Geological Society of Zimbabwe

ABSTRACTS

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Summer Symposium

8am to 5pm, Thursday 6th September 2018
Department of Geology
University of Zimbabwe

Notes

Cover Photo

Serrated Lepidopteris fossil from Manyima Peat - Tony Martin

Start	Topic	Speaker
07:45	**Registration**	
08:00	Welcome	Steve Duma- Geological Society Chair
08:20	Official Opening and Introduction to new School of Earth and Mineral Sciences	Mku T Ityokumbul, UZ-Zimplats Professor, School of Earth and Mineral Sciences.
08:50	**Tea**	
09:10	Introduction to 2018 GSSA AL du Toit Memorial Lecture	Gordon Chunnett
09:20	**Wandering continents of the Indian Ocean**	**Lewis Ashwal - 2018, GSSA AL du Toit Memorial Lecture**
10:20	How the Magondi Belt lost its length: Chemostratigraphic approach to correlation in Precambrian metamorphic belts	Sharad Master
11:20	Mantle Plumes: Fable, Fiction or Fact	Andy Moore
11:50	Tectonic Controls on the intrusion of the Great Dyke and the Bushveld Complex	Tom Blenkinsop
12:20	Geology of the Chewore Inliers and Environs	Peter Fey
13:00	**Lunch**	
14:00	Of syntaxes, secondary continental ribbons and oroclines; onset and accretion of Neoarchean Kalahari Supercontinent	Mark Tsomondo
14:40	The ruby fields of Montepuez Complex, Mozambique – detailed magnetic and radio-element interpretation for target generation	Tenyears Gumede
15:00	**Tea**	
15:15	Arcadia Lithium Project	Adam Moodley
15:35	Grade improvement through multi-disciplinary team synergies – a case study of Unki Mine, Great Dyke of Zimbabwe	Melusi Hlambelo
15:55	Principles of hyperspectral imaging and its applicability to geological samples	Mike Donze
16:15	Surpac Structural Suite - Using orientated data in your geological modelling workflow	Nicky Vlok
16:35	Summary	Tony Martin

2018 A.L. du Toit Memorial Lecture - Wandering continents of the Indian Ocean

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On the last page of his 1937 book "*Our Wandering Continents*" Alex Du Toit advised the geological community to develop the field of "comparative geology", which he defined as "the study of continental fragments". This is precisely the theme of this lecture, which outlines my research activities for the past 15 years, on the continental fragments of the Indian Ocean.

In the early 1990s, my colleagues and I were working in Madagascar, and we recognized the need to appreciate the excellent geological mapping (pioneered in the 1950s by Henri Besairie) in a more modern geodynamic context, by applying new ideas and analytical techniques, to a large and understudied piece of continental crust. One result of this work was the identification of a 700-800 Ma belt of plutons and volcanic equivalents, about 450 km long, which we suggested might represent an Andean-type arc, produced by Neoproterozoic subduction. We wondered if similar examples of this magmatic belt might be present elsewhere, and we began working in the Seychelles, where late Precambrian granites are exposed on about 40 of the >100 islands in the archipelago. Based on our new petrological, geochemical, geochronological measurements, we built a case that these ~750 Ma rocks also represent an Andean-type arc, coeval with and equivalent to the one present in Madagascar. By using similar types of approaches, we tracked this arc even further, into the Malani Igneous Province of Rajasthan, in northwest India. Our paleomagnetic data place these three entities adjacent to each other at ~750 Ma, and were positioned at the margins, rather than in the central parts of the Rodinia supercontinent, further supporting their formation in a subduction-related continental arc.

A widespread view is that in the Neoproterozoic, Rodinia began to break apart, and the more familiar Gondwana supercontinent was assembled by Pan-African (~500-600 Ma) continental collisions, marked by the highly deformed and metamorphosed rocks of the East African Orogen. It was our mentor, Kevin Burke, who suggested that the present-day locations of alkaline rocks and carbonatites (called "ARCs") and their deformed equivalents (called "DARCs"), might mark the outlines of two well-defined parts of the Wilson cycle. We can be confident that ARC rocks formed originally in intracontinental rift settings, and we postulated that DARCs represent suture zones, where vanished oceans have closed. We also found that the isotopic record of these events can be preserved in DARC minerals. In a nepheline syenite gneiss from Malawi, the U-Pb age of zircons is 730 Ma (marking the rifting of Rodinia) and that of monazites is 522 Ma (marking the collisional construction of Gondwana).

