Geological Society of Zimbabwe

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ABSTRACTS

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Summer Symposium

8am to 5pm, Friday 20th November 2015
Caribbea Bay, Kariba

Final

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Geological Society of Zimbabwe Summer Symposium 2015		
20th November 2015, Carribea Bay, Kariba		
Start	**Topic**	**Speaker**
07:00	**Registration**	
07:40	Welcome	Ali Ait-Kaci, Society Chairman
08:00	Official Opening	Temba Hawadi, Director of Geological Survey
08:25	Professional Status and the Geological Society of Zimbabwe	Andrew du Toit
08:45	~~Recommendation of a geochemical mapping exercise for the SADC region~~	~~Zibisane Bagai~~
09:10	**Tea**	
09:25	The vanished orogeny: Geochronology of Palaeoproterozoic “basement” gneisses of the Kariba and adjacent areas, western Magondi Belt (Zimbabwe and Zambia)	Sharad Master (Keynote)
10:25	Impact of hydrothermal solutions on the world economy	Tony Martin
11:25	Implications for the extent of the Zimbabwe Craton, from U-Pb zircon geochronology of the Dete-Kamativi Inlier (NW Zimbabwe) and the Choma-Kalomo Block, of SE Zambia.	Sarah Glynn
11:50	Ruby Bearing Amphibolitic Gneisses - Montepuez Complex, Mozambique	Tenyears Gumede
12:15	Kariba - 60 Years Since Inception. A Geological and Geotechnical Review	Tim Broderick
12:50	**Lunch**	
14:00	Waterberg Pt deposit, update	Gordon Chunnett
14:25	Challenges in the interpretation of luminescence dating of quartz grains in the Kalahari environment.	Andy Moore
14:50	**Tea**	
15:05	Application of Rock Mass Rating in Bord and Pillar Mine Design Layout adjustments and Implication to Business Planning –Unki Mine Case Study	Omberai Mandingaisa
15:30	Summary	Sharad Master

The vanished orogeny: Geochronology of Palaeoproterozoic "basement" gneisses of the Kariba and adjacent areas, western Magondi Belt (Zimbabwe and Zambia).

Sharad Master, Sarah Glynn, Michael Wiedenbeck

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Introduction. The Magondi Belt is a Palaeoproterozoic mobile belt situated on the western flank of the Archaean Zimbabwe Craton, extending from NW Zimbabwe to NE Botswana. It consists of deformed rocks of the Palaeo-proterozoic Magondi Supergroup, a 2.2-2.06 Ga metasedimentary succession with minor volcanic rocks (Master et al., 2010; 2013). On the eastern part of the belt, there are autochthonous units that are in unconformable contact with Archaean granite-greenstone rocks of the Zimbabwe Craton. In the north and northeast of the belt, Magondi Supergroup rocks apparently either overlie older basement gneisses and schists unconformably, or are found in infolds within such basement.

Regional Geological Setting. In the northern part of the Magondi Belt, the crystalline basement consists of a heterogeneous succession of paragneisses and orthogneisses, which vary from foliated granitic leucogneisses to biotite gneisses to migmatites. There are also intercalations of hornblende-diopside calc-silicate gneisses. Granitoids consisting of plugs of granodioritic and tonalitic gneisses intrude the various paragneiss units.

Dirks et al. (1999) dated two biotite tonalite gneisses structurally interleaved with the base of the Makuti Group, which they dated at 2704 ± 0.3 Ma and 2510 ± 0.4 Ma). The Chipisa Paragneisses were dated by Loney (1969), and yielded a recalc. Rb-Sr WR age of 2443 ± 90 Ma. This imprecise result was interpreted by Master (1991, 1996) as indicating a Neorchaean to Palaeo-proterozoic age for the metamorphism that affected these rocks. The Kariba Paragneisses are a northern continuation of the Chipisa Para-gneisses, and also consist of foliated biotite paragneisses with calc-silicate bands and thin leucogneisses. In this area there are also some porphyroblastic biotite gneisses containing euhedral microcline and microperthite porphyroblasts, which are associated with small plugs of adamellite and granodiorite. Sillimanite quartzites occur interbedded within the Kariba Paragneisses, and are regarded as an arenaceous facies of the paragneiss. Loney (1969) obtained a (recalc. WR) Rb-Sr age of 2368 ± 92 Ma for the Kariba Paragneisses. Master (1991, 1996) considered this imprecise age as a minimum, metamorphic age, with the age of sedimentation of the protoliths being unknown, but most probably Neoarchaean or earliest Palaeo-proterozoic. A meta-granite in the Kariba area which is intrusive into paragneisses, was dated by Loney (1969) at 2050 ± 32 Ma (recalc. Rb-Sr WR). Two porphyritic garnetiferous granodiorite gneisses from Kariba were dated by Dirks et al. (1999) and yielded Pb-Pb zircon evaporation ages of 1920.2 ± 0.4 Ma and 1962.7 ± 0.4 Ma.

