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13th Annual AfricaArray Workshop

School of Geosciences
University of the Witwatersrand
Johannesburg, South Africa

24 June - 27 July 2018

Programme

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University of the Witwatersrand, Johannesburg, South Africa

Wednesday 20 June to Friday 14 July		***AfricaArray International Field School***
Sunday 24 June	*9h30-16h00*	***AfricaArray station operator course*** *Andy Nyblade, Ranto Raveloson*
Sunday 24 June	*9h30-16h00*	***Field trip to the Vredefort Dome*** *The largest and oldest meteorite impact crater on Earth* *A UNESCO World Heritage Site*
Monday 25 June & Tuesday 26 June	*8h00-20h00 & 8h00-20h00*	***AfricaArray Scientific Meeting***
Wednesday 27 June	*09h00-13h00*	***Workshop: Research Skills*** *Sarah Stamps, Virginia Tech, USA* Transferrable skills that will make you a more efficient scientist. In particular, you will learn how to use parts of the Google Project Management Suite, specifically Draw (for posters), Presentation, and Docs as well as some LaTeX via Overleaf.
Wednesday 27 June	*9h00-16h00*	***Workshop: ICDP-DSeis Scientific Drilling & Rock Physics*** *held under the auspices of the Japan/South Africa Joint Science and Technology Research Collaboration Project (PIs Yasuo Yabe, Musa Manzi)* An interactive workshop where we will share learnings from the DSeis project with regard to drilling and borehole logging technology and discuss the state-of-the-art regarding borehole geophysics and rock physics.

GLT Lecture Theatre, Geosciences Building, Wits **Monday 25 June 2018**

***Abstract appended**

08:00 - 08:30 **REGISTRATION**

08:30 - 08:40 Welcome
Professor Ebrahim Momoniat (*Dean, Faculty of Science, University of the Witwatersrand*)

08:40 - 09:00 AfricaArray status report - network activities and development plan
Andy NYBLADE (*Penn State University USA*)

09:00 - 09:15 Training and complementary activities
Ray DURRHEIM (*University of the Witwatersrand & CSIR, SOUTH AFRICA*)

09:15 - 09:30 Building geophysics talent and opportunity in Africa: experience from the AfricaArray/Wits Geophysics Field School
Susan WEBB (*University of the Witwatersrand SOUTH AFRICA*)

Theme: Structure and tectonics of Africa

09:30 - 10:00 **Invited keynote address**
*****Nuclear clocks: applications as tracers and chronometer in the Earth System
Mark BASKARAN (Wayne *State University, Detroit, Michigan, USA*)

10:00 – 10:30 ***TEA BREAK***

10:30 – 10:50 Crustal structure beneath some tectonic regions in West Africa
Ofonome AKPAN (*Centre for Geodesy & Geodynamics, NIGERIA*)

10:50 - 11:10 Investigation of shear wave velocity structure in Morocco using surface wave dispersion
Said BADRANE (*CNRST, MOROCCO*)

11:10 - 11:30 *****Lithospheric structure by seismic tomography and gravimetric data: case of the High Atlas
Youssef TIMOULALI (*CNRST, MOROCCO*)

11:30 - 11:50 *****Thinning crust with high Vp/Vs ratio beneath the Abou-Dabbab area, southeast of Egypt
Ahmed HOSNY (*National Research Institute of Astronomy and Geophysics, EGYPT*)

11:50 - 12:10 *****The juncture of the Choma-Kalomo Block, Magondi Belt, and Ghanzi-Chobe Belt in Zambia, Zimbabwe and Botswana: aeromagnetic data and geologic interpretation
Sharad MASTER (*University of the Witwatersrand, SOUTH AFRICA*)

12:10 - 12:30 *****Seismic evidence for plume- and craton-influenced upper mantle structure beneath the northern Malawi rift and the Rungwe volcanic province, East Africa
Andy NYBLADE (*Penn State University, USA*)

12:30 – 12h40 ***GROUP PHOTO***

12:40 - 14:00 ***LUNCH BREAK***

***Abstract appended**

Theme: Reflection Seismology, Mineral & Energy Resources

14:00-14:15 Reflection seismics, seismicity and the deep biosphere
Musa MANZI (*University of the Witwatersrand SOUTH AFRICA*)

14:15 - 14:30 *****Neotectonic and hydrocarbon leakage assessment in the offshore Orange Basin using 3D seismic reflection data
Ahmed ISIAKA (*PhD candidate, University of the Witwatersrand SOUTH AFRICA*)

14:30 - 14:45 *****3D structure of the Congo Basin from joint inversion of surface waves and gravity
Ranto RAVELOSON (*University of the Witwatersrand SOUTH AFRICA*)

14:45 - 15:00 *****Acoustic impedance inversion and seismic frequency attributes in reservoir characterisation: the offshore Orange Basin case study
Chris SAMAKINDE (*Postdoctoral fellow, University of the Western Cape SOUTH AFRICA*)

15:00 - 15:15 The Central African Craton revealed using SHRIMP U-Pb zircon geochronology
Hielke JELSMA (*AngloAmerican, SOUTH AFRICA*)

15:15 - 15:50 ***TEA BREAK***

Theme: Geodesy and space science

15:50 - 16:10 *****Active tectonics on Madagascar: consistent with Somalian plate kinematics?
Sarah STAMPS (*Virginia Tech USA*)

16:10 - 16:25 Determination of geodetic velocity field parameters of Nigeria from GNSS
Joseph DODO (*National Space Research and Development Agency (NASRDA), NIGERIA*)

16:25 - 16:40 *****Analysing ground surface position GPS and meteorology measurements in southern Africa using signal processing techniques
Sikelela GOMO (*MSc candidate, University of the Witwatersrand, SOUTH AFRICA*)

16:40 - 16:55 The use of ground-based GNSS observations for monitoring weather events over Nigeria
Olalekan Adekunle ISIOYE (*Ahmadu Bello University, NIGERIA*)

16:55– 17:10 Estimation of precipitable water vapour from GNSS measurements in Nigeria: spatial distribution and seasonal variation
Joseph DODO (*National Space Research and Development Agency (NASRDA), NIGERIA*)

17:30 - 19:30 **GEophysical iNnovatIon Showcase (GENIuS)**

ATRIUM OF THE BERNARD PRICE BUILDING

GLT Lecture Theatre, Geosciences Building, Wits **Tuesday 26 June 2018**

***Abstract appended**

Theme: Seismic monitoring and hazard assessment

08:30 – 09:00 **Invited keynote address**
*Drilling into seismogenic zones of M2.0–M5.5 earthquakes in deep South African gold mines
Hiroshi OGASAWARA (*Ritsumeikan University, JAPAN*)

09:00-09:15 Active fault mapping in Mozambique
Vladimiro MANHICA (*National Institute of Mines, MOZAMBIQUE*)

09:15 - 09:30 *Seismic Risk Awareness and Emergency Preparedness in Zimbabwe: A case study of Harare Metropolitan City
Gilberta THWALA (*University of Zimbabwe)*

09:30 - 09:45 *Seismic Hazard assessment of the Democratic Republic of Congo and surrounding areas based on recent compiled seismic zonation source models
Georges MAVONGA TULUKA (*Goma Volcanic Observatory DRC*)

09:45 - 10:00 *New insights into the causes and impacts of recent earthquakes in Nigeria and immediate environs
Umar KADIRI (*Centre for Geodesy & Geodynamics, NIGERIA*)

10:00 – 10:45 ***TEA BREAK***

10:45 - 11:00 *Re-assessment of source parameters of major South African earthquakes
Brassnavy MANZUNZU (*PhD candidate, University of the Witwatersrand & Council for Geoscience, SOUTH AFRICA*)

11:00 - 11:15 *Strategic Environmental Assessments: fracking, electricity grid infrastructure & gas pipeline networks
Ray DURRHEIM (*University of the Witwatersrand, SOUTH AFRICA*)

Theme: Mining, near-surface & groundwater

11:15 - 11:30 Bedrock and fracture zone delineation using different near-surface seismic sources
Bojan BRODIC (*Postdoctoral fellow, Uppsala University, SWEDEN)*

11:30 - 11:45 Hydrological modelling
Ruta PLAKANE (*MSc candidate, Uppsala University, SWEDEN)*

11:45 - 12:00 Using empirical relationships to predict PPV for surface explosions
Michelle GROBBELAAR (*Council for Geoscience, SOUTH AFRICA*)

12:00 - 13:30 ***LUNCH***

13:30 - 13:45 *Shallow reflection seismics at Lancaster Mine, Krugersdorp
Emmanuel ONYEBUEKE (*PhD candidate, University of the Witwatersrand, SOUTH AFRICA*)

13:45 - 14:00 *Efficient electromagnetic geophysical methods for evaluating ground water drilling sites for drought relief
Wesley HARRISON (*MSc candidate, University of the Witwatersrand, SOUTH AFRICA*)

