DSI-NRF CIMERA Annual COLLOQUIUM

18 - 19 NOVEMBER 2021

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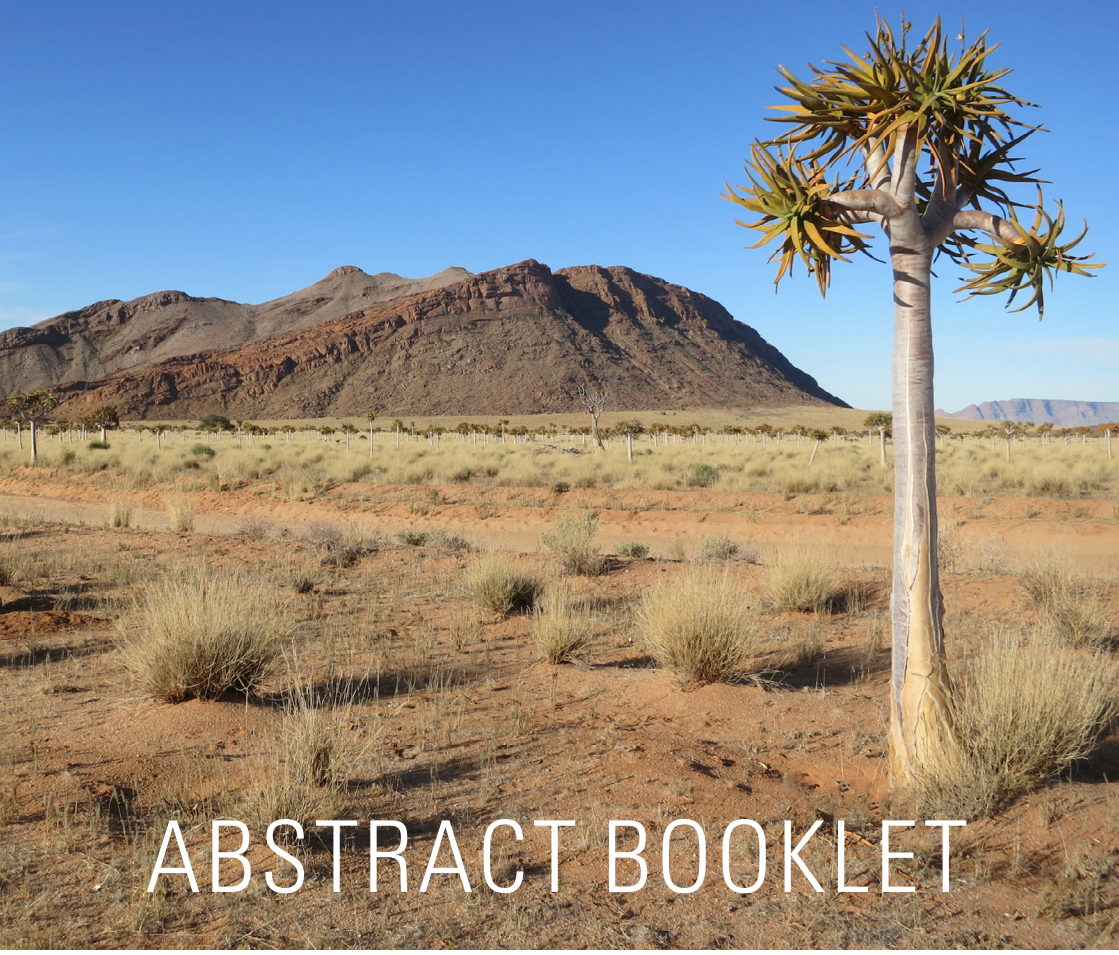
CIMERA – DSI-NRF
Centre of Excellence for
Integrated Mineral and Energy
Resource Analysis



ABSTRACT BOOKLET

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

NRF National Research Foundation | RISA Research and Innovation Support and Advancement

UNIVERSITY OF JOHANNESBURG

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Image: Quiver tree (Kokerboom) on the road to Klein Pella, Northern Cape Province, South Africa. George Henry.

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18 & 19 November 2021

A BLENDED,
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possibly even
PHYSICAL EVENT.
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CIMERA – DSI-NRF
Centre of Excellence for
Integrated Mineral and Energy
Resource Analysis

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Dear All,

We extend a warm welcome to the annual DSI-NRF CIMERA Colloquium, hosted in 2021 by the University of the Witwatersrand in the grand Humanities Graduate Centre. The Colloquium provides a shop window to display our current research projects. The Colloquium will run as a hybrid event again this year, following on the success of the 2020 event and the general trend for conferences post COVID lockdowns. 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.

The virtual platform has enabled the inclusion of two international guest speakers. We welcome: Prof. Dr. Christoph Heubeck (Friedrich-Schiller-Universität Jena, Germany; Science Coordinator); and Prof. Murray W. Hitzman (SFI Professor of Geology; Director iCRAG, Ireland). We look forward to learning more about their research in the ICDP "Moodies" project (Prof. Heubeck) and the northern hemisphere view on the energy transition (Prof Hitzman).

This booklet contains the presentation and poster abstracts. A total of 24 student and 2 staff presentations will be given over the next one and a half days, as well the two keynote presentations. The students will present their research results stemming from the economic geology projects supported by DSI-NRF CIMERA. The 17 poster presentations 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 international COVID linked lockdowns in 2020 and 2021.

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 2021, DSI-NRF CIMERA provided direct and indirect funding support to over 76 postgraduate students hosted at 10 universities across South Africa. The outputs of the research in economic geology benefit the region and the continent, as does the pool of skilled graduate students. Geology and the mining industry is a back-bone of the South African economy, and geoscientists play a vital role in the development of the low carbon economy. Please visit our website (www.cimera.co.za) for more information on our goals, research focus areas and activities.

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. We hope to see as many people as possible at our networking event on the 18th of November at the Origins Centre.

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 18 NOVEMBER 2021**			
08h00-08h45	REGISTRATION AND TEA		
08h45-09h00	**Prof Nikki Wagner** (UJ)	WELCOME (IP)	
TIME	PRESENTER	TOPIC	THEME
09h00-09h10	**Prof Lynn Morris** (DVC (Research & Innovation); Wits)	WELCOME NOTE (IP)	
09h10-09h30	**Lebogang Babedi** (SU)	The application of experimental mineralogy in geoscience – A case study of economic geology and geometallurgy. (V)	Analytical Techniques
09h30-09h50	**Mbili Tshiningayamwe** (Wits)	The use of apatite trace element mineral chemistry and Sr-Nd isotopic determinations for investigating the petrogenesis of syenites and carbonatite. A case study of the Epembe alkaline-carbonatite complex, Namibia. (V)	Analytical Techniques
09h50-10h10	**Brian Mapirenge** (UJ)	Structural constraints on the evolution of the south-eastern Mwanesi Greenstone Belt and adjacent granitoids, central Zimbabwe Craton: implications for gold mineralisation. (IP)	Gold
10h10-10h50	KEY NOTE **Prof Christoph Heubeck** (Friedrich-Schiller-Universität Jena, Germany; Science Coordinator)	**BASE – Barberton Archean Surface Environments: Research drilling in the Moodies Group, Barberton Greenstone Belt.** (V)	
10h50-11h10	TEA BREAK		
11h10-11h30	**Thabo Kgarabjang** (UL)	Characteristics of ore minerals and geochemical variation of host rocks associated with antimony and gold mineralisation in the Murchison greenstone belt, South Africa. (V)	Gold
11h30-11h50	**Daniel Bussin** (UJ)	A characterization and process mineralogical assessment of the karst hosted manganese ore deposits at Paling exploration camp in the Postmasburg Manganese Field, Northern Cape Province, South Africa. (V)	Northern Cape
11h50-12h10	**Senamile Dumisa** (Wits)	Constrains on the genesis of the orbicular granites and sulphide mineralization in the Koperberg Suite, Namaqualand and the Diana's Pool area, Zimbabwe. (V)	Northern Cape
12h10-12h30	**Minenhle Maphumulo** (UJ)	Mineralogical and geochemical characterisation of mineralised and regular NYF-type pegmatites from the Namaqualand pegmatite belt, Northern Cape, South Africa. (V)	Northern Cape

12h30-12h50	**Patrick Richards** (UJ)	Petrographical, mineralogical and geochemical characterisation of the Leinster Deposit, Kalahari Manganese Field, South Africa. (V)	Northern Cape
12h50-13h40	LUNCH		
13h40-14h00	**Emmanuel Onyebueke** (Wits)	In-mine seismic imaging trials of PGM deposits in the Bushveld Complex, South Africa. (V)	Seismic/ Geophysics
14h00-14h20	**Salizwa Plaatjie** (Wits)	A statistical and machine learning approach to analysing faults and dykes at South Deep Gold Mine. (IP)	Seismic/ Geophysics
14h20-14h40	**Michael Westgate** (Wits)	2D reflection seismic constraints on the 1.9 Ga Trompsburg layered mafic intrusion complex, South Africa. (V)	Seismic/ Geophysics
14h40-15h20	POSTER SESSION		
15h20-16h00	TEA	VIRTUAL POSTER VIEWING	
16h00-16h20	**Mpofana Sihoyiya** (Wits)	Re-processing of the 2D legacy seismic data for improved structural imaging and gold exploration in the South Rand Goldfield, South Africa. (IP)	Seismic/ Geophysics
16h20-16h40	**Temitope Love Baiyegunhi** (UFH)	Geochemical evaluation of the Cretaceous mudrocks and sandstones in the Southern Bredasdorp Basin, offshore South Africa: Implications for hydrocarbon potential. (V)	Hydrocarbon
16h40-17h00	**Rethabile Tau** (Wits)	The tectonic evolution of the Bredasdorp Basin and its implications for oil and gas formation. (IP)	Hydrocarbon
17h00-19h00	Networking Function for DSI-NRF CIMERA collaborators VENUE: Origins Center (Wits) – Please confirm your attendance		

DAY 2: **FRIDAY 19 NOVEMBER 2021**			
07h30-08h20	REGISTRATION AND TEA		
08h20-08h30	**Adjunct Prof Glen Nwaila** (Wits) (IP)	WELCOME	
TIME	PRESENTER	TOPIC	THEME
08h30-08h50	**Robyn Ormond** (UJ)	Lithostratigraphy and structural geology of the Namibfontein-Vergenoeg domes in the southern Central Zone of the Damara Orogen, Namibia. (IP)	Other
08h50-09h10	**Khethani Tom Ramphabana** (Univen)	Geochemical characterisation of the Waterberg Coalfield Lithostratigraphy: implications to acid mine drainage, Limpopo Province, South Africa. (IP)	Environmental
09h10-09h30	**Jessica Schapira** (Wits)	Geology-based tools for the prioritising of derelict asbestos mine land rehabilitation and predicting of long-term potentially hazardous geo-environmental signatures. (IP)	Environmental

PROGRAMME

09h30-09h50	**Beberto Baloyi** (UJ)	Nature and origin of Mesozoic Kimberlites from the NW Kaapvaal craton in Botswana. (IP)	Other
09h50-10h10	TEA BREAK		
10h10-11h00	KEY NOTE **Prof Murray W. Hitzman** (SFI Professor of Geology; Director of iCRAG)	**The energy transition: Implications for Geoscience – a view from the North.** (V)	
11h10-11h30	**Christiaan van Zyl** (UP)	Geochronology of the peripheral intrusions to the Kunene Anorthosite Complex in in southern Angola and northern Namibia. (IP)	Kunene
11h30-11h50	**Mafete Malatji** (UFS)	The strontium isotopic stratigraphy of the LCZ-UCZ transition in the Western Limb, Bushveld Complex. (V)	Bushveld
11h50-12h10	**Laurence Robb** (DVP, UJ)	The Vergenoeg strato-volcano – IOCG-like mineralization associated with felsic magmatism in the Bushveld Magmatic Province, South Africa. (IP)	Bushveld
12h10-12h20	COMFORT BREAK		
12h20-12h40	**Mabatho Mapiloko** (Wits)	Chromite and sulphide mineralization of the Uitloop ultramafic bodies in the northern limb of the Bushveld Complex. (IP)	Bushveld
12h40-13h00	**Samer Mashhour** (Wits)	A turbulent magmatic density current and the origin of the anastomosing UG-1 chromitites at Dwars River in the Bushveld Complex. (IP)	Bushveld
13h00-13h20	**Thapelo Sidwell Motaung** (UFS)	The Sr-isotopic stratigraphy of the Eastern Limb of the Bushveld Complex. (V)	Bushveld
13h20-13h40	**Marina Yudovskaya** (Wits)	A hidden basaltic roof of the Bushveld Complex. (IP)	Bushveld
13h40-14h00	**Peace Zowa** (Wits)	Constraining magma sources and the metallogenesis of the Bushveld Complex using Nd isotopes in apatite. (IP)	Bushveld
14h00-14h30	**Prof Nikki Wagner** (UJ)	CLOSING AND PRIZES	
		DEPARTURE – No Lunch	

** Programme subject to change*

** IP – in person*

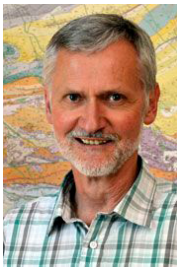
** V – virtual presentation*

POSTERS

14h40-15h14: **THURSDAY 18 NOVEMBER 2021**				
TIME FROM	TIME TO	NAME	THEME	TITLE
14:40	14:42	**Welhemina Mmamokhobo Langa** (UJ) (IP)	Analytical Techniques	Characterisation of South African coal and its associated inorganic matter using hyperspectral imaging.
14:42	14:44	**Loic Le Bras** (Wits) (V)	Analytical Techniques	U-Pb dating of apatite from Phalaborwa: a new insight into the emplacement of the carbonatite-phoscorite complex.
14:44	14:46	**Luyanda Mayekiso** (UWC) (V)	Analytical Techniques	The use of Gaming software and HIVE technology in the construction of virtual field education of the Tanqua Karoo.
14:46	14:48	**Busisiwe Khoza** (Wits) (IP)	Bushveld	A high-precision bulk rock Sr-Nd-Hf isotopic study of the mafic-ultramafic layered sequence of the Bushveld Complex to constrain its magma sources and related vast mineral deposits.
14:48	14:50	**Herman Mabotja** (Wits) (V)	Bushveld	Subsurface investigation of the Bushveld Complex using joint inversion of surface wave and satellite gravity data.
14:50	14:52	**Julia Mapula Maponya** (Univen) (V)	Bushveld	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.
14:52	14:54	**Simona Poelinca** (Wits) (V)	Bushveld	Mantle source, metasomatism and silicate melt evolution as reflected in olivine of the Phalaborwa Complex using trace element and isotope geochemistry.
14:54	14:56	**Agex Cordeiro Ferreira Manuel** (Wits) (IP)	Kunene	Assessing the Ni-Cu-(Co-PGE) Magmatic Sulphide Potential of the Mesoproterozoic Kunene AMCG Complex in Namibia and Angola.
14:56	14:58	**Phumudzo Munyai** (Univen) (IP)	Environmental	Investigation Of metal accumulation In Combretum Imberebe, Cynodon Dactylon and Sporobolus Africanus at Klein Letaba Tailings Dam, Limpopo Province, South Africa.
14:58	15:00	**Fritz Ako Akbor** (UWC) (V)	Hydrocarbon	Petroleum systems and hydrocarbon potential analysis of the Southern Pletmos Basin, offshore of South Africa: Utilizing 3D basin modelling techniques.
15:00	15:02	**Meshaclick Malesela Bopape** (Wits) (IP)	Hydrocarbon	Preliminary evaluation of mapping the Whitehill Formation and Karoo dolerite intrusions in the southeastern Karoo Basin.
15:02	15:04	**Duduzile Gloria Modiba** (UJ) (V)	Hydrocarbon	The assessment of rare earth elements in a borehole core from the Ermelo &Witbank Coalfields, South Africa.
15:04	15:06	**Sarafina Mandevhu** (UWC) (IP)	Northern Cape	Dolerite intrusions within iron ore of the Maremane Dome as possible time markers and stratigraphic control units.
15:06	15:08	**Xolane Mhlanga** (RU) (V)	Northern Cape	The re-characterization of manganese ore deposits in the Postmasburg Manganese Field.
15:08	15:10	**Khensani Moses** (UCT) (V)	Northern Cape	Pyrite and sphalerite morphological and chemical variations: Implications on the genetic model of the Gamsberg zinc deposit.
15:10	15:12	**Vuyolwethu Mahlalela** (Wits) (IP)	Seismic/ Geophysics	Tectonic evolution of the deepwater Orange Basin (South Africa) using 3D reflection seismic data.
15:12	15:14	**Anton Viljoen** (UCT) (V)	Other	The highly micaceous kimberlites from the Man craton: A unique origin.

** IP – in person / * V – virtual presentation*

Image by Robyn Ormond; Folds in the Damara, Namibia.



KEYNOTE SPEAKER: Prof Christoph Heubeck

Friedrich-Schiller-Universität Jena, Germany; Science Coordinator.

