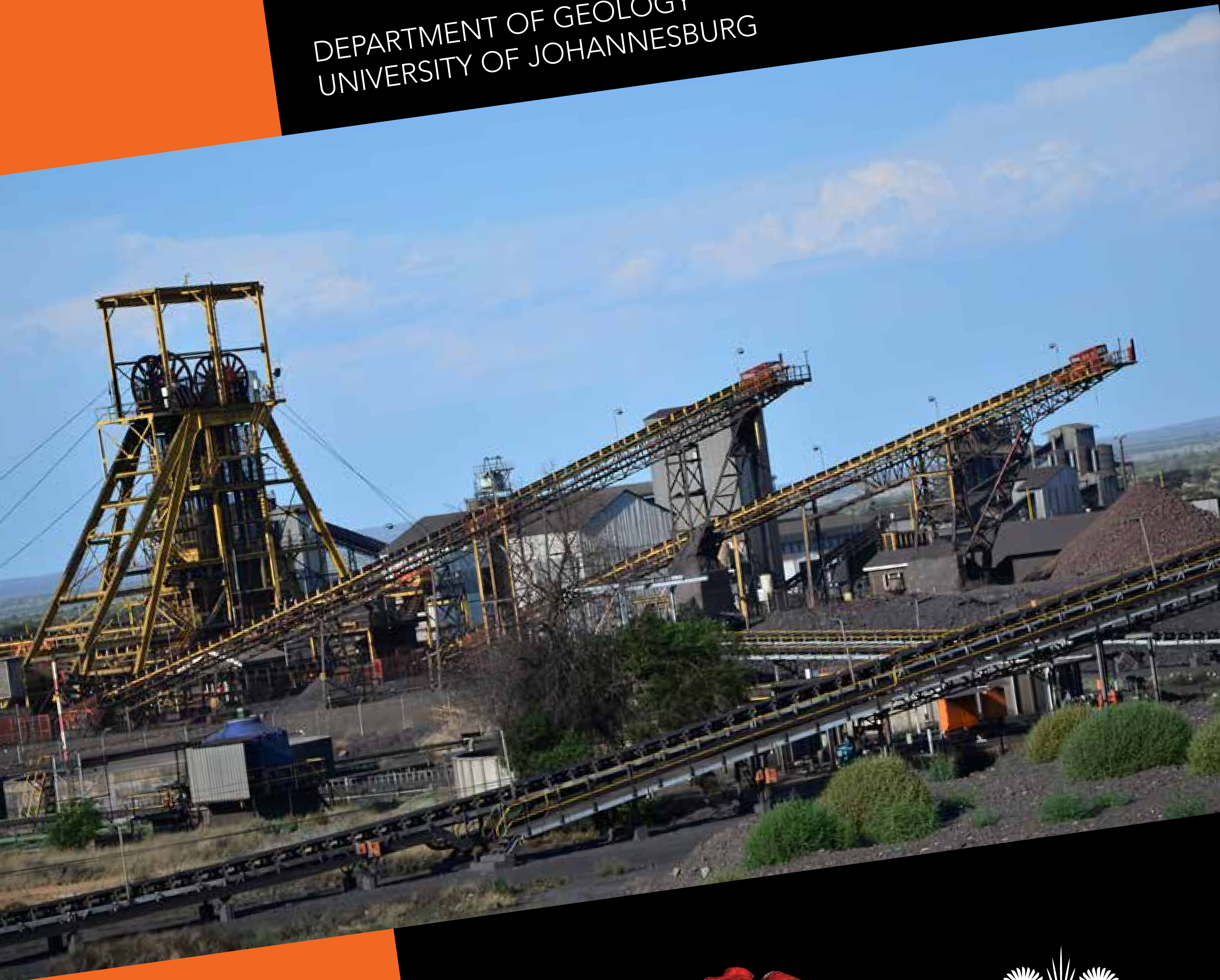
PPM
Annual Report
2011

The Annual Report for the Paleoproterozoic Mineralization Research Group

DEPARTMENT OF GEOLOGY
UNIVERSITY OF JOHANNESBURG



PPM

UNIVERSITY OF JOHANNESBURG

The Annual Report of the Paleoproterozoic Mineralization Research (PPM) Group, compiled and edited by **HM Rajesh** and **Nic Beukes**. Layout and design by **HM Rajesh** and the **UJ Graphic Studio**.

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Salt River Resources Ltd
Two Rivers Platinum Mine
Vale

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Cover photo: The N'Chwaning II manganese mine and plant at Black Rock in the Northern Cape Province (photograph by Bruce Cairncross)
Header photo: Oribi Gorge granitiod exposure
Footer photo: Near Hverfjall crater, Mývatn, North Iceland

INTRODUCTION

The PPM Research Group, formed in 1997 as an informal research group in the Department of Geology, has for the past four years been officially recognized by Management of the University of Johannesburg as one of the Research Centres of Excellence at the University. The PPM Centre receives an annual research grant from the University Research Committee to strengthen the group with respect to funding salaries of support staff and providing additional bursary support to postgraduates and postdoctoral associates. As part of the additional support from UJ, PPM appointed new postdoctoral fellows during 2011. The funds also make provision for the appointment of Professor Jan Kramers and to supplement Professor Nic Beukes' contract appointment following his retirement in 2010. During 2011, research focused in five main areas, namely geometallurgy-kimberlite research, metalliferous mineral deposits, paleomagnetism-provenance studies, early Precambrian environments, coal geology and geoheritage.

PPM Research Group (2011)
Staff and Students

Leaders of the research group

Prof. Nic Beukes, Prof. Fanus Viljoen

Staff Members

Mrs. Lauren Blignaut, Prof. Bruce Cairncross, Dr. Michiel de Kock, Prof. Axel Hoffmann,
Mr. Mike Knoper, Prof. Jan Kramers, Prof. Hassina Mouri,
Prof. HM Rajesh, Mr. Freeman Senzani, Mr. Bertus Smith, Dr. Herman van Niekerk,

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Ms. S Mkhatshwa
Ms. L Mngoma
Mr. T Mxinwa
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Coal Geology

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Mr. P Meyer
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Dr. K Shindo
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Technical Support Staff

Mr. M Chakuparira
Mrs. D Khoza
Mr. L Mangwane
Mr. T Ramaliba
Mr. BT Tshivhiahuvhi

PPM group members on the roof top facing the department. Absentees include Nic Beukes, Hassina Mouri and Bruce Cairncross (photographer)

RESEARCH PROGRESS AND HIGHLIGHTS

Geometallurgical research

As part of the Geometallurgy chair held by Fanus Viljoen, post-doctoral fellow Cora Wohlgemuth-Ueberwasser repaired and optimized the laser ablation inductively coupled plasma mass spectrometer at Spectrau for trace element data for sulfide minerals. Bertus Smith received a DAAD short-term research fellowship and visited TU Bergakademie, Freiberg Germany during March-June 2011. Freeman Senzani attended the 1st International Conference on clays and clay minerals in Africa at the Central University of Technology in Bloemfontein, and published a paper in the Conference Proceedings. Gargi Mishra, Fanus Viljoen, Sindi Mkhatshwa, Derek Rose, Craig McClung and Bryony Richards presented papers at the 23rd Colloquium of African Geology, held at UJ in January 2011. Fanus Viljoen and Craig McClung presented papers at the 10th International Congress for Applied Mineralogy in Trondheim, Norway in August 2011. Cora Wohlgemuth-Ueberwasser presented a paper at the 2011 Goldschmidt Conference in Prague, Czech Republic in August 2011.

Metalliferous mineral deposits

Professor Nic Beukes was appointed on a three-year contract following his retirement in 2010 and he continues to serve as the leader of the PPM Centre assisted by Professor Fanus Viljoen and staff. He continues to receive international recognition and visited India after receiving the Senior Raman Fellowship from FICCI in India. As part of the Fellowship he spent March 2011 in Dharwad India to do geological field work and presented seminars to students and geologists in Dharwad and Bangalore. He also travelled to the Falkland Islands with PhD student Clarisa Vorster. He was awarded a Visiting Professorship by the State University of Sao Paulo (UNESP) Rio Claro Campus which he visited for a period of two weeks. In the time, he presented a short course on mineral deposits linked to the iron and steel industry as well as gold to students and professional geologists. In early December, he also presented a paper at a field workshop organized by Michael Bau from Jacobs University and Bernhard Buhn from the University of Brasilia in cooperation with Vale at the Fe and Mn ore mines of Urucum in Brazil.

Example of Bokkeveld-type fossils (left) and sandstone equivalent to the Table Mountain sandstone (right) in the Falkland Islands

Axel Hofmann established a new field of research entitled Early Earth Life and Mineral Systems within the PPM. The aim of this project is to understand how the early Earth environment functioned, the conditions in which life emerged and evolved, and the near-surface processes that led to metal redistribution and ore formation. This project involves Nic Beukes and Jan Kramers from PPM as co-investigators. In 2011, field work was undertaken in several countries (India, Gabon, Swaziland, Zimbabwe) to investigate early Earth processes and mineralisation. Research drilling related to the ICDP Barberton drilling project was undertaken in 2011 in collaboration with various national and international partners (http://www.peeringintobarberton.com).

Geoheritage

Bruce Cairncross completed two books, one on the Kalahari manganese field and its minerals (co-authored with Nic Beukes) the other a field guide to rocks and minerals to be published by Random House Struik and aimed primarily at school children. Geoheritage research saw the publication of an article in the international "Resources" journal dealing with the South African National Heritage Resource Act of 1999.

Analytical instrument related news

A WITec Alpha 300 (laser: 532 nm) Confocal Raman Microscope (seen in the photo) was installed in the new Raman spectroscopy lab and this will greatly assist research in the PPM Centre. The alpha 300 represents a new generation of Raman imaging systems, allowing nondestructive imaging of chemical properties without specialized sample preparation, and differences in chemical composition, which are invisible in the optical image, will be apparent in the Raman image and can be analyzed with a resolution down to 200 nm.

Professor Kinta Burger (Dean of Science), Mr. Phil Crous (Technical Director ASSORE), Professor Angina Parekh (Deputy Vice Chancellor) and Professor Bruce Cairncross (HOD Geology) in the ASSORE Raman laboratory in the Department of Geology at UJ

The noble gas mass spectrometer and extraction line at Spectrau/Geology Department was brought on-stream for 40Ar/39Ar and U-Th-He dating as well as other noble gas applications. This is the only operating noble gas laboratory on the African continent. The first batch of 40Ar/39Ar dates was prepared and irradiated in the SAFARI1 reactor at Pelindaba late in 2011 (this was successful). The lab will find application in many PPM-related and other projects. Analyses of noble gas abundances and isotope compositions on a mysterious carbonaceous, diamond-bearing, possibly meteorite-related object, studied by a consortium coordinated by Marco Andreoli of NECSA were completed in November 2011. The results unequivocally show the object to be of extraterrestrial origin and our current assessment is that it represents matter from a comet nucleus.

Michiel de Kock heads up UJ's paleomagnetic laboratory (a unique African facility) and this was well used in 2011 by the students of the PPM as well as students or staff from other Institutes (such as the Council for Geoscience, and the University of the Free State). In addition, commercial work was completed for De Beers as well as Sekaka Diamonds, Botswana. Results were presented by students at the CAG meeting held at UJ, and the annual AGU meeting held in San Fransisco, USA.

Twenty-third Colloquium of African Geology (CAG23)

The twenty-third Colloquium of African Geology (CAG23) was held at the Auckland Park Campus of the University of Johannesburg, 8-14 January 2011. It was organized by the University of Johannesburg, as the main host, in collaboration with the University of Witwatersrand, the Nuclear Energy Corporation of South Africa, the Geological Society of South Africa and the Mineralogical Association of South Africa under the auspices of the Geological society of Africa. The theme of CAG23 was "Together in Africa for a Leading Role in Geoscience" with the aim to raise awareness of research and education in the field of earth sciences in Africa.

Apart from being a co-sponsor of the event, members and students of PPM, played key roles in the organization of the event with Hassina Mouri acting as the Chairperson of the Organizing Committee. Sponsorship from various national and international organizations, including PPM, enabled CAG23 to provide important financial support to about 75 students and young scientists from Africa and 131 academics to attend the colloquium.

CAG23 attracted just over 500 delegates from 59 countries of all continents. The official opening ceremony took place at the Soweto Campus of the University of Johannesburg. The colloquium comprised of 16 scientific symposia divided into five parallel sessions per day, with more than 300 oral presentations, 26 keynote/invited speakers, 100 posters and six plenary lectures. In addition, seven workshops, two short courses and eight field excursions were held with members of PPM involved in all of them.

CAG23 participants at UJ

Okiep Copper District, Namaqualand: Europeans earliest mining efforts in South Africa

Bruce Cairncross

The Okiep copper district covers an area of approximately 3 000 km2 and is situated in the Northern Cape Province and includes the towns of Springbok, Nababeep, Okiep, Concordia and Carolusberg. The geographic region is referred to as Namaqualand. The copper mines in the Okiep district of Namaqualand are steeped in South African mining and geological history. The Dutch colonialists discovered the deposits in 1685, although the indigenous Africans may have previously worked copper there for several hundred years. The first mine to be opened by Europeans in South Africa is located in the Okiep district and the first South African mining company was formed there in 1852 to mine copper from the deposits. Other notable 'firsts' for the region are that the first South African geological report and first geological map produced in this country describe and depict the Namaqualand copper fields.

Several famous 18th and 19th century explorers visited the copper deposits before the first mining activities began in the mid-19th Century. Amongst these were famous geologists such as W.G. Atherstone, Andrew Wyley and E.J. Dunn, and also Andrew Geddes Bain and Charles Bell. Bain produced the first geological report published in South Africa. Bell was the Surveyor General in the Cape Colony at the time and in 1855 visited the Okiep mines and the Cornish miners who were already working the deposits. (Bell is well known amongst philatelists as he designed the famous "Cape Triangular" stamps).

The Nababeep copper mine, now closed, photographed in August 2011

Today, the Okiep copper district is virtually devoid of mining activity. The fluctuating copper prices, coupled with a remote and hostile setting, have collectively caused varying degrees of success and failure in the 150-year ("modern") history of the mines. Derelict and abandoned mining apparatus, some imported from Cornwall, can still be seen scattered around at a few of the old mines. Nevertheless, there are some national moments declared in the region including the discovery site of the copper ore outcrop by Simon van der Stel in 1685, and some of the preserved mining equipment from the late 19th century. This Namaqualand region is probably more famous for its early spring flowers than for its cultural and economic history. Although there are proclaimed sites of historical and mining interest in the region, perhaps more could be done to capitalise on this rich and diverse mining landscape.

"Copper! It is a malleable, enduring metal that has served man for untold centuries. Certainly it has served Namaqualand well. More than anything else it has made Namaqualand what it is, and to mention the one without the other is to censor history".

(Steenkamp, 1975)

The town of Springbok in Namaqualand, photographed from the old Blue Mine that overlooks the mine. This was the first mine to be opened in South Africa by Europeans and derives its name from the blue copper carbonate and sulphate staining in the rocks. The mine was opened in 1854, worked periodically and then taken over in 1937 by the Okiep Copper company. It is a national monument

First Argon dating results from the noble gas laboratory at UJ, and outlook

Jan Kramers

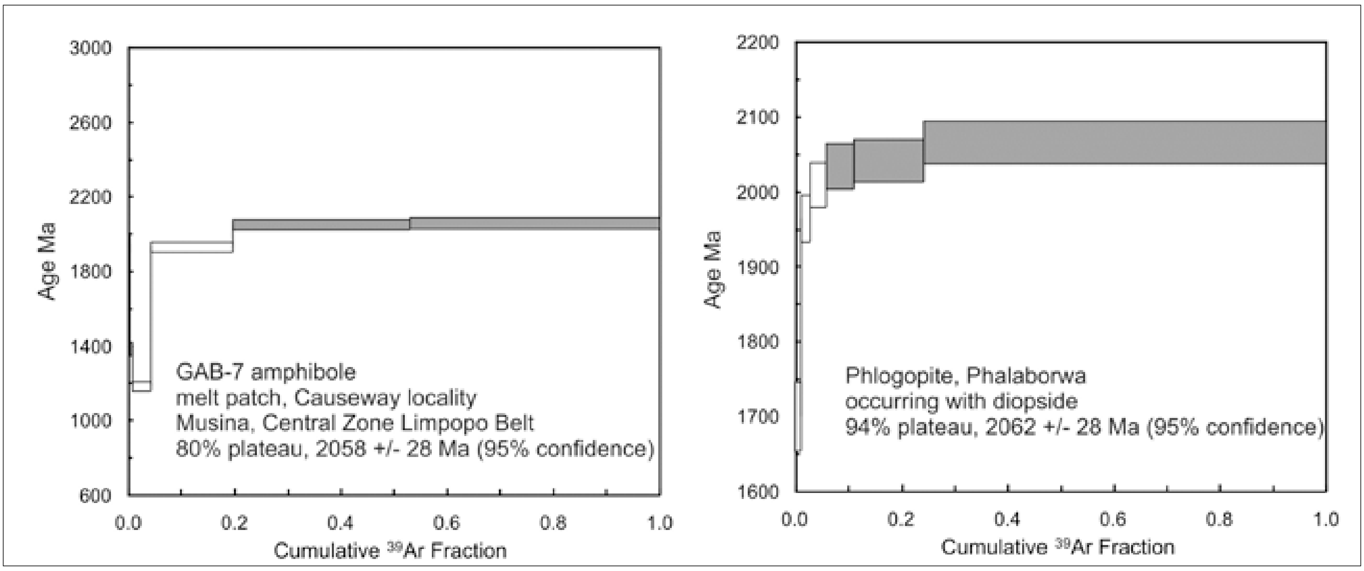
The analysis of the first batch of samples dated by the 40Ar/39Ar method in the revitalised noble gas laboratory of the Spectrau analytical facility and the UJ Geology Department has recently been completed. To wit, this method is a (now almost universally used) variant of the K-Ar method in which samples are irradiated in a nuclear reactor prior to analysis, whereby a small fraction of 39K is transformed into 39Ar, a weakly radioactive argon isotope that is absent in natural minerals. Thus the 40Ar/39Ar abundance ratio is proportional to the 40Ar/40K ratio, which is age-dependent. The 40Ar/39Ar method requires well-dated standards, but has the advantage over the 40Ar/40K method that the sample does not have to be split for separate Ar and K analyses, but a single analysis on a single aliquant yields a date. Further, stepwise heating of the sample releases increments of Ar gas and thereby an internal check on the consistency of the results is often possible. Our system, inherited from De Beers Geosciences Lab., includes a mighty infrared (1064 nm) continuous laser capable of delivering 14 W in Too mode, which we have to date not used beyond ¼ of its power.

Samples are grains up to about 1 mm in size, up to 50 of them can be loaded on a sample stage and placed in the ultrahigh vacuum sample port, where they are individually heated by the laser via a quartz window while being watched through a microscope. After each heating step, the gas is allowed to expand into the mass spectrometer and isotope ratios are measured. The sample gas is then pumped away by ion pumps and the next step is started. In addition to preparation for the Ar/Ar dating application, the unit has been further developed to enable U-Th-He dating. This method is normally applied to low-temperature thermochronology using apatite, but our intention is to use it for dating of soil authigenic minerals such as components of ferricrete, and speleothems. This is a pioneering approach, and will be applied in geomorphological studies as well as in the dating of hominin fossil-bearing cave deposits. The extreme sensitivity of the instrument and low blank of the line allows very small quantities of radiogenic He to be accurately measured. This will enable dating of relatively young (a few Ma) mineral grains containing moderate amounts (around 1 ppm) of U and/or Th. Following published reports that aragonite, hematite and goethite are retentive for He at ambient temperatures, experiments were carried out which demonstrated that samples of these minerals would most probably be datable down to a few hundreds of thousands years – thus bridging the gap between geochronometers of the geological time scale such as Ar/Ar and U-Pb, and the ones applicable to the archaeological time scale, such as U/Th, OSL, and 14C dating. Two projects, one in cave dating and one in landscape evolution, are currently being initiated.

The small sample size also means that many can be irradiated in a single batch. Our first batch included 51 samples and 10 standards. The nuclear reaction producing 39Ar from 39K requires fast neutrons. A location in NECSA's SAFARI1 reactor where such neutrons are abundant had previously been identified by Dave Phillips when he initiated the method at De Beers. This location is still available and has yielded quite satisfactory results.

Of the samples in our first sample batch, some, of known age, were included to validate our approach. These are a phlogopite from the Phalaborwa body (previously dated at 2061 Ma by U-Pb on baddeleyite; Wu et al., 2011, Lithos 127, 309-322) and hornblende from a melt patch previously zircon-dated at 2020 Ma, Jaeckel et al., 1997; J. Geol. Soc. Lond., 154, 25-44) at the Causeway locality in the Sand River near Musina, in the Central Zone of the Limpopo Belt. The results, shown in the figure below, display typical "plateau" behaviour. Low-temperature steps give minor Ar yields with aberrant ages usually reflecting some alteration, and the hotter consecutive steps yield the main gas component (80 and 94% respectively; grey boxes in Fig. 1) defining the true crystallization age which is in these cases consistent with other constraints. Canonically, a plateau is defined if consecutive steps together yielding more than 70% of the Ar from a sample, give ages within error of each other. The Phalaborwa phlogopite dating was done in duplicate and yielded consistency within +/- 2 Ma; this material might one day qualify to be an international standard.

These two simple systems show that the analytical method and approach are working as they should. In addition, we tried many new things, some of them from more complicated systems. The set included amphiboles from poly-high-grade-metamorphic Limpopo Mobile Belt areas, eudyalite and other minerals from the Pilanesberg complex (dating eudyalite with Ar/Ar has never been attempted before), stilpnomelane and riebeeckite from western Transvaal Supergroup, apophyllite from the Manganese fields, and amphiboles separated from ballast stones of a shipwreck site on South Africa's south coast, believed to be from the ship Santa Maria Madre de Deus, investigated by Sharad Master. With these in part quite complicated systems, we are learning lessons: even if they do not yield ages, the Limpopo Belt samples allow to distinguish polymetamorphic from monometamorphic rocks. The apophyllite data point to a tertiary event in the Manganese fields. Eudialite appears to be datable by 40Ar/39Ar in principle but consistency of results needs to be confirmed by further work – and we might at last get a reliable date for the age-elusive Pilanesberg Complex. Lessons learned point to further projects. Given the multifunctionality of the facility, the name here proposed for it is SANGOMA – South African Noble Gas Outfit for Manifold Answers.



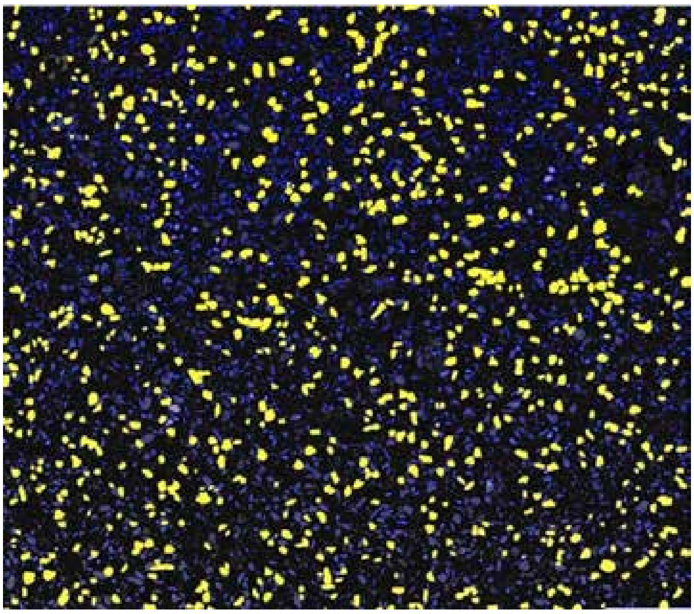
Stepheating age spectra for an amphibole from the Central Zone of the Limpopo Belt and a phlogopite from Phalaborwa, showing plateau ages

HIGHLIGHTS OF RESEARCH FOCUS AREAS

A geometallurgical assessment of the Merensky Reef at the Two Rivers Platinum Mine

Derek Hugh Rose

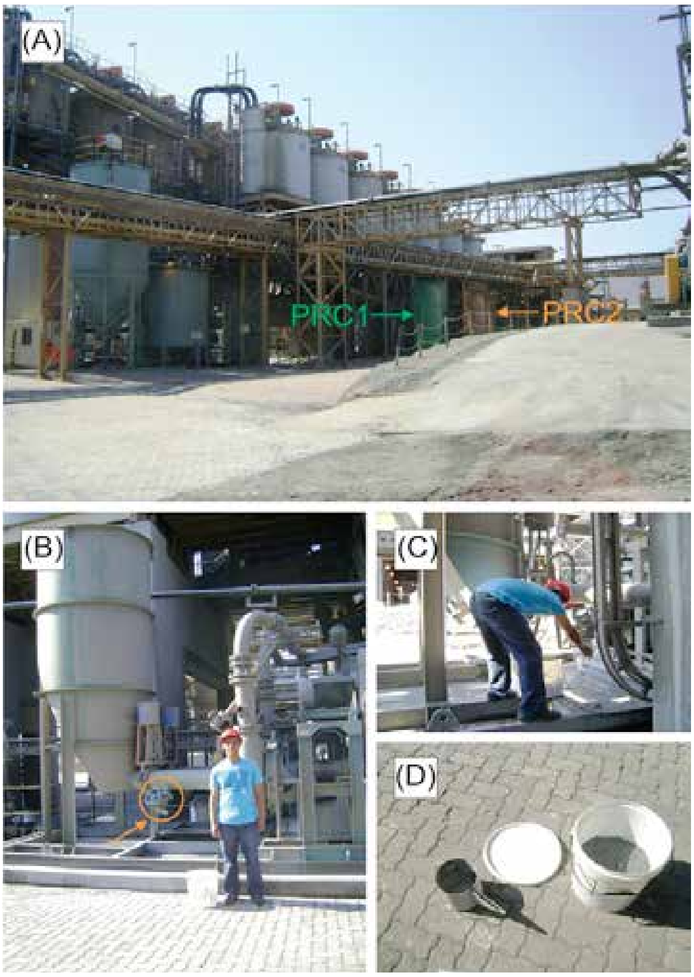
The Two Rivers Platinum (TRP) mine, situated on the Southern Sector of the Eastern Bushveld Complex is approximately 23 km southwest of Steelpoort in Mpumalanga. The TRP processing plant and mining operations have traditionally focused on the UG2 chromitites as the main source of platinum-group elements (PGE's) even though the Merensky Reef also occurs on the property. The high gold and base-metal tenor of the Merensky Reef at the study area along with the record-high gold price in recent times has also made this horizon a lucrative horizon to mine. Life-of-mine planning in recent years has, in addition, necessitated a geometallurgical study on this platiniferous horizon. Previous work on the Merensky Reef at the study area has been based on exploration drill core and from this work four types or facies of Merensky Reef were identified. More recently, mining of the Merensky Reef at TRP has been in the project phase, with the ore being stockpiled and processed through the MF-2 (mill-float, mill-float) plant optimised for UG2 ore. In the MF-2 circuit the primary rougher feed (PRF) is fed to the primary rougher flotation tanks. The fast floaters report to primary rougher concentrate 1 (PRC1) and the slow floaters to primary rougher concentrate 2 (PRC2). The primary rougher tails (PRT) report to a secondary mill and this is fed to the secondary rougher flotation tanks with the fast floaters reporting to the secondary rougher concentrate 1 (SRC1) and the slow floaters to the secondary rougher concentrate 2 (SRC2) with the gangue reporting to the secondary rougher tail (SRT). The concentrates from the primary and secondary rougher circuits are then sent to the cleaners and recleaners to remove the gangue. It is envisioned that this Merensky Reef project will most probably be converted into a full production mining operation in future.