14:15 - 14:15 *Geophysical methods to detect shallow coal mine workings, Ermelo South Africa
Nkimo MOLELEKI (*MSc candidate, University of the Witwatersrand, SOUTH AFRICA*)

***Abstract appended**

14:15 - 15:30 ***TEA BREAK & POSTERS***

Theme: Initiatives allied to AfricaArray

15:30 - 15:45 IASPEI & the African Seismological Commission
Michelle GROBBELAAR (*Council for Geoscience, SOUTH AFRICA*)

15:45 – 16:00 IUGS Resourcing Future Generations initiative
Ray DURRHEIM (CSIR & *University of the Witwatersrand, SOUTH AFRICA*)

16:00 – 16:15 ICSU Regional Office for Africa: Science Plans
Richard GLOVER (*ICSU Regional Office for Africa*)

16:15 – 16:30 American Geophysical Union (AGU) & Society of Exploration Geophysicists (SEG)
Susan WEBB (*University of the Witwatersrand SOUTH AFRICA*)

17:00 – 18:30 **SAGA Talk**
Cluster Computing in Geophysics
Renier DRYER (Crunchyard)

18:30 - 20:00 **POSTERS & SNACKS IN THE BLELOCH MUSEUM**

Posters on display in the Bleloch Museum, 25-27 June 2018

***Abstract appended**

Earth Structure & Resources

*Crust and upper mantle structure beneath Kenya from ambient noise
Mary KARANJA (*PhD candidate, University of Nairobi, KENYA*)

*Geophysical investigation of the Lithosphere beneath Cameroon and implications to the setting of the Cameroon Volcanic Line
Alain Pierre TOKAM KAMGA (*University of Douala, CAMEROON*)

*Vertical Sounding and magnetic survey for targeting groundwater potential zones in the Port Alfred area, Eastern Cape, South Africa.
Mthulisi MPOFU (*University of Fort Hare, SOUTH AFRICA*)

Application of vertical electrical sounding (VES) for subsurface geophysical investigation in Eseka, new gold-bearing area in central Cameroon
Evariste NGATCHOU HEUTCHI (*University of Younde 1, CAMEROON*)

Geodesy and Space Science

*Gravity gradient inversion of the West African Moho depth using tesseroids
Peter HAAS (*PhD candidate, Kiel University, GERMANY*)

*Crustal deformation signatures in the gravimetric geoid models of Tanzania
Prosper ULOTO (*Ardhi University, TANZANIA*)

Tectonics, Earthquakes, Volcanoes & Geohazards

tbc
Sylvanus Tetteh AHULU (*Geological Survey Department, GHANA*)

*Geophysical investigation of the seismicity of the Weija area, southeastern Ghana
Paulinah AMPONSAH (*Geological Survey Department, GHANA*)

*Post-eruptive seismic activity of Mt Cameroon for the period 2005-2017
Bekoa ATEBA (*Institute of Geological and Mining Research (IRGM), CAMEROON*)

*Egyptian National Seismic Network (ENSN), twenty years of continuous recoding, Egypt
Hazem BADRELDIN (*National Research Institute for Astronomy & Geophysics, EGYPT)*

*The Zambia Seismic Network
Mirriam Mwango CHILESHE and Grace MUSONDO (Geological Survey Department, ZAMBIA)

*Strain accommodation of Cenozoic Rifting in the Northern Margin of the Shire Graben, Southern Malawi
Patrick CHINDANDALI (Geological Survey of Malawi, *MALAWI*)

*Geological, geophysical and seismological investigations for siting of seismic stations in Minna and Abakaliki, Nigeria for data reliability
Umar KADIRI (*Centre for Geodesy & Geodynamics, NIGERIA*)

*Tectonic evolution of Macquarie Arc from geologically-constrained geophysical mapping
Khumo LESEANE (*Monash University, AUSTRALIA*)

*Seismicity in the NW Namibia: 01 January – 31 May 2012
Bufelo LUTSHITELE (*Geological Survey of Namibia, NAMIBIA*)

***Abstract appended**

*****The aftershock sequence if the 03 April 2017 - Botswana earthquake
Joseph Rapula MARITINKOLE (*Botswana Geosciences Institute*)

*****Local Site Effects during the Orkney Earthquake of 5 August 2014
Vunganai MIDZI (*Council for Geoscience, SOUTH AFRICA*)

*****Malawi: Nsanje March 8 2018 earthquake occurrence and its effects
Felix MPHEPO (*Geological Survey of Malawi, MALAWI*)

*****Ground motion simulations for Zimbabwe
Anele NCUBE (*National University of Science & Technology, ZIMBABWE)*

*****Recent Seismicity (2014- 2017) of the Okavango Delta Region (ODR): Contribution of Botswana's Seismic Network
Onkgopotse NTIBINYANE (*Botswana Geosciences Institute*)

Seismicity and an overview of Earthquake Observation in Uganda
Joseph NYAGO (*Directorate of Geological Survey & Mines, UGANDA*)

*****Preliminary study on Probabilistic Seismic Hazard for Madagascar
Tsitsi RAKOTONDRAIBE (*PhD candidate, University of the Witwatersrand, SOUTH AFRICA*)

*****Hebron fault scarp in Namibia using a high-resolution satellite-photogrammetry-derived DEM
Guy SALOMON (*University of Cape Town*)

*****Recently felt earthquakes in Durban South Africa
Mayshree SINGH (*University of KwaZulu-Natal, SOUTH AFRICA*)

*****Uganda National Infrasound Network Project
Isaiah TUMWIKIRIZE (*Directorate of Geological Survey & Mines, UGANDA*)

ABSTRACTS

Geophysical investigation of the seismicity of the Weija area, Southeastern Ghana

Paulina AMPONSAH[1] and Mawuli Akoto[2]

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2 Department of Earth Science, University of Ghana, Accra, Ghana
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A geophysical survey was carried out in the Weija area in southeastern Ghana to investigate the seismicity of the area. Three geophysical methods namely Radon gas level monitoring, Very Low Frequency Electromagnetic (VLF-EM) and Magnetic methods were employed to delineate the faults which likely cause the seismic activities. The data obtained were reduced, interpreted and correlated with the geology of the area. The radon gas method was employed as a reconnaissance method and the VLF-EM and magnetic methods were employed as detailed verification survey methods. All three methods employed delineated the Togo/Birimian contact as a fault zone. This fault zone is seismically active as indicated by the alignment of microearthquake epicenters. Other structures which are representative of faults were also delineated. The results confirm that the seismic activity in the Weija area is related to deep seated faults whose near surface expressions are indicated by the faults that have been delineated in the study.

Keywords: Ghana, seismicity, geophysical investigation, fault systems

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Post-eruptive seismic activity of Mt Cameroon for the period 2005-2017

B. ATEBA[1,2] and F.E. Mbossi

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Located in the Gulf of Guinea, Mount Cameroon is part of an alignment on nearly 1600 km of volcanic islands and continental volcanoes. Its volcanic eruptions are usually preceded by seismic swarms, which are thus perceived as amajor precursors. Since its last eruption in 2000, we continued monitoring its seismicity. It is diffuse on the flanks and distributed in the crust and below to depths of more than 60 km. In the crust, there is a correlation between seismicity and tectonics, and the recorded signals are of tectonic origin. On the other hand, events of deeper origin are volcano-tectonic type, and are generally located on the east flank. Seismicity is characterized by a monthly average frequency of 20 to 30 events, all of magnitude <3. During periods of crisis, the frequency is at least doubled. Between 2005 and 2017, three periods of seismic swarms lasting two months or more, were observed in 2010, 2012 and 2014. Monthly frequencies greater than 200 earthquakes were recorded for more than two months in 2014, without resulting in a volcanic eruption. The period following the last 2000 eruption should be characterized by low stress concentrations, which would explain the absence of felt earthquakes or the initiation of a new volcanic eruption. Thus, all seismic swarms on Mount Cameroon do not necessarily announce a volcanic eruption.

