



# Geological Society of Zimbabwe

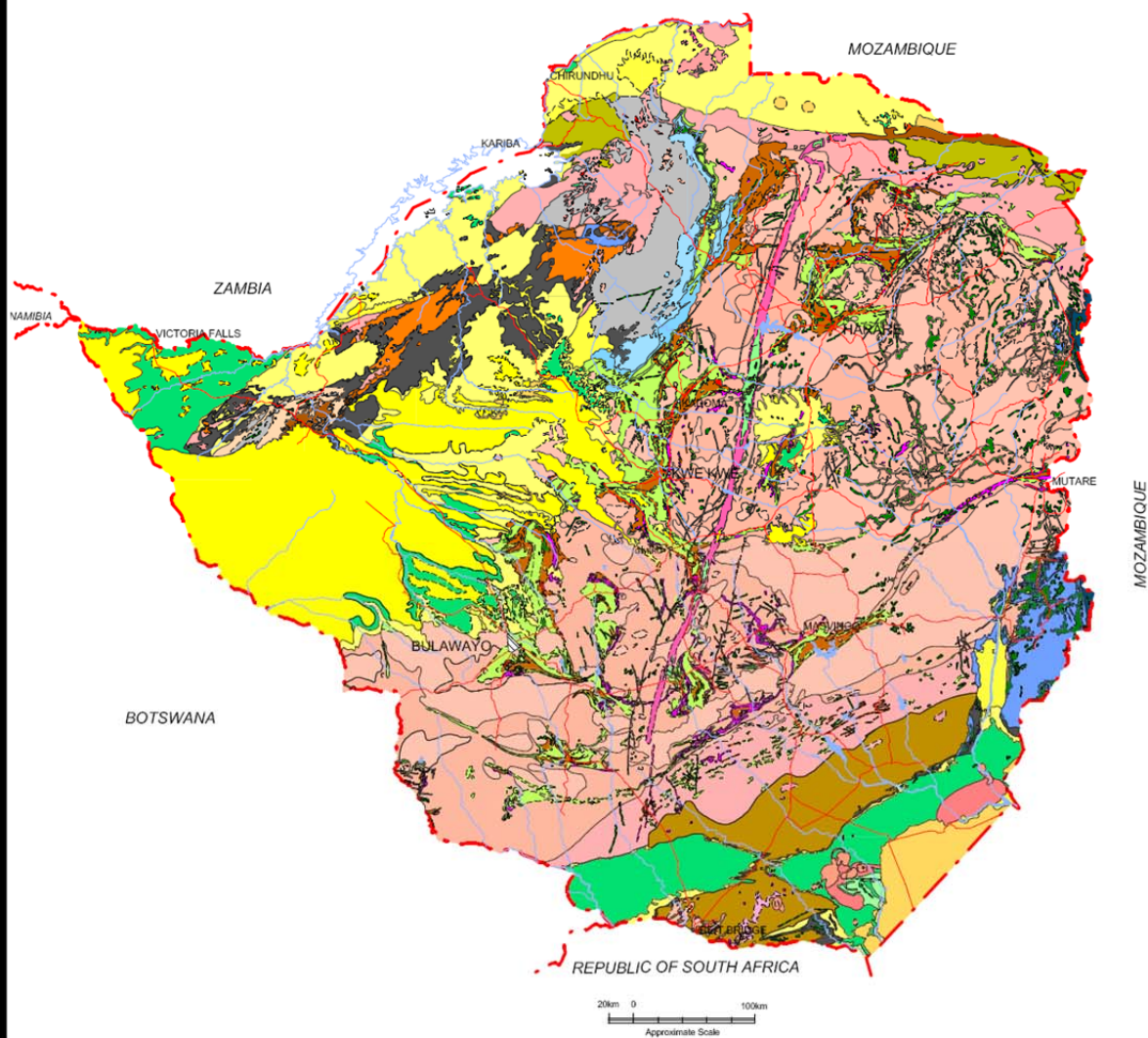


## A HUNDRED YEARS OF GEOLOGICAL ENDEAVOUR THE PAST IS KEY TO THE FUTURE



20<sup>th</sup> – 25<sup>th</sup> October 2010

### ABSTRACTS



## THURSDAY 21 OCTOBER 2010

START	TOPIC	SPEAKER
07.45	REGISTRATION	
08.15	WELCOME	DANIEL CHATORA, CHAIRMAN GEOLOGICAL SOCIETY
08.40	OPENING	THE HONOURABLE OBERT MPOFU, M.P., MINISTER OF MINES AND MINING DEVELOPMENT
09.05	ZIMBABWE GEOLOGICAL SURVEY	TEMBA HAWADI, DIRECTOR OF ZIMBABWE GEOLOGICAL SURVEY
09.30	THE ZIMBABWE-ANTARCTICA LINK: A FORELAND BASIN MODEL FOR THE LATE MESOPROTEROZOIC UMKONDO- RITSCHERFLYA BASIN, PRIOR TO ITS PAN-AFRICAN DEFORMATION	SHARAD MASTER, WITS
09.55	TEA	
10.15	<b>THE ZIMBABWE GEOLOGICAL SURVEY MARKS ITS CENTURY OF ACHIEVEMENT, 1910 – 2010 (Keynote)</b>	<b>TIM BRODERICK, JEREMY PRINCE &amp; ASSOCIATES</b>
11.30	MAPPING CHALLENGES FACING AFRICAN GEOLOGICAL SURVEYS IN 2010 AND BEYOND	NICK BAGLOW, COUNCIL FOR GEOSCIENCE
11.55	AN UPDATE ON THE LIMPOPO BELT	JAN KRAMERS, UJ
12.20	TECTONIC MODELS FOR THE LIMPOPO COMPLEX	JAN KRAMERS ON BEHALF OF STEVE McCOURT, UKZN
12.45	LUNCH	
14.00	<b>FINGERPRINTING OF CONFLICT MINERALS WITH FOCUS ON “COLTAN” (TANTALUM ORES) – NEW ANALYTICAL DEVELOPMENTS AND DISCRIMINATION OF AFRICAN ORE PROVINCES (Keynote)</b>	<b>THOMAS OBERTHÜR, BGR</b>
14.50	THE TECTONIC EVOLUTION OF THE ZIMBABWE CRATON: A UNIFYING PLATE TECTONIC HYPOTHESIS OF THE ca 3.5- 3.2Ga SEBAKWE PROTOGRATON UNDER EXTENSION, ARC MAGMATISM AND HIMALAYAN-TYPE INDENTATION	MARK TSOMONDO, METALLON GOLD
15.15	TEA	
15.35	CORE LOGGING IN THE 21 <sup>ST</sup> CENTURY	JOHN ORPEN, STEREOCORE™ PHOTOLOG
16.00	INVESTIGATION OF THE TEMPORAL RELATION OF THE DIORITE AND TRONDHJEMITE ROCKS IN THE TATI GRANITE-GREENSTONE TERRAIN, NE BOTSWANA	ZIBISANI BAGAI, UNIVERSITY OF BOTSWANA

FRIDAY 22 OCTOBER 2010		
START	TOPIC	SPEAKER
8.00	<b>THE BIRTH OF TWO GREAT LAYERED INTRUSIONS – THE GREAT DYKE AND THE BUSHVELD COMPLEX (Keynote)</b>	<b>ALLAN WILSON, WITS</b>
8.50	ANDEAN-TYPE PLATE TECTONIC EVOLUTION OF THE MIDLANDS GREENSTONE BELT; NEW EVIDENCE FOR EXTENSIONAL AND COLLISIONAL TECTONICS IN THE c2.74Ga UPPER BULAWAYAN SUPERGROUP	MARK TSOMONDO, MIDLANDS GEOLOGICAL SERVICES
9.15	APPLICATION OF REFLECTION SEISMICS IN SOUTHERN AFRICAN PLATINUM DEPOSITS	NIEL DE BRUIN, IMPALA PLATINUM LIMITED
9.40	GEOCHEMICAL INVESTIGATION OF THE DOMBOSHABA GRANITE AND THE KALAKAMATI MONZONITE PLUTONS IN THE VUMBA GRANITE-GREENSTONE TERRAIN, NE BOTSWANA: EVIDENCE FOR SANUKITOID AND CLOSEPET-TYPE MAGMATISM?	ZIBISANI BAGAI, UNIVERSITY OF BOTSWANA
10.05	TEA	
10.25	THE EARTH'S CORE HAS GONE TO POTS	MICHAEL WATKEYS, UKZN
10.50	ZIMBABWEAN ARCHAEOAN STROMATOLITES AND THE HISTORY OF OXYGEN IN THE AIR	EUAN NISBET, ROYAL HOLLOWAY, UNIVERSITY OF LONDON
11.15	BEFORE 1910. ARCHAEOLOGY OF NYANGA REVEALS DIRECT EVIDENCE OF PRECOLONIAL GOLD EXPLORATION AND RECOVERY IN ZIMBABWE'S EASTERN HIGHLANDS	ANN KRITZINGER
11.40	THE HYDROGEOLOGY AND DEVELOPMENT POTENTIAL OF SAND RIVERS	DAVID LOVE, WATEMET
12.05	THE CONTRIBUTION OF GEOPHYSICAL EXPLORATION TECHNIQUES TO SULPHIDE NICKEL EXPLORATION IN BURUNDI	TENYEARS GUMEDE
12.30	WHOLE ROCK GEOCHEMISTRY: A STRATIGRAPHIC TOOL IN THE BOTSWANA KAROO	SORCHA DISKIN, UNIVERSITY OF BOTSWANA
12.55	LUNCH	
14.00	SUMMARY	SHARAD MASTER, WITS
14.45	TEA	
START OF PUBLIC SESSION		
15.15	<b>ALEX DU TOIT LECTURE, HISTORY AND INTRODUCTION</b>	<b>ROD TUCKER, CEO KERNOW EXPLORATION</b>
15.25	<b>ALEX DU TOIT LECTURE : THE OKAVANGO DELTA AND ITS PLACE IN THE GEOMORPHOLOGICAL EVOLUTION OF SOUTHERN AFRICA</b>	<b>PROFESSOR TERENCE McCARTHY, WITS</b>

## THE ZIMBABWE GEOLOGICAL SURVEY

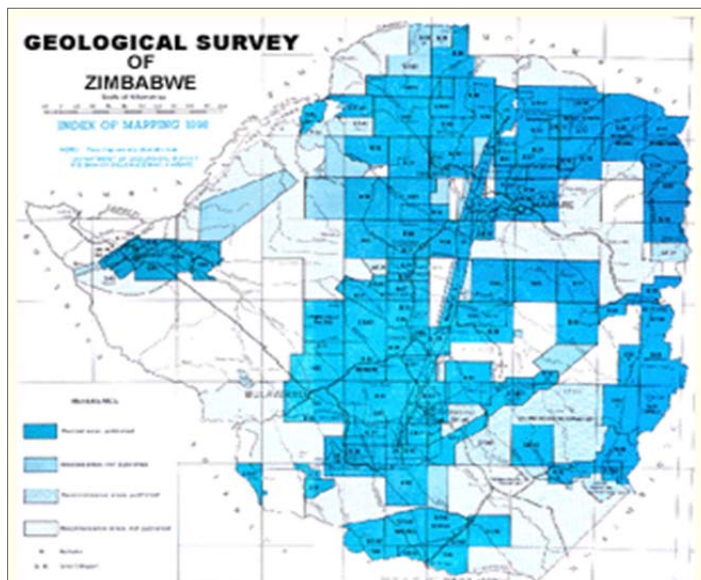
**Temba Hawadi (Director)**

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Zimbabwe Geological Survey [ZGS] is one of the five technical departments in the Ministry of Mines and Mining Development. The other four departments are Mining Promotion [MP], Mining Law [ML], Metallurgy [M] and Mining Engineering [ME]. These were formed to serve the whole mining cycle composed of investment promotion, data acquisition, title registration, exploration, analysis and mining.

