Geological Society of Zimbabwe

Summer Symposium

8am to 5pm, Friday 29th November 2013
Victoria Falls Safari Lodge

SPONSORS:-

BRUKER

ZMDC
ZIMBABWE MINING DEVELOPMENT CORPORATION
"Unearthing the future"

SAMREC VERMICULITE (ZIMBABWE) (PVT) LTD

SMC LIMITED
(Diamond Drilling Specialists)

ZIMPLATS
Member of the Implats Group

AngloAmerican

29th November 2013, Indaba Conference Room at Victoria Falls Safari Lodge		
Registration (incl teas and lunch) $50 for members (non-members should join)		
Start	**Topic**	**Speaker**
07:45	**Registration**	
08:15	Welcome	Hillary Gumbo, Society Chairman
08:35	**Opening**	**Alex Mhembere, President of the Chamber of Mines**
09:00	A fingerprinting method for the identification of uranium sources in alluvial aquifers, Namibia.	Benjamin Mapani
09:20	Using GIS datasets to delineate groundwater bearing structures at hot springs in Southern Africa: Case Studies from South Africa and Namibia.	Peter Nyabeze
09:40	GSSA update - CPD and SACNASP	Gordon Chunnett
09:55	Tea	
10:15	New U-Pb and Pb-Pb geochronology of rocks and minerals from the Proterozoic Dete-Kamativi Inlier (Zimbabwe) and Choma-Kalomo Block (Zambia): regional implications	Sharad Master
11:15	Exploration Techniques: Discovery of Sese and Murowa Kimberlite Fields	Lovemore Chimuka
11:35	Platinum mineralization of the Great Dyke – from sulfide ore via the weathering cycle into placers	Thomas Oberthur
12:05	The northern limb of the Bushveld Complex – a decade of discovery	Judith Kinnaird
12:25	Origin of the zonal PGM and PGE distribution in the platinum reefs of the layered intrusions.	Marina Yudovskaya
12:45	Lunch	
14:00	Volcanic and Volcaniclastic Rocks of the c3.0 Ga Pongola Supergroup: A view of the Earth's Earliest Stable Epicontinental Platform	Allan Wilson
14:45	A new search for ancient detrital zircons in Zimbabwean sediments	Axel Hoffman
15:05	Is the Moroka Granite on south-western margin of the Zimbabwe craton in NE Botswana part of the Chilimanzi Granite?	Zibisani Bagai
15:25	Tea	
15:40	Anthropogenic Global Warming and the History of the Earth's Climate	Tony Martin
16:00	Dinosaurs of Zimbabwe: a review	Ali Ait Kaci
16:20	X-ray and Micro Computed Tomography	Lynsey Singh
16:40	Introduction to German Mineral Resources Agency (DERA)	Herwig Marbler
16:55	Summary	Benjamin Mapani

A fingerprinting method for the identification of uranium sources in alluvial aquifers, Namibia.

Benjamin Mapani, Josefina Hamutoko, Rainer Ellmies, Arnold Bittner

bmapani@unam.na

Namibia is an arid country that depends on groundwater for almost 60% of its population. As such the identification of deleterious elements such as uranium and other radionuclides in aquifer systems is of prime importance. The Rossing uranium mine is located on the banks of the Khan River, and it was important to trace the source of uranium as either from tailings or of natural origin from the rocks. This study aimed at identifying the origin of elevated uranium (as a trace element as well as a radionuclide) and other radionuclides such as thorium and radium concentrations in the Swakop and Khan River alluvial aquifers. A fingerprinting method was used where the $^{234}U/^{238}U$ and $^{235}U/^{238}U$ ratios were used to distinguish natural from anthropogenic sources for the uranium sources. The $^{234}U/^{238}U$ ratio is above unity (1.3 – 1.7) whereas the $^{235}U/^{238}U$ ratio is 0.045 ± 0.015. All elevated uranium and other radionuclides concentrations in groundwater of the study area are as a result of natural dispersion from the mineralized rock formations rather than results of anthropogenic sources. Uranium increases in the lowest part of Swakop River; but there is no gradual change in uranium concentration thus indicating that concentration is related to local factors such as lithology, Eh and pH for each borehole. The secular disequilibrium between elements in ^{238}U decay series is natural due to different fractionation processes that include the decay of radioactive elements. The water in the area is not suitable for human consumption and agricultural usage, as most components such as TDS which has values up to 11123 mg/l and ^{228}Ra which has activities up to 278 mBq/kg exceeded the Namibian and WHO guideline values respectively.

Using GIS datasets to delineate groundwater bearing structures at hot springs in Southern Africa: Case Studies from South Africa and Namibia

Peter Nyabeze, Ben Mapani, Chiedza Dondo- Musekiwa, Anna Nguno, Ayanda Shabalala & Oswald Gwavava

pnyabeze@geoscience.org.za

Groundwater bearing structures at hot springs in South Africa and Namibia were investigated. The project was commissioned to generate information on hot spring occurrences at selected sites in Limpopo Province, South Africa and Omaruru-Okahandja-Rehoboth Districts, Namibia. Satellite imagery data was used to map out lineaments, wetlands, drainage patterns, soil moisture content and vegetation cover. Regional lineaments were inferred from the airborne magnetic data. Geological, geophysical surveys and ground Geological Society of South Africa (GSSA) hydrogeological information was used to determine the geology of the groundwater aquifers. The integration of the GIS based datasets resulted in the mapping of land use patterns and delineation of possible thermal groundwater bearing structures.

Geological Society of South Africa (GSSA) Update

Gordon Chunnett

gchunnett@yahoo.com

The Geological Society of South Africa (GSSA) wishes the Geological Society of Zimbabwe (GSZ) well with another superbly organised and arranged meeting rounding off yet another fantastic Geological year of activity by your committee. The GSSA wishes you well into the coming year 2014 with hopes that you will have another great set of meetings and events.

