GEOclips

VOLUME 60 . MARCH 2020

Council for Geoscience

INSIDE:

Executive leadership visits the Makhonjwa Mountains

(A) The executive delegation at the Malmani Subgroup stromatolites; (B) Discussing geoheritage along the Barberton Geotrail; (C) Dr Taufeeq Dhansay highlighting the formation of stromatolites and early earth atmospheric oxygenation; (D) Dr Mathe explaining the formation of pillow basalts; (E) Mapping taking place across the Tjakastad Shear Zone.

A delegation of the executive leadership of the Council for Geoscience (CGS) undertook a technical field visit to the Makhonjwa Mountains near Barberton in Mpumalanga. The delegation included members of the CGS Board, the Auditor-General and executives in the Office of the CEO. The aim of this visit was to provide the executive leaders with an opportunity of gaining a better understanding and appreciation of the fundamental aspects of the CGS's integrated and multidisciplinary geoscience mapping programme.

Comprising one of the oldest and best-preserved fragments of early continental and oceanic crust on earth, the Makhonjwa Mountains are regarded as an important geological terrain. This is largely because the lithological sequences provide key insights on how the early earth functioned and evolved over geological time. In addition, these mountains underwent numerous tectonic and metasomatic events that resulted in the movement and concentration of significant mineral resources, which have and continue to contribute towards the country's economy.

The trip began with the delegation transecting the lower Transvaal Supergroup. The excursion included an extensive discussion on the Palaeoproterozoic Malmani Subgroup. The subgroup contains interlayered sequences of chert-rich and chert-poor dolomite and siliciclastic units. Rheological variation in these units enabled the thrust-controlled hydrothermal gold deposits to form while stromatolites highlight cyanobacteria-derived oxygenation of the early earth's atmosphere.

The delegates then spent a day familiarising themselves with the fundamental features of greenstone belts and how to identify the various rocks within these sequences. The key themes under consideration included how to determine and describe the primary and secondary mineralogy and structural fabric developed within the various rocks. Special attention was given to regional deformation and how to ascertain localised stress conditions. Insight was provided into how these provide evidence of mineralisation and can be used to predict mineral targets.

The discussion on mineralisation also included potential environmental degradation and corrective rehabilitation mechanisms. The delegation was shown several derelict mines within the Makhonjwa Mountains and considered the necessary rehabilitation strategies and the susceptibility of illegal mining practices. The CGS is playing an important role in enabling effective rehabilitation and monitoring strategies.

With the basic fundamental geoscience principles in hand, the delegation undertook a geoscience mapping exercise across the Tjakastad Shear Zone. Delegates were challenged to identify the various lithologies encountered, measure structural and textural data and to determine the relative stratigraphic positions of the units. Some of the key units uncovered included mylonitic and highly sheared sequences, sheared pillow basalts, volcanoclastic agglomerates and an array of intrusive and plutonic rocks.

Despite the complicated geology encountered and numerous themes and considerations discussed, the executive delegation captured the essence of integrated geoscience mapping. This exposure enabled the delegates to better link the CGS strategy to the developmental goals of South Africa. Furthermore, the CGS scientific programme will undoubtedly benefit from the insight and advice given and will close the gap between science and policy implementation.

The CGS plans to make these kinds of excursions a regular feature to improve its science-driven advisory role at the highest levels of governance in South Africa.

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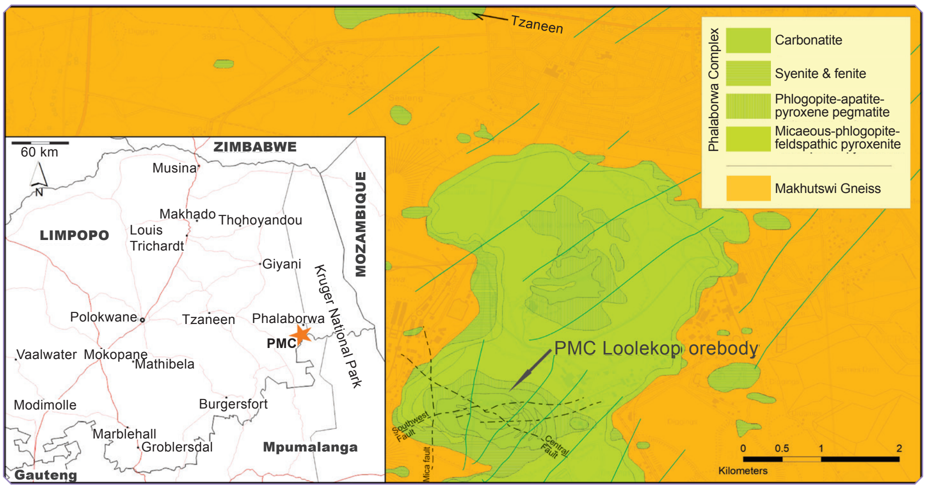
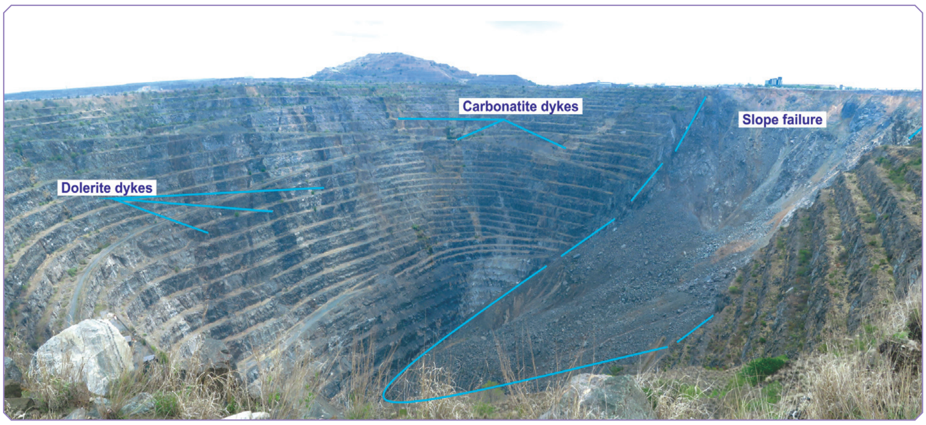
Geological mapping of the Murchison Greenstone Belt and surroundings — Palabora Mining Company field visit

The project team responsible for the mapping of the Limpopo Greenstone Belt visited the Palabora Mining Company (PMC) based in Phalaborwa, Limpopo Province in November 2019. The visit was intended to augment the CGS geoscientific programme which includes the updating of geological maps on a scale of 1:50 000. Staff of the PMC welcomed the CGS team and the PMC geology department, consisting of Ms Thabitha Moya, Mr Robert Brazier, Ms Nyiko Makhubele, Mr Urbanus Human and Ms Paulien Lourens, presented information on different mine operations. Furthermore, the mine management who encourages scientific research and collaboration informed the CGS team that they are welcome to visit the mine at any time for further geoscientific research.