BIOGRAPHY ▪ Christoph Heubeck is Professor of General Geology and Earth History at Friedrich-Schiller-University Jena, Germany. He is principally a regional geologist focusing on deformed sedimentary rocks and has worked on pore-to-basin-scale problems worldwide (Caribbean, California, China, Canada, Chile, South Africa, Europe), both in industry as a petroleum geologist (Amoco, BP) as well as in academia (Free University Berlin, FSU Jena). He never fully disengaged from his PhD thesis in the Barberton Greenstone Belt (1994) and started working there again in 2007, along with his students, focusing on all aspects of the Moodies Group.

Image by George Henry: Banded Iron Formation at Kuruman Kop – University of Johannesburg Geology Honours students' field exercise.

KEYNOTE SPEAKER: Prof Murray W Hitzman

SFI Professor of Geology; Director of iCRAG.

BIOGRAPHY ▪ Murray Hitzman is a Science Foundation Ireland Research Professor in the School of Earth Sciences, University College Dublin and Director of the Irish Centre for Research in Applied Geosciences (iCRAG). He previously served as Associate Director for Energy and Minerals at the U.S. Geological Survey, Charles Fogarty Professor of Economic Geology at Colorado School of Mines, policy analyst in the White House Office of Science and Technology Policy and the U.S. Senate, and exploration geologist conducting mineral exploration worldwide. Hitzman has B.A. degrees in geology and anthropology from Dartmouth College, an M.S. in geology from University of Washington, and a Ph.D. in geology from Stanford University.

TITLE:	**The application of experimental mineralogy in geoscience – A case study of Economic geology and geometallurgy.**
PRESENTING AUTHOR:	**Lebogang Babedi**
AFFILIATION:	Stellenbosch University
EMAIL ADDRESS:	babedi.lebogang@gmail.com
SUPERVISOR/S NAME:	Bjorn Von Der Heyden
DSI-NRF CIMERA THEME:	Base Metals
REGISTERED DEGREE:	PhD Geology
ORAL OR POSTER:	ORAL

The geological and metallurgical communities have been confronted with complex difficulties that requires an unconventional combined strategy to overcome. The inability to do comprehensive research on a molecular scale limits the solutions to these difficulties. To date, the general observation is that, while some fields of geoscience (e.g., petrology or mineralogy) have embraced experimental approaches as a key proxy for characterizing the mechanisms underlying crustal formation, experimental techniques have not been widely adopted in economic geology and in mineral processing. This is submission seeks to present an illustration of experimental mineralogy as a viable proxy to building detailed knowledge of the more complex geo-metallurgical problems encountered in the sulphide minerals. This is accomplished by demonstrating the various types of experimental mineralogy techniques and how they apply to both economic geology and process mineralogy. While the bulk of this presentation is comprised of several thorough case studies of the application of experimentally produced synthetic minerals used to evaluate the influence of metal constituent on the processing response of sulphide minerals. Furthermore, the presentation will demonstrate how experimental mineralogy can assist improve pyrite recovery through using detailed molecular-level mineral investigations as a proxy for the modification of different flotation reagents. This presentation is critical to drawing a larger interest in the experimental aspects of economic geology and process mineralogy as we continue to encounter multi-disciplinary problems that needs a combined multidisciplinary solution.

TITLE:	**The use of apatite trace element mineral chemistry and Sr-Nd isotopic determinations for investigating the petrogenesis of syenites and carbonatite. A case study of the Epembe alkaline-carbonatite complex, Namibia.**
PRESENTING AUTHOR:	**Mbili Tshiningayamwe**
AFFILIATION:	University of the Witwatersrand
EMAIL ADDRESS:	1935597@students.wits.ac.za
SUPERVISOR/S NAME:	Profs Robert Bolhar and Paul AM Nex
DSI-NRF CIMERA THEME:	Critical raw materials
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

The Epembe Alkaline Carbonatite Complex (EACC) in northwestern Namibia was emplaced along a fault zone into medium- to high-grade Palaeoproterozoic basement rocks of the Epupa Metamorphic Complex (EMC), and extends over a distance of 9 km in a south-easterly direction with a width of 1 km. Nepheline syenite with minor syenite constitute the main lithologies, cross-cut by a calcite-carbonatite dyke. Apatite grains from one syenite, six nepheline syenite and five carbonatite samples were studied using cathodoluminescence (CL) imaging, trace element and Sr-Nd isotope compositions as well as U-Pb geochronology. Syenite-hosted apatite is homogenous in CL and contains the highest concentration of REE (9189-44100 ppm) with light rare-earth element (LREE) enrichment (La_N/Yb_N = 4-91) relative to heavy (H) REE and negative Eu anomalies (Eu/Eu* = 0.4-0.9). These features are attributed to the formation of apatite in an evolved mantle-derived melt associated with plagioclase fractionation. Nepheline syenite-hosted apatite is also commonly homogeneous in CL, while core-rim zoning and patchy textures are observed occasionally. Both texturally homogeneous and core-rim zoned apatite are enriched in LREE (La_N/Yb_N = 32-94) relative to HREE, consistent with a magmatic origin. Core-rim zoned apatite is characterized by rim-ward increase in REE concentrations at constant Sr and Nd isotopic compositions, which can be attributed to the re-equilibration of early formed apatite (core) with later infiltrating melt enriched in REE, causing the formation of apatite overgrowths (rims). Patchy apatite is depleted in Na, Y and REE, particularly the LREE (La_N/Yb_N = 4-19) and is enriched in Sr relative to other nepheline syenite apatite, reflecting interaction with fluids (metasomatism). The strontium isotope composition of metasomatic apatite and magmatic apatite is indistinct suggesting a magmatic origin of the alteration fluids. Carbonatite apatite is LREE (La_N/Yb_N = 24-161) enriched relative to HREE and displays core-rim zoning in CL accompanied by a rim-ward increase in REE, attributed to mineral fractionation. No Eu anomalies (Eu/Eu* = 1) in chondrite-normalized REE patterns are observed in any apatite hosted by nepheline syenite and carbonatite. A LA-ICPMS U-Pb age of 1216 ± 11 Ma (MSWD = 4.3, 2 SE) for syenite apatite constrains emplacement of the syenite. Magmatic nepheline syenite apatite ages of 1178 ± 16 Ma, 1150 ± 19 Ma and 1073 ± 22 Ma (MSWDs < 4.0, 2 SE for all ages) determined on three samples probably represent slow cooling after thermal activity related to the emplacement of the latest intrusive phase (carbonatite) in the complex. The Sr and Nd isotopic composition of apatite in syenite ($^{87}Sr/^{86}Sr_{(i)}$ = 0.7035-0.7048; $\varepsilon_{Nd(t)}$ = +2.5 to +3.2), nepheline syenites ($^{87}Sr/^{86}Sr_{(i)}$ = 0.7031-0.7037; $\varepsilon_{Nd(t)}$: +1.5 to +4.4) and carbonatite ($^{87}Sr/^{86}Sr_{(i)}$ = 0.7031-0.7033; $\varepsilon_{Nd(t)}$ = 0 to +3.3) overlap, pointing to a common but heterogeneous mantle source, possibly involving HIMU and EMI components.

TITLE:	**Structural constraints on the evolution of the south-eastern Mwanesi Greenstone Belt and adjacent granitoids, central Zimbabwe Craton: implications for gold mineralisation.**
PRESENTING AUTHOR:	**Brian Mapingere**
AFFILIATION:	University of Johannesburg
EMAIL ADDRESS:	brianm@uj.ac.za
SUPERVISOR/S NAME:	Profs Jeremie Lehmann and Fanus Viljoen, Prof Marlina Elburg (collaborator)
DSI-NRF CIMERA THEME:	Mantle and crustal processes, and metallogenesis
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

The Mwanesi Greenstone Belt (MGB) occupies the central part of the Zimbabwe Craton and trends in a NNE direction. The MGB consists of greenstones (intercalated with banded iron formations, BIF) of the Lower and Upper Bulawayan Supergroup. The MGB is described as a doubly plunging NNE-trending syncline, with BIF units defining fold closures at both the northern and southern ends of the belt. Gold mineralisation is hosted in quartz reefs in the supracrustal rocks and adjacent granitoids and gneisses. The MGB is one of the least studied greenstone belts of the Zimbabwe Craton. In particular, the deformation record of the belt is only known from colonial mapping programs in the 1950s. We report new data from lithological and structural mapping of the south-eastern MGB (the focus of this study) and adjacent granitoids and gneisses.

The south-eastern MGB reveals that the lower structural units of the MGB are composed of mafic rocks (locally pillowed and pyroclastic breccia) and to a less extent felsic volcanic rocks, intercalated with thin-bedded and medium-laminated metasedimentary rocks, traditionally referred to as the Lower Greenstone Series (LGS). These are overlain by phyllites and BIFs (i.e., the Lower Sedimentary Series, LSS). The LGS and LSS are intruded by mafic rocks and are overlain by locally pillowed basaltic rocks of the Middle Greenstone Series. The MGB is underlain to the east by a variety of granites and gneisses, some in intrusive contact with the MGB. The granites and gneisses are transected by a km-wide N-S-striking sinistral shear zone (the Mhou Shear Zone, MSZ). A new LA-(MC-Q)-ICP-MS U-Pb age at 2717 ± 21 Ma (MSWD = 2.1) from a MSZ mylonite is interpreted to date the crystallisation of the granitoid protolith of the MSZ.

Our structural mapping reveals three deformation domains based on the orientation and kinematic interpretation of tectonic fabrics, overprinting relations, and microstructural characteristics. (1) The MGB is characterised by a shallow-dipping bedding parallel schistosity carrying a mineral, intersection lineation. This schistosity encloses dm-scale recumbent, intrafolial folds. The schistosity is overprinted by steeply NE-dipping axial planar cleavage to cm-scale folds, which carries a NNW-plunging crenulation lineation. (2) Orthogneisses west of the MSZ and structurally below the MGB are characterised by a shallow SW-dipping gneissosity (carrying a shallowly NW-plunging mineral lineation), which is associated with a top-to-the NW shearing as evidenced by K-feldspar sigma porphyroclasts. The gneissosity is overprinted by steep NE-dipping axial planar cleavage to cm-scale open folds. (3) Orthogneisses east of the MSZ reveal a shallow SW-dipping gneissosity overprinted by the steeply W-dipping gneissosity and mylonitic foliation of the MSZ. The MSZ carries a shallowly SSW-plunging stretching mineral lineation. Mylonitic foliation in the MSZ is associated with a sinistral sense of shear based on K-feldspar sigma and delta porphyroclasts. We suggest a wrench dominated transpression model to explain the deformation in the MSZ based on shallow-plunging stretching lineation carried by a steep mylonitic foliation.

Gold mineralisation hosted by broadly W-dipping quartz veins occurs in the MGB and MSZ. The crystallisation age of the granitoid protolith of the mylonite in the MSZ is contemporaneous with the intrusion of the Sesombi granitoid suite (2720-2640 Ma) in the Zimbabwe Craton. The lithostratigraphy and deformation record of the south-eastern MGB and adjacent granites and gneisses from our work have important implications for understanding the tectonic evolution of the MGB and the link between deformation and the gold mineralisation in the MGB.

TITLE:	**Characteristics of ore minerals and geochemical variation of host rocks associated with antimony and gold mineralisation in the Murchison greenstone belt, South Africa.**
PRESENTING AUTHOR:	**Thabo Kgarabjang**
AFFILIATION:	University of Limpopo
EMAIL ADDRESS:	kgarabjangts@gmail.com
SUPERVISOR/S NAME:	Prof NQ Hammond
DSI-NRF CIMERA THEME:	Base, Critical Metals, Gold, And Other Deposits
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

The Antimony Line in the Murchison greenstone belt hosts several gold and antimony mineralisations within massive, fractured talcose and carbonate host rocks. Samples from three orebodies, Beta, Athens and Monarch at the Stibium Mopani Mine were studied for the ore minerals and geochemical signatures of host rocks to the mineralisation. 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.

Predominant ore minerals identified include ullmannite, gersdorffite arsenopyrite, stibnite, and pyrrhotite. The relative abundance of these minerals vary from one deposit to another. Gersdorffite is predominant in the Beta deposit while pyrrhotite is predominant in the Athens deposit, and arsenopyrite dominates the Monarch.

Hydrothermal alteration is pervasive along the Antimony Line resulting in variable enrichments and depletion of elements in the host rocks. Elements such as SiO_2, V, Cu, Au, Sb, and K_2O have been added to the host rocks, while CaO, MgO, and Cr_2O_3 were removed. The alteration types identified include carbonatization, muscovitization, potassic, and sulphidation. The Ba-K substitution is seen in the K-bearing minerals such as biotite and muscovite during potassic alteration. There are Sr-Ca and Mg-Ca substitutions in the carbonates while Co and Ni substitution is associated with sulphidation alteration along the Antimony Line.

The enrichment of SiO_2 is indicative of the occurrence of silicification. There was variable degree of enrichment of the trace and pathfinder element (Au, As, Sb and Ag). In particular, Au enrichment was highest at Monarch, while antimony recorded the highest enrichment at Beta. Thus, antimony shows an increasing trend from Monarch to Beta, while gold enrichment increases from Beta to Monarch. The distribution of Au is higher in the Monarch deposit than the Beta and Athens deposits. The enrichment of Au in the Beta and Athens deposits is not very pronounced. Arsernic is mostly occur in the Monarch orebody and exhibit a close association with Au mineralization. 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.

TITLE:	**A characterization and process mineralogical assessment of the karst hosted manganese ore deposits at Paling exploration camp in the Postmasburg Manganese Field, Northern Cape Province, South Africa.**
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DSI-NRF CIMERA THEME:	Manganese and Iron Ore Deposits
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

Paling Pan exploration site contains manganiferous ore and is located ~15 km North of the town of Postmasburg in the Northern Cape Province of South Africa. The Mn-Fe ore is part of the Western Belt of the Postmasburg Manganese Field (PMF). Although the PMF has been studied in the past it has received far less attention than the Kalahari Manganese Field (KMF) which is ~120 North of Paling and accounts for the majority of the world's Mn production.

Most previous studies on the PMF aimed at constructing a general overview of the various ore types, their occurrence and mineralogy within the Western and Eastern Belts. These include petrographic and mineralogical studies (Scheiderhöhn, 1931; Plehwe-Leisen, 1985; De Villiers 1943a, b; 1983; Gutzmer, 1996; and Gutzmer & Beukes, 1996), with some limited major and trace element geochemistry reported by Hall (1926), Nel (1929), De Villiers (1960), Gutzmer (1996) and Gutzmer & Beukes (1996).

The focus of this project was on ore from Paling Pan, more specifically the mineralogy and major element geochemistry of borehole core samples, the susceptibility of the ore to magnetic separation and the crushing and grindability of the ores. The ore minerals found in the MnFe ore were primarily braunite, braunite and partridgeite with minor hollandite in veins and the major gangue minerals are kaolinite and diaspore. The grade of the ore varied greatly but is typically between 22 and 40 weight % Mn with an average ore grade of 31 weight % Mn (n = 269). The upgrading of the ore with magnetic separation was found to be feasible at the particle size at which the test was conducted (2 – 5 mm) with Mn weight % enrichments of between 1 and 15 weight % Mn. However it is unknown whether this would be feasible at the significantly larger particle size at which the ore would be sold as (> 42 mm). The crushing and grindability of the ore were found to be relatively low and will thus not require special equipment for the comminution of the ore.

The ore could thus be seen as feasible to mine, especially if the magnetic separation is as efficient at larger particle sizes, otherwise the ore might require careful blending in order to average out the variable ore grade to a sellable product.

TITLE:	**Constrains on the genesis of the orbicular granites and sulphide mineralization in the Koperberg Suite, Namaqualand and the Diana's Pool area, Zimbabwe.**
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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. Similar to Enzman (1953), the Archean Diana's Pool (DP) orbicular rocks were described by Garvie (1969, 1971), although not in detail. He describes these rocks as outcropping in the Matobo Hills area, within the Matopos porphyritic granite, south of Bulawayo in Zimbabwe. Similar to Enzman, Garvie (1969, 1971) only describes Diana's Pool orbicular outcrop based on field observations, petrography and a bit of geochemistry. They present no in-situ mineral compositions or isotope data to argue for their conclusions on the genesis of these rocks. Hence, the purpose of this study. This study will document a selection of orbicules from the Koperberg Suite and the Diana's Pool area, to understand the genesis of these rocks and the link to sulphide mineralization using petrography, in-situ mineral compositional data and isotope determinations. The DP and the four different orbicular localities in the KS are described including Orbicule Koppie (OK), Hoogskraal Lease (HL), Henderson North (HN) and the Henderson South (HS).

The orbicules are hosted in lithologies ranging from granitic to dioritic in composition. They 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 KS contain chalcopyrite and magnetite and this is not the case in the DP orbicules. 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, DP, and the 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 DP, HS and HL orbicule shells are characterized by radiating textures. However, magnetite, enstatite and actinolite form the radiating texture in these localities respectively. 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, DP 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.

This study has the potential of providing more scientific data for potential areas of exploration for the future mining of Cu in the Northern Cape Province, as it also focuses on sulphide mineralization. Geochemical analysis and isotopic work will be carried out to provide more data on the genesis of these rocks and the metallogenesis of sulphide mineralization.