False colour image of a typical Merensky Reef sample of the primary rougher concentrate 1 generated by the Mineral Liberation Analyzer for a 30 mm round mount. Yellow minerals are the sulfides while the blue minerals are the gangue

A 70,000 ton bulk sample of the Merensky Reef was processed through the MF-2 plant for the first time in September 2011 and during this time a metallurgical set of samples were collected over a period of three consecutive days ee figures below). These samples consist of the primary rougher feed (PRF); primary rougher concentrate 1 (PRC1); primary rougher concentrate 2 (PRC2); secondary rougher concentrate 1 (SRC1); secondary rougher concentrate 2 (SRC2); primary rougher tail (PRT) and secondary rougher tail (SRT). Representative splits of all these samples have been obtained and all 21 were assayed for 6 PGE+Au, Cr, Ni, Cu and S. Preliminary data from the assays indicate that the highest grade of the PGE's are recorded in samples from primary rougher concentrate 1 which is consistent with the higher sulfur content for these samples (i.e. the PGE's are associated with sulfide minerals).

This on-going study thus proposes to focus on a set of metallurgical samples of the Merensky Reef during this project phase over a period of time, as well as a set of geological samples in the form of channel samples that cover the entire mining width as well as the different facies, and which include the Merensky Reef as well as the UG2. The geological samples will be used to carry out a battery of bench-scale laboratory tests with the emphasis being on emulating the TRP processing plant as closely as possible. This work will, on completion, yield a robust model of the Merensky Reef not only for the study area but for the Eastern Limb as a whole. Studies of this nature have been lacking particularly for the Merensky Reef on the Eastern Limb.



Views of the primary rougher flotation circuit and the apparatus used to collect the samples. (A) = Primary rougher concentrator flotation tank cells. (B) = Sample station for PRC1, gate valve and valve indicated by the orange circle and arrow [sample station for PRC2 can be seen in (A), The secondary rougher flotation circuit has the same set but is behind the primary rougher circuit in (A)]. (C) = Sampling of the Merensky pulp/concentrate manually using a hand sampler (D) = Hand sampler and 20 liter bucket used to collect the Merensky metallurgical sample

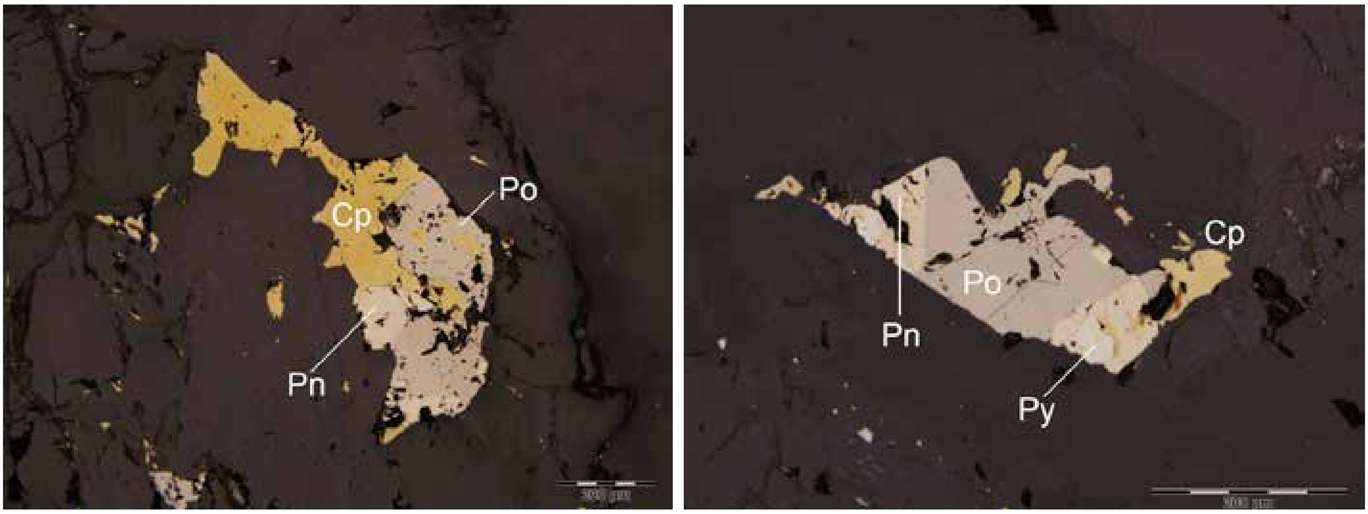
Occurrence and distribution of sulphide minerals in the Merensky Reef at the Two Rivers Platinum Mine

Kazuyasu Shindo

Magmatic sulphide minerals in Ni-Cu-platinum group elements (PGE) deposits are well known to scavenge PGE in the (ultra) mafic magma. Investigating distribution of sulphide minerals in these rocks is useful to find out not only mechanism of sulphide formation but also PGE distribution. Merensky reef samples used in this study were collected from the Two Rivers platinum mine located in the eastern limb of the Bushveld Complex. Studied samples include anorthosite, feldspathic-pyroxenite, associated chromitite stringer and norite

Sulphide minerals include mainly pyrrhotite, chalcopyrite, pentlandite and pyrite, and trace amounts of millerite, siegenite, bornite, sphalerite and galena. Most pyrrhotite grains occur in the feldspathic pyroxenite and associated chromitite stringer. Chalcopyrite, pentlandite and pyrite in all the rocks studied. Millerite and siegenite occur only in anorthosite below the reef. Others trace sulphides occur in the pyroxenite.

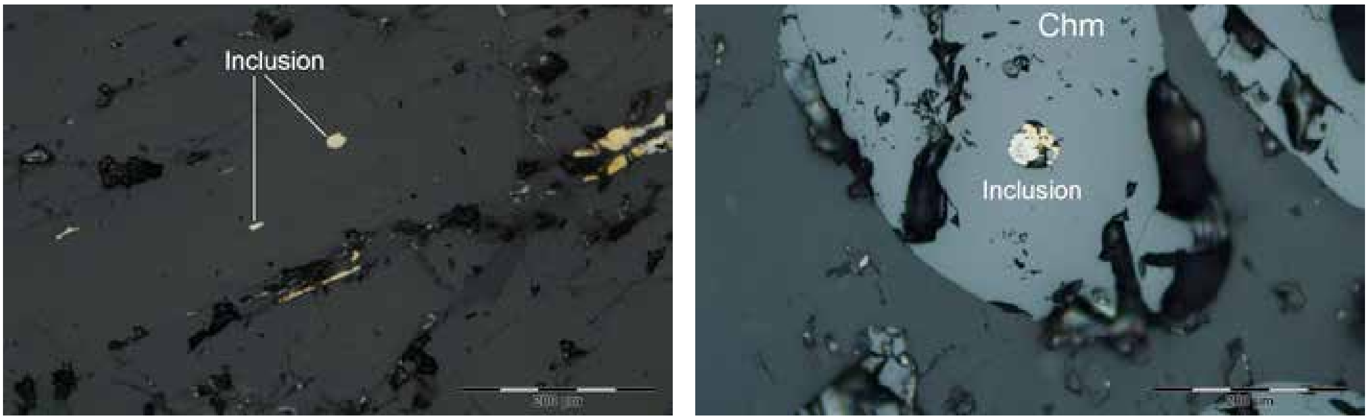
The occurrence of sulphide minerals is dominantly interstitial, with minor occurrence as inclusions. The former sulphide grain has its grain boundary in contact with silicate and/or oxide minerals. Some of the interstitial sulphides are associated with hydrous minerals. Shape of the interstitial sulphide is irregular. Grain size of the sulphides dominantly varies from 30 to several hundreds of micrometers. Few interstitial sulphides are over 1 mm in diameter. The latter sulphide is enclosed by plagioclase, orthopyroxene and chromite grain. The sulphide inclusion is mainly globule in shape and ranges from 3-15 µm in diameter.



Representative images illustrating the interstitial occurrence of sulphide minerals

Sulphide contents in anorthosite and norite are typically <0.1 vol%. Some anorthosite which covers the reef have ~1 vol%. Content of sulphide minerals in the reef varies from <0.1 to 5 vol%. The volume of sulphides in the reef seems to tend to increase from upper part of the reef to upto the chromitite stringer which is observed in lowermost part of the reef. Moreover, irrespective of its grain size, the sulphide grains generally distribute as disseminated in the samples, some of which can be found distributed vertically in the thin sections. Chromitite stringer contains sulphide minerals ranging 0.1-5 vol%.

Sulphide inclusions occur in pyroxene and chromite, although its amount is much smaller than that of interstitial sulphides, implies that sulphur came to be saturated at the relatively early stage of crystallization of silicate minerals at the pyroxenite and chromitite stringer. Siegenite and millerite which are observed in the anorthosite and norite can crystallize only at low temperature, indicating that small amount of sulphide minerals in these rocks were formed by low-temperature hydrothermal fluid.



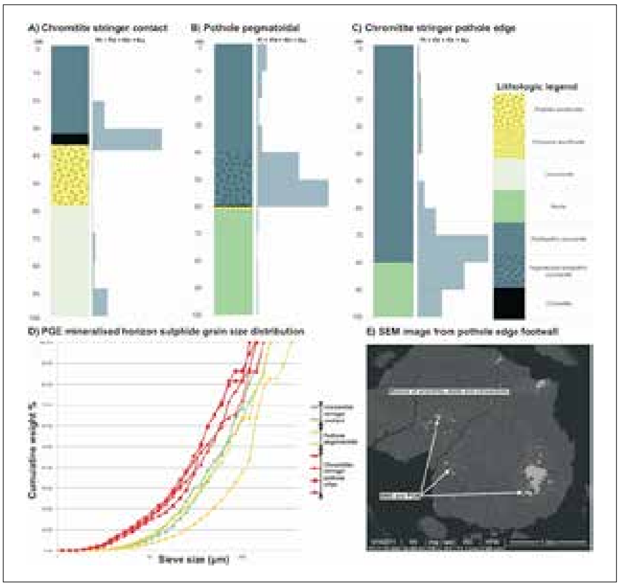
Representative images illustrating the occurrence of sulphides as inclusions

Geological variations in Merensky Reef at the Bafokeng Rasimone Platinum Mine and its influence on flotation performance

AJB Smith

Lateral and vertical variations in the geology and platinum group mineralogy (PGM) of Merensky reef are well known across the Bushveld Complex. The Merensky Reef at Bafokeng Rasimone Platinum Mine (BRPM), situated south of the Pilanesberg on the western limb of the Bushveld Complex, is no exception: eleven distinct Merensky Reef facies types have been recognized and defined based on differences in lithostratigraphy, PGE grade distribution and footwall type of the mineralized zone. The impact of these differences on mineral processing behaviour can be better understood through the medium of geometallurgical characterisation.

Differences in flotation performance of the facies types are observed when comparing e.g. normal elevation chromitite stringer contact, pothole pegmatoidal and pothole edge chromitite stringer Merensky Reef at BRPM, with normal elevation reef performing best and pothole edge reef performing worst. These differences can be related to the PGE grade distribution, mineralogical characteristics of the PGM and base metal sulphides (BMS) in the milled flotation feed, and the in situ mineralisation style of the reef. Normal elevation contact reef has the best 4E flotation response because PGE-sulphides are the dominant and coarsest liberated PGM-type and almost entirely concentrated in the single chromitite stringer that defines the facies. When not liberated, the PGM in the normal elevation contact reef has a high association with well liberated BMS, leading to even better flotation response. Pothole edge facies has the worst response due to poor liberation of the PGE-tellurides, a lower modal abundance of PGE-sulphides, a very fine grain size of BMS in the mineralized zone and a high association of PGM and BMS with feldspar and altered silicates. These results are in good agreement with the fine mineralisation and a well-mineralised norite footwall. The pothole pegmatoidal facies has a medium response based on reasonable liberation of the almost equal PGE-sulphide and PGE-telluride proportions and high association of PGM with altered silicates.



(A – C) Lithology and grade distribution (sum of Pt, Pd, Rh and Au) of the reef intersections of the studied Merensky Reef types at BRPM; D) Cumulative grain size distribution of the sulphides (pyrrhotite, pentlandite, chalcopyrite and pyrite) in the mineralised horizons of the studied reef intersections; and E) Scanning electron microscope (SEM) image from the footwall of the pothole edge Merensky Reef facies at BRPM

Geometallurgical characterization of Merensky Reef at the Lonmin's Marikana Operation

Thomas Dzvinamurungu

The study aims to develop a geoscientific facies analysis into a geometallurgical assessment, including an evaluation of the response of different facies types of Merensky Reef to mineral processing, and the identification of critical characteristics that determine processing behaviour. This is accomplished by obtaining quantitative mineralogical information, combined with laboratory scale milling and flotation testing. Lonmin Platinum's Marikana operation is located on the Western Limb of the Bushveld Complex to the east of Rustenburg. Platinum group elements (PGE) occur in, and are mined from, a variety of facies types of Merensky Reef, and the UG2. For the purpose of the present study, three facies types were sampled, as well as one sample of UG2. The Merensky facies types sampled comprise of the Brakspruit (BK), Rustenburg Platinum Mine (RPM), and Western Platinum (WP) variants.

The mineral assemblages of the various Merensky Reef facies types at this locality comprise varying amounts of orthopyroxene, clinopyroxene, plagioclase, olivine, talc, serpentine, chlorite, chromite, magnetite and sulphides (mainly pyrrhotite, pentlandite and chalcopyrite). Platinum group minerals (PGM) present include cooperite, braggite, maslovite, sperrylite, laurite and PGE alloys, and these occur in close association with the sulphides.

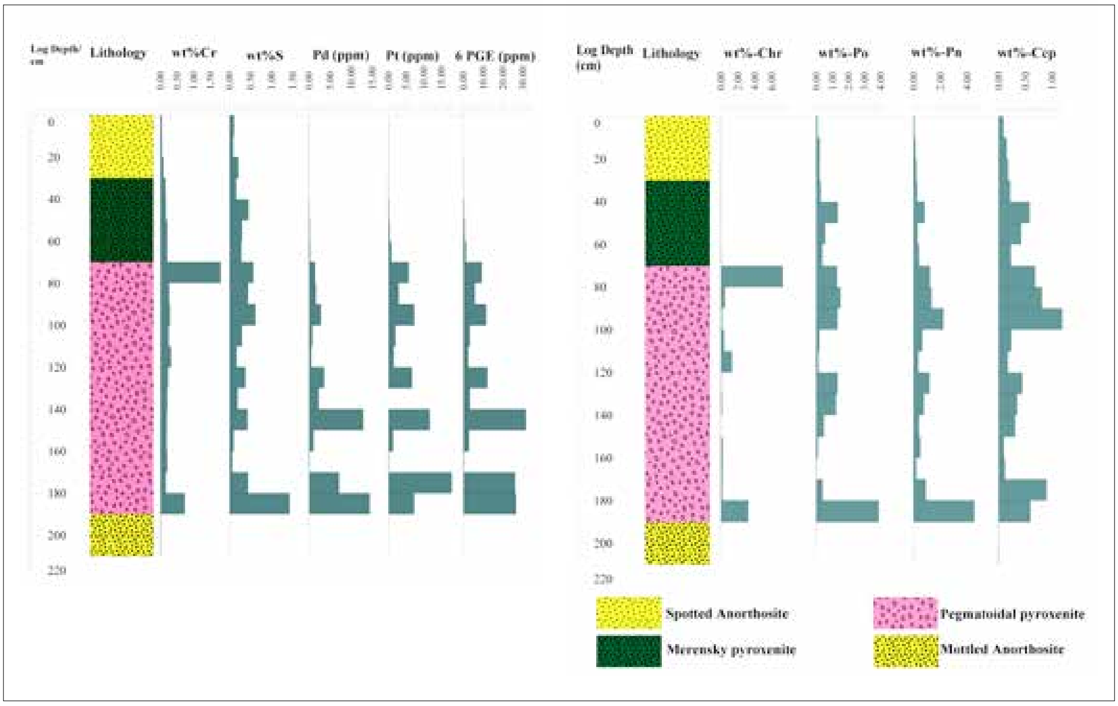


Figure (left) - modal abundances of chromite and sulphides with depth for 10 cm intervals of channel sample of the BK facies of Merensky Reef. Abundant chromite correlate with the position of chromitite stringers. Figure (right) - Distribution of Cr, S (wt%), Pd, Pt and 6PGE (ppm) with depth for individual 10 cm intervals of a channel sample of the BK facies of Merensky Reef. Ccp – chalcopyrite; Po – pyrrhotite; Pn – pentlandite; Chr - chromite

Approximately 20 individual 10 cm channel samples were collected from each of the facies variants of the Merensky Reef (BK, RPM, WP), and the UG2. These were coarsely crushed, mineral modal abundances determined using the MLA, and then analysed for Cr, Cu, Ni, S and 6 PGE (see figures; BK and WP facies samples illustrated). The samples were then combined per facies type, and each of these composites subjected to laboratory scale milling and flotation testing. Abundant sulphide typically occurs with (is associated with) thin chromitite stringers, as is commonly observed for Merensky Reef throughout the whole of the Bushveld Complex. Chromitite stringers are characterised by high PGE concentrations (see figures).

The milling behaviour of the various samples (see figure below), as well as flotation behaviour (cumulative mass pull during flotation), is a function of mineralogy. For instance, the sample of BK facies (with 31 wt% plagioclase) requires longer milling to attain a grind of 60% passing 75 micron, relative to the sample of WP facies (with 15 wt% plagioclase). The influence of ore mineralogy on the various stages of flotation (early, middle and late), the mineralogical makeup of the various flotation concentrates, and the level of recovery of the PGE's during flotation, is currently under investigation.

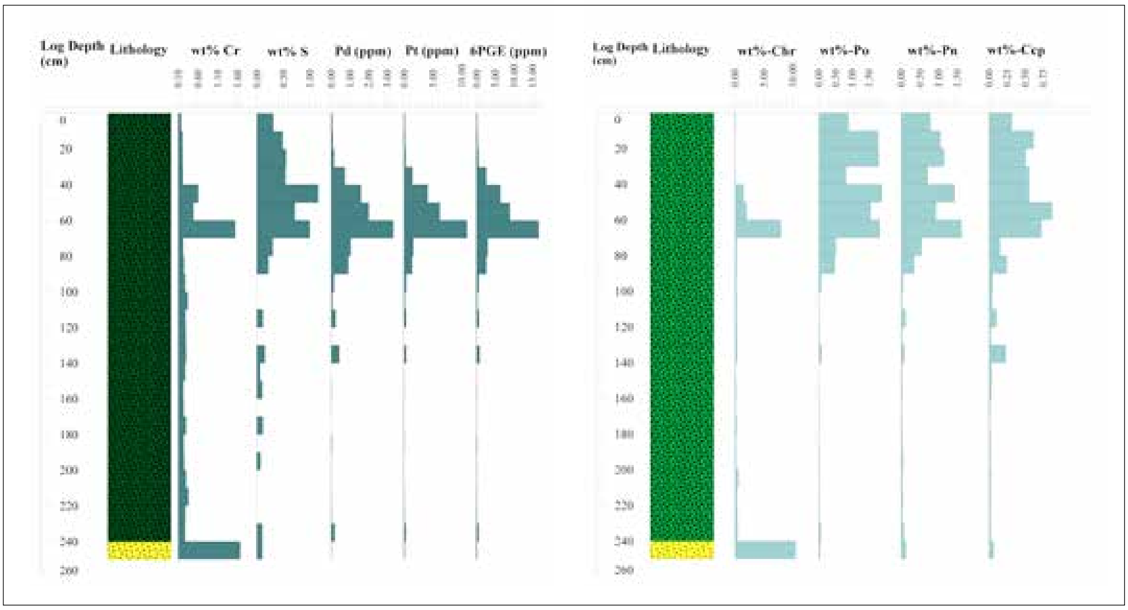


Figure (left) - Modal abundances of chromite and sulphides with depth for 10 cm intervals of a channel sample of the WP facies of Merensky Reef. Abundant chromite correlate with the position of chromitite stringers. Figure (right) - Distribution of Cr, S (wt%), Pd, Pt and 6PGE (ppm) with depth for individual 10 cm intervals of a channel sample of the WP facies of Merensky Reef

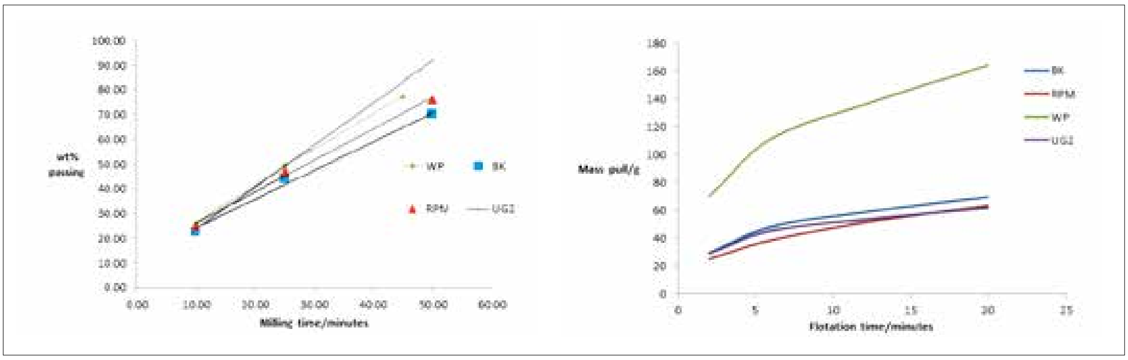


Figure (left) - Grind size (wt% passing 75 micron) plotted as a function of milling time, for the four samples investigated. Figure (right) - Cumulative mass pull during progressive flotation, plotted as a function of elapsed time, for the four samples investigated

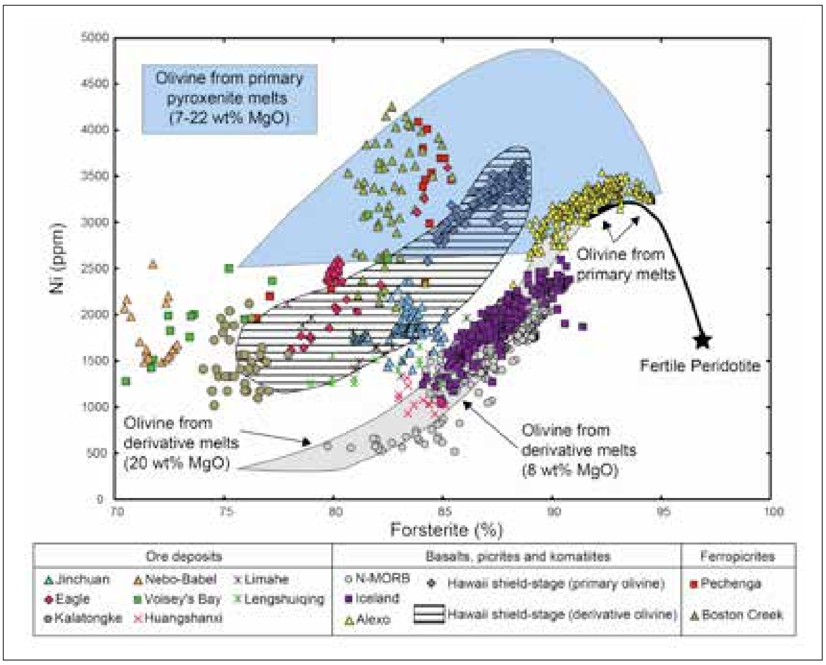
Magmatic Ni-Cu-(PGE) deposits: Exploring the importance and economic significance of mantle source compositions

Nicolas Tonnelier

The metal tenor of magmatic sulfide is controlled by the degree of sulfide liquid/silicate magma interaction and by the composition of the parental magma, which in turn depends on the degree of melting as well as the type of mantle source from which it was produced. In the majority of magmatic ore deposits, a good correlation exist between the metal content of sulfides, the estimated metal content of the parental magma and the calculated sulfide liquid/silicate magma ratio under which sulfide equilibrated. However, some deposits are characterized by relatively elevated Ni, Cu, Co and Au but low PGE indicating that they formed from magmas with different metal contents. Ni-Cu-PGE deposits with these characteristics include many of the deposits discovered in China (Jinchuan, Karatongke, Jinbulake, Lengshuiqing, Huangshanxi, Limahe, Baimazhai), some deposits associated with anorthosite complex (Voisey's Bay, Canada; Nebo Babel, Australia), and deposits associated with picritic and ferropicritic magmas (Eagle, USA; Pechenga, Russia). These deposits are characterized by intermediate Ni/Cu (0.7-2.1) but moderate to high Ni/Ir and Cu/Pd ratios, and are generally interpreted to have formed from PGE-depleted high-Mg basalts and picrites.