The Phalaborwa Complex is a carbonatite-alkaline igneous intrusion hosting a variety



Simplified geological map of the Phalaborwa Complex (inset: map of Limpopo).



PMC open pit showing the various dolerite (black) and carbonatite (white to grey) dykes. The right side of the image shows the bench collapse that occurred around 2003.

PMC open pit in the background showing the various dolerite (black) and carbonatite (white to grey) dykes with Simon Nhamussua (left) and Keletso Mogowe (right) in the foreground.

The CGS team including Tshilidzi Radzuma, Jabu Mathebula, Keletso Mogowe and Thomas Muedi.

of different minerals ranging from copper sulphides, platinum group elements (palladium and platinum), gold, silver, magnetite, uranium, phosphate and vermiculite to zircon, among others. This intrusion is unique in that it is the only carbonatite-alkaline complex in the world with mineable copper sulphide reserves.

The Palabora Mine has been in operation since 1966 when it started as an open pit mine. The pit remains one of the largest in Africa measuring 2 000 x 800 m. Operations shifted underground in 2003 where mining is currently conducted at two different levels. It is impressive how the operation integrates geoscience research with some of the latest technologies in modern mining — underground visualisation integrated with photogrammetry is utilised to study the geological features that affect day-to-day mining operations. This information also feeds into an interconnected database that assists in mapping out the subsurface. The recording of this information assists at a later stage when all the pieces of information are viewed in relationship to one another and structures such as dykes and faults are joined together in order to comprehend their orientations and extensions. The N–S trending Mica Fault is one of the subsurface structures that has been observed in the underground operations.

Around 2003, after the mine had already moved to underground operation, a collapse (slope failure) occurred in the northern section of the mine. This posed a concern for the overall stability of the open pit benches as collapsed material feeds into the underground mining level, thus diluting the ore. Extensive investigations that involved different modelling methods, e.g. numerical, kinematic and physical methods, were conducted to predict the probability of further slope failure. Fortunately, there has not been any major movement of the slope since the collapse. The mine pit is now equipped with sensitive seismic stations to monitor movements which may be hazardous. Additionally, the pit has been fenced off as a safety measure.

The CGS team who visited PMC included Messrs Tshilidzi Radzuma, Simon Nhamussua, Keletso Mogowe, Jabu Mathebula and Dr Thomas Muedi. Dr Muedi, whose interests include geochronology, is keen on investigating the progressive dykes that intrude the complex.

Since the operations are confined to specific mineralised pipes, the mine uses the rest of the land over which it has mining rights as a nature reserve. As such, wild life is seen roaming the area. Most of the land in the Lowveld is managed in this way. It is seen as an effective approach where the land is not suitable for herd farming. Nature reserves present opportunities for detailed geoscientific research, field school training, geoconservation and geoheritage assessment, protection and management.

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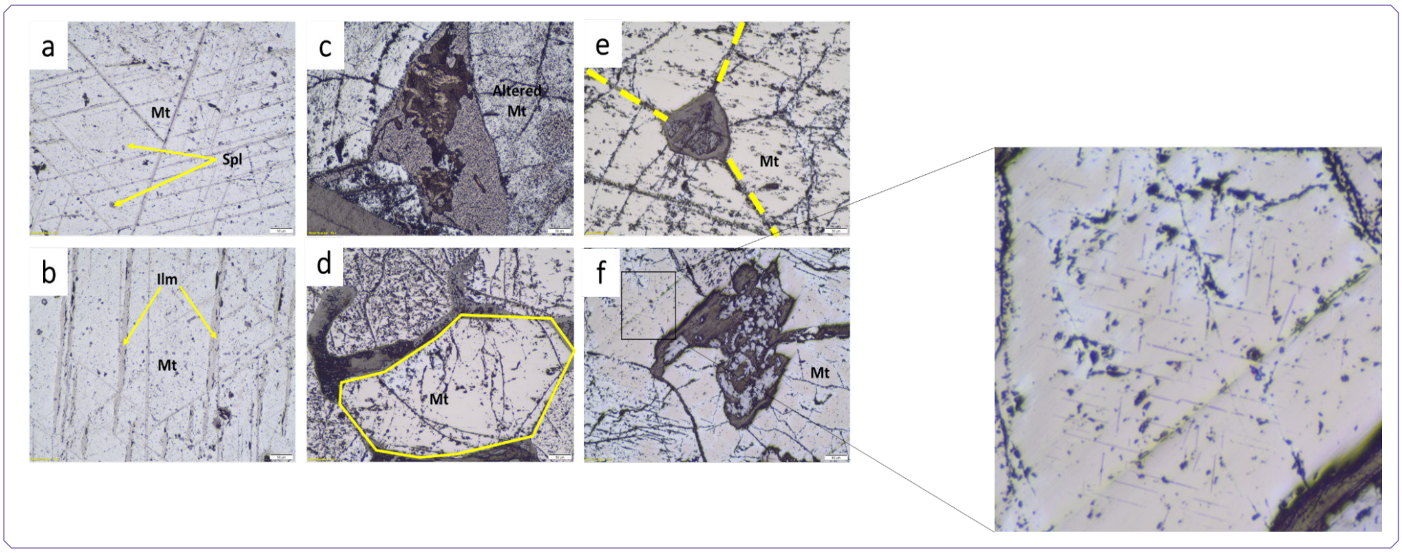
Mineralogical characterisation of vanadium-bearing magnetitite pipes in the Bushveld Complex