The year 2010 marks one hundred years of existence of the Zimbabwe Geological Survey department. This national institute was established in 1910 with its first office based in Bulawayo and with a mandate to undertake geological mapping, offering free geological advice to prospectors and miners and giving a service to determine and analyse rocks, minerals and ores. The purpose of existence of the Geological Survey has not changed much. Its current Key Result Areas are Geo-scientific data generation, Provision of geo-technical services and Mineral exploration monitoring. What has changed is simply the development in areas such as transportation mode, mapping techniques, rock and mineral analysis techniques, and information archiving and dissemination.

ZGS activities in the century have resulted in more than 60% coverage of the country with detailed geological mapping/ re-mapping, a substantial amount of geophysical mapping and the discovery of more than 60 different minerals of which about 40 have been exploited at one time or another. ZGS is indeed the FIRST STOP shop for prospective mining investors by virtue of being the depository of national geological data collected through ZGS mapping and research projects, work done by various prospecting companies, international Aid projects and visits to mines and claims areas. Out-of-Print publications have been scanned and made available to clients.

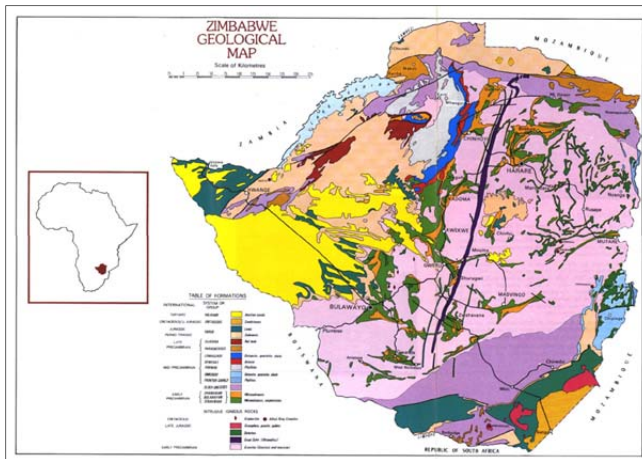


### GEOLOGICAL MAPPING INDEX

The detailed geological mapping was done at a scale of 1:50 000 and maps produced at a scale of 1:100 000.

Each block has a map and an accompanying descriptive text called Bulletin or Short Report.

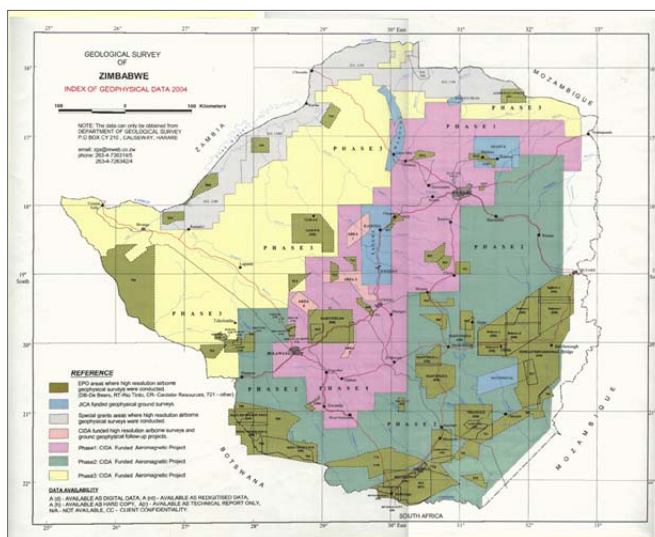




## 1: 1 000 000 GEOLOGICAL MAP

Seven editions were published in 1921, 1928, 1936, 1946, 1961, 1971, and 1977.

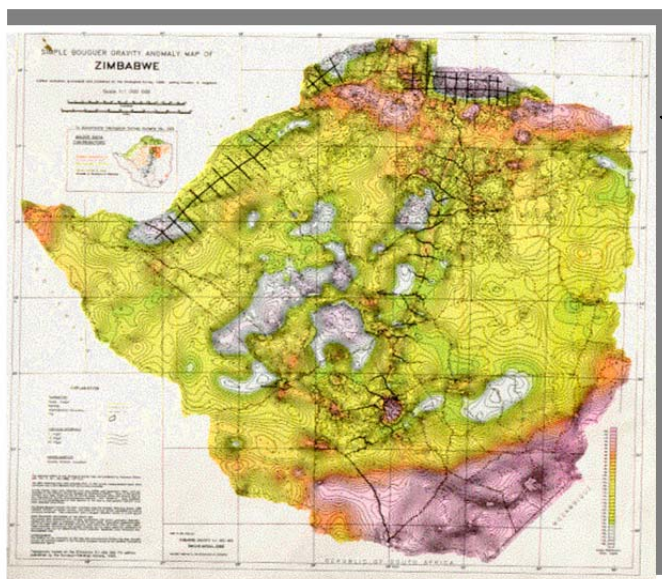
The eighth edition is being produced to coincide with the centenary celebration in 2010.



## GEOPHYSICAL MAPPING INDEX

Geophysical techniques were introduced in the later half of the century but extensive application featured after independence.

Geophysical surveys have been conducted by Government, various companies in



## GRAVITY MAP OF ZIMBABWE

Data contribution was from various sources.

The station density varies from "high density" (less than five km intervals) to "low density" (one station per quarter degree square). The map was created from 12 647 gravity stations within Zimbabwe.

ZGS monitors exploration activities in the country and advises the Mining Affairs Board. Visits are made to mining and claims areas giving rise to technical reports archived in the Library.

The stewardship of the department during the one hundred years has been under the directorship of the following:

PERIOD	NAME	POST
1910 – 1934	Mr. H. B. Maufe	Director
1934 – 1946	Major B. A. Lightfoot	Director
1946 – 1948	Dr. A. M. Macgregor	Director
1948 – 1960	Mr. J. C. Ferguson	Director
1960 – 1962	Dr. F. L. Amm	Director
1962 – 1967	Dr. A. E. Phaup	Director
1967 – 1976	Dr. J. W. Wiles	Director
1976 – 1978	Dr. J. G. Stagman	Director
1978 – 1989	Mr. E. R. Morrison	Director
1989 – 1989	Mr. N. Baglow	Acting Director
1990 – 1993	Dr. J. L. Orpen	Director
1993 – 1994	Mr. S. M. N. Ncube	Acting Director
1995 – 1995	Mr. S. M. N. Ncube	Director
1995 – 1997	Mr. W. Magalela	Acting Director
1997 – 1997	Mr. W. Magalela	Director
1997 – 2002	Mr. F. Mugumbate	Acting Director
2002 – Current	Mr. M. T. Hawadi	Director

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# THE ZIMBABWE-ANTARCTICA LINK: A FORELAND BASIN MODEL FOR THE LATE MESOPROTEROZOIC UMKONDO-RITSCHERFLYA BASIN, PRIOR TO ITS PAN-AFRICAN DEFORMATION

Sharad Master

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A foreland basin system is defined as “an elongate region of potential sediment accommodation that forms on continental crust between a contractional orogenic belt and the adjacent craton, mainly in response to geodynamic processes related to subduction and the resulting peripheral or retroarc fold-thrust belt” (DeCelles and Giles, 1996). In this paper the Umkondo Group is linked with the Ritscherflya Supergroup of Antarctica, and both are interpreted as the products of a foreland basin developed in response to arc collisions in the late Mesoproterozoic, during the formation of the Rodinia supercontinent.

The Umkondo Group is a sedimentary and volcanic succession outcropping in eastern Zimbabwe and adjacent parts of southern Mozambique. While the western domain of the Umkondo Group is generally flat-lying, almost unmetamorphosed and undeformed, nonconformably overlying Archaean granites and gneisses of the Zimbabwe Craton, the eastern domain is an allochthonous fold-thrust belt, along the Mozambique frontier, that was thrust onto the craton from the east, and metamorphosed to amphibolite facies (sillimanite grade) during a Pan-African (late Neoproterozoic to early Palaeozoic) tectonothermal event. Stocklmayer (1981) recognized two distinct facies in the Umkondo Group, the western “Inyanga Facies”, and the eastern “Gairezi Facies”. The “Frontier Series” at the base of the “Gairezi Facies” consists of orthoquartzites and chlorite schists up to 2 km thick, and is overlain by Lower and Upper Pelitic Schist formations. The “Inyanga Facies” of the Umkondo Group consists of stromatolitic carbonates, black shales, and sandstones, overlain by mafic (tholeiitic) volcanic and pyroclastic rocks interbedded with quartzites (Button, 1977). The “Gairezi Facies” is interpreted as a typical passive margin succession (<2.3 Ga, Manhica et al., 2001), in which initial marginal marine orthoquartzites are overlain by deeper shelf pelites, formed in an overall deepening, transgressive sedimentary regime. By contrast, the overlying “Inyanga Facies” represents a regressive, shallowing upward sedimentary regime.

In the Ritscherflya Supergroup on the ca. 3.0 Ga Grunehogna block (Barton et al., 1987) of West Dronning Maud Land, Antarctica, the sedimentary Ahlmannryggen Group is overlain by the volcanoclastic Jutulstraumen and the volcanic Straumnsnutane groups. In the Ahlmannryggen Group, there are two outcrop regions, the Ahlmannryggen and Borgmassivet. In both regions, the succession consists of an upward fining (deepening) sequence overlain by an upward coarsening sequence (Ferreira, 1986a,b; Perritt, 2001). Its depositional environment was largely fluvial, dominated by braided and meandering river and local lacustrine systems (Ferreira, 1986a,b).

