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Council for Geoscience

## INSIDE:



# The Council for Geoscience launches its new hyperspectral core scanner

In 2019, the Council for Geoscience (CGS) purchased a hyperspectral imaging (HSI) system that was delivered early in May 2020. Installation was completed by mid-June 2020, with operation starting immediately after installation at the National Core Library at Donkerhoek near Pretoria. The HSI is fitted with three cameras: a high-resolution natural-colour (RGB) camera, a co-registered VNIR-SWIR (visible near infrared-shortwave infrared) camera (FENIX) and a LWIR (longwave infrared) camera (OWL). This three-sensor HSI scanner is the first of its kind on the African continent.

Training on spectral data acquisition was conducted for a period of one week, starting on 29 July 2020. The first drill core to be scanned was the Bellevue core from the Bushveld Complex (ca 2.95 km deep) and the resulting dataset was used for training purposes. Prioritised boreholes related to the Geoscience Technical Programme are currently being scanned and processed with spectral interpretation having been completed for some of the core.

The CGS hyperspectral core scanner is able to scan full core, slabs, rock chips and soil samples. A data processing workshop using TerraCore's Intellicore platform is currently underway.

**Description of the sensors**

The RGB (true colour) provides the highest spatial resolution imagery, which delivers detailed rock textural information. The image products generated by this sensor can also be used as a reference to all imaged core, even when the physical core has been discarded or can no longer be located due to unforeseen circumstances.

The VNIR has limited detection capabilities on its own, but is invaluable in the identification of minerals when


Hyperspectral core scanner housed at the National Core Library showing three spectral sensors (RGB, SWIR and LWIR).

measured across other wavelength ranges. The SWIR is important in identifying and discriminating the phyllosilicate and clay minerals; most alteration haloes are detected within this wavelength range.

The LWIR identifies primary or rock-forming minerals such as tectosilicates, amongst others. In combination, these ranges provide a good mineral detection system.

### Application of HSI data

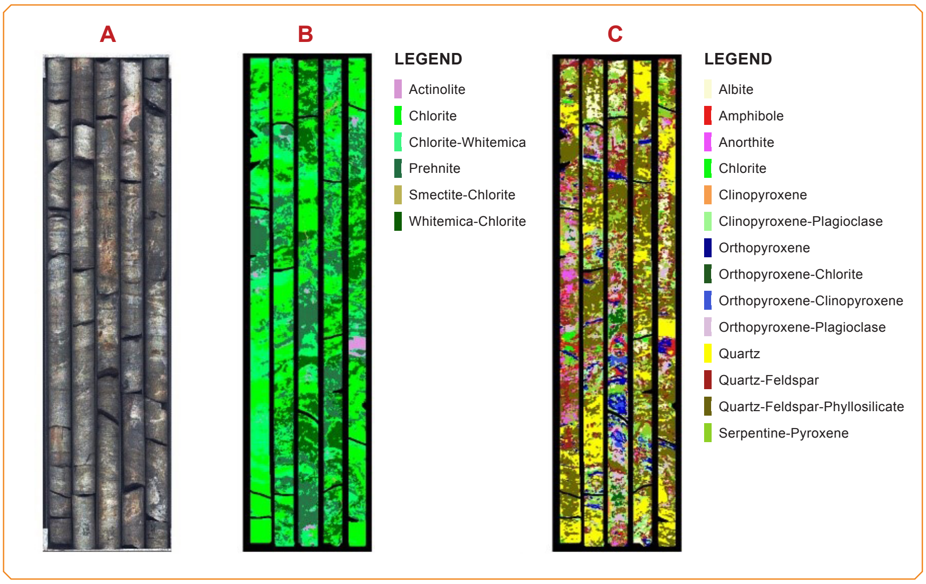
Hyperspectral technology is non-destructive and non-invasive and provides a highly repeatable analytical measurement. It also allows for high volumes of material to be scanned within a reasonable amount of time, for example, over 500 m of drill core can be scanned within a day. The technology can be adopted at various stages/processes throughout the project to identify mineral products. The stages include:

- Exploration phase of the project — the data can be used for the identification of mineralogical and alteration zones related to exploration projects and the characterisation of minerals in terms of their chemical composition, texture and association with other minerals.

- Geological characterisation — hyperspectral data results can be used to aid in discerning lithological boundaries, based on the dominant mineralogy in each interval. In addition, areas of differing alteration can be detected, which may provide clues in regard to fluid composition and fluid pathways within the body.

- Production — often geometallurgy involves materials that are detrimental to recovery, for example, swelling clays and other minerals, such as talc. Hyperspectral imaging provides the detection capabilities to identify and characterise most minerals that have proven to be problematic in mineral recovery plants.

The CEO welcoming and introducing delegates of the Central African Republic to the CGS team at the National Core Library.




Some of the image products generated from the three HSI sensors using IntelliCore. The core tray is from the Bellevue borehole BV1. A: RGB image, B: VNIR-SWIR mineral map dominated by a chlorite-white mica-prehnite alteration assemblage, C: LWIR mineral map dominated by primary silicate minerals (quartz, feldspar and pyroxene).

Hyperspectral imaged data are readily available in different formats after processing, such as image data for visualisation (mineral maps — jpeg/png) and digital data (report file format — csv). The product format can be integrated into other software packages such as 3D modelling software.

### Official launch of the hyperspectral core scanner

The scanner was officially launched by the CEO of the CGS, Mr Mosa Mabuza, early this year. The launch was attended by delegates from the Central African Republic (CAR) and the CGS Marketing and Stakeholder Relations team, along with scientists and technical officers.

The launch was followed by a demonstration of the functions and applications of the hyperspectral core scanner. CAR delegates were also taken on a tour of the two warehouses at Donkerhoek.


Clement Ndou (Spectral Geologist at the National Core Library) demonstrating the applications of the HSI to the CAR delegates.

*Selected mineral groups and their spectral responses (source: TerraCore)*

| | Structure | Group | Example | VNIR response | SWIR response | LWIR response |
|---|---|---|---|---|---|---|
| Silicates | Inosilicates | Amphibole | Actinolite | Non-diagnostic | Good | Good |
| | | Pyroxene | Diopside | Good | Moderate | Good |
| | Cyclosilicates | Tourmaline | Dravite | Non-diagnostic | Good | Moderate |
| | Nesosilicates | Garnet | Andradite | Moderate | Non-diagnostic | Good |
| | | Olivine | Forsterite | Good | Non-diagnostic | Good |
| | | Zircon | Zircon | Good | Non-diagnostic | Non-diagnostic |
| | Sorosilicates | Epidote | Clinozoisite | Non-diagnostic | Good | Moderate |
| | Phyllosilicates | Mica | Muscovite | Non-diagnostic | Good | Moderate |
| | | Chlorite | Clinochlore | Non-diagnostic | Good | Moderate |
| | | Clay minerals | Illite | Non-diagnostic | Good | Moderate |
| | | | Kaolinite | Non-diagnostic | Good | Moderate |
| | Tectosilicates | Feldspar | Orthoclase | Non-diagnostic | Non-diagnostic | Good |
| | | | Albite | Non-diagnostic | Non-diagnostic | Good |
| | | Silica | Quartz | Non-diagnostic | Non-diagnostic | Good |
| Non-silicates | **Carbonates** | Calcite | | Non-diagnostic | Moderate | Good |
| | | Dolomite | | Non-diagnostic | Moderate | Good |
| | Hydroxides | Gibbsite | | Non-diagnostic | Good | Moderate |
| | Sulphates | Alunite | Alunite | Non-diagnostic | Good | Moderate |
| | | | Barite | Non-diagnostic | Non-diagnostic | Good |
| | Borates | | Borax | Non-diagnostic | Good | Uncertain |
| | Halides | Chlorides | Halite | Non-diagnostic | Moderate | Uncertain |
| | Phosphates | Apatite | Apatite | Moderate | Moderate | Good |
| | Hydrocarbons | | Bitumen | Non-diagnostic | Good | Uncertain |
| | Oxides | Hematite | | Good | Non-diagnostic | Non-diagnostic |
| | | Spinel | Chromite | Non-diagnostic | Non-diagnostic | Non-diagnostic |
| | Sulphides | | Pyrite | Non-diagnostic | Non-diagnostic | Non-diagnostic |

Core boxes on the roller table ready for scanning.

