GSSA
Geological Society of South Africa

UFS

GEOCONGRESS 2025

EMBRACING CHANGE THROUGH COLLABORATION

23 - 27 June 2025

BOOK OF ABSTRACTS

CONTACT US

secretariat@geocongress2025.org.za

https://geocongress2025.org.za/

AI-driven GIS-based Mineral Systems Approach to Mineral Prospectivity Mapping

PREDICTIVE MODELLING OF OROGENIC GOLD PROSPECTIVITY IN THE WAWA AREA, WESTERN NIGERIA, USING THREE MOST COMMONLY USED MACHINE LEARNING ALGORITHMS

Sodiq A. Alimi[1] **& Emmanuel J. M. Carranza**[1]

[1] University of the Free State, Bloemfontein, South Africa

The unavailability of prospectivity maps for orogenic gold deposits in western Nigeria has been a significant setback in the federal government's efforts to attract mining investors. Prospectivity modelling is a potent exploration tool that allows for the segregation of large expanses of land into high and low prospectivity zones. To support the Nigerian government efforts in its diversification of the Nigerian economy towards the solid mineral sector and attract mining investments into the country, this research focused on the use of machine learning (ML) models for orogenic gold prospectivity modelling in the Wawa area, a southern extension of the gold-bearing Zuru Schist Belt of western Nigeria. A mineral system approach was applied in this study to translate the characteristics of orogenic gold deposits into nine predictor maps, accounting for heat source, fluid pathway, trapping mechanisms, and favourable host rocks needed for the formation of such deposits. The ML algorithms considered in this research were artificial neural network (ANN), support vector machine (SVM) with three kernel functions (linear, polynomial, and radial), and random forest (RF). Each of these predictive models were trained using nine predictor maps and 174 data points, consisting of known gold deposit and non-deposit points. The ANN and RF predictive models had the highest prediction efficiencies with similar Accuracy and Kappa index of 91% and 81%, respectively; AUC values were >0.94 for both RF and ANN models but < 0.86 for SVM. The results suggest that ANN and RF algorithms are more suitable than SVM for orogenic gold prospectivity modelling in the study area. Further exploration for orogenic gold deposits in the Wawa area will likely be successful within the delineated high prospectivity zones.

Keywords: artificial neural network, random forest, support vector machine, mineral prospectivity analysis

MINERAL PROSPECTIVITY MAPPING VIA L1-DISTANCEOPTIMIZED NEGATIVE SAMPLING IN RF-CA INTEGRATION

Guohao Li[1] & Gongwen Wang[1]

[1] China University of Geosciences, Beijing, Peoples Republic of China

In mineral prospectivity mapping (MPM), the class imbalance between confirmed mineralization sites (positive samples) and non-mineralized areas (negative samples) poses critical challenges for the machine learning applications. Current practices rely on subjective selection of negative samples that risk overfitting, while random selection often leads to underfitting; both scenarios compromise computational efficiency and prediction reliability. To systematically address these challenges, we developed an integrated framework combining optimised sample selection with hybrid machine learning. The proposed L1-distance-based negative sampling operates through three mechanisms: (1) k-means clustering of positive samples into representative centroids, (2) calculation of minimum L1-distance (Dmin) from each unlabelled grid cell to centroid clusters, and (3) filter negative samples proportionally based on Dmin. This geometrically constrained approach generates balanced training sets while preserving characteristic spatial distributions. The refined samples subsequently drive a coupled Random Forest-Cellular Automata (RF-CA) architecture, implemented through three synergistic phases: (1) RF training on optimally weighted samples produces initial mineralization probabilities using five geospatial predictors derived from stratigraphic sequences, aeromagnetic signatures, and fault network topology. (2) CA simulations propagated mineralization potentials through the neighbourhood transition rules constrained by both RF outputs and structural geology parameters. (3) Multi-criteria fusion of RF probabilities and CA stability states generates the prospectivity mapping. Experimental results demonstrate that the proposed L1-distance-based negative sample selection method achieves a 35% reduction in training time and improves the AUROC score from 0.83±0.03 to 0.92±0.02 compared to random sampling, with the improvement being statistically significant. Furthermore, the integrated RF-CA framework outperforms the standalone RF model, showing a 5.2% increase in prediction accuracy and demonstrating superior geological consistency through spatial pattern analysis, indicating stronger alignment with known structural controls of mineralization. In conclusion, the L1distance-based negative sample selection method improves dataset representativeness, addressing overfitting and underfitting issues. The RF-CA integration combines data-driven prediction with spatial simulation, enhancing both accuracy and geological realism in MPM. These findings offer an efficient and precise solution for mineral exploration.

Keywords: MPM L1-optimised sampling, cellular automata, class imbalance

LEVERAGING MACHINE LEARNING FOR GEOLOGICAL DOMAIN MODELLING: A CASE STUDY ON MAPTEK™ DOMAINMCF

David Malisheni[1] & Roxanne Snoer[1]

[1] Australian Institute of Geoscientists

The integration of machine learning into geological modelling is transforming how geoscientists interpret subsurface structures. This session will explore DomainMCF, an AI-driven implicit modelling tool developed by Maptek, and its application in geological domain modelling. DomainMCF enhances traditional modelling techniques by leveraging machine learning algorithms to analyse geospatially mapped domain coded data, such as drill hole data, identify geological patterns, and generate probabilistic models. These models improve the accuracy and efficiency of predicting rock types, mineral distributions, and geological structures. Unlike conventional rule-based methods, DomainMCF learns from drillhole data and makes predictions or decisions without explicit programming. Its machine learning framework continuously analyses data patterns, refining its performance over time. DomainMCF automatically generates geological models from drillhole data, while providing probabilistic outputs to assess confidence levels in geological interpretations. It significantly reduces manual interpretation time, increasing efficiency, and seamlessly integrates with Maptek Vulcan and other mine planning software. By showcasing DomainMCF's capabilities, this session contributes to the ongoing discourse on digital transformation in geosciences, highlighting the role of artificial intelligence in advancing geological modelling practices.

Keywords: Machine Leaning Domain, MCF Geological modelling, Artificial Intelligence

ASSESSMENT OF GOLD PRODUCTION USING TIME SERIES MODELLING TECHNIQUES IN SOUTH AFRICA: INSIGHT INTO FUTURE PRODUCTION, MINERAL RESERVES AND IMPLICATION ON EXPLORATION

Litshedzani Mutele[1] & Emmanuel John M. Carranza[1]

[1] Department of Geology, University of the Free State, Bloemfontein, South Africa

Gold mining in South Africa has spanned for over a century. It has contributed significantly to growth in the and employment creation. Sustainable mining through delineating additional mineral resources and quantifying future production is critical in positioning South Africa's supply risk and security. In the current study, we have examined historical gold production (1990-2018) in South Africa and globally and predicted future trends (2019-2040) by VAR (Vector Autoregressive), ARIMA (Autoregressive Integrated Moving Average), and ARNN (Autoregressive Neural Network) methods. The investigation also weighed in on the influence of yearly production on ore reserves and its supplementation by converting resources to reserves. Finally, we assessed exploration maturity and potential residual ore tonnage resources in selected dormant South African goldfields, including the Amalia-Kraaipan, Murchison, Pietersburg Greenstone Belts, and Sabie Pilgrim's Rest Goldfield. Using RMSE, MAPE, and MAE statistical measures, the ARIMA method performed better than the VAR and ARNN. The projection indicated growth in both global and South African mine production with a compounded annual growth rate of ~2.2% and ~0.6% respectively. The analysis of production-reserves trends highlighted that the majority of mining companies are exhausting ore reserves through production with minimal resources to reserves conversion, at ~2% of the resources per year. We established that the future production will not affect the existing estimated reserves of ~2 Kt Au exclusive of surficial tailings, if the conversion factor is sustained at least 2%/year. However, a minimum of 27% of the current resources will have to be converted to ore reserves by 2040. On the contrary, future production may exhaust the reserves to less than 500 t Au given that the conversion rate decreases to less than 1%/year. Based on Zipf's law, the three-part method of quantitative mineral resource assessment established by the United States Geological Survey, and the generalised deposit density regression, the selected goldfields showed exploration maturity of ~45% and they still contain considerable ore tonnage partitioned within undiscovered deposits. We also noticed that some deposits were undervalued compared to their anticipated tonnage endowment. Hence, the residual estimates could also represent not yet delineated tonnages within known deposits.

Keywords: Gold Production, Exploration Maturity, Time Series Models, Mineral resources Assessment

A DEEP LEARNING FRAMEWORK FOR 3D MINERAL PREDICTION WITH TRANSFORMER-BASED LONG-RANGE DEPENDENCY MODELLING AND EXPLAINABILITY ANALYSIS

Qingming Peng[1] & Gongwen Wang[1]

[1] China University of Geosciences, Beijing, Peoples Republic of China

In this study we propose a three-dimensional (3D) mineral prediction framework based on deep learning, incorporating the Transformer mechanism to model long-range dependencies and enhancing interpretability through explainable AI techniques. Traditional mineral prediction methods often rely on shallow models or statistical techniques, which struggle to capture complex spatial relationships and nonlinear patterns in geological data. To address this, we develop a 3D neural network architecture that integrates convolutional layers for local feature extraction and Transformer blocks for global dependency modelling. To improve the interpretability of the model, we employ 3D Gradient-weighted Class Activation Mapping (3D Grad-CAM) and SHapley Additive exPlanations (SHAP) to visualize and quantify the contribution of geological attributes to the prediction results. Additionally, we leverage attention score analysis within the Transformer layers to further interpret the model's focus areas, highlighting key geological features that influence the mineralization prediction. We evaluate the proposed framework using real-world geological datasets. The results demonstrate that the model achieves higher prediction accuracy and better generalization compared to conventional methods. The explainability techniques effectively reveal the model's decision-making process, providing geologists with valuable insights into the spatial distribution of critical mineralization factors. This study highlights the potential of combining deep learning with explainable AI and Transformer-based global dependency modelling to achieve more reliable and interpretable 3D mineral resource prediction.

Keywords: 3D Mineral Prediction, Deep learning, Transformer, Explainable AI

REMOTELY EXPLORING FOR MINERALIZED PEGMATITES USING THE NON-STRUCTURAL FUZZY DECISION SUPPORT SYSTEM IN THE NAMAQUALAND PEGMATITE BELT, SOUTH AFRICA

Andongma W. Tende[1] & Martin D. Clark[1]

[1] Department of Geology, University of the Free State, Bloemfontein, South Africa

The successful exploration of mineralized pegmatites suffers from sporadic exposures and imprecise geochemical sampling; however, these pegmatites are increasingly significant for global economies due to the presence of critical minerals contained within. Conceptual data integration using alteration zones, gravity and structural lineaments, and known mineralized pegmatite host rocks, were utilised to qualitatively assess the probability of Lithium and Rare Earth Element pegmatite occurrence in the Namaqualand Pegmatite Belt of South Africa. To assess data redundancy and multicollinearity Variance Inflation Factor and the Pearson Correlation Coefficient were used, and a Prediction-Area curve analysis evaluated the reliability of exploratory data through known mineral occurrences. The non-structural fuzzy decision support system (NSFDSS) was used to integrate these exploratory datasets to develop an exploration map based on four models, assessed using the Receiver Operating Characteristic and Area Under Curve analysis. The NSFDSS predictive model identified a high probability of mineralized pegmatite occurrence along NW-SE trend between the Heartriver Shear Zone and Boven Rugzeer Shear Zone in addition to several other locations in the vicinity of Warmbad, Onseepkans, and Vioolsdrift, broadly known for mineralized pegmatites. The accuracy of the four NSFDSS models ranged from 81.7-82%. These findings may better direct exploration for mineralized pegmatites, utilizing remotely sensed and geophysical data, in addition to a robust multivariate data approach.

Keywords: Mineral deposits, Multi criteria, Lithium, Rare Earth Element

SPATIAL-TEMPORAL DUAL-BRANCH TRANSFORMER MODEL FOR THREE-DIMENSIONAL MINERAL PROSPECTIVITY MAPPING

Zhongzheng Wang[1], Gongwen Wang[1] & Qingming Peng[1]

[1] School of Earth Sciences and Resources, China University of Geosciences, Beijing, Peoples Republic of China

Mineral prospectivity mapping (MPM) is recognised as an important method for mineral resource exploration, which has recently gained significant attention due to deep learning algorithms. Mineralization reflects the coupled interaction of various geological features and geological processes across both temporal and spatial scales, normally characterised by multiple stages and clustering distributions. However, existing single deep learning-based MPM models encounter certain challenges in comprehensively extracting the spatiotemporal relationships between mineralization and ore-controlling features. In this study, a spatiotemporal dual-branch transformer (STDBT) model is proposed to make full use of the transformer encoder to excavate the temporal and spatial features of mineralization in three-dimensional (3D) MPM. Specifically, the temporal branch utilises evidence layers that represent critical processes of the mineral system to capture the temporal features of mineralization. The spatial branch treats each voxel and its surrounding neighbourhood as a 3D cube and introduces learnable relative positional encoding to effectively model the spatial features of mineralization. Subsequently, a gating module is employed to adaptively exploit valuable temporal and spatial features from the two branches. Here, the STDBT model is applied to conduct 3D MPM in the Lannigou gold district, China. The comparative experiments demonstrated that the STDBT model, which integrates both temporal and spatial features, outperforms single models that consider only one type of feature in terms of prediction performance. Moreover, the gating module exhibits superiority over other feature fusion methods. This study provides a novel method for constraining data driven MPM with geological prior knowledge, thereby enhancing its interpretability and credibility.

Keywords: spatiotemporal feature dual-branch transformer, mineral prospectivity mapping, Lannigou gold district

All About Igneous Provinces

SOURCE VERSUS PROCESS? EXAMPLES FROM THE PILANESBERG COMPLEX (RSA) AND LARVIK PLUTONIC COMPLEX (NORWAY)

Tom Andersen[1,2] **& Marlina A. Elburg**[2]
[1] University of Johannesburg, Auckland Park, South Africa
[2] University of Oslo, Oslo, Norway

The Proterozoic Pilanesberg Complex (PBG) in South Africa and the Larvik Plutonic Complex (LPC) in the Late Palaeozoic Oslo Rift in Norway are alkaline intrusive complexes emplaced into the shallow crust in continental rift settings. The PBG has preserved its own cogenetic volcanic cover, whereas the LPC intruded a succession of slightly older, latitic lavas of rift-wide extent. The complexes show structural and petrographic similarities, consisting of several ring- (PBG) or arc- (LPC) shaped intrusions of intermediate to syenitic composition, and both formed from mantle-derived parental magmas. Strongly peralkaline nepheline syenite with agpaitic mineralogy (characterised by eudialyte etc.) is common in the PBG, but are rare in the LPC, restricted to a minor body of eudialyte-bearing nepheline syenite, and transitionally agpaitic nepheline syenite pegmatite dykes. Both complexes show an internal evolution from silica (over)saturated to increasingly undersaturated compositions with time, but the degree of silica undersaturation and peralkalinity is distinctly higher in the PBG. The PBG is associated with a suite of minor alkaline and carbonatite intrusions, but recent geochronological data suggest that the spatial association with Mesoproterozoic kimberlites in the Kaapvaal craton are fortuitous. The question addressed in this study is whether the differences between the PBG and LPC in peralkalinity and silica undersaturation are due to different parental magma compositions, or to different conditions of magmatic differentiation, which is addressed by simulation of liquid lines of descent using energy-constrained modelling (Rhyolite-MELTS). The range of rock compositions in the LPC can be explained by polybaric fractionation of a mildly alkaline basaltic parent magma, fractionation in shallow staging chambers (4-5 kbar) giving silica (over)saturated derivative melts, whereas increasingly silica undersaturated and alkaline liquids formed at higher pressures (5-10 kbar). The parent magma of the PBG was nephelinitic rather than basaltic. Simulation of liquid lines of descent show that such parental magma will evolve towards silica-undersaturated compositions regardless of the pressure of fractional crystallization. The main reason for differences in peralkalinity and silica undersaturation between the rocks of the LPC and PBG is therefore the composition of the parent magma rather than conditions of differentiation.

Keywords: alkaline rocks, magmatic evolution

A STUDY OF UG2 CHROMITITE IN THE CRITICAL ZONE OF THE RUSTENBURG LAYERED SUITE, NORTH-WESTERN BUSHVELD COMPLEX

Owen Chingobo[1]

[1] GSSA SACNASP Anglo American Platinum, South Africa

Since 1925, Merensky reef was the principal source of platinum group metals (PGMs) in the Bushveld Complex of South Africa. Exploitation of the Upper-Group 2 (UG2) chromitite reef only commenced in the 1970s and to date, UG2 is now the principal source, accounting for about 65% of mined PGMs. As a result of the longer history of Merensky mining and a shorter history of UG2 mining, there is less publicised research information on UG2 reef when compared to Merensky reef. In addition, although UG2 reef is present along the entire strike of both the Eastern and Western Limbs of the Bushveld Complex, there are some significant local variations in terms of stratigraphy, geological features as well as the distribution and behaviour of gangue and ore minerals, from place to place. The main objective of this study is the characterisation of UG2 chromitite layer in the Amandelbult sub-chamber situated in the northern-most part of the Western Limb of the Bushveld Complex. This involves a re-appraisal of the stratigraphy of the Critical Zone, particularly focusing on the stratigraphic position of UG2 reef, in relation to proximal orebodies, namely the Merensky reefs and other chromitite reefs. This is followed by an in-depth understanding of the UG2 chromitite layer. The study methodology is based on evaluation of available geological information from geophysical surveys, surface and underground exploration diamond drilling, underground mapping, geological interpretations, whole rock chemistry, as well as mineralogical and metallurgical tests. The Rustenburg Layered Suite of the Bushveld Complex of South Africa is a massive layered accumulation of mafic and ultramafic rocks, which is sub-divided into the Marginal Zone, Lower Zone, Critical Zone, Main Zone and Upper Zone. The Critical Zone, which is the subject of this study is in turn, sub-divided into the Upper Critical Zone and the Lower Critical Zone. The major platinum group element (PGE) mineralisation in Merensky reef and the UG2 reef are located in the Upper Critical Zone. Important stratigraphic markers in the Critical Zone include the Bastard Reef, Merensky Reef, Merensky Footwall Marker, Pseudo-Reef 2 (P2), Pseudo Reef (1), UG2, Upper Group 1 (UG1) chromitite, Middle Group (MGs) chromitites, and Lower Group (LGs) chromitites. At Amandelbult, stratigraphic modelling of the Rustenburg Layered Suite rock layers indicate a north-east-south-west strike, dips of about 18-220 to the south-east, and outcrop positions of UG2 and Merensky reef within the lease area. Since both UG2 and Merensky reefs outcrop within the mining lease, this has allowed exploration, evaluation and extraction of both reefs using both open-pit bench mining for near-surface mineral resources and underground conventional breast mining for mineral resources in the deeper portions. In addition, UG2 chromitite is located at stratigraphic elevation ranging from 40m below Normal Merensky reef sub-facies and about 10m to 20m below the various Pothole Merensky Reef sub-facies. This close stratigraphic proximity between UG2 and Merensky reefs has an impact on several parameters such the extraction sequencing or coextraction of both reefs, placement and sharing of footwall development excavations or infra-structure, and geotechnical considerations such as regional and in-stope pillar designs, and stoping panel spans. Recent surface exploration diamond drilling into the footwall of UG2 has led to the exposure and sampling of MG and LG chromitite seems which are

located at distances ranging from 80m to 250m below the UG1 chromitite. Preliminary sampling of these LG and MG chromitites show a higher chromitite content and lower PGM grades compared to UG2 chromitite. More drilling and sampling work are however required for mineral resource and ore reserve definition of MG and LG chromitites to be completed with a reasonably high confidence. The study also shows that at Amandelbult, UG2 has a thickness averaging about 1.5m comprising the lower massive chromitite band with a thickness of about 80cm overlain by the upper alternating 2 to 3 chromitite leader bands separated by 2 to 3 pyroxenitic partings or waste bands. The alternating chromitite leader bands and pyroxenite parting bands have a total thickness of about 70cm and individual layer thickness varying between 10cm and 15cm. Leaving these layers in the hanging-wall during UG2 mining activities occasionally leads to fall-of-ground incidents and is avoided in most mining situations. The minimum stoping width is lower than the minimum normal UG2 thickness and as a result, no resources are discarded on the basis of falling below the minimum stoping width cut-off. UG2 reef is sandwiched between a coarse-grained feldsphathic pyroxenite in the footwall, with a pegmatoidal texture at the bottom-reef-contact, and a coarse-grained feldsphathic pyroxenite in the immediate hangingwall. The feldspathic hanging-wall pyroxenite in place contains a weaker geotechnical unit, the olivine-pyroxenite, near the contact top-reef-contact, and a chromitite stringer, about 3m above the top-reef contact. The two units induce fall-of-ground are taken into consideration, when setting out the ground support strategy. Further to the east, footwall norite is observed in contact with UG2 bottom-reef contact, instead of the footwall feldspathic pyroxenite observed in central and western areas. A number of geological structures affect the UG2 chromitite layer namely faulting and dyke zones, Iron-rich Ultramafic Pegmatites (IRUPs), potholes, slumps and kopjes, which all contribute to geological losses affecting the UG2 ore-body. The footwall norite observed in the eastern part of Amandelbult is associated with higher incidences of rolling or slumping of UG2 reef. Two of the major fault zones at Amandelbult separate Amandelbult area into a horst and graben structure, a configuration that had a say in the placement or positioning of mine shafts. Mineralogy of UG2 Chromitite is dominated by chromite followed by plagioclase feldspar. Other minerals include base metal sulphides with the main phases being cobalt bearing pentlandite and chalcopyrite. The Platinum Group Minerals (PGMs) in UG2 Chromitite are dominated by Platinum-Palladium sulphides, laurite, a Ruthenium sulphide, platinum-iron alloys, Rhodium sulphides and palladium alloys. Some patterns can be observed in chromite, base metal and PGE content. In terms of PGM grades, UG2 is bottom-loaded, with significant amount of metal near the bottom reef contact. This is taken into consideration in defining the UG2 mineral resource cut and mining best cut. In addition, UG2 tends to have more rhodium, and slightly less platinum, when compared to Merensky reef. Notable changes in platinum group minerals occur in zones affected by IRUPs. Metallurgical tests indicate lower metal recoveries associated with UG2 chromite reef affected by IRUPs. A comparison of near surface oxide ores and deep-seating fresh ores show some differences in oxidation, alteration, textures and density.

Keywords: UG2, Chromitite, Sulphides, Mineralogy, PGMs

OLIVINE DECADENCE OF CONTINENTAL FLOOD BASALTS IN THE LIGHT OF RECENT EXPERIMENTS: A CASE STUDY FROM KHANDWA, EASTERN DECCAN VOLCANIC PROVINCE

Simran Dutta[1,2] **& Jyotisankar Ray**[2,3]

[1] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa,
[2] Department of Geology, University of Calcutta, Kolkata, India
[3] Department of Geology, Amity University Punjab, Mohali, India

Large Igneous Provinces (LIPs) are defined as massive bodies of emplaced mafic rocks, both extrusive and intrusive in nature, which are encompassing of continental flood basalts, oceanic plateaus, ocean basin flood basalts, and volcanic passive margins, with an emphasis that LIPs have not formed due to the sea-floor subduction and spreading processes. The detailed study of mafic magmas, with respect to the origin, ascent, storage and emplacement, is pertinent to understanding LIPs, specifically olivine can be a key to bettering the understanding of the genesis of LIPs. A series of cooling experiments carried out with dry basalt for studying the kinetics of crystallisation of olivine, as being controlled by the degree of undercooling. It has also been shown that phenocryst size olivine can form in a magma chamber after thermal disequilibrium induced by magma mixing processes. In many cases, low to moderate undercooling conditions is found to be important to prove skeletal olivine under isothermal conditions. Moreover, initial olivine growth is marked by rapid development of an outer shell that enables the confinement of glass inclusions within the olivine. It has been considered that elongated olivine extended along c- or a- in natural samples, may therefore be associated with (a) nature of undercooling, and (b) coexistence of both newly grown olivine and olivine formed by multiple growth events. An attempt has been made to understand the nature of olivine growth behaviour and its possible decadency from parts of Eastern Deccan Volcanic Province (EDVP), located at and around Khandwa (21º49'N, 76º21'E), Nimur district, Madhya Pradesh, central India. A comparison has been made between the experimentally obtained data and natural samples with focus on corresponding olivine fractionation, by constructing few variation diagrams, Al_2O_3 vs. MgO, P_2O_5 vs. MgO, Al_2O_3 vs. SiO_2, and MgO vs. SiO_2. The deduced parent melt composition involving MgO, SiO_2, Al_2O_3, and P_2O_5, etc. was subjected to CIPW Normative analysis in an attempt to find out nature of the parental melt. The parent melt was inferred to be very close to that daughter melt composition because of very low degree of separation of olivine crystals.

Keywords: Large Igneous Provinces, Deccan Volcanic Province, tholeiitic basalts, cooling experiments

USING GEOPHYSICS TO UNCOVER THE SOUTHWESTERN PART OF THE BUSHVELD COMPLEX

Stephanie Scheiber-Enslin[1], Musa Manzi[1] & Susan Webb[1]

[1] University of the Witwatersrand, Johannesburg, South Africa

The western and eastern limbs of the Bushveld Complex have been extensively studied using geophysical data. In contrast, the southern limb remains less understood due to limited surface exposure and sparse geophysical coverage. Reflection seismic line DG326, which spans approximately 165km, crosses the boundary between the central region of the Bushveld Complex and its southern lobe. This seismic line provides valuable insight into the subsurface geology of the area. The seismic data reveal a range of geological features along the profile, from southwest to northeast, including prominent reflections from dipping, layered rocks of the Transvaal and Witwatersrand Supergroups; chaotic reflections associated with Bushveld granite and granophyre; pronounced updoming of basement rocks in the Dennilton Dome; and strong, coherent reflections from the Rustenburg Layered Suite in the eastern lobe. Regional gravity data suggest the presence of dense material at depth beneath the southwestern section of the seismic line, potentially representing the Rustenburg Layered Suite. However, a strong shallow reflector in the seismic profile limits deep imaging, obscuring direct evidence of this material. Additionally, gravity anomalies on both sides of the Dennilton Dome indicate dense bodies, which are supported by seismic reflections and may also correspond to Rustenburg Layered Suite material. While the seismic data do not provide evidence of Bushveld units at depth in the southwest due to poor imaging, and gravity data is inconclusive, connectivity between the southern lobe and the central complex is supported by borehole data around 40km to the northwest of the seismic line. The borehole is on the edge of Premier kimberlite and intersects Bushveld rocks, i.e., around 200m of pyroxenite, which is proposed to belong to the CZ (Cawthorn and McKenna, 2006).

Keywords: Bushveld Complex, seismics, gravity

THE GEOLOGY OF THE KAROO BASALTS NW OF BULAWAYO, ZIMBABWE

Nikita A. Erasmus[1], Emese M. Bordy[1], Geoffrey H. Howarth[1] & Petrus le Roux[1]

[1] Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa

The main Karoo Basin in South Africa and Lesotho has been well documented and is globally recognised for its economic significance (e.g., coal, uranium, groundwater) and contribution to lessons on the evolution of life, especially in the late Palaeozoic and early Mesozoic. Across southern Africa, the Karoo sedimentation ended with the emplacement of the Karoo-Ferrar Large Igneous Province with the Batoka Basalts capping the top of the Karoo succession in the Mid-Zambezi Basin. Despite extensive research on Karoo basalts in the southern basins, the composition and chemostratigraphy of the basalts formed during the final stages of the Karoo magmatism in the Mid-Zambezi Basin remain poorly understood. This study aims to compare the high-TiO_2 Batoka Basalts in the Nyamandhlovu region (west Zimbabwe) to other Karoo basalt remnants, specifically the high-TiO2 basalts that outcrop in the Tuli Basin and extend south along the Lebombo Monocline. The Nyamandhlovu basalts were sampled from 6 drill cores spanning a thickness of over 140 m. The 67 analysed samples (major elements via XRF, trace elements via ICP-MS, and Sr-Nd -isotopes via MC-ICP-MS) here are all high-TiO_2 basalts, like those in the Tuli Basin. However, they are predominately high-Zr/Nb (HZN), in contrast to the low-Zr/Nb (LZN) basalts or picrites commonly found in Tuli. Interbedded sandstones and brecciated flow tops are indicative of multiple lava flows and volcanic dormancy periods. A major change in basalt geochemistry coincides with occurrences of sandstone layers, indicating not only a pause in basalt extrusion but also a compositional shift in the magma, which is evident in the major and trace elements as well as Sr-Nd isotope variations of the basalts. The sharp change in basalt geochemistry is interpreted to reflect melting of different mantle reservoirs as well as a shift in the mantle melting regime.

Keywords: Karoo, basalt, high-Ti

MINERALOGICAL AND PETROGENETIC CHARACTERISATION OF WITKOP PEGMATITES, NORTHERN CAPE, SOUTH AFRICA

Masonwabe, Jubase[1], Judith, Kinnaird[1], Leonidas, Vonopartis[1] & Nonkuselo, Madlakana[1]

[1] University of the Witwatersrand, Johannesburg, South Africa

Pegmatite, which forms in various tectonic environments and crystallise from highly evolved, volatile-rich felsic melts that have incorporated crustal material from their source, is a significant source of green energy transition metals like Li-Cs-Ta and REEs. Traditionally, pegmatites are believed to originate either through extreme fractionation of a parental granite or by low-degree partial melting of metamorphic rocks. However, the origin of the melt or fluid responsible for forming Li-Cs-Ta pegmatites remains poorly understood. It is still unclear whether this melt formed through extreme fractionation of a cooling parental granite or came directly from the dehydration of metasedimentary rocks during metamorphism. To better understand the origin of the Li-rich melt and why some pegmatites contain Li-minerals while others do not, this study uses detailed mineralogical, major elements in micas as well as trace elements and oxygen isotopes in quartz as proxies to describe the geochemical characteristic and the petrogenetic evolution of the lithium-rich and lithium-poor pegmatites from the Namaqualand Pegmatite Belt. Preliminary mineralogical and chemical data indicates that the lithium-poor pegmatites are characterised by Li-muscovite, while in lithium-rich pegmatites, lithium is hosted within lepidolite and spodumene. Lithium-poor pegmatites record quartz $\delta^{18}O$ values that range from 9.5 to 10.22, whereas the lithium-rich pegmatites, record $\delta^{18}O$ values of >10.22 but <13.00. This suggests that the lithium-poor pegmatites are derived from a more direct igneous source, closer to primary granitic melts, while the lithium-rich pegmatites record igneous source that have interacted with crustal material or fluids, especially with fluids derived from metamorphic dehydration reactions of micas. Thus, it can be concluded that the lithium-bearing fluids in this region likely originated from partial melting of the metasediments, however, trace elements in quartz as well as boron isotopes in tourmaline are underway to further confirm whether metasomatism played a role, as boron from metamorphic sources often has distinct isotopic signatures.

Keywords: Namaqualand, Lithium, Pegmatites

MANTLE SOURCES FOR THE BUSHVELD COMPLEX: INSIGHTS FROM NEW, HIGH-PRECISION Sr-Nr ISOTOPE DATA FROM THE MARGINAL ZONE

Busisiwe Khoza[1], Ben Hayes[1] & Lewis Ashwal[1]

[1] University of the Witwatersrand, Johannesburg, South Africa

The Rustenburg Layered Suite (RLS) is the largest layered mafic-ultramafic intrusion on Earth, encompassing an enormous volume of cumulates postulated to have formed in a short-lived magmatic system (=5 million years). However, the mantle sources for the RLS are not very well constrained or understood. This is partly due to three main issues: (1) A lack of combined Sr-Nd isotopic data; (2) The presently published Sr-Nd isotope data for the RLS show "non-mantle-like" compositions of $^{87}Sr/^{86}Sr$ and ε_{Nd} at the time of emplacement and crystallisation; and (3) The RLS shows decoupling between trace element ratios and $^{87}Sr/^{86}Sr$ compositions. The latter two observations are attributed to either crustal contamination of asthenospheric mantle-derived melt or direct melting of an enriched metasomatised subcontinental lithospheric mantle (SCLM). In this study, we measured trace elements and Sr-Nd isotopic compositions of the Marginal Zone in the RLS to constrain its magma sources and crustal contaminants. Our results show that the Marginal Zone rocks have low Sm/Ybn and variable La/Smn, which implies that its melts were derived from a shallow spinel lherzolite source. Secondly, Th/Nb versus TiO_2/Yb of the Marginal Zone form an array that extends into the SCLM compositional field. Thirdly, the La/Nb and La/Ba compositions also plot in the SCLM compositional field. The Sr-Nd isotope compositions show variable $^{87}Sr/^{86}Sr_{(2.06Ga)}$ compositions (0.703253 — 0.708626) and low $\varepsilon_{Nd(2.06Ga)}$ values (-9.1 to -4.7), with $^{87}Sr/^{86}Sr$ increasing from the B1, B2 to B3 groups of the Marginal Zone, coupled with decreasing $\varepsilon_{Nd(2.06Ga)}$. Based on these Sr-Nd isotope data, along with the large volume of the RLS and its short duration of magmatism, we propose that the primary melts of the RLS were sourced from the asthenospheric mantle that melted in response to the impingement of a mantle plume at the base of the Kaapvaal lithosphere. These melts underwent modification as they passed through the SCLM, with further chemical modification during storage and transportation through the Kaapvaal continental crust before being emplaced into the RLS chamber. This complex magmatic history can explain the enriched isotopic flavour of the RLS.

Keywords: Bushveld, Mantle sources, Isotopes, Geochemistry

GEOCHEMICAL TRAVERSE UP THROUGH THE LEBOMBO GROUP MONOCLINE, KAROO LIP

Martin B. Klausen[1]

[1] Department of Earth Sciences, Stellenbosch University, Stellenbosch, South Africa

This study is based on 282 new bulk rock geochemical analyses of samples collected from stacked picrite, basalt and rhyo-dacite formations of the Lebombo Group, arguably erupted and tilted along a successful rifted margin near a triple rift centre. Two parallel picritic sampling traverses along the Mwenezi and Shingwedzi Rivers represent east-/riftward extensions of the Tuli Basin, while rare exposures following upon extraordinary flooding of the Olifants River in year 2000 provided a continuous geochemical record up through the remainder of the stratigraphy, into Mozambique. Even if latter results are dominated by older XRF trace element data, their Nb, Y and Zr values sufficiently constrain most important changes in incompatible element signatures, as verified by ICPMS-LA data on selected samples. Thus, it is possible to extend geochemically distinct lower members from the Tuli basin, across into neighbouring picrite formations and further south to the basalt formation at Olifants River. Following upon more localised nephelinite eruptions, more extensive picritic fissure eruptions are characterised by having higher Zr/Nb and Zr/Y, arguably reflecting a larger lithospheric mantle source component that was remarkably enriched in incompatible elements. At Olifants, such earlier lavas are overlain by basalts with equally high Zr/Nb but lower Zr/Y, potentially being derived from a more southerly located volcano and reflecting less residual garnet in their source. This geochemically unique member further exhibits an upward differentiation trend, culminating in the section's oldest rhyo-dacite Olifants Beds and likely reflecting the earliest establishment of a crustal magma chamber. At least another two differentiation cycles are identified in overlying basalt members, which share lower Zr/Nb and Zr/Y signatures. Combined, the Lebombo section is best explained by episodic greater incorporation of asthenospheric magmas, generated through decompressional melting during successful rifting, with basalt compositions eventually matching the Bouvet plume. The marked shift to rhyo-dacites is more enigmatic, where most lower flows – in closer proximity to interbedded basalt lavas – have high Zr/Y, while the remainder of the overlying Jozini formation overlap the stronger asthenospheric signatures of the uppermost low Zr/Nb and Zr/Y basalt formations, consistent with being derivatives of these through either fractional crystallization or liquid immiscibility.

Keywords: basalt, rhyo-dacite, petrogenesis

CONTINENTAL BREAKUP, HOTSPOT ACTIVITY, AND MAGMATIC RECORD OF THE INDIAN PLATE FROM 180-60 MA

Kondepudi Pattabhiram[1]

[1] University of Johannesburg, Johannesburg, South Africa

During the Jurassic period, the supercontinent Gondwanaland began to break apart into East and West Gondwana. The fragmentation of East Gondwana continued into the early Paleocene. East Gondwana comprised present-day Australia, Antarctica, India, Madagascar, and the Seychelles. The Indian plate got separated from Australia around ~136 million years ago (Ma), from Antarctica ~126 Ma, from Madagascar around 88 Ma, and from the Seychelles approximately ~63 Ma, contributing to the formation of its present-day continental margins and opening of the Indian Ocean. This period was also marked by widespread volcanism, resulting in the emplacement of several Large Igneous Provinces (LIPs), such as the Rajmahal Sylhet Traps, the Kerguelen Plateau, the Marion and the Deccan Traps. While earlier studies have primarily concentrated on onshore magmatic records of the Indian plate, this study presents a comprehensive review of geochronological data (Ar-Ar, U-Pb, K-Ar isotopic systems, and biostratigraphy) from both onshore and offshore magmatic record from 180-60 Ma. The synthesis provides new insights into the spatio-temporal patterns of magmatism, multiple rifting cycles, and the development of offshore basins in relation to continental breakup events, plume–lithosphere interactions, hotspot track magmatism and the tectonic evolution of the Indian Ocean.

Keywords: LIPs, Hotspot trail, Plumes, continental breakup

MAGMATIC HETEROGENEITY IN THE KUNENE COMPLEX – A GEOCHRONOLOGICAL AND PETROLOGICAL STUDY OF THE ARCHITECTURAL DOMAINS AND EVOLVED ENCLAVES

Thoriso Lekoetje[1], Anne-Sophie Bouvier[2], Glenance Ngomane[3], Grant Bybee[1], Hielke Jelsma[4], Jeremie Lehmann[5], Johanna Marin-Carbonne[2], Lorenzo Milani[3], Maria Ovtcharova[6] & Urs Schaltegger[6]

[1] University of the Witwatersrand, Johannesburg, South Africa
[2] University of Lausanne, Lausanne, Switzerland
[3] University of Pretoria, Pretoria, South Africa
[4] Anglo American Exploration, Johannesburg, South Africa
[5] University of Johannesburg, Johannesburg, South Africa
[6] University of Geneva, Geneva, Switzerland

The Kunene Complex, covering > 50,000 km^2 across Angola and Namibia, is the world's largest Proterozoic massif-type anorthosite. It preserves a long-lived and compositionally composite magmatic history, reflected by a complex internal architecture of spatially and geochemically distinct domains. Dominated by mantle derived anorthosites, the Kunene Complex also features local highly evolved pegmatoidal segregations and layered domains, indicative of dynamic magmatic tectonic records. These features suggest a protracted emplacement history shaped by inherited crustal structures, deformation, overprinting events, and prolonged magmatic activity in the crust during and after its emplacement. However, post-crystallisation processes such as partial loss of daughter nuclides and fluid-assisted alteration significantly overprinted the isotopic systems. This presents a major challenge for constraining the timing and duration of magmatic differentiation and emplacement. To address this, we applied high-precision (CA-)ID-TIMS U-Pb dating to baddeleyite and zircon from key lithologies across the complex. Our results reveal a marked geochronological heterogeneity. Baddeleyite from the layered domains is typically discordant, with young and variable $^{207}Pb/^{206}Pb$ ages. Zircon from pegmatoidal segregations hosted within the oldest anorthosite domains is ~3 million years older than zircon from nearby anorthosites, and significantly older (>110 Myr) than zircon and baddeleyite from the layered domains. Zircon from pegmatoidal segregations and host anorthosite shows clear magmatic geochemical signatures and mantle-like $\delta^{18}O$ values (average: + 5.56 ± 0.52 ‰), supporting an origin of the former as late-stage differentiates of a mantle-derived magma. In contrast, baddeleyite from the younger layered domains shows more variable geochemical compositions and a wide range of $\delta^{18}O$ values (- 0.21 to + 2.75 ‰). This variation in the layered domains is also linked to lithological differences within the domains. These results suggest a complex history involving crustal assimilation, fluid interaction, or thermal overprinting in the KC main lithologies. We interpret the age variation and isotopic complexity as resulting from a combination of Pb-loss, radiation damage, and lithology-dependent recrystallisation or alteration. By integrating petrographic characterisation (BSE, CL, µRaman) with trace element data and oxygen isotope analyses, we distinguish primary magmatic signatures from secondary thermal and fluid overprints from both zircon and baddeleyite grains in KC samples. These results highlight the importance of spatially resolved geochronology and geochemistry in deciphering complex, uniquely long-lived, mafic systems.

The Kunene Complex emerges as a mosaic of compositionally and temporally distinct magmatic domains, with significant implications for understanding Proterozoic crustal growth, as well as ascent and emplacement, and alteration of mantle-derived magmas in crustal reservoirs.

Keywords: Kunene Complex, Baddeleyite, Zircon, High-precision geochronology

CHARACTERISATION OF THE MAFIC INTRUSIONS ASSOCIATED WITH THE GEOLOGY OF THE GHAAP PLATEAU CARBONATES IN THE GRIQUALAND WEST AREA OF THE KAAPVAAL CRATON, SOUTH AFRICA

Rebeun Ngobeli[1], Clarisa Vorster[1], Hervé Wabo[1] & Michiel de Kock[1]

[1] University of Johannesburg, Johannesburg, South Africa

The Kaapvaal Craton in southern Africa is host to regional dyke swarms and sill provinces that may be associated with Large Igneous Provinces (LIPs). Most investigations of the dyke swarms and sill provinces have been conducted in the central and eastern regions of the Kaapvaal Craton, where outcrop exposures are abundant. In contrast, the western region has received less attention due to fewer surface exposures, although some dykes can be recognised as prominent lineaments with different orientations and crosscutting relationships visible on satellite images and existing geological maps. The Ghaap Plateau carbonates in the Griqualand West basin have been intruded by several dyke swarms and sill provinces, named the Ghaap Plateau intrusions. Currently, there is a lack of published data regarding these intrusion nature and timing of emplacement. A total of twenty-six intrusions were collected from surface outcrops, drill cores, and/or percussion drilling. These intrusions represent individual sites that were studied to provide petrological, geochemical, and paleomagnetic data, along with U-Pb baddeleyite and zircon age results. Petrographically, these intrusions are mainly composed of clinopyroxene and plagioclase crystals, which exhibit varying degrees of alteration. Geochemically, these intrusions are classified as basalts with signatures of MORB, EMORB, or within-plate origins, suggesting an asthenosphere mantle-related source. Based on LA-MC-ICP-MS, U-Pb baddeleyite and zircon geochronology, the intrusions can be divided into five groups: Group-A (2146 Ma). Group-B (1931 Ma) Group-C (1846 Ma), Group-D (1660 Ma), and Group-E (1110 Ma). Group-A is characterised by unique geochemical traits and U-Pb ages that do not match any known mafic intrusions in the Kaapvaal Craton. Group-B's U-Pb ages, paleomagnetic data, and geochemical signatures are associated with the Hartley LIP. Group-C's U-Pb ages and geochemical characteristics are comparable to the Black Hills Dyke Swarm. Group-D shows distinct geochemical characteristics and U-Pb ages that do not match any known mafic intrusions in the Kaapvaal Craton, while Group-E's U-Pb ages and geochemical traits are comparable to the Umkondo Large Igneous Province (LIP). Overall, the results from the studied intrusions indicate that the Ghaap Plateau intrusions are probably not related to a single magmatic event but represent swarms of different generations.

Keywords: Geochemistry, LA-MC-ICP-MS, Mafic intrusions, Kaapvaal Craton

DEVELOPING A SEISMIC REFERENCE SECTION OF THE EASTERN BUSHVELD COMPLEX'S CRITICAL AND LOWER ZONES USING BOREHOLE GEOPHYSICAL DATA FROM THE ICDP BUSHVELD DRILLING PROJECT (BVDP)

Treyen Pillay[1], Musa Manzi[1], Stephanie Enslin[1] & Susan J. Webb[1]

[1] University of the Witwatersrand, Johannesburg, South Africa

The Lower and Marginal Zones of the Eastern Bushveld Complex contain crucial geological information for understanding mafic-ultramafic stratigraphy and mineralization processes but remain poorly studied. To address this gap, the ICDP Bushveld Drilling Project (BVDP) was initiated to obtain core and downhole geophysical data in a stratigraphic context of the Lower Critical Zone and underlying Lower Zone. Additionally, we have been able to obtain downhole geophysical data for the CH7 borehole which goes through the Lower Zone, Marginal Zone, and Basal Ultramafic Sequence. Furthermore, there is published lithological data for boreholes CH1 and CH6 for the Lower Zone. This creates an almost complete stratigraphic sequence from the Lower Critical Zone to the underlying Transvaal. At the time of writing the BVDP borehole is at a depth of 1456.55 m within the Lower Zone, but geophysical data has currently only been collected to a depth of 950 m. The geophysical borehole data from BVDP and CH7 give us a unique opportunity to investigate seismic reflectivity and compare this to the legacy seismic line SEK-1. This project is developing a seismic reference section for the Upper Critical Zone, Lower Critical Zone, and Lower Zone by integrating the density and P-wave velocity (Vp) measurements of BVDP and CH7 and assigning velocity values for lithologies in the stratigraphic gap between them. We can use the measured and assigned density and velocity data to calculate the impedance and reflectivity for this section. This will allow us to identify key reflectors and provide a more detailed interpretation of the SEK-1 seismic line, which is only ~4 km to the northwest. This reflection seismic line has only had rudimentary interpretations done due to the lack of existing borehole geophysical data. Further work will include the boreholes BH7771, BH7772, BH8172, BH6958, kindly donated by Impala platinum, which cover the Upper, Main and Upper Critical Zones, which will result in a complete stratigraphic reference section for the Eastern Bushveld Complex, with assigned velocity and density values that can create a more complete cross section through the Bushveld and aid in fully interpreting SEK-1 and future reflection seismic surveys.

Keywords: seismic reference section, Bushveld Complex, BVDP, borehole, geophysical data, Lower Zone

THE MESOPROTEROZOIC GABBRO-NORITE HOSTED OUP Ni-Cu-Co-(Mo) DEPOSIT IN CENTRAL BUSHMANLAND, NAMAQUA METAMORPHIC PROVINCE, SOUTH AFRICA

Abraham Rozendaal[1], Deon le Roux[2], Dirk Frei [1,3] & Rene Heyn[1]

[1] Department of Earth Sciences, University of Stellenbosch, Stellenbosch, South Africa

[2] Gemini Mining and Exploration Ltd, Pofadder, South Africa

[3] University of the Western Cape, Bellville, South Africa

The Oup deposit was discovered in the 1970's and is one of several small mafic intrusives hosted by metavolcano-sedimentary rocks with abundant felsic gneiss and granitoids of the western part of the Gordonia Subprovince, NMP. Over the years, intermittent drilling outlined a resource of 2 million metric tons at a grade of 0.4 per cent nickel, 0.3 per cent copper, 0.05 per cent cobalt and 0.02 per cent molybdenum. Platinum group elements, including gold content is less than 1 ppm. The massive sulphide ore is dominated by magnetic pyrrhotite with minor cobaltian pentlandite, chalcopyrite, marmatitic sphalerite and molybdenite. It is associated with an orthomagmatic mafic suite consisting of gabbro-norite, norite, pyroxenite and minor nelsonite that intruded syntectonically into a suite of granitoid gneisses, granites and granodiorites. The deposit has been tectonised and consists of irregularly shaped, discontinuous bodies. Tectonoclasts are abundant and occur in a matrix of ductile massive sulphides. The clasts have a diverse composition reflecting the associated mafic suite and gneissic wall rocks. Coarse-grained zircons from nelsonite clasts have been in situ dated and provided a U-Pb age of 1151±6.3 Ma. This equates the Oup mafic rocks with the Kum Kum mafic suite of the Richtersveld Subprovince of southern Namibia. The latter hosts the prospective nickel, copper, cobalt and PGE mineralized mafic to ultra-mafic Tantalite Valley Complex. In addition, this demonstrates that these synchronous mafic intrusions straddle the Gordonia and Richtersveld Subprovince boundaries and that their distribution is not restricted to specific tectonostratigraphic terranes. The entire area is considered underexplored, and these two related deposits could indicate the possibility of a nickel-copper district.

Keywords: Oup, magmatic, Ni-Cu-Co, Mesoproterozoic

INTRUSION MECHANISM AND MAGMA DIFFERENTIATION OF THE TIMBAVATI GABBRO: INTEGRATING MACHINE LEARNING AND REMOTE SENSING FOR GEOLOGICAL MAPPING

Rowan Walker[1] & Martin Klausen[1]

[1] Stellenbosch University, Stellenbosch, South Africa

The Timbavati Gabbro (TG) is part of the 1115 ± 0.4 Ma Umkondo Large Igneous Province (LIP), confirmed by a U-Pb baddeleyite age. This short-lived magmatic event consists of dykes, sills, and remnant lavas across the Kalahari Craton. The TG intrudes the granitoid-greenstone basement of the Kaapvaal Craton, forming a ~270 km-long N-S body with thicknesses from ~200 m in the north to ~480 m in the south. In places, it is non-conformably overlain by Karoo strata. It has been proposed to consist of shallow (~20–30°) inward-dipping Hertzian 'cone sheets', though this model remains unverified. Petrologically, the TG is modally layered, with basal olivine melagabbronorites transitioning into upper quartz gabbro (Walraven, 1984). Mineral chemistry (Bullen, 2005) indicates cumulus olivine (Fo68-83), orthopyroxene (En71-82), plagioclase (An39-71), and clinopyroxene. Geochemical traverses (Walraven, 1984) suggest multiple magma injections, while isotopic analyses link the TG's parental magmas to a sublithospheric, spinel-bearing mantle source with lithospheric contributions. Despite well-documented petrology, the TG's structural geometry remains poorly constrained, relying on outdated aerial photogrammetry and limited outcrop mapping (Walraven, 1986). Modern remote sensing (e.g., radar, aeromagnetic), machine learning, and field validation are needed. Mapping is further restricted by the TG's location in Kruger National Park. This study re-maps the TG to refine its geometry, layering, and differentiation. Sentinel-1 Radar, high-resolution satellite imagery, Google Earth Pro, geological maps, and field observations improve mapping accuracy. Machine learning integrates these datasets while adhering to geological constraints, such as avoiding overlap with older NE-SW Black Hill (~1.9 Ga) and E-W Rykoppies (~2.7 Ga) dykes, while considering potential cross-cutting by younger N-S and NW-SE Karoo dykes. The study improves on TG emplacement models, including a proposed saucer-shaped intrusion versus a dyke-and-sheet complex. The WNW-ESE TG segments align with a 1.1 Ga diabase dyke swarm across the Kalahari Craton, suggesting a back-arc rift system. Advanced remote sensing and ground-truthing are crucial for understanding mid-Proterozoic tectonics and LIPs.

Keywords: Large Igneous Provinces (LIPs), Emplacement Mechanisms, Remote Sensing, Modern Techniques

Applied Mineralogy: Providing Practical Solutions to Research and Industry

EVALUATING THE USE OF HIGH-RESOLUTION RGB AND MULTISPECTRAL IMAGING AS A POTENTIAL TOOL FOR DRILL-CORE LOGGING OF THE ROCKS OF THE BUSHVELD COMPLEX

Nomonde Mabogo[1], Martin Clark[1] & Frederick Roelofse[1]

[1] University of the Free State, Bloemfontein, South Africa

The mining industry is actively exploring new technologies to improve efficiency and profitability. While automation and digitalization are advancing, exploration, the most expensive phase, still relies on traditional methods. Drill core logging remains largely manual, making it time-consuming and prone to spatial inconsistencies. The mining industry is exploring reflectance spectroscopy in various mining processes. Here, reflectance spectroscopy using RGB and multispectral imaging is investigated as a potentially cost-effective tool for expediting drill core logging of the rocks of the Bushveld Complex. RGB images can be processed rapidly to discriminate variability between mafic and felsic rocks while multispectral imaging from five bands across 475-842 nm further helps to classify major lithologies such as anorthosite, gabbronorite, and chromitite, with near-infrared and red-edge bands further aiding distinction. In cases where certain lithologies exhibit spectral similarities, statistical analysis is shown to help differentiate them. This contribution shows promise for cost-effective RGB and multispectral logging tools to be deployed into mining processes, without mandating the need to incorporate larger hyperspectral scanners.

Keywords: multispectral imaging, spectral analysis, core logging, Bushveld Complex

MINERAL CHEMISTRY AS VECTORS TO GRANITE ASSOCIATED MAGMATIC-HYDROTHERMAL MINERALISATION IN THE NORTHERN CAPE, SOUTH AFRICA

Nomaswazi Makhombothi[1] **& Leonidas Vonopartis**[1]

[1]University of the Witwatersrand, Johannesburg, South Africa

The demand for critical metals has increased intensively in recent years, with critical metals like tungsten (W) gaining more relevance in the mining industry. Since 2011, W has been considered a critical metal and a vital component in the manufacturing of advanced alloys. There has also been an increased need for exploration of tungsten deposits, with minerals such as quartz and micas having been used in the exploration of other economically significant deposits. This study aims at using these minerals as vectors to discover W deposits in granite associated magmatic-hydrothermal mineralisation. The study sites for this research are located in the Northern Cape Province, South Africa. The first site is Renosterkop which was previously studied by Allane Saad in 1987 however; this study was petrologically focused and does not discuss how Sn-W deposits can be explored for using different exploration techniques. The W from Renosterkop was previously described to be endogranitic. Van Rooi's Vley is the second study site, and the occurrence of W was previously defined to be exogranitic and concentrated in quartz veins. The main research questions for this study revolve around comparing the two sites to one another and looking for similarities in the way in which W-Sn deposits may have formed. The main methods that are to be used include petrography, whole rock geochemistry analysis using EPMA, LA-SF-ICP-MS for dating zircons in the rock samples and comparing ages from the two study areas. Hydrogen and oxygen isotopes will be analysed for identification of the type of fluid source that introduced Sn-W to the host rocks in the study areas. From the analysis of the results, it should be clear on whether or not quartz and micas can be used as vectors in the exploration for Sn-W deposits. The complementary use of quartz and mica from mineralised granitic systems will provide insight into the formation and give a broader understanding of endo- and exogranitic magmatichydrothermal systems. It will add to the limited research on the geochemistry, mineral compositions, and formation of these W-mineralised systems. The research will contribute to a holistic understanding of the systems.

Keywords: Tungsten, Granitoids, Quartz-tourmaline, Alteration-mineralisation

THE PRESENCE OF PLATINUM GROUP ELEMENTS (PGEs) IN PLATINUM-MINE TAILINGS, IN THE WESTERN BUSHVELD AND IMPLICATIONS FOR POTENTIAL REPROCESSING

Thendo Mapholi[1] & Robert Hansen[1]

[1] Department of Geology, University of the Free State, Bloemfontein, South Africa

The Marikana and Kroondal Platinum Mines tailings were investigated to determine the presence and concentrations of PGEs with the purpose of determining the potential of re-processing in the future. The thriving re-processing of gold tailings and lack of exploration and reprocessing of platinum mine tailings for PGEs extraction in South Africa is the main driver of this research. Moreover, it has been discovered with gold that, exploration of old tailings can result in sustainable and profitable strategy for mining. The mineralogical characteristics of the tailings and the concentrations of the of the PGEs in the different tailing's facilities were determined. The dominant mineralogy of the tailings was investigated using XRD and microscopic work and it was observed that the tailings are dominated by chromite and plagioclase. The detection of base metal sulphides and the grain sizes was determined using SEM work and the results showed that the presence of sulphides, pyrite, pentlandite and pyrrhotite. Fire assay results showed the presence of PGEs (Platinum and Palladium) grades are 0.4g/t Pt and 0.23g/t Pd in the Kroondal tailings and 0.28g/t Pt and 0.15g/t Pd in Marikana tailings. The economic viability of re-processing of these tailings does not depend solely on the mineralogy and grades of the tailings, it also depends on the PGEs market. PGE market is affected by the increase in the production of electric vehicles and lithium-ion as well as the production of fuel hydrogen cells.

Keywords: mineralogy, tailings, base metal sulphides, re-processing.

PHOSPHATE MINERALIZATION IN THE NKOMBWA HILL CARBONATITE

Thendo Mapholi[1], R.E. Harmer[2] & Yibas-Babso Bisrat[1]

[1] Department of Geology, University of the Free State, Bloemfontein, South Africa

[2] Rhodes University, Makhanda, South Africa

An increasing demand on food production in the past few years leading to an increase in demand of phosphate and the current conditions of declining industrial reserves of apatite-containing ores, edges the need to focus on other types of phosphate ore. The above mentioned is the main driver of this research. Hand specimen observation and description, microscopic coupled with traditional optical point-counting and SEM were done to better understand the mineralogy, mineralogical composition, texture, and content of phosphate mineral species of the Nkombwa Hill carbonatite. Nkombwa Hill carbonatite contains various phosphate mineral species: apatite, isokite and monazite. Microscopy coupled with optical point-counting revealed that isokite is the most abundant phosphate mineral along with variable apatite content, with monazite occurring in trace amounts. Two phosphate ore types are recognised based on the relative abundances of apatite and isokite: apatite only ore, and apatite-isokite ore. Monazite is restricted to the apatite-isokite ore type. Importantly, optical microscopic work revealed significant textural differences between isokite and apatite. Apatite occurs as either coarse, well-developed prismatic crystals in apatite only ores, and as anhedral crystals, clusters and medium-to- coarse, elongate crystals in apatite-isokite ores. Isokite mostly occurs as small fibrous spherulites, less frequently as larger radiating aggregates of acicular crystal, and on rather rare occasion as veins within apatite. There is currently no viable beneficiation process to produce conventional fertilizers from the magnesian phosphate mineral isokite: for this reason, despite exploration efforts over more than 50 years, the phosphate resource at Nkombwa Hill remain undeveloped. This study has shown that at least part of the phosphate ore at Nkombwa contains a significant amount of apatite. Furthermore, the isokite component of the ore has markedly different crystal form to the apatites: generally elongate needles with high length: breadth ratios that contrast with the more study, prismatic apatite crystals. During pulverizing, the isokite is likely to produce very fine-grained crush (“slime”) relative to the apatites. This feature, along with subtle density differences between these minerals, offers the possibility of producing an apatite concentrate from the Nkombwa ores that could be processed into fertilizer by conventional methods.

Keywords: phosphate-ore, isokite, carbonatite, fertilizers.