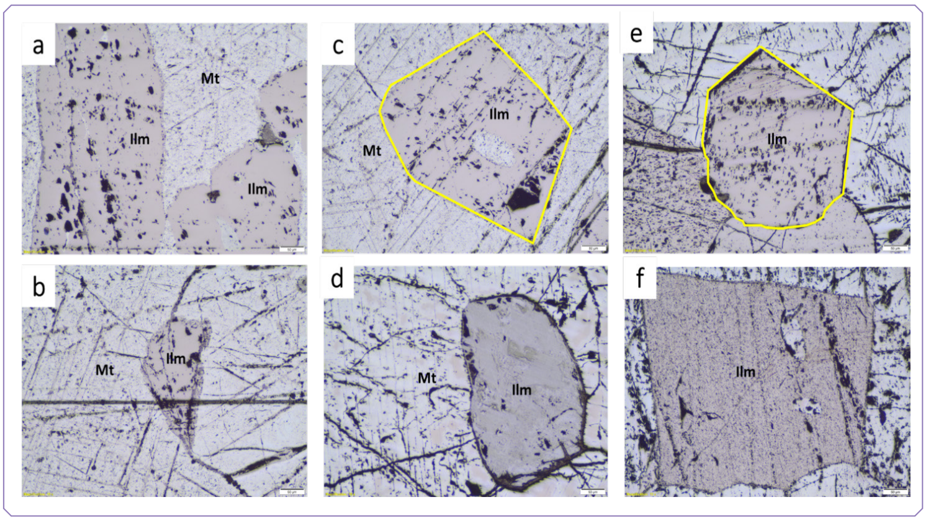
The mafic–ultramafic Rustenburg Layered Suite (RLS) of the Bushveld Complex has the world's largest resource of high-grade primary vanadium, found in vanadium titanomagnetite pipes (VTMP) and as seams of magnetitite. Vanadium titanomagnetite, the most predominant mineral in the magnetitite pipes, contains valuable elements such as iron (50–80%), vanadium (0.2–4%) and titanium (10–25%), which have extremely high potential value. The exploitation of these high titania resources for titanium in the past have been restricted by a combination of the economic viability of smelting such Ti-rich iron ore, the paucity of vanadium and metallurgical problems with the extraction of titanium oxide from the slag. Recent research has, however, resulted in the development of economic processes for the simultaneous recovery of Fe and V_2O_5, and the production of high-titania products is now technically feasible. On the other hand, the recovery of economic minerals depends largely on parameters such as grain size distribution, chemical composition, texture and the presence of inclusions or intergrowths with other minerals. This study focusses on the mineralogy of some vanadium-bearing titaniferous iron ores from ten pipes in the Roossenekal area, and an assessment is given of the potential of these ores for the use as raw materials in the recovery of V_2O_5, TiO_2 and Fe. These results will be considered applicable to all Fe-Ti oxide pipes in the Upper Main Zone (UMZ) and Lower Upper Zone (LUZ) of the Bushveld Complex.

Ore microscopy

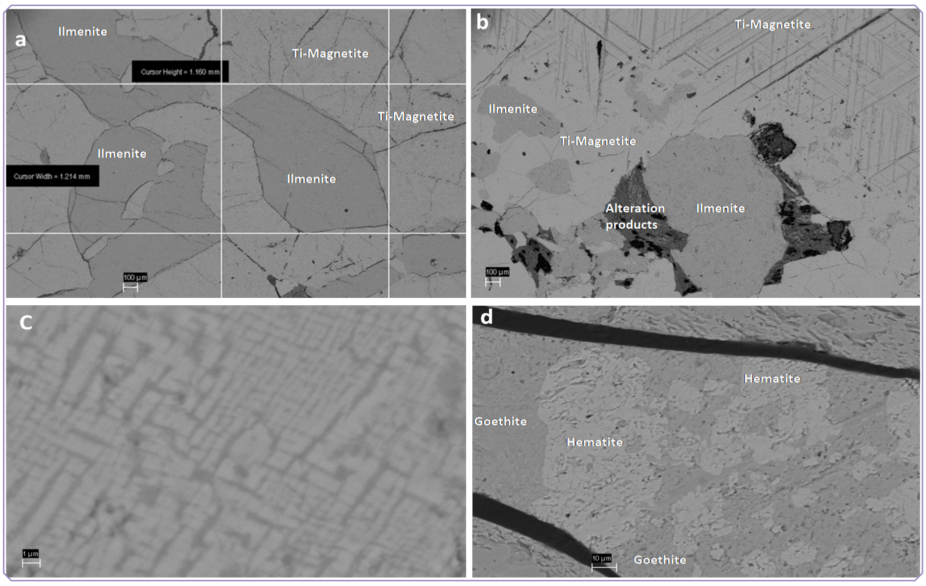
The magnetitite pipes typically consist of 90% magnetite and 10% granular ilmenite. The magnetite comprises 80% titaniferous magnetite and about 20% very minute intergrowths of ilmenite exsolution. The magnetite usually forms a network of intergrown densely packed aggregates of granular polygonal grains generally exhibiting gently curved grain boundaries that meet in distinct triple junctions having interfacial angles of



Photomicrographs of magnetite from magnetitite pipes in the Main Zone of the Rustenburg Layered Suite showing: (a) Extensive development of ilmenite lamellae in a Ti-magnetite grain intergrowth of trellis-type ilmenite lamellae; (b) Coarse-grained ilmenite lamellae which contain pleonaste blebs on titanomagnetite showing sandwich-type lamellae of ilmenite exsolution of a titaniferous magnetite grain as well as ilmenite trellis-type exsolution; (c) Magnetite grain with martitisation; (d) Polygonal grain of magnetite; (e) Magnetite grains showing distinct triple junctions; (f) Spinel trellis-type lamellae of ilmenite in the core of titanomagnetite.



Photomicrographs of Fe-Ti-V oxides from magnetitite pipes in the Main Zone of the Rustenburg Layered Suite. (a) Intergrowth of ilmenite (Ilm) on magnetite (Mt); (b) Ilmenite grain with distinct serrated spineliferous margins; (c–f) Polygonal elongate ilmenite grains forming as intergrowths on Ti-magnetite margins.



Backscattered electron (BSE) images of the magnetite pipe samples. (a) Coarse-grained subhedral ilmenite in magnetite grain boundary; (b) Ilmenite grains of variable sizes in magnetite with spinel trellis exsolution and alteration products (gibbsite, carbonates and clay) along fractures; (c) Submicron cloth-textured exsolution of ulvöspinel within magnetite; (d) Hematite and goethite.

± 120°. Individual polygonal grains are typically large, ranging in size from 1–5 mm and generally euhedral to subhedral showing polygonal outlines/ textures. The Ti-magnetite grains show well-developed exsolution lamellae which are mainly cloth textured, with minor palisade, trellis and sandwich types. Ti-magnetite shows alteration to Ti-maghemite, martite and goethite attributed to low temperature oxidation and hydration during weathering. Transparent spinel exsolution bodies that are not directly associated with ilmenite are only rarely developed within the Ti-magnetite.

