DSI-NRF CIMERA Annual COLLOQUIUM

26-27 NOVEMBER 2020

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Centre of Excellence for
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Resource Analysis

ABSTRACT BOOKLET

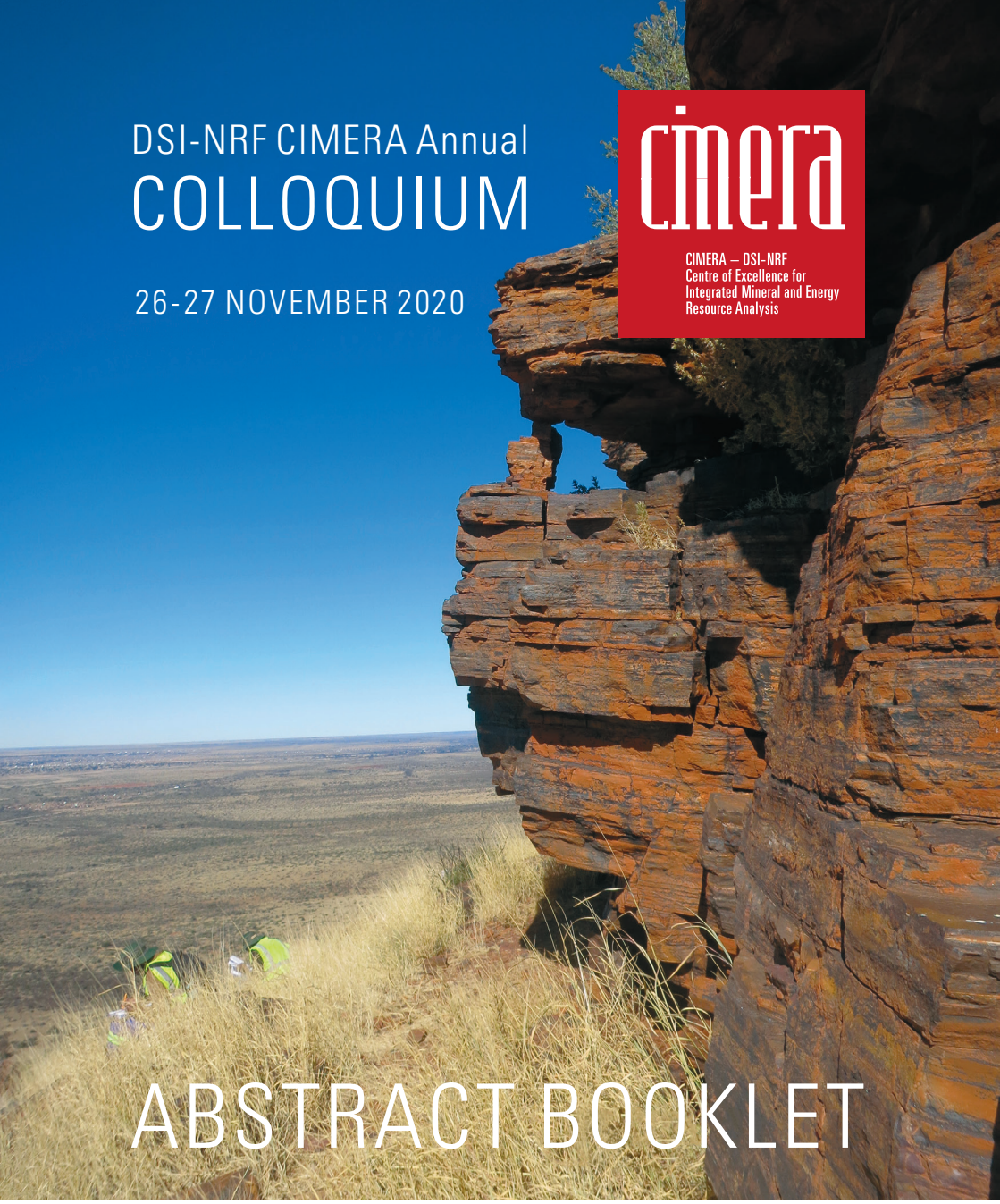

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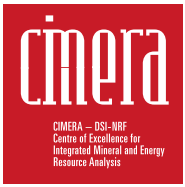
Image: Transvaal Supergroup, banded iron formation, Kuruman Kop, Northern Cape.



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CIMERA – DSI-NRF
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Resource Analysis

DSI-NRF Centre of Excellence for Integrated Mineral and Energy Resource Analysis – CIMERA
Department of Geology
University of Johannesburg | Auckland Park Kingsway Campus (APK)
PO Box 524 | 2006 Auckland Park | South Africa
+27 11 559 4728 (tel) | +27 11 559 4702 (fax)
cimera@uj.ac.za | www.cimera.co.za

Dear All,

We extend a warm welcome to the annual DSI-NRF CIMERA Colloquium, hosted by the University of Johannesburg. The Colloquium will run as a hybrid event this year, triggered by the COVID-19 pandemic lockdown situation and social distancing restrictions. The combination of physical attendance and virtual participation enables some degree of networking, and allows for the inclusion of people who would otherwise not be able to participate in the Colloquium. Unfortunately, UJ will only allow 30 physical attendees; but we hope all participants will feel included. Team building and extensive networking events are not possible in 2020.

The virtual platform has enabled the inclusion of two international guest speakers: Dr Hannah Hughes, a previous DSI-NRF CIMERA bursary recipient who now works at the University of Exeter, Camborne School of Mines; and Distinguished Professor Ross Large, University of Tasmania, previous Director of CODES (Centre of Excellence in Ore Deposits). We look forward to learning about their research interests and experiences beyond DSI-NRF CIMERA (Hannah) and as Director of CODES (Ross).

This booklet contains the presentation and poster abstracts. A total of 24 student presentations will be given over the next one and a half days, as well as 19 poster presentations. The students will present their research results stemming from the economic geology projects supported by DSI-NRF CIMERA. The posters generally show preliminary results, and we look forward to the final presentation of results in 2022 by these students. We congratulate the students on moving forward with their research under the constraints of the national lockdown in 2020.

DSI-NRF CIMERA is a virtual centre of research that concentrates existing research excellence, capacity and resources to enable researchers to collaborate across disciplines and institutions on long-term projects of economic and/or societal benefit in geology, that are locally relevant and internationally competitive. In 2020, DSI-NRF CIMERA aimed to support 77 postgraduate students, 2 research associate projects, and 40 supervisors hosted at 10 universities across South Africa. Sixty-six students received full funding and project running costs. In 2021, we aim to support 73 postgraduate students. The outputs of the research in economic geology is benefitting the region and the continent, as does the pool of skilled graduates. Geology and the mining industry remains a back-bone of the South African economy, despite the current economic climate. Please visit our website (www.cimera.co.za) for more information on our goals, research focus areas and activities.

It would be advantageous to provide additional forums for students to present their work, to network, and possibly to participate in relevant training workshops, either physically or on-line. We are actively seeking opportunities to promote the community of DSI-NRF CIMERA, and welcome any suggestions.

Congratulations to all students on the achievements in your studies to date, and we look forward to interacting with you over the next two days. And please do inform us of your achievements.

Regards,

Professor Nikki Wagner
Director: DSI-NRF CIMERA
nwagner@uj.ac.za

Professor J. Kinnaird
Co-Director: DSI-NRF CIMERA
Judith.Kinnaird@wits.ac.za

PROGRAMME

DAY 1: **THURSDAY 26 NOVEMBER**		
08h00-08h50	REGISTRATION AND TEA	
08h50-09h00	Nikki Wagner (UJ)	WELCOME
TIME	PRESENTER	TOPIC
09h00-09h20	Michael Westgate (Wits)	Reappraisal of legacy seismic data for iron prospection.
09h20-09h40	Frank Ndudzo (UFH)	Investigation of selected kaolin deposits in Grahamstown, South Africa using electrical resistivity, magnetic and geological methods.
09h40-10h00	Jessica Schapira (Wits)	Bioaugmentation-assisted rehabilitation and bioremediation of asbestos contaminated soils.
10h00-10h40	KEYNOTE SPEAKER: **Dr Hannah Hughes** Camborne School of Mines	**The curious case of bursting lamprophyres in the mine** (Online)
10h40-11h00	TEA BREAK	
11h00-11h20	Uwais Ahmed (UJ)	Radionuclides and radioactivity of coals used in South African power plants.
11h20-11h40	Bridgette Murathi (UJ)	The effect of a dolerite intrusion on the petrography and mineralogy of coals from the Witbank Coalfield, South Africa.
11h40-12h00	Itumeleng Venessa Matlala (UJ)	The effect of a dolerite intrusion on coal structure: insights from XRD and NMR.
12h00-12h20	Temitope Love Baiyegunhi (UFH)	Impact of diagenesis on the reservoir properties of the Cretaceous sandstones in the southern Bredasdorp Basin, offshore South Africa.
12h20-12h40	Eric Saffou (UWC)	Geomechanical characterization of CO_2 storage sites: A case study from a nearly depleted gas field in the Bredasdorp Basin, South Africa.
12h40-13h30	LUNCH BREAK	POSTERS UP
13h30-13h50	Sean McQuillan (RU)	A field, petrological and geochemical study of the Keikamspoort Carbonatite.
13h50-14h10	Stephan Dunn (SU)	The origin and timing of hydrothermal gold mineralization in the Amani Hills prospect, southwestern Tanzania.
14h10-14h30	Senamile Dumisa (Wits)	Constrains on the genesis of the orbicular granites and sulphide mineralization in the Koperberg Suite, Namaqualand.
14h30-15h00	Poster presentations	Single slide per presenter to introduce poster.
15h00-16h00	TEA & POSTER SESSION	
16h00-16h20	Lebogang Babedi (SU)	A review of trace element incorporation into pyrite mineral structure in gold ore deposits.
16h20-16h40	Juliet Akoh (UJ)	Petrogenesis and geochemistry of an agpaitic ignimbrite in the Pilanesberg Complex.
16h40-17h00	Julia Mapula Maponya (Univen)	Geology and petrological investigation of iron ore deposits of the Rustenburg Layered Suite: A case study of Ga-Nchabeleng area, Sekhukhune District, Limpopo Province, South Africa.
17h00-19h00	Networking Function for DSI-NRF CIMERA collaborators	Waterford Restaurant (drinks for 30 attendees only)

DAY 2: **FRIDAY 27 NOVEMBER**		
07h30-08h20	REGISTRATION AND TEA	
08h20-08h30	WELCOME	
08h30-08h50	Sara Burness (UJ)	Multiple sulphur isotopic compositions of Kaapvaal Craton eclogites: Implications for sulphur and precious metal crust-mantle cycling.
08h50-09h10	Willem Kruger (Wits)	Magmatic karst in the Bushveld Complex: unique insights into magma chamber dynamics.
09h10-09h30	Siyasanga Dyan (RU)	Modelling the influence of carbonate assimilation of the stability of chromites: A case study of the Flatreef of the Northern Limb, Bushveld Complex.
09h30-10h10	KEYNOTE SPEAKER: **Prof Ross Large** CODES	**The evolution of atmospheric oxygen and its relationship to ore deposit cycles in sedimentary basins.** (Online)
10h10-10h20	Prof S Sinha (DVC R&I, UJ)	**Welcome Note**
10h20-10h40	TEA	
10h40-11h00	Khulekani Khumalo (Wits)	Sr-Nd-Hf isotopic study of the komatiites in the Westonaria Formation of the Ventersdorp Large Igneous Province and implications for their petrogenesis.
11h00-11h20	Busisiwe Khoza (Wits)	Petrogenesis of the Tennis Ball Marker in the Eastern Bushveld Complex South Africa.
11h20-11h40	Maximilian Hasch (Wits)	Regional structures of bifurcating Lower and Middle Group chromitites of the Bushveld Complex, South Africa.
11h40- 12h00	Mbili Tshiningayamwe (Wits)	Constraints on the origin and evolution of the Epembe carbonatite dyke, NW Namibia, using fluor-apatite and zircon geochemistry.
12h00-12h10	COMFORT BREAK	
12h10-12h30	Phulelele Mashele (Wits)	Geology of selected sites along the northern margin of the Barberton Greenstone Belt.
12h30-12h50	Dora Paprika (UJ)	The geology of the Dominion Group in the Ottosdal area.
12h50-13h10	Godfrey Chagodah (UJ)	A search for source magma for Archaean LCT pegmatites in the Bikita and Mweza fields, Zimbabwe.
13h10-13h15	Judith Kinnaird (Wits)	Closing
	NO LUNCH	Departure

POSTERS

15h00-16h00: **THURSDAY 26 NOVEMBER**			
	NAME	AFFILIATION	POSTER TITLE
1	**Elelwani Denge**	University of Limpopo	Maceral types and quality of coal in the Tuli Coalfield: A case study of coal in the Madzaringwe Formation in Vele Colliery, Limpopo Province, South Africa.
2	**Sinelethu Hashibi**	Unversity of Cape Town	A geochemical and thermobarometry study of kimberlite indicator minerals from the Kaapvaal and Zimbabwe Cratons and environs, southern Africa.
3	**Thomas Jones**	University of the Witwatersrand	Rapid fracture network quantification at the Valencia U deposit, Namibia using UAV photogrammetry.
4	**Thabo Kgarabjang**	University of Limpopo	Geochemical characterization of host rocks and hydrothermal alteration associated with antimony-gold mineralization along the Antimony Line, Murchison Greenstone Belt, South Africa.
5	**Lungele Steve Kitoga**	University of Johannesburg	Petrology and geochemistry of the Dando-Kwanza kimberlite 'lavas' in central Angola.
6	**Welhemina Langa**	University of Johannesburg	Advanced non-destructive analytical techniques for the South African coal industry, with a focus on hyperspectral imaging.
7	**Loic Le Bras**	University of the Witwatersrand	X-ray computed tomography analysis of Cu-sulphide textures from Phalaborwa: an indicator for ore-forming processes.
8	**Sanelisiwe Mhlambi**	University of the Western Cape	Feasibility of CO_2-enhanced gas recovery in a tight Gas reservoir offshore South Africa: A case study.
9	**Thangeni Mphanama**	University of Venda	Detailed geological mapping and petrological investigation of rocks within and around the Mushithe coal occurrence, Soutpansberg Coalfield, South Africa
10	**Phumozo Gift Munyai**	University of Venda	Phytoremediation studies of potentially toxic metals from tailings dams in Giyani area: a case study of Klein Letaba and Louise Moore tailings dams.
11	**Tshipeng Mwenze**	University of the Witwatersrand	Whole-rock and Sr-Nd isotope geochemistry of mafic rocks from the Waterberg and Harriet's Wish PGE prospects, far northern Bushveld Complex, South Africa.
12	**Niki Ncube**	University of Johannesburg	Geology of the Kameel gabbroic layered intrusion, Northern Cape, South Africa.
13	**Zandile Ndlazi**	University of Fort Hare	Geochemistry of sandstones and mudstones from the Katberg Formation, Karoo Supergroup, in the Eastern Cape province of South Africa: implications on source rock provenance, tectonic setting, paleo-weathering conditions, and sediment maturity.
14	**Thendo Netshidzivhe**	University of Johannesburg	Nature and origin of Paleoarchean komatiites from the SE Kaapvaal craton.
15	**Ryan Rosenfels**	Stellenbosch University	The geology and geochemistry of the Fungurume 88 deposit: an unusual high grade primary cobalt sulphide deposit.
16	**Mpofana Sihoyiya**	University of the Witwatersrand	Re-appraisal of legacy seismic data using today's technology: examples from goldfields, South Africa.
17	**Rethabile Tau**	University of the Witwatersrand	The tectonic evolution of the Bredasdorp Basin and its implications for oil and gas formation.
18	**Anton Viljoen**	University of Cape Town	The diamondiferous hybrid/transitional kimberlites from the Man Craton (West Africa): A petrographic and mineral chemistry study.
19	**Peace Zowa**	University of the Witwatersrand	Constraining magma sources and the metallogenesis in the Bushveld Complex using Nd isotopes in apatite.

Image: Bushmanland sequence, Big Syncline area near Aggeneys, Northern Cape.

KEYNOTE SPEAKER: Dr Hannah Hughes

BIOGRAPHY ▪ I am an economic geologist and geochemist at the Camborne School of Mines, University of Exeter. My research interests include the metal budget of the mantle, the underlying controls (in space and time) for mineralisation in the crust, the 'fingerprints' of metallic mineralisation and the ancient histories of the oldest portions of the Earth's lithosphere (cratons). I have further research pursuits in the generation and mitigation of gases in igneous rocks, particularly hazardous in some underground mines, and it is this that I would like to talk to you about today. Prior to joining CSM, I was a CIMERA Postdoctoral Fellow at the University of the Witwatersrand and later through the Claude Leon Foundation.

THE CURIOUS CASE OF BURSTING LAMPROPHYRES IN THE MINE.
Rocks that go bang: Applied Mineralogy for Engineering solutions to underground mine gas outbursts

Hannah S.R. Hughes, Priyal Daya, Judith A. Kinnaird, Grant M. Bybee, Musa S.D. Manzi

Gases in rocks may be present as vapour bubbles in fluid inclusions, gas molecules adsorbed onto mineral surfaces, or accumulated within fractures, voids and pore spaces. Gases may also be produced by a number of mechanisms – biogenically (i.e., microbial processes) or abiogenically (e.g., by mineral alteration and reaction). Many mines in South Africa are prone to gas outbursts and the number of flammable gas reports and accidents are steadily rising. For example, methane is recognized as a hazard in gold and platinum mines as well as coal mines. Gases and volatiles present in some lithologies are sensitive to physical changes of the host rock, such as excavation that causes depressurisation of the surrounding rock mass. This can cause a release of gas and is an important consequence of any mining or underground construction activity. In cases of outburst, the release of gas may be very sudden and the sources and pathways of gases must be understood in order to facilitate and implement appropriate health and safety criteria and mine operation regulations.

In this talk, we will look at a case study of a underground platinum mine in South Africa suffering numerous gas outbursts and see how applied mineralogy, petrology, fluid inclusion studies and novel in situ gas analyses together with time-lapse mapping can be used to identify the causes and mechanisms of gas outbursts. Equipped with this knowledge, we hope to be able to forecast the risk of outbursts in the future and thereby help to safeguard miners from injury as well as saving the mine the financial burden caused by these events.