During the late Mesoproterozoic, at c. 1.2-1.1 Ga, during amalgamation of Rodinia, island arc terranes were accreted to the southern and eastern edge of the Zimbabwe-Limpopo-Kaapvaal-Grunehogna continent, in the Namaqua-Natal Belt, and extended to the ca. 1130 Ma Maud Belt in Antarctica. The collision of the Maud Belt with the Grunehogna block produced the Ahlmannryggen foreland basin, in which detritus with a minimum age of ca. 1138 Ma (Perritt, 2001) was shed into a foredeep from the colliding arc to the east. The forebulge of this foreland basin is not exposed in Antarctica. The northern continuation of the Maud belt is found in southern Mozambique (Bingen et al., 2009), where the Vhanduzi Migmatite Gneiss, and ca 1112±18 Ma Nhansipfwe Gneiss and other gneisses adjoin the reworked Zimbabwe Craton 40 km E of the Zimbabwe-Mozambique border (Manhica et al., 2001). In the early stages of foreland basin sedimentation on the eastern margin of the Zimbabwe Craton, a shallow shelf succession of stromatolitic carbonates, formed in subtidal to intertidal environments, was succeeded by deeper water siltstones and shales, as the basin initially deepened, in response to loading by the Maud Belt arc to the east. A forebulge rose to the west, and its erosion led to the regressive outbuilding of a braided fan delta (Button, 1977), comprising arkosic sandstones, over the shallow marine shelf argillites, with palaeocurrents towards the east. The upper part of the arenite succession shows reworking into clean quartzites by northerly-directed longshore currents (Button, 1977). As the forebulge was eroded and gradients were reduced, the arenites were overlain by a sandy argillite succession, representing a meandering river floodplain. This in turn is succeeded by more arkose, marking a renewed pulse of sedimentation, perhaps caused by doming, just prior to the eruption of mafic pyroclastics and tholeiitic lavas, together with intrusion of voluminous sills, of the ca. 1106 +/- 2 Ma Umkondo Large Igneous Province (Hanson et al., 2004), while the Umkondo sediments were still unconsolidated. In Antarctica, similar sills, the Borgmassivet intrusions, are intruded into unconsolidated sediments of the Ahlmannryggen Group.

There are a number of similarities between the Umkondo Group and Ritscherflya, Supergroup indicating that they may have been part of the same large basin: (1) Mafic sills and lava flows in the two areas have the same chemical composition (Krynauw et al., 1991; Munyanyiwa, 1999); (2) the mafic sills intruded into the sediments while they were still unconsolidated (Krynauw et al., 1988, 1994; Master, 2006), indicating similar ages of sedimentation in both basins; (3) the contacts of mafic sills in both areas are contaminated, and converted into granophyres (Button, 1977; Krynauw et al., 1988, 1994; Master, 2006); (4) the Umkondo volcanics and sills have the same palaeopole as the sills in Ahlmannryggen (Jones et al., 2003), in a tightly reconstructed Gondwana configuration (Roeser et al., 1996); (5) the U-Pb baddeleyite ages of mafic rocks from Umkondo Group and Ahlmannryggen is the same, 1106  $\pm$  2 Ma (Wingate, 2001; Hanson et al., 2004); (6) the Rb-Sr age, recording a metamorphic overprint, of mafic rocks from both areas is the same, ca. 1080 Ma (Allsopp et al., 1979; Moyes et al., 1995).

This initially-deepening, then upward-shoaling, Umkondo-Ritscherflya succession represents a basinal response to lithospheric depression by crustal loading, followed by migration and denudation of the forebulge, with regressional infilling of the foreland basin from both the hinterland (colliding arc) and foreland (craton) sides. A similar pattern of basinal infill is found in the Kundelungu foreland basin of the Pan-African Lufilian Orogen in central Africa, where detritus was shed into the basin from the orogenic thrust front, as well as from uplifted basement rocks in the forebulge (Master et al., 2005).

The Kuunga Orogeny (Grantham et al., 2008), as well as a Pan-African collision between East Antarctica and the Grunehogna block resulted in renewed deformation of the Maud belt (Jacobs et al., 2003; Perritt and Watkeys, 2003; Board et al., 2005). The extension of the Maud belt may then have shuffled against the ancient former passive margin succession of the Zimbabwe craton (quartzites of the Gairezi Group), and thrust them over the Umkondo foreland basin succession (Bene and Watkeys, 2004).

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## **THE ZIMBABWE GEOLOGICAL SURVEY MARKS ITS CENTURY OF ACHIEVEMENT 1910 - 2010**

**Tim Broderick**

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From the archaeological record of Zimbabwe we acknowledge the keen observational ability of our Stone Age, San and Ancients in adapting their environment to their way of life. This resulted in their use of appropriate stone for tools, iron for hoes, clay for pots and gold and copper for trade and adornment. The observation of rock relationships and the development of stratigraphic principles came to a head only some 200 years ago and were recognized in the publication of William Smith's first geological map of Britain in 1815. It has been dubbed "The map that changed the World" and it is in the tradition of Smith that regional geological mapping in Zimbabwe and the World follows.

Although Thornton, geologist to Livingstone's Zambezi Expedition of 1858 to 1863, touched Zimbabwe at the Victoria Falls and at Kanyemba, it is the German explorer Carl Mauch who is recognized as the first geologist to traverse Zimbabwean territory. He walked the Bulye River Valley in 1868 before joining Henry Hartley in their quest for gold to the vicinity of the present-day Chegutu. He also recognized and documented the Tati Gold Belt. Mauch returned in 1871 when he crossed the Bempe (Limpopo) River, passed Marungudzi and crossed the waterless Nuanetsi lava field to reach Great Zimbabwe. He continued, to name the Kaiser Wilhelm Gold Belt at Makaha, before migrating east through Mozambique to Quelimane. He chronicled a wealth of geological, botanical and sociological detail, whilst his route was fixed by sextant, chronometer and aneroid barometer.

Organized regional geological mapping in southern Africa began with the Geological Commission of the Cape of Good Hope in 1895. Prof. Ernest Schwarz and Dr A.L. du Toit were on this Commission in 1904 when their masterful geological maps of the Langkloof and Eastern Cape were based on the survey of farm boundaries, but did not reflect the diverse topography they worked within. Schwarz advocated the damming of the Cunene and Chobe rivers and the diversion of waters to flood the Makarikari Pans. This engendered controversy and it was du Toit who was asked to mediate in the feasibility of the scheme. He, with the use of a South African DH9 aircraft, initiated the use of aerial photography in the region by flying sorties out of Livingstone. The irrigation of Botswana was not achieved.

P.B. Fletcher was the first surveyor in Bulawayo. He was invited to plan and survey the streets in 1894 and these form the basis of the CBD and Suburbs today. More importantly, this survey work caused Fletcher to invite his elder brother, R.A. Fletcher and friend W.M. Espin to join him from Johannesburg. They published the first geological map of Matabeleland in 1897, a remarkable feat when the geodetic and primary triangulation of Rhodesia was only initiated in that year. Alexander Simms completed the survey up the 30-degree Arc of Meridian between Bulawayo and Salisbury by 1901, whilst Rubin continued this northwards across the Zambezi. Gordon then linked the chain from the Transvaal in 1906. Further triangulation in the country then remained dormant until 1928.

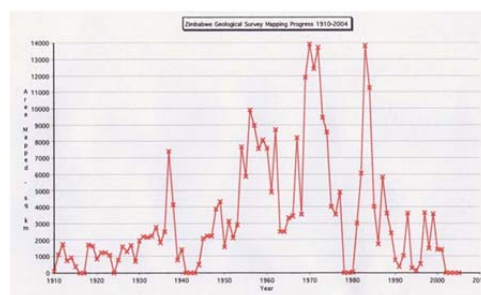
A.J.C. Molyneux was one of the earliest geologists and mining engineers active in the region. He, through the Chamber of Mines, was instrumental in founding both the Rhodesia Scientific Association (1899) and the Rhodesia Museum (1901) in Bulawayo. Chamber of Mines' support for a national museum required that the curator be a geologist. This was Frederick Philip Mennell, whose service to mining and geology in the country earned him the title of being Zimbabwe's 'father of geology'. By 1904 he had accumulated sufficient knowledge on the geology to publish his own map. Mennell was to be one of the main protagonists, again through the Chamber of Mines and the BSA Company, for the establishment of a national Geological Survey, which came to fruition in 1910 with the appointment of H.B. Maufe as its first Director in Bulawayo. He immediately set to work to map the geology of the Enterprise Gold Belt with the aid of mule-drawn buckboard and plane table. He was to serve this country handsomely until his retirement in 1934 and again as Acting Director during WW II.

The first published Geological Survey map was of the Selukwe mining camp, representing the concerted efforts of Maufe, Ben Lightfoot and A.E.V. Zealley through 1911 and 1912 in what we now know to be an area of extreme geological complexity and difficult topography. Zealley had succeeded Mennell as Curator at the Museum before joining the Geological Survey whilst Lightfoot had followed Maufe from the British Geological Survey's Scottish Office. He was experienced in coal geology and went on to assess and map the Great Sabi Coal Syndicate claims and the Wankie Coal Concession in 1912. The mapping was at a scale of 800 Cape Roods to the inch. A.M. Macgregor, who had been Assistant Curator at the Museum, joined the Survey in 1914 and assisted Maufe in mapping Kalahari and Karoo stratigraphy west of Queens

Mine. He returned after war service in 1919 to complete Zealley's mapping of the Somabula diamond field before returning to the Bembezi Valley to complete the geological mapping around the Lonely Mine in 1922. He was to complete a 27-year marathon of geological field work, which only terminated on his appointment as Director of the Geological Survey in 1946. He concentrated his efforts on the Basement Complex and he worked his way south from Kadoma through Battlefields and Kwekwe to Hunters Road, the latter being the first geological map at a scale of 1 : 100 000 and the work resulted in his famous tripartite subdivision of greenstone belt stratigraphy into the Sebakwian, Bulawayan and Shamvaian. As the author of over 50 geological publications, Macgregor's Doctor of Philosophy degree was awarded by the University of Natal in 1947. He was the Geological Society of South Africa Draper Memorial Medallist in the same year, was awarded the OBE in 1949 and became the Society President in 1951.