Granular ilmenite grains are similar to those described for the titanomagnetitite layers. Grain boundaries with Ti-magnetite are irregular and typically serrated due to the development of spineliferous ilmenite rims with abundant pleonaste granules. Ilmenite also occurs as granular primocrysts, often displaying polygonal recrystallised grain boundaries, as distinct from ilmenite derived by exsolution from magnetite. Discrete grains that are typically elongate, in places angular, occur along the Ti-magnetite grain boundaries and intergrowths on Ti-magnetite, and rarely show straight boundaries with 120° interfacial angles. Aggregates of ilmenite grains typically have a polygonal morphology and interfacial angles of 120°, indicating annealing. Granular ilmenite is more rarely observed as polygonal grains with triple junctions with Ti-magnetite grains.

Mineralogical characterisation by SEM-EDS

Polished thin sections of the magnetite pipes were analysed using scanning electron microscopy (SEM) equipped with energy dispersive X-ray spectroscopy (EDS). The aim was to investigate the textural properties, phase associations and grain sizes. The samples were coated with carbon to form a conducting layer to avoid charge accumulation. The Carl Zeiss Sigma 300 scanning electron microscope at the Council for Geoscience was used to analyse the samples. The analytical conditions were set at an accelerating voltage of 20 KV, beam current of 20 na and working distance of 10 mm. The backscattered electron (BSE) images of the samples were collected with X-ray spectra for phase identification. Magnetite is the predominant phase at approximately 90% and ilmenite has a very low amount of alteration products such as hematite and goethite. The observed gangue minerals were traces of alteration phases such as gibbsite, carbonates and iron-rich clays. The magnetite grains are massive and very coarse with variable sizes of ilmenite (<1 µm and >1 mm). The magnetite is characterised by coarse ilmenite lamellae and finer lamellae down to submicron level.

Processing implications

The pipes offer huge economic potential due to the high vanadium (~2% V_2O_5) and titanium (~12%) contents. The generally polygonal magnetite grains are subhedral to euhedral and annealed, suggesting that they will liberate very well upon grinding. The magnetite can be recovered by magnetic separation after comminution and subjected to hydrometallurgical processes involving roasting, leaching and precipitation to recover vanadium as vanadium pentoxide powder. The non-magnetic fraction of the magnetite ore can be targeted to recover ilmenite grains for their titanium content. Alternatively, the pyrometallurgical approach can be used to produce pig iron with vanadium being recovered from the slag. The titanium present in a variety of extremely fine-grained micro intergrowths cannot be liberated by mechanical means.

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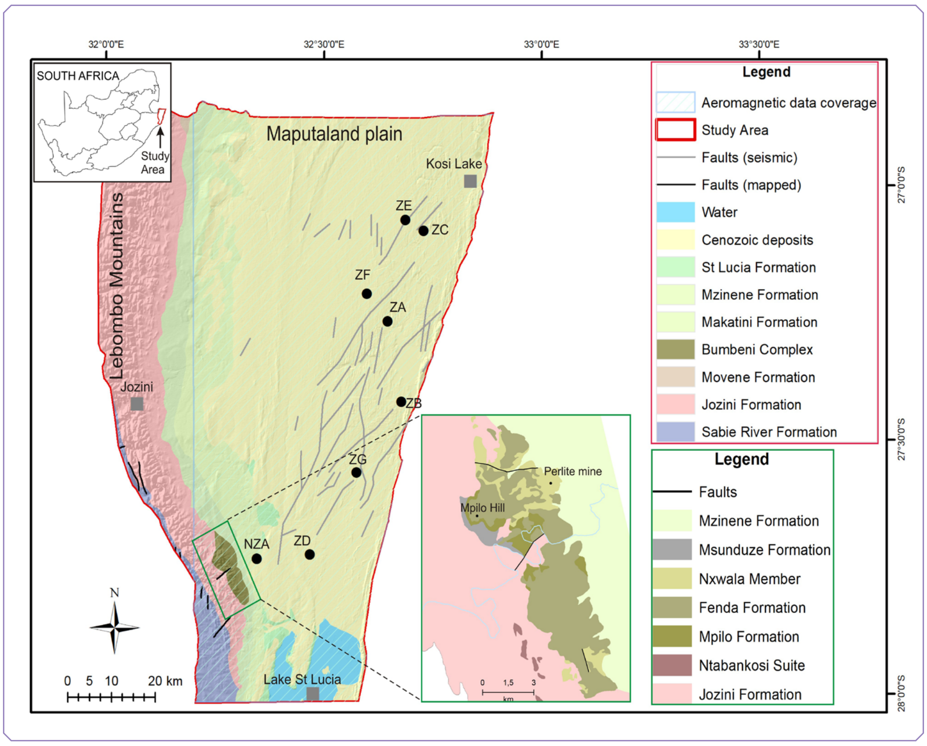
Bumbeni Volcanic Complex, northern KwaZulu-Natal: insights from high-resolution aeromagnetics and field mapping

In 2018, the Council for Geoscience (CGS) acquired high-resolution aeromagnetic and gravity data over the Maputaland coastal plain in northern KwaZulu-Natal to aid Gondwana-breakup research within the CGS 10 year mapping programme. The CGS is also part of a joint collaboration effort with the South African National Energy Development Institute (SANEDI) to assist with basin characterisation for the South African pilot carbon dioxide storage project (PCSP).



Location of the study area and geological map summarising the lithostratigraphy of the area. The inset shows a close-up view of a simplified field map of the Bumbeni Complex. Selected exploration wells drilled as part of the hydrocarbon exploration programme are shown as black circles.

The Mesozoic Zululand Basin developed beneath the Maputaland coastal plain in northern KwaZulu-Natal and is bound to the west by the 700 km long Lebombo Mountain Range representing the easternmost extent of the Karoo Igneous Province (LIP). The mountain range is dominated by a variety of volcanic rocks including basalts, rhyodacites and rhyolites of the Lebombo Group.

The youngest volcanic event in northern KwaZulu-Natal occurred around 133 Ma with the eruption and associated intrusive phases of the Bumbeni Complex which occurs in the Phinda and Mkuze Game Reserves along the southern extremity of the Lebombo Mountain Range. The complex comprises a basal basalt unit, the Mpilo Formation, which is overlain by intercalated felsic lava flows and pyroclastic deposits of the Fenda Formation. Although limited in extent at the surface, the complex forms part of a ~14 km long x 5 km wide basement ridge (the Bumbeni Ridge) which is buried beneath younger Cretaceous and Cenozoic cover sequences. This ridge, identified through aeromagnetic and 2D seismic data, extends northeastwards from the southern margin of the Lebombo Mountain Range into the offshore of northern KwaZulu-Natal.

