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INSIDE:

Training university geology students in the use of geophysical equipment

The CGS is mandated to develop and maintain national geophysical test sites, according to the Geoscience Act (Act No. 100 of 1993, amended in 2010). An important aspect of this project is to oversee students' training. Accordingly, the CGS was approached to train third and fourth year geology students in the use of geophysical equipment. Three scientists from the Minerals and Energy Unit (Matome Sekiba, Emmanuel Chirenje and Simon Sebothoma) conducted the training. The training included acquisition of geophysical data, processing and interpretation. Five geophysical techniques were used to train the students. These are: magnetics, gravity, radiometrics, electrical resistivity and seismics. In order to ensure that students understand the practical aspects of geophysical data acquisition, it was vital to present an introduction to the theory of each technique. As such, the set-up of equipment prior to data collection was demonstrated. After the theory, the students were then taken to the field for a practical demonstration of all the equipment and set-up. All students were given an equal opportunity to practically acquire data along the test lines using the various equipment.

Presentation on the use of the geophysical equipment.

The following aspects of data acquisitioning, processing and interpretation were covered in the training:

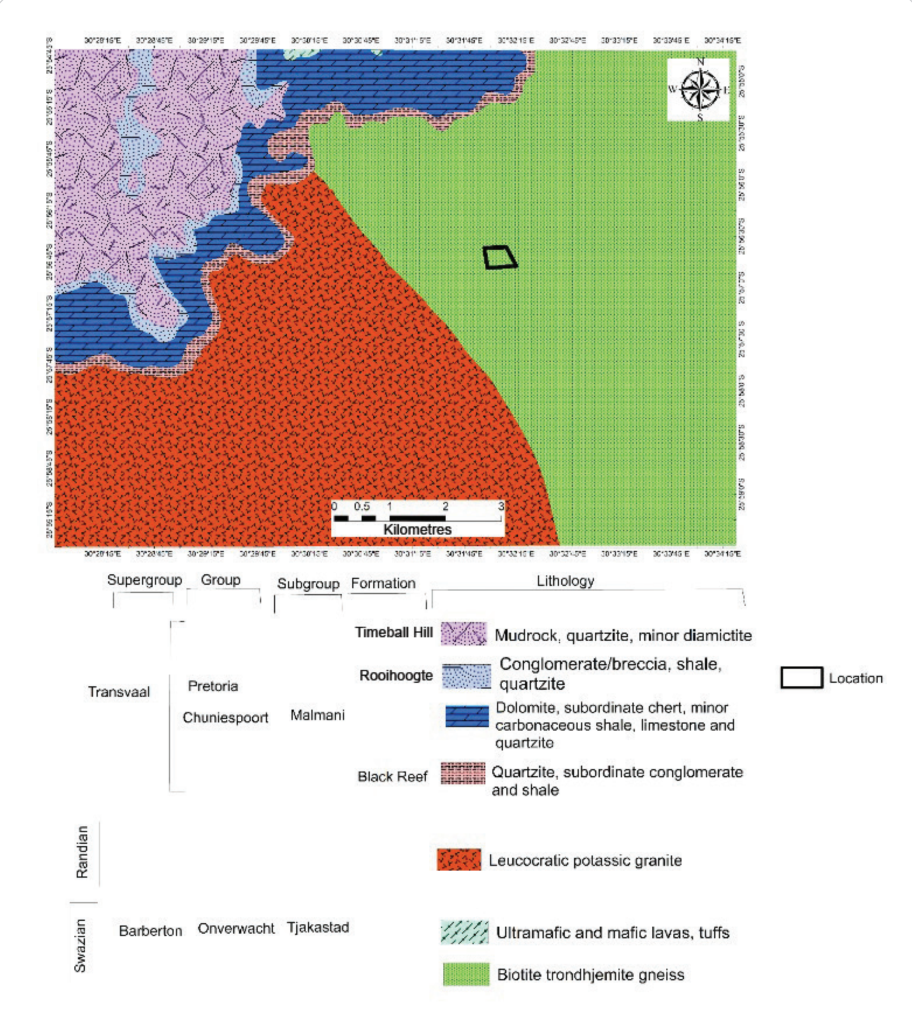
Magnetics	**Gravity and differential GPS (DGPS)**	**Radiometric**	**Resistivity**	**Seismics**
Setting up the magnetometers and synchronising time	Setting up gravity meters and the DGPS	Setting up radiometrics and synchronising time with magnetics	Setting up resistivity	Basic seismic wave theory
Choosing the base station location	Locating gravity base value to link the unknown	Obtaining calibration prior acquisition	Navigation with handheld GPS	Designing seismic survey
Choosing survey parameters	Locating trigonometric beacon to calibrate elevation	Choosing mode of survey	Laying down the cables	Set-up (configuration) the geode seismographs
Navigation with a handheld GPS	Choosing base stations for both gravity and DGPS	Ensure all the vital signs are obtained prior recording	Inserting electrodes	Geode seismograph troubleshooting
Practical acquisitioning of magnetics	Taking gravity base reading every morning, afternoon and end of survey	Practical acquisition	Pouring electrodes with salt water	Acquisition of seismic data
Dumping data into a laptop	Setting up DGPS base every morning	Dumping	Creating sequences with a laptop	Field seismic data quality control
Viewing the data in Magmap2000	Navigation with handheld GPS	Importing data to Geosoft	Uploading a sequence into the equipment	Processing of seismic data
Diurnal corrections	Practical acquisition of gravity and DGPS	Gridding data	Choosing survey parameters	Validation and verification of final models
Exporting data to Geosoft	Dumping data into a laptop	Showing all radioisotope elements	Downloading the data	Interpretations of reflection seismic (Vp) images
De-spiking data	Gravity reduction to obtain Bouguer Anomaly values	Creating ternary image	Removing noise and negative values	
Basic filtering	Importing data to Geosoft	Interpretation	Exporting to RES2DINV	
Interpretation	Gridding the data to obtain Bouguer Anomaly map		Modelling the data	
	Developing residual Bouguer Anomaly map from Bouguer Anomaly map		Further cleaning of data	
	Basic interpretation		Obtaining 2D pseudosection	
			Interpretation	

Setting up the geophysical equipment (a)

Geophysical data acquisition (b)

Demonstration of equipment set-up (a) to begin with acquisition and (b) geophysical data acquisition.

Geophysical surveys were carried out on a farm near Badplaas, Mpumalanga Province. The aim of the study was to map intrusive geological structures as part of a training exercise involving groups of 25 students, totalling 75 students over several weeks. Trainees included a fourth year class of students reading towards an advanced diploma in geology and third year students.



Geology of the study area.

Geology

The current study area is dominated by Eoarchaean biotite trondhjemite gneiss rocks. Ultramafic and mafic lavas and tuffs of the Onverwacht Group are encountered in the northern area. Mesoarchaean leucocratic potassic granite rocks forming a contact with the older gneisses occur within the southwestern part of the study area. In the northwest and parts of the north, younger Transvaal Supergroup sediments are encountered.

