a committee handling a complaint with serious implications is not both prosecutor and judge.
d. That appropriate cases are handled internally by the Society, but that when warranted, cases are passed onto the Statutory Body (SACNASP), or to the judicial system if there is perceived criminal intent.
e. That an independent appeals process be available.

To meet these requirements two independent committees, a Complaints Committee and an Ethics Committee, deal with complaints. **The Complaints Committee** receives and screens all complaints and, if necessary, gathers evidence, before either:

- rejecting complaints as frivolous;
- resolving them; or
- elevating them to the Ethics Committee.

Complaints can involve non-compliance against the Code of Ethics, the SAMCODE or the Constitution of the Society; they may also relate to situations that potentially exhibit dishonesty, intent, repetition or reckless incompetence. Any individual or organisation can make a complaint – a complainant does not have to be affiliated to the GSSA in any way. All complaints, however, whatever their nature, must be referred in writing, to the Chair of the Complaints Committee. Routing should be via the General Manager of the GSSA. **Such complaints need to be detailed and refer to explicit actions/comments by the individual with**

reference to specific clauses in the GSSA Code of Ethics. It is not the responsibility of the Complaints Committee to build the complaint – that is the obligation of the complainant. Any incomplete complaints are simply referred back to the complainant without any action, until full, complete and relevant documentation has been provided by the complainant.

Where a complaint has been processed by the Complaints Committee and found to be substantiated and not resolved, relevant recommendations and/or findings are then passed on to the **Ethics Committee** for assessment and determination. The separation of committees in this way is intended to enable complaints to be handled without an implication of unethical behaviour or bias.

THE COMPLAINTS COMMITTEE

A prime goal of this committee is to protect the reputation of a member while an alleged breach is dealt with. This committee handles all complaints; resolves and rejects frivolous complaints; and actions complaints where there has been non-compliance or if there has been a serious breach such as "unethical behaviour". All cases are to be dealt with confidentially; with the following exceptions: the person who laid the complaint should be notified of the Committees findings and action; and the Stock Exchange must be notified in the case of a finding of non-compliance in relation to the SAMCODE.

A member against whom a complaint is made shall be entitled to notice in writing of the grounds of the complaint and to a reasonable opportunity to be heard in respect of such complaint before the Complaints Committee, and the procedure to be adopted in respect of complaint shall be at the discretion of the Complaint Committee.

The Complaints Committee comprises three Fellows (excluding current members of Council and Fellows sitting on the Ethics Committee) and one current member of Council. Council selects committee members for a three-year term, following a general call for nominations. The Complaints Committee elects its own Chair (not a current Councillor) for a period agreed amongst its members. The Complaints Committee can seek advice from independent experts (for example, but not limited to, SAMREC Competent Persons, or legal practitioners), or it can seek additional evidence relating to the complaint if deemed necessary. It can also seek advice relating to GSSA policy from the President or the Council.

The Complaints Committee will address each complaint, then after deliberation and advice and, within 90 days of receipt of the complaint, will:

- Dismiss the complaint as frivolous or vexatious;
- Refer the complaint back to the parties or to an Alternative Disputes Resolution process if related to dysfunctional contractual arrangements;
- Resolve the complaint if it is deemed a technical breach of a Society Code or Statute;
- Refer the complaint to the Ethics Committee;
- Refer the case to the judicial system if there is perceived criminal intent;

If a technical non-compliance is established, penalties available to the Complaints Committee include personal admonition, mediation and counselling, but not suspension of membership.

THE ETHICS COMMITTEE

The purpose of the Ethics Committee is to deal with all complaints directed to it by the Complaints Committee, as well as appeals against Complaints Committee decisions.

An Ethics Committee constitutes four Fellows (excluding current members of Council and fellows sitting on the Complaints Committee), selected by the Council for a three-year term, following a general call for nominations. One current GSSA member of Council, nominated annually by the Council constitutes the fifth member of the Ethics Committee. A representative from SACNASP may be invited as a sixth member for specific complaints that may go onto SACNASP. The Ethics Committee elects its own Chair for a period agreed amongst its members. Three members constitute a quorum for a meeting of the Ethics Committee. The current Councillor cannot chair the committee. The

Councillor serving on the Ethics Committee has the responsibility to advise the GSSA Council, on a "need to know basis", of any fiduciary or other matters related to Committee business, which could potentially affect Council members.

Notwithstanding the membership conditions outlined above, Complaints and Ethics Committee members must always be independent and declare any Conflict of Interest to the Council, who are then to nominate a replacement for the period of the Conflict of Interest.

In relation to complaints brought before it, the normal "Rules of Evidence" are not to bind the Ethics Committee. It can obtain independent or legal advice on evidence before it but because this committee is set up to judge (not prosecute) it cannot seek additional evidence, nor bring an ethics complaint against any member of its own accord. A member against whom a complaint is made shall be entitled to notice in writing of the grounds of the complaint and to a reasonable opportunity to be heard in respect of such complaint before the Ethics Committee, and the procedure to be adopted in respect of a complaint shall be at the discretion of the Ethics Committee.

A complaint referred to the Ethics Committee must be dealt with as expeditiously as is reasonable. In relation to a complaint brought before it by the Complaints Committee, the Ethics Committee may:

- Find that the complaint has not been established, in which case the Ethics Committee may decide to take no further action;
- Find that a breach of the Code of Ethics has been established, either as "non- compliance" or in more serious cases as "unethical behaviour", and impose an appropriate penalty:
    - o Warn or reprimand the member concerned;
    - o Suspend the membership of the member concerned for a period not exceeding 12 months;
    - o Require that the member undergo further training;
    - o Resolve that the member be suspended or expelled from the Society; or
    - o Forward serious cases of unethical behaviour onto the Statutory Body (SACNASP).

In relation to an appeal against a Complaints Committee decision, the Ethics Committee can

- Uphold the decision of the Complaints Committee, or
- Reclassify the Complaint and the way it is to be handled, as appropriate.

A resolution of the Ethics Committee that a member be expelled shall not take effect until such resolution is confirmed by an ordinary resolution of the Council of The Society, and the member concerned shall be given the opportunity to be heard by the Council before it decides whether or not to adopt any such resolution of the Ethics Committee.

An appeal against a ruling by the Ethics Committee, on any alleged breach of the Code of Ethics, is to be made to an independent arbitrator. A member who is dissatisfied with a decision on an ethics complaint by the Ethics Committee adverse to that member may by notice in writing delivered to the Chief Executive Officer of the Society within 60 days of the giving of such a decision (or within such later time as the Council may by ordinary resolution allow) appeal against such decision.

The Council shall proceed to hear and determine an appeal from a decision of the Ethics Committee as expeditiously as is reasonable. The member appealing shall be given a reasonable opportunity to be heard on the appeal, but otherwise the procedure to be adopted shall be at the discretion of the Council, providing it proceeds with as little formality and technicality and as much expedition as a fair consideration permits. The Council shall decide the appeal by ordinary resolution and shall in reaching a decision as to what should be the outcome of the ethics complaint giving rise to the appeal have all of the powers of the Ethics Committee, and may, within those powers, decide to vary the penalty that was imposed by the Ethics Committee.

The Ethics Committee or the Council may direct that any finding made by the Ethics Committee or the Council (as the case may be) made against a member as a result of an ethics complaint may be reported to members in a publication of The Society, or be reported to appropriate regulatory authorities. A member about whom an ethics complaint has been made and which is subsequently dismissed may publicise that dismissal to the same extent as any publicity given the lodging of the ethics complaint.

Complaints since 2010

Since 2010 the Complaints Committee has dealt with 15 separate cases involving allegations of plagiarism, unprofessional conduct, resource reporting issues and even criminal conduct. Some of these instances were found to be unsubstantiated, frivolous or not pursued by the complainant. As of July 2019, only two of these cases are still current/active with the Ethics Committee.

The bulk of the cases investigated were resolved internally by the GSSA, with only one case being referred to SACNASP. The case of Criminal Conduct was also dealt with independently through both SACNASP and the criminal justice system.

Of the cases investigated by the GSSA, three cases were abandoned because they were not pursued by the complainants who took the time to put in a written complaint (in the form of an affidavit), but then failed to provide follow-up details or evidence when requested by the relevant committee (too much effort or insufficient substance to the complaint?). Such actions, along with the number of complaints found to be unsubstantiated or frivolous, based upon hearsay and personal opinion or bias, highlight an unfortunate, unintended consequence of the C&D process – that complaints are sometimes being used to settle academic and/or professional disagreements. This is an unacceptable abuse of the system; fortunately, the GSSA C&D process is set up to identify such impropriety before it injures the reputation of the respondent.

A major frustration of the committees is that there is a perception that all a complainant has to do is to forward a grievance (either formally or informally) to the committee or the GM with the expectation that the relevant committee will then build the case, hunt down the evidence and progress the complaint on their behalf. In at least one case, the expectation was that the C&D committees would build a case based on piles of alleged evidence on behalf of the complainant. As highlighted earlier in this article, this is not the case – the complainant (and not the Committee) is obliged to provide specific details of the alleged breach, siting specific clauses in the GSSA Constitution, SAMCODE or Code of Ethics.

A second disturbing trend is that complainants often confuse the GSSA Code of Ethics and the SACNASP Code of Conduct – while both types of codes share many similarities, they are not synonymous, having some very specific and important differences, including different clause references. Complaints in terms of the SACNASP Code of Conduct may not be addressed to the GSSA (and vice-versa) and such complaints will not be forwarded to SACNASP on behalf of the complainant. Therefore, complainants are advised to be certain of which Code they are referencing and refer the relevant complaint to the correct organisation.

An understanding of the purpose and the roles of SACNASP vs GSSA might help a complainant in showing which avenue is appropriate under different circumstances, i.e. who to complain to. The GSSA C&D process is there to self-regulate members and the profession, whereas the main purpose of SACNASP is to protect the public – they are different processes (with SACNASP proceedings being a legal process, whereas the GSSA process is a professional, peer-to-peer consideration) with different intentions and differing levels of sanction. While certain complaints dealt with by the GSSA can be handed over to SACNASP, this would usually happen only when the allegations are serious enough that they should follow both processes, or be dealt with in parallel.

A comment frequently levelled at the C&D process is that it takes many months to finalise a matter. While the By-Laws allow for 90 days for the conclusion of a complaint, it is true that some cases have taken significantly longer. The reasons for this are not simple and even though the Complaints and Ethics committees are staffed by volunteers, there is an acknowledgement by the GSSA that cases need to be attended to much more aggressively. However, often the complainants themselves are the main cause of delay, frequently failing

SOCIETY NEWS

to submit the required evidence timeously. In addition, due process must be followed, as defined in both the GSSA Constitution and the laws of South Africa.

The GSSA as an entity (including its structures) cannot and does not raise complaints (GSSA members, or members of the Public, can). The Complaints Committee can investigate and build a case based on a complaint (it doesn't raise them or formulate complaints). The role of the Ethics Committee is to judge the case/facts presented by the Complaints Committee, it does not investigate or formulate a case – this is the principle of separation of roles/powers. So, in summary:

- Every member of the GSSA is subject to the C&D process, as defined in the Constitution
- Complaint is raised by a member of the public (including GSSA members)
- The complaint is investigated by the Complaints Committee who investigate it and try to resolve it amicably between the parties. If this fails, they formulate a case and present it to the Ethics Committee
- The Ethics Committee judge the case presented to it, using the principle of the balance of probabilities (not beyond reasonable doubt which is the standard in legal cases). The Ethics Committee does not investigate or add to the case or complaint.
- At every stage, an independent appeals process is available.

Compiled by Tania R Marshall
(VP Professional Affairs)

all the news fit to print

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(Including CIMERA and PPM)

DST-NRF CIMERA Celebrates 5th Birthday!

The Centre of Excellence (CoE) for Integrated Mineral and Energy Resource Analysis (DST-NRF CIMERA) was launched on the 24th April 2014. It is the only CoE hosted by the University of Johannesburg, in the Department of Geology, and is co-hosted by the University of the Witwatersrand. It celebrated its 5th Birthday with a function in the Reading Room of the Department of Geology, and a number of distinguished guests were invited: Mr Nathan Sassman of the NRF, Dr Carol Nonkwelo (UJ) and Prof Ina Wagenaar (UJ, who attended on behalf of Prof Debra Meyer, Executive Dean of the Faculty of Science). Prof Nikki Wagner (Director of DST-NRF CIMERA) welcomed all, and she and a few of our guests reflected on the success and achievements of our CoE since its inception. She

Prof Nikki Wagner presenting Prof Nic Beukes with his gift.

Prof Jason Ogola (Univen), Prof Ina Wagenaar (UJ, Vice Dean Teaching and Learning) and Prof Judith Kinnaird (Wits)

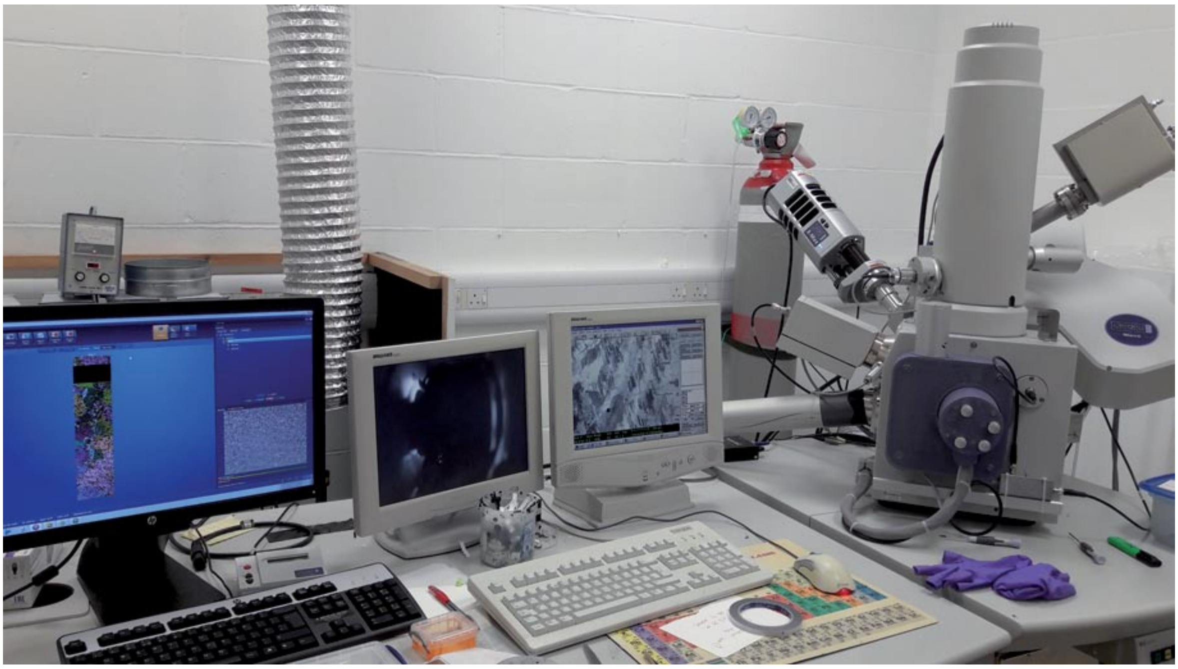
then presented a gift to Prof Nic Beukes, the Founding Director, on his stepping-down at the end of 2018. The function was enjoyed by all, and we look forward to continued success in the future!

Still on CIMERA activities, Prof Nikki Wagner, Prof Judith Kinnaird and Dr George Henry visited the University of Venda (Univen) in Thoyohandou and University of Limpopo (UL) in Turfloop on the 17-18th July 2019 to meet the staff and students affiliated with DST-NRF CIMERA. Prof Wagner gave a presentation about our Centre of Excellence at both venues, and in turn, students supported by DST-NRF CIMERA at Univen gave short presentation about their projects. UL has recently become a collaborating institution, and will be conducting research under our umbrella in the future.

Prof Kinnaird kindly offered to deliver her Society of Economic Geologists (SEG) Lecture on critical metals to the staff and students that was well- received. We thank the staff of Univen and UL for their hospitality, especially Ms Rejune Mundalamo (Univen) and Prof Napoleon Hammond (UL), the main organisers of the visits.

Earlier this year, Trishya Owen-Smith spent two weeks in May at the University of Cambridge, as part of a research collaboration with Dr Zoja Vukmanovic. The main purpose of the trip was to conduct microstructural

Staff and students at Univen with Profs Kinnaird and Wagner. Ms Rejune Mundalamo on left, and Dr Milton Kataka, Head of Department, on right. George Henry took the photo.



An electron back-scatter diffraction analysis underway on the scanning electron microscope in the Cavendish Laboratory at the University of Cambridge.

quantitative analyses by electron back-scatter diffraction (EBSD) on a set of anorthosite samples from the Kunene Complex, to aid in deciphering the emplacement and deformation history of the intrusion, and to get training in the methods of analysis so that we can set up these capabilities here in SA.

The UJ Faculty of Science hosted 45 grade 7 learners from the Crown Mines Primary School for the Mandela Day Science Outreach on the 17th of July. The participation of the Department of Geology included a short lecture titled: The central focus of geology: minerals and rocks. After the lecture, learners were given a chance to "play" with 10 rocks from different parts of South Africa. The selected rocks included important and famous localities such as the ore-bearing Wits gold conglomerate from Johannesburg, the fossil-bearing breccia from the Cradle of Humankind and the pseudotachylite from the Vredefort Impact Structure. This was presented by Tebogo Makhubela and he was assisted by three postgraduate students (Casey Luskin, Amogelang Moila and Boikanyo Matloba), who explained the rocks to the learners and answered their questions.