TITLE:	**In-mine Seismic Imaging Trials of PGM Deposits in the Bushveld Complex, South Africa.**
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DSI-NRF CIMERA THEME:	Manganese and Iron Ore Deposits
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

With an ever-increasing demand for manganese (Mn), linked to exponential increases in steel production, manganese deposits, and the associated Mn ore across the world are becoming more and more valuable. The world-renowned Paleoproterozoic Kalahari Manganese Field (KMF) is host to the world's largest land-based Mn deposit. The KMF is hosted within the Hotazel Formation, which comprises three Mn beds interbedded with four superior-type iron formations. The Leinster Deposit, one of five erosional relics that comprise the KMF, is the northernmost (and least studied) deposit of the KMF. The lack of petrographical, mineralogical and geochemical research is due to the smaller size, predominantly low Mn contents, and lack of high quality and quantity of core samples from the Leinster Deposit in comparison to the remaining four, larger and higher-grade erosional relics to the south of this deposit.

This study provides a detailed geological investigation of the Leinster Deposit, in which 72 samples from five drill cores were provided by Anglo American. The nature of the deposit, as well as post-depositional alteration has also been addressed. The samples were petrographically, mineralogically and geochemically characterised into one of four groups, namely: (1) high-grade BIF, (2) BIF, (3) Mn ore and (4) mafic intrusions. The high-grade BIF group displays the highest Fe_2O_3 content, linked to the highest abundance of magnetite within the samples. This group also shows clear evidence for fluid alteration, including andradite, largeeuhedral secondary apatite grains, as well as the presence of sulphides (pyrite and chalcopyrite). The presence of apatite, with the absence of tephroite indicates that these samples were never exposed to temperatures greater than 700°C. The Fe_2O_3 content (> 60 wt%), combined with the SiO_2 (up to 34 wt%) abundance, restricts these samples from being classified as iron ore, but rather represent slightly upgraded BIFs, due to the leaching of Si (from an alkaline fluid), resulting in moderate residual enrichment of Fe. Rare Earth Yttrium (REY) patterns for this group are similar to Hotazel and Kuruman-Penge iron formations which include being HREE enriched, positive Y and Eu anomalies, as well as having apparent Ce anomalies, all of which are indicative of a marine environment with a hydrothermal component.

The BIF group has been characterised as having Fe_2O_3 contents less than 60 wt%. These samples contain magnetite, but in lesser abundances than the high-grade BIFs, and with a variety of other Fe-, Mg-, and Ca-bearing silicates. The BIF ore comprises primary diagenetic minerals including greenalite and apatite, but also has secondary minerals such as andradite, calcite and pyrite. This group of samples is geochemically very similar (Fe_2O_3, SiO_2 and CaO) to what has been previously reported for Hotazel BIFs. Similar to the high-grade BIF, the REY pattern of this group shows the same trends and anomalies. The BIF, however, is slightly more enriched in REE's compared to the high-grade samples, most likely due to residual enrichment associated with the same fluid responsible for the upgrade of the BIFs to high-grade BIFs.

The Mn ore samples display Mn contents that range between 17 and 35 wt%. The Leinster Deposit has been graphically depicted as being a jacobsitic ore deposit by previous authors. Only one of the ten samples that comprise this group was dominated by jacobsite, whilst the remainder of the samples had Mn-bearing mineral phases such as kutnohorite, manganocalcite, friedelite and tephroite. In conjunction with these phases was the presence of Fe-bearing oxides, silicates and sulphides such as andradite, magnetite and pyrite. Eight of the ten samples within this group come from the same drillcore (TW7), suggesting that there are some preserved Mn beds in the Leinster Deposit. Although there are significant concentrations of Mn within these samples, there are still appreciable concentrations of both Si and Fe. Comparisons of REY patterns of these samples are most similar to Mamatwan-type ore compared to Wessels-type ore, however, they also closely resemble the REY from the two previous BIF groups. These samples show positive La, Y and Eu anomalies, as well as an overall HREE enrichment. The resemblance between both Mamatwan-type ore and the BIF groups suggests that these samples are a type a variation between a low-grade Mn ore group and typical Hotazel BIF.

The intrusion samples are imperative to the characterisation of the Leinster Deposit due to the sheer volume of intrusive material within this deposit. There is a change in the mode of occurrence of these intrusions from the southern MKMD, where they occur as thin dykes, compared to the northern Avontuur and Leinster deposits, where they occur as thick sills. The study of these samples has resulted in the first detailed textural description of pyrophanite for the KMF, as well as provide qualitative and semi-quantitative analyses. Phase-I pyrophanites (Pph-I) are large, euhedral, skeletal crystals that formed while formation temperatures were still relatively high within the intrusion. As the intrusion cooled, phase-II pyrophanites (PphII) formed as accicules within the groundmass. These accicules are dispersed throughout the groundmass and show no preferential alignment. The last phase-III pyrophanites (Pph-III) are found as an anhedral mass situated on the outer margins of both Pph-I and Pph-II. The formation of pyrophanite (rather than ilmenite, a common phase associated with the intrusions) may be explained by an incorporation of Mn from the surrounding country rock. These samples are completely dominated by clinochlore suggesting complete alteration, and most likely represents the contact zone between the intrusion and country rock, which acted as a natural fluid pathway. These intrusion samples are heavily depleted in large ion lithophile elements (LILE), once again suggesting fluid alteration by a low temperature, SO_4 deficient and meteoric fluid. REY patterns of the intrusion samples from the Leinster Deposit are comparable to intrusion sPamples originating from the Avontuur and MKMD deposits.

Since the deposition of the chemical sedimentary units that comprise the Hotazel Formation, the Leinster Deposit has been subjected to hydrothermal alteration, low-grade metamorphism, and most notably, large-scale intrusions. The high proportion of intrusive material has displaced, and in some cases completely destroyed the Mn beds within this deposit. Where Mn beds have been found, they closely resemble BIFs, rather than one of the Mn ore types that have been previously characterised for Mn ores of the KMF. The extent of the intrusions would make this deposit an unlikely future target for Mn exploitation.

TITLE:	**Mineralogical and geochemical characterisation of mineralised and regular NYF-type pegmatites from the Namaqualand pegmatite belt, Northern Cape, South Africa.**
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DSI-NRF CIMERA THEME:	Mantle and crustal processes and metallogenesis
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

The 450 km long and 40-50 km wide Orange River pegmatite belt (ORPB) consists of > 30 000 individual pegmatites that intruded the Namaqua Sector of the Mesoproterozoic Namaqua-Natal Metamorphic Province (NNMP) in Southern Africa at ca. 1 Ga. The Kakamas Domain, located in the central part of the belt is characterised by the occurrence of NYF pegmatites, classified as either complex (e.g., Witkop, Koegab, Sidi-Barrani) or simple (eg: CD-S, ED-S). In addition to the common rock-forming minerals (quartz, feldspars and micas), complex pegmatites are enriched in REE-U-Th-rich mineral phases, are up to tens of meter's thick and show a heterogeneous texture. Simple pegmatites contain minor concentrations of REE-U-Th-rich mineral phases, are of smaller scale (up to few meter-thick) compared to complex pegmatites and mostly show a relatively homogeneous texture. The study therefore aims to understand the differences and similarities between simple and complex pegmatites.

Two pegmatite age groups were identified by LA-ICPMS U-Pb dating. The older generation of pegmatites, analysed using titanite, represented by two simple pegmatites, were emplaced at 1043 ± 5 Ma and 1025 ± 6 Ma. This is contemporaneous with the intrusion of mafic igneous rocks at 1060-1010 in the western part of the NNMP, which occurred during the D3 large-scale folding event. Monazite from the analysed complex pegmatites gave ages of 985 ± 4 Ma, 977 ± 2 Ma and 969 ± 5 Ma. These pegmatites were emplaced during the D4 dextral deformation event that occurred between 1010 and 970 Ma along subvertical structures such as the Pofadder Shear Zone.

The up to 60 Ma age difference between simple and complex pegmatites suggests that they might have been derived from different sources, which were perhaps enriched in REE-Th-U to different extents. The lack of contemporaneous parental granites for the exposed ORPB NYF pegmatites does not favour a model of formation via extended fractional crystallisation of a granitic magma (residual pegmatites). Instead, their formation may be related to favourable conditions of partial melting of crustal sources variably enriched in REE-Th-U, thus favouring an anatectic origin for the pegmatites.

Trace element ratios such as K/Rb, K/Cs, Fe/Mn and Nb/Ta have been proposed as effective markers for the degree of fractionation in pegmatites. Therefore, the trace element compositions of mica have been used to document the extent of fractionation between complex and simple pegmatites to argue for a similar or differing source between the pegmatites. Rare-element enrichment or depletion in micas from complex and simple pegmatites confirmed the probability of the pegmatites being derived from potentially different sources which were likely variably enriched in REE, as there is no systematic pattern of enrichment from simple pegmatites to complex pegmatite.

TITLE:	**In-mine Seismic Imaging Trials of PGM Deposits in the Bushveld Complex, South Africa.**
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REGISTERED DEGREE:	PDRF
ORAL OR POSTER	ORAL

This research project seeks to answer the SAMERDI (South African Mining Extraction Research, Development, and Innovation) Advanced Orebody Knowledge (AOK) call for "Work Package (4.3): technologies that will be used to obtain information ahead of the mining face such as Tunnel Seismic Prediction (TSP)". Mineral exploration relies on the application of advanced geophysical techniques to refine the search for mineral deposits and mine planning. Improving the exploration of deep-seated economic mineral deposits requires that seismic technologies are deployed in a fast and cost-effective manner with less environmental impact. The research presented results of in-mine seismic experiments conducted at Maseve mine, Rustenburg, South Africa. The research is a pilot study with an aim of providing seismic constraints on the complex geological architecture in the area for mining development and continuation.

The project integrated several innovative in-mine active and surface passive seismic experiments by utilizing series of innovative seismic instruments including: (1) 400 Remote Acquisition Units (RAUs) (used for surface passive and active seismic surveys), (2) 4.5 Hz landstreamer receiver; 14 and 100 Hz planted receivers (used for both in-mine and surface-active seismic surveys), (3) 3C Broadband seismometer (used for passive surface seismic recording) installed near the mine operations. Three energy sources such as sledgehammer (10kg, used both in-mine and surface), and 25 kg and 45 kg accelerated weight drop (used for surface seismics). The analysis shows that the near-surface and air waves were attenuated after processing, which involved bandpass frequency filtering with AGC, velocity bandpass, static and normal moveout correction, stacking and migrations. The traces were also normalized with respect to their maximum amplitude of the entire shot gather, and dead traces were removed. The resulted presented in this abstract were acquired 450 m below the surface with a sledgehammer source along Line 1 and 3.

The interpreted results attributed the coherent reflected events to known Platinum Group Metal (PGM) deposits such as Upper Group (UG2 and UG1), Middle Group (MG) and Lower Group (LG). The results revealed the geometries of these known mineralisations as sets of strong high-amplitude coherent reflection markers. Subtle faults were observed, the dip and depth geometries of these mineralised horizons were estimated as well as their stratigraphic intervals with adjacent layers. The result proved to be fast and cheap geophysical technique, which can adequately complement other surface geophysical methods. The research also highlights the possibility of using high-resolution shallow reflection seismic method for underground mineral exploration and mine development planning.

TITLE:	**A Statistical and Machine Learning Approach to Analysing Faults and Dykes at South Deep Gold Mine.**
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DSI-NRF CIMERA THEME:	Gold metallurgy / metallogeny of The Greater Witwatersrand-Pongola Basin
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

The interpretation of 3D seismic data is a fundamental component of reflection seismology. However, the large volume of data makes manual interpretation time consuming, tedious and slows down the process of research. Hence the recent development of statistical analysis tools to aid the interpretation of 3D seismic volumes is an active field of research. These tools can speed up the interpretation and even eliminate the human error that is often coupled with manual interpretation. Major strengths of this methodology also include the robust handling of sparse and disparate input data, labels, incomplete data, and the ability to predict missing data values. In this study we make use of some these automated tools to interpret 3D seismic data with the objective of predicting geometry of complex geological features (faults and dykes) found at south deep mine in the Witwatersrand Basin. The structural attribute analysis includes structural and apparent dip, azimuth and throw. An integrated model of these attributes provides a detailed analysis of the complex structures which dominated the mine.

The target orebody at south deep, which consists of the Ventersdorp Contact Reef (VCR) and the Black Reef (BLR) is currently being mined at depths 2.40 km – 2.65 km. At these depths there is a dominance of geologically complex structures which affect mining operations and pose a safety risk. It is therefore crucial to establish an integrated statistical model which describes the geometry and orientation of the structures. Most of the structures at these depths are near vertical and are not clearly mapped on the 3d seismic volume. In order to enhance these structures, we make use of statistical tools and machine learning to predict their continuity, geometry and orientation in regions with low seismic resolution.

The preliminary results of this study are separated into two distinct regions, the unmined area of interest (AOE) and regional area (RA). Rose diagram analysis shows an average maximum (~89°) & (~87°), minimum (~82°) & (~83°) dip angles and stereonet diagrams shows an average maximum (~294°) & (~270°), minimum (~220°) & (~159°) dip directions for the structures in (RA) & (AOE), respectively. Therefore, confirming that the structures are near vertical. Analysis of the azimuth showed a consistent average of ~101° for both areas. Suggesting a uniform trend to the north and dip to the east.

Further analysis was done using a machine learning algorithm (gaussian regression process) to predict the throw values along the faults. Both regions are confidently described with errors of 1.85 (RMSE) and 0.99 (r-squared). Thus, a throw model was created which can be used to predict the loss of reef.

TITLE:	**2D reflection seismic constraints on the 1.9 Ga Trompsburg Layered Mafic Intrusion Complex, South Africa.**
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DSI-NRF CIMERA THEME:	Deep earth, early earth, mantle and crustal processes and metallogenesis
REGISTERED DEGREE:	PDRF
ORAL OR POSTER:	ORAL

In the late 1980s, several of crustal-scale seismic surveys were conducted across South Africa by Anglo American targeting outliers of the Witwatersrand gold-hosting sediments. Included in these surveys were the vibroseis profiles rt-376 and rt-351b. These yet-unpublished profiles were conducted end-to-end with a 6 s record length and a SW-NE trend through the centre of the ~2 400 km^2 Trompsberg potential field anomaly in South Africa, attributed to the under-examined Trompsberg Complex. The combined length of the two profiles is 108 km. Both profiles have been reprocessed and merged to further constrain the layering and expanse of the Trompsberg Complex along the seismic traverse.

Drilling into the ~1915 ma Trompsberg Layered Igneous Complex revealed a series of layered intrusions composed of mafic igneous rocks including gabbro, anorthosite and magnetite in the north-western zone of the complex, and granitoids in the centre region. Surrounding the complex are dolomites of the Transvaal Supergroup, into which the complex intruded, and overlying shales, sandstones and tillite of the younger karoo supergroup. Physical properties from the drilled boreholes were later used to model the potential field data of the complex and construct a 3d density and magnetic susceptibility model. No other geophysical methods have been used to constrain the geometry of the complex or verify the physical property model. By reprocessing profiles rt-376 and rt-351b, we aim to address this gap by constraining the expanse, both lateral and depth, of the Trompsberg Complex.

Processing of the seismic profiles included a pre-stack flow followed by velocity analysis, residual statics and a post-stack time migration. Throughout the migrated section, shallow (< 400 m) localised reflectors with strong amplitudes are observed, likely due to the dolerite sills that permeate the karoo cover. Where present, these sills obstruct seismic illumination of underlying structures due to their high acoustic impedance contrast with the surrounding softrock sediments of the karoo. A sequence of reflectors is observed beneath the karoo sediments, interpreted as the seismic response of the Trompsberg Layered Complex. Density measurements on recovered core from the drilled boreholes reveal a strong contrast between magnetites and the other mafic rocks contained within the complex. The boreholes lack sonic measurements; however, the density profiles serve as proxies for reflection strengths of the various complex layers.

The reflections associated with the complex begin at a shallow depth of about 200 m near the middle of the southwestern profile, where the profile intersects the southwestern rim of the circular potential field anomalies and thicken and deepen as the seismic profile traverses towards the centre of the complex, attaining a maximum depth of 1.8 km approximately 16 km southwest of the centre of the anomaly. In the north-eastern profile, the thickness of the reflection packages taper to a depth of 400 m where the profile coincides with the north-eastern rim of the potential field anomaly. In summary, the reflections outline an asymmetric bowl shape skewed towards the southwest with a maximum thickness of 1.5 km and a maximum depth of 1.8 km, with a 300 m average thickness of karoo cover.

TITLE:	**Re-processing of the 2D legacy seismic data for improved structural imaging and gold exploration in the South Rand Goldfield, South Africa.**
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DSI-NRF CIMERA THEME:	Gold metallurgy metallogeny of the greater Witwatersrand Pongola basin
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

To better image complex geological structures and explore for the gold-bearing quartz pebble conglomerate near Burnstone mine in the South Rand Goldfield, we reprocessed legacy 2D reflection seismic data using up-to-date seismic processing algorithms. The gold-bearing conglomerate units of the Witwatersrand Basin are interbedded within the metasedimentary rocks such as conglomerates and quartzites with similar seismic velocities and densities, making direct imaging of these deposits with reflection seismics difficult. However, previous studies have shown that these gold deposits can be targeted using seismic methods because they are overlain by basaltic rocks and underlain by shale units, thus providing strongly reflective interfaces that can be used as proxies to map these reefs.