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# National Core Library and core logging — taking geology back to basics

Core logging is the systemic cataloguing of information pertaining to the subsurface lithology (i.e. texture, mineralogy, structure and alteration zones). Consequently, the importance of drill core samples cannot be overemphasised. With explorers searching for new mineral deposits across the span of the country, drilling may be a slow and expensive endeavour. It is roughly estimated that drilling only 300 m could cost in the vicinity of R1.5 million. This estimate is based merely on the drilling-related costs from the drill rig to the laboratory analyses. Hence, core repositories such as the National Core Library (NCL) at Donkerhoek near Pretoria in Gauteng have become a crucial data hub. The NCL serves as the State's repository for archiving subsurface lithologies and earthen material core samples collected during mineral exploration and engineering and geoscience research programmes across the country. The NCL has attracted a worldwide audience, from researchers and mineral explorers to engineers who reuse existing core samples to develop novel ideas about the country's mineral resources, the capacity of the geology of South Africa, and to model the geological forces and features that have shaped the crust.

The NCL, consisting of a warehouse-sized shed, has separate sites for viewing drill core samples and maintains corresponding data files containing location maps, geological descriptions and geophysical and geochemical information. The NCL houses nearly a million metres of drilled core samples archived by and donated to the CGS from numerous mineral exploration and mining projects undertaken in the country over several decades. Other samples are from land use, governmental and scientific academic research. Additionally, the NCL hosts the new SisuRock hyperspectral scanner, a rapid spectroscopic logging and imaging system that uses continuous VNIR-SWIR, OWL LWIR (400–12 000 nm) spectroscopy and digital imaging to noninvasively examine core, samples and cuttings. The SisuRock hyperspectral scanner is used as a complementary tool for logging as it allows for the immediate identification of the mineralogy of the core.

The material in the NCL has contributed to the discovery of many significant valuable mineral deposits, has advanced and increased the life of several mines, and provided water to numerous communities. Moreover, as a result of the core being reusable in exploration programmes, scientific academic research and other engineering projects, this has mitigated the need for additional drilling, thereby reducing environmental disturbances. The Carbon Capture, Utilisation and Storage (CCUS) project is another example of the significance of the NCL and core logging. CCUS is a relatively novel programme in South Africa. Simply put, CCUS is the process of capturing unwanted $CO_2$, transporting and injecting it into a deep-seated reservoir rock where it will be permanently stored thereby mitigating $CO_2$ leakage to the atmosphere. Through the identification and logging of previously collected drill core samples stored in the NCL, the northern portion of the Highveld coalfields was determined, from the geology and its proximity to a single point source emitter of $CO_2$, as an appropriate region for the CCUS pilot project.


(a) The National Core Library shed where a vast repository of drill core (b) is stored.


Logging of the Ventersdorp Supergroup drill core obtained from the Highveld coalfields.

### Logging of the Ventersdorp Supergroup drill core obtained from the Highveld coalfields

The northern portion of the Highveld coalfields presents unique geology where potential storage is the basaltic rocks of the Ventersdorp lava. Extensive exploration work has been undertaken in the area. As a result, a wealth of information, in addition to drill core data and seismic acquisitions, is at the project's disposal in the NCL. To date, over 22 boreholes with a cumulative depth of ca 28 000 m have been identified and physically logged. The logging process has contributed directly towards the rapid characterisation of the potential storage basin. The results of the logging process have highlighted thick agglomeratic mafic-ultramafic sequences of the Ventersdorp Supergroup that may form an ideal target reservoir. Furthermore, these sequences are overlain by numerous finer-grained and porphyritic phases and lava that appear to form impermeable seals. The logging process has also identified extensions of the underlying Witwatersrand Supergroup and younger intrusive rocks of the Bushveld Complex. The work has highlighted the importance of going back to basics by undertaking borehole logging and will play a crucial role in South Africa attaining its national development imperatives.

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# Carbon capture, utilisation and storage in South Africa

**Introduction**

South Africa has a coal-based energy economy and emits carbon dioxide of more than 400 million tonnes per year into the atmosphere. Recognising the anthropogenic effect on global climate change, the country has committed itself to undertake steps to minimise such emissions in concert with other nations. Notwithstanding the recent advances made in the deployment of energy-efficiency measures and renewable energies, it is envisaged that coal will remain a significant component of primary energy supply.

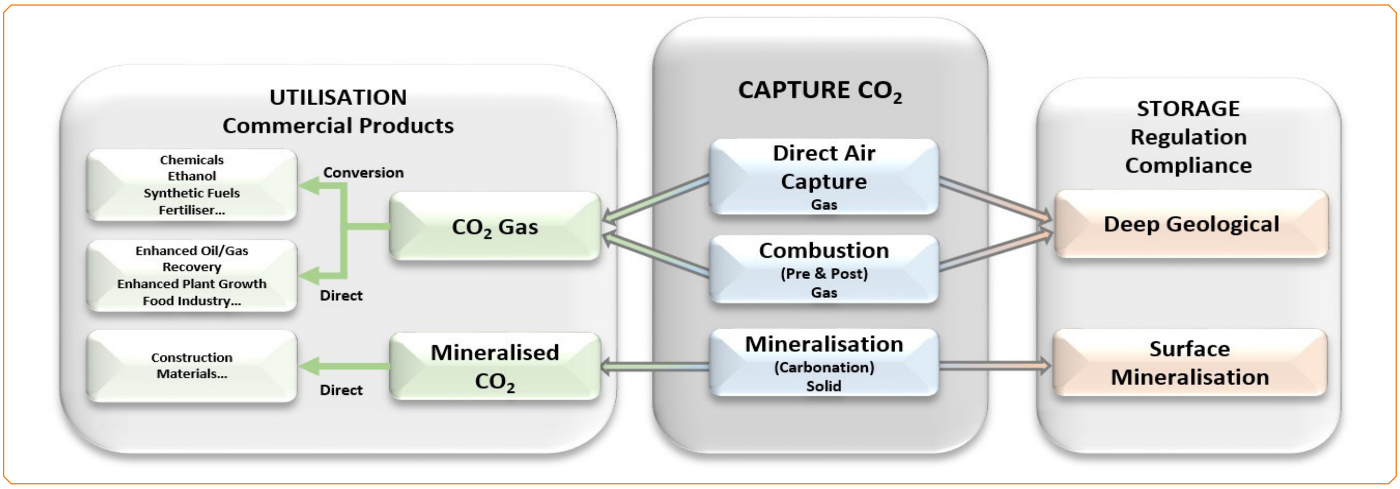
South Africa recognises carbon capture, utilisation and storage (CCUS) as a technology which can be harnessed to mitigate the emission of carbon dioxide into the atmosphere and which forms one of the Nationally Appropriate Mitigation Actions (NAMAs) of the country. CCUS is also one of the National Flagship Projects specified in the South Africa National Climate Change Response White Paper. Hence, CCUS is an enabler for a Just Transition to a future low-carbon energy economy.

**Conceptualisation of CCUS**

Once captured, the high-concentration carbon dioxide may be used for two applications:

- *Storage – regulatory compliance:* Globally, the most common application is for regulatory compliance. This typically takes place when the licence to operate an industry depends on limiting carbon dioxide emissions. Currently, deep geological structures and areas of mineralisation are being investigated in South Africa to assess their suitability for the storage of carbon dioxide. Storage is a cost with a negative impact on the "bottom line".

- *Utilisation – commercial products:* It is possible to use carbon dioxide as a feedstock to produce saleable products. However, this use relies on an energy input to achieve such an objective. The use of renewable energy in this case ensures minimal net carbon dioxide emissions as well as overcoming one of the hurdles of renewables, namely storage.




Modalities of carbon capture, utilisation and storage.

### Pilot $CO_2$ storage project

South Africa embarked on a carbon capture and storage (CCS) programme during 2004 when it was identified that the country had capturable emission and storage opportunities. At a workshop held during 2006 at the CGS, geological storage was identified as a focus area. Without safe and permanent storage, CCS would not be a viable option to mitigate $CO_2$ emissions. Hence, an Atlas on the Geological Storage of Carbon Dioxide in South Africa compiled by the CGS was published, followed by a detailed geological report. The atlas indicated a theoretical geological storage capacity of 150 gigatonnes, of which ~98% was located offshore. The storage quantity supported further investigation for the purpose of CCS in South Africa.

Consequently, a pilot carbon dioxide storage project was initiated, the main purposes of which entailed a "proof of concept" for such an endeavour in South Africa and building human and technical capacities.

The site of the pilot carbon dioxide storage project was chosen to be onshore as such a location offered lower cost than an offshore site as well as access for capacity-building activities. The onshore basins of Algoa and KwaZulu-Natal were investigated with the latter eventually being selected.