REVISITING THE MINERALOGY OF THE VAAL REEF AND THE CRYSTALKOP REEF AT KOPANANG GOLD MINE (SOUTH AFRICA): EVIDENCE OF REFRACTORY ORES

Makatu Casius Mashanyu[1], Frank Nuemann [1,2], Frans Waanders[2] & Quentin Campbell[2]

[1] Unit for Environmental Sciences and Management, North-West University, Potchefstroom, South Africa

[2] School of Chemical and Minerals Engineering, Biofuels Research Group, North-West University, Potchefstroom, South Africa

The Witwatersrand Basin, renowned for its gold deposits, hosts both free-milling and refractory ores, with the Vaal and Crystalkop Reefs at Kopanang Gold Mine serving as examples of the latter. Traditionally, gold ores from the basin are classified as free-milling, with cyanidation providing high recovery rates. However, some reefs contain refractory gold, trapped within sulfides or silicates, necessitating additional processing steps. This study revisits the mineralogy of these reefs, emphasizing their refractory nature and the challenges they pose to gold recovery. Detailed mineralogical analysis was conducted using optical ore microscopy, X-ray diffraction (XRD), mineral liberation analysis (MLA). These analyses revealed significant gold deportment within sulphide and silicate phases. In the Vaal Reef, gold is predominantly associated with sulphides (82.57%), while the Crystalkop Reef shows a more complex gangue minerals assemblage, with significant associations with silicates (10.38%) and rare earth element-bearing phosphate minerals (6.15%). Pyrite is a major phase in both reefs, with zeolite found in the Vaal Reef and pyrophyllite in the Crystalkop Reef. Fire assay (FA) was conducted to determine the grade of both reefs and Laboratory based bottle roll reverse leach tests were conducted to understand the leaching behaviour of the Vaal and Crystalkop Reefs. The results revealed higher gold grades in the Crystalkop Reef (15.64 g/t) compared to the Vaal Reef (7.7 g/t), but the latter exhibited better recovery (70% vs. 65%). The findings of this study demonstrated that the Vaal Reef's gold is mostly inaccessible due to its sulphide association, while the Crystalkop Reef's silicate-locked gold presents additional challenges for recovery. Despite the higher gold grade in the Crystalkop Reef, its lower recovery rate is attributed to the difficulty of leaching silicate-locked gold. These results highlight the importance of understanding ore-specific mineralogy to optimise metallurgical processes, offering insights into improving recovery rates for refractory gold ores in the Witwatersrand Basin and beyond. The study confirms the refractory nature of these ores and the need for tailored processing methods to improve recovery, such as sulphide oxidation for the Vaal Reef and ultrafine grinding to liberate the silicate-locked gold in the Crystalkop Reef.

Keywords: Refractory ores, Vaal Reef, Crystalkop Reef, Witwatersrand Basin

A PROCESS MINERALOGICAL STUDY OF VARIOUS UG2 ORE-TYPES FROM ROWLAND SHAFT OF SIBANYE-STILLWATER MARIKANA PLATINUM OPERATION, BUSHVELD COMPLEX, SOUTH AFRICA

Ernest Moitsi[1], Brad Guy[2], Derek Rose[3] & Fanus Viljoen[4]

1. Department of Geology, University of the Free State, Bloemfontein, South Africa
2. Helmholtz-Zentrum Dresden-Rossendorf, Freiberg, Germany
3. Mintek, South Africa
4. Department of Geology, University of Johannesburg, Auckland Park, South Africa

Various Upper Group 2 Chromitite (UG2) ore types are recognised at the Rowland shaft, including feldspathic-pegmatoidal-pyroxenite, IRUP, transitional, and pothole facies. These differ in terms of layer thickness, mineralogical composition, vertical distribution of platinum group elements (PGEs), base metal sulphides (BMS), platinum group minerals (PGMs), and association with late post-magmatic features such as faults, potholes, and iron-rich ultramafic pegmatites (IRUP). The impact of these variations, especially late post-magmatic alteration like IRUP and hydrothermal fluids, on UG2 processing performance is poorly understood, leading to operational uncertainty. This study investigated the mineralogical composition and metallurgical performance (milling and flotation response) of UG2 ore facies to better understand how these features, particularly IRUP, affect processing behaviour. Channel sampling was conducted at Rowland shaft on different UG2 ores: those with pegmatoidal feldspathic pyroxenite or anorthositic footwalls, altered hanging walls, and IRUP association. These samples underwent petrographic examination, qualitative and quantitative mineralogical analysis using the Mineral Liberation Analyser, and metallurgical testing, including comminution and laboratory-scale flotation. IRUP-rich alteration zones commonly occur as conformable sheets below the reef bottom contact, replacing plagioclase-rich pegmatoidal pyroxenite. This leads to the introduction of Fe, Ti, V, and Ca, forming phases such as titaniferous magnetite and ilmenite, and altering primary silicates (orthopyroxene, plagioclase) into low-temperature hydrous minerals like amphibole, talc, and serpentine. In unaltered UG2, dominant BMS include pentlandite, chalcopyrite, and pyrrhotite (avg. 30 µm), with minor pyrite and millerite; PGMs include laurite, cooperite, and braggite, mostly associated with BMS. The BMS mineralogy in IRUP-affected ore is similar but with slightly coarser grains. The altered ore's PGMs include laurite, Pt-Rh-Fe, and Pt-Pd-Fe alloys. The milling test results show that IRUP facies require the least time (22 minutes) to achieve 75 weight percentage passing a 75-micron sieve compared to transitional facies (26 minutes) and unaltered facies (27 minutes). In addition, flotation test results have illustrated that these ore types follow different flotation behavioural trends; for example, higher cumulative mass pull was recorded for IRUP facies-type relative to others. Overall, the IRUP faciestype shows relatively lower flotation efficiency compared to the transitional and unaltered facies types.

Keywords: Upper Group 2, IRUP, Flotation, pegmatoidal pyroxenite

PROCESS MINERALOGICAL CONSTRAINTS ON THE RECOVERY OF PLATINUM GROUP METALS VIA DIRECT LEACHING OF UG2 ORE IN THE BUSHVELD COMPLEX

Nonhlanhla Ndlovu[1], Glen Nwaila[1] & Nonkuselo Madlakana[1]

[1] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

As global efforts to reduce carbon emissions intensify, the demand for platinum group metals (PGMs) continues to rise. This is driven by their unique physical and chemical properties such as good corrosion and oxidation resistance, high melting temperatures, good conductivity, electronic and catalytic properties, and their important role in platinum-catalysed hydrogen-powered fuel cells for electric vehicles (EVs). Traditionally, PGMs from primary ores such as the Upper Group 2 of the Bushveld Complex in South Africa have been recovered via a crush–mill–float–smelt process followed by multi-stage leaching process to recover base metals and PGMs. However, the complex mineralogy and texture coupled with declining ore grades, often result in suboptimal metal recoveries during flotation and create mounting uncertainties in long-term PGM supply. Direct leaching has attracted significant attention as a potentially cost-effective and environmentally benign alternative to the conventional processing route, particularly for low-grade, mineralogically complex ores. The crux of successful direct leaching hinges on a rigorous mineralogical investigation that explain the distribution, association, and textural attributes of PGM-bearing minerals. In this study, we employed a process mineralogy framework to evaluate the feasibility of direct leaching over froth flotation. Representative samples from the UG2 Reef were characterised using the TESCAN Integrated Mineral Analyzer (i.e. (TIMA), coupled with Electron Probe Microanalysis for mineralogical properties and inductively coupled plasma mass spectrometry (ICP-MS) for chemical composition. TIMA analyses revealed predominantly fine-grained PGM minerals hosted within chromite and base-metal sulphides (BMS) leading to poor liberation which will restrict contact between lixiviants and target valuable metals during direct leaching. ICP-MS data confirmed significant concentrations of base metals (i.e., Ni, Cu, Co), which can compete with PGMs during leaching and may increase reagent consumption and reducing overall PGE recovery during leaching. Understanding these textural complexities and PGM associations is important for modulating key parameters such as particle size distribution, leaching reagent type(s), conducive solution pH and temperature and overall leach kinetics in order to improve recovery of PGMs. Insights gained from this mineralogical investigation offer guidance for developing more efficient direct leaching process route of complex and low grade PGMs.

Keywords: Bushveld Igneous Complex, Direct Leaching, Platinum Group Metals, Process Mineralogy

BEYOND THE SURFACE: THE ROLE OF MINERALOGY IN THE EXTRACTION OF CHROMITE AND PGM's

Simona Poelinca[1], Kirsten Youlton[1] & Lelanie Gryffenberg[1]

[1] SGS South Africa

Mineralogy plays an essential role in the efficient optimisation of mineral processing, particularly when it comes to complex commodities such as chromite and platinum group minerals (PGM's). South Africa, home to the famous Bushveld Igneous Complex (BIC), represents a major source of both chromite and PGM's, alongside other significant deposits worldwide. The extraction of these minerals requires a detailed understanding of their mineralogical characteristics, such as liberation, size distribution, association, and textural properties. Such knowledge enables metallurgists to design tailored processing circuits with an aim to maximise recovery while minimising operational costs. Given the current PGM market, ensuring the best possible recovery of PGMs is vital to maintaining economic feasibility in the industry. Despite chromite and PGM's often occurring together in the same ore bodies, and consequently being closely associated, their processing requires distinct approaches (e.g. physical separation and flotation, respectively). In contrast to a prior chromite-focused processing approach, particularly in UG units of the BIC, recent developments have seen an increased interest in maximising the recovery of both PGM's and chromite within one processing circuit as well as from reprocessing of chromite tailings dams. This introduces additional challenges when extracting PGM's from chromite, sulphides, and/or gangue minerals. Various controls (e.g. PGM speciation, degree of liberation and the presence of fine-grained chromite generated from prior milling in conjunction with chromite entrainment) may hinder the effectiveness of this extraction when using established processing methods. In addition, greater than 3% chromite, when present in a PGM concentrate, is known to result in later penalties, which further increase operational costs. Hence, a thorough mineralogical analysis is necessary to determine optimal strategies for both PGM and chromite recovery. Various case studies are presented highlighting relevant mineralogical data of both chromite and PGM's and their relation to mineral processing. Furthermore, the importance of an integrated approach to ore characterisation in overcoming processing challenges inherent in extracting both chromite and PGM's is explored.

Keywords: mineralogy, chromite, PGM's

UNCONFORMITIES, DIAMICTITES, SYNDEPOSITIONAL FAULTS AND STRATABOUND SULPHIDE MINERALIZATION: THE GAMSBERG ZINC DEPOSIT EXAMPLE FROM THE MESOPROTEROZOIC NAMAQUA METAMORPHIC PROVINCE, SOUTH AFRICA

Abraham Rozendaal[1], Marcel Stalder[1] & Rene Heyn[1]

[1] Department of Earth Sciences, Stellenbosch University, Stellenbosch, South Africa

Gamsberg hosts a supergiant zinc deposit and is one of several that comprise the Gamsberg-Aggeneys Ore District (AGOD). The stratabound ore zone is a Zn/Pb/Fe sulphidic meta-pelite and Fe/Mn/Ba meta-iron formation (Gams Formation) hosted by an essentially meta-siliciclastic sedimentary sequence with minor meta-volcanics (Bushmanland Group). The top of the ore zone is marked by an unconformity of deeply incised erosional channels and overlying polymictic boulder conglomerate with interbedded diamictite of the psammitic Koeris Formation. These sedimentary features, including associated syndepositional faults, are typical of similar sulphide deposits across the globe. Although considered as sedimentary exhalative hydrothermal, their genesis remains controversial, in particular the timing of the main mineralizing event. This study compared the textural and mineralogical features of the diamictite clasts and matrix with the underlying "in situ" Gams Formation with the aim to establish their provenance. The diamictite is polymictic and consists of angular, finely bedded specularite/franklinitic magnetite iron formation and quartzite clasts of variable size, supported by a tectonised matrix of spessartine garnet, quartz, specularite, minor gahnite/ hercynite and apatite with a variable Fe, Mn, Pb and As content. Textural and mineralogical characteristics of the clasts are similar to the stratigraphically underlying zinciferous Fe/Mn-rich C member of the Gams Formation of the East and South orebodies. This relationship clearly illustrates that the latter units and associated mineralization, existed prior to the erosional events that defined the unconformity. This adds further support to the syngenetic nature of the Gamsberg and other base metal deposits of AGOD. On a regional scale, diamictites, where zinciferous, and juxtaposed with unconformities have been used as a guide to similar deposits within the Bushmanland Group and its stratigraphic equivalents.

Keywords: diamictite, iron formation, base metal sulphides

Bolides, Impacts and Shock Phenomena

SEISMIC SIGNATURE OF THE 25 AUGUST 2024 NQWEBA METEORITE, EASTERN CAPE, SOUTH AFRICA

Fenitra Andriampenomanana[1], Musa Manzi[1], Raymond Durrheim[1] & Roger Gibson[1]
[1] University of the Witwatersrand, Johannesburg, South Africa

On 25 August 2024, at approximately 06:50 UTC (08:50 local time), a bright meteor fireball was observed by residents of the broader Gqeberha region in the Eastern Cape, South Africa. The fireball was visible for at least five seconds before disrupting and was followed by a thunder-like noise and ground tremors. Preliminary petrographic analysis identified a fragment that fell into a garden near Nqweba as a brecciated achondrite meteorite. The infrasound station I47ZA, located approximately 530 km and 590 km north of Nqweba and Gqeberha, respectively, recorded an atmospheric disturbance from an energy release between azimuths 176° and 197°, roughly toward these locations. The Centre for Near-Earth Object Studies later estimated the meteoroid to be approximately 1 m in diameter, with an energy release equivalent to 92 t of TNT. This study analyses seismic signals recorded at nearby seismic stations during the event to detect meteor-related seismic signatures, understand their generation mechanisms, and estimate the meteoroid's trajectory. Clear meteor-generated seismic signals were observed at three stations: SVILL (~140 km from Nqweba), BUFB (~106 km), and BFKLF (~330 km) at 06:53 UTC, 06:54 UTC, and 06:57 UTC, respectively. The signals exhibited a two-stage pattern characteristic of meteor-related events. The first arrival, an air-coupled ground wave, consists of dispersive Rayleigh waves generated by shock waves from the meteor's hypersonic entry or terminal burst interacting with the ground. The second arrival, a stronger W-shaped pulse known as the directly coupled airwave, corresponds to a positive overpressure from a ballistic shock. Using these seismic arrivals, the meteoroid's trajectory was reconstructed through an analytical method, yielding: (1) an azimuth of 299±2° (measured counterclockwise from South), consistent with eyewitness reports of the fireball's ENE direction; (2) a low entry angle of 13±1°, explaining its prolonged visibility (~5 s); and (3) a hypersonic entry speed of 19±1 km/s.

Keywords: meteorite, seismic signals, shock waves, trajectory reconstruction

COOLING INDUCED FRACTURING IN IMPACT MELT DIKES DERIVED FROM DRONE PHOTOGRAMMETRY AND PYTHON SIMULATION: EXAMPLE FROM THE LESUTOSKRAAL GRANOPHYRE DIKE IN SOUTH AFRICA

Martin D. Clark[1], Elizaveta Kovaleva[2], Francois D. Fourie[1], Matthew S. Huber[3] & Stephanus Riekert[1]

[1] University of the Free State, Bloemfontein, South Africa
[2] University of Kwazulu-Natal, Durban, South Africa
[3] Planetary Science Institute, South Africa

Large meteorite impact events produce significant amounts of crustal melt, which can be emplaced as dikes below the crater floor over protracted time periods following the cratering process. Their emplacement is theorised to be controlled by stresses associated with the presence and opening of crustal-scale fractures, hydrostatic pressures associated with the overlying melt sheet, and lithostatic stresses of the impacted crust. At least two compositionally distinct phases of impact melt are present within the impact melt dikes at the Sudbury and Vredefort Impact Structures, underpinning the debated concept of a prolonged and multi-phase emplacement process. In this study, cooling fractures within the Lesutoskraal impact melt dike at Vredefort are investigated as a possible pathway to facilitate multi-phase emplacement. Through a combination of high-resolution (0.612 mm/pixel) drone orthophotography and numerical simulation of stress induced during cooling of impact melt shows that (1) the dominant fracture orientation within the impact melt dike is parallel to dike margins, related to a perpendicular and tensional cooling stress, and (2) the magnitude of the tensional cooling stress could reach up to -75 MPa, sufficient to overcome the lithostatic stresses at the observed depth of dike emplacement. Depending on simulation parameters such as the initial temperature of the impact melt, cooling fractures in the impact melt are shown to form within 150 days after their emplacement representing a possible mechanism for emplacement of later phases of impact melt into the centre of earlier impact melt phase.

Keywords: fracture, drone, python, stress

THE EARLY BREAKUP OF METEOROIDS DURING ATMOSPHERIC ENTRY: INVESTIGATING THE LINKS BETWEEN MECHANICAL PROPERTIES, PETROGRAPHY, AND GEOCHEMISTRY OF METEORITIC MATERIALS

Llelani Coetzer[1], Matthew Mayne[1] & Nawaz Mahomed[1]

[1] Department of Earth Sciences, Stellenbosch University, Stellenbosch, South Africa

Understanding the physical properties of near-Earth objects is vital for assessing potential risks during atmospheric entry and fragmentation. These properties also offer insights into planetary accretion processes and material characteristics. Meteoroids often disintegrate under dynamic pressures lower than their meteorites' mechanical strengths, indicating that factors beyond toughness – such as atmospheric drag, microstructure, and porosity – contribute to fragmentation. This study investigates the petrography and geochemistry of meteorites to explore the relationship between geological material characteristics and mechanical behaviour, aiming to better understand early breakup mechanisms under low compressive stress. A suite of iron, stony, and stony-iron meteorite samples was analysed for petrological characteristics. MicroComputed Tomography (μCT) was used to evaluate density, porosity, fracture networks, and inclusion distribution. These scans revealed substantial variability across meteorite types. Stony meteorites generally had higher porosity than iron types. In the Camel Donga meteorite, μCT imaging showed clusters of distinct materials with fractures occurring at their interfaces. Although stony meteorites typically displayed more fractures, notable exceptions included the highly porous yet sparsely fractured stony meteorite NWA 2965, and the heavily fractured iron meteorite NWA 14958. This indicates that while porosity affects fracture propagation, it is not the sole factor influencing early breakup. Building on μCT results, transmitted and reflected light microscopy, as well as scanning electron microscopy were employed to measure mineralogical compositions and textural features, including interstitial materials, internal grain structures, and boundaries. The results show predominantly mafic (high iron and magnesium) compositions and complex, varied textures in stony and stony-iron meteorites. Iron meteorites exhibited distinct crystallographic structures formed by alternating iron- and nickel-rich alloy lathes. Although the mineral compositions of the observed meteorites are generally similar to mafic terrestrial rocks, many of their textures are not observed in the Earth analogues. Consequently, meteoritic entry models that neglect these complex textures may produce inaccurate predictions of fragmentation behaviour. This research forms part of a broader collaboration between Stellenbosch University and the Chinese Academy of Sciences, examining how shock, drag, and ablation influence meteoroid breakup during atmospheric entry. These findings contribute to improved models of meteoroid origins and more accurate risk assessments for potential Earth impacts.

Keywords: meteorite, petrography, material mechanics, breakup

IMPACT-INDUCED HYDROTHERMAL ALTERATION IN THE M4 DRILLCORE, MOROKWENG IMPACT STRUCTURE, SOUTH AFRICA – SUPPORT FOR A PEAK RING CRATER AND DEEP EROSION

R.L. Gibson[1], L. Malelu[1], N. Madlakana[1], R. Bolhar[1] & T. Masiu

[1] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

The ~80 km wide, 146 Ma, Morokweng impact structure (MIS) in North West Province is completely buried beneath Kalahari Group sediments. Centrally located drillcores intersect an up to 800m thick, partially eroded, impact melt body in a 30km wide central basin. In contrast, the M4 drillcore, located ~18 km NNW of the centre, intersects shocked and highly faulted Neoarchaean granitoid basement gneisses and minor dolerites that contain impact-related melt- and clastic-matrix breccia dykes. The M4 core has been interpreted as an intersection through uplifted crater basement belonging to an eroded peak ring. Post-impact hydrothermal alteration exploited the enhanced permeability provided by shock-damaged minerals and impact-related faults and breccias. Cataclasites and clastic breccias are cemented by zeolite±smectite, which are also the primary constituents of fracture-hosted veins; Fe-Mg smectite is the main mineral replacing pseudotachylite and vitroclasts in the clastic-matrix breccias. Neoblastic andradite, titanite, diopside and actinolite indicate Ca-metasomatism at relatively elevated T. Hydrothermal feldspar is a minor component of zeolite-smectite veins and vugs, but local K-feldspar replacement of plagioclase along fracture walls indicates limited K-metasomatism. Biotite is replaced by chlorite+ilmenite±prehnite. Shock-induced features in quartz are replaced and infilled by zeolite, calcite and pyrite. Fe-oxides and oxyhydrates partially replace pyrite, suggesting evolving fluid redox conditions. Anhydrite and calcite veins cut the zeolite-filled fractures and impact breccias. Textural relationships indicate the hydrothermal system followed a conventional retrogressive sequence from an early high-T (>350°C), vapour-dominated, stage characterised by Ca±K-metasomatism, through an intermediate (~350–120°C), mixed vapour-liquid, main stage characterised by chlorite+ilmenite±prehnite replacement of biotite and zeolite+smectite±anhydrite veins, to a low-T (<50°C), liquid-dominated stage involving calcite and Fe-oxyhydrates. The high-T mineral parageneses and Ca-rich nature of the zeolites in the M4 core support other evidence suggesting that the MIS is eroded by 1.5-2 km. The heat driving the hydrothermal system was derived mainly from uplifted mid-crustal rocks and waste shock heat in the peak ring, with a possible additional contribution from frictional sliding along faults. The highly fractured rocks provided enhanced permeability for fluids, and shock- and fault-damaged silicates, including mineral and pseudotachylite glasses, facilitated reaction and cation exchange with circulating meteoric-derived water.

Keywords: impact, structure, hydrothermal, Morokweng, peak ring

THE NQWEBA BOLIDE OF AUGUST 25, 2024 – SCIENTIFIC OBSERVATIONS, ANALYSIS AND RECOMMENDATIONS

Roger L. Gibson[1], Carla Dodd[2], Leonidas C. Vonopartis[1], Peter Hers[3], Peter Jenniskens[4] & Timothy Cooper[5]

[1] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
[2] Department of Geosciences and Institute for Coastal and Marine Research, Nelson Mandela University, Gqeberha, South Africa
[3] Garden Route Centre of the Astronomical Society of Southern Africa, Sedgefield, South Africa
[4] SETI Institute, Mountain View, California, USA
[6] Astronomical Society of Southern Africa, Benoni, South Africa

A bolide travelling in a broadly ENE direction was widely observed travelling inland over the southern Cape coastal region between Mossel Bay and Gqeberha at 08:50:45 on Sunday, August 25, 2024 and was followed by a prolonged sonic boom and associated ground vibrations up to several minutes later. We report on the efforts of a multidisciplinary astronomy-geology team to collate and interpret observer reports of the various bolide phenomena, and evidence of the related meteorite fall in the Nqweba area, in terms of scientific data obtained from US Government sensors, provided by NASA. A total of 147 observer reports – of which 50 involved visual sightings - were collected via dedicated email hotlines, social and mass media appeals, and interviews following word-of-mouth referrals. Four videos of the fireball – including one from a fixed camera - were submitted, and a further two recordings of the sonic boom were obtained. From these and the US Government satellite data, a path trending 070°, extending from Mossel Bay towards Nqweba, was determined. The bolide followed a very low angle (=10°) trajectory and was visible for ~10 s, despite its entry velocity of 20.1 km/s. The lengthy atmospheric passage facilitated the generation of rarely observed concurrent electrophonic phenomena up to several hundred kilometres from the path. The sonic boom and linked ground vibrations were experienced over similar distances several minutes later and lasted >30 s. Footage from the videos was calibrated to determine horizontal coordinates of the path and used to determine orbital data, which supports the petrographic analysis of the meteorite as a HED achondrite and, thus, a source from asteroid 4 Vesta. The impact energy estimate of 0.092 kt from US Government sensor data and density measurements of the recovered meteorite fragments suggest an initial impactor mass of 1.9 tonnes and a diameter of 1.08 m. Apart from the scientific aspects, the project reveals the importance of a rapid, multifaceted, scientific response to such events and of thorough public engagement around bolide phenomena.

Keywords: bolide, electrophonics, meteoroid, sonic boom

PSEUDOTACHYLYTE GENESIS LINKED TO FRICTION MELTING IN LARGE IMPACT-RELATED FAULT ZONES IN THE VREDEFORT DOME, SOUTH AFRICA

Shalene Manzi[1], Auriol S.P. Rae[2] & Roger L. Gibson[1]

[1] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

[2] School of GeoSciences, University of Edinburgh, Edinburgh, United Kingdom

Impact cratering involves significant structural disruption and differential movements within the affected target rock volume that occur at high strain rates. Such conditions tend to favour strain localisation along faults; however, few studies have been able to rigorously constrain fault kinematics in the interior parts of large craters through field observation. A related question is the nature and timing of pseudotachylyte formation during a cratering event and whether the voluminous clast-bearing melt bodies found in several large impact structures can be unequivocally linked to faults. In this study, we constrain the spatial, geometric and kinematic relationships between pseudotachylyte and a pair of large-displacement faults within the central uplift of the Vredefort impact structure that links pseudotachylyte genesis to slip-induced frictional sliding. Kinematic indicators obtained from the displacement of bedding and quartz veins, and outcrop and microstructural observations of structural fabrics, indicate that the two faults form a conjugate set with respective strike separations of approximately 300 m right-lateral and 500 m left-lateral. In their present geometry, this conjugate system is consistent with a shallow NNW-plunging (radial) s1 stress direction and shallow E-plunging (tangential) s2 orientation. However, iSALE-2D numerical modelling of the strain evolution of the rock volume in response to the impact suggests that the faults originated as normal dip-slip faults during the initial stages of the collapse of the transient crater walls (late part of Modification Stage 1 at approximately 65-69 seconds after impact) and that they were rotated to their present orientation during subsequent central uplift rise and collapse. This study provides a first constraint on the timing of melting to produce the large pseudotachylyte volumes observed in the Vredefort Dome and ties their origin to frictional heating along large-slip faults.

Keywords: impact, pseudotachylyte, friction, faulting

THERMAL CONSUMPTION OF XENOLITHS IN IMPACT MELTS IN LARGE TERRESTRIAL IMPACT CRATER FOOTWALL: PRELIMINARY IMPLICATIONS FOR MELT SHEET DYKES OF THE SUDBURY IGNEOUS COMPLEX, CANADA

Stephen Prevec[1] **& Denis Pollney**[1]

[1] Rhodes University, Makhanda, South Africa

A number of fundamental questions remain open relating to the emplacement of impact melt into the floor of large terrestrial impact craters, such as at Sudbury, Canada and at Vredefort, South Africa. These questions include the cause, timing and speed of melt dyke emplacement. Impact melt dykes at Sudbury show evidence of multiple injection episodes. Preliminary thermal modelling of crustal xenoliths (clasts) required construction of a thermal model using Stefan-problem solutions, allowing the reaction or melting front to be dynamic as the clast is progressively consumed (or in some cases enlarged, at least transiently), and to be independent of arbitrary and potentially unsupportable assumptions relating to thermal boundary layer conditions at clast boundaries. Based on typical basaltic magma dyke emplacement estimates by hydraulic fracture propagation from literature, a dyke might be expected to take only a few hours to travel 10 km or so from its source. Cooling times for the dykes to silicate solidus (where sulphides may remain partially fluid) are estimated at an hour for cm-scale texturally-chilled dykes to tens of years for tens-of-metre-wide dykes, arguably extendable to hundreds of years at most, given a sufficiently elevated thermal gradient. A 10 cm clast hosted in ca. 1800°C melt, comparable to estimates for post-equilibration melt sheet, would be consumed within a few hours. Previous studies have proposed intervals between these two magma injections ranging from minutes to thousands of years, with the former case quiring a melt sheet cooling rate of on the order of >1000°/hr, which is texturally inconsistent with observations in metre-scale or wider dykes, down to cooling rates on the order of a degree per year. A 5 cm radius clast injected at 1100°C would survive about 20 hours before complete consumption assuming a liquid host. We conclude therefore that it is unlikely that the two injection episodes were separated by minutes only, and that the second magma could not have transported small clasts for kilometres and had them survive, while surviving clasts are likely to have been transported relatively short distances in a relatively cool host magma.

Keywords: xenolith, impact, melt, thermal

THE NQWEBA METEORITE FALL: INITIAL FINDINGS SUGGEST AN IMPACT-MIXED BRECCIA FROM ASTEROID VESTA

Deon van Niekerk[1], Carla Dodd[2], Leonidas C. Vonopartis[3], Lewis D. Ashwal[3], Nicolas Tonnelier[4] & Roger L. Gibson[3]

1 Electron Microscopy Unit, Rhodes University, Makhanda, South Africa.

[2] Department of Geosciences and Institute for Coastal and Marine Research, Nelson Mandela University, Gqeberha, South Africa

[3] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa.,

[4] Department of Geosciences, Nelson Mandela University, Gqeberha, South Africa

The Nqweba meteorite (proposed name) fell near the town of Nqweba (formerly Kirkwood) in the Eastern Cape Province following a widely witnessed bolide shortly before 9 a.m. on August 25, 2024. Following discovery of the first stone by a young girl immediately after it fell near her, a subsequent search by the authors and volunteers under the auspices of the Eastern Cape Provincial Heritage Authority yielded a further 9 stones. The combined recovered mass is currently 530 g. Below we present findings of our initial study. The stones show = 1 mm thick fusion crust that is variably developed on different facets of individual stones. Where fusion crust has chipped off or a broken face occurs, the interior reveals a brecciated texture with polymineralic (ophitic/subophitic and granular) and monomineralic fragments of =5mm set in a finegrained matrix (variably white or greenish yellow). Optical microscopy, SEM, SEM-TIMA, and EPMA confirm the mineralogy to be enstatite-pigeonite (~72 vol%; En25-83Wo2-20), augite (~4 vol% including exsolution lamellae; En7-41Wo21-43), olivine (~5 vol%; Fo54-75), and plagioclase (~11 vol%); minor phases (<2 vol%) include chromite, Fe-Ni metal, troilite, and phosphate. Pigeonite (and sometimes ferroan enstatite) often contains exsolutions of augite. The average molar Fe:Mn of the pyroxenes is ~30, which is consistent with the Howardite-Eucrite-Diogenite (HED) group of meteorites. Impact melt clasts/pockets are present in the form of olivine (Fo<60), metal with intergrown subhedral to rounded silicate crystals, and partially melted/resorbed grains. Unmelted clasts show variable shock stages S2-S4 with mosaicised pyroxene, undulose plagioclase extinction, and absence of maskelynite. The meteorite is a howardite; it is composed of clastic lithologies equivalent to eucrite (basalt) and diogenite (dominantly orthopyroxenites; some harzburgites) meteorites. HED meteorites have been spectroscopically linked to asteroid Vesta, or to the closely related Vestoids. Howardites are breccias containing surface-to-lower crust lithologies that were mixed by impact on their parent body; impact is a dominant post-crystallization geological force on airless bodies in the solar system.

Keywords: meteorite, Nqweba, howardite, impact

Celebrating 120 Years of the Geology Department at Rhodes University

THE MESOPROTEROZOIC EVOLUTION OF THE NAMAQUA SECTOR: A CONTINENTAL BACK-ARC MOBILE BELT IN THE SOUTHWEST OF RODINIA

Steffen H. Büttner[1]

[1] Department of Geology, Rhodes University, Makhanda, South Africa

In the 1980s the Namaqua Belt was interpreted as an amalgamation of tectonic terranes that developed in a Mesoproterozoic Wilson-cycle type context. Main arguments were the different lithostratigraphy in different “terranes” and the presence of regional shear zones along their inferred boundaries. These “terranes” supposedly collided around ~1200 Ma after the closure of up to seven oceanic basins. However, key evidence for collisional tectonics in the Namaqua Sector is scarce, if not absent. No suture zones with the associated ophiolites and HP-LT metamorphism exist, and the crustal heritage in all “terranes” is practically identical: Paleoproterozoic crust with variably intense Mesoproterozoic reworking and crustal addition. TDM ages in all “terranes” reach back to the Paleoproterozoic (~1.9-2.2 Ga), but nowhere older sources are of significance. ~1230 to ~1080 Ma granites show remarkable uniformity, with A-type granitic, Meso- and Paleoproterozoic crustal, and enriched mantle sources being variably dominant. The metamorphism in the Namaqua Sector is characterised by long-standing (U)HT-LP metamorphism (~700-900°C/5-7 kbar) that existed over at least ~250 myr between ~1250 and ~1000 Ma. The regional HT/UHT peak is followed by an episode of isobaric cooling, in some places with a further (~1100 or ~1060 Ma) isobaric heating-cooling episode. Significant isothermal decompression, characteristic of continent collision, has not been demonstrated in the region. Over the last decade, growing evidence has led to a reinterpretation of the tectonic setting of the Namaqua Sector, which likely evolved as a hot orogen, undergoing tectonic switching from extensional to contractional tectonics, separated by stable periods. “Terranes” have been redesignated as domains, acknowledging their lithologically and structurally different nature, but no longer implying their assembly from once separated locations. All observed features in the Namaqua Sector are compatible with the tectonics of a continental back-arc mobile belt in thin, hot lithosphere near the craton margin of Mesoproterozoic Rodinia.

Keywords: Hot orogen, Long-standing, HT/LP conditions, Tectonic switching, Terranes vs. domains

PLEISTOCENE ENVIRONMENTAL CHANGE THROUGH LAKE-LEVEL CHANGE: SEQUENCE STRATIGRAPHIC MODELLING OF THE KBS MEMBER, KOOBI FORA FORMATION, OMO GROUP

Bukho Charles[1] & Silindokuhle Mavuso[2]

[1] Department of Geology, Rhodes University, Makhanda, South Africa
[2] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

The Turkana Basin, Omo Group, in northern Kenya has been a region of numerous palaeontological, archaeological, and geological investigations in eastern Africa due to its recognised prehistoric repository of biotic evolution, cultural history and rift valley geology. These significant records are archived by the PlioPleistocene volcaniclastics of the Koobi Fora Formation, which includes one of the eight consequential stratigraphy intervals, the KBS Member time-interval deposits. Numerous palaeontological, archaeological, and geological research has been conducted in these deposits; however, there have been limited investigations in understanding source areas, punctuation, and influence of the palaeoenvironmental change in relation to noted lake level fluctuations and how these drove biotic evolution (including hominin adaptation). This study investigates the palaeoenvironmental dynamics of the KBS Member that have shaped its observed stratigraphic succession. This geological study provides comprehensive basin analysis, grounded in extensive fieldwork, through depositional lithofacies and palaeoenvironmental distribution across the KBS Member in space, offering a more detailed palaeogeographical interpretation. The research identifies extensive palaeoenvironmental heterogeneity across the formation's three subregions, with a significant predominance of meandering fluvial channel patterns defined by distributive fluvial systems. Additionally, the sandstones are derived from two primary source rocks: The basement Precambrian Ethiopian outcrops east of the basin; The Kenyan Cenozoic volcano-sedimentary rocks extending north of the basin. Additionally, with the adoption of sequence stratigraphic modelling, two parasequences that reflect two regressive-transgressive cycles characterised by two orders of periodicities are established; this revealed that the origins of these fluctuations primarily originate from climatic-related factors with some tectonic- and volcanic-related forcings. This suggests that ancient Lake Turkana expanded asynchronously in the rift, resulting in variable depositional slopes in times of flooding. The study integrates sedimentary facies analysis and provenance studies to provide a better understanding of the depositional history and stratigraphic controls in the basin. This study contributes to existing work on the region, offering understanding of biotic evolution and the adaptive strategies of organisms (including hominins) in response to changing environmental conditions during the Pleistocene epoch.

Keywords: Pleistocene palaeoenvironments, sequence stratigraphy, lake-level fluctuation, provenance

DEPOSITIONAL HISTORY ASSOCIATED WITH THE EARLIEST EVIDENCE OF HOMININ-CONTROLLED FIRE USE IN THE KARARI SUBREGION: STRATIGRAPHY AND SEDIMENTOLOGY OF THE MIDDLE PLEISTOCENE IN THE OKOTE MEMBER, KOOBI FORA FORMATION

Molatelo Chokoe[1] & Silindokuhle S. Mavuso[1,2]

[1] Department of Geology, Rhodes University, Makhanda, South Africa

[2] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

The Turkana Basin, located in the eastern part of the East African Rift System, represents a Plio-Pleistocene geological and archaeological archive, documenting hominin evolution and advancement over time. The northeastern expression of the basin, the Koobi Fora Formation, has drawn increasing attention for decades due to consequential finds. One significant find is FxJj20, an archaeological site in the Okote Member associated with stone tool use and the oldest controlled use of fire by hominins. Although the site is well preserved, stratigraphic and sedimentological work has been limited due to sparse outcrop. However, there is a nearby thick outcrop that could be used to remedy this. Thus, this study investigates the sedimentology and stratigraphy of the site and its link to a nearby larger outcrop, namely Sarah's Canyon outcrop. A detailed sedimentary facies analysis identified nine distinct lithofacies, indicating dynamic interactions between braided river channels and floodplain environments during the Middle Pleistocene. Stratigraphic correlation between Sarah's Canyon and the FxJj20 Site Complex was achieved by the occurrence of the lower Okote Tuff (1.64 Ma) the upper Morutut Tuff (1.6 Ma), suggesting a period of contemporaneous deposition. The transition from high-energy braided river systems to more stable floodplain settings reveals the influence of hominin in habitat selection; these landscapes would have shaped hominin resource availability. The braided river likely offered diverse, short-term resources, while the floodplain at FxJj20 provided stable access to water, food, and raw materials, supporting the extended occupation. Photogrammetric techniques were also employed to generate a high-resolution digital record of the outcrops for remote study and archiving. This enhanced visualisation aided in refining facies interpretation and capturing palaeoenvironmental variability across stratigraphic intervals. These findings contribute to a deeper understanding of how dynamic environmental conditions influenced early hominin adaptation in the Turkana Basin. By linking sedimentary processes to archaeological context, this research highlights the complex interplay between landscape evolution and human behavioural responses during the middle Pleistocene.

Keywords: Turkana Basin, hominin behaviour, sedimentology, Middle Pleistocene

PETROLOGY AND GEOCHEMISTRY OF THE REE-P MINERALISATION IN THE NKOMBWA HILL CARBONATITE, ZAMBIA

R.E. Jock Harmer[1]

[1] Jock Harmer Consulting, Department of Geology, Rhodes University, Makhanda, South Africa

The Nkombwa carbonatite intrusion is approximately 1.5 x 1.0 km in size and underlies a steep-sided hill rising 300m above the Luangwa valley floor. The intrusion is composite built of several intrusive phases of magnesian carbonatite magma: intrusive contacts and flow foliations in all varieties are sub-vertically disposed. No magmatic silicate rocks have been found in the complex. The earliest recognisable carbonatite phase is a relatively uniform textured, medium-grained dolomite carbonatite ("rauhaugite") which makes up the bulk of the intrusion. Reaction between dolomitic magma and quartzo-feldspathic country rock gneisses generated phlogopite-rich fenites: the marginal facies of phlogopite carbonatite breccia developed at the base of the hill is the result of entrainment of phlogopite from these fenites. Vari-textured, coarse to pegmatoidal, iron-rich carbonatites occur as large sheets and lenses within the rauhaugite and represent carbothermally overprinted later intrusions. Carbonate minerals are more iron-rich ferroan dolomite set in darker, oxidised interstitial ankeritic carbonate. Crystals attain lengths of 8-10 cm but median sizes are 4-5 cm. Outcrops of the vari-textured carbonatite are characterised by open cavities ranging in size from cmscale vugs to cavities 10-15 cms in diameter. Pegmatoidal carbonatites have elevated REE contents, commonly reaching grades of 3-10% total REE oxide. Apatite is an abundant primary cumulus mineral in the dolomitic carbonatites. Carbothermal remobilisation of apatite has generated high phosphate concentrations within the pegmatoidal carbonatites hosted in secondary apatite and isokite ($CaMgPO_4F$). Iron-rich, cherty rocks cap the central parts of Nkombwa Hill and represent a pervasive in situ silica replacement of the carbonatites. Characteristic textural features of the pegmatoidal iron-rich carbonatites are noted in these cherty rocks. Grains of green (Low-Th) monazite are conspicuous. An extensive outcrop sampling programme was undertaken in 2010-2012 and 2150m of diamond core drilling in 2015-16 resulting in the declaration of an inferred REE-P resource. The embargo on reporting the extensive sample and assay data set has recently been lifted and these data will be reviewed in this presentation.

Keywords: Nkombwa Hill, Carbonatite, REE-P, mineralisation

GEOLOGY OF THE KEIKAMSPOORT CARBONATITE

Sean McQuillan[1] & R.E. Jock Harmer[2]

[1] MSA Geoservices, Rhodes University, Makhanda, South Africa

[2] Jock Harmer Consulting Rhodes University, Makhanda, South Africa

In 1993, Verwoerd proposed that the dolomites exposed in the 2 km long whaleback outcrop at Keikamspoort, 23 km south-west of Prieska, represented an intrusion of micaceous dolomitic carbonatite. Despite Verwoerd's stated reservations, including lack of clear intrusive relationships, etc, Keikamspoort has been included in subsequent compilations of World carbonatites. To resolve this ambiguity, the Keikamspoort body was mapped and representative sample sets collected for all major lithological components. The mapping showed that the Keikamspoort outcrop is largely composed of Ghaap Group stratigraphic units that include chert-rich sedimentary dolomites, BIF's, andesitic volcanics and tuffs. However, clearly magmatic carbonatite dykes – typically 0.5-2 m wide – intrude across these sedimentary units along the entire whaleback outcrop. The dykes commonly have distinct finer-grained marginal contact zones. At least two phases of carbonatite intrusion are recognised: earlier intrusions are conformable to the trend of the ridge with the later phase emplaced as a swarm of narrow dykelets at high angle to this trend. Less common are sub-horizontal pavements of carbonatite that represent sill-like intrusions. Carbonatites are exclusively dolomitic types; mostly medium-grained fine-grained dykes less common. Carbonatites are predominantly found in tuffaceous mafic schist and cherty dolomite sediment units. Carbonatite intrusions make up only 5-10% of the Keikamspoort ridge outcrop and there is no evidence of a central carbonatite plug. Optical microscopy has shown that there is a variation in grain-size of the dolomitic crystals with samples exhibiting flow-banding. Magmatically-zoned rhombs of ferroan dolomite are common in the coarser-grained carbonatite samples – BSE imaging shows increasing Fe in dolomite solid solution from core to rim. Monazite, barite and fluorapatite have been identified as interstitial phases. Geochemical data has shown that the carbonatites are enriched in trace elements such as Sr and Ba with REE reaching ore grade concentrations. Significantly, samples of cherty dolomite collected close to carbonatite dykes show elevated Nb and REE concentrations – these reflect metasomatism by fluids released from the carbonatite intrusions (fenitisation). The intrusive age of Keikamspoort carbonatites has not yet been established but are likely to be contemporaneous with the 1304+/-24Ma Waterkop Syenite in the adjacent Marydale Terrane.

Keywords: Carbonatite, Keikamspoort, REE, mineralisation

PRESSURE CONTROL OF REDOX REACTIONS SOLVES THE CHROME MASS BALANCE PROBLEM IN THE BUSHVELD COMPLEX

Chris Hatton[1]

[1] Retired

The calculations of Prof Hugh V Eales demonstrated that proposed parental magmas to the Bushveld Complex could not account for the mass of chrome in the chromitite layers and the associated silicate layers. The solution he proposed was that chromite crystals were carried into the magma chamber in a crystal-liquid slurry. This solution faces the problem of the resultant high viscosity which would immobilise the slurry. The solution proposed in this contribution is that the Bushveld magmas originated in a metal enriched garnetite source at the base of the upper mantle. This source originated in the aftermath of the moon-forming impact when amphibolite was swept down to the 670 km discontinuity at the base of the upper mantle. The increase in pressure destabilised the large ferric ion which broke down to iron and released oxygen which escaped in the siliceous melts from which the continental crust formed. At 2.06 Ga a lower mantle plume stalled below the 670 km discontinuity, triggering the ascent of secondary plumes of metal enriched garnetite. The iron metal created a reduced melt with high concentrations of divalent chrome. Hydrogen in the melt oxidised to water, destabilising silicates and promoting crystallisation of chromite alone in the chromitite layers of the Bushveld Complex.

Keywords: Oxygen fugacity, Pressure

MINERALOGICAL AND GEOCHRONOLOGICAL CHARACTERISTICS OF THE CLAY MINERAL ASSEMBLAGE OF THE MONTANA DE MANGANESO MANGANESE DEPOSIT: EVIDENCE OF A LONG-LIVED HYDROTHERMAL SYSTEM

Joseph M. Madondo[1], Carles C. Canet[2], Eduardo G.P. Gonzalez Partida[3], Jesus S. Sole[4] & Teresa P. Pi[4]

[1] Department of Geology, Rhodes University, Grahamstown, South Africa
[2] Institute of Geophysics, Universidad Nacional Autónoma de México, Mexico City, Mexico
[3] Institute of Geosciences, Universidad Nacional Autónoma de México, Juriquilla, Mexico
[4] Institute of Geology, Universidad Nacional Autónoma de México, Mexico City, Mexico

Extensive fault-and fracture-controlled hydrothermal alteration surrounds the Montaña de Manganeso manganese deposit in northcentral Mexico. Hydrothermal fluids percolated fractures and faults and deposited mainly manganese and iron oxides, quartz, calcite, and minor barite. Mineral deposition was accompanied by intense hydrothermal alteration around the mineralized veins that is reflected in the strong silicification and clay alteration of the host rocks. Shortwave infrared (SWIR) reflectance spectroscopy and X-ray diffraction (XRD) show that quartz, calcite, and clay minerals (illite, kaolinite, smectite, and interstratified illite/smectite) are the dominant hydrothermal minerals in the altered rock samples. Fe and Mn oxides, alkali-feldspars (anorthoclase), and plagioclase (anorthite) are accessory minerals. Illite dominates proximal to the veins and extends into the host rocks, grading into the interstratified illite-smectite and smectite at varying distances from the veins. Kaolinite locally predominates as a product of steam-heated alteration with a typically accompanying silica cap. K-Ar dating of illite (< 89.8 Ma) and the co-existing cryptomelane (> 32 Ma) indicate that alteration and mineralization were a product of a long-lived, multiepisodic hydrothermal system, with manganese mineralization occurring during the waning stages of the system.

Keywords: hydrothermal, clay minerals, argillic, steam-heated

THE PLATINUM-GROUP ELEMENT SYSTEMATICS OF KAAPVAAL MAFIC MAGMATISM

Wolfgang D. Maier[1], Hannah Hughes[2] & Nils Lenhardt[3]

[1] School of Earth and Environmental Sciences, Cardiff University, Cardiff, UK
[2] School of Earth and Environmental Sciences, Camborne School of Mines, University of Exeter, Exeter, UK
[3] Department of Geology, University of Pretoria, Pretoria South Africa

In order to constrain the factors controlling mineral prospectivity, I have compiled precious and base metal data for Kaapvaal mafic-ultramafic magmas formed over a period of nearly 3.5 Ga, including komatiites and basalts from the Barberton Greenstone belt and at Roodekrans, kimberlite from Premier mine, and basalts from the Dominion, Ventersdorp, Hekpoort, Machadodorp, Bushveld, Soutpansberg and Karoo magmatic formations/events. The data show considerable variation in PGE content and fertility (as expressed by Cu/Pd). Significant Pt enrichment in excess of most other global magmas is largely confined to the Bushveld event whereas the Machadodorp basalts are strongly Pd enriched. Both these suites also have Cu/Pd below the primitive mantle value, indicating that they did not reach sulfide melt saturation prior to final emplacement. Several other magmatic suites also show undepleted Cu/Pd ratios, namely basalts from the Hekpoort and Machadodorp formations. Some suites show both fertile and depleted signatures (Dominion, Ventersdorp, Barberton basalts and komatiites). In contrast, most Karoo and Soutpansberg lavas, as well as Premier kimberlites are depleted in PGE (ie Cu/Pd > PM). I consider two possibilities to explain the unusual Pt enrichment of the Bushveld event: (i) Entrainment of PGE from depth where sulfide saturation was reached due to crustal contamination, (ii) Melting of an unusually PGE-rich mantle source. In any case, the data suggest that PGE exploration in South Africa should focus on the Bushveld event.

Keywords: Platinum-group elements, Kaapvaal Craton, Mafic-ultramafic magmatism

SEDIMENTOLOGY AND SEQUENCE STRATIGRAPHIC MODELLING OF THE UPPER BURGI MEMBER, KOOBI FORA FORMATION: EARLY PLEISTOCENE LANDSCAPE EVOLUTION IN THE TURKANA BASIN

Silindokuhle Mavuso[1,2], David Braun[3], Robyn Pickering[4] & Zubair Jinnah[2]

[1] Department of Geology, Rhodes University, Makhanda, South Africa
[2] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
[3] Department of Anthropology and Center for Advanced Study of Human Paleobiology, The George Washington University, Washington DC, USA
[4] Human Evolution Research Institute, Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa

The Koobi Fora Formation, Kenya, represents the northeastern Turkana Basin and preserves a rich PlioPleistocene volcaniclastic sequence renowned for its abundance of palaeontological and archaeological material. Despite this significance, some of the formation's deposits have been comparatively understudied. One such is the upper Burgi Member that records the early Pleistocene during the evolutionary emergence of our genus, Homo. Here we present its comprehensive basin analysis, grounded in extensive fieldwork across six newly documented outcrops. Lithological analysis identifies eight lithofacies associations representing three palaeoenvironmental settings: lacustrine (pelagic, transitional, and marginal lake deposits), deltaic (prodelta, delta front, and distributary channel deposits), and fluvial (meandering channels, overbank deposits, and floodplain sediments). The succession's base corresponds to Palaeolake Lorenyang at approximately 2.08 Ma, marked by lacustrine sediments overlain by coarsening-upward deltaic sequences indicative of lakeward progradation around 1.9 Ma. Additionally, rhythmic mudstone-carbonate alternations signal a diverse fluctuating lake coloumn. A subsequent regression of the lake facilitated fluvial sedimentation (upward-fining sandstones) until about 1.89 Ma. A renewed phase of lacustrine conditions followed, with deltaic inputs and evidence for lake expansion along the margins, including the presence of plant-anchored Potamolepid siliceous sponges. This was succeeded by fluvial system, which persisted until the deposition of the KBS Tuff at 1.88 Ma. Petrographic work of 33 sandstone samples reveals the presence of felsic volcanic, and metamorphic lithic grains, with a trend of increasing sediment maturity from northeast to southwest. When combined with palaeocurrent data, these findings suggest a sediment source from the northeastern Precambrian basement. Sequence stratigraphic analysis delineates three depositional sequences: UB1 (~2.08 Ma) representing lake expansion and deltaic deposition driven by tectonic extension; UB2 (1.95–1.89 Ma) of widespread lacustrine facies and progradation, reflecting localised tectonic pulses; UB3 (1.89–1.87 Ma), dominated by terrestrial fluvial environments, where accommodation space was likely generated by volcanic activity, including the emplacement of the Borana and KBS tuffs. This study enhances our understanding of the palaeoenvironmental evolution of the upper Burgi Member by demonstrating the pivotal role of localised tectonism, particularly in the latter stages of deposition, in shaping the landscape of the Turkana Basin during a formative period in early hominin evolution.

Keywords: Koobi-Fora, Sedimentary basin, hominins

CONSTRAINTS ON CONTAMINATION AS A MECHANISM FOR CREATION OF HYBRID MAGMAS CAPABLE OF CHROMITE SATURATION

Siyasanga Dyan[1] & Stephen Prevec[1]

[1] Rhodes University, Makhanda, South Africa

One of the initially popular mechanisms for triggering chromite precipitation is contamination by granitoid siliceous rocks and proven to be given the strong circumstantial evidence in support of crustal contamination coinciding with stratiform spinel-rich layers. This study examined xenoliths representing a broad compositional range (shale, quartzite, and carbonate) and their immediate surroundings, which consist of Cr spinels and PGE-rich sulfide rocks of the Upper Critical Zone from the northern limb of the Bushveld Complex to determine the extent of localised magma hybridization and the resultant mineralogical effects in each case. Preliminary results suggest the following: • Contamination by shales has resulted in the formation of abundant disseminated Fe-Ti-oxide at the contact between a feldspathic pyroxenite host and Al-rich feldspathic hornfels xenolith. The hybrid contact zone also features significant amounts of sulphide, Al-rich spinels, phlogopite and cordierite. • In contrast, the contamination by silica in the form of quartzite has resulted in a siliceous hybrid composition. The hybrid rock is characterised by high amounts of phlogopite, orthopyroxene and quartz (present as both interstitial grains and inclusions in orthopyroxene). The contact with the quartzite comprises the presence of minor amounts of Cr-rich spinel and an abundance of sulphide. • Contamination by carbonate (dolomite) has resulted in the presence of carbonate, more calcic augite, and Mg-Cr-Fe-rich spinels often exsolving magnetite. This is consistent with increased oxidation by the release of CO_2-rich volatiles. These results show that assimilation of different lithologies strongly affects the composition and oxidation fugacity of the magma which may trigger oxides and sulfide precipitation. Therefore, understanding these interactions provides critical insights into magmatic processes that govern the formation of mineralized zones, contributing to the broader understanding of ore genesis and resource potential in contaminated mafic systems. The disputed role of crustal contamination as a trigger for mineralization is also therefore rehabilitated to some extent.

Keywords: chromite, contamination, crust, oxidation

CLINOPYROXENE MEGACRYSTS FROM MARION ISLAND, ANTARCTIC OCEAN: EVIDENCE FOR A LATE STAGE SHALLOW ORIGIN

R.J. Roberts[1], A.E.J. Botha[1], C.J. Hetherington[2], F.C. de Beer[3], Gelu Costin[4], K.D. Lehong[1] & W.J. Hoffman[3]

[1] University of Pretoria, Pretoria, South Africa
[2] Texas Tech University, Lubbock, USA
[3] NECSA, Pelindaba, South Africa
[4] Rhodes University, Makhanda, South Africa

Clinopyroxene megacrysts (up to 5 cm) from a scoria cone on Marion Island, Antarctic Ocean are zoned, with compositionally distinct low (Al + Ti) and high (Al + Ti) patches arranged haphazardly throughout crystals. Inclusions of olivine, pyrrhotite, oxides, sulphides, and rounded inclusions with euhedral microcrystals interpreted as former melt inclusions are observed. Olivine inclusions have variable compositions, ranging from primary Ti-poor crystals to Ti-rich crystals hosting secondary haematite crystals formed by hydrogenation. The crystals contain voids that are concentrated in the middle of each crystal indicating that the initial crystal growth was skeletal. Subsequent crystallisation filled in the skeletal framework creating the patchy zoning in the crystals. The Marion Island megacrysts are not homogenous, but the combination of crustal clinopyroxene compositions, primary and hydrogenated olivine, and the mode of eruption in scoria eruptions indicates that these crystals most likely formed in a shallow magma chamber. Primary olivines crystallised from a mafic magma and secondary altered olivines were incorporated into a rapidly growing megacryst in a super-saturated, fluid-rich environment, prior to being ejected onto surface in a scoria eruption.

Keywords: Marion Island, clinopyroxene, scoria

Cenozoic Onshore and Offshore Environments of Southern Africa

THE MIOCENE OF OFFSHORE SOUTH AFRICA: NEW INSIGHTS FROM Sr-ISOTOPES AND MICROFOSSIL FORAMINIFERA

Eugene W. Bergh[1], Jared T. Walsh[2], Petrus le Roux[3], Pieter Louw[1] & Susanne Fietz[2]

[1] Unit for Environmental Sciences and Management, Geology, North-West University, Potchefstroom, South Africa
[2] Department of Earth Sciences, Stellenbosch University, Stellenbosch, South Africa
[3] Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa

Previous research on the stratigraphy of the continental shelf of South Africa revealed unconformities and reworking, complicating the interpretation of past marine environments from the region. New data from the continental shelf identified microfossil foraminifera and phosphorites dated to the early and late Miocene. Palaeoenvironmental research from the shelf dated to these periods has been sparse to non-existent and an understanding of how the sediments and past environments from this region responded to climatic changes during the Miocene was not known. This provides an opportunity to document past environments and sedimentary compositions from these time periods. Three cores from the western continental shelf of South Africa (253-270 m water depth) were studied to determine how Neogene to Quaternary environments evolved along the shelf. The sediments were dated using strontium ($^{87}Sr/^{86}Sr$) isotopes and foraminifera index fossils. Basal units of the cores dated foraminifera to 20.45 Ma (early Miocene) and phosphorites to 9.70 Ma (late Miocene). Sediments grade from foraminifera-rich quartzitic muddy sediments to glaucophosphorite-rich units in the Miocene. Foraminifera ecological indicators show that the palaeoenvironment was deeper compared to the modern-day water depth, with moderate oxygen-levels and productivity. During the middle Miocene (Langhian) the environment shifted to warmer subtropical conditions, cooling in the late Miocene and into the Pleistocene. Upwelling was present, but weak. Bottom water environments changed from mesotrophic to eutrophic conditions. The palaeoenvironment shallowed from the Neogene to the Quaternary, consistent with global sea level fluctuations. These results indicate that despite the documenting of unconformities on the shelf, that the use of Sr isotopes and foraminifera can provide important information on the evolution of palaeoenvironments along the western margin of South Africa.

Keywords: Neogene, Benguela, phosphorite, stratigraphy

SEDIMENTOLOGICAL ASSESSMENT OF THE CENOZOIC SANDVELD GROUP AT THE ELANDSFONTEIN MINE IN THE WESTERN CAPE OF SOUTH AFRICA

Tshireletso Khasuli[1], Hayley C. Cawthra[2,3] & Robert A. Muir[1]

[1] Department of Earth Sciences, Applied Geology Unit, University of the Western Cape, Bellville, South Africa
[2] Minerals and Energy Unit, Council for Geoscience, Bellville, South Africa
[3] African Centre for Coastal Palaeoscience, Nelson Mandela University, Gqeberha, South Africa

The Cenozoic Sandveld Group is an important sedimentary archive that records Middle-Miocene to Holocene faunal, landscape, and climatic evolution along the southwestern margin of Africa. It hosts economically important phosphate deposits and preserves a diverse array of vertebrate fossils that are of value to South Africa's mining and ecotourism sectors (e.g., Langebaanweg Fossil Park). However, the lack of quality exposures of the Sandveld Group, particularly where all its constituent formations are exposed together, has resulted in an incomplete understanding of its sedimentary character and, consequently, the nature of the archive. To address this gap in research, an open-pit phosphate mine (Elandsfontein Mine) with freshly excavated exposures of the Sandveld Group and its Elandsfontein, Varswater, Velddrif, Langebaan, Springfontein and Witzand formations provides a unique opportunity to perform a detailed sedimentological analysis of the Sandveld Group in unprecedented detail. The overall aim of this study is to provide a palaeoenvironmental reconstruction through interpreting the depositional characteristics of the Sandveld Group, but not much research has been carried out on these deposits in recent years. In this ongoing study, the fresh 3D exposures will be utilised to conduct detailed sedimentological facies and architectural elements analyses to characterise these deposits in detail and assist in interpreting the depositional environments that presided during their deposition. Additionally, detrital zircon U-Pb geochronology will be utilised to determine any changes in sediment provenance through time, which may reflect drainage changes. These results are anticipated to contextualise phosphate deposits and Middle-Miocene to Holocene ecosystems, therefore contributing towards provenance studies and improving the existing characterisation of this important sedimentary archive.