Results

The students were trained in the identification of lineaments and the interpretation of geophysical results. The residual magnetic map shows NW–SE- and SW–NE-oriented structural lineaments. During their field mapping exercise, the students confirmed the presence of dolerite dykes on the site as a result of the training they had received. They generated an unconstrained 3D model to show the extent and geometry of the interpreted dykes and the possibility of interconnecting sills at a depth of about 220 m below the surface.

Analysis of the radiometric data emphasised the high radio-element concentrations to the east of the block where the granitic gneiss outcrops. The high concentrations of radio-elements were attributed to the composition of granitic rocks which are known for their high potassium feldspar content, as observed during the students' mapping exercise.

The biotite gneiss dominating the study area seems to have been intruded by mafic rocks. A low gravity anomaly may indicate the presence of less dense rocks and a high gravity anomaly may be associated with intrusive mafic igneous rocks. The northwest–southeast-trending high-amplitude values may signal the presence of intrusive mafic rocks.

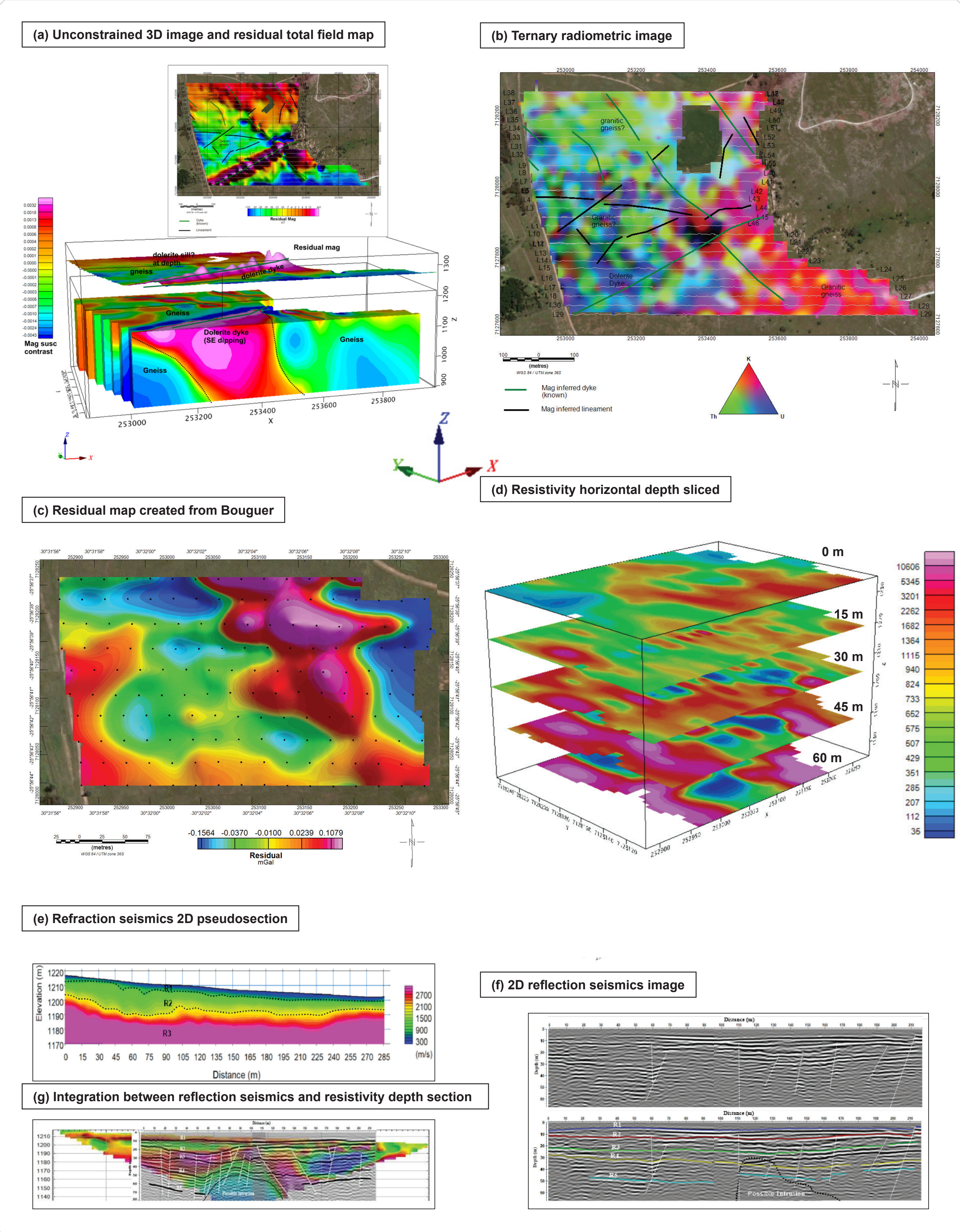
The highly resistive layer may be associated with intrusive mafic rocks, whereas low resistive values more likely relate to fracturing influenced by the intrusion. Fractures usually occur due to rocks breaking in response to stress, as when magma intrudes. A less resistive layer appearing together with a resistive layer may be the result of fracturing.

The intrusion appears to occur over the western and eastern portions of the study area, as revealed by the resistivity depth sections from 30 mbgl to 60 mbgl, with intrusive rocks appearing to be oriented N–S.

Three layered units were mapped through refraction seismic profiling, indicating the existence of the irregularities on the subsurface and suggesting the presence of faulting. A reflection seismic 2D section revealed the thickness of the layer, which appears thinner between 60 m and 120 m, possibly related to an intrusive body. There is a good correlation between the reflection seismics and the resistivity depth sections, with the resistive layer between 60 m and 120 m closely correlated with the intrusive body interpreted on the seismic section (black dashed line).

Conclusion

The host rock early Archaean biotite gneisses have been intruded by mafic rocks, interpreted as dolerite dykes and sills. The trainees were tasked to conduct a geophysical survey to map the intrusive structures and to demonstrate signatures associated with various geophysical techniques.



Ground geophysical results showing (a) an interpreted residual magnetic field and unconstrained 3D magnetic susceptibility model image, (b) a ternary radiometric map, (c) a residual gravity map, (d) resistivity horizontal depth sections, (e) a refraction seismic pseudosection, (f) a 2D reflection seismic image and (g) integration between reflection seismics and a resistivity depth section on the same line.