The UJ lab that hosts the NPII multi-collector ICPMS has a new addition to its stable, with a ThermoScientific iCap Q-ICPMS. After some teething problems, which were blamed on Johannesburg's high altitude, the instrument is now up and running, much to the relief of

Some of the Crown Mines Primary School learners, fascinated by rocks and fossils.

scientists-in-charge Clarisa Vorster and Marlina Elburg. It has been successfully connected to the laser-ablation system, and the first results have been produced in the past weeks. Both zircon U-Pb dating and trace element analyses of silicates and phosphates have provided important new data for graduate students from UJ and Wits. The next challenge will be to attempt so-called split-stream analyses, which would enable zircon trace element analyses (by Q-ICPMS) on the same spots as U-Pb analyses (by MC-ICPMS) – or other applications of simultaneous trace element and isotopic analyses, such as Sr isotopes on plagioclase, which has become an important tool to unravel the petrogenesis of the Bushveld Complex. With the indispensable help of the UJ instrument scientist Henriette Ueckermann, it seems highly likely that the new iCap Q-ICPMS will prove to be another highly successful addition to the UJ laser ablation laboratory.

Earlier this year, on behalf of the Evolutionary Studies Institute (ESI, Wits University) and the Centre of Excellence in Palaeosciences, UJ post-doc Lara Sciscio was given the opportunity to lecture and guide a field-school for the ESI Palaeosciences Accelerator Program. The ESI Palaeosciences Accelerator Program is a wonderful initiative led by the Prof. Jonah Choiniere, and it fosters a friendly and relaxed environment in which passionate undergraduate female students can acquire several transferable skills related to the palaeosciences. Armed with their knowledge of a geoscientist's 'field tool kit' and the techniques discussed in lectures, the Palaeo-Accelerator class spent several days with Lara and ESI MSc student, Viktor Radermacher in the Free State. Here, the team learnt the modus operandi for field work, and practiced map reading, logging a section and describing sedimentary rocks, ichnites, and fossil bone. The ~200-million-year-old fossil footprints (ichnites) at Mafube proved to be really quite exciting and fueled much discussion and descriptive work. At Golden Gate Highlands National Park, they were able to visit several in situ fossil sites, including the Rooidraai Nest Site, and record and discuss the stratigraphic and sedimentological context of the fossils. Overall, everyone was tested with the challenges but also the fun experiences field work presents. Field schools are a vital part of any geoscience program and this one was particularly valuable.

Palaeo-Accelerator class discussing some in situ material with ESI MSc Viktor Radermacher in Golden Gate Highlands National Park.

Professor's Tappe and Viljoen are currently planning the continuation of the annual short course on "Diamond Exploration", which used to be hosted at the University of Pretoria until 2018 under the leadership of Drs Mike de Wit and John Bristow. If all goes well, a revised and updated format of this highly successful diamond short course will be launched in late 2020 at the University of Johannesburg.

Dr. Ofentse M. Moroeng (Lecturer, UJ), along with Prof. Tim Moore (Cipher Coal, Australia), visited the newly established International Center for Coal Geology of the China University of Mining and Technology in Xuzhou, China, at the invitation of Prof. Shifeng Dai (Dean: School of Resources and Geosciences; Co Editor-in-chief: International Journal of Coal Geology) and Prof. Jian Shen (HoD: Department of Geoscience). The purpose of the visit was to initiate research collaboration beginning with geochemical work on the "charcoal-rich" low-rank coals of the Early Cretaceous, Yimin Formation, Hailaer Basin, China.

UJ Geology recently had two of its staff members honoured by the GSSA. Nic Beukes was jointly awarded the Jubilee Medal together with co-authors for their 2018 SAJG article: T.S. McCarthy, B. Corner, *The facility visited by Ofentse Moroeng in China.*

H. Lombard, N.J. Beukes, R.A. Armstrong and R.G. Cawthorn. (2018). The pre-Karoo geology of the southern portion of the Kaapvaal Craton, South Africa. SAJG 121(1), 1-22. Bruce Cairncross was honoured by receiving the Draper Memorial Medal for significant contributions made to a number of geology disciplines including Karoo coal research, southern African mineral and gemstone research and a career long commitment to student teaching and guidance.

Compiled by Bruce Cairncross from various departmental contributors.

STELLENBOSCH JOHANNESBURG

The Department of Earth Sciences at Stellenbosch University has experienced an exciting second quarter of 2019 in which notable student achievements were celebrated, a new staff member welcomed, organization of the 2020 Geocongress initiated, and a high-level research excursion to the Southern Ocean undertaken.

New lecturer in metamorphic geology appointed

From the 1st of June 2019 the Department of Earth Sciences, Stellenbosch University (SU) appointed Dr **Matthew Mayne** as their new lecturer in Metamorphic Petrology following his completion of a consolidoc fellowship at SU. Matthew graduated with a joint PhD degree from SU and Université Jean Monnet (France) which involved the development of the thermodynamic modelling tool "Rcrust" which is distributed from both of these departments' respective websites. Matthew's work is focused on the development of new software

Matthew Mayne

tools for phase equilibria modelling in order to predict the stable phase assemblage of rocks at different conditions. He is involved in a number of projects looking at differentiation of the continental crust and production of granitic magmas as well as the forward modelling of trace element concentrations. His high-level skills in programming combined with interests in big data analysis and machine learning will render him an invaluable asset to SU's Department of Earth Sciences, since transferral of these skills to future SU graduates will ensure that they are equipped with the necessary skills to lead the way in a changing Mineral Resources Industry landscape.

Post graduate students shine at the GSSA Awards ceremony and elsewhere

Lindo Makhathini received the South African Council for Natural Scientific Professions' (SACNASP) award for an exceptional fourth-year Earth Science graduate from southern Africa. Her work relied on an inter-disciplinary approach towards evaluating the chemistry of carbon associated with the Barberton Greenstone Belt mineralization. **Jonathan Gloyn-Jones** received the GSSA's Corstorphine Medal for an MSc thesis in Earth Sciences with exceptional merit (worthy of international recognition) from a South African university. His detailed structural work provided new insights into the structural evolution of the Barberton Greenstone Belt, and clearly highlighted the local structural controls on the siting of gold mineralization in two different gold-bearing reef geometries. The SU Department of Earth Sciences continues to be proud of students' achievements and therefore also congratulates current Hons. student **Andile Mkandla** who has exceptional leadership skills and who was recently recognized as being one of News24's 100 Young Mandelas of the future.

Trace and Experimental Biogeochemistry Research group visit the Southern Ocean. In winter!

Dr Susanne Fietz and a team of students from the Trace and Experimental Biogeochemistry research group at Earth Sciences recently braved the roaring forties and furious fifties at unenviable winter temperatures of the Antarctic ocean. This high-level research cruise was aimed at collecting novel winter-time data that will be used to better understand the trace metal dynamics in various water masses between Cape Town and Antarctica as the ocean region resets itself for the next growth season. This globally critical region, the largest sink of atmospheric carbon dioxide, to a large extent

The TracEx team dressed for contamination-free ocean research.

Jonathan Gloss-Jones

Lindo Makhathini

UNIVERSITY NEWS

Marginal ice zone contains clues to ocean chemistry dynamics

is limited in primary productivity due to the ultralow supply of trace metals or essential micronutrients. Special emphasis was placed on the marginal ice zone which forms every winter around Antarctica thereby changing ocean dynamics and chemistry. For the first time, the TracEx team collected ice cores and frazzle ice to understand transport of trace metals in formational ice and its role in release of micronutrients as the temperatures rise and growth season starts.

Public lecture on the African Light Source Initiative

Synchrotron facilities are used by scientists as sources that produce highly brilliant light that span X-ray, Ultra-violet and Infrared wavelengths. Much like an airport X-ray machine is used to probe the content of your holiday luggage, so this synchrotron light is used to probe information at an atomic to particle scale, providing important observational and mechanistic insights for a range of Earth Science research questions. Dr Bjorn von der Heyden recently presented a public outreach presentation on the African Light Source initiative, which strives towards having a synchrotron facility on the African continent (the only continent other than Antartica that does not yet have one). The implications of this initiative were discussed in terms of how it would enable African scientific and technological competitiveness; how the envisaged facility would upskill local African scientists and curb the currently ensuing diaspora of skilled and qualified African scientists; how a world-class facility would attract 'scientific tourism' from the global synchrotron user base; and what social, economic and political impacts may hinder or advance the conversion of this dream into a reality. For more information on the AfLS initiative please visit:

http://www.africanlightsource.org/

Bjorn von der Heyden

ceres-tulbagh earthquake

Fifty years after the Ceres-Tulbagh earthquake

This month it has been fifty years since one of the most destructive earthquakes in South African history struck the Ceres-Tulbagh area in the Western Cape Province at 10:03 pm SAST on 29 September 1969. The magnitude of the main shock was M_L 6.3 and a maximum intensity of VIII on the Mercalli Modified Scale (1956 version) was observed. Two events of M_L 3.5 and 3.7 preceded the main shock during the same day and were followed by a long series of aftershocks that lasted at least until April 1970. Mainland South Africa has only experienced two other earthquakes during the 20th century of similar magnitude. An earthquake of M_L 6.3 occurred just offshore of St. Lucia on 31 December 1932 and another of M_L 6.2 near Koffiefontein on 20 February 1912. Both events were felt over most of the country but resulted in less damage than at Ceres–Tulbagh because the epicentres were some distance offshore and in rural South Africa, respectively.

In 1969 several geologists initially thought that movement along the large Worcester fault caused the earthquake. However, analysis of the main- and aftershocks in 1969 indicated that this was not the case. The epicentre of the main shock was fixed by the USGS at a position 63 km NE of the linear, WNW–ESE trending zone of aftershocks with phases recorded by a sparse network of seismic stations. Two better constrained events on 10 October 1969 and 14 April 1970, recorded by local seismographs, showed that the presumed epicentre of the 29 September 1969 event was inaccurate. The event was relocated to 33.28˚S and 19.24˚E approximately 1

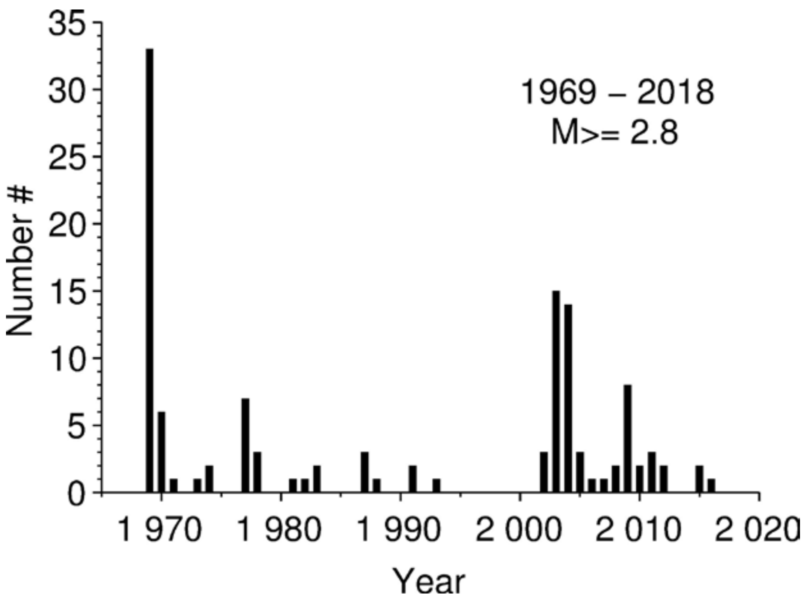
De Oude Drostdy had been gazetted a historical monument a week before the earthquake struck Tulbagh (after Theron, 1974).

km to the north of the zone of aftershocks between Ceres and Prince Alfred Hamlet. The latter zone approximately correlates with the WNW–ESE striking Groenhof fault which has a mapped length of about 15 km and may be continuous with the Saron and Piketberg faults. It can therefore be concluded today that most of the 1969 and 1970 events occurred along a zone of WNW–ESE fractures between Tulbagh and Ceres at the western termination of the 800 km long, E–W striking Ceres-Kango-Baviaanskloof-Coega fault zone.

The earthquakes of 29 September 1969 were followed by many aftershocks varying between M_L 3.3 and 5.1. Two events of M_L 5.1 occurred in the beginning of October and November 1969 almost exactly one month apart from each other and with the first occurring one month after the main M_L 6.3 event. Subsequent relatively large events were the M_L 5.7 event on 14 April 1970 and M_L 5.9, 5.6, 5.1 and 4.4 events in 1977, 1983, 1991 and 2003, respectively. The spacing between post-1969 larger events was therefore 2, 7, 6, 8 and 11 years. The M_L 5.7 event occurred about 6 months after the "main shock" which means that this event should be interpreted as a standalone shock and not part of the aftershock sequence. The seismic events in this area from the late 1960s to the early 1970s are therefore today interpreted as a seismic cluster rather than a classic mainshock-aftershock succession of events.

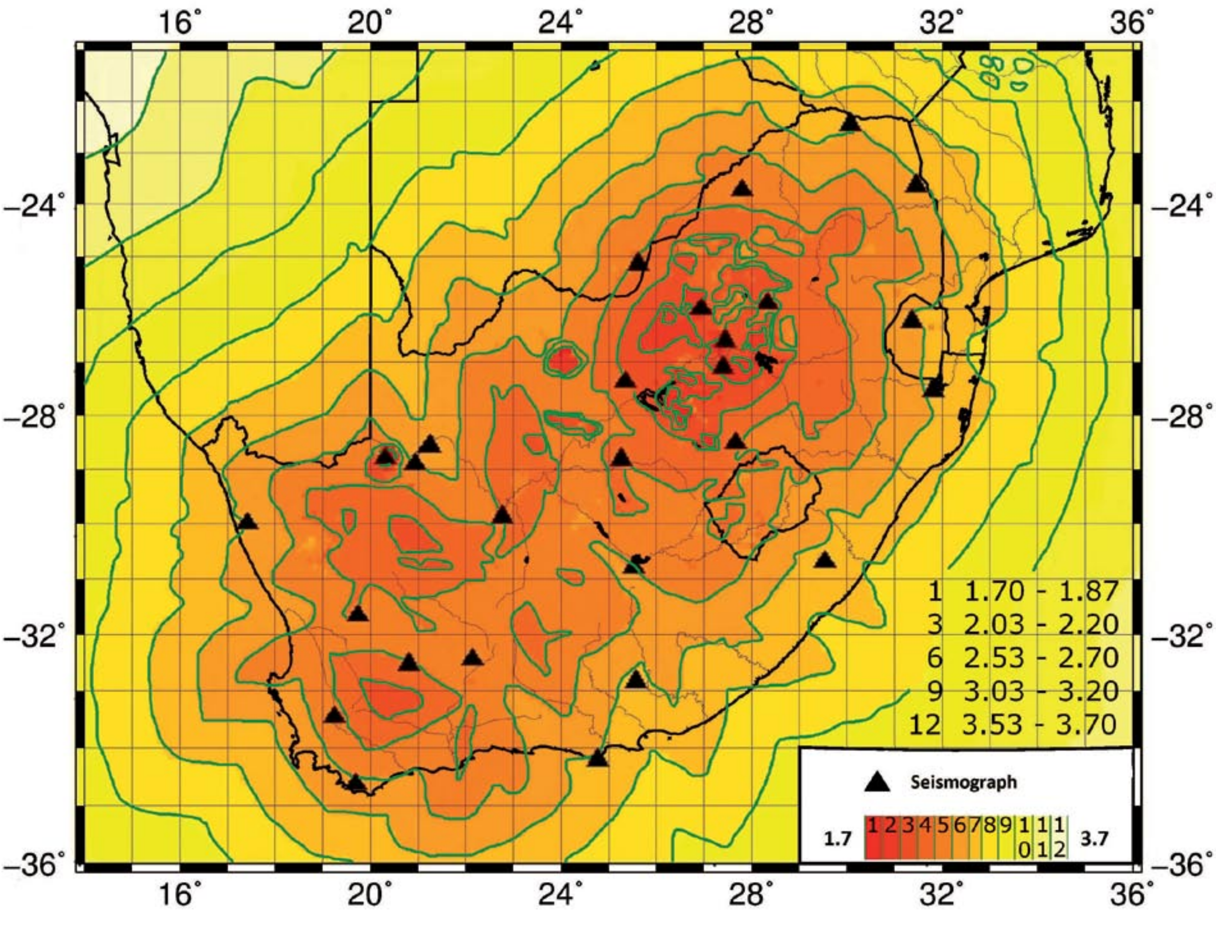
The Western Cape Province has an historical record of intermittent earthquakes dating back as far as 1690.

The number of earthquakes per annum with M_L≥2.8 recorded in the Ceres-Tulbagh area from 1969 to 2018. The largest events can be identified for 1969, 1970, 1977, 1983 and 1991 but only the last standalone shock in 2003 and its aftershocks were recorded completely with a sufficient magnitude threshold by the then expanded and modernised National Seismograph Network.



Since the largest population was in Cape Town for most of the early period, earthquakes in the surrounding areas may be underreported and large earthquakes in Cape Town itself may be described in more detail. The seismically active area around Cape Town is referred to as the "Cape cluster" which also includes, besides Cape Town, the Ceres-Tulbagh-Wolseley area. To date researchers have uncovered records of four earthquakes in the late 1690s, three in the 1700s, fifteen before 1850 and about fifteen between 1850 and 1900. The apparent "increase" in seismicity is a result of the sparsity of population and the subsequent lack of historical sources. The earliest earthquakes that definitely occurred in the Ceres-Tulbagh area were two events at the beginning of the 1920s namely an M_L 5.0 in 1921 and an M_L 3.7 event in 1922. Historical records contain no events for this area until the 1950s when three events estimated to have been of a magnitude of ~M_L 4.2 occurred within two to five years of one another. Events during the 1960s started off with an M_L 4.8 earthquake in 1960 followed by four events between 4.8 and 5 occurring before the 1969 earthquake.