Keywords: Sandveld Group, phosphate deposits, provenance, facies analysis

SUBTROPICAL PALM, MANGROVE AND YELLOWWOOD ENVIRONMENTS ALONG THE SOUTHWESTERN AFRICAN COAST DURING THE PALEOGENE-NEOGENE TRANSITION

Moteng E. Moseri[1], Eugene W. Bergh[1], Frank H. Neumann[1], Mabrouk Bachari[1], Marion K. Bamford[2], Nikiwe Ndlovu[3] & Tshiamo T. Mmatladi[1]

[1] Unit for Environmental Sciences and Management, North-West University, Potchefstroom, South Africa
[2] Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa
[3] Nelson R. Mandela School of Medicine, University of Kwa-Zulu Natal, Durban, South Africa

The Elandsfontyn Formation at Langebaanweg in southwestern South Africa provides an OligoceneMiocene palaeorecord with insights into the history of the Fynbos Biome. To shed more light on the exact timing and evolution of the extraordinarily rich vegetation diversity in this biome and the nature of drivers of change, such as sea level fluctuations and climate, we re-assess the palynology of core BH2 from the late Palaeogene and early Neogene of the Elandsfontyn Formation at the site. Standard palynological procedures were applied to process 77 sediment samples for light microscopy, from which 104 palynomorph taxa including pollen, spores and dinoflagellate cysts were recorded. Palynomorph fluctuations signalling varied climatic parameters were recorded in a pollen diagram and statistically evaluated using Detrended Correspondence Analysis (DCA). Palynological and statistical results confirm the existence of a (sub)tropical forest dominated by Podocarpaceae, palms, vines and ferns, providing evidence of humid, (sub)tropical conditions caused by a strong component of summer rainfall. Evidence of mangroves points to warm sea surface temperatures. Patches of proto-fynbos with Ericaceae and Proteaceae might have formed an understorey or forest-edge component of the tropical-subtropical forest and they co-fluctuated with the forest elements. As forests retreated, wetlands comprising Sparganiaceae, Restionaceae, Cyperaceae and Poaceae expanded. Marine fluctuations, linked to global late Oligo-Miocene sea level changes, were imposed on the terrestrial environment, as indicated by three marine transgressions (I to III). These correspond with global transgression events that occurred between 27.2 Ma (late Oligocene) and 18.5 Ma (early Miocene). With increasing sea levels and aridity, forests were gradually replaced by a woodland thicket with trees such as Combretaceae, Peregrinipollis nigericus (Brachystegia), proto-fynbos and adjacent Restionaceae-dominated wetlands. The progression of transgression II led to the demise of this woodland thicket, and sea levels remained high throughout transgression III, possibly inducing the evolution of the Fynbos Biome.

Keywords: Palaeogene-Neogene, Fynbos evolution, Transgressions, Climate change

THE INFLUENCE OF THE ANGOLA-BENGUELA FRONT ON PLEISTOCENE PAST ENVIRONMENTS AND SEDIMENTS

Mulalo Netsianda[1], Bradley Schoombee[1] & Eugene Bergh[1]

[1] Unit for Environmental Sciences and Management, North-West University, Potchefstroom, South Africa

The Angola-Benguela Front (ABF), situated along the continental margin of southern Angola and northern Namibia, aids in regulating the climate and marine sedimentation in the region. The ABF forms the boundary between two major ocean currents, namely the warm, southward-flowing Angola Current and the cold, northward-flowing Benguela Current. This front influences the exchange of heat, moisture, and nutrients between the ocean and the atmosphere, affecting regional weather patterns and climate. In addition, sedimentation in this region is also controlled by this front. Very few marine geological studies have been conducted in this area. This study aims to address this by analysing samples obtained from cores ODP1079 and ODP1080. Previous shipboard dates place the cores within the Pleistocene (<700 ka). The cores provide a high-resolution sedimentary record ideal for reconstructing past oceanographic and climatic variations. The samples were analysed for their mineralogical and micropalaeontological content to determine how climate variations influence the palaeoenvironment and sedimentation on the margin of southern Angola and northern Namibia. Results from this study indicate the sediments to be high in calcium carbonate with minor quartz. The highest proportions are clay content with smectite, illite and kaolinite. These clay minerals, together with the silica and feldspathic occurrences, are sourced from the adjacent Kunene River. Foraminifera form the major component in the sand-sized fractions of the core and indicates a high influence of subtropical waters in the area as a response of the warm Agulhas Current. Benthic foraminifera suggest a moderate level of oxygenation and productivity, showing mesotrophic to eutrophic conditions. Epifaunal taxa occur in low to moderate abundances and infaunal taxa in moderate to high abundances. These results point to the contrasting influences of the Angola and Benguela currents. Further analyses of the sediments will include determination of past sea surface temperatures (SSTs), bottom water current circulation and trace element analyses.

Keywords: Angola, Namibia, Quaternary, Foraminifera

HOLOCENE PALAEOENVIRONMENTAL RECONSTRUCTION FROM MASHISHING FEN, MPUMALANGA, NORTHEASTERN SOUTH AFRICA

Frank Harald Neumann[1], C. Sievers[2], E.A. Orijemie[3], J. Knight[2], J. Olatoyan[2,4], J.P. Celliers[5], M. Evans[2], M.H. Schoeman[2] & S. Woodborne[6,7]

[1] Unit for Environmental Sciences and Management, North-West University, Potchefstroom, South Africa
[2] School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, Johannesburg, South Africa
[3] Department of Archaeology and Anthropology, University of Ibadan, Ibadan, Nigeria
[4] Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa
[5] Gustav Klingbiel Nature Reserve, Lydenburg Museum, Lydenberg, South Africa
[6] Stable Isotope Facility, Mammal Research Institute, University of Pretoria, Pretoria, South Africa
[7] iThemba LABS, Johannesburg, South Africa

A 5.5 m-long core from a wetland in northeast South Africa provides evidence for climate and environmental change spanning the Holocene in an area in which continuous paleoenvironmental records are absent. Furthermore, this record may inform on climate variability throughout the Holocene as well as climatic periods such as the Holocene Climatic Optimum. From c. 11500-11100 BP minor charcoal values point, together with strong Stoebe and Artemisia, elevated Ericaceae percentages, and an absence of tree pollen, to low temperatures. The Early Holocene warming period c. 11100-10000 BP is reflected in increasing savanna/woodland taxa such as Olea, Canthium and Combretaceae, whereas charcoal values remain low. In contrast, charcoal strongly increases from 9000-5000 BP during the Holocene Climatic Optimum, which may be related to increasing temperatures and higher biomass. Simultaneously, Savanna elements such as Searsia, Combretaceae, and Euphorbia expand. The late Holocene, from 5000-650 BP, is characterised by a retreat of woody taxa and grass, while drought-resistant Amaranthaceae strongly increases. Fluctuations, especially of Amaranthaceae, might indicate drought spells. Since c. 1000-700BP, large Poaceae pollen grains were detected, probably pointing to middle farming communities in the region. During that period, a peak in moisture-demanding Cyperaceae, accompanied by a decrease in Amaranthaceaes might also signal slightly wetter conditions. From 650-150 BP a sudden tree pollen decrease is accompanied by a strong Amaranthaceae and charcoal peak. This might be a function of a dry period cumulating c. 300 BP. The last 150 years BP reflect colonial influence through the occurrence of exotic taxa such as Pinus and Platanus.

Keywords: Palynology, Holocene, wetlands, Mpumalanga

EVOLUTION OF THE MAPUTULAND BARRIER DUNE IN THE LATE QUATERNARY (CENTRAL KWAZULU-NATAL COASTAL PLAIN)

Daria Semikolennykh[1], Alastair Cunningham, Axel Hofmann[2] Jasper Knight[1], Mary Evans[1] & Rachel Haupt[1]

[1]School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, Johannesburg, South Africa

[2] Department of Geology, University of Johannesburg, Auckland Park, South Africa

The dunes along the northeastern coast of South Africa are a unique palaeogeographic archive, reflecting the evolution of the region's natural environment during the second half of the Pleistocene. Changes in climatic and geomorphological conditions are primarily expressed in the complex internal structure of the dunes. The aeolian relief of Maputaland has attracted the attention of researchers for many years; however, a consensus on the structure of the dunes, their age, and stages of evolution remains elusive, mainly due to the morphological diversity and complexity of their internal structure. We attempted to investigate the late Quaternary evolution patterns of Maputaland's most iconic dune, the Barrier Dune. In November 2024, we examined an abrasion exposure of the Barrier Dune, 4.5 km northeast of Richards Bay Port. The dune here is 40–50 m high and consists of strata of varying ages. The RB-1 section was excavated from the dune summit to a depth of about 11 m. Seven samples were collected for quartz (OSL) and feldspar (IR, pIR) luminescence dating, and 16 samples were collected for granulometric and mineralogical analyses. Preliminary studies have revealed three formations of different ages and determined their time frames. The upper light-brown stratum of aeolian sands, rich in grains of heavy minerals, was formed in the second half of the Holocene and is related to the Sibaya formation. Below, a stratum of brown sands from the KwaMbonambi formation, characterised by ferruginous crusts and concretions with signs of diagenesis and soil formation, was exposed. This stratum formed during the transition from the Late to the Middle Pleistocene. The lower stratum is represented by white and greenish sands of the Kosi Bay formation, with an absolute predominance of quartz grains accumulated in the Middle Pleistocene. In Richards Bay, the barrier dune is a complex overlay of three generations of dunes, consisting of sediments that are aged from hundreds to hundreds of thousands of years. The most likely periods of active dune formation are associated with global climate cycles.

Keywords: luminescence dating, sedimentology, aeolian deposits, Late Quarternary

Coal in the Future

EVALUATION OF THE COAL FROM THE LIMPOPO COALFIELD, SOUTH AFRICA, AS A SOURCE OF RARE EARTH ELEMENTS

Sanki Biswas[1,2], Nicola J. Wagner[1] & Ofentse M. Moroeng[1]

[1] DSTI-NRF CIMERA/Carbon Ore Research Group, Department of Geology, University of Johannesburg, Auckland Park, South Africa

[2] PPM Research Group, Department of Geology, University of Johannesburg, Auckland Park, South Africa

Coal has come to light as a potential alternative source of rare earth elements (REY), which are essential for various high-tech applications, including electric vehicles, wind turbines, solar panels, and advanced defence systems. This study examines the No. 6 Seam coal from the Limpopo Coalfield in South Africa to evaluate its viability as a REY resource. A suite of advanced analytical techniques, including inductively coupled plasma mass spectrometry (ICP-MS), mineral liberation analysis (MLA), and scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDS), was employed to investigate the distribution, occurrence, and mineralogical associations of REY within the coal samples. The coal from the No. 6 Seam is classified as medium-rank-B bituminous coal, with a moderate vitrinite content (avg. 41.5 vol%). The mineralogical composition dominated by kaolinite and quartz, alongside minor phases such as muscovite, siderite, dolomite, pyrite, and calcite. The total REY concentrations in the coal samples range from 79.9 to 332.1 mg/kg (avg. 213.2 mg/kg, on whole-coal basis), exceeding the global average for hard coal. The enrichment patterns, assessed through concentration coefficients, indicate moderate enrichment of most REY elements, except for certain heavy-REY such as Ho, Tm, and Lu. Distinct REY enrichment patterns are evident across different coal horizons – the coal from the lower horizon exhibits enrichment in light-REY (LREY) and medium-REY (MREY), whereas the middle horizon coals are enriched in medium-REY (MREY) and heavy-REY (HREY). The average concentration of critical REY (Nd, Eu, Tb, Dy, Y, Er) is 70 mg/kg, with Nd and Y comprising nearly 86% of the total. The bright-phase search via MLA and SEM was employed to identify REY-bearing mineral phases, while EDS facilitated the determination of their elemental composition. Rare earth elements were primarily associated with monazite and xenotime, as well as REY-bearing carbonates and aluminosilicates. The high proportion of critical REY (REYdef,rel%: 29.85–39.75%) and an outlook coefficient of = 0.7 suggest that the coal from the No. 6 Seam of the Limpopo Coalfield holds significant promise for REY recovery.

Keywords: rare earth elements, enrichment, mineral associations

RECONSTRUCTION OF PALEO-DEPOSITIONAL ENVIRONMENTS FOR THE PERMIAN VEREENIGING-SASOLBURG COALFIELD, SOUTH AFRICA

Fatima Zonke Chitlango[1], Marvin Moroeng[1] & Nicola Wagner[1]

[1] University of Johannesburg, Auckland Park, South Africa

Coal samples from four boreholes drilled as part of an exploration project in the Vereeniging-Sasolburg Coalfield, Coalbrook Sub-basin, South Africa, were studied to understand the paleo-depositional environment of the mire using organic petrography (macerals, microlithotypes, and vitrinite reflectance), geochemistry (XRF, rare earth and trace elements data), and mineralogy. The study aims to expand the understanding of this part of the Main Karoo Basin (MKB) coalfields. The samples are classified as lowrank A sub-bituminous to medium-rank D bituminous with variable maceral composition, dominated by inertinite group macerals ranging from 42.0 to 90.6 vol % (semifusinite, fusinite, and inertodetrinite) and moderate vitrinite (at 5.8 to 48.0 vol%). The dominance of inertinite in these coals suggests oxidation and paleofires in and around the mire. The vitrinite to inertinite ratio (V/I) varies from 0.06 to 1.14 (highest in sample B from SLD01a) and suggests a dry and oxidising paleoenvironment with the dominance of inertinite group macerals, except for sample B from SLD02a. The occurrence of both inertinite and vitrinite also reflects variations in the paleomire conditions, from oxic to anoxic. Sr/Cu and U/Th ratios ranging from 1.24 to 49.28 and 0.1.0 to 0.32, as well as positive and slight negative Ce anomalies indicate climate variations between humid and arid conditions, with a predominance of dry conditions. While geochemical ratios of Th/U and Sr/Ba ratios suggest a transitional semi-brackish to freshwater depositional setting influenced by sea level fluctuations, with a dominance of freshwater settings. The dominant minerals in the studied coals are kaolinite (mainly detrital) and quartz (detrital), showing a syngenetic mode of occurrence. Authigenic kaolinite precipitated in cell lumens and maceral pores under acidic pH levels. The geochemical plot and Al_2O_3/TiO_2 ratios indicate that the detrital minerals in the coals were mostly derived from intermediate and felsic sources. Eu anomalies in all the studied coals are <1 (negative anomalies) with values ranging from 0.45 to 0.97, at an average of 0.69, further supporting a felsic to felsic-intermediate source region. The microlithotypes facies plot suggests that the coals from the Coalbrook Sub-basin were deposited in lacustrine and lower deltaic depositional environments.

Keywords: Vryheid Formation, petrography, macerals, redox conditions

STRATIGRAPHIC DISTRIBUTION OF RARE EARTH ELEMENTS WITHIN THE SOUTPANSBERG COALFIELD, TSHIPISE SUB-BASIN, SOUTH AFRICA

Rhulani W. Hlungwane[1], O.M. Moroeng[1] & N. Wagner[1]

[1] University of Johannesburg, Auckland Park, South Africa

This study assessed coal and associated clastic partings extracted from a borehole core to gain insight into the stratigraphic distribution of rare earth elements as well as yttrium and scandium (abbreviated to REY+Sc) in the Soutpansberg Coalfield, Tshipise Sub-basin, South Africa. Forty-one (41) samples were milled to 106 µm, prepared using microwave digestion, and analysed using inductively coupled plasma-mass spectroscopy (ICP-MS) to determine the REY+Sc concentration. The results show that REY+Sc concentration is higher in the bottom lower seam (SBL) (at a depth of 59.5 m) and associated parting (P6) compared to samples from higher up in the sequence. Compared to the upper continental crust (UCC) values, the REY+Sc in the samples towards the top are comparatively low, whereas the concentrations are higher towards the bottom. In addition to the UCC, concentrations for the latter samples exceed the average values reported for Chinese, US, and world coal. Most samples exhibit negative Eu anomalies, which suggest detrital input of REY-bearing sediments from felsic to intermediate sources. In contrast, two samples show positive Gd and Y anomalies, suggesting infiltration of natural waters and/or hydrothermal fluids. This is supported by the presence of L-M and M-H types of REY enrichment, which also shows diverse sources for the REY+Sc and the influence of different geological processes on the No. 6 Seam. The samples are promising for REY recovery, as the coefficient outlook is between 0.7 and 1.9. The dominant minerals in the samples are quartz and kaolinite, with minor carbonate and pyrite, except in two samples (31 and 31), dominated by carbonates. The vitrinite maceral group dominates most samples (25–65 vol%), and the vitrinite reflectance values range from 0.82 to 0.84, classifying the coal samples as medium-rank C bituminous. In addition, the samples have Al_2O_3/TiO_2 ratios of between 16.2 and 22.7, confirming detrital input from a felsic to intermediate source. Therefore, alongside the host minerals, the REY+Sc may also have a detrital origin, i.e., weathered and transported together with the detrital materials and deposited into the palaeomire. The results provide an understanding of the stratigraphic distribution of REY+Sc in the Soutpansberg Coalfield.

Keywords: Stratigraphic distribution, Rare earth elements, ICP-MS, Detrital origin

RARE EARTH ELEMENTS OCCURRING IN THE VRYHEID FORMATION, WITBANK COALFIELD, SOUTH AFRICA

Nthabiseng Lethobane[1], Marvin Moroeng[1] & Nicola Wagner[1]

[1] University of Johannesburg, Auckland Park, South Africa

Coal is a potential alternative source for rare earth elements (REEs), which are used in modern technologies. Research assessing the concentration and distribution of REEs has been conducted in the Karoo Basin, and positive results confirming the presence of the elements were obtained. However, further research is required to determine if comparable findings can be found in another part of the basin and further interrogate the host minerals and REE source. The study area for this research is in the Delmas portion of the Witbank Coalfield. This study aims to determine and understand the concentration and origin of REEs in the coal horizons and associated clastic sediments extracted from a borehole core intersecting the Vryheid Formation. Following detailed core logging, 28 samples were selected. Organic petrography, proximate, geochemical, and mineralogical analyses were applied to characterise the samples. The stratigraphy of the borehole includes carbonaceous shales, sandstones, and coal seams. The total REE concentration determined using inductively coupled plasma mass spectrometry (ICP-MS) analysis ranges from 40 to 840 ppm, with 23 samples showing results higher than the average values reported for the Upper Continental Crust (UCC =179.4 ppm), Chinese (137.9 ppm), USA (62 ppm), and World coals (72.4 ppm). The ICP-MS results show higher REE concentrations in the clastic lithologies (150-840 ppm) compared to the coal seams. The highest REE concentrations for the coal samples are from the No. 2 Seam (35 - 280 ppm). The studied Vryheid Formation samples are rich in light-REEs, followed by medium-REEs, with heavy-REEs being the least abundant. The concentrations were normalised to the UCC and show a high enrichment for Ce, Nd, Sm, Gd, Dy, Er, and Y. The samples show a negative Eu anomaly. Given the geochemical characteristics of the samples, XRD and SEM-EDS analyses will be conducted to identify host minerals and examine their morphologies to understand the modes of occurrence.

Keywords: Witbank Coalfield, Coal, REEs.

THE ROLE OF FLUID MIGRATION IN COAL MATURATION IN THE SABINAS BASIN, NORTHWEST MEXICO: EVIDENCE FROM FLUID INCLUSIONS, STABLE ISOTOPES AND MINERALOGY

Joseph M. Madondo[1], Aurea González-Betancourt[2], Eduardo G.P. González-Partida[2], Juan J. Enciso-Cárdenas[3], Luis C. Camacho-Ortegon[3], Luis Martínez[4], Pura Alfonso[5] & Sumit M. Mishra[2]

[1] Department of Geology, Rhodes University, Makhanda, South Africa

[2] Instituto de Geociencias, Universidad Nacional Autónoma de México, Juriquilla, México

[3] Centro de Investigación en Geociencias Aplicadas, Universidad Autónoma de Coahuila, Coahuila, México

[4] Institut de Physique Du Globe de Strasbourg, CNRS-Université de Strasbourg EOST, Strasbourg Cedex, France

[5] Departament d'Enginyeria Minera, Industrial i TIC, Universitat Politécnica de Catalunya, Manresa, Spain

The Sabinas Coal Basin of northwest Mexico, spanning 37,000 km^2, accounts for over 90% of Mexico's coal production. Its geologic origin is linked to the Proto-Gulf of Mexico's opening and the Laramide Orogen's tectonic closure. Structural highs, such as the Coahuila Peninsula, and faults including La Babia and San Marcos, border the basin. The basin hosts the coal-bearing Olmos Formation, an Upper Cretaceous Formation that originated in marsh, lagoonal, and deltaic environments under a subtropical climate. This study examines diagenetic calcites and sulphides, focusing on fluid inclusions and stable isotopes ($\delta^{13}C$, $\delta^{18}O$, $\delta^{34}S$ Fluid inclusions show homogenisation temperatures of 82–150°C and salinity between 1.9% and 5.4% Eq. Wt. NaCl. The $\delta^{34}S$ values of sulphides range from +7.5‰ to +20.0‰, while calcite isotopes show $\delta^{13}C$ between -7.87‰ and -11.1‰, and $\delta^{18}O$ ranging from -5.01‰ to -11.80‰ (vPDB). The findings indicate a two-stage coal maturation process, involving an earlier coalification process within the catagenesis temperature range due to deep burial and a later hydrothermal fluid induced alteration process. Initially, organic matter from upper plants underwent decarbonisation in a closed system, facilitating sulphate reduction to sulphides with minimal isotopic fractionation. Hydrothermal sulphides and carbonates were produced during late-stage basin evolution under the influence of organic CO_2 and deep-circulating meteoric waters. These findings highlight the role of geochemical conditions and hydrothermal processes during coal maturation in the Sabinas basin.

Keywords: Sabinas Basin, coal fluid inclusions, C–O–S stable isotopes

EXPLORING SOUTH AFRICAN COAL AS AN UNCONVENTIONAL SOURCE OF RARE EARTH ELEMENTS: A CASE STUDY OF THE WATERBERG COALFIELD

Maluleke Nsovo[1] **& Christopher Baiyegunhi**[1]

[1] University of Limpopo, Polokwane, South Africa

The global demand for rare earth elements (REE) has surged in recent years due to their critical role in advanced technologies, renewable energy systems, and defence applications. Traditional REE-bearing ores are increasingly unable to meet this rising demand, prompting a growing interest in alternative, unconventional sources. Recent studies have shown that coal is a potential untapped resource for REE. In this study, coals collected from various zones within the Grootegeluk and Vryheid Formations of the Waterberg Coalfield were investigated for their geochemical and mineralogical characteristics. A total of 19 coal samples were obtained from all stratigraphic zones of both the Grootegeluk and Vryheid Formations. These samples were analysed using organic petrography, x-ray diffraction (XRD), proximate analysis, scanning electron microscopy coupled with energy dispersive spectrometry (SEM+EDX), and inductively coupled plasma mass spectrometry (ICP-MS). The organic petrography studies classify the coal as lowvolatile bituminous coal. The ash content trends differ between the formations; the Vryheid Formation exhibits an upward-increasing ash pattern, whereas the Grootegeluk Formation shows a decreasing trend in its lower zones, with no consistent pattern in overlying zones. Quartz, kaolinite, and dolomite are the dominant minerals, with kaolinite displaying an upward-increasing trend. Monazite and xenotime are the only identified REE-bearing minerals, typically interlocked within clay minerals and organic matter. The total REY+Sc (rare earth elements and yttrium plus scandium) concentrations range from 113 to 381 ppm, which is higher than average values reported for USA and world coals. The Vryheid Formation shows a positive correlation between REE concentration and ash content, particularly in its upper zones. Light REE (LREE) and Middle REE (MREE) are more enriched than heavy REEs and show a stronger association with inorganic matter. The Zone GF7B of the Grootegeluk Formation and the upper two zones of the Vryheid Formation exhibit the highest REE concentrations and thus represent the most promising targets for future economic exploitation. Further investigation of the ashed coal samples from these zones is recommended to assess their full resource potential and recovery feasibility.

Keywords: Grootegeluk Formation, Vryheid Formation, REY+Sc, LREE, MREE, HREE

THE SIGNIFICANT ROLE OF PETROGRAPHY IN HIGHLIGHTING THE IMPACT OF MODE OF OCCURRENCE IN MINIMISING MINERAL MATTER DURING COAL BENEFICIATION

Itumeleng Matlala[1], Marvin Moroeng[1] & Nicola Wagner[1]

[1] University of Johannesburg, Auckland Park, South Africa

Coal heterogeneity causes challenges during beneficiation. This is partly related to inorganic components, whose behaviour depends on the mode of occurrence. It can be difficult to separate minerals from biological debris, particularly small mineral particles with syngenetic modes of formation (detrital and authigenic). In addition to maceral and reflectance analysis, organic petrography provides for the quantification and qualification of the mode of occurrence of minerals. The present study assesses five (5) run of mine (ROM) coal samples from the No. 4 Seam of the Highveld Coalfield. The ROM samples were subjected to density fractionation using relative densities (RD) of 1.7 (F1.7) and 1.9 (F1.9) g/cm^3 to understand the behaviour of the organic and inorganic matter. Petrography was undertaken to determine coal type (macerals and microlithotypes) and rank; proximate analysis to determine coal grade; and X-ray diffraction (XRD), to understand the mineral composition. The ROM coals are rich in inertinite (semifusinite and inertodetrinite) and low in vitrinite and liptinite. Reactive macerals (a combination of vitrinite, liptinite, and reactive semifusinite) are generally enriched in F1.7 samples (float at 1.7 g/cm^3). The high carbominerite contents (particularly carboargillite, carboankerite and carbosilicates) are high in the F1.9 samples, and especially in the sink products. This relates to slightly higher kaolinite and quartz in F1.9 and the sink products. The partitioning behaviour of minerals in the Highveld coals during density fractionation is related to the size of the component, primarily controlled by the mode of occurrence. Some sink samples from the 1.7 g/cm^3 RD are higher quality (because of the nature of the parent) than float samples acquired at 1.9 g/cm^3 from other locations. In addition to higher inertite contents, there is also a high fraction of carbominerite, which is often linked with epigenetic and large-sized syngenetic mineral particles. This shows that further beneficiation of selected 1.7 sink products at higher density fractions may result in medium ash feedstock. These findings are supported by statistical analysis (R-Factor). The parent coals exhibit lateral heterogeneity composition across Highveld Coalfield, indicating the need for different beneficiation techniques; one size does not fit all.

Keywords: Coal quality, Coal utilisation, Macerals, Carbominerite

Environmental Geoscience

SEDIMENT CHARACTERISATION OF BEACH SEDIMENT ALONG A PART OF THE WEST COAST OF INDIA

Pratiksha Prashant Bagul[1] **& Milind A. Herlekar**[1]

[1] Savitribai Phule Pune University, Pune, India

Coastal zones are dynamic environments influenced by natural processes and anthropogenic activities, leading to significant seasonal and spatial variations in sediment characteristics. Understanding these variations is critical for managing coastal erosion, habitat conservation, and sustainable development. The Ratnagiri coast of Maharashtra, located along the eastern Arabian Sea, is characterised by complex geomorphological features and increasing human interference, making it essential to investigate the sedimentary dynamics of this region. This study aims to analyse seasonal changes in the textural properties of beach sediments and explore the underlying environmental processes using multivariate statistical techniques. The seasonal variations in the textural parameters and Principal Component Analysis (PCA) of beach sediments were collected along the Purangad to Gaonkhadi coast of the Ratnagiri district, Maharashtra, India. A total of 56 samples (28 samples from each season i.e., pre- and post-monsoon) were collected from multiple beach locations, encompassing diverse geomorphological features. The foreshore sediments show symmetrical to strongly fine skewed whereas, backshore sediments are fine skewed to strongly fine skewed. During the post-monsoon (POM) season, foreshore and backshore sediments are coarse-grained sand, whereas raised beach and foredune sediments show fine-grained sand. The foreshore sediments are poorly sorted to very poorly sorted, while the backshore and raised beach sediments are moderately sorted to poorly sorted. The linear discriminant analysis (LDA) plots of sediments fall in a shallow marine environment, while few sediments fall in a shallow beach environment. PCA revealed distinct clusters corresponding to different beach environments, highlighting the influence of local geological sources and human activities on sand composition. The first two principal components explained approximately 78% of the total variance, with grain size and mineralogy being the most significant factors. This analysis underscores the utility of PCA in environmental geosciences, providing insights into sediment dynamics and the ecological implications of coastal processes. The findings contribute to a deeper understanding of coastal sedimentology and offer a framework for future beach system resilience and management studies.

Keywords: Foreshore, Sediments, Coastal sedimentology

ASSESSING GOVERNANCE EFFECTIVENESS IN GROUNDWATER MANAGEMENT

Bonang Bathobakae

Groundwater resources, despite their crucial role in the ecosystem and in supporting the livelihoods of local communities in Botswana, have long been underappreciated and overlooked in national governance frameworks. Hence groundwater is subject to deteriorating quality and diminishing quantity, with limited regulation and policy interventions to address emerging challenges. This research seeks to explore the implications of this neglect on Botswana's sustainable development efforts by assessing existing policies and regulatory frameworks to identify the gaps that contribute to the degradation of groundwater resources. The study adopts the Institutional Theory and the Institutional Analysis and Development (IAD) Framework as its theoretical basis, enabling a deeper understanding of how governance structures and institutional arrangements influence groundwater management and sustainability. Through a combination of document reviews, key informant interviews, depth integrated water sampling, and static water level (SWL) measurements the study comprehensively examines both qualitative and quantitative aspects of groundwater resource management in Botswana. The data collected will be analysed using thematic analysis to identify recurring patterns, challenges, and institutional relationships that may be the factors influencing groundwater governance. Multivariate Analysis of Variance (MANOVA) will be employed to assess aquifer quality. Additionally, aquifer stability and variability will be determined from SWL measurements, providing insights into the physical condition of the aquifer. The study emphasises the need for stronger institutional coordination and legislative reforms to address the degradation of groundwater resources and ensure sustainable management. The study serves as a call to action for policymakers to prioritise groundwater in national resource management strategies, urging the integration of sustainable practices in addressing groundwater availability and quality issues.

Keywords: Governance, Sustainable, Groundwater, Wellfield, Management

EVIDENCE OF CONTAMINATION IN SOUTH AFRICAN COASTAL WATERS AND SEDIMENTS DUE TO ANTHROPOGENIC ACTIVITIES

Eugene W. Bergh[1], Kgaugelo E. Lekota[1], Michael Fourie[1] & Tinelle Grobler[1]

[1] Unit for Environmental Sciences and Management, North-West University, Potchefstroom, South Africa

Coastal water bodies are increasingly at risk of contamination from anthropogenic activities. It is estimated that more than half of coastal ecosystems in South Africa are affected by pollutants, including potentially toxic elements (PTEs). These PTEs accumulate in water and sediments and can be tested through geochemical analyses. Twelve sites across the Knysna Estuary were identified, where water and sediment samples were collected and analysed using inductively coupled plasma mass spectrometry (ICP-MS). Contamination indices and statistical analyses were calculated to determine possible pollution or contamination. Findings reveal elevated levels of Cr, Co, Ni, Cu, As, Cd, Bi and U, with particularly high contamination of chromium (Cr) and nickel (Ni) in the samples, above thresholds from natural sources. The highest concentrations of these elements were recorded in the sediments of the upper reaches of the estuary. The identification of a closed and abandoned nearby gold mine may relate to elevated contamination of some of these elements. The results of this study therefore indicate that potential contamination is caused by industrial and recreational activities, as well as runoff from the surrounding areas. Uncontrolled and further contamination of such coastal water bodies pose implications for ecological, recreational and economic activities in these urbanised regions.

Keywords: Geochemistry, pollution, aquatic, estuary

INFLUENCE OF PROVENANCE, DEPOSITIONAL CONDITIONS AND ENVIRONMENTAL FACTORS ON SELENIUM CONCENTRATION IN MUDROCKS: INSIGHTS FROM UPPER CRETACEOUS AND PALEOGENE MUDROCKS IN THE SOUTHERN BENUE TROUGH, NIGERIA

Aitalokhai J. Edegbai[1], Erepamo J. Omietimi[2], Jennifer B. Owonaro[3], Jubemi A. Pajiah[4] & Nils Lenhardt[1]

[1] Department of Geology, University of Pretoria, Pretoria, South Africa
[2] Department of Geology, Niger Delta University, Amassoma, Nigeria
[3]Department of Marine Geology, Nigeria Maritime University, Okerenkoko, Nigeria
[4] Department of Geology, University of Benin, Benin City Nigeria

The selenium (Se) concentration in rocks and soil is influenced by the underlying geology, organic matter, and geochemical conditions such as pH and redox state. Although numerous studies have focused on Se concentrations in food and human body fluids, investigations into Se levels in soils and rocks in developing countries often lack adequate geologic context and stratigraphic control. Furthermore, background Se concentrations in sediments and rocks of varying ages remain primarily undocumented, particularly in Nigeria, where such data could elucidate the geological controls on Se-related diseases. This study x-rays the geologic controls on Se concentration mudrocks and provides baseline data on Se concentration in parts of southern Nigeria using materials from Upper Cretaceous and Paleocene strata in the wider Southern Benue Trough, Nigeria. Geochemical analysis and pH measurements were conducted on 73 mudrock outcrop samples from the Latest Campanian to Mid-Maastrichtian Mamu Formation and ditch cuttings from water wells that penetrated the Paleocene Imo Formation from the Anambra and Niger Delta basins (sub-basins in the Southern Benue Trough), respectively. Major and trace element concentrations were determined using X-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICPMS), with additional analyses of total carbon (TC), total inorganic carbon (TIC), total organic carbon (TOC), and pH. The results reveal that the Imo Formation calcareous mudrock unit possess higher Fe, Mg, K, Ca, Ni, Co, V, Cr, Mo, Cu, Se, Zn, Ba, and Sr, when compared to the Mamu Formation dark mudrock unit, which exhibit higher concentrations of Si, Al, Ti, and U. Additionally, the Imo Formation calcareous mudrock samples have higher (computed) calcite and total inorganic carbon levels. They are less acidic (mean pH 5.92) than the Mamu Formation, which has a pH of 5.02 and a higher TOC. Selenium concentrations in the Imo Formation reach up to 21 ppm, significantly exceeding those in the Mamu Formation. This enrichment is attributed to significant detrital contribution from silica-poor source rocks, which are higher in Se and Fe (oxide) content, together with stronger marine and hydrothermal influences. The foregoing is illustrated by higher (inferred) calcite, illite and chlorite abundance. In addition, the covariation of TOC with elements such as Pb, Zn, Mo, and U suggests reducing conditions, particularly in the proximal environments of the Imo Formation.

Keywords: hydrothermal influence; provenance, inorganic carbon, Benue Trough

AN INVESTIGATION INTO THE ANTIMICROBIAL PROPERTIES OF ESTUARINE AND MARINE MUDROCK LEACHATES: INSIGHTS FROM UPPER CRETACEOUS AND PALEOGENE STRATA, SOUTHERN NIGERIA

Aitalokhai J. Edegbai[1,2], T.O. Ekhomalomen[2], B.O. Isichei-Ukah[3], D.K. Matthew[2], N.I. Odiaka[2,4] & G.O. Ofie[3]

[1] Department of Geology, University of Pretoria, South Africa
[2] Department of Geology, University of Benin, City of Benin, Nigeria
[3] Department of Microbiology, University of Benin, City of Benin, Nigeria
[4] Dennis Osadebay University, Anwai, Asaba, Nigeria

Research into the antimicrobial properties of mudrocks is beginning to gain traction due to the proliferation of antibiotic-resistant bacteria. Reports show low pH, high Fe, Al, Cu and Zn concentrations are drivers of the antimicrobial response seen in certain mudrocks. In this study, an evaluation of antimicrobial response of 10 estuarine and marine mudrocks to cultures of skin infection causing bacteria and fungi such as Aspergillus spp., Multi-Drug-Resistant Pseudomonas spp., Susceptible Pseudomonas spp., Methicillin Resistant Staphylococcus spp., and Susceptible Staphylococcus spp. Elemental analysis using ICP-MS, together with pH and EC measurements were conducted on the samples. For the antimicrobial test, sample preparation involved hand milling 10 g of samples, before sieving out particles greater than 0.063 mm in diameter. 2 g of the mud sized particles where thereafter hydrated with deionised water, centrifuged, and allowed to soak for 48 hours, before pipetting appropriate volumes for antimicrobial investigation on bacteria and fungi isolates, which were purified with Mueller-Hinton agar (for bacteria) and sabouraud dextrose agar (for fungi). Antimicrobial tests were conducted with clay leachate concentrations of 12.5%, 25% and 50% to determine minimum inhibitory concentration (MIC) and minimum bactericidal/fungicidal concentration (MIC). Of the 10 clay samples screened for antimicrobial activity, no mudrock sample showed antimicrobial activity against Aspergillus spp. In contrast, three estuarine mudrocks (U- 5B, IMI-11B, IMI-19A) showed bacteriostatic activity against the bacteria isolates and recorded zones of inhibition ranging from 11 mm to 16 mm. The MIC for all bacteria cultures was 50 mg/ml in the U-5B sample; in the IM-11B the MIC for the Susceptible Staphylococcus spp. was observed to be 50 mg/ml. Similarly, the MIC for Multi-Drug-Resistant Pseudomonas spp. and Susceptible Staphylococcus spp. were 50 mg/ml and 25 mg/ml respectively. It is hypothesized that absence of microbial activity in the marine mudrocks is due to higher pH and $CaCO_3$, which buffered the mobility of Fe and Al which are essential to the antimicrobial properties of clays. Furthermore, it is unclear why two estuarine mudrocks showed no antimicrobial response. Nevertheless, it seems probable that lower Al, K, and Cr concentrations seen in the samples are suspect. The findings from this study show that mudrock leachates hold a promising future for the treatment of microbial skin infections.

Keywords: Antimicrobial, Clays, Anambra Basin, Medical Geology, Niger Delta Basin

USING OPEN SOURCE InSAR TO MONITOR THE JAGERSFONTEIN TAILINGS DAM

Kamogelo Baloyi[1], Stephanie Scheiber-Enslin[1] & Susan Webb[1]

[1] University of the Witwatersrand, Johannesburg, South Africa

The rising global demand for raw earth materials has driven a significant increase in the construction and expansion of tailings dams. However, failures of these structures have resulted in severe environmental and infrastructural damage, adverse health effects, and, in many cases, loss of life. These risks underscore the urgent need for more rigorous protocols in the design, construction, management, and monitoring of tailings dams. Notably, many tailings dam failures are preceded by detectable warning signs. Interferometric Synthetic Aperture Radar (InSAR) is one technique that enables early detection and mitigation of potential failures. InSAR works by analysing electromagnetic wave reflections from the Earth's surface captured by orbiting satellites. The technique calculates the distance between the satellite and the Earth's surface based on phase shifts in these reflected signals. This study employs InSAR to monitor the Jagersfontein tailings dam prior to its collapse on 11 September 2022. The analysis reveals an uplift signal emerging as early as April 2022 – five months before the failure. The signal indicates an accumulation of approximately +4 cm at the dam's southeastern wall, where an independent study also observes a structural bulge. By June, the signal shifts to show subsidence, reaching roughly -14 cm by early September, just six days before the collapse. These deformation patterns may reflect oversaturation, followed by the gradual failure of the eroded section where the breach ultimately occurred. The successful detection of precursory signals at Jagersfontein demonstrates the potential of InSAR as a valuable tool for monitoring other tailings dams and enhancing early-warning capabilities.

Keywords: InSAR, Tailings dams, Jagersfontein

THE ENVIRONMENTAL AND FINANCIAL ASPECTS OF THE USE OF PIT LAKES FOR SUSTAINABLE MINE CLOSURE

A.C. Johnstone[1]

[1] GCS Water & Environmental Consultants, Johannesburg, South Africa

Mine closure has become an integral part of mine planning to ensure sustainable closure of mines and to avoid post-closure social and environmental risks, requiring concurrent rehabilitation to minimise closure liabilities. Opencast mining operations result in a final mine void, which, on closure, fills with water, forming a pit lake. Pit lakes are becoming an increasingly acceptable form of mine closure provided that long-term environmental risks can be mitigated. In addition, pit lakes may negate costs associated with backfilling of the final mine void and potential water treatment costs. Sustainable mine closure is assessed in terms of the appropriate mitigation measures to ensure no long-term environmental liabilities. The paper discusses a number of South African case studies in different locations, mining environments and commodities where pit lakes are used in mine closure. The case studies involve coal, diamond, chrome, and manganese mines in South Africa. The case studies asses the financial and environmental aspects of using pit lakes as a sustainable mine closure option.

Keywords: mine closure, pit lakes, water management, financial provision

APPLICATION OF THE ELECTRICAL RESISTIVITY TOMOGRAPHY GEOPHYSICAL METHOD IN GEOTECHNICAL INVESTIGATIONS WITHIN THE BUILT ENVIRONMENT

Hardy Luttig[1], Jandre de Beer[1] & Louis Jonk[1]

[1]GEOSS South Africa (Pty) Ltd, Stellenbosch, South Africa

Geophysical surveys investigations provide a rapid, detailed, and cost-effective means of exploring subsurface conditions across diverse environments. In recent years, their application within the built environment has expanded significantly. Among these methods, Electrical Resistivity Tomography (ERT) has proven particularly valuable for characterising subsurface conditions, identifying problematic soils and areas of interest or concern, and delineating geological structures in geotechnical investigations. This study presents several case studies demonstrating the effectiveness of ERT in addressing key engineering challenges across varied geological settings. One case study in Stellenbosch, South Africa, highlights the use of cross-pattern ERT surveys with IDW interpolation to map shallow granitic bedrock, enabling the redesign of a proposed basement excavation. Another Stellenbosch study utilised parallel ERT lines to pinpoint, within a one-meter accuracy, a weak gully-infill structure posing stability concerns for an eight-meter-deep excavation. In Cape Town, perpendicular ERT surveys successfully delineated the geometry of a perched water table, informing a cost-effective dewatering strategy for a deep basement excavation. Additionally, parallel ERT lines, oriented perpendicular to natural water channels, proved instrumental in assessing surface water–groundwater interactions, aiding environmental impact assessments for proposed modifications to these channels. Ongoing use of the electrical resistivity method across the diverse geological settings of a particular region enhances data reliability by enabling comparisons between resistivity pseudosections and actual geological units through boreholes, test pits, and auger holes. To this end, an ongoing initiative aims to correlate and extensive collection of ERT profiles with physical borehole and test pit data to establish a regional resistivity reference for various geological formations in the Western Cape of South Africa. This effort will enhance the predictive capability of ERT by refining resistivity signatures associated with Cape Granite Suite granites, Table Mountain Group sandstones, metamorphosed shales of the Malmesbury Group, and unconsolidated Quaternary-aged surficial cover. Developing this resistivity inventory will improve the reliability of ERT for regional geotechnical and environmental assessments, facilitating better-informed engineering and environmental decision-making.

Keywords: Geophysics, Electrical Resistivity Tomography, Geotechnical, Built environment

A GIS- AND REMOTE SENSING-BASED APPROACH FOR IDENTIFICATION AND CHARACTERISATION OF MINE TAILINGS IN SOUTH AFRICA

Gaone Joseph[1], Linda Iaccheri[1] & Stephanie Enslin[1]

[1] University of Witwatersrand, Johannesburg, South Africa

Mine tailings are scattered throughout southern Africa, forming a legacy of the continent's rich mineral wealth. While tailings are generally located near active or former mining operations, their exact position, size, composition, and condition remain largely unknown. Despite publicly available mine data from the Department of Mineral Resources and Energy, a comprehensive inventory of mine tailings in South Africa is lacking. The importance of cataloguing mine tailings lies in two key areas. Firstly, mine tailings can pose significant environmental challenges, such as heavy metal contamination affecting water bodies, human health, and plant life. Secondly, they may represent an underutilised source of critical minerals, which could be reprocessed for further mineral extraction. This catalogue serves as the foundation for future research aimed at addressing the environmental and economic impacts of mine tailings in South Africa. The study introduces a GIS- and remote sensing-based approach to efficiently identify and mineralogically characterise mine tailings. Tailings were identified and mapped using Google Earth Pro, based on distinct characteristics such as shape, size, and surface discolouration. Over 400 tailings were recorded across South Africa, with a focus on the Witwatersrand Basin and the Barberton Greenstone Belt. Given the large number of tailings, mineralogical characterisation was conducted on two key sites – the West Rand Goldfields of the Witwatersrand Basin and the Fairview Gold Mine in the Barberton Greenstone Belt. Multispectral satellite data from ASTER and Sentinel-2 was analysed in ArcMap, generating false-colour maps and composite band ratios to enhance mineralogical variations, facilitating a general characterisation of tailings minerals. To validate the mineralogy identified from satellite imagery, five samples from each tailings deposit were collected for analysis using X-ray diffraction (XRD), the Tescan Integrated Mineral Analyser (TIMA), and petrography. By addressing both environmental risks and resource underutilisation, this research highlights how technology-driven solutions can enhance mine tailings management, promoting environmental sustainability, and economic development in South Africa.

Keywords: Mine tailings, Remote sensing, Mineralogical characterisation, Environmental sustainability

ASSESSING THE DATA QUALITY OF ERA5 DATASETS IN RELATION TO SUMMER TEMPERATURE INDICES OVER SOUTH AFRICA: 1979-2023

Nicolle Loader[1,2], Adriaan van der Walt[1,3], Ramontsheg Rapolaki[1,4] & Sarah Roffe[1,5]

[1]Department of Geography, University of the Free State, Bloemfontein, South Africa
[2]Centre for Mineral Biogeochemistry, University of the Free State, Bloemfontein, South Africa
[3] Afromontane Research Unit, University of the Free State, Bloemfontein, South Africa
[4] Marine Research Unit, South African Weather Service, Cape Town, South Africa
[5] Agrometeorology Division, Agricultural Research Council – Natural Resources and Engineering, Pretoria, South Africa

Global surface temperatures have increased by ~1.07°C since 1970, predominantly due to human-induced greenhouse gas emissions, leading to more frequent and intense extreme hot temperature events (e.g., heatwaves). These trends are evident across South Africa, whereby maximum and minimum temperatures have, since 1960, increased significantly over many regions, while the frequency, intensity, and magnitude of extreme hot events have also increased, with many statistically significant trends. These temperature changes and the increase in heatwave characteristics pose severe risks to agriculture and water resources, contributing to food insecurity and water shortages. Focusing on the whole South African region, this study aims to explore the reanalysis of data quality for temperature indices across South Africa from 1979 to 2023. A range of temperature indices has been identified (e.g. TXge30, TXge35, TX90t, and SU). These are some of the indices used for the data evaluation, along with the Mann-Whitney U test and Spearman's correlation test, while also considering the bias towards the weather station data. Although the analysis is still ongoing, the results are expected to be reliable since the ERA5 datasets are of good quality. The findings will inform strategies for mitigating the impacts of extreme temperatures on agriculture and water management, emphasising the importance of using accurate temperature indices and datasets to understand and address climate variability.

Keywords: ERA5, Temperature indices, Climate change, SAWS

A GEOLOGICAL ASSESSMENT OF SELECTED SOUTH AFRICAN CONCRETE AGGREGATES SUSCEPTIBLE TO ALKALI-SILICA REACTION

Sivuyile M. Mkhondweni[1,2], Nonkuselo M. Madlakana[1] & Yunus B. Ballim[3]

[1]School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

[2]Mandela Mining Precinct, Johannesburg, South Africa

[3]School of Civil and Environmental Engineering, University of the Witwatersrand, Johannesburg, South Africa

Concrete deterioration is one of the biggest concerns in civil and environmental engineering, as it affects the service life of concrete structures. While the sources of concrete deterioration vary, this study focuses on alkali-silica reaction (ASR). ASR is a chemical reaction between the alkalis in the cement and certain forms of silica in the rock aggregate, that can lead to cracking and loss of material integrity. Given the nature of concrete manufacturing and the mechanism of ASR, studying rocks as aggregate is critical for understanding aggregate behaviour in concrete. In South Africa, many concrete structures have been reported to be affected by ASR; however, the reasons behind these effects are not well understood. Therefore, the potential impact of petrographic studies on our understanding of ASR in South Africa has led to this research investigation. This study focuses on seven selected aggregate types used in South African concrete, sampled from known quarries due to suspected or reported ASR. A geological assessment of these aggregates and their constituent minerals was performed using optical microscopy, X-ray diffraction, and Tescan Integrated Mineral Analyzer. The results were compared with the expansion behaviours exhibited by the aggregates during the Accelerated Mortar Bar Test (SANS 6245). The findings reveal that rocks containing high silica concentrations, an abundance of microcrystalline and strained polycrystalline quartz, the presence of microcracking, and intense undulatory extinction of quartz crystals were more expansive. The Witwatersrand quartzite and metashale, Dwyka tillite, and Malmesbury feldspathic metawacke exhibited expansions greater than 0.1% on day fourteen, indicating potential alkali reactivity. In contrast, the Natal arkosic sandstone and Cape Granite Suite monzogranite showed expansions less than 0.1% on day fourteen. Although undulatory extinction is globally recognised as an important indicator of ASR susceptibility, this study suggests that the occurrence of ASR requires a combination of high crystalline lattice distortion, high reactive silica concentrations, available pore space (through microcracking), and increased surface area of quartz grains. These results also provide valuable insights for engineers and geologists on suitable aggregates for concrete production, emphasising the importance of integrating geological techniques for accurate ASR susceptibility and expansion prognosis.

Keywords: alkali-silica reaction, concrete aggregates, geological assessment, Accelerated Mortar Bar Test (SANS6245)

EXTRACTION AND SYNTHESIS OF SILICA NANOPARTICLES FROM MINE RESIDUES OF THE SOUTH AFRICAN BUSHVELD IGNEOUS COMPLEX

Sameera Mohamed[1], Elizabet M. van der Merwe[2] & Frédéric J. Doucet[1,2]

[1] Council for Geoscience, Pretoria, South Africa,

[2] Department of Chemistry, University of Pretoria, Pretoria, South Africa

The mining sector in South Africa plays a crucial role in the country's economy. However, it also contributes significantly to the generation of toxic waste streams, including acid mine impacted water and large volumes of solid mine residues. When stored over time, solid mine residues pose a major environmental concern for mining operations. Proper planning and monitoring are essential to mitigate potential environmental risks such as tailings dam failures and leaching of toxic metals into the ground. Stricter regulations have been implemented to address the environmental and social risks associated with the disposal and management of these waste materials, but effective waste management remains a challenge. Despite the potential for valuable and critical metals and minerals recovery from South African mine tailings, there is currently a lack of efficient and economically viable methods for their extraction and utilisation. This represents a significant challenge for the sustainable management and utilisation of mine tailings and potentially a missed opportunity for economic growth and innovation within the mining sector. This study aims to develop sustainable solutions for the recovery of valuable metals and minerals from mine residues produced from the Bushveld Igneous Complex, which will assist in minimising their disposal and make the treatment processes more economically viable. In this paper, we investigate the extraction of elements from a plagioclase-bearing mine residue originating from the Bushveld Igneous Complex and demonstrate the successful production of silica nanoparticles. Elemental extraction was achieved via a multistage process consisting of a calcination pre-treatment followed by direct acid leaching. A sol-gel method was used to produce silica nanoparticles. The physicochemical properties of the synthesised nanoparticles were assessed using a range of complementary techniques such as X-ray diffraction, scanning electron microscopy, transmission electron microscopy, and Brunauer Emmett-Teller method. Silica nanoparticles with a controlled spherical morphology were successfully synthesised. These nanoparticles had a primary particle size of <50 nm, a high surface area (576 m^2/g), and a purity of 99%. They may be suitable for various industrial applications, such as catalyst support, pollutant adsorption, CO_2 capture and enhancing the growth of cereal crops.

Keywords: Bushveld Igneous Complex, mine residues, elemental extraction, acid leaching, silica nanoparticles

INVESTIGATING THE DIFFERENCE IN THE RELATIVE ALKALINITY GENERATION BETWEEN WEATHERED OLD AND FRESH SLIME KIMBERLITE TAILINGS FROM CULLINAN: IMPLICATIONS ON THEIR USE AND POTENTIAL FOR ACTIVE SEQUESTRATION

Zakhele H. Nkosi[1,2], Avela Mantshontsho[2], Karel S. Viljoen[1], Nhlamulo Mafueka[2], Thandiwe Nhlabathi[2] & Wladyslaw Altermann[3]

[1]Department of Geology, University of Johannesburg, Auckland Park, Johannesburg, South Africa
[2]Department of Geology, University of Pretoria, Pretoria, South Africa
[3]South African Committee for Stratigraphy (SACS), Pretoria, South Africa

Weathering cell experiments were conducted to investigate the alkalinity generation potential of fresh and weathered kimberlite tailings. Fresh tailings, currently in the talc/serpentine wilson weathering stage (WWS) and transitioning to the chlorite/vermiculite stage, exhibit a high potential for CO_2 sequestration. Weathered tailings, having already passed the chlorite/vermiculite WWS, represent more stable secondary weathering phases. The experiments involved bi-weekly 50 ml flushing of deionised water through ~65g samples of both tailings over 200 days. Weathered tailings showed an initially high cation (Ca and Mg) output, which subsequently decreased. In contrast, fresh tailings displayed lower initial cation output, which progressively increased throughout the experiment. Fresh tailings also exhibited a slightly greater buffering capacity than their older, weathered counterparts. Both tailings are predicted to generate alkalinity, with paste pH above 8, low acid potential values (=0.313 kg/t), and positive net neutralisation potential (NNP) values. However, the fresh tailings have a higher NNP. These findings suggest that fresh kimberlite tailings have a greater capacity for long-term alkalinity generation and CO_2 sequestration compared to weathered tailings, highlighting implications for their utilisation and potential in active carbon sequestration strategies.

Keywords: Kimberlite tailings, Alkalinity generation, Weathering, CO_2 Sequestration

ADVERSE EFFECTS OF A COLLAPSED TAILING DAM ON THE LIMNOLOGY OF A SUBTROPIC DAM DOWNSTREAM

Petri Oberholster[1], Dirk Jungmann[2], Mariana Erasmus[3] & Melusi Thwala[1]

[1]Centre for Environmental Management, University of the Free State, Bloemfontein, South Africa
[2]Institute of Hydrobiology, Dresden Technical University, Dresden, Germany
[3]Centre for Mineral Biogeochemistry, University of the Free State, Bloemfontein, South Africa

On 11 September 2022, after the collapse of a tailing dam at the town of Jagersfontein in the Free State, South Africa, tailing dam sludge of approximately 5.8 million m^3 poured across the landscape, impacting the surrounding area and the Kalkfontein Dam. Kalkfontein Dam has a capacity of 304.05 mil m^3, covers an area of 4219.22 ha at 100% capacity, and supplies drinking water to numerous towns in the region. To assess the impact of the tailing sludge spill on the limnology of Kalkfontein Dam, the following objectives were set: (1) to determine the adverse effects of the mine sludge on the phytoplankton and zooplankton assemblage over a period of a year (2023), and (2) to determine if any modification in the hydrological cycle of Kalkfontein Dam occurred over space and time. Temperature depth profiles taken from Kalkfontein Dam during the sampling period indicated that Kalkfontein Dam was homothermic throughout the study period. High levels of turbidity (NTU) were measured during September (379 NTU) and October 2023 (555 NTU) at the riverine zone of the dam. The months of February and March 2023 had the lowest percentage (16.59%) light exposure rate/day for phytoplankton in the main basin of the dam. The dominant diatom over the one-year sampling period was Aulacoseira sp. which is known to dominate phytoplankton communities under turbid conditions and is also associated with water column mixing, high flood conditions, and erosion events. During the sampling period, zooplankton community assemblage consisted of three major groups, namely Cladocera, Copepodes, and Rotifers. Overall, the one-year sampling period was characterised by very low biodiversity at all sites, which may likely be due to the measured high water column turbidity as a consequence of the inflowing mine sludge in suspension.

Keywords: Tailing sludge, Diamond mining, Hydrological cycle

THE MANYCH DEPRESSION IS A KEY LINK IN THE DRAINAGE SYSTEM OF NORTHERN EURASIA (LATE QUATERNARY)

Daria Semikolennykh[1] & Andrei Panin[2]

[1]School of Geography, Archaeology and Environmental Studies, University of the Witwatersrand, Johannesburg, South Africa

[2]Institute of Geography, Russian Academy of Sciences, Moscow, Russia

The Manych Depression is a narrow, elongated valley that connects the Caspian Sea with the Azov-Black Sea Basin. During the Quaternary period, the Caspian Sea periodically released water through this depression into the Black Sea, a process that is evidenced by the deposits found in the Manych Depression. The discharge of Caspian Sea waters into the Azov-Black Sea basin via the Manych Depression is a fascinating topic in the palaeogeography of the Ponto-Caspian region and Northern Eurasia as a whole. However, it remains insufficiently studied. It has recently been discovered that the Caspian Sea could have been, like the Black Sea, an intermediate basin for water discharge on a global scale, and the Manych Depression, in this case, was the main link in the system of this discharge. We summarise a decade of our research on the Manych Depression and present a detailed overview of the sedimentary deposits from the Late Quaternary period found in the depression's outcrops and boreholes. We studied more than 30 sites, performing lithological, geochronological, and faunistic analyses. Based on these analyses, we reconstruct the evolution of the natural environment of the Manych Depression in the Late Quaternary. The most critical stages of the Late Quaternary history of the depression are two episodes of Caspian water discharge into the Azov-Black Sea Basin at the end of MIS 5 and the end of MIS 2. The discharge channel opened due to Caspian waters reaching the water divide with the Azov-Black Sea Basin. The causes of the transgressions are rooted in the positive water balance of the Caspian during the transitional periods from the interglacial to the glacial and vice versa. The main components of the Caspian water balance are the increase in the inflow of river waters and the decrease in the evaporation level. In addition, the "drainage" of dammed lakes in the north of the European part of Russia and Western Siberia could also contribute to the increase in the Caspian water balance. This research was financially supported by the Russian Science Foundation (Project 25-1768043).

Keywords: geochronology, sedimentology, discharge, Ponto-Caspian

ASSESSING THE POTENTIAL OF NOVEL TRACERS TO DISCRIMINATE SOIL TYPES AS SEDIMENT SOURCES IN A DEGRADED CATCHMENT

M.H. Stander[1], J.J. le Roux[1], Liu Gang[2] & M.A.M. Abd Elbasit[3]

[1]Department of Geography, University of the Free State, Bloemfontein, South Africa
[2]State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Northwest A&F University, Yangling, China
[3]Department of Physical and Earth Sciences, Sol Plaatje University, Kimberley, South Africa

Anthropogenically accelerated soil erosion poses serious environmental challenges, including land degradation, water quality deterioration, and reduced agricultural productivity. In the upper Caledon River catchment, South Africa, overgrazing and poor land management have intensified erosion, particularly in areas with highly erodible duplex soils. Despite the known erodibility of these soils, their relative contribution to sediment yield in fluvial catchments remains poorly quantified, particularly in relation to other soil groups. In addition, sediment fingerprinting techniques lack standardisation, and the performance of emerging tracers, such as chemical weathering indices and spectral reflectance data, is not yet well understood. This study investigates the dominant sediment sources in a degraded catchment within the upper Caledon River, South Africa, with a particular focus on the role of different soil types. Sediment fingerprinting was applied using a suite of tracers, including trace and major elements, chemical weathering indices, and spectral reflectance-derived colour coefficients. Fifty-one composite samples were collected from distinct soil types and from a farm dam within a gully catchment. Statistical analysis and source apportionment using a mixing model (FingerPro in RStudio) revealed that planosols (which typically have a dublex texture) were the primary sediment source, with acrisols along the midslope-footslope boundary also contributing substantially. Leptosols made only a minor contribution. The results support the utility of trace and major elements in sediment source discrimination, while weathering indices and spectral reflectance were less effective in this context. Whether these limitations are site-specific or more broadly applicable remains an open question, warranting further research into the development and evaluation of novel tracers for soil-source fingerprinting.