The Burnstone Mine is a relatively new gold mine in the South Rand Goldfield, it commenced exploration under Great Basin Gold (GBG) in 2011 until placed under care about a year later, and in 2014 it was bought by Sibanye Stillwater. Sibanye is assessing the feasibility of deepening the mine to access gold reserves up to a depth of 1.3 km below surface and is concerned about the dominant, steeply dipping normal and reverse faults, as well as dolerite intrusions that crosscut the tubular gold orebody and complicate the extraction of the ore in the mining region. Therefore, we envision that the reprocessing of the legacy seismic data could provide improved structural information and minimize geological risks during drilling.

To investigate the potential source of reflectivity in the seismic legacy profile, we performed 2D acoustic finite-difference modelling using geological information and physical properties from previous studies. This is the widely used method in the hardrock environment to identify the target reflections. The pre-stack data quality was improved by careful application of the filters to remove noise and static corrections to enhance the continuity of the reflection events. Improved structural imaging was then achieved using pre-stack time migration (preSTM) and pre-stack depth migration (preSDM) through careful velocity analysis. In particular, preSDM provided better imaging of near-surface and deep-seated stratigraphic units, relative to older post-stack migrated images produced in 1993 by the initial processing team.

Other re-processing improvements include accurate imaging of key strongly seismic reflective interfaces that can be used as proxies to 3D map gold deposit, its dip variations, and geological structures (faults/dykes) crosscutting it. Synthetic shot gathers data computed using 2D finite-difference algorithm provided some insight into the source of seismic reflections observed on the reprocessed seismic data. The new structural information from reprocessing is essential for enhancing ore resource evaluation and guiding future exploration projects in the region.

TITLE:	**Geochemical Evaluation of the Cretaceous Mudrocks and Sandstones in the Southern Bredasdorp Basin, Offshore South Africa: Implications for Hydrocarbon Potential.**
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DSI-NRF CIMERA THEME:	Other
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	ORAL

The southern Bredasdorp Basin, off the south coast of South Africa, is only partly understood in terms of its hydrocarbon potential when compared to the central and northern parts of the basin. Hydrocarbon potential assessments in this part of the basin have been limited, perhaps because the few drilled exploration wells were unproductive for hydrocarbons, yielding trivial oil and gas. The partial integration of data in the southern Bredasdorp Basin provides another reason for the unsuccessful oil and gas exploration. In this study, selected Cretaceous mudrocks and sandstones from exploration wells E-AH1, E-AJ1, E-BA1, E-BB1 and E-D3 drilled in the southern part of the Bredasdorp Basin were examined to assess their total organic carbon (TOC), thermal maturity, organic matter type and hydrocarbon generation potential. The organic geochemical results show that these rocks have TOC contents ranging from 0.14 to 7.03 wt.%. The hydrogen index (HI), oxygen index (OI), and hydrocarbon index (S2/S3) values vary between 24–263 mg HC/g TOC, 478 mg CO_2/g TOC, and 0.0118 mgHC/mg CO_2 TOC, respectively, indicating predominantly Type III and IV kerogen with a minor amount of mixed Type II/III kerogen. The mean vitrinite reflectance values vary from 0.601.20%, indicating that the samples are in the oilgeneration window. The Tmax and PI values are consistent with the mean vitrinite reflectancevalues, indicating that the Bredasdorp source rocks have entered the oil window and are considered as effective source rocks in the Bredasdorp Basin. The hydrocarbon genetic potential (SP), normalized oil content (NOC) and production index (PI) values all indicate poor to fair hydrocarbon generative potential. Based on the geochemical data, it can be inferred that most of the mudrocks and sandstones in the southern part of the Bredasdorp Basin have attained sufficient burial depth and thermal maturity for oil and gas generation potential.

Keywords: *Bredasdorp basin; geochemical parameters; kerogen type; thermal maturity; hydrocarbon potential*

TITLE:	**The tectonic evolution of the Bredasdorp Basin and its implications for oil and gas formation.**
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REGISTERED DEGREE :	MSc
ORAL OR POSTER	ORAL

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 makes for an interesting study to examine the existence of gas traps and possible hydrocarbon migration pathways. Furthermore, the study can be taken one step further and examine 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 enhance 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). Synthetic seismograms are used to generate accurately picked horizons. Using well logs, certain features that show changes will lithology will assist in building a clearer picture of how the lithology changed over time, the presence or absence of gas and its content. This project aims to shed light on the potential of South Africa's petroleum systems and exploration industry.

TITLE:	**Lithostratigraphy and structural geology of the Namibfontein-Vergenoeg domes in the southern Central Zone of the Damara Orogen, Namibia.**
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DSI-NRF CIMERA THEME	Mantle and crustal processes and metallogenesis
REGISTERED DEGREE:	PhD Geology
ORAL OR POSTER:	ORAL

The Central Zone of the Pan-African Damara Orogen is well-known for its mineral wealth, with various deposits hosting uranium, lithium, tin, niobium, and gold mineralisation. Specifically, the Namibfontein-Vergenoeg (NV) domes are found within a 50 km radius of two major uranium-producing sites (Valencia and Rossing mines) in the southern Central Zone, making the NV domes an area of potential economic interest. Good exposure across the NV domes allows for detailed remote sensing and thus, we use a combination of Google Earth and ASTER satellite imagery, and airborne gamma-ray spectrometry to explore the geology and economic potential of these domes. Complementary detrital zircon geochronology is used to interrogate existing geological maps, which show that the NV domes are cored by Paleoproterozoic Abbabis Metamorphic Complex (AMC) basement rocks. Detailed field-based structural geology is used to better understand the spatial distribution of different rock types, and to determine possible structural controls on any significant mineralisation.

The rocks of the NV domes include variably pegmatitic granite and leucogranite, stromatite migmatite (with evidence of crustal anatexis), and meta-sedimentary rocks [1] metamorphosed to upper amphibolite facies. The structural geology of the NV domes is complex with preliminary results suggesting at least three deformation phases. The earliest deformation phase formed N-S-striking S_{0-1} fabrics preserved in F_2 hinge zones. The second deformation phase, a folding event with a roughly E-W-striking fold axial plane, formed the overall ENE-WSW elongation of the domes. 1-3 cm-sized sillimanite nodules show a shape-preferred orientation parallel to S_2 fabrics. F_2 folds were refolded by NNE-E-plunging F_3 folds with NW-N-striking fold axial planes. This last folding event formed the central Karub Syncline that separates the two sub-domes: Namibfontein (east) and Vergenoeg (west). Similarities in fold axis orientation between the F_2 and F_3 folds, and the pervasive, strongly developed mineral lineation parallel to both fold axes create the impression that the domes formed predominantly by bulk constriction [2]. However, clear field overprinting relations, a lack of sheath folds, and a paucity of structural asymmetry instead support multiple folding events formed under bulk pure shear, rather than constriction.

Processing of remote sensing products shows a more complex distribution of rock types in the cores of the domes compared to the current literature [1]. However, the detrital zircon geochronology of four samples near the cores of the NV domes supports the current mapping of the AMC basement in the lowest structural levels of the NV domes. Airborne gamma-ray spectrometry data do not support uranium mineralisation in the leucogranites of the domes. While the NV domes may not be as endowed in uranium as the surrounding areas, the NV domes are important as detailed fieldwork reveals D_3 structures whose orientations are uncommon for the sCZ and rework the typical 'Damaran' NE-SW-striking structural trend (D_2 this study).

[1] Geological Survey of Namibia. Geological map of Namibia: 1:250 000 geological series

[2] Poli, L.C., and Oliver, G.J.H. (2001). Constrictional deformation in the Central Zone of the Damara Orogen, Namibia. *Journal of African Earth Sciences*, 33, 303-321.

TITLE:	**Geochemical Characterisation of the Waterberg Coalfield Lithostratigraphy: Implications to Acid Mine Drainage, Limpopo Province, South Africa.**
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DSI-NRF CIMERA THEME:	Environmental Geology
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	ORAL

Coal is one the most significant source of energy worldwide fuelling almost 40% of electricity worldwide, it played a significant role for centuries and not just in electricity generation but also in steel and cement production, there is an increase in environmental awareness such as depletion of natural resources and the impact on the environment.

Coal plays a significant role in society by increasing the revenue of the country and creating jobs, however, it also causes significant environmental degradation. Coal is getting depleted due to rapid increase in population which necessitates generation of more energy consequently putting more pressure on the coal resources and increasing environmental degradation at the same time.

South Africa's coal production has remained stagnant since 2003 and this stagnation is due to the depleted coal at Witbank, Ermelo and Highveld coalfields in Mpumalanga Province. Coal has a greater potential to cause Acid Mine Drainage (AMD) and affect the environment by deteriorating water quality both on the surface and underground.

South Africa depends largely on coal to fulfil its energy demand and as a result coal mining is unavoidable. South Africa has four significant coalfields namely Witbank, Highveld, Soutpansberg and Waterberg coalfields however the Witbank and Highveld coalfields are depleted meaning the Waterberg is the only coalfield with sufficient coal to save the South African coal industry.

The South African Coal Road Map (SACRM) suggested the medium and long term development of South African coal industry depends on opening the Waterberg coalfield of Ellisras Basin, if this is implemented environmental impacts associated with coal mining should be taken into consideration. The coal quality at the Waterberg coalfields is not studied in detail as the quality of the coal is assumed to be the same as that of the Grootegeluk mine.

The acid mine drainage in some parts of the Waterberg coalfields is shown to be associated with the oxidation of pyrite within the interburden. The discards at the Grootegeluk mine is indicated to have high acid generating potential. The acid mine drainage is shown to have impacts on the groundwater as the monitoring wells indicated high concentrations of dissolved elements.

This study will focus on geochemical characterisation of the Waterberg coalfield and its potential to cause Acid Mine Drainage (AMD) of the lithostratigraphy of the Waterberg (Grootegeluk and Goedgedacht) and the proximate properties of the coal in the area. This will involve Acid Base Accounting (ABA) tests, geochemical analysis, and petrographic studies to determine the sulphide and carbonate minerals. Proximate analysis will be conducted to determine the moisture, ash, volatile and fixed carbon content to determine the economic utility of the coal. This study will involve collection of 10 core drills from the Waterberg coalfield for collection of coal and interburden samples. The samples will be analysed by XRF and XRD to determine their geochemistry and a petrographic microscope will be used to study the structure, form and morphology of the sulphide minerals. Microsoft excel will be used for plotting of graphs.

Keywords: *Waterberg coalfield, Acid Mine Drainage, Coal impacts, Acid Mine Drainage, Lithostritigraphy, Acid Base Accounting, Proximate analysis*

TITLE:	**Geology-based tools for the prioritising of derelict asbestos mine land rehabilitation and predicting of long-term potentially hazardous geo-environmental signatures.**
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DSI-NRF CIMERA THEME:	Environmental Geology/Geology for Society
REGISTERD DEGREE:	PhD
ORAL OR POSTER:	ORAL

The mineral wealth of South Africa was and is impressive and so too are the subsequent environmental and human health problems resulting from mining. The Council for Geosciences have identified over 6000 derelict and ownerless (D&O) mine sites in South Africa of which, 248 are abandoned asbestos mines. The magnitude of derelict mines that require rehabilitation and the associated costs needed to perform this have led to the development of a methodological approach for prioritising which of these abandoned mine sites are of highest risk and should be rehabilitated first. The primary approach to addressing the problem of derelict asbestos mine lands includes identifying the sites, characterising the sites based on physical, environment and socio-economic impact assessment, prioritising for rehabilitation based on site characterisation results, selections and implementation of suitable rehabilitation strategies and finally, monitoring to rehabilitation efforts. However, the methodology for both prioritising and monitoring rehabilitation is fundamentally flawed as it fails to incorporate the geological aspects of these sites. The mineralogical, geochemical and geological characteristics of solid rock wastes, tailings and dumps at the abandoned asbestos mine sites exert paramount and foreseeable controls on the environmental signatures that have and still could originate from the lack of appropriate mitigative and preventative actions. Thus, developing successful mitigation, rehabilitation and predictive practices demands an adequate comprehension of the environmental geology, mineralogy and geochemistry of the mined and discarded mineral deposits. Why then has the South African government awarded incomprehensibly expensive tenders for the rehabilitation of abandoned asbestos mine lands, which are currently underway, but not a single piece of recognised scientific literature on the mineralogical and geochemical properties of the inorganic material, central to the problem, been published? The paper identifies and describes the historical, vast and neglected issue of asbestos mine waste as constraining ideal healthy living and sustainable environments. Several cost-effective analytical techniques were employed to mineralogically and geochemically characterise four different asbestos-containing mine rock wastes collected from different mine locations in Africa in order to gauge their individual potential toxicity on human health and the environment. It examines the potential environmental and human hazards associated with residue deposits of asbestos mining. It highlights and emphasises asbestos waste mismanagement as a major issue with regards to environmental pollution, human health and economic sustainability. The data gathered from this study demonstrates the interconnectedness of the natural environment and exemplifies the value of incorporating the chemical characterisation of the geological source during evaluations regarding environmental contamination and health risks, for prevention and predictive rehabilitation strategies.

TITLE:	**Nature and origin of Mesozoic kimberlites from the NW Kaapvaal craton in Botswana.**
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DSI-NRF CIMERA THEME	Deep earth, early earth, mantle and crustal processes and metallogenesis
REGISTERED DEGREE:	MSc
ORAL OR POSTER	ORAL

The global Mesozoic-Cenozoic "kimberlite bloom" has been associated with the breaking up of Pangea. In southern Africa, Mesozoic kimberlite magmatism appears to be closely related to the dispersal of Gondwana within the Pangea supercontinent assembly. The vast majority of the kimberlites located in the southern African region are associated with the kimberlite bloom and are expected to have similar geochemical-petrological characteristics and magma emplacement styles. Southern African kimberlite magmatism is unique, mainly because the region hosts all types of kimberlites (Group-1, Group-2, and transitional kimberlites) and is home to the three largest diamond gems in the world. Group-1 kimberlites are petrologically classified as mica-poor, whereas Group-2 kimberlites are mica-rich. There are some poorly documented cases where the rules do not apply (e.g., the Jwaneng cluster appears to have petrological and mineralogical features of Group-1 kimberlites but is isotopically identified as a Group-2 kimberlite cluster). This study will focus on two areas within Botswana, namely Jwaneng Pipe-8 and the KX36 pipe in the Central Kalahari, both kimberlite occurrences located on the NW Kaapvaal craton. We have conducted petrological and geochemical analyses on fresh magmatic kimberlites from the two localities with the aim of understanding their nature (e.g., Group-1 versus Group-2, or a transitional character), provide a detailed comparison between the two, and understand the deep mantle processes associated with the two localities. Petrographically, the Jwaneng kimberlite consists of olivine and phlogopite set in a groundmass of olivine, spinel, perovskite, Mn-ilmenite, carbonate, and minor phlogopite. KX36 pipe has a high abundance of phlogopite and olivine as macrocrysts and micro-phenocrysts set in a groundmass of mica, spinel, perovskite, calcite, and Mn-ilmenite. The petrography shows that Jwaneng has a strong affinity to Group-1 kimberlites, whereas KX36 resembles Group-2 kimberlites. Olivines found in Jwaneng have a core-rim structure even though some are highly fractured. The olivine cores yielded high NiO with low CaO compared to the rims. The olivine population of Jwaneng records Fo values of up to 94 that overlap between Group-1 and Group-2 kimberlites. The whole rock data for Jwaneng show that the pipe is MgO-rich with 32-34 wt.% coupled with a high concentration of Pb, K, Ba and LREE at low Nb, which is suggestive of being a Group-2 type and possibly sourced from the continental mantle lithosphere. The Th/Nb, Ba/Nb, La/Nb ratios are slightly elevated, and Jwaneng samples plot on the Group-2 kimberlite field compared to other kimberlites from Africa. Based on these results, we propose that Jwaneng is a Group-2 kimberlite or transitional kimberlite with a strong affinity to Group-2 kimberlites (also supported by preliminary Sr-Nd-Hf-Pb isotope data). If correct, there appears to be an extension of Group-2 kimberlite magmatism from the more central and western parts of the Kaapvaal craton all the way to its north-western periphery, from where Group-2 kimberlite magmatic activity was previously unknown. This requires a revision of genetic models for Mesozoic kimberlite magmatism on the Kaapvaal craton.

TITLE:	**Geochronology of the peripheral intrusions to the Kunene Anorthosite Complex in in southern Angola and northern Namibia.**
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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

Several small ultramafic to mafic intrusive bodies have been identified along the southern and western margin of the Mesoproterozoic Kunene Anorthosite Complex of Angola and Namibia. These intrusions are generally small (a few km^2), range in composition from dunite to harzburgite, pyroxenite, gabbro, troctolite, and anorthosite, and can be Ni-Cu-(PGE) mineralised. The similarities with the world-class Ni-Cu-Co(-PGE) sulphide deposit of Voisey's Bay in the Nain anorthosite suite, Canada, led to various exploration campaigns in the Kunene area in the past 30 years. A renewed interest in the economic potential of the area came after the recent publication of geophysical maps that suggest a possible extension of the Kunene Complex below cover to the east.