Several upcoming events are what drawn to your attention and hoping that we will see some of your participation:

1) IMA 2014.The 21st Meeting of the International Mineralogical Association: 1-5th September 2014 Sandton Convention Centre, Gauteng South Africa. The web site is: http://www.ima2014.co.za/

2) Kimberley Diamond Symposium & Trade Show (following IMA 2014) 11 to 13 September 2014 in Kimberley South Africa. The web site is : www.rca.co.za click on the diamond logo

3) CDP (Continuing Development of Professional) rollout is under serious planning by the GSSA.

4) SACNASP is continuing with its renewal and is expanding its influence at a rapid pace, it is the law in South Africa that all scientists shall be registered, in our case all Geoscientists, inclusive of Academics. Registered member numbers are increasing at almost 20% annum, mostly driven by young professionals coming on board. Many companies are now registering all their scientists, believing that it will give them an edge when competing for new clientele. Please take note of the Professional Indemnity Insurance offered for SACNASP registered persons. The rates are at almost a tenth of what the alternatives are currently offered in the market. Please visit the Sacnasp website for detail (www.sacnasp.org.za) under the “scientist” tab. Also visit the website for information on the latest courses and conferences, or stay automatically informed through the SACNASP Facebook page.

New U-Pb and Pb-Pb geochronology of rocks and minerals from the Proterozoic Dete-Kamativi Inlier (Zimbabwe) and Choma-Kalomo Block (Zambia): regional implications.

S. Master, S. Glynn, D. Frei, D. Davis and T. Oberthür

sharad.master@wits.ac.za;

The Dete-Kamativi Inlier is situated in western Zimbabwe, in a window of Precambrian rocks surrounded by late Palaeozoic, Mesozoic and Cenozoic rocks of the Karoo and Kalahari basins. It forms part of the Palaeoproterozoic Magondi Belt, which flanks the western part of the exposed Archaean Zimbabwe Craton (Lockett, 1979; Master et al., 2010). The only previous geochronological work in the Dete-Kamativi inlier was done by Priem et al. (1972). They obtained (recalculated) Rb-Sr whole-rock ages on granodioritic gneisses and intrusive granites of 2159 ± 100 Ma and 2000 ± 80 Ma, respectively. These poorly constrained ages reflect magmatic episodes on the western side of the Magondi basin pre- or syn-kinematic (granodioritic gneisses), as well as postkinematic (unfoliated granites), with respect to the Magondi Orogeny. The granodioritic gneisses probably represent a calc-alkaline magmatic arc, while the granites were interpreted as post-collisional crustal melts following granulite-facies metamorphism and migmatite formation (Master et al., 2010). U-Pb dating of paragneisses intersected in the Gweta borehole of NW Botswana showed a youngest detrital zircon age of 2125 ± 6 Ma, indicating a maximum depositional age for the sedimentary protolith (Mapeo et al., 2001). Majaule et al. (2001) obtained a TIMS U–Pb zircon age of 2039.2 ± 1.4 Ma for granitoids exposed at Kubu Island in Botswana, some 80 km SE of the Gweta borehole, indicating a southward extension of granitoids emplaced during the Magondi Orogeny.

Our new U-Pb ages on zircons were obtained using LA-ICP-MS. Detrital zircons from a leucogneiss (meta-arkose) (ZDK/9C) of the Malaputese Formation have ages ranging from 2254 ± 18 to 2796 ± 17 Ma, with a strong age peak at ca. 2.7 Ga. In terms of age and lithology, the correlation of the Malaputese Group with the Deweras Group (which has a maximum age of 2235 ± 32 Ma; Glynn et al., 2012), as suggested by Master et al. (2010), is confirmed. These rocks are slightly older than the Gweta paragneisses of NW Botswana. The detrital zircon population indicates a Neoarchaean, ca. 2.7 Ga provenance, with a lesser contribution from Palaeo-proterozoic sources. A foliated megacrystic K-feldspar-porphyritic granitoid (ZDK/2) is dated at 2035 ± 3 Ga, similar in age to the Kubu Island granitoids from Botswana. A strongly foliated quartz-feldspar-biotite granitoid gneiss (ZDK/1) has complex inherited zircons, with ca. 3.2 Ga cores, new zircon growth at ca. 2.7 Ga, with latest (igneous or metamorphic?) overgrowths at 2.08 Ga. Finally, a highly deformed and migmatized biotitic granitoid gneiss (ZDK/11) gives a 2698 ± 4 Ma age; while another more mafic quartz-plagioclase-hornblende-biotite granodioritic gneiss (ZDK/12) from close to Kapami gives a 2031 ± 3 Ma age. These age data indicate the formation of an Andean-type magmatic arc on the western edge of the Zimbabwe Archaean craton at about 2.08-2.03 Ga, some 80-30 Ma prior to the onset of the Magondi Orogeny. The 2.7 Ga granitoid is also the westernmost occurrence of Archaean granitoids in Zimbabwe, and indicates that the Zimbabwe Archaean craton extended much further west under the Magondi Belt than previously thought.

The Choma-Kalomo (C-K) Block is a large expanse of Precambrian basement characterized by NE-SW structural trends which is present in southern Zambia. It is flanked to the NW by the late Neoproterozoic Hook Batholith, to the north by the Pan-African Zambezi Belt, and to the SE and SW by sedimentary and volcanic rocks of the Permo-Triassic Karoo Supergroup of the Mid-Zambezi Basin, which separates it from the Palaeoproterozoic Magondi Belt of Zimbabwe and Botswana.