Keywords: sediment fingerprinting, weathering indices, spectral reflectance

MEASUREMENT AND NEAR-ROAD DISPERSION MODELLING OF AIRBORNE POLLUTANTS ALONG VEHICULAR CORRIDOR IN ILE-IFE, NIGERIA

Adekunle B. Toyeje[1], A.S. Adebayo[2], B.D. Adejumo[2], O.A. Babatunde[3], A.P Olufemi[2] & O.R. Omokungbe[4]

1. University of Ilesa, Osun State, Nigeria
2. University of Medical Sciences, Ondo State, Nigeria
3. Mountain Top University. Ibafo, Ogun State, Nigeria
4. Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria

This study investigated air pollution along traffic corridors in Ile-Ife, Nigeria, measuring gaseous pollutants and particulate matter. Researchers used a low-cost network of air quality monitoring sensors at seven locations along high-traffic areas over 18 weeks. The study aimed to identify pollution sources, evaluate air quality, and model pollutant dispersion. Results showed pollutant concentrations exceeded World Health Organization (WHO) standards, except for NO_2. Measured concentrations ranged from: (392.20-1540 ppb for CO, 431.70-539.20 ppmv for CO_2, 58.65-75.80 ppb for O_3, 10.77-5.13 ppb for NO_2, 4.02-44.22 ppb for NO, 16.06-32.29 µgm-3 for PM2.5, 49.11-306.10 µgm-3 for PM10). The Air Quality Index (AQI) indicated poor air quality, implying atmospheric pollution. Positive Matrix Factorization identified four pollution sources: Domestic emission (14%), Traffic emission (24%), Dust re-suspension (30%), Secondary emission (32%). Conditional Bivariate Probability Function identified pollutant source directions. The Research-Line dispersion model revealed high pollutant concentrations, affecting pedestrians and nearby shops within 50m from the road. The study concludes that high Air Quality Index values pose severe health and environmental implications. The findings suggest urgent need for emissions reduction strategies, air quality monitoring, public awareness campaigns, and policy implementation to mitigate air pollution. This research contributes to understanding air pollution in Nigerian urban areas, informing policy decisions to protect public health and the environment.

Keywords: Air Quality, PMF, CBPF

INVESTIGATING THE GEOCHEMISTRY OF ARSENIC AND URANIUM IN WETLAND SEDIMENTS NEAR MINING SITES IN WELKOM, SOUTH AFRICA

Bokang Tsiane[1], Mariana Erasmus[2], Megan Welman-Purchase[3], Robert Hansen[3] & Yolandi Schoeman[2]

[1]Centre For Environmental Management, University of the Free State, Bloemfontein, South Africa
[2]Centre For Mineral Biogeochemistry, University of the Free State, Bloemfontein, South Africa [3]Department Of Geology, University of the Free State, Bloemfontein, South Africa

Arsenic (As) and Uranium (U) are contaminants of significant environmental and public health concern due to their toxic and radioactive properties, respectively. Arsenic is known to induce carcinogenic effects and cause organ damage, while uranium exposure primarily results in nephrotoxicity and radiation-induced diseases. The accumulation of these elements in wetland sediments, particularly in areas proximal to mining activities, poses substantial long-term exposure risks through contaminated water, food chains, and ecosystems. Despite the evident environmental hazards associated with As and U, the mechanisms governing their retention and mobility within wetland environments remain inadequately explored in the Welkom region of South Africa. This study aims to investigate the biogeochemical behaviour of As and U in the wetland sediments of Welkom, South Africa. Field sampling was conducted to collect both water and sediment samples, and in-field measurements of pH, oxidation-reduction potential (ORP), electrical conductivity (EC), and temperature were recorded to characterise the physicochemical conditions at the study sites. Subsequent laboratory analyses of the collected samples revealed that both As and U concentrations at site WW01 exceeded the South African National Standards (SANS) for drinking water quality, while As concentrations were below detection limits at site WW02, and U concentrations remained below SANS thresholds at this location. The detection of As and U water samples underscores the necessity of understanding their biogeochemical dynamics to effectively mitigate potential environmental and health risks. Consequently, the findings of this study emphasise the importance of developing targeted remediation strategies to reduce contaminant exposure and safeguard ecosystem health.

Keywords: Geochemistry, Arsenic, Uranium, Heavy metal contamination

SOUTH AFRICA'S INORGANIC SURFACE WATER CHEMISTRY DATASET (1972-2022): HARMONISATION STUDY FOR WATER QUALITY TREND ASSESSMENT AND DECISION-MAKING

Natalia Vylegzhanina[1], Jan Marten Huizenga[1] & Sascha Roopa[2]

[1]Norwegian University of Life Sciences, Ås, Norway
[2]North-West University, Potchefstroom, South Africa

South Africa faces increasing water stress driven by high demand and poor water quality. These challenges are driven by climate change, population growth, inadequate management of drinking water services, and the impact of mining, agricultural, and industrial activities. To address these issues, robust monitoring efforts are essential. This poster introduces a harmonised dataset of inorganic surface water chemistry parameters from the National Chemical Monitoring Programme (NCMP), covering nearly 50 years (1972-2022) of measurements. The dataset addresses critical information needs in water and sanitation sectors, aligning with South Africa's National Water Resource Strategy (2023) and UN Sustainable Development Goal 6 (Clean water and sanitation). The NCMP evolved from irrigation suitability assessments to a comprehensive national programme, currently managed by the Department of Water and Sanitation (DWS). Currently, it encompasses ca. 2000 sampling stations, predominantly in rivers, lakes, and dams. This extensive spatiotemporal dataset includes parameters like electrical conductivity, pH, alkalinity, and major inorganic ions, providing a unique resource for assessing environmental changes over the years. Although openly accessible, the raw NCMP data requires substantial preprocessing due to inconsistent sampling frequencies and a high number of incomplete records. To ensure data integrity and usability, the dataset was processed using integrated approach involving scripting, geospatial, and spreadsheet software (e.g., Python, Esri ArcGIS Pro, Microsoft Excel). This included removing duplicates, standardising station names and geographic coordinates, consolidating measurements, filtering incomplete analyses, applying stoichiometric charge balance (SCB) criteria, etc. The harmonised dataset includes over 550000 measurements across South Africa. Data quality was significantly improved, resulting in a set of unique, standardised records. Two subsets were compiled: all analyses, and those that met the SCB criteria. The SCB validation retained nearly 70% of records following initial data cleaning. The highest frequency of invalid analyses was in urban areas, which also have the greatest number of sampling stations and measurements. This poster details data engineering and harmonisation processes undertaken to create the dataset, aligned with FAIR (Findable, Accessible, Interoperable, and Reusable) principles for scientific data management, and its potential for supporting research and decision-making in addressing South Africa's water challenges.

Keywords: South Africa, surface waters, inorganic water chemistry, water quality data

Geo-Energy and Petroleum Resources

1D AND 2D BASIN AND PETROLEUM SYSTEMS MODELLING, IN ASSESSING THE HYDROCARBON GENERATION-MIGRATION-ACCUMULATION POTENTIAL FOR THE KAROO BASIN, SOUTH AFRICA

Selwyn Adams[1]

[1]Petroleum Agency of South Africa, Cape Town South Africa

South Africa's longstanding history of intermittent controlled power outages and the approaching gas cliff necessitated it to pursue a diversified energy mix to ensure security of energy supply, whilst aligned to the principals and goals set out in the 2023 Integrated Resources Plan and the 2023 Just Energy Transition Investment Plan. The Karoo Basin of South Africa, globally ranked as the eighth largest potential source for shale gas resources, could be a strategic energy source, and thus earned much research and investment interest from academia, oil and gas explorers, and government agencies. The Petroleum Agency South Africa (PASA) carried out basin and petroleum system analysis and modelling (BPSM) to assess possible shale gas plays and conventional resources of the Karoo Basin. The study comprised 1) the construction of five mega regional cross-section connecting 31 wells for in depth 2D BPSM, 2) the analysis of ~120 core and rock chip sample from three recently drilled stratigraphic boreholes and three legacy exploration boreholes characterising source and reservoir rock properties, and 3) Apatite Fission Track Analysis to characterise likely maximum paleotemperature and thermal histories and the chronology of the basin tectonics and geodynamics. The results from the multi 2D basin analysis study suggest that the main driver for thermal maturation is burial and not volcanic activity. This is corroborated by a consistent burial and uplift model constrained by temperature, Vitrinite Reflectance, and apatite fission track data explaining regional maturity variations. Up to 7 km of erosion were assumed near the present-day front of the Cape Fold and Thrust Belt, attributed to the Late-Palaeozoic thrusting event or syn-tectonic sedimentation. Modelling of the Drakensberg lava intrusion and emplacement suggest limited and only proximal impact on thermal maturity. Integration of the 2D basin models, the reservoir and source characterisation results and reference to shale gas play analogues defined a new shale gas sweet spot area, especially for the Whitehill Formation. The modelling suggests likely preservation of wet gas or even condensate oil. Likely preservation of oil and gas below the outcropping edge of the dolerite areas is not discounted and may require further investigation.

Keywords: Basin and Petroleum System Modelling, Karoo Basin, Shale Gas

SUBSURFACE MODELLING AND CO_2-BRINE-OIL INTERACTIONS IN A HYDROCARBON RESERVOIR, BREDASDORP BASIN, SOUTH AFRICA

Blessing A. Afolayan[1], Eric Mackay[2] & Mimonitu Opuwari[1]

[1]Petroleum Geosciences Group, Department of Earth Sciences, University of the Western Cape, Bellville, South Africa

[2]Institute for GeoEnergy Engineering, Heriot-Watt University, Riccarton, Edinburgh, UK

Geological carbon storage provides an efficient technology for the large-scale reduction of atmospheric carbon, and the drive for net-zero emissions may necessitate the future usage of oil reservoirs for CO_2 projects (without oil production). Dynamic modelling of an oil reservoir for CO_2 storage in the Bredasdorp basin, South Africa, was therefore conducted. Injection into the reservoir was for 20 years (2030 – 2050) and 100 years (2050 – 2150) to study the CO_2-brine-oil interactions, with sensitivities carried out on reservoir boundary conditions. The closed boundary scenario experienced pressure buildup with a target injection rate of 0.5 Mt/year, and a cutback on injection rate progressively until 2050 to not exceed the fracture pressure of the reservoir. The CO_2 plume migration was not rapid due to the reduced volume of CO_2 injected and the confining pressure. The system was gravity dominated, and gravity stability was not attained at the end of the simulation as fluid interfaces were not yet flat. The open boundary reservoir did not experience a pressure buildup because all boundaries were open, the target injection rate was achieved, and it was a viscous-dominated system. In both cases, the dissolution of CO_2 in oil and brine was active, and there was a growing increase of CO_2 fraction dissolved in water and oil, a decline in gaseous mobile CO_2 phase between 2050 and 2150, and active trapping mechanisms were structural trapping, dissolution in oil and water, and residual trapping. The study showed that boundary condition was very crucial to the success of the project, with direct impacts on injection rate and pressure. This pioneering study has opened a vista on the injection of CO_2 into an oil reservoir, and CO_2-brine-oil interactions, with sensitivities carried out on reservoir boundary conditions in a closed and an open hydrocarbon system in South Africa.

Keywords: Geological carbon storage, Dynamic modelling, Boundary conditions, Active trapping mechanisms

RE-EVALUATING THE OFFSHORE SEDIMENTARY BASIN EXTENTS ALONG THE EASTERN MARGIN OF SOUTH AFRICA: IMPLICATIONS FOR HYDROCARBON PROSPECTIVITY

Reagan Africa[1] & Sean Davids[1]
[1]Petroleum Agency SA, Cape Town, South Africa

Historically, the offshore sedimentary basins along South Africa's eastern margin have been defined using vintage 2D seismic and bathymetric data, with a focus on shallow-water settings particularly the Zululand Basin (ZB) and Durban Basin (DB), demarcated by the Tugela Cone (TC). The result, ambiguity in the spatial extent and nomenclature of the deep-water basins. Especially the Natal Valley (NV), Transkei Basin (TB), and distal portions of the Durban Basin beyond the Tugela Cone. We re-evaluate the offshore basin extents along the eastern margin using a multidisciplinary approach focused on high-resolution 2D seismic data, complemented by gravity and magnetic data to constrain crustal affinities. The study area, ~445,000 km^2 in size, is confined by the Mozambique-South Africa border in the north, the Mozambique Ridge (MozR) in the east, and the Agulhas Plateau to the south. Mapped seafloor depths range between 0.22 to 7.2s (TWT). The shallowest zones are on the shelf, the Zululand Basin, and Tugela Cone. Seafloor deepens significantly towards the Mozambique Ridge and into the Natal Valley (>4s), reaching maximum depth in the Transkei Basin (7.2s). Basement depths vary between 0.29 and 8.3s (TWT). They are shallowest in the Zululand Basin and exhibit structural complexity proximally in the Durban Basin, marked by a prominent basement high in the South Tugela Ridge (STR). East of the STR, basement plunges into a under-recognised distinct depocenter, herein referred to as the Durban Deep Basin (DDB). The DDB remained geologically independent up until the Cenozoic. The basement in the Natal Valley is smooth, gradually deepening from 7.4s to 8.3s in the Transkei Basin. Sediment thickness varies between 1.1 to 4.8s (TWT). It is thickest over the Tugela Cone, Durban Deep Basin, and in the Natal Valley (3 to 4.8s). Gravity and magnetic grids and modelling suggest attenuated continental crust beneath the Zululand, Durban, and Durban Deep Basins, transitioning to oceanic crust in the Natal Valley and Transkei Basin, which aids basin demarcation based on crustal affinity. This study resolves spatial and naming inconsistencies by delineating the East Coast basins. The results directly impact the understanding of potential reservoir distribution and source rock development in these frontier basins.

Keywords: offshore sedimentary basin, seismic interpretation, Durban-Deep Basin, Natal Valley

OUTSIDE THE BOX, INTO THE BASIN – A LOOK AT FRONTIER PLAYS WITHIN THE ORANGE BASIN, SOUTH AFRICA

Reagan Africa[1] & Anthony Fielies[1]

[1]Petroleum Agency SA, Cape Town, South Africa

The Orange Basin along the west coasts of Namibia and South Africa, has experienced unprecedented global interest in recent years. With an estimated 60% to 75% of the basin situated in South African waters, this offers compelling opportunities within this part of the basin. Initial seismic analysis has highlighted several potential leads, ranging from conventional type plays to mixed depositional systems extending from shallow to deepwater. These leads include intra Mass Transport Complex (iMTC) plays, Graff and Mopane type plays, a Venus analogue, and Mixed Contourite-Turbidite plays. Intra Mass Transport Complex (iMTC) plays are described as the intermixing of the MTCs with other types of often high-amplitude deposits such as turbidite channels, fans, and frontal splay complexes cocooned within it. The relief facilitated by MTCs, results in opportunistic pathways for reservoir-prone sediment deposition. The Graff discovery in Namibia is possibly an example of where turbidites are ponded by MTC relief. A Graff type analogue, the Tierhaai play, is encapsulated within MTCs. It is found in water depths between 1500 m to 1950 m, with calculated thicknesses between 35 m and 15 0m. It consists of multiple stacked channels and lobes covering a region of roughly 200 km^2. The spookhaai lead is a Mopane type play within the lower-upper Cretaceous located at depths of 4.3s (TWT) to 5.2s (TWT) within a 450 km^2 area. The Sandhaai lead is a mixed Contourite, while Turbidite play is a lower Cretaceous basin-floor fan which has been reshaped by later bottom-water activity represented by sediment waves. It occurs in water depths of 2300 m to 2700 m and at 4300 m to 4800 m depth. It was mapped over a 423 km^2 area with thickness up to 200 m. The Venus analogue, referred to as Walvishaai, is an ultra-deep, likely Apto-Albian basin floor fan found at 2500 m to 3150 m water depths, and at 6365 to 6955 mbsl. It is estimated to be between 30 m to 200 m thick, covering a region of 1900 to 5800 km^2. However, underlaying the success of all these leads depends on the presence of a mature Barremian-Aptian Kudu source rock, not yet intersected in South Africa, but proven in Namibia.

Keywords: Mass Transport Complexes, South Africa, Orange Basin, Prospectivity

MAGNETOTELLURIC IMAGING OF THE TULU MOYE GEOTHERMAL FIELD: INSIGHTS INTO DECOUPLED MAGMA-HYDROTHERMAL SYSTEMS IN THE MAIN ETHIOPIAN RIFT

Tinsae Nigatu Alemu[1], Fisaha Solomon Unduche[2] & Girmay Mesfin Araya[3]

[1]DebreDallol Geoengineering, Megenegna, Addis Ababa, Ethiopia,
[2]Hydrologic Forecasting and Water Management at the Government of Manitoba, Canada,
[3]Applied Geology Department, College of Computational Science, Mekelle University, Ethiopia

The Main Ethiopian Rift (MER), a key segment of the East African Rift System, is marked by active tectonic-volcanic processes and hosts geothermal systems supported by shallow magma reservoirs. The Tulu Moye Geothermal Field has significant potential for sustainable, low-carbon energy development. To assess the subsurface structure and geothermal viability of Tulu Moye, we conducted a high-resolution magnetotelluric (MT) survey using 41 broadband MT stations. Data from 0.001 to 1000 seconds was analysed to model electrical resistivity, image geological structures, and geothermal resources. This study showed the interactions among hydrothermal reservoirs, magmatic heat sources, and rift-related tectonics. The 3D inversion of the MT data reveals a conductive anomaly at depths of 0.8–2.9 km, interpreted as a high-enthalpy hydrothermal reservoir influenced by hydrothermal alteration. The models do not indicate an active magmatic system directly beneath this reservoir. Instead, forward modelling of tipper responses identifies partial melt zones at lower crustal depths (~21–29 km). This observation suggests the geothermal system is thermally decoupled from nearby magmatic sources. These findings challenge the assumption that shallow magmatism is a prerequisite for rift-hosted geothermal systems. This study enhances our understanding of magma-hydrothermal interactions and supports the MER's role in Ethiopia's transition to green energy, with broader implications for continental rift settings.

Keywords: Main Ethiopian Rift, Magnetotellurics, Geothermal energy, Hydrothermal system

CHARACTERISTICS AND INFLUENCING FACTORS OF LATE CRETACEOUS RESERVOIR IN NORTH-CENTRAL TUNISIA

Mabrouk Bachari[1], Eugene Bergh[1], Mohamed Hedi Negra[2] & Yves Geroud[3]

[1]Unit for Environmental Sciences and Management, Geology, North-West University, Potchefstroom, South Africa

[2] Géoressources et Environnement" Lab, Tunis El Manar University, Tunis, Tunisia

[3]Ecole Nationale Supérieure de Géologie, Lorraine University, Vandoeuvre-les-Nancy, France

The Cretaceous is the primary exploration target in Tunisia due to its promising potential for oil and gas discoveries. This study employs a multidisciplinary approach to investigate Late Cretaceous reservoir analogues well-exposed in the Mellegue Basin (north-central Tunisia). The research has enabled the identification of detailed layering within these heterogeneous, multi-layered reservoir rocks. Several of the analysed layers exhibit relatively high reservoir potential. The methodology potentially applicable to future subsurface petroleum system studies integrates sedimentological, petrographic, and petrophysical analyses using various physical parameters. The analysis focuses on measurements of grain density, P-wave velocity, thermal conductivity, and porosity. The primary objective is to better understand the key factors controlling petrophysical properties in porous systems and to identify the most prospective zones based on their reservoir characteristics in the Mellegue Basin. This study enhances our understanding of pore-type heterogeneity and its impact on petrophysical signatures within the Cretaceous carbonate formations equivalent to the Bireno and Douleb Formations. The data provide valuable insights into variations in reservoir quality and reveal that the lower part of the Coniacian Douleb carbonates contains the most promising reservoir intervals. Detailed petrographic and petrophysical analysis of the Turonian-Coniacian series indicates that porosity is strongly influenced by facies types, fracturing, and diagenetic processes. The highest helium porosity values (ranging from 6.8% to 9.2%) and permeability values (ranging from 4.5 to 11 mD) were recorded in the lower part of the Coniacian Douleb equivalent member, composed mainly of fractured micritic limestones. These units are primarily affected by dissolution and matrix dolomitization, which enhance secondary intercrystalline and intracrystalline porosity. In contrast, compaction and cementation tend to reduce reservoir quality.

Keywords: Mellegue basin, Petrography, Petrophysics

DIAGENESIS OF SANDSTONES FROM THE NEOPROTEROZOIC KWAHU-BOMBOUAKA GROUP OF THE VOLTAIAN SUPERGROUP: IMPLICATIONS FOR RESERVOIR QUALITY CHARACTERISATION

Susanna S. Boateng[1], Bruce K. Banoeng-Yakubo[1], Daniel K. Asiedu[1], David Atta-Peters[1], Emmanuel Nyavor[1] & Jennifer Agbetsoamedo[1]

[1]Department of Earth Science, College of Basic and Applied Sciences, University of Ghana, Legon, Ghana

The diagenesis of sandstones within the Kwaku-Bombouaka Group of the Voltaian Supergroup plays a critical role in determining their reservoir quality and potential for the exploration of natural resources. This paper investigates the diagenetic processes affecting these sandstones, focusing on their mineralogical, textural, and geochemical transformations. Through a combination of petrographic analysis, scanning electron microscopy (SEM), X-ray diffraction (XRD), and geochemical analysis, this study elucidates the diagenetic pathways and their impact on porosity and permeability. Preliminary petrographic analysis indicates the sandstones are quartz arenites, ferruginous sandstones, subarkoses, and lithic arenites, each exhibiting distinct textural and mineralogical characteristics. Authigenic minerals include quartz (existing as overgrowths on detrital quartz grains), clay minerals, carbonates and hematite. The diagenetic processes that have affected these sandstones include cementation, compaction, recrystallization, replacement, mineral overgrowths and dissolution. These processes have passed through early, late and uplift- related diagenesis. Understanding these diagenetic processes is essential for accurate reservoir quality characterization, as they directly affect the storage and flow properties of fluids within the sandstones as reservoir rocks within a petroleum system. This paper provides valuable insights into the diagenetic evolution of the KwahuBombouaka sandstones and offers implications for improved exploration and exploitation strategies in similar geological settings. The findings highlight the crucial role of comprehensive diagenetic studies in improving predictions of reservoir quality and optimizing the recovery of resources, including water, mineral reserves, and hydrocarbons.

Keywords: diagenesis, reservoir quality, scanning electron microscopy (SEM), voltaian supergroup

1D BASIN MODELLING ON OCEANIC CRUST OFFSHORE SOUTHEAST AFRICA

Sean Davids[1] **& Reagan Africa**[1]

[1]Petroleum Agency SA, Cape Town, South Africa

The hydrocarbon prospectivity of offshore southeastern Africa remains largely unexplored, particularly in the deepwater Natal Valley, where seismic data is sparse. Despite this constraint, seismic anomalies identified in the region, along with preliminary resource estimates, justify further investigation. This study explores the viability of hydrocarbon generation on oceanic crust through 1D basin modelling. The Natal Valley is geologically distinct due to its foundation of transitional and predominantly oceanic crust, raising questions about its capacity to host hydrocarbon-bearing systems. To assess this potential, a 1D basin model was developed using PetroMod. A pseudo-well was constructed based on regional geological analogues and theoretical parameters to evaluate the generation potential of the mapped seismic anomalies. The stratigraphy of the adjacent onshore hinterland comprises Karoo to Lower Jurassic mudstones, sandstones, and shales. However, extensive rifting and subsequent movement along the Agulhas-Falkland Fracture Zone (AFFZ) have substantially removed sediment cover. Regional seismic mapping has revealed five Early Cretaceous seismic anomalies over transitional and oceanic crust, prompting further geochemical and thermal modelling. Key input parameters for the pseudo-well include a 50 m Aptian source rock with 3% Total Organic Carbon (TOC), a 100 m Cenomanian sandstone reservoir with 10% porosity, and Type III kerogen kinetics. Heat flow constraints were derived from peak rifting conditions (~95 mW/m^2 at 140 Ma) and subsequent thermal cooling (40–46 mW/m^2 for oceanic crust). Vitrinite reflectance estimates from the Durban Basin well completion reports range between 0.5% and 1.8% Ro, informing thermal maturity assessments. The 1D modelling results indicate that hydrocarbon generation within the oceanic crust of the Natal Valley is feasible. The Aptian source rock is predicted to generate early to peak oil during the Lower Cretaceous, transitioning to wet and dry gas generation in the Upper Cretaceous. This aligns with potential reservoir deposition intervals, enhancing the region's prospectivity. The study highlights the value of 1D basin modelling in frontier basins, providing a preliminary risk assessment for the seismic anomalies and resource potential of the area.

Keywords: 1D basin modelling, Oceanic basement potential, Natal Valley

A COMMUNITY OF PRACTICE TO DEVELOP HIGH-LEVEL SKILLS IN PETROLEUM GEOSCIENCE: A STATUS REPORT

Raymond Durrheim[1]

[1]University of the Witwatersrand, Johannesburg, South Africa

The South African government launched Operation Phakisa in 2014 to fast-track critical development opportunities. The Oceans Economy Lab was established under the management of the South African International Maritime Institute (SAIMI). Offshore oil and gas exploration was identified as a key topic, and geophysics, geology, petrophysics, and reservoir engineering were identified as core disciplines with a significant capacity deficit. Total announced the Brulpadda deep-water gas condensate discovery in February 2019. Shortly thereafter, the NRF, DSTI, and SAIMI initiated a process to establish a Community of Practice (CoP) to develop local academic expertise. Here we report on progress since Geocongress 2023. Significant petroleum discoveries have been made in the offshore Orange Basin north of the Namibia-South Africa border. Activity in South Africa has been slower owing to delays in enacting the Petroleum Resources and Development Bill and protests by civil society groups to offshore seismic surveys. In July 2024, TotalEnergies announced its withdrawal from Blocks 11B/12B, where the Brulpadda discovery was made. However, in August 2024, Shell announced its intention to drill a well in the Northern Cape Ultra Deep Block, and the Department of Mineral and Petroleum Resources announced plans to conduct a geophysical survey of the south-central Karoo Basin. The CoP Steering Committee comprises representatives from government, industry, and academia. The core academic members are the historically disadvantaged coastal universities that have programmes in petroleum geoscience (Cape Peninsula University of Technology, University of Fort Hare, Nelson Mandela University and the University of the Western Cape) and the University of the Witwatersrand. Researchers at South African universities have undertaken projects that range from seismic surveys of geological structure in the vicinity of the Beaufort West deep stratigraphic hole and the Leandra carbon capture and storage test hole, assessment of the carbon storage capacity of the Bredasdorp Basin, evaluation of source rocks in Block 11A of the Pletmos sub-basin, and seismic characterisation of mass transport deposits in the Orange Basin. In 2023 and 2023, 28 papers were published in refereed international journals, while eight MSc and seven PhD candidates graduated.

Keywords: Oil gas skills

UNDERSTANDING THE INTERNAL VARIABILITY OF MUDSTONE RESERVOIRS: INSIGHT FROM MAASTRICHTIAN DARK MUDSTONES, MAMU FORMATION, SW ANAMBRA BASIN, NIGERIA

A.J. Edegbai[1,2] & W.O. Emofurieta[2]

[1]Department of Geology, University of Pretoria, Pretoria, South Africa
[2]Department of Geology, University of Benin, Benin City, Nigeria

Commercial production of petroleum from bright spots in shale gas / shale oil assets is hinged on identifying brittle zones with suitable mineralogy and good petrophysical properties, which are suitable for hydraulic fracturing. The objective of this research was to investigate the geology of approximately 6 m of Campano-Maastrichtian dark mudstone succession outcropping at Uzebba, Benin Flank, SW Anambra Basin, Nigeria, using sedimentological, geochemical, mineralogical, and palynofacies techniques. Our findings show that the mudstone succession can be subdivided into three broad units from bottom to top. Unit 1 is characterised by weak to moderate bioturbation, high quartz content (=50 %) as well as grained dominated microfabric with planar to wavy laminations. Unit 2 has the lowest particle size, zero to mild bioturbation, low quartz content, as well as matrix dominated microfabric with thin to indistinct laminations, which are mostly planar. Unit 3 shows intermediate particle size, weak to moderate bioturbation, moderate quartz content, as well as grain dominated microfabric with wavy to curved laminations that are much thicker than units 1 and 2. Similarly, geochemical and palynofacies proxies for detrital influx and paleoproductivity are congruent. They show that units 1 and 3 received significant detrital contribution as well as high terrestrial paleoproductivity under low relative sea level, which promoted the development of suitable mineralogy and hypothesised good petrophysical and geomechanical properties that are suitable for fracking. Conversely, Unit 2 received less significant detrital contribution as well as increased marine paleoproductivity under higher relative sea level.

Keywords: unconventional reservoirs, Cretaceous, shale gas, sedimentology

AN INVESTIGATION FOCUSING ON THE SUB-CIRCULAR DEPRESSIONS LOCATED WITHIN THE MPUMALANGA PROVINCE OF SOUTH AFRICA FORMED THROUGH THE EMANATION OF NATURAL HYDROGEN

Sebastian Huggins[1], Adam Bumby[1] & Ansie Smit[1]

[1]University of Pretoria, Pretoria, South Africa

Over 4000 elliptical shaped shallow depressions (or 'pans') characterise the landscape of the Mpumalanga Highveld. Current explanations for the occurrence of these pans focus on deranged drainage of former fluvial systems. The pans are similar in size and shape to sub-circular depressions reported from numerous localities globally that have been associated with the flux of natural hydrogen from deep geological sources into the atmosphere. We measured hydrogen concentration both around the perimeter of pans and on a regional scale, and have recorded concentrations of hydrogen as high as 45000 ppm on the edge of pans. Hydrogen concentrations away from pans are typically below 2.5 ppm. All surveyed pans have some elevation of hydrogen in soil gas. This suggests that the formation of the Mpumalanga pans is linked to hydrogen flux. These pans are almost exclusively underlain by Ecca Group strata, which unconformably overlie Archaean aged greenstones and granites, ultramafic to mafic volcanic rocks of the Nsuze Group, or ultramafic to mafic intrusive rocks of the buried southern limb of the Bushveld Complex. Any of these lithologies could be considered a source of natural hydrogen either by serpentinisation or radiolysis. It is plausible that the Ecca Group acts as a trap for the hydrogen, and pans form where hydrogen leaks to the surface along faults.

Keywords: Natural Hydrogen Depressions, Geo-Energy

HIGH-RESOLUTION REFLECTION SEISMIC FOR HYDROCARBON EXPLORATION IN BEAUFORT WEST, SOUTH AFRICA

Marcus Nyiko Mkhomazi[1], Mpofana Sihoyiya[1], Joseph Matamela[1,2], Mimi Mokoele[3], Musa Manzi[1], Sean Johnson[3], Selwyn Adams[3] & Tshifhiwa Mabidi[3]

[1]University of the Witwatersrand, Johannesburg, South Africa
[2]Council for Geoscience, Pretoria, South Africa
[3]Petroleum Agency SA, Cape Town, South Africa

The study focuses on the Karoo Basin in South Africa, a region with significant potential for shale gas exploration, particularly in the organic-rich Whitehill Formation of the Ecca Group. The basin's complex geology, including intrusive dolerite dykes and sills, poses challenges for hydrocarbon exploration. This research aims to image subsurface structures and lithological boundaries to assess shale gas potential using a cost-effective and environmentally friendly seismic survey. A high-resolution 2D reflection seismic survey was conducted northeast of Beaufort West. The team employed a 500 kg drop hammer as a seismic source and wireless nodal recorders with 5 Hz geophones, spaced 15 m apart. Data acquisition involved 224 shots along a 3.5 km profile, with advanced processing techniques, including noise suppression, static corrections, velocity analysis, and Kirchoff migration. The workflow emphasised enhancing signal-to-noise ratio and delineating deep reflections. The seismic data successfully imaged subsurface geology down to 3 km, identifying major lithological boundaries and stratigraphic markers, such as the Whitehill Formation at ~2.5 km. The survey revealed flat reflections correlating with data from borehole KDD-01, as well as discontinuities suggesting faulting or gas-escape structures (e.g., breccia pipes). Dolerite sills and key group boundaries (Beaufort, Ecca, Dwyka, and basement) were also mapped, providing critical insights for shale gas exploration. The study demonstrates that lightweight, eco-friendly seismic sources combined with nodal systems can effectively image deep hydrocarbon reservoirs and complex structures in hard rock environments. The results highlight the Karoo Basin's potential for shale gas development while underscoring the impact of igneous intrusions on resource assessment. This approach offers a sustainable model for future exploration, balancing efficiency with minimal environmental impact. Significance The findings provide a foundation for optimizing large-scale seismic surveys in the Karoo Basin, aiding in the strategic planning of shale gas exploration and contributing to South Africa's energy resource development.

Keywords: Seismics, Reflection, Hydrocarbon production, imaging

NATURAL ENHANCEMENT OF THE PETROLEUM POTENTIAL OF TIGHT OIL & GAS RESERVOIRS IN TUNISIA

Mohamed Hedi Negra[1], Akrem Soltani[1] & Mabrouk Bachari[2]

[1]Faculty of Sciences of Tunis, Campus Universitaire, University of Tunis El Manar, El Manar, Tunisia
[2]Unit for Environmental Sciences and Management, Geology, North-West University, Potchefstroom, South Africa

Tunisia is facing the increased need for non-renewable energy and the decline of production from most of the "classical" petroleum systems; as such, adequate alternatives must be proposed. A preceding step could be envisaged to avoid opting for non-conventional production immediately. We suggest focusing on tight reservoirs as potential targets since they are volumetrically abundant and occupy provinces where petroleum system components are available, especially source rocks and traps. As done in the South (Chott Basin, Ghadames Basin, etc.), where most targets are tight Paleozoic siliciclastic reservoirs, special attention could be paid to tight Mesozoic carbonate reservoirs from which numerous oil and gas discoveries were realised. The Abiod, Bou Dabbous, and M'Cherga Formations, which are respectively upper Cretaceous, lower Eocene, and Aptian in age, are essentially composed of fine-grained micritic to chalky limestones where initial porosity and permeability are dramatically low. It is classically known that hydrocarbon production from these tight reservoirs is only due to fracturing that enhances the reservoir quality. However, our modest experience has shown that in addition to fracturing, other processes linked to sedimentary "perturbations", diagenesis, and sometimes salt tectonics and volcanisms, play a crucial role in the enhancement of the quality of such reservoirs. Based on recent oil discoveries or gas shows and some case studies, the main goal of the present work is to show how the reservoir quality of the fine-grained carbonates could be enhanced to transform these "tight" rocks into porous and permeable reservoir rocks. The approach used a fieldwork undertaken on tight reservoir analogues cropping out in central Tunisia. Based on bed-by-bed logging, sections have been surveyed and well-documented. The collected carbonate samples are analysed under a polarizing microscope and SEM. Analyses are especially focusing on the linkage between diagenesis and the petrophysical properties, particularly porosities and permeabilities.

Keywords: Tight reservoirs, Fracturing, Diagenesis, Tunisia

REASSESSMENT OF HYDROCARBON POTENTIAL IN THE PLETMOS BASIN, SOUTH AFRICA: A PETROGRAPHIC AND GEOCHEMICAL ANALYSIS

Busiswa Moloi[1,2]

[1]University of Fort Hare, Alice, South Africa
[2]Petroleum Agency SA, Cape Town, South Africa

Rising energy demand has prompted a reassessment of vintage oil and gas fields to determine their hydrocarbon potential. The focus is on four wells (Ga-Z1, Ga-M1, Ga-S1, and Gb-J1), targeting Late Jurassic to Early Cretaceous shallow marine sandstones. The Pletmos Basin was selected over the Zululand Basin for several reasons. It offers a more mature exploration history, greater seismic coverage, proven gas shows, and a well-documented stratigraphic and tectonic framework, whereas the Zululand Basin is less mature in exploration, with limited data. The study aims to assess reservoir quality and diagenetic evolution to refine interpretations of hydrocarbon prospectivity. It integrates core, well log, geochemical, mineralogical, and petrological data, focusing on key parameters such as total organic carbon, porosity, permeability, and clay content. This study provides a detailed evaluation of reservoir heterogeneity and net pay potential to identify underexplored intervals with localised promise. Results indicate poor to moderate porosity (4.5–13.8%) and very low permeability (0.0–0.16 mD), largely attributed to extensive quartz and calcite cementation. Source rock analysis reveals low TOC values (0.31–0.51 wt.%, avg. 0.4 wt.%), with Type III kerogen dominating, confirming a gas-prone but low-quality source rock. Despite recorded gas shows, low hydrocarbon saturation, diagenetic alteration, high water saturation, and low resistivity values contribute to poor reservoir quality. Of the wells analysed, Ga-S1 and Gb-J1 demonstrate more favourable shale content and meet net pay criteria, while Ga-Z1 and Ga-M1 have higher shale volumes and reduced reservoir potential. Reservoir quality is further constrained by thin, shaly sandstone beds and silty seals. Beyond hydrocarbons, the Pletmos Basin shows significant potential for CO_2 storage. Its structural complexity, moderate porosity zones, and extensive faulting enhance its capacity for safe and long-term carbon storage through structural and stratigraphic trapping. While the hydrocarbon potential remains limited, this study refines reservoir understanding through integrated characterisation and highlights underexplored intervals of interest. Reservoir characterisation is fundamental for evaluating the hydrocarbon prospectivity of oil and gas fields on a regional scale and serves a critical role in guiding drilling decisions. Expanding the well dataset and focusing on gas-show zones will support further assessment of both hydrocarbon and carbon storage prospects in the Pletmos Basin.

Keywords: Pletmos Basin, TOC, net pay criteria, reservoir quality

AN INTEGRATED GEOLOGICAL ANALYSIS OF THE SPRINGBOK FLATS BASIN

Zainab Mowzer[1], Selwyn Adams[1] & Xavier Schalkwyk[1]

[1]Petroleum Agency SA, Cape Town, South Africa

This abstract presents an evaluation of hydrocarbon prospectivity of the Springbok Flats Basin, since this sedimentary basin is of considerable geoeconomic significance, underpinned by a diverse suite of energy and mineral resources. These include prospective coal seams, coal bed methane (CBM), uranium mineralization, and conventional natural gas. The basin's geological setting, characterised by thick, laterally extensive coal deposits and a dense distribution of borehole data, offers a unique opportunity for advanced petroleum systems assessment. Considering the progressive depletion of South Africa's coal reserves, unconventional gas resources – particularly CBM – present a compelling alternative to sustain the country's energy supply. This study integrates operator and in-house datasets, and peer-reviewed academic literature to evaluate the CBM and conventional gas potential of the basin. The primary objective is to compile and synthesise geological and structural data into a coherent subsurface model. The methodology employed combined extensive data acquisition, meticulous quality control, and advanced geologic modelling techniques. This model serves as the foundation for constructing a basin-wide petroleum systems model, to allow quantitative hydrocarbon resources and reserves assessment. Over 940 borehole records were captured, digitised, and validated through cross-referencing with hardcopy documents and operator datasets. Initial analysis using Rockworks Geological Modelling Software enabled stratigraphic and lithological correlation. The well data information was migrated to Petrel to enhance the data, upscale lithological logs, cross-reference stratigraphic, structural attributes, generate key geological surfaces and fault geometries. Four major post Karoo-aged faults were identified and divides the basin in the southwestern and central parts. The coal bearing Ecca group (particularly within the Vryheid formation) indicate an average thickness between 15 and 50 m and contain high quality coal strata for CBM generation. These outputs are shown on the isopach maps, structural contour maps, and depth-to-target horizons maps. The project is ongoing, and the initial work completed has achieved key project milestones, which give new insights into the basin's stratigraphy, structural geology, and hydrocarbon potential. The future basin and petroleum system analysis and modelling, likely incorporating paleo-temperature and coal proximate analysis data, will inform coal bed methane prospectivity and the quantification of estimate resource in-place for the Springbok Flats Basin

Keywords: Springbok Flats Basin, coal bed methane, resource potential

INSIGHTS INTO THE STRUCTURAL DEVELOPMENT AND HYDROCARBON POTENTIAL OF THE DEEP-WATER ORANGE BASIN FROM 3D SEISMIC IMAGING

Nombuso Ngcobo[1], Musa Manzi[1] & Zubair Jinnah[1]

[1]University of the Witwatersrand, Johannesburg, South Africa

High-resolution 3D reflection seismic data from the deep-water Orange Basin, offshore western South Africa, provide vital insights into the basin's hydrocarbon potential, depositional history, and tectonic evolution. The seismic interpretation reveals nine key stratigraphic surfaces marking major geological events along the southwestern African margin, including the Late Cretaceous (Albian, Turonian, Santonian, early and late Campanian, and Maastrichtian) and Cenozoic (Oligocene, Miocene, and present-day seafloor) surfaces. A prominent Late Cretaceous gravitational collapse system dominates the basin's structural framework. This system, detaching on Turonian shales – a key thermogenic hydrocarbon source – comprises a transitional domain with superimposed normal, thrust, and oblique-slip faults, and a distal compressional domain characterised by fold-and-thrust belts. Although thrust faulting ceased around the Campanian, reactivation of the normal and oblique-slip faults in the translational zone likely facilitated hydrocarbon migration. Over 500 faults were mapped, forming an arcuate pattern with clockwise-rotating strikes, indicative of radial extension and spreading. This collapse system significantly influenced fluid migration, giving rise to features such as an elongated mud volcano, polygonal faults, high-amplitude seismic anomalies, and pockmarked surfaces. Numerous vertical conduits – pipes, chimneys, and faults – originate from the Turonian interval, aiding fluid escape. Notably, a 4.2 km-long mud volcano breaches the seafloor, and pockmarks are preserved on both the modern seafloor and the late Campanian surface. These expressions of mud volcanism and fluid seepage coincide with the hydrocarbon maturation window of the Turonian shales. Stratigraphically, an Oligocene canyon, >13 km in length and ~2.3 km wide, incised perpendicular to the slope, likely formed in response to a major sea-level fall. In the overlying Miocene section, a ~14 km-wide belt of slope-parallel, sinuous channels reflects intensified oceanic circulation driven by the Benguela Upwelling System and arid climatic conditions between ~12–10 Ma. Modern seafloor instability is evidenced by slumps and slides associated with seafloor pockmarks. Together, the structural and stratigraphic features delineated underscore the complex geological evolution of the Orange Basin. Understanding the interplay between fault architecture, sedimentary dynamics, and fluid migration is critical for refining hydrocarbon exploration strategies and evaluating the basin's resource potential.

Keywords: gravitational collapse system, hydrocarbon migration, seismic stratigraphy, Orange Basin

ROCK EVAL ANALYSIS OF SOURCE ROCKS FROM A FRONTIER AREA (MANIAMBA BASIN, MOZAMBIQUE): IMPLICATION FOR HYDROCARBON PROSPECTIVITY

Nelson Nhamutole[1,2], Belarmino Massingue[3], Marion Bamford[2], Paulo Alves de Souza[4], Sandra Sitoe[2] & Tais Freitas da Silva[5]

[1]Ministry of Mineral Resources and Energy, Maputo, Mozambique
[2]Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa
[3]Universidade Eduardo Mondlane, Maputo, Mozambique
[4]Laboratório de Micropaleontologia da Universidade de Brasília, Brasília, Brazil
[5]Núcleo de Estudos de Carvão e Rocha Geradora de Petróleo, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil

In order to further our understanding regarding the petroleum potential of the Maniamba Basin, Mozambique, organic rich sediments from four outcrops were investigated. Organic-rich shales, claystones, sandstones and siltstones were sampled for geochemical organic analyses that included TOC (Total Organic Carbon), and Rock Eval Pyrolysis. The pyrolysis analysis showed that the TOC ranges from good to excellent, thus indicating a potential for hydrocarbon generation. Based on the hydrogen index (HI) versus oxygen index (OI) diagram, most samples were classified as kerogen type III or IV, however, a mixed type II and III was also observed. The data suggest that the Organic Matter (OM) is of terrigenous origin with the occurrence of organofacies C, CD and D. The majority of the studied samples are found to be at mature to overmature stages. The overmaturation of the OM may be associated with tectonic events during the process of basin subsidence, and close proximity to igneous intrusions. Further, an indigenous nature of the hydrocarbon has been identified. Similar organic matter properties of the studied sections are correlatable with those from Moatize Minjova, Sanangoé-Mefidezi (Mozambique), Ruhuhu (Tanzania), Cahora Bassa Basin (Zimbabwe), Lwangwa Basin (Zambia) and the Main Karoo Basin in South Africa (e.g., Whitehill Formation). Overall, the results of this study suggest a good potential for gas as supported by Kerogen analysis (palynofacies) and hence more work is needed in order to unpack the other elements characteristic of a working petroleum system in this overlooked frontier Basin.

Keywords: petroleum, organic matter, organic facies, rock eval

INTEGRATION OF ROUTINE CORE DATA AND PETROGRAPHIC ANALYSES TO DETERMINE THE SANDSTONE RESERVOIR FLOW UNITS IN THE BREDASDORP BASIN, OFFSHORE SOUTH AFRICA

Nobathembu Tyhutyhani[1], Moses Magoba[1] & Oswald Gwavava[1]
[1]University of Fort Hare, Alice, South Africa

Routine core permeability and porosity are crucial in assessing flow units within the reservoir because they define a reservoir's storage and flow capacities. A limited amount of work has been conducted on the Lower Cretaceous (Barremian to Valanginian) sandstones in the Bredasdorp Basin, offshore South Africa, focusing on the flow zones and the possible effect of diagenetic minerals on the individual flow zones, limiting understanding of reservoir quality and fluid flow across the field. Nine hundred routine core analysis data were used to determine the flow units within the reservoir from three wells (F-A10, F-A13, and F-O2) from independent methods, namely: Pore Throat Radius, Flow Zone Indicator, Stratigraphic Modified Lorenz Plot, and Improved Stratigraphic Modified Lorenz Plot. The results showed six flow units: fracture, superconductive, conductor, semi-conductor, baffle, and semi-barrier. The pore throat radius revealed that the pores ranged from nano-porous (less than 1 μm) to megaporous (more than 10 μm). The best reservoir intervals had megaporous radii and were classified as high or super-conductive flow units. The super-conductive flow units contributed the most flow, whereas the semi-barrier and baffle units contributed the least flow. Petrography analyses revealed that the diagenetic minerals present were smectite, illite, glauconite, siderite, micrite-calcite, and chlorite. The pore-filling minerals reduced the pore spaces and affected pore connectivity, significantly affecting the flow contribution of the baffle and semi-barrier units. Micrite calcite, and siderite cementation in FU5 of F-A13 and FU9 of F-O_2 significantly reduced the intergranular porosity by filling up the pore spaces, resulting in tight flow units with impervious reservoir quality. It was noted that where the flow unit was classified as super-conductive, authigenic clays did not significantly affect porosity and permeability as they only occurred locally. However, calcite and silica cementation significantly affected pore connectivity, where the flow unit was classified as a very low, tight, semi-barrier, or barrier.

Keywords: porosity, permeability, flow capacity, diagenetic minerals

RESERVOIR CHARACTERISATION AND BASELINE ROCK PHYSICS INVESTIGATION FOR CO_2 STORAGE IN THE BREDASDORP BASIN, OFFSHORE SOUTH AFRICA

Sandisile Vandala[1] **& Moses Magoba**[1]

[1]University of Fort Hare, Alice, South Africa

This study aimed to characterise the Hauterivian sandstones of the Bredasdorp Basin in order to assess their potential for CO_2 storage based on their petrophysical, petrographic and rock physical properties. Data from three wells (E-E1, E-S3, and E-W2) included geophysical wireline logs, geological well completion, routine core analysis reports, and core photographs. Thin sections and scanning electron microscopy were used to investigate the effects of mineralogy on the ability of the sandstones to store CO_2 sufficiently. Furthermore, pore throat radius was determined to assess the potential storage and fluid flow through the reservoir. E-W2 recorded the lowest porosity, whereas E-E1 and E-S3 recorded the highest porosity. E-E1 and E-W2 showed the lowest permeabilities (<100 mD), E-S3 with higher values. The calculated average porosity, water saturation, clay volume, and permeability values ranged from 6.89 – 10.88 %, 51.78 – 67.94 %, 19.55 – 27.19 %, and 0.34 – 5.35 mD, respectively. The complementary acoustic properties of the reservoirs show a bulk density of 2.49 – 2.55 g/cc, with shear and compressional velocities between 3743.43 – 4792.12 m/s, respectively. CO_2 substitution notably reduced density in all wells except E-W2, which remained unaffected due to its micro- and nanopores. E-E1 and E-S3 showed a higher heterogeneity in the pore throat size distribution, and E-W2 showed the lowest heterogeneity, meaning that E-W2 would have a consistent fluid flow when CO_2 is injected. A high heterogeneity in the pore-throat size distribution affects the CO_2 distribution and flooding processes. E-W2 had carbonaceous cement filling the pore spaces and compaction and concave-convex (long) contact diagenesis, thus affecting porosity. Clay minerals such as kaolinite and illite-smectite acted as grain coating and pore-filling cements, subsequently affecting porosity and permeability. Silica and carbonate cements significantly affected pore throat radius. The preliminary reservoir analysis showed that Hauterivian sandstones have low permeability, which will hinder the injectivity of CO_2, making them unsuitable for CCS projects that require efficient and rapid injection or monitoring. Despite high water saturation and excess glauconite and smectite, E-S3 remains the most promising CCS site. It is recommended that future studies focus on the seal, migration pathway, pressure and faulting to get a complete outlook of the potential storage. The reason these were not included in the abstract is that they were not part of the study, and the authors acknowledge that the seal, migration pathway, pressure and faulting all play an important role; however, the aim of the study was looking at the properties of the reservoir and their ability to store CO_2.

Keywords: permeability, porosity, Gassmann, fluid substitution, clay minerals

PLETMOS BASIN: A FRONTIER HYDROCARBON PROVINCE WITH COMPELLING EXPLORATION OPPORTUNITIES

S'lindile Wela[1], A. Davids[1], S. Davids[1], M. Mokoele[1], J. Salomo[1], T. Sopete[1], R. Tshikovhi[1] & C. van Bloemenstein[1]

[1]Petroleum Agency SA, Cape Town, South Africa

The Pletmos Basin, South Africa, presents a promising frontier for hydrocarbon exploration, that are characterised by two key play fairways: the Kimmeridgian-Tithonian and the Valanginian ages. The basin's prospectivity is underscored by documented oil and gas shows below the Valanginian level, indicative of an active petroleum system even in areas with limited Kimmeridgian penetration. The Kimmeridgian play features both source and reservoir rocks within three distinct grabens in the Pletmos Basin, the Superior Plettenberg, and Central Grabens. Secondary porosity in cracked pebbles within conglomerates offers enhanced reservoir potential. Leads are identified along graben-bounding faults, where hydrocarbon buoyancy and structural gradients could drive secondary migration into younger reservoirs. The Tithonian source rocks, deposited during mid-basin formation, are likely equivalent to the onshore Kirkwood Formation. Rapid burial has matured this source to a dry gas phase. The Valanginian play offers a distinct advantage with source rocks being less confined to the grabens, potentially being equivalent in age to the onshore Sundays River Formation. Reservoirs are anticipated along graben axes and adjacent footwalls, presenting stratigraphic trapping mechanisms due to pinch-outs. Identified prospects lie directly above mature source kitchens, where vertical migration pathways can enhance the charge potential. The Berriasian reservoir is mapped on seismic data and is validated by wells with hydrocarbon shows below the Valanginian level. "Sweet spots," identified via Common Risk Segment (CRS) mapping, highlight areas with direct overlap of source, reservoir, and seal, representing the most promising areas for hydrocarbon accumulation. These combined factors – proven hydrocarbon occurrences, multiple play fairways, identified leads and prospects, with favourable source rock and reservoir characteristics – make the Pletmos Basin an attractive target for exploration investment and potential discoveries. Further exploration efforts focused on source rock maturity, reservoir facies distribution and understanding fault seal integrity are warranted to unlock the basin's full hydrocarbon potential.

Keywords: Pletmos Basin, Hydrocarbon Exploration, Play Fairways, Petroleum System

Geodynamic Evolution of the Pan-African Orogeny and Implications for Mineral Exploration and Mining.

GEOLOGY AND STRUCTURE OF THE SPITSKOP VOLCANIC CENTRE, SOUTHERN GARIEP BELT, ROSH PINAH MINE, NAMIBIA

Wayne P Colliston[1] & Christoph Gauert[1,2]

[1]University of the Free State, Bloemfontein, South Africa

[2]Landesamt fur Geologie und Bergwesen Sachsen-Anhalt, Germany

Our study of the economic potential of the deformed Spitskop volcanics north of Rosh Pinah provides a structural framework for the understanding of the effects of late Proterozoic/early Palaeozoic Gariepian fold and thrust belt tectonics on the stratigraphy of the bi-modal Spitskop volcanics and associated volcanosedimentary units (Rosh Pinah Formation). Prominent NW-trending structural features – on various scales (cm to km) – form the structural grain of the project area, comprising: (1) A series of map-scale nappe and sheath-fold nappes, and isoclinal folds, refolded by SW-verging back-folds; the Mesoproterozoic Namaqua Basement overthrusts the Spitskop volcanics. (2) Fold axes of the various phases – including the long-axes of sheath folds, are coaxial, and trend and plunge shallowly to the NW, indicating a tectonic transport direction to the SE. (3) Thrusts and nappes deformed by SE sinistral shear zones along their boundaries and within folded banding. A model of differential movement in a thrust regime is deduced from the regional and local disposition of structures where large-scale regional thrusting and nappe emplacement takes place towards the authochthonous Mesoproterozoic Namaqua Metamorphic Complex foreland in the southeast. The stratigraphy of the project area has been subdivided into a structural stratigraphy confined to the dominant nappes identified and restored to D2, namely, the Rosh Pinah, Pisbos, VMU (volcanoclastic marker unit - tuffaceous sandstone with interbanded carbonate and iron formation (TsCG) units), Waterfall and Kudu sheath fold nappes. If the fold nappes are restored to D1, then it is deduced that the order of structural age of the nappes would be from Rosh Pinah (oldest) to Kudu (youngest). Since the nappes control the distribution of the stratigraphic units regionally and locally in the Eastern Gariep Belt, the spatial distribution of Zn-Pb-(Ag,Ba,Cu) deposits is also structurally controlled; the understanding of the tectonics of the region is a critical forward step in modelling the economic potential of the base-metal province.

Keywords: nappes, sheathfolds, structural stratigraphy

Cu-Ag MINERALIZATION IN THE KALAHARI COPPERBELT, EASTERN NAMIBIA: RECENT EXPLORATION INSIGHTS

Stephan Dunn[1]

[1]Remote Exploration Services, Cape Town, South Africa

Well-exposed sections of the northeast-trending Meso- to Neoproterozoic Kalahari Copperbelt in central Namibia have historically been the focus of extensive copper exploration and mining. As these areas approach exploration maturity, recent efforts targeting stratabound Cu-Ag deposits have shifted eastward, demonstrating that the belt has significant mineralization potential beneath Cenozoic cover in eastern Namibia. This contribution highlights how soil sample analysis via portable X-ray fluorescence (pXRF) and inductively coupled plasma mass spectrometry (ICP-MS) effectively targets mineralization beneath shallow (<15 m) Kalahari cover. Both techniques successfully distinguished anomalous copper concentrations in the regolith from adsorption trends related to iron, clay, and organic matter, underscoring pXRF as a rapid and cost-effective tool for surface exploration in this region. Additionally, diverse mineralization styles encountered beneath Kalahari cover, hosted within the Eskadron and Blaubeker Formations, are showcased. Emphasis is placed on how the interplay between cyclical deposition, receptive host rocks, and structural permeability is crucial in the formation of economically viable Cu-Ag mineralization.

Keywords: Kalahari, Copperbelt, Namibia, Exploration, Copper

UNRAVELLING THE ENIGMATIC MAGNETIC ANOMALY OF THE PAN-AFRICAN DAMARA BELT: INSIGHTS FROM GEOPHYSICAL MODELLING

Elikplim Abla Dzikunoo[1,2], Bufelo Lushetile[3] & Jeremie Lehmann[1]

[1]Department of Geology, University of Johannesburg, Auckland Park, South Africa
[2]Department of Earth Science, University of Ghana, Accra, Ghana
[3]Department of Geological Survey, Ministry of Mines and Energy, Namibia

A prominent yet enigmatic long wavelength negative magnetic anomaly is situated under and parallel to the Northern Central Zone (nCZ) of the Pan-African Damara Belt in Namibia. The nCZ geology consists of a thick succession of Neoproterozoic sediments located in between the southern arc region and the northern foreland of the Damara Belt. The scale and expression of this remanent magnetic anomaly, also seen as a conductive zone in magnetotelluric and electrical resistivity profiles, suggests its significance in the geodynamic evolution of the belt. Its origin, however, remains an enigma with a number of evolutionary models proposed, including a relict Pan-African subduction zone or inverted graben predating the PanAfrican orogeny. New insights into the geodynamic evolution of the nCZ are being investigated through an integrated analysis of regional magnetic and gravity data, complemented by seismic reflection/refraction, magnetotelluric, petrophysical, and geological data. Information from xenoliths from Cretaceous ring complexes and kimberlite pipes also provide constraints on the nature of the lower crust and upper mantle under the nCZ. The nCZ negative magnetic anomaly is not systematically associated with low or high densities as the gravimetric signature varies in intensity along the nCZ. However, comparison of limited gravity and magnetic profiles across the zone show that in specific areas, the nCZ negative magnetic anomaly correlates with high density signal, while adjacent higher magnetic amplitudes to the north and south generally correspond to low density signatures. This correlation suggests that some tectonic processes and/or alteration patterns control the origin of the nCZ negative magnetic anomaly. Preliminary Euler solutions constrain the depth extent of the long wavelength anomaly to between ~ 5 km to ~ 37 km below the surface; findings which align with prior interpretation by de Beer et al. (1982) based on resistivity data. This multi-scale, multi-method approach is offering a progressive refinement of the understanding of the geodynamic history of the Damara Belt, particularly within the nCZ. These have significant implications for regional tectonic reconstruction and mineral prospectivity, especially in identifying metallogenic zones associated with such an orogen.

Keywords: Damara Belt Geodynamic Evolution Northern Central Zone Magnetic Anomaly

AGE AND PROVENANCE OF THE KLIPHEUWEL GROUP – ANATOMY OF A CAMBRIAN-ORDOVICIAN FAILED RIFT IN SOUTHWEST GONDWANA

Ruan F. Raath[1,2], Alex F.M. Kisters[1,2], Cameron R. Penn-Clarke[3] & Clarisa Vorster[4]

[1]TECT Geological Consulting, Somerset West, South Africa

[2]Department of Earth Sciences, University of Stellenbosch, Stellenbosch, South Africa

[3]Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

[4] PPM Research Group, Department of Geology, University of Johannesburg, Auckland Park, South Africa

The coarse-siliciclastic, rift-type Klipheuwel Group in the Western Cape, South Africa, captures a critical tectonic transition from Pan-African orogenesis to post-collisional extension, culminating in the subsequent development of the Cape Supergroup. The Klipheuwel Group consists of NW-trending outcrops, preserved as isolated erosional relics, which can be grouped into two distinct depocentres: the northern Klipheuwel Group depocentre (Eendekuil, Redelinghuys, and Elands Bay) and the southern depocentre (Klipheuwel Quarry and Klapmutskop). The north features 300-450 m thick, laterally continuous, multi-storey braided fluvial facies deposited on a peneplained Pan-African basement, while the south comprises >2000 m of moderately NE-dipping, laterally discontinuous, channelised braided deposits preserved in half-graben structures that developed along the reactivated NW-trending Colenso Fault. Novel detrital zircon geochronology constrains the maximum depositional age of the Klipheuwel Group to 488.7 ± 4.8 Ma, indicating a Late Cambrian to Early Ordovician depositional age. The northern depocentre exhibits a bimodal zircon age distribution (1200–1030 Ma and 640–540 Ma), suggesting a source influence from both the Namaqua Metamorphic Complex and the South American Brasiliano orogenic belts. In contrast, the southern depocentre shows a unimodal zircon age signature (560–520 Ma), consistent with derivation of detritus from the underlying Cape Granite Suite. These differences underscore distinctly variable source terranes, controlled by differing structural settings in each depocentre. Regionally, the development of the Klipheuwel Group correlates well with other petrological indicators inferring a widespread tectonothermal event, including emplacement of post-Pan-African A-type granites (510–505 Ma), mafic dykes (487 Ma), and Ar-Ar ages (495–485 Ma) in basement rocks across southwestern South Africa. Collectively, these features indicate an extensional tectonic setting immediately post-Gondwana amalgamation, involving crustal thinning and mafic underplating. Correlation with coeval rift-related sedimentary and volcanosedimentary successions throughout SW Gondwana supports the interpretation of regional-scale extension along the peri-Gondwanan margin, likely driven by slab rollback along the Terra Australis convergent margin. Thus, the Klipheuwel Group represents the surface expression of post-orogenic, pre-Cape Supergroup extensional tectonics, which likely set the stage for later thermal subsidence and basin development that facilitated deposition of the Cape Supergroup.