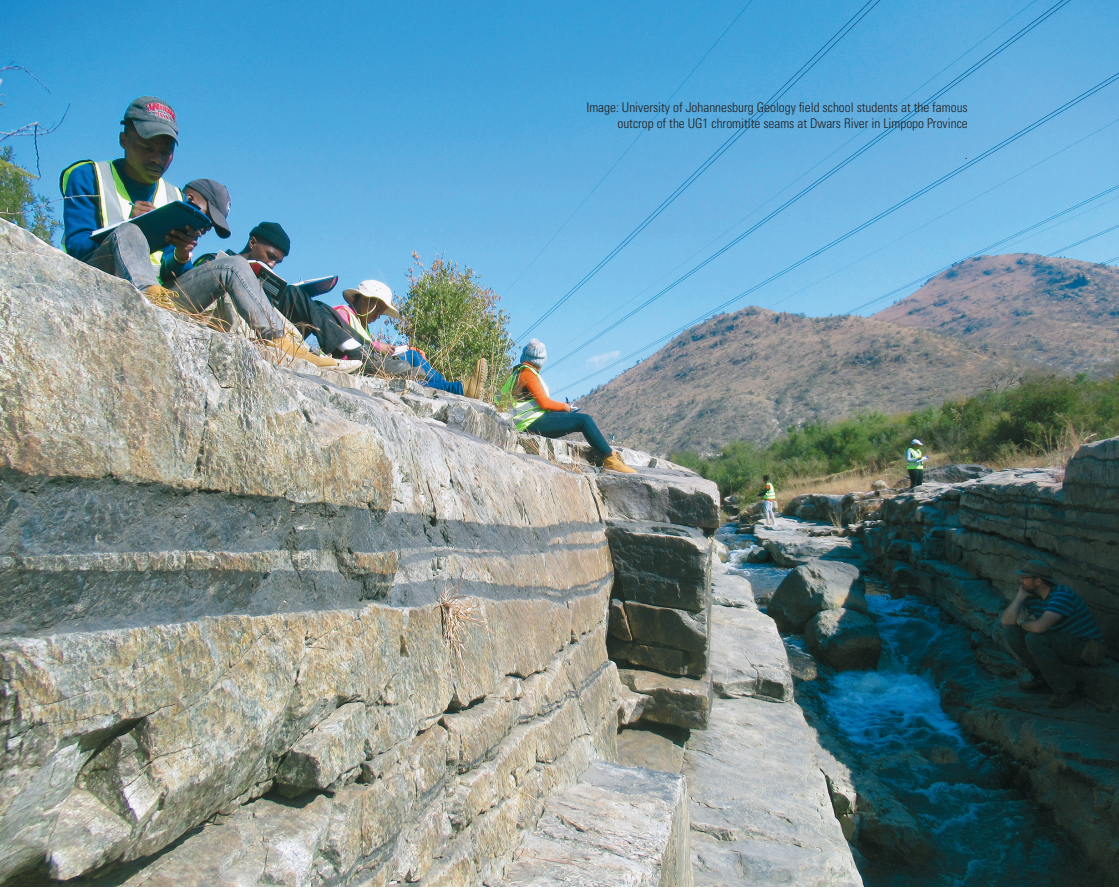


Image: University of Johannesburg Geology field school students at the famous outcrop of the UG1 chromitite seams at Dwars River in Limpopo Province

KEYNOTE SPEAKER: Prof Ross Large

BIOGRAPHY ▪ Professor Large is a Distinguished Professor of Geology at the University of Tasmania and the recent past Director of CODES, the ARC Centre of Excellence in Ore Deposits. Ross gained his PhD from the University of New England in 1973 and undertook a CSIRO Postdoctoral Fellowship at the University of Toronto in 1974. For 10 years Ross worked in mineral exploration in the Northern Territory, Queensland and Tasmania. In 1984 he joined the University of Tasmania and, five years later, established CODES as a National Key Centre jointly funded by the Australian Research Council, University of Tasmania, the Mining Industry and the State Government. Under his leadership, CODES has grown to become recognised as one of the top ore deposit research centres in the world, with a current research staff of 40 geoscientists, 80 postgraduate students, and an operating budget of around $11 million pa.

His research has involved close collaboration with the global mining industry to determine the geological and geochemical factors that control the genesis of, and exploration for, stratiform sediment- and volcanic-hosted gold and base metal mineral deposits. Recently he has developed an interest in the history of trace elements in the ocean and their relationship to ore deposits through time. Ross has gained a number of awards for his research, including the 1983 SEG Lindgren Award, 1989 AusIMM Presidents Award, 2005 Haddon King Medal, 2010 SEG Silver Medal and the 2011 BJ Skinner Award.

TITLE:	**Reappraisal of legacy seismic data for iron prospection**
PRESENTING AUTHOR:	**Michael Westgate**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	Michael.westgate@wits.ac.za
SUPERVISOR/S NAME:	Musa Manzi
DSI-NRF CIMERA THEME:	Geometallurgy, geophysics, analytical development, and small mining opportunities
REGISTERED DEGREE:	Post-doctoral Research Fellow
ORAL OR POSTER:	ORAL

The reflection seismic imaging method has seen successful applications in numerous case studies spanning a multitude of fields. In South Africa, the method has been used extensively to map the wealth of hydrocarbons and minerals found within the hard rock setting, such as platinum, gold, uranium and chromium. The advancement of technology has allowed for refining of the processing flow of reflection data, consequently rendering the reappraisal of legacy data as a worthwhile and fruitful endeavour, as the legacy data are usually improved and provide new insight.

In this study, legacy 2d reflection seismic data located near Sishen mine in South Africa are reprocessed to investigate the extent of the local haematite mineralisation. The target iron orebody at the open pit Sishen mine has been comprehensively documented in the literature (Basson et al. 2017; Stoch et al. 2017), however the extent of the iron mineralisation beyond this scope is not well-documented, validating the objectives of this study. The seismic profile KBF01 comprises two 6 s overlapping profiles whose combined length is 130 km. These profiles were originally acquired by the Anglo American corporation in 1994 in search of gold-bearing conglomerates belonging to the Witwatersrand basin. The composite profile lies 10 km south of Sishen mine and conveniently runs across a magnetic high caused by the iron mineralisation that is located primarily within the Kuruman Formation. As such, this profile, along with supporting borehole and magnetotelluric data also collected in the area, serves as a good candidate for investigating the iron deposits close to Sishen mine for potential future mine developments.

The reprocessed data reveal a fault-controlled syncline within the Griqualand West Supergroup sediments, including the iron-hosting metasediments, which overlie the extensive lavas of the Ventersdorp Supergroup. Near vertical ($>60^0$) faults are seen throughout the section as well as a possible ~200 m thick intrusion zone that intersects the entire sequence. The faults are mostly parallel to the fold axis of the syncline. This is likely due to fold axial foliation, where the strain field within the strata was uniform along the fold axis during folding.

The iron-hosting metasediments comprising the Daniëlskuil and Kuruman formations are found within the syncline up to a depth of 900 m, with an average thickness of 500 m. They are disrupted by multiple faults as described above as well as the intrusion zone. The subsurface geometry of these metasediments support the viability of future mining endeavours along the along the profile.

By reprocessing the legacy seismic profile KBF01, originally acquired for locating gold-bearing horizons of Witwatersrand outliers, we have comprehensibly imaged the subsurface geometry of iron-hosting metasediments located beneath the seismic profile. We thus provide evidence via case study of the practical benefit of legacy data reappraisal.

TITLE:	**Investigation of selected kaolin deposits in Grahamstown, South Africa using electrical resistivity, magnetic and geological methods**
PRESENTING AUTHOR:	**Frank Ndudzo**
AFFILIATION:	University of Fort Hare
EMAIL ADDRESS:	201515553@ufh.ac.za
SUPERVISOR/S NAME:	Prof Oswald Gwavava and Prof Ken Liu
DSI-NRF CIMERA THEME:	Geometallurgy, geophysics, analytical development, and small mining opportunities
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

High quality kaolin deposits in South Africa are found in Grahamstown. However, following the closure of most kaolin mining companies after 1990, it resulted in the under extraction of the mineral deposit, which impacted the community and the Country's economy negatively in terms of employment and ceramic industry, respectively. Kaolin has a wide range of economic significance in paper manufacturing and ceramics industry. It is also used for pigments and additives and production of ink, and paint. Four kaolin sites were selected namely Makana, Palmer 1, Manley flats road deposit and Rhini deposit to determine the parent material and formation process on individual kaolin deposit, to determine the variation in quality of kaolin from different deposits using XRD, SEM, EDX and thin sections to determine the kaolin thickness, depth and stratigraphic layering in relation to other lithiologies using electrical resistivity and magnetic methods. Preliminary electrical resistivity modelling results showed a significant amount of kaolin is found from the second layer in all the inferred deposits. Palmer 1 deposit has the thickest kaolin stratum that is 17.2 m thick overlain by a top layer of about 0.6 m. All the inferred deposits are sandstone and hydrothermal quartz dominated.

TITLE:	**Bioaugmentation-assisted rehabilitation and bioremediation of asbestos contaminated soils**
PRESENTING AUTHOR:	**Jessica Schapira**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	708715@students.wits.ac.za
SUPERVISOR/S NAME:	Dr Sharad Master, Prof Robert Bolhar and Prof Karl Rumbold
DSI-NRF CIMERA THEME:	Environmental and groundwater geology
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

Characterised by excellent mineralogical properties, asbestos was extensively mined and exploited globally for centuries, i.e. 3000 – 2000 BC in Egypt. However, physicochemical properties harmful to humans resulted in its mining and usage being banned completely in 67 countries globally. Now the world is scarred with a lethal legacy of widespread asbestos-associated pollution of the environment and no appropriate means of remediating this recalcitrant inorganic carcinogen. In South Africa environmental asbestos exposure perseveres and so does the subsequent 'invisible epidemic' of asbestos-related diseases (ARDs). Upon examination into the contemporary state of this insidious asbestos legacy certain questions become apparent. Why is it that this 'grandfathers' problem still burdens antecedent mining communities, particularly in South Africa? Why are current methods so ineffective at mitigating risk of exposure? The rehabilitation of asbestos mine dumps in South Africa is conducted in accordance with the technical guidelines developed by the Department of Minerals and Environment (DME) whereby the mine dumps are covered with asbestos-free topsoil on top of which indigenous vegetation is planted. Capping rehabilitation methods do not provide a decontamination solution but rather confinement efforts and thus cannot free a contaminated area of these carcinogenic contaminants. To a greater degree, asbestos contaminated soils are often associated with other contaminants, such as heavy metals and nutrient impoverishment. The effectiveness of the capping and re-vegetation rehabilitation method is severely limited by the above factors. The ineffectiveness of plant establishment and growth on these capped sites has left the 'rehabilitated' sites open to the effects of weathering and erosion that ultimately result in the wind and water dispersion of both asbestos fibres and heavy metal co-contaminants. The establishment of vegetation is one of the main objectives for the rehabilitation of any mine, being displayed as the apparent answer to attaining rehabilitation success on discarded mine sites. Thus, there is urgent need to (1) improve plant survival and establishment on these capped sites; (2) detoxify the recalcitrant pollutants in situ and (3) diminish the presence and effects of any other co-contaminants to mitigate the health effects on both humans and the environment. The present scenario of environmental asbestos pollution calls for immediate attention towards the remediation and detoxification of these hazardous agents in order to provide a healthy living environment for humans and the implementation of bioaugmentation, in addition to ongoing rehabilitation strategies, has been proposed as an inexpensive and environmentally friendly approach to ameliorate reclamation and reduce the risk from chronic exposure to toxic fibres. This research is aimed at exploring the feasibility of a bioaugmentation-assisted rehabilitation approach by using various interdisciplinary scientific methods and laboratory experimental procedures to evaluate the potential of field scale asbestos bioremediation.

TITLE:	**Radionuclides and radioactivity of coals used in South African power plants**
PRESENTING AUTHOR:	**Uwais Ahmed**
AFFILIATION:	University of Johannesburg
EMAIL ADDRESS:	Uwais78692@yahoo.com
SUPERVISOR/S NAME:	Prof Nikki Wagner
DSI-NRF CIMERA THEME:	Environmental geology / Energy resources
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

Coal is the major source of energy in South Africa (SA). Depending on the area from where the coal is mined, it contains varying amounts of radioactive elements. Because of combustion, the concentration of most radioactive elements in coal combustion residues (CCRs) are multiple times higher than the concentration in the original coal. When compared with the rest of the world, limited information regarding the main radioactive elements from SA coal fired power plants (CFPPs) is available in the public domain. Hence, this presentation aims to highlight the radioactive elements in coal and CCRs from a selection of CFPPs in SA and to present their potential human health risks that were found during the investigation.

Coal and ash were obtained from three CFPPs located in three different provinces in SA. The U and Th concentrations for the coal used in the selected CFPPs were above the world averages of 1.9 mg/kg and 3.2 mg/kg respectively. The concentrations of the main radionuclides i.e. ^{40}K ^{226}Ra and ^{232}Th determined during the study were in line with the world ranges. The radionuclide concentrations (^{40}K, ^{226}Ra and ^{232}Th) in the CCRs (fly ash and bottom ash) were studied in relation to the quality of coal in terms of their enhancement ratios. The values obtained for these activity concentrations were also in close proximity with the world average concentrations. The enrichment of the radionuclides (^{40}K, ^{226}Ra and ^{232}Th) from the feed coal to the fly ash was directly proportional to the quality of coal in terms of the ash content, as demonstrated by the mathematical equation:

The radionuclide activity concentrations in the ash stored in the ash heaps adjacent to a CFPP located in the Limpopo Province were used to quantify the radiological impacts. The radium equivalent activity, external and internal hazard index, gamma index and excess cancer lifetime risk were determined to be 258,43 Bq/kg, 1.09, 0.70, 1.80 and 0.49×10^{-3} respectively. With the exception of the internal hazard index (which was slightly above the limit of 1), all other indices were within prescribed ranges found in literature.

The results obtained in this study were lower than the thresholds set for radiological regulation by the National Nuclear Regulator; i.e. less than 0.5 Bq/g for naturally occurring radioactive nuclides of U and Th, and less than 50 Bq/g for ^{40}K. The specific reference levels for exposure due to radionuclides in the ash heaps were established and the mean total annual effective dose of 0,01 mSv/y received by plant workers is below the IAEA safety criterion of 1,0 mSv/y . Thus, the results indicate that coal fed to these CFPPs and ash produced do not pose any harmful radiological threat to the people surrounding these plants.

TITLE:	**The effect of a dolerite intrusion on the petrography and mineralogy of coals from the Witbank Coalfield, South Africa.**
PRESENTING AUTHOR:	**Bridgette Murathi**
AFFILIATION:	University of Johannesburg
EMAIL ADDRESS:	bridgettem@uj.ac.za
SUPERVISOR/S NAME:	Dr Marvin Moroeng, Prof Nikki Wagner and Dr TV Makhubela
DSI-NRF CIMERA THEME:	Energy resources
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

South African coals of the Main Karoo Basin are affected by Triassic-aged dolerite intrusions associated with the emplacement of the Drakensburg lavas, affecting coal quality. This study investigates the effects of a dolerite intrusion on the petrography, mineral, trace element, and rare earth element compositions of dyke affected, inertinite-rich coals from Manungu Colliery, located in the western limb of the Witbank Coalfield. The main focus of the research is to gain an understanding of changes in the mineralogy of the coals with distance from the intrusion. Coal samples were collected from the No. 2 Coal Seam 1.25 m either side of the 40 cm wide dolerite intrusion. The samples were analysed using: (1) routine coal analysis (proximate, ultimate, and gross calorific value); (2) petrography (maceral composition and thermal maturity); (3) X-ray diffraction (XRD); (4) X-ray fluorescence (XRF); and (5) Inductively coupled plasma mass spectroscopy (ICP-MS). Only the petrography and mineralogy are discussed in this presentation. Total reflectance (Rt%) increased from 1.48 Rt% to 3.67 Rt% towards the contact of the dolerite on the western side. In comparison, the eastern side recorded lower Rt% values, which is an unexpected result. Both sides of the dolerite are dominated by inertinite (54.2 vol.% - 77.5 vol.%). Similar to published literature, carbonates dominate the mineralogy of the coals. Specifically, dolomite occurs as cleat and fracture infilling, consistent with an epigenetic mode of occurrence and suggesting a possible source from the dolerite intrusion. The geochemistry appears to vary between the eastern and western side. Comparable studies in literature did not consider changes in petrography, mineralogy and geochemistry on both sides of the dolerite intrusion.

TITLE:	**The effect of a dolerite intrusion on coal structure: insights from XRD and NMR**
PRESENTING AUTHOR:	**Itumeleng Venessa Matlala**
AFFILIATION:	University of Johannesburg
EMAIL ADDRESS:	ivmatlala@gmail.com
SUPERVISOR/S NAME:	Dr Marvin Moroeng and Prof Nikki Wagner
DSI-NRF CIMERA THEME:	Energy resources
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

Manungu Colliery is located in the Witbank Coalfield. Within the colliery, a 14 m thick dolerite sill is emplaced above the No. 4 Seam; this has led to the devolatilization of the seam around this area. Further, the sill developed fingers that intrude into the lower coal seams, including into the productive No. 2 Seam. Coals from the No. 2 Seam near a 0.4 m finger were studied to determine the changes in chemical structure as a result of rapid heating. Petrographic analysis (macerals and reflectance), X-ray Diffraction (XRD), and Nuclear Magnetic Resonance (NMR) were applied to understand the response of coal to heating by the intrusion. Total reflectance (%RoTmr) ranges from background values of 1.52% for the unaltered sample (Un-C) to 2.77% on the western side (coal-dolerite contact). Whereas on the eastern side, RoTmr reaches a maximum of 2.88% (at 0.5 m from the dolerite), but decreases to only 1.93% at the coal-dolerite contact. The halo extends out more than 3-times the dyke thickness, which is curious given that the intrusion is only 0.4 m in thickness. All coals, including Un-C, are dominated by inertinite (84.5 – 100 vol%, mmf). Liptinite is apparently lost above 2.28 %RoTmr. The structural parameters obtained using XRD and NMR were correlated with %RoTmr to determine changes in coal structure with an increase in coal maturity. XRD showed that the interlayer spacing increases and that crystallite height decreases with an increase in coal maturity. NMR revealed that aromaticity and aromatic clusters similarly increase with coal maturity. Therefore, the increase in the thermal maturity influenced the structural ordering and graphitization of the coals. Rapid heating thus caused the inertinite-rich coals to be become highly aromatic.

