Geological Society of Zimbabwe

Summer Symposium

8am to 5pm, Friday 1st September 2023

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Start	Topic	Speaker
07:45	**Registration**	
08:30	Welcome	Tenyears Gumede- Geological Society Chair
08:50	Geotourism, Geotrails and Geoparks – golden opportunities for sustainable social and economic development	Patrick James
09:30	Exploration under the Auspices of Exclusive Prospecting Orders (EPOs) in Zimbabwe	Forbes Mugumbate
10:00	**Tea**	
10:20	A review of the timing of gold mineralisation in the Zimbabwe Craton	Brian Mapingere
11:00	Copper and Molybdenum mineralisation in the Mutandahwe Complex of the Nuanetsi Igneous Province	Linda Iaccheri
11:25	Petrography and geochemistry of Dorowa rocks. Implications for petrogenesis.	Maideyi Meck
11:50	Machine Learning Models for the Kadoma-Chegutu Greenstone Belt using Magnetics, Radiometrics, and	Tenyears Gumede
12:15	The mineralogy and geochemistry of Archaean late-granite suites along the southern extent of the Zimbabwe Craton	Godfrey Chagondah
12:55	**Lunch**	
14:00	Eureka Mine 3D modelling	Steve Duma
14:30	The Benefits of Digital Transformation in Mining	Vimbayi Matarirano
15:00	**Tea**	
15:20	An Analysis of Alteration Styles Associated Au-Cu Mineralization at May Mine, Chinhoyi-Guruve	Beaman Goredema - Mwatahwa Candidate - UZ
15:40	Summary.	Tony Martin

Geotourism, Geotrails and Geoparks – golden opportunities for sustainable social and economic development

Professor Patrick James, University of South Australia

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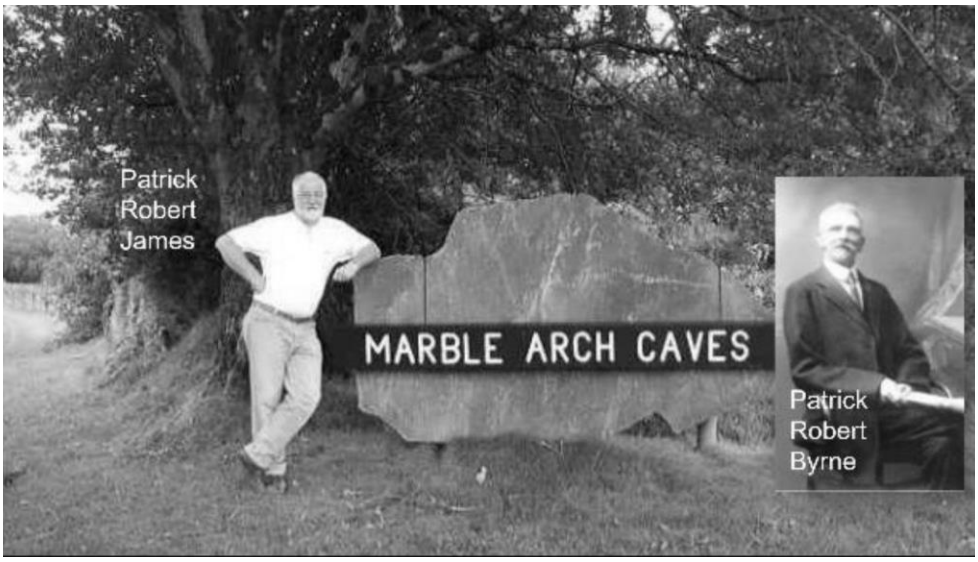
Geotourism is a growing world-wide recreational and educational activity and is one component of Nature-based or Eco-tourism. This activity has been promoted and enhanced by an increased awareness of the need to protect and conserve our rich and varied "Abiotic" geological heritage (Geoheritage). The great range of geological and geomorphological landscapes, terrains, forms, features and processes provide a natural Geodiversity which is as precious and critical as the living "Biotic" equivalent so keenly and passionately defended by Biodiversity supporters. Geological conservation (Geoconservation) movements have begun to find a rightful place amongst popular, educated and scientific groups as the awareness of the fragility of our earth's substrate and material spheres (geosphere, hydrosphere, biosphere, atmosphere) become more critical and mainstream, in terms of its effects on our global "Cultural" heritage, especially regarding changing global climates and rising sea levels. Thus, the A, B, C (Abiotic, Biotic and Cultural) themes embedded in Geotourism are becoming increasingly valuable as tools to increase the awareness and value of this activity to the increasing array of visitors and tourists.