Magnetic results revealed a positive total field anomaly that may be related to intrusive structures. Furthermore, lineaments were also interpreted based on discontinuities depicted on the magnetic map. The high concentrations of radio-elements were attributed to the composition of granitic rocks which are known for their high feldspar content. The gravity results revealed a low gravity anomaly possibly signalling the presence of less dense rocks of granitic composition and a high gravity anomaly that may be associated with intrusive mafic igneous rocks. It appears that the high-amplitude NW–SE-oriented values could indicate denser rocks (i.e. dolerites). The resistivity results show that the resistive layer at depth ranging from 30 mbgl to 60 mbgl may be related to dolerites. The refraction seismic profile mapped three layered units indicating the presence of subsurface irregularities related to faulting. The reflection seismics 2D section suggests the possible presence of an intrusive body. A positive correlation between the reflection seismics and resistivity depth sections was demonstrated.

The geophysical interpretation relied solely on the 1:250 000-scale geological information to infer the presence of intrusive rocks. The current postulated information is regional, and owing to ambiguity associated with geophysical interpretation it is recommended that more studies such as structural, detailed mapping and/or drilling be conducted to constrain the geophysical results.

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The importance of critical raw materials to Africa

Critical raw minerals (CRMs) are raw materials that are economically and strategically crucial to a country's economy (primarily developed countries), but whose supply is fraught with risk. Access to specific raw materials that is both reliable and unrestricted is becoming increasingly important in industrialised countries and around the world. Several advanced economies, including those of the United Kingdom, the United States, and the European Union (EU), have compiled a list of important raw materials, which is frequently reviewed and updated. The most recent 2020 EU list, for example, includes 30 raw materials. These are antimony, fluorspar, magnesium, silicon metal, baryte, gallium, natural graphite, tantalum, bauxite, germanium, natural rubber, titanium, beryllium, hafnium, niobium, vanadium, bismuth, heavy rare earth elements, platinum group metals, tungsten, borates, indium, phosphate rock, strontium, cobalt, lithium, phosphorus, coking coal, light rare earth elements and scandium.

It is worth noting that these materials are not classified as “critical” by virtue of their rarity; rather, they are so classified for the following reasons: 1). They are important to key sectors of the European economy, including consumer electronics, environmental technologies, automotive, aerospace, defence, health, and steel. 2). They face a significant supply risk due to their high reliance on imports and the concentration of some important raw materials in specific countries. 3) Owing to the very distinctive and robust qualities of these materials for existing and future applications, there are no viable replacements. As a result, CRMs are vital because they are related to all sectors and supply chain stages, as well as to clean technologies. CRMs are indispensable in the manufacture of solar panels, wind turbines, electric vehicles, and energy-efficient lighting. Additionally, access to a rising number of raw materials is required for technological advancement and improved quality of life.

CRM for Africa, which is mostly made up of developing nations, is different. When industrialisation is limited, as is the case for many African countries, the preservation of reliable commodity inputs to a manufacturing industry is less important, because developing countries are merely net exporters of raw materials such as CRM. In cases where African countries earn considerable revenue from raw material exports, such as CRMs, the CRM lists from the developed world will be adopted by Africa, with a focus on Africa’s ability to provide these materials as exports. However, if the growth and development of African countries is a priority, the raw materials that are important and strategic to the developing world are very unlikely to be the same as those in the developed world. Commodities used in energy, agriculture and construction, such as aggregates, cement and phosphates, are more likely to be regarded as critical to the African continent.

For Africa to grow and compete in international markets, Africa first has to develop, and alleviate hunger. Africa also needs energy which is the basis of industry, economy, transport, communication, expansion of large cities, and the overall well-being of societies. Infrastructure has been a major stumbling block to growth and development, resulting in limited intra-African trade and trade with other regions. The population of the African continent accounts for 12% of the world's population and yet Africa generates only 1% of global GDP and 2% of global trade. This discrepancy reinforces the need for rapid infrastructure modernisation. Poor road, rail, and port infrastructure adds 30–40% to the costs of products exchanged between African countries. In addition, World Bank research on infrastructure discovered that deficient infrastructure in sub-Saharan Africa, specifically electricity, water, roads and information and communications technology, lowers annual national economic growth by two percentage points and slashes corporate productivity by up to 40%.

Commodities used in energy, agriculture, and infrastructure, such as aggregates, cement and phosphates, are thus critical to Africa to facilitate and accelerate growth and development on the continent. Despite its infrastructure hurdles, Africa is endowed with mineral resources, some currently regarded as CRMs. These include platinum group elements from the Bushveld Complex in South Africa and the Great Dyke in Zimbabwe; Sn from deposits in Central Africa, granites from the Bushveld and Morocco; Ta from pegmatites in Ethiopia and from pegmatite and alluvial/elluvial deposits in Central Africa and carbonatite-associated rare earth elements from Malawi, Namibia, South Africa, Tanzania and Kenya, to name a few. These materials can and will continue to earn Africa revenue through exports.

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CGS participation in the Science and Technology Research Partnership for Sustainable Development (SATREPS) mineral carbonation project

The South African National Climate Response White Paper presents the government's vision and commitment in contributing to the call made by global communities to reduce and/or control greenhouse gas emissions, and to promote environmental sustainability, to improve the quality and social status quo of people of South Africa in general. Carbon dioxide (CO_2) is a major contributor to greenhouse gas emissions which result in rising global temperatures and climate change. Various research initiatives are investigating suitable CO_2 utilisation, storage and mitigation strategies with an aim to reducing the emissions of greenhouse gases.

The CGS is currently investigating suitable technologies and methods for carbon capture and storage through its carbon capture, utilisation and storage (CCUS) project. The overall objective of the project is to reduce greenhouse gases, primarily CO_2, by capturing emissions at source and preventing their release to the atmosphere by utilising the CO_2 in projects that are beneficial to society or by sequestration of the CO_2 in geological formations, where it may be physically trapped and/or where it reacts with natural materials to form carbonate minerals.

The CGS has signed an MOU with various institutions of higher learning

A coal fly ash heap in South Africa.

— the University of the Western Cape, Cape Peninsula University of Technology (CPUT), the University of Cape Town and Tohoku University, Japan, to collaborate on a project titled "Development of a carbon recycling system towards a decarbonised society by using mineral carbonation". The project forms part of the SATREPS programme for research projects targeting global issues and involving partnerships between researchers in Japan and developing countries. The SATREPS programme is a Japan Science and Technology Agency and a Japan Science Cooperative Agency initiative. From the South African side, the project is coordinated by the Department of Science and Innovation with CPUT being the lead institution. At the CGS, Dr Ravi Vadapalli and Dr Henk Coetzee are coordinating the project activities.