Consequences for the tectonic framework of coastal northern KwaZulu-Natal

The basement to the coastal plain of northern KwaZulu-Natal is represented by volcanics of the Lebombo Group, with the rhyolites of the Jozini Formation exhibiting systematic N–S and E–W fracture orientations, of which the N–S groupings are commonly associated with strike-slip faults. In contrast, the younger volcanics of the Bumbeni Complex in the Phinda Game Reserve are characterised by NW–SE and NE–SW orientations.

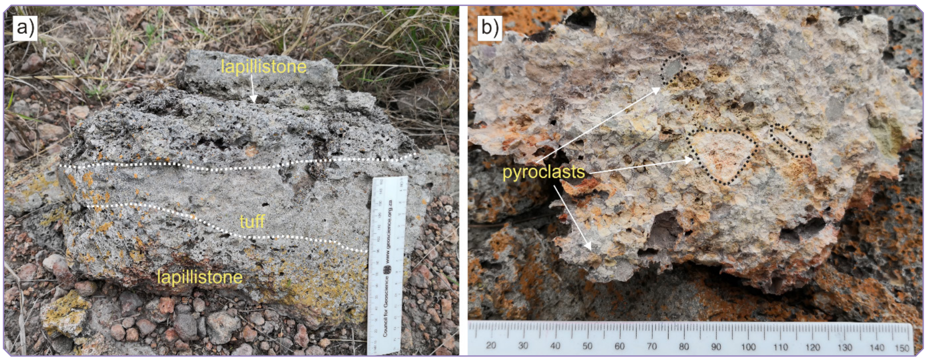
The structural analysis suggests that the N–S trending fault zones of the Jozini Formation are the product of a Jurassic-age Gondwana breakup related tectonic event. However, the dominant NW–SE and NE–SW fracture orientations in the Bumbeni Complex suggest that a rotation in the palaeostress regime may have occurred during Gondwana breakup related extension in the early Cretaceous.

In order to understand the eastward propagation of the enigmatic Bumbeni Ridge, and the history of the basement beneath the Maputaland coastal plain, high-resolution aeromagnetics and radiometrics were obtained over the study area. Through the delineation of distinct magnetic signatures four domains (1–4) were identified beneath the coastal plain. The different domains are defined by variations in the orientation, spacing and the size of magnetic anomalies/lineaments.

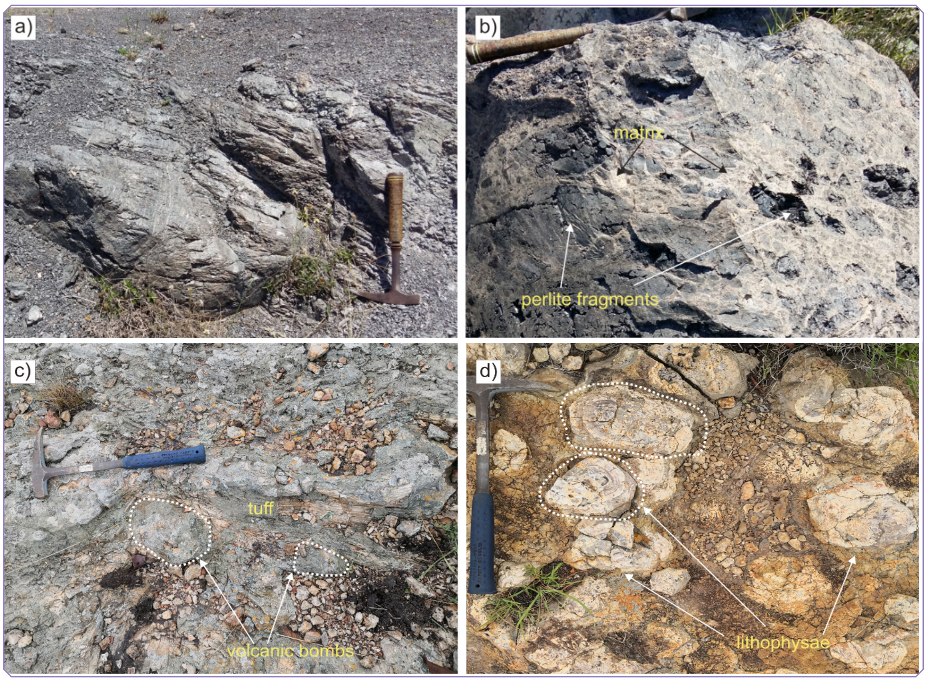
Domain 1 occurs to the west of the area showing low magnetics (blue colour). The aeromagnetics show dominant N–S and NNE–SSW striking lineaments similar to the N–S oriented fracture sets of the Jozini Formation. Domain 2 is represented by a higher magnetic anomaly (red colouration) than Domains 1 and 3 to the west and east, respectively. A number of N–S to NNE–SSW oriented narrow lineaments in this domain are interpreted as either shallow fractures or a possible extension of the N–S trending Rooi Rand dyke swarm which intrudes west of the Lebombo Mountain Range. Domain 3 shows low magnetic signatures, with much less pronounced ~NE striking lineaments potentially representing older structures, or localised basement faults as noted in the seismic data. The dominant NE–SW and E–W lineaments in Domains 2–4 (in the FVD map) that disrupt or occur at the termination of other lineaments are most likely related to shallow fractures.

Interesting magnetic signatures occur around the Bumbeni Complex and along the Bumbeni Ridge, where variations in high and low signatures are associated with possible plutonic bodies related to long-lived volcanism, similar to that which produced the Bumbeni Complex.

(a) Amygdaloidal and vesicular basalt of the Mpilo Formation. (b) Close-up view of the amygdales and vesicles.