TITLE:	**Impact of diagenesis on the reservoir properties of the Cretaceous sandstones in the Southern Bredasdorp Basin, offshore South Africa**
PRESENTING AUTHOR:	**Temitope Love Baiyegunhi**
AFFILIATION:	University of Fort Hare
EMAIL ADDRESS:	201814648@ufh.ac.za, lovedestiny324@yahoo.com
SUPERVISOR/S NAME:	Prof Kuiwu Liu and Prof Oswald Gwavava
DSI-NRF CIMERA THEME:	Energy Resources
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

The Cretaceous sandstone in the Bredasdorp Basin is an essential potential hydrocarbon reservoir. In spite of its importance as a reservoir, the impact of diagenesis on the reservoir quality of the sandstones is almost unknown. This study is undertaken to investigate the impact of digenesis on reservoir quality as it pertains to oil and gas production in the basin. The diagenetic characterization of the reservoir is based on XRF, XRD SEM + EDX, and petrographic studies of 106 thin sections of sandstones from exploration wells E-AH1, E-AJ1, E-BA1, E-BB1 and E-D3 in the basin. The main diagenetic processes that have affected the reservoir quality of the sandstones are cementation by authigenic clay, carbonate and silica, growth of authigenic glauconite, dissolution of minerals and load compaction. Based on the framework grain–cement relationships, precipitation of the early calcite cement was either accompanied or followed up by the development of partial pore-lining and pore-filling clay cements, particularly illite. This clay acts as pore choking cement, which reduces porosity and permeability of the reservoir rocks. The scattered plots of porosity and permeability versus cement + clays show good inverse correlations, suggesting that the reservoir quality is mainly controlled by cementation and authigenic clays.

Keywords: *diagenesis; reservoir quality; porosity; sandstones; Bredasdorp Basin*

TITLE:	**Geomechanical characterization of CO2 storage sites: A case study from a nearly depleted gas field in the Bredasdorp Basin, South Africa**
PRESENTING AUTHOR:	**Eric Saffou**
AFFILIATION:	University of the Western Cape
EMAIL ADDRESS:	esaffou@uwc.ac.za
SUPERVISOR/S NAME:	Prof Jan van Bver Donker
DSI-NRF CIMERA THEME:	Energy resources
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

Geomechanical analysis and integrity assessment of hydrocarbon reservoirs upon depletion and injection are crucial to ensure that CO_2 storage projects can be safely implemented. The Bredasdorp basin in South Africa has a great potential for CO_2 storage given its hugely available exploration data. However, there has not been any geomechanical characterization carried out on this basin to determine its integrity issues. The aim of this study is to provide a guideline as to how geomechanical analysis of depleted fields can be done for a safe CO_2 sequestration practice. The results obtained from the geomechanical model constructed for the depth of 2570 m indicated that the magnitude of the principal vertical, minimum and maximum horizontal stresses in the field are respectively 57 MPa, 41 MPa and 42–46 MPa, indicating the presence of a normal faulting regime in the caprock and the reservoir. However, according to the pore pressure-stress coupling assessment, this normal faulting is much severe in compartment C3 of the reservoir. Fault reactivation and fracture stability were also investigated after depletion and it was found that faults in the compartments C1 and C2 are stable after depletion. However, normal faults (FNS8 and FNS9) in compartment C3 dipping SW were critically stressed and may be reactivated without a proper injection planning. Fractures in compartment C3 were also critically stressed, highlighting a great potential of leakage from this compartment upon injection. It was also revealed that the sustainable maximum fluid pressure of 25 MPa would not induce any fractures in the reservoir during CO2 storage.

TITLE:	**A field, petrological and geochemical study of the Keikamspoort Carbonatite**
PRESENTING AUTHOR:	**Sean McQuillan**
AFFILIATION:	Rhodes University
EMAIL ADDRESS:	seanmcquillan.jhb@gmail.com
SUPERVISOR/S NAME:	Prof R.E. "Jock" Harmer
DSI-NRF CIMERA THEME:	Base metal, gold and scarce metal deposits
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

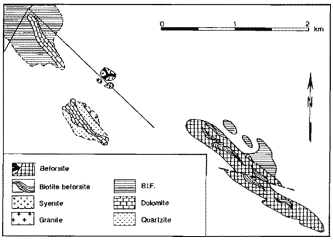
The Keikamspoort body was first described by Verwoerd (1993) in an update to his 1967 Memoir on the carbonatites of South Africa and Namibia (fig. 1). After a radiometric survey, completed by Anglo-American in 1970, revealed a Th anomaly over Keikamspoort: Verwoerd visited the body in 1977 to conduct a "limited petrographic investigation" to which he concluded that Keikamspoort was a dolomitic carbonatite dyke. Verwoerd found that the field evidence was equivocal in that "no cross-cutting relationships were found", contacts were sand-covered, and the dyke conformed to the country rocks. Verwoerd describes the mineralogy as being "atypical" of carbonatites with the presence of K-feldspar and high-thorium monazite. Despite Verwoerd's reservations and lack of evidence regarding the magmatic origin of the carbonatite, Keikamspoort has been included in world-wide databases (Kjarsgaard, 2008) and compilations (Woolley, 2001) of carbonatites.

New field work has revealed clear evidence of multiple episodes of intrusion of magmatic dolomitic carbonatite. The aim of the study is to document and characterise the intrusions using field relationships, petrography/mineralogy and geochemistry.

The Keikamspoort ridge is located on the extreme south-western boundary of the Kaapvaal craton and consists of Ghaap Group sedimentary and volcanic sequences. Dolomitic carbonatite dykelets and sheets or pavements are hosted predominantly in tuffaceous mafic schist and cherty dolomite. Field evidence shows that there are at least two phases of carbonatite intrusion, the earlier intrusions are conformable to the trend of the ridge (Cd1 = dolomitic carbonatite 1) with the later intrusions emplaced as a swarm of narrow dykelets at high angle to this trend.

Geochemical data has shown that the dolomitic carbonatites are enriched in characteristic trace elements such as Sr, Ba and the REE. In addition, there is evidence that some of the country rocks in close spatial association to the carbonatites have been metasomatically enriched in Ba and REE by fluids released from the carbonatites.

Optical microscopy has shown that there is a variation in grain-size of the dolomitic crystals with samples exhibiting flow-banding.



Detailed SEM/EDS study has revealed the presence of zoned (to increasing Fe/Mg) medium-grained rhombs of dolomite in a groundmass of fine-grained ferroan dolomite. Monazite, barite and fluorapatite have been identified as interstitial phases. The carbonatite intrusions make up only 5-10% of the Keikamspoort ridge outcrop and mapping of the carbonatite is located below the current landsurface.

Figure 1. A sketch map of the geology of the Keikamspoort ridge (Taken from Verwoerd. 1993).

TITLE:	**The origin and timing of hydrothermal gold mineralization in the Amani Hills prospect, southwestern Tanzania**
PRESENTING AUTHOR:	**Stephan C. Dunn**
AFFILIATION:	Stellenbosch University
EMAIL ADDRESS:	stephanchalmers@gmail.com
SUPERVISOR/S NAME:	Dr Bjorn von der Heyden
DSI-NRF CIMERA THEME:	Base, gold and scarce metal deposits
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

Alluvial gold in the Amani area of southwestern Tanzania was first discovered during the early 1990s. Here, gold nuggets occur in conglomeratic horizons of braided river valleys. Since its discovery, the primary source of gold responsible for the alluvial occurrences remained unknown. However, a recent mapping campaign of the Amani area highlighted several prospects that contain primary Cu-Au mineralization, one of which being the Amani Hills prospect.

The Amani Hills prospect contains kilometre-scale, NW-SE to E-W trending D_2 brittle-ductile reverse shear zones. These shear zones contain a network of steeply dipping shear- and sub-horizontal extensional quartz-carbonate veins that host the mineralization. The mineralized veins are hosted in quartz-muscovite schists of the Amani Group and minor high-grade gneisses belonging to the Kabelege Group. $^{40}Ar/^{39}Ar$ dating of muscovite from the metasedimentary host rocks constrained the timing of gold mineralization between c. 550 – 600 Ma. Gold mineralization in the Amani area is thus related to the D_2 Pan-African reworking of the Ubendian Belt during the assembly of supercontinent Gondwana, which resulted in a collision between the Tanzania Craton and Bangweulu Block.

The main sulphide minerals in these veins are pyrite-pyrrhotite-chalcopyrite, with free-milling gold occurring predominantly in quartz and along sulphide grain boundaries. These gold-bearing veins are associated with sericite-muscovite-chlorite-epidote-albite alteration of the wallrocks. The $\delta^{18}O$ value of hydrothermal quartz from the Amani Hills prospect ranged between 10.22-15.53 ‰, corresponding to a calculated $\delta^{18}O_{fluid}$ composition of 4.92-10.23 ‰ for the hydrothermal fluid in equilibrium with quartz. Such a $\delta^{18}O_{fluid}$ composition is consistent with fluids derived from either crustal metamorphism and/or magmatic intrusions. The equivocal nature of the fluid source is further highlighted by fluid inclusion microthermometry, which indicates an ore-forming fluid regime composed of two distinct fluid types: (1) a moderate temperature (228-317 °C) and low-salinity (≤ 12 wt.% NaCl eq.) CO_2-H_2O-CH_4 fluid of metamorphic origin; and (2) a high temperature (320-560 °C) and hypersaline (32-54 wt.% NaCl eq.) H_2O-NaCl-CO_2 fluid that originated from either metamorphic devolatilization of higher-grade rocks or magmatic intrusions. Textural evidence suggests that both inclusion types occur in similar fluid inclusion assemblages, with secondary hypersaline inclusions also overprinting earlier assemblages. Fluid immiscibility by unmixing of a homogenous parent fluid is unlikely given the large homogenization temperature and compositional disparities of the two fluid inclusion types, instead they represent different fluid pulses that are physically and chemically distinguishable from another. Gold mineralization occurred under minimum P-T conditions of 350 °C and 2.56 kbar (crustal depth of 9.6 km), corresponding to greenschist facies metamorphic conditions.

Collectively, these characteristics are indicative of an orogenic gold deposit and these new results have major implications for gold exploration in the southern Ubendian Belt of southwestern Tanzania.

TITLE:	**Constrains on the genesis of the orbicular granites and sulphide mineralization in the Koperberg Suite, Namaqualand**
PRESENTING AUTHOR:	**Senamile Dumisa**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	869622@students.wits.ac.za
SUPERVISOR/S NAME:	Prof Paul Nex and Dr Grant Bybee
DSI-NRF CIMERA THEME:	Base, critical metals, gold and other deposits
REGISTERED DEGREE:	MSC
ORAL OR POSTER:	ORAL

Located in Namaqua Metamorphic Complex in the O'okiep copper district (Bushmanland Subprovince) are numerous, predominantly E-W trending, and < 1 km in strike length dykes and sill-like bodies of the 1020-1040 Ma Koperberg Suite (KS) that intrude the Namaqua-aged granitic gneisses and granites (1300-1000 Ma). The KS members are dominantly anorthosite and diorite, but also include syenite, quartz anorthosite, quartz diorite, biotite diorite, hypersthene diorite, biotite diorite and glimmerite, some of which are associated with Cu-sulphide ores. The principal sulphide ore parageneses in the KS is chalcopyrite + pyrrhotite, pentlandite, bornite + Ti-free magnetite. The KS also contains zones with orbicular textures, which are thought to form through either magmatic, metamorphic and/or metasomatic processes. Enzman (1953) observed that these orbicular rocks, in 63 different localities, are all associated with steep-structures described as discordant anticlines. Shells of contrasting mineral abundance and textures around a central core characterize these textures. In addition to the controversial petrogenesis of these textures, some orbicular zones in the KS are associated with Cu sulphide mineralization, leading some researchers to suggest a connection between orbicule formation and metallogenesis. This study aims to contribute to the understanding of the genesis of these rocks and their link to sulphide mineralization using field, petrographic, geochemical and isotope data. Four different orbicular localities in the KS are described including Orbicule Koppie (OK), Hoogskraal Leese (HL), Henderson North (HN) and the Henderson South (HS).

The orbicules are hosted in lithologies ranging from granitic to dioritic in composition. The orbicules are characterized by felsic matrices dominated by plagioclase (75%), biotite (20%), alkali feldspar (10%) and minor enstatite (10%). The matrices are similar in composition to the cores. However, modal abundances differ slightly from one locality to another. They are medium-grained, but this is not the case in the OK orbicules, which are characterized by coarse-grained matrices. The matrices from all the localities contain chalcopyrite and magnetite. However, chalcopyrite occurs as massive and disseminated grains in the matrices compared to the fine-grained and disseminated chalcopyrite in cores and shells. Sharp contacts between matrices and shells are observed in the HL and OK orbicules, however, the transition from the matrices to the shells is gradational in the HS and HN orbicules. The different localities are characterized by alternating mafic and felsic shells. This is not the case in the OK orbicules, which are characterized by single shells. The HS and the HL orbicule shells contain enstatite, which forms the radiating textures only restricted them. The concentration of chalcopyrite and magnetite generally increase from the matrices to the shells and chalcopyrite occurs as disseminated grains. Gradational contacts between shells and cores are observed in these orbicules. However, the transition from shells to the cores in HL orbicules is represented by sharp contacts. The cores are generally medium-grained and dominated by plagioclase (55%) with minor biotite (30%), opaque minerals (10%), alkali-feldspar (5%) and accessory chlorite and epidote (10%) on average. However, the HN and HS orbicules contain enstatite, which is not the case in the OK and HL orbicules. These cores are dominated by disseminated chalcopyrite and magnetite grains that occur as poikitic inclusions in enstatite, biotite and plagioclase. The concentration of chalcopyrite and magnetite generally decreases from the cores to the shells. Chalcopyrite is replaced by magnetite in all the orbicular structures in these localities and by bornite in HS orbicules.

In previous studies, radiating textures, alternating layers of contrasting mineral assemblages and shells characterised by sharp outer boundaries have been attributed to magmatic processes, rather than metasomatic and metamorphic processes. The replacement of chalcopyrite by magnetite has in the past been attributed to oxidation due to peak metamorphic conditions.

TITLE:	**A review of trace element incorporation into pyrite mineral structure in gold ore deposits**
PRESENTING AUTHOR:	**Lebogang Babedi**
AFFILIATION:	Stellenbosch University
EMAIL ADDRESS:	Babedi.lebogang@gmail.com
SUPERVISOR/S NAME:	Dr Bjorn von der Heyden
DSI-NRF CIMERA THEME:	Base, gold and scarce metal deposits
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

Pyrite is an iron disulphide (FeS_2) mineral which is the most abundant sulphide mineral in the Earth's crust and which is commonly associated with several hydrothermal deposits classes globally (e.g., epithermal deposits, orogenic deposits etc.). Although not of economic significance in its pure state, pyrite is known to be an important mineral host for a wide range of valuable trace elements including Ni, Co, Te, Se, and most importantly, gold (Au). As such, pyrite in many hydrothermal systems can be important as a source of these metals when present at acceptable grades. In addition, trace metals such as Co, Au, As and Ni are suggested as reliable proxy to predict ore forming process responsible for the occurrence of different ore deposit classes.

In this study we present an extensive review of the trace elements distribution within pyrite obtained from a global dataset reported in recent literature from four types of deposits: epithermal, Carlin-type, porphyry and orogenic gold deposits. The current study illustrates the different signatures of both major and trace elements across different ore deposits, while also establishing the trends of the trace element concentration within the core and rim of pyrite grains. The dataset is further utilized to test the robustness of different trace element proxies that are commonly used to distinguish between different ore genesis processes. This is augmented with Principal Component Analysis (PCA) to establish a novel approach towards utilising trace element signatures as a suitable discriminator between the different ore deposits. The study also illustrate the role of physicochemical parameters of the mineralizing hydrothermal fluids such as redox conditions and temperature on the consequent trace element incorporation into pyrite lattice structure or as nanoparticles. The study presents a body of work that is quintessential not only on a geological context but also to mineral processing. This is due to alteration in the electronic properties of pyrite upon the incorporation of trace elements resulting to the multiple responses exhibited by pyrite during flotation and leaching processes of different ores.

TITLE:	**Petrogenesis and geochemistry of an agpaitic ignimbrite in the Pilanesberg Complex**
PRESENTING AUTHOR:	**Juliet Akoh**
AFFILIATION:	University of Johannesburg
EMAIL ADDRESS:	ugbedeojocool@gmail.com
SUPERVISOR/S NAME:	Prof Marlina Elburg
DSI-NRF CIMERA THEME:	Base, gold and scarce metal deposits
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

The Pilanesberg Complex (PC) is hosted by the ca. 2.05 Ga Bushveld Complex located on the Kaapvaal Craton, in the Northwest Province of South Africa. The PC is the third largest alkaline complex in the world, consisting of a sequence of intrusive and extrusive rocks of syenitic to nepheline syenitic composition. Recent fieldwork has shown an unusual ignimbrite sheet in the northern part of the complex, the ignimbrite carries rare minerals and it is being described here for the first time. Although exposure is poor, this unit can be seen to have a very heterogeneous appearance with sub-rounded clasts (up to 15 cm diameter) set in a finer-grained matrix, which wraps around the clasts.

The primary mineralogy of the ignimbrite includes alkali-feldspar, aegirine, nepheline, apatite, titanite, fluorite, Fe-Ti-oxides, lamprophyllite, rinkite and eudialyte; the last three are minerals that characterise highly peralkaline (agpaitic) nepheline syenites. Based on its mineralogy, the ignimbrite crystalized at about 500 °C at a pressure of about 1 kbar, and the oxygen fugacity is around the FMQ buffer, with low water activity. Mineral textures and enrichments in some lithophile elements, suggest that a late hydrothermal phase brought about the alteration of nepheline and alkali feldspars followed by the formation of cancrinite, sodalite, analcime and natrolite, by metasomatic processes.