A general outline of how and when Gondwana broke apart into the current configuration of continental entities, starting at about 180 Ma, has been known for some time, because this record is preserved in the magnetic properties of ocean-floor basalts, which can be precisely dated. A current topic of active research is the role that deep mantle plumes may have played in initiating, or assisting, continental fragmentation. I am part of a group of colleagues and students who are applying complementary datasets to understand how the Karoo (182 Ma), Etendeka (132 Ma), Marion (90 Ma) and Réunion (65 Ma) plumes influenced the break-up of Gondwana and the development of the Indian Ocean. Shortly after the impingement of the Karoo plume at 182 Ma, Gondwana fragmentation began as Madagascar + India + Antarctica separated from Africa, and drifted southward. Only after 90 Ma, when Madagascar was blanketed by lavas of the Marion plume, did India begin to rift, and rapidly drifted northward, assisted by the 65 Ma Deccan plume, eventually colliding with Asia to produce the Himalayas. It is interesting that a record of these plate kinematics is preserved in the large Permian – Eocene sedimentary basins of western Madagascar: transtensional pull-apart structures are dextral in Jurassic rocks (recording initial southward drift with respect to Africa), but change to sinistral in the Eocene, recording India's northward drift.

Our latest work has begun to reveal that small continental fragments are present in unexpected places. In the young (max. 9 Ma) plume-related, volcanic island of Mauritius, we found Precambrian zircons with ages between 660 and 3000 Ma, in beach sands and trachytic lavas. This can only mean that a fragment of ancient continent must exist beneath the young volcanoes there, and that the old zircons were picked up by ascending magmas on their way to surface eruption sites. We speculate, based on gravity inversion modelling, that continental fragments may also be present beneath the Nazareth, Saya de Malha and Chagos Banks, as well as the Maldives and Laccadives. These were once joined together in a microcontinent we called "Mauritia", and became scattered across the Indian Ocean during Gondwana break-up, probably by mid-ocean ridge "jumps". This work, widely reported in international news media, allows a more refined reconstruction of Gondwana, suggests that continental break-up is far more complex than previously perceived, and has important implications for regional geological correlations and exploration models. Our results, as interesting as they may be, are merely follow-ups that build upon the prescient and pioneering ideas of Alex Du Toit, whose legacy we appreciatively acknowledge.

How the Magondi Belt lost its length: Chemostratigraphic test for correlation in Central African Precambrian metamorphic belts.

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The Palaeoproterozoic Magondi Supergroup, consisting of the Deweras, Lomagundi and Piriwiri groups, occurs in the Magondi Belt flanking the western border of the Archaean Zimbabwe Craton [1]. Master (1991; 1994)[2,3] reviewed the geology of the regions to the north of Magondi Belt, in eastern Zambia, NW Mozambique and western Malawi. He noted that the protoliths of the lithologies present in the highly metamorphosed Sinda and Lusandwa groups of the "Mozambique Belt" of eastern Zambia, namely quartzo-feldspathic meta-arkoses with interbedded metapelites, marbles, and amphibolite sills, correlate well with the lithologies of the Deweras Group. He also noted that protoliths of Mvuvye Group marbles, quartzites, and graphitic schists, together with base-metal sulphide mineralization, corresponded very closely to the lithological sequence in the Lomagundi and Piriwiri groups, with which they were correlated. These lithological correlations implied that the region of eastern Zambia could have been a northern continuation of the Magondi Belt, but which was at a higher metamorphic grade (granulite facies) than most of the Magondi Belt of NW Zimbabwe. The Magondi Belt was thus thought to continue northwards across the Zambezi Valley into the Eastern Province of Zambia, Zambezia Province of Mozambique, and the Chipata District of Malawi [2,3].