A key driver for this rise in public awareness and knowledge of the importance and relevance of geotourism, has been the spectacular growth of UNESCO Global Geoparks across almost all continents. This movement began only recently (early 2000s) within Europe and China with the almost parallel development and opening of large numbers of Geoparks. A consortium of more than 30 Geoparks which were organised under the banner of the European Geoparks Network (EGN), provided the impetus for the rapid expansion of this movement, and the subsequent UNESCO Global Geoparks network further established more than 30 geoparks in China and a few others on most continents. These paved the way for the promotion of geology and geotourism to much larger swathes of the global populace. There are now 195 UNESCO Global Geoparks in 48 countries, largely based still in Europe (94) and China (41) but with increasing numbers in SE and E Asia (Vietnam (3), Japan (10), Korea (5), Malaysia (2), Thailand (2) Indonesia (10)), plus S/Central America (12) and Canada (5) and only 2 in Africa in Morocco and Tanzania. Australasia has also just gained its first Geopark – the appropriately named Waitaki Whitestone Geopark in New Zealand.

There are many attributes required to become a Global Geopark. These include significant international Geoheritage, local bottom-up support of local governments/councils, Geological Surveys, Museums, Universities. Business plans, management structures and financial models are required and Geotourism infrastructure and interpretation are needed with well-marked geosites, geotrails, signage and publicly available information and interpretation (brochures, web sites, apps).



Marble Arch Caves Global Geopark (renamed as Cuilcagh Lakelands) was Pat's first experience of a UGGP, following the 2nd International Global Geoparks conference in September 2006. This Geopark now (post Brexit) crosses major national borders between Europe (Ireland) and the UK and demonstrates the value of UGGPs in reducing rural deprivation by significantly increasing (Geo)tourism. It is part situated in Connacht where Pat's Great Grandfather (after whom he was named) fled from equivalent rural poverty in the 1860's due in part to the infamous potato famine.

Exploration under the Auspices of Exclusive Prospecting Orders (EPOs) in Zimbabwe

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Comprehensive evaluation of many countries' mineral resources potential is done through systematic regional exploration by companies with requisite risk capital and technical capabilities. In Zimbabwe such exploration is done in Exclusive Prospecting Orders (EPOs). These are areas up to 65 000 ha issued by the President of Zimbabwe in terms of the Mines and Minerals Act (Chapter 21:05) over defined areas for a period not exceeding 3 years but renewable for up to another 3 years.

The administration of the EPO system is done by the Mining Affairs Board (MAB), with the Geological Survey playing a major role as part of the MAB secretariate. The MAB comprises government officials and stakeholders who include representatives of miners and farmers. This composition is meant to creäte transparency in the issuance of mining titles and resolution of disputes.

Exploration in EPOs has resulted in discoveries or re-discoveries of significant economic mineral deposits since 1947 when the system was legislated. Other advantages of the EPO system include;

- Thorough evaluation of the EPO area's geology and mineral potential since exploring companies have obligations to implement certain agreed work programmes, and to spend certain amount of money to fund the exploration.
- Importation of foreign capital and new ideas and technologies.
- Generation of new geological information and enhancement of existing knowledge.
- Creation of employment directly and downstream.
- Occasional identification of mineral deposits suitable for exploitation by small-scale miners.
- Creation of other industries such service providers including drillers and assay laboratories.