The paragneisses and their associated intrusive granitic orthogneisses and ortho-amphibolites record a major orogenic cycle, the Hurungwe Orogeny (Master, 1991, 1996), that is imprecisely dated, but apparently predated the ca. 2.1 Ga Magondi Supergroup. The age constraints on this orogenic cycle are very poorly defined. The only dating of the paragneisses, by Loney (1969), indicates ages that span 2533 to 2276 Ma, i.e. Neorchaean to

Palaeoproterozoic. The Hurungwe orogenic cycle may have involved subduction of oceanic crust underneath the Zimbabwe craton, with orogenic obduction of an accretionary wedge onto the western edge of the craton (Master, 1991, 1996).

New SIMS U-Pb zircon age data. We made a reconnaissance sampling traverse through three regions of the northern Magondi Belt in 2013, in both Zimbabwe, as well as in the Siavonga area of Zambia along the shores of Lake Kariba. The first area was the Chiroti Gneiss (Broderick, 1976), where two samples, ZMB13/5 and ZMB13/6 were collected. The second area was in the northern part of the Hurungwe gneisses, where fresh exposures of deformed garnetiferous quartzofeldspathic gneisses were found in a roadcutting, and sample ZMB13/8B was collected. The third area is around the town of Kariba in Zimbabwe, and the nearby town of Siavonga, across the border in Zambia, located along the northeastern shores of Lake Kariba. Here samples ZMB13/10 (a porphyritic granitoid, from 10 km E of Kariba), ZMB13/11 (sillimanite quartzite, from Kariba Heights, Kariba) and ZMB13/12 (a quartzo-feldspathic biotite gneiss from Manchinchi Bay, Siavonga, Zambia) were collected. In all samples, zircons were extracted using standard heavy liquid preparation techniques. Electron microprobe backscatter imaging (BSE), and cathodoluminescence (CL) imaging of the zircons were used to help in the selection of sample spots for U-Pb dating on the CAMECA 1280 SIMS instrument at GfZ, Potsdam.

(a) Sample ZMB13/5 of the Chiroti granitic gneiss was collected at 17°05’52.2”S; 29°01’38.0”E. Petrographically it consists of quartz, plagioclase, microcline and biotite. It has a gneissic fabric, marked by a preferred alignment of elongated quartz and feldspar grains. The zircons in ZMB13/5 have yielded ages of 2038.9 ± 2.7 Ma, 2.15 Ga, and 2.25 Ga. The age of intrusion is regarded as 2.039 Ga, while the older zircons reflect inheritance from older crust dated at 2.15 and 2.25 Ga.

(b) The second sample of Chiroti Gneiss, ZMB13/6, is also a granitic gneiss, collected from 17°04’52.8”S; 29°04’08.5”E. It contains large microcline grains surrounded by quartz, sericitized K-feldspar, biotite partly retrograded to chlorite, with accessory white mica, apatite, sphene and zircon. The zircons in ZMB13/6 have yielded ages of 2.027 and 2.9 Ga. The age of intrusion is regarded as 2027 Ma, while the older zircons reflect inheritance from older Neoarchaean crust dated at 2.9 Ga.

(c) The Hurungwe Gneiss, *Sample ZMB13/8B,* collected near 16°33’S, 29°33’E, on the Karoyi-Chirundu road, is a biotite garnet granitic gneiss, containing quartz, K-feldspar, plagioclase, biotite, garnet. Biotite schieleren 2-4 mm wide help to define a gneissic foliation in the rock. The zircons have yielded ages of 2020.7 ± 6.6 Ma, which is regarded as the age of the intrusion. No inherited zircons were found in this sample.

(d) The Kariba porphyritic biotite granitoid gneiss (16°30’40.6”S, 28°50’30.3”E) is coarse-grained, with a weak gneissic fabric, and contains large K-feldspar phenocrysts, and numerous decimetric slab-like mafic xenoliths. It contains small garnets rimmed and replaced by biotite. The zircons dated have oscillatory zoning in the centre (of igneous origin), but the margins have been affected by metasomatic alteration zones, and in some cases have discrete overgrowth rims. The zircons have yielded ages of 1962.9 ± 8.5 Ma and

2.1-2.17 Ga. The age of intrusion is regarded as 1.963 Ga, while the older zircons reflect inheritance from older crust.