The suggested correlations were tested by using carbon isotope values of marbles in the Mvuvye and Sinda groups in the Chindeni Belt of eastern Zambia, sampled during the IGCP 363 field excursion in 1996 [4]. The isotopic analyses were done, using the protocol of Master et al. (2013)[16], at the University of Manitoba. These marbles, however, show only near-to-zero $\delta^{13}C$ values of 0.47 to -1.3 ‰ V-PDB, n = 6 (Table 1), differing from ^{13}C enrichments ($\delta^{13}C$ > 8 ‰ V-PDB) characteristic of the Lomagundi and Deweras group carbonates [1, 5-7], and thus they are not correlative on chemostratigraphic grounds with high $\delta^{13}C$ carbonate rocks of the Magondi Supergroup. Schidlowski et al. (1976) [5] first utilized the Lomagundi C-isotope excursion to show that the Tengwe River Group carbonate rocks in the Urungwe Klippe did *not* correlate with the Lomagundi Group, since their C-isotope compositions were very different. It has subsequently been established with radiometric dating that the rocks of eastern Zambia are part of a Mesoproterozoic arc terrain, the Southern Irumide Belt, which has ages of around 1.4-1.0 Ga [8]. The Southern Irumide Belt was accreted to the Congo-Tanzania-Bangweulu craton, and is separated from the Kalahari craton (of which the Zimbabwe craton is a constituent part) by an eclogite-bearing suture zone formed during the Pan-African Damaran-Lufilian-Zambezi Orogeny [8,9,10,11,12]. Thus we agree with Treloar [13] that the Magondi Belt does not correlate with any terrains that are currently to the north of it; its logical continuation is to the SW, where it disappears under younger cover, and seems to link with the Limpopo Belt, marking the southern boundary of the Zimbabwe craton before its ~2.0 Ga collision with the Kaapvaal craton.

Our study illustrates that structural, lithological and metamorphic trends are insufficient for robust geological correlation in Precambrian orogenic and metamorphic belts, and they need to be backed up with good geochronology and chemostratigraphy. In the past, the structural trends of lithologies from eastern Zambia were correlated with regions of the Southern Province (Choma-Kalomo Block) [9]; and the Great Dyke and Atchiza complexes as well as the Magondi and Chindeni belts were all correlated on the basis of lithological and structural trends [1,2]. None of these correlations now hold, and the terrains in Zimbabwe and Zambia south of the Zambezi-Makuti-Rushinga belts can no longer be correlated with regions to the north [12,14,15] - they are separated by a major suture where the Congo and Kalahari cratons collided in the Neoproterozoic-Palaeozoic Pan-African Damara-Lufilian-Zambezi Orogeny. The Magondi Belt consequently has lost its former supposed length, and is truncated to the north by the Makuti Group and the Escarpment Fault, and does not continue across the Zambezi Valley to Eastern Zambia, Mozambique, and Malawi [1].

Acknowledgements: We thank CIMERA/NRF for financial support.

Table 1: Carbon and oxygen isotope geochemistry of marbles from the Mvuvye and SInda groups, Chindeni Belt (Southern Irumide Belt), of eastern Zambia

Mvuvye Gp	$\delta^{13}C$ ‰V-PDB	$\delta^{18}O$ ‰V-PDB
V-2	0.30	- 8.80
MV-3	-0.28	-10.53
MV-5	0.47	- 9.27
Sinda Gp		
CD-1	-1.30	-12.50
CD-3	-1.30	-12.70
CD-4	1.21	-12.31

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Mantle Plumes: Fable, Fiction or Fact

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Time progressive volcanic chains such as Hawaii have been interpreted to reflect movement of the plate over stationary mantle plumes, which were initiated at the core-mantle boundary. The marked kink in the Hawaiian chain is interpreted to reflect a change in rotation of the Pacific plate. The plume model was extended to explain a variety of other processes. Thus, for example, it was suggested that plumes rising beneath Gondwana initiated the break-up of the super-continent. It has also been suggested that a superplume beneath southern Africa could explain the unusually high elevation of the southern African plateau, with an average elevation of 1000m, which contrasts with average elevations of 500m for shield areas in Australia, Canada and Europe.