Presently there are 38 active EPOs and 230 applications at various stages of processing for approval. Considering that there were over 400 current EPOs at peak exploration in the mid-1990s, the prevailing situation can be said to show the presence of bottlenecks in the management of the system. The slow processing of EPO applications has resulted in sterilization of vast tracts of land against exploration, and the consequent current impasse.

A review of the timing of gold mineralisation in the Zimbabwe Craton

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The Zimbabwe Craton (ZC) is well endowed with gold deposits and most known deposits are hosted in Archean greenstone belts and to a lesser extent, the surrounding granites. The majority of gold deposits show a strong structural control, consistent with formation during deformation. Our understanding of gold mineralisation in its whole spectrum in the ZC is dependent among other factors on constraining the timing of major gold deposition events better, and relating them to the geological events that shaped the craton. In this contribution, we provide an overview of the relative, and where possible the absolute, timing of gold mineralisation hosted in Archaean greenstone belts and the surrounding granites of the ZC, and discuss the significance of major gold deposit formation events in light of craton forming and modifying events. We also compare the timing of gold mineralisation in the ZC to the global gold mineralising events. This review is however affected by a limited number of relative and absolute time constraints of gold mineralisation in the ZC.

An ~ 2.8-2.6 Ga craton-wide gold mineralisation event is recorded in the greenstone belts of the ZC, and it was coeval with the age of peak metamorphism recorded in most greenstone belts of the craton. This event gave rise to structurally and lithologically controlled deposits throughout the craton and was synchronous with the late Archaean deformation of the craton e.g., 2688-2615 Ma dextral shearing in the south-eastern Mwanesi Greenstone Belt and 2680-2643 Ma thrusting in the Bindura Shamva Greenstone Belt. Regionally, the late Archaean gold-forming event in the ZC was broadly coeval with the emplacement of large volumes of crust-derived ~ 2.6 Ga Chilimanzi Suite of granites, but it is not clear to what extent these porphyritic granites contributed towards the mineralising fluids that formed the gold deposits besides acting as host rocks. The late Archean gold-forming event however has been overprinted by a later gold deposition in some cases. Globally, the ~ 2.6 Ga gold forming event in the ZC was broadly coeval with the second global episode of gold mineralisation.

Copper in the Central Zone of the Limpopo Belt: the Messina and the Mutandahwe mines

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The geological significance and metallogenic potential of the Central Zone of the Limpopo Belt is not well understood. The Central Zone of the Limpopo Belt, also called Messina Block, shows great structural complexity and a multitude of rock types, dominantly represented by high-grade metamorphic rocks. It is poorly studied due to its remote location, limited access, not continuous outcrop exposure, and thick Karoo sedimentary and volcanic covers.

The Central Zone of the Limpopo Belt hosts two intriguing copper deposits: the Messina and the Mutandahwe. Both deposits are hydrothermal and experienced extensive mining activities in the middle of the 1900s with operations closing by the 1980s/1990s, but their mineralogical and petrological significance has not been explored.

The origin of the copper sulphides (chalcopyrite, bornite, chalcocite) Messina deposit is contentious because the age and the ore-forming processes are not constrained. The consensus is that the Messina deposit is:

1. structurally controlled, as the mining operations occurred along the Messina Fault with an ENE-WSW Limpopo Lineament trend;
2. hydrothermal, as associated with pervasive alteration of high-grade meta-sedimentary (amphibolites, quartzites and meta-ironstone) country rocks;
3. dominantly hosted in vertical quartz breccia pipes which reach depths of more than 1km from the surface.

The source of the hydrothermal fluids in the Messina deposit has been traditionally attributed to the neighboring magmatic rocks of the Nuanetsi Igneous Province of Southern Zimbabwe. However, this hypothesis has never been tested and is not unanimously accepted, because the exposures of the Nuanetsi Igneous Province do not extend south of the Limpopo River.