The goal of the South Africa Pilot Carbon Dioxide Storage Project (PCSP) is to carry out small-scale carbon dioxide injection, storage and monitoring that include injection of ca 10 000–50 000 tonnes over a two-year period, with monitoring activities to extend beyond injection. The storage location is a previously selected onshore Mesozoic sedimentary basin (geologically termed the Zululand Basin) which lies beneath the uMkhanyakude District Municipality in northeastern KwaZulu-Natal.

These characterisation efforts integrate the legacy data from the basin to identify potential carbon dioxide pilot storage sites and to create the framework for the geological modelling efforts. Characterisation activities reduce uncertainty related to the entire process of generating a permit-ready pilot carbon dioxide storage site, from basin down-selection to selected subareas to a proven site.

Two sites were identified and a field rollout dependent on stakeholder clearance was envisaged.

### Utilisation of $CO_2$

Whereas the storage of carbon dioxide is a regulatory compliance matter with its associated costs, the utilisation of carbon dioxide as a feedstock can be developed into a commercial venture. With the PCSP underway, attention is now being given to utilisation. Globally, most carbon dioxide is utilised for enhanced oil/gas recovery and the production of urea. In South Africa, the following have been identified as possible technologies:

a) Direct utilisation – enhanced plant growth, food/beverages, wastewater treatment, concrete curing, enhanced oil/gas recovery.

b) Conversion – synthetic fuels (for which South Africa already has a well-established industry based on coal/gas), chemicals, fertilisers. The use of renewable energies will further mitigate $CO_2$ emissions be instrumental in overcoming a major hurdle for renewables, namely storage.

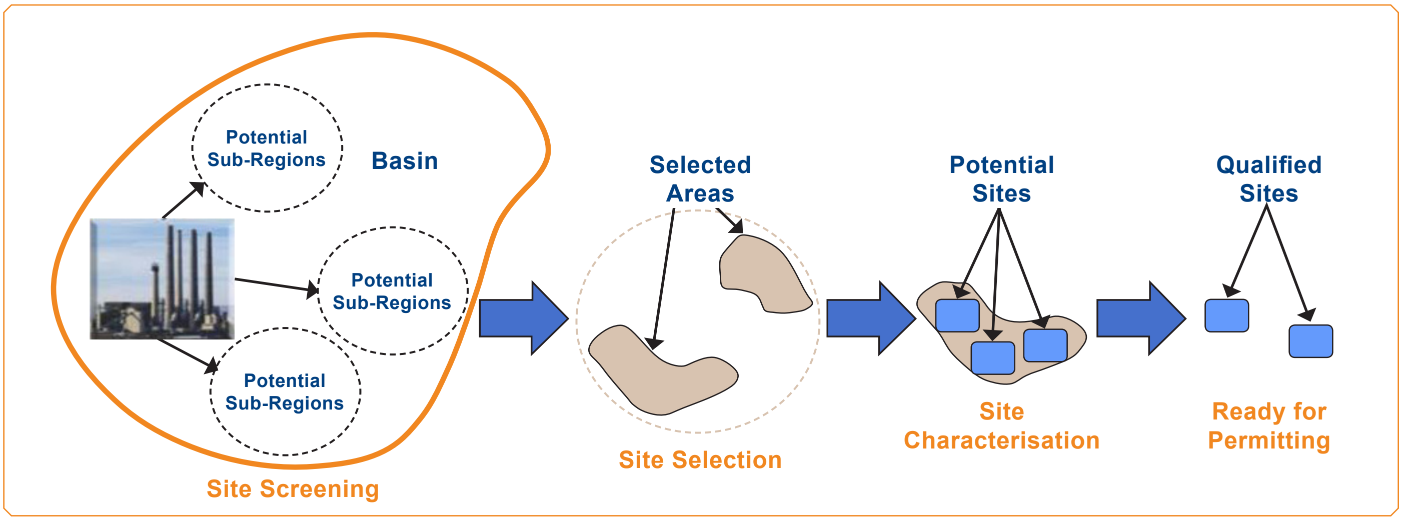
c) Mineralisation – Construction materials.

Based on previous preliminary work undertaken, the South African CCUS programme has the following main features:

a) Market assessment;
b) International commercial examples;
c) Selection of appropriate products/ technologies through stakeholder engagement; and
d) Implementation of a commercial pilot plant.

### Transfer to the CGS

In March 2020, the Minister of Mineral Resources and Energy authorised the transfer of the CCUS programme from the South African National Energy Development Institute (SANEDI) to the




Down-selection process from site (basin-scale) screening to verification of qualified sites that are ready for permitting.

CGS. The transfer was completed on 1 September 2020. This is a logical step as SANEDI had been working with the CGS throughout the CCS programme. The move has resulted in extra staff available to work on the programme. Moreover, it has led to two major revisions in the CCUS programme:

a) Since the launch of the original atlas, the CGS has undertaken further geological analyses indicating additional possible geological storage sites. Consequently, the PCSP has been moved from KwaZulu-Natal Province to Mpumalanga Province – closer to the source of point $CO_2$ emissions.

b) The following technologies — enhanced coal-bed methane, underground coal gasification and enhanced geothermal energy extraction have been added to the scope of the utilisation under investigation.

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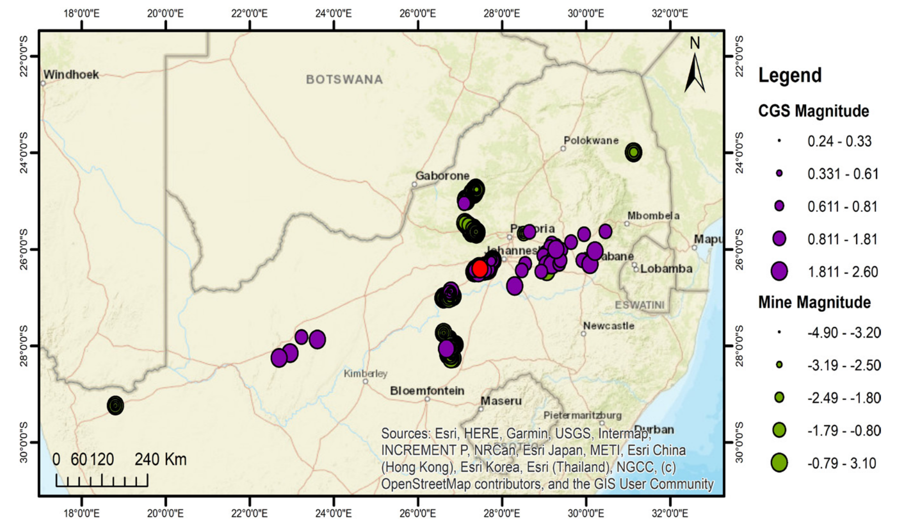
# The intensified monitoring of seismicity in response to the Amendment of Regulations of the published National Disaster Management Act of 2002

The Seismicity and Rockfalls Ad Hoc Committee was established in response to the Amendment of Regulations of the published National Disaster Management Act of 2002, gazetted on 16 April 2020 — in particular regulation 11K (3) which stipulates that “the monitoring and impact of seismicity through the Council for Geoscience must be intensified with immediate effect”. The committee consists of representatives from the Mine Health and Safety Council (MHSC), the Council for Geoscience (CGS), the Minerals Council, the Department of Mineral Resources and Energy (DMRE), AngloAmerican, Sibanye Stillwater and AngloGold Ashanti.




Map of the epicentral locations in the mining regions of the country for the period 1–7 February 2021 from the mines and the CGS. The largest seismic event (magnitude 3.1) located by the mining industry occurred in the FWR mining region and is indicated by the red circle.

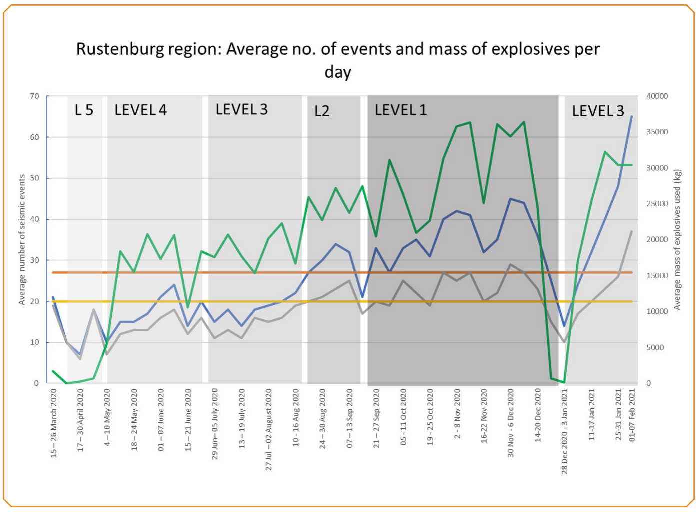
The committee utilised the DMRE and Minerals Council databases to contact mines that have seismic monitoring capabilities and requested them to share seismic and blasting information with the CGS. The data are captured on templates compiled by the CGS. The mining companies have been uploading the requested data onto the CGS’s File Transfer Protocol (FTP) site every Monday at 12:00 since the amendment of the regulations.