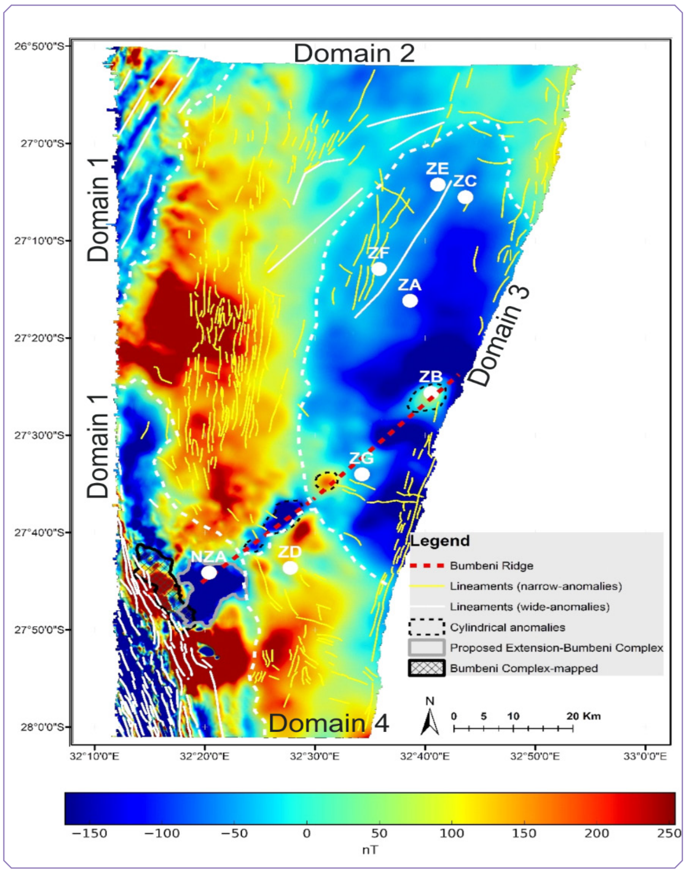


(a) Intercalated lapillistone and tuff of the Fenda Formation. (b) Close-up view of the lapillistone with individual pyroclasts shown with dashed black lines.

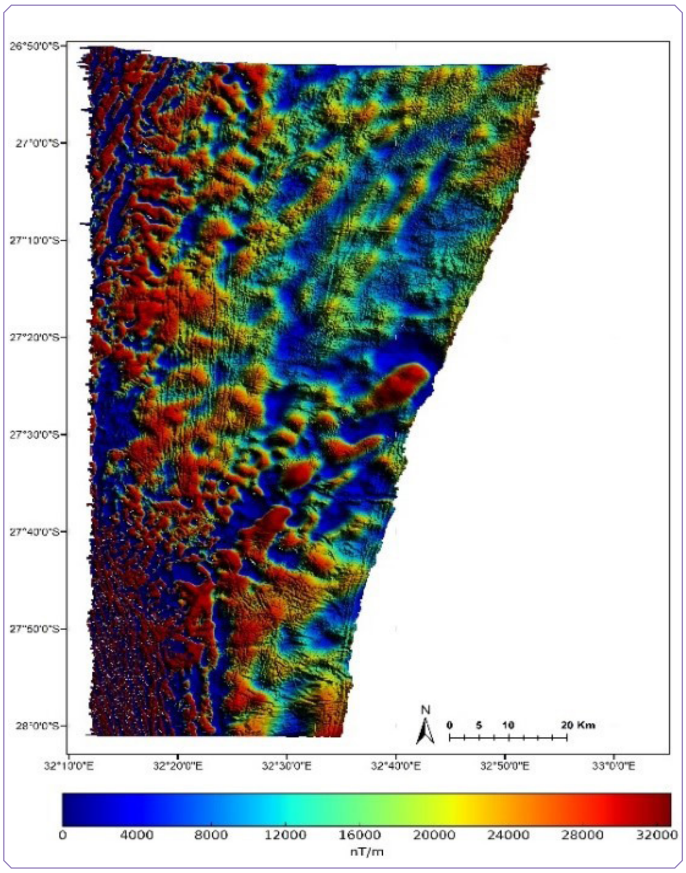


(a) Characteristic perlite of the Nxwala Member. (b) An example of an autobrecciated flow top comprising perlite fragments set in a light grey matrix. (c) Lapilli tuff with bomb-sized pyroclasts in laminated tuff. (d) The subrounded lithophysae, developed in a tuff.

Both the structural and high-resolution aeromagnetic data have played an important role in defining the difference in the tectonic framework between the Jurassic Lebombo Group and the early Cretaceous Bumbeni Complex. Furthermore, this study has highlighted the importance of high-resolution data in revealing geologically significant detail that cannot be revealed by coarse geophysical data or be seen on surface exposures.



RTP map of the study area showing Domains 1–4 (domain boundaries are shown with dashed white lines). The NE striking Bumbeni Ridge/Lineament intersects Domains 1–3 and is shown with a dashed red line. The locations of the boreholes are shown in white circles labelled with borehole names. The black polygon to the west of the NZA borehole corresponds to the mapped Bumbeni Complex. The grey polygon shows an extended Bumbeni Complex based on the positional correlation of the mapped Bumbeni Complex and the confirmed Bumbeni Complex bedrock at 545 m (as per borehole NZA).



The first vertical derivative (FVD) map of the study area.

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National Science Week 2019 launch in Kimberley, Northern Cape

The launch of National Science Week 2019 (NSW2019) was held at the Mittah Seperepere Convention Centre in Kimberley in the Northern Cape Province. The National Science Week is an annual event of science, technology, engineering and mathematics (STEM) that is led by the Department of Higher Education, Science and Innovation. The event aims to celebrate and communicate awareness in science, engineering and technology as well as to highlight some of the captivating science that is being carried out in South Africa and its relevance to our everyday lives. The Minister and Premier of the particular area and various stakeholders including students and educators from primary schools, high schools and universities as well as the public normally attend the event. Various stakeholders and role players conduct activities or provide outreach platforms that promote an awareness of the value of science, engineering and technology to the broader community.

The theme for NSW2019 was “Facing the harsh realities of climate change”. Climate change is any long-term change in average weather conditions such as temperature, rainfall and wind. These changes may take place due to the dynamic processes of the earth (e.g. volcanic eruptions or earthquakes), changes in the intensity of solar radiation or fall of large meteorites. Deforestation, tree burning or the three types of pollution — land, air and sea — may result in an ecological imbalance, the disappearance of certain animal and plant species, and the appearance of other species. The reduction of climate change is of the outmost importance because of the critical role that climate plays in the formation of natural ecosystems and the human economies and civilizations on which they are based.

The Council for Geoscience (CGS) was amongst the 100 exhibitors who were invited to exhibit at the NSW2019 launch and was represented by Ms Sisanda Makubalo (Geoscience Mapping) and Ms Rethabile Makwela (Marketing, Communication and Stakeholder Relations). The team engaged with the learners, students and stakeholders and they shared information on the range of CGS services, bursaries, internship programmes and career opportunities with the delegates. The CGS's exhibition stand showcased books, posters and pamphlets on the geological storage of carbon dioxide, mining and climate change in South Africa. During her engagement with the students, Ms Makubalo outlined a project related to climate change, conducted by the CGS Engineering Unit in Alberton. The students were fascinated by the role the CGS is playing in the country.

The NSW2019 programme was led by Dr Phil Mjwara, the Director-General of the Department of Higher Education, Science and Innovation who also offered a welcome address and highlighted why science matters not only to the science community, but also to society at large.