(e) The Kariba sillimanite quartzite Kariba Heights, Sample ZMB13/11. (16°31’26.5”S, 28°47’33.6”E) is an aluminous quartzite consisting mainly of quartz and sillimanite. The zircons have yielded concordant ages of 2.018 Ga, 2.172, 2.220 and 2.70 Ga. The maximum age of the quartzite is 2.018 Ga, the age of the youngest detrital zircon, while the other zircons reflect a provenance from older crust dated at 2.17, 2.22, and 2.70 Ga. Three youngest zircons have ages between 1.955 and 1.963 Ga, reflecting possible resetting during intrusion of the 1.96 Ga granitoids.

(f) The Manchinchi Bay migmatitic granitic gneiss, near Siavonga, Zambia, Sample ZMB13/12, is a strongly polydeformed gneiss, with intrafolial folds. The zircons from the gneiss have, in most instances, an oscillatory-zoned core, with prominent zones of metasomatic alteration, and high uranium (CL-bright) overgrowth rims. The zircons have yielded ages of 1967.5 ± 8.4 Ma (cores) and 545.8 ± 4.8 Ma (rims). The age of intrusion is regarded as 1967.5 Ma, while the younger rims reflect resetting at 545.8 ± 4.8 Ma, during the peak of the Pan-African Zambezi Orogeny.

Discussion. Our new age data show that many of the granitoids in the supposed pre-Magondi basement are actually post-Magondi intrusive rocks, which are part of an extensive magmatic arc formed on the western flank of the Archaean Zimbabwe Craton at between 2.06 and 1.96 Ga (Master et al., 2010; 2013). There is no indication from the new geochronological results, which are the best quality dates obtained from the NW Magondi Belt, for any pre-Magondi Palaeoproterozoic orogeny (“Hurungwe Orogeny”) between 2.6 and 2.2 Ga. The new geochronological data are best interpreted as indicating that the Magondi Supergroup was intruded by an Andean-type magmatic arc in the west, and then affected by the Magondi Orogeny, through collision with an unknown continent to the west (Terra Incognita; Master et al., 2010). High temperature metamorphism in the Magondi Belt, which reached granulite facies in the west, was partly caused by heat input from the magmatic arc (Munyanyiwa & Maaskant, 1998). During the Pan-African Zambezi Orogeny, the Makuti Group was thrust over the NW Magondi Belt, and resulted in renewed deformation, metamorphism, and geochronological overprinting at about 546 Ma.

Hydrothermal Fluids and Their Impact on the World Economy

Tony Martin

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Depending upon one's definition of hydrothermal fluids virtually every metal and many other commodities used by man have been naturally deposited or enriched to economic levels with the involvement of water. Definitions place the lower temperature limit of these fluids at 50°C but this is an arbitrary number and I would include any transporting fluid of whatever temperature. This broader definition allows the inclusion of supergene enrichment; there are many metals that form by surface processes, but bauxite is the only one that relies entirely on these. Hydrothermal fluids commonly form commercial deposits by accumulating valuable elements, but hydrothermal removal of gangue minerals can also produce ore.

There are a number of different types of hydrothermal deposits and the most common in Zimbabwe are veins and pegmatites. But the list of includes porphyries, volcanogenic massive sulphide and sedimentary exhalative deposits, metasomatic deposits, iron oxide copper gold uranium, sedimentary-hosted copper/cobalt and carbonatites.

The only element that has never been commercially produced from hydrothermal deposits is chromite, and the bulk of the production of others (platinum group elements and nickel) has also come from magmatic sources. Nevertheless, without water, the earth would not have concentrated the elements that we mine and have come to take for granted in our daily lives.

Field and laboratory evidence shows that hydrothermal fluids have very wide ranges of compositions, temperatures and pressures. This presentation illustrates this variability from observations of a number of different hydrothermal deposits.

Implications for the extent of the Zimbabwe Craton, from U-Pb zircon geochronology of the Dete-Kamativi Inlier (NW Zimbabwe) and the Choma-Kalomo Block, of SE Zambia.

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The Choma-Kalomo Block is a north-east trending, terrane located in southern Zambia. It is composed of a gneissic basement, overlain by a high-grade metamorphosed supracrustal metasedimentary sequence, which is intruded by granites and gneisses of the Choma-Kalomo Batholith, dated between ca. 1.37 and 1.18 Ga.