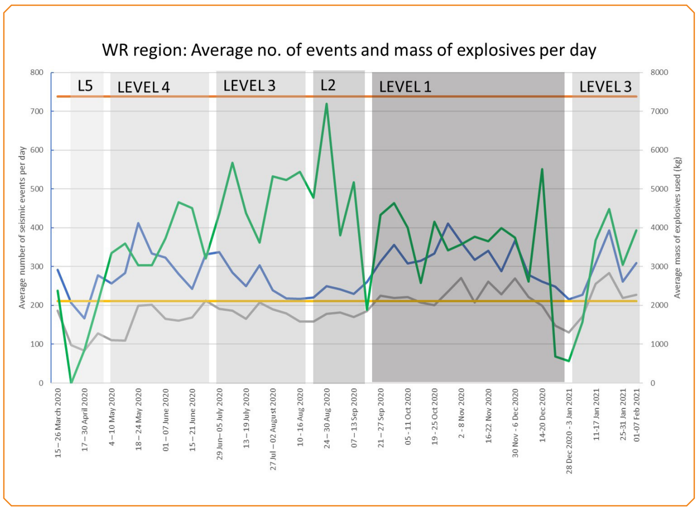
There are currently 29 mining operations that submit their blasting and seismic information to the CGS on a weekly basis and the initial data obtained date back to 15 March 2020. In order to set a baseline, the mines have been requested to submit data from January 2020 before the COVID-19 lockdown.

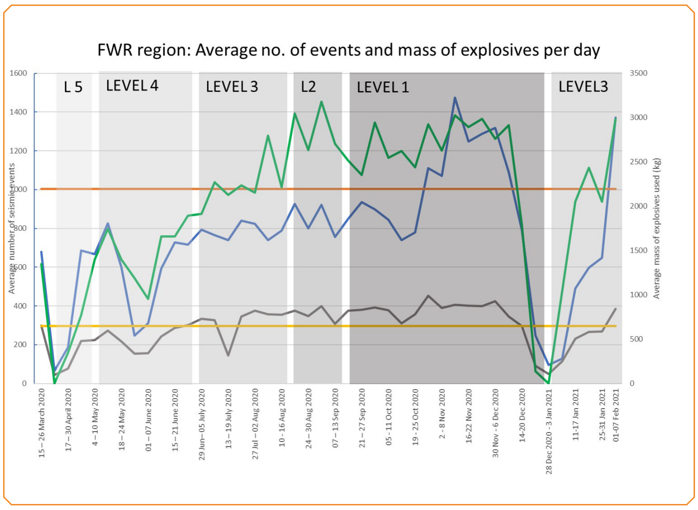
Data from the mines are combined with data from the CGS by first correlating the two catalogues chronologically. The duplicates (from the CGS) are removed and the mining events are retained because of their high level of accuracy as a result of the proximity of their respective stations to the events.

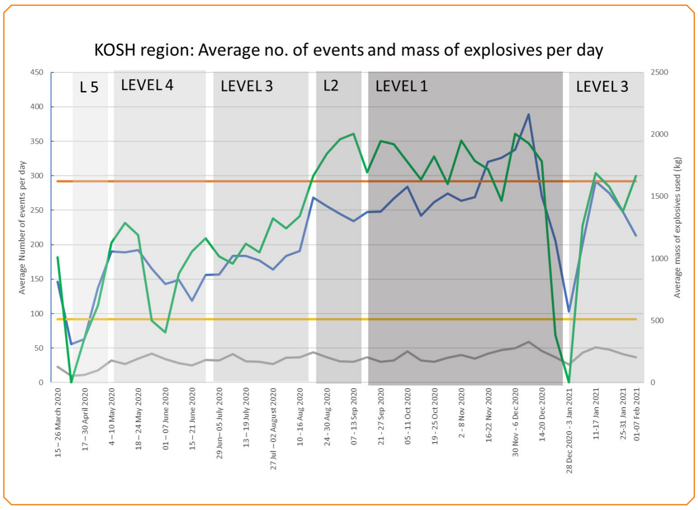
The data are analysed and filtered, and presented in weekly reports addressed to the Minister of the DMRE. In addition, the report is shared with the mining industry to gauge stakeholders’ opinions on the observed patterns and to solicit their recommendations.

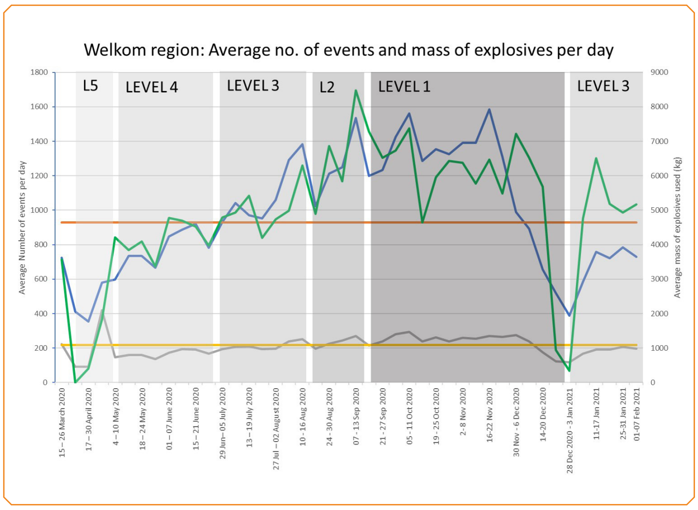
Typically, the range of magnitudes recorded by the mining industry every week is between -4.9 and 3.1. A seismic event of magnitude 3.1 occurred in the Far West Rand (FWR) mining region




**Legend**

- Baseline for entire magnitude range
- Baseline for magnitudes ≥ - 2
- Number of events for entire magnitude range
- Number of events for magnitudes ≥ - 2
- Mass of explosive (kg)

Comparisons of the average mass of explosives used per day with the average number of seismic events per day for the Rustenburg, WR, FWR, KOSH and Welkom regions.

and was recorded by the Mponeng mining operation. The seismic event was located outside the mine borders. There was a difference between the mining event and CGS data of 2.8 km in location and 0.09 km in depth. The magnitude of the seismic event measured by the CGS was 2.66. The range of magnitudes recorded by the CGS every week typically varies between 0.24 and 3.22.

The different magnitude ranges recorded by the mines and the CGS are mainly attributable to the proximity of the instrumentation to the seismic events being recorded. Thus, the mines are able to record magnitudes of up to -4.9, although not regularly, because their instrumentation is closer to the seismic events.

Owing to their local coverage, resources and dense networks, the mines are able to detect considerably more events than the CGS and the mines are able to locate events at much lower magnitudes than the CGS. However, after consultations with the mining industry, it was noted that the seismic systems deployed within the mining operations typically have a threshold magnitude of -2 across their operations and, thus, it was suggested that the number of seismic events above a threshold of magnitude -2 also be examined to obtain a more representative figure across the regions.

The graphs display the average number of seismic events (compared to the baseline) recorded per day in the Rustenburg, West Rand (WR), Far West Rand (FWR), Klerksdorp–Orkney–Stilfontein–Hartebeesfontein (KOSH) and Welkom mining regions, respectively. In addition, they include the average number of seismic events with magnitudes greater than and equal to -2 (compared to the baseline), the average amount of explosives used and the levels of lockdown imposed by the government in response to the COVID-19 pandemic.

When examining the average amount of explosives used per day, it is clear that the patterns observed in the seismicity are driven by the blasting activities, especially for the seismic events of all magnitudes. This is especially obvious when examining the blasting data for Rustenburg and the FWR, which report rates that are close to the maximum values reported in 2020. However, the seismic events of magnitudes greater than and equal to -2 seem to be fairly constant and less affected by the blasting activities.

The drop in activity in April 2020 and late December 2020 is correlated with the dates during which the mines were non-operational. The fluctuations in seismicity for January 2021 show similar trends to the observations during April and May 2020, especially in the KOSH, Welkom and WR mining regions. This is to be expected, as these are the periods when the mines restarted their operations.

The patterns observed in the FWR and Rustenburg mining regions differ from those observed in April and May 2020 and, although the initial pattern is similar, they display a steep increase in seismicity. Once again, this may be attributed to the fact that the blasting activities within the mining region are also much higher than in April and May 2020. Interestingly, Rustenburg records seismicity that is much higher than the highest recorded number of seismic events since 15 March 2020 within the region.