The first 1:1 million-scale geological map of Southern Rhodesia was published in 1921 and then again in 1928 to coincide with the 1929 World Geological Conference held in Pretoria. Accelerated progress of geological mapping was facilitated by the introduction of motorized transport in 1925 and the inauguration of aerial photography in 1935, when A.E. Phaup and F.O.S. Dobell were mapping the Lower Umfuli Valley. Maturity of the 1:1 million map continued to show itself through the 1936, 1946 and 1961 editions, the latter being the first to be scribed as opposed to being purely hand drawn. The 1970's saw an upsurge in the number of geologists employed in regional geological mapping, their efforts culminating in publication of the 1971 1:1 million map, designed to coincide with the Geological Society's international Granite '71 Conference. The passion for regional mapping was at its height under the directorship of Wiles and Stagman and the 1977 version of the million-map reflected this advance. The map and its accompanying bulletin remain definitive in the perspective of the Geological Survey of Zimbabwe as it has now been reprinted four times, although interpretive changes have been made in the 1996 publication of the 1:1 million-scale Tectonic map of Zimbabwe, an initiative that resulted from the British Geological Survey project on structural controls of gold mineralization in the country, but included the minds and research of others, notably Phillip Oesterlen, Tom Blenkinsop and Jim Wilson.

The Geological Survey now has access to digital mapping techniques and a modern linework camera. Extensive areas of new geological mapping have resulted from renewed efforts during the 1980's and 1990's and this has allowed for the compilation of a new national geological map. This is a landmark map that sorely requires to be published in the national interest, as information dissemination is essential for development planning and implementation, especially in this, our time of need. The challenge is there. If a map could change the course of geological thinking and a nation's, or indeed the World's fortunes in 1815, a similar one could certainly help Zimbabwe now. And, if Macgregor is anything to go by, there is a need for the passion and determination that he showed to pull this project off and to revive the pressing need for the continuation of basic and routine mapping and documentation of our geological resource.



## **MAPPING CHALLENGES FACING AFRICAN GEOLOGICAL SURVEYS IN 2010 AND BEYOND**

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What is the state of geological mapping in Africa? Why is it important for the continent's development? These are critical issues for African Geological Surveys in considering what kind of mapping is needed, how to ensure that our geologists have the expertise necessary to undertake that duty, and how our organizations should be structured to be able to respond to the mapping and other challenges facing us. We also have to reflect on the global challenges facing mankind. Global changes are diverse and substantial; they include urbanization, poverty alleviation, food supply, energy demand, water resources, and compounding them all, climate change.

So we need to deliberate on what type of mapping we should be engaged in. Internationally in the developed world strategic aims of Geological Surveys commonly seek to replace current regional mapping programmes with more thematic, project-oriented data capture and interpretation. Standardization of data will be regularly updated to provide seamless national coverage at any desired scale, and mapping resources will be reassigned to address the above challenges. But the core function of a national Geological Survey, whose mission is both long-term and responsive, remains: to acquire, interpret and enhance the national geoscience knowledge base so as to improve quality of life.

Of course, these aims are equally desirable for our national Surveys in Africa, but the difference is that whereas developed countries with their knowledge-based economies can base their strategies on generally complete geological coverage, African countries have resource-based economies, where mineral exploration often remains a primary objective for economic growth. Yet we do not even have sufficient basic geological mapping at an appropriate scale to achieve this.

Strong public institutions create the basis for developing public services and encourage society to embrace development policies, and as such have the potential of being a positive force in poverty reduction. A vibrant Geological Survey which comes to terms with issues of sustainability, environmental concerns, groundwater infrastructure, natural hazard mitigation and land-use planning can still be the driving force to make the minerals sector a catalyst for economic growth and poverty reduction. In aligning our Geological Surveys to the changing African environment an innovative approach to institutional development is required, requiring transformation at all levels; adopting new norms and values along with new organizational structures. Stronger links need to be built to eg environmental and water departments and development agencies on the continent – therefore venturing out of the strictly minerals-defined arena.

People are the vital resource of a scientific organization, which should have the organisational culture and values needed to deliver on the challenges of any strategy. Training through large international collaborative mapping projects has its place, but is often not sustainable beyond the short-term; we need to take more responsibility for our own professional development and to aim for greater independence from outside skills. This could involve sharing of specialised geoscience skills across the continent and greater emphasis on focussed in-house mapping projects that hone these skills and enable us to interrogate and add value to our data, past and future.

By acknowledging that we are part of a changing global environment and that geoscience can play a pivotal role in providing solutions for many of the problems these changes present, we as African Geological Surveys can significantly contribute to the development of our continent and we should pro-actively focus on re-engineering ourselves to make this happen.

## **AN UPDATE ON THE LIMPOPO BELT**

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By 1992, a self-consistent model for the formation of the high grade metamorphic Limpopo Mobile Belt appeared to be established: the crustal thickening and metamorphism resulted from a continental collision of the Zimbabwe and Kaapvaal cratons between 2.7 and 2.6 Ga. In the 1990's, many dates, clustering close to 2.02 Ga, were obtained on metamorphic garnet, pyroxene, titanite, hornblende, as well as aluminosilicates. These allowed a direct link-up to tectonism and demonstrated a tectonometamorphic event up to high grade. In the Southern Marginal Zone this event is not recorded. A controversy, lasting several years, on whether the main Limpopo orogeny occurred in the Neoproterozoic or in the Paleoproterozoic, has now been largely resolved. A collision, probably preceded by accreting arc (in the Northern Marginal Zone), lasted from 2.7 to 2.58 Ga and affected all three Zones of the Belt and caused high grade (and some high pressure) metamorphism. Widespread anatexis in the thickened Central Zone produced the Singelele-type gneisses. At 2.02 Ga, regional strain, related to the Magondi orogeny, became focused in the Central Zone, probably because the crust was weakened by (possibly Bushveld-related) magmatic underplating (also causing renewed metamorphism), and large-scale transcurrent shear zones were developed.

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## **TECTONIC MODELS FOR THE LIMPOPO COMPLEX**

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Published models for the Limpopo Metamorphic Complex (aka Limpopo belt) as a whole include Neoproterozoic (~2.65 Ga) continent-continent collision, Turkestan-type terrane accretion, and plume-related gravitational redistribution within the crust. In addition, models related to westward emplacement of a giant nappe and Paleoproterozoic (~2.0 Ga) dextral transpression have been proposed specifically for the Central Zone. In this paper, aspects of these models and hypotheses are reviewed and tested against new data from geophysics (chiefly seismics and gravity), isotope geochemistry (mainly Sm-Nd and Lu-Hf data), geochronology and petrology. This analysis reveals that the Neoproterozoic collision model remains as a viable working hypothesis, although in contrast to published versions the Zimbabwe Craton appears to be the overriding plate, with the Northern Marginal and Central Zones of the Limpopo Complex as its (possibly Andean-type) active margin and shelf, respectively. Paleoproterozoic reactivation of the Central Zone is linked to far field stresses related to the Magondi convergence along the NW margin of the Archaean continent. The Paleoproterozoic metamorphism is characterized by near-isobaric prograde paths, which (along with combined teleseismic and gravity data) suggest magmatic underplating. This magmatism could be related to the Bushveld Complex, and may have weakened the crust, leading to the focusing of regional strain into crustal scale shear zones within the Central Zone.

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## **CORE LOGGING IN THE 21<sup>ST</sup> CENTURY. INTRODUCING STEREOCORE™ PHOTOLOG**

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New photogrammetric software that provides a user-friendly platform for digitally logging drill core. Hand-held photographs are processed to create a virtual 3D model of the core which is depth registered to automatically calculate core recoveries, RQD indices and establish an accurate 'e-measure' along its length. Lithological intervals can then be 'picked' on the images and described in detail and similarly all geological structures, planar and linear, can be picked to automatically measure their attitude relative to the core axis and the vertical plane in oriented core. Then, once the borehole survey is imported, these angles are automatically rotated to derive dip and dip direction, which data is plotted 'live' stereographically.



## **FINGERPRINTING OF CONFLICT MINERALS WITH FOCUS ON “COLTAN” (TANTALUM ORES) – NEW ANALYTICAL DEVELOPMENTS AND DISCRIMINATION OF AFRICAN ORE PROVINCES**

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Mining and trading of ores of tantalum, tin, tungsten, and gold have been financing ongoing violent conflicts in Africa, especially in the Democratic Republic of the Congo (DRC). As a consequence, the Group of Experts on the DRC of the United Nations Security Council has recommended to develop a traceability system for mineral commodities with the aim of preventing illegally produced or traded ores (“conflict minerals”) to reach the world market.

Artisanal and small-scale mining dominates mineral production of tantalum, tin and tungsten ores in Central Africa's Great Lakes Region. Currently, nearly 50% of the world's tantalum production originates from African countries, especially from the DRC. Indeed, the high monetary value to volume ratio of these ores makes their illegal mining and trading highly profitable. Therefore, “coltan” (trade name for tantalum ores, from columbite-tantalite) has been identified as a suitable object for a study on the development of a method capable of distinguishing the origin of ore concentrates in Central Africa.

The German Federal Institute for Geosciences and Natural Resources (BGR) has set off two initiatives aiming at fostering transparency and responsibility in mineral production and trading chains of metal ores potentially linked to conflict financing: (1) The approach “Analytical Fingerprint” (AFP) aiming at the identification of the origin of ore samples, and (2) a concept for a chain of custody assurance system (“Certified Trading Chains”, CTC), based on the establishment of transparent and traceable mineral trading chains.

The AFP method aims at identifying the origin of a concentrate or ore by comparing its characteristic mineralogical and geochemical features with data from samples of known provenance analysed previously and stored in a reference database. Coltan concentrates frequently are mixtures of a large number of minerals, commonly dominated by columbite-tantalite group minerals. Multi-disciplinary research on a wide range of tantalum ore and concentrate samples originating from Central Africa and worldwide has so far revealed the following key parameters pointing to the origin of coltan concentrates: (i) The mineralogical composition and variability of ore concentrates, based on parameters like modal mineralogy, grain size distribution and intergrowth relationships. (ii) The geochemical composition of various tantalum minerals (mainly columbite), i.e. the concentrations of major and trace elements in a representative number of columbite-tantalite grains from a given sample. Normalised REE concentration patterns can also be used to differentiate between individual locations. (iii) The geological ages of tantalum minerals and mineral assemblages.

Following initial tests on a wide range of analytical methods, a streamlined AFP methodology has now been established which allows fast and cost-sensitive analysis. A three-stage analytical protocol has been established and is used at present: (a) Preparation of polished sections of concentrate material, followed by (b) quantification of mineral proportions in ores/concentrates using automated scanning electron-microscopy (SEM) and mineral liberation analysis (MLA), and (c) determination of the chemical composition (major and trace elements, uranium and lead isotopes for U-Pb ages) of about 40 individual tantalum mineral grains per sample, using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS).