The project investigates the feasibility of beneficiating calcium-rich wastes from cement and construction industries as well as other calcium-rich waste streams such as fly ash from coal- fired power stations. Carbon dioxide is used to produce re-usable by-products. Another objective of the project is to produce raw materials such as $CaCO_3$ that can be utilised in mine water treatment, in view of reducing overall CO_2 emissions and life-cycle environmental costs, which would have been generated using conventional materials. Life-cycle assessments of these processes will be undertaken to quantify the reduction in CO_2 emissions and other environmental impacts. Moreover, other suitable applications (add-ons to the construction material) of the by-product may be explored. This project, which kicked off in January 2022, is believed to demonstrate a technology that can help to reduce carbon dioxide emissions, which will assist with the mitigation of key environmental challenges. The research area falls within the scope of the Water and Environment and Geoscience Mapping units of the CGS and is in line with the mandate of the organisation. Moreover, the project presents opportunities for skills transfer and the training of scientists in the field and laboratory. Koena Ramasenya from the CGS, for example, is planning to enrol at the University of Cape Town for a related Master's programme. In addition to carrying out the mandate of the CGS, the project team is excited to partner with other higher educational institutions.

Planning meeting with South African local partners.

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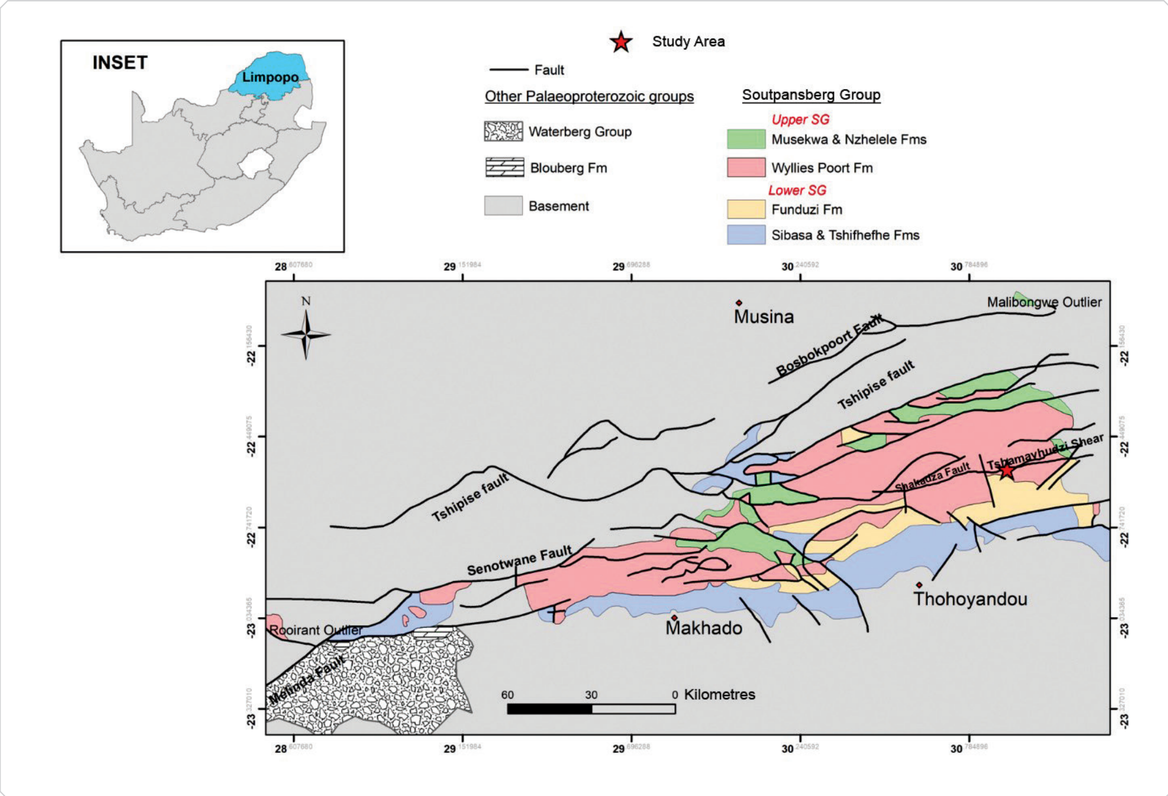
Petrogenesis of the porphyritic metagabbro of the Musunda Mafic Intrusion (MMI) and implications for the evolution of the Soutpansberg Group

The region between the Central Zone and the Southern Marginal Zone of the Limpopo Mobile Belt in the northern Kaapvaal Craton hosts the Soutpansberg Group, a ca 1.85 Ga volcano-sedimentary succession preserved above the Tshipise-Palala Shear Zone. The Soutpansberg Group comprises an upper and a lower succession with three formations each and a regional unconformity separating the successions. The lower succession comprises the Tshifhefhe, Sibasa and Funduzi Formations and the upper succession comprises the Wyllie's Poort, Musekwa and Nzhelele Formations. The low-grade greenschist facies rocks comprise conglomerates, shales, greywackes, quartzites and basalts.

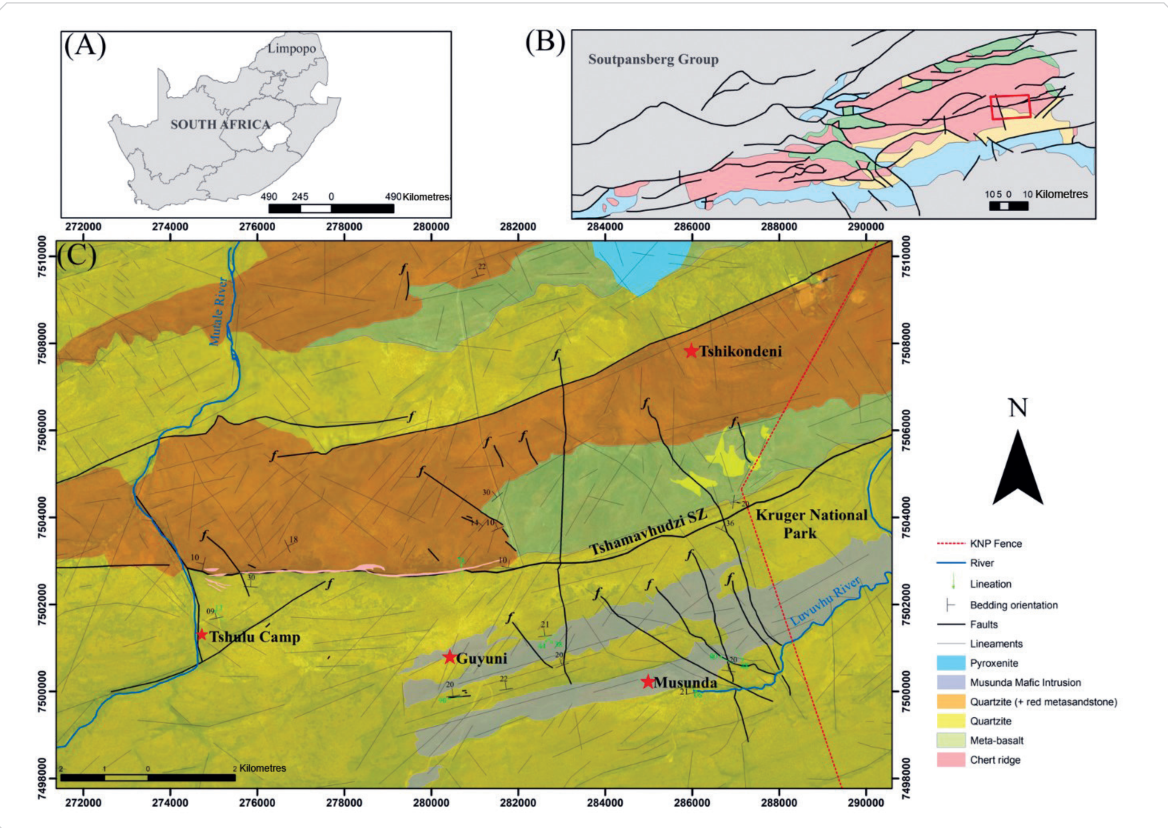
Unlike other geological domains in South Africa, certain parts of the Soutpansberg Trough still remain poorly studied. Most of the published literature on the Soutpansberg Group focusses on the sedimentology of the group with little work published on magmatism affecting the units before the emplacement of the Karoo Large Igneous Province (LIP).