The DMRE regularly uses information produced within these reports to gain an understanding of the seismicity within the regions. The data provide an opportunity to compare the trends between different periods and to query any inconsistencies that are noted.

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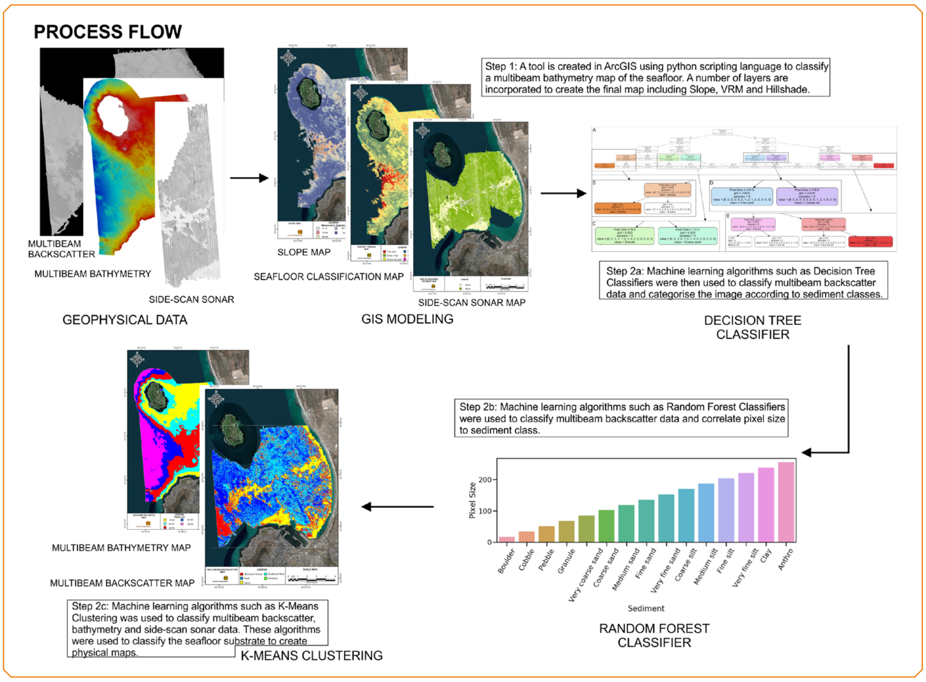
# Merging geoscience and biological science with machine learning: a marine mapping context

A project to map seafloor substrates using machine learning, based primarily on geophysical data including multibeam bathymetry, backscatter and side-scan sonar, has been undertaken to produce a custom-designed benthic habitat classification method that digitally integrates marine geophysics and biological science data, with relevance to all elements of the local substrate. This was the first time such a method was attempted in a South African context. The benefit is that human error is reduced and efficiency in processing time is enhanced. The algorithm is able to produce "automated" biophysical

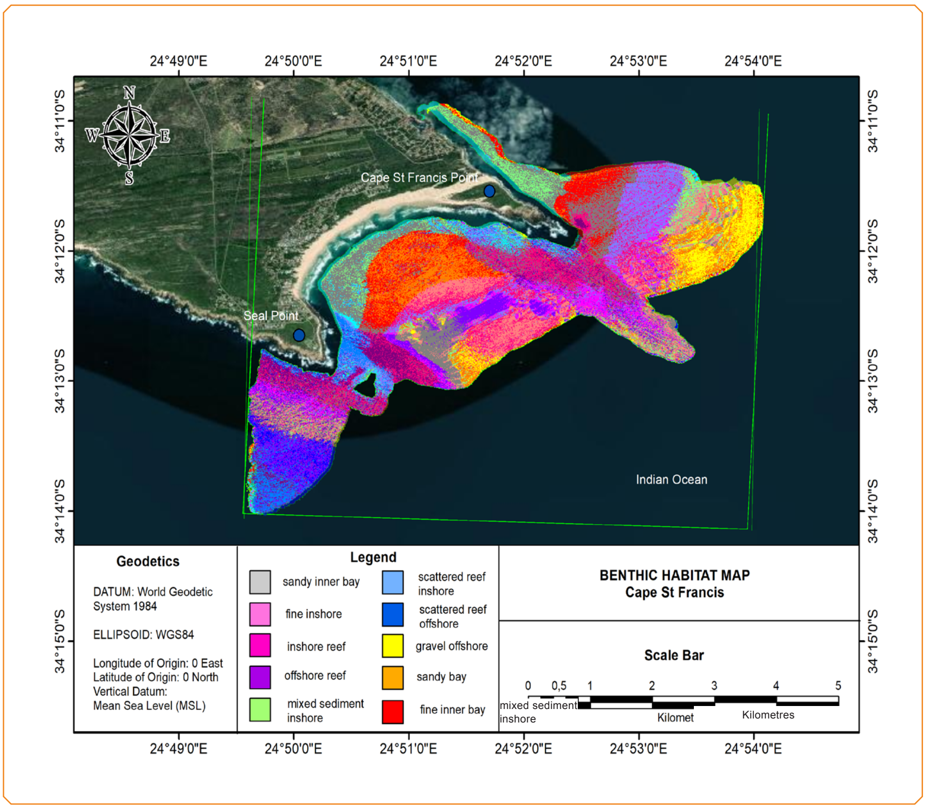



Overview of the methods described to classify the side-scan sonar, multibeam bathymetry and multibeam backscatter data.

benthic habitat maps and this will be extended along the continental shelf of South Africa as new datasets are collected and the algorithm is supplemented.

From the outset, this work has focussed on broad categories of rock and detailed categories of sediment. Four study sites with varying substrates and in different settings were selected to holistically build the algorithm that followed a tiered machine learning approach. The sites were Table Bay, Clifton, Koeberg Harbour and Cape St Francis. Table Bay was used to develop a new method of physical seafloor classification by comparing and contrasting a number of statistical algorithms and software programs. Clifton was used to test the developed clustering algorithm and Koeberg, which is 35 km to the north, was used to validate the algorithm because sediment samples, along with drop-camera footage, were integrated to better define the results. The resulting verified algorithm was tested at Cape St Francis, where Remotely Operated Vehicle (ROV) footage was acquired in addition to geophysical data. In the first phase of the process towards developing an algorithm, a customised tool was created within ArcGIS using python scripting language to classify seafloor bathymetry, which can be applied to any area of seafloor. The tool was based on pioneering work done by the National Oceanic and Atmospheric Administration (NOAA) on a benthic terrain modelling toolbox and adapted to include side-scan sonar data.

In the second phase of work, multibeam bathymetry, backscatter and side-scan sonar data that were processed using Qimera, Fledermaus Geocoder Toolbox and Navlog processing software were classified using different machine learning techniques, including Decision Trees, Random Forests and k-means clustering computer algorithms. The results from these algorithms were compared with manually digitised polygons which had been created to classify the seafloor substrate distribution by indicating different textures. Integrating all results facilitated a quantitative comparison that illuminated advantages and




Benthic habitat map of the Cape St Francis study area.

disadvantages of each machine learning technique and, ultimately, the k-means clustering techniques were found to be the simplest to implement and understand. These techniques worked most efficiently, based on their seafloor segmentation capabilities in Table Bay, against all three geophysical datasets (multibeam bathymetry, backscatter and side-scan sonar).

In the third phase of work, ground-truthed seafloor characterisation maps were produced for the two study areas of Clifton and Koeberg Harbour. This was done by applying multibeam bathymetry and backscatter data collected and processed using machine learning clustering techniques. These maps were ground-truthed using drop-camera footage and the data were classified using the Collaborative and Automated Tools for Analysis of Marine Imagery (CATAMI) substrata classification scheme. Sediment grab samples were processed using a settling tube and formulae based on the statistics of Wentworth (1922) and Folk and Ward (1957). The resulting statistics were used to refine and define the sediment categories that were added into the clustering algorithm. The algorithm results show the distribution of sediment within the respective study areas and indicate that the majority of samples range from medium-grained to very fine-grained sand, and statistically range from very well sorted to moderately well sorted, with an overall negatively skewed trend. These findings corresponded well with actual sediment data. Repeat surveys were carried out at Koeberg Harbour, allowing for further enhancement of the algorithm and analysis of repeatability.

In the fourth phase of this work, multibeam bathymetry, backscatter and ROV footage were collected in Cape St Francis and the geophysical data were processed using machine learning clustering techniques that had been developed up to this point. The k-means clustering algorithm was used to map the distribution of sediment at different depths within the study area and ROV footage was classified using the CATAMI substrata classification scheme. ROV footage from eight dives along the three transects located off Seal Point were collected and ranged from 30–80 m in depth to identify biota to family levels. The most common Phyla in order from greatest to least abundance were Cnidaria, Mollusca, Echinodermata, various fish species, Crustacea, Bryozoa, and various sponge and ascidian species.