The Nuanetsi Igneous Province consists of 7 felsic intrusive ring complexes, which are located along the strike from the Messina Mine in an ENE-WSW Limpopo Lineament. Its relative age is defined as post-Karoo because it intruded the local Karoo volcanic sequences. The Cu mineralisations associated with the Nuantetsi Igneous Province are found in the most exposed and eastern ring complex, the Mutandahwe Complex.

The Mutandahwe Complex once a vibrant mining environment, dotted with active prospects for Cu, W, Mo, and minor Au and Ag, is now mainly loci of artisanal mining activities. Copper and W showings are not directly within the circular felsic intrusion, but they are rather found in the surrounding Karoo country rocks. Copper sulphides (mostly chalcopyrite) and pyrrhotite are observed in stockworks of quartz-carbonate and carbonatic veins and sulphide veinlets within malachite-stained, biotite-enriched basaltic host rocks (for example, in the Mutandahwe mine). Tungsten (mainly scheelite) is found in carbonates stockwork veins within highly sheared, altered, and chloritised basaltic country rocks (for example, in the Buona Fortuna prospect). Evidence of Mo mineralization is instead found within the Mutandahwe quartz-syenite body, for example in the Lazeno Project, where molybdenite (with pyrrhotite and chalcopyrite) is observed in stockwork mineralisation within a brecciated and fine-grained felsic rock, greisenised quartz-syenite, and gossans.

Microscale characteristics of REE bearing phases in the Dorowa ring complex- rocks - Zimbabwe: Implications for petrogenesis of the ring complex

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The main resource of interest in the Dorowa complex is phosphate, but it also has a natural anomaly of metals and critical elements associated with the rock phosphate. The PhD study data (XRD and ICP–MS) by Meck 2011 showed the presence of REE-Zr-Nb-Ta-Ce in the samples, with concentrations higher than the crustal averages. The 2011 study by Meck identified minerals that contain more than 2% REE as apatites, enstatite, and augite. However, the concentrations though higher than the crustal levels are not high enough to be considered as ore like in other phosphates deposits. Understanding of the petrogenesis of the alkaline complex and its relationship to the regional tectonics is vital in understanding the nature of these REE containing phases. The origin of the Dorowa ring complex and its Rare Earth element distribution are the main objectives of this study. This work contributes to this understanding by investigating the microscale characteristics of rare earth element (REE) bearing phases in the Mesozoic Dorowa ring complex, Zimbabwe, which is one of the largest carbonatite complexes in Africa.

Previous authors have proposed different models for the petrogenesis of the complex, based on various features. Some of them (Mennell, 1938; Macgregor, 1947) suggested a sedimentary origin for the carbonatite, involving the interaction of limestone with gneiss or the emplacement of marble blocks. Others (Tyndale Biscoe, 1950; Swift, 1952; Lee, 1973; Harmer and Gittins, 1998) favored a magmatic origin, either from primary carbonate magmas or from fenitization of granitic gneiss.

The methods used include optical microscopy, cathodoluminesce and elemental mapping using micro-XRF and SEM of thin sections to determine REE deportment among the minerals. The rock suite analysed consists of fenites, syenites, ijolites and carbonatites. This study found new evidence from microanalytical observations that support a magmatic origin for the carbonatite. The evidence include crystalline, porphyritic and spherulitic textures, as well as euhedral phenocrysts, that indicate a magmatic rather than a hydrothermal or replacement process. The micro analysis observed textural variations that imply multiple stages of formation for the rocks. There is also evidence in some minerals that points to possible ascent or convection of magma in different chambers. The geochemical trends of the rock suites are consistent with a common origin thus making fenitization of granitic gneiss less likely as the major genesis of the rock and primary carbonate magma more likely. It should however be noted that the sodic alteration observed supports fenitization of the rocks in the multiple stages of formation for the rocks. The observations from this can be applied to other phosphates deposits with lower REE concentrations. The study provides new insights into the origin and evolution of the Dorowa ring complex and its REE mineralization.