The C-K Block has a strongly deformed and metamorphosed basement consisting of a variety of granulitic and migmatitic gneisses which are mainly paragneisses of metasedimentary origin, in which there are linear metasedimentary schist belts (consisting of quartz – biotite ± muscovite ± garnet ± kyanite schists). This basement is intruded by a large composite granitic batholith, known as the Choma-Kalomo (C-K) Batholith, consisting of hornblende and biotite granites and granite-gneisses (Hanson et al., 1988). The basement rocks of the C-K Block are intruded by numerous quartz-muscovite pegmatites of several types. Of economic importance is a belt of pegmatites containing tin in the form of cassiterite, together with minor Ta, Nb and W, which constitute the “tin belt” of Southern Province (Legg, 1972).

Hanson et al. (1988) dated several phases of the composite C-K Batholith, and obtained U-Pb zircon ages of ca. 1.345 and ca. 1.20 Ga. They also obtained a Rb-Sr isochron age of ca. 1.23 Ga from what they considered a D2 shear zone in the granite gneiss. Bulambo et al. (2004, 2006) did further SHRIMP U-Pb geochronology on the C-K Batholith, and were able to reproduce the two ages of granitic magmatism in this batholith, with better precision, at ca. 1.37 and ca. 1.18 Ga. Neither Hanson et al. (1988) nor Bulambo et al. (2004, 2006) managed to date any of the basement gneisses or schists intruded by the C-K Batholith.

Bulambo et al. (2004, 2006) proposed a model which regards the C-K Block as an exotic terrane, caught up between the Hook batholith and the Magondi Belt during the Pan-African Damaran-Lufilian-Zambezi orogeny, and implying no links between the C-K Block and the Kamativi area prior to the Pan-African orogeny, with the C-K Block having an ancestry from the Kibaran Belt, from which it was supposed to have rifted away prior to being caught up in the collision between the Congo and Kalahari Cratons (Bulambo et al. 2004, 2006). However, there is a strong similarity between the C-K Block and the Kamativi belt, in terms of the nature and age of tin-bearing pegmatites in both areas. The tin-bearing pegmatites of the C-K Block occur along regional NE-trending shear zones, with no associated granitic intrusions recognized, and their mineral associations include muscovite, tourmaline, cassiterite, tantalite, columbite and rare wolframite (Legg, 1972). In the Kamativi area there are cassiterite-bearing quartz-feldspar-muscovite pegmatites, with accessory tantalite, columbite and amblygonite, and tourmaline-bearing quartz pegmatites with cassiterite, wolframite and scheelite (Watson, 1962; Rijks and van der Veen, 1972; Lockett, 1979).

A strong argument for a link between the tin pegmatites of the C-K Block and those of the Kamativi area comes from radiometric dating. Muscovite from the tin-bearing pegmatite at the Phoenix Mine (situated at 16°49’S, 27°02’E, in the C-K Block) was dated using both the Rb-Sr and K-Ar methods (Snelling et al., 1966). These ages were recalculated using updated decay constants as 1080 ± 31 Ma (Rb/Sr, Ri = 0.705), and 1060 ± 40 Ma (K/Ar), while in the Kamativi area, the tin-bearing pegmatites were dated at 1025 ± 15 Ma (Rb-Sr isochron) (Cahen et al., 1984). Galena from the Elbas Mine in the Inyantue Formation of the Dete-Kamativi Inlier was shown to have a near-concordant $^{207}Pb/^{206}Pb$ age of about 1.18 Ga (Master, 1991). This Pb mineralization event may be related to the coeval granitic plutonism in the C-K Block, which is dated at precisely the same age, 1.18 Ga (Bulambo et al., 2004, 2006).

Pb-Pb dating, using ID-TIMS on columbite and plagioclase, and LA-ICPMS on monazite, has produced new ages for the tin pegmatites at Kamativi, and their host rocks (Davis, 2012). A Pb-Pb isochron based on columbite and plagioclase gives an age of 1030 ± 9 Ma for a tin pegmatite (indistinguishable, within error, from the age of the Phoenix tin pegmatite in the C-K Block), while regression of the ages of two clusters of metamorphic monazite grains, probably derived from the country rocks invaded by the tin pegmatites, gives ages of 1844 ± 9 Ma and 2028 ± 9 Ma (Davis, 2012).

We have dated a series of detrital zircons (U-Pb, LA-ICPMS) from a biotite-muscovite schist (Z9), just south of the C-K Batholith near Choma in Zambia. The detrital zircon ages fall into four separate clusters: 3394 ± 13 Ma, 2709 ± 20 – 2617 ± 11 Ma, 2123 ± 13 – 1725 ± 18 Ma (with a huge peak at about 1880 Ma), and 1554 – 1278 ± 27 Ma. The ages of the detrital zircon populations indicate the ages in the provenance of the sedimentary protolith of the schist that was dated. The ages do not reflect derivation from the C-K batholith, whose older granites were dated at 1368 ± 10 Ma (Bulambo et al., 2004, 2006) to ca. 1345 Ma (Hanson et al., 1988), since there are only two zircon ages (1368 and 1326 Ma) falling into that range, indicating that the batholith had not yet been fully exhumed and exposed at the time of sedimentation. The bulk of the detrital zircon ages are Palaeoproterozoic, with a huge peak, including the bulk of the zircons analysed, between 1.8 and 1.9 Ga. Some of the older Palaeoproterozoic ages correspond to ages of igneous events in the Magondi Belt of western Zimbabwe (Glynn et al., 2012; Master et al., 2013), while the large peak corresponds to the age of metamorphism in the Magondi Belt (between 2.0 and 1.8 Ga; Rb-Sr and Pb-Pb ages on granulites, Master et al., 2010; and U-Pb ages on monazites, Davis et al., 2012). The oldest zircons, of Mesoarchaean (3394 ± 13 Ma) and Neoarchaean (2709 ± 20 – 2617 ± 11 Ma) age, match closely the ages of Archaean rocks from the adjacent Zimbabwe craton, where the Sebakwe protocraton has ages between 3456 to ca. 3350 Ma (Horstwood et al., 1999), and the Upper Bulawayan greenstones have ages between 2.7 and 2.6 Ga (Blenkinsop et al., 1997). By contrast, detrital zircons from the Nzilo Group in the Kibara Supergroup of D.R. Congo have age ranges from 3214 ± 7 Ma to 1329 ± 32 Ma (Kokonyangi et al., 2007). The bulk of the Kibaran detrital zircons (75%) have ages between 2434 ± 5 Ma and 1696 ± 18 Ma, with peaks at 2050 and 1850 Ma, and a significant Mesoproterozoic population (1499 ± 49 Ma to 1329 ± 32 Ma). The Kibaran detrital zircon population lacks zircons as old as the 3394 ± 13 Ma, or as young as 1278 ± 27 Ma (which are present in sample Z9), and it has peaks, such as at 2.05 Ga, which are absent in the Z9 population. Thus the histograms of ages from the Z9 sample and the Zimbabwe Craton (together with the Magondi Belt) match quite well, while there is a serious mismatch with the age histograms from the Kibaran Belt. Hence it is very unlikely that the C-K Block is derived from the Kibaran belt, and there is growing evidence that it may be a part of the Magondi Belt, on the western flank of the Zimbabwe Craton.