Keywords: Mount Cameroon, seismicity, seismic swarms, volcanic eruptions

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Egyptian National Seismic Network (ENSN: Twenty years of continuous recording, Egypt

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Egypt is distinguished by low to moderate earthquake activity that is related to the relative motion between African, Arabian and Eurasian plates. Egypt has experienced many damaging earthquakes in both historical and recent time. It is one of the few regions of the World where evidence of historical earthquake Activity has been documented over the history from 2200 B.C. The beginning of earthquake recording in Egypt started by installing the first seismic station at Helwan (25 km south of Cairo) in 1899, then it became one of the American World Wide Standardized Seismograph Network (WWSSN). In 1975 another two stations were installed in Aswan and Abu- Simbel south of Egypt due to the importance of this region as it contains Aswan High Dam and Abu Simple Temple. After 14 November 1981 Aswan earthquake with magnitude 5.6 , 13 telemetric short period seismic stations were installed around Kalabsha fault and Nasser Lake for monitoring the local seismic activity in that area , few years later all of these stations converted to broad band stations. The 12 October 1992 earthquake (Mb 5.8, 561 deaths, injured 9832 and left a damage of more than 35 million U$) was the main reason of installing and operation the Egyptian National Seismological Network (ENSN). From 1997 to present continuous earthquakes data have been collected from ENSN . There are 70 seismic stations distributed in the whole area of Egypt and five sub-centres send their data to the main centre in Helwan . According to the general distribution of the recent major earthquake epicenters in Egypt and vicinity, the most active seismic zones have been divided into seven regions; Aswan, Abu Dabbab, Beni Suef, Dahshour, The Gulf of Suez region, The Gulf of Aqaba region, and The Northern Egyptian Continental Margin.

Keywords: ENSN, Seismicity, Egypt.

Nuclear Clocks: Applications as Tracers and Chronometer in the Earth System

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Applications of isotopes, both radioactive and stable, have revolutionized our understanding of the Earth system and our environment. The applications of isotopes as tracers and chronometers have permeated not only every sub-branch of geosciences, but also archaeology, anthropology, and environmental forensics. In particular, the short-lived radioactive isotopes have served as powerful tracers and chronometer in quantifying the environmental changes that have taken place in Anthropocene. In this presentation, we show the applications of a suite of short-lived radionuclides from U-Th series (^{210}Pb, ^{210}Po, ^{222}Rn, ^{223,224,226,228}Ra), cosmogenic (^{7}Be) and anthropogenic (^{134,137}Cs, ^{238,239,240}Pu) radionuclides as tracers and chronometers. The vastly differing geochemical and nuclear properties of these nuclides aid in using these as proxy for quantifying the fate and transport of other organic and inorganic species, including particle-reactive species (with high K_d), water soluble species (low K_d) and non-reactive species (noble gases). Applications of radon (^{220,222}Rn) along with He/Rn ratio as a precursor for predicting earthquakes will be summarized. The need for a short-lived radioactive counting lab with alpha, beta, gamma spectrometers and other accessories will be made as this is anticipated to significantly enhance the research productivity and help building human capital in South Africa and other countries in the African continent.

Keywords: Applications of short-lived isotopes; ^{210}Pb, ^{137}Cs, Pu-based chronology, coastal water mass mixing

Methodologies for site characterization using seismic method at urban, mining and other sites: three-component digital-based seismic landstreamer and beyond

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To support urban infrastructure planning projects, along with various other applications, a multicomponent landstreamer was developed. The landstreamer was built with broadband (0-800 Hz), three-component (3C) micro-electro-mechanical system (MEMS) sensors. The MEMS sensors are of similar nature as those found in "smartphones" nowadays and their digital nature makes the developed landstreamer insensitive to electric/electromagnetic noise. The landstreamer's design and its seismic imaging capabilities, along with the MEMS technical specifications, were evaluated in several studies. When comparing signals recorded with the landstreamer against planted MEMS sensors, no negative effects of the design were noted. Compared to different geophones tested, the streamer produced higher quality and broader signal bandwidth data. Additionally, a seismic study conducted in a tunnel demonstrated its electric/electromagnetic noise insensitivity. The streamer combined with wireless seismic recorders was used to survey logistically challenging areas for improved imaging and characterizations, without interference with traffic at various sites.

At one of the sites, the seismic response of fractures and their extent between a tunnel and the surface was studied. The velocity model obtained using the traveltime tomography approach showed well-characterized known fracture systems and indicated additional ones formerly unknown. Additionally, compressional- and shear-wave velocities, seismic quality factors, Vp/Vs and dynamic Poisson's ratios of the known fracture zones were obtained. Fractures and/or weakness zones in the bedrock were imaged using refraction and reflection imaging methods at a site contaminated with a cancerogenic pollutant in southwest Sweden, illustrating the potential of the streamer for environmental-related applications. Landstreamer's potential for imaging previously known, steeply dipping, ore body was illustrated at a site in central Sweden to support the idea of cost-effective seismics for mining applications. Here, the steeply dipping ore body was well imaged and the results confirmed by numerous boreholes.

We will also show results from other studies where going beyond conventional application of seismic methods has proven beneficial for 2D/3D site characterization, such as SH-wave reflection seismic imaging from a vertically oriented impact source and properties of randomly distributed array of seismic recorders for seismic imaging.
Keywords: landstreamer, 3C, unconventional seismics

The Zambia Seismic Network

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Zambia has been involved in the monitoring of seismological activities since 1950s when it started operation of the Zambia Seismic Network (ZSN) at Broken Hill Kabwe. This network has undergone major phases in its digitization processes from single analog component stations to the current three components. The Zambia Seismic Network currently includes digital broadband seismographic stations which are; KMZ, KTWE, ITZ, MONG, PTZ, LSZ and KSMZ. The ZSN has been operational since early 1980s with respective stations having operational and none operational epochs. The aim of the network is to monitor seismic activities in Zambia and surrounding areas and to advance the Government of the Republic of Zambia on the incidence of the earthquake activity.

Keywords: Zambia, Instrumentation, Monitoring.

Strain Accommodation of Cenozoic Rifting in the Northern Margin of the Shire Graben, Southern Malawi Rift

Wesley Prater[1], Kevin I. Vélez-Rosado[1], Alejandra Santiago-Torres[1], Amy R. Pritt[1], Daniel A. Laó Dávila[1], Elias Chikalamo[2], **Patrick CHINDANDALI[3],** Lois Kamuyango[2], Estella A. Atekwana[1], Mohamed G. Abdelsalam[1], and Jalf Salima[3]

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The NW-trending Shire Graben in southern Malawi is a Jurassic rift structure that marks the termination of the N-S striking Malawi Rift. Previous studies suggest that structures of the Shire graben accommodate extension of Cenozoic rifting by reactivation of normal faults as strike-slip faults. We conducted fieldwork to document and analyze the kinematics of structures at the northern escarpment of the Shire Graben, defined by the Mwanza and Thyolo faults. The escarpment is composed of Precambrian gneisses, schists, and amphibolites. These rocks have undergone deformation that generated well-developed foliation, folds, shear zones, and boudins. In the Thyolo escarpment, foliations strike NW-SE and NE-SW. Two different types of magma intruded the Precambrian rocks exposed in the Thyolo escarpment. Precambrian rocks within the Mwanza escarpment have foliations with a dominant NW-SE strike and a SW dip. The foliation is cut by NW-trending and NE-dipping strike slip faults. Few dikes were observed in the Mwanza escarpment area. Based on the data collected from both escarpments, we observe: (1) Dikes, associated to the regional Karoo Jurassic igneous event, dominate in the Thyolo Escarpment and not in the Mwanza Escarpment; (2) propagation paths of intrusions are not localized along foliation planes in the Precambrian rocks, but rather cut across it; (3) Faulting is rarely observed at the meso-scale in the Thyolo Escarpment, yet it is localized as strike slip faulting of unknown age in the western Mwanza Escarpment; (4) there are no fault surfaces that contain multiple striation directions observed in the study area that would indicate reactivation of faults. These results indicate that there is no meso-scale deformation observed in the Thyolo Escarpment that can be associated with current extension in the Malawi Rift. Strain is most likely accommodated along poorly-developed border faults to the north or along blind faults within the Shire Graben.

Keywords: Malawi Rift, Shire Graben, Strain Accommodation, Cenozoic rifting.

Strategic Environmental Assessments: fracking, electricity grid infrastructure & gas pipeline networks

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We report on the Seismic Hazard Assessment component of several Strategic Environmental Assessments (SEA) that have either been completed (shale gas development) or are in progress (electricity grid infrastructure, gas pipeline networks). The Department of Environmental Affairs commissioned the shale gas development SEA. We assessed the risk, if any, posed by earthquakes triggered by the injection of fluids. Natural earthquakes occur occasionally within the Karoo, and the increase in risk posed by fracking is considered to be slight. A range of mitigation measures are recommended. ESKOM has commissioned the energy corridor SEAs, which are still in progress. We will present the objectives, methodology and preliminary findings of these studies.