The rocks are highly evolved with Fe# close to unity in all samples, the composition is phonolitic and therefore one of the most evolved peralkaline rocks within the PC having Agpaitic Indexes up to 1.76, in agreement with the presence of lamprophyllite. The rocks are highly enriched in LILE, HFSE and LREE abundances but depleted in HREE.

The ignimbrite exhibits limited geochemical variation in the different field locations, however, decreasing whole rock contents of MgO, FeO, CaO, Ti_2O, P_2O_5, Sr, Ba, U and Y against the Fe# show that fractional crystallization is clearly the principal differentiation process. Although other magmatic processes such as magma mingling between a least and a more evolved magmas could accounts for the mineral zonation and mineralogical difference observed in the rocks. The ignimbrite exhibits a compositional variation between a crystal rich and crustal poor locality thus indicative of a zoned reservoir formed due to crystal-melt separation and mineral accumulation prior to eruption from a compositionally heterogeneous magma. The ignimbrite is interpreted to represent a single eruption from a weakly compositionally zoned magma chamber, the difference in mineral assemblage suggest different physico-chemical characteristics during crystallization and the rocks are classified in the agpaitic group according to their mineral assemblages.

TITLE:	**Geology and petrological investigation of iron ore deposits of the Rustenburg Layered Suite: A case study of Ga-Nchabeleng area, Sekhukhune District, Limpopo Province, South Africa**
PRESENTING AUTHOR:	**Julia Mapula Maponya**
AFFILIATION:	University of Venda
EMAIL ADDRESS:	mapulajulia4@gmail.com
SUPERVISOR/S NAME:	Emeritus Professor J.S. Ogola and Dr H.R. Mundalamo
DSI-NRF CIMERA THEME:	Manganese and iron ore deposits
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

The study area falls within the Sekhukhune District Municipality in Limpopo province. It is situated near the contact between the Bushveld Igneous Complex and the Transvaal Group sedimentary rocks. The Rustenburg layered suite which represents the Bushveld Igneous Complex in this region, consists of several igneous rock types varying from dunite and pyroxenite to norite, gabbro, anorthosite. The study aimed to investigate the geology and petrological study of iron ore deposit of Ga-Nchabeleng area.

The outcrops of the iron ore covers mainly the four hills with the host rocks forming mainly contacts between the iron ore. The geological mapping was conducted along traverses drawn across the general strike of the lithology. Iron ore and host rock samples were collected at an exposed area within and around four hills, and the detail geological map was produced. Ore sampling was done following the trend of the ore deposits. Collected rock and iron samples were characterised and X-ray fluorescence spectrometry method was used for selected samples for geochemical characterisation.

A detailed geological map was produced which revealed distribution of the lithologies within the study area and the geological setting of the iron ore in the area. The distribution of the iron ore revealed the stock-work - stringers - finger-like structures wherein geologic structures such as veins acted as conduits. Several lithologies were identified that included; varieties of gabbronorite, norite and an iron ore magnetite. The XRF results revealed gabbronorites with minimum and maximum FeO_3 wt% of 1.31% and 44.22% respectively while minimum and maximum values of FeO_3 wt% in magnetite ore samples were found to be 43.38% and 54.55% respectively with an average value of 52.36%. The magnetite revealed high concentration values of Zn (221 ppm), Ni (225 ppm), Co (163 ppm), Cr (503 ppm) and V (8981 ppm).

The study concluded that the iron ore is hosted by intermediate to felsic igneous rocks which were found to be gabbronorite and norite and the magnetite ore formed stringers zones that were randomly oriented veins associated with fractional crystallization of the layered complexes. The magnetite ore within the study area was of good grade with average value above 50% and rich in V, Cr, Ni, Zn and Co. Further investigation on ore mineralogy and ore-microscopy of the iron ore was recommended to further deduce the mode of occurrence, paragenesis and genesis of the Ga-Nchabeleng iron ore deposit.

Keywords: Iron ore, Bushveld Igneous Complex, Rustenburg Layered Suit, Ga-Nchabeleng, Mode of occurrence, fractional crystallisation

TITLE:	**Multiple sulphur isotopic compositions of Kaapvaal Craton eclogites: Implications for sulphur and precious metal crust-mantle cycling**
PRESENTING AUTHOR:	**Sara Burness**
AFFILIATION:	University of Johannesburg
EMAIL ADDRESS:	sarab@uj.ac.za
SUPERVISOR/S NAME:	Prof Sebastian Tappe
DSI-NRF CIMERA THEME:	Diamonds, kimberlites and deep crustal processes
REGISTERED DEGREE:	Post-doctoral Research Fellow
ORAL OR POSTER:	ORAL

Multiple sulphur isotopes, ^{32}S, ^{33}S, ^{34}S and ^{36}S, are effective tools used to trace the occurrence and potential antiquity of recycled surficial material in the Earth's mantle due to the inherent differences in crustal versus mantle sulphur isotope signatures. Mass-dependent sulphur isotope fractionation in modern terrestrial reservoirs (continental and oceanic crust) is prevalent due to relatively low temperature (<600 °C) bio-geochemical and metamorphic processes, which produce fractionations in $\delta^{34}S$ that can range between -50 and +40 ‰. At temperatures above 800 to 1000 °C, sulphur isotope fractionation becomes minute ($\delta^{34}S$ = <0.3 ‰) because sulphur isotopes are not notably fractionated as a result of igneous processes such as partial melting and crystallisation. During the Archean and Paleoproterozoic, $\delta^{34}S$ values of surface reservoirs were near zero because of a lack in oxygenation potential of the atmosphere. Moreover, photolytic reactions resulted in mass-independent sulphur isotope fractionation (S-MIF) of ancient sediments as a further consequence of the absence of a modern atmosphere. Both fresh MORB samples and sulphide inclusions in peridotitic diamonds point towards a relatively restricted mantle $\delta^{34}S$ value of -1 ± 0.5 ‰. Therefore, mantle-derived melts or rocks that have $\delta^{34}S$ values that differ significantly from this mantle value may reflect isotopic fractionation during low-temperature processes (<600 °C) or the incorporation of surficial material into the deeper mantle. In addition, non-zero $\Delta^{33}S$ values (S-MIF) indicate the presence of recycled Archean 'surface' sulphur in the geological record.

In this study, we present multiple sulphur isotope compositions of sulphides from a collection of well-characterised kimberlite-derived eclogite xenoliths from the Kaapvaal craton in South Africa. The eclogites equilibrated between ~140 and 220 km depth, and they represent fragments of subducted oceanic crust that underwent subduction-modification before incorporation into the lithospheric mantle [1]. Despite their oceanic crustal precursors, the eclogites also display distinct effects of secondary metasomatism by kimberlite- and flood-basalt-related mafic magmas, with enrichments in incompatible elements, specifically the REEs. The metasomatic events in particular had a significant effect on the formation and modification of the sulphides hosted in these eclogites, producing disparate PGE patterns that indicate complex histories of melt depletion and secondary enrichment. The sulphides display a wide range in $\delta^{34}S$ values from -5.72 to +29 ‰ and, with eclogite equilibration temperatures >1000 °C, suggests input from recycled crustal material. The $\Delta^{33}S$ values of the eclogitic sulphides essentially fall within error of sulphur mass-dependent fractionation ($\Delta^{33}S$ = 0 ± 0.2 ‰), which indicates that the recycled sulphur component may not necessarily be Archean in age and may relate to the metasomatic mobilisation of younger (post-Archean) crustal materials. Finally, the integration of the geochemical compositions of the host eclogites with the sulphide multiple sulphur isotope compositions allows us to elucidate the cycling of sulphur into the mantle and further, differentiate between recycled and primordial origins for these eclogitic sulphides and the precious metals that they tend to capture. *[1] Burness et al. (2020). Chemical Geology, 119476*

TITLE:	**Magmatic karst in the Bushveld Complex: unique insights into magma chamber dynamics**
PRESENTING AUTHOR:	**Willem Kruger**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	871839@students.wits.ac.za
SUPERVISOR/S NAME:	Prof Rais Latypov
DSI-NRF CIMERA THEME: (See attached flyer)	Metallogeny and paleogeographic Implications of Layered Igneous Complexes (LICs) and Large Igneous Provinces (LIPs)
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

If we wish to come to a complete understanding of the inner workings of magma chambers there are three questions we simply must be able to answer: where, why and how do magma chambers crystallize and differentiate? Potential solutions to these questions are diverse and there exists very little consensus among experts on the subject. Here we focus on crystallization processes within a fascinating environment in the Bushveld Complex that may provide some unique insights into the matter.

Our journey began with the discovery of an outcrop of the lowermost massive magnetitite layer in one of the open pits of the Rhovan vanadium mine from the Bushveld's Western Limb. The layer displays several features that are common to massive magnetitites of the Bushveld Complex, like a generally sharp bottom contact with an anorthositic footwall, and a gradational contact into the overlying magnetite anorthosite. One particularly exciting feature of this outcrop is the presence of several, typically elongated anorthosite inclusions that may range from a couple of to several tens of centimetres in size. Similar inclusions have previously been recorded in other layers of the Bushveld Complex (such as the Merensky Reef) but their origin still remains elusive. However, the presence of such inclusions in massive magnetitite provides a unique opportunity to finally solve their origin due to one remarkable feature of this rock type: the extreme compatibility of the trace element Cr into magnetite, with a crystal/liquid partition coefficient that may be in excess of 600 in basaltic melts. During the crystallization of magnetite, Cr in the magma is rapidly depleted, producing Cr concentration gradients within massive magnetitite layer that may be in excess of 3000 ppm/cm. By studying the two-dimension distribution of Cr in magnetitite, it becomes possible to observe the propagation of a solidification front on a centimetre scale. If we can observe the interaction of the solidification front with the inclusions, we may gain some important insights into their origin.

By geochemically mapping the outcrop using a portable XRF spectrometer, we observe a general decrease in Cr upwards within the magnetitite layer, indicating a general upwards propagation pattern of the solidification front towards the chamber interior. However, Cr contents are generally elevated around anorthositic inclusions, indicating nucleation and growth of magnetite directly on their outer surfaces. Our results strongly suggest the inclusions had to be present in their current positions and completely surrounded by melt prior to the crystallization of the magnetite. Their origin is ascribed to magmatic karstification of the anorthositic cumulates of the footwall, whereby the anorthosite is partially dissolved and/or melted by superheated magma along fractures and planes of weakness. This results in a complex environment of interconnected anorthositic fragments that appear isolated in two-dimensional outcrops.

In regard to the opening three questions, our results suggest that crystallization occurs in situ at the base of the magma chamber. Points of incipient nucleation and growth of the magnetite are located in areas where heat loss through the underlying cumulates on the floor will be most efficient (such as in depressions or close to inclusions), indicating cooling through the floor controls magmatic crystallization. Furthermore, magmatic kartstification results in crystallization within extremely confined spaces. In spite of this, magmatic differentiation within these confined areas is still a very effective process, suggesting that crystal/liquid fractionation possibly occurs by the convective removal of thin boundary layers around in situ growing crystals.

TITLE:	**Modelling the influence of carbonate assimilation of the stability of chromites: A case study of the Flatreef of the Northern Limb, Bushveld Complex**
PRESENTING AUTHOR:	**Siyasanga Dyan**
AFFILIATION:	Rhodes University
EMAIL ADDRESS:	dyansiyasanga@gmail.com
SUPERVISOR/S NAME:	Prof Stephen Prevec Dr Nicolas Tonnelier
DSI-NRF CIMERA THEME:	Metallogeny and paleogeographic implications of Layered Igneous Complexes (LICs) and Large igneous Provinces (LIPs)
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

The northern limb of the Bushveld Complex consists of various mineralized horizons, one of which is the Flatreef. The Flatreef is believed to be the correlative equivalent of the Critical Zone in the eastern and western limbs of the Bushveld Complex[1]. The northern limb is emplaced in direct contact with the Transvaal Supergroup sediments (quartzite, shale, dolomite and BIF) and shows significant evidence for magma-footwall interaction recorded petrologically and geochemically. Previous work in the Panzhihua oxide-mineralized intrusion (China) hosted on a carbonate platform demonstrated that assimilation of carbonate material liberated significant amounts of CO_2, which increased the overall oxidation state of the melt and subsequently promoting the saturation of Fe-Ti-V-type spinels[2]. Carbonate assimilation plays a significant role in promoting the stability of spinels by increasing the oxygen fugacity of the melt [2–4]. Thus, it is important to constrain the oxidation state of ores in order to discern between the influence of crustal contamination and other genetic models on ore formation. Previous researchers in the Bushvelds Complex have shown the influence of crustal contamination on spinels, however little work has been undertaken to constrain the recorded oxygen fugacity on chromite ores.

Evidence for carbonate assimilation in the Flatreef includes the presence of abundant high-temperature skarns and the formation of hybrid units at the magma-carbonate interaction zone. The hybrid units are characterized by enhanced crystallization of clinopyroxene with a high Ca-Tschermak component and high Fe^{3+}/Fe^{total} ratio, crystallization of olivine and also the high abundance of Cr-spinels. Assimilation-fractional crystallization modelling of the Critical Zone parental liquid with ~30% dolomite produced the mineral assemblages that are present in the contaminated zone, simultaneously liberating about 9 wt% CO_2 into the melt, without degassing. This provides further evidence that large quantities of CO_2-rich fluids were mobilized during partial decomposition of dolomite, contributing to the increase in oxygen fugacity conditions. The overall oxidative effect of CO_2 would be more prominent proximal to the skarns and progressively decrease away from the contaminated units into the interior of the magma.

The examined chromitites from the Flatreef are present as two main seams; the 'UG-2' equivalent that is occurs as semi-massive to massive chromitite, and a heavily disseminated lower chromitite seam. The semi-massive 'UG-2' chromitite comprises chromites with relatively higher Fe^{3+}/Fe^{total} ratio of up to 0.33, and the oxygen fugacity of about NNO+0.3. Oxygen fugacity of chromites from the lower chromitite seam are similar to that of the semi-massive 'UG-2', however their Fe^{3+}/Fe^{total} ratios are slightly lower (~ 25). Adjacent to the contaminated unit, chromites from the massive 'UG-2' have slightly lower Fe^{3+}/Fe^{total} ratio (~ 0.27) and higher oxygen fugacity values, at an average of NNO+1. Modelling simulations performed using rhyolites-MELTS demonstrate that increasing oxygen fugacity in the melts would potentially promote early stability of chromite at the expense of orthopyroxene by increasing the chromite/silicate ratio of the melt, potentially inducing the formation of a chromitite ore. Although these results are not a perfect match to Flatreef chromite, they provide crucial evidence of for influence of oxygen fugacity on their ore-formation.

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TITLE:	**Sr-Nd-Hf isotopic study of the komatiites in the Westonaria Formation of the Ventersdorp Large Igneous Province and implications for their petrogenesis**
PRESENTING AUTHOR:	**Khulekani Khumalo**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	1148016@students.wits.ac.za
SUPERVISOR/S NAME:	Prof Lewis Ashwal and Dr Ben Hayes
DSI-NRF CIMERA THEME:	Metallogeny and paleogeographic implications of Layered Igneous Complexes (LICs) and Large Igneous Provinces (LIPs)
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

Komatiites are generally restricted to the Archean and they are thought to be produced by large-degree melting of asthenospheric mantle. The 2.7 Ga Ventersdorp Large Igneous Province (VLIP) in South Africa is made up of continental flood basalts that were mostly emplaced into the Witwatersrand Basin on the Kaapvaal craton. The VLIP is subdivided into the Klipriviersberg Group, Platberg Group, and Pniel Sequence. The basal formation of the Klipriviersberg Group is the Westonaria Formation, which consists of komatiitic lava flows (MgO = 19-25 wt. %). We present new trace element data as well as the first Sr-Nd-Hf isotopes for the Westonaria komatiites in order to constrain their petrogenesis. In comparison to Barberton-type komatiites, the Westonaria komatiites are highly enriched (10 – 100x) in REE, and they show L/HREE enrichment. Two discrete groups of L/HREE enrichment were identified in the Westonaria komatiites – one with La/Sm_N of ca. 1.6 and one with La/Sm_N of ca. 2.7. They are also Al-depleted (subchondritic Al_2O_3/TiO_2 = 4.6 to 9.) with TiO_2 contents of ca. 1 wt. %. Ce/Yb ratios increase whereas MgO contents decrease up-section in the Westonaria komatiites. Our precise initial (2.7 Ga) isotopic compositions were measured by MC-ICP-MS following elemental extraction using the isotope dilution method. The Rb-Sr isotopes (initial $^{87}Sr/^{86}Sr$ = 0.7066 to 0.7164) show significant disturbance, possibly caused by low-grade metamorphism mobilising Rb. More reliable Sm-Nd (initial εNd = -1.72 o +2.16) and Lu-Hf (initial εHf = -1.62 to +3.60) isotopes are consistent with komatiite generation from a depleted mantle source. The Westonaria komatiites exhibit decoupling in L/HREE versus εNd, and in εNd versus εHf. The komatiitic nature of the Westonaria lavas, their enrichment in incompatible trace elements, and the decoupling of the Nd-Hf isotopic systems, point to a petrogenetic model that is somewhat different from typical (e.g., Barberton-type) komatiites. These elemental and isotopic variations could either be explained by: (1) melting of a garnet-bearing enriched domain in the SCLM; (2) melting of a garnet-bearing peridotitic source in the asthenospheric mantle followed by olivine-only fractional crystallization in upper crustal komatiitic magma chambers that caused melt depletion in MgO and enrichment in L/HREE; and/or (3) some amount of crustal contamination of komatiitic staging chambers in the upper crust. We will discuss some of these possibilities for the petrogenesis of the Westonaria komatiites.