Two models have been proposed to account for the current position of the Choma-Kalomo Block. The first model stipulated that the Choma-Kalomo Block, the Dete-Kamativi Inlier and the Kibara Belt in the DRC were once connected. For this to be valid both the Choma-Kalomo Block and Dete-Kamativi Inlier have to be considered as exotic terranes with respect to the surrounding Zimbabwe Craton and Palaeoproterozoic Magondi Belt. However, our recent geochronological investigations of the Choma-Kalomo Block and Dete-Kamativi Inlier have demonstrated that the Kamativi region is floored by Archaean basement. From this we have concluded that the Zimbabwe Craton extends further west under the Magondi Belt than previously thought, and that the Dete-Kamativi Inlier is not an exotic terrane, thus refuting this first model.

The second model suggests that only the Choma-Kalomo Block is an exotic terrane, having become caught up between the Hook Batholith and the Magondi Belt, after rifting off of the Kibara Belt during the Pan-African Damara-Lufilian-Zambezi orogenic event. This implies no links between the Choma-Kalomo block and the Kamativi area prior to the Pan-African. However, there are strong similarities between the Choma-Kalomo block and the Dete-Kamativi Inlier, particularly with both regions having abundant Palaeoproterozoic zircons. The Choma-Kalomo Block has until now been considered Mesoproterozoic in age, hence the claims it is exotic with respect to the neighbouring Archaean Zimbabwe Craton and Palaeoproterozoic Magondi Belt. However, our new U-Pb zircon ages in combination with information on the nature and age of Sn-bearing pegmatites in both the Choma-Kalomo Block and the Dete-Kamativi Inlier indicate that the Choma-Kalomo Block is not an exotic terrane. Rather we propose that the Choma-Kalomo Block is a metacratonic region belonging to the Zimbabwe Craton.

Ruby Bearing Amphibolitic Gneisses - Montepuez Complex, Mozambique

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In order to better understand the specific associations of garnets, corundum, and ruby with their respective host formations, which are the amphibolitic gneisses, it was deemed worthwhile to survey existing workings within the Montepuez area of Mozambique. To this end, a team consisting of members from Zimbabwe and Mozambique conducted ground magnetic and very low frequency (VLF) electromagnetic surveys in May 2015 over several known deposits.

The Montepuez area is characterized by a substantial overburden of weathered material, extending across an approximate area of 22000Ha. Geophysical means were seen to be most efficacious in attempting to glean characteristics of formations at depth, and for subsequent application into the area.

Observations derived from analyses on post-survey data were incorporated into producing a more refined framework for identifying potential targets that may host ruby and/or garnets.

The International Geomagnetic Reference Field (IGRF) is a standard mathematical description of the Earth's main magnetic field and its secular variation. Subtraction of the IGRF from the measured magnetic field provides the magnetic field of the crust. This is essential for compilation and comparison of magnetic anomaly maps from different datasets and merging of multi-year data sets. To this effect, magnetic data from Montepuez area and control sites collected in Year 2014 and Year 2015 respectively needed an IGRF correction in order to compare anomalies on absolute magnetic intensities and generate a supervised auto-classification of the magnetic anomalies for target generation.

Data from control sites were one dimensionally filtered to remove the IGRF using the 2005 model, such that a residual field was then gridded. In magnetic surveys, the IGRF may be calculated at each point within an area and gridded separately. This grid may then be subtracted from the total magnetic field to effectively remove the IGRF. The resultant is a residual magnetic field map that can be used for direct comparison (as opposed to relative) with data from other areas.

The IGRF removed residual magnetic field maps for the ruby/corundum control sites were used to generate a color look up table (zone file) for eventual application onto the greater Montepuez are in order to map potential ruby hosting rocks.

Analyses conducted on magnetic data showed that there were discernible points of commonality between the corundum/ruby hosting formations on the one hand, and garnet hosting formations on the other. Respective signatures were then produced from the data distinguishing between magnetic signatures that typify rubies/corundum hosting formations from garnet hosting formations.

The following were observed from the Ruby control sites targets;
i) The peak residual magnetic anomalies are 65nT and 59nT for on the two corundum/ruby bearing sites. The peak values have been interpreted as being associated with the amphibolitic gneiss that hosts the corundum/ruby.
ii) The artisanal pits are generally located to the south of the anomalies, being the shallower hangingwall. Based on analysis of data on control sites, a lookup color table (LUT) was created to subsequently apply for target location of corundum/ruby hosting formations. Trough signals are as low as 615nT– implying varied country rock.