Machine Learning Models for the Kadoma-Chegutu Greenstone Belt using Magnetics, Radiometrics and Mineral Occurrence Data

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Machine learning is an application of statistical learning that identifies patterns in data and then makes predictions from those patterns Advances in sampling and computing power have brought machine learning to the forefront in many industries and will change traditional workflows and create new opportunities. When machine learning is applied to geoscience data e.g. geophysical data and images, tasks are transformed ranging from acquisition, imaging, interpretation, and prediction of mineralization. This paper presents models, using random forest classifier, unsupervised and checkerboard clustering of mineral occurrence for the Kadoma-Chegutu Greenstone Belt.

Classification algorithms. Supervised learning is considered the best option for this project out of the three types of machine learning techniques (supervised, unsupervised, and reinforcement learning), as its major objective is to develop a model from labelled training data that will enable prediction. The word "supervised" refers to a collection of samples where the predicted variables (magnetics and radiometrics) and the desired output signals (mineral occurrences) are both already known. Here, the following five machine-learning methods are tested:

i) the k-means clustering method, an unsupervised learning technique that is used to solve clustering problems in machine learning or data science;
ii) the naïve Bayesian method, which uses Bayes theorem to evaluate the probabil-ity of an event (class) to occur given the value of the input data;
iii) support vector machine, which is a discriminative classifier formally defined by a separating hyper¬plane;
iv) classification trees, which are decision trees built by using thresholds on input features at each split and;
v) (5) ensemble algorithms.

All algorithms can be tuned with a series of various algorithm-specific parameters that significantly contribute to the robustness, variance, and bias of the classification. The choice of the best parameters is done through the training/validating process. Here, the algorithms and the tuning tools in Python ScikitLearn Library (Pedregosa et al., 2011) have been used for the implementation.

Choosing the training and testing data sets. The data set was split into a training set composed of 70% of Mineral Occurrence data and a testing set composed of the remaining 30% of Mineral Occurrence data. The random forest classifier from ScikitLearn Library, samples randomly the set of features ahead of time such that for each one of those datasets, there will be a different set of features to be used, with a potential overlap.

The training set is used to tune/optimize algorithm parameters and evaluate the prediction success of the algorithms.

Training and validation. The training step is used to choose the best-suited algorithm and combination of parameters for the classification problem. The goal is to assess these models.

A metric called F-scoring is used by selecting a model with both low variance and bias. K-fold cross-validation is a useful technique to obtain reliable estimates of the model generalization error (i.e., how well the model performs on unseen data). The data was split into K subsets. The training was on K-1 subsets and tested on the Kth subset. The result is assessed using the accuracy metric. The process is repeated each time changing the subset for testing to determine the mean and standard deviation. This step is critical as it significantly improves the success rate of the final prediction.

The mineralogy and geochemistry of Archaean late-granite suites along the southern extent of the Zimbabwe Craton

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The southern margin of the Zimbabwe Craton (ZC) exhibits well-exposed Archaean granitoid-gneiss complexes of the tonalite-trondhjemite-granodiorite (TTG) suite and volcano-sedimentary greenstone belts which are in tectonic contact with the Northern Marginal Zone (NMZ- previously assigned to the Limpopo Belt). The ca. 3.5-2.67 Ga granitoid-gneiss complexes include Chingezi and Sesombi-Somabula suites. The NMZ is a high-grade terrain consisting of magmatic granulite gneisses (enderbites and charnockites) of the TTG magma-suite. The NMZ and the ZC display elevated contents of heat-generating elements K, Th and U. Younger (ca. 2635-2620 Ma) syn- to late potassic granites of the Chilimanzi and Razi suites intrude both granitoids and greenstone belts.

Harker and trace element variation diagrams show that the Razi and Chilimanzi suites have similar geochemistry and that fractional crystallization was the main evolutionary process for the granitic magmas. Our mineralogical and geochemical data demonstrate that TTGs are the likely protoliths to the granite suites and this proposition is given credence by other previous studies which show evolved isotopic signatures, unradiogenic Hf isotopic compositions and presence of xenoliths and inherited zircons in the younger granites. Small geochemical differences are attributed to modal mineralogy, and levels at which the granites are preserved. The Razi Suite represents the lower crustal section of the ZC, whereas the Chilimanzi Suite was emplaced and preserved at higher crustal levels of the same Archaean craton.