A combination of late stage processes can explain the PGE depletion of a mantle-derived melt but it requires unique conditions that will be physically and geochemically difficult to achieve. Alternatively, we discuss the possibility that parental magmas of these deposits were derived from melting of an olivine-free pyroxenite mantle source, similar to Hawaiian basalts and ferropicrites. The metal contents of these lavas, as well as numerical melting models, show that pyroxenite-derived melts have high Ni and Cu and relatively low PGE, consistent with the composition of the studied deposits. Each deposit also exhibit olivine compositions (high Ni, see Figure, and low Ca and Fe/Mn ratio), isotopic signatures (decoupling of Sm-Nd and Re-Os), and major element contents that are characteristic of pyroxenite-derived magmas.

The contribution of pyroxenite mantle during magma genesis has gained acceptance within the geochemical community and has been proposed to explain the composition of magmas in many geodynamic environments. Therefore, in some instance pyroxenite-derived melts may have led to the formation of magmatic ore deposits. Although many studies have explored the influence of melting processes on magma and ore compositions, very few have addressed the potential influence of different mantle lithologies. The implications of pyroxenite melting are important for exploration of magmatic ore deposits as it would produce melts propitious to ore formation. as is illustrated in Figure 2.The study serves to demonstrate the complexities introduced into flotation of Ni ores through variable ore texture, mineralogy, and alteration.



Composition of olivine crystallized from peridotite- (Alexo, N-MORB, Iceland) and pyroxenite-derived magmas (Hawaii, Pechenga, Boston Creek), and olivine in magmatic ore deposits characterized by a relative depletion of PGE compared to Ni and Cu (Jinchuan, Nebo-Babel, Limahe, Eagle, Voisey's Bay, Lengshuiqing, Kalatongke, Huangshanxi). Olivine compositions are compared with the modelled compositional range of olivine calculated from batch melting of mantle peridotite and pyroxenite, and range of olivine composition after fractional crystallization of peridotite-derived melts between 8-20 wt% MgO

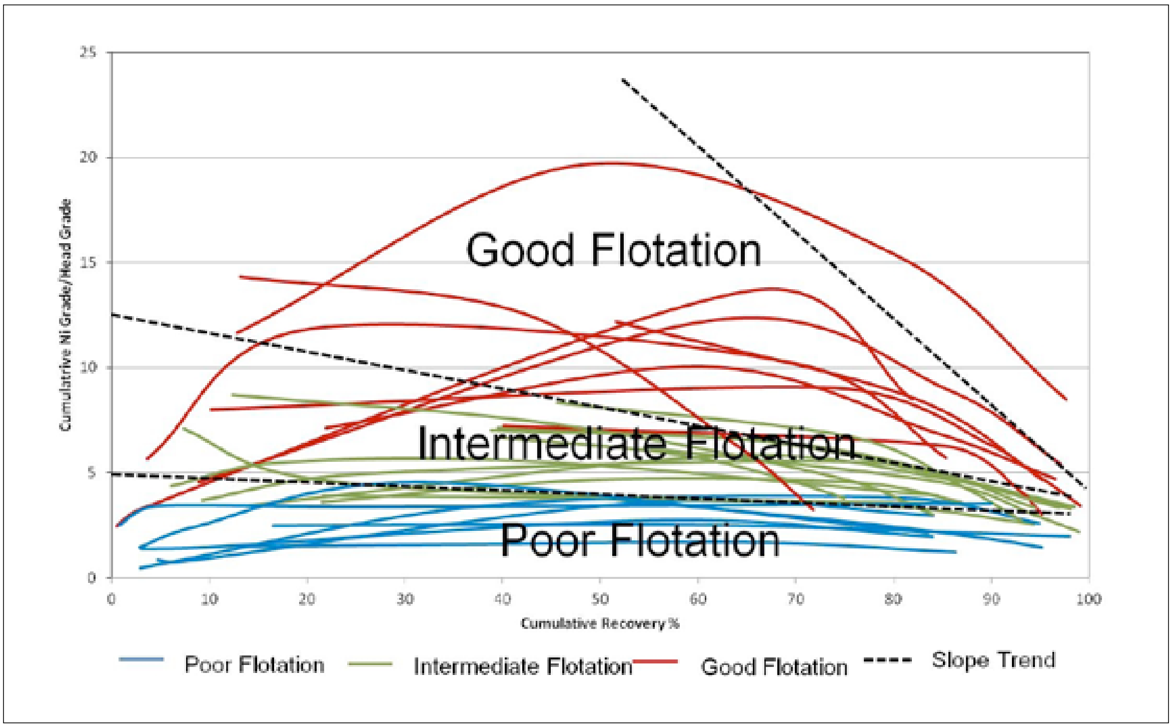
The influence of ore texture and mineralogy on the flotation of samples from Pit 3, Nkomati Mine, Mpumalanga

Gargi Mishra

The aim of this study is to characterize the different ore variants associated with the Main Mineralized Zone in Pit 3 of the Nkomati Mine, with a specific focus on geometallurgical issues. Based on the visual examination of drill core and petrographic studies of samples from Pit 3, the following sulphide ore textures were recognized: Net textured sulphide, bleb textured sulphide, disseminated sulphide and massive to semi-massive sulphide. Based on these ore textures, as well as mineralogy and alteration, a total of twenty-nine representative samples were selected for laboratory scale flotation studies

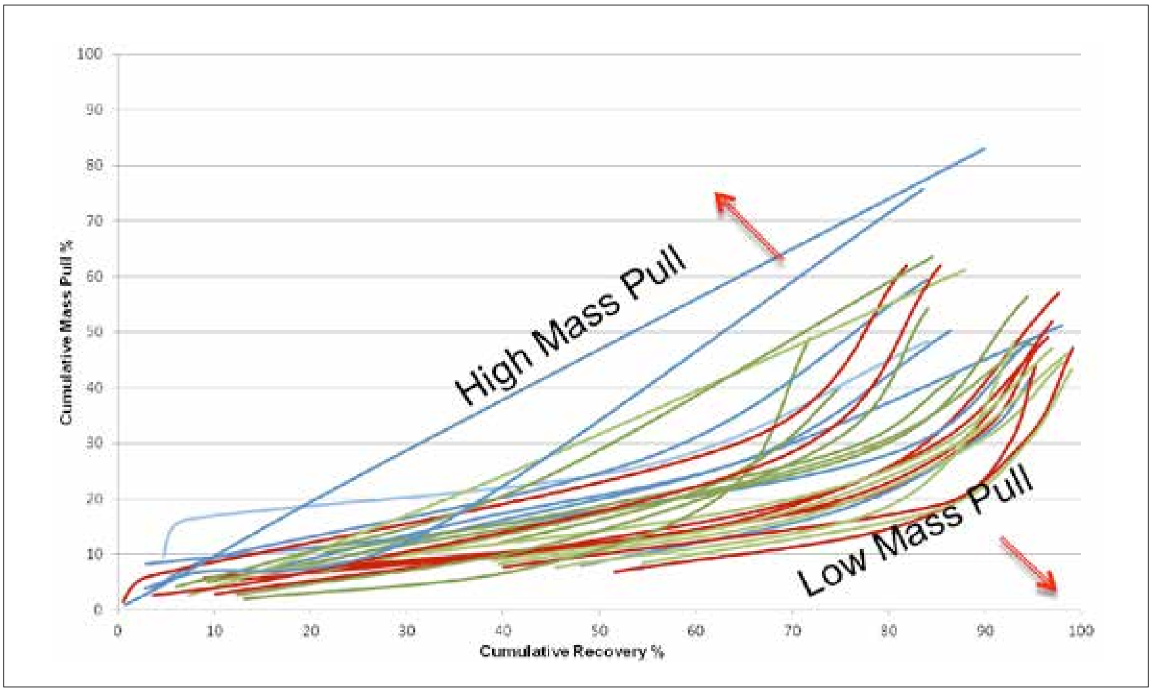
In order to understand the various flotation behaviours exhibited by these samples, cumulative grade ratios (i.e. the grade of the concentrate/the grade of the feed) were compared to the cumulative recoveries for Ni. Three main populations can be described based on their flotation response (see figure below):

- **Good flotation response** (samples with a high ratio of Ni concentrate grade to feed). Relevant factors are: (1) an unusually high abundance of sulphides such as pentlandite, pyrrhotite and chalcopyrite, which are generally coarse-grained, and (2) a low abundance of silicates and altered silicates. Typical ore textural types include massive to semi-massive ores, as well as coarse-grained net-textured ore variants. A coarse grain size assists in improving the liberation of pentlandite which also results in increased efficiency of flotation, while a low abundance of altered silicates results in less dilution of the concentrate. However, not all samples with a good flotation response necessarily result in acceptable Ni recoveries (i.e. >90% Ni recovered), as is clear from Figure 1 where a worst-case scenario is apparent for one sample, with very good flotation response, but with only 73% of the total Ni recovered. The reason for this is currently under investigation.



Cumulative concentrate Ni grade/head grade vs. cumulative Ni recovery for all samples processed. Rapid ('good') flotation results in a steep gradiant on the diagram, while slow ('poor') flotation results in a shallow to flat slope

- **Intermediate flotation response** (samples with an intermediate ratio of Ni concentrate grade to feed, and a constant rate of Ni recovery). This type of flotation response is characteristic of samples where the Ni recovery is initially poor relative to the previous category of flotation response ('good' flotation), and which then stays constant until eventually most of the Ni is recovered (e.g. 85-95% recovery). Ore textural variants include bleb-textured samples, as well as fine net-textured samples.These samples are also characterised by a high abundance of altered silicates, and associated alteration products such as serpentine. Such minerals are known to be naturally floating ('naturally floatable gangue') and hence result in a dilution effect in the resulting concentrates during progressive flotation.
- **Poor flotation response** (samples with a low ratio of Ni concentrate grade to feed, but with a constant rate of Ni recovery). These ore samples typically contain abundant inclusions (xenoliths) of metamorphic calc-silicate, as well as occasionally abundant pyrite. The texture of this ore type is defined by disseminated- to bleb-textured varieties. The exceptionally poor flotation response obsewwrved may result from an unusually high degree of dilution of the flotation concentrates by naturally floatable gangue (e.g. talc and various amphiboles) as well as pyrite (which is a fast floater). This will result in a high mass pull, as is illustrated in Figure 2.The study serves to demonstrate the complexities introduced into flotation of Ni ores through variable ore texture, mineralogy, and alteration.

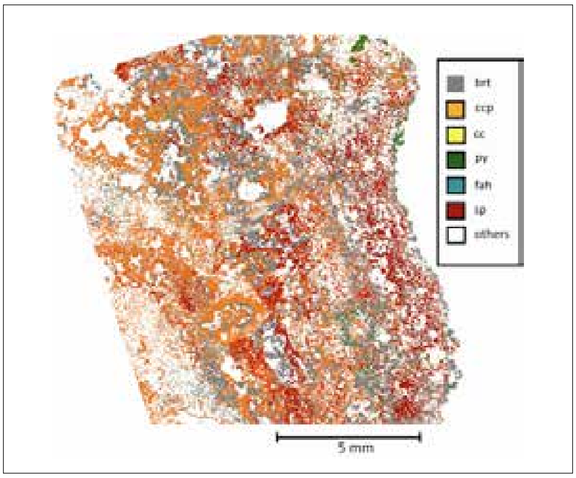


Graph showing cumulative mass pull expressed as a percentage of total mass, plotted as a function of cumulative Ni recovery. Low mass pull implies less dilution of the concentrate by e.g. naturally floatable gangue, and possible also pyrite

Trace elements in black smoker sulfides: influence of host-rock composition and recrystallization processes

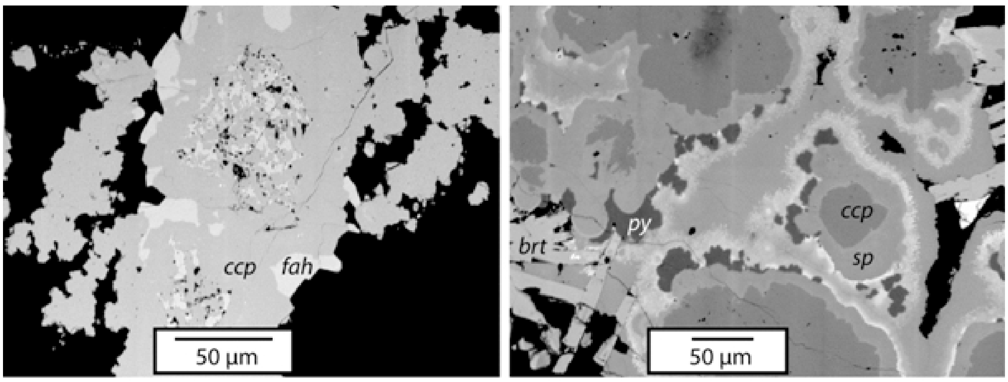
Cora Wohlgemuth-Ueberwasser

Volcanogenic massive sulfide (VMS) deposits are an important resource of Cu and Zn, and also represent a significant source of Pb, Au and Ag. Co- and by-products are e.g. Co, Sn, Ba, S as well as Se and Te. Until as recently as the 1980s, little was known about the processes responsible for the formation of these sometimes giant deposits – until the discovery of the first active, metal-precipitating hydrothermal fields on the sea floor. The research of the last thirty years revealed many details concerning the formation of VMS deposits through the investigation of active vent fields, as well as the roots of ancient, land-based fossil systems whch also provided insights into processes below currently active vents.



MLA map of a sample from a black smoker chimney in the felsic-hosted Satanic Mills hydrothermal field (PACMANUS field). Barite (brt), chalcopyrite (ccp), chalcocite (cc), pyrite (py), fahlore (fah; tetrahedrite), sphalerite (sp), others (silicates and holes in the polished section)

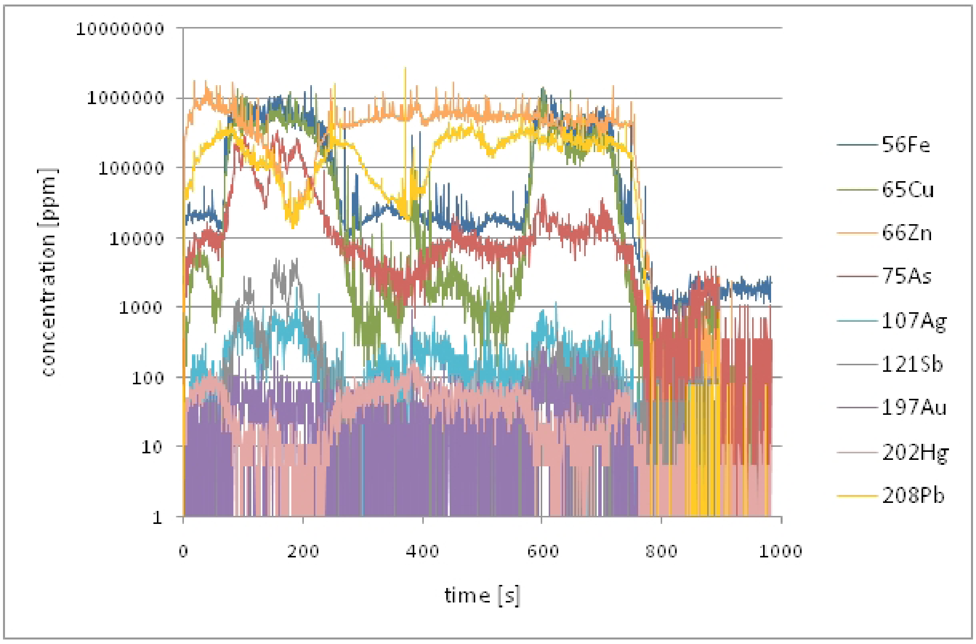
However, the effect of recrystallization processes on the mobilization and redistribution of trace elements in VMS is still very poorly understood. The present study attempts to determine how As and Sb, as well as Se and Te, may be affected by different processes e.g. during active precipitation of sulfide minerals within black smoker edifices, and subsequent modification by dissolution-reprecipitation processes through late-stage hydrothermal modification. Samples of black smoker chimneys from a variety of tectonic settings, including active and inactive vents, were investigated using an electron microprobe (EPMA), mineral liberation analyser (MLA), electron microscope (SEM) and laser ablation inductively coupled plasma mass spectrometer (LA-ICP-MS). This multi analytical approach resulted in a comprehensive dataset consisting of mineralogical and textural information, as well as major, minor and trace element element geochemistry.



Back scattered electron images of the sample in the above figure

The trace elements Se and Te provide information on the temperature of the fluid from which the host minerals crystallise, and may also provide information on the degree of partial melting in the root of a hydrothermal system. The concentration of elements such as As and Sb in VMS are controlled by the geological setting and are strongly redistributed during dissolution-reprecipitation processes. In the present study trace metals in hydrothermal sulfides from three different host rock settings were analysed e.g. the felsic-hosted PACMANUS field (Roman Ruins and Satanic Mills; Figures 1 and 2), the basaltic-hosted Turtle Pits field and the ultramafic-hosted Logatchev hydrothermal field. Se and Te in sulfides from the Logatchev hydrothermal field clearly reflect the ultramafic host rock mineralogy, with elevated concentrations in this mid ocean ridge basalt (MORB) setting due to a high degree of partial melting. High concentrations of Au, Zn, Pb and Ag in association with low As concentrations at Roman Ruins in the PACMANUS hydrothermal field, is consistent with an increased involvement of subducted crustal components at this locality, compared to Satanic Mills which is also located in the PACMANUS field (Figure 3). Au concentrations in sulfides from Turtle Pits are lower than expected (e.g. enrichment of Au predicted by subseafloor boiling). This anomaly is likely caused by erratic, and limited, localised boiling of hydrothermal fluids, with samples investigated in the present study precipitated from fluids that have not been phase separated by boiling.

Environments favourable to the production of high grade Au deposits in seafloor environments are those contributing Pb (in addition to Au) to the hydrothermal vent system e.g. subduction zone settings. These may also host a temperature environment which favours the precipitation of sphalerite, i.e. fluid temperatures in the range of 175 to 250°C. Subsequent recrystallisation of the sulfides will not result in major loss of Au to secondary hydrothermal fluids, as the solubility of Au is primarily controlled by Pb in sphalerite, which is immobile. However chalcopyrite, in contrast, contain little Au in the crystal lattice, with Au occurring primarily as micro-inclusions. During recrystallization these will likely migrate out of the chalcopyrite host to grain boundaries, where the Au is then likely to be removed by late hydrothermal alteration and leaching.



Ablation traces acquired on the LA-ICP-MS of the sample in Figures 1 and 2, showing variations in trace metal concentrations during ablation (time in seconds) of chalcopyrite (high Cu and Fe) and sphlarite (high Zn). These minerals are characterised by elevated abundances of As, Sb and Ag, likely due to the ablation of micro-inclusions of sulfosalts of these elements

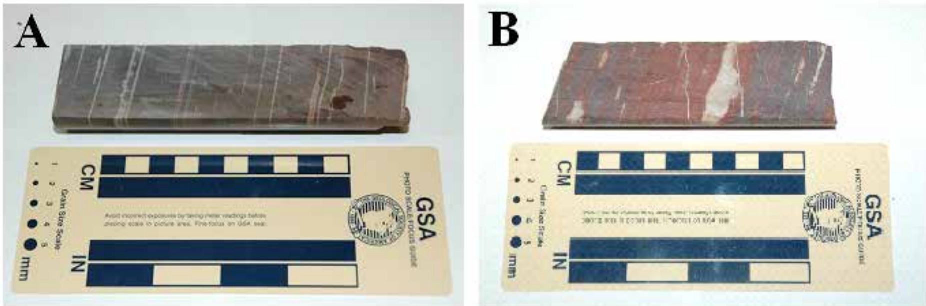
Geochemical and geometallurgical analysis of the Kalahari Manganese Deposits, Transvaal Supergroup, Northern Cape – controls on hydrothermal metasomatism and metal upgrading

Lauren Blignaut

Manganese is an essential commodity and is fundamental as a strengthening agent in the steel-making process. At present the steel industry consumes approximately 95% of the global Mn production with South Africa being one of the world's largest producers of the ore. Roughly 80% of the world's Mn reserves reside in the ± 2220 Ma Kalahari Manganese Field (KMF), which is situated in the Northern Cape Province. The largest and most important deposit of the KMF is the 320 km2 Kalahari Manganese Deposit (KMD).

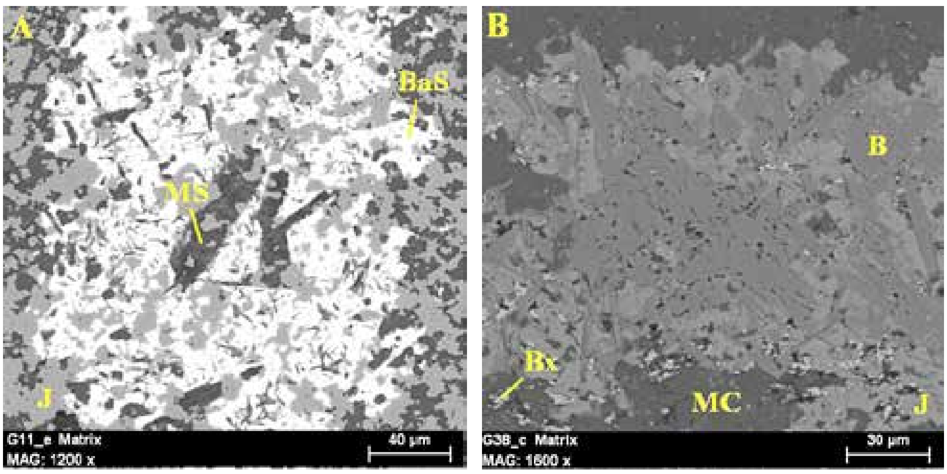
The Mn in the KMD is exploited from three Mn beds that are interbedded with hematite lutite and banded iron formation (BIF). The lowermost Mn bed is the thickest and most Mn-rich and, thus, most favourable for mining.

A thorough understanding of the ores mined in the KMF, particularly in the KMD, is necessary, so that a high output, in terms of quantity and quality of the ore, can be maintained. In order to optimize exploitation of the deposit, the genesis, transport and deposition, diagenesis and metamorphism as well as hydrothermal alteration of the Mn ore needs to be addressed.

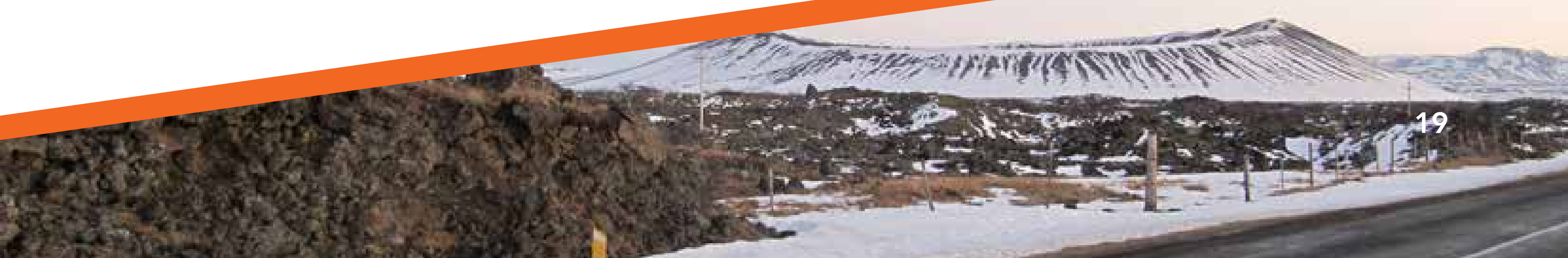


Hand samples of partially altered ore; showing large carbonate veins (some cross-cutting) as well as banding

Emphasis needs to be placed on the spatial distribution of the mineral assemblages, mechanism of the Mn-enrichment from the low to high-grade ore, fluid characteristics and fluid-rock interactions. These interactions lead to the presence of boron (B) and other light elements. Boron is regarded as a deleterious element in the steel-making industry. Concentrations > 400 ppm are undesirable and highly detrimental to the steel quality. Thus, studying the spatial distribution, the location and the source of the boron throughout the orebody as well as finding ways of dealing with its presence is of great importance in order to reduce its impact in the final high-grade product. This study, therefore, aims to geochemically and geometallurgically characterise both the upper and lower Mn beds from both the Gloria and N'chwaning mines (Assmang) in Black Rock, Kuruman, which has never been undertaken before. Samples, thus far, have been subjected to X-ray diffraction (XRD), scanning electron microscopy (SEM), electron microprobe analysis (EMPA) and mineral liberation analysis (MLA). Results obtained indicate that the samples contain oxides (braunite, jacobsite, hematite, bixbyite); carbonates (kutnahorite, rhodochrosite); silicates (serpentine, friedelite) and hydroxides (brucite, manganite).