An equivalent exercise using data from garnet rhodolite control sites was undertaken to create a zone file (LUT) for identification

Of garnet related targets. The following features were observed:
i) The peak residual values were -8.0nT, -8.2nT, 5.5nT and -7.0nT. In general all the garnet target fields have a negative residual magnetic field. Artisanal pits are generally directly above the peaks of magnetic anomalies Except for one, which shows an exploited strike of 1800m, most of the garnet sites surveyed exhibit short strike lengths and are related to quartzite ridges
ii) The peak value from the zone file (LUT) is -8.2nT below the regional field
iii) Generally pinching and swelling occurs along strike
iv) The minimum trough value is observed to be -74.3nT (see LUT to the right

A sample set of known classes of magnetic anomalies is located on feature spaces i.e. in the case the feature spaces consist of the two respective signatures derived from control sites at for corundum/ruby host rocks, and for garnet host rocks. The feature spaces use zone files for classification of the whole data/image. Using the two features spaces, classification of the magnetic data on exploration sites was carried out in combination with other derived parameters in order to prioritize targets. The application of the feature space as a filter to map priority areas is complimented by other derived parameters such as mineral presence, strike length, etc. to better rank the priority targets.

Kariba – 60 years since inception. A geological and geotechnical review

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Kariba Gorge on the Zambezi River has forever been a point of intrigue and attraction. The first geologist to enter the gorge was Richard Thornton during Livingstone's 1856 Zambezi Expedition. At the turn of the 20th Century the area was recognized as being a possible river crossing point for the Chinhoyi-Kafue rail link, and with the dam potential, these options were pursued through the 1930's. J.T.S. Jeffares was commissioned by the SR Government to survey the river, ascertain the hydropower potential and select a possible dam site in 1941. Phaup and Amm followed up on early site investigations. Geoffrey Bond assessed the Karoo geology of the Sebungwe and future dam basin. The Cementation Company undertook penetrative site investigations at a number of sites between 1952 and 1954, whilst Stagman and Amm examined the cores and geology. Eventually Site X was chosen.

The decision to construct Kariba Dam was made on 1st March 1955, the Federal Power Board were appointed as were the consulting engineers, Gibb Coyne & Sogei with Andre Coyne the chief designer and Henry Olivier the resident chief engineer. Their first site visit was in May 1955. Only 7 diamond drill holes had been drilled across Site 'X'. Cementation continued their site investigation by means of exploratory shafts and adits, and then became involved in construction of the south-bank upstream and downstream portals and the diversion tunnel, and of the north-bank cofferdam into 1956. The Irrigation Department under the guidance of Eng's Savory and Bill Wild undertook construction of the innovative route from Makuti, mostly following elephant paths, whilst A.G. Burton Ltd championed the north-access, which would be the conduit for all cement requirements supplied by Chilanga. Impresit of Italy was appointed as the main civil engineering contractor on 13th July 1956, and construction work on the dam, and township progressed with gusto.

- Stagman assisted by Amm continued their presence at Kariba, logging cores, mapping and reporting on various excavations and potential quarry sites across the dam site.
- O'Brien and Reeves of the Northern Rhodesia Geological Survey described drilling and mapping for the underground powerhouse and approach tunnel in 1956.
- Concerns relating to leakage from the reservoir and around the dam had to be dispelled through the investigations of an independent geologist, Dr Francis Jones.
- Dr Louis Dubetret was appointed Consulting Geologist for Kariba to Gibb, Coyne & Sogei.
- Brian Hitchon began his geological mapping of the Kariba area in Northern Rhodesia, paying particular attention to the dam site, and identifying the north-bank stone quarry on exposed augen gneiss in the Shamba valley. His correlations were to the Sebakwian for the gneisses, the Lomagundi for quartzite and Deweras for pink feldspathic gneiss.

The coffer dam was flooded in March 1957, pumped dry by July and blown on 6th to allow river diversion. The central coffer dam was constructed, but flooded in March 1958 when

10,000 m^3/s was coming over the Victoria Falls, coinciding with local floods. The dam was redesigned with six floodgates.

Construction proceeded rapidly and the last skip of concrete was poured by Sir Roy Welensky on 22nd June 1959. Excavation of the south bank power house proceeded in stages whilst foundation investigations continued through the construction phase by means of diamond drill, adit and shaft. J.L. Knill of Imperial College and K.S. Jones from Gibbs built on interpretations of the late Francis Jones and Louis Dubetret. The north bank was found to be on a sound footing but complications arose in association with the interaction of quartzite and biotite gneiss up on the south bank. Thrust faulting resulted in intercalation of the rock types and a synclinal relationship with dips often into the gorge. Ground water circulation resulted in deep weathering at the interface, and a hitherto undefined 'mica seam' became apparent. Knowledge of the geology evolved following extensive exploration and jetting and grouting of the quartzite. The decision to proceed with mass replacement of the 'mica seam' with hydraulic concrete buttresses was made in July 1961. Hence the south-bank car park.