Limited ages have been produced for the intrusions: a U-Pb baddeleyite SHRIMP age of 1220 ± 15 Ma on the Ohamaremba troctolite in Namibia (Maier et al., 2013) and an unpublished TIMS U-Pb zircon age of 1803.4 ± 1.1 Ma on the leucodioritic Caongoquepia intrusion in Angola (Langa, 2019). These results leave open the question of whether the intrusions represent satellite bodies coeval to the KAC or if they are not related to it, pre- or post-dating the Kunene magmatism. The collection of new ages on the peripheral intrusions is crucial not only to the understanding of the petrogenesis of the area but also to the planning of future exploration.

We measured two LA-ICPMS U-Pb zircon ages on two troctolites of the Namibian Ohamaremba and Otjijanjasemo intrusions and we also obtained LA-ICPMS U-Pb in-situ ages on apatite crystals from two orthopyroxenites of the Oncocua intrusion in Angola. At Ohamaremba, 7 zircons produced a concordia age of 1407 ± 5 Ma, which we interpret as the crystallisation age. Two concordant zircons were measured at 1755 ± 6 Ma and 1723 ± 6 Ma. At Otjijanjasemo, 2 zircons were recovered, which produced a discordia age of 1762 ± 8 Ma. We suggest that zircons with ages of about 1.7 Ga are xenocrysts, coeval with the Palaeoproterozoic host rock basement. The in-situ U-Pb ages obtained on the Oncocua apatite provided an age in the range of 1350 – 1450 Ma. These ages, combined with BSE imaging and LA-ICPMS trace element analyses on the dated apatites, support a Kunene crystallisation age for this intrusion. In order to verify the presence of datable minerals at Oncocua, for which only polished thin sections are available, we performed Tescan Integrated Mineral Analyser (TIMA) mineral mapping on two thin sections. We identified 2 zircons and 16 baddeleyites of size exceeding 20 µm, which are potentially datable via SIMS. More geochronological data are required to better understand the relationship between these intrusions and the main Kunene Complex. However, the new data suggest that at least some of the intrusions are coeval to the main anorthosite body.

TITLE:	**The strontium isotopic stratigraphy of the LCZ-UCZ transition in the Western Limb, Bushveld Complex.**
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DSI-NRF CIMERA THEME:	Metallogeny and Paleogeographic Implications of Layered Igneous complexes (LICs) and Large Igneous Provinces (LIPs)
REGISTERED DEGREE:	Master of Science (Geology)
ORAL OR POSTER:	ORAL

ABSTRACT: Data on the modal mineralogy, whole-rock geochemistry, plagioclase mineral chemistry and Sr-isotopic compositions in lithologies covering an interval of ~100 m across the UCZ-LCZ transition in the Western Limb of the Bushveld Complex are presented in this study. The aims of this study were to (1) investigate the presence or absence of isotopic disequilibrium in plagioclase (2) to investigate differences between the LCZ and UCZ from a geochemical, petrological and Sr-isotopic perspective and (3) to refine chromitite formation models using the data obtained over the course of the study. Samples were obtained from the BH7929 drill core donated by Impala platinum to the University of the Free State. Samples were analysed using transmitted light microscopy, X-Ray FluorescenceSpectrometry (XRF), Inductively Coupled Plasma Mass Spectrometry (ICPMS), Electron Probe Micro-Analyzer (EPMA) and Laser Ablation Multi-Collector Inductively Coupled Plasma Mass Spectrometry (LA-MC-ICPMS) to produce whole-rock major and trace element and plagioclase elemental and isotopic compositional profiles across the UCZ-LCZ transition.

Results reveal that the LCZ is composed of orthopyroxene-dominated lithologies that display cryptic layering, hosting two chromitite layers (MG1-2). Plagioclase dominates the UCZ lithologies that display modal layering, hosting two chromitite layers (MG3-4). Compositional breaks in whole-rock major and trace elements are detected at the UCZ-LCZ transition and at the level of the chromitite layers, reflecting variations in the dominant mineral phases. Fractionation indices including whole-rock Mg# and Cr/V ratio reveal little variation throughout the study interval in silicate-dominated lithologies, with variations mostly detected at the level of chromitite layers. Plagioclase An% averages 82.10 ± 1.90% in the UCZ, whereas it averages 73.58 ± 2.60% in the LCZ. Chromitite layers in both zones reveal lower An% values in comparison with adjacent silicate lithologies, which reveal very little overall variation across the study interval. The UCZ exhibits a more radiogenic Sr_i value averaging 0.7059 ± 0.0003, whereas Sr_i in the LCZ averages 0.7054 ± 0.0004. Decreases in the Sr_i value of plagioclase are observed at the level of the chromitite layers in both zones.

The data provide credence to the importance of magma mixing as a process operational in the formation of chromitite layers within the LCZ and UCZ and argue against recent models suggesting in-situ crystallization as a dominant process in the formation of chromitite layers. We propose that the UCZ-LCZ transition displays credible evidence for the repeated intrusion of batches of isotopically distinct magmas, with chromitite layers forming in response to the mixing of newly introduced and resident magma in a manner analogous to that envisaged by Irvine (1975, 1977).

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TITLE:	**The Vergenoeg strato-volcano – IOCG-like mineralization associated with felsic magmatism in the Bushveld Magmatic Province, South Africa.**
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DSI-NRF CIMERA THEME:	Metallogeny and Paleogeographic Implications of Layered Igneous complexes (LICs) and Large Igneous Provinces (LIPs) Mantle and crustal processes and metallogenesis
REGISTERED DEGREE:	Academic
ORAL OR POSTER:	ORAL

The Vergenoeg Igneous Complex (VIC) defines a strato-volcano that erupted as the terminal phase of the bimodal Rooiberg Group (RG), the latter representing the extrusive component of the 2057-2054 Ma Bushveld Magmatic Province. The RG was extruded immediately prior to emplacement of both the mafic (Rustenburg Layered Suite – RLS) and felsic (Lebowa Granite Suite – LGS) intrusive phases of the Complex. The lowermost portion of the RG comprises the basaltic-to-andesitic Dullstroom Formation, much of which occurs beneath the RLS and therefore pre-dates the main layered mafic intrusion. The upper portions of the RG, including the VIC, comprise the dacitic-to-rhyolitic, Damwal, Kwaggasnek and Schrikkloof Formations, which are closer in composition to the highly fractionated A-type granites of the LGS. The VIC hosts world-class fluorite mines associated with a Fe-F-(Cu-REE) mineralization style that has marked IOCG affinities.

Numerous polymetallic, magmatic-hydrothermal mineral deposits occur throughout the various felsic phases of the Bushveld Magmatic Province and these are typically represented by a three-stage paragenetic sequence: early magmatic Sn-W-Mo-F ores (600°C > T > 400°C), followed by a Cu-Pb-Zn-As-Ag-Au paragenesis (400°C > T > 200°C) and then late-stage Fe-F-U mineralisation (< 200°C). Borehole core from mineralized intervals of the VIC reveals a sharp, erosional contact (~35°) between the uppermost RG volcanics (i.e. the Schrikkloof Formation) and pyroclastic rocks of the VIC, suggesting that the latter post-dates the RG and may be synchronous with subjacent LGS emplacement. A well-defined vent occurs in the centre of the complex and is also the site of the world-class F-Fe-REE deposit of the Vergeneog Mine. The vent preserves a coarse volcaniclastic breccia comprising mainly hematite (goethite/siderite)-fluorite-magnetite-fayalite – minor minerals include apatite, cassiterite, monazite, titanite and REE-carbonate phases. It is zoned vertically and records a complex interplay between volcanic eruptive processes, magmatic-hydrothermal remobilization of ore constituents and later supergene overprinting. Prominent sulphide mineralization occurs in the form of pyrite and chalcopyrite with lesser arsenopyrite and sphalerite. Away from the vent, subaerially-deposited volcaniclastic material defines a strato-volcano (ca. 10x5 km in extent) comprising two distinct units, becoming finer grained with increasing distance from the vent. The lower portion of the VIC is built of siliceous ignimbrite with a minor rhyolitic component. This is overlain by volcanic hematite-fluorite breccia intercalated with laminated, locally reworked, fan-delta sediments, all deposited in a maar-like structure. The recently developed Nokeng fluorite mine is hosted in these bedded VIC volcaniclastic sediments, distal to the vent.

Genesis of the polymetallic mineralization in the VIC, and other felsic phases of the Bushveld Complex, remains poorly understood. The association between intrusive and extrusive pulses of felsic magmatism, together with evidence for widespread magmatic-hydrothermal Fe-F-(Cu-REE) mineralization processes, define a Bushveld metallotect that has similarities to other iron-oxide-copper-gold (IOCG) provinces in, for example, Brazil and Sweden. An IOCG footprint in the felsic phases of the Bushveld event would render them more prospective than previously thought.

TITLE:	**Chromite and sulphide mineralization of the Uitloop ultramafic bodies in the northern limb of the Bushveld Complex.**
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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 Rustenburg Layered Suit in the Northern limb is stratigraphically different from the main Bushveld Complex south of the Thabazimbi-Murchison Lineament (TML). In the Northern limb, the Lower Zone is formed as chonolith-like bodies, which intruded through the Archaean granitegneisses and sedimentary rocks of the Transvaal Supergroup (van der Merwe, 1976; 1978). These bodies host Cr and Ni-Cu-PGE sulphide deposits while the Lower Zone in the rest of the Bushveld Complex is barren. Grasvally, south of the Ysterberg-Planknek fault, hosts high-quality chromite deposits and PGE-Cu-Ni magmatic mineralisation (Hulbert and von Gruenewaldt, 1982; 1985). Different types of PGE-Cu-Ni sulphide mineralization have also been recognised within the Platreef Unit along its strike in the northern limb (Yudovskaya et al., 2013). Platreef style mineralization as well as provisional chromite mineralization and anticipated silicate Ni of the Zebediela project on the Uitloop farm are the targets of the recent exploration campaign (Mapiloko, 2020).

The Uitloop satellite intrusion remains one of the least studied areas in the Northern limb, this study aims to contribute towards a better understanding of the geology of the Uitloop area. Initial investigations on the Uitloop farm were sparked by a hypothesis that the Lower Zone intrusions in contact with dolomitic footwall rocks have the potential to generate Platreef-style sulphide mineralization in the area (Croll et al., 2012). A previously unknown extension (offshoot) of the Platreef has been recognized southeast of the northwestern part of the Uitloop II body (Mapiloko, 2020, Jobin-Bevans and Hancox, 2021). The main intrusive body of the Platreef is located northwest of the Uitloop farm, where it is overlain by the Main Zone and underlain by the Uitloop II body. The Platreef offshoot on the Uitloop farm is sandwiched between the metasedimentary rocks of the Transvaal Supergroup (Lowman, 2007; Mapiloko, 2020; Jobin-Bevans and Hancox, 2021). The relationship between the Platreef offshoot and the Lower Zone satellite bodies on the Uitloop farm is unclear because of the complex interfingering unexposed contacts and composite structure of the Platreef that itself includes ultramafic intrusions. The irregular intercalation of mafic and ultramafic lithologies in the Uitloop area could provisionally be explained by out-of-sequence silllike emplacement (Kinnaird et al., 2005; Mungall et al., 2016; Scoon et al., 2020; Mitchell et al., 2019) that also requires careful investigation.

The economic potential of the Lower Zone satellite intrusions and the Platreef offshoot on the Uitloop farm, are not well established, their stratigraphy, parental magmas, emplacement mechanism as well as crystallization history and order are not entirely clear. This study will identify and distinguish petrogenetic processes based on mineralogical and geochemical signatures of rocks and minerals that are important for defining the mineralization types and stratigraphic correlation of the Uitloop area to the rest of the Bushveld Complex.

TITLE:	**A Turbulent Magmatic Density Current and the Origin of the Anastomosing UG-1 Chromitites at Dwars River in the Bushveld Complex.**
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DSI-NRF CIMERA THEME:	Mantle and crustal processes and metallogenesis
REGISTERED DEGREE :	PDRF
ORAL OR POSTER	ORAL

Stratiform chromitites in large mafic-ultramafic intrusions are prominent for their economic potential of chromium and platinum group elements and their petrogenesis has been long debated – simply because they represent a significant mass balance problem (i.e., a large volume of basaltic magma is required to produce a single layer of chromitite). The origin of the UG-1 chromitites at Dwars River in the eastern limb of the Bushveld Complex has been vigorously debated for this reason, but also because it is characterised by enigmatic anastomosing layering. Although the UG-1 chromitites are not a significant ore deposit in the Bushveld, understanding their development provides insights into the origin of stratiform chromitites in the Bushveld and in layered mafic-ultramafic intrusions elsewhere.

We propose that the UG-1 chromitites formed in response to the emplacement of a turbulent magmatic density current into the developing magma chamber. We use theoretical constraints in fluid mechanics to describe the evolution of the current that was turbulently injected into a resident magma as an instantaneous fixed volume of dense plagioclase-charged magma. Soon after emplacement, the current became stratified into: (1) A basal granular layer - caused by the accumulation of the initial cargo of plagioclase laths by crystal settling to form a feldspathic mush at the chamber floor; and (2) An upper melt-rich layer that outrun ahead of the feldspathic mush. Magnesian basaltic magma that was resident in the chamber was entrained and efficiently admixed into the plagioclase-saturated upper melt-rich layer of the propagating current. Mixing of such compositionally distinct liquids produces a chromite-saturated hybrid melt (e.g., Irvine, 1977). Chromite precipitation from this hybrid melt led to the formation of a series of chromite-laden slurries that flowed back into the current and were split ('bifurcated') as they passed around rising buoyant plagioclase diapirs in the crystal mush. The chromite slurries merged in the tail of the current and eventually back-injected into the solidified anorthosite on the chamber floor—forming the main 2-m thick UG-1 chromitite layer. This model explains why the thinner chromitite layers merge into a single layer and why their combined thickness is equal to the thickness of the main UG-1 chromitite layer – something which has eluded other models for the formation of the Dwars River chromitites.

Our model for the formation of the UG-1 chromitites at Dwars River not only explains the development of the anastomosing layering, but it also deals with the mass balance problem, as non-cotectic proportions of chromite are produced by magma mixing in the resident chamber. The emplacement of magmatic density currents and intra-chamber magma mixing may be pertinent to the development of stratiform chromitites in incrementally constructed magma chambers. This shows that layered intrusions are chaotic magmatic environments that are continually replenished with fresh magma – which leads to dynamic mixing reactions with resident magmas and the formation of igneous layering.

TITLE:	**The Sr-isotopic stratigraphy of the Eastern limb of the Bushveld Complex.**
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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

Data on the modal mineralogy, whole-rock geochemistry, mineral chemistry and Sr-isotopic compositions of plagioclase from the broadly pyroxenitic Lower Critical Zone to the gabbroic Upper Zone in the Eastern Limb of the Bushveld Complex are presented in this study, covering an interval of approximately 5000 m. Rock samples collected from drill cores (BH7772, BH7771, BH6958, BH8172) forming part of the International Continental Scientific Drilling Program (ICDP) project on the Bushveld Complex were analysed using transmitted light microscopy, X-Ray Fluorescence Spectrometry (XRF), Electron Probe Micro-Analyzer (EPMA) and Laser Ablation Multi-Collector Inductively Coupled Plasma Mass Spectrometry (LA-MC-ICPMS) to produce a continuous and relatively high-resolution profile of variations in mineral chemistry, whole-rock major and trace elements and Sr-isotopic composition of plagioclase.The drill cores were donated by Impala and Marula Platinum, and are housed and curated by the Department of Geology of the University of the Free State.

The results show Sr-isotopic trends that are similar to those observed in the Western Limb, with the first isotopically heterogeneous stage named the "integration stage", whereby there are fluctuating initial $^{87}Sr/^{86}Sr$ compositions from the Lower Critical Zone (~0.7051) to the Lower Main Zone (~0.7084). These variations are attributed to repeated influxes of compositionally different magmas. The Lower-Upper Critical Zone boundary is characterized by a sharp increase in initial $^{87}Sr/^{86}Sr$ ratios from 0.7054 to 0.7062 while the Critical Zone and Lower Main Zone boundary is characterized by a sharp increase from 0.7065 to 0.7080.

The isotopically homogeneous "differentiation stage" includes the Upper Main and Upper zones. This interval is characterized by relatively uniform initial $^{87}Sr/^{86}Sr$ compositions of ~0.7073. Limited variation in Sr-isotopic compositions suggests that this stratigraphic interval was formed through fractional crystallization with limited or no injections of new magma. The last major addition of magma into the Bushveld magma chamber is recorded by fluctuations in plagioclase An% and initial $^{87}Sr/^{86}Sr$ ratios at the level of the Pyroxenite Marker, which occurs at the boundary between the Lower and Upper Main zones.