The Kaapvaal Craton is intruded by many mafic intrusions, most of which have been studied in detail and form part of distinct LIPs (eg Barberton and Ventersdorp Supergroup volcanics, the Palaeoproterozoic Bushveld layered mafic intrusion and the Mesozoic Karoo LIP). However, the Craton has other mafic intrusions whose age, composition and extent have not yet been determined.

One such intrusive body was identified in this study. The MMI intrudes into



Simplified geological map of the Soutpansberg Group.

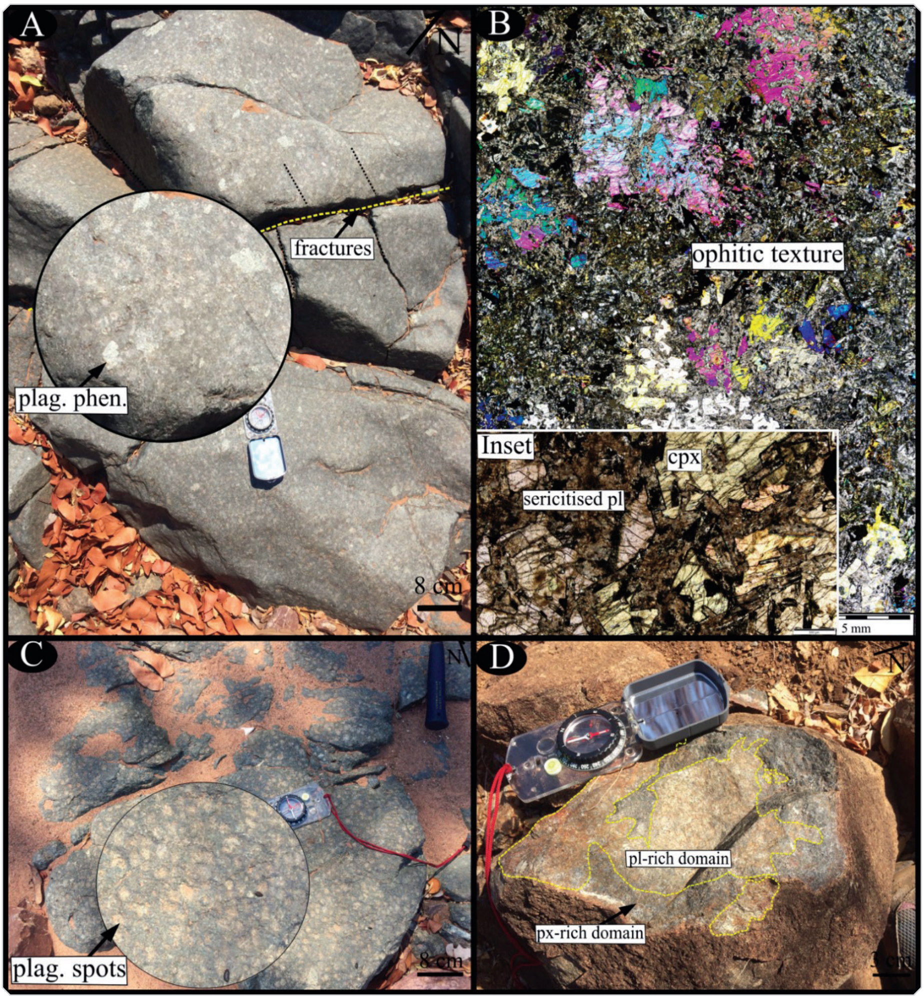


(A) Provincial map of South Africa. (B) Geological map of the Soutpansberg Group. (C) Geological map of the study area. The letter f denotes faults.

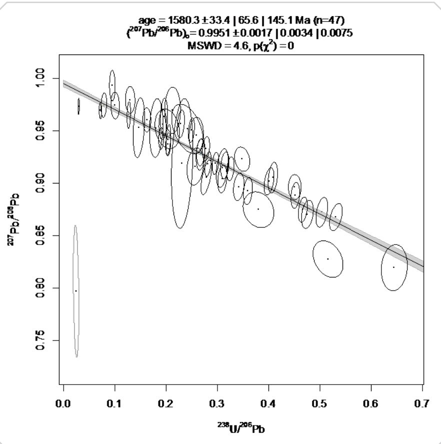
meta-sedimentary rocks belonging to the Wyllie's Poort Formation of the Soutpansberg Group between Guyuni and Musunda in Limpopo. Although a number of unknown intrusions make up the MMI, three of these have been identified. The intrusions comprise porphyritic metagabbro, meta-diabase and dolerite. The most widespread of the three intrusions along the length of the MMI are the porphyritic metagabbro, with the meta-diabase and dolerite outcropping as cross-cutting dykes. The porphyritic metagabbro comprises angular to circular phenocrysts of plagioclase set in a phaneritic matrix. The plagioclase phenocrysts range from millimetre scale to ~5 cm in size.

ICP-MS U-Pb titanite age

The porphyritic metagabbro outcrops exhibit varying degrees of hydrothermal alteration along the length of the MMI, resulting in the porphyritic metagabbro being altered to epidosite in some parts of the complex. The most reliable estimate for the oldest age for the MMI is established from ICP-MS U Pb secondary discordant titanite ages determined from analysing grains extracted from epidosite. The U-Pb secondary titanite age is determined to be ~1 580.3 ± 33.4 Ma. This age helps to narrow down the known magmatic events within the Kaapvaal Craton with which to compare the rocks of the MMI.



Photographs and photomicrographs of porphyritic metagabbro. (A) Fractured outcrop with plagioclase phenocrysts. (B) Photomicrograph in crossed polarised light. Inset is a photomicrograph in plane polarised light showing the main minerals making up the unit (clinopyroxene and sericitised plagioclase). (C) Plagioclase spots set in a mafic matrix. (D) Boulder preserving plagioclase- and pyroxene-rich zones. (pl and plag – plagioclase, px – pyroxene).