Keywords: Gondwana, failed rift, Cambrian, sedimentation

NEW INSIGHTS FROM 3D MODELLING INTO MESO-SCALE FOLD GEOMETRIES IN THE SOUTHWESTERN CENTRAL ZONE OF THE DAMARA BELT, NAMIBIA

Christoph Tuitz[1]

[1]SRK Consulting, Johannesburg, South Africa

For several decades, the deformation of the Central Zone of the Damara Belt, a Late Precambrian to Early Palaeozoic African mobile belt, has been a central topic of scientific discourse. Various models have been proposed to explain the characteristic dome-and-basin structures of the zone, with researchers continuously gathering field evidence to support or challenge these interpretations. In addition to the collection and interpretation of macro-scale field data, such as foliation and lineation orientations and kinematic indicators, the meso-scale geometry of folds, domes, and basins has been studied to strengthen or refute arguments for specific models. In this work results from regional-scale litho-structural 3D modelling of an area located southeast and south of the Rossing Dome are presented. For this, digital elevation data, satellite imagery, and published geological maps of the region were analysed to extract the regional geometry of folded lithological units. This was made possible by the exceptional outcrop conditions in the area, with minimal vegetation and limited surface weathering, unlike other regions in Africa that have been subjected to high rates of precipitation over time. Until now, geological maps and cross-sections have been the primary tools used to graphically represent the geological geometries of large areas in the Central Damara Belt. However, unlike 2D geological maps, 3D modelling compels geologists to construct realistic geometries of geological bodies rather than simply drawing lines or areas on a flat plane. As a result, traditional maps often fail to account for the complexity and uncertainty of geological geometries, leaving room for multiple interpretations. The resulting 3D model provides an alternative interpretation that enhances our understanding of the deformation processes in the Central Zone of the Damara Belt. Contrary to the previous understanding that the outcropping formations in this area consistently follow a normal stratigraphic sequence, where younger rocks are exposed at the surface while progressively older rocks are found at depth, it was discovered that, in some areas, the sequence is reversed.

Keywords: Damara Central Zone, 3D modelling, Deformation, Folding

LARGE-SCALE PAN-AFRICAN-BRASILIANO STRUCTURES OF SOUTHWESTERN GONDWANA

Katherine Susan Winkler[1]

[1]AEON – Earth Stewardship Science Research Institute, Nelson Mandela University, Gqeberha, South Africa

A dataset of continental scale, capturing the short-wave infrared mineral response (albeit broad band) from space, provides the context for further understanding geology on the earth's surface. Initial interpretations were verified by correlation with local geophysical datasets covering the Damara Belt. A strong and dominant Pan-African-Brasiliano structural overprint is seen in enhanced Landsat 8 satellite images covering Africa and eastern South America. The continuity of these structures, as viewed from space, provides a means to unravel mega-scale movement that affected Southwestern Gondwana. Structures in the Neoproterozoic Damara Belt, the Lufilian Arc and Zambezi Belts in Zambia, as well as those that affected the Dom Feliciano Belt in South America, relate to pre-breakup Gondwana configuration ca. 500 Ma. Further and on-going deformation, superimposed on older geology in Southern Africa, is also evident in the satellite image coverage. The main feature of lithospheric folds is that they strike perpendicular to the maximum stress direction of the active tectonic stresses. By identifying these strike directions, crustal movements of a very large scale, not observable on the ground, are interpreted. The fold structures, seen in satellite images covering Africa and eastern South America and brought together in pre-breakup Gondwana configuration (500 Ma), shows that N-S (present day) compressional stress, affected Western Gondwana. These stress vectors are attributed to have prevailed following the opening and closure of the Iapetus Ocean during the Neoproterozoic and opening of the Rheic Ocean in the Paleozoic. To date, geology mapped on surface and that mapped indirectly through specific rock properties in the subsurface, by geophysical methods, have provided a fundamental understanding geodynamics. The objective of identifying large-scale, dominant Pan-African (overprint) structures interpreted from these enhanced satellite data, and covering thousands of square kilometres, is to further clarify geological interpretation and economic opportunity. This is demonstrated by interpretation of the data covering the Lufilian Arc Copper Belt, the Damara Belt, and other areas of economic interest in Southern Africa

.

Keywords: Pan-African-Brasiliano structures, Southwestern Gondwana, geodynamic interpretation, satellite imagery

REMOTE SENSING AND STRUCTURAL GEOLOGY OF THE ROOIKUISEB ANTICLINORIUM IN THE SOUTHERN CENTRAL ZONE, DAMARA BELT, NAMIBIA

Atavile Ximbi[1], Jérémie Lehmann[1] & Robyn MacRoberts[1]

[1]University of Johannesburg, Auckland Park, South Africa

The NE-trending Damara Belt formed during collision of the Congo and Kalahari cratons between 590 and 470 Ma. The Rooikuiseb Anticlinorium (RK) is a regional structure in the southern Central Zone (sCZ) of the Damara Belt, Namibia. The deformation record of regional-scale dome structures in the sCZ has either been reconciled into a single phase of progressive deformation or multiple phases of deformation. The study aims to understand the structural evolution of RK. Additionally, the stratigraphy of the northern RK is investigated using remote sensing and field mapping. The stratigraphic units of the Neoproterozoic Damara Supergroup at RK include the Etusis, Tinkas, and Karibib formations, from the base upwards. Groundtruthed Landsat 8 remote sensing reveals that the rocks of the Tinkas Formation rest directly on those of the Etusis Formation. Much of the Swakop Group is missing. Lack of localised shearing at the Etusis/Tinkas contact and existence of a characteristic continuous marble unit of regional extent located towards the base of the Tinkas Formation indicate that this stratigraphic gap is not due to tectonism but is a primary stratigraphic hiatus, in agreement with previous studies. The metamorphic conditions of deformation are supra-solidus, upper amphibolite facies, with garnet, biotite, sillimanite, hornblende, and cordierite assemblages and structurally controlled leucosomes. Structural mapping reveals two deformation events: (1) D1 structures include shallow-dipping metamorphic and stromatic foliations carrying NE-trending stretching lineation, and enclosing recumbent and isoclinal folds. Common asymmetric boudinage of S1 fabrics suggest top-to-SW shearing during D1. (2) D2 produced the dome-scale buckling of D1 architecture, with local outcrop-scale Type 3 fold interference pattern between F1 recumbent and F2 inclined folds. D2 operated under NW-SE shortening and gave rise to the shallowly NE-plunging regional RK anticlinorium, with broadly steep NW- and SE-dipping limbs. Based on the data, two deformation phases best explain the observed structures. D2 NW-SE shortening is related to collision of the Congo and Kalahari cratons. However, the origin of lower crustal, early, D1 top-to-SW shearing is cryptic. Future work will focus on constraining the age and prograde, peak P-T or retrograde character of the D1 deformation event at the Rooikuiseb Anticlinorium.

Keywords: Damara Belt, ductile, deformation

Geoheritage, Geotourism, and Geoparks

ADVANCES IN THE DEVELOPMENT OF VIRTUAL GEOLOGICAL TOURS FOCUSED ON THE CAPE GRANITE SUITE, CAPE AND KAROO SUPERGROUPS

Charl D. Cilliers[1], Jan M. van Bever Donker[1]& Matthew S. Huber[2]

[1]Department of Earth Sciences, Faculty of Natural Sciences, University of the Western Cape, Bellville, South Africa
[2]School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Durban, South Africa

South Africa's rich geological diversity includes many sites of special significance from scenic, geohistorical, educational, and economic perspectives. Just a few examples include the famous Big Hole (Kimberly), greenstones and stromatolites (Barberton Mountains), turbidity sequences (Tanqua Karoo), Cape Fold Belt (at Seweweekspoort), and the Sea Point Contact, which was visited by Charles Darwin back in 1836. Along with vast mineral riches, some of these "geosites" preserve the history of continents, and the evolution of life (e.g. the Robberg Formation at Plettenberg Bay). Primarily driven by the Geological Society of South Africa, several initiatives have accordingly been developed to identify and document such outcrops for preservation, geotourism, and educational purposes. Within this framework, our team at the University of the Western Cape (UWC) is busy developing virtual geological tours (VTs) of specific Cape Granite Suite, Cape Supergroup, and Karoo Supergroup outcrops, with three primary objectives. These are to create comprehensive geo-education focused virtual tours to assist university students to prepare for field excursions, to produce web-based geotourism/geoheritage-focused VTs, and to potentially contribute to the Geodyssey platform. Although the production of interactive VTs is technologically complex in terms of software requirements and understanding, we have made significant progress since 2024. In particular, we have successfully refined our workflow to effectively utilise a DJI Mavic 3 Pro Cine drone alongside an Apple iPhone 15 Pro Max equipped with the 3D LiDAR scanner app and a lavalier lapel microphone to create high resolution VTs without the need to transport bulky photographic and cinematic equipment into the field. Notably, although the educational efficacy of some of our earlier VTs has already been proven, at the UWC we are currently increasing our testing database via honours and 1st-year student trials. We aim to showcase some of our most recently developed VTs at GeoCongress 2025 to give you a glimpse of what is possible, and would welcome any suggestions for improvement, specifically regarding geoheritage, geoeducational, and geotourism aspects.

Keywords: geotourism, geoheritage, geo-education

ONE HUNDRED AND FIFTY YEARS OF DATA AT RISK – CAN WE AFFORD TO LOSE OUR WITS BASIN GEOHERITAGE?

Vaughan Chamberlain[1] & Linda Iaccheri[2]

[1]AMIRA.GLOBAL

[2]School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

Over the hundred and fifty years of mining the Witwatersrand reef, billions of rand (in current monetary terms) of geological data have been generated. Borehole core and drillhole databases exist in core yards and companies' data clouds across central South Africa. Along with these records there are thousands of reports, many deemed secret at the time they were generated and unseen since. Examples of these secret reports abound and just two examples are the Basin Analysis report completed by Anglo American in the 1990's which examined in detail the development of the Witwatersrand basin, and the results of the drilling in the Bethlehem area that intersected a Transvaal aged basin almost identical to the Griqualand West basin in the Northern Cape. How many other gems are out there ready to be unveiled? It is proposed that a collaborative project funded by industry, government, and possibly philanthropic organisations, could bring together the disparate data in a single system available to all. In order to protect our geological heritage, it is essential that the geological community stand together. Without this data being protected and made available to both academia and industry, how will the future exploration efforts in Witwatersrand be informed? There are millions of ounces of gold remaining to be mined in the basin and without protecting this data the process will have to start from scratch!

Keywords: Wits Basin, historical drillhole database, open access and management

GEOHERITAGE, GEOTOURISM, AND GEOPARKS IN AFRICA: AN OVERVIEW

Khodani Matshusa[1] & Llewellyn Leonard[1]

[1]Department of Environmental Sciences, University of South Africa, Pretoria, South Africa

Africa is endowed with many geological sites of international significance; however, many sites are not properly identified and preserved. Therefore, there is a need for increased attention on the contribution of geoheritage, geotourism, and geoparks to sustainable development. This study reviews geoheritage and its protection with a focus on research trends, methodologies on inventory of geoheritage, identification, inventory, and management of geoheritage, development and management of geotourism and geoparks, geoheritage contribution to socio-economic development, geoeducation and promotion of geoheritage, geoconservation, and governance of geoheritage, geotourism, and geoparks in Africa. It is therefore critical that projects on geoheritage in African areas are supported to enhance the geoconservation, geotourism, and geoparks while contributing to socio-economic development.

Keywords: Africa, geoheritage, geoconservation, sustainable development

THE USE OF SOFTWARE AND HIVE TECHNOLOGY IN THE CONSTRUCTION OF VIRTUAL FIELD EDUCATION OF THE TANQUA KAROO

Luyanda Mayekiso[1,2]

[1]University of the Western Cape, Bellville, South Africa
[2]Petroleum Agency South Africa, Cape Town, South Africa

Geology is a field-based profession where it is mandatory for students to travel to distant locations for field-based training. However, factors such as the recent COVID-19 pandemic, budget constraints, and large class sizes make organising multiple field trips increasingly challenging. With digital technology moving to a position where "virtual" visits to geological sites could offer some of the information and interactions that are commonly acquired through field excursions, the creation of Virtual Field Trips (VFTs) has become attainable. VFTs offer a solution by simulating real-world environments through digital means. They enhance accessibility, preserve sites, and aid in education. This study focused on developing a VFT of the Tanqua Karoo study area to introduce fourth-year geology students at the University of the Western Cape to information they need to understand before going on the physical field excursion. To evaluate the impact of the VFT on students' performance, the final reports of two distinct student groups from 2021 and 2022 were examined. The designing of the VFT and its effect on improving student understanding of the Tanqua Karoo VFT was created using a collection of software, including the Pano2VR, a software that can incorporate large amounts of data, producing a pathway for incorporating data in fine detail into a complex Virtual Field Trip. The final product is a composite tour visiting seven stations incorporating data such as videos, high resolution panoramas, Lidar models, 360 photographs, and drone videos and -images. The web-based format allows easy access, and students explored it in the Highly Immersive Visualization Environment (HIVE) prior to their field excursion. The developed field area simulations allowed students to familiarise themselves with the sites in advance, enhancing their preparation for the excursion and enabling repeated visits to the field. Comparing student performance in 2021 and 2022 showed that the VFT positively impacted learning. However, further research with larger samples is needed to validate these findings. The results of this study demonstrate that the VFT can be used at university level and adapted by both local and international Geoscience communities, providing flexible access to field excursion sites.

Keywords: Virtual Field Trip, Drone Videos, Panoramas, Karoo

SONGIMVELO GAME RESERVE AND ITS WIDER CULTURAL-GEOLOGICAL LANDSCAPE: FOUNDATION FOR UNESCO GLOBAL GEOPARK NOMINATION

Thibedi Ramontja[1] & Baojin Zhao[2]

[1]School of Mining Engineering, University of the Witwatersrand, Johannesburg, South Africa
[2]Department of Environmental Sciences, University of South Africa, Pretoria, South Africa

Although South Africa is endowed with a diverse and world-renowned geology and exceptional biodiversity, the country still does not have a United Nations Educational, Scientific and Cultural Organization (UNESCO) Global Geopark. This paper assesses Songimvelo Game Reserve, located in the southeastern part of the Mpumalanga Province in South Africa, and its wider cultural and geological landscape as a potential UNESCO Global Geopark. The assessment is based on field observations and UNESCO's self-evaluation checklist for aspiring global geoparks. The UNESCO checklist comprises seven criteria, which consist of 101 detailed questions designed to evaluate eligibility for recognition as a global geopark. The area is located within the UNESCO Barberton Makhonjwa Mountain and attracts local and international geoscientists. It is characterised by the occurrence of the globally recognised Barberton Greenstone Belt. It has a diverse flora and fauna and a rugged landscape traversed by the iconic Komati River. The cultural heritage of the communities in and adjacent to the game reserve offers an opportunity that could be integrated into geotourism and create sustainable job opportunities. While there are significant qualifying attributes for the area to be a good candidate for designation as a global geopark, the checklist revealed several identifiable gaps that will have to be addressed. The gaps include a lack of structured educational programmes, insufficient visibility and awareness programmes, and the absence of an exhibition room. By highlighting these issues, the paper encourages and provokes a dialogue about the potential of the site to be inscribed as a global geopark. Accordingly, it is recommended that a committee comprising relevant stakeholders be established to commence with the dialogue and initiate the process of making the area a UNESCO Global Geopark.

Keywords: UNESCO Global Geopark, Songimvelo Game Reserve

Geoscience and Society

WANING OR REVIVAL – WHAT`S UP AT THE SOUTH AFRICAN COMMITTEE FOR STRATIGRAPHY (SACS)?

Wladyslaw Altermann[1] **& Frederick Roelofse**[2]

[1]South African Committee for Stratigraphy, Freelance Geological Consultant
[2]Department of Geology, University of the Free State, Bloemfontein, South Africa

The South African Committee for Stratigraphy (SACS) is an academic, non-governmental organisation (NGO). Since 1971, SACS has overseen the stratigraphic definitions of lithostratigraphic and lithodemic rock units, soils, and unconsolidated deposits in South Africa. After many successful activities and excellent publications in the first three decades, SACS gradually became dormant. Funding was problematic, and sporadic activities were often subsidised privately through university resources. The position of the National Secretary, managing SACS's affairs, has not always been filled. The National Committee is typically not consulted, e.g., when the Secretary's position was advertised and filled by the Council for Geoscience (CGS) in 2023-2024. The SACS webpage (https://www.stratigraphy.org.za/), run through the CGS, has not been functional for many years. The revival of a national stratigraphy body, adhering to the guidelines of the International Sub-commission on Stratigraphic Classification (ISSC) of the International Commission on Stratigraphy (ICS), and the International Stratigraphic Guide (ISG) should become the major, outstanding task for Geoscientific academia, the GSSA, the CGS, and SACS itself. Alternatively, a new university- or GSSA-hosted academic NGO should take over the goals of SACS. The "Proposal for the 5th Adjustment and Modification of the South African Code of Stratigraphic Terminology and Nomenclature", discussed during Geocongress 2023, has been published in the *South African Journal of Geology* (SAJG 2024, 127-4). This modification of the Code paves the way for SACS for substitution of inappropriate colonial, disrespectful stratigraphic terms with inclusive names reflecting democratic South Africa. SACS should focus on ratifying the proposal for the 5th Adjustment of the Code and promote stratigraphy education among young Geoscience academics. Stratigraphic and geographic names considered offensive to most of the population must be replaced in the Lexicon of Lithostratigraphic Terms and in map legends, but, critically, such replacement must follow the rules of SACS and the ISG. This initiative can attract national funding and involve graduate students updating maps, field descriptions, and lithological and geochemical data of relevant stratigraphic units which will create opportunities for fieldwork and publication in the SAJG, ultimately contributing to the revival of stratigraphy in South Africa.

Keywords: SACS, Code, Stratigraphic, Terminology

COGNITIVE PROCESSES MEDIATING BEHAVIOURAL AND ATTITUDINAL RESPONSE TO WATER STRESS IN DROUGHT-PRONE LIMPOPO REGION: A CITIZEN SCIENCE CASE-STUDY

Lawrence Diko Makia[1]

[1]Department of Earth Sciences, University of Venda, Thohoyandou, South Africa

Water security remains a significant challenge in South Africa. With the advent of the Makhado Musina Special Economic Zone (MMSEZ) in the Vhembe District of Limpopo Province, water demand associated with economic growth, urbanisation, and population growth is projected to increase. Sustainable management of water resources, therefore, constitutes a critical element for the success of the MMSEZ initiative. Central to this success is the role of consumers in initiating and/or adopting water risk-reduction measures. This study interrogates the role of cognitive processes mediating behavioural and attitudinal responses to water stress experienced in the drought-prone Limpopo region. The Modified Protective Motivation Theory (MPMT) was employed as the underpinning framework to assess participants' readiness to initiate sustainable water use practices. Focus group discussions were conducted to elicit participants' threat and coping appraisal with water scarcity. By highlighting the interaction with an augmented model of PMT and behavioural biases, the study sheds light on potential reasons why consumers are unlikely to adopt water risk reduction measures. Findings comprise a discussion on the advantages of the MPMT over the traditional PMT in achieving protection motivation and adaptive coping strategies. By augmenting the two main stages in the PMT (threat and coping appraisal) with ownership appraisal, the MPMT explicitly elicits the extent to which consumers' positive attitudes towards water-saving measures are critical for sustainable resource management. The MPMT is thus proposed as a plausible framework for citizen science education for potentially at-risk communities along the proposed MMSEZ.

Keywords: Protection Motivation Theory, water stress, resilience, Limpopo Province

FAST4FUTURE: FOCUS ON AFRICA SPACE SCIENCE AND TECHNOLOGY 4 FUTURE DEVELOPMENT

Stephanie Scheiber-Enslin[1], Fulvio Franchi[2], PAPSSN and F4F Team[1] & Roger Gibson[1]

[1]University of the Witwatersrand, Johannesburg, South Africa

[2]University of Bari Aldo Moro, Bari, Italy

The future prosperity of Africa depends on its ability to increase Science, Technology, Engineering, and Mathematics (STEM) education, including Planetary and Space Science Technology (PSST). PSST requires the inclusion of the right set of skills in Higher Education Institutions (HEIs) to deliver the workforce necessary for the development of this technology. Strengthening the HEIs capacity in PSST is needed to help address some of Africa's greatest 21st-century developmental challenges. This will bring considerable economic and societal opportunities, sustainable economic growth, and boost the digital transformation toward the 4th Industrial Revolution and the Knowledge Economy. The Pan-African Planetary and Space Science Network (PAPSSN) was established in 2021. This initiative focuses on enhancing the development of skilled graduates in the fields of planetary and space sciences within Africa. The follow-on project from PAPSSN is FAST4FUTURE, which started in 2023. The project also aims at strengthening Science, Technology, Engineering, and Mathematics (STEM) in African higher education by: (i) Increasing the accessibility to STEM in African higher education; (ii) Modernising existing PSST programmes in collaboration with industry and policy makers; (iii) Fostering the internationalisation of partner HEIs by promoting mobility of staff; and (iv) Promoting standardisation of PSST in Africa in support of students' mobility. These aims are being achieved through the creation of a Centre of Excellence in PSST (CESST) linked to a virtual platform. This virtual platform has opened new pathways for the dissemination of high-quality academic contents that can potentially reach thousands of STEM students across the continent and facilitate access to STEM disciplines for Africans living in remote areas and conflict zones and will, eventually, improve the number of women in STEM. The partner institutions include the University of Botswana, Botswana International University of Science and Technology, University of Zambia, Copperbelt University, South African National Space Agency, University of the Witwatersrand, Air Force Institute of Technology(Nigeria) and University of Nigeria Nsukka.

Keywords: PAPSSN, F4F, planetary, space

A NEW AGE OF PALAEOMAGNETISM AT UKZN

Lauren Hoyer[1]

[1]Department of Geosciences, University of KwaZulu-Natal, Durban, South Africa

The palaeomagnetism laboratory at the University of KwaZulu-Natal (UKZN) has recently been upgraded with state-of-the-art equipment not available elsewhere in southern Africa, and complementary to the University of Johannesburg Alex du Toit Palaeomagnetism Laboratory. Central to the upgrade is the AGICO MFK2 Kappabridge Susceptibility Bridge, which measures both bulk magnetic susceptibility and anisotropy of magnetic susceptibility (AMS) of rock and soil samples. Bulk susceptibility offers valuable correlation with aeromagnetic survey data, while AMS provides insight into rock fabric, often used as a proxy for magma flow in magmatic and volcanic igneous rocks. The Kappabridge is paired with the AGICO CS4 furnace, enabling thermal variations in susceptibility with measurements up to 700°C. This identifies the Curie temperatures of magnetic phases, aiding in the determination of magnetic mineralogy. Additionally, the AGICO PAM1 Pulse and Anhysteretic Magnetiser complements the existing AGICO LDA5 Alternating Field Demagnetiser and JR-6A Spinner Magnetometer. This suite allows for the acquisition of low-field isothermal remanent magnetisation (IRM and ARM), which supports the determination of palaeointensity and characterisation of magnetic domain states and grain sizes. To further enhance thermal demagnetisation capabilities, the Magnetic Measurements MMTD80A thermal demagnetiser (80-sample capacity) is being procured. This will significantly increase throughput for thermal demagnetisation studies and integrate efficiently with existing instrumentation. Current and upcoming projects at UKZN include: (1) Palaeomagnetism and magma flow in felsic and mafic lavas of the ~133 Ma Bumbeni Complex; (2) Age constraints and magnetic properties of the Sithilo Complex, a small ultramafic body within the Mandeni Thrust Sheet of the Tugela Terrane; (3) Palaeomagnetism of the Rooi Rand Dyke Swarm in northern KwaZulu-Natal and Eswatini; (4) Magma flow dynamics in high-level Karoo dolerite dykes of the eastern Drakensberg; and (5) Magnetic fabric and flow patterns in the Gap Dyke Swarm, Eastern Cape. The UKZN team invites collaborators to explore opportunities for joint projects and to make use of the advanced capabilities now available at UKZN.

Keywords: Anisotropic Magnetic Susceptibility, palaeomagnetism, thermal demagnetiser

HOW TO OBTAIN COMMUNITY BUY-IN DURING RESEARCH DRILLING: ICDP BASE PROJECT, MOODIES GROUP, BARBERTON GREENSTONE BELT

Phumelele Mashele[1,2,3,4], Astrid Christianso[5], Chris Rippon[3], Christoph Heubeck[6], Derrik Dludlu[3], Dora Paprika[3], Musa Mavimbela[3], Nicolas Beukes[1], Rodney Tucker[3], Ryan Tucker[3], Thikho Mufamadi[3] & Victor Ndazamo[7]

[1]Department of Geology, University of Johannesburg, Auckland Park, South Africa
[2]CIMERA
[3]Barberton Archean Surface Environments drilling project
[4]School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
[5]Barberton Tourism, Barberton, South Africa
[6]Department of Geosciences, Friedrich-Schiller University Jena, Jena, Germany
[7]Barberton Mines, Barberton, South Africa

The ICDP Barberton Archean Surface Environments (BASE) Project, managed by DSI-NRF CIMERA, drilled eight research boreholes in the Moodies Group of the Barberton Greenstone Belt to investigate the conditions under which the 3.2 Ga terrestrial and shallow-marine strata of the Moodies Group formed. Because most of the drill sites were located in the Barberton Makhonjwa Mountains World Heritage Site (BMM WHS), significant societal engagement formed an essential component of the project from its very beginning, with the aim of obtaining public support and advancing science and tourism. EOP (Education, Outreach and Publicity) activities took place in all four project phases: During Phase 1 (2017 - 2020), governmental and local communities were consulted and briefed on the concept and objectives. During Phase 2 (March - Oct. 2021), landowners, local community leaders and governmental agencies, including BMM WHS Management, Environmental Agencies, Water Affairs, SAHRA, and local community leaders were informed in detail; media releases spread the news. Persistent lobbying of regional government by local stakeholders, led by the local tourism manager, secured an ideal location for the project work in the centre of Barberton, which we utilised for geological displays, core processing, and storage. Phase 3 (Nov. 2021 - July 2022), the drilling campaign, saw near-daily visits, briefings, interviews, guided tours etc. Much of the success during this peak phase resulted from efficiently combining (1) teaching using our information displays, (2) real-time observation of hands-on core processing, and (3) visits to active drill sites. Individuals and groups of scientists, school learners, university students, local community leaders, tourists, heritage and nature interest groups, as well as government officials in the tourism and education sectors visited the project during this phase. We spread the word through radio interviews, TV appearances and through social media platforms. Phase 4 (Aug. 2022 - present) saw the construction and completion of a permanent new display room in the regional museum, dedicated to geological education and showcasing results of research initiated by BASE. Overall, the transparency of the project gained the interest and support of the Barberton community, hopefully inspiring a new generation of geoscientists.

Keywords: Geotourism, Barberton, Outreach, Drilling

UPDATE ON THE STATUS OF THE SOUTH AFRICAN COMMITTEE FOR STRATIGRAPHY SECRETARIAT

Mawande Ncume[1], Johann Neveling[1], Ndivhuwo C. Mukosi[1], Netshitungulwana Robert[1], Taufeeq Dhansay[1] & Tsholofelo Chiloane[1]

[1]Council for Geoscience, Pretoria, South Africa

The South African Committee for Stratigraphy (SACS), established in 1971 by the Council for Geoscience (CGS) (previously Geological Survey of South Africa), functions as the official body which regulates the nomenclature and definition of lithostratigraphic and lithodemic rock units, and unconsolidated deposits and soils. The support of SACS finds expression within the mandated functions of the CGS, which was established by the Geoscience Act No. 100 of 1993 (as amended). In line with the Geoscience Act, the CGS in the recent past (2018/2019) initiated and prioritised the Integrated and Multidisciplinary Geoscience Mapping Programme (IMMP) which seeks to meet the South Africa's broader developmental goals through geosciences. The establishment and deployment of this mapping programme necessitated a reassessment of the CGS programmes, including SACS. The recent acceleration to the IMMP has led to significant progress, as evidenced by the substantial increase in the country's geological and geohydrological map coverage at a 1:50 000 scale and production of ~18 SACS lithostratigraphic descriptions. Although this is the case, there are numerous stratigraphic challenges that need to be addressed, including racial and derogatory terminology and incorrect mapping and subdivision of geological units considering new radiometric dates. The solution to these challenges requires full functionality of the National and Task Group committees of SACS. The CGS management (the Board and Executive Officers) is aware of the challenges, controversies, and inaccurate assertions made by some members of the geoscience community. These assertions are misleading about SACS and derogatory to the organisation. Therefore, in support of SACS and to correct contentions and inaccuracies, the CGS has appointed a permanent SACS Secretariat. Through the role of the Secretariat, the CGS is, amongst other activities, reviewing the Abridged Lexicon of South African Stratigraphy and developing a SACS constitution. Once completed, the latter will be made available for public input to ensure inclusivity and transparency. The constitution will support the establishment of the SACS committees that reflect the skills and demographics of the geoscience community, support the update of the lexicon, and address derogatory and divisive lithostratigraphic names, such as the Kaffirskraal Complex.

Keywords: South African Committee for Stratigraphy, Council for Geoscience, Geoscience Act No. 100 of 1993 (as amended)

ADVANCING MINING THROUGH GEOSCIENTIFIC RESEARCH AND INNOVATION

Michelle M. Pienaar[1]

[1]Mandela Mining Precinct, Johannesburg, South Africa

The mining industry is evolving in response to growing global demands for safer, more efficient, and environmentally responsible resource extraction. At the heart of this evolution is the integration of geoscientific research and technological innovation to improve decision-making, minimise risk, and unlock greater value from complex orebodies. The Advanced Orebody Knowledge (AOK) programme, led by the Mandela Mining Precinct, exemplifies this shift by aiming to transform how geological information is acquired, processed, and applied within the mining cycle. AOK introduces the concept of "Glass Rock"—a vision of full geological transparency that enables mining teams to understand what lies beneath the surface with greater clarity and confidence. This is particularly important as operations move into deeper, more geologically challenging environments, where traditional methods often fall short in predicting geological hazards such as faults, dykes, gas pockets, and changes in reef topography. The programme is structured around three core technology pillars: data acquisition and capture, data processing and analysis, and visualisation and prediction. It leverages advanced sensing systems, geostatistical tools, and machine learning to produce real-time geological insights. These technologies enhance orebody characterisation, guide safer and more effective mine planning, and contribute to a stronger culture of risk management and safety. Collaboration is key to AOK's success. By working closely with universities, scientific councils, government bodies, and mining companies, the programme ensures that new methods are not only scientifically robust but also tested and refined in real mining environments. This approach bridges the gap between research and application, driving both innovation and practical impact. Through its integrated and forward-thinking approach, the AOK programme is redefining resource intelligence and cementing the role of geoscience as a foundation for smart, sustainable mining in South Africa and beyond.

Keywords: Advancing mining research and innovation, Glass Rock Collaboration

GEOSCIENCE OUTREACH FOR BLIND AND VISUALLY IMPAIRED LEARNERS: A JOURNEY TO "SEE" EARTH AND SPACE DIFFERENTLY

Tanja Reinhardt[1]

[1]Science and Technology Education Centre, University of KwaZulu-Natal, Durban, South Africa

The Science and Technology Education Centre at the University of KwaZulu-Natal (STEC@UKZN), which includes the Geology Education Museum, is a place of hands-on informal science learning with the emphasis on Geoscience Education. Numerous geoscience related workshops and educational material have been developed by us. Over the last few years, the aim of the South African Department of Science and Innovation is to provide inclusive science education, and to provide equitable learning opportunities for learners with diverse abilities. This proves to be difficult especially for learners with visual impairment, as the majority of science experiments rely heavily on visual instruction techniques. In collaboration with astronomy researchers, we wanted to provide the same informal teaching and hands-on geoscience activities to learners with visual impairment. In this inclusive education approach, we decided to adapt some of our geoscience material for learners with difficulty seeing. We used different innovative strategies to improve their learning experience by employing a multisensory approach. Traditional teaching methods rely heavily on visual cues, creating barriers for those learners. To address this challenge, our method incorporated tactile and experiential elements, such as two- and three-dimensional models, and audio and sensory stimulations. Models are particularly beneficial to learners when learning about science. This is especially true for learners with visual impairments, as they have to rely on senses like touch. With these models' learners are provided with a tactile experience, they can explore and examine the different structures and make them "visible".

Keywords: geoscience education

ENGAGED GEOSCIENCE FOR HERITAGE PRESERVATION: INVESTIGATING SINKHOLE FORMATION AT THE JAN SMUTS HOUSE MUSEUM

Jureya Dildar[1], Gillian Drennan[1], Musa Manzi[1] & Robyn Symons[1]
[1]School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

Addressing geological hazards requires an interdisciplinary approach that integrates science with societal needs. This study by the University of the Witwatersrand's School of Geosciences examines sinkhole formation at the Jan Smuts House Museum using geological, hydrogeological, and geophysical methods. Beyond advancing knowledge of karst processes, the research aims to support heritage conservation and public safety. Located on the dolomitic bedrock of the Malmani Subgroup, the museum is prone to sinkholes due to subsurface erosion. Expanding cracks in one building raised concerns about subsidence, prompting a volunteer research initiative. Seismic surveys, ground-penetrating radar, electrical resistivity tomography, and water quality assessments revealed a natural cavity with high water saturation above it, likely caused by irrigation or leaking taps and underground pipes. Water ingress into this cavity is the primary driver of subsidence, posing a long-term risk of stability of the cavity and potential sinkhole formation. Mitigation efforts should focus on water management and behavioural change – repairing leaks, reducing irrigation, and ensuring water management practices prevent further erosion. Ongoing monitoring may be required to assess stability and determine if foundation reinforcement is necessary. Additionally, high nutrient levels in a nearby stream suggest contamination from surface runoff, potentially linked to irrigation for lawns in the catchment suggesting wider community behaviours may not be ideal for the long-term stability and safety of this sensitive landscape and more targeted conversation about water management with residence is needed. Long-term solutions include catchment monitoring, water management and bioremediation. This research highlights the value of community engagement and cross-disciplinary collaboration in addressing geological risks. By working with museum staff and stakeholders such as Friends of Smuts House, the project demonstrates how geoscience can directly inform conservation strategies, water management policies, and public awareness of environmental hazards.

Keywords: engaged science, Smuts House Museum, sinkholes, heritage

CONTENT ANALYSIS OF THE NQWEBA FIREBALL OBSERVER REPORTS AND THE ROLE OF PUBLIC ENGAGEMENT

Robyn Symons[1], Carla Dodd[2], Leonidas C. Vonopartis[1], Peter Hers[3], Roger L. Gibson[1] & Timothy Cooper[4]

[1]School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
[2]Department of Geosciences and Institute for Coastal and Marine Research, Nelson Mandela University, Gqeberha, South Africa
[3]Garden Route Centre of the Astronomical Society of Southern Africa, Sedgefield, South Africa
[4]Comet Asteroid and Meteor Section Director, Astronomical Society of Southern Africa, Benoni, South Africa

On August 25, 2024, a bolide was widely observed over the Southern and Eastern Cape regions of South Africa. Within hours, over 30 citizen reports were submitted through social media, email, and local networks. These and subsequent reports collected by the team included descriptive narratives, GPS coordinates or place names, and in some cases, visual or audio recordings. This preliminary study uses content analysis to evaluate the quality and consistency of these citizen science contributions. In total, 147 reports were received, several of which were rejected due to insufficient useful information, leaving 129 reliable reports for further analysis. Of these, 4 were video reports, 28 were visual reports, 75 were audio reports, and 22 were mixed audiovisual reports. These reports contained several interesting insights: 22% referenced colour phenomena, and 9% mentioned animal behaviours. There were also five confirmed accounts of concurrent sounds accompanying visual sightings and one of sounds accompanying the meteorite fall. Reports were coded for specific sound-related keywords linked to meteor phenomena. Notable words related to normal sounds (e.g., boom, rumble, blast), acoustic waves (e.g., shaking, vibration, tremor), and anomalous concurrent sounds (e.g., burning, hiss, buzz) were isolated for analysis. A secondary analysis flagged multiple references to splashdowns or sea impacts, highlighting the early spread of misinformation, often linked to news media speculation. Several of these claims were countered by detailed citizen reports that included inland GPS data and firsthand trajectory observations. Time-related language appeared across many reports, supporting the potential for crowd-sourced reconstruction of the event timeline. Also the timestamp of when the account was recorded can also be used to track variation in accounts since the event. Location mentions and GPS data allowed for spatial mapping of sound propagation and consistency in observational data. These findings support the use of public engagement as a rapid, decentralised sensing system, capable of providing valuable, verifiable information for meteoric events, and the value of an engaged and science-curious public as source of scientific data and the potential for public data to correct misinformation in real-time. Further analysis (including keyword correlation, time-series plotting, and spatial clustering) is ongoing.

Keywords: bolide, citizen science, meteorite, Nqweba

MINING'S BAD IMAGE: CAN ESG AND MARKETING SHIFT PUBLIC PERCEPTION?

Sara Turnbull[1]

[1]SRK Exploration, Johannesburg, South Africa

The mining industry is facing a critical challenge in reshaping public perceptions of its role in society. Diamonds, once a symbol of enduring value, are now increasingly dismissed as unnecessary indulgences with no inherent worth. Similarly, lithium (a cornerstone of the battery revolution) faces growing scrutiny as the demand for sustainable energy solutions rises. These commodities, among others, are caught in a broader narrative that questions the necessity and ethics of mining itself. For the first time in decades, mining companies are turning to sector-wide marketing strategies, aiming to promote not just individual brands but the very concept of mining as a vital industry. The introduction of Environmental, Social, and Governance (ESG) principles has provided a framework to address some of these concerns, offering a pathway to demonstrate accountability and sustainability. However, the question remains: is this enough to shift public opinion? Study after study has shown that the general public harbours a deep mistrust of mining, often perceiving it as a destructive force rather than a necessary contributor to modern life. This presentation will explore whether the industry's current efforts, including ESG initiatives and sector marketing, are sufficient to bridge this gap. It will also examine the role of geosciences in fostering public understanding and trust, particularly through outreach, citizen science, and community engagement. Can the mining industry leverage these tools to make a compelling case for its necessity in a world increasingly focused on sustainability? Or will it remain unwilling (or unable) to confront the deeper societal concerns that continue to undermine its reputation?

Keywords: ESG, Marketing, Geoscience, Outreach

MAXIMISING THE VALUE OF NATURE DEPENDENT RESOURCES, MINING AND FARMING, NOW AND IN THE FUTURE

Philip Viljoen[1]

[1]Department of Geology, University of the Free State, Bloemfontein, South Africa

Mining businesses must deal effectively with nature's complexity as well as the complexity of extraction, price and demand fluctuations and then must regenerate the land back to productivity. Their goal is to make more money now and in the future for the life of the mine and leave productive land behind. Therefore, they must manage their systems to maximise value, become more and more profitable, and regenerate nature while subjected to large variability for all parts of the system during the life of mine. The key to effectively manage this very complex system is to discover the existing inherent simplicity and then learn what rules are necessary to maximise the performance of the system, not the parts. The underlying premise is that maximising the performance of the parts does not maximise the performance of the whole. Every nature-dependent enterprise has the natural resource as the strategic system constraint, a capacity constrained resource and a finite demand that must be satisfied very well to maximise value for stakeholders. This presentation applies the Theory of Constraints management philosophy and the principles of holistic regenerative farming to develop a management system that focuses on these three interactive constraints and proposes how to manage them to deal with the complexities and extreme uncertainties of mining and subsequent farming systems. It is a model of how to manage for improving the value delivered to stakeholders continually.

Keywords: regeneration, improvement framework, holistic management, system thinking

Groundwater

ASSESSMENT OF GROUNDWATER RESOURCES FOR BULK WATER SUPPLY ENHANCEMENT IN EXCELSIOR, FREE STATE

Leor Bester[1] **& Fanie de Lange**[1]

[1]Institute for Groundwater Studies (IGS), University of the Free State, Bloemfontein, South Africa

The primary objective of this investigation was to conduct a comprehensive assessment of the groundwater resources in and around the town of Excelsior, with the goal of informing strategies for the augmentation of bulk water supply from groundwater resources hosted within the local Karoo-type aquifers. This is done practically through the use of geophysical analysis, by which subsurface heterogeneities can be located and identified, which are commonly targeted for the drilling of abstraction boreholes. The town of Excelsior is located approximately 82 km east-north-east of Bloemfontein, in the Mantsopa Local Municipality in the Thabo Mofutsanyane District. The town of Excelsior is located predominantly on the Balfour Formation of the Beaufort Group, with the eastern portions of the study area situated on the Tarkastad Formation. This investigation employed a multi-faceted approach. A comprehensive desktop study was initially conducted to collate existing relevant information. Geophysical data were then gathered and analysed using magnetic and Electrical Resistivity Tomography (ERT) techniques. Field data collection involved conducting aquifer tests in situ to inform aquifer characterisation. Analytical methods were applied to classify the aquifers and determine appropriate safe yield. Finally, chemical analyses were performed to assess the suitability of the groundwater for domestic use. The results of the geophysical component of this project were the identification of several subsurface dolerite intrusions which were then targeted for drilling purposes. Of the boreholes that were drilled, three candidates were determined to have sufficient groundwater reserves and were subjected to further testing in the form of 24-hour constant rate pumping tests. The pumping tests resulted in safe yields of 1.05 L/s, 1.13 L/s and 0.5 L/s, respectively. The chemical analyses resulted in perfectly suitable drinking water. In conclusion, the groundwater reserves in and around the study area should be carefully managed, as the quantity of water present may be a limiting factor. The newly drilled boreholes result in a combined yield of approximately 9650 L/hour. The town currently relies of surface water, and the abstracted water could help to alleviate the water question, but not completely resolve the problem.

Keywords: groundwater, sustainability, geohydrological assessment, drinking water

THE DIDO VALLEY "SPRING" – A TALE OF URBAN HYDROGEOLOGY AND HISTORY IN THE DEEP SOUTH OF CAPE TOWN

Dylan Blake[1], Abdullah Hunter[2], Keanan Woolf[1] & Unathi Noludwe[3]

[1]Umvoto, Cape Town, South Africa

[2]Zutari, Pretoria, South Africa

[3]City of Cape Town Water and Sanitation Directorate, Cape Town, South Africa

The City of Cape Town's (CCT) 2015 "Spring Use Strategy" aims to identify and develop groundwater springs within CCT municipal boundaries, through using spring water for non-potable public benefit purposes, and to offset municipal potable water use. To this extent, the CCT investigated the Dido Valley "Spring" (DVS), situated in a narrow valley between the South Peninsula suburbs of Glencairn and Simon's Town. The DVS is comprised of water discharging from two adjacent pipes at surface, namely a 110 mm PVC pipe with a relatively constant flow rate of ~0.5-1 L/s, and a 370 mm concrete pipe with variable seasonal flow rates ranging from ~16 L/s in winter to ~0.1 L/s in summer. Water discharge from each pipe also has a slightly different but distinct quality, despite the pipes being only ~2 m apart. The aims of the DVS hydrogeological investigation were to determine whether the "spring" source was groundwater discharge or leaking water reticulation infrastructure, and in the event of a groundwater source, to characterise and determine the feasibility of non-potable use of the DVS. Source investigation and characterisation of the DVS was undertaken through a historical literature review, remote/field-based geological/lineament mapping, surrounding groundwater user hydrocensus, electrical resistivity tomography surveying, weekly field-based flow rate and water quality measurements, and detailed hydrochemical analysis (including macrochemistry, microbiology, metals, hydrocarbons, pesticides, PFAS, and stable isotopes). Collated data indicated an anthropogenically-altered groundwater discharge source from two interacting aquifer types for both DVS pipes (with significant stormwater input into the concrete pipe during winter rainfall) – the thin (~1-5 m thick) surficial primary aquifer comprised of Holocene Witzand Formation (Sandveld Group) calcareous dune sand and other weathered Quaternary alluvial scree/talus/colluvium, and the thicker (~300 m in this area) underlying Ordovician Peninsula Formation (Table Mountain Group) quartzite fractured aquifer. It can be observed that in addition to ~550 million years of geological processes, over 250 years of modern human history and development have influenced groundwater flow and discharge at surface in the Dido Valley, but despite the latter this urban hydrogeological spring system is still suitable for non-potable use in terms of yield and quality.

Keywords: Cape Town, spring, Peninsula Formation, urban hydrogeology

EVALUATION OF INTERPOLATION METHODS FOR MAPPING POTENTIAL HYDROGEN FOR WINDHOEK MUNICIPAL BOREHOLES

Silas David[1]
[1]YES NETWORK, Namibia

Groundwater plays a vital role in geological and hydrogeological systems, yet its quality is increasingly threatened by both natural processes and human activities. One of the essential indicators of water quality is potential hydrogen (pH), which affects the solubility and bioavailability of chemical elements in the subsurface environment. Mapping the spatial variation of pH in Windhoek's municipal boreholes is crucial for enhancing groundwater monitoring and sustainable management efforts in the area. This research employed spatial and geostatistical analysis to evaluate various interpolation techniques based on observed pH values from 55 municipal boreholes. Using ArcGIS 10.6, the study compared deterministic methods such as Radial Basis Function (RBF) and Inverse Distance Weighting (IDW) with geostatistical methods, including Ordinary Kriging and Empirical Bayesian Kriging (EBK). Although interpolation allows for estimating values at locations without direct measurements, the accuracy of these estimations is highly dependent on factors such as sampling density, spatial distribution, and underlying geological variability. The effectiveness of each method was assessed using key statistical metrics, including mean square error (MSE), root mean square error (RMSE), mean standardised error, and root mean square standardised error. Results indicated that EBK, combined with a linear semivariogram model, produced the most reliable estimates, showing the lowest error values compared to other techniques. Overall, the findings highlight the advantage of geostatistical interpolation, especially EBK, for representing the spatial distribution of pH in Windhoek's municipal groundwater system under the prevailing geological conditions.

Keywords: GIS, Geostatistical, Boreholes, pH

GROUNDWATER OCCURRENCE IN THE CRITICAL ZONE IN THE WESTERN LIMB OF THE BUSHVELD COMPLEX

Sbusiso Dumakude[1]
[1]Anglo American Platinum, South Africa

This study investigates groundwater ingress into an underground mine on the northern edge of the Western Limb of the Bushveld Igneous Complex (BIC). The water ingress occurs at depths ranging from less than 300 m to over 1000 m below ground surface and presents an opportunity for the mine to potentially use the groundwater and reduce reliance on potable water supplies. Striking the balance between keeping the mine dry and maintaining a water supply presents a challenge that can only be overcome by fully understanding the quantity, quality and source of the groundwater. Underground mapping, hydrochemistry sampling, and stable isotope analysis were undertaken to delineate the quantity, quality, and possible source of the groundwater. The BIC is known to have low primary porosity and groundwater occurrence is therefore largely associated with the fractures that make up the fractured rock aquifer. However, underground mapping and the diamond drilling database revealed that in addition to fractures, there are certain lithological units that are prone to groundwater ingress. Groundwater chemistry showed three groundwater facies and a generally good water quality that can be largely classified as Class II as per the SANS 241 standards. The stable isotopes showed a varied groundwater source between the shallower levels and deeper levels. The Crocodile River Fragment is proposed to be a major recharge source via the Crocodile River Fault and the Middellaagte Graben Fault systems. A move away from grouting to a groundwater management system centred around active dewatering and monitoring is proposed to ensure a water supply, as well as dry and safe mining conditions. The continuous updating of the conceptual hydrogeological model with monitoring data is recommended.

Keywords: Bushveld Complex, Fractured Aquifer

MAG ASSEGAI: DRONE MAGNETICS PLATFORM COLLABORATIVE PROGRAMME

Stephanie Scheiber-Enslin[1], Francois Galluser[2], Laurent Ameglio[3] & Martin Clark[4]

[1]University of the Witwatersrand, Johannesburg, South Africa
[2]COLEOPTERE s.a.r.l., France
[3]EXIGE Pty Ltd, South Africa
[4]University of the Free State, Bloemfontein, South Africa

The University of the Witwatersrand and the University of the Free State, in partnership with EXIGE Pty Ltd (Australia & South Africa) and COLEOPTERE s.a.r.l. (France), have launched MAG ASSEGAI – a pioneering South African collaborative initiative focused on drone-based magnetic mapping. This programme is centred around the deployment of the VAMPair 'Scarab' drone magnetics platform, aimed at supporting both fundamental and applied research across South Africa. The integration of the 'Scarab' platform with Wits and UFS research capabilities opens up a wide range of applications that go well beyond traditional geological and structural mapping. It offers a powerful tool for identifying geohazards such as subsurface heavy metal contamination, structural instabilities like faults and sinkholes, and for applications in conservation and precision agriculture through soil condition mapping. This programme provides new opportunities for interdisciplinary collaboration. The drone system is operated under a third-party South African Civil Aviation Authority (SACAA)-certified Remote Operating Certificate (ROC) and piloted by a licensed Remote Pilot (RPL) from UFS. These stringent operational protocols ensure a high standard of safety and reliability, establishing a solid foundation for the long-term success of the MAG ASSEGAI programme. The initiative exemplifies the potential of open collaboration between academia and industry. The first project under MAG ASSEGAI involved high-resolution magneto-structural mapping of the Rising Star cave network. The drone, flying at an altitude of 15 m with 20-m line spacing, collected magnetic data to delineate fracture zones associated with cave entrances. These fractures appear in the magnetic data due to infill with high magnetic susceptibility material eroded from surrounding hills. This mapping provides a valuable tool for guiding further exploration of the cave system. The upcoming project will focus on the Vredefort impact structure, one of the world's largest and oldest known meteorite impact sites. Previous ground magnetic surveys have identified a network of linear magnetic lows, believed to be associated with collapse-related fracturing following the impact. The drone platform will be used to extend and refine these datasets, improving our understanding of the fracture systems and the broader geological history of the structure.

Keywords: Drone, magnetic, MAG ASSEGAI

WHEN EASY BECOMES MISLEADING: A CRITICAL LOOK AT GROUNDWATER DETECTORS

Francois Fourie[1], Greg Hodges[2], Libuseng Kolobe[3], Megan Naidoo[4], Stephanie Enslin[5,6], Susan Webb[6] & Wesley Harrison[4]

[1]Institute for Groundwater Studies, University of the Free State, Bloemfontein, South Africa
[2]Ottawa, Ontario, Canada
[3]Morethetho Drilling and Construction, Maseru, Lesotho
[4]SRK, Johannesburg, South Africa
[5]School of Geoscience, University of the Witwatersrand, Johannesburg, South Africa
[6]CIMERA, University of the Witwatersrand, Johannesburg, South Africa

In recent years, several nonstandard geophysical technologies for groundwater exploration have gained popularity among geologists and hydrogeologists who often lack formal training in geophysics. These systems are usually much more affordable than conventional geophysical equipment and are typically very easy to operate. In South Africa, systems that measure the natural variation in the Earth's electric field have become popular, particularly during and after the drought of 2018-2021. These systems claim to measure multiple frequency components of the electrical potential difference between two grounded electrodes. The frequencies are subsequently converted to depths of investigation by using a simplified equation for the skin depth of an electromagnetic plane wave penetrating a conductive medium. The recorded data are displayed as pseudo-sections of the magnitude of the measured potential difference (mV) against estimated depth of investigation (m). In this study, we critically examined from physical principles the assumptions on which groundwater detectors are based and evaluated examples of field data recorded with these systems. We identified several concerns, including: (1) To convert from frequency to depth through calculation of the skin depth, an average resistivity for the subsurface is assumed. Due to the heterogeneity of the subsurface, large errors in the estimated skin depth can be expected. (2) The skin depth corresponds to the depth at which the amplitude of a plane EM wave penetrating a conductive medium decreases by 63% due to attenuation, and does not in itself equate to the depth of investigation. (3) For each measurement, the recorded signal is attributed to subsurface locations vertically below the centre points between the grounded electrodes. (4) The pseudo-sections obtained are not subjected to inversion to obtain models of the subsurface. The raw data are directly interpreted in terms of changes in the subsurface properties at particular horizontal positions and at the estimated depths. (5) The repeatability of the results obtained with the groundwater detectors is questionable. To compare the results obtained with the groundwater detector to those obtained with standard geophysical methods (magnetic, frequency-domain electromagnetic, two-dimensional electrical resistivity tomography, self-potential and induced polarisation), we performed geophysical surveys with these methods on a single profile. Our results cast further doubt on whether the groundwater detector gives measurements from which the subsurface geological structure and groundwater content can be derived, and we conclude that the results obtained from these systems should be viewed with circumspection.

Keywords: Groundwater detector, Concerns, Assumptions, Nonstandard methods

CHALLENGES IN IMAGING LOCALISED CONDUCTIVE ZONES IN THE SUBSURFACE WITH 2D ERT SURVEYS

Kobus Haumann[1], Francois Fourie[1] & Surina Esterhuyse[2]

[1]Institute for Groundwater Studies, University of the Free State, Bloemfontein, South Africa

[2]Centre for Environmental Management, University of the Free State, Bloemfontein, South Africa

The two-dimensional electrical resistivity tomography (2D ERT) method responds to subsurface resistivity contrasts. It may, therefore, be used to investigate the presence of groundwater-bearing zones, which commonly manifest as localised low-resistivity zones in inverse models. These zones may be restricted in their spatial extents, either laterally, vertically, or in both directions. This study used forward and inverse modelling to evaluate the capability of 2D ERT to detect conductive zones in the subsurface, with a particular focus on the influence of physical and inversion parameters. Three idealised target geometries were considered: vertical conductive zones (VCZs), horizontal conductive zones (HCZs) and isolated conductive zones (ICZs) occurring at different depths and having different resistivity contrasts with their hosts. Modelling was done for the Wenner, Wenner-Schlumberger and Dipole-Dipole arrays using different spatial data densities. The modelling results show that inverse resistivity models obtained from 2D ERT data give reasonably accurate representations of ICZs and HCZs in the subsurface when these zones occur at shallow depths and when the resistivity contrast with the host rock is relatively small. In contrast, VCZs are generally poorly retrieved in the inverse models, even when these zones occur at small depths. The thicknesses of the VCZs are also generally overestimated. For deeper conductive zones and larger resistivity contrasts, the ability of the inverse models to retrieve the input models decreases. For both VCZs and ICZs, artefacts in the form of conductive zones laterally displaced from the input models appear in some of the inverse resistivity models for the Wenner and Wenner-Schlumberger data sets. These artefacts are due to the non-uniqueness of solutions to the inverse problem and could potentially be misinterpreted to correspond to subsurface conductive features, posing significant risks for groundwater exploration. Of particular importance is the fact that the HCZ thicknesses are overestimated in the inverse models when the conductive zones do not occur in the shallow subsurface as well as for large resistivity contrasts. In these models, the principle of equivalence affects the results. Inaccurate estimates of conductor thickness would likely lead to incorrect resource assessments.

Keywords: 2D ERT, groundwater, conductive zones, inversion artefacts

GROUNDWATER DETECTORS GEOPHYSICAL GROUNDWATER EXPLORATION: AN OPPORTUNITY AND A CHALLENGE

Modreck Gomo[1]

[1]Institute for Groundwater Studies, University of the Free State, Bloemfontein, South Africa

In recent years, several geophysical techniques have emerged for groundwater exploration. The Groundwater Detector is one of those approaches. Groundwater Detectors use the natural electromagnetic field to deduce information about groundwater potential. Based on the principles of the natural electric field frequency selection approach, a variety of equipment has been developed over the years in the Republic of China. There are two main types of Groundwater Detectors on the market: Telluric Electric Frequency Selection Method (TEFSM) and Telluric Magnetic Frequency Selection Method (TMFSM). The TEFSM appears to be more popular. Due to its low purchase and operation cost, the technology has been favourably received in many developing countries. While numerous studies are reporting successful application of the TEFSM approach in groundwater exploration, several challenges are also emerging. The presentation discusses the challenges and positive experiences from the application of the TEFSM approach in groundwater exploration to stimulate further research work needed to improve the knowledge base of the approach.

Keywords: Aquifers, Borehole siting, Telluric Electric Frequency Selection Method (TEFSM), Telluric Magnetic Frequency Selection Method (TMFSM)

GROUNDWATER POTENTIAL ZONE CONTROLLING SOURCE AND FLOW USING MULTI-CRITERIA DECISION-MAKING ANALYSIS (MCDMA) BASED ON ANALYTICAL HIERARCHICAL PROCESS (AHP) OF YANKARI GAME RESERVE AND ITS ENVIRONS, NORTHEAST NIGERIA

Josiah N. Jabbo[1,2], Adamu U. Mohammed[3], Ahmad Z. Aris[1,4], Mohammad F. Ramli[4] & Noorain M. Isa[1]

[1]Department of Environment, Faculty of Forestry and Environment, Universiti Putra Malaysia, Selangor, Malaysia
[2]Department of Geological Technology, School of Science and Technology Abubakar Tatari Ali Polytechnic Bauchi Nigeria
[3]Department of Applied Geology, Abubakar Tafawa Balewa University, Nigeria
[4]International Institute of Aquaculture and Aquatic Sciences, Universiti Putra Malaysia, Negeri Sembilan, Malaysia

Groundwater plays a crucial role in sustaining ecosystems and meeting the water demands of both human and wildlife populations. This study applies Geographic Information System (GIS) and Analytical Hierarchy Process (AHP) techniques to delineate groundwater potential zones within the unique ecological context of Yankari Game Reserve in Northeast Nigeria. The aim is to comprehensively understand the groundwater resources' spatial distribution and variability, aiding in sustainable water resource management. Eleven (11) thematic layer GIS component spatial datasets maps, which include rainfall, lineaments, geology, drainage density, soil types, landuse landcover, slope, curvature, topographic roughness index (TRI), topographic position index (TWI) and topographic wetness index (TPI), were integrated to create a comprehensive database for analysis. AHP, a multi-criteria decision-making technique, was then applied to assign weights to these factors based on their relative importance in influencing groundwater occurrence. The weighted layers were combined using GIS tools to generate a groundwater potential map, categorising the study area into high to low-potential zones. After cross-validation with data on the region's groundwater prospects, the output accuracy was 70% and above. Three classes were identified from the resulting groundwater potential zone map: high, moderate, and low. The results of the analysis found that a moderate groundwater potential zone dominates the study area's 88.11% (2,887.21 km^2), high groundwater potential zones dominate 11.85% (388.32 km^2), while low groundwater potential zones dominate 0.04% (1.20 km^2) of the study area. Only a small portion of the basin's total area is classified as having very high or very low potential zones. The study contributes to the scientific understanding of groundwater potential in Yankari Game Reserve and addresses the critical need for water resource management in ecologically sensitive areas. The delineation of groundwater potential zones facilitates informed decision-making for sustainable water supply planning, habitat preservation, and biodiversity conservation. The methodology presented can also serve as a model for similar studies in other regions, fostering a holistic approach to groundwater resource assessment and management. Ultimately, integrating GIS and AHP techniques proves to be a valuable tool set in supporting evidence-based decision-making for the sustainable utilisation of groundwater resources in environmentally significant areas like Yankari Game Reserve.