Within the "integration stage" where significant variations in initial $^{87}Sr/^{86}Sr$ ratios of plagioclase are recorded, there is limited variation in plagioclase An% compared to the "differentiation stage", which is characterized by a dominantly normal differentiation trend shown by decreasing plagioclase An% with increasing stratigraphic height and limited variation in initial $^{87}Sr/^{86}Sr$ ratios of plagioclase. This trend between plagioclase An% and initial $^{87}Sr/^{86}Sr$ ratios of plagioclase is also observed in the Western and Northern Limb of the Bushveld Complex. In the Lower Main Zone of the Northern limb, plagioclase display both inter- and intracrystalline variations in initial $^{87}Sr/^{86}Sr$ ratios, a phenomenon that will also be investigated in this study.

TITLE:	**A hidden basaltic roof of the Bushveld Complex.**
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DSI-NRF CIMERA THEME:	Metallogeny and Paleogeographic Implications of Layered Igneous Complexes (LICs) and Large Igneous Provinces (LIPs)
REGISTERED DEGREE:	Academic
ORAL OR POSTER:	ORAL

The Rustenburg Layered Suite (RLS) has crosscutting relationships with host Transvaal sedimentary rocks and overlying Rooiberg lavas with volcanic rocks of the oldest Dullstroom Formation being locally present below and above the RLS. The Dullstroom lower flows are mainly basaltic but change upwards to dacitic and rhyolitic in composition. The spatial, temporal and geochemical characteristics of the Rooiberg lavas suggest that they were formed as an early phase of the Bushveld LIP although it is disputed.

Here we report on a ~850 m thick sequence of fine-grained to porphyritic gabbroic rocks that overlie the top of the Upper Zone (UZ) sequence composed of olivine gabbro, magnetite gabbro, troctolite and anorthosite. This succession is intersected by a 3 km deep borehole NP1 drilled by Rand Mines Ltd on the Non Parella farm in the northern limb of the Bushveld Complex north of the Hout River Shear Zone and west of the Waterberg Project area that hosts a world-class PGE sulfide deposit. Several interlayers of metasedimentary rocks 3-10 m thick occur at the interfingering contact between the gabbro and UZ olivine-rich rocks. The igneous sequence has been eroded and covered by ~2.0 Ga Waterberg Group sedimentary rocks with a paleosol at the base. The whole rock geochemistry of the gabbro is similar to that of both the RLS units and Dullstroom basalts. The gabbro consists of clinopyroxene Mg#33-73, plagioclase An39-77, orthopyroxene Mg#47-61 and common hornblende whereas the magnetite-bearing UZ top rocks are composed of olivine Fa85-95, clinopyroxene Mg#17-35 and plagioclase An38-49, The gabbro section includes multiple cross-cutting quartz-feldspar-magnetite granophyric veins 0.01-2 m thick, which are absent in the UZ. The Sr isotope composition of plagioclase from the gabbro indicates a primitive source with initial Sr ratio (Sr_i at 2.055 Ga) from 0.7042-0.7066 (mean 0.7052, n=70) compared to Sr_i from 0.7064-7073 of UZ plagioclase. Based on the Sr isotope signature we interpret the gabbro as the result of contact metamorphism and recrystallization of Dullstroom basalts. A study is underway towards resolving whether the granophyric veins crystallized from the UZ residual melts or from anatectic partial melts.

TITLE:	**Constraining magma sources and the metallogenesis of the Bushveld Complex using Nd isotopes in apatite.**
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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

Despite several advances over the years, controversy still surrounds the magma source(s) and metallogenesis of the Rustenburg Layered Suite (RLS) of the Bushveld Complex. In this study, we analysed Nd isotopes in apatite from the RLS in order to constrain the source(s) of magma to the RLS and the origin of its platinum mineralisation. 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. Lu-Hf isotopes of accessory zircon show a limited range in $eHf_{(2.06\ Ga)}$ of -8.6 ±1.2 throughout the entire RLS, which contrasts to variable bulk rock isotopic signatures (Zirakparvar et al., 2014). Apatite is also an accessory phase in the RLS and it crystallised at a late-stage from volatile and incompatible trace element-enriched pore melt that was trapped in the crystal mush. Apatite is also a good indicator of igneous processes and has the ability to retain important geochemical information during magmatism as it is a major repository of REE, Sr, Pb, Mn, and halogens (Sha & Chappell, 1999; Belousova et al., 2002; Chu et al., 2009; VanTongeren & Mathez, 2012)to investigate the potential usefulness of apatite as an indicator mineral in mineral exploration. Apatites derived from different rock types have distinctive absolute and relative abundances of many trace elements (including rare-earth elements (REE. Nd isotopes were measured using LA-MC-ICP-MS following the use of a TESCAN Integrated Mineral Analyzer (TIMA) which was used for cathodoluminescence (CL) and backscattered electron (BSE) imaging. BSE and CL images show homogeneous internal textures in interstitial, subhedral apatite grains that are <200 µm in size. A total of 144 apatite grains from the RLS, Marikana dykes and Phalaborwa were also analysed for major elements using a Cameca SX-100 electron microprobe in order to classify the grains and to quantify chemical zoning. Apatite grains in norites at the Merensky Reef (MR) have both Cl-rich and F-rich compositions while apatite grains in pyroxenites throughout the Critical Zone have only Cl-rich compositions. The MR apatites may reflect an influx or interaction of chemically distinct hydrothermal fluids and/or melts in a chemically evolving magma chamber (Boudreau et al., 1986; Boudreau and Kruger, 1990; Kruger, 1994; Kruger and Marsh, 1982)phlogopite, and amphibole indicate that the high-temperature hydrothermal fluids which affected the lower portions of the Stillwater and Bushveld Complexes were Cl-rich. Apatites from the platinum-group element (PGE. Apatite in the Marikana dykes and Phalaborwa Complex show only F-rich compositions. Nd isotopes were obtained for the Marikana dykes and produced $eNd_{(2.06\ Ga)}$ values ranging from -8.56 to -2.27 (average -5.99 for 29 grains). Our $eNd_{(2.06\ Ga)}$ values in apatite are similar to the bulk rock Nd isotope values for the RLS in Maier et al (2000). We also analysed Phalaborwa apatites that gave $eNd_{(2.06\ Ga)}$ 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). This preliminary work suggests that apatite may show homogeneous eNd values throughout the RLS, mimicking eHf in zircon. On this basis, it could be argued that the magmas that formed the RLS were generated by melting of the sub-continental lithospheric mantle as suggested by Zirakparvar et al. (2014). However, magmas may have also been generated in the asthenospheric mantle and subsequently contaminated by partial melts of the SCLM and/or crust (Zeh et al., 2020). Either way, Nd isotopes in apatite mimic the restricted Hf isotope variation in zircon through the RLS stratigraphy. Our apatite eNd 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. The use of the TIMA, EPMA and LA-MC-ICP-MS in characterising the chemistry of apatite provides a novel tool to investigate magmatic petrogenesis in the Bushveld Complex.

TITLE:	**Characterisation of South African coal and its associated inorganic matter using hyperspectral imaging.**
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DSI-NRF CIMERA THEME:	7 Energy Resources
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	POSTER

Exploration is the principal method used to investigate the reserves and resources of all ore deposit, including coal, and is a significant stage in planning the future of the mine, setting up a processing plant, and estimating the commodity market. However, the traditional core logging and laboratory-based analyses are time consuming, and the accuracy of the data depends entirely on the experience of a geologist. Hyperspectral imaging is one of the automated core logging techniques enhanced by 4IR to improve the level of accuracy and rapidly acquire logging and analytical data during exploration. Hyperspectral imaging is a non-destructive technique that measures the spectral response caused by vibration or electronic processes of molecular bonds within mineral crystals. Minerals within the borehole core are characterised based on their unique spectral properties within specific infrared range and presented as a function of reflectance vs wavelength. In this study, borehole core from Zibulo Colliery, Witbank, was examined within three spectral regions: visible and near infrared (0.4 – 1 µm), shortwave infrared (1 – 2.5 µm), and longwave infrared (8 to 12 µm). The phyllosilicates (mainly kaolinite), coal and sulphates were depicted within the visible and near infrared and shortwave infrared throughout the borehole core. The coal was depicted by the spectral feature at wavelength 1617 - 1639 µm and 2220 – 2430 µm which is the characteristic of an organic matter. Coal spectral features associated with wavelength position of 1919 – 1926 µm representing water bounded in phyllosilicates, which is also consistent with water feature at wavelength 1380 – 1420 µm. Kaolinite was detected as a dominant mineral within the sedimentary succession associated with coal seams. Some of the kaolinite spectral signatures were associated with an increased water depth at wavelength position 1944 µm, which indicates an influence of sulphate mineral (gypsum). The LWIR depicted the spectral feature at 8600 µm representing quartz Si-O-Si bond with both coal seams and sedimentary successions associated with coal seams. Other Si-O-Si bonds are associated with a distinctive feature at 8962 µm, which indicate an influence of kaolinite. Minor carbonates, phosphates and illite were located within the coal seams. This study established that hyperspectral imaging could identify and produce mineral map which includes both organic and associated inorganic matter.

TITLE:	**U-Pb dating of apatite from Phalaborwa: a new insight into the emplacement of the carbonatite-phoscorite complex.**
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DSI-NRF CIMERA THEME:	Mantle and crustal processes and metallogenesis
REGISTERED DEGREE:	PDRF
ORAL OR POSTER:	POSTER

The Loolekop Pipe of the Phalaborwa Igneous Complex, Limpopo, South Africa, is the only known occurrence of carbonatite- and phoscorite-hosted Cu-sulfide deposit. Despite an extensive investigation of the pipe intrusive mechanisms, some characteristics of the emplacement processes remain unclear. This study aims at identifying these processes using apatite textures and U-Pb ages from all principal rock types.

The Loolekop Pipe is composed of three main units: Phoscorite, early calcio-carbonatite (banded carbonatite) and late magnesio-carbonatite (transgressive carbonatite). Each of these three rock types is characterized by the presence of apatite in different modal abundances. Phoscorite is particularly enriched in apatite relative to banded carbonatite. Apatite geothermochronometry can serve as a novel tracer for igneous and metamorphic processes.

Three distinct texture types are observed and appear uncorrelated with the host-rock: (i) concentric banding parallel grain boundaries, referred to as oscillatory zoning; (ii) irregular, patchy areas within grains and (iii) no visible zonation in well-crystallized apatite. The latter texture suggests the ascent of a silicic-carbonatitic melt during rapidly crystallizing primary apatite. The presence in some grains of oscillatory or patchy zoning indicates overgrowth and an associated episode of fluid alteration followed by recrystallization (Odlum and Stockli, 2020).

Apatite from the Loolekop Pipe provides a range of U-Pb LA-ICP-MS ages for all three main rock types: 2083.9 ± 41.9 Ma (n=33) for phoscorite, 2020.4 ± 116.7 Ma (n=18) for banded carbonatite and 2034.3 ±39.0 Ma (n=17) for transgressive carbonatite. All individual ages combine to 2054.3 ± 21.4 Ma (n=68), identical to published zircon and baddeleyite U-Pb ages. It appears possible that the Loolekop Pipe was emplaced over an extended time period. Alternatively, the age difference could reflect isotopic diffusion within apatite during late-stage reheating of the pipe when the transgressive carbonatite intruded.

Unexpectedly, apatites overlap compositionally with ultramafic and not alkaline igneous rocks (using logSr/Y vs logLREE: O'Sullivan et al., 2020), indicating that minerals hosted by alkaline rocks in the Loolekop Pipe possibly crystallized in another environment and were subsequently entrained and transported by the phoscorite and carbonatite parent melt as xenocrysts.

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TITLE:	**The use of Gaming software and HIVE technology in the construction of virtual field education of the Tanqua Karoo.**
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DSI-NRF CIMERA THEME:	Energy Resources
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

The Tanqua submarine fan complex is situated in the southwestern Karoo basin of South Africa and consists of four basin floor fans and one slope fan. The basin floor fans of the Tanqua sub basin are moderately undeformed and characterize an exceptional analogue for hydrocarbon reservoirs in medium to fine grained turbidite systems characterized by an approximate sandstone-shale ratio of 40-50%. This research aims to develop a preparatory interactive virtual tour of the Tanqua Karoo for teaching and improving student understanding of the depositional processes and facies distribution within fine-grained deep-water fan systems and their association to reservoir and non-reservoir distribution, heterogeneity, architecture, and quality.

Geology is a field-based profession where it is mandatory for students to travel to distant locations for field-based training. However, in times such as the COVID 19 global pandemic and tight budget constraints, embarking on multiple field trips is challenging to achieve. Currently, computer software and hardware are progressing to a position where "virtual" visits to geological sites could offer some of the information and interactions that are commonly acquired through field excursions. Recent advances in immersive technologies with regards to visualisation and interactions, have made virtual reality (VR) progressively more appealing to scholars. Virtual field trips attempt to portray a real-world environment of a particular location through a compilation of data and photographs. The virtual field trip does not replace the conventional field excursions but introduces students to the basic skills essential to understand their environment prior to going on the field excursion. This research will make use of Pano2VR as well as the Unity 3D software as it can incorporate large amounts of data, producing a pathway for incorporating data in fine detail into a complex virtual field tour. By developing a method for doing so, a pathway for digitization outcrops is possible. The final virtual tour format is going to be web based for easy accessibility as it does not need hardware specifics to run. This is going to be demonstrated in the Highly Immersive Visualization Environment (HIVE) for the students to explore the effectiveness of a virtual field tour in preparing for the field excursions.

TITLE:	**A high-precision bulk rock Sr-Nd-Hf isotopic study of the mafic-ultramafic layered sequence of the Bushveld Complex to constrain its magma sources and related vast mineral deposits.**
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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 mafic-ultramafic Rustenburg Layered Suite (RLS) of the Bushveld Complex is the largest known layered igneous intrusion on Earth. It hosts world-class reserves of precious metals in the UG-2 chromitite, Merensky Reef, Platreef, and Main Magnetite Layer. The RLS is one of the most-studied layered intrusions, and there are vast bulk rock major and trace element databases that give us essential clues on the evolution of its magmas. However, there are insufficient combined Sr-Nd-Hf isotope data that is critical for constraining the mantle sources and the crustal contaminants for the RLS magmas. Existing isotopic data for the RLS includes initial $^{87}Sr/^{86}Sr$ isotopic ratios that suggest the RLS formed in two magmatic stages termed 'Integration stage' and 'Differentiation stage' (Kruger, 1994; 2005). The Integration stage is characterised by variability in $^{87}Sr/^{86}Sr$, with upward decreases and increases, which is explained by the replenishment of isotopically distinct magmas and mixing in the chamber. The few $^{143}Nd/^{144}Nd$ isotope data show that Sr-Nd isotopes are decoupled in the RLS (Maier et al., 2000). There is no existing bulk rock $^{176}Hf/^{177}Hf$ isotope data for the RLS – although Hf isotope studies of zircon by LA-ICP-MS indicate homogeneous compositions throughout the entire RLS (Zirakparvar et al., 2014), further suggesting that there is isotopic decoupling in the RLS that may be explained by unusual mantle sources or different contaminants. The mantle sources, the composition of the crustal contaminants, and the role of the sub-continental lithospheric mantle (SCLM) in the petrogenesis of the RLS all remain elusive. Because of the vast volumes of basaltic magma preserved in the RLS (>1 Mkm^3), their rapid emplacement (Zeh et al., 2015), and the inferred komatiitic parent magmas (Wilson et al., 2012), the RLS magmas probably originated from a mantle plume, which caused large-scale partial melting of the sub-lithospheric mantle. However, the existing isotope data show that the magmas were isotopically enriched, which must be explained by either the assimilation of SCLM or the lower crust in a deep crustal sill complex. In this study, I will produce ~100 new high-precision Sr-Nd-Hf for the RLS using the ultra-clean WIGL, a Parr digestion vessel (for Hf dissolution), and the new ID-TIMS instrument at Wits. This dataset will be used to (1) Constrain the mantle sources of the RLS; (2) Constrain the crustal contaminant(s) and role of the SCLM; and (3) Provide constraints on the origin of the vast reserves of precious metals. My study will initially be focused on certain parts of the RLS, including the Marginal Zone. The Marginal Zone is a series of pyroxenites-gabbros-gabbronorites that have quenched textures, and hence they may represent liquid compositions. I recently collected ~25 new samples of the Marginal Zone in the eastern limb of the Bushveld Complex that will be analysed for Sr-Nd-Hf isotopic compositions. These will provide new insights into the origin of the Marginal Zone magmas and whether they represent feeder magmas to the RLS or residual liquids to the recently discovered Basal Ultramafic Sequence.

TITLE:	**Subsurface investigation of the Bushveld Complex using joint inversion of surface wave and satellite gravity data.**
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DSI-NRF CIMERA THEME:	Bushveld Complex
REGISTERED DEGREE:	MSc Geology
ORAL OR POSTER:	POSTER

Several different models for the Bushveld Complex have been proposed based on geophysical data. Gravity and teleseismic data have been important in constraining these models. Meyer and De Beer (1987) came up with a model to explain gravity anomalies over the Eastern and Western limbs as being due to sheets that are inwardly inclined thin layer that get narrower towards the middle of the complex. The assumption of this model of gravity is primarily the fact that the mass of the Bushveld Complex is small enough so that the crust could maintain the load without experiencing significant deformation. Cawthorn and Webb (2001) took gravity modelling one step further, and instead of just modelling the Bushveld Complex they also included the Moho, assuming that emplacement of the Complex resulted in flexure of the crust. The depth values for the Moho from the South African Seismic Experiment (SASE) in the 1990s, showed that the Moho is deeper below the complex because of its significant weight on the crustal rocks (Nguuri et al., 2001). Including the Moho in the gravity model allowed the Rustenburg Layered Suite of the Bushveld Complex to be modelled as a connected model, with the Eastern and Western limbs connected at depth.