Analytical data obtained from samples of known origin are fed into a reference database for comparative analyses. The origin of an unknown sample is verified by cross-referencing sample data with the database which currently contains >5700 individual analyses representing ca. 150 ore concentrate samples from 110 locations worldwide. In case of non-fit, however, the analytical data set acquired of the unknown sample will often exclude certain provinces of origin (for example by age) and may on the other hand pin-point to similarities typical for distinct regions or areas. In general, however, mineralogical and geochemical attributes of coltan concentrates allow distinction of single deposits within certain age provinces.

In essence, an analytical scheme to identify the origin of ore concentrates, in this case of tantalum ores, is available for the first time. Application of the method to tantalum ores (development of schemes for tin and tungsten ores is in progress), and its use either as a forensic instrument or in conjunction with CTC, would allow to control mineral exports from Central Africa's conflict regions.

Besides obtaining analytical fingerprints from the in-depth analysis of coltan ores, a number of intriguing scientific by-products have emerged from the studies. One example is the elaboration of five major, distinct “age provinces” of tantalum ores in Africa using the U-Pb isotope system: (1) Archean, e.g. Zimbabwe (Benson mine, Bikita mine; ~2.6 Ga); (2) Paleoproterozoic, e.g. Birimian of West Africa (Kokobin, Ghana; 2080 Ma); (3) early Neoproterozoic, e.g. Kibaran and Namaqualand Province (DRC, Ruanda, Namibia; 1010 – 920 Ma); (4) the Panafrican Belts of eastern Africa (Ethiopia; Egypt; Mocambique), Namibia (Damara orogen) and Nigeria, with ages ranging from 530-440 Ma; and finally, (5) Mesozoic ring complexes of Nigeria.

After a short look at the political background, the field and laboratory methods employed in the analytical fingerprint (AFP) of coltan ores will be described and the results obtained so far will be presented. The possible extension of the AFP to tin and tungsten ores will be discussed.

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## **THE TECTONIC EVOLUTION OF THE ZIMBABWE CRATON: A UNIFYING PLATE TECTONIC HYPOTHESIS OF THE CA 3.5-3.2GA SEBAKWE PROTOCRATON UNDER EXTENSION, ARC MAGMATISM AND HIMALAYAN-TYPE INDENTATION**

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A new subduction-related plate tectonic hypothesis for the late Archaean Zimbabwe craton recognizes the validity of regionally correlatable ca 2.7Ga Bulawayan Supergroup above a Manjeri-type passive continental margin marker overlain by conformable volcanic sequences (Eastern & Western Successions and Sesombi-Wedza TTG suite; Wilson 1979; Prendergast 2004) and a main-cleavage producing NW-SE regional compression with SW-directed lateral expulsion (Coward and Treloar 1990; Treloar & Blenkinsop 1999). Exponents of neoarchaean plate tectonics recognize, as we do here, crustal evolution by arc magmatism around a ca 3.5Ga Sebakwe protocraton but the former (Kusky & Kidd 1992, Kusky 1998, Dirks & Jelsma 1998, Jelsma & Dirks 2002, Dirks *et al* 2002, Hofmann *et al* 2001) controversially invoke tectonostratigraphic terranes on a craton-wide scale or regard the Manjeri-type BIF as marking regional tectonic thrusts carrying obducted oceanic plateau basalts. The age data relating to direction(s) of growth of an Archaean orogen (Jelsma & Dirks 2002) is enigmatic. In this contribution, the structural and stratigraphic criteria for west-directed thrust accretion in the longest Midlands Greenstone Belt (Dirks *et al.* 2002) is refuted in favour of a greenstone cover-over-parautochthonous basement, E-to SE-vergent thrust-and-fold belt in Kwe Kwe and Kadoma. The Zimbabwe craton records phases of tectono-magmatic accretion onto a 3.5-3.2Ga Sebakwe protocraton involving cycles of 1) Andean-type arc-back arc complexes formed outboard from  $\geq 3.2$ Ga and  $\geq 2.8$ Ga continental passive margins, 2) intra-protocraton rift basaltic volcanism (the Eastern Succession) and 3) multiple Himalayan-type collisional events. Based upon time-space distribution of  $\geq$ ca 3.2 basement, platformal assemblages and depositional basin asymmetries, a curved Sebakwe continental margin-arc complex can be reconstructed regionally; one segment extends due S from Kwe Kwe, through Shurugwe to Belingwe, and beyond, and the other, NE into Chegutu-Harare-Shamva belts. A NW Sebakwe protocraton promontory in the Kwe Kwe region provides the missing key to unraveling a case for multiple collisions, control by pre-existing basement and puzzling orogen-parallel younging data in tonalites, adamellites, and Shamvaian Supergroup sedimentation. After extensional rift-tectonics and basaltic volcanism, a sinistral oblique-slip convergent regime occurred during SE-directed subduction of an inferred oceanic crust in the NW and NW-directed indentation by the Sebakwe block into the evolving ca 2701Ma-2670Ma Maliyami calc-alkaline volcanic arc to generate  $D_1$ - $D_2$  ( $S_{1-2}$ ), craton-vergent fold and thrust belts in Kwe Kwe, Kadoma, and Harare-Shamva greenstone belts. That event heralded ca 2680Ma Shamvaian (?forearc basin) sedimentation, but Shamvaian ages young NE away from the indenter promontory, being 2645Ma in Harare belt then 2610Ma in Makaha belt. Protracted NW-SE shortening caused a SW-escape of a Shangani Arc block that was counteracted in the SW by a major arc-arc collision ( $D_3$ ,  $S_{2-3}$ ) in NE Botswana with major NE-thrusting, regional NW fabrics and, elsewhere, dextral transpression. Caught between boundaries of the Sebakwe protocraton and the accreted terranes of NE Botswana, a SSE-promontory of a new Gwanda-Shangani block developed and indented, 1) the re-activated, wedge-shaped Sebakwe Block, and 2) the Limpopo Belt, to produce NE-escapes in both domains. As in the Shamvaian case, this, now SSE-directed impingement accounts for the progressive NE-younging exhumation history (spanning 152Ma) of the syntectonic Razi granites of the NMZ, being 2669Ma at the indenter pivot, but 2517Ma some 180km NE. The history of indentation convergence enhanced delamination of the continental lithosphere mantle by extensional thinning but the trigger is inferred to be the earlier SE-directed subduction of an oceanic plate in the NW beneath a Mayilami magmatic arc domain.

# **INVESTIGATION OF THE TEMPORAL RELATION OF THE DIORITE AND TRONDHJEMITE ROCKS IN THE TATI GRANITE-GREENSTONE TERRAIN, NE BOTSWANA**

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Neoproterozoic plutonism in the Tati granite-greenstone terrain in northeastern Botswana includes trondhjemites and diorites. A U-Pb study of zircons placed age constraints on this plutonic activity, and whole-rock Sm-Nd isotope and mineral Oxygen isotope were used to characterize magmatic sources. U-Pb results indicated that the trondhjemite and diorites are contemporaneous and were emplaced at ~2.72 Ga. This temporal relation together with spatial relationship between the diorites and trondhjemites indicates that their genesis may be somehow linked. The geochemical data does not suggest any petrogenetic link between the diorites and trondhjemites. The initial epsilon values of the diorites range between +4.46 and +2.92 indicating a depleted mantle source while O isotope composition suggests a non-mantle origin for the diorite. High  $\delta^{18}\text{O}$  values for the diorite, which range from +7.1 to +8.3 ‰ suggest an input from a high  $\delta^{18}\text{O}$  source such as fluids from subducting oceanic crust. Similar  $\delta^{18}\text{O}$  values have been reported from sanukitoid diorites in Western Superior Province. Trondhjemite sample recorded a very low Nd epsilon value of -7.25, which suggests an enriched source like an old crust. O isotopic data from the trondhjemite recorded a value that is characteristic for I-type granitoids. Thus the diorite and trondhjemite in the Tati granite-greenstone terrain are coeval but not co-genetic.

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## **THE BIRTH OF TWO GREAT LAYERED INTRUSIONS - THE GREAT DYKE AND THE BUSHVELD COMPLEX**

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The Bushveld Complex and the Great Dyke are two of the most important layered intrusions and remarkably also rank, respectively, as the largest and second largest resources of platinum known on Earth. They are dissimilar in many aspects, such as structure and late stage lithologies, but also have remarkable similarities in other features, particularly in terms of magmatic processes. This paper will highlight those similarities and also investigate what caused the observed differences and how these are reflected in the rocks.

The crucial history of a magma chamber (which ultimately becomes a layered intrusion) is in the initial stages of filling by primary magma, and the sources of that magma. The Great Dyke filled by a series of distinct pulses of magma into a juvenile chamber, which resulted in the development of the Ultramafic Succession with its distinct cyclic units of chromitite, dunite and pyroxenite. Knowledge of the Bushveld filling stage has only recently come to light with a new discovery (by deep diamond drilling) of a thick sequence of ultramafic rocks below the Marginal Zone, up to now believed to be the lowest exposed unit. However, the manner in which this initial filling took place was different between the two intrusions and produced different layering styles and compositional variations. This was partly due to the form of the magma chamber with the elongate Great Dyke resulting from more episodic emplacement of magma through localized feeders, whereas the extensive basin-like structure of the Bushveld Complex caused simultaneous magma emplacement from possible synchronous sources.

The layering, compositions and fractionation will be compared for these two great intrusions in the very earliest part of their development and how this ultimately led to very different characteristics in the important platinum-rich layers higher in the sequence.