A) Matrix composed of barium sulphide (BaS), jacobsite (J) and an unnamed Mn-silicate (MS). B) Matrix composed of elongated braunite (B) needles, manganocalcite (MC), jacobsite (J) and bixbyite (Bx)



Gold, U and Th deportment at the Rand Uranium Gold Mine

Lethuxolo Mngoma

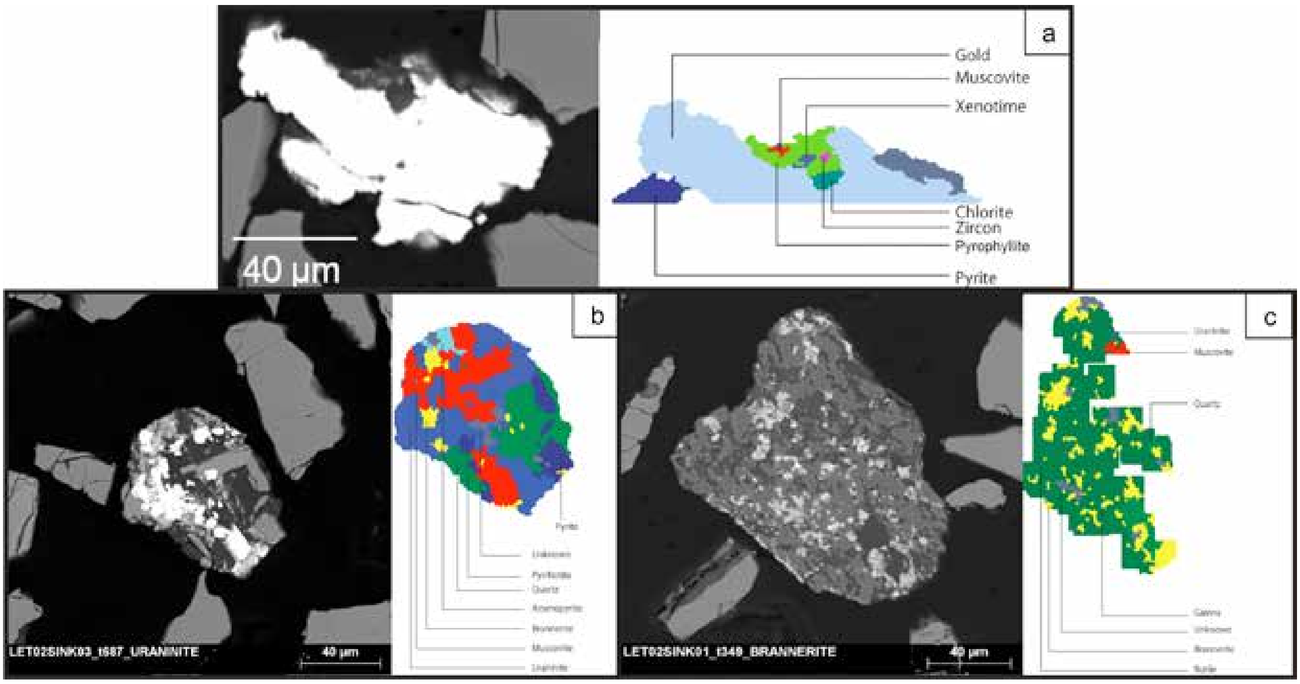
The Witwatersrand Supergroup is host to several auriferous and uraniferous reefs which are mined extensively throughout the basin. The mineralization and mineralogy of the Witwatersrand basin has been studied extensively for the purpose of exploitation of the reefs. This study seeks to extend on the metallurgical research which has been conducted thus far by means of a chemical deportment complimented by the employment of automated mineralogical techniques for the characterization of the mineralogy of these reefs.

From Rand Uranium's Cooke 3 Shaft, entire reef panels from the UE1A and A1 reefs were randomly sampled and prepared for a chemical and mineralogical deportment study. These samples were milled and crushed down to 80% passing 75µm and processed for head chemistry assays, grading analysis as well as heavy liquid separation analysis as part of the chemical deportment.

The mineralogical characterisation was completed using the FEI 600F field emission Mineral Liberation Analyser (MLA). The analyses were conducted on 30mm grain mounts (polished blocks) created from the sinks fraction obtained from heavy liquid separation. Two types of searches were conducted; a Sparse Phase Liberation (SPL_DD_Lite) search, for bright particles such as gold, uraninite and brannerite. Given the relative abundance of the uranium- and coarse grained sulphide- species in the concentrated sinks, an X-ray Backscatter Electron (XBSE) search was conducted for investigation of these species. The data obtained from these measurement modes yields information such as mineral types, mineral associations, mineral grain size distributions, modal mineralogy, liberation as well as locking statistics.

The head chemistry assays indicate that the reefs have varying gold grades, with two of the four samples having an average grade less than 2 g/t gold. Uranium and thorium grades for all the samples are low, less than 554 ppm and 103 ppm, respectively. The typical head chemistry chemical compositions indicate that the reefs are predominantly rich in SiO_2 (>84 wt%), Al_2O_3 (>4 wt%), and Fe_2O_3 (>1.80 wt%). The sulphide content varies from 1.44% to 4.33%, whilst organic carbon accounts for less than 0.05%.

From the grading analysis, it is evident that most of the gold, uranium and thorium are relatively fine grained (<75 µm), with some gold and sulphur reporting to the coarser fractions (>106 µm). The heavy liquid separation assays indicate a clear upgrading of gold and sulphur into the sinks, whilst uranium and thorium are lost to the slimes and floats fractions.



SPL_Lt BSE images (left) and mineral maps (right) showing: (a) an irregular or hackly gold grain. (b) Complex uraninite particle with associated pyrrhotite, quartz, arsenopyrite, brannerite, and muscovite. (c)Disseminated brannerite grains in a rutile particle

The results of the MLA analysis on the concentrated sinks indicate that there are two gold hosting species, native gold and electrum, and two uranium phases, uraninite and brannerite in the heavy liquid separation sinks. The gold species are commonly associated with sulphides such as pyrite and arsenopyrite along with quartz. Uraninite and brannerite are commonly found in the same particle often associated with quartz, pyrite, and muscovite. Data from the SPL_DD_Lite further confirmed the fine grained nature of the samples, with more than 60 wt% of the gold passing <75 µm, 70 wt% of the uraninite passing 75 µm, and 80 wt% brannerite passing 75 µm.

Liberation and locking data from the sink concentrates illustrated that there is a moderate degree of liberation for gold (40%-50%), a poor degree of liberation for uraninite (20%-40%) and a poor-to-moderate degree of liberation for the brannerite (30%-50%). Most of the gold is either locked in or associated with pyrite (possible solid solution) and quartz. Uraninite and brannerite occur as singular complex particles with pyrite, arsenopyrite, and quartz. Brannerite is also associated with rutile.

There is a possibility that some of the gold is microscopic or invisible, and may be of a refractory nature, along with brannerite which has been referred to as a refractory mineral. Both of these phases pose problems during extraction, and may result in losses or may require additional pre-treatment steps before recovery.

The combination of chemical and mineralogical deportment data presented in this study give detailed evaluations of the Witwatersrand reefs currently being mined at the Cooke 3 Shaft, and also gives the possible implications for metallurgy, particularly during the process of extraction.

Application of automated mineralogical analysis to investigate the mineralogy of New Vaal Colliery's coal with its supply to Eskom's Lethabo power station

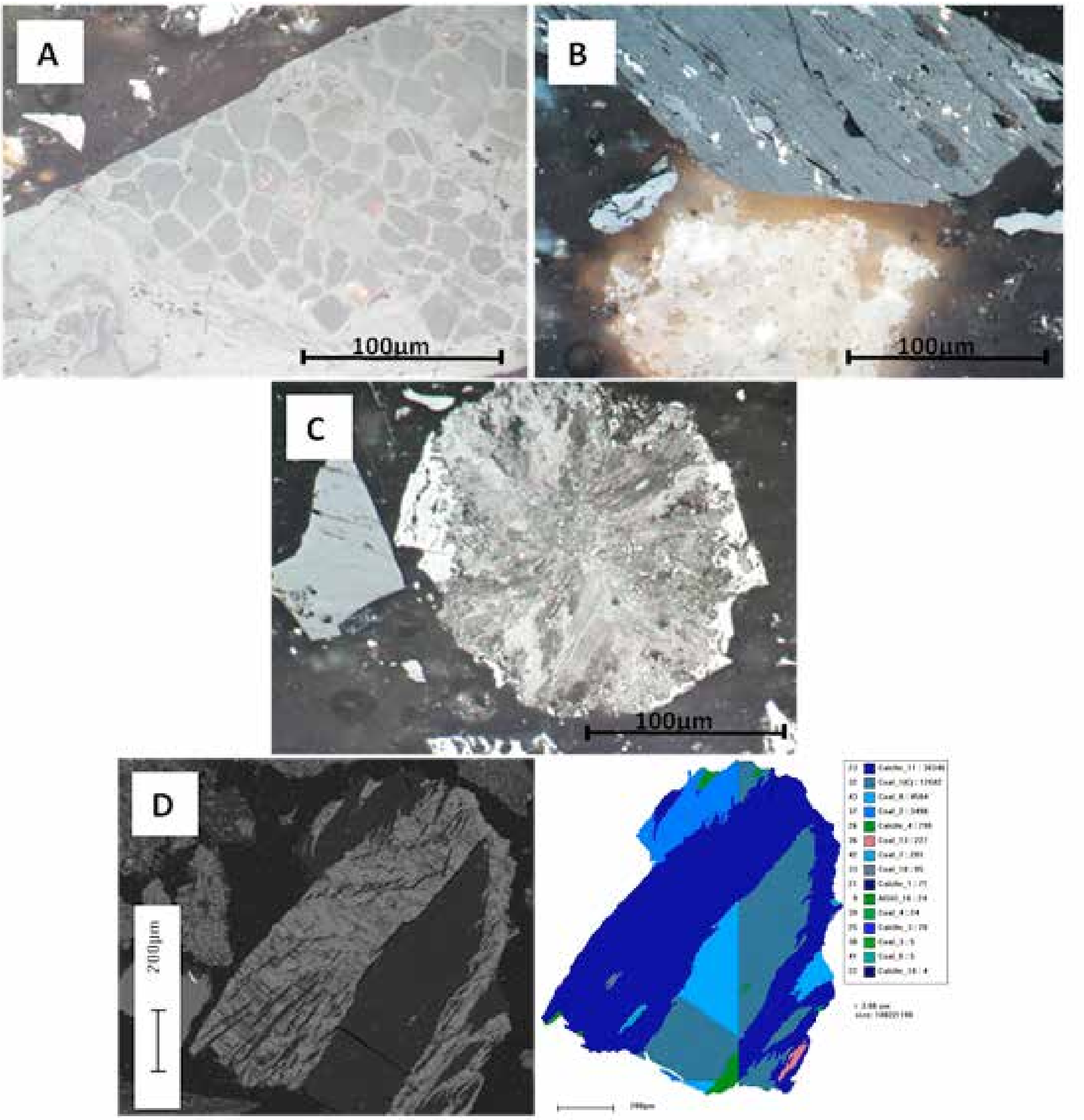
Donavan Pretorius

Coal is still the dominant energy source for South Africa. Characterization maturity of coal will have to improve and evolve to which the characterization will not just define the chemical attributes of coal assemblages, but will also deal with the predictive understanding of utilization performance. Coal has been widely characterized by traditional/conventional analytical analysis such as proximate analysis (moisture, ash and volatile matter) and ultimate (carbon, hydrogen, nitrogen and sulphur quantification) analysis. Coal petrography is also a well-used method for the characterization of organic constituents with inorganic minerals. Frequently the mineralogical data is being obtained by traditional XRD and XRF techniques to determine the elemental composition of the ash residue. Mineralogical information is beneficial as it will be more suitable and preferred than elemental assay information, as minerals are the source of these elements and different minerals have different impact on utilization performances. To obtain fast reliable mineralogical distribution and associations, automated mineralogy has widely been applied to commodities such as PGM's, base metals, and uranium and gold deposits, especially with the utilization of the fast QEMSCAN analytical technique.

Only recently did the application of automated mineralogy techniques become possible and reliable application on coal deposits due to the complex organic and technique interaction. With the addition of extensive and improved coal characterization techniques, automated mineralogy will assist to meet the demands for the different and potential markets quality specifications. The high ash coal from the Sasolburg-Vereeniging coalfield can be seen a representative of the lowest quality coal at the end of the quality spectrum in South Africa (low calorific value and high ash content). In the near future energy production and coal beneficiation technologies will be based on this type of coal that is from the Sasolburg-Vereeniging coalfield. The coal product from New Vaal Colliery of the Sasolburg-Vereeniging coalfield was investigated with supply to Eskom's Lethabo power station. The combustible pulverized fuel technology from Lethabo power station will be a good example on the combustion and utilization of a low calorific value and high ash coal to rest of the world energy markets.

Automated mineralogical technique such as QEMSCAN has been successfully applied to coal within the coal industry with limited MLA applications. With the high mineral content of the New Vaal Colliery coal, the MLA 650 FEG at Spectrau was utilized and tested to determine if it can analyze the minerals in the coal matrix, the handling and interaction capabilities of the MLA with coal and the development of the mineral classification standardfile. The MLA's XBSE automated mineralogical technique was able to determine the modal mineralogy, elemental assay, liberation, association etc. on the different crushed size fractions -1mm, -212 µm and -75 µm respectively. The results that are produced from the MLA technique were compared to the conventional techniques such as coal petrography, XRD, and XRF. The minerals that were encountered are: ankerite, calcite, dolomite, kaolinite,

albite, anorthite, microcline, muscovite, hematite, ilmenite, hedenbergite, quartz, galena, gypsum, jarosite, pyrite and sphalerite. The organic constituent (coal) was divided into low-S and high-S coal. Trace element geochemistry analysis was conducted on the different crushed size fractions and the possible source from minerals will be considered. Recommendations will be made to assist the improvement of the future applications of automated mineralogical MLA technique, especially at Spectrau.



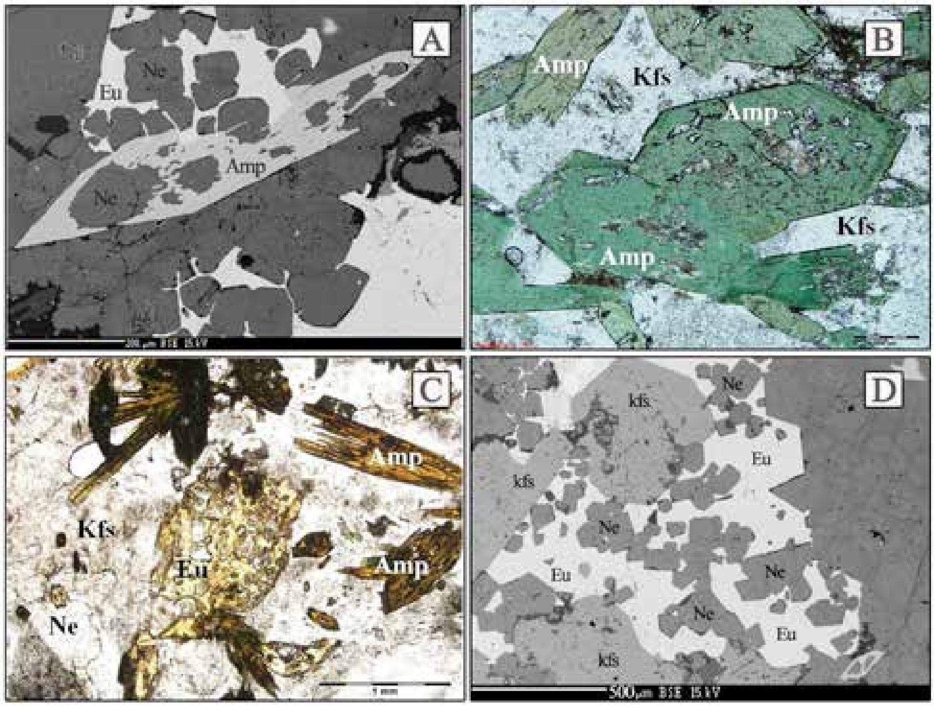
A) Preserved cell structure with inertinite cell walls with vitrinite and syngenetic pyrite cell infillings in coal petrography. (B) A radioactive mineral (coal petrography) that is possibly monazite were also detected giving rise to the elevated Thorium levels in the trace element analysis next to a pyrite and fusinite in banded vitrinite particle. (C) Epigenetic radiating carbonate mineral (most likely calcite) located within an inertinite particle (coal petrography). (D) MLA BSE and characterized pixel image of syngenetic monograinular calcite (Calcite_11) and ankerite (Calcite_10) inclusion with a dendritic growth texture in multigrainular multiphase coal (Coal_8) particle

Eudialyte-group minerals associated with lujavrites from the Pilanesberg Alkaline Complex

Sara Turnbull

The wide spectrum of minerals seen in peralkaline igneous rocks like agpaitic nepheline syenites are important repositories of large ion lithophile elements such as Na, K and Li, as well as the rare earth elements and high field strength elements such as Zr, Hf, Nb, Ta, U and Th. Magmatic, late magmatic to hydrothermal processes, or a combination of these have been invoked to account for the range of minerals seen in these agpaitic rocks.

The Mesoproterozoic Pilanesberg alkaline complex, emplaced into the Paleoproterozoic Bushveld Complex, has been reported to have occurrences of eudialyte group mineralisation (EGM). Lurie reported eudialyte as an accessory mineral in a number of the major rock types occurring within the complex. The present project aims to characterise the eudialyte mineralisation associated with lujavrites from the Pilanesberg alkaline complex. The lujavrite studied occurs as an arcuate ring-dike unit in the southern part of the complex. Metre scale mapping of the lujavrite exposures indicate a very wide range of textures and modes as a result of flow differentiation, crystal sorting and accumulation. Trachytic texture due to flow alignment of felsic and mafic phenocrysts are obvious in most of the exposures examined.

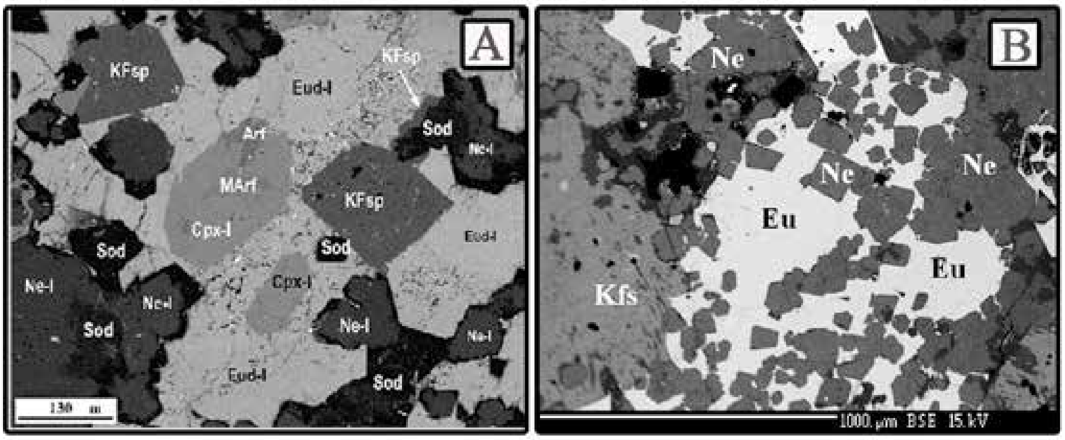


(A) Back-scattered electron image and (B) a photomicrograph in plane polarised light of euhedral amphibole grains with a poikilitic texture. (C) Photomicrograph in plane polarised light and (D) back-scattered electron image of an anhedral poikilitic eudialyte grain containing nepheline inclusions

Preliminary electron microprobe analyses (carried out at Spectrau) indicate alkali feldspar, nepheline, aegirine and amphibole as the dominant minerals in the lujavrite. Albite and sodalite rich regions occur in certain exposures. Other prominent minerals, identified so far, which occur as large crystals in some hand specimens include eudialyte, astrophyllite and fluorite.

Eudialyte is a sodium, calcium, cerium, iron, manganese, zirconium silicate hydrous silicate. Calculation of a balanced mineral formulae for eudialyte is problematic as the crystallographic structure of the mineral is quite complex and the main cations can occupy different crystallographic sites. Compilation of mineral chemical data on eudialytes from different alkaline complexes around the world indicates that there are two main groups of eudialyte, with their Mn/Fe ratio being important. The first group is rich in iron and form by magmatic processes; the second, manganese-rich EGM forms by post-magmatic or hydrothermal processes. Mitchell and Liferovich identified 3 types of eudialyte within aegirine lujavrites from the Pilanesberg alkaline complex. Backscattered electron (BSE) images as well as the

chemical data (the eudialytes are manganese-rich) indicate that all 3 types of eudialytes reported by Mitchell and Liferovich are altered, due to hydrothermal processes. The eudialyte minerals studied from the Ledig lujavrites in this study are rich in iron and show a magmatic to late-magmatic origin. The early magmatic origin of eudialytes studied here goes hand in hand with their general association with amphibole, similar to those reported from the literature. The compilation exercise using mineral chemical data shows that early magmatic eudialytes are associated with amphibole, while post-magmatic or hydrothermal ones are associated with clinopyroxene.



(a) Eudialyte grains from the green lujavrites associated with clinopyroxene (from Mitchell and Liferovich study). (b) Eudialyte grains studied from the Ledig lujavrites, poikilitic eudialyte grain containing nepheline inclusions

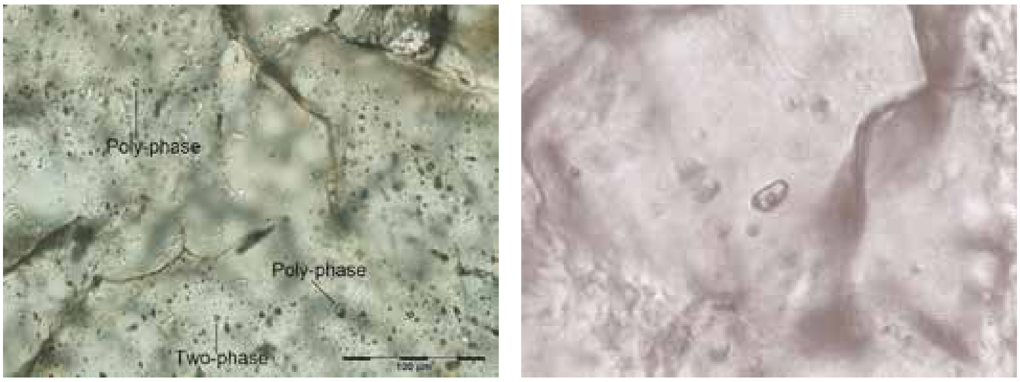
Fluid inclusions in spodumene pegmatites from the Greenlands Formation, Vredefort impact structure

Brandon Zacharopoulos, Kazuyasu Shindo

Spodumene pegmatites occur as isolated patches within amphibolites in a north-east trending shear zone in the Greenlands Formation, Vredefort impact structure. South of the shear zone, spodumene pegmatites occur as isolated patches within greenschist (dominantly actinolite-chlorite schist). Although the contact is not exposed, the spodumene pegmatites do not exhibit deformation and metamorphic fabric seen in the amphibolites, and therefore postdate the shearing event. Based on the occurrence of holmquistite (lithium amphibole) replacing hornblende, Bisschoff and Bisschoff suggested the presence of a meter-wide metasomatic aureole within the host amphibolites due to the lithium bearing fluids emanating from spodumene pegmatites.

Field photographs illustrating the spodumene pegmatite, and vein of psuedotachylitic breccia cutting across spodumene pegmatite

Fluid inclusions are good tools for understanding the physical and chemical properties of magmatic-hydrothermal fluids during crystallization of magma. Two types of fluid inclusions were found in quartz from the spodumene pegmatite. They are two-phase and poly-phase inclusions. Two-phase fluid inclusions are the most ubiquitous, and are observed as isolated and trails in quartz. Minor amount of poly-phase inclusions occurs as isolated phases, indicating that the inclusions were formed at the same time as crystallization of the host mineral. Homogenization temperatures (Th) of two-phase inclusion indicates two populations – one at ~219 °C and other between 350-400 °C. Detailed measurements on inclusions in quartz and spodumene crystals are currently underway.