Using the multibeam bathymetry and backscatter maps that were classified using the k-means clustering algorithm, supplemented with the CATAMI classified ROV data, the first integrated benthic habitat map of the Cape St Francis seafloor revealed ten discrete habitat types. Any area of continental shelf mapped to this point, composed of these already-defined benthic habitats and substrate types, will be recognised by the algorithm. These results corroborate that a combination of different input datasets provide more reliable and accurate final map products, and that repeat geophysical surveys and surveys in areas with greater seafloor variability were integral to refining the algorithm at the outset and producing accurate seafloor maps. It is anticipated that the maps may be used to model biological communities and produce benthic habitat maps for use in marine science and management. On expansion of the algorithm, real-time delineation of habitats may eventually be realised.

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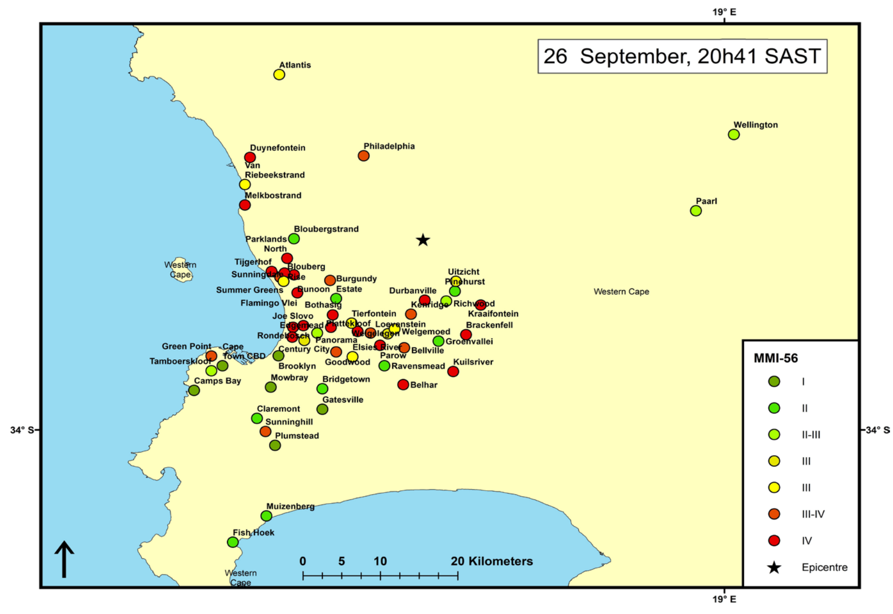
# The earthquakes that shook the southwestern Cape in September 2020

### Introduction

Following the occurrence of three earthquakes in the Western Cape region affecting the area around Cape Town in late September 2020, the Council for Geoscience (CGS) sent a team of scientists to conduct a three-day field survey to investigate the macroseismic effects of the events.

The first earthquake occurred at 20:41 South African Standard Time (SAST) on 26 September 2020. The event was located at coordinates -33.768°S; 18.650°E (determined by nine stations), about 4 km from Helpmekaar Quarry, north of Durbanville. This earthquake registered $M_L$ 2.6 on the local magnitude scale at a hypocentral depth of ~2 km, recorded by the South African Seismograph Network. The second earthquake was felt at 09:13 SAST on Sunday, 27 September 2020. This earthquake registered $M_L$ 2.4 on the local magnitude scale, with its epicentre located at -33.755°S; 18.686°E at a depth of 3.9 km (determined by nine stations), 5–6 km north of Durbanville. A few minutes later, a smaller earthquake of $M_L$ 1.7 occurred at 09:28 SAST at -33.789°S; 18.739°E at a depth of about 4.4 km near Fisantekraal outside Durbanville.




$M_L$ 2.6 earthquake of 26 September 2020 (20:41), first tremor.

### Methodology

Following the subsequent press releases by the CGS and reports in the media, the CGS received 91 questionnaires that were submitted via the CGS web service (http://www.geoscience.org.za/).

Prior to the field investigation, a desk study was carried out, accessing news reports via the Internet (including online newspapers) as well as telephone enquiries to various wine estates, small airfields, tourist venues, small towns, farms and local tourism offices. Local newspapers were also contacted. The CGS approached Eskom employees based at the Koeberg Nuclear Power Plant at Duynefontein and the National Disaster Management Centre in Cape Town to obtain as many online questionnaires as possible.

Ms Sinovuyo Myendeki and Mr Brian Zulu from the CGS carried out a field investigation and collected 46 and 29 questionnaires for the tremors on 26 and 27 September 2020, respectively. This brought the total to 166 usable questionnaires.

**Results**

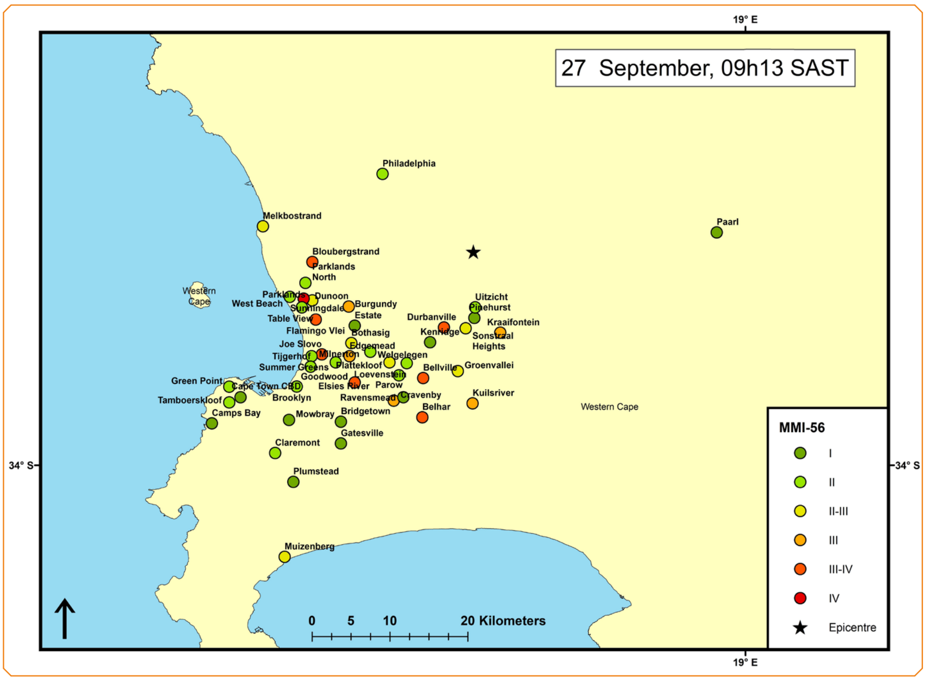
Earthquake intensity is measured using the Modified Mercalli Intensity (MMI) scale (1956).

For the tremor of 26 September 2020, 61 intensity data points (IDPs) were identified (five of which were "not felt"), the tremor of 09:13 SAST on 27 September 2020 produced 49 IDPs (12 of which were "not felt") and the tremor of 09:28 SAST 44 IDPs (17 of which were "not felt").