The matching of the ages of tin pegmatites of the C-K Block and those of the Kamativi area is a strong indication that the two regions were already juxtaposed at ca. 1.02 Ga. The fact that the schist Z9, with a maximum age of 1278 ± 27, is deformed, and so is the ca. 1.18 Ga phase of the C-K Batholith, indicates a post- 1.18 Ga deformation event- which is likely to be the Pan-African deformation event which juxtaposed the Hook Batholith to the west, and the Zambezi Belt to the north, with the C-K Block (Hanson et al., 1988).

The rocks of the Tara Outlier and the Sinakumbe Group on the C-K Block show similarities with the Sijarira Group on the Magondi Belt of western Zimbabwe, and if they are correlated, would serve as an “overlap” sequence deposited on both geological provinces. Further studies are under way to firm up the possible links between the C-K Block and the Magondi Belt- these include a study of the U-Pb ages of the basement gneisses in both regions, and of detrital zircons in the cover sequences in both areas, in addition to $^{40}Ar/^{36}Ar$ studies of micas from pegmatites, schists and gneisses.

Acknowledgements
We thank the Carnegie Corporation (New York) for a Large Research Grant to SM. The South African National Research Foundation is thanked for supporting SG through a student grant. We thank Jeremie Lehmann, Kalinn Neydanov and Lorenzo Milani for assistance with sampling in the Choma-Kalomo Block, and we thank Rio Tinto Corporation for funding for the Zambian research, and for permission to publish some of that work.

References
Blenkinsop, T.G., Martin, A., Jelsma, H.A. & Vinyu, M.L. 1997. The Zimbabwe Craton. In: de Wit, M.J. and Ashwal, L.D. (Eds.), Greenstone Belts. *Oxford University Press*, Oxford, 567-580.

Bulambo, M., De Waele, B., Kampunzu, A.B. & Tembo, F. 2004. SHRIMP U-Pb geochronology of the Choma-Kalomo block (Zambia) and geological implications. Abstracts volume, 20th Colloquium of African Geology, Orleans, France, 2-7 June 2004 , p. 96.

Bulambo, M., De Waele, B., Kokonyangi, J., Johnson, S.P., Kampunzu, A.B. & Tembo, F. 2006. SHRIMP zircon U-Pb geochronology and geochemistry of the Choma-Kalomo Block granitoids (Zambia): geological implications. 21st Colloquium of African Geology (CAG21), Maputo, Mozambique, Abstracts.

Cahen, L., Snelling, N.J., Delhal, J., Vail, J.R., Bonhomme, M. & Ledent, D. 1984. Geochronology and Evolution of Africa. *Clarendon*, Oxford, 512 pp.

Davis, D. 2012. U-Pb geochronology of Columbite-Tantalite from the Kamativi Mine, Zimbabwe and from Abu Dabbab, Egypt. Unpublished Report, Department of Earth Sciences, University of Toronto, Canada, 15 pp.

Glynn, S.M, Master, S., Armstrong, R.A., Hofmann, A. & Bekker, A. 2012. New U-Pb (SHRIMP) ages for the Palaeoproterozoic Magondi Supergroup, Zimbabwe. Abstract, IMSG4, 4th Annual Meeting of the Igneous and Metamorphic Studies Group, 15-17 January 2012, University of the Witwatersrand, Johannesburg, South Africa.

Hanson, R.E., Wilson, T.J., Brueckner, H.K., Onstott, T.C., Wardlaw, M.S., Johns, C.C. & Hardcastle, K.C. 1988. Reconnaissance geochronology, tectonothermal evolution, and regional significance of the middle Proterozoic Choma-Kalomo block, southern Zambia. *Precambrian Research*, **42**, 39-61.

Horstwood, M.S.A., Nesbitt, R.W., Noble, S.R. & Wilson, J.F. 1999. U-Pb zircon evidence for an extensive early Archean craton in Zimbabwe: A reassessment of the timing of craton formation, stabilization, and growth. *Geology*, **27**, 707-710.

Kokonyangi, J.W., Kampunzu, A.B., Armstrong, R., Arima, M., Yoshida, M. & Okudaira, T. 2007. U-Pb SHRIMP dating of detrital zircons from the Nzilo Group (Kibaran Belt): Implications for the source of sediments and Mesoproterozoic evolution of Central Africa. *Journal of Geology*, **115**, 99-113.

Legg, C.A. 1972. The tin belt of the Southern Province. *Econ. Rep. Geol. Surv. Zambia*, **29**, 58 pp.

Lockett, N.H. 1979. The geology of the country around Dett. Bull. Geol. Surv. Rhodesia, 85, 198 pp.