The National Seismograph Network was expanded and modernised after the Ceres-Tulbagh earthquake. In the late 1960s only a few analogue seismographs were deployed in South Africa and the main shock was recorded at stations located at Grahamstown, Gariep Dam, Pretoria and Bloemfontein. Between 1970 and 1990 seventeen stations were added with four of the stations situated in the Western Cape at Ceres, Tulbagh, Bellville and Beaufort West. The Ceres station and its later upgrades/replacements has been in continuous operation since 1970; it records and locates seismic events throughout South Africa in conjunction with the rest of the seismograph network. The network remained analogue with a few digital stations being introduced in the 1990s. In the early 2000s all the analogue instruments were replaced with modern digital broadband equipment. Real-time data transfer by cellular GSM commenced in 2006 and during this time the network increased to 34 stations. In the present day the National Seismograph Network is again being modernised; the emphasis in present-day seismology is on less stations with a higher signal-to-noise ratio and better data quality. This allows real-time algorithms



Magnitude completeness of the National Seismograph Network from October 2012 to February 2017 (after Brandt, 2019).

to better identify seismic signals and auto-locate earthquake epicentres and determine magnitudes. The most recent performance of the National Seismograph Network is graphically illustrated in Figure 3 in terms of its magnitude detection capabilities.

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Martin Brandt, Nicky Flint, Eldridge Kgaswane and Ian Saunders (in alphabetical order)
Council for Geoscience,
Engineering and Geohazards Unit

eersteling monument

GeoHeritage – Eersteling Monument

The Eersteling Monument stands almost forgotten outside the town of Pietersburg/Polokwane, in the Limpopo province. The monument commemorates the first discovery of gold in the Zuid-Afrikaanse Republiek and the first crusher imported to South Africa. The mining activity also led to the recognition of the donkey's key role in establishing the South African mining industry.

The Eersteling monument is located about 20 km outside Pietersburg and can be reached via a fairly accessible dirt road off the R101 South to Potgietersrus, meandering through the Ysterberg until the tower looms up in front of you. The first commemorative plate simply read: "*Eersteling, die plek waar Suid-Afrika se goudmynbedryf begin het. Voordat goud in Barberton en Pelgrimsrus of in 1885 aan die Witwatersrand ontdek en ontgin is, is goud reeds in 1871 by Eersteling ontdek.*" (Eersteling, the place where South Africa's gold mining industry started, before gold was discovered in Barberton and Pilgrim's Rest or in 1885 on the Witwatersrand, gold was already discovered in 1871 at Eersteling). More recently, Caledonian Mining Corporation erected an information board on the site. Pietersburg was founded after the residents of Schoemansdal abandoned the town due to continued attacks from the warring and migrating tribes in area. Today Schoemansdal is an outdoor museum. Gold was first discovered on the farm Eersteling in mid-1870 by farmer-turned- prospector Jacobus du Preez. At that time, the Northern and Eastern parts of the Transvaal were home to many gold prospectors after the unsuccessful Tati gold rush of 1868 to 1869. Not having sufficient fare to return home, they were in search of a new gold strike. Du Preez was sure that the deeply weathered quartz vein that traversed his farm was indeed auriferous. He approached Edward Button who was actively prospecting in the area, and Button believed the vein was mineralised enough to warrant development. The gold-bearing quartz vein was subsequently christened the Natalia Reef, after the short-lived Republic of Natalia from where Button hailed.

Eersteling Monument

Road sign to the Eersteling Monument.

Button travelled to Pretoria to report the discovery and submit samples for government inspection. Convinced by the nature of the samples and a report by the Transvaal's surveyor-general, the Volksraad proclaimed Eersteling a public digging and named the area the Marabastad Goldfield. A mini gold rush followed to Eersteling, with about 30 prospectors staking claims on the farm by the end of 1871.

Samples were also sent to London and returned an assay of 2.5 g/kg. Button bought the farm Eersteling for £50 and then went to London to float the Transvaal Gold Mining Company (TGMC) and buy mining and crushing equipment. At the same time, he evicted all the other prospectors from the farm. While he was in London, his partner William Pigg started mining the upper weathered part of the vein. The initial ore-crushing was done by hand and processed 50 – 70 kg of ore per week. Pigg then started using a 500 kg boulder for ore-crushing and some local labour was recruited to assist with the mining. It was operated by two labourers, who, sitting on either end of a tree branch, rocked the boulder back and forth while quartz was fed beneath the boulder. Interestingly, this boulder is still in existence and can be viewed at the Ditsong National Museum of Natural History, in Pretoria.

Inscriptions on the Eersteling Monument.

In 1873 the first ore-crusher, a 12-stamp batter, was imported and transported by ox-wagon to the Eersteling mine. Button also bought enough dressed Scottish stone to build a boiler and chimney. A year later the ore-crusher was taken into service and by January 1875, some 10,107 grams of gold had been recovered. However, due to the increasing difficulty in recovering gold from the fresh quartz material and hostilities from the Pedi, Button was forced to close the operations in 1876. During the Eerste Vryheids Oorlog (First Freedom War), at the siege of Marabastad on 17 March 1881, the Boere Kommando brought in two old boats, with obsolete guns, and used handmade munition. The round shot ammunition was handcrafted from beaten iron, that came from the Eersteling Mining Company.

The Eersteling gold mine was in erratic operation over a 30 years period by various ventures until the start of the Second Freedom War (Tweede Vryheids Oorlog) between the Transvaal and Oranje Vrystaat Republics against the British Empire. After the discovery of more lucrative gold deposits first at Barberton and then on the Witwatersrand, the Pietersburg goldfield was abandoned. The Eersteling mine came back in operation, with the Eersteling Good Hope Gold Mine Company operating it between 1934 and 1938. The Eersteling site was declared a National Monument under old NMC legislation on 29 June 1938. There was periodic interest in the mine; during the 1980's AngloGold conducted a drilling campaign and in the early 1990's the Doreen, Pienaar and Girlie structures were targeted by Severin Mining Development. The most recent prospecting right holder of the Eersteling Mine was Caledonian Mining Corporation, but no activity has been reported in recent years.

The city of Pietersburg also erected a monument in honour of the donkeys that toiled at South Africa's first gold mine. On 31 July 1986 a statue was unveiled in front of the civic centre with a plaque that reads: "Donkey by Jo Roos. Burdened with the industry of gold, the donkey carried Pietersburg through the mining era, 1871-1892. Presented by Pietersburg district agricultural union 1986.07.31".

Pietersburg Greenstone belt

The Pietersburg Greenstone belt is of Archaean age and consists of an upper- and lower sequence. The upper sequence is mainly conglomerate, grit and sandstone and the lower sequence is undifferentiated mafic and ultramafic volcanic rocks and intrusives, with banded iron formation and chert. The ENE trending Willemse shear and related structures control most gold mineralization in the Eersteling area (Caledonian, 2007).

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Donkey, Pietersburg Monument (image_ Eseltjierus archive)

Nicolaas C Steenkamp

geo-curiosity

Gabon's Natural Fission Sites

The first man-made nuclear fission plants were only developed in the 1950's. The probability of natural fission was theorized by Paul Kuroda in a 1956 paper, but not proven until seventeen natural fission sites were discovered in Gabon in 1972 and became commonly known as the "Gabon Reactors".

The French had been mining uranium in Gabon, at Oklo, for several years to utilise in their nuclear power plants. During a routine isotopic measurement of uranium ore from Gabon, it was noticed that the uranium ore did not have a uranium-235 content of 0.720% as most other known deposits. The uranium ore was anomalously depleted in uranium-235, containing only 0.717%. However, there were high concentrations of elements like cesium, curium, americium and even plutonium to be found. It was considered very important to the officials to account for this "missing" uranium-235. Further exploration discovered sixteen natural nuclear reactors in uranium mines at Oklo. An additional seventeenth natural nuclear reactor was also discovered at Bangombé, located about 30 km to the southeast of Oklo.

By the time the significance of the discovery was realised by the scientific community, the sixteen natural nuclear reactors at Oklo had been destroyed, completely mined out for their rich uranium ore. Only a limited number of specimens remained that were made available for study. In the late 1990s, there was danger that the last natural nuclear reactor at Bangombé would be mined as well. In 1997 Francois Gauthier-Lafaye wrote a plea to the journal Nature advocating that mining of the Bangombé uranium be stopped.

Oklo-natural-reactor as seen in the underground mining operation (image United States Department of Energy).

Natural Fission

It is suggested that the Gabon nuclear reactors spontaneously began operating around two billion years ago, and continued to operate in a stable manner for up to one million years. The radioactive products of the nuclear fission have been safely contained over the entire period. The energy produced by these natural nuclear reactors was modest. The average power output of the Gabon reactors is suggested to have been equivalent to about 100 kilowatts, which would be enough to power about 1,000 light bulbs.

It was suggested by Kuroda (1956) that the conditions necessary for a natural nuclear reactor to develop could have been present in ancient uranium deposits. It has been suggested that two billion years ago, there would have been about 3.6% uranium-235 present in uranium ore on the Earth's crust, about the proportion of uranium-235 used in pressurized boiling water reactor nuclear power plants. In theory, an ancient uranium deposit could have spontaneously developed a self-sustaining nuclear fission, assuming the uranium was concentrated enough, there was a substance (most likely water) to act as a moderator and there were not significant amounts of neutron-absorbing elements nearby.

The reason uranium only became concentrated enough around two billion years to initiate natural fission, has been linked to the "Great Oxidation Event" that started around 2.4 billion years ago (Gauthier-Lafaye and Weber, 2003). At that time the levels of oxygen in the atmosphere rose significantly, from <1% to ≥15%. In most rocks on Earth, uranium is present only in trace quantities (ppm or ppb) in a number of minerals. Uranium is generally concentrated by hydrothermal circulation, which picks up uranium and concentrates it as a secondary hydrothermal deposit. For this hydrothermal circulation to concentrate uranium, that uranium must be soluble in order to be mobilised. When uranium is in its reduced form (U4+), uranium tends to form very stable compounds that are not easily brought into solution. However, when uranium is in its oxidized form (U6+), it easily forms soluble complexes. As the dissolved CO_2-content increase, so does the mobility of these uranium species.

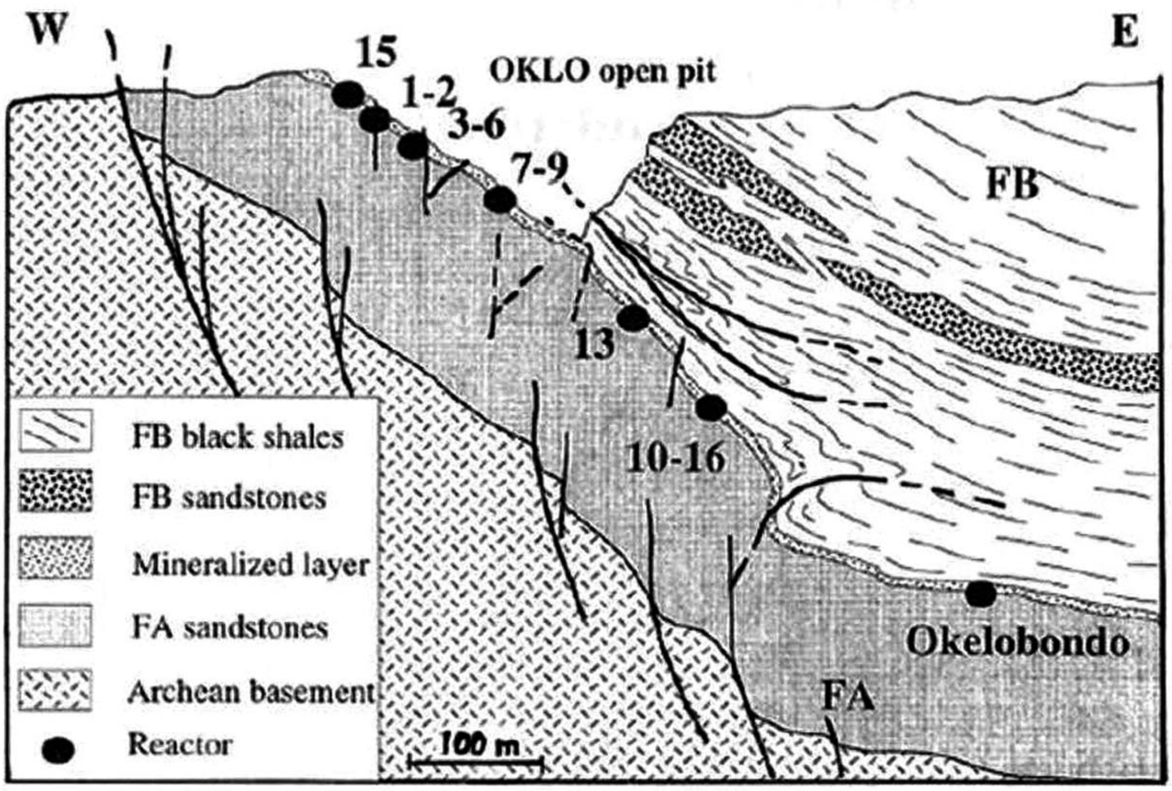
The Gabon Reactors were formed in a marine sandstone layer in the Franceville Basin. Uranium-bearing minerals are present in the underlying granite basement rock (Meshik, 2005). The sandstone unit was infiltrated by oxidizing water, which dissolved the uranium-bearing minerals along the bottom contact then mobilised and concentrated the uranium in several deposits towards the top of the sandstone layer. The uranium content in fact became extraordinarily well-concentrated. Fission of uranium could have begun when the uranium concentration reached 10%; the Gabon uranium deposits in which the natural nuclear reactors developed is estimated to have contained about 25% to 60% uranium (Meshik, 2005).

The Gabon reactors were able to meet the requirements that Kuroda (1956) had suggested, in as far as that there were high enough concentrations of uranium which still contained a significant amount of highly-fissionable uranium-235 and water was able to percolate into the permeable sandstone containing the uranium deposits. This water acted as the neutron moderator, slowing neutrons down so that they were more likely to hit atomic nuclei and cause fission reactions There appear to also have been no significant quantities of neutron-absorbing elements to inhibit the self-sustaining fission reaction (Meshik, 2005). It is suggested that the Gabon Reactors would have been active over a period of several hundred thousand years and would have acted like modern geysers. For approximately 30 minutes the reaction would go critical, with fission proceeding until the water boils away. Over the next ~150 minutes,

Expression of one of the Oklo fission sites on surface (image_US department of Energy).

there would be a cooldown period, after which water would flood the reactive zone again and fission would restart. This interpretation is based on examining the concentrations of xenon isotopes that become trapped in the mineral formations surrounding the uranium ore deposits. Eventually, the fissionable uranium-235 was depleted to such an extent that the Gabon natural reactors became inactive.

The last factor that has significant scientific value to both geologist and nuclear scientist is the fact that the Gabon natural reactors, over their entire life, never contaminated large areas of country rock surrounding it. The natural nuclear reactors in Gabon seem to have



Oklo-site simplified geological setting (Mossman et al., 2008).

been largely protected by enveloping carbonaceous substances and clay, which created and maintained reducing (low oxygen) conditions which largely inhibited the movement of uranium and other radioactive by-products of nuclear fission. In addition, it was found that the plutonium and cesium fission by-product was effectively captured. According to an article in Forbes, barium (the 'trace' element left after the full breakdown of the plutonium and cesium) is not found evenly distributed in the country rock, but rather found in nests surrounded by a thin layer of ruthenium-compounds. It has been suggested that containers made of ruthenium alloys could be used to safely store radioactive waste for a very long time and would be resistant to exposure to radioactive material and corrosion by water over vast geological periods. The problem, however, is that ruthenium is expensive and rare. Research is underway to examine the molecular structure of the ruthenium that is holding onto the radioactive cesium to better understand how the two elements are bound together. It is hoped that this research will provide a way to adapt iron to hold onto the radioactive elements in spent nuclear fuel.

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Nicolaas C Steenkamp

ARTICLES

isotopes in diamonds

Summary of: Sulfur isotopes in diamonds reveal differences in continent construction

Published in: Science, vol 364, issue 6438, pages 383-385
Authors: Karen V. Smit, Steven B. Shirey, Erik H. Hauri, Richard A. Stern

Diamonds are one of the most valuable gemstones and are also very valuable to geoscientists. Mineral inclusions in diamonds are the most direct samples we have from the inaccessible depths of Earth, and they have given geoscientists information about water in the Earth's interior, mineralogy of the deep Earth and metallic phases in the deep Earth. Also, because there is no direct way to determine a diamond's age from the diamond itself, mineral inclusions trapped within diamond provide the only way to date diamonds. So although inclusions in diamonds are often considered to be undesirable in the gem trade, they are extremely valuable scientific samples.

In our study, we measured the sulphur and rhenium-osmium isotopes in sulphide inclusions in diamonds from the Zimmi region of Sierra Leone. The sulphides are tiny minerals, often between 100 and 300 micrometers across, trapped in the diamonds during growth.

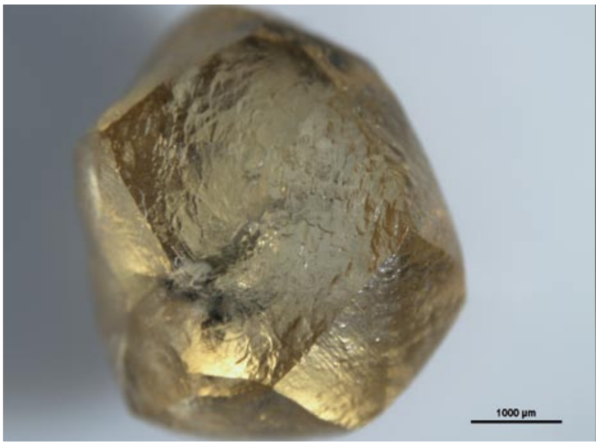
We found that the sulphides recorded two episodes of subduction in the West African continent. Subduction is when the oceanic crust is thrust into the deep Earth during collision with another tectonic plate. The first subduction event recorded by Zimmi sulphides occurred around 3 billion years ago, the second around 650 million years ago.