Eureka Mine 3D modelling

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Visualisation of mines can be significantly improved by using specialized software that can create a three-dimensional representation of the surface and interpretation of the ore body which remains underground. Modern software can convey an object's size, shape and texture. The concept of 3D geological modelling is no longer restricted to the creation of wireframes of the reef into block models, using the well-known software packages, but it is has now been expanded to allow the user to glean information about how mining can and is progressing.
The Eureka ore body was interpreted by various teams of geologists starting in 1906 when the mine was "discovered" and mined by the French South African Development Company. The interpretation of the ore body has been progressively improved as new technology brings new opportunities. In 2022, a mathematical model which was guided by structural mapping of exposure was used to simulate reef trends and improve grade prediction. This new interpretation has been used to sustain Zimbabwe's largest open pit gold mine (by volume) in the present era.
Based on the characteristics of the host rock and structural trends, digital mine construction has been applied at the project by collating multi-source data and multi-modelling methods of integration, to improve visualization and analysis of multidimensional data at the mine.
The 3D models of the mine are useful in evaluating the mineral resource and providing scientific evidence to management to help improve mining efficiencies during the various stages of mining. The models can be used to build an accurate production history of the operation by fully integrating the mining data to spatial information systems. The 3D model can be dynamically updated and gradually improved during the process of mine exploration, development, and reclamation.

The Benefits of Digital Transformation in Mining

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This presentation will highlight the immerse benefits which are realised when digital transformation is adopted and implemented properly by organisations. Well thought out processes and the integration of personnel are also key to the successful adoption of digital transformation in mining.

The use of Remotely Piloted Aircrafts (RPA) in data collection for magnetic, topographic and volumetric surveys has resulted in improved service quality, efficiency, profitability and customer satisfaction. This process has further improved accuracy in surveying and exploration, with high resolution data generated for powerful insights for decision making.

With this we call upon the mining industry to embrace and adopt digital enabled Remotely Piloted Aircraft services for exploration and surveying.

An Analysis of Alteration Styles Associated Au-Cu Mineralization at May Mine, Chinhoyi-Guruve Greenstone Belt.

Beaman Goredema - Mwatahwa Candidate - UZ

Muriel Mine is a well-known gold producing mine that recovers gold from the runoff mine from an open pit production, and also from the slimes of previously processed ore. This mine also owns the ancient gold claims at an adjacent location, the May claims, where there is an intended resuscitation of production. The unavailability of exploration data pertaining to this area necessitated the re-identification and delineation of the orebody.

Mapping efforts have been put forward by a scholar who mentioned that the area is characterized by various lithologies ranging from meta-basalt, diorite, feldspar porphyry, quartzites, granites, ultramafic units (UMF) and serpentinites (Kamutunga, 2017). He also noted that the area is punctuated by shears, joints and joint sets which counterfeit those at the Muriel Mine premises. Mineralization in this region from Eldorado, through Mutorashanga to Ayshire Mine (CGGB) is hydrothermal, associated within sulphides (Blenkinsop et al. 1996).

This research focused on analyzing the spatial association of structures and mineral alterations with gold-copper mineralization. It was accomplished through geological mapping (surface and trench mapping), lithological logging, sampling, assaying and petrographic analyses. The results of which will aid in orebody identification and interpretation of its behavior.

The gold-copper mineralization at May claims is hosted in hydrothermally fractured, jointed, sheared zones that are altered and oxidized across different lithologies. Mineralization is associated with silicification, sulphidization; limonite and chlorite alterations.

However, apart from the identified structures and alterations, the results of this study showed that there is also economic mineralization in intact and unaltered lithologies at May claims.