Majaule, T., Hanson, R.E., Key, R.M., Singletary, S.J., Martin, M.W. & Bowring, S.A., 2001. The Magondi Belt in northeast Botswana: regional relations and new geochronological data from the Sua Pan area. *Journal of African Earth Sciences*, 32(2), 257-267.

Mapeo, R.B.M., Armstrong, R.A., Kampunzu, A.B., 2001. SHRIMP U-Pb zircon geochronology of gneisses from the Gweta borehole, NE Botswana: implications for the Palaeoproterozoic Magondi Belt in southern Africa. *Geological Magazine*, 138, 299-308.
Master, S. 1991. *The origin and controls on the distribution of copper and precious-metal mineralization at the Mangula and Norah mines, Mhangura, Zimbabwe*. Ph.D. thesis, Univ. Witwatersrand, Johannesburg, 385 pp.
Master, S., Bekker, A. & Hofmann, A. 2010. A review of the stratigraphy and geological setting of the Palaeoproterozoic Magondi Supergroup, Zimbabwe: type locality for the "Lomagundi" global carbon isotope excursion. *Precambrian Research*, 182(4), 254-273.
Master, S., Glynn, S. & Frei, D. 2013. New U-Pb zircon geochronology of the Palaeoproterozoic Dete-Kamativi Inlier, Magondi Belt, Zimbabwe, and implications for the western boundary of the Archaean Zimbabwe Craton. Abstract, CAG24, 24th Colloqium of African Geology, Addis Ababa, Ethiopia, 8-14 January 2013.
Priem, H.N.A., Boelrijk, N.A.I.M., Verdurmen, E.A.Th. & Verschure, R.H. 1972. Isotopic dating in the Kamativi Tin Belt, Southern Rhodesia. *Geologie en Mijnbouw*, 50, 619–624.
Rijks, H.R.P. & van der Veen. A.H. 1972. The geology of the tin-bearing pegmatites in the eastern part of the Kamativi District, Rhodesia. *Mineralium Deposita*, 7, 383-395.
Watson, R.L.A. 1962. The geology of the Kamativi and Lubimbi areas. *Bull. geol. Surv. S. Rhod.*, **57**, 42 pp.

Exploration Techniques: Discovery of Sese and Murowa Kimberlite Fields

Lovemore Chimuka

lovemore.chimuka@riotinto.com

Murowa and Sese (538 Ma) kimberlites lie near the southern edge of the Zimbabwe Craton and intrude the 2.6 Ga Chibi granite batholiths emplaced into the ~ 3.0 Ga Buhwa Greenstone Belt 10-20 km north of the boundary of the Northern Marginal Zone of the late Archean Limpopo Mobile Belt. The greenstones are believed to rest on non-outcropping ~3.5 Ga gneissose Tokwe Segment basement. The prospective shield forming the central Zimbabwe craton was selected for a loam and stream sediment reconnaissance sampling. Initial target was the Tokwe Block, a 3.5Ga Archean tonalitic gneiss complex representing the oldest exposed core of the Zimbabwe craton. The country rock is dominated by the 2.6Ga Chibi granite. The drainage pattern is trellis type with NE-SW and NW-SE trending fractures suggesting a strong brittle environment for kimberlite emplacement. The well-developed drainage system was suitable for stream sediment rather than loam sampling which was being applied in the flatter Lowveld EPOs. Exploration techniques employed in the discovery of the two kimberlite fields were conventional stream sediment sampling on predefined surface densities of 5-10km2 per 60 kg of concentrates. The method involved selecting the best trapsites along the river beds draining a catchment area. The trapsites play hosts to kimberlite indicator minerals (KIM) which were sort for in sieve size of -2mm + 425umm. These indicator minerals are the mineralogical and chemical signature that identifies a kimberlite source rock. The KIM comprised of pyrope garnets, spinel chromite, chrome diopside (pyroxene), ilmenite and micro diamonds. Ilmenite was not identified in any of the samples collected and processed in this area of study. KIM methodology is done on a regional and recognisance basis to identify occurrence of kimberltic bodies like pipes, dykes and sills. In alluvial diamond exploration techniques the use if KIM is avoided due the destructive nature of fluvial regimes. KIM is vulnerable to attrition and breakage during transportation. Chrome diopsides are lost in the next 500m; spinel and pyrope can travel beyond 2km whilst microdiamonds can go over a thousand kilometres. The granite greenstone terrains which host the two kimberlite fields produced relatively small volumes of heavy mineral concentrates of approximately 500g, whilst samples within the Great Dyke vicinity produced concentrates of up to 1kg dominated by pyroxene and chromite mineral assemblages. In positive KIM defined areas further techniques were employed: airborne and ground emi (Max-Mini), gravity, magnetics and radiomatrics. These techniques were used as follow up methods to close in on anomalous areas. Ground electromagnetic induction was used on grids of various dimensions ranging from 4000 to 10 000km2. Airborne remote sensing geophysics was applied on large grids of prospective ground to identify large ore bodies. Geochemistry involved analysis of the fine soil (-75 µ) fraction by XRF. In the granitic/gneissic terrain a suite of Mg, Cr, Ti, Nb and Ni was found to be sufficiently diagnostic. Orientation work at Sese showed that dispersion of the selected elements in the soil cover was minimal and typically limited to a few meters. The collection of samples is quick and analyses relatively cheap so that close spacing was not a major concern. The XRF results were available within a few weeks with the diamond laboratory consequently allowing a quick follow-up on the positive prospect. After successfully homing in on geochemical and geophysical anomalies, mapping of the grids was done to identify the outcropping lithological units, soil and vegetation anomalies. Trenching and pitting targets where generated from the mapping exercise.