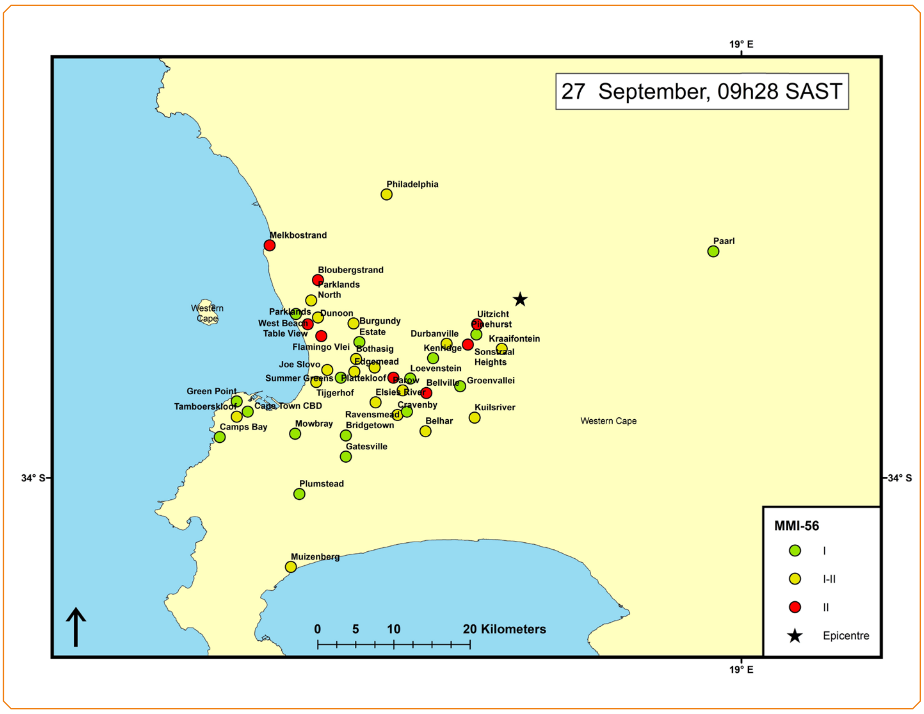
The maximum intensity experienced at 20:41 on 26 September and at 09:13 on 27 September was intensity IV. Windows, walls and doors rattled, crockery and glassware were heard to clink and, in some cases, wooden walls and frames creaked. Some hanging object swung around. Open containers of water were slightly disturbed and standing motor cars noticeably rocked. Key to the description was the sensation of vibration like the passing of heavy trucks and/or the sensation of a jolt like a heavy ball striking the walls. The direction of the earth movement was estimated by many observers and was generally consistent with the relationship between their location and the epicentre of the quake.

The maximum intensity experienced at 09:28 on 27 September was intensity II, which some people described as a vibration, especially on upper floors of multistorey buildings. Sometimes hanging objects were seen to swing around, especially if delicately suspended. Trees, structures, liquids and bodies of water were seen to move, doors swung open slowly, while birds and other animals may have been affected. Some people experienced dizziness or nausea. Intensity II is, however, not always recognised as an earthquake or tremor.

The three tremors were distinctive in that they were mostly experienced as a peculiar rumbling sound. Some witnesses said that the tremor felt like a large aeroplane flying low overhead with the event ending in a nearby dull thud (some people said that they experienced a slight




$M_L$ 2.4 earthquake of 27 September 2020 (09:13), second tremor.




$M_L$ 1.7 earthquake of 27 September 2020 (09:28), third tremor.

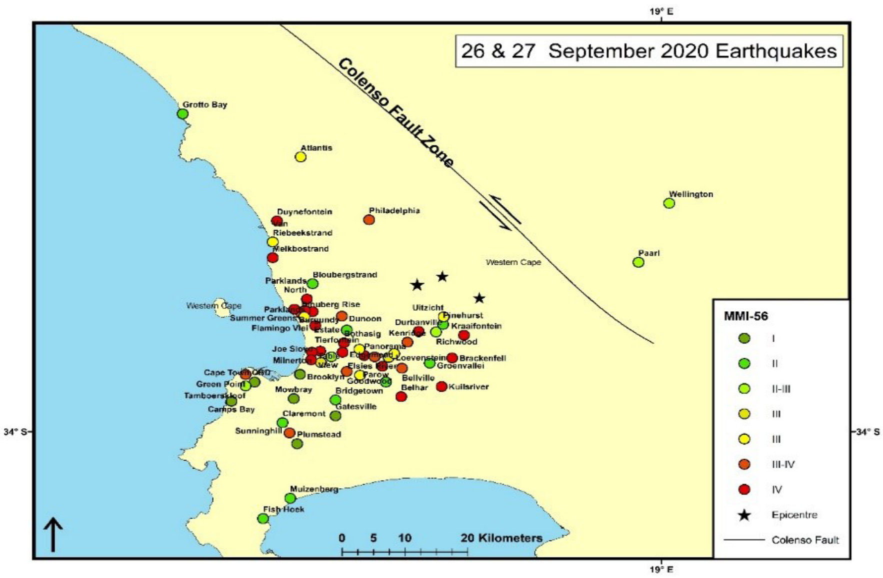
"shock wave" along with the termination of the noise).

Most people described the noise overhead, but in order to assess the intensity it was necessary to focus on those observers who had mentioned and/or described a shaking motion and its effect on people, houses, furniture and small household objects.

Given the small magnitude of the earthquakes, it was unexpected that their shaking was felt widely in the Cape Town region, with the highest intensity levels of IV being registered for the first two events. High intensity values along the coast may have been influenced by thick soil sediments, which are known to influence ground motion. Similar effects were reported for events felt in Durban.

### MMI intensity scale description

| Intensity scale | Description |
|---|---|
| I | Not felt |
| II | Felt by very few people |
| III | Tremor noticed by many, but they often did not realise that it was earthquake |
| IV | Felt indoors by many. Rattling of windows and doors. Felt like a truck had struck the building |
| V | Felt by nearly everyone; many people awakened. Swaying trees and poles may have been observed |
| VI | Felt by all; many people ran outdoors, furniture moved, slight damage occurred |
| VII | Everyone ran outdoors. Poorly built structures considerably damaged; slight damage elsewhere |
| VIII | Specially designed structures damaged slightly, others collapsed |
| IX | All buildings considerably damaged, many shifted off their foundations; noticeable cracks in the ground |
| X | Many structures destroyed; ground was badly cracked |
| XI | Almost all structures failed; very wide cracks in ground |
| XII | Damage nearly total; waves seen on the ground surfaces; objects tumbled over and were tossed around |




Map showing the Colenso fault and the three tremors.

### Source of the earthquakes

The earthquake tremors occurred proximal to the larger Colenso fault region. This is quite a wide, significant fault zone which forms the boundary between the Tygerberg and Swartland Terranes of the Malmesbury Group. This fault zone is believed to be active and dates back to the Saldanian Orogeny (ca 550–500 Ma) and the Mesozoic breakup of Gondwana. The Colenso fault zone is a NW–SE-trending zone. This fault zone is a moderate "probability of activity" zone owing to its geomorphological expression and its orientation relative to the maximum horizontal stress field. The total length is 180 km, and the area can be segmented into two parts of around 106 km and 74 km, respectively.

Further studies will need to be conducted to determine the activity of the Colenso fault region and the size of the earthquakes that can be expected to occur along the fault zone and associated transverse faults in future. Events larger than the earthquakes reported here may cause widespread earthquake effects and possibly damage, given that these small-magnitude events were so widely felt in the region.

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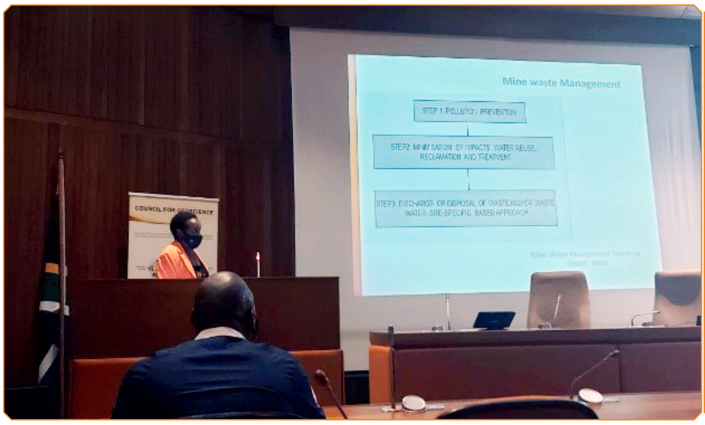
# Collaboration between the Council for Geoscience and the University of Venda through the integrated geoscience mapping programme in Limpopo Province

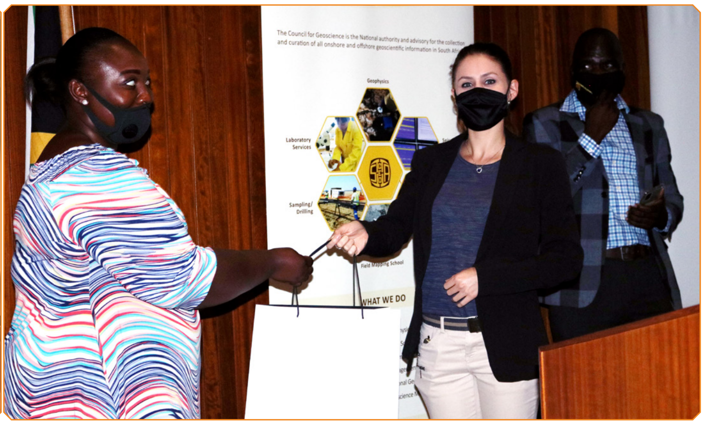
The Council for Geoscience (CGS) has embarked on an integrated geoscience mapping programme in Limpopo Province. The integrated approach includes geological mapping, geochemistry, geophysical investigations, hydrogeological and environmental studies. The programme aims to resuscitate mineral exploration and investment in the region by characterising the potential targets for mineral deposits, addressing societal challenges which may have health impacts on humans and adding to the body of knowledge with regard to the tectonic and geological settings of the greenstone belts in Limpopo Province. The CGS values collaboration with other earth science institutions conducting fundamental geoscience research and, as such, the University of Venda (UNIVEN), through the Department of Mining and Environmental Geology, was identified as one of the institutions with whom the CGS could collaborate/partner. The department has a history of geoscience research in the Giyani Greenstone Belt (GGB) and surrounding areas aimed at postgraduate studies.