Keywords: Analytical Hierarchical Process, Groundwater Potential Zones

COMPARISON OF NUMERICAL MODELLING AND ANALYTICAL SOLUTIONS IN DEWATERING DESIGN FOR EXCAVATIONS: CASE STUDIES ACROSS CONTRASTING LITHOLOGIES

Louis Jonk[1], Albie Charles[1] & Hardy Luttig[1]
[1]GEOSS South Africa (Pty) Ltd, Stellenbosch, South Africa

Effective dewatering of the subsurface environment is playing an ever increasingly important role in urban developments. Understanding the dewatering requirements prior to construction is an essential but often overlooked consideration and can lead to expensive cost and time overruns, especially with regard to legislative considerations. Effective dewatering designs, especially for deeper excavations, therefore, require careful hydrogeological analysis to predict groundwater inflows and develop effective pumping and water transport strategies. Numerical modelling of the environment in a 3D space represents a powerful tool for this; however, this is typically a time-consuming and expensive exercise. Conversely, more simplistic 2D analytical solutions represent a much quicker and cost-effective option but may be ineffective to capture water movement in more geologically complex environments. Four case studies are presented, comparing numerical modelling and analytical solutions across contrasting lithological environments, assessing their accuracy and applicability in environments typical to urban areas of the Western Cape of South Africa. The first case study examines dewatering in cobble dominated alluvial deposits within a palaeo river course, where heterogeneous permeability within the *x*- and *y*-axes can greatly affect groundwater flow. The second case study involves well-sorted medium sands typical of coastal deposits where the relatively homogeneous system should favour analytical solutions. The third case explores clays, overlain by fine- to medium-grained colluvium, where variable layer permeabilities and morphologies necessitate a more complex approach, favouring the 3D capabilities of a numerical model solution. The final case focuses on a modified system, where a thick succession of unconsolidated sands overly a concrete slab, which in turn, overlies fractured shales of the Malmesbury Group. Modelled predictions could be compared to actual dewatering rates observed during excavation in some of the case studies presented with the accuracy between predicted and actual inflows highlighting the strengths and limitations of both approaches. Overall, analytical methods provided cost effective, first-order estimates, particularly in homogeneous settings, whereas numerical models better captured heterogenous environments, and systems with inherent anisotropic flow conditions. These findings reinforce the importance of selecting the appropriate modelling approach based on geological conditions, while also emphasising the value of field verification to refine dewatering designs.

Keywords: Dewatering, Modelling, Flow Conceptualisation, Groundwater

INVESTIGATING THE DIURNAL INFLUENCE ON TELLURIC ELECTRIC FREQUENCY SELECTION METHOD (TEFSM) GEOPHYSICAL SURVEY GROUNDWATER EXPLORATION

N. Matshotsa[1] & M. Gomo[1]

[1]Institute for Groundwater Studies, University of the Free State, Bloemfontein, South Africa

The Telluric Electric Frequency Selection Method (TEFSM) is a new geophysical technique used for groundwater exploration that measures natural electric currents to evaluate subsurface geology. Despite some successful applications in groundwater exploration, questions remain about TEFSM's measurement consistency regarding the diurnal effect on measurements. The TEFSM measures the natural electric currents, and the earth's electromagnetic field is subject to diurnal variation. It was hypothesised that TEFSM measurements are influenced by diurnal variation. This study investigates the diurnal effects on the TEFSM measurements and its influence on detecting a fractured-rock sandstone aquifer at the University of Free State Bloemfontein Campus Aquifer Test Site in South Africa. TEFSM surveys were conducted at various stations over four days during daytime (12 PM - 2 PM) and nighttime (7 PM - 9 PM). Electric Potential Difference (EPD) was recorded at 5-m depth intervals to a maximum depth of 300 m below ground level. Daytime and nighttime EPD readings were statistically compared. Results show that nighttime EPD readings were consistently higher. However, this did not influence the nature of the anomalies associated with the detection of a known fractured Karoo sandstone aquifer that occurs between depths of 15 m and 25 m. A strong positive correlation was found between daytime and nighttime EPD readings, indicating similar trends. The study contributes to improving reliability and establishing best practices for the application of TEFSM in groundwater exploration. Future research can look at the time series effect and the influence of noise on the TEFSM measurements.

Keywords: Electric potential difference, Groundwater exploration, Telluric Electric Frequency Selection Method, Karoo sandstone aquifer

HYDROGEOCHEMICAL ANALYSIS OF CLIMATE CHANGE IMPACTS ON GROUNDWATER IN THE NORTHEASTERN UPPER KAROO HYDROGEOLOGICAL REGION, SOUTH

Ouma Ngoepe[1], Amy Allwright[2], Paul Lourens[3] & Robert Hansen[4]

[1]Institute for Groundwater Studies, University of the Free State, Bloemfontein, South Africa
[2]Centre for Mineral Biogeochemistry, University of the Free State, Bloemfontein, South Africa
[3]Department of Earth Sciences, Stellenbosch University, Stellenbosch, South Africa
[4]Department of Geology, University of the Free State, Bloemfontein, South Africa

Climate change is increasingly altering the natural systems, with groundwater resources amongst the most vulnerable to the long-term influence of temperature and precipitation patterns. Amid the growing climate variability, this research project aims to explore how the long-term impact of climate change trends influences the groundwater hydrogeochemistry. To assess the influence of climate change on groundwater hydrogeochemistry, the study utilised the historical hydrogeochemical data (1993-2023) from the six monitoring stations within the Northeastern Upper Karoo hydrogeological region. Climate data of the same period, focusing on the annual precipitation and temperature trends, were analysed to determine the correlation with groundwater changes. The groundwater hydrogeochemical analysis focused on key physicochemical parameters such as pH, EC, TDS, TAL, Cl^-, K^+, Na^+, F^-, NO_3^-, Mg^{2+}, Ca^{2+}, and SO_4^{2+}. The hydrogeochemical approaches (Piper, GIBBS, PHREEQC, and SAR), geospatial tools (QGIS), and statistical analyses (correlation and WQI) were used to understand groundwater hydrogeochemistry. In addition, general circulation models were employed to establish the projected climate change trends (2024 - 2044), for insight into the potential future change in groundwater. The study has completed the analysis of groundwater hydrogeochemistry, showing trends across the stations. The hydrogeochemical results revealed that the groundwater across the study area is predominantly classified as Ca-HCO_3 and Na-HCO_3 types, shaped by the evaporation-precipitation hydrogeochemical mechanism. A distinct hot spring station, Aliwal North station, stands out from the rest of the stations, with elevated concentrations of F, Cl, Na, and high EC values, suggesting local geochemical or geothermal influence. The station also presented high SAR values, making the groundwater unsuitable for drinking, and a very poor WQI. While this component has been completed, the quantification of climate change impacts is still underway. However, preliminary climate data indicate high ion concentrations during hotter years, suggesting potential climate-driven influence on hydrogeochemistry. The final integration of the datasets will allow for more informed interpretation on how climate variability influences groundwater hydrogeochemistry.

Keywords: groundwater, hydrogeochemistry, climate change, Northeastern Upper Karoo hydrogeological region, general circulation model

DIKE-INDUCED AQUIFER MODELS FROM HIGH RESOLUTION MULTI-SPECTRAL SATELLITE IMAGERY: IMPLICATIONS FOR GROUNDWATER EXPLORATION

Samkelo Radebe[1] **& Martin Clark**[1]

[1]Department of Geology, University of the Free State, Bloemfontein, South Africa

The Main Karoo Basin of South Africa exemplifies an expanding arid region reliant on groundwater resources. Dolerite dikes in this region significantly influence subsurface groundwater flow and are often associated with high-yielding boreholes. This study remotely assesses the impact of dolerite dikes on groundwater flow using the Modified Soil Adjusted Vegetation Index, derived from high-resolution multispectral satellite imagery. Analysis of wet and dry season imagery from 2018 and 2021 identified two dominant dike-induced aquifer models across 505 mapped dikes: (1) barrier-controlled aquifers (56% of dikes) and (2) fractured aquifers (35% of dikes). Vegetation indices further confirm that areas overlying these aquifers sustain plant growth through dry seasons, demonstrating their hydrological resilience. These findings highlight the effectiveness of vegetation-based remote sensing in rapidly characterising dike-related aquifers and assessing their seasonal sustainability, critical for groundwater exploration and management in arid environments.

Keywords: Groundwater, Dolerite dikes, Aquifer models

ADVANCING NEAR-SURFACE GROUNDWATER PROSPECTIVITY USING MULTI-VARIATE MACHINE LEARNING MODELS: A CASE STUDY FROM THE MAIN KAROO BASIN OF SOUTH AFRICA

Samkelo Radebe[1] **& Martin Clark**[1]

[1]Department of Geology, University of the Free State, Bloemfontein, South Africa

Increasing drought intensity and frequency in arid and semi-arid regions necessitate advanced groundwater exploration techniques. This study assesses near-surface groundwater availability in the Main Karoo Basin (MKB) using machine learning models that integrate 24 conditioning factors, including spectral indices, topography, geological formations, and hydrological parameters. Among five models tested, the Fast Tree Decision Model demonstrated the highest classification accuracy (81.4%) and a robust ROC score of 0.87. The resultant groundwater prospectivity model exhibited a statistically significant correlation ($p < 0.00001$) with high-yielding boreholes, springs, and groundwater-dependent vegetation. High groundwater potential areas were identified along the Drakensberg Escarpment, the Cape Fold Belt, and the eastern MKB near the Indian Ocean. In the arid western MKB, localised high-prospectivity zones align with major geological structures and drainage network intersections, where borehole yields exceed 9 L/s. These findings illustrate the effectiveness of machine learning in regional groundwater assessment, particularly in data-scarce, arid environments.

Keywords: Near-surface Groundwater, Machine learning, Main Karoo Basin

USING GEOPHYSICS TO DETECT WATER-HOSTING FRACTURES IN THE VREDEFORT DOME

Elvis Tamilo[1], Stephanie Enslin[1] & Susan Webb[1]
[1]University of the Witwatersrand, Johannesburg, South Africa

The granitic Vredefort Dome, located 120 km southwest of Johannesburg, is the deeply weathered central uplift of a ~2-billion-year-old meteorite impact crater. Several fractures have been mapped in the region and are assumed to be due to late-stage collapse. The town of Parys is situated in the northwestern part of the dome, and for several years has been experiencing severe water shortages due to inadequate infrastructure and poor maintenance. This study investigates these fractures to determine their subsurface geometry and whether they host water, in an attempt to assist the local community, particularly farmers. The Wits University Africa Array field school has been conducted in the area since 2016, and the annually collected magnetic data shows several linear magnetic lows within the granitic terrane. It is assumed that the magnetic lows result from weathering and alteration of magnetic materials in the fractured granites. Several of these fractures line up with vegetation and have been mapped on surface. During the 2019 field season, an electrical resistivity survey (dipole-dipole) was conducted over one of these magnetic lows (~500 nT magnetic low) to determine if the low, assumed to be a fracture, could host water. This magnetic low correlated with a region of low resistivity values (~500 Ωm), suggesting it could host water. Euler deconvolution and magnetic modelling suggested an overburden thickness of ~10 m, and fracture width of 10–15 m. The fracture appears to extend to the south, based on visual clues (a similarly trending row of trees), and correlates with two boreholes 618 m south of the survey site. These boreholes, located 10 m lower in elevation, have water levels at ~6 m. This depth correlates with the depths from Euler deconvolution and modelling results. If these fractures can be reliably identified using magnetic data, this faster alternative to the resistivity method could support local communities, especially farmers, by helping to minimise the risk of drilling dry wells.

Keywords: Vredefort dome, fractures, electrical resistivity, magnetic data

HYDROGEOLOGICAL CONTROLS IMPROVE PORE PRESSURE MONITORING FOR UNDERGROUND SUPPORT AND SLOPE STABILITY MANAGEMENT

Amantle Tiroyame[1] & Reece van Buren[1]
[1]Digital Surveying, Carletonville, South Africa

Pore pressure monitoring is a critical component of hydrogeological management in both open-pit and underground mining operations. As mining activities and infrastructure projects expand, they impact upon the local pore pressure which significantly impact slope and underground face and hanging wall stability due to the increased hydraulic forces exerted on the rock mass, as well as the reduction in friction along existing fractures. To mitigate these risks, detailed hydrogeological modelling is conducted utilising groundwater monitoring data acquired within boreholes at significant expense. Wireline formation evaluation, often referred to generally as downhole geophysics, plays a pivotal role in selecting suitable boreholes for installation and in identifying optimal locations within boreholes for the installation of piezometers. This approach not only improves overall pore pressure management but also reduces costs associated with poor borehole selection and sensor placement, thereby supporting safer, more efficient and cost-effective mining operations. Selecting the right borehole for instrumentation installation presents challenges. Mine models, while useful, may not perform well in areas with complex aquifers where underground water movement is controlled by the primary matrix and/or fracture networks. Additionally, ensuring boreholes are in the correct condition for accurate measurement is crucial. This involves checking borehole integrity, identifying washout and breakout zones, and the location of piezometers near water strikes or active flow areas. Installation of the sensors requires effective grouting of the boreholes, the estimation of which is also aided by knowledge of borehole geometry. To address these challenges, expert combination of in situ measurement technologies, including callipers, flow meters, televiewers, and borehole magnetic resonance (BMR), accurately characterise litho-structural features (including fracturing), formation saturation (total porosity), free and bound fluid components, and hydraulic conductivity. Central to the detailed hydrogeological characterisation of aquifer zones is the BMR technology which directly detects hydrogen nuclei within the formation, continuously along the entire length of the borehole. This revolutionary technology allows the differentiation of free and bound fluid volumes, which when combined with fracture network information forms a powerful toolkit for the modern mining team enabling the execution of high confidence groundwater management programmes.

Keywords: magnetic resonance, depressurisation, slope stability

MAPPING GROUNDWATER POTENTIAL ZONES USING ARTIFICIAL INTELLIGENCE (AI) TECHNIQUE AND GIS: A CASE STUDY IN CAPRICORN AND SEKHUKHUNE DISTRICTS, SOUTH AFRICA

P.J. Tleane[1], B. Mahlase[1], G. Mohale[1], H. Coetzee[1], S. Ndumo[1] & T. Ramukumba[1]

[1]Council for Geoscience, Pretoria, South Africa

Groundwater mapping is essential for meeting the water requirements of people. The Council for Geoscience (CGS) conducted research studies in the Capricorn and Sekhukhune Districts, Limpopo Province, South Africa, with the objective of mapping groundwater potential zones of the area using a CGS Artificial Intelligence Groundwater Development (AI-GWD) software and a Geographic Information System (GIS) platform. The regional basement geology of the study area mostly consists of granitoids and greenstones that formed the stable Kaapvaal Craton during the Archaean age. For delineating groundwater potential zones, the AI software was used by applying the overlay and index techniques based on the knowledge discovery in databases (KDD) process. This technique was applied to integrate a total of seven thematic layers, namely drainage density, slope, geology, soil, geomorphology, rainfall, and land use / land cover. These thematic layers were then converted to rasters using GIS. Layers were assigned weights (1-10) using the weighted index overlay analysis according to the relative importance based on expert knowledge of the groundwater system. The aggregate weight value of each sub-class in the integrated layer was categorised into four individual groups (high, moderate, low, and very low) as groundwater potential zones. The results show that the Capricorn District has a moderate to high groundwater potential zone, whereas the Sekhukhune District has a low groundwater potential zone which is generally influenced by low rainfall and the local geology- associated with the rocks of the Bushveld Complex. The validation of the model was performed using available borehole yield values from the GRIP database. The Receiver Operating Characteristic curve (ROC) method was used for the validation process and the accuracy was calculated at 81%, which is classified as Good.

Keywords: Artificial intelligence (AI), Groundwater potential, Knowledge Discovery Databases (KDD), Capricorn and Sekhukhune Districts

DIAGENETIC PROCESSES AND THEIR IMPACT ON POROSITY EVALUATION IN THE OTAVI MOUNTAIN LAND CARBONATES OF THE DAMARA SEQUENCE: IMPLICATIONS FOR RESERVOIR QUALITY

Wilhem Tomas[1] **& Collen-Issia Uahengo**[1]
[1]University of Namibia, Windhoek, Namibia

The Otavi Mountain Land (OML) carbonates, part of the Damara Sequence in northern Namibia, hold significant potential as hydrocarbon and groundwater reservoirs due to their complex diagenetic history. This study investigates the diagenetic processes such as dolomitisation, calcitisation, karstification and silicification that have altered the porosity and reservoir quality of these Proterozoic carbonates in the Otavi Mountain land. By combining field mapping and sampling with laboratory techniques including petrographic analysis, X-ray diffraction (XRD), scanning electron microscopy (SEM), and mercury injection capillary pressure (MICP) testing, the research aims to identify the key diagenetic alterations. Understanding these processes is crucial for storage and flow potential of these carbonates. The findings will contribute to a better understanding of diagenetic controls on reservoir properties in carbonate systems and support future exploration strategies for hydrocarbons and mineral resources in the Damara Belt.

Keywords: Damara Sequence, Otavi Mountain Land, Diagenesis, Carbonates

FALSE SIGNALS: THE FIGHT FOR INTEGRITY IN GEOPHYSICAL METHODS

Susan J. Webb[1], Francois Fourie[2], Greg Hodges[3], Megan Naidoo[4], Stephanie Enslin[5] & Wesley Harrison[4]

[1]CIMERA and School of Geoscience, University of the Witwatersrand, Johannesburg, South Africa
[2]Institute for Groundwater Studies, University of the Free State, Bloemfontein, South Africa
[3]Ottawa, Ontario, Canada
[4]SRK, Johannesburg, South Africa
[5]School of Geoscience, University of the Witwatersrand, Johannesburg, South Africa

The very first paper in the inaugural issue of Geophysics (1936), titled "Black Magic in Geophysical Prospecting", highlights how the industry has long grappled with unproven and unscientific methods claiming to detect everything from oil and minerals to groundwater. These practices continue to undermine the credibility of legitimate geophysical research and applications. While scientifically trained geophysicists can often spot these flawed approaches, explaining their limitations to non-specialists and decision-makers remains challenging. Groundwater exploration is especially vulnerable, frequently targeted by techniques such as dowsing and a host of other methods having no scientific basis or credible proof they work. Similar issues arise in mineral and energy sectors, where exaggerated claims of precision and success persist. Common warning signs include vague or implausible physical principles, claims of sensitivity and interpretation far beyond any other method, secrecy around methodology, and defensiveness when challenged. Whether driven by enthusiasm, poor science, or intentional deception, the result is the same: wasted resources, misinformed decisions, and erosion of trust in sound geophysical science. In this work, we review several well-documented cases of fraudulent or discredited geophysical methods, as well as instances where legitimate science has been misrepresented or oversold. We also propose a practical framework for evaluating new and nonstandard geophysical techniques. To minimise costs, organisations often turn to tools that promise fast, inexpensive solutions but fail to adhere to fundamental physical principles. While the appeal of cost savings is understandable, the long-term risks of relying on such methods are significant – particularly in water-stressed regions, where poor decisions based on faulty methods can deepen resource scarcity. To protect both scientific integrity and public investment, funding agencies, regulatory bodies, and industry stakeholders should implement independent, transparent technical assessments by qualified experts before endorsing or funding nonstandard geophysical technologies. These evaluations must be rigorous, reproducible, and publishable. Refusal to undergo such scrutiny should be treated as a serious warning sign. Promoting scientific accountability does not stifle innovation – it ensures new tools are grounded in transparent, testable science. This is especially crucial in groundwater exploration, where the line between science and pseudoscience is often dangerously thin.

Keywords: Unconventional Geophysics, Quality Control, Groundwater Technique validation

SEEPAGE ALONG AN UNLINED TAILINGS DAM IN THE WITWATERSRAND BASIN

Jordyn Young[1,2]
[1]University of Pretoria, Pretoria, South Africa
[2]Knight Piesold, South Africa, Sandton, South Africa

Seepage from unlined gold tailings storage facility (TSF) is a possible source of contamination to the underlying aquifers. Seepage was observed to emanate along the northwest toe of a tailings dam in Free State, South Africa. This necessitated research to identify where the seepage was arising from and suggest possible solutions to control and mitigate contamination of the underlying aquifers, which are utilised by surrounding landowners for domestic and stock watering purposes. The aim of this study is to identify the possible contaminant migration pathways for seepage from the TSF towards downgradient receptors and how mitigation strategies can be optimised to protect groundwater resources. The underlying geology is comprised of mudstones and sandstones, which have been intersected by dolerite dykes. The mudstones have low permeability and high storativity, while the sandstones have high permeability and low storativity due to bedding planes. The intruded dolerite dykes have created possible pathways for groundwater to flow along the geological contacts. The methodology implemented included data analysis of surface and groundwater monitoring data collected over three years. Piper Plots were populated using surface water quality data, and samples that plotted in the same hydrogeological facies were identified. A key finding was that two samples from opposite sides of the TSF exhibited similar chemical signatures. This was confirmed through Stiff Plots. The same methodology was used for analysing groundwater chemistry. Piper Plots and borehole locations helped identify outliers. Downgradient samples were expected to be impacted by contamination from mining processes, while upgradient samples were anticipated to reflect fresh recharge. This hypothesis was supported for most samples but was rejected for one downgradient borehole. The explanation for this change in hydrogeological facie is possibly a change in permeability of the underlying geology, thereby containing or reducing the impact of poor-quality seepage at that point. Trends in data showed an inverse relationship between chloride and nitrate ions, suggesting two primary contamination sources: chloride from mining activities and nitrate from farming. The findings confirm that the TSF is releasing contaminants into groundwater, highlighting the need for mitigation procedures to prevent further deterioration of groundwater resources.

Keywords: seepage, contamination, flow pathways, hydrochemical

Kimberlites, Diamonds and the Deep Lithosphere

DIAMOND GROWTH AND DESTRUCTION CONSTRAINED USING DIAMOND MORPHOLOGY AND SURFACE ETCH FEATURES, ROBERTS VICTOR KAAPVAAL LAMPROITE, AND COMPARISON WITH KIMBERLITIC DIAMONDS

Michelle A. Brits[1], Geoffrey H. Howarth[1], Sara Burness[1] & Yana Fedortchouk[2]

[1] Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa

[4] Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia, Canada

Diamonds that form in the deep mantle are important time capsules of Earth's evolution. Diamond morphology and surface features reflect the conditions diamonds have been subjected to in the mantle. 4502 small diamonds (1 – 4 mm in diameter) were sampled from the Early Cretaceous (126 Ma) Roberts Victor Kaapvaal lamproites in South Africa. They are classified into categories based on their morphologies and surface features, using optical microscopy and SEM. Morphological categories include octahedra, tetrahexahedra (THH), aggregates, cubes, spheres, and broken fragments. They are subdivided by their edge sharpness, {111} face shape, and surface features. 2009 broken diamonds are excluded from the study. Of the entire parcel, including the fragments, octahedra and THHs constitute 30 % and ≈15 %, respectively. Pre-lamproitic (mantle) dissolution results in various etch features developing on octahedral faces, including laminae, deep hexagonal and trigonal pits, etc. These features are compared with previous experiments to confine their origin and conditions for their development. Mantle resorption forms trigonal {111} faces and pronounced surface etching. Lamproitic resorption produces rounded, ditrigonal {111} faces and THHs. Lamproitic dissolution can either be fluid-bearing, i.e. dominated by H_2O or CO_2, or volatile-undersaturated. Fluid-bearing resorption develops rounded diamonds with minor etch features, while fluid-undersaturated resorption develops significant etching, preserving the general shape, but extensively corroding the {111} faces. Trigons are common on the octahedral faces. Their dimensions are determined by Atomic Force Microscopy (AFM). Their geometries provide insight into the volatile types, and their proportions involved in the dissolution of diamonds within the lamproitic melt. Point-bottomed (p/b) trigons form from CO_2-rich resorption, whereas flat-bottomed trigons (f/b) are from H_2O-rich resorption. Three trigon combinations were identified: 1) only f/b trigons, 2) only p/b trigons, and 3) both types, on {111} faces. Most (>90 %) of 1221 ditrigonal octahedra and 672 THHs display the first variety, suggesting H_2O as the dominant volatile in the magma. Type 2 is the least common among the diamonds, suggesting that CO_2 played a smaller role in dissolution. This is consistent with the highly micaceous nature of Kaapvaal lamproites, implying elevated H_2O contents, relative to typical kimberlites.

Keywords: diamond, morphology, Kaapvaal, lamproites

DIAMONDS IN THE KAROO

Mike C.J. de Wit[1]

[1] University of Stellenbosch, Stellenbosch, South Africa

In the early 1930s diamonds were found in terrace gravels along the Sak River, upstream of Brandvlei (Northern Cape Province) over a distance of some 70 km. The bedrock of the gravels comprises rocks of the Middle to Lower Ecca Group, while the headwaters of the Sak River drain Beaufort Group sediments near Sutherland. The gravels occur at two stratigraphic levels. The higher-level gravels, that occur between 40 and 50 m above the present river, have been assigned a Miocene age based on palaeontological evidence. The lower-level terraces, at an elevation of some 20 to 30 m above river level, are Plio-Pleistocene in age. The high-level deposits have been partly reworked to form hill slope and fan deposits, while the lower terraces resemble proximal braided stream deposits on expansion bars. More recent bulk sampling confirmed the presence of diamonds that are only lightly abraded and are mostly dodecahedron in shape. The colour of quit a number of these diamonds are shades of brown. In addition to diamonds, the older gravels also contain polished and well-rounded typical 'Orange River' clasts such as BIF, calcedony, agate, jasper as well as unabraded pieces of silcrete that are linked to the Late-Cretaceous African Surface. Since these deposits occur stratigraphically and topographically well above the Dwyka, the latter can be excluded as the source of these exotics. These are rather linked to a palaeo-course of the Orange River, also referred to as the Karoo River, that then followed a more southerly route. Up to the Mid-Cretaceous this palaeo-river supplied diamonds from the Kaapvaal Craton to the coastal areas of southern Namaqualand. Around the Albian/Cenomanian, it was captured by the Kalahari River, a palaeo-Molopo/Lower Orange River, and its exit shifted northwards to approximately the position of the present Lower Orange River. During the Miocene, diamonds that were left behind in remnant Karoo River terraces south of Brandvlei were reworked by the palaeo-Sak River and preserved in Miocene gravels. The younger Plio-Pleistocene terraces along the Sak trapped diamonds that were derived from erosion of the Miocene terraces and from the last Cretaceous remnants in its upper reaches.

Keywords: alluvial diamonds, palaeo-drainage, Karoo, Sak River

TECTONIC PROCESSES AFFECTING THE CENTRAL KAAPVAAL CRATON

Fezeka Dliwako[1], Karen V. Smit[1] & Linda M. Iaccheri[1]

[1] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

The Kaapvaal Craton is one of the best-preserved ancient terrains for studying early Earth processes. While extensive geochronological work has focused on the Barberton Greenstone Belt and the Ancient Gneiss Complex in the eastern Kaapvaal, the central Kaapvaal crust remains less explored. Our study aims to shed light on the tectonic processes that shaped the heart of the Kaapvaal Craton and the continental assembly and tectonic events that influenced this ancient part of southern Africa. To investigate the age and evolution of the central Kaapvaal Craton, our study will analyse Archaean TTG gneisses from the Nooitgedacht Platform in the Johannesburg Dome. The 29 TTG samples from the Nooitgedacht Platform exhibit metaluminous to peraluminous compositions (SiO_2 ~70 wt.%), high Na_2O (3–7 wt.%), and LREE enrichment with HREE depletion, consistent with metasomatism observed in global Archaean TTGs. Zircons separated from four TTG samples were characterised to determine their crystallisation history. A total of 138 zircon grains were recovered, with the majority being magmatic and a subset displaying metamorphic characteristics. The magmatic zircons exhibit oscillatory zoning, with some showing sector zoning, while the metamorphic zircons are unzoned. Zircons will be dated using in situ U-Pb isotopes to constrain crystallisation and metamorphic ages for the zircons. These crustal ages will be supplemented by Sm-Nd and Lu-Hf isotopes on a subset of samples to shed light on the timing of crustal formation and the potential protolith of the TTGs. Our work on the central Kaapvaal crust will be augmented with work on peridotite xenoliths from Roberts Victor, that represent the lithospheric mantle below the central Kaapvaal Craton. At Roberts Victor, prior research has primarily targeted the abundant eclogite xenoliths, with peridotitic xenoliths receiving little attention due to their rarity and extensive weathering. Investigating the specific age relationships between the mantle roots of cratons and their overlying crust will help constrain the mode of craton formation, whether at convergent margins, within a stagnant or partially mobile lid, and with either plume and/or subduction geochemical signatures. Preliminary results show that the Roberts Victor xenoliths have pyroxenitic-lherzolitic assemblages, similar to Voorspoed diamond mineral inclusions. Pressure-temperature estimates (2.8–5.2 GPa, 681–1021 °C) suggest a lithospheric thickness of 220–230 km. We aim to date these xenoliths using Lu-Hf isotopes in garnets and Pb-Pb and Rb-Sr isotopes in clinopyroxenes.

Keywords: Archaean, TTG, peridotite, Kaapvaal Craton

USING GEOPHYSICS TO EXPLORE FOR KIMBERLITES: A BOTSWANA CASE STUDY

Oleg Brovko[1], Stephanie Scheiber-Enslin[1] & Susan Webb[1]

[1] University of the Witwatersrand, Johannesburg, South Africa

As the “easy” kimberlites have already been found worldwide, there is a need for improved detection and characterisation of kimberlites in regions with significant sedimentary cover. This research demonstrates the benefits of integrating multiple geophysical methods for improved exploration and understanding of the kimberlite morphology. This research investigates the geophysical characteristics of the Tsabong kimberlite field in Botswana, focusing on the integration of magnetic, gravity, electromagnetic (EM), and audiomagnetotelluric (AMT) methods to detect and characterise kimberlite pipes under thick sedimentary cover. The research highlights key findings related to geophysical signatures, with 67 out of 68 kimberlites exhibiting distinct magnetic anomalies, including dipolar, monopolar and remanent dipole signatures. Additionally, a correlation was identified between gravity low anomalies and conductive EM responses, indicating the presence of a low-density, clay-rich crater infill. A detailed case study of the Molopo 1 kimberlite demonstrated the effectiveness of combining geophysical techniques for modelling subsurface structures. The magnetic data revealed three distinct lobes with varying susceptibilities and depths, while gravity and AMT modelling confirmed the crater’s asymmetrical geometry.

Keywords: kimberlite, geophysics, Botswana, exploration

GEOCHEMICAL DIFFERENCES BETWEEN DOLOMITIC AND CALCITIC SOUTHERN AFRICAN CARBONATITES EXPLAINED BY VARYING EXTENTS OF MELT-PERIDOTITE INTERACTION

Philip E. Janney[1], Ibiyemi Ogungbuyi[1] & Manoka Marageni[3]

[1] Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa

Carbonatites represent the smallest-degree mantle melts that reach the Earth's surface. Southern Africa hosts an unusually large number of carbonatite complexes, consisting of dolomite- and/or calcite-bearing varieties, which are in often combination with silica-undersaturated igneous rocks (syenites, ijolites, lamprophyres, trachytes etc.). We have obtained a large suite of radiogenic and stable isotope and ICP-MS trace element data on Cretaceous to recent carbonatites from western South Africa (Salpeterkop, Zandkopsdrift) and Namibia (Marinkas Quellen, Teufelskuppe, Keishoë, Dicker Willem, Agate Mountain, Osongombo, Ondurakorume, Okorusu, Kalkfeld). This new data, combined with literature data, demonstrate that, on the whole, dolomitic carbonatites show significantly greater diversity in trace element ratios (e.g., Ba/Nb, Th/Nb and La/Nb) than calcitic carbonatites. This is independent of the radiogenic isotope compositions of the carbonatites, which range from enriched mantle (EM I) to HIMU affinities. A plausible explanation for this difference is that dolomitic carbonatites have managed to ascend through the lithospheric mantle with minimal interaction with lithospheric peridotite, whereas calcitic carbonatites likely began as dolomitic, but they underwent grain boundary flow to a much greater degree and experienced significantly more melt- rock reaction with the surrounding lherzolite. This process would have resulted in enrichment of the nearby mantle in clinopyroxene and olivine, and depletion in orthopyroxene, converting the lherzolite into metasomatic wehrlite (e.g., Dalton & Wood, 1993; Lee and Wyllie, 2000) and the conversion of the originally Mg-rich carbonatite melts into calcite carbonatites. This reaction appears to have provided a buffering effect that limited the trace element variation of the calcite carbonatites. This is also supported by the fact that ratios of HFSE to REE, for elements of nominally similar incompatibility (particularly Zr/Sm and Ti/Eu), are significantly lower on average in dolomitic carbonatites, and are higher and closer to primitive mantle values in calcite carbonatites, the latter of which is what would be expected for melts that have experienced significantly greater exchange with mantle peridotite.

Keywords: carbonatite, peridotite, metasomatism

GEOCHEMICAL COMPARISON OF MANTLE LITHOSPHERE ON AND OFF THE EASTERN KAAPVAAL CRATON: PERIDOTITE XENOLITHS FROM EAST GRIQUALAND AND NORTHERN LESOTHO KIMBERLITES

Teboho Nkotsi[1] & Philip Janney[1]

[1] Department of Geological Sciences University of Cape Town, Rondebosch, South Africa

Peridotite xenoliths from on-craton kimberlites in northern Lesotho (SE Kaapvaal craton) and East Griqualand (southern Lesotho and adjacent portion of the Eastern Cape in the Namaqua-Natal Province) are similar in that they display an exceptionally wide range of modal mineralogies, from highly depleted harzburgites to highly metasomatised peridotites with large modal proportions of clinopyroxene, phlogopite and/or amphibole. Similarly, peridotites from these two regions display an extremely wide range of textural types from coarse granular to fluidal porphyroclastic and even mylonitic textures, and both groups tend to fall at higher temperatures for a given pressure relative to the average Kaapvaal geotherm) The extremely wide lithological and textural diversity of these xenoliths (compared to those from other nearby on- and offcraton kimberlites) is curious given that the northern Lesotho (~90 Ma) and East Griqualand kimberlites (~150-200 Ma) differ substantially in age. We present new mineral major and trace element data for peridotite xenoliths from Matsoku (northern Lesotho) and East Griqualand kimberlites. We will present reconstructed whole-rock major and trace element compositions of xenoliths based on modal analysis and mineral data and use this information to estimate: (1) degrees and depths of partial melting, (2) metasomatic fluxes and compositions of metasomatic melts. We will further compare these estimates for northern Lesotho and East Griqualand peridotites with those calculated similarly for nearby localities for which data have been reported. Our aims are to provide insight into the processes responsible for the extreme diversity in the extents of melt depletion and metasomatism experience by the regional mantle lithosphere and to determine whether these peridotites constitute a distinct population that might indicate a distinct history (e.g., possibly related to a common phenomenon such as proximity to the upwelling mantle plume responsible for Karoo magmatism).

Keywords: mantle, peridotite, metasomatism, kimberlite

REVIEWING THE IMPLICATIONS OF WEATHERING ON KIMBERLITES FOR MINERAL CARBONATION AT THE CULLINAN/PREMIER DIAMOND MINE

Avela Mantshontsho[1] **& Zakhele Nkosi**[1,2]

[1] University of Pretoria, Pretoria, South Africa,
[2] University of Johannesburg, Auckland Park, South Africa

Studies on mineral carbonation suggest that kimberlites may have significant carbon sequestration potential as they comprise accessible mafic minerals highly reactive with atmospheric CO_2. To empirically validate the carbon sequestration potential and reactivity of these kimberlite target minerals at an industrial scale, it is necessary to conduct a thorough mineralogical characterisation of them. This study explores the impact of weathering on the mineral composition of kimberlites and their resulting tailings, with a specific focus on understanding how this weathering affects the reactivity, particularly the dissolution rate, of essential calcium- and magnesium-bearing minerals crucial for natural mineral carbonation. Thus, this study sets out the following objectives: First, identifying and characterising the minerals in the blue ground kimberlites and their ~80-year-old and contemporary fine residue tailings. Secondly, the relative abundance of these minerals is assessed to evaluate the impact and extent of weathering on the tailings compared to the blue ground samples. Finally, the study aims to compare the mineral assemblage between the blue ground kimberlite and the tailings, validating their respective weathering pathway. Six blue ground kimberlite samples, along with their fine residue tailings obtained from the Cullinan Diamond Mine, were the subject of this study. Semi-quantitative XRD characterisation was performed on both the kimberlites and the tailings to gain insight into the specific mineral phases present. The findings revealed the presence of talc and serpentine in the kimberlites, alongside other primary clay minerals. Serpentine was consistently observed in the tailings, while vermiculite and smectite showed a distinct prevalence in the contemporary tailings and talc and clinochlore in the 80-year-old tailings. Comparing the mineralogy and physical properties of the [unweathered] blue ground kimberlite with those of its weathered tailings is key to understanding the extent and limitations of mineral carbonation within the latter. The hypothesis, therefore, is that kimberlite weathering negatively impacts mineral carbonation. This is because the resulting stable minerals restrict the dissolution rates of required cations for reacting with carbon dioxide to create carbonated minerals. These are beneficial by-products for natural and potentially enhanced carbon sequestration in mines.

Keywords: mineral carbonation, carbon sequestration, kimberlites, clay minerals

SPECTROSCOPIC CHARACTERISATION OF PALMIETGAT DIAMONDS

Puleng Nthebe[1,2], Karen V. Smit[1], Lewis D. Ashwal[1] & Susan J. Webb[1]

[1] University of the Witwatersrand, Johannesburg, South Africa

[2] Gemological Institute of America, USA

The Palmietgat Group I kimberlite dykes intruded into the northern Witwatersrand Block of the Kaapvaal Craton around 100 Ma. The Palmietgat kimberlites are located in the centre of the 2.06 Ga Bushveld Igneous Complex, providing an opportunity to assess how the Kaapvaal lithospheric mantle and its diamond budget was affected by plume magmatism. Our ongoing research aims to characterise a suite of Palmietgat diamonds using Fourier Transform Infrared (FTIR) spectroscopy, Ultraviolet-Visible (UV-Vis) absorption spectroscopy, along with analysis of diamond external morphology. Preliminary FTIR results indicate that the diamonds in our suite are predominantly Type Ia, with varying concentrations of A and B nitrogen aggregates. The FTIR data will be used to determine mantle residence temperatures of the Palmietgat diamonds, and whether these diamonds resided at higher temperatures in the lithospheric mantle due to the thermal impact of the Bushveld Complex. UV-Vis spectroscopy is being employed to detect any optical centres that may be responsible for diamond colour. The external morphology and surface features of Palmietgat diamonds will be described using a combination of optical and Scanning Electron Microscopy (SEM). These morphological observations will be integrated with spectroscopic data to provide insights into the diamonds' formation history and transport mechanisms. Collectively, these findings will contribute to a more comprehensive understanding of the geological processes that shaped the diamond potential of the Palmietgat lithospheric mantle and kimberlites.

Keywords: Palmietgat, diamonds, spectroscopy, morphology

THE ORIGIN OF MEGACRYSTS AND THEIR RELATIONSHIP TO THE HOST KIMBERLITE - CAMP ALPHA KIMBERLITE, LIBERIA, WEST AFRICAN CRATON

Ellwin Taleni Shiimi[1], A. Giuliani[2], G.H. Howarth[1], P.E. Janney[1] & S.E. Haggerty[3]

[1] Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa
[2] Earth and Planets Laboratory, Carnegie Institution for Science, Washington DC, USA
[3] Earth and Environment, Florida International University, Miami, USA

Kimberlites often contain large, chemically homogeneous crystals and intergrowths called megacrysts, though their origin and connection to kimberlite magmatism remain debated. This study investigates 366 megacrysts—garnet, clinopyroxene, orthopyroxene, ilmenite, and zircon—from the Camp Alpha kimberlites in Liberia, within the West African Craton (WAC), using major and trace element analyses, along with Sr-Nd-Hf-Pb isotopic data for a representative subset. The majority of the megacrysts belong to the Cr-poor suite, showing broad compositional variation and coherent fractionation trends that are consistent with crystallization from similar evolving melts. Clinopyroxene thermobarometry indicates equilibration at 1,396–1,444 °C and 6.1–6.2 GPa, implying formation near the lithosphere-asthenosphere boundary (~201 ± 10 km depth), consistent with geophysical and xenocrystic estimates for WAC lithospheric thickness. A subset of megacrysts, including garnet and ilmenite with higher Mg# and pyroxenes with elevated Ca#, exhibits features transitional between Cr-poor and Cr-rich types. These are more enriched in incompatible elements, suggesting open-system behavior involving progressive interaction with metasomatized mantle lithosphere. Their equilibration temperatures and pressures (946–1,336 °C, 4.3–6.7 GPa) reflect crystallization at various depths within the SCLM. Zircon U-Pb dating yields an age of 763 ± 7 Ma, while the Sm-Nd isochron defined by garnet and clinopyroxene define an age of 807 ± 40 Ma—closely aligning with the time (762 ± 9 Ma) of kimberlite emplacement. Sr isotopic values of clinopyroxene (0.7022–0.7033) overlap with groundmass perovskite (0.7023–0.7031), reinforcing a genetic link, though clinopyroxenes extend toward less radiogenic compositions. The trace element concentrations of melt compositions in equilibrium with megacrysts match Camp Alpha kimberlites, supporting derivation from a common proto-kimberlite melt. Combinations of major elements Nd-Hf isotopes in the megacrysts suggest a petrogenetic scenario where Cr-poor megacrysts crystallised from primary asthenospheric melts similar to kimberlites whereas transitional Cr-richer megacrysts formed later after progressive interaction between melt and metasomatised lithospheric domains with peridotite affinity. We propose that Cr-poor megacrysts formed via high-temperature fractional crystallization of proto-kimberlite melts at the base of the lithosphere, while ascending melts assimilated surrounding metasomatised mantle, generating transitional megacrysts at lower melt/rock ratios.

Keywords: Megacrysts, Kimberlite, Fractional Crystallization, Metasomatism

PLUME-RELATED DIAMOND FORMATION IN REWORKED ARCHAEAN MANTLE: SM-ND AGE CONSTRAINTS FROM VOORSPOED PERIDOTITIC AND ECLOGITIC DIAMONDS (KAAPVAAL CRATON)

Karen V. Smit[1], Gareth R. Davies[2], Ingrid L. Chinn[3], Janne Koornneef[2] & Michael U. Gress[2]

[1] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

[2] Vrije Universiteit, Amsterdam, The Netherlands

[3] De Beers Exploration, Johannesburg, South Africa

Here we study silicate inclusion-bearing diamonds from the Voorspoed Group II kimberlite (also known as carbonate-rich olivine lamproites—CROLs) in the central Kaapvaal Craton. The peridotitic garnet and clinopyroxene inclusions define three compositional groups that are temporal with lithospheric refertilisation and re-healing related to 2.79–2.68 Ga Ventersdorp-related plume magmatism across the central Kaapvaal craton. Three harzburgitic G10 inclusions define an isochron of 2877 ± 249 Ma, with initial ε_{Nd} = -15 ± 10, that correlates with the oldest Kaapvaal enriched components as represented by crust in the 3.66–3.22 Ga Ancient Gneiss Complex, and is consistent with harzburgitic diamond formation in the oldest >3.2 Ga Kaapvaal lithospheric mantle. Five lherzolitic G9 garnet and 11 Cr-diopside inclusions with La_N >1 and low (Sm/Nd)N (0.4–3.8), define a 2606 ± 95 Ma Sm-Nd isochron with an initial ε_{Nd} = -6.9 ± 5.4 that is consistent with diamond formation in enriched >2.7 Ga lithospheric mantle. Four lherzolitic G9 garnet and five Cr-diopside inclusions with La_N <1 and higher $(Sm/Nd)_N$ (1.4–3.7), define a 2560 ± 51 Ma Sm-Nd isochron with an initial ε_{Nd} = 9.8 ± 7.8. This initial ratio overlaps with depleted mantle indicating rapid rehealing of the lithospheric mantle after the 2.79–2.68 Ga Ventersdorp-related plume magmatism. Sixteen eclogitic inclusions (10 garnets and 6 omphacites) define an isochron of 2196 ± 61 Ma, with initial ε_{Nd} = 9.3 ± 3.9. Growth of Voorspoed eclogitic diamonds correlates temporally with magmatism and failed rifting at the time of the 2.25–2.23 Ga Hekpoort LIP and related magmatism across the Transvaal Basin. Lowpressure protoliths for the eclogite host rocks are supported by the presence of omphacite that is not stable as a high-pressure liquidus phase, along with Eu anomalies in the majority of eclogitic inclusions. The likely host rocks for eclogitic diamond formation are subduction-related eclogites in the lithospheric mantle that may be similar to those sampled at nearby Lace. The Voorspoed peridotitic and eclogitic diamonds document multiple episodes of melt impingement and modification of older lithospheric mantle and have allowed us to place diamond formation and preservation in the context of the long history of plume impingement on the Kaapvaal lithospheric mantle.

Keywords: Voorspoed, diamond ages, lithospheric mantle, Kaapvaal

KIMBERLITES AND CARBONATE-RICH OLIVINE LAMPROITES (CROLS) SAMPLING DEPTHS USING AL-INOLIVINE THERMOMETRY

Merrily M. Tau[1], Andrea Giuliani[2] & Geoffrey H. Howarth[1]

[1] Terrestrial and Planetary Research Group (TAPP), Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa

[2] Earth and Planets Laboratory, Carnegie Institution for Science, Washington, DC, USA

Olivine is the dominant constituent of kimberlites and carbonate-rich olivine lamproites (CROLs), comprising 40-50 vol.% of these rocks. It occurs as rounded to subhedral macrocrysts (>0.5 mm) and euhedral to subhedral microcrysts (<0.5 mm), the majority showing sharp compositional zoning between xenocrystic cores and magmatic rims. The xenocrystic cores display variable compositions (Mg# = 75 – 95) corresponding to those that characterise mantle xenoliths, including granular and sheared peridotites as well as megacrysts (Giuliani, 2018). The abundant olivine xenocrysts offer great potential for characterizing the subcontinental lithospheric mantle (SCLM) traversed by kimberlites and CROLs and to reveal predominant sampling depths. We present electron microprobe (EPMA) and laser ablation (LA-ICP-MS) trace element data for xenocrystic olivine cores from on-craton CROLs (Finsch, Newlands, Bellsbank, Roberts Victor, Star, Sanddrift, Marsfontein, Klipspringer, Southern Fissures, Makganyene) and on-craton kimberlites (Jwaneng, Jagersfontein, Monastery, Benfontein, Damtshaa, Karowe, Letšeng, Kao, Mothae, Colossus) from across the Kalahari craton. Over 80 grains were analysed per locality. Olivine cores from the CROLs are predominantly Mg-rich with Mg# of 90.0 – 95.0. More Fe-rich (Mg# <90) olivine cores constitute less than 4% of the analysed grains. The olivine population is more variable in kimberlites, with Fe-rich cores comprising between 10% (e.g., Jagersfontein) and 55% (e.g., Damtshaa) of the analysed grains. The compositional criteria of Bussweiler et al. (2017) and Soltys et al. (2020) were used to screen out olivine derived from mantle lithologies other than coarse granular peridotites. Using the Al-in-olivine geothermometer (i.e., Bussweiler et al., 2017), coupled with mantle xenolith-derived paleo-geotherms for each location, equilibration P-T-depth are estimated for each olivine core sourced from garnet peridotite lithologies. Olivine xenocrysts depth distribution suggests lithospheric mantle sampling mainly up to ~180 km and a broad normal mode of sampling at ~120-170 km across all CROLs. Except for Jwaneng, kimberlites from the Kalahari craton show shallow dominant sampling of refractory olivine at ~120-150 km. In the deeper lithosphere Fe-rich metasomatism have modified olivine compositions which, therefore, have not passed the screening criteria. Therefore, Al-in-olivine thermometry offers great potential for revealing predominant sampling depths and evaluation of diamond potential of kimberlites and CROLs.

Keywords: kimberlites, CROLs, Al-in-olivine, thermometry, SCLM

A GEOCHEMICAL AND MINERALOGICAL CHARACTERISATION OF THE SEKAMENG KIMBERLITE PIPE, BUTHA-BUTHE, LESOTHO

Nkopane J. Tohlang[1], Jarlen J. Keet[1] & Bisrat Yibas[3]

[1] University of the Free State, Bloemfontein, South Africa

Pyrope garnets are widely recognised as key diamond indicator minerals due to their formation in the Earth's mantle under conditions conducive to diamond stability. Similarly, spinel, particularly Cr-rich type, has been identified as a complementary indicator in diamond exploration. This study aims to assess the geochemistry, mineral chemistry, and petrography of mantle-derived pyrope garnets and spinel to enhance the understanding of the genesis of the Sekameng kimberlite pipe in Lesotho and infer its diamond potential to improve resource evaluation. The investigation will focus on characterizing the composition and mineralogical properties of pyrope garnet and spinel to deduce the pressure-temperature conditions of their formation and their genetic link to diamond-bearing mantle environments. Samples for this study will include pyrope garnet and spinel recovered from the western, central, and eastern lobes of the Sekameng kimberlite pipe. The pipe, located 5 km south-southeast of the Butha-Buthe township at an altitude of 1890 m, intruded massive Cave Sandstone immediately underlying the Stormberg Lavas of the Karoo Supergroup. Petrographic analysis will be conducted using optical microscopy to classify the kimberlite facies and identify mineral assemblages within different lobes. Mineral phases and mineral chemistry will be determined through scanning electron microscopy (SEM), electron probe microanalysis (EPMA), and Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS). Additionally, X-ray fluorescence (XRF) will be employed to quantify the major and minor element compositions of the rock units. The kimberlite breccia exhibits high silica content, likely due to contamination from the sedimentary wall rock of the Stormberg Group, with country rock xenoliths. By incorporating both pyrope garnet and spinel geochemistry, this study will provide a more comprehensive approach to assessing the diamond potential of the Sekameng kimberlite pipe.

Keywords: geochemistry, petrology

Palaeozoic-Mesozoic Sedimentary Environments in Southern Africa

LATE DEVONIAN SEDIMENTARY DEPOSITS OF THE WITPOORT FORMATION (WITTEBERG GROUP)

Christopher Harris[1], Cameron R. Penn-Clarke[2], Robert W. Gess[3] & Zubair A. Jinnah[1]

[1]School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
[2]Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa
[3]Albany Museum and Rhodes University, Makhanda, South Africa

The Witpoort Formation, a Late Devonian (Famennian) coastal siliciclastic sedimentary succession, has not received a detailed sedimentary facies analysis in the past three decades despite significant palaeontological discoveries from its strata. Here, sedimentary facies, sediment dispersal patterns, and ichnology are, for the first time, applied in combination to form a sedimentological background to the only high-latitude palaeoecological dataset from its time stage. The results indicate a non-marine, sheet-braided fluvial deposit in which transgression of the coast led to the development of marginal-marine, estuarine facies, favouring the preservation of body and trace fossils. The deposits accumulated in erosively-based, valley-fill fluvioestuarine cyclothems along an approximately WNW–ESE trending shoreline bordering the Agulhas Sea. Fossil biodiversity of the Witpoort Formation is principally known from the Waterloo Farm locality, which is here shown to be lower in the stratigraphic column, and therefore older, than previously thought. This deposit appears to have formed in a fresh- to brackish-water inner estuary, possibly tens of kilometres from the shoreline. Analysis of a new fossil locality, Rabbit Ridge, from lower in the stratigraphy, presents a comparable estuarine depositional environment to Waterloo Farm. Higher degrees of marine influence at Rabbit Ridge are indicated by the invertebrate and trace fossil signatures. The ecology of invertebrate communities and trace fossils indicate variable salinity levels and depositional rates from a spectrum of estuarine sub-environments that occurred at intervals in the stratigraphic column. Analysis of eustatic patterns from the global Famennian stratigraphic record and comparison with the stratigraphy described herein indicates that eustacy formed an important control on sedimentation in the Witpoort Formation. This presents the strongest present evidence for constraining the chronology of its strata. There is a need for further multi-proxy analyses, especially geochemical and palynological, as have been conducted in Euramerican strata, to increase the chronostratigraphic resolution and recognition of Late Devonian extinction events in the Witteberg Group.

Keywords: Famennian, Devonian, Gondwana

CLASSIFYING THE MASSIVE DEPOSITS IN THE LOWER JURASSIC CLARENS FORMATION OF SOUTHERN AFRICA

Howard V. Head[1] & Emese M. Bordy[1]
[1]University of Cape Town, South Africa

Dust deposits are considered sensitive markers of global climate fluctuations as it relates to atmospheric circulation patterns. However, its identification in the geological record remains challenging owing to its massive nature which limits a definitive classification. The Lower Jurassic Clarens Formation is dominated by massive sandy siltstone deposits, and, despite the lack of classical outcrop-scale dust features, these have been interpreted as loess. In order to classify these massive deposits, sedimentary grain characteristics such as grain size, grain shape, and sorting were utilised to assess the origins of these abundant structureless strata compared to strata with a known origin (large-scale cross-bedded sandstone). These grain characteristics allowed for the identification and interpretation of six different facies types (Facies 1–6). Facies 1 has very similar grain features to the large-scale cross-bedded strata and is interpreted as the product of migrating dunes that appear structureless. The dominant grain size with a large proportion of very fine-grained sand and the random grain fabric suggests that Facies 2 resulted from sandy dust fall (short-term suspension), whereas Facies 3 is interpreted as aeolian dust, having features consistent with modern and ancient loess due to its dominant silt grain size and random grain fabric. Features in Facies 4 are undiagnostic and could reflect a range of aeolian processes, although a dominant silt grain size may suggest an overwhelming loess component. Facies 5 and 6 show features that are consistent with primary aeolian processes with the preferred grain orientation suggesting reworking of aeolian material in an aqueous setting (e.g., lake, stream). These six facies types reflect a spectrum of depositional processes that occurred in response to erg migration and climatic changes along this Early Jurassic erg margin. This diversity of facies is evidence for active dry and windy conditions in SW Gondwana during the Sinemurian to Pliensbachian, whereas reworking of these aeolian sediments occurred within various fluvial and lacustrine settings throughout the evolution of the Clarens erg system.

Keywords: Loess, Aeolian, grain size, Clarens Formation

BIOSTRATIGRAPHY OF TWO DRILLING CORES FROM THE MANIAMBA BASIN, MOZAMBIQUE (CENTRAL GONDWANA): INSIGHTS ON AGE AND PALEOENVIRONMENTS

Nelson Nhamutole[1], Cristina Moreira Felix[2], Dermeval Aparecido do Carmo[3], Jardel Julio Peu[4], Marion Bamford[1] & Paulo Alves de Souza[2]

[1]Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa
[2]Laboratorio de Palinologia Marleni Marques Toigo, Instituto de Geociencias, UFRGS, Brazil
[3]Laboratorio de Micropaleontologia da Universidade de Brasília, Brasília, DF, Brazil
[4] Eduardo Mondlane University, Departamento de Geologia, Maputo, Mozambique
[1]Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, South Africa

In the present work, dark siltstones, claystones, shales, coals, and carbonaceous shale were critically investigated to identify palynofloral assemblages in Mozambique's overlooked Karoo-aged Maniamba Basin. The study was based on two borehole cores. It unveiled a rich and diversified microflora composed of four distinct palynoassemblages dominated by striate and non-striate bisaccate pollen grains that have prevailed under humid, warm and arid climate conditions in these Gondwana strata. The lower palynoassemblages 1 (P1) and 2 (P2) in both borehole cores are marked by the occurrence of common and abundant striate and non-striate bisaccate pollen, *Protohaploxypinus* spp., *Protohaploxypinus limpidus*, *Striatopodocarpites cancellatus*, *Lueckisporites* spp., *Scheuringipollenites* spp. and colpate *Cycadopites cymbatus*. Late Permian key taxa such as *Marsupipollenites triradiatus*, *Plicatipollenites gondwanensis*, and *Guttulapollenites hannonicus* are found herein. The palynoassemblages 3 (P3) and 4 (P4), were assigned to the Early Triassic based on the First Appearance Datum of key taxa, chiefly *Platysaccus papilonis*, *Lunatisporites* spp., *Lundbladispora* sp. and *Krauselisporites* sp. A younger age is assigned to the K5 Formation in the Maniamba Basin correlating well-known Gondwana sequences from the Katberg and Balfour formations from the Main Karoo Basin (South Africa), the Moatize-Minjova Basin (Mozambique), Sakamena Group (Madagascar), Raniganj-Panchet formations (India), Mid-Zambezi valley (Zambia), and the Salt Range Basin (Pakistan). Fossil wood occurrences support the assigned ages. Although other proxies are needed to identify the Permo-Triassic transition, the obtained new palynological data could spark interest in exploring methane associated with coal beds.

Keywords: biostratigraphy, Permian; biozones, palynoflora, Early Triassic.

SEEING FLAMES: INVESTIGATING A LACUSTRINE ECOSYSTEM THAT EXISTED ON AN EARLY JURASSIC VOLCANIC LANDSCAPE OF THE MAIN KAROO BASIN

Onkabetse E. Sebogodi[1], Hendrik Minaar[1] & Robert A. Muir[2]

[1]Department of Geology, University of the Free State, Bloemfontein, South Africa

[2]Department of Earth Sciences, University of the Western Cape, Bellville, South Africa

The early Toarcian (Early Jurassic) of southern Gondwana was marked by extensive, rapid volcanism that caused significant global environmental disturbances and a worldwide extinction event. Numerous studies have linked this volcanism (Karoo and Ferrar LIPs) with marine faunal extinctions far from the eruption sites. However, few have explored continental environmental conditions at the locus of volcanism. While macro-scale assessments of fluvial and aeolian sandstone interbeds within the basalt-dominated Drakensberg Group provide some insight, previously unrecognised carbonate deposits remain unexplored. This study describes and interprets a limestone interbed within the Drakensberg Group using facies analysis, petrography, and U-Pb geochronology. Nine facies were identified across five outcrops, including laminated and massive carbonates, fine-grained sandstone, fossiliferous sandstone, and basalt. These findings shed light on the depositional environment and sedimentary processes of the lacustrine system. For petrographic analysis, 23 thin sections were prepared—19 from carbonate facies and four from clastic rocks (sandstone). The carbonate facies are categorised as biomicrite, intraclast-bearing micrite, and intramicrite, which typically consist of micrite containing ostracod fossils along with clastic feldspar, quartz, and basalt lithic fragments. The sandstones are feldspatho-quartzose and quartzo-feldspathic. Out of 120 selected zircon grains for U-Pb geochronology, only 60 were suitable due to their small grain size. The ages range from the Paleozoic to Mesozoic, with only a few approximating the known depositional age (181.2 ± 1.0 to 181.4 ± 0.8 Ma) of the basalts in the Golden Gate Member (GGM). Therefore, the zircon data are interpreted as reflecting provenance rather than a maximum depositional age (MDA). This study addresses a gap in understanding continental environmental conditions during early Toarcian volcanism and how carbonate deposits within the Drakensberg Group reflect its environmental impact. The carbonates likely formed in localised lacustrine settings during volcanism. Rather than being extruded as $CaCO_3$, they formed through biological and chemical processes. The presence of biologically derived carbonate suggests that microbial or algal life temporarily thrived in these environments, indicating a window of ecological stability between eruptive phases. These settings were buried by ongoing lava flows, capturing a snapshot of post-volcanic recovery and a short-lived ecosystem development.