Acronyms

EPOs	Exclusive prospecting orders
KIM	Kimberlite indicator minerals
EMI	Electromagnetic Induction
Max-Mini	Horizontal loop electromagnetics
XRF	X-ray fluorescence

Platinum mineralization of the Great Dyke – from sulfide ore (pristine MSZ) via the weathering cycle (oxidized MSZ) into placers

Thomas Oberthür

Thomas.Oberthuer@bgr.de

The world's prime sources of metallurgical chromite and platinum-group elements (PGE) are layered intrusions of Proterozoic and Archean age (e.g. the Bushveld Complex, South Africa; the Great Dyke, Zimbabwe; and the Stillwater Complex, USA).

The Great Dyke of Zimbabwe hosts the world's second largest reserve of PGE after the Bushveld Complex in neighbouring South Africa. Economic PGE mineralization is restricted to sulfide disseminations in pyroxenites of the Main Sulfide Zone (MSZ), sited some metres below the transition of the Mafic and the Ultramafic Sequence of the Great Dyke.

In general, the MSZ is up to some meters thick and is composed of a basal PGE-rich subzone that slightly overlaps with a base metal sulfide-rich subzone on top. Stratigraphically upwards, the MSZ displays metal profiles characterized by increasing Cu/Ni, Pt/Pd and PPGE/IPGE ratios, accompanied by a general element decoupling in the order: IPGE $\rightarrow$ Pd $\rightarrow$ Pt $\rightarrow$ [Ni,Cu,Co,S(sulfides),Au,Te,Bi]. The fine structure of the MSZ is regarded to reflect primary magmatic features of consecutive batches of sulfide accumulation, concomitant scavenging of PGE, and fractionation.

Mineralogically, most of the Pd and Rh are hosted in pentlandite, whereas Pt is dominantly present in the form of discrete platinum-group minerals (PGM). Within the MSZ sequence, sperrylite is present throughout the PGE subzone of the MSZ, cooperite/braggite occur mainly in its basal part, and the (Pt,Pd)-bismuthotellurides concentrate at the top. Furthermore, regional mineralogical differences of the PGM assemblages are present. These findings indicate that a large proportion of the PGE, primarily concentrated in sulfide under magmatic conditions, was redistributed in the subsolidus stage and formed discrete PGM with available reaction partners. Chemical gradients and magmatic-hydrothermal fluids probably led to small-scale redistribution of PGE within the MSZ.

The behaviour of the PGE in the exogenic cycle was examined in a number of profiles of oxidized Main Sulfide Zone ores, in which the general metal distribution patterns of the pristine MSZ are grossly preserved. However, at similar Pt grades, significant proportions of Pd have been lost from the system. This indicates that Pd is more mobile than Pt and is dispersed in the supergene environment. Sperrylite and cooperite/braggite are stable in the oxidized MSZ. In contrast, the (Pt,Pd)-bismuthotellurides, common in pristine MSZ ores, have disintegrated, and ill-defined (Pt,Pd)-oxides or -hydroxides have formed. Furthermore, elevated contents of Pt and Pd are found in iron- and iron-manganese-oxides/hydroxides. The resource of ~250 Mt of oxidized MSZ calls for novel exploitation methods for these ores.

The assemblage of detrital PGM present in rivers draining the Great Dyke indicates further mineralogical changes. Sperrylite largely remains stable whereas most cooperite/braggite grains have been partly altered or completely destroyed. Grains of Pt-Fe alloy are ubiquitous in the alluvial sediments. Most likely, these grains are neo-formations that either formed from pre-existing, unstable PGM, or via a solution stage under low-temperature conditions.

In a follow-up of the Great Dyke work, we have now entered into similar studies on the Bushveld Complex and will present first findings from these investigations.

The northern limb of the Bushveld Complex – a decade of discovery

Judith Kinnaird

judith.kinnaird@wits.ac.za

Platinum mineralisation in the northern limb of the Bushveld has been known since the time of Hans Merensky in 1925. Detailed mapping by van der Merwe in 1978 led to a better understanding of the lithological variability along the exposed 110 km of the limb. Lower Zone rocks were identified as satellite bodies, the Platreef was mapped and regarded as the base of the Main Zone, whilst the Main Zone and Upper Zones were regarded as similar to, but thinner than their equivalents in the eastern and western limbs of the Bushveld Complex.
In the last decade, many new discoveries have furthered our understanding of the northern limb. The Lower Zone has been shown to be more extensive than originally thought, with thick packages of pyroxenite-harzburgite locally beneath PGE-bearing Platreef. The Mg-rich composition of some olivines, shed doubts on previous models of parental magma compositions. The world-class PGE-bearing Platreef, which may be several hundreds of metres thick, has been shown to be a series of complex sills, often with interlayers of country rocks between the sills that have contaminated the Platreef magma to varying degrees and influenced the grade and stratigraphic position of the mineralisation. Zircon age-dating has shown that the Platreef is the age-equivalent of the Merensky Reef. For the Main Zone, two reefs with economic grades of PGE-Cu-Ni mineralisation have recently been traced along 17 km of strike beyond the known exposed part of the northern limb, one of which is associated with troctolitic rocks, a feature that is unique to this part of the Bushveld Complex.

Origin of zonal PGM and PGE distribution in the platinum reefs of the layered intrusions

Marina Yudovskaya & Judith Kinnaird

marina.yudovskaya@wits.ac.za

An offset zonal distribution of platinum group elements (PGE), Au and base metals has been recognised through mineralised reefs in some layered intrusions (such as Great Dyke, Munni Munni etc). In contrast, Bushveld reef-style mineralisation generally shows coeval variations in PGE, Au and base metals with the highest concentrations closely associated with chromitite seams or changes in rock types. This persistent pattern was explained by continued sulfide segregation as a result of multiple magma mixing events whereas the offset profiles require an involvement of a more complicated mechanism. Here we describe the zonal distribution of platinum group minerals (PGM) in a vertical section through the PGE reef at Turfspruit (the northern limb of the Bushveld Complex). The Turfspruit PGE reef is a mineralized zone 8 m thick hosted in olivine-bearing plagioclase orthopyroxenite within the Platreef sequence. The highest grade is confined to two top chromitite seams 0.8-1 cm thick. The chromite-bearing interval contains predominantly Pt-Pd sulfides (up to 90 vol. % of total