The Plume concept has become widely accepted, no doubt in large measure because of the elegance and simplicity of the model, but a variety of inconsistencies and contradictions have been flagged. Thus, there are a number of major alkaline volcanic lineaments in southern Africa which show age progressions. However, while the ages cover a number of major reorganizations of spreading of the African plate, they do not show prominent kinks such as that seen on the Hawaiian chain. Further, Ken Bailey has noted that Africa has been characterized by episodic volcanism since the break-up of Gondwana, with these different episodes widely distributed across the continent. In terms of the plume model, this would require pulsating, synchronized plumes.

The disruption of Gondwana to a large extent followed crustal lines of weakness represented by the late Proterozoic Pan-African fold belts. The Plume model would have to explain how plumes generated at the Core-mantle boundary were able to unerringly target such lines of weakness. To circumvent this problem it has been suggested that plumes may be channelled beneath the lithospheric plate towards the zones of weakness represented by the fold belts. However, modifications to the basic model such as channelled plumes and pulsating synchronized plumes render the model essentially non-falsifiable.

Invoking plumes to account for the anomalously elevated topography of Africa predict that the central plateau should have a domal symmetry, and thus be associated with a radial drainage system. However, instead of the modelled domal topography, the interior of southern Africa is the site of the major Kalahari basin. Further, seismic tomography provides no evidence for the existence of a putative plume beneath southern Africa.

We discuss how these apparent conflicts with the Plume model can be resolved in terms of stresses in the lithosphere linked to plate motion on a non-spherical globe, which draws strongly on the membrane tectonics concept of Turcotte and Oxburgh.

Tectonic Controls on the intrusion of the Great Dyke and the Bushveld Complex

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Introduction. The Great Dyke and the Bushveld Complex, both in southern Africa, represent intrusive events on a spectacular scale in the Late Archean and Paleoproterozoic respectively. Problems posed by these events include how to generate, store and emplace such vast volumes of magma in relatively short time periods. The timing of these events relatively early in Earth's history also poses questions about the secular evolution of the Earth, and the role of mantle in their formation.

The Great Dyke. The Great Dyke is a mafic-ultramafic intrusion 550 km long and up to 11 km wide, intruded at 2.575 Ga (Oberthür et al., 2002). The cross section consists of a wide shallow upper part, close to a sill in geometry, tapering downwards to a thin lower keel . A very approximate volume of 3 300 km3 can be estimated using an average cross-sectional area of 6 km2. There are two main satellite dykes to the Great Dyke: the East Dyke lies ~ 20 km to the east, and the Umvimeela dyke about 10 km to the west: both are present beside the Great Dyke along most of its length, but are much thinner. A conjugate fault system formed in NNE and NW orientations in the Zimbabwe Archean craton (Wilson, 1990), related to convergence of the Northern Marginal Zone of the Limpopo Belt, before the intrusion of the Great Dyke. The NNE set of these conjugate faults was intruded by the Great Dyke and its satellites (Wilson, 1990). Tectonic controls on the intrusion of the Great Dyke are therefore quite evident.

The Bushveld Complex. The Bushveld Complex is a bowl-shaped mafic-ultramafic intrusion 7500 to 9000 m thick, with an area of at least 65 000 km2, and an estimated volume of up to 1 m km3(Cawthorn and Walraven, 1998). The Bushveld Complex intruded at 2.055 Ga in less than 1 Ma (Zeh et al., 2015). The pre-Bushveld Thabazimbi-Murchison Lineament may have acted as a feeder to the Complex (Clarke et al., 2009). The Molopo Farms Complex (MFC) in southern Botswana is part of the Bushveld Complex, which was emplaced syntectonically with deformation in the Kheis belt. along the Jwaneng-Makopong Shear Zone (JMSZ), a western extension of the TML (Key and Mapeo, 2018).

Relationship to the Supercontinent cycle? The Assembly of Nuna at 1.9 – 1.8 Ga follows the Bushveld complex intrusion. The existence and configuration of supercontinents or supercratons before Nuna is contentious, but the intrusion of the Great Dyke would correspond to a time early in the history of the putative Superia supercraton/supercontinent.