The Minister of Higher Education, Science and Innovation, Dr Blade Nzimande, with the winners of the Eskom Expo for Young Scientists.

Ms Sisanda Makubalo interacting with learners at the NSW2019 launch.

The launch was well attended by various stakeholders, learners, educators from schools in the Kimberley area, as well as by students from the Sol Plaatjie University (SPU). International dignitaries from Kenya, Malawi and Mauritius were amongst the delegation. There was also an address on climate change by Dr Tendai Musvuugwa, a microbiologist from SPU who highlighted the effects of climate change on animals forced to migrate because of the rising of the sea level. After the talk on the effects on climate change, the Minister of Higher Education, Science and Innovation, Dr Blade Nzimande, delivered a keynote address, and one of the key factors he emphasised was innovation. He mentioned that South Africa needs to beneficiate its own minerals and refrain from being a country that constantly exports.

The Department of Higher Education, Science and Innovation hosts an annual science camp for girls to introduce them to science research and to demonstrate that the field of science is open both to men and women.

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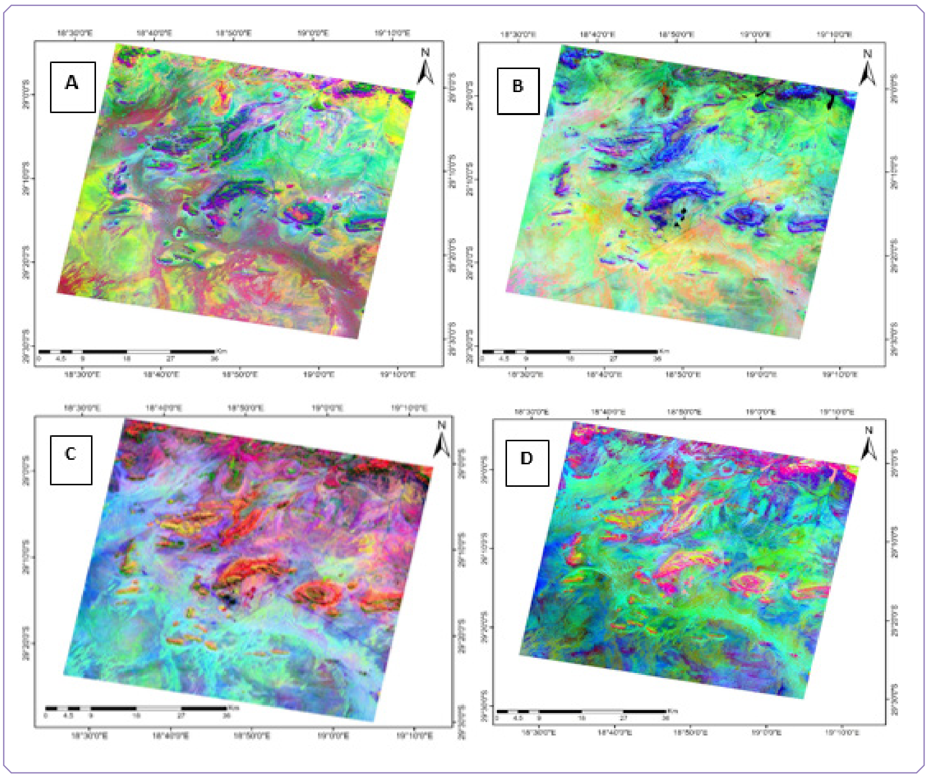
Council for Geoscience wins JOGMEC/ SADC competition in Botswana

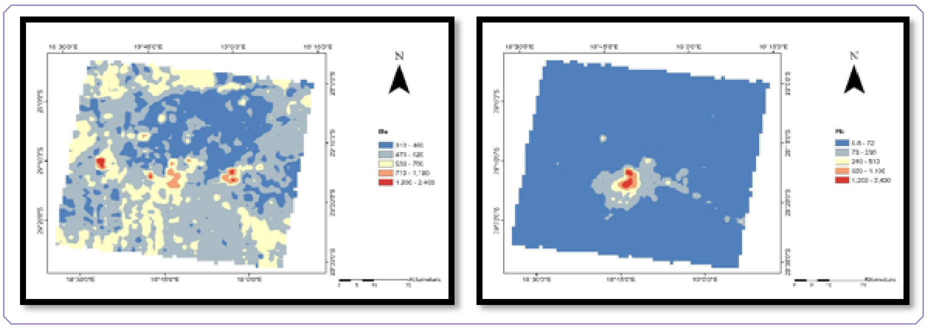
JOGMEC, the Japan Oil, Gas and Metals National Corporation has been hosting the annual JOGMEC competition, seminar and workshop for SADC countries since 2009 to transfer remote sensing technical skills to geologists and exploration experts and to verify the capability of remote sensing data in mineral exploration.

The seminar and workshop took place in Lobatse, Botswana and was attended by 13 SADC countries. The countries represented were South Africa, Botswana, Namibia, Tanzania, Lesotho, Malawi, Zimbabwe, Angola, Mozambique, Zambia, Eswatini, Madagascar and the Democratic Republic of the Congo. The JOGMEC competition lasted for four days with a one-day seminar and was facilitated by Rentaro Shimizu (Assistant General Manager), Satoshi Yoshimaru (Geologist, JOGMEC) and Molatlhegi Moseki (Geologist and Certified Instructor) of the Botswana Geological Remote Sensing Centre. The theme for the competition was free analysis and competitors were given the option to choose their area of interest not only in their own country, but also in other countries of the world. JOGMEC provided the satellite sensor data covering the area of interest to the participants on the first day of the competition. The teams processed the data during the competition and presented an oral account of the outcomes from the satellite data analysis in the SADC seminar. Three delegates from the Council for Geoscience, Noluvuyo Dudumashe (Geophysics and Remote Sensing), Hakundwi Mandende (Geoscience Mapping) and Neithel Mashiane (Economic Geology and Geochemistry) attended the competition and seminar held from 28 October to 1 November 2019. Two other delegates, Matome Sekiba and Zininzi Phikiso, attended the seminar and workshop.

Dr N. Ishikawa (left) and Dr K. Hirose (right) presented the trophy and certificate to Neithel Mashiane, Noluvuyo Dudumashe and Hakundwi Mandende as the winners of the competition.



Some of the remote sensing results. (A) Principal component analysis (PCA), (B) Gossan ratio (blue), (C) Iron-oxide ratio (yellow), (D) Minimum noise fraction on ASTER to delineate areas associated with SEDEX mineralisation.



Distribution of Ba and Pb in soil data using inverse distance weighting.