PGM); PGMs in the adjacent underlying interval are represented mostly by Pt-Fe alloy (up to 90 vol. %) that shows a transition to assemblages of predominant Pt-Pd bismuthtellurides and, finally, sperrylite. We suggest that this type of mineralogical zonation is related to evolution of a sulfide liquid starting with cotectic sulfide-silicate crystallization at sulfide saturation. A eutectic mix of Pt-Pd sulfides, Pt-Fe alloy and pyrrhotite crystallizes first from sulfide liquid with Bi, Te, As -enriched remains migrating downwards. Previously, a lateral variation of PGM mineralogy was reported for the Merensky Reef and Platreef; whereas we have now noted a vertical zonation in the Platreef on Turfspruit. This may occur where there is a significant reef thickness.

Volcanic and Volcaniclastic Rocks of the c3.0 Ga Pongola Supergroup: A view of the Earth's Earliest Stable Epicontinental Platform

Allan Wilson

allan.wilson@wits.ac.za

The Mesoarchaean Pongola Supergroup is an exceptionally well-preserved succession of volcanic and sedimentary rocks that extends for 270 km close to the eastern margin of the Kaapvaal Craton in South Africa and Swaziland. It is therefore one of the most extensive coherent Archaean terrains in the world and the oldest volcano-sedimentary continental deposit of this extent. Its characteristics are unique amongst supracrustal terrains of this age and unlike those of Archaean greenstone belts. The unique nature of the Pongola Supergroup is that it marks the transition in southern African crustal development from preceding early greenstone belts, such as Barberton, to late Archaean stable crustal basin formation. The sequence developed in a continental environment with extensive epicratonic volcanism and basin sedimentation.

The focus of this talk is on the occurrence, field relations and correlation of the volcanic rocks in both the Nsuze (lower) and Mozaan (upper) Groups. The compositional range from basalt to rhyolite is remarkable, and this paper focuses on the distribution of different magma types and styles of eruption throughout the belt, including the first record of ultramafic compositions in the Pongola Supergroup, as well the oldest occurrence of felsic ignimbrites. No single tectonic setting, on modern day analogues, can explain the Pongola volcano-sedimentary belt and the current evidence for the Nsuze Group is consistent with a continental arc, the oldest known to date, migrating into a continental rifted environment to the north, and overlain by the Mozaan Group formed in a cratonic basin following thermal relaxing after the preceding voluminous volcanism.

A new search for ancient detrital zircons in Zimbabwean sediments

Axel Hofmann, Robert Bolhar, Sandra Wind, Martin Whitehouse & Tony Kemp

ahofmann@uj.ac.za

Following the study of Dodson et al. (1988), we have initiated a new systematic search for ancient detrital zircons in Zimbabwe using samples from different Archaean sedimentary successions. The aim was to better define the crustal evolution of the Zimbabwe craton, to provide age constraints of previously undated successions and to pinpoint areas in Zimbabwe that may have preserved very ancient rocks. We have undertaken zircon dating by ion probe of six samples, four from the c. 2.9 to 2.8 Ga old (Wilson et al., 1995) Belingwean/Bulawayan groups and two from the previously undated Sebakwian Group. Zircons were also subjected to O and Hf isotope analysis, results for which are beyond the scope of this presentation.

Two samples were investigated from the Wanderer Formation, Shurugwi greenstone belt. The sandy matrix from a conglomerate contains zircons with a $^{207}Pb/^{206}Pb$ age range (<10% discordance) of 3.7 to 3.54 Ga, whereas zircons from a quartzite cobble from the same conglomerate have a more restricted age range of 3.35 to 3.32 Ga. A sample of quartzite from the Buchwa greenstone belt yielded zircons with an age of 3.59 to 3.11 Ga. These results are similar to those reported by Dodson et al. (1988) from the same stratigraphic units, although we failed to observe any 3.8 Ga zircons in these rocks.

A sandstone of the Mafic Formation of the Midlands greenstone belt, resting unconformably on the 3.56 Ga Sebakwe River Gneiss (oldest known preserved crust of Zimbabwe, Horstwood et al., 1999), was also investigated. Zircons range in age from 3.58 to 3.3 Ga, with a prominent population of 3.55 Ga reflecting the local provenance.

Furthermore, we dated two samples of fuchsitic quartzite from the Sebakwian Group from the Rhodesdale batholith complex. One sample yielded zircons with an age range of 3.64 to 3.39 Ga, while a second sample gave a much larger spread of ages between 3.82 to 3.13 Ga, containing a very prominent zircon population of 3.8 Ga.

While each analysis provides new geological constraints for each of the sampled stratigraphic units, the following main inferences can be made. (1) There appears to be a general dearth of zircons younger than 3.1 Ga old, suggesting the absence of exposed felsic rocks 3.1 to 2.9 Ga old during times of deposition of the Bulawayan Group. (2) Sebakwian Group rocks dated in this study are younger than 3.12 Ga and thus may not necessarily be part of a separate, older stratigraphic unit at the group level. (3) The presence of large amounts of 3.8 Ga old zircons in one Sebakwian Group quartzite sample presents a promising perspective for the presence of yet to be discovered Eoarchaean crust in Zimbabwe.

References

Dodson, M.H., Compston, W., Williams, I.S. & Wilson, J.F. 1988. A search for ancient detrital zircons in Zimbabwean sediments. Journal of the Geological Society of London, 145, 977-983.