Discussion. The geometries of the two intrusions are apparently different as expressed at the surface of the Earth today, but in fact they have significant similarities in as much as the lower parts of the intrusions are likely to be dykes or at least fed through tabular bodies. Both intrusions crudely show a dyke-to-sill transition. The linear trace of the Great Dyke and the possible role of the TML and JMSZ in controlling the emplacement of the Bushveld Complex indicate that both intrusions were emplaced under conditions of unequal horizontal stresses, raising the possibility that tectonic triggers were important for their intrusion. Emplacement can be related to the late Archean deformation of the Zimbabwe craton and the Kheis belt, respectively.

A fundamental observation about both the Great Dyke and the Bushveld Complex is that they intrude centrally through their respective cratons, even though they extend towards the cratonic margins. The difficulty of intruding magma through a thick SCLM has been pointed out by Maier et al. (2012), and strengthens the argument that tectonic controls are vital, unless the SCLM has delaminated (Olsson et al., 2011). Delamination is unlikely for the Great Dyke (Nägler et al., 1997).

Higher heat flow and/or volatile fluxing in the mantle leads to voluminous basaltic magmas (Bailey, 1980). The effects of volatiles can reduce or eliminate the requirement for particularly high temperatures or delamination (Ivanov and Litasov, 2014). The Great Dyke was indeed formed from melting of a hydrated mantle (Mukasa et al., 1998). On the other hand, the Great Dyke and especially the Bushveld are exceptional in terms of scale. This could be an argument that some extra temperature was necessary for these really large intrusions i.e. they may have resulted from a combination of volatiles and higher heat flow in the early Earth. A chilled margin of komatiite described by Maier et al. (2016) does seem to require asthenospheric melting, but the implications for wider mantle participation in the formation of the Bushveld are unclear. Neither intrusion has an obvious relationship to the supercontinent cycle, perhaps suggesting that the melting event that created their magmas was not an expression of profound changes in mantle circulation, or necessarily involved the deep mantle.

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Geology of the Chewore Inliers and Environs

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The Chewore Inliers, a group of gneissic horsts regarded as of Mesoproterozoic age, cover approximately 800 km² of remote and rugged country in the extreme north of Zimbabwe, and extend across the Zambezi River into Zambia. Together with adjacent terrain to the east and south they were geologically mapped only between 1988 and 1994. Research undertaken since then includes further mapping, terrane analysis and geochronology.

Protruding through cover of Karoo Supergroup sediments the Inliers comprise four geologically distinct but tectonically juxtaposed terranes. Largest is the Gneiss Terrane, a heterogeneous assemblage of quartzofeldspathic gneisses, in part of sedimentary origin, with lesser metaquartzites and amphibolites. The terrane cannot be correlated with paragneisses on the Escarpment to the south but has affinities with Basement gneisses occurring directly to the north and northeast in Zambia and Mozambique. The Quartzite Terrane comprises metaquartzites and metapelitic gneisses whereas the Granulite Terrane is dominated by anhydrous garnet-bearing gneisses, mafic granulites, metaquartzites and rare enderbites. Concordant orthogneisses in the Granulite and Gneiss Terranes predate all tectonic events and were emplaced at *c.* 1080 Ma. There are at least three ages of pegmatite.

After the original geological survey had been completed a small area in the far southeast of the Chewore Inliers was remapped and interpreted as a dismembered, relict ophiolite and island arc sequence. This Ophiolite Terrane, dated at 1393 ± 22 Ma, is regarded as the oldest dated remnant of oceanic crust in Africa.

In the Gneiss and Quartzite terranes three periods of folding have been determined, compared with only two in the Granulite Terrane. Since transport vectors in the latter differ from those in the other three terranes it is believed to have developed in isolation and retains evidence of high-grade metamorphism (M_1) dated at *c.* 945 Ma. The terranes were reworked during the Pan-African amphibolite facies metamorphic cycle (M_2), which peaked at 524 ± 16 Ma. This collisional orogeny culminated in northeast over southwest-directed tectonic transport, overthrusting and terrane juxtaposition.

The virtually undeformed, layered Chewore Complex was emplaced across the tectonic contact between Granulite and Quartzite Terranes towards the end of the M_2 metamorphic cycle, then tilted and dismembered into four fragments which trend and young to the southwest. Thin chromite seams occur in the two largest, predominantly ultramafic fragments.