Keywords: Carbonate facies, Micrite, Ostracods

AN ANALYSIS OF LYSTROSAURUS CALCIUM APATITE: INSIGHTS INTO THE SURVIVAL STRATEGIES ACROSS THE PERMO-TRIASSIC BOUNDARY

Thabile M. Seerane[1,2], Pia A. Viglietti[3,2] & Grant M. Bybee[1]

[1]School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
[2]Evolutionary Studies Institute University of the Witwatersrand, Johannesburg, South Africa
[3]Negaunee Integrative Research Centre, Field Museum of Natural History, Chicago, Illinois, USA

Lystrosaurus is one of the survivors of the end-Permian Mass Extinction event. It was able to occupy a wide geographical range and increase its abundance post-extinction. In the upper Katberg formation, it coexisted with no other herbivores. It has been proposed in the literature that the observed increase in abundance and wide geographic range can be attributed to the species' classification as an r-strategist, its opportunistic nature and its adaptation to consuming tough vegetation. Lystrosaurus had a relatively short stratigraphic range, with its abundance predominantly observed at the Permo-Triassic Boundary. Trace elements compositions found in fossil apatite holds record of the type of diet, diagenetic history, water composition, position in the food chain and temperature, hence, stable isotope analysis is of great use in archaeology and palaeontology. Trophic structuring of extinct and extant biota is often done using geochemical archives namely bones and teeth. However, diagenesis becomes a limiting factor in trophic structuring of extinct biota due to the fossilisation process of skeletal tissue changing both the chemical and isotope composition of the geochemical archives. Interestingly, major inorganic component like calcium shows no change in both chemical and isotopic composition over time unlike major organic and trace elements. The reason for this is that calcium fractionation doesn't take place through the blood, urine, or mineralised tissue degradation processes. To test whether calcium isotope analysis could expose recovery patterns that promote survival strategies following terrestrial extinction events, we investigated the isotope composition of Lystrosaurus species to determine any species strategies or trophic level traits that promoted survivorship in the end-Permian Mass Extinction Event. We collected calcium isotope ratios ($\delta^{44}Ca/\ ^{42}\delta\ Ca$ and $\delta^{43}Ca/\ \delta^{42}Ca$) of the four Lystrosaurus species and compared them based on their biostratigraphic ranges and estimated body size. Isotope compositions were measured using three techniques: 1) preparation of samples, 2) ion-exchange chromatography and 3) Isotope ratio mass spectrometry. We can confidently say that calcium isotope analysis is expected to provide crucial insights into the survival strategies of Triassic communities, and ongoing work will refine these interpretations.

Keywords: Calcium Isotope Analysis, Lystrosaurus, Permo-Triassic Boundary, Recovery patterns

RECONSTRUCTING THE JURASSIC-CRETACEOUS PALAEOCLIMATE FROM THE KIRKWOOD FORMATION, ALGOA BASIN (EASTERN CAPE), SOUTH AFRICA

Kalila Stewardson[1], M. Abrahams[2], M.D. Welman-Purchase[1] & R.A. Muir[3,1]

[1]University of the Free State, Bloemfontein, South Africa
[2]University of Cape Town, Cape Town, South Africa
[3]University of the Western Cape, Bellville, South Africa

The Jurassic-Cretaceous boundary (JKB) is one of the least understood chronostratigraphic boundaries of the Phanerozoic Eon. This is largely due to the strong provincialism of the fossil record and lack of robust age constraints in historically studied northern hemisphere localities. The southern hemisphere, in contrast, is generally overlooked in JKB assessments; however, recent work in these localities, such as the Neuquén Basin, Argentina, offers novel insights into the JKB. Our research will provide another potential southern hemisphere locality for assessing the JKB by providing a baseline for Late Jurassic to Early Cretaceous palaeoclimate from the Kirkwood Formation (Uitenhage Group), Algoa Basin, South Africa. Herein, stratigraphical logs were produced from outcrops, consisting of varicoloured mudstones with palaeosols, interlayered with medium-grained beige sandstone beds and thin conglomerate layers. 78 mudstone samples were collected and analysed from the Kirkwood Formation. From its stratotype core (CO1/67), 51 samples were collected, which contain strong age constraints. Twenty-seven (27) samples were collected from its stratotype outcrop near the town of Nqweba, which lack age constraints, at regular intervals. X-Ray Fluorescence (XRF) was used to determine bulk rock major element chemistry and calculate weathering indices (WI), which is our palaeoclimate proxy, and X-Ray Diffraction (XRD) was used to validate our results. The core samples had an average WI value of 75 for the Chemical Index of Alteration (CIA) with a standard deviation of 7. These WI results indicate that a sub-tropical palaeoclimate was prevalent in the Late Jurassic and Early Cretaceous Algoa Basin. This contrasts to the arid climate of the Elliot Formation, another fluvial unit that is comparatively well studied, and aligns with flood plain depositional temperatures of 25-30^{o}C with seasonal rainfall of 100-500 mm per annum determined from the presence of mottled palaeosols. The WI results placed alongside the borehole core log indicated a fluctuating palaeoclimate which changes systematically to wetter conditions from the Late Jurassic to Early Cretaceous. In addition to these results, four samples are being analysed for detrital zircon geochronology to determine the maximum depositional age to improve age constraints. Eight samples are being palynologically assessed to provide palaeoclimate proxies and palaeo-environment reconstruction.

Keywords: Palaeoclimate, Kirkwood Formation, Jurassic-Cretaceous boundary, Weathering-Index

Petrogenesis and Metallogenesis of Layered Intrusions

CHEMISTRY AND AGE OF THE TROMPSBURG COMPLEX, FREE STATE, SOUTH AFRICA AND COMPARISONS WITH THE BUSHVELD COMPLEX

Geoffrey H. Grantham[1], Petrus le Roux[2], Richard Armstrong[3] & Wolf D. Maier[4]

[1] Department of Geology, University of Johannesburg, Auckland Park, South Africa

[2] Department of Geosciences, University of Cape Town, Rondebosch, South Africa

[3] RSES, Australian National University, Canberra, Australia

[4] School of Earth and Environmental Sciences, Cardiff University, Cardiff, United Kingdom

Approximately 150 samples of core from six boreholes drilled into the covered Trompsburg Complex in the late 1940s have been analysed by ICP-MS for a range of major and trace elements. Samples from borehole R5, which intersected marginal carbonates surrounding the complex, are chemically distinct from other boreholes, consistent with contamination by marginal carbonates. A stratigraphic profile constructed from borehole position and limited dip information, available in the literature, has been constructed. The samples show variable alteration. The chemistry of the major and trace elements shows strong mineralogical control by dominant silicate and oxide phases namely clinopyroxene, plagioclase, magnetite, ilmenite and apatite. Ni and Co are weakly correlated with MgO, both elements being hosted in olivine and/or clinopyroxene. Vanadium, Ta, Nb, TiO_2, Cr, FeO_T and MnO are correlated, suggesting distributions controlled by magnetite and/or ilmenite. Strontium, Rb and Ba are strongly correlated with K_2O, Na_2O and Al_2O_3 – all typically being hosted in plagioclase. REE's are correlated with P_2O_5, suggesting apatite control. Total REE contents increase upwards until the stratigraphic level intersected by borehole R4, after which they decline. Most samples are characterised by strong positive Eu anomalies typical of cumulate plagioclase. Comparisons of the data with the Bushveld Complex shows they are comparable with the Upper and Main Zones of the Bushveld Complex. This conclusion is emphasised for elements typically enriched within the Upper and Main Zones. Similarly, EMPA analyses of clinopyroxene and plagioclase show limited compositional ranges comparable with the Upper and Main Zones of the Bushveld Complex. The data suggest that, compared to the Bushveld Complex, layers hosting PGE's and Cr deposits are only likely at depths much greater than the 1800 m boreholes. U/Pb SHRIMP data from an aplitic vein provides an upper intercept age of 1913±23 Ma confirming a published minimum age for the complex of 1915± 6 Ma. ε_{Nd} calculated at ~1915 Ma varies between ~+5 and ~-5, suggesting a juvenile mantle source with little to no contamination. In contrast ε_{Sr} varies between ~15 and ~50 suggesting possible contamination from a source with significant radiogenic Sr, a potential source being carbonate wall rock equivalent to the Malmani Dolomite.

Keywords: Trompsburg Igneous Complex, Bushveld Igneous Complex, Geochemistry, Geochronology

A Sr ISOTOPIC INVESTIGATION OF THE BROWN SUGAR NORITE AT TWO RIVERS PLATINUM, EASTERN LIMB, BUSHVELD COMPLEX

Jarlen Keet[1] & Gomolemo Mahlangu[2]

[1] Department of Geology, University of the Free State, Bloemfontein, South Africa

[2] Impala Platinum Mine, Rustenburg, South Africa

During the trial mining of the Merensky Reef at Two Rivers Platinum Mine, unusual lenses of melagabbronorite, locally termed 'brown sugar norite' (BSN), were discovered within the hanging wall and pyroxenite. The BSN occurs as fine-grained lenses and is not laterally consistent within the mining area. In this study we report the Sr-isotope composition of plagioclase within the Merensky Reef interval where BSN is intersected. Laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) was used to analyse plagioclase grains, determining both inter- and intracrystalline strontium variations. Light microscopy and SEM were used to investigate the petrographic characteristics of the samples and semiquantitative mineral chemistrym respectively. An increase in initial $^{87}Sr/^{86}Sr$ (Sr_i) from core to rim is observed in Merensky Reef pyroxenite, with values ranging from 0.7059 in the core domains to 0.7083 at the rims. This isotopic trend is also evident in the pegmatoidal pyroxenite and footwall anorthosite, although these rocks display relatively lower Sr_i values. These rim-core isotopic variations suggest interactions with radiogenic fluids, possibly linked to footwall carbonate devolatilization or an overprint of a radiogenic fluid. The BSN lenses have an average Sr_i of 0.7064, displaying isotopic signatures typical of the Upper Critical Zone.

Keywords: Bushveld Complex, Merensky Reef, Brown Sugar Norite, Sr isotope

TRACING MAGMATIC ORES: SETTING UP Fe-Cu-Zn STABLE ISOTOPE METHODS TO TRACE MINERALISATION IN LAYERED INTRUSIONS

Khulekani B. Khumalo[1], Frederick Roelofse[2], Grant M. Bybee[1], Henriette Ueckermann[3], Karen V. Smit[1], Rachel Mey[1] & Saumik Samanta[1]

[1] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

[2] Department of Geology, University of the Free State, Bloemfontein, South Africa

[3] Department of Geology, University of Johannesburg, Auckland Park, South Africa

Southern Africa hosts multiple Large Igneous Provinces (LIPs), both economic and non-economic – including the Bushveld LIP, the world's largest layered mafic intrusion and a globally significant repository of critical metals. Despite decades of research, there is lack of agreement regarding the origin, spatial distribution, and controls on mineralisation (Ti, V, Cr and PGEs) within the intrusion. This study seeks to address these aspects by applying non-traditional Fe, Cu, and Zn isotopes as tracers of petrogenetic processes and metal mobility. Fe-Cu-Zn isotope systems have proven useful in fingerprinting petrogenetic processes such as fractional crystallisation, magma mixing, sulphide saturation, and redox evolution as well as distinguishing contributions from mantle sources and assessing the extent of contamination. We aim to constrain the geochemical signatures of mantle-derived magmas and identify the processes that concentrated metals. Preliminary data on the Upper Zone of the Bushveld LIP, analysed relative to IRMM524b (δ^{56}Fe= 0.01 ± 0.01 ‰), show a distinct isotopic fractionation between lithologies. Massive magnetitites exhibit heavier isotopic compositions, ranging from 0.16 ± 0.01 ‰ to 0.26 ± 0.02 ‰, while the silicate-rich rocks span lighter values from -0.24 ± 0.03 ‰ to 0.02 ± 0.01 ‰. This is interpreted to reflect the influence of modal magnetite and Fe^{3+}-bearing mineral phases during magmatic differentiation. While Fe isotope data exist for portions of the Bushveld LIP, much of it remains spatially limited or lacks higher lithological resolution across key mineralised and non-mineralised units. As such, this study focuses on the development of robust Fe isotope analytical protocols at the Wits Isotope Geoscience Laboratory (WIGL). Our current focus is on optimising the Fe isotope purification and measurement protocols using ion-exchange chromatography and multi-collector ICP-MS. Initial tests on certified reference materials demonstrate excellent column yields of at least 98.3%. Future method development will include Cu and Zn isotopes, to ultimately enable a multi-isotope approach to better resolve the genesis of mineralisation in southern African LIPs. Our contribution outlines our analytical progress, conceptual framework and invites collaboration and discussion with researchers working on layered intrusions, stable isotope geochemistry, and magmatic ore-forming systems.

Keywords: Fe-Cu-Zn isotope geochemistry, magmatic ore systems, layered intrusions

ASSESSING THE ROLE OF LATE-STAGE FLUIDS OR MELTS ON ANORTHOSITE AND MAGNETITITE LAYERS IN THE UPPER ZONE OF THE BUSHVELD COMPLEX

Willem Kruger[1] **& Rais Latypvov**[2]

[1] SAES, University of KwaZulu-Natal, Durban, South Africa

[2] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

Our understanding of processes operating within magmatic systems have been greatly enhanced by layered intrusions. However, an obstacle often encountered is uncertainty regarding the primary magmatic origin of layering features. Here we study the interface between magnetitite and anorthosite layers of the Upper Zone of the Bushveld Complex to better understand the effect of late-stage modification of cumulates. We attempt to determine if (1) late-stage fluids or melts could be responsible for reverse zoning observed in plagioclase grains (2) whether late-stage fluids or melts could result in more advanced exsolution of ilmenite at the base of the magnetitite layer, possibly producing the Cr-rich domes previously documented, (3) if fluids or melts may have affected the initial Sr-isotopic ratio, and (4) what their sources may be, e.g., internally or externally derived. Our results show that late-stage hydrothermal/magmatic activity resulted in the following changes: (1) Dramatic increases in the An-content of plagioclase, from 56 to 90 at the anorthosite-magnetitite contact, suggesting that fluids might be responsible for generating reversals towards high An-content of plagioclase elsewhere throughout the intrusion. (2) Many distinct ilmenite grains have formed at the base of the magnetitite layer, suggesting the presence of an oxidizing fluid. This results in enrichment of the surrounding magnetite from 1.0 wt. to more than 6.0 wt. % Cr. However, the effect is of very limited spatial extent (less than a mm around ilmenite grains) and cannot explain the occurrence of Cr-rich domes at the base of the magnetitite layers. (3) Significant scatter is observed in the spatial distribution of Sr-isotopic ratios in plagioclase that may have been caused by late-stage fluid activity. Initial $^{87}Sr/^{86}Sr$ ratios are, however, within limits of the remainder of the Upper Zone, suggesting the fluids were internally generated.

Keywords: Bushveld Complex, magnetite, anorthosite, layered intrusions

PETROGENESIS OF THE AKANVAARA LAYERED INTRUSION

Anton Kutyrev[1,2], Wolfgang Maier[1], Tuomo Karinen[3] & Sarah-Jane Barnes[4]

[1] School of Earth and Environmental Sciences, Cardiff University, Cardiff, UK
[2] School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
[3] Geological Survey of Finland (GTK), Espoo, Finland
[4] Université du Québec à Chicoutimi, Québec, Canada

The Akanvaara layered intrusion in Finland contains several PGE-bearing chromitite seams and a Pd-Au mineralised anorthosite interval, making it a valuable case study in layered intrusion petrogenesis. We present new high-precision whole-rock geochemical and PGE data, acquired by Ni-sulfide fire assay and ICP-MS, integrated with legacy drill core geochemical data and petrography from the Geological Survey of Finland, to investigate the intrusion's petrogenesis and the origin of its mineralised zones. The ~3.4 km thick stratigraphy is divided into lower (LZ, MZ) and upper (UZ) zones. The LZ and MZ host multiple chromitite seams, anomalously enriched in Ti and V, but depleted in MgO and PGEs relative to Bushveld analogues. The cumulative chromitite thickness recalculated to pure chromite (6.1 m) is comparable to the thickness of the Bushveld Critical Zone chromitites, despite Akanvaara being much smaller and more evolved. Chromitites appear unusually early in the stratigraphy and are locally hosted by granophyric or felsic-contaminated matrices, implying in-situ interaction with evolved melts or wallrock. Their formation is associated with compositional reversals, indicating repeated replenishment by fractionated siliceous high magnesium basaltic (SHMB) magmas. Cr mass balance calculations show that the bulk Cr content (1270 ppm) cannot be reconciled with the intrusion's MgO content (7.1 wt%) or with known parental magma compositions, unless >50% of residual melt was expelled. The UZ contains only ~50 ppm Cr and is interpreted to record crystallisation from residual melt. Modelling suggests that the UZ represents ~21% to ~50% of the liquid produced, implying ~50% to ~79% melt evacuation. Chromitite formation likely occurred through interaction of primitive SHMB melt (=12 wt% MgO) with silica-rich residual melt, triggering chromite saturation. Sulfide saturation had minimal effect on chromitites; most are enriched in IPGE and Pt, with low Pd and Cu. The Pd–Au-rich anorthosite below the magnetite gabbro represents a separate mineralisation style. Its low Ca, high K, and trace element enrichment are unlike Bushveld anorthosites but resemble Skaergaard ones. PGE enrichment likely reflects small-scale sulfide saturation or porous flow remobilisation from overlying units. The 30 m vertical offset between PGE and Cu peaks suggests multistage sulfide mobilisation and complex kinetic control.

Keywords: layered intrusions, chromitite, anorthosite, platinum-group elements

NATURE OF THE LOWER CRITICAL - UPPER CRITICAL ZONE TRANSITION IN THE CLAPHAM TROUGH AREA, EASTERN BUSHVELD COMPLEX: EVIDENCE FOR THE INTRODUCTION OF CRUSTAL FLUIDS IN RESPONSE TO PLAGIOCLASE STABILISATION?

Justine Magson[1] & Frederick Roelofse[1]

[1] Department of Geology, University of the Free State, Bloemfontein, South Africa

The boundary between the Lower Critical Zone (LCZ) and the Upper Critical Zone (UCZ) of the Rustenburg Layered Suite represents a significant stratigraphic transition across the entire intrusion, shifting from intercumulus plagioclase in the LCZ to cumulus plagioclase in the UCZ. There is no consensus on the nature of this boundary. Some suggest that plagioclase reaches cumulus status here due to continued fractionation of the resident magma, while others propose the introduction of compositionally distinct magma(s) at this level of the intrusion. In this study, we present in-situ Sr-isotopic compositions for plagioclase, as well as whole-rock major and trace element geochemical and mineral chemical data across the LCZ-UCZ boundary, as observed in borehole BH6958 on the Forest Hill farm in the eastern Bushveld Complex. Major and trace element data support the idea that no compositionally distinct magma was added at this level of the intrusion. However, Sr- and Nd-isotopic data indicate open-system behaviour. This isotopic excursion cannot be explained by mixing between the resident (B1) magma and other proposed parental magmas (e.g., B2 or B3). Modelling suggests that the isotopic shift could be explained by mixing of the resident (B1) magma with small amounts of lower crustal melts. Another possible explanation for the isotopic excursion is the mixing of resident (B1) magma with small amounts of crustal fluids. In this scenario, the introduction of these fluids appears to have occurred gradually, with $^{87}Sr/^{86}Sr_i$ in plagioclase being higher in the rims of the LCZ than in the cores, and even higher in the lower UCZ. Based on thermodynamic modelling, we argue that as plagioclase began to crystallize, the system contracted at a rate faster than before plagioclase stabilization, with fluids from the surrounding hydrothermal system entering the magma chamber to compensate for the volume loss caused by the cooling process.

Keywords: Lower Critical Zone, Upper Critical Zone, Parental magmas, Crustal Fluids

NICKEL-Cu-PGE-Cr MINERALISATION IN THE ULTRAMAFIC BASAL PORTION OF THE STILLWATER COMPLEX, MONTANA, USA

Wolfgang D. Maier[1], Albie Brits[2], Daniel Grobler[2] & Sarah-Jane Barnes[3]

[1] School of Earth and Environmental Sciences, Cardiff University, Cardiff, UK

[2] Stillwater Critical Minerals, Vancouver, Canada

[3] Sciences de la Terre, Universite du Quebec a Chicoutimi, Canada

The Stillwater Complex of Montana is one of the largest layered intrusions on Earth, with an estimated surface and sub-surface extent of ~1500 km^2. It is also one of only five layered intrusions currently mined for PGE, together with Bushveld, Great Dyke, Sudbury, and Lac des Iles, and it contains the richest PGE reef on Earth, the JM reef, located in the complex's Banded Series, some 2.5 km above the base. In contrast to the large number of papers published on the J-M reef, relatively few recent publications have dealt with the mineralisation in the lower portion of the complex. Here we report on the results of exploration by Stillwater Critical Metals (SCM) in the Ultramafic and Basal Series of the complex. Whereas historic drilling has shown the presence of PGE and Ni-Cu sulfide mineralisation along much of the basal contact of the Complex, the new drilling of SCM found higher grades over a greater thickness than previously reported. In addition, the drilling provided new insight into the stratigraphy, style of layering and structural complexity of the complex, including hitherto unknown, fault-controlled, PGE mineralised ultramafic rocks located below the Basal Series. Based on the new data we propose a refined model for the petrogenesis of the mineralisation of the Ultramafic and Basal Series.

Keywords: Stillwater Complex, layered intrusion, platinum-group elements, nickel

LATERAL VARIATION IN PGE CONTENTS OF SILICATE ROCKS BETWEEN THE UG2 CHROMITITE AND THE MERENSKY REEF

Wolfgang D. Maier[1], David L. Reid[2], Frederick Roelofse[3], Justine Magson[3], Sarah-Jane Barnes[4] & Stephen A. Prevec[5]

[1] School of Earth and Environmental Sciences, Cardiff University, Cardiff, UK,
[2] Department of Geological Sciences, University of Cape Town, Rondebosch, South Africa
[3] Department of Geology, University of the Free State, Bloemfontein, South Africa
[4] Sciences de la Terre, Universite du Quebec a Chicoutimi, Canada
[5] Department of Geology, Rhodes University, Makhanda, South Africa

We present new high-precision data on the concentrations of PGE (Os, Ir, Ru, Rh, Pt, Pd) and Au in the silicate rocks of the interval between the UG2 chromitite and the Merensky Reef in the western limb of the Bushveld Complex. We compare our results to previous data from our group and those of other authors from Union Section, Northam mine, Rustenburg section and the Platreef/Flatreef of the Northern limb of the Bushveld Complex. The initial results suggest a broad trend of elevated PGE contents at Amandelbult and Northam sections, with slightly lower levels at Union section (particularly in norites and anorthosites), and still lower levels in the southern portion of the western limb. This trend broadly correlates with differentiation indices such as Mg# of whole rocks and orthopyroxene, and An content of plagioclase which also decrease from the NW to the SE of the western lobe. The data gathered so far could suggest that the PGE budget of the silicate rocks in the Bushveld Complex can be used as a proxy towards the magma feeder zones, but this hypothesis needs further support. To this effect, more than 200 additional samples are currently being processed. The next step will be to test this model at other layered intrusions.

Keywords: Bushveld Complex, Upper Critical Zone, Platinum-group elements

IN SITU MULTIPLE SULPHUR ISOTOPE ANALYSIS BY SIMS OF PYRRHOTITE, PENTLANDITE, AND CHALCOPYRITE IN THE FLATREEF, NORTHERN LIMB, BUSHVELD COMPLEX

Johannes Malebati[1], Christoph D.K. Gauert[1] & Jarlen J. Keet[1]

[1] Department of Geology, University of the Free State, Bloemfontein, South Africa

The Platreef, located in the northern limb of the Bushveld Complex (BC), exhibits significantly greater crustal contamination than the Merensky Reef (MR) in the eastern and western limbs. Despite extensive research, no consensus exists on whether its mineralization aligns with that of the MR in the rest of the BC. The heterogeneous nature of the Platreef has made correlations with the stratigraphy in other parts of the BC challenging. The discovery of the Flatreef, a world-class PGE-Ni-Cu deposit and a downdip extension of the mineralized Platreef unit on the farms Turfspruit and Macalacaskop, presents an opportunity to investigate a potentially less contaminated segment of the Platreef's magmatic stratigraphy. This study refines the understanding of the contamination degree in the Flatreef's stratigraphic sequences and improves insight into the formation and evolution of the Flatreef, Platreef, and MR. While previous studies have focused on whole-rock $\delta^{34}S$ analyses of the Platreef, with recent work extending to the Flatreef, in situ multiple sulphur isotope analysis of the Flatreef remains unexplored. Here, we report the first in-situ multiple S isotope analysis of pyrrhotite, pentlandite, and chalcopyrite from borehole UMT-393 on the farm Macalacaskop using a Secondary Ion Mass Spectrometer (SIMS). This data supports findings that 1) the Flatreef is the Upper Critical Zone–Main Zone (UCZ-MZ) transition correlative in the northern limb and 2) its sulphides and correlatives in the BC initially formed in a deep staging chamber. The similar in situ multiple sulphur isotope $\delta^{34}S$ data of the MR and the Bastard Reef (BR) units of the Flatreef suggest that these units formed without substantial crustal contamination, comparable to the MR in the rest of the BC. The MIF $\Delta^{33}S$ signatures observed in Footwall Cyclic Unit (FCU), MR, and BR, along with the wide range of $\delta^{34}S$ isotopic signatures, indicate that the Flatreef magma likely experienced some degree of contamination in a staging chamber prior to its emplacement in the upper crust.

Keywords: Bushveld Complex, Platreef, Flatreef, SIMS

INFLUENCE OF THE PAARL FAULT ON PLATINUM GROUP ELEMENTS DISTRIBUTION AND MINERALIZATION IN THE SELUKWE SUBCHAMBER, GREAT DYKE, ZIMBABWE

Takudzwa Mwagura[1]

[1] University of Zimbabwe; The Geological Society of Zimbabwe

The economical extraction of platinum group elements (PGEs) is heavily dependent on a comprehensive understanding of the geological factors that influence their concentration and distribution. This research project focused on the impact of the Paarl Fault on the main sulphide zone in the Selukwe Sub chamber of the Great Dyke, crucial for the extraction of PGEs. The study aimed to assess the fault's effects on PGE concentration and distribution, as well as the alteration mineral assemblages associated with it. The research has uncovered that PGE concentrations are spatially associated with the Paarl Fault, indicating that the fault may act as a channel for mineralizing fluids. Notably, areas closer to the fault exhibit higher PGE grades, with some reaching up to 5.28 grams per tonne. Assay results from drill core samples were categorised into two datasets based on their proximity to the fault: Dataset Paarl A (254 m from the fault) and Dataset Paarl B (448 m from the fault). Dataset Paarl A showed a highest 4PGE grade of 5.28 g/t in sample PAR49, with an average grade of 4.38 g/t and a standard deviation of 0.556 g/t. In contrast, Dataset Paarl B recorded the lowest grade of 3.64 g/t in sample PAR42, with an average grade of 3.83 g/t and a standard deviation of 0.196 g/t. Key lithological units identified included gabbronorite, websterite, orthopyroxenite, pegmatoidal pyroxenite, and serpentinite. Notably, petrographic analysis has identified changes within the MSZ, such as the emergence of serpentine, which aligns with the introduction of hydrothermal fluids by the fault. These alterations could significantly affect mining operations, as the development of secondary minerals like serpentine and the textural changes in pegmatoidal pyroxenite near the fault zone may lead to zones devoid of PGEs. The findings of this study underscore the critical role of fault structures in the distribution of PGEs and emphasise the necessity of integrating geological considerations into mining plans for the Great Dyke's optimal exploitation.

Keywords: Platinum Group Elements, Great Dyke, Main Sulphide Zone, Paarl Fault

HIGH-PRECISION GEOCHRONOLOGY OF THE ROOIBERG GROUP TO CONSTRAIN THE SHALLOW CRUSTAL EFFECTS OF THE BUSHVELD LIP

Faith Nyathi[1], Daniel Condon[2], Nils Lenhardt[3], Scott Maclennan[1] & Simon Tapster[2]

[1] University of the Witwatersrand, Johannesburg, South Africa

[2] British Geological Survey, Keyworth, Nottinghamshire, United Kingdom

[3] University of Pretoria, Pretoria, South Africa

The Bushveld Complex – comprising the Rustenburg Layered Suite, the Lebowa Granite Suite, and the Rashoop Granophyre Suite – represents the most significant layered intrusion in the world and serves as one of the most important global sources of platinum group metals (PGMs), vanadium, and chromium. This complex intruded into the Rooiberg Group, which is recognised as one of the largest Silicic Large Igneous Provinces globally. The available geochronology indicates that the Rooiberg Group predates Bushveld magmatism by several million years, whereas field relationships and geochemistry suggest a very short temporal difference. Consequently, recent studies propose that the Rooiberg Group serves as the extrusive counterpart of the Bushveld Complex. In this contribution, we utilised U-Pb Chemical Abrasion Isotope Dilution Thermal Ionization Mass Spectrometry (CA-ID TIMS) high-precision zircon geochronology to constrain the ages of the entire stratigraphy of the Rooiberg Group. Statistical techniques, including the Bayesian age-depth model, were used to determine the eruption ages and eruption rates of the stratigraphy of the Rooiberg Group. Preliminary results show that there is little age difference between the Rooiberg Group and the Bushveld Complex, which may suggest that they share a contemporaneous relationship.

Keywords: Rooiberg Group, Bushveld Complex, Geochronology, CA-ID-TIMS

PETROGENESIS OF THE MAIN ZONE-UPPER ZONE TRANSITION IN THE WESTERN BUSHVELD COMPLEX BASED ON PLAGIOCLASE COMPOSITIONAL VARIATION

Pelele Lehloenya[1], Stephen Prevec[1] & Frederick Roelofse[2]

[1] Rhodes University, Makhanda, South Africa

[2] University of the Free State, Bloemfontein, South Africa

A sample suite across the contact between the uppermost Main Zone and the basal Upper Zone in the western limb of the Rustenburg Layered Suite, including the Pyroxenite Marker (PM) has provided the basis for a mineral chemical and isotopic study of this postulated magmatic interface zone. A key feature is the compositional reversal across the upper 300 m or so of the Main Zone, which have inspired a range of innovative magmatic recharge processes to explain in the literature. In addition to confirming the observations of previous studies in terms of whole rock and plagioclase major element compositional variation, novel findings of this study include the observation of a prominent spike in radiogenic $^{87}Sr/^{86}Sr_i$ across the PM not noted in Sr or Nd isotopes at this horizon elsewhere, and an apparently gradual transition in $^{87}Sr/^{86}Sr_i$ from the Main to Upper Zones, in marked contrast to the stepwise isotopic compositional shift reported in some previous work, and as conventionally reported. Implications for the positive $^{87}Sr/^{86}Sr$ are that this does not represent a crustal contamination event corresponding to a new influx of magma, as no high field strength or large ion lithophile elements show corresponding enrichment. This is consistent with the absence of a similar peak in other equivalent sections. In fact, elsewhere the PM interval is isotopically characterised by erratic or variable compositions, consistent with locally open system behaviour. In this case, the apparently $^{87}Sr/^{86}Sr$ enrichment can be explained by a depletion in Rb, resulting in under correction for age decay for the initial ratio calculation. The gradational change in isotopic composition commencing below the PM may suggest that the PM itself does not represent a new magma influx (i.e., of a ferrogabbronoritic Upper Zone magma). An alternative model for the Upper Main Zone involving symmetrical bottom-up and top-down crystallisation (over a 600 m interval) is also examined.

Keywords: Pyroxenite Marker, Sr isotopes

PLATINUM-GROUP ELEMENTS IN THE UG1 FOOTWALL AT RUSTENBURG, WESTERN LIMB, BUSHVELD COMPLEX

Frederick Roelofse[1], Justine Magson[1] & Mariska Nicholson[1]

[1] Department of Geology, University of the Free State, Bloemfontein, South Africa

We report on the results of a high-resolution geochemical investigation aimed at quantifying the concentrations of PGEs (Os, Ir, Ru, Rh, Pt, Pd) and Au in the complexly bifurcated chromitites and intervening anorthosite layers that constitute the footwall of the UG1 chromitite, as exposed by underground mining activities at Rustenburg in the Western Limb of the Bushveld Complex. Samples originated from four sample cuts across the footwall, which allowed us to assess both vertical and lateral variations in whole-rock PGE+Au concentrations. The chromitite and intervening anorthosite layers exhibit similar chondrite-normalised PGE patterns. The concentrations of individual PGEs and Au are, however, significantly higher in the chromitite layers compared to the anorthosite layers. There appear to be no definitive correlations between the concentrations of individual PGEs and S, suggesting that the PGEs are not controlled by sulphides. We discuss our results in the context of models that have been proposed to explain the formation of the enigmatic bifurcations observed in the UG1 footwall.

Keywords: Bushveld Complex, Platinum-group elements, UG1 chromitite

Tectonics and Geodynamics

EVALUATION OF GOLD MINERALISATION POTENTIAL USING AIRBORNE MAGNETIC AND GEOELECTRICAL METHODS OVER MIDDLE PART OF ZURU SCHIST BELTS, NW NIGERIA

Abdulrahaman Idris Augie[1], Abubakar Adamu[1] & Muhammad Naziru Yahaya[2]

[1]Department of Applied Geophysics, Federal University Birnin Kebbi, Kebbi State, Nigeria

[2]Department of Physics with Electronic, Federal University Birnin Kebbi, Kebbi State, Nigeria

This study delineated the potential zones for gold mineralisation using aeromagnetic, 2D electrical resistivity tomography (ERT), and induced polarisation (IP) techniques. Half-degree airborne magnetic data sheets of 96_Shanga and 119_Yelwa that covered the study area were obtained from the Nigerian Geological Survey Agency (NGSA). The tilt derivative (TD), analytic signal (AS), and centre for exploration targeting (CET) methods developed in Oasis Montaj Geosoft were applied to these datasets during the data processing and analysis. The TD, AS, and CET results revealed areas of high amplitude magnetic anomalies (zone H) and major magnetic structures (lineaments), which are associated with granite gneiss, quartzite, gneiss, partially decomposed granite, migmatitic augen gneiss, and medium to coarsegrained biotite in comparison to the geological setting of the area. Major zones of structures and high magnetic anomalies were found in the eastern regions of the Ngaski-Yauri boundaries (Mararraba), Shanga (Sabon Gari), Agwara, and Magama (Irana), and these have agreed with earlier magnetic studies conducted in the region. These sites could potentially be favourable for metallic minerals, particularly gold mineralisation. However, some regions (Ngaski/Yauri boundaries and Sabon-Gari) obtained through the magnetic method for potential gold mineralisation were further investigated using 2D ERT and IP detailed techniques in a dipole-dipole configuration. The geoelectric method results along profiles 1, 2, and 3 revealed three major zones of gold mineralisation potential, denoted as G1, G3, and H1. These regions have low/high resistivity (1.5 to 460 Ω /1890 to 7873 Ω) and high chargeability (= 20 msec), which could be interpreted as potential for metallic mineral exploration, especially for gold. The zones are in northern Mararraba, Bajida, and Gonan Goli in Kebbi state. The results of integrated geophysical techniques yielded a database of precise coordinates, lateral lengths, and thickness/depths for potential gold mineralisation zones. This database could help with the exploration of gold minerals in the region.

Keywords: Gold Mineralisation Zones, Centre for Exploration Targeting (CET), Tilt Derivative (TD), Analytic Signal (AS), Electrical Resistivity Tomography (ERT), Induce Polarisation (IP)

BMAD: BEATTIE MAGNETIC ANOMALY ICDP DRILLING PROJECT

Stephanie Scheiber-Enslin[1], BMAD Team, Lauren Hoyer[2] & Nigel Hicks[3]

[1]University of the Witwatersrand, Johannesburg, South Africa
[2]University of KwaZulu Natal, Durban, South Africa
[3]Council for Geoscience, Pietermaritzburg, South Africa

The Beattie Magnetic Anomaly (BMA) extends in an east–west direction across a significant portion of South Africa. It originates in the western Karoo, below the escarpment, and terminates near the east coast, close to Port St. Johns. At its easternmost extent – where the BMA source is at its shallowest depth (estimated at 2–3 km) – it is truncated by the Agulhas-Falkland Fracture Zone. This truncation suggests that the anomaly-forming body predates the breakup of Gondwana. The BMA, along with the Namaqua-Natal Belt, has been correlated with an orogenic belt that stretches from western Dronning Maud Land (WDML) to central Dronning Maud Land (CDML) in Antarctica (Gose et al., 1997; Jacobs et al., 1998). Rocks in this Antarctic region display geological, geochemical, chronological, and magnetic similarities to those of the Margate Terrane, which hosts the Williston anomaly – located north of the BMA (Jacobs et al., 1996). First identified in the early 20th century (Beattie, 1909), the BMA has been the subject of numerous geophysical investigations aiming to determine its origin. Hypotheses regarding the nature of the anomaly have varied widely, proposing interpretations such as a suture zone (de Beer and Gough, 1980), thrust faults (Corner, 1989), or shear zones (Scheiber-Enslin et al., 2014; Thomas et al., 1992). More recent studies in the Western Karoo Basin have identified the anomaly's source at depths of approximately 10–15 km (Lindeque et al., 2011; Stankiewicz et al., 2007; Weckmann et al., 2007). It is proposed that the high magnetic susceptibility of the rocks associated with the BMA results from exsolved hematite-ilmenite intergrowths within granulite-facies mid-crustal rocks of the Natal Belt (Quesnel et al., 2009; Scheiber-Enslin et al., 2014). These lamellae have been shown to possess high natural remanent magnetisation, reaching values up to 30 A/m (McEnroe et al., 2009; Robinson et al., 2002). An application has been made to the International Continental Scientific Drilling Program (ICDP) to target the BMA's source body and resolve long-standing questions regarding its origin, and offer valuable insights into Proterozoic crustal evolution, and younger overlying cover.

Keywords: Beattie Magnetic Anomaly, ICDP

CONSTRAINING DEFORMATION AGES WITHIN THE SOUTHERN STRUCTURAL DOMAIN OF THE PONGOLA BASIN, SOUTHEAST MARGIN OF THE KAAPVAAL CRATON, SOUTH AFRICA: RELATIONSHIPS FROM FIELD MAPPING

Nigel Hicks[1,2], John Dixon, Mawande Ncume[1,2], & Steve McCourt[2]

[1]Council for Geoscience, Pietermaritzburg, South Africa

[2]Discipline of Geological Sciences, School of Agricultural, Earth and Environmental Sciences, University of KwaZuluNatal, Westville, South Africa

Constraining deformation ages within Archaean cratons greatly increases our understanding of crustal processes during the early part of Earth history. Detailed 1:10 000-scale field mapping within the Nsuze River gorge in central KwaZulu-Natal, South Africa, indicates that deformation events affecting the Mesoarchaean Pongola Supergroup and spatially related Hlagothi Complex along the southeastern margin of the Kaapvaal Craton, predate intrusion of the 2.66 ± 2 Ga White Mfolozi Dyke Swarm. Within the study area, undeformed NE-SW trending porphyritic dykes crosscut both folded Pongola Supergroup stratigraphy and the intrusive Hlagothi Complex, thereby providing a minimum age of deformation for the Mesoarchaean sequences. These geological relationships suggest that a N-S compressional event occurred in the Meso- to Neoarchaean, sometime between 2.86 Ga and 2.66 Ga, which caused folding and thrusting of the Pongola Supergroup within the Southern Structural Domain. These results question the long-standing view that the southeastern margin of the Kaapvaal Craton was intensely deformed by north-verging structures associated with the Mesoproterozoic (ca. 1.1 Ga) Namaqua-Natal Orogeny and promotes discussion as to what effect the orogeny actually had on the craton during terrane accretion.

Keywords: Pongola Supergroup, Pongola, Orogeny

ANALYSIS OF HIGH-RESOLUTION SATELLITE IMAGERY TO STUDY NEOTECTONIC FAULT SCARPS IN SOUTHWESTERN NAMIBIA

Anele Matsebula[1], Alastair Sloan[1], Benjamin Whitehead[1], Beth Shaw-Kahle[2], James Hollingsworth[3], Liam Nell[4], Robert Muir[5,6] & Tyron Galant[1]

[1]University of Cape Town, Cape Town, South Africa
[2]Ludwig Maximilians-Universität München, Munich, Germany
[3]Université Grenoble Alpes, Grenoble, France
[4]Binghamton University, New York, USA
[5]University of the Free State, Bloemfontein, South Africa
[6]University of the Western Cape, Bellville, South Africa

Recent findings indicate that southern Africa can experience large earthquakes away from the Eastern African Rift, including within stable continental regions (SCRs) such as Namibia. These SCRs are characterised by low strain rates and long recurrence intervals, leading to an incomplete seismic record and a limited understanding of their tectonics. This region offers a valuable opportunity to investigate normal faulting in an SCR setting, as most of the relatively well-studied SCRs lie within compressional stress regimes. One notable discovery is the identification of large neotectonic faults in Namibia. However, a detailed geomorphological analysis of these faults has not been conducted due to the unavailability of high-resolution digital elevation models (DEMs) at the time of discovery. Conducting a high-resolution geomorphological analysis of these paleoseismic fault scarps is essential for understanding the magnitude, timing, and geological context of these events, which is crucial for future seismic risk assessments and the protection of critical infrastructure. For the first time, we are presenting high-resolution digital elevation models (DEMs) obtained through stereophotogrammetry and tri-stereo Pléiades satellite data. Using this data, we mapped out two ruptures to look for evidence of segmentation and investigate event frequency and magnitude, thereby gaining a clearer understanding of these fault scarps. Analysis revealed that the AnusiTafelkop scarp is approximately 15 km long with an average throw of 2.0 meters, while the /Gãb scarp extends 23 km with an average displacement of 1.6 meters. Further calculations from these results indicate that both structures have the potential to generate earthquakes of magnitude greater than Mw 6.5. These findings have significant implications for seismic hazard assessments, as the current Namibian seismic catalogue considers the maximum possible earthquake to be Mw 5.5. Therefore, there is a critical need to update the seismic risk assessment to better prepare for potential large earthquakes.

Keywords: SCR seismicity, normal faulting, neotectonics, tectonic geomorpology

SEISMIC AND ELECTRICAL RESISTIVITY IMAGING OF MARINE TERRACES AND DETERMINATION OF DEPTH TO BEDROCK AT DUYNEFONTYN, KOEBERG NATURE RESERVE, SOUTH AFRICA

Zusakhe Nxantsiya[1], Andisani Makhado[1], Emmanuel Chirenje[1], Matome Sekiba[1], Melvin Sethobya[1] & Simon Sebothoma[1]

[1]Council for Geoscience, Pretoria, South Africa

High resolution ground geophysical surveys were conducted in Koeberg Nature Reserve in Duynefontyn, South Africa. The surveys were done in support of SSHAC (Senior Seismic Hazard Analysis Committee) Level 3 Probabilistic Seismic Hazard Assessment (PSHA). The objective of the surveys were to delineate marine terraces, determine depth to bedrock and thickness of the widespread sand overburden in support of formulation of Site Safety Response (SSR) chapters for the proposed Duynefontyn site under the Duynefontyn Nuclear Siting Project (DNSP). Both Seismic Refraction and Electrical Resistivity profiles were conducted at 5m station spacing, perpendicular and oblique to the NNW-SSE trending coastline. The station spacing was chosen to maximise imaging microstructures such as local faults and fractures. Four prominent seismic velocities were distinguished and interpreted as an upper layer of dry aeolian sands underlain by wet/moist marine and aeolian related sediments on top of unweathered bedrock lithology. Resistivity models delineated the weathered bedrock horizon. Interpretation of the survey results reveal approximate bedrock elevations below aeolian and marine related sediments of the Cenozoic overburden. Resistivity also mapped the interpreted steep dipping low resistivity layers that are possibly shales towards the end of Line E. Seismic refraction interpretation reveals the overburden thickness to vary between 15-25 m. A comparison of borehole logs and geophysics models were done, and the results were used to adjust interpretations where applicable. Seismic refraction proves to be the best method to delineate marine terraces and to characterise beach sand profiles. In comparison electrical resistivity appears to lack resolution due to the lack of contrasts between different profiles.

Keywords: Marine terraces, Bedrock, Seismic refraction, Electrical resistivity

GEOMORPHOLOGICAL ANALYSIS FOR ACTIVE FAULTS IN EASTERN LIMPOPO BELT AND SOUTHERN MOZAMBIQUE BELT: EARS SOUTHWARDS PROPAGATION IMPLICATIONS

Anzani Ramagadane[1], Alastair Sloan[1] & Beth Kahle[2,1]
[1]University of Cape Town, Cape Town, South Africa
[2]Ludwig Maximilian University of Munich, Munich, Germany

Paleo-seismology is increasingly being incorporated in seismic hazard assessments for stable regions like Southern Africa. This is necessary because the threat of faults with long (10-100 Ka) recurrence times may not be represented in <100 years old instrumental catalogs. Although infrequent, earthquakes in stable regions can be large and devastating. The 2017 Mw6.5 Moiyabana earthquake in Botswana and the 2006 Mw7 Machaze earthquake in Mozambique occurred in areas previously considered low-risk, but fortunately these areas were sparsely populated. Regardless, the geodetic data suggests slow extension rates for these regions, e.g., <1 mm. yr-1 near the Machaze earthquake epicenter. We investigated past earthquakes, using stereophotogrammetry, on three active extensional structures (Bosbokpoort Fault, Tshipise Fault and Mazenga Grabens) in southern Africa regions previously considered to be low-risk: The Limpopo Belt in South Africa and the Mazenga region in Mozambique. We used TanDEM-X elevation maps to extract elevation profiles and then measured the scarp sizes. The scarp parameters were incorporated in earthquake scaling equations to estimate the potential magnitudes of earthquakes on these faults. The Kruger-Malale scarp of the Bosbokpoort Fault, located in the Limpopo Belt, has 9 m cumulative slip and 55 km length. The Nwanedzi-Brak scarp of the Tshipise Fault, located in Limpopo Belt, has 6m cumulative slip and 140 km length. The Mazenga Grabens in Mozambique are ~10 km wide, up to 150 km long and have up to 40 m average cumulative slip. All three structures have potential magnitudes greater than 7. If they rupture entirely, they will raise the potential seismic risk in their respective areas. Additionally, there are two possible continuations of the Eastern African Rift System (EARS), and it is unclear which one may dominate. (1) The Bosbokpoort Fault and Tshipise Fault inherited the Limpopo Belt's ENE-WSW orientation. This orientation is nearly consistent with the NNE-SSW Urema Rift, the EARS southmost member, which terminates at the eastern limits of the Limpopo Belt. If the Limpopo Belt and Urema Rift deformation persists like this, the two structures may eventually link-up. (2) Alternatively the Urema Rift may branch eastwards into the Machaze earthquake NNW-SSE aftershocks trend, which is consistent with the N-S trending Mazenga Grabens.

Keywords: paleoseismology, EARS, extensional deformation, stable regions

WHITHER THE RIFT? FACTORS CONTROLLING ACTIVE FAULTING IN SOUTHERN AFRICA

R. Alastair Sloan[1], Anele Matsebula[1], Anzani Ramagadane[1], Beth Kahle[1,2], Khumo Leseane[1,3] & Robert Muir[4]

[1]Department of Geological Sciences, University of Cape Town, Cape Town, South Africa
[2]Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität Munchen, Munich, Germany
[3]Department of Geological Sciences, University of Botswana, Gaborone, Botswana
[4]Department of Earth Sciences, University of the Western Cape, Bellville, South Africa

As the Eastern African Rift System moves southwards, the spreading rate becomes slower and the rift structures less well defined. A separate presentation highlights geomorphological evidence for rifting surrounding the Zimbabwe Craton, and here we highlight a number of recently discovered active faults in Botswana and Namibia. Comparing these structures with geophysical data we find that all of these faults reactivate structures in mobile belts, Jurassic-Cretaceous Rifts, or – in the case of the newly described Xade Complex Fault – associated with a layered igneous complex within a craton. If we consider the broader Eastern African Rift System this alignment with pre-existing crustal structures seems to be the defining control on the location and orientation of active faulting, with variation in lithosphere strength associated with thick, cold cratonic roots only playing a secondary role. Worryingly, structures which appear to have only undergone relatively minor recent cumulative displacements have fault traces similar to relatively mature faults. This is likely due their exploitation of long, straight, pre-existing weak zones, and means that they may be capable of failing in major earthquakes. Consequently, incipient rifting in these areas could lead to very infrequent damaging events (similar to the M7 Macheze earthquake in Mozambique) which need to be taken into account when designing critical infrastructure.

Keywords: Tectonics Intraplate Earthquakes Rating

FROM DEPTH TO DEFORMATION – UNRAVELLING THE BASEMENT ARCHITECTURE AND STRUCTURAL FEATURES ALONG THE SOUTH AFRICAN SOUTHERN MARGIN

Chantell van Bloemenstein[1] **& Anthony Fielies**[1]

[1]Petroleum Agency SA, Cape Town, South Africa

We evaluate basement architecture and structural features along South Africa's southern continental margin using 2D seismic data from the 1970s to 2000s with variable quality and resolution. This seismic analysis focuses on four key basins – Pletmos, Bredasdorp, Southern Outeniqua, and Mallory Basins. Basement along the margin ranges in depths from 0.15s to 9s (TWT), is shallowest in the Bredasdorp Basin, and at its deepest in the Mallory Basin. Sediment thickness reaches up to 6s (TWT), and is the thickest in the Pletmos Basin, thinning towards the Bredasdorp Basin and Agulhas Bank. Seismic basement character is a mix of incoherent to chaotic, transparent to semi-transparent signatures, occasionally displaying internal reflections. These intrabasement reflections are sometimes depicted as deep-seated detachments and shear zones, and possibly Moho within the Mallory Basin. Fault kinematic analysis reveals NW-SE to E-W orientation in the Pletmos Basin with fault dips ranging between 0.2° and 89°. Bredasdorp faults are orientated NW-SE, NE-SW and E-W, dipping between 10° and 30°. The NW-SE and NE-SW fault trends found in the Southern Outeniqua Basin dips between 17° and 67.5°. The Mallory Basin's near vertical faults dip between 87° to 90°, and trends NW-SE and N-S. The E-W orientation is mostly confined to the inboard Pletmos and Bredasdorp Basins. Seismic data also reveals complex subsurface structures resulting from both compressional and extensional regimes marked by thrusts, fault-bend folds, imbricate fans, rollover anticlines, and flower structures. Basement architecture plays a significant role in hydrocarbon accumulation by providing the structural framework, accommodation space, migration pathways, and reservoir enhancement. Basement faults and fractures, function as conduits for hydrocarbon migration, enabling oil and gas to move from source rocks to Fractured Basement reservoir accumulations. Fluid escape features are visible on seismic showing fluid movement through and from Basement into the sedimentary column. Basement architecture influence basin geometry and deformation patterns, which control the formation of traps inherited from the pre-existing Cape Fold Belt. Basement records periods of successive tectonic deformation and reflects the structural complexity along the margin. It reiterates the dynamic tectonic evolution influenced by the Gondwanide Orogeny, transform faulting, and regional compressional and extensional forces.

Keywords: Basement architecture, structural features, southern margin, South Africa

ROCK HARDNESS ESTIMATION FROM ACOUSTIC BOREHOLE IMAGING

Reece van Buren[1] & Warren Krynie[1]
[1]Digital Surveying, Carletonville, South Africa

Rock hardness, defined as the resistance of rock against an object impacting its surface, is a critical parameter in mining operations, influenced by the mineral composition, bonding capacity, and strength of the matrix material. Accurate estimation of rock hardness is essential as it directly impacts the efficiency of drilling and blasting operations, and further downstream processes such as milling and ore processing. Traditional methods for determining rock hardness, such as uniaxial compressive strength (UCS) tests, are costly and time-consuming due to the need for careful sample selection and preparation. Non-destructive hardness tests, like Schmidt hammer hardness (SHH) and Shore scleroscope hardness (SSH), offer viable alternatives by providing portable, low-cost measurements. Another method of obtaining rock hardness includes the direct measurement of the acoustic impedance, measured in situ. This study presents a novel approach to correcting critically compromised reflection amplitude responses in acoustic televiewer (ATV) borehole images (ABI) caused by tool eccentricity within the borehole. By analysing the eccentricity, precise gains can be applied to correct these anomalous amplitude responses, recovering valuable data and making the ATV images useful beyond traditional litho-structural interpretations. The corrected data can be used to develop robust empirical models correlating measured rock hardness properties against acoustic reflectance without the compromising artefacts associated with eccentricity. The methodology involves detailed analysis of travel time data, determination of eccentricity, and optimised compensation of amplitude data. The dominant artifact due to eccentricity is a 180-degree wavelength attenuation of the amplitude response, primarily due to the angular relationship change between the acoustic pulse travel path and the borehole wall. Traditional approaches involve averaging the radial response, which is still affected by reduced amplitudes due to eccentricity. The proposed compensation workflow effectively mitigates these artifacts, retaining a high degree of data fidelity. The rapid and in situ estimation of rock hardness enabled by this workflow can significantly impact mining operations by improving lithological and geotechnical knowledge of the rock mass, optimising upstream drilling methods, and downstream chemical and mechanical processes of rock breakage. The authors intend to further this research and integrate the outcomes into standard data processing workflows.

Keywords: Hardness, Televiewer, Eccentricity, Compensation

The Archaean Earth: From Mantle Dynamics to Conditions for Early Life

EOARCHEAN CONTINENTAL CRUST FORMATION AND EVOLUTION INFERRED FROM 3.9 TO 4.0 GA OLD DETRITAL ZIRCONS IN THE TANZANIA CRATON

Robert Bolhar[1], Axel Hofmann[2], Balz S. Kamber[3], Heejin Jeon[4], Jeffrey D. Vervoort[5], Joas Kabete[6], Manuela Botero[5], Martin J. Whitehouse[4] & Roland Maas[7]

[1]University of the Witwatersrand, Johannesburg, South Africa
[2]University of Johannesburg, Auckland Park, South Africa
[3]Queensland University of Technology, Brisbane, Australia
[4]Swedish Museum of Natural History, Stockholm, Sweden
[5]Washington State University, Pullman, USA
[6]University of Dar es Salaam, Dar es Salaam, Tanzania
[7] The University of Melbourne, Melbourne, Australia

The Eoarchaean geological record remains scarce on the African continent, impeding our understanding of early continental crust formation. To augment the very limited dataset, we present zircon U-Pb ages, trace metal and O-Hf isotopic compositions obtained by SIMS and LA-MC-ICPMS. New insights into source rock melt compositions, crystallisation temperatures, modes of crust-mantle differentiation and redox conditions allow evaluation of crust formation models for the Early Earth. Primary unaltered REE (and Ti) compositions in oscillatory-zoned >3.8 Ga zircons suggest crystallisation from TTG-like melts at temperatures of 832 ± 34°C. Zircon REE-based oxybarometric estimates of -3.4 to +1.8 FMQ resemble both modern and Archean mantle values. Zircon O isotopic compositions overlap the mantle range, while initial Hf isotopic ratios are uniformly near-chondritic. These signatures limit the involvement of strongly depleted mantle and evolved continental crust as source reservoirs or reworking after prolonged periods of crustal residence. Also, models involving partial melting of hydrated (ultra)mafic precursor materials (volcanic-tectonic burial), assimilation of surface-derived material (subduction), or hydrothermal activity (impact-related or involving meteoric water in a subaerial setting) appear unlikely. An alternative model is proposed whereby TTG-like melts formed through infiltration of basaltic or picritic melts into, followed by hybridisation with, residual mid-(proto?) continental crust in an intraplate setting. Near-chondritic zircon Hf isotope compositions require contemporaneous formation of incoming melts and pre-existing crust.

Keywords: Eoarchaen, zircon, Tanzania Craton, TTG

AEOLIAN DUNES IN THE 2.64 GA VRYBURG FORMATION OF THE TRANSVAAL SUPERGROUP, GRIQUALAND WEST, SOUTH AFRICA

Vittorio Colicci[1], M. Colin Marvin[1], Mathieu G.A. Lapôtre[1], Michael Hasson[1] & Wladyslaw Altermann[2]

[1]Stanford University, Stanford, California, USA

[2]Freelance Geological Consultant, Pretoria, South Africa

Seven occurrences of putative aeolian strata have been reported from the Archaean sedimentary record, most of which have limited exposures. One notable exception is found in the ~2640 Ma Vryburg Formation in Griqualand West. It develops transgressively over an unconformity on the Ventersdorp Supergroup, and was dated to 2740-2720 Ma. The missing ~100 myr are marked by pronounced schistose deformation zones in the underlying Ventersdorp lavas, which are absent in the overlying Transvaal Supergroup. The most prominent exposures of the Vryburg Formation are found along the southwestern edge of the Kaapvaal Craton. The up to ca. 200 m-thick unit consists of a basal conglomerate, overlain by lenticular, immature sandstone and shale intercalations with rare carbonate beds. These occasionally develop into stromatolitic layers, metres thick and hundreds of metres in extent. The deposits are covered by shales, fluvial sandstones, and conglomerates, and by lavas in the eastern edge of the basin. Further up section, sandstones mature into clean, massive, and thick quartzites, which are eventually overlain by the Lokammona Shale Formation. Here, we characterise the stratigraphy of the Vryburg Formation and test its aeolian origin by examining the surface features of disaggregated zircon grains via a new technique. The sandstone consists of metre-thick tabular and trough cross-beds with high-angle foresets, inverse grading, and pervasive pinstripe lamination. In places, paleosurfaces are exposed with preserved symmetric and asymmetric, decimetre-wavelength, sinuous ripples with cm-scale amplitude. Rock samples were collected in several sandstone facies, and zircon grains were extracted using electric pulse disaggregation and imaged using a scanning electron microscope. Preliminary sedimentological observations are consistent with deposition in a field of decametre-scale aeolian dunes with episodically wet interdunes. At the GSSA Geocongress 2025, we will confirm whether this interpretation is consistent with observed zircon microtextures and assess the size of the dunes that formed these deposits. Our findings will provide new quantitative evidence and further context for what could be one of Earth's oldest, best preserved, and thick aeolian deposits.