# ANDEAN-TYPE PLATE TECTONIC EVOLUTION OF THE MIDLANDS GREENSTONE BELT; NEW EVIDENCE FOR EXTENSIONAL AND COLLISIONAL TECTONICS IN THE C2.74GA UPPER BULAWAYAN SUPERGROUP

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New structural and stratigraphic mapping in the central portions (Kwe Kwe) of the Midlands Greenstone Belt indicates that unconformity-bound, sequence stratigraphic models are applicable in this belt and provide the strongest evidence for the occurrence of a D2, east-vergent, hinterland-foreland thrust belt that resembles an Andean-type accretionary arc complex at greenschist grade. South of the Sebakwe River, the 3565Ma Sebakwe protocraton preserves a rifted, Manjeri-type passive margin representing continental arc extension, intrusion of the 500m-wide, Kwe Kwe Ultramafic Complex and syn-rift extrusion of mostly basaltic lavas of the ca2.74Ga Upper Bulawayan Supergroup of the Zimbabwe craton. The D2 thrust-excision of overturned fold limbs featuring the basal rift-phase Manjeri-type sedimentary marker provides new and robust field evidence challenging previous criteria for a west-directed thrust-stacking of allochthonous terranes in the Midlands Greenstone Belt (Dirks *et al.* 2002). Rather than preserving 10 tectonostratigraphic units representing small-scale accretion bounded by the Sherwood and Taba Mali Shears, the Kwe Kwe region preserves hitherto unrecognised 3 basement-granite slices that are entirely enclosed by infolded Upper Bulawayan cover. In addition, the regional Munyati shear history of sinistral transpression involves a much wider (>20km) terrain south of the shear than previously recognised; specifically, both the Taba Mali and Sherwood Shear zones (Campbell & Pittfield 1991) among several others, record an earlier phase of west-dipping, sinistral oblique shear that was overprinted by dextral transpression. Besides thin-skinned oblique plate convergence, elements of the plate tectonic setting in a NW-SE transect of the belt include 1) a suture zone in the >100km long, 3km-wide Munyati Shear Zone, 2) an enclosed forearc basin comprising the c2.65Ga Shamvaian Sedimentary Supergroup, 3) ca 2.70-2.64Ga Maliyami calc-alkali arc, 4) an associated subduction-related Sesombi-suite TTG magmatism forming a NNE-SSW arc, and 5) missing SE-dipping subduction zone and accretionary prism to the NW. On a Sebakwe craton-wide basis, the Upper Bulawayan features contrasting intra-plate Eastern Successions and bimodal Western Successions (Wilson 1979; Prendergast 2003) associated with volcanic arcs. Given that the Koodovale felsic volcanism forms the base of the Upper Bulawayan in this belt (Prendergast 2003), the bimodal 3.0-2.9Ga Belingwean Supergroup (Bend-Hokonui-Koodovale) probably formed precursors to the well-developed volcanic arcs of the Midlands Greenstone Belt.

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## APPLICATION OF REFLECTION SEISMICS IN SOUTHERN AFRICAN PLATINUM DEPOSITS

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The worldwide demand for platinum over the past decade has provided the impetus and experimental latitude that have led to vast improvements in the acquisition, processing and interpretation of the surface seismic reflection technique. The presentation provides a brief overview of the historical development of the technique as applied to the Bushveld Igneous Complex from the point it was first introduced for the acquisition of two-dimensional (2-D) seismic sections, to its current high-resolution application and integration into the mine planning process. The early 2-D data sections are compared to data derived from the most recent three-dimensional (3-D) volumes acquired for *Impala Platinum*. The discussion covers the geophysical lessons that have been “learnt” as well as the challenges or limitations that we currently face in providing accurate structural models of the target reefs. Since the first interpretation of high-resolution data, significant advances have been made in the imaging, understanding (and hence recognition) of important geological features and their associated seismic signatures. These findings are presented with focus on the improved delineation of ultramafic igneous replacement bodies, slump structures and dykes. Examples of the effective integration of aeromagnetic, wireline and seismic data are also illustrated.

# **GEOCHEMICAL INVESTIGATION OF THE DOMBOSHABA GRANITE AND THE KALAKAMATI MONZONITE PLUTONS IN THE VUMBA GRANITE-GREENSTONE TERRAIN, NE BOTSWANA: EVIDENCE FOR SANUKITOID AND CLOSEPET-TYPE MAGMATISM?**

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The Vumba granite-greenstone terrain in NE Botswana forms part of the Francistown Arc Complex. It is a greenschist to lower amphibolite grade Neoproterozoic terrane of predominately metavolcanic and less common metasedimentary rocks intruded by various plutonic rocks. The plutonic rocks include foliated hornblende quartz monzonite and post-tectonic potassic biotite  $\pm$  hornblende monzogranite of the Kalakamati Monzonite and Domboshaba Granite, respectively. Metaluminous to weakly peraluminous compositions of the quartz monzonite and monzogranite indicate that they are I- or M-type granitoids. In terms of K-series the quartz monzonite and monzogranite are exclusively shoshonitic and high-K to shoshonitic, respectively. Nd isotopic values overlap with contemporaneous depleted mantle indicating that the granitoids represents melts derived from predominately juvenile mantle or crust. The high Mg# and high contents of compatible trace elements (e.g. Cr, Ni) in the quartz monzonite preclude a crustal source. On the other hand the quartz monzonite is LILE-rich with strongly fractionated REE patterns. These are some of the main features of the sanukitoid rocks. The monzogranite display wide range of silica content, low to moderate Mg#, strongly fractionated REE patterns, low contents of compatible elements and variable LILE-enrichment. Some of these geochemical characteristics are at variance with those of sanukitoid and closepet-type granitoids.

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## **THE EARTH'S CORE HAS GONE TO POTS**

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During the last 150 years the Earth's dipole magnetic field intensity has decreased by an average of 5 to 10% and by 30% at Cape Town. This decay may be related to the growth of a patch of reversed field flux in the Southern Hemisphere over the South Atlantic Ocean and southern Africa. Numerical simulations of the geodynamo suggest that the development of such patches may be a precursor to geomagnetic reversals, fuelling speculation about the onset of such an event. If a longer record were preserved, extending back in time beyond the data available from modern magnetic observatories, it would be possible to have a better understanding about the nature of this decline. Unfortunately southern Africa has a dearth of Holocene and Quaternary rocks suitable for developing such a record. However an alternative possibility is to use archaeological objects that, during their formation, experienced temperatures above the Curie temperatures of their constituent magnetic minerals. Palaeointensity analyses of such fired artefacts, commonly known as archaeomagnetism, have yielded longer term geomagnetic records in the Northern Hemisphere but there are no extensive records from the Southern Hemisphere. The opportunity to develop such a record exists in southern Africa due to the Bantu migrations and colonisation of this region during the last two millennia. The firing of ceramics, burning down of huts and grain bins, and the hearths of fires and smelters, all potentially contain a record of the intensity of the Earth's magnetic field at their time of formation. Furthermore, the pottery stratigraphy that has been developed for the region provides well constrained dates from about 450 AD for the ceramics found at various Iron Age sites. The results to date suggest that Iron Age ceramics contain magnetic minerals of appropriate composition and size to retain a high resolution record of past field intensity. Preliminary data reveal previously unsuspected changes in the palaeointensity of the Earth's magnetic field over southern Africa, particularly at about the time of the decline of Mapungubwe in the Limpopo valley and the rise of Great Zimbabwe.



## ZIMBABWEAN ARCHAEOAN STROMATOLITES AND THE HISTORY OF OXYGEN IN THE AIR

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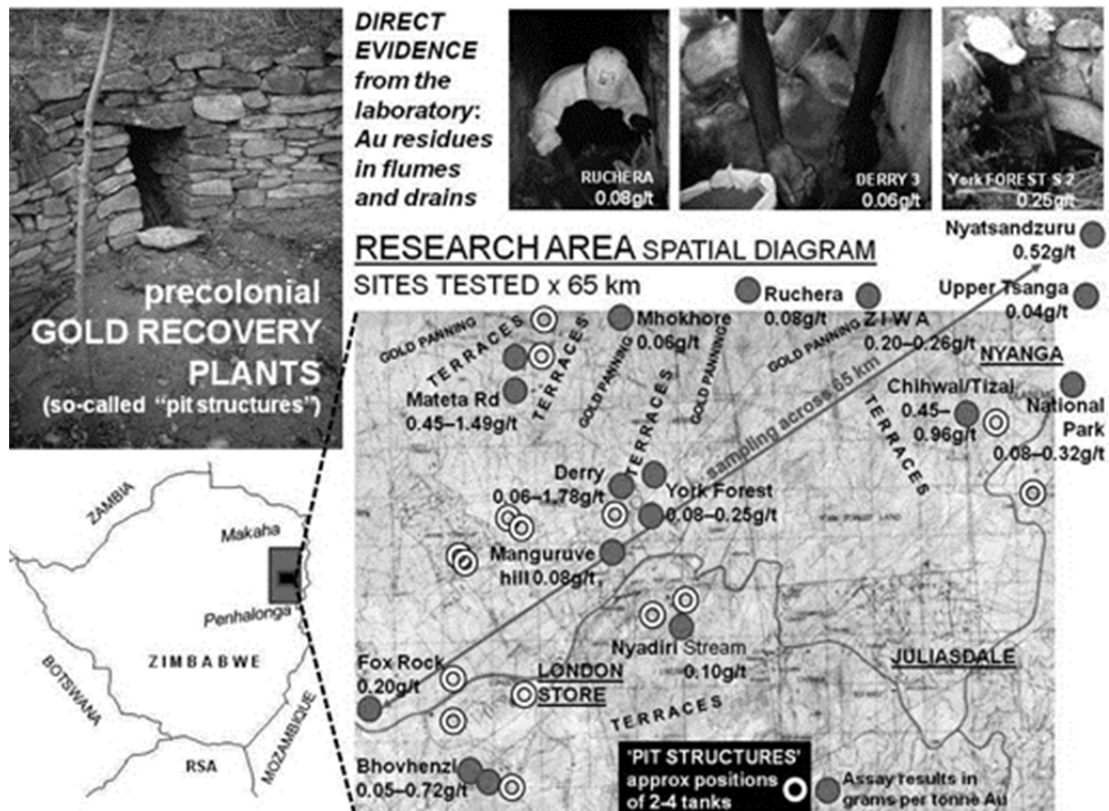
Archaean stromatolites have been known in Zimbabwe since their discovery in the Huntsman Limestones by A.M. Macgregor (*Trans. geol. Soc. S. Afr.*, **43**, 9, 1940), when working for the Geological Survey (Bull. Geol. Surv. Rh. **30**, 1937). The rocks were shown to be Archaean by Bond, Wilson and Winnal (*Nature*, **244**, 275). In the 1970s, late Archaean stromatolites were reported in the Belingwe belt by Bickle et al., (*Earth Plan Sci Lett.* **27**, 155-162, 1975) and by Martin (Bull. Geol. Surv. Rh., 83, 1978). The Cheshire Fm. stromatolites are now thought to be about 2.65Ga old, while the underlying Manjeri Fm. examples are close to 2.7 Ga old. Not far away, the Mushandike stromatolites were described by Orpen and Wilson (*Nature*, **291**, 218-220, 1981). These are now thought to be older than 2.83 Ga, almost exactly the age of the similar strata at Steep Rock, Ontario and in the Pongola Supergroup, South Africa (see review of dating by Nisbet et al., *Geobiology*, **5**, 331-355, 2007).

C isotopic records in these rocks, when interpreted in the context of S isotopes and petrography, as well as other indicators of local oxygenic habitats, imply strongly that rubisco-mediated oxygenic extraction of carbon from CO<sub>2</sub> was occurring (Nisbet et al., op.cit.). In contrast to pre-3Ga Archaean strata, in which the C and S isotopic records suggest methanogenesis and anoxygenic photosynthesis, the 2.9 Ga Mushandike, Steep Rock, and Pongola carbonates may record the start of oxygenic photosynthesis. By the time of the ~2.7 Ga Belingwe stromatolites and associated organo-sedimentary deposits, a biochemically complex microbial community had probably evolved, with emission of oxygen into local photic-zone waters, though the bulk of the deep seawater and the air likely remained anoxic.