Photomicrographs showing occurrence of fluid inclusions in spodumene-bearing pegmatites. Two- and poly-phase inclusions (left). Inclusion which is on the center of right photograph is isolated. Diameter of the inclusion is approximately 10 µm

Pyrite associated with gold mineralisation in the Witwatersrand Basin

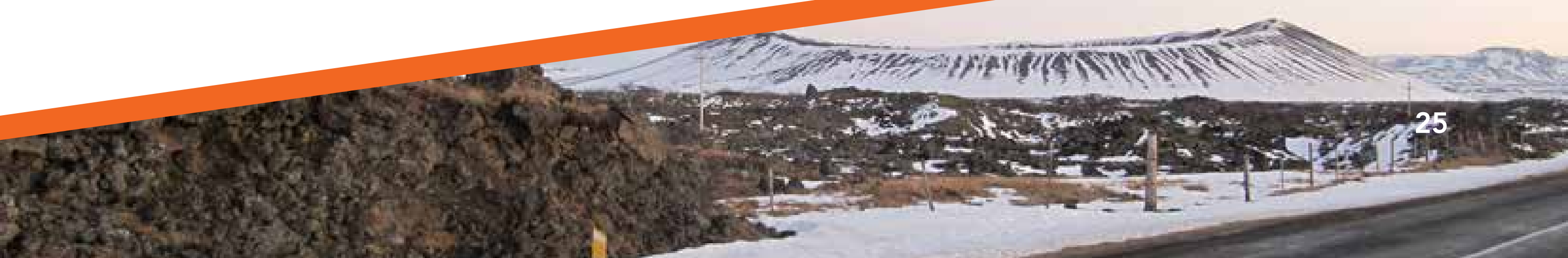
Andrea Agangi, Axel Hofmann

The metasedimentary succession of the Witwatersrand Basin, located in the Kaapvaal Craton, South Africa, hosts the largest known Au deposit in the world, with an estimated 48 000 tons of gold produced between the year of first discovery, 1886 and 2000. The Witwatersrand Basin was deposited at ~3.1 – 2.7 Ga, followed by a complex post-depositional history of metamorphism and hydrothermal activity spanning several hundreds of million years. Successive events of pyrite formation accompanied the basin evolution from sedimentation to diagenesis and metamorphism. Pyrite composition and texture are expected to reflect the widely varying conditions experienced during its long crystallisation history, and can give information on the evolution stages of the ore system.

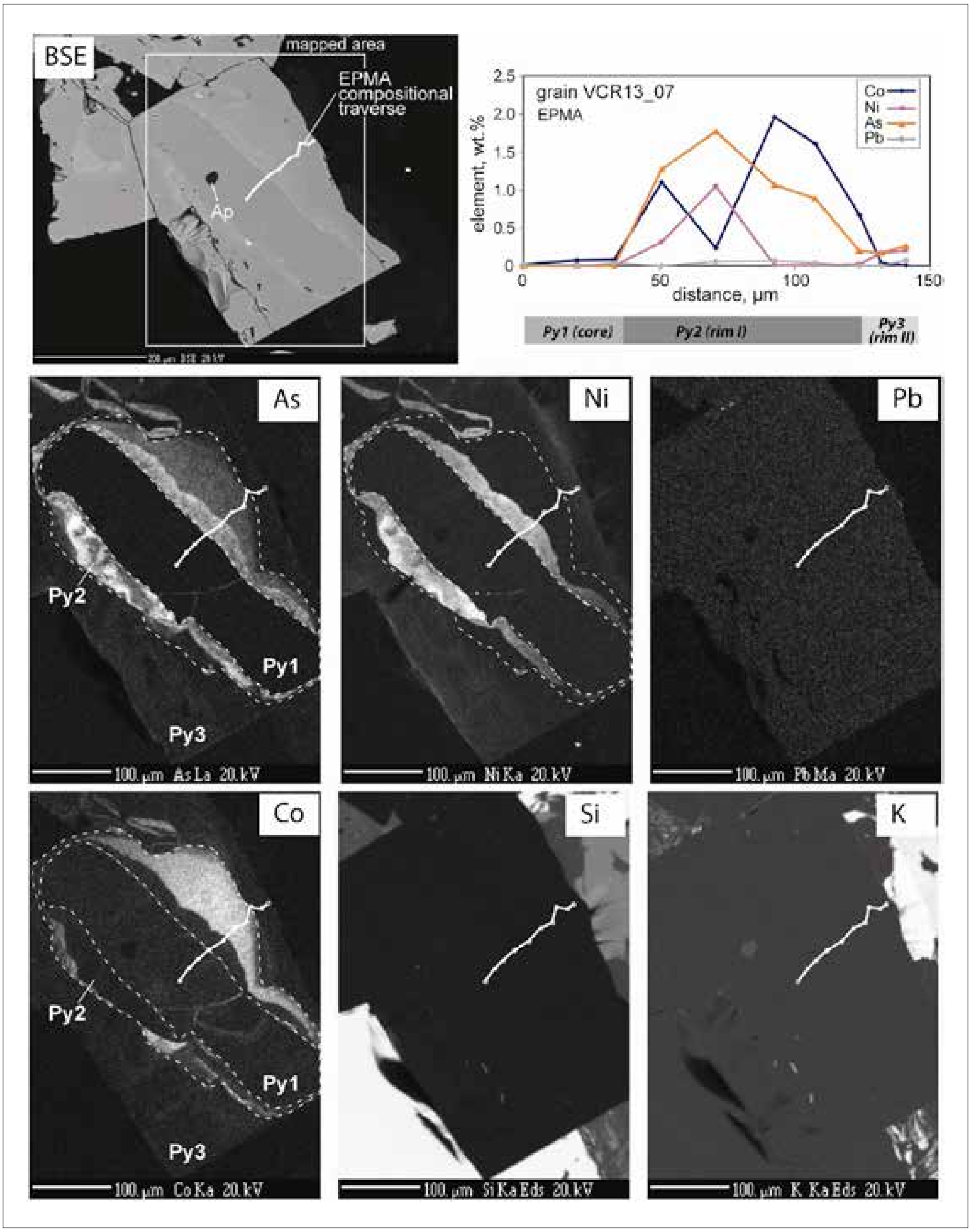
Pyrite and gold in the Witwatersrand are tightly related, and their origin has been the subject of a long-standing debate. Existing models envisage either a detrital origin for both pyrite and gold, followed by remobilisation in hydrothermal conditions ("modified placer" model), or a secondary hydrothermal introduction ("hydrothermal" model). The presence of pyrite as a detrital mineral in these deposits has also significant implications on the composition of the early atmosphere. This study includes the analysis of pyrite trace element and isotope compositions using different microanalytical techniques (X-ray mapping, laser ablation ICP-MS and ion microprobe). Different types of pyrite are being studied (compact, porous, concentrically laminated).

Trace element zoning of pyrite from the Ventersdorp Contact Reef, studied by X-ray elemental (As, Ni, Co, and Pb) maps and laser ablation ICP-MS, indicates successive stages of pyrite formation, each characterised by different textures and trace element composition. Four stages, or generations, have been distinguished: pyrite generation 1 is detrital to syn-sedimentary, generations 2 to 4 are post-depositional; generation 4 pyrite formed at near-peak metamorphic conditions for these rocks (T = 270-350°C, chlorite geothermometry).

The study of S isotopes has proven to be a powerful tool in the study of S cycle in ancient rock successions, especially since it was discovered that Archean rocks carry anomalous S isotopic ratios, which are interpreted to be the result of reactions distinctively occurring in the early atmosphere. Analysis of Fe isotopes and has been used to infer biological and abiotic processes in Archean and Phanerozoic rock successions. The study of pyrite S and Fe isotopic compositions in the VCR has identified two distinct S pools, each characterised by different values of mass-independent fractionation, a processes interpreted to derive



from ultraviolet radiation in the upper atmosphere. One S pool has Δ33S >0, and was identified in porous pyrite grains. The other pool has Δ33S <0, and was identified in concentrically laminated pyrite grains. These S reservoirs originated in the atmosphere, possibly as different S species, and were kept separate during S deposition onto the Earth's surface as gas or aerosols, until pyrite formation. Compact anhedral pyrite has Δ33S largely within the limits of mass-dependent fractionation, and might have been sourced from even another S reservoir.

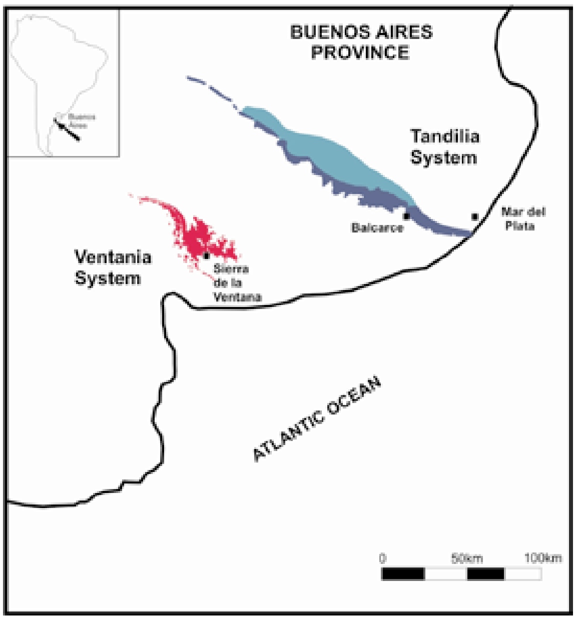


X-ray trace element maps of a pyrite grain from the Ventersdorp Contact Reef

Detrital zircon age populations and provenance of the Cape–Karoo succession in South Africa and correlatives in Argentina

Clarisa Vorster

The similarities in litho- and biostratigraphy between the rock successions in the Paleozoic Cape-Karoo basin in Southern Africa and the Sauce Grande basin in Argentina as well as the structure of the Cape and Sierra de la Ventana folded mountain belts that deformed strata of these basins along their southern margins as part of the Gondwanide tectonic terrane, have long been recognized. In order to better constrain the provenance terrains for the two basins, a comparative U/Pb age study of detrital zircon populations was undertaken using LA-ICP-MS. Arenaceous samples were collected in the southwestern Cape region of South Africa, and at Mar del Plata and the Sierre de la Ventana in Argentina. Samples came from the broadly equivalent Ordovician-Silurian Table Mountain and Curamadal Groups, Devonian Bokkeveld and Ventana Groups, uppermost Carboniferous to lowermost Permian glaciogenic Dwyka and Sauce Grande diamictites and greywackes of the lower Permian Ecca and Bonete successions.



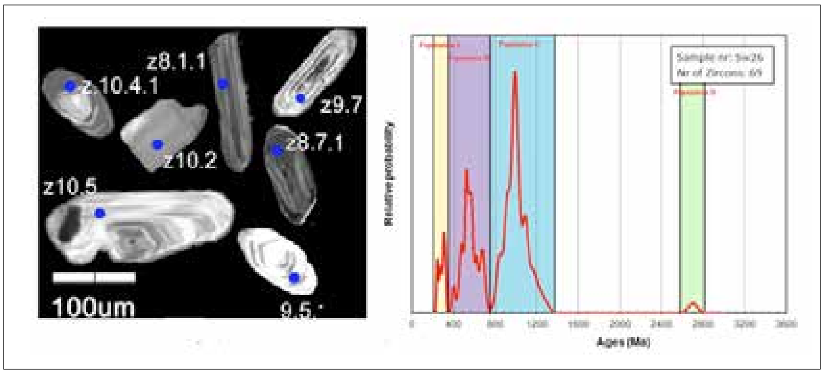
Generalized location of the Ventania and Tandilia System of Argentina, South America

Results display remarkable similarities but also important subtle diffences in detrital zircon age populations between the two basins, Most characteristic of both areas is the dominance of two major populations of zircons namely late Mesoproterozoic (1200 – 1000 Ma) and late Neoproterozoic to Cambrian (600 – 500 Ma) with perhaps a subordinate late Paleoproterozoic (1900 – 1700 Ma) population in some samples with absolute scarcity or absence of any older zircons. Apart from the glaciogenic Sauce Grande Formation in the Ventana region, all the other formations sampled in this area essentially hold only a late Neoarchean – early Phanerozoic zircon population. In contrast the samples from the western Cape in south Africa are virtually all characterized by both late Neoproterozoic – early Phanerozoic and late Mesoproterozoic age populations. Interestingly a sample of arenite from Mar del Plata along the west coast of Argentina also displays the two major zircon age populations that are characteristic of the correlative Table Mountain arenites in the western Cape. Results indicate that the successions in the Western Cape and eastern part of the Sauce Grande basin were mainly sourced from late Neoproterozoic Pan African/Brasiliano and late Mesoproterozoic Namaqua-Natal metamorphic belts. Rocks in the Ventana area, however, were essentially sourced from Brasiliano terranes. A prominent early Permian zircon population is present in the Bonete Formation of the Ventana region suggesting transport from a juvenile source to the south in the Gondwanide orogen.

Provenance of the KaNyaka Island system as determined by U/Pb dating of detrital zircons using LA-ICP-MS

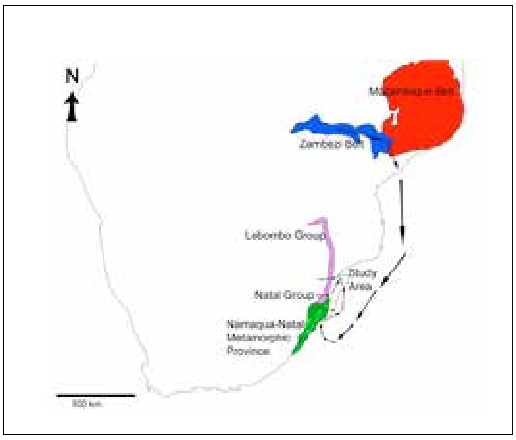
Marieke Peché

The KaNyaka Island System is an extension of the coastal dune cordon which separates the Mozambique coastal plain from the Indian Ocean. The aim of this study was to determine the main source of sediment in this area. This would help in understanding the dispersal of sediment along the South East African coast. Therefore a provenance study was done on samples taken from various ancient dune systems and some of the modern sedimentary environments of the KaNyaka Island system. The method used for this study was U/Pb dating of detrital zircons using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). A ThermoFisher X-SeriesII ICP-MS, equipped with a New Wave UP-213 Nd:YAG laser ablation system based at UJ was used.



Cathodoluminescence images of some of the zircons analysed and a probability density diagram constructed for the detrital zircon grains analysed for one of the ancient dune systems. It shows three age populations of different sizes namely: 220 to 360 Ma, 400 to 750 Ma and 800 to 1300 Ma, with a single grain with an age of 2700 Ma

The results showed that there are no significant variations in the age populations of the detrital zircons between the different samples analysed. This suggests that the source area for the sediment did not change significantly during the evolution of the KaNyaka Island system and also that a large amount of sediment of the island system is derived from cannibalism of the older formations of KaNyaka Island itself. The majority of the detrital zircons had U/Pb ages which fell in the Neoproterozoic and Mesoproterozoic eras, which co-inside with the Grenvillian and Pan-African metamorphic events. Regions with geology of these ages occur in the Natal sector of the Namaqua-Natal Metamorphic Province situated south of the study area and the Mozambique- and Zambezi Belts, situated north of the study area. This suggests that the majority of the sediment which built up the KaNyaka Island system was transported to the area by the south flowing Agulhas current and the north flowing longshore current. A small amount of zircons did though yield ages equivalent to that of the Lebombo Group and a few ancient grains with ages of that of the Barberton greenstone belt and the Limpopo metamorphic terrain are also present. Areas where these geological units are present are all situated in the drainage areas of the rivers feeding into Maputo Bay. Since these zircons make up less than 10% of the total detrital zircons for which ages were produced it can be assumed that the sediment from these rivers contribute only a minimal amount of sediment to the KaNyaka Island system.



Probable provenance areas for the detrital zircons of the KaNyaka Island system

Petrology, petrography and geochemistry of anomalous boreholes core sequences in the Highveld coalfield: A case study for diatreme activity

Byron Van Der Walt

A study of three anomalous borehole core sequences from the north eastern Karoo Basin was conducted. The boreholes are located up to 30 km from each other and are lithostratigraphically completely atypical for the Vryheid Formation, Ecca Group, Karoo Supergroup. The lithologies of the three boreholes are intensely brecciated for the most part, while all of the surrounding boreholes reveal normal stratigraphy their sedimentary strata are normally horizontal with no faulting present. The only disturbances in the study area are the occurrence of intrusive mafic dolerite sills and dykes, which are known to have been contemporaneous with and immediately following the eruption of the Drakensburg Group basaltic lavas.

The borehole core lithologies are described in the study with reference to their textural, mineralogical and petrographic characteristics. All breccia clasts present within the sequences, are locally derived sedimentary rocks or dolerite fragments; the abundance, type, size and distribution of breccia clasts is inconsistent, but all are angular and randomly orientated. The clast-supporting breccia matrix consists of angular to sub-angular grains of (but not restricted to) quartz with medium-to-low sphericity, microcline, muscovite and carbonaceous materials, all cemented with calcite. Grain sizes vary greatly and most grains show moderate to intense fracturing; the fractures are often filled with calcite. Sediment dominated breccia occurs within 'vein-like' features throughout certain and have same characteristics and composition as that of the general clast-supporting breccia matrix; they crosscut and offset host sedimentary rock laminations, implying the 'intrusion' of breccia into the host.

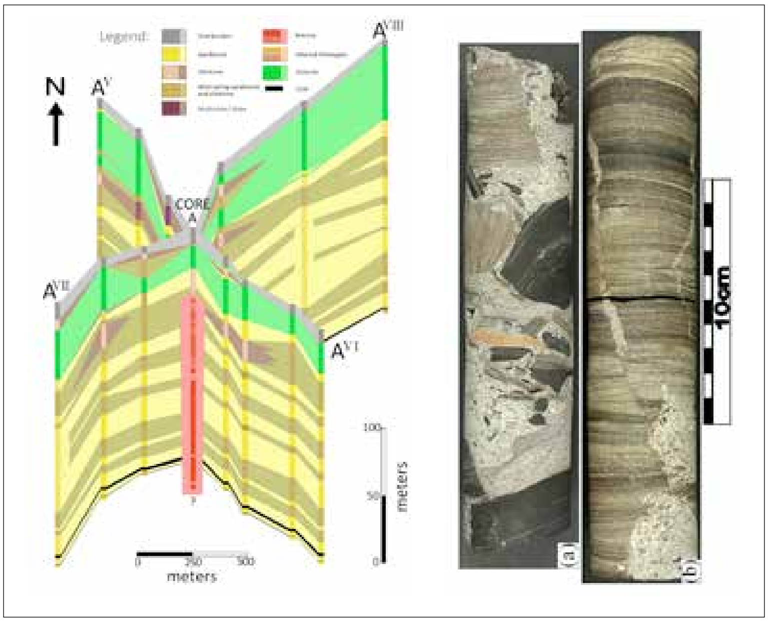


Figure (left) - Fence diagram around a brecciated core sequence from the study. The horizontal scale refers to distance between boreholes, whereas the vertical scale refers to core depth. Figure (right) - Typical examples of core from the brecciated borehole core sequences as referred to in the text (a) A breccia sample with large clasts , (b) brecciated cross-laminated sandstone

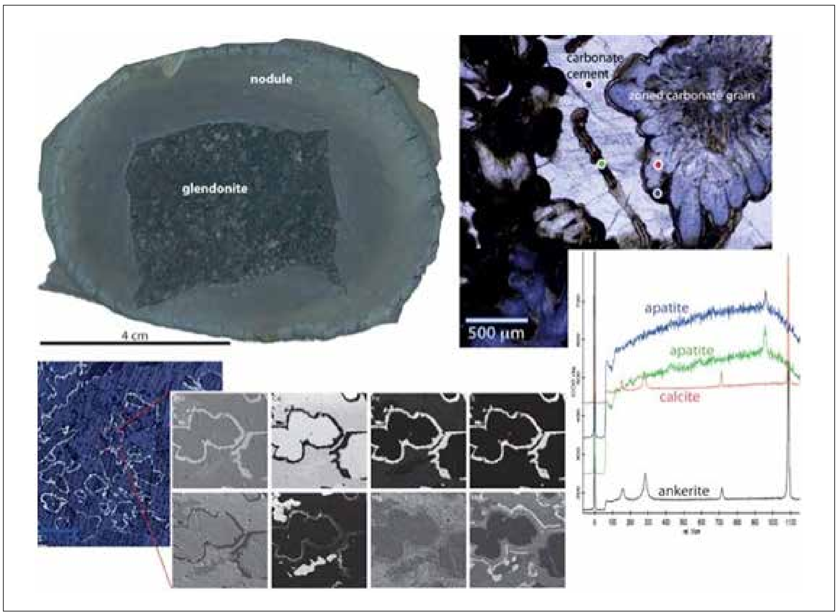
Mineral chemical, geochemical and stable isotope data was obtained for comparisons between altered and unaltered samples. Of particular interest is the alteration of dolerite fragments present in the breccia's relative to samples from an un-deformed, normal core sequence. Altered dolerites have variable amounts of sericite and chlorite (after plagioclase and pyroxene); iddingsitic olivine occurs in minor amounts in addition to calcite and rare epidote occurring in micro-fractures; reddish-brown discolouration of dolerite fragments is due to the oxidation of iron.

The isolated occurrences, lithologies, petrography, alteration, mineral chemistry and geochemistry of the sequences are used in the study to argue that the Vryheid Formation, intersected in the form of the three anomalous boreholes, was disturbed by diatreme activity, genetically related to the late dolerite sill emplacement into the Karoo Supergroup rocks.

Geobiology of African hydrocarbon paleoseeps

Barbara Cavalazzi

An understanding of the relationship between biosphere and geosphere may rely on the ability to decipher evidence of life preserved in the rock record. The relationships between microorganisms, in particular prokaryotes, and their environment are an important example of these interactions, resulting in differentiated and widely distributed microbial sediments and mineralization. Thus recognizing evidences of microbial activities, biosignatures, in rock record remains a central challenge in geobiology studies, and a possible tool in prospecting. Surface prospecting for hydrocarbons includes different techniques ranging from the direct detection of hydrocarbons escaping from subsurface accumulations and source beds to identifying secondary responses in the soils, rocks and biota in the closed proximity to such accumulations or source beds. Hydrocarbon seep-related deposits are now known to be common in different geological settings and ages, and teeming with life based on chemosynthetic microbial symbiosis, and typified by depleted 13C Ca-Mg-carbonate deposits. However, the geologic record of hydrocarbon-seeps is still fragmentary for reasons that remain unclear. Paleoseeps are rarely recorded in Precambrian and Paleozoic strata as well as most of the ancient seeps have been described in Africa. The focus of my research is to investigate the nature of features and biosignatures of know and potential fossil hydrocarbon seep deposits in Africa. The geological sites investigate in this project are Paleozoic hydrocarbon-related carbonates in Africa geologic scenarios (Morocco and South Africa).



Glendonites from the top strata of Dwyka Group show a granular internal fabric with concentrically zoned Ca-carbonate grains lined by carbonaceous matter-rich phosphate and Mn-Fe-rich rims, cemented by Fe-rich carbonate and pyrite. The zoned calcite grains represent the ikaite replacement phase. The presence of pyrite in the pore space suggests microbially mediated methane oxidations via sulphate reduction. Their high $\delta^{18}O$ and depleted $\delta^{13}C$ values suggest an early diagenetic phase that forms in the zone of suboxic diagenesis in organic matter (OM) rich sediments, and possibly associated to potential hydrocarbon seepage

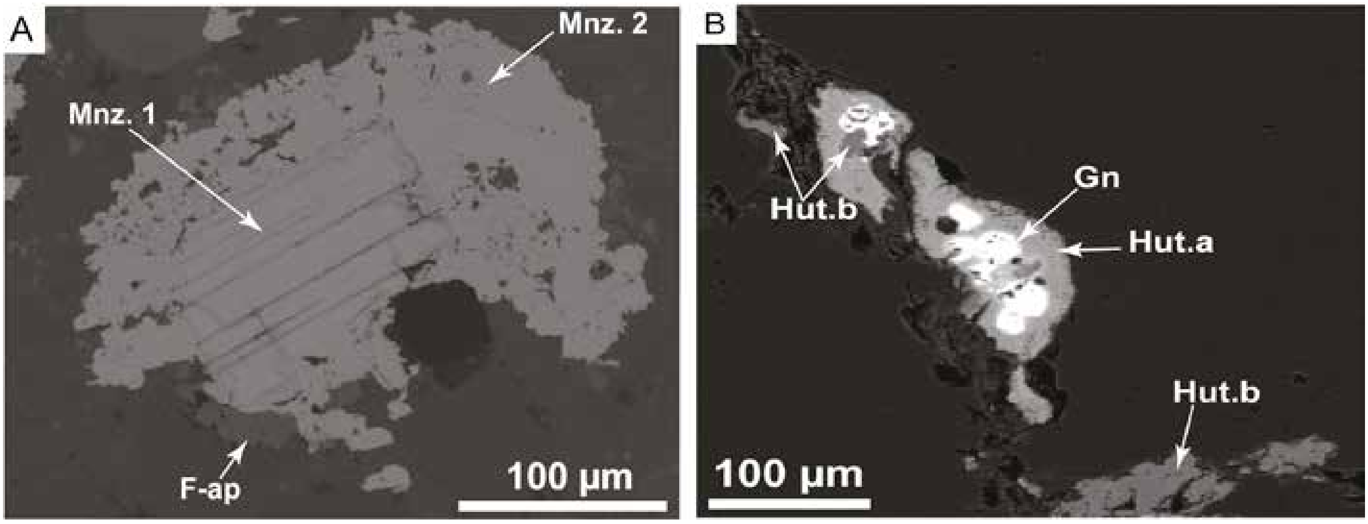
To date, any hydrocarbon paleoseeps deposits have been described in South Africa. However, the presence of seep-related carbonates from the Namibian glaciomarine Dwyka Group likely suggests potential hydrocarbon seepage during Late Carboniferous deglaciation in the Karoo Basin. New mineralogical, petrographic, geochemical (SEM-EDX, EMPA, Raman, XRD, C-O stable isotope) data of nodules with glendonite collected at the top of Late Carboniferous glaciomarine strata of Dwyka Group, Great Karoo Basin, South Africa, and field evidences also support the hypothesis of a hydrocarbon/methane release associated to dissociation of clathrate hydrate during the deglaciation. Glendonite is the pseudomorph after Ikaite (Ca-carbonate hexaydrate), a metastable carbonate that only forms in specific environmental condition such as near-freezing temperatures, high alkalinity, elevated orthophosphate, and in presence of hydrocarbon/methane-dominated vent and anaerobic decomposition of methane during the early stage venting.