After prolonged uplift, downwarping and basin formation began in the Late Carboniferous or Early Permian. The basins were filled by Karoo Supergroup sediments for whose lower portion a new, local stratigraphy has been erected. Since earth movements continued in post-Karoo times Basement-Karoo contacts range from faulted to unconformable. East and south of the Chewore Inliers the Dande Sandstone Formation conformably overlies the Karoo strata which elsewhere are locally covered by unconsolidated Jesse Sand comprising reworked Kalahari sediments.

Soon after its discovery in 1955 the Chewore Complex was explored for Cr, Ni and Pt, but no economic mineralisation was found. Two occurrences of low rank, high ash coal discovered early in the 20th century on the eastern flank of the Chewore Inliers remain to be evaluated.

Of syntaxes, oroclines and secondary continental ribbons: accretionary orogenesis overlapping Limpopo continent-continent collision in c. 600Myr Kalahari Supercontinent cycle (3.1-2.5Ga)

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Archean events on the Kaapvaal and Zimbabwe cratons are hereby unified under a 600Myr (par for the course!) Kalahari supercontinent cycle representing Mesoarchean arc-accretionary orogenesis (around host-Tokwe and Kaapvaal protocratons1,2,3) that complexly overlapped a protocraton-protocraton dominated Neoarchean collision across the Limpopo orogen. Until recently, just where and when the 'Alpine-Himalayan style' Limpopo orogeny started was unknown together with its time-integrated global tectonic history covering syn-collisional (2.75-2.65Ga) and post-docking plate re-organisation involving 2.65-2.50Ga indenter-stoked 'hot orogen' stage featuring granite-cored4 megasheath folds in the Central Zone. Besides unknown indenter shape, size and rheology, the missing links for global tectonic reconstructions5 included, (1) a lack of accurate Archean tectonic domains map of the Zimbabwe craton centred on its host-Tokwe protocraton, preserved as a dextral σ-shaped tectonic inclusion/ribbon, (2) the neglected geophysical evidence for a south-convex Limpopo orogen5 in the face of long-standing traditional consensus6,7 on a linear ENE-WSW trending Limpopo belt, (3), absence of both strain model for the Limpopo Belt and mismatched plate boundaries or promontories pinning vertical axis rotation and back-arc formation8, and (4) not considering alternative interpretation for sinistral 'thrust-wrench'-lineation trajectories in the Hout River Shear Zone9,10 as key evidence for both oblique convergence and transpressional 'extrusional' orogen-parallel motions for the Southern Marginal Zone. Examples of orogenic curvature are rather widespread and include the traditionally-linear North Limpopo Thrust Zone that is clearly kinked northwest toward Tokwe foreland near Buchwa; such convexity is replicated by the domainal11 35km-wide Triangle Shear Zone in the structural hanging wall within the Northern Marginal Zone. The Shangani arc batholith is convex-east against Tokwe foreland western margin. The map-view Tschipise suture11 shows arc-parallel extension juxtaposed with arc-perpendicular shortening. The southern margin of the Kaapvaal craton was previously compared to an Aegean arc12 of oroclinal13 character. This summary therefore explores global perspectives for pinned deformation, syntaxes, and defines both extra-orogenic secondary continental ribbons and S-coupled oroclines using the improved available geological-geophysical-geochronological datasets. The unexpected occurrence of secondary lithospheric ribbon/microplate indenters is intriguing yet predictable from the lateral heterogeneities of Kaapvaal protocratonic crust. The new interplate Tokwe-Swazi-(land) ribbon continent is the key to unravelling the flanking convergent-collisional-extensional domains14 characteristic of the Kalahari supercontinent cycle in each craton together with aspects of lithospheric-scale oroclinal delamination15, buckling and bending16 during indentation tectonics. The Kaapvaal craton is like the New England Orocline, characteristically an ear-shaped orocline pinned in the east by the stiff Swazi ribbon, the hinterland indenter for the Zimbabwe craton. Without the Swazi ribbon the Meso-Neoarchean tectonic evolution of both the Kaapvaal and Zimbabwe craton remained enigmatic. For the first time, the hallmarks of Alpine-Himalayan tectonics of syntaxes, oroclines and Adria-like or India-type microplates have been defined for an oroclinal Kalahari supercontinent.