# BEFORE 1910. ARCHAEOLOGY OF NYANGA REVEALS DIRECT EVIDENCE OF PRECOLONIAL GOLD EXPLORATION AND RECOVERY IN ZIMBABWE'S EASTERN HIGHLANDS

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Nyanga district of Zimbabwe's Eastern Highlands is not known for the occurrence of gold. Paradoxically, and supported by recent discoveries of primary sources in its terraced hills, today's undercover gold panners are living testimony to the presence of gold in the region. Anomalous quantities of quartz rubble on manmade terraces between the Makaha and Penhalonga goldbelts, and much crushed quartz in and around their associated 'pit structures', are not mentioned in previous research. For the past century a theory of livestock stallfed in the 'pit structures' to provide manure to enable terrace cultivation on infertile hillslopes has dominated interpretation of the archaeology. In 2005 when Kritzinger was granted a Research Council of Zimbabwe permit to study the archaeology from a mining perspective questions about gold in Nyanga took a new direction. This paper presents empirical proof of precolonial gold enterprise from field observation and a self-funded geochemical pilot totalling 101 assays to date. Thirty residue grades of 0.04-1.78g/t Au from 26 'pit structures' sampled across a 65-km radius is direct evidence of their role as gold recovery plants. Geological clues that Nyanga's massive land modifications derive from strip-mining and stream-working challenge theories of intensive farming.

# THE HYDROGEOLOGY AND DEVELOPMENT OF SAND RIVERS

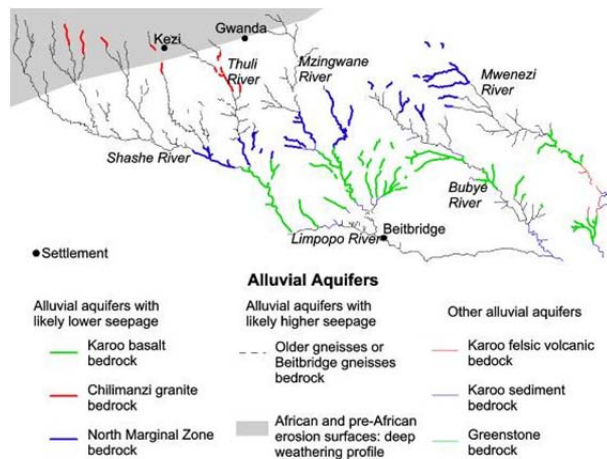
David Love

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Sand is not the most exciting of geological resources, and some would say that sand rivers, which only flow for a few months of the year, are not the most exciting of rivers either. However, the sandy beds of these rivers form alluvial aquifers, which have great potential as an alternative to conventional surface water reservoirs for storage – or for conjunctive use with surface reservoirs.

Sand rivers at several sites in southern Zimbabwe, and on varied geological backgrounds were studied. The largest sand river studied, the Lower Mzingwane, was shown to store around  $38 \times 10^6 \text{ m}^3$  of water, most of that storage being beyond the reach of evaporation. Current water usage can be more than tripled: the catchment could supply water for currently-planned irrigation schemes (an additional 1,250 ha), and the further irrigation of two strips of land along each bank of the Mzingwane river (an extra 3,630 ha) – without construction of any new reservoirs.

Studies of smaller sand rivers showed that seepage is the major loss of water from an alluvial aquifer, and so the geological environment is critical. Seepage is likely to be highest on the older (cratonic) gneisses and lowest on Karoo basalts and Chilimanzi granites. It is thus possible to suggest exploration targets for alluvial groundwater in sand rivers, the aquifers identified from remote sensing.



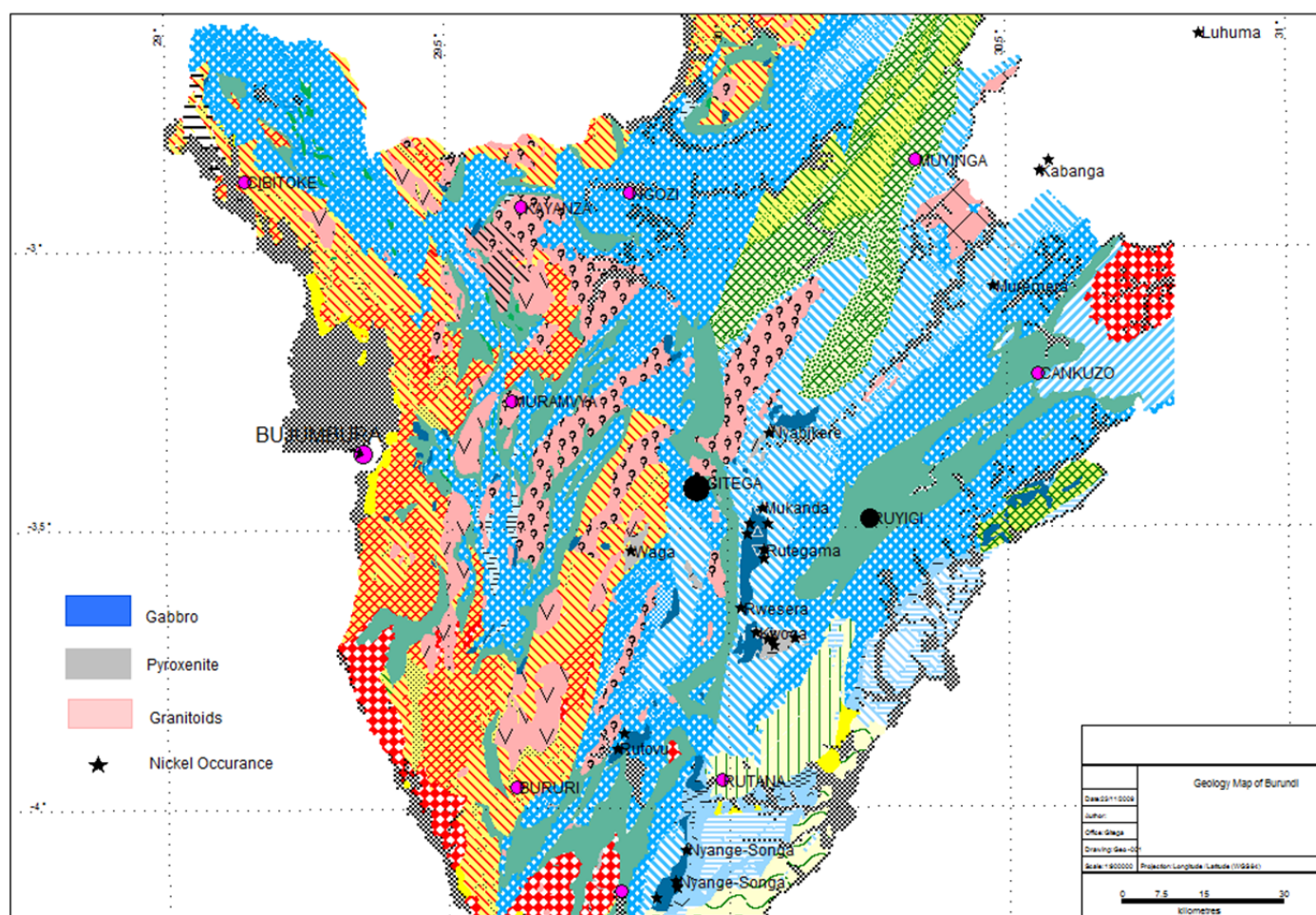
# THE CONTRIBUTION OF GEOPHYSICAL EXPLORATION TECHNIQUES TO SULPHIDE NICKEL EXPLORATION IN BURUNDI

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Burundi, a small country in central Africa lies within 1330-1250 Ma old Kibaran metamorphic belt. It hosts a number of intrusions, which are part of a 350km metallogenic belt, which includes Kabanga sulphide nickel deposit in Tanzania. The intrusions are hosted in continental shelf Qz-Fs sediments as stratiform sills and lenses.

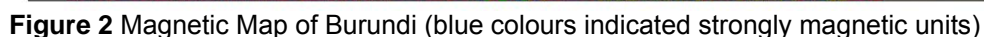
Eight intrusions have been documented in Burundi (Deblond, 1993, 1994). They include, from north to south, the Muremera, Nyabikere, Waga, Mukanda-Buhoro, Musongati, Rutovu, Nyange-Songa and Mugina intrusions (Fig. 1). Among them, two broad types of intrusions can be defined: those, which mainly consist of ultramafic rocks, such as Waga, Musongati, Nyabikere and Muremera, and those dominated by gabbroic rocks, such as Mukanda-Buhoro, Nyange-Songa, Rutovu and Mugina (Jean-Clair Duchesne, Jean-Paul Lie'geois, André' Deblond, and Luc Tack 2004).



**Figure 1** Geology Map of Burundi

Outcrops are scarce hence; rock sampling is only possible through drilled cores. Regional magnetic data flown at a km line spacing shows NNE striking anomalies associated with sediments and strongly magnetic Nyabikere, Musongati, Waga intrusions that are more ultramafics and relatively lower intensities on Mukanda/Buhoro gabbroic units (Fig. 2).