The title of the case study was “The sensitivity of remote sensing data in mineral prospecting with reference to Zn-Pb-Cu in the Gamsberg–Aggeneys”. The reason behind choosing this particular case study was that the Gamsberg–Aggeneys ore district has economic potential for the exploration of SEDEX deposits. This area is characterised by four major Pb-Zn deposits with a long history of exploration using conventional geological methods. The aim of the study was to demonstrate the capabilities of optical multispectral ASTER (VNIR + SWIR) and Landsat data in mineral prospecting for Zn-Pb-Cu in the Gamsberg–Aggeneys area. The objectives were digital processing of Landsat and ASTER data using various band ratios subjected to different methods of spectral indices, to determine the spectral signatures of known Zn-Pb-Cu occurrences, to delineate new target areas with signatures comparable to the known mineralisation for continued research and exploration and to evaluate remote sensing techniques for mineral exploration.

The results of the remote sensing data were supported by the known geology and geochemistry of the area. A predictive knowledge-driven model based on four parameters, base metal bearing lithologies, gossans, alteration indices and thrust faults, was derived. The model outlined known mineral deposits in the area (Gamsberg–Aggeneys–Swartberg). New target areas were predicted in which all four parameters were met. It is recommended that the new target areas be investigated at a local scale to obtain high-resolution geophysical data.

The team from South Africa won the competition for the first time, with second place obtained by Namibia, and Zimbabwe and Tanzania obtaining third and fourth place, respectively.

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Other building stones of the Union Buildings: granite and norite

Although sandstone is the main stone used for the construction of the Union Buildings, some structural and aesthetic use of granite and norite also took place. An amount of about 400 m^3 of granite is said to have been used mainly on the plinth of the building.

(a) Granite visible in the plinth of the Union Buildings in the public parking area. (b) Granite with sandstone railings on the steps leading from the public parking space in front of the Union Buildings to the upper area. (c) Red granite (possibly syenite) columns used in the Station Building. Mined from Hammanskraal, north of Pretoria. Annual Report of the Geological Survey for 1910. (d) Google Earth image of a red syenite quarry south of Hammanskraal on the farm Klipdrift 116JR that likely supplied building stone for the columns used in the old Station Building and the Union Buildings.

Archaean granite

In the 1910 Geological Survey Annual Report it is mentioned that the grey, medium-grained biotite granite blocks used for constructing the basement portion of the Union Buildings were Archaean granites from the Johannesburg dome taken from the Witkoppen area north of Johannesburg. The same granite, with a slightly pinkish tint, was quarried at Halfway House for use in the old Station Building in Pretoria and later for the renovation of Church Square. Wybergh mentioned in 1932 that the workings at Witkoppen, Halfway House and some other granite quarries were conspicuous outcrops of large, rounded boulders and that, in only a few instances, solid granite was mined.

It would appear that granite was used for the stairs rising from the public parking area in front of the building. These stairs are unfortunately not accessible to members of the public. The use of granite in high traffic areas is accounted for by the higher abrasion resistance of the granite compared to the sandstone.

Granite/syenite

There is some controversy as to whether the rock used for the columns in the old Station Building as well as for the Union Buildings is indeed granite, as the rock used for the columns in the Station Building has also been described as syenite in some publications. On the 1:250 000-scale geological map sheets of the Council for Geoscience, an outcrop of syenite is shown south of Hammanskraal in the general vicinity where a syenite quarry, thought to have supplied the stone, is located. For the purpose of this article granite is used, as this term was generally used in most references.

Dr Kynaston mentioned in the supplement to the Explanation of Sheet 2 – Pienaars River Map, dated 1913, that low-quartz red granite columns were mined for use in the Union Buildings from a site next to the railway line approximately three miles south of Hammanskraal. This most likely refers to the same locality mentioned in the Annual Report of the Geological Survey for 1910 from where the red granite used for the first time to construct the columns of the old Station Building in Pretoria, was sourced.

During 2006, the author visited an abandoned quarry of red syenite on the farm Klipdrift 116JR, south of Hammanskraal. This is most likely the quarry that would have supplied the building stones mentioned above. According to the then farm owner, mining took place as late as 1994.

(a) Broken blocks of syenite strewn across the workings (photo: R. Opperman, 2006). (b) Photo showing possible red granite columns used on the ground floor **of the central court**. (c) Bon Accord norite quarry, north of Pretoria. Annual Report of the Geological Survey for 1910. (d) Norite fireplace and column (behind backrest of the chair) in the President's office as in 1989. (e) The International Conference Centre in a publication commemorating the 75 year anniversary of the Union Buildings showing the black norite columns at the centre of the picture. (f) Norite kerbstone showing smoothed surface due to heavy pedestrian traffic.

In 1910, describing the central court of the Union Buildings, William Lucas stated "Giving relief to the masses of red freestone, on the lower floor are double columns (single on face) of finely-wrought, but unpolished, red granite, supporting arches; while on the upper floors are triple columns (double on face), in one instance with arches and in the other with lintels; …". Photo B seems to fit this description closely and the lighter coloured columns of the ground floor are therefore likely red granite. William Lucas also made reference to red granite used for the columns and handrail for the main staircases of the double flights of stairs in the courtyards.

Norite

The main source of norite used in the Union Buildings was the Bon Accord Quarry north of Pretoria.

Wagner, in 1924, mentioned that some columns in the congress hall and in the President's office, as well as a fireplace in the President's office had been constructed using norite from the Bon Accord Quarry.

In the Official Year Book of the Union, no. 1 – 1917, mention is made of a circular conference room, 50 feet in diameter with a domed ceiling where "the galleries – carried on polished granite columns – are designed for ladies and distinguished visitors". In early industry (even commonly today), norite was often referred to incorrectly as granite. Wagner, in 1924, correctly spoke of norite and Photo E from a publication commemorating the 75 year anniversary of the Union Buildings is almost identical to the black-and-white photo of Wagner's 1924 publication, showing the norite columns in what was then called the conference chamber.

In addition, the kerbstones of the parking area in front of the building also comprises rough-dressed norite, in similar fashion to the norites still visible in places in the old city centre of Pretoria. Years of pedestrian traffic have smoothed the kerbstone surfaces quite a bit, showing one engineering property of norite – although it is a very competent rock suitable for aggregate, railway ballasts, etc., norite surfaces exposed to wear tend to smooth and polish easily. This can result in reduced skid resistance, therefore norite is generally not favoured for being used as a wear course on the surface of tarred roads.

In conclusion, compared to some of the sandstone used for the construction of the Union Buildings, the granite and norite have aged very well and have proven to be very durable.

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