The frequency of load-induced earthquakes associated with the filling of the Lake rose sharply in 1963 at all magnitudes to 5.7. Records were continued by the Goertz Observatory, Bulawayo, Pretoria and the USGS National Earthquake Information Centre. The Federal Survey measured precise levels to record depression of Earth's crust.

Seismic and jacking tests in the adits showed that the quartzite and deep weathered contact with gneiss would be unstable under saturation when compared with similar tests on sound gneiss on the north bank. In particular it was likely that the quartzite mass would creep downslope, especially downstream of the buttresses where cross faults defined a dangerous block above the tailraces. A comprehensive geodetic monitoring system evolved including wall targets and beacons, crest level studs, and joint meters within the dam galleries, strain meters and thermometers in the wall and buttresses, and pendulums in shafts and boreholes to monitor the downslope movement. Spray due to the opening of the floodgates, necessary to develop the stilling pool, added some 100mm of precipitation per day to the abutments. The threat of landslip increased as movement downstream of the buttresses was being measured in centimetres, and with heavy rain the trend accelerated. Concrete walls were constructed at the foot of the fault block, surface cracks were sealed and drainage was improved, overburden was removed and stone pitching placed, some 400 upwardly inclined drain holes were drilled from surface and adit, and passive and post-tensioned anchors were installed (but in some the drill string had to be abandoned and grouted in place due to the creep). Movement reduced after 1975 and stabilization of the slope was achieved in 1979 following realignment of the access road and extensive sculpting of the right bank slope.

Peter Loney gained his PhD from Leeds University in 1969 on aspects of Kariba geology, including early geochronology and a study of the amphibolites. With fieldwork in 1972-73, T.J. Broderick made his contribution to the regional geology *East of Kariba*, published in 1976.

Considerable use of grouting and rock bolting had been made to stabilize the rock in some 7000 drill holes during Phase 1. Investigations were ongoing for the Phase 2 north-bank underground machine hall during the 1970's. D.G. Matheson of the Zambian Geological Survey showed that folded biotite mica bands within the gneiss, especially when flat lying in the roof, were a danger with respect to potential rock falls. Despite extensive use of 3m-long epoxy-resined rock bolts and wire mesh, rock falls continued, sometimes fatally. Work was halted and Drs J. Knill and C. Jaeger consulted in 1972. Shackleton showed that biotite mica thickened in fold closures and that vertical jointing with weathering running parallel to the gorge contributed significantly to the instability, whilst decompression caused unfavourable stress-strain patterns in the cavern despite the apparent soundness of the rock.

The intended erosion of the Stilling Basin to dissipate energy was achieved by progressive opening of floodgates between 1960 and 1966. Following each spill the pool was plumbed and after underwater inspection undesirable erosion was sealed with grouted rockfill and anchor bars were inserted. By 1981 the pool had reached the predicted depth of 81m when it stabilized. About 150,000 m^3 of rock had been eroded. A modern bathymetry survey in March 2011 showed no significant change, but only a limited number of gates had been used in spilling. Reshaping of the plunge pool has been designed based on an hydraulic model established at the Coyne et Bellier laboratory in France. This will take the plunge pool volume to 295,000 m^3 with the geometry being satisfactory for any situation of gate opening or power house function (Noret *et al.*, 2012).

Recently two new 180MW generators have been installed in the north-bank power house, with ancillary intake and tailrace infrastructure. It is intended to install 2 x 150MW units in the Kariba South Extension Project. This is alongside the installed 750MW capacity, and will involve Chinese contractors and finance.

The presentation is in part a celebration of Waalko J. Dingemans, artist, who recorded the progress of Kariba in paint, and to his son, David, a geologist.

A Review of Optically Stimulated Luminescence Dating in Southern Africa

Mary Evans

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The optically stimulated luminescence (OSL) dating laboratory at the University of the Witwatersrand is ideally located within the southern African geological and archaeological context. It is aligned with the national research entities: the African Origins Platform, the AfricaArray network as well as the Institute for Sustainable Development – all of which are hosted within the University of the Witwatersrand. As the only OSL dating facility in South Africa, it can provide chronological support to most Quaternary geology and archaeology research projects for users within southern Africa and the African continent. It is within the context of the laboratory's main research focus – Quaternary environmental reconstruction - that a review of OSL dating in southern Africa is set. The main focus of this review is on the properties and behaviour of the quartz grains in southern Africa in deriving the OSL age.