Keywords: strategic environmental assessment, seismic hazard assessment, earthquakes, landslides, shale gas development, fracking, electricity grid infrastructure, gas pipeline networks

Analysing ground surface position GPS and meteorology measurements in Southern Africa using signal processing techniques

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Continuous Global Position System (GPS) surface measurements reveal seasonal vertical and horizontal surface displacements. These displacements are due to tectonic and non-tectonic processes. Examples of non-tectonic processes are residual atmospheric delays, measurement noise, and human-induced errors. The research aims to understand the effects of change in meteorological processes, in Southern Africa, on surface displacement using time series analysis techniques. A comparative study between displacement, temperature, pressure, humidity, and rainfall data from 13 GPS and meteorological stations with an observation period of 4 years is conducted. The spectral analysis methods used to conduct the research are Fourier Transforms (FT), Wavelet Transforms (WT), Wavelet Semblance (WS), Cross Spectral Density (CSD), Coherence, and the Mean Resultant Length (MRL). FT and WT are used to decompose, detect, and quantify cyclicities in a time series. The WS, CSD, MRL and Coherence analysis methods are used to determine and quantify the relationship between the time series as a function of frequency. The time series are also correlated in the time domain using visual plots, cross-correlation plots, and Pearson's correlation.

Decomposing the surface displacement and meteorology time series, it is observed that the time series are often composed of an annual and a semi-annual signal. The semi-annual signal is often weak or non-existent in most of the meteorology time series. The temperature and surface displacement correlation is observed to be high in the frequency domain and moderate to low in the time domain analysis. The pressure and surface displacement correlation reveal a high negative correlation in the frequency domain and a low to no correlation in the time domain analysis. Rainfall, humidity, and surface displacement correlation seems to vary as a function of seasonal rainfall. In climatic zones where the rainfall season is in summer, the correlation between rainfall, humidity, and surface displacement is high to moderate in the frequency domain and low in the time domain. However, in climatic zones where the rainfall season is in winter, the correlation between rainfall, humidity, and surface displacement is high and negative in the frequency domain and low in the time domain.

We suggest that temperature and pressure could be the dominant meteorological factors contributing to seasonal fluctuation of surface displacements measurements. This is because if variations in rainfall and humidity were more influential to surface displacement; we would expect the phase difference between these processes and variations in surface displacement to be consistent throughout and the phase of the surface displacements to vary as a function of seasonal rainfall – which is not the case. The analysis of the data is still in progress, and we are exploring other possible interpretations and explanations.

Keywords: GPS, Surface displacement, Meteorology, time series, Fourier transforms, Wavelet transforms, Semblance, Mean Result Length, Cross Spectral Density.

Gravity gradient inversion of the West African Moho depth using tesseroids

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Satellite gravity data are well-suited to study crustal architecture, especially in those regions, where terrestrial data is lacking. One of those remote areas is the West African Craton (WAC) and its surroundings, where large areas are poorly covered with seismic information. Inversion of satellite gravity data can help to define a proper crustal model and to get a better image of the location of the Moho depth. Sensitivity tests have shown that the signal of gravity

gradients mainly arise from the upper crust, whereas the signal source of normal vertical gravity is more sensitive to deeper sources. We take this as a motivation to invert for the gravity gradient in order to enhance the crustal model of WAC and to link tectonic units inside the craton and in a West Gondwana configuration.

The topographic corrected satellite gravity gradient data are embedded into a novel inversion network, which allows to invert any arbitrary gravity component at a user-defined study area. As an initial Moho depth we take a novel model of global Moho depth, derived by geostatistical kriging analysis, based on the USGS active seismics database. The inverted Moho is constrained by terrestrial measured seismic Moho depths. Our final model shows long-wavelength features with a thickening of the Moho depth towards the southern part of WAC. We compare our Moho model to other recent models of the study area. The inversion is developed further into a Gondwana configuration, with the aim that seismic constraints of the whole Western Gondwana landmass control the distribution of the Moho depth.

Efficient electromagnetic geophysical methods for evaluating ground water drilling sites for drought relief

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Two locations in the Western Cape were selected for groundwater investigations during a drought. Two geophysical methods were used, direct current (DC) resistivity and magnetotellurics (MT). The first site near Hopefield in the Western Cape is on commercial farm land underlain by a ≈ 40 m thick clay layer. Beneath the clay lies a freshwater sandstone aquifer. Prior to drilling, The MT inversion models mapped a ≈ 40 m thick conductive clay layer overlying a resistive sandstone aquifer. The sandstone aquifer was penetrated at ≈ 41 m depth in agreement with the MT inversion model. The second target in the town of Robertson was located 1 km east from the town center. The survey objective was to find a fresh water sand stone aquifer, forming part of the Table Mountain sandstone (Peninsula Formation), for a residential complex near the survey site. The DC resistivity inversion model mapped a 5 - 7 m thick 2 - 10 Ω·m conductive overburden layer. Beneath the overburden layer is a 40 - 200 Ω·m resistive layer. The MT inversion models mapped a ≈ 9 m thick 5 - 10 Ω·m conductive overburden layer. A resistive 400 - 1000 Ω·m layer, which is interpreted as the sandstone aquifer target, is mapped at 50 - 90 m deep in the MT inversion model. At 200 m along the traverse, the contact at the 400 - 1000 Ω·m layer was chosen as the drill target. The MT models predicted the contact to be between 105 -115 m. The site was drilled and the contact was struck at ≈ 111 m, agreeing with the MT results. In both cases drilling was guided by geophysical modeling which resulted in need of fewer drill sites and more efficient fresh water exploration in time sensitive drought conditions.

Keywords: DC resistivity, magnetotellurics, drought relief.

Thinning crust with high vp/vs ratio beneath the Abuo Dabbab area, southeast of Egypt

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In this research study, the physical properties of the crust of the Abou Dabbab area have been investigated by computing the receiver functions. The results revealed a thinning crust of 26-27 km thickness and vp/vs ratio of 1.86, which reflect the effect of the red sea rift system. The observed average vp/vs ratio of the crust is considered relatively high compared to the near region areas, Hurghada, and Mars Alam area, 1.75 and 1.74, respectively. This high ratio reflects a combination effect of the regional and local stress, regional due to the heat that disseminate through lateral

faults linked the crust of the Abou Dabbab area with the red sea rift axes. While the local stresses could be due to some magmatic activity existed in the uppermost mantle, that has not yet reached to the surface as a volcanic activity.

When considering another reason to explain that high vp/vs ratio, which could be due to the low shear wave velocity of the existing serpentine rocks in the crust. Results of this study are consistent with many other previous studies conducted on the same study area. Additional geophysical measurements, such as computing the heat flow to confirm if thermal or igneous activity could be the reason of this high vp/vs ratio and the frequent earthquake swarms occurred in the study area.

Keywords: Thinning crust, Abou Dabbab, Egypt

Neotectonic and Hydrocarbon Leakage Assessment in the Offshore Orange Basin Using 3D Seismic Reflection Data

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A high-resolution 3D seismic reflection dataset was analyzed to produce a detailed description of the half-graben bounded AK Fault in the Ibhubesi gas field of the offshore Orange Basin. The main objective of the study was to provide insights into hydrocarbon leakage and neotectonic activities along the west coast shelf of South Africa. Seismic analysis of the fault involved the combination of both conventional seismic interpretation and seismic attributes. The study revealed that the AK Fault consists of five seismically detectable segments, whose evolution reflects the characteristics of both the "coherent" and the "isolated" end member model of segmented fault origin. Diapiric structures that are direct indicators of vertical fluid movement were also observed along the AK Fault system, providing evidence of the significant roles that the fault plays in promoting the vertical migration of hydrocarbon in the Orange Basin. Recent reactivation of the fault was also revealed by the study to have occurred along an oblique extensional regime that is dominated by normal dip-slip faulting, with minor shear components along the tips.

Keywords: Neotectonic, Hydrocarbon migration, Reflection Seismic, Diapir

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The Use of Ground-based GNSS Observations for Monitoring Weather Events over Nigeria

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This study represents a foremost study on the application of ground-based global navigation satellite system (GNSS) continuous stations for weather studies over Nigeria and thus addresses very fundamental issues of GNSS meteorology as it concerns the region. A weighted tropospheric mean temperature model was developed for the region of Nigeria and was used to retrieve precipitable water vapour (PWV) from zenith tropospheric delay(ZTD) estimated from ground-based GNSS stations for the period of 2010- 2014. The GNSS derived PWV estimates were compared with PWV from a satellite remote sensing technique (Atmospheric Infrared Sounder (AIRS)), and a global reanalysis model (ERA-Interim) and the results indicated that GNSS PWV as observed over the study area represents a remarkable and useful source of humidity information which could be used to further probe the atmosphere and improve the application of numeric weather models in the region. In this study, GNSS PWV daily estimates were grouped into monthly and seasonal averages; the variations in the monthly and seasonal estimates of GNSS PWV were characterized and correlated with different weather events that are regarded as good climate change indicators. They were broadly classified into rainfall events [rainfall, relative humidity, daylight cloud amount and wind speed] and solar activity [temperature, sunspot number (SSN), total electron content (TEC), and total solar radiation (TSR)]. The results revealed that the spatiotemporal changes in PWV content are largely subjugated by the effects of latitude, topographical features, the seasons and the continental air masses. Our study shows that there is a very strong seasonal interplay among the

GNSS PWV, relative humidity, rainfall and cloud estimates. Also, GNSS PWV and TEC estimates show an opposite relationship; the semi-diurnal relationship between GNSS PWV and TEC is stronger than the seasonal relationship. The seasonal relation among GNSS PWV, temperature and wind speed appears weak, while very strong interplay exists among the GNSS PWV, SSN, and TSR estimates. Our results confirm that GNSS PWV is a good pointer for weather forecasting/monitoring and fit for climate monitoring if available on a longer timescale. Finally, we recommend the densification of the GNSS network in Nigeria, as this will enable 3D profiling of PWV, thereby providing more information on GNSS PWV time series, which is needed for long-term climatology.