TITLE:	**Petrogenesis of the Tennis Ball Marker in the Eastern Bushveld Complex South Africa**
PRESENTING AUTHOR:	**Busisiwe Khoza**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	687999@students.wits.ac.za
SUPERVISOR/S NAME:	Prof Rais Latypov and Dr Sofia Chistyakova
DSI-NRF CIMERA THEME:	Metallogeny and paleogeographic implications of Layered Igneous Complexes (LICs) And Large Igneous Provinces (LIPs)
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

Orthopyroxenite cumulates occur as layers that are interlayered with norites, gabbronorite, and chromitite. However, the orthopyroxenites at the Tennis Ball Marker occur as Spherical Bodies that are encased by a gabbronorite matrix. This feature is interpreted as a result of the spherical aggregation of suspended orthopyroxene crystals in a magma that was crystalizing plagioclase, orthopyroxene, and clinopyroxene. This hypothesis does not attest to the following observation: (a) variety of shapes possessed by orthopyroxenite cumulates (e.g. spherical, semi-circular, lath-like, arc, rectangular, and oval); (b) spherical orthopyroxenite chains; (c) the layering of the Tennis Ball Marker; (d) bending of the matrix beneath spherical orthopyroxene cumulates. Additionally, orthopyroxene crystals are known to be denser than basaltic melts. Hence, they would most likely gravitate to the chamber floor as soon as they crystallize to form a pyroxenite layer. In this study, we report a new field, petrographical, geochemical, and Sr-Nd-Hf isotope data for the TBM rocks to propose a new model for the origin of this feature. These show that: (1) the spherical orthopyroxene cumulates and the gabbronorite matrix are composed of the same mineral assemblage made up of plagioclase, orthopyroxene, clinopyroxene, quartz, biotite, oxides, and sulphides; (2) the spherical orthopyroxenite cumulates and the gabbronorite matrix are petrographically distinct; (3) the orthopyroxene and plagioclase crystals on the spherical orthopyroxenite cumulates have a higher Mg# and An content, respectively, compared to those on the gabbronorite matrix; (4) the whole rock Mg# and normative anorthite content on the spherical orthopyroxenite cumulates, is higher than those of the gabbronorite matrix; (5) the feldspar and pyroxene geothermometers, indicate a minimum crystallization temperature of the spherical orthopyroxenite cumulates, to be higher than those of the gabbronorite matrix; (6) The whole-rock trace elements distribution diagram for the spherical orthopyroxenite cumulates and the gabbronorite contrasting Ba and Sr anomalies; (7) the REE patterns of the spherical orthopyroxenite cumulates and the gabbronorite matrix, show contrasting Eu anomalies; (8) the REE patterns of the gabbronorite matrix are steeper than those of the spherical orthopyroxenite cumulates and they also show enrichments in REE with an increase in height; (9) The spherical orthopyroxenite cumulates and the gabbronorite matrix have similar Sr_i (0.706490-0.7077254); Nd_i (0.509622-0.0509703); Hf_i (0.281139-0.281241); εNd (-6.7 to -5.1) and εHf (-11.7 to -8) values which are constant with height. We propose a hypothesis that envisages an intrusion of an orthopyroxene saturated magma that crystallized to form an orthopyroxenite layer at the base. The fractionation of orthopyroxene in the magma evolved the magma in the chamber and feeder to the eutectic. The gabbronorite magma that ascended on the feeder to the chamber broke up the orthopyroxenite layer as it was opening up the bushveld chamber. The new magma percolated in between the orthopyroxenite fragments, eroded and transported them to the south. The spherical shapes of the orthopyroxenites were achieved by a chemical dissolution process that erodes the edges and corners at a higher rate compared to the planar surface.

TITLE:	**Regional structures of bifurcating Lower and Middle Group chromitites of the Bushveld Complex, South Africa**
PRESENTING AUTHOR:	**Maximilian Hasch**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	1972442@students.wits.ac.za
SUPERVISOR/S NAME:	Rais Latypov
DSI-NRF CIMERA THEME:	Metallogeny and Paleogeographic Implications of Layered Igneous Complexes (LICs) and Large Igneous Provinces (LIPs)
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

The Bushveld Complex is exposed in 5 lobes: the eastern Lobe, the Western Lobe, the Northern Lobe, the South-Eastern Lobe and the Far Western Lobe. Of these, the Eastern and Western Lobe are studied in this work. Stratigraphically the Bushveld Complex is subdivided into the Marginal Zone, the Lower Zone, the Critical Zone, the Main Zone and the Upper Zone. The Critical Zone is well known for its thick and laterally extensive chromitite layers, which are exposed at numerous open pits and within underground mines. These are both economically viable and a scientific conundrum as to their formation mechanism. The chromitites are subdivided into seven Lower Group chromitites (LG), four Middle Group chromitites (MG), and two to three Upper Group chromitites (UG). Their great thickness is not explainable by conventional crystallisation mechanisms. Consequently, numerous formation models have been postulated and there is to date no agreement as to which of these is correct.

This study aims at contributing to the discussion through field observations made at a multitude of outcrops in the Eastern and Western Lobes of the Bushveld Complex. As the focus of recent works has been mostly on the Upper Group, this study analyses Lower and Middle Group chromitites. The LG6 has been closely examined and the morphology and petrology of MG chromitite layers have been analysed.

A regional structure in the Eastern Lobe has been discovered by combining observations from a plethora of outcrops and drill core studies. Different outcrops present distinct numbers of chromitites and variable spacing between them. This indicates a structure of regionally bifurcating chromitites to be present in the Middle Groups. Several kilometres wide lenses of silicate in chromitite layers may cause them to split, which would result in the differences in number of chromitite layers and their spacing at the various outcrops.

This structure may have formed from multiple pulses of superheated magma that each eroded part of the chamber floor and, upon cooling, crystallised first a chromitite and then a silicate layer. After one sequence deposited, the next pulse of magma would have eroded either part of or the entire previous silicate layer. Different erosion rates would have acted at each location, causing either a single or several chromitite layers to form from subsequent magma pulses.

This theory implies two things: first, that extensive magmatic erosion had taken place as new magma entered the chamber and second, that chromitite layers were formed by various magma pulses. Local observations provide evidence for magmatic erosion. Two potholes, circular to elliptic depressions within chromitite layers, were studied. These two cases show an erosive contact between the chromitite and its footwall. Furthermore, clasts of footwall orthopyroxenite were found to protrude into the chromitite, but to still be attached to the footwall. This suggests footwall rock around the clasts to have been eroded. Evidence, suggesting chromitite to have formed from multiple magma pulses, comes from the LG6. In this 1.5m thick chromitite, several sublayers of different petrological characteristics were observed. This suggests the LG6 to have been formed by various magma pulses. The next step of this PhD work will be to carry out chemical analyses of an LG6 drill core in order to verify sublayering in its chemistry.

The observations presented here suggest the general formation of thick chromitite layers in the Bushveld Complex to have taken place by influx of multiple pulses of magma. Each of these pulses would have first eroded part of its footwall and later crystallised a chromitite layer (see e.g. Latypov et al. 2018).

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TITLE:	**Constraints on the origin and evolution of the Epembe carbonatite dyke, NW Namibia, using fluor-apatite and zircon geochemistry**
PRESENTING AUTHOR:	**Mbili Tshiningayamwe**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	1935597@students.wits.ac.za
SUPERVISOR/S NAME:	Prof Robert Bolhar and Prof Paul Nex
DSI-NRF CIMERA THEME:	Early earth mineral systems and metallogenesis
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

Fluor-apatites and other associated minerals (calcite, pyrochlore, aegirine, zircon, biotite, feldspar and monazite) from representative carbonatite rocks of the Mesoproterozoic Epembe alkaline carbonatite complex in northern Namibia were studied with respect to their petrographic context, occurrence and chemistry, using SEM, EPMA and LA-ICP-MS. Fluorapatite occurs in clusters, as disseminated grains or as inclusions within aegirine, pyrochlore and zircon indicating that it crystallized early. Its REE concentration increases with increasing Na, suggesting intake of REE according to the coupled substitution mechanism: $Ca^{2+} + Ca^{2+} \varepsilon Na^{+} + REE^{3+}$. REE are relatively low in calcite, zircon, feldspar, biotite and aegirine due to early crystallization of fluorapatite, which served as an early sink of these elements. While present in low abudances, pyrochlore and hydrothermal monazite contain relatively high REE concentrations when compared to fluorapatite. LA-ICP-MS U-Pb dating on zircon gives an age of 1198 ± 5 Ma (MSWD = 1.8, n = 9). The age-corrected ε_{Nd} in fluorapatites from different carbonatite samples display a narrow range from 0.0 to +3.3, while the age-corrected ε_{Hf} values for zircon are in the range of +0.5 to +1.9. Whole rock major geochemistry reveals broadly linear trends that can be attributed to fractional crystallization. Primitive mantle-normalized whole rock trace element compositions are characterized by elevated incompatible elements with depletions in some HFSE and negative Pb. Combined $\varepsilon_{Nd(t)}$ and $\varepsilon_{Hf(t)}$ with whole rock trace element compositions are consistent with minor interaction of asthenospheric mantle-derived magma with a metasomatically altered, depleted lithospheric mantle. Despite some geochronological and isotopic similarities with the Kunene Complex, certain geochemical characteristics are different, pointing to distinct mantle sources and petrogenetic histories.

TITLE:	**Geology of selected sites along the northern margin of the Barberton Greenstone Belt**
PRESENTING AUTHOR:	**Phumelele Mashele**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	geode19@outlook.com; 458861@students.wits.ac.za
SUPERVISOR/S NAME:	Prof Judith Kinnaird, Prof Christoph Heubeck and Prof Paul Nex
DST-NRF CIMERA	Early earth metallogenic processes
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

Volcano-sedimentary complexes and adjacent plutonic rocks in the basement of Archean cratons, such as the Barberton Granite Greenstone Terrane (BGGT), remain our primary source of information about early Earth processes. Part of the global significance of the BGGT is that it contains some of the best-preserved, continuous strata of early Archean age on Earth. Through the years, researchers have studied various components of the BGGT, collectively producing plausible reconstructions of early Earth conditions and processes.

Extensive work has been completed on such diverse topics as the evolution of the lithosphere and construction of continents, the origins of life, life's emergence from marine to terrestrial environments, composition of the atmosphere and oceans, meteorite impacts, climate and weathering, the response of the early crust to regional stresses and the implications for ore-forming processes. Although many of these topics - or aspects thereof - remain debated, the global significance of the BGGT is universally acknowledged. As a result, a large part of the BGGT was declared a World Heritage Site (WHS) in 2018 principally based on geological merit.

This study addresses the scientific outreach objective of both CIMERA and the management authority of the Barberton Makhonjwa Mountains WHS by collating, updating and disseminating geological knowledge about selected outcrops within the BGGT. To broaden the appeal of the Barberton Makhonjwa Mountains World Heritage Site as a tourist destination, I have focused on eight geologically significant and instructive sites along or near the R38 road, skirting the northern margin of the BGB. This road links Barberton to the southern gates of Kruger National Park.

The sites represent contact zones of the BGB supracrustal sequence and surrounding granitoids, mineralisation associated with ultramafic intrusives, highly strained conglomerates, and low-grade metamorphism. Objectives vary between original scientific work (including high-resolution geological mapping, petrographic and bulk chemical analysis, elemental mapping using µ-XRF etc.) and synthesising pre-existing scientific data.

By placing the selected sites in the context of modern BGB stratigraphy and tectonics as well as preparing learning objectives for laypersons, this study produces both original geological literature as well as laying the base for educational products aimed at the general public, including adequately phrased pamphlets and guidebooks.

TITLE:	**The geology of the Dominion Group in the Ottosdal area**
PRESENTING AUTHOR:	**Dora Paprika**
AFFILIATION:	University of Johannesburg
EMAIL ADDRESS:	dpaprika@uj.ac.za
SUPERVISOR/S NAME:	Prof Axel Hofmann and Dr Andrea Agangi
DSI-NRF CIMERA THEME:	Early earth mineral systems and metallogenesis
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

The Mesoarchaean Dominion Group (DG) is the oldest intracontinental volcano-sedimentary cover sequence of the Kaapvaal craton. It consists of three formations. The lowermost unit is the Rhenosterspruit Formation (RsF), a fluvial sedimentary sequence of sandstone and conglomerate with sub-economic gold and uranium mineralisation. It is followed by the Rhenosterhoek Formation (RhF) that consists of mafic to intermediate lavas and tuffs. The uppermost Syferfontein Formation (SF) is composed of subaerially emplaced felsic lavas and locally intercalated sedimentary rocks. The DG is of low metamorphic grade, has a maximum thickness of about 2500 m (1), and is discontinuously exposed in four main areas in the Kaapvaal craton: Ottosdal, Hartbeesfontein-Klerksdorp, Vredefort and Ventersdorp. In this study, the volcanic succession of the DG will be discussed from the Ottosdal area.

Outcrops in the Ottosdal area are mostly restricted to the SF. The RhF is poorly exposed but was studied in drill cores. Well-preserved amygdaloidal or rare variolitic basaltic to andesitic lavas, welded tuffs and brecciated volcanic rocks (i.e. hyaloclastite, autobreccia, pyroclastic breccia) occur, which are related to different volcanic processes. Thin intercalations of sandstone and shale are uncommon. Rock types suggest predominantly subaerial volcanism in the area with brief periods of sub-aqueous conditions.

The felsic volcanic rocks of the SF are very similar in characteristics and show coherent, porphyritic or spherulitic, poorly or non-vesicular textures and flow foliation structures that record subaerial volcanism. Locally, pyroclastic rocks such as ignimbrite or agglomerate occur, but have a restricted lateral extent. Pyrophyllite-rich sedimentary rocks locally known as 'wonderstone` (2) form several distinct units up to 80 m thick and are intercalated with the felsic volcanic rocks. The 'wonderstone` consists of turbiditic sandstone and shale inferred to have been deposited in volcanic lakes (3). While felsic volcanism shaped the ancient landscape mapping revealed four laterally extensive 'wonderstone` layers that were deposited during periods of volcanic quiescence. Locally, alteration profiles typical of palaeoweathering (e.g. corestones) and also hydrothermal activity (e.g. alteration zones and veins) are present below 'wonderstone` units. Similar to the Klerksdorp area (4), the contact between the SF and the Witwatersrand Supergroup is erosional and unconformable and is characterized by a basal conglomerate and sandstone overlain by shales of the Parktown Formation. Minor mafic intrusions disturbed the otherwise moderately tectonised sequence.

Regional-scale open, upright or steeply inclined, gently plunging folds with NNW-SSE axis affected the DG, as well as the overlying West Rand Group. NW—SE oriented faults resulted in a notable thickening of the sedimentary rocks locally. Another normal and reverse fault system striking ENE—WSW is resulting in common offsets of the strata.

The geological observations of the Ottosdal area play an important part to better understand the evolution of the Witwatersrand basin. In addition, they assist the local operating pyrophyllite mines to target new prospects more efficiently.

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TITLE:	**A search for source magma for Archaean LCT pegmatites in the Bikita and Mweza fields, Zimbabwe**
PRESENTING AUTHOR:	**Godfrey Chagondah**
AFFILIATION:	University of Johannesburg
EMAIL ADDRESS:	geolochagondah@yahoo.com
SUPERVISOR/S NAME:	Prof Axel Hofmann
DSI-NRF CIMERA THEME:	Early earth mineral systems and metallogenesis
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

The southern margin of the Zimbabwe craton hosts Neoarchean LCT pegmatites in the Bikita and Mweza fields. The pegmatites occur in greenschist-amphibolite grade greenstones, which are enclosed and intruded by syn- to post-tectonic granitoids. However, the source magma of the world-class rare metal pegmatites and their relationship to the spatially and temporarily associated granite plutons is unknown. Thus, the association of the pegmatite fields and granitoids along the southern margin of the Zimbabwe craton present a natural laboratory to test the pegmatite genesis model as differentiates of parental granite plutons (e.g. Trueman and Černý, 1982). We employed an integrated approach including precise U-Pb zircon geochronology and whole-rock geochemistry on granites as well as mineral chemistry on pegmatites and the surrounding granite plutons in order to get an insight into the relationships of the felsic intrusions.

U-Pb zircon dating constrained the age of the pegmatites across both fields at c. 2628-2616 Ma (Melcher et al 2014; Detrich et al. 2018), whereas the spatially associated I-type granites yielded ages of c. 2637-2622 Ma for the marginally peraluminous Chilimanzi suite and c. 2626 Ma for the metaluminous Razi suite. Thus, based on the age data it is conceivable for the pegmatites to be products of the spatially associated granite suites. Whole-rock magmatic fractionation indicators such as K/Rb, K/Ba, Rb/Sr, Zr/Hf and Nb/Ta show that Chilimanzi and Razi suite granitoids in the environs of the Bikita field are more fractionated and enriched in trace elements (e.g. Rb, Sn, Li, Cs, Ta, Nb, and W) relative to the same suites in the Mweza field, which we attribute to exposure of the intrusions at different structural levels. Furthermore, mica and K-feldspar chemical data show that the more fractionated plutons from both suites are enriched in fluxing components (Li, F and P) compared to the less fractionated plutons. Muscovite and K-feldspar display resembling fractionated chrondrite-normalized REE patterns in granites and pegmatites which indicates a common source. K/Rb chemical fractionation versus Li, Rb, Tl, and Cs concentrations in muscovite and K-feldspar reveal linear and continuous trends from the granites through to the pegmatites which suggests their close linkage. We conclude on the basis of geochronological and geochemical data as well as field relation evidence that the LCT pegmatites from the Bikita and Mweza fields are late-stage differentiates of the spatially associated evolved plutons, which is consistent with a fractional crystallization model for the pegmatite origin.