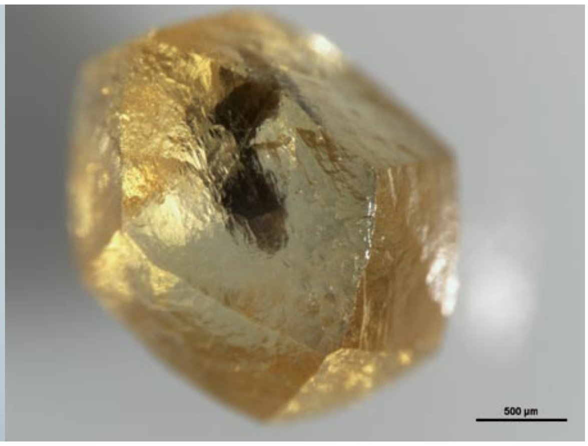
3 billion year old subduction

The sulphides have isotopic compositions that indicate their sulphur was cycled through the ancient atmosphere prior to the rise of oxygen 2.5 – 2.3 billion years ago (Farquhar et al., 2001). This is because the sulphur does not have mass dependent isotopes as would be expected for modern terrestrial materials. Instead, sulphur has mass-independently fractionated (MIF) sulphur isotopes. These MIF isotopic signatures are thought to only arise in the ancient atmosphere prior to oxygenation of the atmosphere[1]. The presence of MIF isotope signatures indicates that the sulphur had a surficial origin in the Earth's ancient atmosphere. The sulphides were likely emplaced into the deep Earth around 3 billion years ago – a time that has been well established for subduction and incorporation of oceanic crust material into the mantle[2,3].

650 million year old subduction

We also measured the rhenium-osmium isotopes in these sulphide inclusions. Rhenium-osmium is the most widely used technique to date the time of diamond formation[4]. Zimmi diamonds were found to have 650 million year old ages[5], an age that overlaps with subduction and





Rough diamond from Zimmi in West Africa, near the Sierra Leone-Liberia border. It contains a sulphide inclusion with compositions that give clues to how the West African continent formed. Photos by Karen Smit/GIA.

collisional mountain building in the region, between 700 and 550 million years ago. Subduction of oceanic crust and subsequent dehydration of the oceanic crust would have introduced into the deep Earth the carbon-bearing fluids for diamond formation[6].

Why do we find this interesting?

Earth's oldest continents (called cratons) are stabilized by lithospheric mantle keels. The stability of Earth's continents in the face of destructive tectonic activity is an essential geologic backdrop for the emergence of life on our planet. Since this is the only tectonically active, rocky planet that we know, understanding the geology of how our continents formed is a crucial part of discerning what makes Earth habitable.

The stability of cratons depends on the underlying mantle keels that are around 150 – 200 km thick. The processes for how these mantle keels form are still debated, and there are several different theories for their origin. Some of the models for craton formation involve subduction-style plate tectonics where plates are subducted into the deep Earth and stabilise the cratonic keels. Other models do not invoke subduction, and instead require deeper mantle processes like melting in mantle plumes or melting at oceanic plateaus.

Luckily these mantle keels have the ideal conditions for diamond formation. Because the majority of natural diamonds form in these cratonic mantle keels, diamonds have become important samples that can be used to investigate how the stabilising keels below the oldest continents are formed.

Sulfur isotopes in diamonds, combined with their rhenium-osmium ages, can be used to track multiple subduction events during craton growth, even those separated by billions of years. Subduction processes were essential to the growth and modification of the West African craton over a period of 2 billion years.

We compared our results to diamonds from southern Africa and northern Canada. We found that this combined isotopic approach also reveals differences in craton construction worldwide. Similar to the Zimmi diamonds, diamonds from the Jwaneng and Orapa mines in southern Africa contain MIF sulfur[1,7]. This indicates that subduction was also an important process in the construction of the cratonic mantle in southern Africa.

But diamonds mined in northern Canada do not show the same sulphur chemistry. Diamonds from the Ekati mine have 3.5 billion year old rhenium-osmium ages and do not have MIF sulphur[8,9]. This means that the mantle keel in this region originated in some way that did not incorporate surface material. The sulphur in the Canadian diamonds does not tell us how the mantle keel formed, only how it did not.

Our work shows that sulphide inclusions in diamonds are a powerful tool to investigate craton construction processes.

How did we do this?

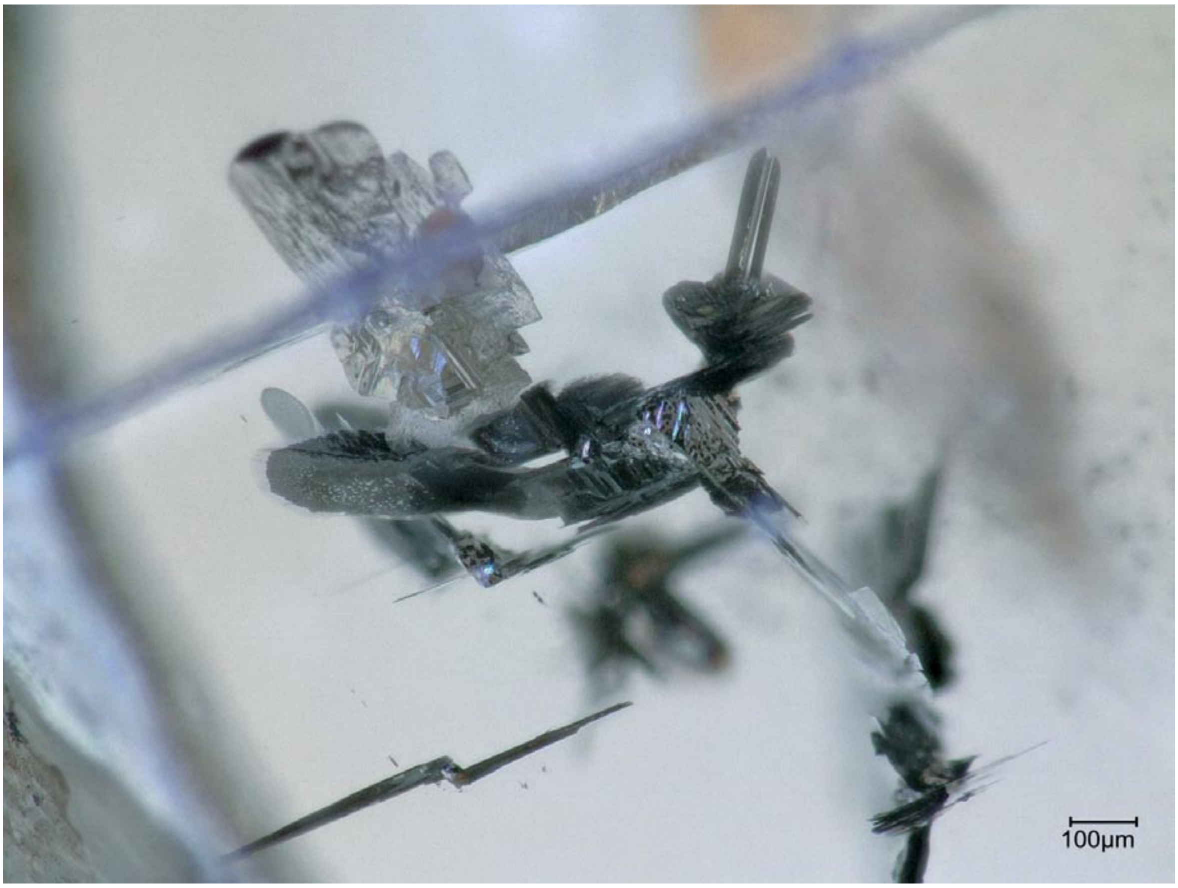
To characterise the diamonds and image the inclusions, we first laser cut and polished double-sided plates of the diamonds.

Rhenium-osmium isotopes

We broke the diamond plates using a small hammer and a steel cracker to release the sulphide inclusions. The inclusions are tiny and weighed between 3 and 162 micrograms. After breaking each inclusion out of the diamond we imaged it and analysed its major element composition using a scanning electron microscope.

In a clean laboratory, we then dissolved the sulphide in some acid along with a known amount of tracer solution known as an isotopic spike. Chemical procedures are done to separate rhenium and osmium into different acidic solutions. The solutions that contain rhenium and osmium are each dried down on a hotplate.

The dried-down salt of osmium is placed on a metallic filament, which is then placed in a thermal ionisation mass spectrometer (TIMS). The filament is heated to produce ions that are then accelerated through the instrument and the different osmium isotopes are measured on a very sensitive detector.



Sulphide inclusions still trapped in the Zimmi diamonds. Sulphides are silver-grey in appearance and are surrounded by blackened fracture systems. These fractures develop during kimberlite ascent because the sulphides expand more than the diamond. Photos by Karen Smit/GIA.

/Continued on pp. 32


DSV

The dried-down salt of rhenium was taken up into a dilute acid solution. That solution was introduced into a multi-collector inductively coupled mass spectrometer (MC-ICP-MS). The solution was ionised in a plasma and those ions were accelerated through the instrument, where the two different rhenium isotopes were measured simultaneously on very sensitive detectors.

The amount of rhenium and osmium that we measured in the sulphides is in the femtogram to picogram range - where 1 femtogram is 10-15 g or 1 part per quadrillion (ppq) and 1 picogram is 10-12 g or 1 part per trillion (ppt). Because we are measuring such tiny amounts, any small amount of contamination can ruin the sample. This is why it is essential to do this work in a clean laboratory with dedicated supplies for diamond inclusion work.

Rhenium-osmium analyses were done using chemistry labs and a Thermo-Fisher Triton instrument at the Department of Terrestrial Magnetism at the Carnegie Institution for Science.

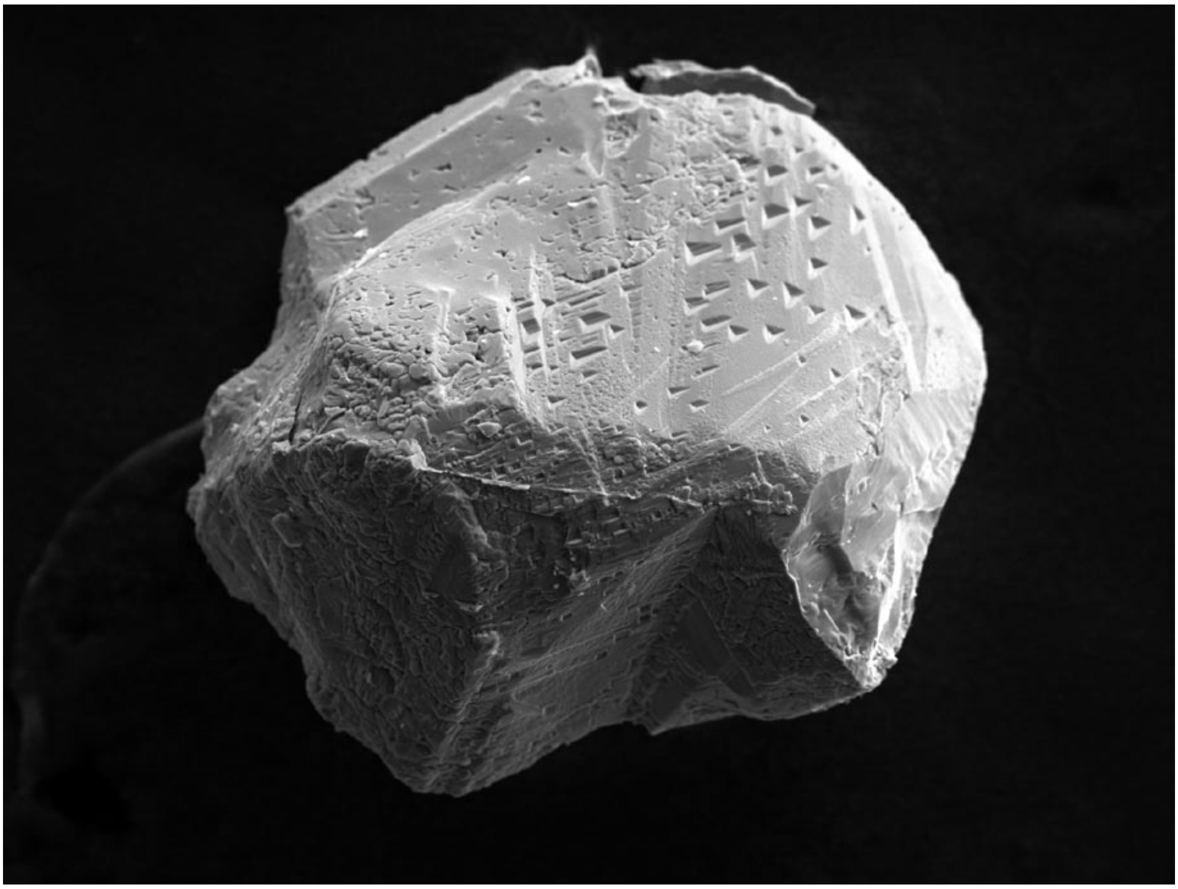
Sulphur isotopes

Sulphide inclusions were not broken out of the diamonds for sulphur isotope measurements. Instead we polished the diamond plates down further with a diamond scaife to expose the sulphide inclusions. It took a few hours to a day to expose each inclusion.

Diamond plates with the exposed sulphide inclusions were placed in a secondary ion mass spectrometer (SIMS). The samples were bombarded with a cesium ion beam to create small pits in the sulphides. The material released from the sulphides was then accelerated through the instrument and the four different sulphur isotopes were measured simultaneously on very sensitive detectors.

Sulphur isotope measurements were done using a Cameca IMS 1280 instrument at the University of Alberta. Preliminary measurements were done using a Cameca NanoSIMS at the Department of Terrestrial Magnetism at the Carnegie Institution for Science.

Sulphide inclusion that has been broken out of a diamond and imaged in a scanning electron microscope. This sulphide has cubo-octahedral morphology and trigons on its surface. Both these features were imposed on the sulphide by the diamond. Image by Karen Smit/GIA.



About the diamonds themselves

Diamonds for this study are from the Zimmi alluvial deposit in Sierra Leone. The Zimmi mining area is located south of the town Zimmi, near the Libera-Sierra Leone border. The Zimmi locality is known for producing yellow diamonds with abundant sulphide inclusions.

The Zimmi diamonds have nitrogen impurities in the rare isolated form that classifies them as Type Ib diamonds. Type Ib diamonds are exceptionally rare among natural diamonds and account for less than 0.1% of worldwide natural diamonds.

About the authors

Karen V. Smit has been a research scientist at the Gemological Institute of America (GIA) since 2014. She is interested in using diamonds and their mantle host rocks to understand diamond formation processes in the deep Earth. Her research focusses on the origin of the Earth's continents, how plate tectonic processes influence diamond stability, and most recently in using the spectroscopic features of natural diamonds to distinguish them from lab-grown and treated diamonds.

Steven B. Shirey has been a staff member at the Department of Terrestrial Magnetism of the Carnegie Institution for Science for 34 years. Shirey's research focusses on the evolution of Earth's continents, especially as a function of mantle evolution. His interest in diamonds began more than 20 years ago as a way to examine continent formation and plate tectonics from the deepest possible perspective in the mantle.

Erik H. Hauri (now deceased) was a staff member at the Department of Terrestrial Magnetism of the Carnegie Institution for Science for 24 years. He passed away in 2018. Hauri was interested in the geochemical cycles of volatiles on the Earth and moon and their relationship to planetary dynamics. Hauri's remarkable expertise in secondary ion mass spectrometry led to breakthroughs in understanding the water content of the moon, and the analysis of stable isotopes in diamonds and their mineral inclusions.

Richard A. Stern is a research scientist and ion probe facility manager at the University of Alberta. His research over the last 25 years has focussed on developments and applications of secondary ion mass spectrometry to a broad range of topics in geochemistry and geochronology, most recently emphasizing light stable isotopes.

Read more

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inclusions in diamond

Barry Hawthorne: His role in the study of mineral inclusions in diamond.

The arrival in Kimberley of Barry Hawthorne as Chief Geologist of De Beers Consolidated Mines in 1970 coincided with the return of another Kimberley citizen Mick Harris who was appointed the Chief Evaluator at the Diamond Sorting Office of the same group of Companies. I first visited Kimberley in 1969, under the auspices of the Diamond Producers Association and on a visit to the sorting office in Consolidated Buildings in Kimberley, was given a five star display of three piles of diamonds of different sizes from an alluvial diamond deposit called Namaqualand Venture. Observations of these diamonds showed a progressive difference in shape as a function of size and over the next year a diamond classification scheme was devised.

On my visit in 1970 the classification scheme was further developed by an enthusiastic Barry and because of the long friendship between Barry and Mick, permanent facilities to study diamonds from all of the De Beers mines operating at that time was easily established with budgetary concerns being the responsibility of Barry. The classification of the shape and colour of diamonds as a function of size was considered as a prospecting project. Over the next few years and with considerable help from two staff seconded from the personnel of Mick's sorting office, this work showed that distinctions could be made between the diamond characteristics from the main mines and that the alluvial diamonds from the Transvaal were not derived from the proximal Helam mine at Swartruggens. In the mid-seventies, classification was considerably further enhanced by the contribution of Derek Robinson who emphasised the importance of diamond surface features.