Keywords: Global Navigation Satellite System (GNSS), rainfall events, precipitable water vapour (PWV), climate indicators, solar activity, total electron content (TEC), climate change, weather monitoring.

Spaced-based GNSS Radio Occultation Technology for Weather and Climate Studies over Nigeria: Feasibility studies and Performance Evaluation

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The Earth's atmosphere is critical to the environment and to life on Earth. Studying the atmosphere plays an important role in many scientific areas and in particular meteorology. However, observing the atmosphere is a challenging task due to its dynamic nature and complexity of its processes. Current station-based observations and satellite remote sensing techniques have different limitations (e.g. limited coverage, and/or limited resolution). Better observation techniques are desirable to capture the detailed status and processes of the atmosphere properly. Recent developments of the Global Navigation Satellite Systems (GNSS) radio occultation (RO) technique have offered an exciting potential for meteorological research. This GNSS RO technique offers an innovative approach for monitoring global atmospheric temperatures, pressures, ionospheric disturbances, and moisture distributions with high spatial resolution. GNSS RO fulfill the requirements for climate monitoring in the upper troposphere and lower stratosphere(UTLS) with regards to its featuring characteristics such as long term stability, SI traceability, all-weather capability, global coverage, and high accuracy and vertical resolution. However, while a range of studies across the globe have shown the efficacy of GNSS RO; it has not yet been explored in Nigeria and Africa at large. This study explores the developments, challenges, and efficacy of the GNSS RO approach to addressing meteorological and climatic needs of the science community in Nigeria. Atmospheric profiles from the constellation observing systems for meteorology, ionosphere, and climate (COSMIC) mission were retrieved and compared with radiosonde measurements across Nigeria. The results show good agreement between COSMIC and radiosonde measurements. This study provides a good benchmark for planning of future international and regional RO missions and with the proposed improvements in the COSMIC, GRACE (gravity recovery and climate experiment), and MetOp missions (i.e., COSMIC-2, GRACE-FO (follow - on), and MetOp-SG), the number of RO events are expected to increase globally and will further enhance the efficacy of the technique.

Keywords: Global Navigation Satellite System (GNSS), Radio Occultation (RO), Tropopause, Zenith Tropospheric Delay, Climate change, Meteorology.

Geological, Geophysical and Seismological Investigations for Siting of Seismic Stations in Minna and Abakaliki, Nigeria for Data Reliability

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The goal of this study is to adopt international standard criteria to carefully select sites to host seismic stations in Minna and Abakaliki, Nigeria, that can give reliable seismic data with high network detectability, monitor local seismicity and record local events with improved accuracy. By this, mistakes made during the construction of existing stations in Nigeria would be avoided systematically. To achieve these therefore, detailed field assessments were carried out to select most suitable site amongst the four potentials sites earlier proposed to host the sensitive seismic equipment for each area. These steps were later followed with detailed geological, geophysical and seismological investigations to ascertain the rock types at the sites; determine the depth of the bedrock where the sensor would be placed; and evaluate the signal to noise ratios and sources of possible noise to the pre-selected sites. Results from the various investigations have helped a team of seismologists, geologists, geophysicists and GIS experts drawn from the Centre for Geodesy and Geodynamics (CGG), Federal Ministry of Science and Technology and the National Emergency Management Agency (NEMA), to select most reliable sites for seismic stations in Minna and Abakaliki. As this is the first time these kind of investigations have been undertaken to select a site for seismic equipment in Nigeria, it is expected this study would set standard practices for future site selection for sensitive equipment in Nigeria and in the sub-region.

Keywords: Nigerian seismic network; seismic stations' site selection criteria; Minna and Abakaliki seismic stations; data quality

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New Insights into the Causes and Impacts of Recent Earthquakes in Nigeria and Immediate Environs

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The aim of this study is to adopt an integrated approach to unravel, the hitherto unknown causes of recent earthquakes in Nigeria and environs, and propose seismic hazard mitigation scheme for the country. Observance of tremors in Nigeria started in 1933; but for the first time, the July 10, 2016 Igbogene tremors in Bayelsa and Rivers states, the September 11 & 12, 2016 Kwoi events in Kaduna state, and chain of earth vibrations with loud sounds of 2-9 June, 2016 Shaki tremors, in Oyo State, all in Nigeria, caused wide spread damages to properties with attendant vast panic to residents in the affected communities. Inclusive investigations which involved acquisition and analysis of macroseismic intensity data from structured questionnaires, earthquakes relocation using modern algorithm, field surveys (sites' response, vulnerability and geological studies), seismological and aeromagnetic data interpretations, were carried out. Results from data processing and analysis showed that, magnitudes of the events ranged from Mw 2.5 to Mw 4.0 with intensities of III to VI on the Modified Mercalli scale. Findings also indicated that the causes of the events at Kwoi and Shaki are tectonic in nature, while those at Igbogene were triggered by activities of oil exploration. It was established that the visible damages to structures resulted from soil amplification, and in some cases, sub-standard construction materials. As a fall out from this work, immediate deployment of short-period sensors for routine local monitoring has been proposed to Government of Nigeria to build seismic hazard mitigating capacity for the country. Robust seismotectonic and seismic hazard studies in affected communities in South-South, North-West and South-West regions of Nigeria are also proposed for planning purposes.

Keywords: Nigeria and environs, recent earthquakes, Causes and Impacts, Integrated Investigations, disaster mitigation Planning

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Crust and Upper Mantle Structure beneath Kenya from Ambient Noise

Mary Muthoni **KARANJA**

The aim of this study is to carry out a structural investigation of Kenya by applying ambient seismic noise analysis. Data will be used from permanent stations in Kenya as well as previously deployed temporary stations. Furthermore, deployment of three additional temporary stations is planned in 2018. First, the noise will be analyzed to estimate its source distribution. Second, phase- and group-velocity dispersion curves for station pairs in the region will be measured from cross correlations of the ambient seismic noise. The velocity dispersion curves will then be inverted to produce group and phase velocity maps. Local dispersion curves will be inverted for 1-D shear-wave velocity profiles at selected points in the study area. This will allow for characterization of the crust in different tectonic units. All components of the correlation tensor will be analyzed and structural information extracted from both Rayleigh and Love waves. This helps constraining radial anisotropy. Finally, velocity maps will be compared to other Geological and Geophysical information.

Tectonic Evolution of the Macquarie Arc: Geologically constrained geophysical mapping

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The study aims to conduct a geologically constrained potential field's data interpretation to understand the evolution of Ordovician-Silurian Macquarie Arc, Tasmanides, Australia. We map the concealed and exposed geology and related structures to test if the evolution of Macquarie Arc architecture is consistent with recently developed tectonic models for the evolution of Lachlan Fold Belt. In particular, we test the (Moresi et al., 2014; Musgrave and Cayley, 2011) orocline model which is interpreted to have formed in response to the collision between Vandieland microcontinent and East Gondwana during the Late Ordovician to Early Silurian. Fieldwork observation on major fault reveals kinematics that lacks sizeable strike-slip displacement, which is predicted by the orocline tectonic model. The mapping reveals folding in the Ordovician-Silurian litho-packages of the Molong and Rockley-Gulgong Volcanic belts preserved on the flanks of Devonian Rift Basin of the Hill End Trough. The back-arc basin (Devonian Hill End Basin) underwent E-W extension then E-W shortening, and finally NE-SW and NW-SE shearing. Further work is ongoing to understand the later stages of deformation that overprint/obliterate old events that form an important part of Macquarie Arc evolution.

Keywords: Orocline, Macquarie Arc, geophysical interpretation.