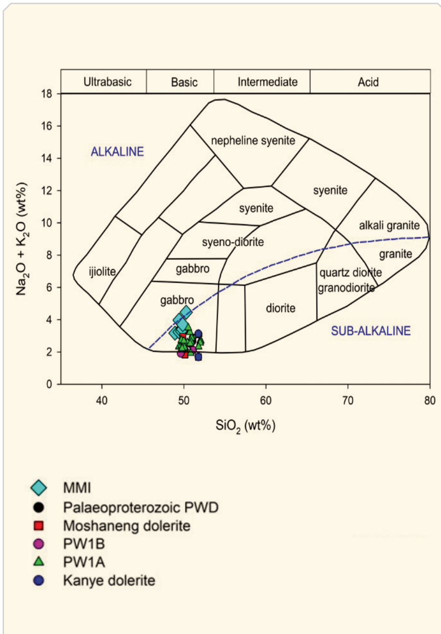


U-Pb Concordia age diagram of 47 titanite grains obtained from epidosite.

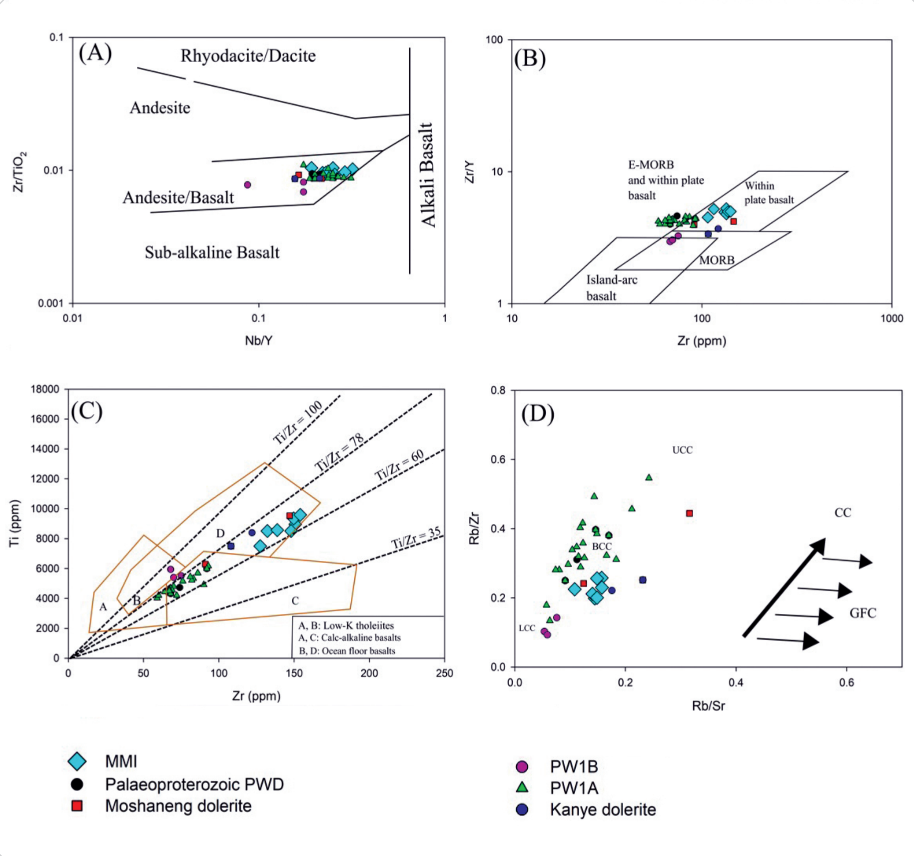
Geochemical analysis results and implications

Major and trace element geochemistry analyses were carried out on seven MMI porphyritic metagabbro samples to better understand the composition of the intrusion and to constrain the MMI to a known magmatic event on the Kaapvaal Craton. Bivariate plots indicate that the porphyritic metagabbro is classified as a sub-alkaline basic and plots in the andesite/basalt field according to the Nb/Y versus Zr/TiO_2 basalt discrimination diagram. The metagabbro plots as a “within plate basalt” according to the Zr versus Zr/Y discrimination diagram; it plots as ocean floor basalts according to the Zr versus Ti discrimination diagram for modern basalts and plots in the bulk continental crust (BCC) field according to the variation diagram of Rb/Sr versus Rb/Zr ratios. Degrees of crustal contamination are based on location on the crust, as determined by Rb/Sr and Rb/Zr ratios.

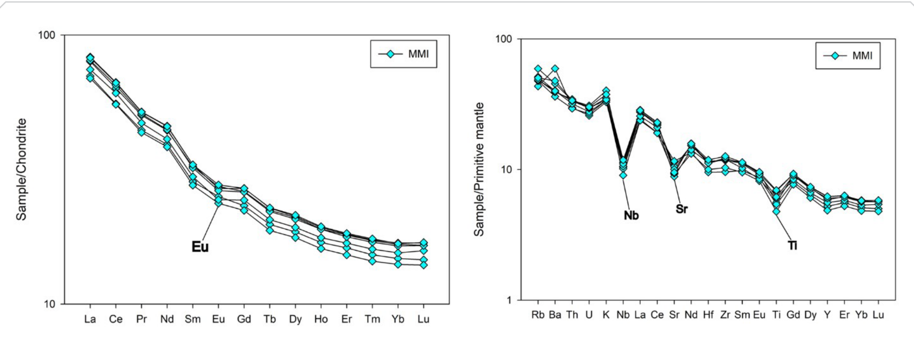
Chondrite-normalised REE plots for the porphyritic metagabbro with normalising values indicate light REE enrichments and heavy REE depletions with respect to chondrite. Primitive mantle-normalised plots for the porphyritic metagabbro indicate LILE enrichments (K, Rb, Ce, and Ba) and depletions in the HFSE (Nb,



Total alkalis versus silica diagram for plutonic rocks.



Discrimination diagrams showing compositions and geological domains for MMI porphyritic metagabbro and PW1 sills. (A) Nb/Y versus Zr/TiO$_2$ basalt discrimination diagram. (B) Zr versus Zr/Y discrimination diagram. (C) Zr versus Ti discrimination diagram for modern basalts. (D) Variation diagram of Rb/Sr versus Rb/Zr ratios, showing degrees of crustal contamination based on location on crust as determined by Rb/Sr and Rb/Zr ratios. (LCC – lower continental crust, BCC – bulk continental crust, UCC – upper continental crust, CC – continental crust, GFC – gabbro fractionation).



(A) Chondrite-normalised REE diagram of MMI porphyritic metagabbro indicating position of a slight negative Eu anomaly. (B)Primitive mantle-normalised incompatible element diagram of MMI porphyritic metagabbro.