The ruby fields of Montepuez Complex, Mozambique – detailed magnetic and radio-element interpretation for target generation

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Northeastern Mozambique is located at a geologically critical junction between the north-south trending Mozambique Belt and the east-west trending Zambezi Belt. Both are "treasure-bearing" orogenic belts. Major thrusts and shear zones separate several major geological complexes. Complex thermal and deformational events provided ideal temperature and pressure for forming ruby, garnet, and other economic minerals.
The area has had a more detailed 300m line spacing magnetic and radiometric data. The broader magnetic data shows variations of formations within the Montepuex complex, which is largely composed of metamorphosed felsic rocks including marble. The geophysical data shows the mapped granitic gneiss as populated by, NE SW trending magnetic features and NW SE features defining the wedge shaped feature of the Montepuez Complex which is wedged to the Nairoto Complex to the north.

The magnetic anomalies clearly map the folded Montepuez Complex with the fold axial plane being N S. Parasitic and isoclinal folds are also mapped within the area. Ruby targets are associated with major ductile faults, which are oriented NE SW and amphibolitic gneisses that exhibit an elevated magnetic intensity. In addition, isoclinal fold enclosures are characterised by depleted radioelement anomalies while the ruby target, lying on the fold limbs are also deficient in the same, mapping the areas that may be amphibolitic, being the primary host rock for the rubies.

Arcadia Lithium Project

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The Arcadia Project is located some 35 ENE of the capital, within the Harare Greenstone Belt.

It is a series of 14 flat laying stacked pegmatites of the L-C-T (lithium caesium tantalum) class. The known strike length is over 4km, but surface exposure is minimal. The pegmatites are mineralogically quartz-feldspar rich, with significant concentrations of petalite, and spodumene, with subsidiary amounts of tantalite.

Historically one of the bodies; the so – called Main Pegmatite was mined sporadically in the '60s and '70s for lithium and beryl. Limited drilling programs were carried out by Central African Minerals (CAM) in the early '80s', and the Geological Survey of Rhodesia before Zimbabwe gained independence.

Prospect Resources hold around 14 sq km of claims over the project area. Chip sampling of the old pit was started in May 2016 followed by the Phase 1 DD programme in June. At various times two to five drill rigs have been utilised. Six phases of drilling have now been completed; 90 DD holes (>10,000m) and 192 RC holes (>15,000m). Over 5,000 assay samples have been analysed for multi-elements, with 2,000 XRDs done to define the detailed mineralogy.

25 dedicated metallurgical test core holes have been drilled, and over 8 tonnes of bulk sample sent for test work.

The current mineral, resource estimate has defined 57 Mt @ 1.1% Li2O, with a high grade core (0.8% cut off) of 35 Mt @ 1.4% Li2O.

A main pit some 1.5km long, maximum depth of about 140m is planned, based on reserves of 24mt @ 1.34%

A pre-feasibility study has been released detailing the profitable extraction of 1.2 Mtpa and production of varying grades of spodumene and petalite, for a CAPEX of > $55m.
Work is now concentrating on producing a feasibility study for a dedicated lithium carbonate plant production facility.

Regional exploration; mapping and soil sampling continues to identify satellite and associated bodies.

Arcadia is Africa's largest and the World's 5th largest JORC compliant hard rock resource. Pre-stripping and mine construction are scheduled to begin the fourth quarter of 2018.

Grade improvement through multi-disciplinary team synergies – a case study of Unki Mine, Great Dyke of Zimbabwe

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Unki Mine is located in central Zimbabwe, on the Great Dyke, which is a unique elongate layered intrusion. The mine extracts platinum group minerals (PGMs) and base metals (BMs) within a 2-3 m thick Main Sulphide Zone (MSZ) reef layer. Current production of 150 kt/month is from an underground trackless bord-and-pillar mining operation. Ore is processed at an on-site concentrator plant with an original nameplate capacity of 120 kt/month. Following various initiatives during 2012, aimed at increasing underground ore production, which included changes in the trackless mobile equipment (TMM) suite, a catastrophic drop in grade resulted. By 2014 the operation was threatened by viability challenges, attributed largely to decreasing feed grades which were exacerbated by decreasing global metal prices and escalating production costs. One of the turnaround strategies formulated was to focus on grade improvement, taking cognizance of having a fixed concentrator capacity where marginal revenue increases derived from increased tons were much less than those obtained from a quality-driven strategy. To this effect, Unki embarked on a grade improvement drive, which resulted in grade improvement from 3.11 g/t in Q1 of 2015 to 3.41 g/t in Q4 of 2015.