On a field trip in Siberia research interest in the mineral impurities in diamonds was principally developed by Russian scientists after the discovery of the Siberian diamond mines in 1955, with some additional early work at University College London from 1963-1972, on inclusion-bearing diamonds mostly from Sierra Leone and Ghana. The absence of information about the minerals in South African diamonds certainly concerned Barry, particularly in view of the potential prospecting value of such studies developed in the early seventies by John Gurney in Cape Town. In addition, the immense success of the First International Kimberlite Conference (1973) in which Barry played a stellar role, aroused

With Louis Ahrens at the First International Kimberlite Conference in 1975

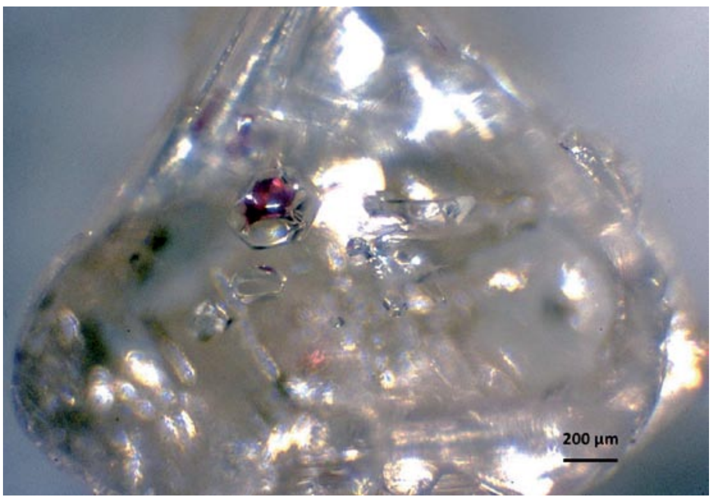
dramatic interest in kimberlite and diamond research. So around 1973 inclusion studies easily became part of the work conducted in the Kimberley diamond sorting office. Over the next ten years, representative inclusion-bearing diamonds from most of the DeBeers South African mines were collected, with diamonds also from Roberts Victor and Bellsbank, and the inclusion chemistry was determined in John Gurney's laboratory in Cape Town University. During this time the new mines in Botswana became part of this work, facilities in the Gaborone sorting office being arranged by Barry. The results of these studies were regularly published because Barry had a view that the lead-in time for the research was about a year to eighteen months, sufficient time for a Company to act on any important research outcomes. These works were also linked to the chemistry of similar minerals either in mantle xenoliths or from mining concentrate.

In the early-eighties a contentious issue was whether or not diamond was a phenocryst or a xenocryst in kimberlite. This subject may seem odd nowadays, but such is our evolution. A meeting was held in Kimberley between Barry, Tony Erlank from Cape Town University, a young research scientist called Steve Richardson and myself. The upshot of the meeting was that if the Industry could supply 400 garnet inclusion-bearing diamonds from the peridotitic growth environment and from two sources, an attempt to determine the age of the diamond could be made. Barry asked a simple, but crucial question, which was whether I and the team in the sorting office, now increased to four personnel, could collect such a quantity of diamonds. The answer was yes and the genesis age dating of diamond, which has grown phenomenally since then, was born. Nowadays, because of advances in analytical capabilities, the aliquot of Nd-Sm from 400 garnets is reduced to a single inclusion, as is the case with Re-Os analyses to date diamonds via sulphide inclusions. There were probably a hundred reasons why Barry could have not bothered to ask the key question, but that was not the way Barry Hawthorne worked.

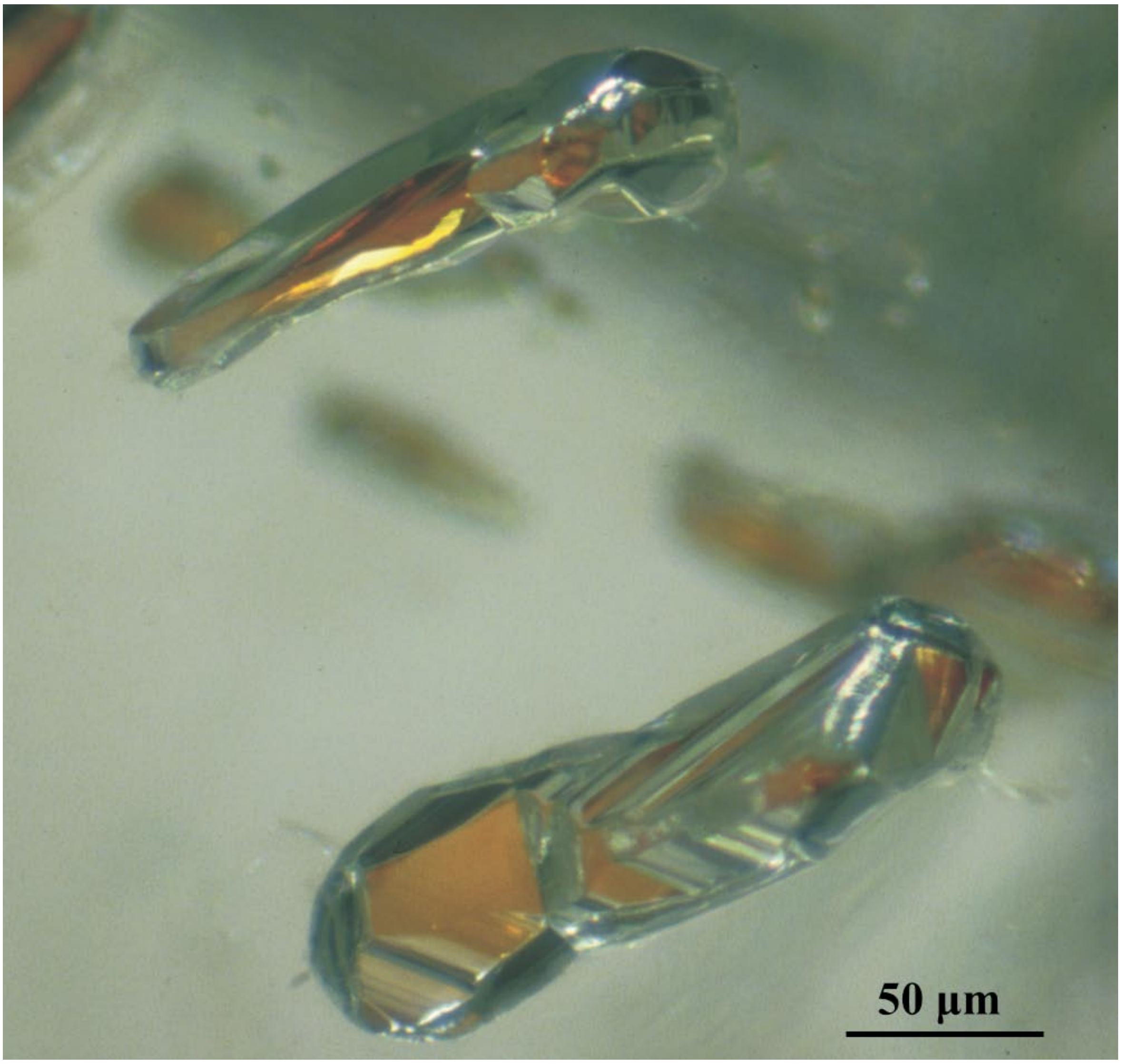
By the time Barry retired, inclusion studies on diamonds was established and considered to be an important aspect of DeBeers contribution to diamond research in major Universities and equivalent institutions around the world. By then these research projects had determined not only the major and trace element conditions worldwide of three principal diamond growth environments, but also the pressure and temperature of these worldwide environments. Also worldwide diamond genesis ages had been shown to be mostly greater than 1Ga, the oldest being 3.5Ga (75% of the age of the Earth). Studies on the diamonds from which the inclusions had been obtained were an additional integral part of the research, with the evaluation of carbon and nitrogen isotopes, the amount and the aggregation states of nitrogen, diamond's commonest elemental impurity. Other diamond studies involved fluid inclusions in cloudy or milky diamonds and He-isotope studies in more typical diamonds. Results from this type of work have now enabled quite a detailed hypothesis for the formation of natural diamond to be proposed.

Although the first lower mantle diamond was recorded from a small De Beers prospect trench at Orroroo, north of Adelaide in South Australia in 1981, better evidence for the presence of so-called 'deep diamonds' came initially from majorite inclusions in diamonds from the Monastery mine detailed by Rory Moore and John Gurney in 1985. At about this time De Beers established an alluvial diamond mine in Sao Luiz in Mato Grosso Province in Brazil. The diamonds from this source were exceptional not because of their value, but because the inclusions indicated that few, if any, lithospheric diamonds occurred in this deposit. On hearing this, Barry made the necessary arrangements for the collection of inclusion-bearing diamonds over the period (1985 to 1990) from the De Beers Diamond Trading Company offices in London. Two Ph.D Theses and papers with and by Ben Harte and others, (see Ben's paper in the 10th International Kimberlite Conference (IKC) volume for a lead-in to earlier work) showed that diamond formation covered most of the deeper mantle and the first 150km of the lower mantle at 810km. At present these deeper diamonds, from other sources than Brazil, are a principal focus of current research.

In later retirement Barry reflected on two incomplete research topics that involved mineral inclusions, a proof of the source(s) of the Namaqualand and Namibian alluvial diamonds and the eruption age(s) of



A pyrope garnet inclusion from the peridotitic paragenesis showing a cubo-octahedral shape which visually is aligned to the rounded octahedral form of the diamond in which it is encapsulated. Because of internal reflections the pyrope colour does not extend to the true edges of the inclusion. Just below and to the right of the pyrope are colourless olivine inclusions. The diamond is from the Finsch mine and was typical of those inclusion-bearing diamonds used to determine the first diamond genesis age.



Two orange garnets from the eclogitic paragenesis deep within an octahedral diamond from Premier (now Cullinan) mine. The inclusion elongation is closely parallel to the octahedral edge of the diamond. The large flat face of the upper inclusion is also closely parallel to an octahedral surface and the lower inclusion shows a distinct triangular and stepped appearance similar to that found on octahedral diamond faces. These inclusions can also be used to determine diamond genesis ages using Sm-Nd analysis.

the diamonds in the western Transvaal alluvials. Barry was very satisfied with the paper by Dave Phillips in the 12th IKC volumes, which used Ar-Ar age dating from clinopyroxene inclusions to determine the eruption ages of the coastal diamonds and then link these dates to the eruption ages of the kimberlites within southern Africa, but still wondered about the western Transvaal.

Barry Hawthorne created a diamond and inclusion research framework which has had, and still does have, an immense impact on our understanding of mantle processes. That framework also provided opportunities for scientists around the world to develop their ideas. Had he not returned to Kimberley all those years ago, one wonders just how much of the above story could have been told.

Two examples of inclusions in diamond are shown to illustrate what the starting material looks like. From major studies involving hundreds of thousands of diamonds, usually in the 2-3mm size range, the average useful inclusion from the major De Beers mines operating in South Africa and Botswana in the 1980's constituted one percent of their total production. Thus a sharp eye and a great deal of patience were the order of the day.

Jeff Harris
(Consultant to De Beers between 1970 and 2006 responsible for De Beers outside diamond research projects in Universities and equivalent research Institutions worldwide).

obituary

Barry Hawthorne †

Success
By Bessie Anderson Stanley

He has achieved success who has lived well, laughed often, and loved much, who has enjoyed the trust of pure women, the respect of intelligent men and the love of little children, who has filled his niche and accomplished his task, who has left the world better than he found it, whether by an improved poppy, a perfect poem, or a rescued soul, who has never lacked appreciation of Earth's beauty or failed to express it, who has always looked for the best in others and given them the best he had, whose life was inspiration, his memory a benediction.

I have been asked to deliver the eulogy, commemorating Barry's life, on behalf of Margie and the family. I have known Barry for 31 years and yet I knew him for only a fraction of his life. The family sat together the other night and recalled many stories of a life well lived. Discussing his life and our memories of him brought some laughter back into our conversation. When someone has lived a long life and achieved great success as an adult it is easy to forget that they were once also a child and that the happiness of their childhood was as much a part of their lives as the success of their adult life. Barry was born in Kimberly on the 19th of May 1934. He spent his youth in Kimberly where his father owned a book shop and his mother was an artist. By all accounts his youth was happy and he was close to his brother Nay.

When he was 11 his parents introduced him to the Kruger Park that he loved so much and where he spent his last few days with Margie and Pat. Barry and Margie met in 1954 in Geography 1 at Rhodes University. On the 15th of December they would have been married for 62 years. Together they raised four children and were blessed with 10 grandchildren. Over the years the family spread across the globe. However they managed to keep the family close through their many trips to visit Michael and Philip in the USA and Pat in New Zealand. They also maintained a welcoming home first in Gonubie and then in Scarborough where all of us felt welcome and were happy to return to time and time again. On the 5th of December we will all gather again in Scarborough to celebrate the life of a father to us all.

Barry qualified as a geologist and went on to work for DeBeers and AAC for 40 years, finally retiring as deputy technical director for the company. He was instrumental in driving advances in scientific approaches to kimberlite exploration and also achieved academic recognition, having a geology scholarship at UCT named after him. He travelled extensively for work and built relationships across the geological community. His travels took him to many exotic places like Siberia, Mongolia, Madagascar and the Magellan straits. The Hawthorne house was always full of visiting geologists from all over the world and these visits turned into some memorable parties. Barry had a major impact on the scientific approaches to geological exploration, that opened up opportunities for growth for De Beers and AAC. The messages that we received after his passing however reflect a deep respect for him as a leader and a mentor who was instrumental in moulding the careers of a generation of geologists.

While out in the field Barry developed a new passion that he would spend a major part of his life sharing with Margie. Birding and Barry became synonymous. Together they scoured the earth in search of new birds. I remember clearly Barry "refusing" to take Margie to Venice because there were no birds there. Annual visits to the Kruger Park were also ruled by optimal birding times. We were all hauled out of bed at the crack of dawn so that we could be the first car at the gate and returned after 10h00 when the birds settled down for the hot part of the day. Birding brought Barry into contact with a whole new community of friends and both he and Margie moved up the rankings of birders. His South African life list included 873 species and his world list was just short of 3000 species.

Those who only got to know him later in life may not believe that he was a champion pole-vaulter, hurdler and high jumper at University. He also had a passion for Rugby and could easily watch multiple games in one day. Margie shared this love of rugby but they had very different viewing styles. Barry would sit quietly and watch while Margie stood in front of the TV abusing the ref and the players. This irritated him to the point where he suggested separate TV's. This reminded Margie of Mark Andrews parents who used to watch games in separate rooms, but rushed together to celebrate tries and wins.

In the last few years Barry developed a passion for mapping the various family trees that contributed to his children's and grandchildren's heritage. He was always relating stories about the interesting characters, both good and bad, that made up the clan. As with all his passions he approached this with a diligence that was unmatched. He was a great planner. He planned everything well in advance, from the daily meals to the various trips around SA and overseas. He had a list for everything, mostly scrawled on loose pages. He packed for trips way in advance and packed for any eventuality (including travelling with a printer). He was a stickler for time and was invariably rearing to go 15 minutes before the appointed time.

Barry also had a great love of food and good wine and his sweet tooth thwarted all Margie's efforts to limit his calorie intake. He couldn't help hanging around the kitchen when food was being prepared and stealing little titbits from the cutting board or the pot. A meal was only complete with dessert. He had a dairy allergy but could not resist ice-cream, which triggered a sneezing fit after meals. He could be quite stern and his scowl, when confronted with incompetence, was legendary and led to the nickname Grandpa Grinch. However, as a father and grandfather he was always kind and extremely generous and gave to all of us of his time and resources. His passing has left a void that will never be filled. The love and support of friends has been a great consolation, especially the wonderful memories that people from across the world have been sharing with us.

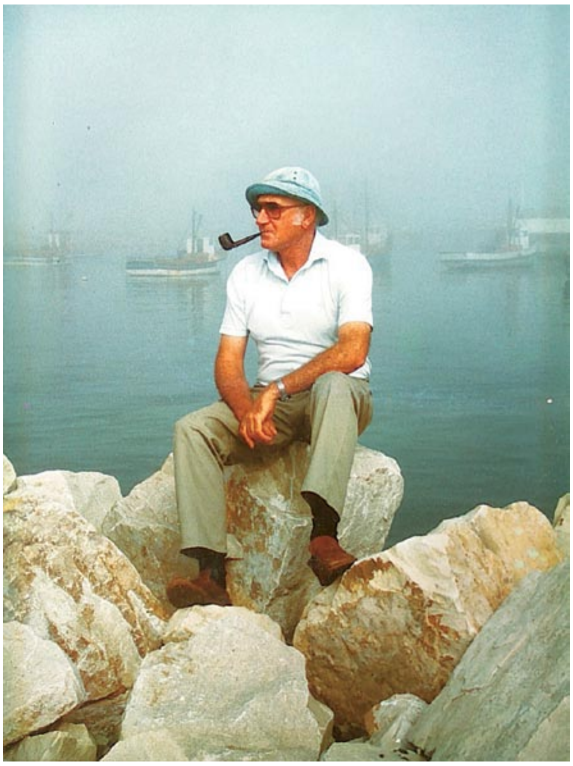
I would like to close with a poem by an unknown author called: **As We Look Back**

As we look back over time
We find ourselves wondering
Did we remember to thank you enough
For all you have done for us?
For all the times you were by our sides
To help and support us
To celebrate our successes
To understand our problems
And accept our defeats?
Or for teaching us by your example,
The value of hard work, good judgement,
Courage and integrity?
We wonder if we ever thanked you
For the sacrifices you made.
To let us have the very best?
And for the simple things
Like laughter, smiles and times we shared?
If we have forgotten to show our
Gratitude enough for all the things you did,
We're thanking you now.
And we are hoping you knew all along,
How much you meant to us.