Despite these studies over the Bushveld Complex, we still have an unclear picture of the complex's subsurface structure. So, to improve the resolution of the lithospheric model, in this study I will create a three-dimensional shear wave velocity and density models of the lithosphere derived from a joint inversion of surface wave and satellite gravity data. The surface wave data will come from a total of 23 Africa Array stations that collected data from January 2015 to December 2019 in the Bushveld Complex, South Africa (https://doi.org/10.7914/SN/ZT_2015). While the gravity data will come from the GOCE satellite mission (http://earth.esa.int/GOCE). Here we present preliminary result.

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.**
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DSI-NRF CIMERA THEME:	Manganese and iron ore deposits
REGISTERED DEGREE:	Masters of earth sciences in mining and environmental geology
ORAL OR POSTER:	POSTER

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:	**Mantle source, metasomatism and silicate melt evolution as reflected in olivine of the Phalaborwa Complex using trace element and isotope geochemistry.**
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DSI-NRF CIMERA THEME:	Mantle and crustal processes and metallogenesis
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

South Africa's ecomony relies strongly on the mineral wealth generated by magmatic and hydrothermal deposits including the 2.06 Ga Phalaborwa Complex (PC) in the Limpopo Province. The PC is a large contributor of copper and phosphate associated magnetite, vermiculite, uranium, sulphuric acid, anode slimes and nickel sulphate. Therefore, it is important to better understand the formation of such depos its (e.g. carbonatite complexes) that lead to economically important mineralization. However, debates involving mantle source, petrogenesis, and metasomatic events related to the formation of the PC remain contentious. As an early crystallizing phase, olivine records information regarding primitive melt composition(s) (Foley et al., 2011). Olivine has the potential to preserve the signature of early mantle-melting processes in their cores, thus registering variation of chemical compositions that assist in understanding the nature and origin of these mineral grains and their host rocks. Geochemical data obtained from individual olivine grains also help in understaing geothermobarometry (De Hoog et al., 2010). Four primary rock types (micaceous pyroxenite, phoscorite, banded- and transgressive carbonantites) contain both fresh and altered olivine in various modal concentrations. The following research questions will be adressed: (1) Can elemental systematics (e.g., Al, Ti, Cr, Ni etc.) serve as a proxy to mantle source(s), partial melting, fractional crystallization, and melt extraction and metasomatism? (2) Can existing single-mineral empirical geothermobarometers, cross-reference onto geotherms and indicate a lithospheric mantle origin? (3) Will O isotope systematics of olivines show deviations from the established mantle range of 5-6 ‰ (Eiler, 2001)? Several geochemical methods will be used including a SEM-EDS, electron microprobe, and LA-ICP-MS as well as SIMS. Detailed petrographic examination has established olivine modal abundances, size, degree and type of alteration (serpentinized veins), mineral association/paragenesis, internal mineral zoning, and presence of inclusions. Back-scattered electron and phase mapping will augment petrographic interpretation for all rock types of the Loolekop intrusion. Olivine is most abundant in phoscorite, and least abundant in micaceous pyroxenite. Even though olivine is documented as 'rare' in both carbonatite phases, multiple olivine grains were identified. Coupled LA-ICP-MS and EMP analyses will detect spatial compositional variations within and between grains of all rock types.

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TITLE:	**Assessing the Ni-Cu-(Co-PGE) Magmatic Sulphide Potential of the Mesoproterozoic Kunene AMCG Complex in Namibia and Angola.**
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REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

The Mesoproterozoic Kunene AMCG Complex (KC: 1438-1376 Ma) in southern Angola-northern Namibia shares similar features to the Nain Plutonic Suite (NPS: 1289-1363 Ma) in eastern Canada which hosts the 1334 Ma mafic-ultramafic (MUM) Voisey's Bay Intrusion (VBI) – a world-class Ni-Cu-(Co-PGE) magmatic sulphide deposit. The KC and NPS have similar ages, magmatic timescales (>60 Myr), volumes of MUM intrusions, and were emplaced into Paleoproterozoic-Archean basement rocks. These similarities suggest that the KC has the potential to host a significant magmatic Ni-sulphide deposit. However, little research has been done to date on this potential and this project intends to rectify this by undertaking a petrological and geochemical study on a suite of MUM intrusions in the KC.

The KC is the largest example of a Proterozoic massif-type anorthosite on Earth (>18,000 Km^2), and it is dominated by anorthosite senso stricto, leucotroctolite, leuconorite and leucogabbronorite. A suite of MUM intrusions is also present in the KC – particularly at its southwestern margin in Angola (e.g., Oncocua) and around the Zebra Mountain anorthosites (e.g., Ombuku and Ohamaremba) in northern Namibia. These MUM intrusions are currently being precisely age-dated at PCIGR in Vancouver, Canada. Troctolites and leucotroctolites in the KC and NPS have similar trace element systematics with L/HREE-enrichment and negative Nb-Ta and Th-U anomalies – suggesting they were derived from similar mantle sources. At the VBI, there is trace element and isotopic evidence of crustal contamination which triggered the segregation of an immiscible sulphide liquid (by sulphur addition) – an important step in the generation of a Ni-sulphide deposit. In addition, there is petrological and geochemical evidence (of interaction with crustal inclusions) to suggest that sulphur addition took place in a dynamic magmatic conduit system – which enabled the recycling of upgraded sulphide liquids prior to their concentration into a significant economic deposit.

In my research project, I will conduct the following objectives to determine if similar ore-forming processes were operative in a dynamic conduit environment in the MUM intrusions of the KC: (i) Field work at the economically promising Oncocua Intrusion to understand magma emplacement dynamics; (ii) Analysis of a large bulk rock major and trace element database of KC anorthosites and MUM intrusions to constrain parent magma sources and crustal contamination; (iii) High-precision bulk rock radiogenic isotopes of Sr-Nd-Hf to track magma sources and crustal contamination; (iv) Electron microprobe analysis of zoned minerals in MUM intrusions (e.g., Fo-Ni in olivine and Cr in pyroxene) to constrain magma replenishment; and (v) Sulphur and oxygen isotope analyses of sulphides and mafic silicates to establish the crustal sources of sulphur. This holistic and multidisciplinary approach will help us to determine the Ni-Cu-(Co-PGE) metal potential of the KC and will be used to develop a genetic model for Ni-S mineralisation that can be applied to subsurface parts of the KC in Angola.

TITLE:	**Petroleum systems and hydrocarbon potential analysis of the Southern Pletmos Basin, offshore of South Africa: Utilizing 3D basin modelling techniques.**
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DSI-NRF CIMERA THEME:	Energy Resources of Karoo-aged Basins
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	POSTER

The Southwestern passive continental margin of South Africa is virtually unexplored, although the various offshore gas field discoveries have proved some potential. In this study, the hydrocarbon potential of the Pletmos Basin within this continental margin is being assessed through source rock samples and basin and petroleum system modelling investigations. Based on well and seismic constrained by geochemical data, using PetroMod simulation software, the petroleum systems, maturity distribution, generation, migration dynamics, and accumulation trends within the Ga-A gas field were modelled and assessed. The Ga-A gas field is characterized by predominantly dry gas with minor condensate quantities assess maturity distribution, generation, and migration trends/dynamics.

Three phases of deformation in the basin aided in developing petroleum systems and possibly exerted substantial control on the architectural development, hydrocarbon distribution, and/or charging. The basin comprises multiple petroleum systems characterized by Mesozoic marine shales with up to ~ 4% TOC. Source rock sample analyses reveal Type II, Mixed Type II/II, and Type III kerogen potential that corroborates with the hydrocarbon discoveries at the Bredasdorp basin. Among the five investigated and modelled source rocks, the most expulsive ones are Kimmeridgian and Aptian. However, gas and condensate production are associated with Kimmeridgian, Valanginian, and Aptian source rocks. The most important reservoirs of the basin are thinly bedded clastic facies associated with deltaic or tidal slopes and basinal fan deposits.

The Southern section of the basin demonstrates higher hydrocarbon potential and lower exploration risk, particularly within the distal parts. Various traps associated with rifting tectonics promote hydrocarbon accumulations within the Hauterivian and Barremian – Aptian reservoirs. These reservoirs have decent hydrocarbon charge access to multiple source rocks, particularly within Block 11a. Likewise, efficient sealing from the major faults systems. Source to trap timing risk is marginal since traps are older. Downward expulsion of petroleum from the Kimmeridgian source rock into the basement seems reasonable. Gas and condensate generation, expulsion, and migration (subsurface) model results indicate favourable potential.

TITLE:	**Investigation Of metal accumulation In *Combretum Imberebe, Cynodon Dactylon* and *Sporobolus Africanus* at Klein Letaba Tailings Dam, Limpopo Province, South Africa.**
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DSI-NRF CIMERA THEME:	Environmental geology
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	POSTER

The Giyani Greenstone belt is known for its gold mineralisation and it has been exploited at Klein Letaba, Louis Moore, Birthday, Golden Osprey and Fumani mines. The potentially toxic metals within their respective tailings dams can cause environmental problems. Gold mine waste is considered as the major source of toxic metals in the environment; however these toxic metals can be removed from the mine waste, soil and water by a process called phytoremediation which involves the use of plants to remove and stabilize toxic metals. This study focused on the Klein Letaba Tailings Dam which has toxic metals such as Pb, Zn, Cu, As, Ni and Cd. The main purpose of this study is to investigate the metal accumulation in *Combretum imberbe* (Leadwood tree).

Field work involved collection of 20 plant, 20 tailings and 5 soil samples at Klein Letaba Tailings Dam. From the 20 plant samples, 8 *Combretum imberbe*, 6 *Cynodon dactylon* and 6 *Sporobolus africanus* were collected respectively. Two control plant samples together with their respective soil samples were collected 5 to 10 km away from the tailings dam in the north easterly direction towards the cultivated area. Tailings and soil samples were analysed using X-ray fluorescence and ion chromatography at the Department of Mining and Geology, University of Venda. Plant samples were analysed using ICP-OES (Inductively Coupled Plasma-Optical-Emission-Spectrometry) at Madzivhandila laboratory. Klein Letaba tailings were found to be highly contaminated with metals such as lead, nickel, chromium, copper, arsenic and zinc with maximum concentrations of 11885.7 ppm, 2049.3 ppm, 1275.7 ppm, 1271.3 ppm, 695.2 ppm and 139.8 ppm respectively. The soil around the study area was contaminated with metals from the tailings.

Combretum imberbe, Cynodon dactylon and *Sporobolus africanus* accumulated high concentrations of metals with high concentrations in the roots then followed by the leaf and stem. Pb (11885.7 ppm) was high in the roots then followed by the stem and the leaf. The plants (*Combretum imberbe, Cynodon dactylon* and *Sporobolus africanus*) under investigation are hyper-accumulators as they are able absorb and store high concentrations of metals in their organs. The study recommends the use of these plants for extraction and stabilization of metals.

Keywords: *Klein Letaba Tailings Dam, Toxic metals,* Combretum imberbe, Cynodon dactylon *and,* Sporobolus africanus

TITLE:	**Preliminary evaluation of mapping the Whitehill Formation and Karoo dolerite intrusions in the southeastern Karoo Basin.**
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DSI-NRF CIMERA THEME:	Energy Resources of Karoo-aged Basins
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

The 700 000 km^2 Main Karoo Basin of South Africa is considered a potential host of economically viable shale gas in its hydrocarbon-rich Whitehill Formation of the Ecca Group. The Whitehill Formation appears as a highly conductive marker horizon persistent in thickness throughout the entire Karoo Basin. Estimates of how much possible recoverable shale gas is available in this Lower Permian sedimentary unit depends on understanding the subsurface structure of the Karoo Basin. The Karoo Supergroup rocks are intruded by an interconnected network of dolerite dykes and sills that solidified during the emplacement of 367 000 km^2 volumes of magma and their presence could affect the amount of shale gas stored in the Karoo Basin. Furthermore, the extent of these high temperature dolerite intrusions around the possible shale gas-bearing Whitehill Formation needs to be evaluated for the purpose of targeting areas of potential shale gas exploration. We aim to map the depth of the Whitehill Formation and Karoo dolerite intrusions in the south-eastern region as this part of the Karoo Basin has limited scientific studies and few drilled boreholes. Recently, reflection seismics has been introduced as a geophysical technique able to image greater depths and identify subsurface dolerite sills in the Karoo Basin. In this study we will digitize old paper seismic images from the 1960s Southern Oil Exploration Corporation (SOEKOR) seismic profiles to estimate the depth of the Whitehill Formation and dolerite intrusions in the south-eastern Karoo Basin. These seismic data will be further integrated with magnetic data to observe the regional distribution of distinct magnetic bodies in the study area. Electromagnetic, magnetotelluric survey data and information from boreholes drilled near the reflection seismic lines are included to expand the knowledge of the south-eastern Karoo Basin.

TITLE:	**The assessment of rare earth elements in a borehole core from the Ermelo and Witbank Coalfields, South Africa.**
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DSI-NRF CIMERA THEME:	Energy Resources of Karoo-aged Basins
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	POSTER

Internationally, there has been an increase in the demand for critical elements such as uranium, germanium and rare earth elements (Sc, Y, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb) with the advent of the fourth industrial revolution (4IR), green energy, and the need to reduce global Green House Gas (GHG) emissions (Bullock et al., 2018; Dai & Finkelman, 2018; Hower et al., 2018; Hower et al., 2020; Bourg, n.d.).

According to Haque et al. (2014), the major uses of rare earth elements, including yttrium and scandium (REY+Sc), are in the renewable energy industry, specifically in the manufacturing of wind turbines, batteries, catalysts, and electric cars. Currently, China has 36.7% of the world's known REY+Sc and is responsible for 70.6% of the total global production (Manzanaro & Abellan-Matamoros, 2019). This brings about enormous pressure on China to supply the commodity (and they are decreasing their exports), and also heightens geopolitical supply risks. The global demand for REY+Sc is estimated to increase exponentially; in financial terms: from $8.1 billion recorded in 2018, to more than $14.4 billion by the year 2025 (Borzykowski, 2019).

Dai and Finkelman (2018) published a review paper assessing coal as a promising alternative source of REY+Sc. There is a knowledge gap concerning the potential that South African coal deposits may have in this field. The knowledge gap sparked this research: to determine the concentration of selected critical raw materials (CRMs) including REY+Sc in South African coals. The hypothesis is premised on the argument that there is a potential to extract REY+Sc and select CRMs from South African coals and/or associated sediments.

The expected results from this project include: the determination of REY+Sc and other applicable CRM of relevance to South Africa; the determination of REY+Sc and other applicable CRMs in the coal seams and adjacent sediments from three borehole cores extracted from three coalfields in South Africa. The coalfields to be considered are Witbank and Ermelo (Mpumalanga Province), and the Waterberg (Limpopo Province). For the purposes of this poster, the results pertaining to the borehole core from Ermelo and Witbank Coalfields will be presented. The proposed analyses to be conducted include coal petrography; chemical analyses (proximate and ultimate analysis and CV determination); mineral analyses (XRD and XRF); and elemental analyses (ICP-MS, LA-ICP-MS and SEM-EDX). Not all results will be discussed in the current poster; however, the distribution of REY+Sc in the core will be assessed.