Seismicity in NW Namibia: 01 January – 31 May 2012

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The WALPASS experiment comprised of 28 temporary seismic stations which was deployed in NW Namibia from October 2010 to November 2012. The WALPASS project aimed to image the lithospheric and deeper upper mantle structure in the ocean-continent transition beneath the passive continental margin of northern Namibia and find seismic anomalies related to the postulated hotspot track from the continent to the ocean along the Walvis Ridge. Bird et al (2006) and Viola et al (2005) resolved the presence of Wegener stress anomaly in southern Africa with a NW-SE compressive horizontal principal stress. A shell finite element model by Bird et al (2006) predicted high strain rate along the western arc through Angola, Namibia and South Africa. The local seismicity were analysed using the SEISAN software. On the 24th of March 2012, an earthquake with origin time 4:43:52, location -20.127°S and

14.146°E, depth of 0.1 km and magnitudes of 4.7M_L occurred approximately 60 km northwest of Khorixas in the Damara Orogenic Belt. A study from January-May 2012 about the seismicity recorded 281 earthquakes of which 149 were aftershocks with local magnitudes ranging from -0.4 to 4.7 M_L . Seismicity recorded correlated to Walvis Ridge, Damara Orogenic Belt, Okahandja lineaments and Windhoek graben seismic zones. Two clusters oriented in the NE-SW and NW-SE direction which may be due to complex faulting in the Khorixas area were resolved. There was also an observation of several foreshocks around the mainshock which might have been a signal associated with stress build up in and around the fault leading to the major rupture. There is a strong correlation between seismicity recorded to the predicted high strain rate through Angola, Namibia, South Africa and to less active Mozambique.

Keywords: Wegener stress, Namibia, Local seismicity.

Reassessment of source parameters of major South African earthquakes

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Moderate to large earthquakes within an earthquake catalogue have a significant impact on the seismic hazard and risk assessment results of any region. Thus it is prudent to ensure these events have reliable source parameters. The aim of this project is to identify such earthquakes of magnitude greater than or equal to 5.0 that occurred in South Africa and were recorded in local and international databases. A total of 147 events were obtained by scrutinising the Council for Geoscience and International Seismological Centre databases. Of these, 117 events had phase data which enabled us to relocate the events using the SEISAN software package, currently used velocity model and local magnitude relation. The accuracy of the relocations was determined by producing and analysing GAP, RMS and location error data. This information showed 'accurate' locations for most of the new results. An effort was also made to evaluate newly calculated values to published ones. A significant change in the values was observed which resulted in many of the events being dropped from the database as their values were now less than the cut-off value of 5.0. This left only 63 events from the instrument period that met the cut-off criterion. Thirty historical / early instrument events did not have phase data or waveform records. It is likely their original source parameters were determined using intensity data. Their source parameters were reviewed and magnitude values reconfirmed where possible using originally compiled macroseismic data. Twenty-eight events were confirmed as 'possibly' having magnitude values greater than or equal to 5.0. However, some doubt is cast on these values because most were determined only using I_{max}. A few of the events were analysed in previous studies using the software MEEP2 with collected macroseismic data, including one event whose analysis was conducted in this study. Thus the final resulting database has a total of 91 events with magnitude values greater than or equal to 5.0.

Keywords: Macroseismic, Seismic hazard, South Africa, catalogue.

Geophysical methods to detect shallow coal mine workings, Ermelo South Africa

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Abandoned underground coal mines result in surface cracks induced by the stress of the roof rock due to void migration as the collapse of bord areas occurs and in some cases pillar failure. These voids must be delineated if there is a need to use the abandoned mine area for surface constructions or re-mining. The aim of this study is to delineate and determine the dimensions of the tunnels at Driehoek coal mine in Ermelo. Of utmost importance is to find out how deep the

tunnels are below surface, how wide they are and their strike. The expectation is that the tunnels' dimensions may or may not be uniform depending on the way mining was carried out. Geophysical methods used in this study are magnetic, time-domain electromagnetic (TDEM), 2-dimensional electrical resistivity and microgravity methods. The resistivity method is used as a reconnaissance technique to characterize the overburden thickness and estimate the depth to the tunnels. This information is used to forward model the microgravity and magnetics data using Grav2dc and Mag2dc modelling software, respectively, to see if they are feasible methods for the study. From the resistivity data, the tunnels are believed to be ~5 m from surface, ~4 m wide and a height of ~2 m. From modelling of gravity field data, the tunnels are seen to be ~4 m from surface, ~3 m wide and a height of ~2 m. These dimensions are almost in agreement with the resistivity data. These gravity data were also gridded in Geosoft Oasis Montaj to produce a 3-dimensional model (voxel) to visualize the orientation of the tunnels. The processing of the other datasets (magnetic and TDEM) is not completed to satisfaction and thus their results will be presented in a later paper. After completion of processing of the latter two datasets, the next phase will be to correlate all the datasets and build an integrated model that addresses the question of the tunnel dimensions, location from surface and distances between tunnels.

Keywords: Tunnels, time-domain electromagnetics (TDEM), microgravity and model.

Vertical Electrical Sounding for targeting groundwater potential zones in the Port Alfred area, Eastern Cape, South Africa.

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Sustainable development and management of groundwater resource requires precise quantitative assessment based on scientific principles and modern techniques. Vertical electrical sounding using the Wenner-Schlumberger electrode configuration was executed to determine thickness of aquifer zones and locate potential subsurface aquifers in an area underlain by sandstone, shale and quartzite lithology of the Port Alfred area. A total of 5 VES were obtained using the Schlumberger array with maximum electrode spacing of 340 to 540 meters. The resistivity data obtained was then processed and interpreted using RES2DINV software. The results show the approximate 2D pseudosection image of the subsurface resistivity distribution which represents different lithologies. Low resistivity readings (<120Ωm) in the study area suggest ground water potential while high resistivities (>700 Ωm) suggest low potential groundwater zones. It is inferred from vertical electrical sounding results that the Port Alfred area has a good potential of groundwater that could be hosted in low resistivity zones, which may be characterised by presence of fractures.

Keywords: Port Alfred, vertical electrical sounding, groundwater, resistivity

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Integrated geophysical survey for investigation of the subsurface architecture in a shallow gold mine: a case study

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Application of integrated geophysical approach (seismic and electrical resistivity techniques) was employed to investigate the subsurface architectures at Lancaster Gold Mine in South Africa mining district. The mining activities in the area were mainly carried out within the Kimberley Reef Package (KRP) in the upper Central Rand Group (CRG) of the Witwatersrand Supergroup (WS) that hosts several Au bearing conglomerate reefs. These reefs are thin and intermittent but consists a continuous Boulder Reef that dips $28^{o} – 32^{o}$ south and has been completely mined up to 95%.

The employed integrated geophysical approach was to minimize the ambiguities in geophysical data interpretation. However, the study area was characterized by variable low-velocity and resistivity weathered layer overlying high-velocity rock mass that exhibits variable vertical to lateral velocity and resistivity changes near the subsurface. The low-velocity layer introduces significant static shifts in reflection seismic. Moreover, the prominent bedrock-overburden contact and environmental noise produce various wave conversions near the surface and undesirable signals that contaminated the shot gathers as high-amplitude, source-generated and monochromatic noise. Hence, the seismic data were subjected to standard reflection seismic data processing to eliminate the unwanted signals. The final stacked depth migrated sections produced high-resolution images of the subsurface from ~10 to ~100 m depth constrained with ground truth information from the nearby boreholes. The results were further correlated with velocity depth sections produced with first arrival travel time series analysis and electrical resistivity tomography (ERT) inversions. The reflection seismic provides information in delineating the approximate interfaces between different materials with greater penetration depth based on reflection seismic characters. In addition, the refraction and resistivity tomograms provide more detailed images of the top 20-30 m of the subsurface and depict the approximate shallow geometry of the fluid migration path, mine-out zones, and bedrock-overburden boundaries. We conclude that integration of different geophysical method as adopted in this study is a useful technique for environmental and engineering geophysical study in the area.

Keywords: Integrated geophysical survey, subsurface architecture, Kimberly Reef Package, Reflection and refraction seismic.

The 2017 Botswana earthquake and its aftershocks: contribution of Botswana Seismological Network (BSN) stations

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On Monday 3rd April 2017, Botswana and much of southern Africa were shaken by a local magnitude 6.5 earthquake located in the Central Kalahari Game Reserve (CKGR) region about 250 kilometers north-northwest of the capital Gaborone. This was the largest Botswana earthquake in 65 years subsequent to the magnitude 6.7 Okavango event of 11th October 1952. The magnitude 6.5 main shock was followed by a sequence of aftershocks clustered around the epicentral locality of triggering event. Botswana Seismological network (BSN) stations maintained by Botswana Geoscience Institute were operating across Botswana and contributed in recording the event and its aftershocks. The aftershocks were also monitored through a six-station temporary seismic network deployed over a period of 3 months within the collaboration of the Botswana Geoscience Institute and the South African Council for Geoscience. The waveform dataset was processed using a seismological program called SEISAN.

The juncture of the Choma-Kalomo Block, Magondi Belt, and Ghanzi-Chobe Belt in Zambia, Zimbabwe and Botswana: aeromagnetic data and geologic interpretation

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The region along the Zambezi River basin where four countries Namibia, Zambia, Zimbabwe and Botswana meet is a geologically complex area, where the Mesoproterozoic Choma-Kalomo Block, the Palaeoproterozoic Magondi Belt and the Neoproterozoic Ghanzi-Chobe Belt meet. However, the geological and structural relationships between these belts

is unclear, because the critical areas are buried under Late Palaeozoic to Mesozoic Karoo Supergroup and Cenozoic Kalahari Group cover rocks.