Stephen Dippenaar

obituary

Arthur Fuller †



Arthur Fuller (1926-2019)

Arthur Fuller, a former Head of the Department of Mineralogy and Geology at UCT died in May 2019 aged 92. Arthur was born on August 28th 1926, and matriculated at Diocesan College (Bishop's) in Rondebosch. He then studied at UCT, obtaining a BSc (Hons) in 1950 and an MSc in 1951 for a thesis on the Critical Zone of the Bushveld Igneous Complex. He spent a year at Pennsylvania State and then three years at Princeton, where he obtained his PhD for a thesis entitled "The Witwatersrand System". Those who remember him as the department sedimentologist at UCT would be surprised to learn that his major subjects at Princeton were igneous petrology, mineralogy and geochemistry. Nowadays this would be lauded as interdisciplinary; then it was probably a necessity given that university academics were expected to teach everything.

Arthur spent several years in industry with Union Corporation and was involved in exploration mapping in northern Canada and Venezula. He also worked as a taxi driver while a student.

Arthur joined UCT as a lecturer in the then Department of Mineralogy and Geology in 1957, becoming Associate Professor in 1972 until his retirement in 1989. As well as sedimentology, he at various times taught geophysics, geostatistics (the first stats course at UCT), economic geology, engineering geology, and was responsible for obtaining the departments first X-ray diffraction equipment. He also taught field geology and became firm friends with a Laingsburg farmer by the name of Colenso van Wyk. This led to the department obtaining a 99 year lease on an old coaching station that became the 'Colenso van Wyk Field Station' that still serves as the base for second year mapping fieldtrips.

At the time Arthur started as an undergraduate, the Fuller family was already long associated with UCT. Arthur's father had been Head of the Department of Anaesthetics, his aunt Minnie was an early female UCT graduate, after whom the Fuller Hall residence is named, and uncle Barnard Fuller played a key role in the establishment of the UCT Medical School.

Arthur was a fellow of the Geological Society, serving as President in 1983-4, and was a fellow and member of council of the Royal Society of South Africa. Arthur was an exceptional sportsman; he boxed at school, he held the SA under 19 and UCT javelin record, and was also a South African discus champion. He was the UCT golf champion in 1948, and in 1949 was the Champion Golfer at Mowbray Golf Club and represented Western Province. Arthur spent his last retirement years at Helderberg Village in Somerset West, where for many years he was captain of the golf club, and it was during his tenure that the golf course was converted from a 9-hole to an 18-hole course by creating dual tee-boxes and making other changes. His non-geological interests were wide and varied and he was an excellent photographer and loved jazz and playing the piano. He read extensively on a wide range of subjects and almost until he died his mind was alert and enquiring.

His personal department file contains a 1972 letter of reference written by ESW Simpson that describes Arthur as 'a man with a positive, forceful personality who does not suffer fools gladly'. He was a superb anecdotalist, who was at his best at morning tea. His students were somewhat in awe of him, and stories about Arthur were constantly being retold and embellished. Perhaps the most famous of these concerned facial injuries caused by his pipe exploding as it was lit.

At a memorial service held at his daughter's house in Somerset West, Maarten de Wit spoke about Arthur. Maarten revealed that he had had asked Arthur whether there was any truth in the exploding pipe story; yes there was. It was due to the presence of a .22 bullet that had accidently been put back into his tobacco pocket, and this happened on a GSSA Western Cape Branch fieldtrip while examining dropstones in the Dwyka. Simpson also wrote in his 1972 reference letter that 'Dr Fuller......submits for publication only those views or research results which he considers to be a positive, useful, and original contribution to knowledge'. As a consequence, Arthur's list of publications is not long but is extremely diverse, including economic geology, marine geology, fracture zone distribution, impact structures, and geochemistry (of Wits shales). His 1958 paper on the Witwatersrand System was one of the first to suggest a hydrothermal origin for Wits gold. Arthur was a dedicated teacher and numerous letters and memoranda survive in his file that attest to the concerns he had about teaching at UCT. As well as sedimentary rocks and fieldwork, Arthur was involved with the teaching of economic geology and was the prime mover in the establishment of the Professorship in Economic Geology. Arthur continued to be interested in geology long after his retirement, and told his daughter, Sushsy that at 90 years old he would have been a better teacher than he had been in his early sixties.

Our condolences go to Arthur's family, his two daughters born in Princeton, and a much larger number of grandchildren and great-grandchildren.

Chris Harris
Department of Geological Sciences
University of Cape Town

With thanks to **Maarten de Wit, Anton le Roex, Pierre Hofmeyr**, and especially **John Rogers** for an eyewitness account of the pipe incident, and Arthur's daughter **Shushy Hugo-Hamman**.

obituary

Alfred Kröner †

In Memoriam, Alfred Kröner (1939-2019), Professor emeritus

Alfred Kröner passed away on May 22, 2019. With him the geoscience community lost a geologist and friend who made major contributions to our understanding of the geological evolution of ancient continental crust. Although he had been carrying out research in many corners of the world, his favourite stomping grounds were the Precambrian terrains of southern Africa.

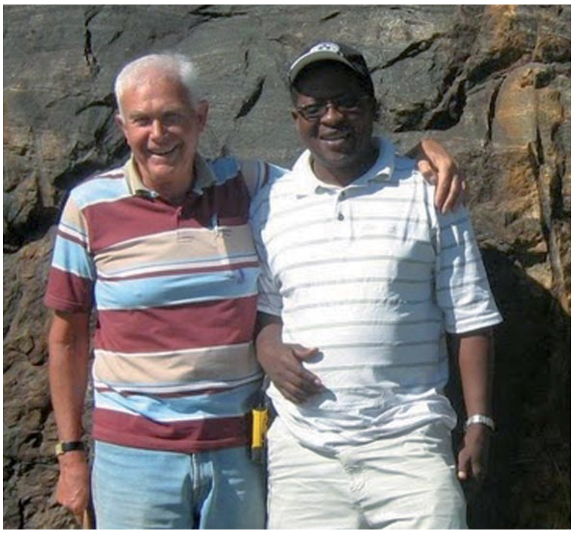
Alfred was born in 1939 in Kassel, Germany. He studied Geology at the Technical University of Clausthal-Zellerfeld, the University of Vienna (where he also studied music at the Vienna Conservatory), and the Technical University of Munich, where he received his Diploma in Geology in 1965 for a project in the Austrian Alps. Together with his wife Marion, and supported by a scholarship of the Government of the Republic of South Africa, he then moved to Cape Town where he undertook Ph.D. studies as a member of the Precambrian Research Unit (PRU) of the University of Cape Town. In 1968 he was awarded a Ph.D. degree for his study "The gneiss-sediment relationships north-west of Vanrhynsdorp, Cape Province" under the supervision of John de Villiers.

OBITUARY

After a short spell as exploration geologist in Windhoek, Namibia, he returned to the PRU in early 1970 as a Senior Research Fellow and later held the position of Acting Director in 1974-1976. His research involved field studies on Neoproterozoic rocks in the Richtersveld, and the Namib Desert of Namibia. He later expanded these studies to the Damara Orogen of Namibia and Damara equivalents in southern Angola, and even undertook sedimentological studies on Neoproterozoic glacial deposits. His geological experience made him an expert on the regional geology of Africa and this expertise was also the beginning of a lifelong affection for this part of the world. It was also during his time in Cape Town that his two children, Thomas and Petra, were born.

While undertaking field work in Namaqualand, and trying to distinguish different gneiss suites on structural grounds, he realized the central role of geochronology in understanding Precambrian tectonics and crustal evolution. He thus made himself familiar with radiometric dating methods early on, initially at the Bernard-Price Institute of Geophysical Research at Witwatersrand University, Johannesburg. He later continued these isotope studies at Leeds University, UK, and the Universities of Montpellier and Strasbourg, France.

In 1977 Alfred returned to Germany to become a Full Professor of Geology at the Johannes Gutenberg University of Mainz where he initiated a close scientific relationship with the Abteilung Geochemie, established by the team of Albrecht Hofmann at the local Max-Planck-Institute (MPI) for Chemistry. Having access to mass-spectrometry and the geochronological expertise of Wolfgang Todt a short walk away from his office allowed him to investigate Precambrian rocks from many countries of Africa and also Saudi Arabia, India, and Sri Lanka. Generous and steady financial support from the German Science Foundation and other agencies enabled him to collaborate with scientists and students from these countries and pay for reciprocal visits and follow-up studies at Mainz University. For many key localities of these regions he provided the first reliable radiometric ages that led the groundwork for subsequent studies and enabled the community to develop geodynamic models.



Alfred and Kenneth Ndlovu from the Geological Survey of Swaziland in front of the oldest (dated by Alfred in the mid-1980's) rocks of Africa. The rocks, which are part of the Ancient Gneiss Complex of Swaziland, were visited during a field workshop in 2010.

In 1981/82 Alfred spent a sabbatical leave at Stanford University, USA, and became involved in palaeomagnetic studies in the Damara Belt of Namibia and the Archaean Barberton granitoid-greenstone terrain, South Africa. A further sabbatical leave in 1985/86 led him to the Research School of Earth Sciences, Australian National University, where he learned to operate SHRIMP I for the determination of U-Pb zircon ages. From that time on zircon geochronology became a central aspect of his research and he a regular visitor to the SHRIMP Centre in Perth, Australia. He also employed the zircon evaporation mass spectrometry technique quite successfully in Mainz, which provided him with many radiometric dates, rapidly and at no cost.

Thermal ionisation mass spectrometer at the MPI for Chemistry in Mainz. Alfred evaporated many zircons on an instrument like this. The lab no longer exists. In fact, the former institute is a barricaded eyesore in the middle of the university campus.

In 1982, as one of the first western geologists, he initiated scientific collaboration with scientists from China, undertaking field-based research on Archaean rocks in the North China Craton and the Qinling Orogenic Belt. He later became interested in the

Drilling for palaeomagnetic studies at the Fish River Canyon, Namibia, in the early 1980's.

Central Asian Orogenic Belt, where he spent many years collaborating with Chinese, Mongolian and Russian scientists.

In 2006 Alfred retired from his teaching position at Mainz University and continued his research as Professor Emeritus. He accepted an invitation for a long-term collaboration with the SHRIMP Centre of the Chinese Academy of Geological Sciences in Beijing and its director Dunyi Liu. At the SHRIMP Centre he spent several months every year, followed by visits to Min Sun's lab at the University of Hong Kong for Lu-Hf in zircon isotope analyses. The association with the SHRIMP Centre allowed him to continue to travel the world to study the origin of Precambrian rocks and to constrain them with ion probe zircon dates. He also organized many international field trips during that time, many of which were to southern Africa.

Alfred always assisted colleagues and students finding ways and means to obtain funding and analytical data for their research. And he steadily encouraged students and young researchers to publish their results. Sitting on data that were generated with the aid of public funds was foreign to him, even in the case when the

Reception with Minister of Science and Technology Yi Fan (right) and Minister of Geology Xun Zhu (centre) in the Great Hall of the People in 1983 at the occasion of an international conference on Precambrian crustal evolution in the Temple of the Sleeping Buddah, Beijing.

results were of regional significance only. Accordingly he published more than 400 research papers in Earth Science journals and books, was a co-author of one textbook, an editor of five multi-author books, and an editor of several special issues of international journals.

The scientific community appreciated Alfred´s science with many awards. He received the Jubilee Medal of the Geological Society of South Africa, the Ananda Coomaraswamy Memorial Medal presented by the Geological Society of Sri Lanka, the Emanuel Boricky Medal of Charles University in Prague, the Distinguished Service Medal of the Province of Rhineland-Palatinate in Germany, the Steinmann Medal of the Geologische Vereinigung of Germany, and the Friendship Award of the Chinese State Administration of Foreign Experts Affairs in Beijing. He represented as Honorary Professor of Northwest University of Xi'an in China, as Honorary Fellow of the Geological Societies of America and South Africa, and as Honorary Professor of the Chinese Academy of Geological Sciences, Beijing. In 1999 he delivered the Du Toit Memorial Lecture of the Geological Society of South Africa, and in 2017 the Chinese Academy of Geological Sciences in Beijing honoured him for his impressive publication record with an H-Index of 100.

In his long career Alfred gave much of his time to help the advancement of the Earth Science community. He was Secretary of the IUGS Commission on Tectonics, Chairman of Working Group 3 of the International Lithosphere Program, Leader of IGCP Project 280 "The Oldest Rocks on Earth", President of the Geologische Vereinigung of Germany, Vice-President of the European Union of Geosciences, Co-Chairman of the ERAS-Project of the International Lithosphere Program, and Member of the IGCP Scientific Board. And finally, he found time for many years to be a co-editor of Terra Nova and Precambrian Research and a member of the editorial board of five other major international journals. Throughout his career, he was an inspiration for young researchers, and a great motivator to everyone else who shared his passion for old rocks.

Alfred did not spend much time at home. Instead, with seemingly endless energy, he was constantly moving, connecting with people, sampling, and analysing, but also enjoying the company of his fellow travellers or hosts in some far-away country. Alfred enjoyed being out in the field, dismissing any potential and real obstacles as well as health risks, to collect a bunch of samples, typically some gneisses of various shades of grey. A disaster was when samples got stuck at some border or got lost somewhere on the way to the lab. Local political issues were of no importance to him.

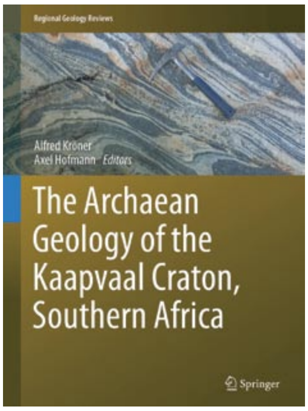
But it wasn't all plain sailing. In early 2000 Alfred suffered a heart attack while undertaking field work in northern Namibia. Without the help of Karl Heinz (Charlie) Hoffmann and everyone else on that trip, it could have meant the end of it there and then. Five years ago he contracted prostate cancer but managed to fight it off until recently. Alfred had dedicated his life to science, but in recent years he developed stronger ties to his children and grandchildren, taking time off to be with them in between his regular trips to China and South Africa. He disliked the cold and loved the African sun; unsurprisingly he spent an unforgettable month over Christmas and New Year's 2018/19 amongst his children and grandchildren in his favourite city of Cape Town.

Back in Germany in early 2019 a very advanced stage of cancer was confirmed and he undertook emergency radiotherapy. He moved from Mainz to Freiburg for further treatment and to be near his daughter, who dedicated herself to his recovery. In early May it appeared as though his situation had stabilized and that he was slowly recovering. During a visit in Freiburg ongoing research was discussed, and there was talk about a trip to Beijing, where his Chinese colleagues were organising a colloquium to celebrate his 80th birthday.

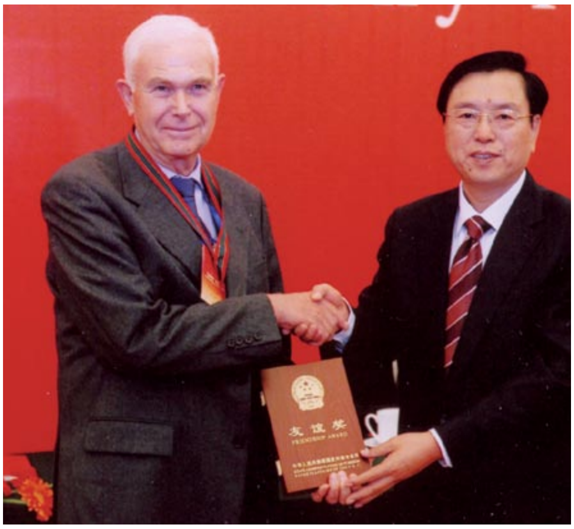
On May 20th Alfred stumbled in his apartment and sustained a head injury from which he was not able to recover. Though his passing away was sudden and unexpected, Alfred will stay in our mind. Special volumes in American Journal of Science and Precambrian Research in his honour have been proposed, and many colleagues still have joint data for publications on aspects of the puzzle that stands for Precambrian geology. In South Africa an "Early Earth Workshop" is scheduled for November 2020, and many of his collaborators and friends have expressed interest in participating.

With Alfred Kröner we will be missing a truly outstanding geoscientist, mentor and friend. His amazing dedication and enthusiasm for Geology has contributed uniquely to our understanding of the origin of continents in general and the African continent in particular.

Compiled from various sources by **Axel Hofmann** and **Ernst Hegner**, with contributions from **Thomas Kröner**.



Cover of Alfred's most recent contribution to Kaapvaal Craton geology published in 2019.



Presentation of the Friendship Award by Vice Premier Zhang Deijang, September 2010.

Alfred having a nice cup of tea on a trip to the charnockites of the Trinvandrum Block, South India, in 2003.

WITWATERSRAND GOLDFIELD DIAMONDS

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Finding an economic ore deposit that contains both gold and diamonds would constitute a bonanza, and interestingly, the Witwatersrand goldfield falls into this category. The caveat however is that while the gold content is certainly economic, the presence of diamonds in some of the gold-bearing reefs does not constitute a payable resource. However, the fact that diamonds have been recovered during gold extraction processes, albeit in small quantities, is scientifically very important as recently discussed by Smart et al. (2016). Working with Witwatersrand goldfield diamonds from the Johannesburg Geological Museum collection, these authors used nitrogen content, and nitrogen and carbon isotopic signatures of the diamonds to interpret the relatively early onset of modern-style plate tectonics as early as 3.6 billion years ago. This is recent and novel research. However, the initial discovery of diamonds in the Witwatersrand placer conglomerates pre-dates this modern work by some 119 years.

Denny (1897) describes the discovery of diamonds in 1893 from the Gold Estate Reef in the Klerksdorp goldfield. This is a typical large pebble conglomeratic reef that outcropped in an area called the Gold and Diamond Estates Mynpacht. Gold and Diamond Estates Mine exploited the reef during the late 19th Century via surface workings. Interestingly, the mine's name suggests that in this particular instance, diamonds were perhaps a sub-economic by-product of the gold operation. Furthermore, in an 1896 GSSA discussion on one of Dr David Drapers papers (Transactions of the Geological Society volume 1, page 30), a certain Mr P.O. Wilson remarked that he was currently working a conglomeratic reef in the Klerksdorp goldfield. He too had discovered green diamonds, some of which he sent to England for positive identification because Dr Hugh Exton thought they might have been green grossular garnet. The 1893 Klerksdorp goldfield diamonds discovery was verified by an affidavit written by Francois Johannes Roos who under oath stated that he had 15 diamonds in his possession, all green, and the largest weighing 8 carats. These diamonds were found in the Mynpacht owned by the Klerksdorp Estates (Denny, 1897). The diamonds were accidently discovered when a mortar box of a 5-stamp battery was being cleaned.