TITLE:	**Maceral types and quality of coal in the Tuli Coalfield: A case study of coal in the Madzaringwe Formation in Vele Colliery, Limpopo Province, South Africa**
PRESENTING AUTHOR:	**Elelwani Denge**
AFFILIATION:	University of Limpopo
EMAIL ADDRESS:	Elelwani.denge@ul.ac.za
SUPERVISOR/S NAME:	Dr Christopher Baiyegunhi
DSI-NRF CIMERA THEME:	Energy resources
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

The Permian stratigraphy of the Tuli Coalfield in the Vele colliery, from the base to the top, consists of the Tshidzi Formation, Madzaringwe Formation, Mikambeni Formation and Fripp Formation. The Madzaringwe Formation in the former Vele colliery (now referred to as Vele MC Mining) is the focus of this study and it is one of the coal-bearing late Palaeozoic units of the Karoo Supergroup, consisting of sandstone and shale with thin coal seams. In the Vele colliery, seven coal samples were collected from the three existing boreholes OV125149, OV125156, and OV125160 to determine the rank and other intrinsic characteristics of the coal. Maceral group analysis was conducted on the coal samples under oil immersion using a Zeiss Axiolmager reflected light petrographic microscope fitted with a Hilgers Diskus- Fossil system. The results are reported on a percentage volume (vol.%) basis and it excludes or free of mineral matter (mmf). The petrographic characterization revealed that vitrinite is the dominant maceral group in the coals, making up to 81-92 vol.% (mmf) of the total sample. Collotellinite is the dominant vitrinite maceral, with total count varying between 52.4 vol.% (mmf) and 74.9 vol.% (mmf), followed by corpogelinite, collodetrinite, tellinite and pseudovitrinite with count ranging between 0.8-19.4 vol.% (mmf), 1.5-17.5 vol.% (mmf), 0.8-6.5 vol.% (mmf) and 0.3-5.9 vol.% (mmf), respectively. The dominance of collotellinite gives a clear indication that the coals are derived from the parenchymatous and woody tissues of roots, stems and leaves. The mean random vitrinite reflectance values range between 0.75 and 0.76%, placing the coals in the medium rank category (also known as the high volatile bituminous coal) based on the UN-ECE coal classification scheme. The inertinite content is low, ranging between 4-16 vol.% (mmf) and it is dominated by fusinite with count of about 1-7 vol.% (mmf). The high amount of inertinite, especially fusinite with empty cells and semifusinite in the coals will pose a threat to coal mining because it aids the formation of dust.

Keywords: *Coal, maceral, quality, Madzaringwe Formation, Tuli Coalfield*

TITLE:	**A geochemical and thermobarometry study of kimberlite indicator minerals from the Kaapvaal and Zimbabwe Cratons and environs, southern Africa**
PRESENTING AUTHOR:	**Sinelethu Hashibi**
AFFILIATION:	University of Cape Town
EMAIL ADDRESS:	Phil.janney@uct.ac.za
SUPERVISOR/S NAME:	Prof Philip Janney and Dr Alastair Sloan
DSI-NRF CIMERA THEME:	Diamonds, Kimberlites and Deep Crustal Processes
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

Southern African lithosphere is constituted of the Archean Kaapvaal and Zimbabwe cratons and surrounding Proterozoic mobile belts. The Archean age Limpopo mobile belt is sandwiched between the two cratons. Cratons are underlain by a thick mantle keel which is chemically and physically distinct from mantle underlying post-Archean terranes. Part of this lithosphere was imaged by seismic tomography (Kaapvaal Seismic Experiment, KaapSeis, James and Fouch, 2002), which shows that the interiors of Kaapvaal and Zimbabwe cratons have higher mantle velocities, relative to 'disturbed' cratonic regions (e.g., the area beneath the Bushveld Complex) and post-Archean terranes (James and Fouch, 2002). Mantle xenolith studies have provided key data on the composition and thermal structure of the lithospheric mantle, but these data come from only a small number of xenolith-bearing kimberlites. In contrast, virtually all kimberlites have yielded kimberlite indicator minerals (KIM). Investigation of KIMs, such as garnet (e.g., Kobussen *et al.*, 2008, 2009) and clinopyroxene (Robles-Cruz *et al.*, 2012) have proved to be a powerful method of studying the chemical and thermal structure of the mantle.

KIM data from approximately 200 kimberlite localities from across southern Africa (largely data collected by or in association with the diamond exploration industry) have been compiled and analysed for purposes of geochemical characterisation and determination of equilibration temperatures and pressures by single mineral xenocryst thermobarometry for both garnet (Ryan *et al.*, 1996) and clinopyroxene (Nimis and Taylor, 2000). This data is used to assign paragenesis to the KIMs, evaluate the extent of melt depletion and metasomatism recorded by peridotitic KIMs and to investigate variations in geothermal gradient (using fitplot program of Mather *et al.*, 2011) and constraints on lithospheric thickness in time and space. This approach is similar to that of Kobussen et al., (2008,2009), but applied to wider area and uses clinopyroxene in addition to garnet. Emphasis is placed upon using "big data" approaches to statistically analyse and visualise data from more than 40 000 garnet and 10 000 cpx analyses, nearly half of which include trace element data. Our main goals are to (1) determine the extent to which major variations in KIM chemical and thermal characteristics correlate with crustal tectonic boundaries between cratons and mobile belt terranes, and (2) how they can be correlated with seismic velocity variations from KaapSeis and other published tomographic models (e.g. global surface-wave models). Identified correlations could be used to infer lithospheric structure beneath areas of southern Africa not imaged by KaapSeis.

Preliminary results from a few on- and off-craton kimberlites showed comparable average temperatures, which could be suggestive of similar thermal states of the lithospheric mantle they sampled. Average titanium contents of group 1 and group 2 kimberlites in this dataset appear more consistent than previously reported in similar studies (Kobussen *et al.*, 2008,2009). More results will be presented at the oral presentation as this is an ongoing study.

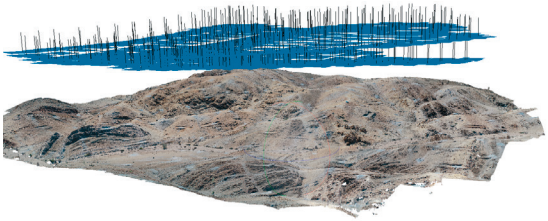
TITLE:	**Rapid fracture network quantification at the Valencia U deposit, Namibia using UAV photogrammetry**
PRESENTING AUTHOR:	**Thomas Jones**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	2187333@students.wits.ac.za
SUPERVISOR/S NAME:	Prof Judith Kinnaird and Prof Paul Nex
DSI-NRF CIMERA THEME:	Base, gold and scarce metal deposits
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	POSTER

Mineralogical and geochemical investigations of hand samples recently suggested that U^{6+}-silicates (e.g. boltwoodite and uranophane) found along fractures and veins are an important component of uranium deposits in the Erongo region of Namibia. These U^{6+} silicates are easily leachable and hence understanding their distribution within deposits is of economic significance. Despite this, the brittle fracture networks hosting these U^{6+} silicates have not been studied in detail.

We undertook a quantified study of the fracture network at the Valencia uranium deposit using a small unmanned UAV. An initial UAV survey was flown over the deposit area at 110 meters altitude to produce an orthorectified aerial photograph and digital elevation model with a resolution of ~3cm per pixel. These datasets were used to produce a lineament map showing the 2D orientation of the fracture system. This lineament map was imported into FRACPAQ, which allowed automatic calculation of numerous fracture attributes, including the relationship between fracture orientation and length, and an estimate of the 2D connectivity of the fracture network.

Three key outcrops were then identified and photographed from all angles using the UAV. We aimed to capture 90% overlap between individual photographs. Structure-from-motion photogrammetry was then used to compute 3D digital outcrop models of these outcrops. These digital outcrop models were visualised in 3D on a high-spec workstation-computer, allowing us to collect digital structural measurements (dip and strike) with an accuracy comparable to that obtained from a standard compass-clinometer in the field. Over 400 fracture planes were measured and recorded digitally on the computer screen in ~4 hours. We are currently investigating the potential of using this technique for measuring the length of individual fracture planes and to quantitatively analyse the spacing between fractures.

Preliminary results suggest that there are 2 main steeply dipping, orthogonal, fracture sets striking 1) NNW-SSE to north-south, and 2) ENE-WSW to east-west. The fractures are overwhelmingly joints and they display a strongly clustered distribution, forming laterally extensive sub-parallel corridor structures. The fracture network is poorly connected overall, which may limit the ability of fluids to infiltrate and flow through the otherwise impermeable crystalline rocks. Fracture connectivity is however locally higher where the N-S and E-W striking fractures intersect.



TITLE:	**Geochemical characterization of host rocks and hydrothermal alteration associated with antimony-goldmMineralization along the Antimony Line, Murchison Greenstone Belt, South Africa.**
PRESENTING AUTHOR:	**Thabo Kgarabjang**
AFFILIATION:	University of Limpopo
EMAIL ADDRESS:	kgarabjangts@gmail.com
SUPERVISOR/S NAME:	Prof Napoleon Hammond
DSI-NRF CIMERA THEME:	Base, gold and scarce metal deposits
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

The Antimony Line is a 50 km long, 250 m wide linear shear or fault zone that occurs at the center of the Murchison greenstone belt. It is characterized by intense deformation and represents a central, semi-brittle deformation zone within a broad ductile shear zone with oblique to a dip-slip sense of movement (Boocock et al. 1984). The Antimony Line hosts several gold and antimony mineralization within massive, fractured talcose and carbonate schist host rocks. The Winchester and Floyd (1977) geochemical plot was used to determine the protolith from geochemical data of host rocks from the Beta, Athens, Monarch and Louwskop orebodies along the Antimony Line. The Winchester and Floyd (1977) geochemical plot utilizes immobile elements such as Ti, Zr, Y, Nb, Ce, Ga, Sc to distinguish and classify volcanic suites from altered and metamorphosed equivalents. The geochemical data from the host rocks along the Antimony Line shows several characteristics distinctive to schists of basaltic origin, but exhibiting some degree of differentiation from andesitic to alkaline basalt. Additional distinguishing characteristics include the unusually high Mg contents and relatively low Na and Ca contents. The data further indicates relatively low SiO_2 contents.

Hydrothermal alteration is pervasive along the Antimony Line. During hydrothermal alteration, the parent rock may undergo mass/volume and elemental changes, where elements are added or removed from the parent rock depending on the physical and chemical properties of the hydrothermal fluids. The Grant Isocon (Grant 1986) was used to quantify the hydrothermal alteration along the Antimony Line in the Murchison greenstone belt. The quantitative relationship for the mass change (ΔC_i) is given as:

$$\Delta C_i = \left(M^A/M^0 * C_i^A\right) - C_i^0$$

where: c_i^A = concentration of an element after alteration. M^0 = mass of an element before alteration.

M^A = mass of an element after alteration. ΔC_i = change in element concentration.

C_i^0 = concentration of an element before alteration.

Elements that remained immobile during fluid-rock interaction plot on the isocon, which defines a straight line through the origin given by $c_i^A = \frac{M^0}{M^A}\left[C_i^0\right]$, where the ratio M^0/M^A is equivalent to the slope of the straight line. A slope of one represents isovolumetric behavior. Components that lie above the isocon indicate enrichment in the altered rock, and depletion if they plot below the line. Along the Antimony Line, elements such as SiO_2, V, Cu, and K_2O have been added to the host rocks as a result of hydrothermal alteration while elements including CaO, MgO, and Cr_2O_3 were removed. The enrichment of SiO_2 is indicative of the occurrence of silicification. However, despite the significant enrichment and depletion of elements in the host rocks, there was no significant change in the mass/volume of host rocks during hydrothermal alteration as illustrated by the isovolumetric Isocon.

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TITLE:	**Petrology and geochemistry of the Dando-Kwanza kimberlite 'lavas' in central Angola**
PRESENTING AUTHOR:	**Lungele Steve Kitoga**
AFFILIATION:	University of Johannesburg
EMAIL ADDRESS:	stevek@uj.ac.za
SUPERVISOR/S NAME:	Prof. Sebastian Tappe
DSI-NRF CIMERA THEME:	Diamonds, kimberlites and deep crustal processes
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

The extreme rarity of kimberlitic lavas and their pronounced alteration in the Igwisi Hills area (Tanzania), the only locality where they crop out, have hampered evaluations of petrologic conditions for such unusual occurrences. Commonly, kimberlites occur as sills/dykes or as diatremes (pipes), caused by multi-phase explosive magma eruptions. Kimberlite magma compositions are believed to influence their emplacement mode. Fresh kimberlitic lava lakes and plugs occur in the Dando-Kwanza (DK) area on the Congo craton in central Angola, but have not yet undergone a detailed mineralogical or geochemical study, in spite of their potential to unravel petrologic conditions that can favour kimberlitic lavas to flow out at the Earth's surface. We have conducted mineralogical and geochemical investigations on the Dando-Kwanza lavas with the aim to understand the main conditions which can make kimberlitic melt to effusively erupt instead of forming a volcanic pipe through an explosive eruption.

The results show that the coherent archetypal DK kimberlitic lavas consist of olivine and spinel phenocrysts set in a groundmass of olivine, spinel, monticellite, apatite and calcite. Olivine grains generally have a core-rim structure. Cores have a dominant xenocrystic origin and yield higher NiO but lower CaO than the magmatic rims. The DK kimberlites and their magmatic olivine population record some of the highest Mg-values among kimberlites worldwide, suggesting that the sampled mantle lithosphere is highly depleted beneath the DK area of the Congo craton. In addition, the Fe-in-monticellite oxybarometer demonstrates that the DK lavas crystallised under very high oxygen fugacity conditions, only matched by the Eocene Lac de Gras kimberlites in Canada. The high oxygen fugacity supports that the DK kimberlite lavas did not lose a considerable amount of their magmatic CO_2 by degassing. Low SiO_2 in these rocks suggests that although orthopyroxene assimilation occurred during crystallisation of the olivine rims (strong NiO decrease in olivine rims), it was not significant enough to cause a drastic drop in CO_2-solubility, which is typically considered to be a main factor in triggering explosive kimberlite magma eruptions and associated pipe formation. In addition, low Sr contents of apatite grains, similar to those observed in kimberlite sills and dykes from Kimberley, demonstrate that during final-stage crystallisation the DK kimberlites evolved as dykes or sills rather than as pipes.

On the basis of these results, we propose that an extremely depleted lithospheric mantle similar to that sampled by some North American kimberlites is instrumental for kimberlitic melt to reach the Earth's surface. Interaction with such mantle lithosphere allows the melt to conserve the CaO-rich and SiO_2-poor character of primary kimberlitic melts, hampering liberation of CO_2, which is thought to cause explosive eruptions. As a consequence, the kimberlitic magma system evolves as a sill or a dyke without important CO_2 liberation, and if local geological conditions like a thinner cratonic crust allow, a low-viscosity kimberlitic melt can potentially erupt at the Earth's surface. The rarity of kimberlitic lava flows could be related to the scarcity of extremely depleted mantle lithosphere, with surface erosion only playing a minor role in the biased kimberlite rock record.

TITLE:	**Advanced non-destructive analytical techniques for the South African coal industry, with a focus on hyperspectral imaging**
PRESENTING AUTHOR:	**Welhemina Langa**
AFFILIATION:	University of Johannesburg
EMAIL ADDRESS:	welheminasito@gmail.com
SUPERVISOR/S NAME:	Prof Nicola Wagner and Dr Phil Harris
DSI-NRF CIMERA THEME:	Energy resources
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	POSTER

Exploration is the principal method used to investigate the reserves and resources of coal. It is also a significant stage in planning the future of the mine, setting up a processing plant, and estimating the commodity market. Exploration involves three stages: drilling, core logging, and sample analysis; and all stages require a competent scientist. In the coal industry, drilling is the method to investigate subsurface geology. The core is logged to describe the different sedimentological units, their thickness, mineral composition and the number of seams intersected by drilling. Core sampling is done for laboratory analyses for confirmation of the coal grade, rank and type. Exploration is a lengthy process, and the fourth industrial revolution (4IR) can improve the process by the introduction of advanced techniques that can be used during the exploration and exploitation. This study aims to establish the viability of selected advanced techniques for the rapid characterisation of South African coal during exploration and coal quality assessment.

Digital core-logging (DCL), core scan hyperspectral imaging (CS-HI), handheld x-ray fluorescence (hXRF), and core scan x-ray fluorescence (CS-XRF) are the four advanced techniques identified by this study for rapid characterisation of coal, with a specific focus on CS-HI. These advanced techniques are intended to simplify the analytical procedures, improve the level of accuracy, rapidly acquire data and might reduce the dependence of human beings. CS-HI, hXRF, CS-XRF and DCL are non-destructive techniques that do not require any specific sample preparation apart from a clean core. Various authors have shown that CS-HI can be successfully used for mineral mapping, lithological differentiation, and identifying structures and the type of contact. CS-XRF and hXRF techniques are used to obtain major and minor elements. DCL provides a more efficient way of logging core compared to the traditional method of core logging, where saved images and logged core can readily be retrieved and re-assessed on a computer.

These advanced techniques have not been widely used in the South African coal industry due to lack of research but have been successfully used in exploration of other commodities. Coal is heterogeneous and requires different ways of handling and analysis relative to other rock types. Therefore, it is significant to test and demonstrate the use of CS-HI, hXRF, CS-XRF and DCL to characterise South African coal. This study will compare the data obtained from analytical traditional methods such as x-ray diffraction (XRD), laboratory-based x-ray fluorescence (XRF), optical microscopy (petrography), scanning electron microscopy, and microprobe, with the advanced techniques to validate their viability on South African coal.

TITLE:	**X-ray computed tomography analysis of Cu-sulphide textures from Phalaborwa: an indicator for ore-forming processes**
PRESENTING AUTHOR:	**Loic Le Bras**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	loic.y.lebras@gmail.com
SUPERVISOR/S NAME:	Prof Robert Bolhar, Dr Grant Bybee and Prof Paul Nex
DSI-NRF CIMERA THEME:	Base, critical metals, gold, and other deposits.
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	POSTER

The Loolekop Pipe of the Phalaborwa Igneous Complex (South Africa) is the only known carbonatite-hosted Cu-sulphide deposit. Despite significant attempts to identify ore-forming mechanisms, the latter remain poorly constrained. This study aims at determining the mechanisms responsible for Cu-sulphide formation by studying Cu-sulphide textures using microfocus X-ray computed tomography (microCT) applied to sulphide-rich drill core samples from various principal rock types of the Loolekop Pipe.