There are two main problems associated with OSL dating of sediment. The first relates to the light exposure and history of the sedimentary grains, as the inherent assumption of OSL is that all grains have been exposed to sufficient sunlight to have emptied all the electron traps prior to deposition. The second problem relates to the physical properties of the quartz grains from a sample as it is assumed that the quartz OSL signal is dominated by the fast component, however it has been demonstrated that a dominant fast component is not always present (Jain *et al*., 2003; Choi *et al*., 2003a,b).

To date there are more than thirty publications detailing OSL dating in southern Africa and the focus of this review is to highlight the problems associated with the OSL dating of southern African sites relating to the degree of bleaching of the quartz grains and to the inherent physical properties of the grains.

Challenges in the interpretation of luminescence dating of quartz grains in the Kalahari environment

Andy Moore

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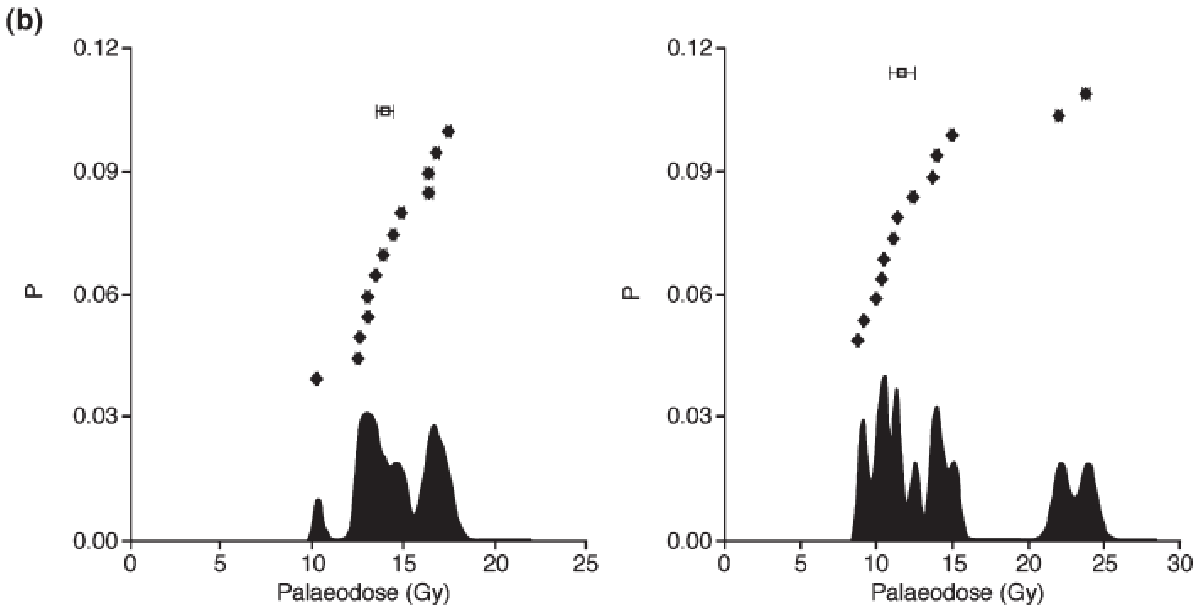
Luminescence dating of quartz grains can in principle provide a chronological window into the past 250 - 300 thousand years (ka), and well beyond the upper limit or ^{14}C dating (~50 ka). It thus offers a potentially valuable tool for refining our understanding of events during the latter part of the Quaternary, including climate change and evolution of our species, *Homo sapiens*. This is reflected in numerous recent studies of fossil landforms in the Kalahari, with a particular focus on palaeo-dune fields in south-central Africa, and fossil shorelines of the Makgadikgadi palaeo-lake in Botswana. However, the rapidly growing database of quartz luminescence ages in the Kalahari is producing a number of geologically anomalous results. The purpose of this talk is to highlight a number of these anomalies with the purpose of stimulating debate on what the luminescence data may be telling us.



Examples of multiple OSL D_e replicates from (a) typical pristine dune samples (b) linear dunes at the Tsodilo Hills, Botswana (Thomas

Fig. 1

Fig. 1 illustrates the result of a quartz luminescence dating study by Bateman et al. (2007) on a single sample from palaeo-dunes near the Tsodilo Hills, northern Botswana. The sample was split into two subsamples and each of these was split into a further 13 sub-samples (total of 26 samples), which were analysed. Instead of the expected narrow unimodal age spread, there is a wide variation in ages, with the data for the two subsamples showing very contrasting age frequency distributions. What is this spread of ages telling us?