We have utilized a stitched version of the regional aeromagnetic maps of Zambia, Zimbabwe and Botswana, to gain an insight into the deep basement geology underlying the cover sequences. We have done directional filtering to remove the magnetic signal of the c. 180 Ma Okavango Dyke Swarm, which is part of the Karoo volcanic province. Various other kinds of processing were also done, such as low-pass and high-pass filtering at 20, 40 and 80 km depth cutoffs. The magnetotelluric (MT) line of [1] has been tied to the aeromagnetic data. Finally, our newly acquired geochronological data [2,3] has been used to interpret the geophysical trends.

Our data show that the aeromagnetic trends from plutons of the Choma-Kalomo Batholith in southern Zambia continue into Zimbabwe beneath the Batoka Basalts of the Victoria Falls area, and can be traced into NE Botswana. Most zircons (88%) from the ~<1.06 Ga Ghanzi-Chobe belt are derived from a provenance dated at 1460-1000 Ma [4], indicating that the Choma-Kalomo batholith aged magmatism was also present in Ngamiland in Botswana. A smaller percentage of zircons (~15%) with ages 2150-1700 Ma [4] are derived from the Magondi Belt [2]. The Ghanzi-Chobe fold belt seems to curve northwards as it approaches the Choma-Kalomo Block, and the strongly folded sequence of metasedimentary rocks exposed on the northwestern edge of the Choma-Kalomo Block, in the Zimba area, may represent a continuation of the Ghanzi-Chobe fold trends, caused by the collision of the Kalahari and Congo Cratons in the late Neoproterozoic [5]. Magnetic anomalies north of the Dete-Kamativi inlier of the Magondi Belt can be traced northeastwards into the southern part of the Choma-Kalomo Block, where they correspond with outcrops of the Chezya paragneiss, Ndonde schist and Siamambo paragneiss, which constitute the highly metamorphosed Palaeoproterozoic basement of the Choma-Kalomo Block [3]. The aeromagnetic signature of the deformed supracrustal rocks of the Dete-Kamativi Inlier can be followed SW into the Gweta region of Botswana, where drilling of a gravity high, and geochronological studies, have confirmed the presence of deformed and highly metamorphosed Palaeoproterozoic gneisses and schists [6], buried under 286m of Karoo and Kalahari cover rocks. The Deka Fault marks the boundary between the Karoo rocks capped by the Batoka Basalts, of the Victoria Falls region, and the Dete-Kamativi Inlier. Its position corresponds to a major change in lithospheric thickness between the Choma-Kalomo Block, and the adjacent Magondi Belt, where the lithosphere is 40 km thicker [1,3].

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Keywords: Palaeoproterozoic, Mesoproterozoic plutons, Neoproterozoic deofrmation, Zimbabwe, Zambia, Botswana

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Drilling into seismogenic zones of M2.0–M5.5 earthquakes in deep South African gold mines (DSeis)

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Deep South African gold mines have allowed us a closest look at seismogenic zones. In-mine seismic network, CGS SA National Seismograph Network, and Japan-SA seismological collaboration have elucidated some of the seismogenic zones very well. In August 2016, ICDP allowed us full core drilling followed by geophysical borehole logging to probe seismogenic zones at depth much better than past other fault drilling projects. As of June 2018, we are nearly completing drilling into seismogenic zones of M2.0–M5.5 earthquakes.

One of our drilling targets includes the 2014 Orkney M5.5 earthquake, which took place on a nearly vertically-dipping unknown geological structure in West Rand group (about 2.9 Ga). The upper edge of the fault was several hundreds of meters below the Moab Khotsong mine. We have drilled two NQ holes from 2.9km depth to the aftershock zone. Both

were drilled obliquely to the strike of the M5.5 strike-slip fault with plunges of about 40 degrees downward. This carefully designed drilling layout minimized drilling damage on the core and allowed core recovery of more than 95%. The first 800m hole (Hole A) nearly reached the aftershock zone with a sharp upper cut-off of seismicity and traversed from the upper fringe of the aftershock zone to a few hundreds of meters below the fringe. This allowed us to elucidate lithology sequence of the West Rand host rock (SE dipping beddings of quartzite, siltstone, shale, and lava with Vp = 5.5 - 6 km/s, occasionally intruded by sills with Vp = about 7 km/s) and stress spatial variation which jumped up at the fringe of the aftershock zone. The 2nd 700m hole (Hole B) intersected a fault zone of a few meter width in a lithology that seems like a lamprophyre dyke. Rock mass was as intact as Hole A until the fault zone was intersected. It was too sudden for us to switch from double-tube to triple-tube core-barrels to better recover very fragile fault breccia or fault gauge. However, a preliminary XRD analysis detected talc and biotite with very low frictional coefficient, which was also found in SAFOD project. A branch hole was drilled to recover fault zone material better. Water and gas are sampled for geomicrobiological work. Legacy data of surface seismic reflection survey are re-processed and re-interpreted to better understand geological structure, revealing a vertically dipping structure capable to the M5.5 event and the cross-cutting relationship between the M5.5 fault and the known faults above mining horizons.

Other drilling was conducted at Cooke 4 mine, recovering fractures quasi-statically evolved in space and time ahead of mining faces, which is capable to a Mw>1.5 event. These are compared with the fractures exhumed and mapped in the stope.

Because of mine closure, we couldn't conduct ICDP drilling at Savuka or Tau Tona mines to better prove seismogenic zones of M3 earthquakes. However, Savuka mine allowed us to investigate into cores from two AX holes intersecting a M3.5 earthquake. The cores were occasionally highly discted by high stress due to a drilling direction and there some core losses as well. However, we could investigate spatial variation of stress in detail.

Analyses of cores and logging as well as lab studies are going on to integrate all of the above results.

The DSeis activity of the researchers from Japan, South Africa, Switzerland, Israel, US, Germany, India, and Australia is supported by Anglogold Ashanti, Sibanye Gold, Harmony Gold, Lesedi, Digital Surveying, ICDP, JSPS, Japan MEXT, SA NRF, German DRF, US NSF, Israeli-German bilateral program, ETH, Tohoku University, UN university, and Ritsumeikan University.

Keywords: Drilling, seismogenic zones, ICDP.

Seismic Hazard Assessment of the Democratic Republic of Congo and surrounding areas based on recently compiled seismic zonation source models

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A new probabilistic seismic hazard assessment has been performed for the Democratic Republic of Congo (DRC) and surrounding areas. The DRC encompasses both intra-plate and active tectonic areas associated with the Congo Craton and the western branch of the East African rift system, respectively.

The seismic hazard assessment is based on a new Sub-Saharan-Global Earthquake Model (SSA-GEM) earthquake catalogue with homogeneous magnitude representation (Mw). The initial declustered catalogue has 782 events. After taking account of the completeness of the catalogue, the final catalogue declustered used for the seismic hazard assessment spans 55 years, from 1960 to 2015 with 398 events and a magnitude of completeness of about 4.5. The seismotectonic zonation into 15 seismic source areas was done on the basis of the regional geological structure, neotectonic fault systems, basin architecture and distribution of thermal springs and earthquake epicenters. Also, consideration was given to a regional strain rate model developed for the East Africa Rift by Stamps et al. in the frame of the GEM Strain Rate Project. Tectonic information was derived mostly from scientific literature and by integration of available datasets.

The current area source model consists of a total of 15 seismic zones distributed over 6 main tectonic groups which we assume to have comparable rheological and mechanical behavior with respect to the underlying crustal geology. The Gutenberg-Richter seismic hazard parameters were determined by the least square linear method and compared with direct inversion method of incremental (non-cumulative) earthquake occurrences using a nonlinear least-square approach.

Hazard computations have been performed using the latest OpenQuake-engine (Version 2.7.0). Spectral acceleration has been computed at PGA and for the response spectral periods of 0.05 s, 0.1 s, 0.2 s, 0.5 s, 1 s and 2 s using four GMPE: two for active shallow crust (Chiou and Youngs ; Akkar et al.) and two for stable continental conditions (Atkinson and Boore ; Pezeshk et al.), for site soils corresponding to Vs30 =600, 760 and 1500 m/s . Result obtained in term of PGA is consistent with that obtained by Damien et al., using average value of PGA computed from three regional GMPE in 4 cities in Kivu Rift segment using Crisis 2012 software.