Authigenic minerals as mineralogical markers for the thermal history and spatial-temporal distribution of U-bearing sedimentary units of the Francevillian Group, southeastern Gabon

Frantz Ossa Ossa

Some decades ago, in the U deposits of the Paleoproterozoic Franceville Basin (southeastern Gabon), nuclear events previously unknown to have occurred in a natural environment have been revealed to the world. Indeed, these deposits are the only known case where nuclear fission reactions have occurred in nature ca. 1950 m.y ago. Sixteen natural nuclear reactors have been described between Oklo and Bangombé. The Franceville Basin consists of five formations from FA to FE. U mineralization and natural nuclear reactors are located in the upper deltaic part of the FA Formation. The thermal history of the sedimentary succession and the spatial-temporal distribution of U enrichment at the scale of the Franceville Basin are still poorly understood.

The U mineralization is interpreted to have formed as a result of leaching of U-bearing detrital minerals, such as monazite and zircon, followed by precipitation along redox-boundaries between the FA and FB formations. In some cases, dissolution of detrital monazite is followed by the formation of secondary monazite, fluorapatite, huttonite and galena. Present as overgrowths around detrital monazite, the paragenesis of secondary monazite and fluorapatite illustrates a mineral transformation process as usually observed in hydrothermal settings. Additionally, clay mineral composition characterized by berthierine and chamosite-berthierine mixed layers have been observed in association with secondary monazite as fracture fillings and feldspar replacements only in the upper part of the FA Formation. Estimates of crystallization temperatures of these clay minerals indicate values up to 300 °C consistent with a hydrothermal setting. These mineral assemblages might be used as markers to illustrate past hydrothermal activity in the FA Formation across the Franceville Basin. Hydrothermal alteration played a major role in the leaching of U-bearing detrital minerals, which allowed the release of significant quantities of U into the Franceville Basin. Further, the observation of berthierine and chamosite-berthierine mixed layers in the upper FA Formation may help to better illustrate the spatial and temporal distribution of sedimentary units associated with ore bodies.



A: Backscattered electron photomicrograph of detrital monazite (Mnz. 1) showing overgrowth of secondary monazite (Mnz. 2) and fluor-apatite; B: Backscattered electron photomicrographs of secondary Th-silicate phase, La-poor huttonite (Hut.a) and La-rich huttonite (Hut.b); and Galena (Gn)

Significance of the presence of stilpnomelane in iron formations of the Transvaal Supergroup

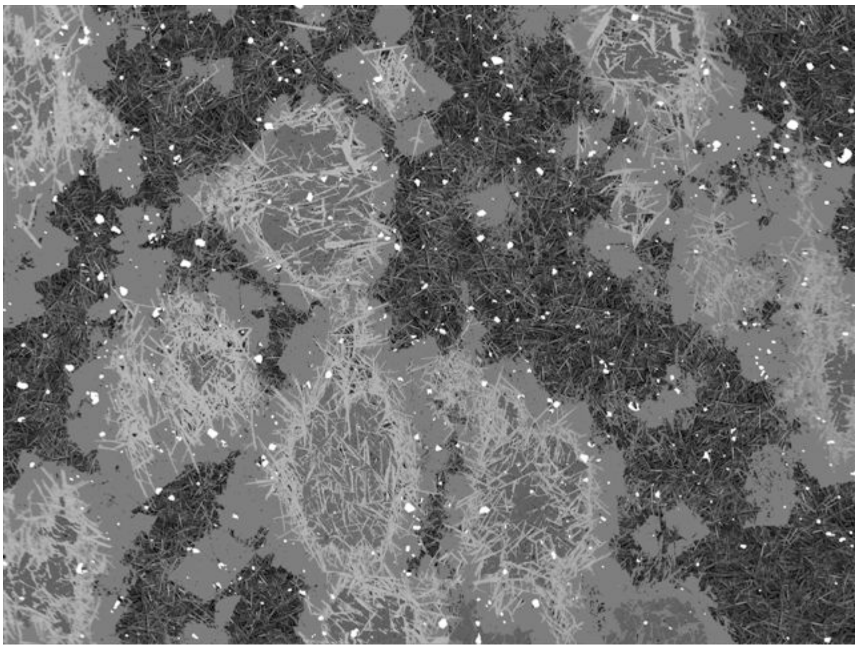
Fanie Kruger

Stilpnomelane is an important index mineral in the paragenetic sequence in low grade metamorphism of iron formations. It is generally found with chlorite, muscovite and albite in greenschists (e.g. western Otago, New Zealand), but also together with magnetite as a major constituent of silicate iron formations, e.g. Mesabi Range, Minnesota, and Hamersley. This mineral was also found in the iron formations of the Postmasburg Group in the Kalahari region.

The major minerals in all four samples are usually quartz, with less chlorite and stilpnomelane. This mineral is more common than generally expected as it occurs dispersed in the silica and carbonate matrix of certain iron bearing rock types. It is only in concretionary masses where visible macroscopical occurrences of stilpnomelane were found.

The mineral chemistry of this iron silicate, as well as that of chlorite, was determined by means of electron microprobe analyses. The hosts material, namely ankerite and silica, were also chemically characterized. By means of this information and the mineral relationships observed by electron beam examination, the paragenetic sequence of mineralization of the bore-hole specimens could be deciphered up to a sub-microscopic scale.

The paragenetic sequence can probably be described in general terms as follows: Chemical sedimentation started with the accumulation of silica. Fe appeared to be abundantly available, magnetite crystallized first, visible as small idiomorphic crystals. Thereafter Fe-silicates started to crystallize, and depending on the cation abundance and variety present, either a first generation of stilpnomelane or chlorite formed in the silica matrix. A change in chemical conditions caused the precipitation of ankerite as primary carbonate in the silica matrix. This was followed by the development of a secondary growth of ankerite as a corona on the primary ankerite. Lastly, a second generation of stilpnomelane formed. These acicular crystals are much larger than those in the silica matrix and occur mainly in the secondary ankerite, but growth extends beyond this carbonate into the primary ankerite, and even into the silica matrix.



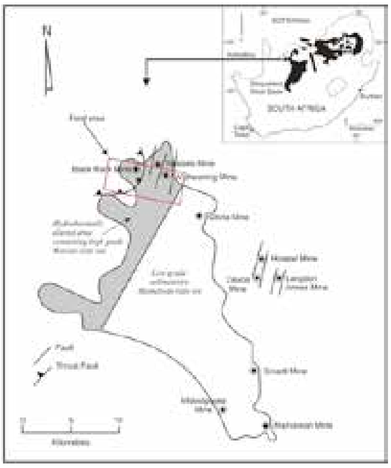
Backscatter image displaying the different modes of occurrence of stilpnomelane in three matrix materials

The Hotazel iron ores: Oxygen isotope geochemistry

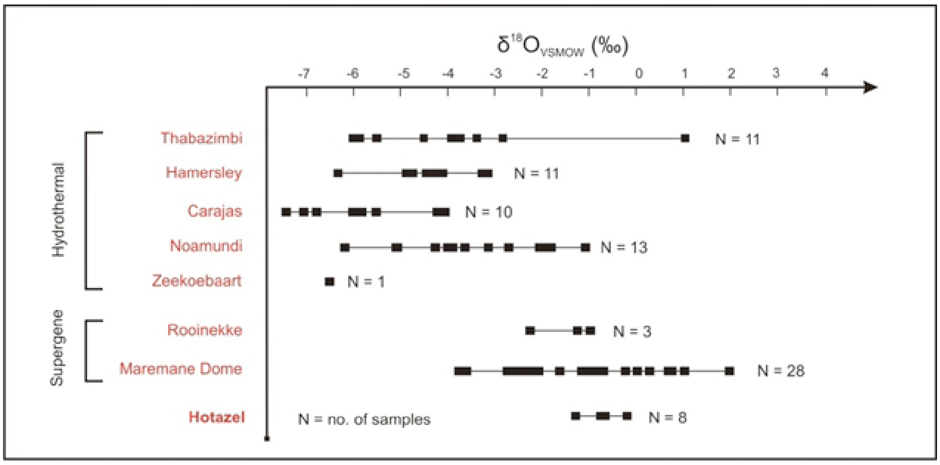
Benny Chisonga

The Hotazel Formation, in the Kalahari Manganese Field, is characterized by alternating succession of banded iron formation and manganese bearing units, both resting conformably on andesitic Ongeluk lava. A medium – high grade iron ore unit (35 ~ 60 wt% Fe), which is at most a few meters thick, is consistently developed over a wide area in the Kalahari Manganese Field where the pre-Mapedi erosional unconformity intersects the Hotazel Formation. The unit occurs both as laminated and massive ore as well as in places, poorly sorted conglomeratic hematite ore.

The oxygen isotope signatures (δ18O) of hematite ores from the Hotazel Formation were studied with the objective of establishing the processes occurring during ore formation. The samples were dominated by microplaty hematite whereas the remaining two samples had martite in addition to microplaty hematite. The results show that the δ18O composition of both microplaty hematite and martite to hematite from the Hotazel Formation range, narrowly, from -0.6‰ to -1.4‰. Gutzmer et al provided a detailed assessment of the δ18O composition of some of the major BIF-hosted high-grade hematite to martite deposits of the world. Netshiozwi used fluid inclusion studies to characterize the Thabazimbi deposit as hydrothermal in origin. Thus, the δ18O composition obtained for co-genetic hematite and carbonates should be viewed as an indicator that those iron ores are products of hydrothermal enrichment. Therefore, to attach a genetic meaning to the values obtained for the Hotazel iron ores, they were compared to other high- grade deposits whose geneses are better constrained.



Map showing drill cores sampled from the Kalahari Manganese Field



δ18OSMOW signatures of hematite from the Hotazel Formation

The deposits presumed to be hydrothermal in origin have a δ18O composition in the range +1‰ to -7.3‰ while those that have been subjected to supergene enrichment range variably between +2.3‰ and -4.1‰. Also within the same deposit districts there seems to be minor but consistent variation in δ18O composition depending on the textural – type of hematite, which was analyzed. The samples in the present study plot close to Supergene derived iron ores, such as those at Sishen on the Maremane Dome.

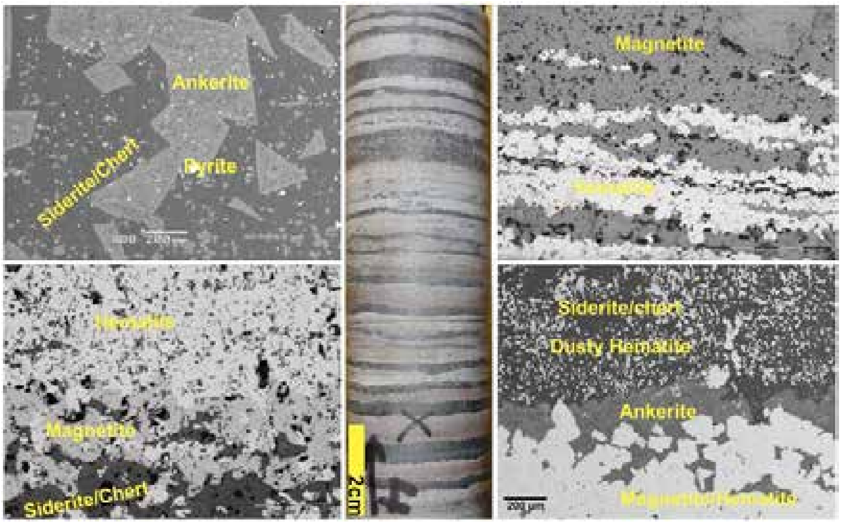
Gutzmer et al.'s evaluation of the δ18O composition of high-grade hematite ores provided constraints within which high-grade iron ore deposits of unknown age could be categorized. However, the major drawback of the evaluation by Gutzmer et al. is that there is considerable overlap for δ18O values of different deposit districts. The data obtained for the Thabazimbi deposit show depletion of up to -7.3‰ δ18O values while that for the Maremane Dome ores only reaches -3.9‰. The narrow range of δ18O values obtained for the Hotazel iron ores would fall within range of supergene-enriched iron ores more so than hydrothermal deposits. It is concluded, therefore, that the δ18O values in general point to a supergene enrichment process that has experienced minimum hydrothermal alteration. This confirms the earlier interpretations that the 2200 Ma supergene enrichment is associated with the Mapedi unconformity, with later hydrothermal alteration along normal faults at circa 1100 Ma.

Beneficiation potential of unmineralized Kuruman Iron Formation to produce saleable iron ore

JC Beyeme Zogo

The Early Paleoproterozoic Kuruman Iron Formation of the Asbestos Hills Subgroup, Transvaal Supergroup, is one of the giant iron formation successions of the world reaching a thickness up to 750 m and outcropping over a distance of more than 550 km along strike in Griqualand West Basin. The succession comprises of interbedded stilpnomelane lutite, sideritic chert, iron carbonate, greenalite, mixed iron carbonate-magnetite and magnetite-hematite facies iron formation. Of these the latter two facies could possibly be considered a potential source of iron if they could be upgraded by beneficiation to saleable ore with an iron metal content of more than 58 percent. In order to evaluate the potential of the two facies for producing a saleable ore product their physical, mineralogical and geochemical properties were studied. Apart from petrographic descriptions, emphasis was on determining thicknesses of iron-rich versus chert-rich mesobands, density measurements and whole-rock chemical analyses of different types of mesobands.

Four drill cores were studied to determine the physical and geochemical properties of the of the banded iron formation. Results indicated that iron-rich mesobands bands are commonly 1 to 10 mm thick and comprises of microbanded ferhythmite made up of finely alternating magnetite, hematite and chert ± iron carbonate (siderite and ankerite) microbands. In contrast chert-rich mesobands appear massive to microbanded with the latter commonly composed of iron carbonate in the case of mixed iron carbonate-magnetite facies iron formation and hematite plus magnetite in oxide facies iron formation.

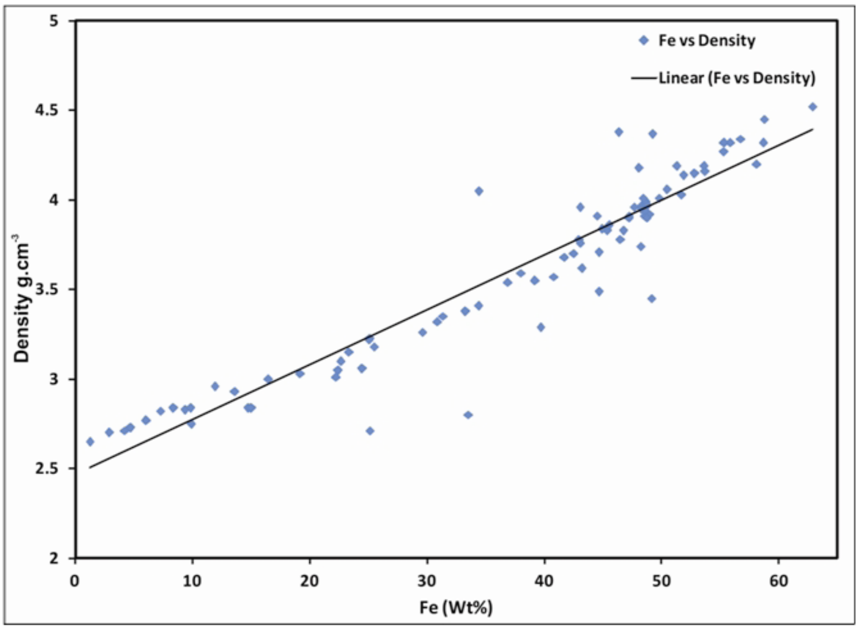


Example of magnetite-hematite facies iron formation in the middle with microphotographs on the left describing chert-siderite-ankerite (top) and magnetite-hematite (bottom) mesobands and on the right magnetite-hematite (top) and ankerite along the contact between chert and magnetite (bottom) mesobands

Table - Characteristics of individual bands of the Kuruman Banded Iron Formations

Mesobands	SiO2 (Wt. %)			Fe2O3 (Wt. %)			Density		
	Av.	Min	Max	Av.	Min	Max	Av.	Min	Max
Chert-rich	68.69	51.23	90.77	21.93	1.81	44.79	2.95	2.65	3.35
Magnetite-hematite	23.97	3.59	43.73	68.07	47.49	89.84	3.92	3.38	4.52
Fe-carbonate-magnetite	50.55	25.96	70.42	29.37	8.6	64.79	3.05	2.71	3.83

Densities of the different types of mesobands vary from an average of 2,95 for chert-rich mesobands to 3,05 for iron carbonate-magnetite mesobands and 3,92 for magnetite-hematite mesobands. This implies that the various types of mesobands could be separated by dense media metallurgical processes if the iron formation was to be crushed to sufficient fineness of between 1-10 mm. However, the chemical compositions of individual mesobands, even the most dense hematite-magnetite mesobands, seldom if at all reach iron metal grades of more than 60 wt % (see diagram of density versus iron contents).



Correlation between density and iron metal contents of a range of mesobands in the Kuruman Iron Formation

Paleomagnetic constraints from the Uitkomst Complex: Implications for the timing of intrusion

Herwe Wabo, Michiel de Kock

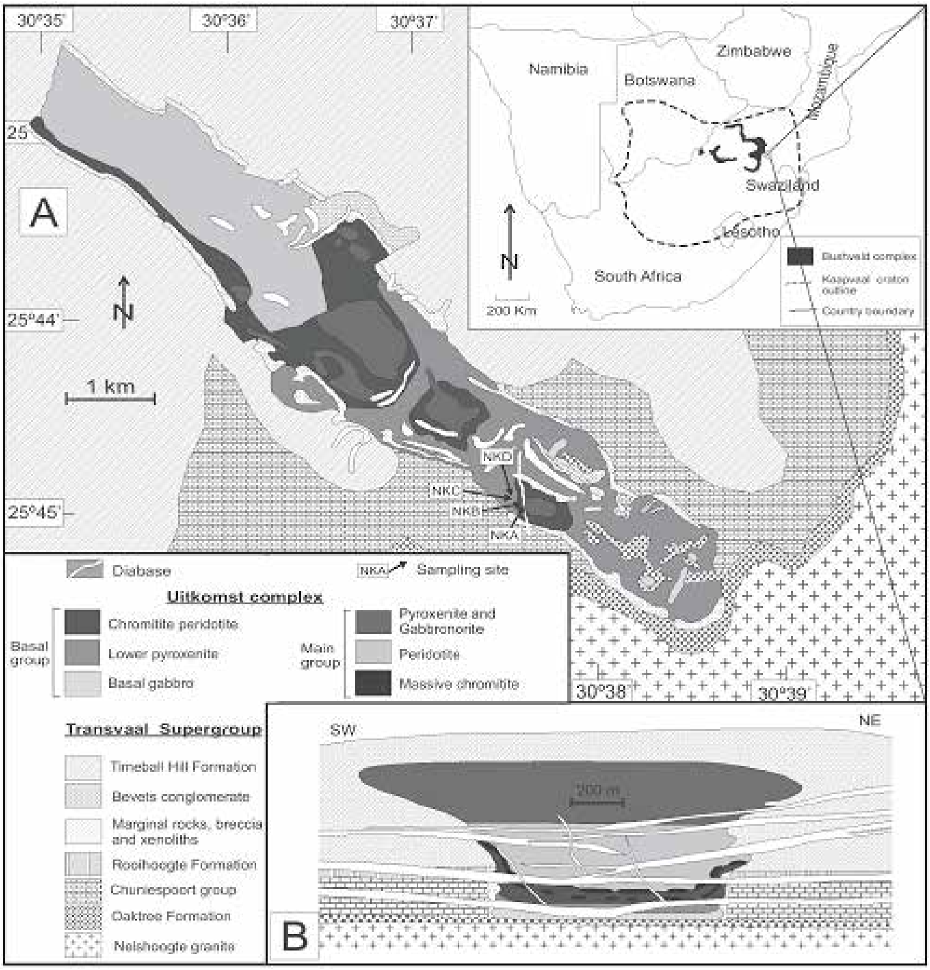
The Uitkomst Complex occurs 70 km to the SE of the eastern limb of the Bushveld Complex in the escarpment area of the Mpumalanga Province (South Africa). The accepted age for this intrusion is the 2044 ± 8 Ma 207Pb/206Pb zircon age of De Waal et al, who suggested a temporal link with the Rustenburg Layered Suite of the Bushveld Complex (at the time dated at 2054+1.6-1.1 Ma). When compared with recent geochronological constraints from the Bushveld Complex, the Uitkomst Complex at worst to have intruded at least six million years after, and at best immediately after the emplacement of the Rustenburg Layered Suite. Here, we report paleomagnetic results from the Basal group of the Uitkomst complex in support of post-Rustenburg Layered Suite emplacement.

We sampled the Basal Group of the Uitkomst Complex and a younger cross-cutting dyke within pit 2 of the Nkomati Mine. A total of 21 oriented cores s were drilled from the Lower Pyroxenite (NKC and NKD) and Chromatitic Peridotite (NKB) units. Five additional oriented cores and one sample for geochemistry were collected from the north-south trending dyke (site NKA). For the samples from the Basal Group of the Uitkomst Complex (NKB, C and D), demagnetization steps above 400°C reveal the existence of north-east and down oriented high-temperature magnetic component. Further demagnetization generally gives way to unstable demagnetization behaviour between 560°C-580°C as specimen intensity drops below the noise level of the sample handler. The dyke samples demagnetized clearly towards the origin via linear demagnetization trajectories between ~350°C and 585°C. These higher stability components are all northerly and downward directed.

In terms of geochemistry, the dyke sample falls at the high end of the Mg# range reported for different high-Ti Uitkomst Complex rocks. Like the high Na2O contents of the high-Ti Uitkomst Complex rocks, the dyke sample also

has high Na_2O content, thereby falling in the trachybasalt field in the TAS plot. The high Fe_2O_3t content attests a tholeiitic affinity to the rock in the AFM plot. The different major and trace element contents of the dyke sample, like high Na_2O, Fe_2O_3t, TiO_2, CaO, V and low Cr, Ni, clearly indicates its similarity to the high-Ti Uitkomst Complex rocks.

The combined Basal group and dyke pole Uitkomst Complex appears to be distinct from the ~2060 Ma Phalaborwa Complex pole and the 2058 to 2054 Ma Rustenburg Layered Suite poleby Letts et al. Our Uitkomst pole does, generally, shares similarities with the 2054 ± 3.5 Ma lower Waterberg Group pole and to a lesser extent the 2023 ± 4 Ma combined Vredefort impact pole. Additionally, the Uitkomst pole does not fall near the 1.93-1.87 Ga apparent polar wander path of the Kaapvaal craton. This suggests that the Uitkomst Complex was emplaced after the Rustenburg Layered Suite but before the events of ~1.93 Ga to ~1.87 Ga. The above results have allowed us to propose a new conceptual model for the timing of the intrusion of the Uitkomst complex. This observation is in line with the $^{207}Pb/^{206}Pb$ zircon constraints, and suggests a small, but significant shift between 2060 and 2044 Ma poles in the Orosirian apparent polar wander path of the Kaapvaal craton. This result necessitates the proposal of a new conceptual model for the timing of the intrusion of the Uitkomst complex.



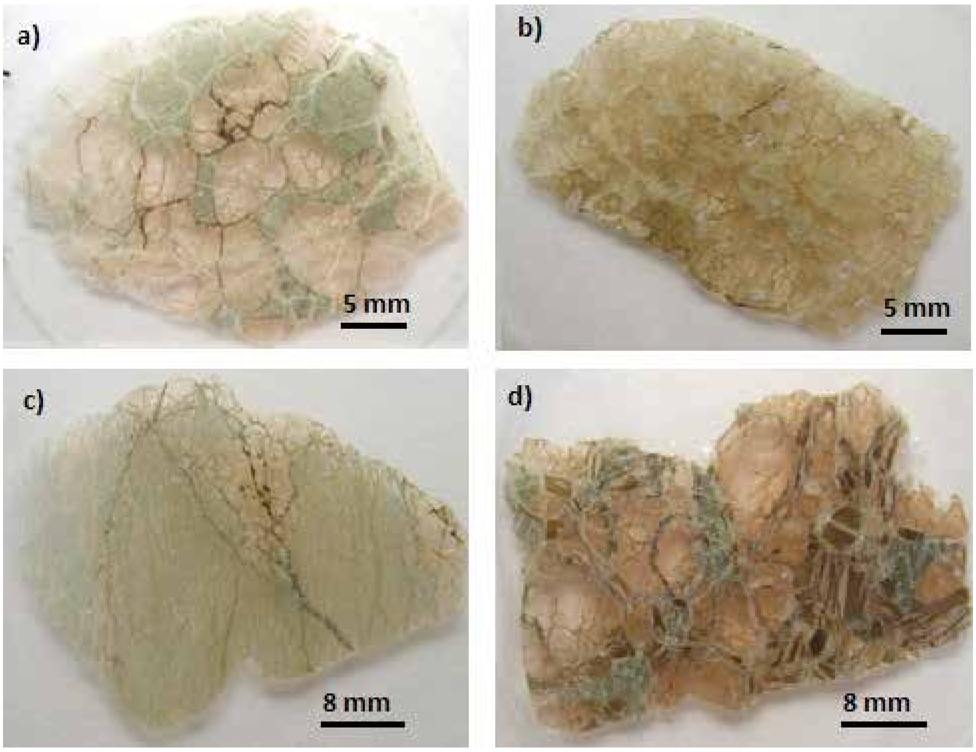
Geological map (A) and N-W oriented cross-section (B) of the Uitkomst complex showing the different sampling sites

Petrology of a mantle-derived eclogite xenolith suite from the Balmoral kimberlite, Kimberley region

Thandikhaya Mxinwa

High pressure eclogite xenoliths are commonly encountered in kimberlite pipes on the Kaapvaal craton, and may be diamond – bearing. Although eclogite xenoliths are comparatively less abundant than peridotite xenoliths, diamond – bearing eclogites, by contrast, are comparatively abundant relative to diamond-bearing peridotite xenoliths, and have been recorded from several kimberlite diatremes.