A few years later in 1889, two diamonds were found at the Wolhuter Gold Mine and the Percy Gold mine (Young, 1917). Then in 1913 a diamond was found at the Modderfontein "B" Gold mine. These were all characteristically green. It is interesting to note that Young (1917) states that after hearing of the abovementioned diamond discoveries he advised that the "black sands" produced at various Witwatersrand gold mines should be carefully examined for diamonds. The result was that "*some hundreds of stones have been found at the Modderfontein "B" mines and other mines*" (Young, 1917, page 35). Furthermore Tucker et al (2016) state that the Modderfontein Gold and Diamond Mining Company extracted diamonds from the Nigel Reef in the East Rand Goldfield. This was possible because the gold-bearing conglomerate was still processed prior to the fine milling of the ore for the cyanidation process. Even so, some diamonds were still recovered up until the 1960s, albeit rarely (Raal, 1969).

The Witwatersrand goldfield diamonds are ubiquitously green, with colours ranging from light yellow-green,

through dark green to almost black. In all cases, this colouration is surficial and exists as an outer coloured rind surrounding colourless interiors. Raal (1969) investigated 38 green Witwatersrand goldfield diamonds loaned to him by the Anglo American Corporation of South Africa Ltd and he deduced from his analyses that the green colour is caused by irradiation, presumed to emanate from the uranium present in the ores.

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MINERAL SCENE

Banff and Yoho National Parks

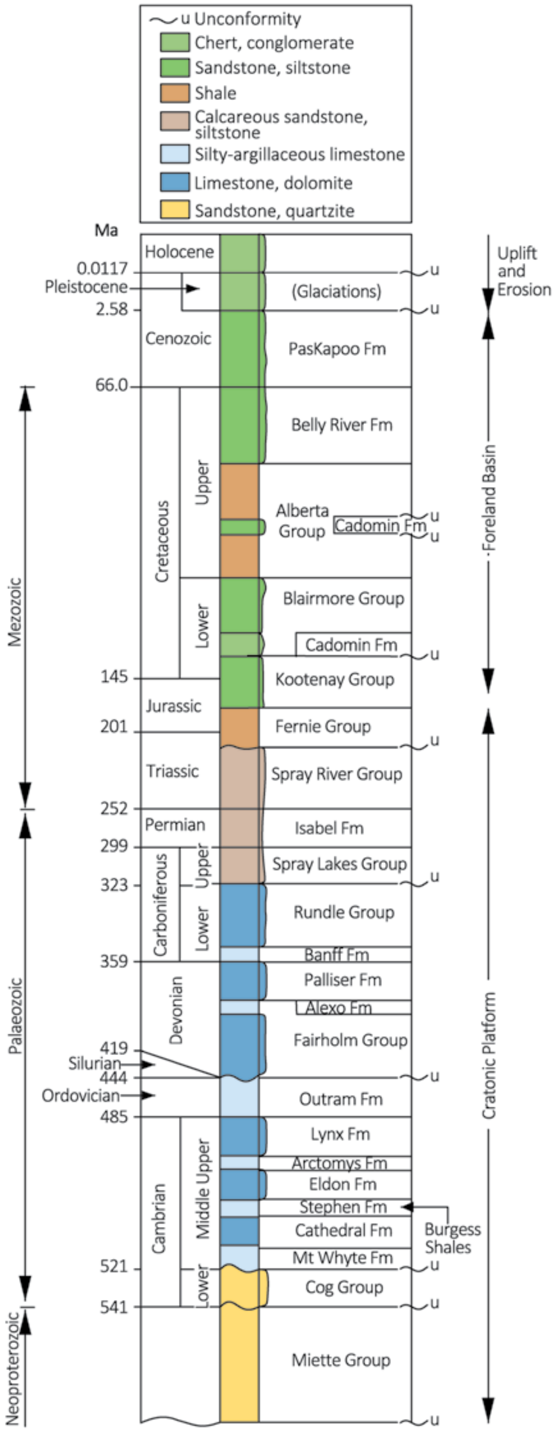
THE GEOTRAVELLER

By Roger N Scoon

Geology of the Canadian Rocky Mountain National Parks (2):

Glacial Lakes and Cambrian Fossils

A simplified stratigraphic column for the Canadian Rocky Mountains (after Leckie, 2017).



The Banff and Yoho National Parks cross the continental divide of the Rocky Mountains, being located in the provinces of Alberta and British Columbia, respectively. The parks are well known for the spectacular mountain scenery. Highlights include the glacial lakes of the Lake Louise region (Banff) and the marine fossils of the Burgess Shales (Yoho). An overview of the regional geology with descriptions of the Jasper National Park was presented in the previous Geotraveller. This included simplified maps, but for ease of reference the stratigraphic column is reproduced here.

Banff is Canada's oldest national park, having been established in 1885. The area of 6,641 km² is dominated by peaks of the snow-clad Rocky Mountains which contain numerous small icefields and slope glaciers. The park is accessed from the south and east via the Trans-Canada Highway. This road follows the upper reaches of the Bow River, a major tributary of the South Saskatchewan River system. The main commercial centre is the regional town of Banff, located in the Bow Valley. The river cuts through resistant Triassic sandstones at Bow Falls. The Bow Valley also reveals vertical pinnacles or pillars, locally known as "hoodoos". They consist of cemented glacial till and fluvial gravels. Leckie (2017) observes that their unusual shapes are related to preferential erosion relatively poorly cemented till. The till is related to an ice advance towards the end of the Main Ice Age (at approximately 29,000-26,000 BP).

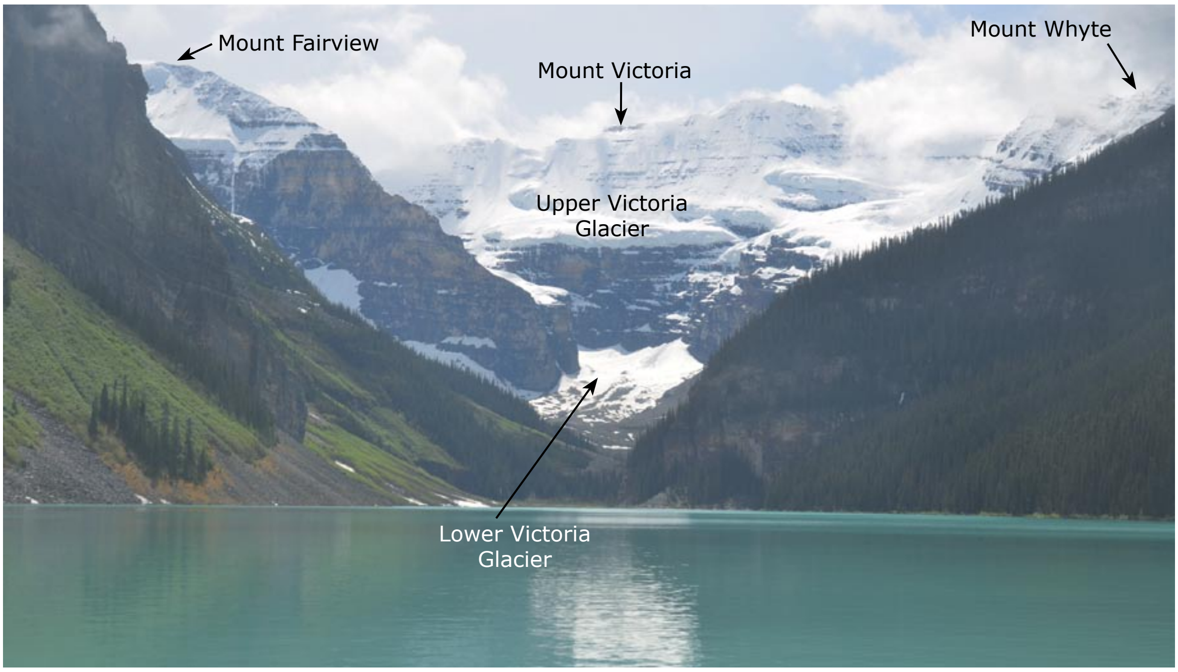
Archaeological evidence shows that the thermal springs at Sulphur Mountain, Banff were used by indigenous peoples for thousands of years prior to coming to the attention of workers of the Canadian Pacific Railway. The mountain is named for the sulphurous hot groundwater that circulates through Carboniferous limestones associated with Sulphur Mountain Thrust. The springs

Geothermal deposits, Cave Spring, Banff (internet: https://www.google.com/gonewiththewynns.com%2Fbanff-alberta-mountains-hot-springs&psig

are entered via a cave system located in a thick deposit of travertine.

The Mount Norquay view site at Banff reveals views of the Bow Valley and the eastern rampant, or Front Ranges, of the Rocky Mountains. The complexity of the thrust sheets associated with these ranges is discussed by Leckie (2017). Some thrust sheets have been transported by as much as 32 km eastward. Individual thrust sheets are stepped one upon the other.

The location of Lake Louise proximal to the Canadian Pacific Railway, in the northern part of the Banff National Park encouraged development of a major tourist centre in Victorian times. The 70 m-deep, turquoise-coloured lake occurs in a steep-side valley located at the foot of Mount Victoria (3,464 m). The castellated peaks of Mount Victoria, together with Mounts Whyte (2,983 m) and Fairview (2,745 m) are typical of the eastern part of the Main Ranges. The ***Lake Louise*** *valley reveals bench-and-cliff topography associated with relatively flat-lying sedimentary strata (Leckie, 2017). The most prominent cliff faces are related to the 1 km-thick Gog Group quartzite (Lower Cambrian). This unconformably overlies the Miette Group (Neoproterozoic) and is in turn overlain by quartzite and limestone of the Middle*



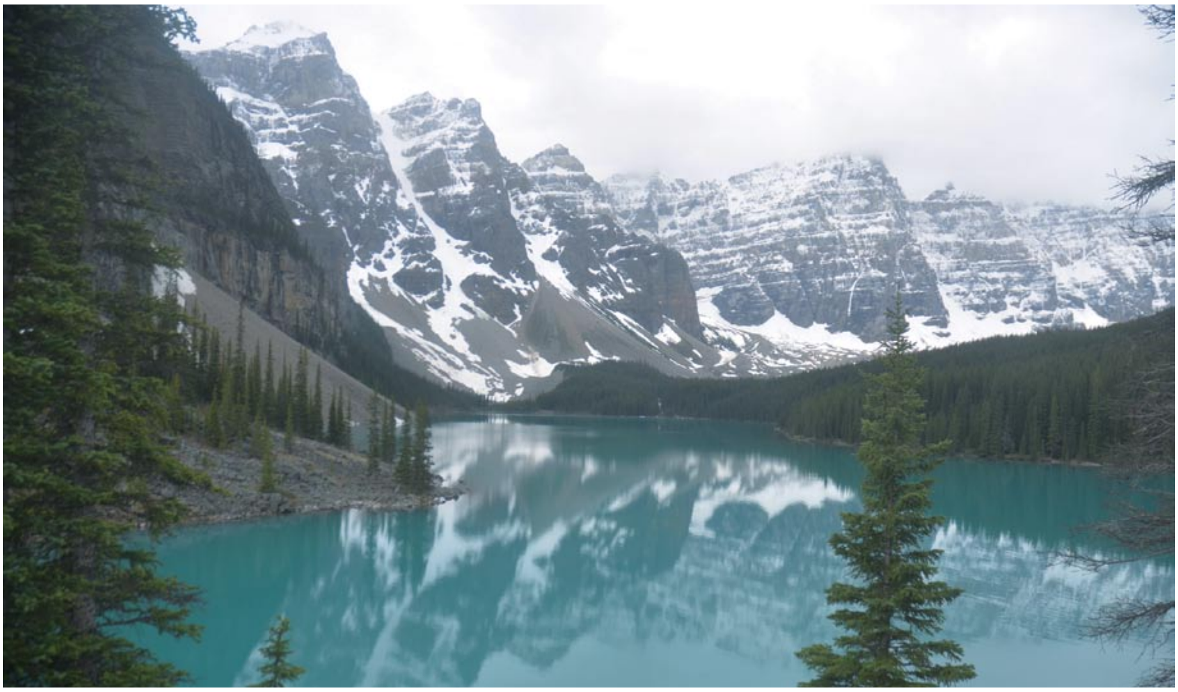
View of Lake Louise looking southwest towards the high peaks of Mount Victoria. The two glaciers on the lower flanks are separated by a barren rock face comprised of Cog Quartzite.

Quartzites of the Miette Group (Neoproterozoic) reveal a moderate dip on the south-eastern side of Lake Louise. Fan-shaped debris deposits illustrate the instability of the slopes.

Cambrian Cathedral and Eldon Formations. Steeply-dipping and folded slate of the Miette Formation can be most readily observed close to the junction between the Icefields Parkway and the Trans Canada Highway.

Lake Louise is primarily fed by meltwater from the Lower and Upper Victoria Glaciers. A large terminal moraine dammed the valley at approximately 10,000 BP. The moraine can be viewed near the imposing Lake Louise Hotel. The glaciers at the head of the Lake Louise Valley are retreating despite the ice moving at approximately 30 m/year; this is insufficient to compensate for melting (Leckie, 2017). Parts of the glaciers are covered by debris. The hiking trail around the northern side of the lake

The characteristic turquoise colour of Lake Louise is pronounced in a view looking towards the rugged peaks of Mount Fairview. The gently-dipping strata are quartzites of the Miette Group (base) and Cog Group (upper).



The turquoise-coloured Moraine Lake, one of the most scenic of the glacial lakes in the Canadian Rockies is located in the Valley of the Ten Peaks.

is suitable for most visitors, with more strenuous trails accessing hanging lakes. The hike to Lake Agnes includes the opportunity to experience the Victorian tradition of visiting a mountain teashop.

*Located to the south of Lake Louise is **Moraine Lake**, reached by a winding road that exploits a hanging valley perched above Lake Louise. Moraine Lake occurs at the base of the Valley of Ten Peaks, or Wenkchemna Peaks.*

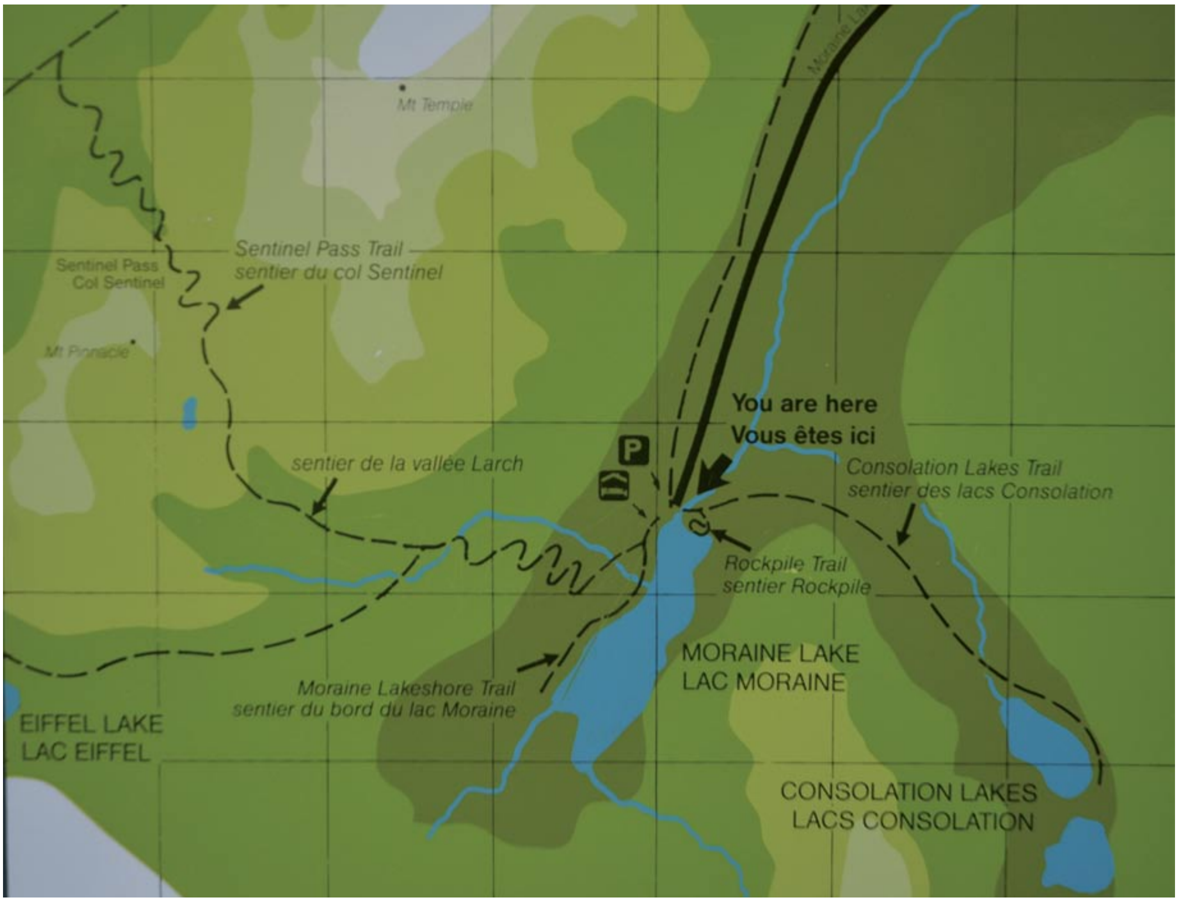
The near-vertical cliffs are located above prominent, cone-shaped scree (talus) deposits. The Ten Peaks are comprised of Cambrian strata, primarily the resistant Cog Group quartzite, similar to the Lake Louise Valley, but a significant difference is they are steeply-dipping. Moraine Lake is fed by the Wenkchemna Glacier (area of 4 km^2) which includes a terminal moraine associated with an advance during the Little Ice Age (approximately1300-1850 AD).