Keywords: Archaean, aeolian, Transvaal, zircons

RETURN TO THE VAALRAND ENIGMA: SEDIMENTARY FACIES OF QUARTZITES NEAR BALFOUR, MPUMALANGA

Michiel de Kock[1]

[1]PPM, Department of Geology, University of Johannesburg, Auckland Park, South Africa

An isolated east-west trending range of steeply dipping quartzites known as the Vaalrand hills near Balfour, Mpumalanga have perplexed stratigraphers. Unique features include the considerable thickness of the quartzites and the steep dipping nature of the beds. Uncertainty about the stratigraphic assignment of these quartzites is reflected in regional geological maps, with assignment to the Moodies Group or it being mapped as undifferentiated Witwatersrand Supergroup. The Vaalrand strata was studied along a profile on the farm Vlakfontein. Here the strata are dominated by medium to thinly bedded, normal graded, poorly sorted medium to course-grained pebbly quartzites. The ~360m-thick succession is monotonous without any other interbedded lithologies. Bedding architecture is planar and parallel without obvious basal scouring. Pebbly bases are not well-bedded (Gm), often discontinuous, and vary from a few centimetre to 15 cm thick. They are dominated by medium-sized pebbles of milky quartz, banded chert and, rarely, quartzite that are sub-angular to rounded. Pebbly bases grade into dominantly horizontally laminated (Sh) or massive (Sm) quartzites. Occasionally, tabular cross-stratification (Sp) is well-preserved. Symmetrical ripple marked surfaces are rarely exposed (Sr). The strata dip steeply (~70-80 degrees) to the North, while normal grading and cross-stratification indicate overturned bedding. There was no evidence of structural duplication and the younging direction was consistently to the South. The basal and top contacts of the succession are obscured by non-outcropping younger cover of the Ecca Group. The facies characteristics are indicative of a shallowmarine clastic environment in relative proximity to its sediment source. The observed facies exclude correlation to units of the West Rand Group, but are reminiscent of quartzites belonging to the Elsburg Formation of the upper Central Rand Group. There are, however, currently no conclusive reasons to exclude assignment to the Moodies Group either, even though conglomerates of the latter contain abundant quartzfeldspar porphyry and occasional metavolcanic clasts. U-Pb dating of detrital zircon grains and a comparison to published U-Pb zircon data from the Witwatersrand Supergroup and Moodies Group, but also the Dominion Group will hopefully help to assign these quartzites to their correct stratigraphic position.

Keywords: Facies, Witwatersrand Supergroup, Moodies Group, Quartzite

EAST EUROPEAN CRATON IN THE STORY OF COLUMBIA/NUNA

K.G. Erofeeva[1], A.V. Samsonov[1] & A.V. Skoblenko[2]

[1]Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, Russian Academy of Sciences, Russia

[2]Department of Geology, University of Johannesburg, Auckland Park, South Africa

The study focuses on results from 2.2–2.0 Ga orogens of the East European Craton (EEC), which emerged during the earliest stage of the Columbia/Nuna assembly. The Volgo-Don Orogen (VDO) is the largest Paleoproterozoic orogen in the EEC. Its western flank – the West Sarmatian Composite Terrane – was formed at 2.20–2.05 Ga in an active margin environment. The Don and Losevka Terranes, located at the eastern margin of the Archean Block, are mainly composed of metamagmatic supra-subduction rocks. The Vorontsov Terrane, situated to the east of the Losevka Terrane, hosts weakly metamorphosed flysch accretionary prism sequences sourced from the intraoceanic island arcs of 2.2–2.08 Ga. The eastern flank of the VDO – the South-Volga Terrane – is composed of high-Al granulites (PT peak at ~8 kbar, 970?), followed 'clockwise' evolution reflected by their protolith accumulation at ca. 2.2–2.05 Ga, subsequent burial at ca. 2.05–1.97 Ga, and exhumation of the metamorphic complexes. Unimodal zircon age distribution in the granulites of the central part of the terrane and polymodal - in the vicinity of the Archean block margin, favor for the accumulation of the rocks' protoliths at the expense of both juvenile island-arc and older crustal complexes. The Vyatka-Kama Orogen (VKO) located in the northern part of the Volgo-Uralia segment of the EEC, hosts metavolcanogenic-sedimentary sequences intruded by S-granitoids aged 2.05 Ga. The supracrustal rocks have supra-subduction juvenile signatures and contain magmatic zircons aged of 2.2–2.08 Ga, indicating intraoceanic island-arc systems of different ages as a source of materials. The Lapland-Kola Orogen (LKO) is exposed within the Fennoscandian Shield and consists of metamorphosed volcanogenic-terrigenous rocks with supra-subduction juvenile characteristics. The polymodal detrital zircon age distribution in the granulites of the LKO (1.99–3.4 Ga) indicates Palaeoproterozoic island arcs formation close to the Archean crust or at the Archean continental margin. LKO and VKO might hence comprise different parts of a single extensive Paleoproterozoic orogen that united the Archean blocks of the Volgo-Uralia, Fennoscandia and probably Siberian craton. If so, this orogen might represent a tectonically weakened zone after the assembly of Columbia/Nuna, along which subsequent rifting occurred during the supercontinent break-up.

Keywords: geochronology, Sm-Nd, Paleoproterozoic, orogens

A REVIEW OF FACTORS RESPONSIBLE FOR WITWATERSRAND GOLD MINERALIZATION

Axel Hofmann[1]

[1] Department of Geology, University of Johannesburg, Auckland Park, South Africa

The exceptional gold mineralisation in quartz pebble conglomerates of the Witwatersrand Basin is attributed to a combination of factors. These factors are linked to the co-evolution of the atmosphere, hydrosphere, lithosphere and biosphere, at a very specific time in Archaean geological history and the evolution of the Kaapvaal Craton. Following craton stabilisation and its subaerial emergence, intense chemical weathering and erosion of large volumes of granitoid-greenstone basement released detrital and dissolved gold. Shallow-marine reworking in a long-lived and slowly subsiding basin subjected to episodic compressional deformation and relative sea-level oscillations led to sedimentary concentration of detrital gold. The interaction between acidic, anoxic, and sulfurous surface runoff and more oxidising marine waters in a near-coastal oxygen oasis supported microbially mediated diagenetic pyrite formation and incorporation of dissolved gold in the pyrite crystal lattice. Erosion and reworking of diagenetic pyrite gave rise to detrital pyrite that characterise most reefs. Abundance of detrital uraninite in conglomerates, derived from erosion of Mesoarchaean granites, and episodes of hydrocarbon migration through sedimentary strata during deep burial set the scene for further enhancement of gold grades in the reefs. Granular and seam pyro-bitumen formed by radiation-induced polymerisation of hydrocarbons around detrital uraninite. Gold dissolved in migrating hydrothermal fluids was then reduced and precipitated upon interaction with the reef pyrobitumen during hydrothermal placer modification.

Keywords: Archaean, gold mineralisation, Witwatersrand Basin, quartz pebble conglomerate

U-Pb AGE DETERMINATION OF ZIRCONS FROM TUFFACEOUS SANDSTONES OF THE MOODIES GROUP, BARBERTON SUPERGROUP, FROM ICDP-BASE DRILL CORE

N.C. Mazibuko[1], C. Vorster[1], H. Wabo[1] & M. De Kock[1]

[1]Department of Geology, University of Johannesburg, Auckland Park, South Africa

The Moodies Group is the youngest subdivision of the archean (ca. 3.5-3.2 Ga) Barberton Supergroup located in Mpumalanga, South Africa and Eswatini. Previous attempts to constrain the exact timing of the 3.2 Ga Moodies Group have resulted in bracketing ages for the sedimentary succession. Constraints for the deposition of these sediments include tectonism and deformation, making them non-representative of the Moodies Group itself but of that which came after. Attempts to constrain the base of the Moodies strata include the Dalmein Pluton with (U-Pb) zircon and (Th-Pb) titanite crystallisation ages of 3216+2/-1 Ma and 3215± 2Ma respectively. This pluton crosscuts Onverwacht Group rocks upon which the Moodies Group is folded in the Kromberg Syncline. The basal conglomerate of the Moodies Group occurring at the Eureka Syncline consists of granitic clasts which yield zircon U-Pb ages of 3226± 8 Ma and 3224 ± 6 Ma. The basal Clutha Formation of the Moodies has a detrital zircon population of 3228 ± 8 Ma in the Eureka Syncline. Ages used to possibly constrain the top of the Moodies include 3207 ± 2 Ma dacitic dikes through the base of the Moodies, 3109 +10/-8 Ma Salisbury Kop Pluton that crosscuts the folded Barberton Supergroup and 3207 ± 2 Ma and 3224 ± 0.4 Ma porphyritic dikes through the Moodies Group at the Heights Syncline. The ages are scattered in different localities within the Barberton Mountainland area. 43 Drill core samples of reworked tuffaceous sandstone were acquired from the stratigraphy of the Moodies Group through the Intercontinental Drilling Program (ICDP) of Barberton Archean Surface Environments (BASE) in BASE 5A and 5B. Samples underwent Selfrag mineral liberation, heavy liquid extraction and handpicking to acquire zircons for Laser Ablation-MultiCollector-Inductively Coupled-Mass Spectrometry (LA-MC-ICP-MS) analysis. Ages determined aided in constraining the timing of these sediments. U-Pb results obtained fall within ca. 3223-3209 Ma. Zircon ages with reasonable errors will be considered for high precision Thermal Ionisation Mass Spectrometry (TIMS) dating.

Keywords: archean, drill core, tuffaceous, sandstone, zircon

GEOCHEMISTRY AND GEOCHRONOLOGY OF MAFIC DYKES FROM THE MUSINA MINE IN THE MUSINA AREA

Yonela Mnothoza[1], Humbulani R. Mundalamo[2] & Linda M. Iaccheri[1]
[1]University of the Witwatersrand Johannesburg, South Africa
[2]University of Venda, Thohoyandou, South Africa

Understanding the geochemistry and geochronology of mafic dykes is important for revealing the Earth's geological history, the evolution of its continents, and the timing of mineralisation events. This study focuses on constraining the geochemistry, age, and isotopic compositions of mafic dykes in the Musina Mine area, situated in the Central Zone of the Limpopo Mobile Belt near Musina, South Africa, to constrain the age of copper mineralisation. The dykes within the Musina Mine area exhibit no evidence of metamorphism and display a predominant NE-SW orientation. A total of ten samples were analysed using petrographic analysis, major and trace element geochemistry (XRF, ICP-MS), and U-Pb zircon geochronology. The study analysed zircon U-Pb ages from 19 zircon grains, with a minimum of four grains dated from each of the five dolerite samples. Preliminary geochemical analysis revealed four groups of samples with unique compositional characteristics. These groups show trends consistent with magmatic differentiation through fractional crystallisation. The samples had SiO_2 content between 35.37% and 52.73%, whilst MgO ranged from 3.03% to 16.12%. Trace element patterns showed enrichment in Light Rare Earth Elements (LREE) relative to Heavy Rare Earth Elements (HREE), with variations between groups. Zr concentrations ranged from 19.49 to 737.75 ppm, whilst Nb varied from 2.99 to 32.02 ppm. The geochemical diversity amongst the sample groups suggests multiple magmatic events or sources. The variations in elemental concentrations, particularly in Zr and Nb, indicate different stages of magmatic differentiation and possibly distinct mantle-derived sources. Geochronological analysis yielded a range of ages, spanning from approximately 1918 Ma to 2723 Ma, with most ages clustering between 1900 Ma and 2700 Ma. These ages correlate with several geological events in the Central Zone of the Limpopo Mobile Belt. Samples dating around 2700-2600 Ma align with the Neoarchean granulite-facies metamorphism (~2700-2600 Ma). Ages around 1900-2000 Ma indicate Palaeoproterozoic reworking and metamorphism (~2000-1900 Ma). Some intermediate ages may be related to pre-Bushveld Igneous Complex events. Cathodoluminescence (CL) imaging (TIMA data) is pending to assess zoning patterns and distinguish magmatic versus inherited zircons.

Keywords: geochronology, large igneous province, mafic dykes

EVALUATION OF ARCHAEAN BANDED IRONSTONE FORMATIONS IN THE SOUTHEAST COLLAR OF THE VREDEFORT DOME

H.W. Ostmann[1], Eugene. W. Bergh[1] & Ricart B. Boneschans[1]

[1]Unit for Environmental Sciences and Management, Geology, North-West University, Potchefstroom, South Africa

Greenstone terrains in South Africa provide essential information on the geological history and Archaean evolution of the Kaapvaal Craton. The Greenlands Formation, exposed in the basement complex of the Vredefort Dome, is accepted to represent an ancient greenstone sequence of metamorphosed komatiitic lavas associated with banded, ferruginous metapelites. While the precise age of this formation has yet to be determined, the presence of localised iron formations in the Broodkop Shear Zone has led to its interpretation as a primitive oceanic crustal remnant. This study evaluated the meta-sedimentary component of the Greenland's Formation and investigated whether this sequence might represent a younger supracrustal unit of the lower Witwatersrand Supergroup. Three main iron formations, including from the Broodkop Shear Zone (Greenlands Formation) and the Water Tower and Contorted beds of the Parktown Formation (outcropping near the Greenlands Formation), were sampled and prepared for petrographic, mineralogic, and geochemical analyses. Mineralogy and textural characteristics were assessed with petrography and were aided with X-ray diffraction analysis to determine mineralogical composition. Bulk rock geochemistry was obtained by X-ray fluorescence, which additionally provided semiquantitative analysis of selected rare earth elements (REEs). Samples from the Broodkop Shear Zone indicate similar major and trace element compositions to the Water Tower and Contorted bed formations and fall within similar ranges on binary and spider diagrams which indicate a corresponding MgO enrichment in samples found closer to the komatiitic intrusions. In addition, a similar coherence is seen in mobile and immobile trace elements (Zr, Hf, Pb, Th), which further signifies a possible connection. On a AKFM plot, all samples are found within the same fields as typical iron formations within the Witwatersrand, indicating similar parental components and metamorphic conditions, which is further supported by their mineralogical characteristics that display corresponding grunerite textures. The strong correlation in textural and chemical characteristics points to the likelihood that the iron formation found at the Broodkop Shear Zone might not form part of the Greenlands Formation and rather represents a dismembered portion of the Parktown Formation.

Keywords: Witwatersrand Banded Ironstone, Vredefort Dome, Greenlands Formation, Komatiitic basalt

INTRA-CRATONIC ARCHITECTURE AND METALLOGENIC SIGNIFICANCE OF THE KAAPVAAL CRATON

Patience M. Ratshalingwa[1], Karen Smit[1] & Linda Iaccheri[1]

[1]School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa

The Kaapvaal Craton, one of Earth's oldest and most stable continental regions, provides key insights into Archaean crustal evolution. Understanding its crustal growth history is essential for reconstructing early geodynamic processes. However, the relationships between different intracratonic crustal blocks within the Kaapvaal Craton and the genetic relationship between granite-greenstone assemblages across the craton are not well constrained. This study aims to constrain the timing of crustal formation and growth while delineating intra-cratonic boundaries through the integrated use of U-Pb zircon dating and Lu-Hf, Sm-Nd, and Rb-Sr isotopic systems. Uranium-Pb crystallisation ages have been compiled from published sources. These data were analysed in ArcGIS using Empirical Bayes Kriging (EBK) for spatial analysis, while probability density plots were generated in Isoplot to examine the spatial and temporal distribution of U-Pb ages across the craton. Age distribution patterns across the Kaapvaal suggest that crustal formation initiated in the Swaziland Block and progressed towards the Pietersburg Block and Kimberly Block, where rocks predominantly have crystallisation ages of <2.9 Ga. Our age compilation indicates that the formation of the Kaapvaal continental crust occurred between 3.6 Ga and 2.5 Ga, with major magmatic peaks at 3.0 Ga-3.3 Ga, 3.45 Ga–3.55 Ga and 2.7 Ga–2.8 Ga. These peaks, along with crystallisation break at 3.55 Ga–3.6 Ga, reflect episodic magmatism associated with continental growth, mantle-derived magmatism, and shifts in tectonic regimes. A globally recognised period of extensive volcanic and intrusive activity at 2.7 Ga is also evident, particularly in the Swaziland Block and Pietersburg Block. Compilation of Sm-Nd isotopic data indicate that the Kaapvaal Craton has a wide range of eNd values ranging from 7.72 to -8.42. The trend from positive/near-zero eNd values in the early stages of craton formation (~3.6–3.4 Ga) to increasingly negative eNd values (-2 to -8.42) indicate that the Kaapvaal Craton underwent early juvenile crust formation (~3.6 Ga), followed by progressive crustal reworking and recycling over time (~3.0–2.7 Ga). The integration of geochronology data and isotopic data provide valuable insights into the timing of magmatic events, crustal architecture and magmatic source of the Kaapvaal Craton.

Keywords: Kaapvaal Craton, U-Pd geochronology data, Crustal evolution

NEW ZIRCON U-Pb AGE DATA FROM THE MACKOP FORMATION, MURCHISON GREENSTONE BELT, SOUTH AFRICA: SIGNIFICANCE FOR MESOARCHAEAN SEDIMENTATION WITHIN THE KAAPVAAL CRATON

Samuel Nunoo[1,2], Axel Hofmann[1], Marlina Elburg[1] & Marylou Vines[1]

[1]Department of Geology, University of Johannesburg, Auckland Park, South Africa

[2]Department of Earth Science, University of Ghana, Accra, Ghana

The Murchison greenstone belt (MGB) of the Pietersburg terrane of the Kaapvaal Craton of South Africa is renowned for its economic endowment of antimony and gold. Previous zircon (incl. detrital) U–Pb ages from the MGB have bracketed emplacement age of the volcano-sedimentary succession between 3.07 and 2.97 Ga. Regional deformation-metamorphism is bracketed between 2.97 and 2.90 Ga. However, further age information is scarce in comparison to other greenstone belts on the Kaapvaal Craton. The mafic-ultramafic packages of the Leydsdorp Formation are infolded with siliciclastic sedimentary rocks of the MacKop Formation. The latter unit is dominated by sandstone units of unknown depositional age or source(s). This study attempts to relate these sandstones to siliciclastic rocks of the Witwatersrand and Pongola supergroups, and similar units in the Pietersburg terrane. Zircon U-Pb age data is presented from 4 sandstone samples. Detrital zircon grains (n = 218) within 10% discordance record ages in the range of 2909 ± 7 Ma and 3598 ± 5 Ma. Several age fractions at 2.94, 3.09, 3.16 and 3.46 Ga are present, but most grain ages vary between 3.05 and 3.30 Ga. The maximum depositional age is constrained at 3.0 Ga. However, one volcaniclastic sandstone sample records a younger age cluster with an upper intercept age of 2936 ± 8 Ma, likely indicating syn-depositional volcanism. A similarity index of 36 to 76% exists among the zircon dates from all samples, which indicate a fraction of the detritus likely came from similar sources or different sources of the same age. The zircon age fractions reflect a derivation of sediments from plutonic rocks of such ages. For instance, TTGs exist within the Pietersburg block with ages of 2939 to 3343 Ma that are a potential source for detritus in this age bracket. Older grains may be sourced from the Kaapvaal Craton interior where rocks as old as 3.6 Ga exist. The age of deposition of the MacKop Formation may be synchronous with the West Rand Group, containing detrital zircons in the age range of 2923-3596 Ma. The data may further indicate an earlier time of sedimentation compared to the Uitkyk Formation of the Pietersburg greenstone belt, deposited between 2.88 and 2.69 Ga.

Keywords: Murchison greenstone belt, South Africa, Archaean, Kaapvaal Craton

GRANITOID XENOLITHS FROM THE LOWER CRUST OF THE CENTRAL KAAPVAAL CRATON RECORD A PROTRACTED MULTISTAGE EVOLUTION IN MESO- TO NEOARCHEAN TIMES

Anfisa Skoblenko[1], Axel Hofmann[1], Juergen Reinhardt[2], Kseniya Erofeeva[3] & Yuliya Larionova[3]

[1]Department of Geology, University of Johannesburg, Auckland Park, South Africa
[2]University of the Western Cape: Bellville, South Africa
[3]Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry Russian Academy of Sciences, Moscow, Russia

Apart from sampling the mantle, kimberlites provide insights into the evolution of the deep crust via xenoliths transported to shallow crustal levels. A set of rare granitoid samples from the Roberts Victor and Phoenix (Star) mines in the central Kaapvaal craton have been studied. The Roberts Victor xenoliths of biotite granite (± amphibole) contain zircons, which demonstrate complex features of replacement and overgrowth under CL. REE-enriched zircon cores yielded $^{207}Pb/^{206}Pb$ age ranges of 3081–3050 and 3148–3060 Ma, whereas REE-deficient zircon overgrowths gave younger ages of 3048–3029 and 3060–3038 Ma. These ages are interpreted to reflect emplacement in the lower crust subjected to high-grade metamorphic conditions at 3.1 to 3.03 Ga. The Star mine hosts lower crustal UHT-granulitic xenoliths (UHT metamorphism recorded at 2720–2715 Ma); gneissic xenolith samples are amphibole-biotite (± clinopyroxene) tonalites and leucogranites. Granitoid zircon cores yield 3168–3060 Ma ages with occasional xenocrysts of 3252, 3282 and 3421 Ma. The zircons frequently display sector zoning or possess convoluted rims; newly grown zircon with a weak zonation is also present. The younger zircon ages cover the ranges of 3062–3021, 3001–2868, 2841–2818 and 2791–2707 Ma, which are thought to record overprinting episodes of metamorphism and lower crustal anatexis. The Roberts Victor granitoids have Nd model ages (TNd(DM)) of 3.25 and 3.24 Ga with $\varepsilon_{Nd(t)}$ of +0.9 to +1.1. The Star Mine granitoids show a variation in TNd(DM) from 3.13 to 2.96 Ga with $\varepsilon_{Nd(t)}$ of +2.4 to +4.9, indicating formation from melting of a juvenile source. TNd(DM) 3.38 Ga and $\varepsilon_{Nd(t)}$ = -1.6 for one sample implies a mixed source of juvenile melts with the older crust. The ages retrieved for the granitoid xenoliths of the Roberts Victor and Star mines suggest their formation as part of granitic batholiths by 3.06 Ga, followed by episodes of high-grade metamorphism. These may include collision between the Witwatersrand and Kimberley blocks at 2.93-2.88 Ga, postorogenic granitoid magmatism at < 2.88 Ga, and lower crustal heating linked to the Ventersdorp mantle plume at 2714 Ma.

Keywords: Lower crustal xenoliths, Mesoarchean, Sm-Nd signatures, granitoid magmatism

The Proterozoic in Africa

PETROGRAPHY AND GEOCHEMISTRY OF THE TAMALE-OBOSUM GROUP, VOLTAIAN SUPERGROUP, GHANA: IMPLICATIONS FOR PROVENANCE

Jennifer E. Agbetsoamedo[1], Chris Yao Anani[1], Daniel Asiedu[1] & Zubair Jinnah[2]

[1]Department of Earth Science, University of Ghana, Accra, Ghana

[2]University of Witwatersrand, Johannesburg, South Africa

Petrographic and geochemical analyses were conducted on samples from the Tamale-Obosum Group within Ghana's Voltaian Supergroup to understand their sediment provenance. The Voltaian Supergroup is Neoproterozoic to early Paleozoic in age and incorporates three Groups: Kwahu-Bombouaka (Lower), OtiPendjari (Middle) and Tamale-Obosum Groups (Upper). The Tamale-Obosum Group consists of the undivided Obosum, Sang Conglomerate, Tamale Sandstone, Densubon Sandstone and Dunkro Sandstone formations. Samples from all of these formations were point counted and geochemically analysed using the ICP-MS and XRF for bulk-rock elemental compositions. The Tamale Sandstone and undivided Obosum formations are primarily quartzose and sourced from cratonic interiors and recycled orogens, while the Dunkro Sandstone and Densubon Sandstone formations show transitional arc and mixed provenances. The Densubon Sandstone and Dunkro Sandstone formations are dominantly derived from granitoid plutonic lithologies. The Tamale Sandstone and undivided Obosum formations display mineralogical characteristics aligned with metamorphic terranes, predominantly gneisses. Geochemical classification reveals three distinct rock types: quartz arenites, wackes, and litharenites. Positive correlations between Al_2O_3 and other oxides highlight clay mineral control, while SiO_2 shows an inverse correlation with Al_2O_3. UCC-normalised data further underlines compositional variations, with litharenites depleted in most elements except for Na_2O and CaO. Weathering intensity was assessed using the Chemical Index of Alteration (CIA). The Tamale Sandstone and undivided Obosum formations reveal intense and intermediate source area weathering respectively and significant potassium depletion, while the Densubon Sandstone and Sang Conglomerate formations exhibit weak weathering, influenced by plagioclase-rich sources. The Tamale Sandstone Formation shows minimal K-metasomatism despite intense weathering and Densubon Sandstone Formation exhibits evidence of the former. Combining CIA with the Index of Compositional Variability (ICV) provides insights into source uniformity and weathering conditions. The Tamale Sandstone Formation indicates uniform sources and intense weathering, whereas Densubon Sandstone, Sang Conglomerates and undivided Obosum formations show diverse provenance and varied weathering. Tectonic interpretations suggest passive continental margin settings for the Tamale Sandstone and undivided Obosum formations, while active continental margin or island arc environments characterise the Densubon Sandstone and Sang Conglomerate formations. Overall, the Tamale-Obosum Group demonstrates dominant felsic igneous provenance with minor mafic influences, reflecting dynamic geological processes.

Keywords: Voltaian provenance, geochemistry, petrology

PETROGRAPHIC AND GEOCHEMICAL STUDY OF THE Cu-Ni SULFIDES IN THE MAFIC-ULTRAMAFIC INTRUSIONS PERIPHERAL TO THE KUNENE COMPLEX IN ANGOLA

Rahul Das Gupta[1], Lorenzo Milani[1], Nthatisi S. Makhoba[2], Ben Hayes[2] & Hielke Jelsma[3]

[1]University of Pretoria, Pretoria, South Africa
[2]School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
[3]Anglo American Group, Johannesburg, South Africa

The occurrence of Cu-Ni sulfides has previously been reported from mafic-ultramafic intrusions along the margin of the Mesoproterozoic Kunene Complex in Angola and Namibia. The distribution of trace elements in magmatic sulfides is controlled by their compatibility with the Fe-rich Monosulfide Solid Solution (MSS) or the Cu-rich Intermediate Solid Solution (ISS). The petrography and geochemical composition of magmatic sulfides reflect different stages during fractionation of the sulfide liquid and hence provide important clues to understand their formation. The sulfides analysed in this study are from five mafic-ultramafic intrusions in Angola: Lufinda, Oncocua, Malola, Chiange and Otchinjau. Sulfides were analysed for major and trace elements using EMPA and LA-ICP-MS. The mineralized lithologies at Lufinda and Oncocua include gabbro, gabbronorite and norite, whereas the sulfides occur within troctolite, pyroxenite and dunite at Malola, Chiange and Otchinjau. Pyrrhotite (Po), occurs as massive or semi-massive segregations at Lufinda and Oncocua, associated with silicates and oxides. In contrast, Po occurs as disseminated sulfides in the ultramafic rocks at Malola, Chiange and Otchinjau. Chalcopyrite (Ccp) crystallised as anhedral patches or blebs within Po and pentlandite shows three types of textures: (i) granular, (ii) loop-textured and (iii) as exsolution lamellae in Po. Chalcopyrite is characterised by high concentrations of Zn, Cd, In and Te. The 2Zn/(3Se+5Sn) vs Se diagram shows that most of the Ccp at Oncocua formed from an Fe-rich MSS below 1200 °C, whereas Ccp from Lufinda, with lower 2Zn/(3Se+5Sn) ratios, likely formed by exsolution of an ISS below 500 °C. Pentlandite (Pn) shows relatively high concentrations of Pd (0.14–1.7 ppm), suggesting formation of late-stage Pn during a peritectic reaction between a Pd-poor MSS and a Cu-Pd-rich residual liquid. The preservation of loop-textured Pn at Lufinda may indicate the presence of a fractionated Cu-Pd-rich residual liquid, associated with the gabbroic host rocks, whereas the presence of only granular Pn and MSS-like Ccp in norite and gabbronorite in Oncocua favours a more primitive sulfide liquid.

Keywords: Kunene Complex, magmatic sulfides, chalcopyrite, pentlandite

WHY AGES MATTER: THE PILANESBERG ALKALINE PROVINCE

Marlina A. Elburg[1], Michiel de Kock[1] & Tom Andersen[2,1]
[1]Department of Geology, University of Johannesburg, Johannesburg, South Africa
[2]National History Museum, Oslo, Norway

The Pilanesberg Alkaline Province (PAP) consists of numerous alkaline complexes, mainly of nepheline syenitic to carbonatitic compositions. The PAP is broadly Mesoproterozoic in age, unlike any other igneous rocks on the Kaapvaal Craton. However, published ages vary widely, from 1138±45 to 1430±50 Ma. Even without the spatially and compositionally anomalous Bull's Run Complex and Premier Kimberlite, the range is still ca. 240 Myr. This contrasts with, for instance, the Devonian Kola Alkaline Province in Russia-Finland, where ages are concentrated within 20 Myr. As some of the dates for the PAP were obtained as early as the 1950s, there could be some doubt about their reliability, but even ages published in the last ten years show a range of 150 Myr. This makes it harder to interpret the geochemical evolution of the province and the underlying tectonic causes for this magmatism. Perhaps more importantly, the scarcity of rocks of this age on the Kaapvaal Craton makes them of great importance for plate tectonic reconstructions, but only if their age can be reliably constrained with uncertainties of 10 Myr or less. Expanding on our age of the Pilanesberg Complex proper of 1397 ± 10 Ma, we carried out LA-ICPMS U-Pb dating on titanite and apatite from two samples of the Pilanesberg dyke swarm. The previously published age for these dykes of ca. 1300 Ma has been used in publication on the apparent polar wander path for the Kaapvaal Craton. Titanite from the nepheline syenite dyke near Maanhaarrand yielded an age of 1406 ± 8 Ma, and apatite from the monzodioritic Robinson dyke in Johannesburg gave a somewhat more poorly defined age of 1409 ± 19 Ma. These ages show that the Pilanesberg Complex proper and its dyke swarm were formed at the same time, within the uncertainty of the analytical techniques used here. These improved ages mean that the difference in the published palaeopoles of the Pilanesberg Complex and its dykes becomes hard to explain, and that the palaeogeographic position of the Kaapvaal Craton remains unconstrained.

Keywords: U-Pb dating, Mesoproterozoic, alkaline rocks, plate tectonic reconstructions

TIMING OF GOLD MINERALIZATION IN THE NANGODI GREENSTONE BELT OF GHANA

Kwame Fynn[1], Axel Hofmann[1], Marlina A. Elburg[1], Riana Rossouw[2] & Samuel Nunoo[1,3]

[1]Department of Geology, University of Johannesburg, Johannesburg, South Africa
[2]Central Analytical Facilities, Stellenbosch University, Stellenbosch, South Africa
[3]Department of Earth Science, University of Ghana, Legon, Accra, Ghana

The Birimian of the West African Craton comprises a Paleoproterozoic granitoid-greenstone terrain. Among the greenstone belts is the NE-SW-trending Nangodi greenstone belt, situated in the northeastern part of Ghana. It comprises volcanic (from basalt to rhyolite) and volcaniclastic rocks, as well as immature sedimentary rocks (including greywacke and shale), which are flanked on both sides by extensive granitoid complexes. These rocks have been impacted by the Eburnean orogeny around 2120-2095 Ma, which deformed and metamorphosed them under greenschist facies conditions, contemporaneous with gold mineralization. Until the recent discovery of a gold deposit by Cardinal Resources in the Nangodi belt (Namdini Gold Project), there was very little attention given to the rocks in this belt and the associated gold mineralization. This study presents (ore) petrographic observations, whole-rock major and trace element data, mineral chemistry data on sulphides and carbonates, and U-Pb zircon ages from outcrop and drill core samples from the Nangodi greenstone belt. The results indicate that the rocks are predominantly arc-related mafic to intermediate metavolcanic rocks, together with organic-rich metasedimentary rocks. These have been intruded by amphibole-bearing alkali feldspar granite and muscovite-bearing granite. The rocks are deformed to varying degrees and altered by CO_2-rich hydrothermal fluids. Gold mineralization is associated with disseminated sulphides found at the selvages of deformed quartz-carbonate veins or along foliations, typically within high-strain zones in the metavolcanic rocks and shales. Compositional zoning in the sulphides suggests two distinct stages of ore deposition resulting from changes in the chemistry of ore-forming fluids; stage I represents an early deposition of pyrite-arsenopyrite, while stage II denotes a late-stage deposition of pyrite. Gold is refractory and hosted in arsenian pyrite and arsenopyrite as a solid solution. U-Pb zircon ages reveal that the volcanic units were deposited at ca. 2160 Ma, followed by intrusions of muscovite-bearing granite and the amphibole-bearing granite at ca. 2120 Ma and 2100 Ma, respectively. Gold mineralization occurred during the interval between the emplacement of the granitic bodies.

Keywords: Nangodi greenstone belt, Ghana, gold mineralization, age, Paleoproterozoic

THE TECTONIC SETTING AND GENESIS OF THE MARBLE DELTA DEPOSIT, KWAZULU-NATAL, SOUTH AFRICA

Geoffrey H. Grantham[1], Bruce Eglington[2], Juergen Reinhardt[3], M. Satish-Kumar[4], Renelioe Tshise[1] & Wiebke Grote[5]

[1]Department of Geology, University of Johannesburg, Johannesburg, South Africa
[2]College of Arts and Science, University of Saskatchewan, Saskatoon, Canada
[3]Department of Earth Sciences, University of the Western Cape, Bellville, South Africa
[4]Department of Geology, Niigata University, Niigata, Japan
[5]Department of Chemistry, University of Pretoria, Pretoria, South Africa

The Marble Delta Carbonate deposit forms a crudely oval deposit, ca. 4 x 5 km wide and long, and is located in the Margate Terrane of the Natal Metamorphic Province. The Margate Terrane is dominantly underlain by ca. 1000-1100 Ma granitic gneisses with subordinate supracrustal metapelite, metagreywacke and metabasic gneisses. The carbonates are dominantly very pure, mined for high-grade industrial mineral products, contain varying degrees of dolomite, with accessory metamorphic mineralogy typical of high-grade metamorphism (diopside, olivine) with limited hydration retrogression reflected in tremolite, serpentine and phlogopite. The metabasite gneisses are interlayered with carbonate as well as forming layers adjacent to and external to the marble deposit. Mineralogy of the metabasite comprises plagioclase, hornblende, biotite and clinopyroxene. The whole-rock chemistry of the metabasites is comparable to E-MORB and OIB basalt compositions. Whole-rock compositions of the carbonates are typical of carbonates deposited in an open ocean tectonic setting. Limited published radiogenic isotope data reflect juvenile compositions for the carbonates, without recognisable input from older crustal sources. From the oblong shape of the exposure without any strike extent, the purity of the carbonates with little accessory silicate content, the juvenile isotopic composition of the carbonates and similarity to open ocean carbonates, the association with deep water metasediments and MORB-like metabasites, it is inferred that the depositional setting of the carbonates was probably on top of an oceanic seafloor seamount, removed from the coast and away from significant crustal input.

Keywords: Marble Delta Carbonate, chemistry, tectonic setting

TRACING THE SOURCE OF THE MINERALIZATION FLUID AND METAMORPHISM OF THE NAMPALA GOLD DEPOSIT, SOUTHERN MALI: CONSTRAINTS FROM STABLE (OXYGEN AND HYDROGEN) ISOTOPES AND RAMAN SPECTROSCOPY

Sory I.M. Konate[1] & Elhadji Mory Traore[1]

[1]Pan African University Life and Sciences Institute, Ibadan, Nigeria

The Nampala gold deposit is a sub-world-class occurrence in Mali's Birimian Terrain. Although numerous detailed investigations have been conducted on Mali's gold deposits, the debate on the origin of the mineralising fluid remains unresolved. To address that knowledge gap this study presents oxygen and hydrogen isotope data for auriferous quartz veins, along with Raman spectroscopy analysis of graphitic schist to investigate the genesis and evolution of the mineralising fluid of the Nampala gold deposit and the associated metamorphic grade. The isotopic signatures of quartz veins and their fluid inclusions reveal δD values ranging from -48 to 0.3‰ (mean -25.98‰, n=15) and $\delta^{18}O$ values from 15.23 to 16.57‰ (mean 16.14‰, n=15). The narrow $\delta^{18}O$ range of auriferous quartz veins indicates a common hydrothermal fluid source, while the high δD values suggest meteoric water influence. The Nampala gold deposit likely formed from metamorphic fluids derived from nearby metasedimentary rocks during regional metamorphism, with Au deposition driven by fluid pressure drops and interaction between meteoric and metamorphic fluids with wall rocks. Metamorphic studies indicate greenschist facies with temperatures ranging from 358 °C to 486 °C (avg. 416 °C ± 50 °C). The gold-enriched fluid at Nampala precipitated gold through metasomatism driven by interaction with surrounding rocks and decreases in temperature and pressure.

Keywords: stable isotope, origin, metamorphism, Raman spectroscopy

DETRITAL ZIRCON U-Pb AND Lu-Hf DATA FROM THE CENTRAL ZONE OF THE DAMARA BELT, NAMIBIA: IMPLICATIONS FOR PROVENANCE INVESTIGATIONS

Robyn J. MacRoberts[1], Jérémie Lehmann[1], Marlina A. Elburg[1], Pieter J. Delport[2] & Thabiso Sibanyoni[1]

[1]University of Johannesburg, Johannesburg, South Africa
[2]Stoneman Labs, University of Pretoria, Pretoria, South Africa

Can detrital zircon U-Pb ages and Lu-Hf data from the Central Zone of the Damara Belt help determine the relative positions of the Kalahari and Congo cratons in the Rodinia Supercontinent prior to its breakup? There is a debate regarding the positions of these cratons in Rodinia, with two end-member models. The first model suggests that the cratons were adjacent in Rodinia and were separated by a narrow Khomas Ocean during Rodinia breakup and prior to Gondwana assembly, a model based on the lack of HP rocks marking a suture zone. A second model suggests the two cratons were farther apart, separated by a wide Khomas Ocean, based on contrasting provenances for Damara Supergroup rocks from across the orogen. However, the provenance of these rocks in the Central Zone, and those of the Paleo- to Mesoproterozoic Abbabis Metamorphic Complex (AMC) basement is understudied. Here we present new detrital zircon U-Pb ages and Lu-Hf data from the Central Zone. Three AMC samples record 2140–1848 Ma zircon ages (ε_{Hf} 4.6 to 9.2), similar to the Rehoboth Province (Kalahari Craton) and the Kunene Complex basement rocks (Congo Craton). Zircons from two Etusis Formation samples record main age peaks at 2160–1790 Ma (ε_{Hf} 4.5 to 7.7) and 1080–970 Ma (ε_{Hf} -15.9 to-18.2). We interpret the older group as derived from proximal reworking of the underlying AMC based on similar ages and ε_{Hf} values. Younger Etusis Formation zircons show distinctly negative ε_{Hf} values, similar to those from Kalahari Craton (meta)sedimentary rocks (e.g., Malmesbury Terrane, Port Nolloth Zone, Nama Basin). A Kuiseb Formation metapelite records 1030–850 Ma (ε_{Hf} 13.7 to -7.8), 720–610 Ma (ε_{Hf} 4.3 to -4.7), and 570–530 Ma (ε_{Hf} 4.3 to -4.8) age groups. Tonian and Cryogenian groups have potential sources in both the Kalahari and Congo cratons, while the <570 Ma group likely records Pan-African metamorphism. Younger ages and distinctly more positive ε_{Hf} values for Kuiseb Formation zircons indicate a change in source from the older rocks. Preliminary results suggest various sources for Central Zone rocks, introducing ambiguity in their provenance and ultimately in continental reconstructions based thereon.

Keywords: detrital zircon, U-Pb, Lu-Hf

GEOCHRONOLOGY AND STRUCTURAL GEOLOGY OF OHAMAREMBA AND OMBUKU NORTH MAFIC-ULTRAMAFIC INTRUSIONS AT THE PERIPHERY OF THE KUNENE COMPLEX IN NORTHERN NAMIBIA

Cicilia K. Motha[1], Ben Hayes[2], Jeremie Lehmann[1], Lorenzo Milani[3] & Thabiso W. Sibanyoni[1]

[1]Department of Geology, University of Johannesburg, Johannesburg, South Africa
[2]School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa
[3]Department of Geology, University of Pretoria, Pretoria, South Africa

The Kunene Complex (KC) is a large massif-type anorthosite complex covering parts of northern Namibia and southern Angola. The southern portion of the KC in northern Namibia, the Zebra Lobe (ZL), is a 40 km-wide SW-plunging antiform surrounded by Ni-Cu-PGE-hosting mafic-ultramafic intrusions. The intrusions have conflicting crystallisation ages and their relationship with the well-dated KC is not well constrained. This study aims to clarify this relationship and use structural analysis to determine the ages of two intrusions at the margins of the ZL – Ohamaremba and Ombuku North. Ombuku North, located at the western margin of the ZL, near the hinge zone, is a NNE-SSW-striking body. To the west of the intrusion, fully transposed dm-scale Ombuku North norite sills intruded the basement granite gneiss but share an E-W-trending and steeply dipping foliation, testifying to pre- to syn-tectonic emplacement during WNW-ESE shortening. Additionally, the intrusion and adjacent KC anorthosite are locally crosscut by leucogranite-filled shear zones, formed during a heterogeneously developed NNW-SSE shortening. Ohamaremba is an E-W-striking body located south of the E-W-trending long limb of the ZL regional fold. It forms an open syncline, depicted by a change in orientation of the strong magmatic foliation defined by plagioclase laths and magnetite stringers. The fold geometry and inferred kinematics are compatible with the smaller-scale tight and closed folds in the basement rocks surrounding Ohamaremba. Notably, the fold axes in the basement migmatites are shallowly plunging to the west, coaxial with the pi-axis of the fold of the intrusion, suggesting folding during N-S shortening. Overall, the structural geology of the two intrusions reveals that Ombuku North intruded as a steep body before or during regional WNW-ESE shortening, while Ohamaremba was emplaced as a shallow-dipping body. Both intrusions were affected by a regional N-S to NNW-SSE shortening event, but their structural responses were different due to (i) the orientation of existing country-rock gneissic foliation (steep and E-W-striking at Ombuku North vs shallow dipping to the west at Ohamaremba) and (ii) the position of the intrusions in the Zebra Lobe fold (strain shadow at Ombuku North and strain cap at Ohamaremba). It is possible that Ombuku North is older than Ohamaremba, and ongoing U-Pb dating will assist in clarifying this point.

Keywords: Ohamaremba, Ombuku North, structural geology, ages

THE LITHOSTRATIGRAPHY OF THE T'GOOB SEQUENCE, EASTERN MESOPROTEROZOIC AGGENEYS TERRANE, NAMAQUA MOBILE BELT, SOUTH AFRICA

Wayne Justin Nel[1] **& Wayne Patrick Colliston**[1]
[1]University of the Free State, Bloemfontein, South Africa

Structural-stratigraphic mapping in the eastern Aggeneys Terrane reveals a series of macroscopic thrust sheets containing megascopic sheath folds, characterised by both unique and shared stratigraphic features. Among these is the Lekdam thrust sheet, the megascopic T'Goob sheath fold that hosts the T'Goob Sequence with lithologies that are similar to the Wortel Formation and are distinguished by distinctive interbanded metavolcanic and metasedimentary units. It is stratigraphically significant that the T'Goob Sequence is structurally detached from the Wortel Formation and represents a distinct stratigraphic component of the Aggeneys Subgroup, eastern Aggeneys Terrane. The lithological framework of the sequence comprises eight units which are compiled by stratigraphic profiling along the upright limb of the T'Goob sheath fold. Unit 8 (top) consists of massive corundum-sillimanite-rutile rock (previously mined) and biotite-sillimanite schist. Units 7–5 form a metavolcanic marker sequence of biotite gneiss interbanded with actinolite-diopside-hornblende-cummingtonite layers, feldspathic quartzite, dark-blue quartzite, and biotite-sillimanite schist. Unit 4 contains biotite-sillimanite schist interbanded with garnet quartzite. Unit 3 consists of nodular sillimanite quartz-feldspar rhythmite, while Unit 2 is a massive, poorly bedded white orthoquartzite. Unit 1 (bottom) features nodular sillimanite quartz-feldspar gneiss interbanded with biotite-sillimanite schist. The T'Goob Sequence expands the stratigraphic framework of the Aggeneys Subgroup and introduces a previously unrecognised facies variant of the Wortel Formation. Its distinct lithological characteristics underscore the structural and stratigraphic complexity of the eastern Aggeneys Terrane.

Keywords: Mesoproterozoic Aggeneys Terrane, T'Goob mega sheath fold, T'Goob Sequence, corundum-sillimanite-rutile rock

THE TECTONICS OF THE AGGENEYS TERRANE, NAMAQUA MOBILE BELT, NORTHERN CAPE, SOUTH AFRICA

Wayne Justin Nel[1] **& Wayne Patrick Colliston**[1]

[1]University of the Free State, Bloemfontein, South Africa

The Aggeneys Terrane (~1.7-1.3 Ga) is one of several tectonostratigraphic units of the western Namaqua Mobile Belt associated with crustal accretion/collision events related to the 1.1-1.2 Ga Namaqua Orogeny. This accretion stage of the Namaqua Orogeny produced co-planar and co-linear LS-tectonite fabrics of sillimanite and upper amphibolite metamorphic grades that are sub-parallel to the SW-directed tectonic overthrust transport direction of the terranes. As with the other terranes, this terrane is bound by kilometer-scale interterrane thrust faults, such as the Groothoek thrust in the north with the ~2 Ga Pofadder Terrane, the Skelmpoort thrust with the ~1.8 Ga Steinkopf Terrane in the west, and to the south the Geelvloer thrust defining a boundary with the Bladgrond terrane. Regional structural-stratigraphic projects provide structural control on pre-tectonic rocks defining six stratigraphic formations inside the Aggeneys Subgroup, with the upper Gams Formation hosting stratabound sulphide and new assemblages identified in the eastern part of the terrane. Six phases of deformation have affected the Aggeneys Terrane during progressive ductile shear. The sub-horizontal attitude and juxtaposition of the older Pofadder Terrane over the Aggeneys Terrane provides the required proof for thrust tectonics associated with the 1.2 Ga Namaqua Orogeny. A major product of this deformation are kilometer-scale sheath folds and syntectonic inter-sheeted granitoids which occur at amphibolite grade and formed under ductile conditions. The sheath folds provide information about the nature and orientation of the regional strain ellipse, where the sub-horizontal X-Y plane of the regional fabric trends easterly and dips northwards with the stretching direction (X-direction) subparallel to the southwesterly trending direction of overthrusting.

Keywords: Aggeneys Terrane, progressive ductile shear, ductile conditions, sheath folds

PETROGRAPHY OF 2.1 Ga FC FORMATION CHERTS FROM THE FRANCEVILLE BASIN: IMPLICATIONS FOR THEIR STATE OF PRESERVATION

Lauriss Ngombi Pemba[1], Alexis Ndongo[2], Benjamin Musavu Moussavou[2], Stellina Lekele Baghekema[2] & Stevy Retonda Kondja[1]

[1]Université des Sciences et Techniques de Masuku, Franceville, Gabon
[2]Institut de Recherches Technologiques, Libreville, Gabon

Precambrian cherts are often used as proxies for reconstructing palaeoenvironmental conditions of the early Earth. However, their use is debated due to the various origins of cherts, including hydrothermal, sedimentary, and volcanic silicification. While only sedimentary-origin cherts can be used to constrain Precambrian paleoenvironmental conditions, even the most pristine chert samples may have undergone post-depositional alteration, such as meteoric weathering, hydrothermal fluid circulation, or metamorphism. This study presents a petrographic analysis (optical microscopy and SEM) of 2.1 Ga cherts from the FC Formation within the Palaeoproterozoic Franceville Basin in Gabon. The aim is to assess their state of preservation since their formation. Fifteen samples were collected from two outcrops, at Bambaye and Matébélé. Field work and microscopic observations revealed three distinct lithofacies: granular, massive, and stromatolitic cherts. Stromatolitic and granular cherts dominate the Matébélé and Bambaye outcrops, respectively. Granular cherts contain intraclasts, peloids, oncoids, and are associated with carbonate and pyrite minerals disseminated within the chert matrix. Microfossils occur mainly within the stromatolitic cherts, which also preserve oncoid ghosts and abundant pyrite. These chert samples display various textures of quartz crystals: mostly microquartz (grain size < 20µm and irregular boundaries), megaquartz (50–200µm), fibrous quartz (mainly consisting of spherulitic length-fast chalcedony) and quartz veins. Fibrous quartz and megaquartz appear scattered within intergranular porosity and associated with quartz veins. In the Bambaye outcrop, quartz veins (0.5–1 mm wide) are common, with chalcedony lining vein margins and megaquartz occupying cores. These petrographic features indicate that the FC cherts formed primarily by carbonate replacement, with some direct silica precipitation, and were later affected by fluid circulation and diagenesis. However, the presence of spherulitic length-fast chalcedony suggests low-temperature fluid activity, likely insufficient to significantly alter the composition of the original microquartz (earliest quartz form). Overall, this study supports the conclusion that Francevillian cherts have not been affected by late processes such as metamorphism or hydrothermal fluid circulation. Therefore, they are suitable for reconstructing Palaeoproterozoic environmental conditions. Previous studies have shown that these rocks contain the oldest, well-preserved Gunflint-type microfossils, confirming their good state of preservation.

Keywords: Palaeoproterozoic cherts, Franceville Basin, petrography, preservation state

SIGNIFICANCE OF CARBONACEOUS SEDIMENTARY ROCKS TO THE PALEOPROTEROZOIC BIRIMIAN GOLD MINERALIZATION, NW GHANA: INSIGHT FROM TEXTURAL AND ISOTOPIC ($\delta^{13}C$ AND $\delta^{34}S$) RECORDS

Samuel Nunoo[1,2], Axel Hofmann[1], Mike Butler[3] & Minoru Ikehara[4]

[1]Department of Geology, University of Johannesburg, Johannesburg, South Africa
[2]Department of Earth Science, University of Ghana, Accra, Ghana
[3]National Research Foundation, iThemba Labs, Johannesburg, South Africa
[4]Kochi Core Centre (KCC), Kochi University, Kochi, Japan

Sulphide-rich marine black shales are considered a prominent metallogenic source for orogenic gold deposits. Such rocks are common in the ca. 2.2 Ga Birimian Supergroup of Ghana and are associated with meta-sedimentary and volcanic rocks that host gold as either a free-milling type in quartz veins or as a refractory type within quartz vein-associated sulphide. Organic-rich shale and greywacke from the Julie volcano-sedimentary belt (NW Ghana) have been investigated as a host for gold mineralization, but also for their potential as a gold source. The Au content in sulphides was measured with EPMA at the University of Johannesburg (UJ), and Au in bulk rock was analysed at the BVM Lab (Canada). Carbon-$\delta^{13}C$ and sulphur-$\delta^{34}S$ ratios and total organic carbon contents (TOC) were determined at the NRF-iThemba Labs (South Africa) and Kochi University (Japan). Greywacke contains fine-grained pyrite with distorted colloform features of irregular concentric laminae of pyrite. Sheared shale is marked by Qz-Cb veins associated with arsenopyrite and pyrite with minor chalcopyrite. Arsenopyrite dominates with needle-like shapes along foliation and occurs as intergrowths/overgrowths largely with pyrite. Sulphides occur as disseminations but are mostly restricted to cleavage planes rich in carbonaceous matter and chlorite. The TOC of samples ranges from 0.02 to 5.10%. The shales and greywackes have respective $\delta^{13}C$ values in the range of 19.6 to -28.9‰ and -27.2 to -29.3‰, and $\delta^{34}S$ values from -8.0 to -22.0‰ and -0.8 to +5.0‰. Bulk rock Au content is trace in greywacke (1.8 to 4 ppb) relative to sheared shales (1.3 to 1482 ppb), and Au in arsenopyrite and pyrite in sheared shale ranges from 4 to 176 ppm. Current data support the following deductions: colloform pyrite in greywackes depicts a diagenetic growth process within a sedimentary environment; the pyrite growth developed largely via biogenic activity or pseudomorphic replacement. In sheared shales, the textures of sulphides within foliation planes suggest syn-kinematic and syn- to late metamorphic crystallisation of sulphides, and hydrothermal activity marked by quartz-carbonate veins. Isotopic records indicate that the carbonaceous matter (CM) and pyrite components of the examined rocks are biologically sourced. The CM influenced pyrite formation, gold transportion and precipitation.

Keywords: Paleoproterozoic-Birimian, Ghana, gold, carbonaceous matter

STRUCTURAL GEOLOGY OF THE MAFIC-ULTRAMAFIC OMBUKU SOUTH AND OTJIJANJASEMO INTRUSIONS AT THE PERIPHERY OF THE KUNENE COMPLEX, NORTHERN NAMIBIA

Thabiso W. Sibanyoni[1], Ben Hayes[2], Cicilia K. Motha[1], Jeremie Lehmann[1] & Lorenzo Milani[3]

[1]University of Johannesburg, Johannesburg, South Africa
[2]University of the Witwatersrand, Johannesburg, South Africa
[3]University of Pretoria, Pretoria, South Africa

Mafic-ultramafic intrusions located along the southwestern margin of the Mesoproterozoic Kunene Complex (KC) in SW Angola and NW Namibia host magmatic Ni-Cu-PGE sulphide mineralisation. This geotectonic setting is similar to that of the world-class Voisey's Bay Ni-Cu-PGE sulphide deposit, which is coeval with the Mesoproterozoic Nain Plutonic Suite. However, establishing a temporal and genetic linkage between the KC and the surrounding mafic-ultramafic intrusions remains challenging due to the difficulty of dating mafic-ultramafic rocks, which typically lack suitable minerals for radiometric dating. In this study, we investigated igneous and tectonic fabrics of the N-S-trending Ombuku South and E-W-trending Otjijanjasemo intrusions and their country rocks in the Namibian KC. The Ombuku South and Otjijanjasemo intrusions were emplaced either synchronously or after the development of a newly recognised regional E-W shortening event active at suprasolidus conditions. This event produced steep, N-S-striking gneissic and stromatic foliations in the country rocks of both intrusions. Ombuku South was emplaced along this foliation as evidenced by its distinct sub-vertical, N-S-striking compositional layering, characterised by alternating cm-scale bands of anorthosite and norite, with well-defined plagioclase and orthopyroxene lamination. Ombuku South, together with its country rocks, was subsequently heterogeneously affected by a WNW-ESE shortening event, typified by numerous cm- to m-scale, granite-infilled shear zones. Unlike Ombuku South, the Otjijanjasemo intrusion was not emplaced along the N-S-striking foliation of its country rocks. Instead, the intrusion forms a gently W-plunging synform marked by plagioclase lamination in leucotroctolite and elongated gabbroic-anorthositic glomerocrysts. The synform pi-axis is subparallel to a fold axis within the country rock, where a sillimanite lineation runs parallel to the fold axis, indicating that folding occurred at high-grade metamorphic conditions. This folding is likely of regional significance and is compatible with the discrete shear zones of the Ombuku South area. The structural analysis of Ombuku South and Otjijanjasemo has revealed key deformation features, some of which were active in the presence of melt or during the crystallisation of felsic magmas. Future U-Pb zircon and monazite dating of those syntectonic melts and magmas will provide important constraints on the age of these intrusions and their link to the KC. Understanding this temporal and genetic link is essential for refining exploration strategies, particularly in evaluating whether the Voisey's Bay exploration model is applicable to the mafic-ultramafic intrusions surrounding the KC.

Keywords: mafic-ultramafic intrusions, Kunene Complex, linkage, syntectonic melt, magmas

MANGANESE AND THE GREAT OXIDATION EVENT – THE SOUTH AFRICAN PERSPECTIVE

Albertus J.B. Smith[1]

[1]PPM Research Group and DSTI-NRF CIMERA, Department of Geology, University of Johannesburg, Johannesburg, South Africa

It is generally accepted that the Paleoproterozoic (~2.5-2.2 Ga) Great Oxidation Event (GOE) marks the first time in Earth's history that atmospheric oxygen levels were high enough to establish an ozone layer. However, the exact timing and nature of this event and whether free oxygen production preceded it are debated. Manganese (Mn), a major redox-sensitive element common in chemical sedimentary environments, provides some insight into the history of oxygenation in South Africa's geological record. Mn is transported in surface waters in its reduced, dissolved state, and precipitates when oxidised, with the latter requiring free oxygen and microbial mediation. Mn enrichments in the Mesoarchean Witwatersrand-Mozaan iron formations and shales suggest oxygen production already at ~2.9 Ga in the oceans on the Kaapvaal Craton, although Mn is only preserved in its reduced state. The oxidation of Mn as a precipitation mechanism is implied by its depositional relationship with iron (Fe) and its occurrence in light-carbon-enriched carbonates. Mn is generally absent thereafter for ~400 million years until gradually increasing Neoarchean to Paleoproterozoic Mn enrichments are recorded in the Transvaal Supergroup, becoming significant in the ~2.43 Ga Koegas Subgroup and peaking in the ~2.41 Ga Hotazel Formation. The latter formation hosts the world's largest land-based Mn deposit and marks the oldest preservation of oxidised Mn. Other than the latter, the oxidation of Mn as a precipitating mechanism is also supported by its depositional relationship with Fe, its occurrence in light-carbon-enriched carbonates and trace element characteristics. However, the common occurrence of Mn(II)-silicates in parts of the depositional basin complicates the traditional understanding of Mn precipitation mechanisms and suggests paleoenvironmental heterogeneity. The timing of Mn enrichment in the Transvaal Supergroup and its apparent overlap with age estimates of the GOE suggest that it records rising oxygen levels and supports the hypothesis that the GOE was gradual and protracted, maybe even episodic. However, the role of changing mantle dynamics, decreasing Fe supply to oceans and depositional basin architecture also need to be considered before using the Transvaal Supergroup's Mn content as a global fingerprint to Earth's surface oxygenation.

Keywords: manganese, GOE

IGNEOUS DYKES IN THE SOLITAIRE REGION, NAMIBIA: A STRUCTURAL, PETROGRAPHICAL AND GEOCHEMICAL INVESTIGATION

Rowan Walker[1] & Martin Klausen[1]

[1]Stellenbosch University, Stellenbosch, South Africa

Magmatism linked to Rodinia's formation has been widely studied due to abundant related igneous rocks across southern Africa. The dykes analysed in this study formed along the westernmost edge of the Kalahari Craton within what must have been an active back-arc rift margin, contemporaneous with the larger Umkondo LIP. We investigate the field relationships, petrography, and geochemistry of dyke swarms intruded into the ~1.2 Ga Gamsberg Granite Suite in Namibia to understand their source, petrogenesis, differentiation, and emplacement within a proposed back-arc rift setting. Since later deformation by the Damara Orogen impacted the margin, dyke geometries also act as strain indicators. Thirty-six doleritic and one rhyolitic post-Gamsberg dykes were analysed petrographically and geochemically. XRF and ICPMS-LA data, including REEs, reveal three geochemical groups: Low La/Yb (LLY), Intermediate La/Yb (ILY), and High La/Yb (HLY), with HLY including the rhyolite and a single andesite. Field evidence suggests emplacement in at least two major tectonic events under slightly different paleo-stress fields, where rare cross-cutting relationships indicate N-S-trending dykes predate NE-SW ones. Younger dykes exhibit fresher mottled textures, while both sub-swarms contain varying plagioclase phenocryst proportions, with older dykes appearing more altered. The dominant LLY dykes across both swarms share similar incompatible element patterns, indicating a cogenetic origin from a common parent melt through plagioclase, olivine, and/or augite fractionation. This parent was likely derived from an overwhelmingly asthenospheric, spinel-bearing mantle source, favoring a back-arc rift setting. The more lithospheric ILY group likely formed through additional local crustal assimilation during fractional crystallisation (AFC), evidenced by crustally derived quartz xenocrysts in the HLY andesite. The ~N-S-trending rhyolite may represent an even more evolved AFC product or direct crustal anatexis. Despite emplacement under two distinct paleo-stress regimes, both subswarms likely formed in the same back-arc rift, related to the ~1.3-1.0 Ga Namaquan Orogen. During later rifting stages, magmas were sourced from a similar ambient asthenospheric mantle, with some selectively assimilating continental crust. Since both sub-swarms are equally tilted by the Damara Orogen, we rule out younger dyke emplacement.

Keywords: mafic intrusives, Rodinia magmatism, Mesoproterozoic, Namaquan Orogeny