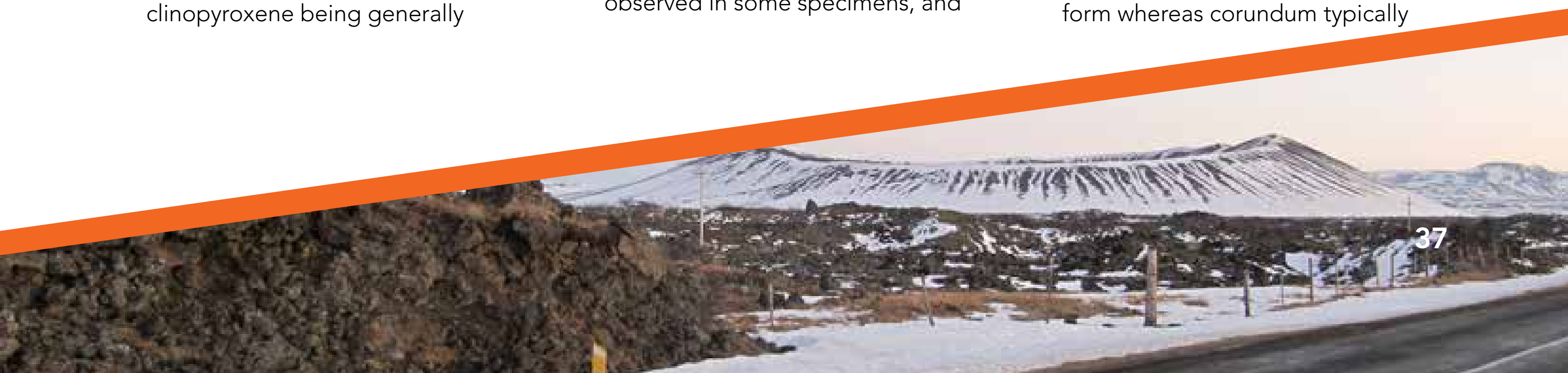
A total of 85 eclogite xenoliths (with diameter sizes of ±2cm), collected at Balmoral kimberlite, were investigated in this study. None of these are diamond-bearing. Based on geochemical characteristics (all mineral phases in these eclogites were analysed by electron microprobe) the studied eclogites are classified as group II eclogites, with Na_2OGrt and K_2OCpx <0.09 wt.% and <0.08 wt.%, respectively. These typically (world-wide) have a texture consisting of irregular anhedral to straight-edged garnet and clinopyroxene with a tightly interlocking fabric, contrasting with a texture for Group I eclogites comprising rounded garnets set in a matrix of clinoypyroxene. Texturally the bimineralic eclogites at Balmoral are poorly defined as Group I or Group II, and are best described as having an 'intermediate' texture.



Photographs of polished examples of eclogites from the Balmoral kimberlite: (a) bimineralic eclogite with brownish-pink garnet and green clinopyroxene (b) corundum-bearing eclogite with brown garnet, pale green clinopyroxene and pale purple corundum (c) exsolution lamellae of garnet in clinopyroxene (d) dark brown mica in a bimineralic eclogite

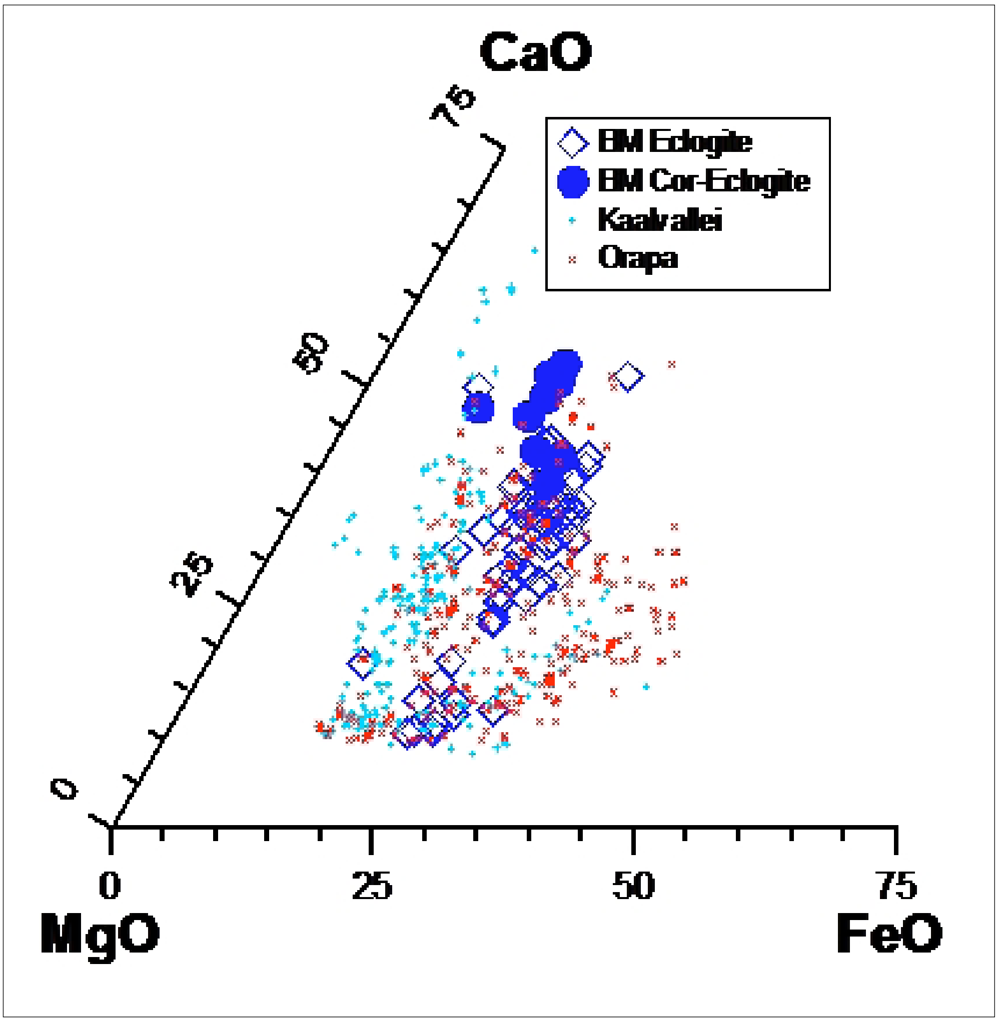
The eclogite xenoliths from Balmoral were subdivided into 2 groups, being bimineralic eclogites and corundum-bearing eclogites.

- Bimineralic eclogites are the most abundant eclogitic rocks that occur at the Balmoral kimberlite pipe. Most of this type of eclogite exhibit alteration to varying degrees with clinopyroxene being generally more altered than garnet. Although garnet and clinopyroxene are the main phases present in these rocks, mica (phlogopite) is also observed as an accessory phase (and is often altered). This occurs mainly within clinopyroxene along cleavage plains and fractures. Exsolution lamellae of garnet within clinopyroxene are observed in some specimens, and are likely a consequence of cooling from higher initial temperatures of crystallisation to ambient mantle temperature, during which garnet exsolved from clinopyroxene.
- Corundum-bearing eclogites constitute about 9% of the eclogite xenolith suite investigated. Garnet and clinopyroxene are irregular in form whereas corundum typically



occur as elongate, lath shaped grains. Clinopyroxene is always highly altered and satisfactory microprobe analyses were never obtained. Garnet, and corundum, is usually fresh to partially altered.

The chemistry of the garnets in the eclogites from Balmoral comprise two groupings on a Ca-Mg-Fe diagram (Figure 2), with a high-Ca suite and a lower-Ca suite. These garnet compositions are typical of eclogite xenoliths world-wide, although Fe-contents are somewhat lower e.g. relative to some of the eclogites from the Kaalvallei kimberlite in South Africa and the Orapa kimberlite in Botswana.



CaO-FeO-MgO ternary diagram illustrating the compositions of garnets in eclogites from the Balmoral, Kaalvallei and Orapa kimberlite pipes. BM=Balmoral

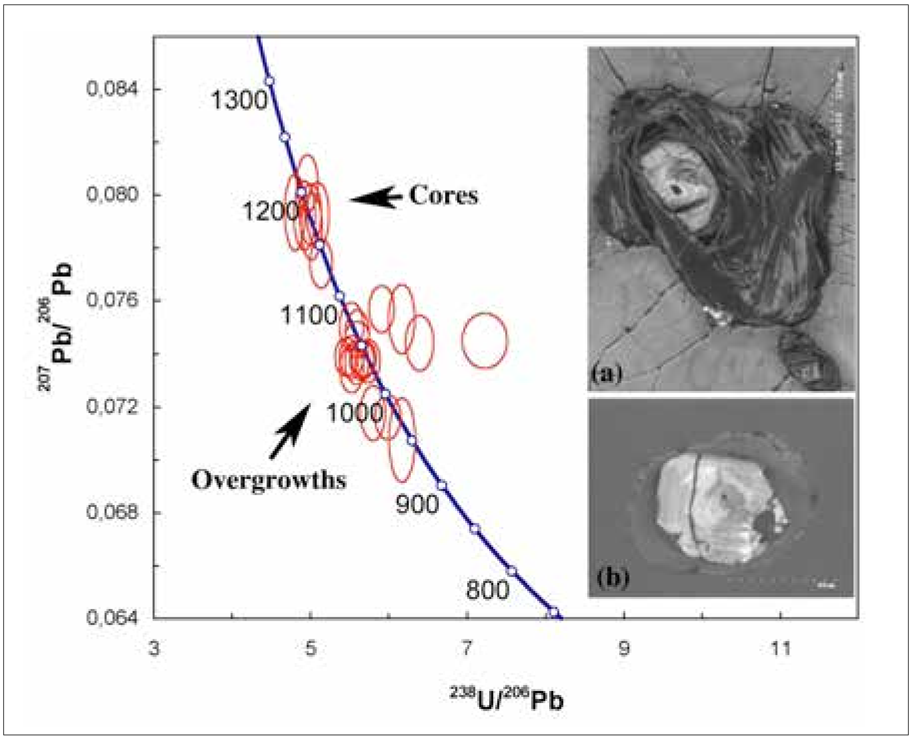
Ion probe dating and CL -imaging of zircons from the high-grade metamorphic rocks from Vaalput, Namaqualand Metamorphic Complex

Hassina Mouri

Zircons are considered to be very resistant to resetting, preserving part of their isotopic signature when affected by high-grade metamorphism. The combination of ion microprobe dating and cathodoluminescence (CL) imaging of zircons from the high grade granulitic rocks from Vaalputs area provides a powerful tool to constrain the age of protolith and metamorphism of some contentious rocks in an orogenic belt riddled with unresolved issues.

Zircons from polished thin sections of quartz-magnetite bearing granulites and single grains separated from sillimanite-quartz-feldspar bearing granulites were prepared for CL-imaging and Ion probe dating. In both rock types, SEM based CL-imaging shows that the grains display complex zoning at their cores overgrown by unzoned 10 to 30 µm wide outer rims. Ion probe dating of cores from all the samples yield a concordant 207Pb/206Pb age of ~1156 ± 51 Ma, interpreted as the age of the protolith. Rims yielded a concordant age of ~1034 ± 34 Ma tentatively interpreted as a period of protracted magmatic and high-T radiogenic heating in the area.

Our data are within error of the published, 1235 ± 65 Ma ages obtained from detrital zircons cores from other granulites in the recently proposed Vaalputs/Garies Terrane, tectonically distinct from the significantly older Okiep/Aggeneys Terrane to the north. Likewise, the age of the zircon overgrowths is within error of the published or proposed ages for the metamorphism (~1030 ± 10 Ma), terrane assembly (~1040 Ma) and granitic magmatism (1060 Ma) that affected much of the western of the Namaqualand Metamorphic Complex.



U–Pb concordia diagram (207Pb/206Pb vs. 238U/206Pb) plotting analyses from the studied rocks (error ellipses are plotted using 2δuncertainties) and CL-images illustrating the internal structure of the zircon grains: (a) zircon grain included in quartz from a polsihed thin section of the magnetite-quartz bearing granulite and (b) separate grain from the sillimanite-quartz-bearing granulites

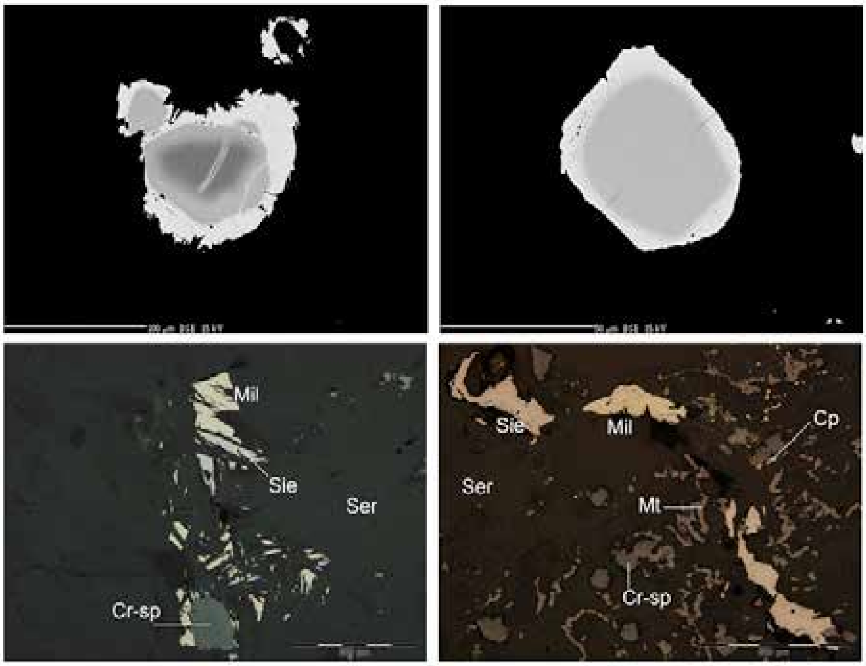
Two types of Cr-spinels in serpentinites from the Barberton granite-greenstone terrain

Kazuyasu Shindo

Chromian spinel is a common mineral in mafic and ultramafic rocks, and its chemical composition is well known to be affected by geotectonic environment where it forms. The tectonic setting of Archean granite-greenstone terrains is a subject of intense debate, with some studies suggesting the operation of subduction processes, while others discussing against it. The well-preserved Barberton granite-greenstone terrain in the Kaapvaal Craton has also same argument. Few mineralogical studies have been carried out to suggest the possible tectonic setting of this terrain.

Two types of chromian spinel were identified with regard to their chemical zoning in the serpentinites. The core of the less dominant type Cr-spinel (Cr-sp1), which has three zones (core-intermediate-rim), preserves the primary composition. Chemical compositions of the intermediate and rim zone of the Cr-sp1 are affected by hydrothermal fluid which led to serpentinization and are similar to their compositions of those of the dominant type chromian spinel (Cr-sp2) which has two chemical zoning (core-rim). Rim part of both Cr-sp1 and Cr-sp2 is magnetite composition with small content of Cr.

Core zone of Cr-sp1, which retained its original composition during serpentinization, is only applied to assume geotectonic setting of the serpentinites. On the basis of this chemical composition, tectonic setting of the protolith rock which contains the chromian spinel can be estimated. This geotectonical implication has an important role for debate of tectonic processes in the Barberton granite-greenstone terrain.



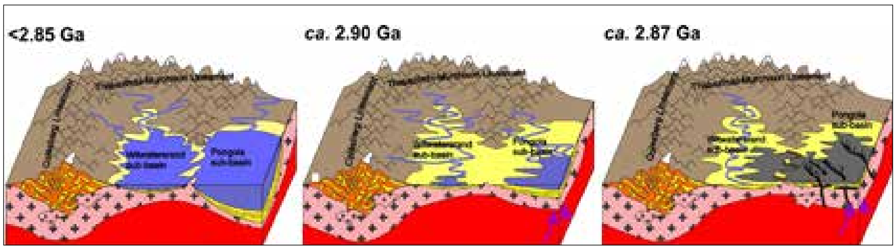
Top back-scattered images illustrate representative of the two kinds of chromian spinel grains in the serpentinites. Top left image is Cr-sp1 type and top right image is Cr-sp2 type, respectively. Others bottom two photomicrographs (polarized light) show representative of occurrence of sulphides in the same rocks. These two pictures were taken under reflected light. Ser – serpentine group mineral; Cr-sp – chromian spinel; Mt – magnetite; Mil – millerite; Sie – sigenite; Cp – chalcopyrite

The identification of fragments from a Mesoarchaean Large Igneous Province on the Kaapvaal Craton

Ashley Gumsley, Mike Knoper

The Hlagothi Complex comprises a series of layered sills in northern KwaZulu-Natal, on the southeastern terrane of the Kaapvaal Craton. The sills consist of meta-peridotites, pyroxenites and gabbros, with at least two distinct pulses of magmatism intruding into Pongola Supergroup strata. U-Pb baddeleyite ages on the Hlagothi Complex, and an associated NW-trending dyke of 2866 ± 2 Ma and 2874 ± 2 Ma respectively, reveal an unexpected ca. 2.87 Ga magmatic event on this region of the craton. The geochemical signature of the Hlagothi Complex recognises a high Mg# and low Mg# magmatic source that is chemically distinct from those of the older Nsuze and Dominion groups, as well as the younger Ventersdorp Supergroup, all of which have been linked with rifting. The resurgence of high MgO magmatism bears similarity to komatiitic lithologies within the Barberton Greenstone Belt further north, and is indicative of a more primitive magma source. Incorporating magmatic events of similar age and geochemistry such as the Thole Complex and gabbroic phases of the Usushwana Complex further north, and flood basalts seen within the upper Witwatersrand and Pongola supergroups, allows us to propose a new Large Igneous Province (LIP) on the Witwatersrand block of the Kaapvaal Craton during the Mesoarchaean. This is due to the large volume of intra-plate magmatism involved, as well the areal extent.

Contact between the Nsuze Group quartzites and the Hlagothi Complex in the Nkandla area



From left to right, the Kaapvaal Craton prior to 2.90 Ga, with the orogeny involving the Kimberley and Witwatersrand blocks leading to the creation of a cratonic foreland basin with the more proximal Witwatersrand sub-basin and the distal Pongola sub-basin. At ca. 2.90 Ga, a mantle plume leads to uplift under the Pongola sub-basin, creating a fluvial dominated Witwatersrand sub-basin, and shallow marine Pongola sub-basin. At ca. 2.87, the mantle plume under the Pongola sub-basin led to erosion, and the eruption of flood basalts covering the Pongola sub-basin, as well as more eastern portions of the Witwatersrand sub-basin, with the associated plumbing system of dykes and sills of which the Hlagothi Complex and NW-trending dykes are part of

Palaeomagnetic data identifies a possible primary magnetisation within the least-altered lithologies of the Hlagothi Complex (with a virtual geographic pole at 23.4 °N, 53.4 °E, dp = 8.2° and dm = 11.8°). The bulk of samples however, displayed two episodes of remagnetisation. These are likely to be associated with ca. 2.85 to 2.75 Ga aged granitoids across the southeastern Kaapvaal Craton, and tectonic activity in the nearby Meso- to Neoproterozoic Namaqua-Natal mobile belt. The movement of the Kaapvaal Craton during the Meso- to Neoarchaean along an apparent polar wander path from poles established for the Nsuze event, to poles established for the Ventersdorp event would suggest greater dynamics within the mantle at this time.

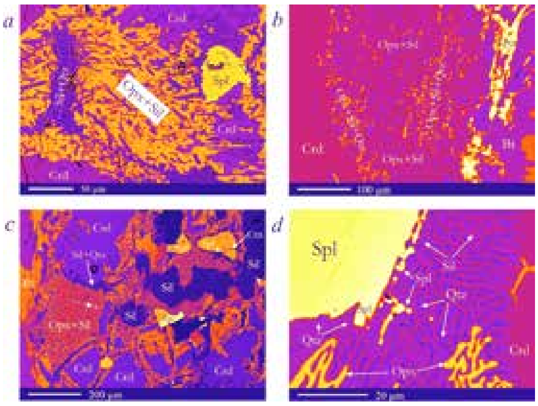
This LIP was possibly generated by a short-lived mantle plume (≤ 8 Ma). Such a plume would also control sedimentation within the Pongola-Witwatersrand basin. Uplift and erosion, followed by the eruption of flood basalts coeval to the Hlagothi Complex, would have been fed through a series of feeder dykes and sills, of which the Hlagothi Complex and NW-trending dykes are part of during the plume thermal maximum. Marine incursion and sediment deposition during subsidence would occur during cooling.

This new ca. 2870 Ma addition to the barcode of the Kaapvaal Craton allows new comparisons to be made to other coeval units on cratons around the world, specifically the Millindinna Complex and the Zebra Hills dykes on the Pilbara Craton. Precise dating on these units is needed to confirm a link, which if substantiated would assist in further validating the existence of Vaalbara during the Mesoarchaean.

Ultrahigh temperature metamorphism from an unusual Al-Mg granulite from the Southern Marginal Zone, Limpopo Complex

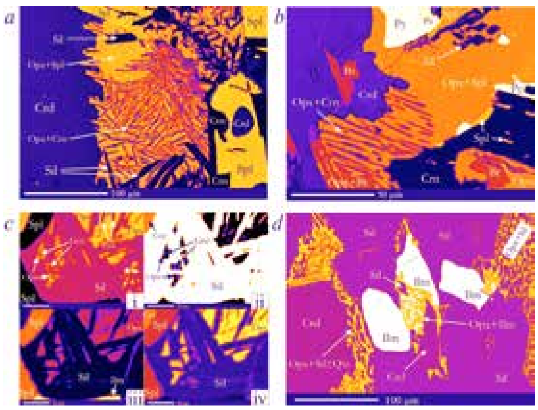
George Belyanin

Petrographic and mineral chemical characterization of an Al-Mg granulite from the Southern Marginal Zone was carried out. The granulite has a gneissic fabric with distinct Al-rich and Si-rich layers, with the former preserving the unusual lamellar (random and regular subparallel) intergrowths of corundum and symplectic intergrowth of spinel with orthopyroxene. The estimated composition of the homogenous phase that existed prior to random lamellar intergrowth with corundum is similar to Fe-Mg-rich garnet. Although the reintegration of the pre-exsolution composition of orthopyroxene with regular subparallel corundum lamellae is similar to orthopyroxene with an anomalously high alumina content (~21 wt.%), we recognize that such high alumina contents have not been reported even at extreme temperatures in aluminous granulites, nevertheless, they may be possible given the uniqueness of the texture reported here.



False color back scattered electron images from the Al-rich layer illustrating, (a) and (b) orthopyroxene+sillimanite±quartz adjacent to or surrounding cordierite, spinel and silimanite, (c) EDS mapping of orthopyroxene+sillimanite±quartz assemblage, indicating quartz present and quartz absent domains, and (d) spinel+quartz in association with orthopyroxene+sillimanite

The Al-rich layer preserves mineral assemblages such as rutile with ortho pyroxene+sillimanite±quartz, Al-rich orthopyroxene (~11 wt.%), spinel+quartz, and corundum+quartz, while the Si-rich layer preserves antiperthites and orthopyroxene+ sillimanite±quartz, all considered diagnostic of ultrahigh-temperature metamorphism. Application of Al-in-opx thermometry, ternary feldspar thermometry and construction of suitable pressure-temperature phase diagrams, compositional and model proportion isopleth results indicate P-T conditions as high as ~1050-1100°C and ~10-12 kbars for the Al-Mg granulite. Our report concurs with Tsunogae et al. on ultrahigh temperature conditions for the Southern Marginal Zone and raises the temperature estimate to ~1100°C.



False color back scattered electron images from the Al-rich layer illustrating, (a) and (b) the unusual lamellar intergrowths (randomly oriented corundum lamellae and regular subparallel corundum lamellae) of corundum±spinel with orthopyroxene grains, (c) EDS mapping of tiny garnet inclusion in orthopyroxene within sillimanite, and (d) symplectic intergrowth of ilmenite and orthopyroxene

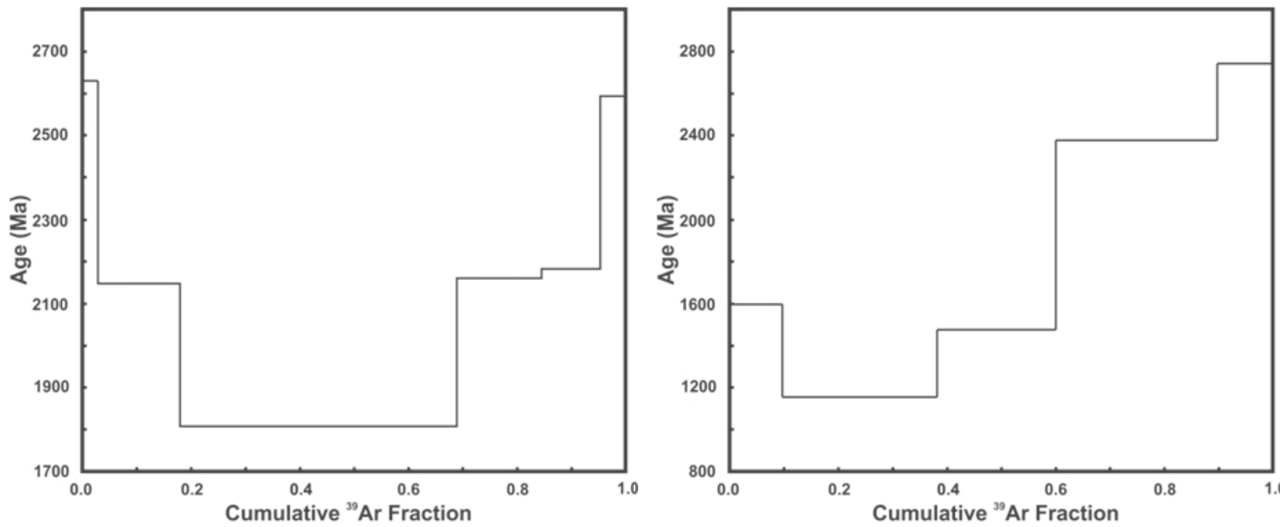
$^{40}Ar/^{39}Ar$ study of selected fabric-forming potassium-bearing minerals and mafic intrusions in the Limpopo Complex, South Africa

Nicholas Stylianou, Mike Knoper, Jan Kramers

Faults, shear zones, and mafic intrusions were identified within the Southern Marginal Zone of the Limpopo Complex based on published geological maps and by using remote sensing spatial filtering techniques on Landsat band 7 images. Two locations were targeted in the Southern Marginal Zone, the N'tabalala Shear Zone and the Shiel Alkaline Complex for follow up field work. Suitable samples containing fabric forming K-bearing mineral phases, in particular amphibole, were collected for 40Ar/39Ar age determination.