Moraine Lake is fringed by prominent fan-shaped scree deposits.

Moraine Lake is dammed by a terminal moraine and landside deposit (comprised of large blocks of Cog Group quartzite) accessed by a short trail.

Moraine Lake is dammed at the north-eastern end by a combination of a terminal moraine (deposited towards the end of the Main Ice Age at approximately 12,000 BP) and landside deposit. Most blocks in the landslide deposit are Cog Group quartzite. An information board located here records that in 1884 Walter Wilcox, one of the early visitors described the view of Moraine Lake as "no scene has ever given me an equal impression of

An information board showing the trails around Moraine Lake and Consolation Lakes.



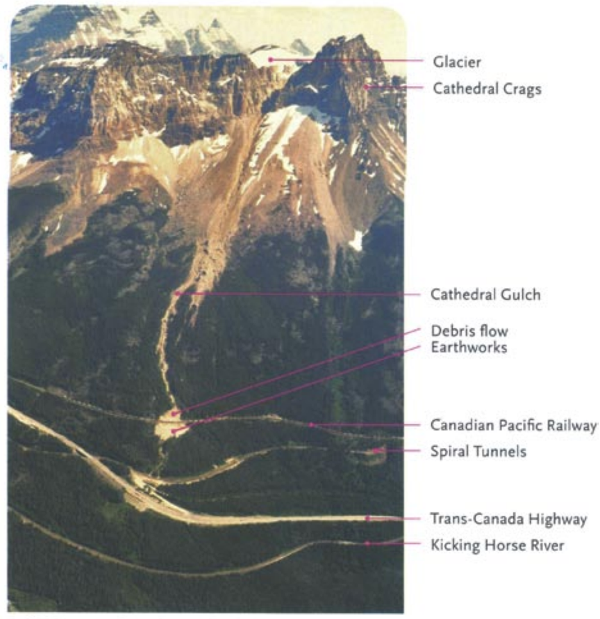
inspiring solitude and rugged grandeur". In comparison, Consolation Lakes to the southeast of Moraine Lake occur in a remote and rather gloomy valley.

The turquoise colour of glacial lakes in the Canadian Rockies is widely prized by artists and photographers. The distinctive colour is restricted to lakes fed by waters which contain only suspended particles of clay and silt. The fine-grained nature of the sediment absorbs the red through orange colours of the spectrum with only the shortwave length blue and green components being reflected. The colour varies between shades of blue and green as the coarser clay particles preferentially reflect only green light, and the very fine-grained silts reflect only blue light. The fineness of the particles is a function of the clay and silt, or rock flour, sourced by glaciers that grind the ancient bedrock. Many lakes are fed by meltwater containing only rock flour. The coarser sands and gravels, which impart a white or pale grey discolouration to meltwater in fast-flowing rivers, are typically deposited upstream from lakes.

Several turquoise lakes are accessed by the Icefields Parkway in the northern part of the Banff National Park. This section of the road passes through a spectacular U-shaped valley rimmed by ice-capped mountains of the Front Ranges. ***Peyto Lake*** *is located approximately 40 km north of Lake Louise and is an example of a turquoise lake where braided streams of meltwater, derived from the small Peyto Glacier, have deposited coarse detritus in a broad delta between the glacier and lake. The very fine particles of rock flour then enter the lake as turbid plumes. The high-altitude Emerald Lake, situated near Bow Summit (2,088 m), is another such example. The turquoise colour is enhanced during late spring and summer by an increase in the volume of rock flour entering the lakes from braided streams. In winter, the volume of sediment is lower and is dominated by fine-grained silts which impart a deep blue colour.*

The Yoho National Park is accessed from the east via the Kicking Horse Pass, the route opened up by the Canadian Pacific Railway and now also exploited by the Trans-Canada Highway. The steepness of the pass resulted in construction of two spiral tunnels for the railway, involving blasting of underground loops within Cog Group quartzite. A pullout provides views of the spiral tunnels and a large debris fan associated with the unstable face of Cathedral Mountain that not only crosses the railway lines but also affects the road. Several mine adits are visible in the face of Cathedral Mountain. Deposits of lead, zinc, and silver were exploited from the Cathedral Formation (Middle Cambrian) between 1888 and 1952. They are classic examples of Mississippi

The Icefields Parkway occurs in a giant U-shaped valley in the northern part of the Banff National Park. The valley is fringed by the Front Ranges which are dominated by well-bedded Lower Palaeozoic metasediments which have been thrust eastward over tens of kilometres.



The debris fan associated with the unstable face of Cathedral Mountain, on the northern side of Kicking Horse Pass, Yoho National Park, affects the Canadian Pacific Railway and Trans-Canada Highway. Original photograph and annotation of Leckie (2017).

Valley-type lead-zinc deposits which have replaced their host carbonates (Paradis et al., 2007).

The Yoho National Park is considerably smaller than Banff and Jasper, with an area of 1,313 km^2. Yoho is an expression of amazement in the language of the indigenous Cree people, a reaction to the landscape of jagged mountain peaks with numerous small icefields and glaciers. Several discrete ranges occur, including the Ottertail Range in which the highest peak is Mount Goodsir (3,567 m). The location on the western slopes of the Rockies results in considerably higher precipitation than in Banff and Jasper, and the area is accordingly more thickly forested.

Natural Bridge is the site of a knickpoint on the Kicking Horse River. The "bridge" is associated with a resistant bed of Middle Cambrian calcareous slate (Chancellor Formation) that is being eroded into a narrow gorge. The slates reveal prominent cleavage. Upstream, the river is several hundreds of metres wide but at the Bridge is concentrated into a narrow slot only a few metres wide.

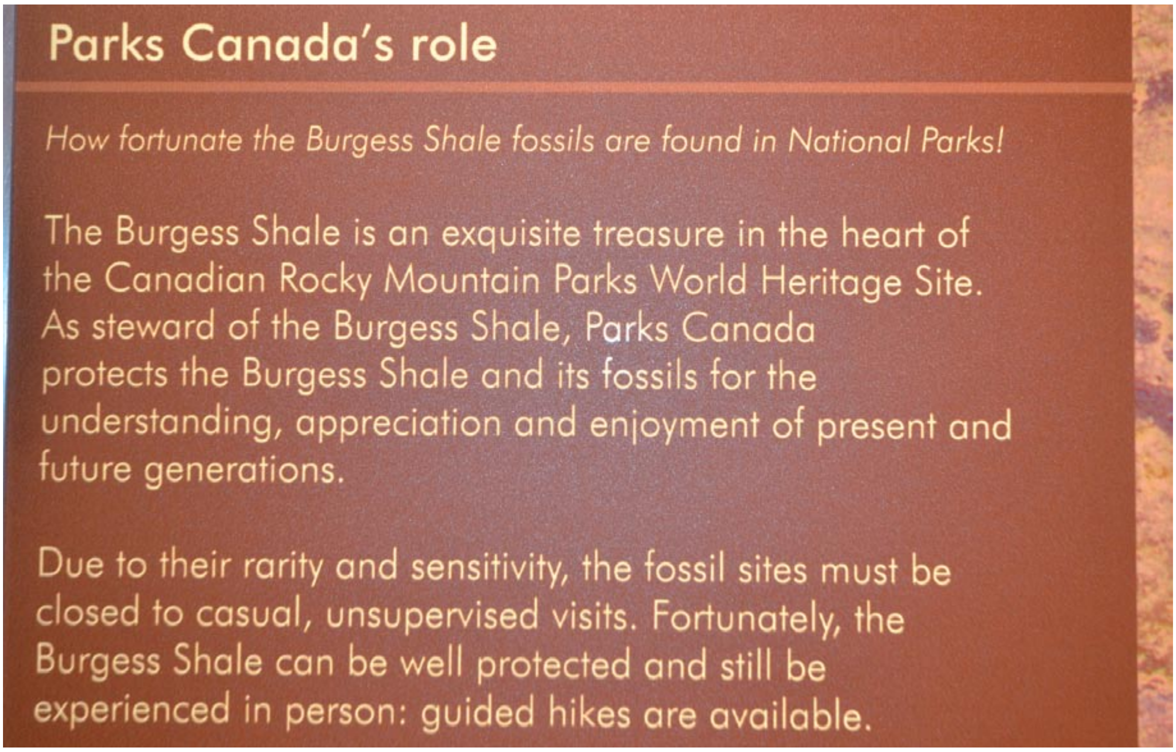
***Emerald Lake** is another example of a high-altitude, glacial lake with the characteristic turquoise colour. The view of Emerald Lake with the mountainous ridge on the western side has featured in many paintings. The lake is dammed by and is developed within a moraine associated with the Main Ice Age. Emerald Lake occurs at the base of Wapta Mountain (2,778 m) which is comprised of massive carbonates of the Eldon Formation (Middle Cambrian). The face of the mountain, which is visible from the trail around the lake, reveals two large dolomite pipes, hydrothermal features similar to those that host the ore deposits of Cathedral Mountain. The pipes are lighter in appearance in comparison to the host dolomite (Leckie, 2017).*

Natural Bridge, Yoho National Park is associated with a knickpoint on the Kicking Horse River.

Prominent cleavage of calcareous slate of the Chancellor Formation at Natural Bridge.

The view southeast from Emerald Lake reveals Mount Burgess (2,599 m) after which the famous Burgess Shales are named. The shales are now categorised as part of the Stephen Formation which outcrops extensively on Mount Stephen (3,199 m) to the south of Kicking Horse Pass. The Burgess Shales are famous for containing the most complete record of Middle Cambrian fossils. The age of 505-510 Ma makes this the oldest occurrence of fossils with imprints of the soft parts of marine fauna. The description Cambrian Explosion of Life emphasizes the rapid diversification of fossils, which occurred over approximately 40 Ma after onset of the Cambrian Period at 541 Ma. The Burgess Shales were described in great detail by palaeontologist Charles Walcott who spent most field seasons at Fossil Ridge on the lower slopes of Mount Wapta between 1909 and 1924 excavating in the area. In total he amassed over 65,000 specimens. The fossils were, however, first discovered by workers on

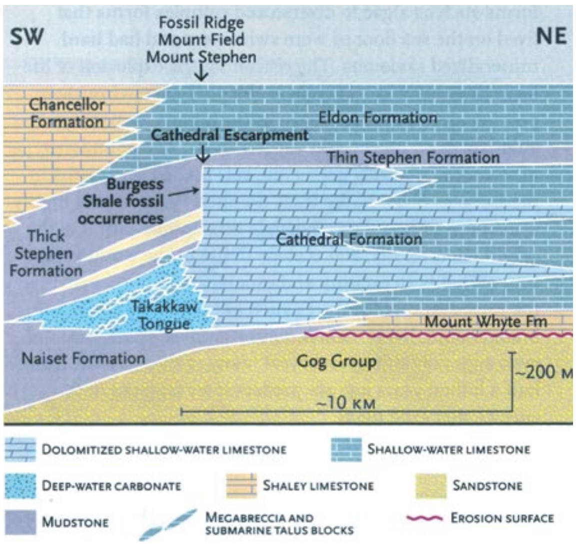
View of Emerald Lake, Yoho National Park.



Fossil Ridge on the lower slopes of Mount Wapta is a protected region within the Yoho National Park.

the Canadian Pacific Railway (Royal Ontario Musuem, 2011), probably in 1886. The site, despite the location high above Kicking Horse Pass was investigated for timber required for the railway sleepers (ties). The Walcott Quarry at Fossil Ridge is a historical site. New quarries have been established higher on the ridge since the original work. The area can only be visited as part of an organized group with strict guidelines on collecting of fossils. The hike from Emerald Lake is 21 km (round trip) and involves some steep slopes.

The Burgess Shale consists of calcareous mudstones deposited in a shallow tropical sea. Of fundamental importance to the occurrence and evolution of the marine life, as well as preservation of the fossils, was the location of the shallow sea at the base of a 160 m-high palaeo-escarpment. The escarpment formed the edge of a major carbonate platform preserved as the Cathedral Formation, on the western margins of the coast of the Laurentian Craton. The escarpment can be traced for more than 100 km (Leckie, 2017). The carbonates of the Cathedral Formation are resistant to compression, resulting in such extreme tectonic fracturing fossils are almost impossible to find. Conversely, the "thick" Stephen Formation at the base of the palaeo-escarpment contains such pristine fossils as tectonism associated with the Laramide orogeny was absorbed by the carbonate platform. The Stephen Formation was originally thought to have accumulated in anoxic conditions, but recent evidence suggests oxygen was present in the sediment.



Stratigraphic relationships of the Burgess Shales at Fossil Ridge, Yoho National Park. The fossils occur in the "thick" Stephen Formation at the base of the platform carbonates of the Cathedral Formation and "thin" Stephen Formation. Original with stratigraphic correlation of Leckie (2017).

Some fossils from the Burgess Shales have proven to be not only unique species but also entirely different from others in the geological record e.g., Opabinia *which is a fish with five eyes and a snout shaped like a vacuum cleaner. The fossils of the Burgess Shales have been widely investigated which has created some controversy, as discussed, by for example, Collins (2009). The book "Wonderful Life" introduced the fossils of the Burgess Shales to a worldwide audience (Gould, 1989). The extraordinary diversity of the fossils was interpreted by Gould to indicate that life*

Large slabs of the Burgess Shales in the interpretative centre at Field contain typical Middle Cambrian marine fossils, including a large trilobite, Ogygopsis.

forms in the Middle Cambrian were more disparate in body form than those that survive today. Many of the unique lineages were envisaged as evolutionary experiments that became extinct. These interpretations were based on detailed work by palaeontologists, including Morris (1986) who compiled a detailed reinterpretation of Walcott's original collection. However, Morris disagreed with Gould's views and preferred an explanation whereby the fauna could be classified into modern day phyla. It is now widely accepted that the original explanations of Walcott were broadly correct in that many of the fossils are predecessors of modern life. The interpretative centre at Field, the principal entrance to the national park includes detailed explanations and large cut slabs of the Burgess Shales.

In recent years, the Burgess Shales have been of interest to palaeo-climatologists, many of whom predict future climatic cycles. The Cambrian Explosion of Life is linked to rapid climatic changes which some have predicted will reoccur some 500 Ma into the future i.e. when there is a possibility of extreme temperature (due to declining CO^2 and O^2 levels associated with an expanding sun) similar to those thought to have occurred in the Archaean.

All photographs by the author except where referenced

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THE GEOTRAVELLER

The Sustainability Issue
CONSERVATION / DEMAND AND SURETY
16TH GROUND CONFERENCE AND EXHIBITION, PORT ELIZABETH | 20 - 23 OCTOBER 2019

20-23 OCT 2019

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Port Elizabeth, Eastern Cape, South Africa

The Ground Water Division of South Africa and its Eastern Cape Branch invite **businesses, universities, municipalities, water authorities and the private groundwater users** to join us in discussing and addressing these critical issues. Come and share your knowledge, your products, and your experience; or come and gain vital exposure and knowledge that you can take back to your clients or your business partners to be more water prepared!

Groundwater has proven to be a reliable **source** for decades, within the agricultural sector as well as the municipal sector, but the recent droughts in South Africa have prompted an explosion of private drilling in residential erven. Private groundwater usage has therefore increased beyond the point where it can be managed by the water authorities or even the private users themselves. Water quality, availability and sustainability are therefore key issues to consider when trying to protect this vulnerable and limited resource.

Conservation has become a key word where water scarcity is experienced. Cities/ towns throughout South Africa had to impose water restrictions, but also made progress in making people aware of the need to use less water. Educational programs have been put in place to educate the water user to adjust usage of water according to the availability thereof. Gone are the days where increasing water demands are being met with increased source development, as there are simply no more sources to develop. We simply need to use less water and use it more efficiently.

Surety of water supply is suddenly not a given. Large-scale developments for housing, hospitals, clinics, etc. must now first consider the long-term availability of water and surety of supply before they can implement their planned developments. This places tremendous pressure on water service providers and water authorities as groundwater is a complex, hidden source and requires intense scientific research, management and monitoring to fully understand.

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28 March	SAMOG Compliance	NH The Lord Charles Hotel, Cape Town
12 April	Geophysics Workshop	Mandela Mining Precinct, JHB
25 – 26 April	Coal Day Evaluation of Coal Data	Glenhove Conference Centre
09 May	Core Logging	Mandela Mining Precinct, JHB
16 - 17 May	SAMREC Compliance and Reporting	Glenhove Conference Centre, JHB
27–29 May	Economic Evaluation of Mineral Deposits	Glenhove Conference Centre, JHB
13 June	Critical Metals	Glenhove Conference Centre, JHB
18 July	The Internet of Things and Data AGM	Glenhove Conference Centre, JHB
14 – 16 August	Geoskills	Glenhove Conference Centre, JHB
22 – 23 August	Structural Geology for the Mine Geologist and Structural Modeling	Glenhove Conference Centre, JHB
18 - 20 September	Drilling Methods	Avianto Muldersdrift / Rustenburg
10 – 11 October	Iron and Manganese Day	Northern Cape
20 – 23 October	16^{th} Groundwater Division Conference and Exhibition	Port Elizabeth
31 October – 01 November	Geochemistry in Exploration	Glenhove Conference Centre, JHB
13 November	Fellows Dinner	Johannesburg Country Club, Woodmead
14 -15 November	Technology Day African Exploration Showcase	Glenhove Conference Centre, JHB

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