The grade reached a peak of 3.49 g/t in Q4 of 2016 and has since been sustained at that level to date.

The remarkable improvement in grade was a product of a multi-disciplinary team approach which focused on selecting the best cut giving the maximum 4E revenue, accurate face marking, reduction of the mining cut to achieve the best cut stope width, tactical deployment of TMM, correct identification of the reef slice, optimizing blast designs, and improvements in drilling and blasting techniques to reduce or avoid mining overbreak. Other controls adopted included monitoring of muck cleaning to prevent footwall overbreak and cross-tramming of ore and waste. These initiatives had key performance indicators (KPIs) which were tracked daily and communicated to all stakeholders. The stope width, which is a major lever for grade improvement, decreased from an average of 2.19 m in Q1 of 2015 to 2.11 m in Q4 of 2015. A further decrease of the stope width to an average of 2.04 m was realized in Q4 of 2016 and has been sustained to date. Improved drilling and blasting resulted in excellent dimensional control, evident from a half-cast barrel factor on roof and sidewalls increasing from an average of 10% to an average of 29% for the mine, with some teams achieving up to 52% over the same period.

Principles of hyperspectral imaging and its applicability to geological samples

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While infrared imaging has been widely applied in satellite and airborne applications, applications in proximal environments are still being explored and further developed. Infrared imaging has huge potential in contributing to many geological and economic decision-making applications. In reflectance spectroscopy light is reflected or scattered from a rock sample surface. Some of this light is reflected, some of this light is absorbed, while some light passed through the material (Clark, 1995). Reflected or scattered light from the sample surface can then be measured

The infrared region of the electromagnetic spectrum is divided into regions passing from the visible into the near-infrared, mid-infrared and into the far infrared. The near-infrared is subdivided into the visible-near infrared (VNIR) and the shortwave infrared (SWIR). The SWIR region provides identification of many clays, phyllosilicate and OH-bearing mineral species. The mid-infrared is divided into the midwave infrared (MWIR) and the longwave infrared (LWIR). LWIR is suitable for identification of many silicate mineral species possible. One of the significant challenges of infrared imaging is the processing and handling of the large volumes of data. The data needs to be converted to data products so that it can be integrated with the geological environment to extract its full value. The products can be broadly divided into classification and distribution images.

Infrared imaging can be undertaken at different spatial resolutions. Imaging at sub-millimeter scales on small samples allows mineral concentrations and even powders to be analyzed. If the targeted minerals can be detected, then these techniques provide a rapid and non-destructive technique for mineral content mapping. Prepared in-situ sample slabs can also be imaged at the high spatial resolution allowing assessment of larger populations of samples to be analyzed to ensure sample selection for more detailed analyses are representative. Hand specimens can also be imaged and used for characterization of the material. These studies provide value in the characterization of the geology through the mineralogical occurrences and associations. Drill chip samples can also be imaged providing mineralogical parameters that can be combined with assay values or geological logging. The imaging of diamond drill core is a significant application of infrared imaging. For samples of this type the potential to image complete sample suites rapidly provides significant value. Analytical data from the full geological sample suite provides the important base for determining properties, behaviors and even economic value determination.

Surpac Structural Suite - Using orientated data in your geological modelling workflow

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The Structural Suite for Geovia Surpac can be used for the visualization and analysis of any orientated data.

The Geovia Surpac Structural Suite allows you to include orientation data into your geological modelling workflow. It can also make use of contact orientations, foliations, as well as information such as joint orientations from core logging or televiewer data and any mapped structure data.

The visualization of this orientated data can assist in identifying high risk areas in your open pit or underground operations, enabling you to improve decision making for support and construction and increasing the overall safety for these operations. More than 20 tools exist in the current version of Geovia Surpac.