An amphibolite sample taken from the N'tabalala Shear zone and a hornblende syenite sample from the Shiel Alkaline Complex were prepared for 40Ar/39Ar dating, by crushing, selecting, and separating amphibole with grains sized between 0.5mm and 1.5mm in preparation for irradiation at the nuclear research reactor in Pelindaba.

The irradiated grains were step heated using the Nd-YAG Laser, with the last step melting the mineral, to extract all the gas including argon. The results of the isotope analysis of the gas yielded disturbed spectra (see below) giving integrated ages for the amphibolite of 1975±23 Ma and 1845±59 Ma for the hornblende syenite. The second batch of analyses is currently in progress.



Ar age spectra for the amphibolite (left) and hornblende syenite (right) samples

STAFF NEWS

Lauren Blignaut

Lauren Blignaut joined the Geology Department and PPM group in June 2011 as a permanent academic staff member. Her current research interest is on geochemical and geometallurgical analysis of the Kalahari manganese deposits, with major emphasis on the controls of hydrothermal metasomatism and metal upgrading.

Post-doctoral Research Associates

From left to right, Andrea Agangi, Nicolas Tonnelier, and Frantz Ossa Ossa joined the department to further the research activities of PPM. Andrea, who received PhD from CODES, Australia, has research interests in igneous petrology and volcanology, especially of felsic rocks. Nicolas, who received PhD from the Laurentian University of Sudbury, Canada, has research interests in the genesis of magmatic Ni-Cu-PGE ore deposits and the process of crustal sulfur devolatilization around magmatic intrusions. Frantz, who received PhD from the University of Poitiers, France, has research interests in the chemostratigraphy, geochemistry and mineralogy associated with mineralization (e.g. Fe, Mn and U) and life in Precambrian rocks.

STUDENTS IN PPM – 2010

Student	**Thesis topic**	**Advisors**
Belyanin, George (PhD)	Magmatic and metamorphic characteristics from the Limpopo Belt.	D.D. van Reenen, H.M. Rajesh
Beyeme-Zogo, Jean-Clement (PhD)	Low grade iron ore potential of iron formation of the Transvaal Supergroup in the Griqualand West region of the Northern Cape Province, South Africa.	N.J. Beukes
Bradley, Guy (MSc)	Morphological, textural, chemical and isotopic characterisation of pyrite from the Mesoarchean Witwatersrand Supergroup.	N.J. Beukes
Chisonga, Benny (PhD)	Relation of mafic dykes and sills to genesis of high-grade iron ore.	N.J. Beukes, H.M. Rajesh
Da Silva, Richard (MSc)	Characterisation of the Lucknow, Neylan and Matsap quartzites in the Koegas-Postmasburg area.	N.J. Beukes
De Villers Mike (MSc)	Petrographic and geochemical characterization of kamafugites from southwest Uganda	H.M. Rajesh
Dreyer, Daphne (MSc)	Geochronology and correlation of red beds of the Paleoproterozoic Elim Group, Griqualand West.	H. van Niekerk, N.J. Beukes
Dzvinamurungu,Thomas (MSc)	Geometallurgical characterization of Merensky Reef and the UG2 at Lonmin's Marikana Operation, Bushveld Complex, South Africa.	K.S. Viljoen, M.W. Knoper
Gumsley, Ashley (MSc)	Towards establishing a 'bar code' for the south-eastern terrane of the Kaapvaal Craton in northern KwaZulu-Natal,South Africa.	M.W. Knoper, H.M. Rajesh, M.O. de Kock
Guy, Bradley (PhD)	Mass independent sulphur isotope fractionation in the Witwatersrand succession.	N.J. Beukes, J. Gutzmer
Mabunza, Themba (MSc)	Characterization of syn-Bushveld sills from the Uitkomst Complex.	H.M. Rajesh, M.W. Knoper
Mishra, Gargi (PhD)	A geometallurgical assessment of the geological and mineralogical influences on plant performance at the Nkomati Nickel Mine, Mpumalanga.	K.S. Viljoen , H. Mouri
Mkhatshwa, Sindile (MSc)	Assessment of the mineralogical variability of the UE1A and A5 reefs at Rand Uranium properties, Cooke Section, using MLA-based automated mineralogy.	K.S. Viljoen, H. Mouri
Mngoma Lethuxolo(MSc)	MLA-based mineralogical assessment of gold and uranium mineralization at Cooke Section, Rand Uranium, Randfontein	K.S. Viljoen , H.M. Rajesh
Nel, Brian (MSc)	Stratigraphy, petrography and geochemistry of iron formations of the Koegas Subgroup of the Transvaal Supergroup.	J. Gutzmer, N.J .Beukes

Student	Thesis topic	Advisors
Peche, Marieke (MSc)	The sedimentary characteristics and origin of Inhaca Island.	N.J. Beukes, H. v Niekerk
Pretorius, Donavan (MSc)	Mineralogical assessment of coal from New Vaal Colliery through the application of automated mineralogy with a view on possible beneficiation	K.S. Viljoen, B. Cairncross
Rose, Derek (PhD)	A Geometallurgical Investigation of the Merensky Reef at Two Rivers Platinum Mine.	K.S. Viljoen
Smith, Bertus (PhD)	Geometallurgical characterisation of the Merensky Reef facies at Bafokeng Rasimone Platinum Mine, South Africa.	K.S. Viljoen
Stylianou Nicholas (MSc)	. $^{40}Ar/^{39}Ar$ study of selected fabric-forming potassium-bearing minerals and mafic intrusions in the Limpopo Complex, South Africa.	M.W. Knoper, J.D. Kramers, H.M. Rajesh
Thandikhaya Mxinwa (MSc)	Petrology of a kimberlite – derived eclogite xenolith suite from the Balmoral kimberlite, South Africa.	K.S. Viljoen, H. Mouri
Turnbull, Sara (MSc)	REE-bearing minerals from the Pilanesberg alkaline complex.	H.M. Rajesh, J.D. Kramers
Van der Walt, Byron (MSc)	Petrography, geochemistry and origin of anomalous boreholes intersections in the Northern Karoo Basin.	B. Cairncross, H.M. Rajesh
Vorster, Clarisa (PhD.)	Developing ICP-MS laser ablation zircon dating at Spectrau with application in the Cape Supergroup.	J. Kramers, N.J. Beukes, H. v. Niekerk
Wabo, Herve (PhD)	Paleomagnetism and high precision chronology of the Bushveld complex, using Bushveld related intrusions (satellites bodies, sills and dykes)	M.O. de Kock
Zacharopoulos Brandon (MSc)	Geochemistry and mineralogy of lithium bearing pegmatites in the Vredefort area.	M.W. Knoper, H.M. Rajesh

POST–DOCTORAL ASSOCIATES

Agangi, Andrea Dr.	Textures and trace element composition of quartz as indicators of the evolution of gold mineralisation in South Africa.	A. Hofmann
Belyanin,George Dr.	The Limpopo Complex of Sourthern Africa:Outstanding issues with emphasis on ultra high - temperature - high - pressure metamorphism and granitoid magmatism	J. Kramers
Cavalazzi, Barbara Dr.	Microbial paleontology, biosedimentology, geomicrobiology, astrobiology in different extreme environments.	N. Beukes
McClung, Craig Dr.	Geometallurgical assessment of the massive sulfide deposits in the Aggeneys - Gamsberg District in the Namaqua Metamorphic Province, with an emphasis on mineralogy and location of deleterious elements.	K.S. Viljoen
Ossa Ossa,Franz Dr.	Mineralogy and geochemistry associated with mineralization	A. Hofmann
Richards, Bryony Dr.	Characterization of the Kolo kimberlite pipe: Constraints on the composition and genesis of the diamondiferous lithospheric mantle below the eastern margin of the Kaapvaal Craton.	K.S. Viljoen
Shindu, Kazuyasu Dr.	Fluid inclusion study on samples from the Bushveld complex.	H.M. Rajesh
Tonnelier, Nicolas Dr.	Working on the influence and mantle compositions (peridotite vs. pyroxenite) on the metal contents of primary mantle-derived magmas and its influence on the composition of magmatic ore deposits.	K.S. Viljoen

THESES COMPLETED - 2011

ALEXANDRA CROSSINGHAM (MSc): Modelling of diamond precipitation from fluids in the Earth's mantle
Supervisors : J.M. Huizenga, K.S. Viljoen

DEREK ROSE (MSc): The Merensky Reef at Dwarsriver 372 KT with reference to the mineral chemistry and platinum – group minerals in the Merensky Reef chromitite stringers. **Supervisors : M.W. Knoper, H.M. Rajesh and K.S. Viljoen**

VAN DER MERWE, FRITS (MSc)
A mineralogical investigation of Lonmin's Akanani platinum group metal project **Supervisors : K.S. Viljoen, M.W. Knoper**

PUBLISHED PAPERS

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Bailie, R., Gutzmer, J., Rajesh, H.M. (2011) Petrography, geochemistry and geochronology of the metavolcanic rocks of the Mesoproterozoic Leerkrans Formation, Wilgenhoutsdrif group, South Africa – back- arc basin to the Areachap volcanic arc. South African Journal of Geology, V. 114, pp. 167-194.
Bailie, R., Gutzmer, J., Rajesh, H.M., Armstrong, R. (2011) Age of ferroan A-type post-tectonic granitoids of the southern part of the Keimoes Suite, Northern Cape Province, South Africa. Journal of African Earth Sciences, V. 60, pp.153 - 174.
Blanco, G., Germs, G. J. B., Rajesh, H.M., Chemale Jr., F., Dussin, I.A., Justino, D. (2011) Provenance and paleogeography of the Nama Group (Ediacaran to early Palaeozoic, Namibia): Petrography, geochemistry and U–Pb detrital zircon geochronology. Precambrian Research, V. 187, pp. 15 - 32.
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Beukes, N.J., Nel, B.P. and Gutzmer, J. "CE Anomalies in ~2.4 Ga iron and manganese formations as proxy for oxygenation of oceanic environments prior to the great oxygenation event". Abstracts Volume, 23rd Colloquium of African Geology, p. 44.

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Cairncross, B. Rare geological specimens as geoheritage artifacts – a South African perspective. Abstract. Colloquium on African Geology, Johannesburg, 8th – 15th January, pp. 61.

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Cavalazzi B, Barbieri R, Franchi F, Ori GG, Rossi AP, Westall F. Seafloor seepages, methane-related carbonate fabrics and clues for the search for cold seep and gas hydrate systems in the geological record: examples from North Africa. CAG 23, University of Johannesburg, South Africa, 08-14 January, 2011.

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Guy, B., Beukes, N.J., Ono, S. and Gutzmer, J. " A multiple-sulfur and organic carbon isotope record from the Mesoarchean Witwatersrand Supergroup, South Africa". Abstracts Volume, 23rd Colloquium of African Geology, pp. 173.

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McClung CR, Viljoen F. Mineralogical assessment of sphalerites from the Gamsberg deposit, South Africa – The manganese conundrum. Minerals Engineering 24 : pp. 930 - 938.

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Mishra G, Viljoen F, Mouri H (2011) The Nkomati Ni-Cu-Co-PGE-Cr deposit: Geology and Mineralisation. Abstracts 23rd Colloquium of African Geology, Jan 8-14, 2011, Johannesburg, South Africa, p. 278.

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Rose DH, Knoper M, Viljoen KS, Rajesh HM (2011) The Merensky Reef interval at Dwarsriver 372KT, eastern Bushveld complex. Abstracts 23rd Colloquium of African Geology, Jan 8-14, 2011, Johannesburg, South Africa, second abstract volume supplement, p. 6.

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Van der Walt, B., Cairncross, B. and Rajesh, H. Possible post-Permian diatreme activity in the N-E Karoo Basin, South Africa. PPM Annual Meeting 3rd November, Auckland Park, Johannesburg.

Viljoen KS, Harris JW, Ivanic T, Richardson SH, Whitehead K (2011) Peridotitic diamond genesis at Premier and Finsch, South Africa: thermal and metasomatic influences. Abstracts 23rd Colloquium of African Geology, Jan 8-14, 2011, Johannesburg, South Africa, p. 415.

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Wohlgemuth-Ueberwasser CC, Schuth S, Berndt J, Viljoen F (2011) Analysis of As and Sb in samples from Turtle Pits hydrothermal field using new standard material. Goldschmidt 2011, Prague, Czech Republic, August 14-19. Mineralogical Magazine, 75(3) : 2169.

CONFERENCE PRESENTATIONS

Beukes N.J.Origin of Precambrian Iron Formation-hosted Manganese Deposits and their Paleoenvironmental Significance, Geological Society of India in Bangalore, March 17, 2011.

Genesis of high-grade iron ore deposits with special reference to Africa, Shango Solutions, Northcliff, Johannesburg.

Lecture to students and staff in the Department of Geology, University of Karnataka, Dharwar entitled January 2011.

"Origin of High-grade Iron-ore Deposits with Special Reference to BIF-hosted Hematite Ores". March 2011.

Lecture to staff and students in the Department of Civil Engineering at SDM College in Dharwar entitled "South Africa's Mining Industry, the Environment and Civil Engineering Challenges". March , 2011

Genesis of Neoproterozoic manganese deposits. PPM biweekly seminar, UJ, Johannesburg,

Talks at UNESP, Rio Claro Brazil, May 2011

Iron Formation Classification, Sedimentology, Basin Analyses, Mineralogy, Geochemistry, Temporal Distribution, Genesis and Paleoenvironmental Significance,October, 2011.

High-grade iron ore deposits of the world, with emphasis on classification and genesis, and chrome and vanadium deposits of the 2,05 Ga Bushveld Complex, October, 2011.

Classification and origin of Precambrian Manganese Deposits, October, 2011.

Phanerozoic Manganese Deposits and coal deposits of the Karoo Supergroup in Southern Africa, October 2011.

Gold deposits of the Mesoarchean Witwatersrand-Mozaan basin and acid mine water drainage problems, October, 2011.

Sedimentology and paleoenvironmental significance of Neoproterozoic iron formations and manganese deposits, Vale manganese meeting, Corumba, Brazil. November, 2011.
Cairncross, B. Rare geological specimens as geoheritage artifacts – a South African perspective. Abstract. Colloquium on African Geology, Johannesburg, 8th – 15th January, 2011.
Cairncross, B. The popularization of South Africa's geological and mineral geoheritage. Abstract. Colloquium on African Geology, Johannesburg, 8th – 15th January,2011.
De Kock, M.O. A Unique african facility for Africa, 23rd Colloquium of African Geology 2011, Johannesburg, South Africa.
Evans, D.A.D., Kirschvink, J.L., and De Kock, M.O. Nic Beukes and the renaissance of South African paleomagnetism. 23rd Colloquium of African Geology 2011, Johannesburg, South Africa.
De Kock, M.O., and Beukes, N.J. (2011) Paleomagnetism of a Mesoproterozoic carbonate succession from India. 23rd Colloquium of African Geology 2011, Johannesburg, South Africa.
Kramers, J 12th April 2011, Faculty of Science (UJ) public lecture
"The dating of hominin fossils in the Cradle of Humankind and emerging patterns of climate change over the last 3 million years."
This talk was repeated on two occasions with the same title but slightly adapted content:
Kramers, J, Gems and Minerals Club, June, 2011.
Kramers, J, Archaeological Society, t July, 2011.
Maré, L.P., de Kock, M., Mouri, H. and Cairncross, B. Magmatic evaluation of the geothermal history of the Western Karoo Basin. Abstract. Geosynthesis, Cape Town.
Moore M, Shaikhaidarov R, Petrashov V, Viljoen F. Probing inclusions in diamonds with fine beams of synchrotron X rays. British Crystallographic Association Spring Meeting, University of Keele, United Kingdom, April 2011.
Mouri, Bowden, Mogessie - Colloquia of African Geology — A Retrospective of CAG. CAG23, 23rd Colloquium of African Geology, South Africa, January, 2011.
Mouri, H.1, Maier, W.2, Andreoli, M.3, Brandl, G.4 and Rebay, g. First occurrence of komatiites in the archaean high-grade polymetamorphic central zone of the limpopo belt, South Africa: P-T-X(major-trace-PGE) evolution, CAG23, 23rd Colloquium of African Geology, South Africa, January, 2011.
Mouri, On Medical Geology in South Africa: 4th International Medical Geology Conference, Bari, Italy, Sep 2011.
Senzani, F.E.D., Mulaba-Bafubiandi, A.F., Viljoen, K.S. Distribution of clay mines and quarries in South Africa. 1st International Conference on Clay and Clay Minerals in Africa (1stICCCM) & 2nd International Conference on Geophagia in Southern Africa (2ndICGSA), 19-21 October 2011, Bloemfontein.
Theart, H.F.J.1, Ghavami-Riabi, R.2 And Mouri, H. high-grade metamorphic terrains and recognition of the alteration pipe in the vms deposits based on box plot: an example from the namaqua province South Africa. CAG23, 23rd Colloquium of African Geology, South Africa, January, 2011.
Van der Walt, B., Cairncross, B. and Rajesh, H. Possible post-Permian diatreme activity in the N-E Karoo Basin, South Africa. COALTECH Annual meeting Witbank, July 2011.
Wabo, H., De Kock, M.O., and Beukes N.J. Paleomagnetism of post-Transvaal sills and dykes in the Eastern Kaapvaal craton. 23rd Colloquium of African Geology, Johannesburg, South Africa, January 2011.
Wabo H., De Kock, M.O., Rajesh, H., and Beukes, N.J. Paleomagnetism and geochemistry of Bushveld-related intrusions, eastern Kaapvaal craton. AGU annual meeting 2011, San Francisco, U.S.A, December, 2011.

ANNUAL RESEARCH COLLOQUIUM

University of Johannesburg
Department of Geology
PALEOPROTEROZOIC MINERALIZATION RESEARCH GROUP

Venue The University of Johannesburg, Auckland Park Kingsway Campus, Main Building, B Les 103, Kingsway, Auckland Park

Date Wednesday, 31 October 2012

Time 13h00 – 20h00

The Paleoproterozoic Mineralization Research Group (PPM) in the Department of Geology at the University of Johannesburg, Department of Geology was formed in 1997. At present (2011), research involves thirteen academic staff members, four post-doctoral researchers, eight PhD and seventeen MSc students.

The PPM research group receives funding from South Africa's mineral industry, the National Research Foundation and Research Grants provided by the University of Johannesburg.

THE OBJECTIVES OF PPM INCLUDE:

- To study and model the relationship between environmental change and styles of mineralization in the Precambrian, with a specific focus on the Paleoproterozoic Era.
- To apply the knowledge for evaluating the mineral exploration and beneficiation potential of that era (1.6 - 2.5 billion years ago) on a global scale.
- To ensure a competitive edge for industrial partners in global mineral exploration and acquisition markets by studying the temporal and spatial distribution, composition, and origin of mineral deposits, on local and regional scale.
- To train postgraduate students in the fields of especially, but not exclusively, Economic Geology and Geometallurgy.

PURPOSE OF THE COLLOQUIUM

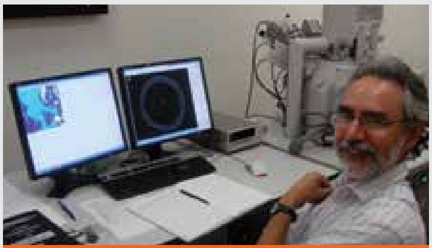
The research colloquium is aimed to present major findings of different research focus areas of PPM to professionals from the industrial and academic environment as well as current and prospective post-graduate students. Attendance is free of charge but booking is essential. More information can be obtained from **Michael Chakuparira (email: michaelc@uj.ac.za; tel 011-559-4715)**

PPM ANNUAL RESEARCH COLLOQUIUM PROVISIONAL PROGRAMME

Date: Wednesday, 31 October 2012
Place: University of Johannesburg, Kingsway Campus, Building B Les 103
Time: 13h00-20h00

13.00 - 13.30	Registration, Tea & Coffee	
13.30 - 13.35	Opening Remarks	Nic Beukes
13.35 - 13.55	Magmatic Ni-Cu-(PGE) Deposits: Exploring the Importance and Economic Significance of Mantle Source Compositions	Nicolas Tonnelier
13.55 - 14.15	First Argon dating results from the noble gas laboratory at UJ, and outlook	Jan Kramers
14.15 - 14.35	Pyrite associated with gold mineralisation in the Witwatersrand Basin	Andrea Agangi
14.35 - 14.55	Detrital zircon age populations and provenance of the Cape–Karoo succession in South Africa and correlatives in Argentina	Clarisa Vorster
14.55 - 15.15	Ar-Ar eudialyte geochronological and geochemical constraints on lujavrites from the Pilanesberg Alkaline Complex	Sara Turnbull
15.15 - 15.35	The identification of fragments from a Mesoarchaean Large Igneous Province on the Kaapvaal Craton	Ashley Gumsley
15.35 - 15.55	Tea	
15.55 - 16.15	Iron isotope fractionation in stromatolitic oncoidal iron formation, Mesoarchean Witwatersrand-Mozaan Basin, South Africa	Bertus Smith
16.15 - 16.35	Geometallurgical characterization of Merensky Reef and the UG2 at Lonmin's Marikana Operation	Thomas Dzvinamurungu
16.35 - 16.55	Characterization of the Hotazel iron ores	Benny Chisonga
16.55 - 17.15	Fluid inclusions in spodumene-bearing pegmatites from the Greenlands Formation, Vredefort impact structure	Brandon Zacharopoulos
17.15 - 17.35	Paleomagnetic constraints from the Uitkomst Complex: Implications for the timing of intrusion	Herve Wabo
17.35 - 17.55	A geometallurgical assessment of the Merensky Reef at the Two Rivers Platinum Mine	Derek Rose
17.55 - 18.05	Concluding Remarks	Fanus Viljoen
18.05 - …….	Wine and Snacks	

SPECTRAU



MLA Lab

EPMA Lab

Ar/Ar Lab

ICP-MS Laser Ablation Lab

Paleomag Lab

SPECTRAU, the Central Analyrtical Facility of the Faculty of Science at UJ, was established in 1999 as a one-stop state-of-the-art analytical facility that is managed and staffed to ensure an accessible analytical service not only for UJ staff and students but also for outside clients.

SPECTRAU operates 24hrs per day and offers wide and comprehensive solutions for a broad range of applications utilizing modern high-tech equipment that include a PANalytical X'Pert Pro XRD, PANalytical Magix Pro XRF, a Jeol 733 microprobe, a Jeol 5600 SEM, two ThermoFisher X-SeriesII ICP-MS's, a Spectro ARCOS ICP-OES, a SHIMADZU QP2010 GC-MS, a Metter Toledo DSC 822e DSC, a Varian Unity Inova NMR system, a ThermoFisher DFS (High resolution GC-MS), a ABI 3130xl genetic znalyser, a BD FACSAria flow cytometer as well as Zeiss Axioplan 2 compound and Zeiss Discovery stereo microscopes.

SPECIALIZED GEOSCIENCE APPLICATIONS AT SPECTRAU

Apart from the more general instrumentation at Spectrau mentioned above, it also houses five facilities geared rather specifically to Geoscience applications and the needs of PPM. **Two of these represent unique African facilities with another a unique African university-housed facility. They are:**

- A MAP-215 noble gas mass spectrometer with both infrared and ultraviolet lasers. This instrument will be utilized for Ar-Ar geochronology as well as research into other isotopic systems. It is a unique African facility.
- A fully functional paleomagnetic laboratory, unique in Africa, which has recently been upgraded with a fully automated snake chain sample changing system and a state of the art SQUID magnetometer. This will allow for rapid and much more efficient measurement of samples for paleomagnetic studies.
- Two MLA's (Mineral Liberation Analysers), the one being an older generation FEI XL-40 and the other a state of the art FEI 600F field emission system. These instruments are extensively used in research in the field of geometallurgy and are the only ones housed at a University in Africa.
- A New-Wave UP-213 Nd:YAG laser permanently connected to the one ThermoFisher X-SeriesII ICP-MS which is dedicated for laser ablation studies, especially for the age determination of detrital zircons.
- A new Cameca SX-100 electron microprobe equipped with 3 wavelength dispersive detectors and one energy dispersive detector making it ideal for in-situ chemical analysis of minerals.

For further information and cost of services please contact:
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Email: willieho@uj.ac.za