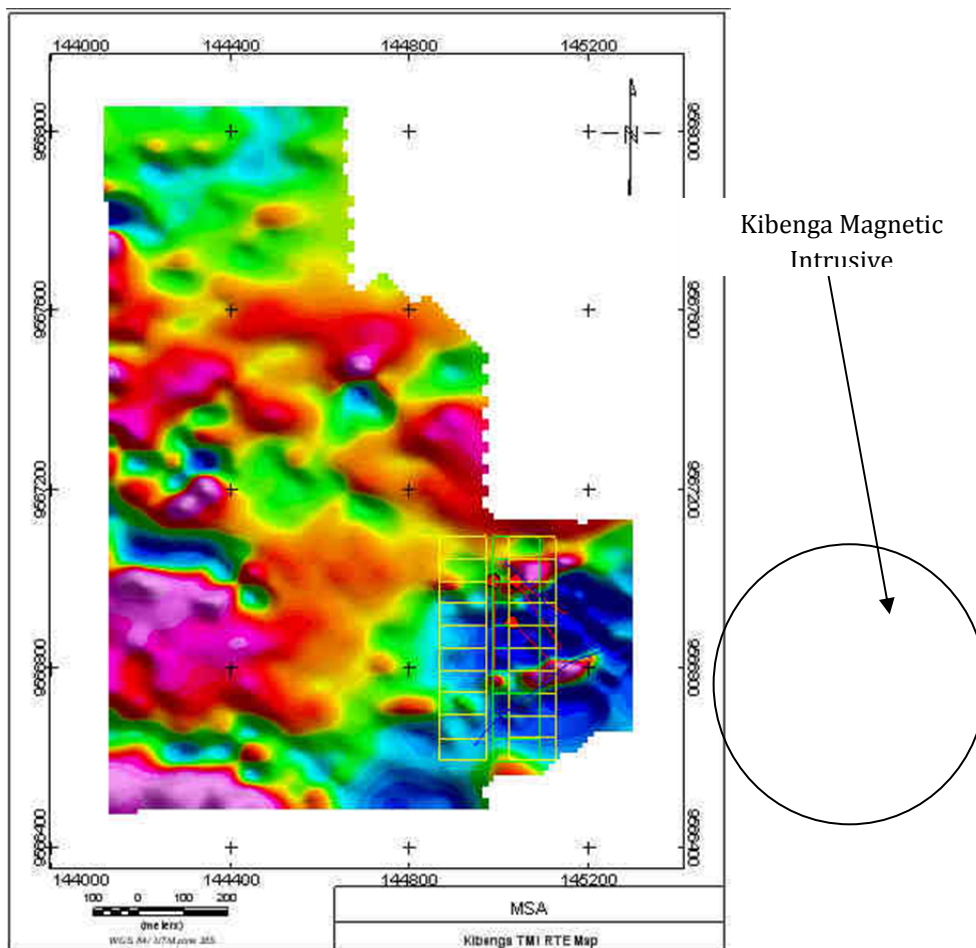




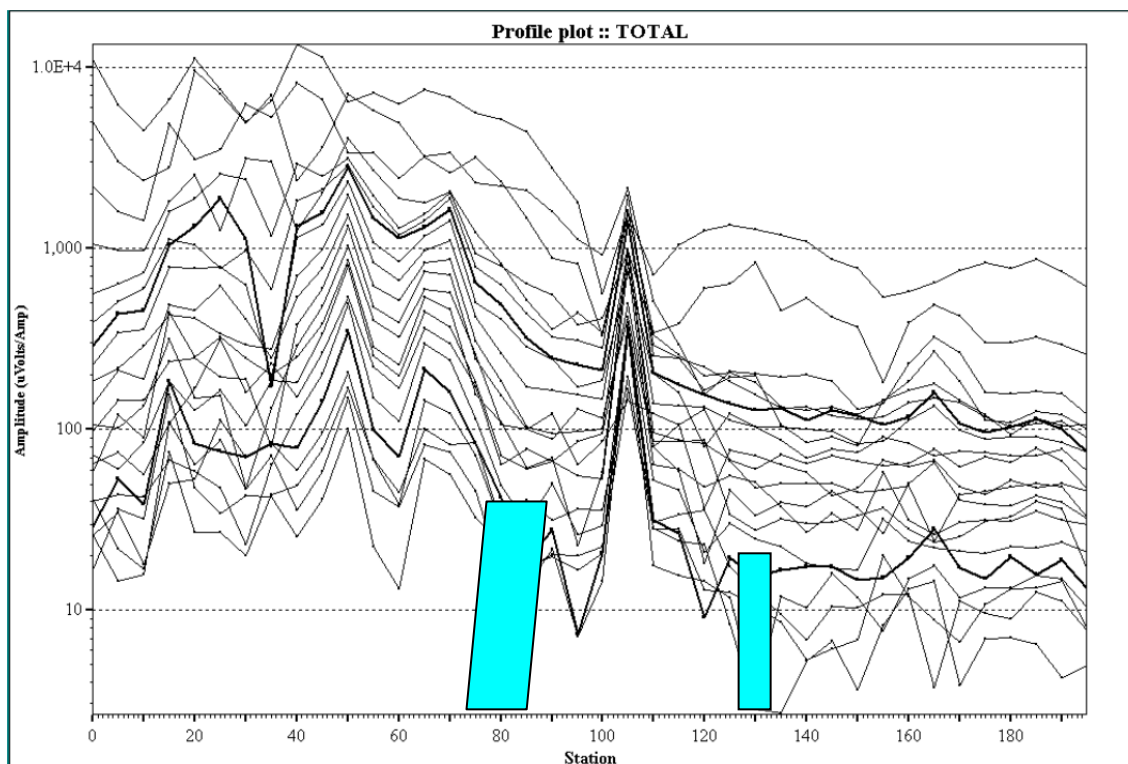
On Kibenga prospect within the Rutovu intrusive, an indication of an ultramafic unit plunging SE beneath the quartzite manifests from the ground magnetic data and previous drilling campaigns failed to intersect the contact (Fig. 3). An easterly trending structure cuts the intrusive and responds strongly to the slingram survey indicating that it is steeply dipping. Down hole surveys on the drilled holes indicated that the holes completely missed the more conductive unit to the west (Fig. 4).

Exploration over the Mukanda-Buhoro intrusive was largely by detailed ground magnetic surveys and single loop configuration TEM surveys using the terraTEM system. The northwesterly trending magnetic anomalies are largely due to mafic units and anomalous dB/dt from TEM have been identified (Fig. 5).

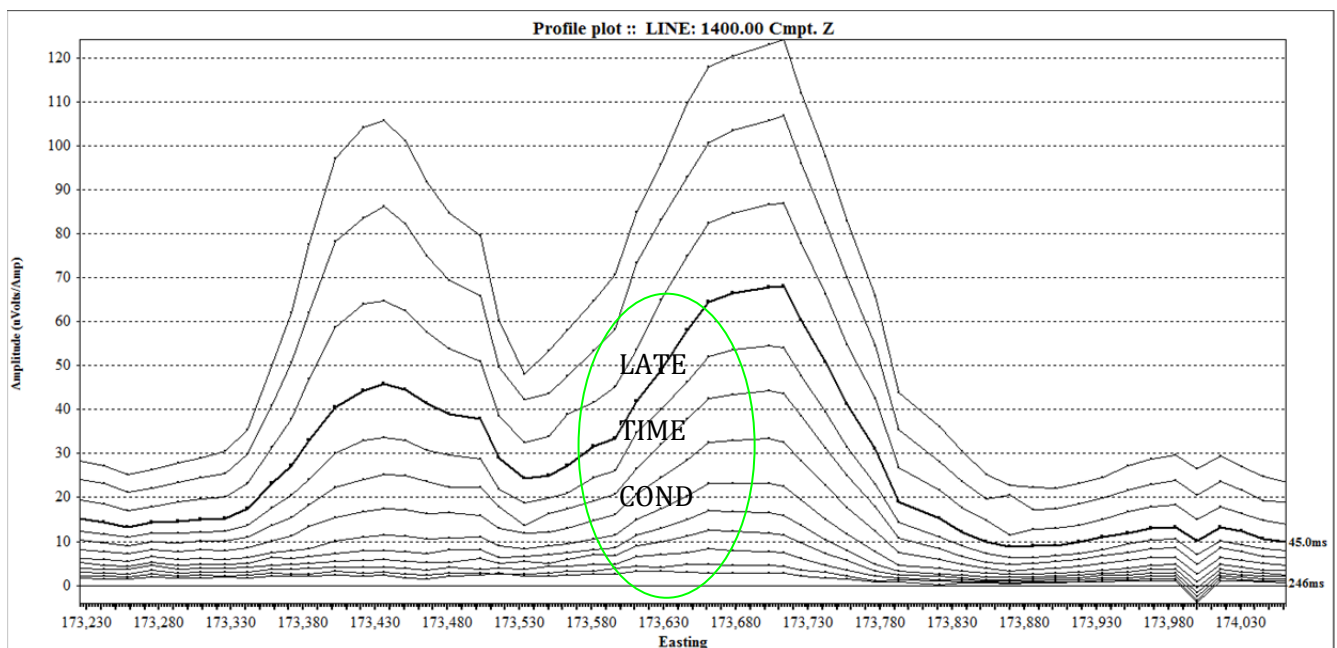




**Figure 3** Magnetic Map of Kibenga Prospect (blue colours indicated strongly magnetic units)



**Figure 4** Component: Total Vector (Local conductor dipping from hole)



**Figure 5** dB/dT Profile for Late Channels (Channels 48 to 60)

## WHOLE ROCK GEOCHEMISTRY: A STRATIGRAPHIC TOOL IN THE BOTSWANA KAROO

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The Karoo Supergroup of Botswana unconformably overlies Archaean and Proterozoic rocks. They are however, poorly exposed being in turn overlain by up to 200m of Kalahari Beds. This Carboniferous - Jurassic succession comprises sequences of sedimentary and volcanic rocks, which are spread across southern Africa. In Botswana, rock complexes have been correlated between widely spaced boreholes based on macroscopically similar appearance and similar position in the succession. In neighbouring South Africa and Namibia these rocks are well exposed and the lithostratigraphy is well constrained by the fossil record. The Karoo units of Botswana have been correlated with these more precisely defined successions on the basis of lithostratigraphy only and are unsupported by other criteria and as such are limited; especially considering the different depositional settings between Botswana and South Africa.

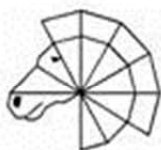
Two boreholes from the Western Central Kalahari Sub-basin of the Botswana Karoo (10181C-Kang; CKP-8C-Tshane) were sampled (fine grained sediments) throughout its length through the Beaufort and Ecca Groups with a view to establishing a chemostratigraphy. The strata represent the transition from the glacial Dwyka below through lacustrine conditions at the bottom of the Ecca with a prograding and then retrograding delta throughout the mid and late Ecca and a return to lacustrine conditions in the Beaufort Group.

Major element discriminant analyses show that the deltaic material of the Kweneng Formation and Boritse Formation was sourced from recycled continental crust. The basinal mudstone and siltstone below and above fall into an intermediate-mafic igneous field. Most samples have distinct negative europium anomalies ( $\text{Eu}/\text{Eu}^* = 0.49-1.27$ ; av. = 0.75) and most values are characteristic of sediments of cratonic derivation. A clear shift in  $(\text{Gd}/\text{Yb})_N$  in the basinal pro-delta shales (the Bori Formation) is generally 2.0 or greater, which is typical of an Archaean signature, whereas post-Archaean rocks usually have  $(\text{Gd}/\text{Yb})_N$  1.0 – 2.0 as seen for the strata above the delta mouth bars and channels (average 1.6). In a diagram in which  $(\text{La}/\text{Yb})_N$  plotted against  $\text{Ce}_N$  shows a relationship between REE fractionation and provenance, the samples from the Ecca's lacustrine Kwetla Formation and Bori Formation fall into the Intermediate Igneous Provenance Field along with data from the Dwyka, whereas the deltaic Kweneng and Boritse Formation belong to the quartzose provenance field. This agrees with indicators from the major element discriminators.

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