Hf, Zr, Th, and U). The patterns exhibit negative Nb, Ta, Sr and Ti anomalies with slight enrichments in Rb, Ba, K and Gd.

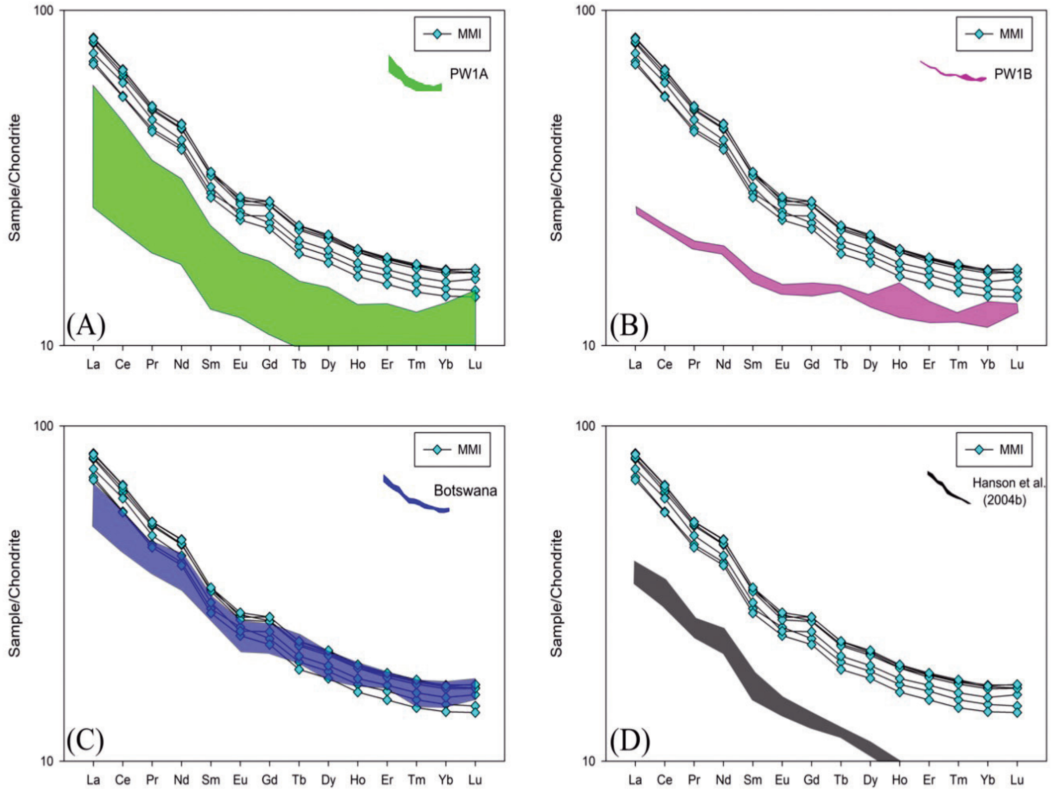
A comparison of the major element geochemistry of the MMI porphyritic metagabbro and Palaeoproterozoic post-Waterberg sills in Botswana and South Africa reveals a consistently strong correlation in geochemical trends between the Moshaneng dolerite in Botswana and the MMI samples. The Moshaneng samples plot in similar fields to the MMI porphyritic metagabbro in bivariate plots. Chondrite-normalised patterns for the Botswana sills are also LREE enriched and HREE depleted with respect to chondrite. The similarities in geochemical trends of primitive mantle-normalised patterns for Moshaneng dolerites and MMI samples indicate they may have the same mantle source.

There are variations in trace element geochemistry between the MMI samples and the Palaeoproterozoic post-Waterberg sills of South Africa, with the sills having lower Ti and Zr values resulting in them plotting as calc-alkaline basalts in The Zr vs Ti discrimination diagram where the MMI samples plot as ocean floor basalts. The greatest difference between the MMI samples and these sills is seen in the chondrite and primitive mantle-normalised plots where there is no correlation between the element patterns. The MMI samples appear to be more enriched in REE with respect to chondrite and in the incompatible element plots, the Palaeoproterozoic post-Waterberg sills lack the Sr anomaly that is present in both the MMI porphyritic metagabbro and the Moshaneng dolerite.

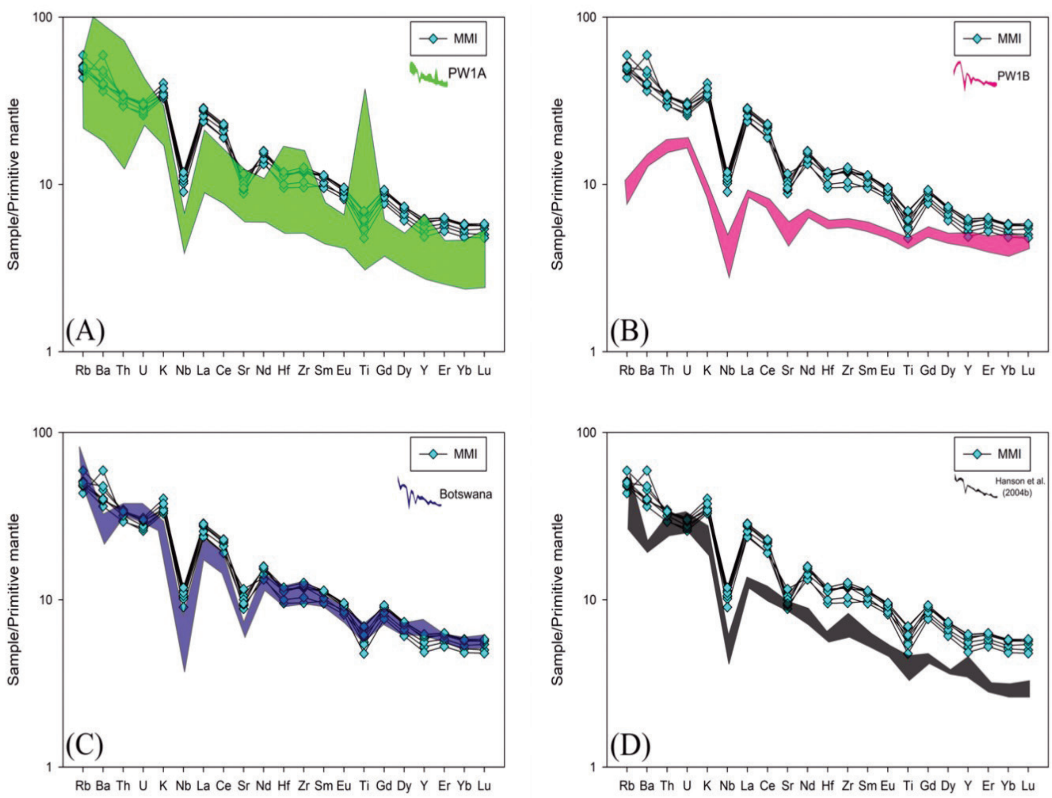
The geochemical links between the Moshaneng dolerite and the MMI porphyritic metagabbro suggest that the latter may be genetically linked to the dolerite which has previously been linked to the Hartley Formation basalts of the Olifantshoek Supergroup. A major rifting event at ~1928 Ma, resulting in the development of a passive continental margin, is said to linked to the Moshaneng dolerite. This rifting event may also be responsible for the first pulse of magma for the MMI, resulting in the porphyritic metagabbro intrusion.