The CGS team, led by the CEO of the CGS, Mr Mosa Mabuza, met with key researchers from the University of Venda on 24 July 2020. The purpose of the meeting was to strengthen collaboration between the two institutions, based on an existing Memorandum of Understanding (MoU), and to identify areas of mutual interest. The key researchers from the University of Venda were represented by Emeritus Professor J.S. Ogola, who is a Professor of Economic and Mining Geology. Prof. Ogola has broad research experience ranging from mineral exploration focussing on gold-sulphide and fluorite mineralisation to mining impacts with an emphasis on tailings dams and waste rock dumps. One of the outcomes of this meeting was to plan a joint workshop within the next three months where researchers from both institutions would be granted the opportunity to present various research projects that could benefit the scientific objectives of the integrated mapping programme in Limpopo. Subsequently, the technical workshop was hosted at the CGS head office in Pretoria on 23 October 2020, where scientists from both institutions presented talks on different scientific fields. Scientists from the CGS included Mr M. Bensid, who gave a talk titled "*The use of the soil geochemistry data for a better understanding of the geology and mineralisation of the Giyani Greenstone Belt and surroundings"; Dr A. Thomas's talk was titled "Usefulness of Sentinel-2B scenes to aid in geological mapping of five 1:50 000-scale sheets of the Murchison Greenstone Belts area"; Mr D. Ngobeni presented on the "Geophysical investigation of geological structures in the Giyani Greenstone Belt", and Ms N. Mukosi's talk was titled "The integrated geoscientific mapping in the Giyani and surrounding areas". Scientists from UNIVEN included Dr H.R. Mundalamo, who gave a talk*

The CGS team led by the CEO, Mr Mosa Mabuza, visited the University of Venda. (Left to right) Ms Lerato Maibelo (Office of the CEO), Mr Sibongiseni Hlatshwayo (Manager: Economic Geology and Geochemistry), Ms Angel Monnakgotla (Stakeholder Relations Officer), Ms Ndivhuwo Mukosi (Geoscientist), Dr Taufeeq Dhansay (Manager: Geoscience Mapping) and Mr Robert Netshitungulwana (Chief Scientist).

Mr Mosa Mabuza handed over a token of appreciation to Emeritus Professor Ogola.




(a) Dr Mundalamo (UNIVEN) presented a talk during the CGS Technical Workshop. (b) Ms Munyai (UNIVEN) (left) received a token of appreciation for having given the best presentation at the technical workshop.

*titled "Environmental and social impacts of mine wastes within the Limpopo Province, South Africa"; Mr N. Nemapate's talk was titled "Valuation of economic potential of gold tailings dams: Case studies of the Klein Letaba and Louise Moore tailings dams, Limpopo Province, South Africa"; Ms P.G. Munyai presented her Ph.D. research work titled "Phytoremediation of tailing dams within the Giyani Greenstone Belts, Limpopo Province", and Mr T. Chauke presented his research work titled "Geology and geochemistry of Muyexe Magnesite deposit, Giyani Greenstone Belt, Limpopo Province, South Africa*".

The technical workshop triggered robust discussions amongst the scientists, further finding expression in areas of mutual interest, and helped define the renewal of the MoU. Key themes proposed by both institutions for collaboration during the workshop included environmental impacts related to historical mining in Limpopo Province, clay characterisation research, coal geoscience research and capacity building in analytical techniques.

The workshop was concluded by the presentation to Ms G. Dube (CGS) of an award for her excellent contribution to the workshop. A token of appreciation for best presentation was awarded to Ms P.G. Munyai (UNIVEN Ph.D. student).

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# Building a new nearshore survey boat for marine surveys, the R/V Nkosi

The marine team of the Council for Geoscience (CGS) has not had its own vessel for nearshore marine geophysical data acquisition since the vessel GeoManzi was sold in 2017. In this interim period, the CGS has had to hire a suitable vessel when required. Over and above the costs and time-consuming process of procuring a suitable vessel, was the realisation that, if the CGS does not own its own equipment, the execution of annual deliverables can be adversely affected. The CGS will then be reliant on other companies who would rather use their own assets as opposed to hiring it out for the CGS's purposes. As a result, the decision was taken in 2019 to perform a cost beneficiation analysis to determine if it will not be more feasible to buy or rent a small boat and/or to motivate for the building of a new vessel, learning from the many pitfalls experienced by the building and ownership of the vessel GeoManzi.

The motivation to proceed with a tender for building a new boat had been approved in March 2019 and subsequently the specifications were drawn up for advertising the tender. It was very important during this process that the CGS learned from mistakes made while building GeoManzi and that these be rectified in the new build to minimise long-term costs and maximise vessel usability. The main considerations were that it must be possible to transport the vessel by trailer using a bakkie or SUV. Moreover, the vessel needs to be small enough to be stored in the boatshed at the CGS office in Bellville. The most important factors controlling transport of the vessel are the overall weight of the boat and trailer. It was therefore decided to specify that the boat be constructed out of aluminium, which is a lighter construction material than fibreglass. As part of the weight consideration, the new boat is slightly shorter than the GeoManzi and the cabin much smaller. Weight distribution was also a key factor to consider and the boat builder was given the instruction that the internal layout of the cabin would require the data acquirers to be separated from each other and positioned symmetrically opposite each other. The final stipulation was that the geophysical equipment poles used to deploy the echosounders be sourced from the world leader in pole design in the USA. Very pleasingly, when the boat was weighed on the trailer after construction had been completed, she came in just under 3 tonnes, which is well under the maximum 3.5 tonnes specified by most car licences in South Africa.

The tender was duly advertised with all the submissions assessed and a letter of award was issued to the successful bidder in November 2019. Building of the vessel commenced in February 2020 after the contract was finalised in late January 2020. The building process was subdivided into a number of milestones with each linked to a payment upon completion of the specified milestone. These milestones were closely monitored by CGS marine personnel who paid regular visits to the boat during its build and responded to queries by the boat builder of CGS requirements throughout the entire process. Although the building process coincided with the Covid-19 pandemic sweeping the globe, remarkably little time was lost and the boat was completed and sea-trialled in the first week of August 2020, with the CGS taking ownership on 27 August 2020. Shortly before sea trials took place, it was decided to honour the deceased Mr Elijah Nkosi, considered one of the foremost mineral separation experts in the world, for his service to the CGS by naming the new boat after him. It was therefore registered as R/V (research vessel) Nkosi.

Key features of the boat include:
- Garmin autopilot, chart plotter and depth sounder
- VHF radio
- Built-in buoyancy (to obviate the inclusion of a life raft)
- A lockable cabin
- Split work stations
- In-line backup UPS
- Glazed windows
- Ventilation ducts installed on the cabin roof


a – The jig used to start constructing the hull; b – All of the plates for constructing the hull and cabin welded together, the roof of the cabin must still be added; c – The completed cabin with most of the windows fitted. The hull construction jig has now been removed; d – Looking forward into the cabin showing the skipper's position and instrument control panel cut out; e – Finalising the seating positioning, configuration and work station layout for data acquisition; f – The boat launched during sea trials.

- 2 x USM mounting poles which can recover inboard of the survey vessel
- 2 x 30 kg lifting davits for mounting the CGS multibeam and sub-bottom pinger equipment
- Built-in fuel compartments as well as the ability to "plumb" in removable, emergency fuel canisters.

The boat and the trailer have been registered in the CGS's name along with obtaining an ICASA radio station licence for the boat. Additional outriggers for the boomer sub-bottom profiler and hydrophone array have been fabricated and the CGS personnel have made new cables for various components of their survey equipment. The CGS multibeam echosounder has been returned from its manufacturers in America after undergoing repairs to some of its hardware and updating the firmware. Some provisional testing of the CGS boomer seismic system has already taken place with more equipment testing due to follow.

The CGS will eventually be the owners of the most advanced nearshore geophysical survey vessel in the country and on the continent and will be empowered to collect data wherever necessary within a swathe of 30 nautical miles around the South African coastline.

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