Horstwood, M.S.A., Nesbitt, R.W., Noble, S.R. & Wilson, J.F. 1999. U-Pb zircon evidence for an extensive early Archean craton in Zimbabwe: a reassessment of the timing of craton formation, stabilization, and growth. Geology, 27, 707-710.
Wilson, J.F., Nesbitt, R.W. & Fanning, C.M. 1995. Zircon geochronology of Archaean felsic sequences in the Zimbabwe craton: a revision of greenstone stratigraphy and a model for crustal growth. In: Coward, M.P. & Ries, A.C. (eds) Early Precambrian processes. Geological Society Special Publications, 95, 109-126.

Is the Moroka Granite on south-western margin of the Zimbabwe craton in NE Botswana part of the Chilimanzi Granite?

Bagai, Z., Koitsiwe, K. & Kehelpannala, W.K.V.

bagaizb@mopipi.ub.bw

The Moroka Granite which is located within the Francistown Arc Complex in NE Botswana extends into Zimbabwe up to the Matopo Hills near Bulawayo. The Matopo Hills are regarded as part of the suite of granites called the Chilimanzi. The emplacement of the Chilimanzi suite occurred over a large area of the Zimbabwe craton about 2.6 Ga ago. The Chilimanzi intrusion is considered to be monzogranitic in composition. Detailed modal analysis of the Moroka Granite indicates that the granitoid is quite heterogeneous in composition which raises some doubts regarding its relation with the Chilimanzi suite granite. Our detailed field, petrographic and geochemical investigations on the Moroka Granite indicate that the granite formed through K-metasomatism of once a tonalite or trondhjemite and possible quartz monzodiorite. The main metasomatic transformation is characterized by formation of new microcline and myrmekite. Petrographic evidence shows that almost all microcline is of replacement origin. Sericitization and muscovitization of feldspars is common in the Moroka Granite. Geochemically, the Moroka Granite display low Mg#, high-K, I-type and calc-alkaline affinities.

Anthropogenic Global Warming and the History of the Earth's Climate

Tony Martin

anthony.martin@enrc.co.za

There is currently considerable alarm about the impact of CO_2 on the earth's climate with claims that extreme weather events, retreating glaciers, loss of ice and a commensurate rise in sea levels can be attributed to a dramatic rise in global temperatures linked to increased levels of atmospheric CO_2. But what is the science behind these claims: how are global temperatures measured today and what is the historical record in the recent past and further back in geological time? The earth's atmosphere in the Archaean and Palaeoproterozoic was dominated by CO_2 but oxygen was created and the earth survived. Since then it has survived catastrophic super-volcanic and extra-terrestrial events, possible total freezing and extreme warm periods. Given the geological record, it would appear that the alarm is unwarranted. But what is the evidence to support this statement and why are politicians, "green" activists and a few "scientists" so confident in their support for the theory of anthropogenic global warming.

Dinosaurs of Zimbabwe: a review

Ali Ait-Kaci

ali_aitkaci@yahoo.fr

In Zimbabwe, dinosaur remains and prints are found in three lithostratigraphic levels, from Late Triassic to Early Cretaceous.

● In the Forest Sandstone Formation (or equivalents, Late Triassic to Early Jurassic), bones of mainly *Massospondylus*, *Syntarsus* and probably *Euskelosaurus*(?), are found
at Sentinel Ranch in the Limpopo Basin,
at various locations north of Bulawayo in the mid-Zambesi Basin and
at Chitake and Mana-Angwa in the Lower Zambezi Basin

● In the Batoka basalts, remains of *Volcanodon karibaensis* are found in interflow sandstones of several islands of the Kariba Lake, in the Sibilobiloarea.

● In the Post Karoo Gokwe and Dande Sandstone Formations (Mid to Late Jurassic, may be early Cretaceous)
large undefined sauropod bones were found South of Gokwe
at Kadzi-Ambi, in the Lower Zambezi Basin, bones of giant sauropods, of the *Barosaurus, Brachiosaurus,Dicraesaurus, Tornira,?Camasaurus,* were found as well as the femur of an allosaurid theropod.
to the West, the Ntumbe River site displays numerous dinosaur footprints of various sizes, left by the theropods and giant sauropods, probably those found at Kadzi-Ambi.

X-ray and Micro Computed Tomography

Lynsey Singh

lynsey.singh@bruker.co.za

Micro computed tomography is X-ray imaging in 3D, by the same method used in hospital CT scans, but on a small scale with massively increased resolution. It really represents 3D microscopy, where very fine scale internal structure of objects is imaged non-destructively.

Bruker microtomography is available in a range of easy-to-use desktop instruments, which generate 3D images of your sample's morphology and internal microstructure with resolution down to the sub-micron level.

We show that microCT allows imaging and identification of micron sizegranules of different minerals in 3D. Possibility of application of microCT technique for natural samples such as geologic rocks and limitations of the technique have been discussed.

The German Mineral resources Agency and their activities in South Africa

Herwig Marbler

herwig.marbler@bgr.de

The availability of mineral raw materials as well as their sustainable supply is fundamental to the German industry. The total value of German commodity imports in 2012 was about 140 billion € of which over one third was spent on metals. The German Mineral Resources Agency (DERA) at the Federal Institute for Geosciences and Natural Resources (BGR) was founded in 2010 for consulting advisory to decision makers of companies and politics on specific issues, in particular availabilities, current market trends and the diversification of raw material sources. The DERA analyses and evaluates the international raw materials markets and the potentials for mineral resources with the aim of enhancing the market transparency and describing the potentials of raw materials.

International cooperation projects at both state and industry level enable us to establish networks with resource rich countries. The aim of this co operations and partnerships is to assess raw material potentials and investment options for German companies in the raw materials sector. The DERA is active in several countries worldwide. Southern Africa is in particular focus in terms of mineral resources. Currently the DERA is working on an Investor's Guide for deposits of critical metals in South Africa, including special terms and conditions for investment in the mining sector. Platinum and other PGEs are of great importance for the German Industry, in particular for the car industry. Due to their high concentration of producing countries, these elements are among the most critical raw materials. Zimbabwe is therefore also within the focus of international commodity interests of the DERA.