MicroCT analysis of samples from banded carbonatite, phoscorite and transgressive carbonatite show that Cu-sulphides occur as subvertical layers, parallel to magnetite- and silicate-bearing cumulates as well as to banded carbonatite and phoscorite layering. Several types of magmatic sulphides can be identified: (i) <1 mm rounded bornite- and chalcopyrite-composed grains disseminated within the gangue, (ii) >1 mm elongated assemblages of chalcopyrite and bornite and (iii) mm-wide chalcopyrite cumulates. The irregular and granular surface of elongated aggregates parallel to the layer axis suggests that they formed by accumulation of discrete sulphidic melt.

Vein-hosted hydrothermal chalcopyrite is also observed. The veins show a sharp contact with the gangue, suggesting that chalcopyrite precipitated along fractures. High-temperature hydrothermal fluids precipitating large amounts of chalcopyrite along fractures across the Loolekop Pipe also circulated within small fracture networks adjacent to the hydrothermal vein itself, forming small-sized chalcopyrite veinlets in the host-rocks.

Microscopic observations and microCT analysis show an alteration of magmatic sulphides by late-stage fluids as well as their dissolution and re-precipitation as valleriite along adjacent fractures. A dissolution – (re)precipitation cycle related to late-stage fluid circulation is considered most likely, but valleriite may be predominantly the result of in-situ magmatic sulphide alteration, as shown by the dominant presence of valleriite along the external boundaries and along fractures within magmatic sulphide phases. Late-stage valleriite, as alteration products of magmatic sulphides, may locally represent a significant part of the mineralization, as observed as fractures cross-cutting the Cu mineralization, indicating the limited mobility of Cu during the late-stage alteration cycle. The absence of fractures in some samples and the lack of primary sulphide alteration points to a heterogeneous alteration of sulphides within the Loolekop Pipe.

The modal composition of sulphide assemblages differs from one layer to another, which can be interpreted as involvement of several sulphide liquids in the formation of Cu-sulphides. The alternating distribution of banded carbonatite and phoscorite within the Loolekop Pipe and the interaction of several ore-forming sulphide liquids reinforce the notion that the banded carbonatite – phoscorite complex, as well as the sulphide layers, are the result of emplacement of several magma pulses. Melt immiscibility, torsion of the intrusive volume and involvement of several magma pulses may have resulted in the formation of alternating bands of carbonatite and phoscorite. Formation of sub-vertical sulphide layers hosted by these two rock types is linked to the same processes.

TITLE:	**Feasibility of CO_2-enhanced gas recovery in a tight gas reservoir offshore South Africa: A case study**
PRESENTING AUTHOR:	**Sanelisiwe Mhlambi**
AFFILIATION:	University of the Western Cape
EMAIL ADDRESS:	3555622@myuwc.ac.za
SUPERVISOR/S NAME:	Prof Jan van Bever Donker
DSI-NRF CIMERA THEME:	Energy resources
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	POSTER

Oil and gas operators are now increasing their focus on improving the recovery of hydrocarbons from mature hydrocarbon fields as a result of plummeting oil prices, growing energy demand, declining field productivity, and difficulty in finding new giant fields. This is paired with the understanding that the continuous release of unsustainable anthropogenic carbon dioxide (CO_2) from the combustion of fossil fuels or other industrial sources into the environment has contributed to the greenhouse effect and global warming.

One attractive and emerging technology for climate change mitigation due to CO2 emissions is CO_2-enhanced gas recovery (CO_2-EGR). Further, since a large amount of original gas in place is typically left in the reservoir after primary gas recovery, such as pressure depletion-drive mechanisms, CO_2-EGR has proved to be a useful technique for rejuvenating the production of gas through repressurising the reservoir and displacing methane with CO_2. This study has, therefore, set out to identify the potential of CO_2-EGR and sequestration in a mature gas field, with the help of integrated inputs from various geophysical and reservoir engineering studies.

The case study is the F-O Gas Field, located on the northeast flank of the Bredasdorp Basin south of the Infanta Embayment and 110 km offshore SSE from Mossel Bay and 400 km SE of Cape Town in the F-O Tract. The reservoir consists of Valanginian-age upper shallow marine deposits (USM) and the field is described as a dry gas accumulation with low porosity (10 %) and low permeability (0.1mD to 20mD; average 1 mD) in an over-pressured, very tight sand reservoir. In such a tight reservoir, the definition of the true reservoir and its flow capacity under economic rates in a long time period is critical. While the current Operator has used some of the best technologies at their disposal for the development of this field, EGR techniques have not been tested. Therefore, there exists a need to explore this option in order to extract and/or improve deliverability in the field over an economic timeframe.

TITLE:	**Detailed geological mapping and petrological investigation of rocks within and around the Mushithe coal occurrence, Soutpansberg Coalfield, South Africa**
PRESENTING AUTHOR:	**Thangeni Mphanama**
AFFILIATION:	University of Venda
EMAIL ADDRESS:	thangeni95@gmail.com
SUPERVISOR/S NAME:	Emeritus Prof J.S. Ogola, Dr H.R. Mundalamo and Dr L.R Kone
DSI-NRF CIMERA THEME:	Energy resources
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

According to the WCA (2016) South Africa is the 7th largest producer of coal. South Africa's coal consumption comprises domestic consumption and export. Domestic consumption is mostly used by Eskom power Stations for electricity generation and by Sasol for coal derived synthetic fuels and petrochemical products (Mathu and Chinomona, 2013). Even though natural gas, renewable energy sources, and nuclear energy are forecasted to increasingly contribute to the primary energy supply, coal will remain South Africa's major energy source into the foreseeable future, due to its low cost and relative abundance (Jeffrey, 2005). South African coalfields such as Witbank, Highveld, Ermelo and Waterberg coalfields have been extensively explored and exploited, but coalfields such as the Soutpansberg have until recently received much less attention from researchers. Witbank and Highveld coalfields are nearing depletion and other additional sources for coal supply must soon be identified if the South African coal industry is to continue in the 21st century. Mushithe coal occurrence which is located within the Soutpansberg Coalfield has received much less attention from researchers as compared to other coal occurrences in Tshikondeni area which had previously hosted the Tshikondeni coal mine (Hancox and Gotz, 2014). The Mushithe coal occurrence is located within the Pafuri sub-basin of the Soutpansberg Coalfield.

The study is aimed at undertaking detailed geological mapping, geochemical and petrological study of rocks within the Mushithe coal occurrence. Field work involves Geological mapping and sampling while laboratory work include; X-Ray fluorescence spectrometry and petrographic studies. The study area was delineated into a 5.14 km by 3.22 km area and divided into 6 traverses of 857 metres each cutting across the regional strike direction of the lithology. A 1: 10 00 geological map and cross-section of the study area were produced. The general strike direction and dip direction is at north-easterly and north-westerly directions respectively with an average dip angle of around 23°. Based on macroscopic, petrographic and whole rock geochemical studies of the rock samples, six different types of rocks were identified, namely; basalt, quartz intrusion, sandstone, shale, calcrete and quartzite.

The study of geology and the geological map were used for site location for borehole drilling and to understand the distribution of lithologies with depth. Consequently, the proposed area for borehole drilling was established. The study recommended further investigation on coal occurrence and quality for the establishing of coalbed sequence, chemical, mineralogical and maceral composition of the Mushithe coal.

Keywords: *Soutpansberg Coalfield, Mushithe coal occurrence, Geological mapping, Coalbed sequence and Coal quality.*

TITLE:	**Phytoremediation studies of potentially toxic metals from tailings dams in Giyani area: a case study of Klein Letaba and Louise Moore tailings dams**
PRESENTING AUTHOR:	**Phumudzo Gift Munyai**
AFFILIATION:	University of Venda
EMAIL ADDRESS:	munyaip@gmail.com
SUPERVISOR/S NAME:	Emeritus Prof J.S. Ogola, Prof I. Chimuka and Dr H.R. Mundalamo
DSI-NRF CIMERA THEME:	Environmental and groundwater geology
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	POSTER

Phytoremediation is an environmental technique that uses green plants to reduce, remove, de-grade, or immobilize environmental toxins, primarily those of anthropogenic origin, with the aim of restoring sites to a condition for private or public use. Phytoremediation of contaminated sites is a relatively inexpensive and aesthetically pleasing to the public compared to alternate remediation strategies which involve excavation or chemical in-situ stabilization. Giyani tailings dams lack prerequisite data to support the potential of phytoextraction of metals from the mine tailings with the use of green plants. This would lead to an environmentally friendly technology that exploits the potential of selected plant species to remove, stabilise, degrade, metabolize, or immobilize a wide range of contaminants in the environment to safer concentrations. The study focused on the phytoremediation of metals from the Giyani tailings dams using green plants for either rehabilitation or metal extraction and seeking ways of extracting and or stabilizing the soil.

The study area falls within the Giyani District Municipality which is in Limpopo province with the focus on Klein Letaba and Louis Moore tailings dams. Fieldwork involved collection of plant, tailings and soil samples at Klein Letaba and Louis Moore tailings dams. Three different types of plant species were collected on both tailings which included: Combretum Imberbe (16), Cynodon Dactylon (12) and Sporobelus Africanus (12). Tailings samples were collected at the same location as the plant samples. Consequently, a total of 40 samples from plants and tailings samples were collected. A total of 5 soil samples were collected at a distance of 5 to 10 km away from the tailings dams in the north-easterly direction coinciding with the general wind direction in the study area. X-ray fluorescence spectrometry method was conducted on selected samples for geochemical characterisation of the samples. XRF results of tailings recorded a maximum value of Pb (11885.7 ppm) and lowest value of Cd (0.1 ppm). The abundance of the toxic metals ranged as follows from highest to lowest; Pb>Ni>As>Cr>Zn>Cu>Co>Cd. The tailings were also contaminated with Ni (2049.3 ppm), As (1275.7 ppm) and Cr (1271.3 ppm).

Analysis of plants is still to be conducted at Wits University using ICP-OES, ultimately models for geochemical speciation will be analysed using PHREEQC software released by the United States geological survey (USGS). The expected outcome will be used to understand the distribution of species of potentially toxic trace metals. This would be a remediation strategy not only in the studied sites, but can be applied elsewhere.

Keywords: *Phytoremediation, Rehabilitation, Metal extraction, Giyani gold mine tailings, Toxic metals*

TITLE:	**Whole-rock and Sr–Nd isotope geochemistry of mafic rocks from the Waterberg and Harriet's Wish PGE prospects, far northern Bushveld Complex, South Africa**
PRESENTING AUTHOR:	**Tshipeng Mwenze**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	tshipeng.mwenze@wits.ac.za
SUPERVISOR/S NAME:	Prof Judith Kinnaird and Dr Marina Yudovskaya
DSI-NRF CIMERA THEME:	Metallogeny and Paleogeographic Implications of Layered Igneous Complexes (LICs) and Large Igneous Provinces (LIPs).
REGISTERED DEGREE:	Post-doctoral Research Fellow
ORAL OR POSTER:	POSTER

The study aims at further investigating the genetic relationship that exists between the Waterberg and the Harriet's Wish PGE deposits.

Recent studies have shown that the Waterberg and Harriet's Wish PGE prospects are located in the Southern Marginal Zone of the Limpopo Belt to the far north of the northern limb of the Bushveld Complex (Kinnaird *et al.*, 2017; Van Scheltema, 2019). These two prospects are adjacent to each other with Harriet's Wish located south of the Waterberg prospect. In terms of stratigraphy, the Waterberg PGE deposit consists of the basal Ultramafic Sequence (UmS) which is capped by the Troctolite-Grabbronorite-Anorthosite (TGA) Sequence and the Upper Zone (UZ). The PGE mineralisation are confined to the F and T zones in the UmS and to the top of the TGA sequence, respectively (Kinnaird *et al.*, 2017; Huthmann *et al.*, 2017, 2018; McCreesh *et al.*, 2018).

Detailed studies have suggested that the rock succession of the Waterberg deposit extends up to 40 km further south and can be equated to that at the Harriet's Wish prospect (McDonald *et al.*, 2017; Van Scheltema, 2019). Based on core logging, magnetic susceptibility, mineralogy and major and trace elements geochemistry, Van Scheltema (2019) suggested that the lower and upper lithological units (LLU and ULU) at Harriet's Wish can be correlated to the TGA and UZ units, while the UmS is believed to be absent, deeper or eroded as a result of the later emplacement of the LLU gabbroic melts. Additionally, it has been suggested that the lower and upper mineralised units at Harriet's Wish can be correlated to the F zone and the T zone at the Waterberg prospect, respectively, despite differences in the chemical compositions of the host rock and gold contents (Van Scheltema, 2019). The lack of sufficient knowledge to account for these differences therefore requires further studies to contribute to our current understanding of processes involved during the genesis of these deposits.

Considering the above, at least six drill cores from the Waterberg and Harriet's Wish PGE prospects will be logged. Rock samples from each stratigraphic and mineralised horizon at these localities will be collected for petrography and for major, trace and whole-rock Sr and Nd isotope geochemistry. The ultimate objective of this study is to determine the Sr and Nd isotopic compositions of magmas at the Waterberg and Harriet's Wish prospects to assess the lateral extent of the PGE mineralisation useful for future mining in the far northern Bushveld Complex.

TITLE:	**Geology of the Kameel gabbroic layered intrusion, Northern Cape, South Africa**
PRESENTING AUTHOR:	**Sinikiwe Ncube**
AFFILIATION:	University of Johannesburg
EMAIL ADDRESS:	sinikiwen@uj.ac.za
SUPERVISOR/S NAME:	Dr T.M. Owen-Smith, Dr Herve Wabo
DSI-NRF CIMERA THEME:	Metallogeny and paleogeographic implications of Layered Igneous Complexes (LICs) And Large Igneous Provinces (LIPs)
REGISTERED DEGREE:	PHD
ORAL OR POSTER:	POSTER

The Kameel Complex (KC) is a layered mafic intrusion that is located close to the western part of the Kaapvaal Craton. It intruded the Archean to early Proterozoic Transvaal Supergroup rocks in the Griqualand West Basin. The Kameel Complex is completely covered by a layer of Cenozoic Kalahari sediments and is therefore only known from drill core.

The present study aims to provide preliminary stratigraphic, petrographic, geochemical and geochronological information on the Kameel Complex using drill core samples. Of the drill cores available, the K1 drillhole consists of the only known entire stratigraphy of the Kameel gabbroic layered complex. Two other drillholes, W1a and W1b that intersect the country rock were also logged for comparison.This intrusion consists of three rock types or layers. In the K1 drillhole, the lowermost layer consists of olivine gabbro, followed by a leucogabbro and magnetite gabbro at the top. The olivine gabbro and gabbro layers are seperated by an intrusive contact with a ~2 m layer of olivine gabbro in between the leucogabbro.

Whole-rock major, trace and REE analyses are presented for selected samples, from the drillholes. The rocks of the Kameel Complex become more evolved upward and follow a tholeiitic differentiation trend with enrichment of Fe and Ti upward. The most plausible parental magma is a tholeiitic liquid that formed at shallow depth. Differentiation of the intrusion was driven by fractionation of an assemblage of clinopyroxene + plagioclase ± titanomagnetite ± olivine.

TITLE:	**Geochemistry of sandstones and mudstones from the Katberg Formation, Karoo Supergroup, in the Eastern Cape province of South Africa: implications on source rock provenance, tectonic setting, paleo-weathering conditions, and sediment maturity.**
PRESENTING AUTHOR:	**Zandile Ndlazi**
AFFILIATION:	University of Fort Hare
EMAIL ADDRESS:	201206979@ufh.ac.za
SUPERVISOR/S NAME:	Dr K. Madi, Prof K. Liu
DSI-NRF CIMERA THEME:	Energy resources
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

The geochemical data of 20 samples of sandstones and mudstones from the Katberg Formation were analysed for major by X-Ray Fluorescence (XRF) and trace elements by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). This was done to determine the provenance, source rock weathering, tectonic setting, paleo-weathering conditions and sediment maturity of the Katberg Formation. The major element occurrence in both sandstone and mudstone samples occurs in the decreasing order of SiO_2, Al_2O_3, Fe_2O_3, K_2O, Na_2O, CaO, and MgO. The oxides TiO_2, MnO, P_2O_5, BaO, SrO, ZrO_2, and V_2O_5 are in depletion with values ranging below 1 wt %. The abundance of SiO_2 and Al_2O_3 is linked to their resistance to nature during weathering, diagenesis, and metamorphism. The occurrence of trace elements (La, Ce, Sc, Rb, Th, U, Nb, Y, and Hf) indicates the highly insoluble and immobile nature of elements during weathering and metamorphism indicating the mineral composition of the source rock. The geochemical plot of Log (SiO_2/Al_2O_3) vs Log (Fe_2O_3/K_2O) points out that the Katberg Formation sandstones were derived from the arkose and wacke source rocks. The tectonic setting of Katberg Formation sandstones and mudstones plotted between the Active Continental Margin (ACM) and Continental Island Arc (CIA). The indices of Palaeoweathering: chemical index of alteration (CIA), chemical Index of weathering (CIW), and plagioclase index of alteration (PIA), with averages ranging between 58.79 -74.42, 64.05-94.54, 60.52-92.25 respectively. The paleoweathering indices have values greater than 50, suggesting a moderate to a high degree of weathering and alteration. The index of compositional variability (ICV) has an average of 0.78 which indicates the chemical maturity of the Katberg Formation sediments.

Keywords: *provenance, tectonic setting, paleo-weathering, sediment-maturity, Katberg Formation*

TITLE:	**Nature and origin of Paleoarchean komatiites from the SE Kaapvaal craton**
PRESENTING AUTHOR:	**Thendo Netshidzivhe**
AFFILIATION:	University of Johannesburg
EMAIL ADDRESS:	thendon@uj.ac.za
SUPERVISOR/S NAME:	Prof Sebastian Tappe and Prof Fanus Viljoen
DSI-NRF CIMERA THEME:	Early earth mineral systems and metallogenesis
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	POSTER

The Paleoarchean Buffalo River Greenstone Belt (BRGB) is characterised by low-grade volcano-sedimentary rocks exposed over an area of 10 km^2 along the Buffalo River and its tributaries in Kwazulu Natal. Mafic and ultramafic rocks of basaltic and komatiitic affinity are found within three basement inliers, which together make up the Sifula Subgroup mostly covered by Karoo strata. In this study, detailed field and petrographic data are collected for this poorly studied portion of the Kaapvaal craton and, coupled with a thorough whole-rock geochemical investigation, we are able to constrain the nature and composition of the mantle source for these komatiites and associated basalts.