TITLE:	**Dolerite intrusions within iron ore of the Maremane Dome as possible time markers and stratigraphic control units.**
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DSI-NRF CIMERA theme:	Manganese and Iron Ore Deposits
REGISTERED DEGREE:	MSc
ORAL OR POSTER:	POSTER

The Maremane Dome (MD) lies in the Griqualand West basin of the Northern Cape and hosts iron (Fe) ore deposits, which are among the richest in South Africa. High-grade iron ores in South Africa belong to the Neo-Archaean to Early-Paleoproterozoic Transvaal Supergroup. The largest iron deposits are attributed to the Asbestos Hills Subgroup of the Ghaap Group, Griqualand West. These iron deposits are developed along the 2.2-2.0 Ga erosional unconformity zone (so-called pre-Gamagara unconformity), where it crosscuts the Banded Iron Formations (BIFs). The current model of the Fe ore formation is a supergene origin, attributed to the leaching of the silica component from the BIFs as a result of alteration at the surface, with the largest deposits developed within karst environments. Multiple ferrugenized dolerite sills intersect the BIFs and the ore at various stratigraphic levels [1]. The geochemistry, age, and deformation history of these magmatic intrusions are not well understood. A detailed study of the dolerite sills, including their formation and deformation history, can potentially provide robust markers for the iron mining industry and improve the understanding of the geological history of the region. Present research focuses on these enigmatic intrusions, their textural, mineralogical, and geochemical characteristics, addressing a need for the mining industry to have reliable stratigraphic markers and control when correlating drill cores with each other and with the regional stratigraphy. A total of 40 dolerite samples were collected from eight diamond drill cores, one from Khumani mine and seven from the ASSMANG exploration camp. From the eight drill cores, two sampled non-ferrugenized dolerites (both at ASSMANG exploration camp) and the rest sampled ferrugenized dolerites. The dolerites have intruded within the BIFs at various stratigraphic levels (40 to 300 m) and appear as irregular intrusions, usually 40 to 60 m thick. The dolerites show differing degrees of weathering and ferrugenization, depending on their depths in the drill core and its position related to the Black Ridge thrust fault. Below the Black Ridge fault, the dolerites are not ferrugenized, and above the fault, they are intensely ferrugenized. Representative samples from the non-ferrugenized rocks are medium- to coarse-grained and dark-grey to dark-green in color, showing ophitic to subophitic textures. The ferrugenized samples are dark-red to brown and are very fine-grained, showing significant alteration, which has caused the local growth of serpentine at the expense of pyroxene. Most of the sampled dolerites classify as basalts to basaltic andesites using the classification system of [2], and fit in the field of tholeiite series using the AFM (Na_2O + K_2O - FeO - MgO) ternary diagram. The non-ferrugenized samples have relatively uniform compositions, whereas the others show considerable variations. The ferrugenized samples have relatively higher Fe_2O_3 content (6.08-29.40 wt.%) compared to the non-ferrugenized samples (2.24- 15.10 wt.%). Moreover, the non-ferrugenized samples show a significantly narrower range of the SiO_2 (48.80-55.13 wt.%), while the ferrugenized samples show a wide range of SiO_2 compositional variation (30.29-65.52 wt.%). QEMSCAN (Quantitative Evaluation of Minerals by Scanning Electron Microscopy) mapping shows the presence of accessory apatite, baddeleyite, and zircon (0.0018, 0.0024, and 0.0128 vol.% respectively) in both series, which makes it possible to conduct isotopic dating of melt crystallization. Preliminary dating results of the non-ferrugenized samples yielded Pan-African ages (ca. 500 Ma), not reported from the area previously. More geochronological data will be done for the ferrugenized samples to test their relationship with the non-ferrugenized ones.

REFERENCES: [1] Smith & Beukes, 2016, IUGS, 39, 269–284. [2] Winchester & Floyd, 1977, Chem. Geol., 20, 325–343.

TITLE:	**The re-characterization of manganese ore deposits i n the Postmasburg Manganese Field.**
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DSI-NRF CIMERA THEME:	Manganese and Iron Ore Deposits
REGISTERED DEGREE:	Post-doctoral research fellowship
ORAL OR POSTER:	POSTER

The PMF deposits are found in a region south of the KMF, and specifically in the eastern and western limbs of a major anticlinal structure known as the Maremane Dome. The latter region exposes carbonate rocks (chiefly dolostones) of the Campbellrand Subgroup, which dominates the lower stratigraphic portion of the Transvaal Supergroup. Iron ores are found in karstic depressions ("sinkholes") containing Mn-lean, massive hematite ore, thought to have formed at the expense of collapsed iron formation of the Asbestos Hills Subgroup that regionally overlies the Campbellrand dolostones. Manganese-rich deposits are spatially associated with the above hematite iron ores and occur in two modes: (i) karstic "linings" of massive, siliceous Mn-rich material ("eastern belt" ores) in association with an interpreted solution collapse breccia developed atop weathered dolostone; and (ii) laminated, ferruginous deposits ("western belt" ores) associated with shales. It is worth noting that both sub-types of Mn ore in the PMF exhibit an association with alkali-rich mineral assemblages that are akin to those observed in the altered ores of the northernmost KMF. The divisions were made based on their varying bulk chemical and mineralogical compositions in conjunction with their different stratigraphic sub-settings. Presently, both deposit types are explained as variants of supergene mineralisation that would have formed through a combination of intense ancient lateritic weathering in the presence of oxygen, extreme residual enrichments in Mn (and Fe), and accumulations in karstic depressions at the expense of underlying manganiferous dolostones.

This study revisits the aforementioned deposit types with the aim of further characterizing and understanding their origin from various localities spanning the Eastern and Western Belts in order to provide new insights into the processes that were responsible for the genesis of these deposits at a local and regional scale, through a combination of mineralogical and bulk and trace element geochemistry. Comparative considerations made between the bulk geochemistry of the different end-member ore types revealed no clear-cut compositional distinctions and therefore do not support existing classifications between siliceous (Eastern Belt) and ferruginous (Western Belt) ores. This is supported by trace and REE element data as well, when normalised against BIF. The geochemistry reflects the bulk mineralogy of the ores which is broadly comparable, whereby braunite and hematite appear to be dominant co-existing minerals in both Eastern Belt (Khumani) and Western Belt (Bishop) ore, with Hollandite dominating the Lomoteng ore. In the case of the McCarthy locality, manganese ore is cryptomelane-rich and appears to have involved recent supergene overprint over Eastern Belt type ore, whereas the Leeuwfontein ores are far more ferruginous than at any other locality studied and therefore represent a more complex, hybrid type of oxide-rich Mn mineralisation within massive hematite iron ore. In terms of gangue mineralogy, the ores share some close similarities through the presence of barite, and the abundance of alkali rich silicate minerals. Eastern Belt ores contain abundant albite and serandite whereas the main alkali-rich phase in Western Belt ores is the mineral ephesite. In both cases, Na contents are therefore, high. The alkalis do not support a classic supergene processes of ore formation but could suggest hydrothermal processes involving alkali rich brines across the broader Maremane Dome region instead of distinct processes.

TITLE:	**Pyrite and sphalerite morphological and chemical variations: Implications on the genetic model of the Gamsberg zinc deposit.**
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DSI-NRF CIMERA THEME:	Base metals
REGISTERED DEGREE:	PhD
ORAL OR POSTER:	POSTER

The Gamsberg zinc deposit, located in the Northern Cape, forms part of the Mesoproterozoic Broken Hill-type Pb-Zn-Cu-Ag Aggeneys-Gamsberg Ore District (A-GOD). The A-GOD deposits are a result of base metal precipitation in distinct half-graben controlled sub-basins, each with slightly different physico-chemical environments, fluid evolution, and distance from the hydrothermal exhalative vent (Rozendaal, et al., 2017). The supracrustal sequence has been affected by polyphase deformation and at least two phases of metamorphism (Rozendaal, et al., 2017).

While the basin development, structural development, regional metamorphism, stratigraphy and mineralogy of the Gamsberg is well understood, thus far, the genetic model for the Gamsberg deposit is mainly constrained by the wall rocks and their assumed close genetic relationship with the base metal sulphide ores, as well as gangue minerals within the ores, i.e. barite beds above the ores in Gamsberg east, graphtonite in phosphatic iron formations above the ores, primary apatite nodules in the transition from siliciclastic-hosted pyrite-sphalerite-graphite ores to calc-silicate-hosted pyrrhotite-sphalerite ores (Stadler and Rozendaal; 2002, 2004, 2005; McClung, et., 2007).

This approach has left questions such as the source of base metals, the temperature of ore formation, the nature (composition) as well as evolution of the fluid responsible for mineralization unanswered (owing to the development of analytical techniques too).

From this study, at least five morphological variations of pyrite were observed at the Gamsberg zinc deposit, with the degree of homogenization increasing from the northern limb towards the overturned eastern limb. In no paragenetic order, the first are disseminated, rounded and cubic microcrystals, as small as 1 µm at the footwall of the ores. The second is anhedral, inclusion-rich, banding-defining pyrite, which exists either as free pyrite grains or as the core of pyrite grains with an inclusion-free overgrowth/rim. The third is inclusion-free, predominantly euhedral, coarse-grained pyrite. Some of the coarse-grained pyrite is annealed to 120° tripe junctions and elongated along the main fabric of the rock. The fourth is mottled/mymmerkitically intergrown pyrite with sphalerite. The fifth is cataclastic pyrite, fractured and infilled by pyrrhotite, as well as pyrite infilling fractured silicates and oxides.

From microprobe analyses, major element compositions down stratigraphy show that there are at least four populations of sphalerite. The major impurities in sphalerite are Fe and Mn with a stratigraphic control on their prevalence. The concentration of impurities in sphalerite also correspond to its colour in hand specimen, with marmatite containing more Fe and Mn, while honey-coloured sphalerite contains no Mn and very little Fe in wt%. Sphalerite in the upper, chemogenic unit is predominantly homogenous, with the least Fe and Mn in wt%. On the other hand, sphalerite in the lower, metapelites is inhomogeneous/zoned and contains more Fe and Mn. This zoning is sphalerite is also evident on QEMSCAN colour contrast images, where the cores are richer in Fe and Mn, but lower in Zn and vice versa for the rims, exhibiting a negative correlation between Zn and Fe+Mn.

Such mineral characteristics make it challenging if not impossible to separate pure fractions for wet methods of analysis. To account for the morphological and chemical variations of the same sulphide mineral, bulk analysis can no longer be employed but rather in situ microanalysis such as LA-ICP-MS is required.

Sphalerite and pyrite are refractory in nature. Provided that complete recrystallization does not occur, pyrite can record its evolution by preserving patterns of morphological, chemical, and isotopic zoning (Ingham, et al., 2014). Pyrite can incorporate a wide range of minor and trace elements, Ag, As, Au, Bi, Co, Cu, Mn, Mo, Ni, Pb, Sb, Se, Tl and Zn, whose content reflects their availability during various stages and environments of formation (Gregory, et al., 2015).

Sphalerite can also incorporate a broad range of trace elements, Fe, Mn, Cd, Co, Cu, Mo, Ag, Sn, Sb, W, Tl, Pb, Ge, Ga, In and Bi. Primary metal sources, concentration of metals in the initial fluid, physico-chemical conditions during initial deposition (pH-Eh, temperature, pressure), and element partitioning between sphalerite and co-existing sulphide minerals are dominant in defining the concentrations of trace elements in sphalerite (Cook, et al., 2009; Lockington, et al., 2014; Bauer, et al., 2019; Zhuang, et al., 2019).

From the trace element signature, one can determine the relative timing and cation content of depositional, hydrothermal, and metamorphic fluids (Gadd et al. 2016; Zhou et al., 2020) and in turn simulate the evolution of hydrothermal systems and provide a good proxy for characterizing metallogeny (Lee et al., 2019). These morphological and chemical variations in pyrite and sphalerite are the basis upon which in situ trace element studies will be conducted in order to determine the origin, nature and evolution of the ore forming fluid(s) and in turn the metallogeny at the Gamsberg zinc deposit.

TITLE:	**Tectonic evolution of the deepwater Orange Basin (South Africa) using 3D reflection seismic data.**
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ORAL OR POSTER:	POSTER

The Orange Basin, the largest of South Africa's offshore basins, covers an area of approximately 160,000 km^2. More than 30 exploration and appraisal wells have been drilled within the ~400m water depth, leading to some oil and gas discoveries. However, the deepwater areas within the Orange Basin remain underexplored. In this study, we use high-resolution 3D reflection seismic data, acquired by Shell Global Solutions International B.V., to constrain the structural architecture of the deepwater Orange Basin that may control the migration of hydrocarbons. To enhance seismic interpretation, we used 3D seismic attributes such as edge detection and ant-tracking attributes (Manzi et al. 2012). This allowed for the detection of faults with a vertical displacement as small as 12 m, which can have a direct impact on mapping the extent of structurally-controlled hydrocarbon plays.

The study area is characterised by two basal detachment layers in the contractional domain. The basal detachment that formed first possibly coincides with the Cenomanian-Turonian boundary at 4150 ms, approximately 7800 m deep, and the second detachment layer is observed at the base of the Coniacian at approximately 3600 ms, approximately 5700 m deep. 3D reflection seismic data show that the area is dominated by thrust faults dipping landwards with a planar geometry, becoming slightly curved as they connect with the basal detachment at the Cenomanian-Turonian boundary. However, the thrust faults that attach to the Coniacian basal detachment maintain a planar geometry. The thrust faults strike 290° with a N to NNE dip direction.

The edge detection attribute computed for the seafloor seismic horizon shows good enhancement of elongated depressions, interpreted as pockmarks, trending subparallel to the continental slope in water depths of approximately 2000 ms (roughly 2000 m). Six pockmarks were identified with diameters between 700 m and 1100 m and depths between 75 m and 103 m. The pockmarks are elongated in a WNW-ESE direction. The ant-tracking technique was computed to delineate structures that are possible conduits for fluid migration to the seafloor. The results from the ant-tracking suggest that the thrust faults exploited S-SW dipping normal faults to transport gas to the seafloor to form pockmarks. One submarine canyon is seismically detected on the seafloor on the lower slope at water depths of approximately 2000 m. The canyon wall trends parallel to pockmarks and the Coniacian-Santonian thrust faults. The submarine canyon is 45 km wide and incised to depths of 650 m. The maximum slope dip recorded along the walls of the canyon was 50° decreasing to 25° to the west.

The shale detached thrust faults, pockmarks and submarine canyons observed in this study are not unique to the deepwater Orange Basin and have been documented in other deepwater areas along passive margins. This structural information is important for future hydrocarbon exploration in the deepwater Orange Basin. This study has shown that the deformation styles in sedimentary basins offshore passive margins are not always controlled by the type of detachment, i.e., they may have formed independently from the detachment, such as the folds that are seismically imaged in the deepwater Orange Basin. These structures are similar to those reported in sedimentary basins offshore the western margin of Africa, particularly the Niger Delta.

TITLE:	**The highly micaceous kimberlites from the Man craton: A unique origin.**
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Sierra Leone contains two Jurassic aged diamondiferous volcanic clusters, namely Koidu and Tongo, consisting of individual eruptive pipes at Koidu and NE-SW trending dikes at both Koidu and Tongo. To successfully constrain the classification and to delineate the petrogenesis of these rocks, a combination of detailed petrographic observations, and phlogopite, spinel and olivine chemistry was used.

Olivine is present as macrocrysts and microcrysts, while phlogopite is occasionally present as macrocrysts and abundantly present as groundmass microcrysts. Other groundmass minerals include spinel, perovskite, apatite, and calcite set in a base of serpentine possibly containing secondary carbonate. The presence of carbonate, the absence of monticellite and diopside and the high abundance in phlogopite reveal that these diamondiferous rocks can either be micaceous kimberlites or unevolved orangeites.

Phlogopite core compositions are characterized by enriched Al_2O_3 and depleted FeO and TiO_2, consistent with kimberlitic phlogopite. Phlogopite rim compositions are characterized by depleted Al_2O_3 and TiO_2 and enriched FeO, consistent with tetraferriphlogopite observed in orangeites. This phlogopite evolution is a characteristics seen in both archetypal kimberlites and orangeites. Spinel compositions display initial enriched Cr_2O_3, moderate FeO and depleted Fe_2O_3 contents, which evolve to a depleted Cr_2O_3, and enriched FeO and Fe_2O_3 contents. This composition change is characterized by the titanium magnesian aluminous chromite (TIMAC) to magnesio- ulvöspinel-magnetite (MUM) evolution. Based on Cr/(Cr+Al), $Fe^{2+}/(Fe^{2+}+Mg)$ and $Fe^{3+}/(Fe^{3+}+Al+Cr)$ variation diagrams, the trajectory of this evolutionary trend aligns between kimberlitic trend 1 and orangeitic trend 2 and previously studied worldwide archetypal kimberlites and orangeites have had similar trends.

Olivine core compositions are divided into Mg-rich (Mg# >89) and Fe-rich (Mg# <89) endmembers, with Koidu and Tongo cores being dominantly Mg-rich and have fewer Fe-rich cores. The overall olivine core compositions range between Mg# 84.7 to 94.5 for Koidu and between 83.2 to 94.6 for Tongo. The Mg-rich olivine cores often contain intensely resorbed margins as opposed to Fe-rich endmembers, which have resorbed margins to a lesser extent. Olivine rim compositions have Fo contents which are relatively homogenous, with a main population and a minor population. The main olivine rim population includes Koidu sample Y5774 and all samples from the Tongo dikes. The respective mean olivine rim Mg# for this main population is 88.3 ±0.5 for Koidu, 88.71 ±0.8 for Kundu, 89.09 ±0.9 for Lando and 89.37 ±1.6 for Pandebu. The minor olivine rim population only includes sample Y5770 from Koidu, consisting of a mean Mg# of 87.1 ±0.6. Olivine rims often contain mineral inclusions of groundmass spinel grains. Olivine cores are interpreted as being mantle derived, whereas olivine rims are interpreted as having crystallized from a host magma.

Koidu and Tongo rocks do not compare to worldwide archetypal and micaceous kimberlites when comparing phlogopite and oxide abundances to mean Mg# olivine rim compositions and are more aligned with similar orangeite data. Thus, the Koidu and Tongo rocks have ultimately been classified as highly micaceous kimberlites. This classification was made in conjunction with previously studied bulk rock geochemistry results from Tongo, revealing a kimberlitic source. For this to occur, a unique source region model has been suggested, whereby, the SCLM of the Man craton experienced localized intense metasomatism similar to an orangeite.

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