In southeast Namibia, palaeo-dunes, with quartz luminescence ages of ~ 5 – 25 ka, are cut by the Auob River, which must thus post-date the dunes. However, terraces in the Auob contain Early Stone Age lithic artefacts, which date to > 300 – 500 ka, and thus more than an order of magnitude earlier than the luminescence ages for the dunes (Miller, 2014). How does one resolve this geological anomaly?

A final example is provided by the synthesis of published ages for fossil dunes in south-central Africa, generally inferred to reflect hyper-arid conditions, and ages for Makgadikgadi shorelines, ascribed by some to episodes of elevated rainfall. There is a complete overlap of dune and shoreline ages.

One of the assumptions of luminescence dating, is that quartz grains remain in-situ following burial. However, this important assumption is almost certainly violated in the Kalahari environment. This is highlighted by kimberlite exploration programmes in the Kalahari, which have successfully discovered kimberlites overlain by 60- 100m of younger Kalahari cover, following the recovery of kimberlite minerals in surface soils directly above kimberlites. The kimberlite minerals have thus been translocated from the sub-Kalahari kimberlite to the surface, which is generally ascribed to bioturbation.

While a variety of species contribute to bioturbation, termites appear to be one of the major agents involved. The late Palaeogene and Neogene were associated with the evolution and expansion of grasslands at the expense of forests, linked to progressive global climate aridification. Expansion of the grasslands was, in turn associated with a major radiation in termites. A remarkable feature of the relatively young (5 Ma) sediments of the Central Kalahari, Botswana, is the complete absence of sedimentary structures. In contrast, delicate sedimentary features are present in late Cretaceous sediments of the Owambo basin of northwest Namibia. These differences are ascribed to a significant increase in bioturbation during the Neogene, linked to the radiation of the termites.

Application of Rock Mass Rating in Bord and Pillar Mine Design Layout adjustments and Implication to Business Planning –Unki Mine Case Study

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Several poor ground zones are intersected in day to day operations in bord and pillar mining on the Great Dyke. This results in reduction in advances per blast and bord face length reduction in order to mitigate the negative effects of these conditions. It is important for Rock Engineers to incorporate the rock mass conditions in their design layouts for a lasting solution for known poor ground zones. It calls for a rock mass rating based approach to be taken in anomalous conditions to ensure stability of excavations is not undermined.
This application involves the use of rock mass rating to adjust design parameters to suit prevailing ground conditions thereby producing an equivalent down-rated rock mass strength (Mining Rock Mass Strength - MRMS). The mining rock mass strength is applied in design calculations using the Hedley and Grant formula and back analysis is carried out to generate the pillar dimensions. The Unki experience has proved that there are other considerations that will need to be taken into account for this method to be fully applicable on the Great Dyke. Unki Mine has successfully applied this approach leading to successful mining through a very poor ground zone and re-establishment of the main return airway. This presentation highlights the process followed, the design, challenges and mitigations as well as their links to the business planning process.

Schedule

Day	Date	Time	Activity
Thursday	19-11-2015	08:45	Meet near Karoi - Twin Rivers Hotel
			Drive to Kariba with several geology stops along the way
Thursday	19-11-2015	17:00	Check in Kariba
			Overnight Carribea Bay or althernatives
Friday	20-11-2015	07:00	Start Summer Syposium
			Summer Syposium at Carribea Bay
Day	Date	Time	Activity
Friday	20-11-2015	16:00	Ferry departs Kariba
			Overnight travel across Lake in Ferry, with dinner and breakfast
Saturday	21-11-2015	07:00	Passengers disembark at Sinamwenda
			Walk 5km each way to crater, packed lunch, carry out various surveys - leader Sharad Master
Saturday	21-11-2015	15:00	Passengers return to ferry and leave for Musango
			Overnight travel across Lake in Ferry, with dinner and tea at 5am
Sunday	22-11-2015	05:30	Passengers disembark at Musango to view various fossils and stone age artifacts
Sunday	22-11-2015	08:00	Passengers return to ferry and leave for Kariba
			Travel across Lake, breakfast then lunch
Sunday	22-11-2015	14:00	Ferry arrives in Kariba
Sunday	22-11-2015	14:00	Drive back to Harare

Cover Photo:- Tim Broderick