The typical mafic volcanic rocks, emplaced as pillow basalts throughout the greenstone belt, are characterised by the mineral assemblage, actinolite-tremolite-serpentine in a talc-chlorite matrix. The komatiite lava flows preserve spinifex textures that coarsen from the top of the flow to the bottom. A randomly orientated spinifex zone at the top of the flow is characterized by olivine blades of 1-3 cm in length, whereas the platy spinifex area preserves a parallel order of blades between 1 and 11 cm. These ultramafic volcanic rocks are dominated by serpentine + magnetite±carbonates in a talc-tremolite-actinolite matrix. These textural characteristics are typical of komatiite flows found within the Barberton Greenstone Belt-of the Kaapvaal craton and the classic Pyke Hill outcrop of the Abitibi Greenstone Belt on the Superior craton, where good exposures of a basal olivine cumulate layer (B unit) and an upper spinifex layer are observed (A unit).

Komatiites are subdivided geochemically on the basis of their Al_2O_3/TiO_2 ratios into three distinct groups. Our samples from the BRGB represent a compositionally diverse suite of rocks, which comprises all three types of komatiites within a single volcanic assemblage. The results show that the spinifex textured komatiites classify as Al-depleted komatiites (ADK), with subchondritic Al_2O_3/TiO_2 ratios between 6 and 12. The Al-undepleted komatiites (AUK) have chondritic Al_2O_3/TiO_2 ratios between 16 and 24, and the Al-enriched komatiites (AEK) display supra-chondritic Al_2O_3/TiO_2 ratios of >25. The Al-depleted komatiites show slight depletions in LREE to near flat patterns with $(Gd/Yb)_N$ ratios of 1-2; the Al-undepleted komatiites have relatively flat REE patterns. In contrast, the Al-enriched group shows significant depletions in LREE with HREE enrichments (Gd/Yb_N = 0.2-0.9). Distinctly different Al_2O_3/TiO_2 ratios of the three komatiite groups have been linked to the presence (ADK) or absence (AEK) of majoritic garnet in the mantle source, a high-pressure phase that is only stable between ~300-600 km depths. Our findings from the Buffalo River Greenstone remnant show that ADK and AUK are geochemically similar to komatiites from the 3.5 Ga Komati and 3.3 Ga Weltevreden formations of the Barberton Greenstone Belt, whereas the Al-enriched komatiites are similar to the 3.3 Ga komatiites of the Commondale Greenstone Belt on the SE Kaapvaal craton. For the first time it can be demonstrated that the three komatiite types may occur in a single volcanic succession, which requires komatiite melt extraction from distinct mantle sources at different P-T conditions – currently best explained by plume-lithosphere interaction beneath the growing Kaapvaal 'continent' at 3.5 Ga.

TITLE:	**The geology and geochemistry of the Fungurume 88 deposit: an unusual high grade primary cobalt sulphide deposit**
PRESENTING AUTHOR:	**Ryan Rosenfels**
AFFILIATION:	Stellenbosch University
EMAIL ADDRESS:	18984959@sun.ac.za
SUPERVISOR/S NAME:	Dr Bjorn von der Heyden
DSI-NRF CIMERA THEME:	Base, gold and scarce metal deposits
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

The Fungurume 88 deposit located in the Tenke Fungurume Mining (TFM) district is situated on the northern apex of the Lufilian fold-and-thrust belt. It is a unique sedimentary stratiform copper deposit of the Central African Copper Belt (CACB), since it contains anomalously high grade hypogene carrollite mineralization in the lower SD Formation of the Mines subgroup. These lithologies are normally regarded as being barren to poorly mineralized, here however, they boast cobalt concentrations as high as 2 wt. % in the mineralized zone. Detailed logging of drill core revealed that the sediments of the Fungurume 88 deposit hosting this mineralization differ to the well-recognised Long Facies sediments exhibited by the majority of deposits in the TFM district - including the overlying Fungurume 8 deposit. Petrographic studies have shed light on this and have also revealed a range of mineralization styles present in the Fungurume 88 deposit. These include the dominant disseminated style, stratiform style, bedding parallel jack veins and crosscutting veins. Host rock geochemistry obtained from SEM analyses together with LA-ICP-MS analyses on sulphide phases have helped to constrain the mineralizing process in the Fungurume 88 deposit by corroborating fluid-rock interaction, sulphide mineral paragenesis and metal endowments as well as mineralization episodes. Thermodynamic modelling using the R-package CHNOSZ has also indicated that the relative solubility of copper and cobalt complexes vary under a range of physicochemical conditions which has helped to explain the zonation of metals and local cobalt enrichment that we see in the SD-1b sub-unit of the Fungurume 88 deposit.

The diversity of mineralisation styles depicted here, supported by trace element signatures, reflect two episodes of sulphide mineralization and support a multiphase hypogene Cu-Co model. The specific timing of the mineralisation events include an early diagenetic phase (Phase 1) as well as a later syn-orogenic phase (Phase 2), and thus indicate the presence of at least two mineralizing fluids. Fluid inclusion microthermometry of the respective episodes also supports this with distinct fluid compositions. This has also helped to refine the thermodynamic model of the Fungurume 88 deposit which illustrates the variability in the stability of Cu vs Co phases at the conditions experienced by these fluid interactions with the host rocks. The detailed petrographic host rock analyses shows that the sediments of the Fungurume 88 deposit potentially belong to the Kalumbwe Facies or a geochemically similar deep marine sedimentary facies rather than the usual Long Facies. This lithological variation was likely the key ingredient, providing an optimal reducing environment "trap site" for the precipitation of carrollite and other copper sulphides in the SD-1b subunit. These geological and geochemical observations have thus allowed a genetic model for the unfamiliar Fungurume 88 deposit to be proposed and placed in the regional context and understanding of mineralization throughout the copperbelt. Moreover, it highlights that the northern apex of the Lufilian fold-and-thrust belt and the broader CACB hold vast exploration potential for similar deeper-water sub-basins which may host significant, and yet-undiscovered metal (notably Co) resources.

TITLE:	**Re-appraisal of legacy seismic data using today's technology: examples from goldfields, South Africa**
PRESENTING AUTHOR:	**Mpofana Sihoyiya**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	1284606@students.wits.ac.za
SUPERVISOR/S NAME:	Prof Musa Manzi
DSI-NRF CIMERA THEME:	Geometallurgy, geophysics, analytical development, and small mining opportunities cross cut the above focus areas.
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

Reflection seismic method in combination with drilling, field geological mapping, and other geophysical methods nowadays are proving their significance in mineral exploration and mine planning. However, the use of the former method is not widespread due to increased challenges such as costs, noise, and inaccessibility when acquiring high-resolution reflection seismic data. Rigorous and continuous re-appraisal of legacy seismic data is likely to be beneficial in regions faced with such challenges, increase data bandwidth, and enhance legacy seismic data to contemporary seismic data standards.

This study demonstrates the value of retrieving, reprocessing and interpreting legacy seismic data around the Burnstone mine in the town of Balfour in Mpumalanga. Our area of interest belongs to the Witwatersrand goldfields one of the most important gold provinces in South Africa. The development of today's seismic solutions (e.g. interferometry, curvelet denoising, and diffraction imaging) which offer an improved resolution in hard rock seismic imaging make re-appraisal of seismic legacy data worthwhile.

Historically, in South Africa, as early as 1983 the gold division of the Anglo-American Corporation (AAC) had started conducting seismic reflection surveys over the goldfields of the Witwatersrand basin. They acquired a series of 2D vibroseis seismic profiles with approximately 16 000 km total length over a period of 16 years. South Africa holds one of the world's most extensive legacy seismic data coverage in the Kaapvaal Craton for gold mine planning and development. However, some of this legacy seismic data have poor quality in regions where there are publications which makes it difficult to use for today's mine planning and development.

The study aims to apply contemporary standards of reflection seismic processing systems to the legacy seismic data which incorporate forward modelling and advanced denoising schemes. The objective is to explore the applicability of contemporary seismic solutions on legacy seismic data by focusing on seismic forward modelling, conventionally reprocessing legacy seismic data, and curvelet denoising. Studies show that curvelet denoising is yet to be applied to these data as it is an image based denoising scheme. This study therefore hypothesises that the application of the contemporary seismic solutions will have the effect of improved resolution in these legacy seismic data.

The research is on preliminary results stage on different seismic software packages. The 2D legacy seismic data was recovered from the 1990s storage systems and transferred to today's storage system. Seismic modelling of the data is created on tesseral pro seismic modelling software. The legacy seismic data is processed on Vista Schlumberger reflection seismic processing software. Curvelet denoising is conducted on a Matlab GUI for user interaction with Curvelab program.

TITLE:	**The tectonic evolution of the Bredasdorp Basin and its implications for oil and gas formation**
PRESENTING AUTHOR:	**Rethabile Tau**
AFFILIATION:	University of Witwatersrand
EMAIL ADDRESS:	800746@students.wits.ac.za
SUPERVISOR/S NAME:	Dr Stephanie Enslin, Prof Musa Manzi and Dr Zubair Jinnah
DSI-NRF CIMERA THEME:	Geometallurgy, geophysics, analytical development, and small mining opportunities
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

In this study, we utilize high-resolution3D seismic data to decipher the tectonic evolution of the offshore Bredasdorp Basin in South Africa and draw conclusions about the basin's oil and/or gas capacity and location. The Bredasdorp Basin has been explored for hydrocarbons since 1987. The exploration took place in the northern flank of the Basin and yielded results exhibiting a quality reservoir of upper shallow marine sandstones in a trapping situation. The significant porosity and permeability of this sandstone heralded the Mossgas development project, which focused on gas and condensate production from the F-A platform in 1992. Since then, over 200 boreholes have been drilled and burial studies have shown potential maturity over large areas of the basin to have generated and expelled oil. In addition, multichannel reflection seismic and a variety of geological studies (palaeontology, geomechanics, petrography, and geochemistry) have been utilized to explore the basin's potential for hydrocarbons. Through drilling, TOTAL made a large gas discovery in a region between Bredasdorp Basin and Southern Outeniqua Basin, Brulpadda, and is estimated to contain approximately one trillion barrels. Given the proximity of the TOTAL gas discovery to the project study area in Bredasdorp Basin, it begs the question if there might be a sizeable quantity of gas in the chosen study area and if so, what are the quantities. This thesis addresses the relationship between tectonics and hydrocarbons, as well as determine which seismic attributes are best at detecting hydrocarbons and sub-seismic structural features. Furthermore, a 3D model will be built and used in collaboration with literature and well data to estimate gas volume in area. To achieve this, 3D seismic data are imported into DUG Insight software and Petrel Schlumberger software. This will enable structural and stratigraphic interpretation through qualitative processes known as manual and autotracking, which involves identifying the reflective horizons on seismic sections. In addition, a quantitative process of using seismic attributes to increase seismic resolution will be applied thus allowing for the detection of small-scale features and lithological interpretation. Furthermore, this process will assist in analysing the geometry and physical parameters of the observed subsurface. We will use horizon seismic attributes (i.e. dip and dip azimuth, and edge detection) or volumetric seismic attributes (i.e. curvature and ant tracking). This project aims to shed light on the potential of South Africa's petroleum systems and exploration industry.

TITLE:	**The diamondiferous hybrid/ transitional kimberlites from the Man Craton (West Africa): A petrographic and mineral chemistry study**
PRESENTING AUTHOR:	**Anton Viljoen**
AFFILIATION:	University of Cape Town
EMAIL ADDRESS:	vljant002@myuct.ac.za
SUPERVISOR/S NAME:	Dr Geoffrey Howarth
DSI-NRF CIMERA THEME:	Diamonds, kimberlites and deep crustal processes.
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

West African diamondiferous rocks occurring within Sierra Leone are currently known to be a type of hybrid or transitional kimberlite. They contain features that are petrographically similar to orangeites (previously group 2 kimberlites) but geochemically more similar to archetypal kimberlites (previously group 1 kimberlites) or occasionally lamproites.

The current study will focus on two areas within Sierra Leone, namely Tongo and Koidu to better understand the hybrid nature of these rocks. The Tongo area consists of individual NE-SW trending dike swarms. There are several dike swarms in the area but only those with a diamond resource estimation have been studied. These dike swarms are named Kundu, Lando, Pandebu and Tongo dike – 01.

The dike swarms share many petrographic similarities and generally can be described as a coherent micaceous kimberlite with macrocrystic tetraferriphlogopite. The groundmass consists of carbonate, phlogopite, serpentine, spinel and occasionally apatite and perovskite. The Kundu dike phase is altered, olivine macrocryst rich (>15%) and has additional atoll spinel within the groundmass and occasionally minor apatite with no or minor perovskite. The Lando dike phase is slightly altered, olivine-macrocryst rich (>15%) and has occasional minor additional perovskite in the groundmass and no apatite. The Pandebu dike phase is slightly altered and has roughly 10% olivine macrocrysts with occasional minor perovskite in the groundmass.

The Tongo dike – 01 dike phase is slightly more complicated. It is observed that the dike consists of four sub-phases which will be addressed as phase A-D. Phase A is slightly altered, olivine macrocryst-poor (0-5%), contains additional needle-like oxides in the groundmass and contains no apatite or perovskite. Phase B is olivine macrocryst-poor (0-5%) and contains additional apatite and perovskite in the groundmass. Phase C is olivine macrocryst-rich (>15%), contains additional perovskite in the groundmass and no apatite. Phase D is olivine macrocryst-rich and contains additional atoll spinel and perovskite in the groundmass.

The Koidu area also consists of individual NE-SW trending dike swarms, but with two prominent kimberlite pipes intersecting these dike swarms in different areas, namely K1 and K2. As with the Tongo area, the samples share many petrographic similarities and generally can be described as a coherent micaceous kimberlite with macrocrystic tetraferriphlogopite. The groundmass consists of phlogopite, carbonate, serpentine, spinel and occasionally apatite and perovskite. Two kimberlite mineralogical varieties are observed. The first phase is olivine macrocryst-rich (>15%) and contains additional diagnostic needle-like oxides within the groundmass (similar to Tongo dike-01 phase A) and occasionally apatite. The second phase is olivine macrocryst-rich (>15%), contains additional perovskite in the groundmass and occasional atoll spinel and apatite.

To further successfully classify these diamondiferous rocks, electron microprobe analyses will be done on a select number of olivine, phlogopite and spinel grains from samples within Tongo and Koidu. These results will then be contrasted with data obtained from similar deposits within the same area as well as data from cratons globally.

In addition, the Al-in olivine thermometer will be used to determine the effectiveness of using olivine as a potential kimberlite indicator mineral.

TITLE:	**Constraining magma sources and the metallogenesis of the Bushveld Complex using Nd isotopes in apatite**
PRESENTING AUTHOR:	**Peace Zowa**
AFFILIATION:	Student
EMAIL ADDRESS:	2399607@students.wits.ac.za
SUPERVISOR/S NAME:	Dr B. Hayes and Dr G. Bybee
DSI-NRF CIMERA THEME:	Metallogeny and paleogeographic implications of Layered Igneous Complexes (LICs) and Large Igneous Provinces (LIPs)
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

Despite several advances over the years, by many researchers, controversy still surrounds the magma source(s) and metallogenesis of the Rustenburg Layered Suite (RLS) of the Bushveld Complex. In this study, we are attempting to analyse Nd isotopes in apatite from the RLS in order to constrain the source(s) of magma to the Bushveld Complex and the origin of its platinum mineralization. Stratigraphic variations in bulk rock isotopes (both radiogenic and stable) in the RLS have been interpreted to reflect: (1) mixing of multiple pulses of magma (ranging in composition and volume) in a chemically evolving magma chamber; and (2) significant pre-emplacement crustal and/or lithospheric mantle contamination of the parent magma. However, Lu-Hf isotopes of zircon, measured by Zirakparvar et al. (2014), throughout the entire RLS show a limited range in $\varepsilon Hf_{(2.06\ Ga)}$ of -8.6 ± 1.2, which is in contrast to the variable bulk rock isotope signatures. Apatite is an accessory phase in the RLS and it crystallized at a late-stage from volatile and incompatible trace element-enriched pore melt that became trapped in the crystal mush. Apatite is a good indicator of igneous processes (e.g. fractionation, partial melting, magma mixing, metasomatism and differentiation) and has the ability to retain important geochemical information during magmatism as it is a major repository of REE, Sr, Pb, Mn, and halogens. Nd isotopes in apatite can also be routinely analysed by LA-ICP-MS, which provides a rapid, sensitive, and cost-effective way to analyse statistically large numbers of individual grains, which are relatively more abundant in mafic intrusions compared with zircon. These recent developments in the understanding of the chemistry of apatite provide a novel tool to investigate magmatic petrogenesis. New LA-ICP-MS Nd isotopic data obtained for 29 apatite grains for 2 samples from the Marikana dykes in the Western Bushveld Complex give $\varepsilon Nd_{(2.06\ Ga)}$ values ranging from -12.53 to -4.44 (average -5.99). We also analysed a Phalaborwa apatite standard that gave $\varepsilon Nd_{(2.06\ Ga)}$ values ranging from -6.02 to -7.04 (average -6.62 for 14 grains), that are consistent with the values reported by Wu *et al.* (2011). These εNd values in apatite are in agreement with the εHf values recorded in zircon for the RLS and suggests that apatite may show homogeneous εNd values throughout the RLS, mimicking εHf in zircon through the RLS stratigraphy. On this basis, it could be argued that the magmas that formed the RLS were generated by melting of the sub-continental lithospheric mantle. However, magmas may have also been generated in the asthenospheric mantle and subsequently contaminated by partial melts of the SCLM. Either way, Nd isotopes in apatite are consistent with Hf isotope data for zircon and appear to indicate a key role of the SCLM in the evolution and metallogenesis of the RLS. Our apatite εNd data also lend support to the notion that the Marikana dykes are fossilised melt channels that drained evolved residual melts derived from within the RLS.

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