The Palaeoproterozoic post-Waterberg sills in South Africa and Botswana have been dated at ~1.88 Ga and ~1.93 Ga, respectively. Differences in Palaeomagnetic pole data, geochemistry and age have led to the conclusion that these form part of separate magmatic events.

The MMI was previously grouped with other sills in the Soutpansberg Group as the “Soutpansberg sills” and was correlated with the Palaeoproterozoic post-Waterberg sills in South Africa, given that they are encountered north of the ~1.88 Ga Black Hills Dyke swarm.



Chondrite-normalised REE diagrams of MMI porphyritic metagabbro which include shaded patterns of chondrite-normalised REE patterns of Palaeoproterozoic post-Waterberg dolerites. (A) MMI porphyritic metagabbro and PW1A. (B) MMI porphyritic metagabbro and PW1B. (C) MMI porphyritic metagabbro and Palaeoproterozoic post-Waterberg dolerites from Botswana. (D) MMI porphyritic metagabbro and Palaeoproterozoic post-Waterberg dolerites.



Primitive mantle-normalised spider diagrams of MMI porphyritic metagabbro which include shaded patterns of primitive mantle-normalised incompatible elements of Palaeoproterozoic post-Waterberg dolerites. (A) MMI porphyritic metagabbro and PW1A. (B) MMI porphyritic metagabbro and PW1B. (C) MMI porphyritic metagabbro and Palaeoproterozoic post-Waterberg dolerites from Botswana (D) MMI porphyritic metagabbro and Palaeoproterozoic post-Waterberg dolerites.

Based on differences in geochemistry, it is assumed that the MMI does not share a mantle source with these sills. However, the MMI does share a mantle source with the Moshaneng dolerite in Botswana. The findings of this study indicate clear geochemical distinctions between Palaeoproterozoic post-Waterberg sills in South Africa and MMI porphyritic metagabbro and Moshaneng dolerite. These findings suggest distinct magmatic events for the 1.88 Ga Palaeoproterozoic post-Waterberg sills and the 1.93 Ga Palaeoproterozoic post-Waterberg sills.

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Vision and values

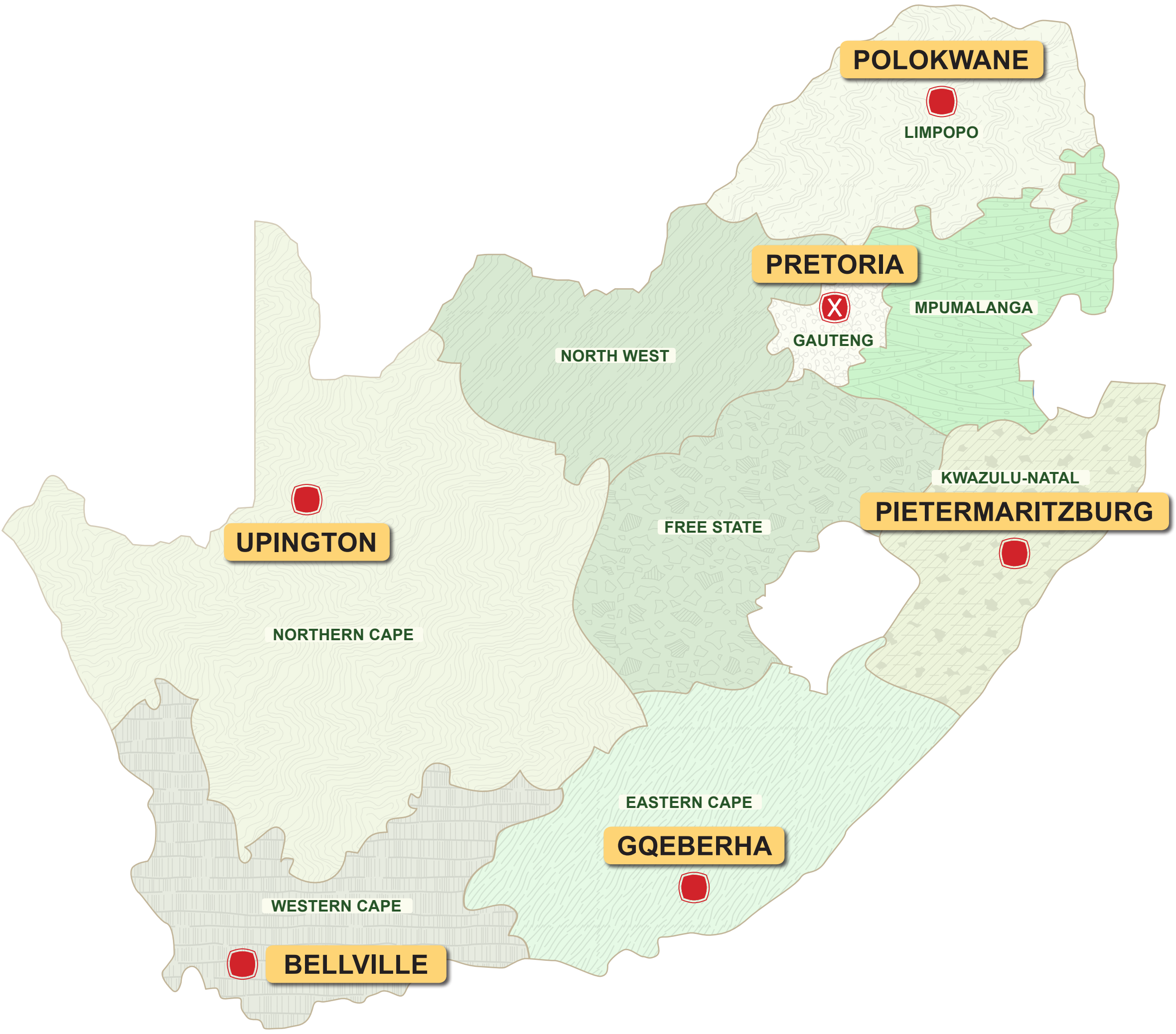
OUR VISION

A prosperous and transformed society enabled by geoscience solutions.

OUR VALUES

- Innovation
- Diversity
- Excellence
- Accountability
- Learning
- Safety, Health and Environment
- Transparency

CGS offices



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