Keywords: probabilistic seismic hazard assessment ; seismic zonation source model; earthquake catalogue; openquake engine

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Local Site Effects during the Orkney Earthquake of 5 August 2014

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Site response analysis is conducted at 37 seismic stations located in the Gauteng, North West and Free State provinces in South Africa, using the Nakamura H/V spectral ratio technique on records of the Orkney 5 August 2014 earthquake. The earthquake, of magnitude M_L = 5.5, led to the unfortunate death of one person and damage of more than 600 houses. Intensity data collected soon after the event showed that the effects of the earthquake appeared to vary significantly across the region. This motivated the authors to conduct a more detailed investigation of the effects of site conditions on seismic station records in the region. Resonance frequency values obtained from the H/V ratios were observed to vary strongly across the region and also within seismic station clusters. Similar behaviour was observed with the peak amplitude of the ratios at the resonance frequency, except for the Johannesburg area whose results showed a relatively simple shape of the ratios implying less complex velocity structure. All the H/V ratios exhibit dominant peaks at resonant frequencies that varied between 0.5 and 35 Hz. The average observed resonant frequency was f = 7.9 Hz. The amplitude of the dominant peaks also varied strongly from 1.66 to 11.69, with only two sites exhibiting maximum peaks with amplitude smaller than 2. These results serve as a strong motivation or justification for the on-going microzonation studies in South Africa, where a detailed study of the velocity structure will be used to obtain reliable information on site amplification and resonance.

Keywords: Site response, Orkney, Nakamura, South Africa, H/V ratios, resonance

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MALAWI: March 8, 2018 Earthquake Occurrence and its effects

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Malawi as the country that lies within the East Africa Rift System (EARS) which runs for ~800 km , is prone to tectonic activities that result in earthquakes, etc. Instrumental observation showed that on March 8 2018, Malawi experienced an earthquake of M5.4 which had its epicenter in Mozambique approximately 6 km South East of Tengani Trading Center and 10 km North East of Nsanje District which is also to the Southern tip of the EARS. The continuing study and monitoring shows that the occurrence was due to the movements within the EARS which correspond to the extensional movement within the EARS (Stamps et al., 2008).The earthquake was felt in many places which includes the central part of the country. The event caused one house to collapse and some primary schools were affected due to the impact of the event, two pupils sustained minor injuries leading to temporally closure of the schools. The macroseismic study is still undertaken within the affected areas.

Keywords: Malawi, Mozambique, EARS, earthquake

Ground-Motion Simulations for Zimbabwe

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Using "synthetic data" from ground-motion simulations, some ground-motion prediction equations (GMPE's) were derived. The "synthetic data" was obtained using Physics-based stochastic models in the form of the Fourier Amplitude Spectra (FAS) of the SMSIM Fortran programs for simulating ground-motions. The input parameters to these models (source, path and site parameters) were obtained from previous researches, derived from seismograms or inferred from geological maps. The GMPE's were derived from the "synthetic data" using Linear Least-Squares Regression (LLSR), for four different seismogenic zones around Zimbabwe (i.e., Kariba-Zambia, Northern Botswana, Southern Botswana and Mozambique. The derived GMPE's were compared with "observed strong-motion data" and with GMPE's of Jonathan (1996) and Twesingomwe (1997). The "observed strong-motion data" was for the Botswana Mw 6.5, Mozambique (Machaze) Mw 7.0 and Mozambique (Dondo) Mw 5.6 earthquakes. The difference between predicted values and these observed values is given in terms of logarithm of residuals (log Residual). It was assumed that the range of acceptable log Residual values is ± 0.6 in log (base 10) units. In general, the log Residual values for the observed events lie within the acceptable range, which suggests that the simulation models are reliable representations of actual conditions. On average, the derived GMPE's give the lowest absolute difference between observed and predicted data (i.e., 0:33 %g) compared to the GMPE's of Jonathan (1996) and Twesingomwe (1997). In seismic hazard applications, the derived GMPE's are meant to be used for moment magnitudes: $4.0 \leq M \leq 8.0$ and epicentral distances: $10 \text{ km} \leq R \leq 500 \text{ km}$, for source zones with typical stress drop of ($\Delta\sigma$= 17.4 bars).

Keywords: Ground-motion simulations, Ground-Motion Prediction Equations, Zimbabwe.

Recent Seismicity (2014- 2017) of the Okavango Delta Region (ODR): Contribution of Botswana's Seismic Network

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The Okavango delta composed of upstream panhandle and the downstream mega-fan situated in the middle of the Kalahari Basin. The Okavango Delta Region (ODR) has been observed to have elevated occurrence of seismic events compared with other regions in Botswana. Previous studies argue that the region sits on an incipient arm associated with the East African Rift System (EARS) and hence seismic events are expected to occur in the future (Scholz, 1975). According to the International Seismological Commission (ISC) bulletins, seismic events in this were detected by distant seismic stations at distances beyond 500 Km from the ODR, thus resulting in relatively poor location.
Here we present the results from the NARS (Network of Autonomously Recording Stations)-Botswana Project seismic network. The project consisted of 21 broadband seismic stations across Botswana aimed at studying the earth structure beneath Botswana and to obtain a better understanding of its complex tectonics. The network now forms part of the Botswana Seismological Network (BSN) in addition to the Lobatse (LBTB) and Maun (MAUA) stations which are part of the IMS and Africa-Array networks respectively.
The network coverage allow for a better computation of hypocenters, magnitude, focal mechanism and understanding the nature of causative faults in the region.

Keywords: Okavango Delta Region, Broadband Seismic Stations, Botswana Seismological Network (BSN)

Seismic evidence for plume- and craton-influenced upper mantle structure beneath the northern Malawi rift and the Rungwe volcanic province, East Africa

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P- and S-wave tomographic models have been developed for the northern Malawi rift and adjacent Rungwe Volcanic Province (RVP) using data from the SEGMeNT (Study of Extension and maGmatism in Malawi aNd Tanzania) project and data from previous networks in the study area. The main features of the models are a LVZ with δVp = ~1.5 - 2.0 % and δVs = ~2 - 3% centered beneath the RVP, a lower amplitude LVZ (δVp = ~1.0 - 1.3 % and δVs = ~0.7 - 1%) to the southeast of the RVP beneath the center and northeastern side of the northern Malawi rift, a shift of the lower amplitude anomaly at ~-10 to -11 degrees to the west beneath the central basin and to the western side of the rift, and a fast anomaly at all depths beneath the Bangweulu Craton in northeastern Zambia. The LVZ widens further at depths > ~150-200 km and extends to the north beneath northwestern Malawi, wrapping around fast anomaly beneath the Bangweulu craton. We attribute the LVZ beneath both the RVP and the northern Malawi rift to the flow of warm, superplume mantle from the southwest to the northeast, upwelling beneath and around the Bangweulu Craton lithosphere. As the flow encounters the edge of thick Bangweulu Craton lithosphere, it rises beneath thinner orogenic belt lithosphere to the east, creating the low velocity anomalies that are imaged. The presence of an LVZ extending under the RVP and much of the northern Malawi rift strongly indicates that the rifted lithosphere has been thermally perturbed. Given that volcanism in the RVP began earlier than much of the rift faulting, it is likely that thermal and magmatic (metasomatism, local heating) weakening of the lithosphere began prior to the onset of rifting. The amplitude and location of the RVP LVZ may arise, at least in part, from warm mantle pooling on the underside of locally thinned lithosphere. The RVP is located beneath the intersection of Mesozoic and Cenozoic rift zones, and lithospheric extension in the RVP area during the very initial stages of rifting may have resulted in a region of thinned lithosphere where upwelling material could have ponded. Our overall interpretation is consistent with high 3He/4He values from the RVP, which indicate melt contributions from a deeply sourced upwelling.

Seasonal Variations of Manning's Coefficient Depending on Vegetation Conditions in Tärnsjö, Sweden

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Hydrological models are used widely and they demand multiple input variables and observations. One of those variables is Manning's roughness coefficient, which relates the water flow and vegetation growth within the stream. In the current literature the variability of the coefficient poses an unknown uncertainty. This study examines a small river channel located in central Sweden and aims to determine the variability and uncertainty of the roughness coefficient during diverse vegetation conditions within the channel. During multiple field visits to the location, slope, water level and cross-section examination is performed. With numerical simulation, discharge and roughness coefficients are obtained. With the hydraulic model (HEC-RAS), stage-discharge rating curves are produced and extrapolation is applied to obtain high flows. Manning's roughness coefficients and their uncertainties are assessed by two different approaches. Determining the coefficient in a simplified sensitivity analysis by using Manning's equation and calibrating HEC-RAS while applying Mean absolute error (MAE) calculation. The calculated roughness coefficients presents higher range when using Manning's equation (summer vegetation conditions – 0.2, winter vegetation conditions – 0.095). On the contrary MAE provides values closer to each other (summer – 0.15, winter – 0.11). The obtained results indicate a high variance between summer and winter vegetation conditions, producing 38 cm water level differences during high flows using Manning's equation and 6 cm difference using the calibration of the model in HEC-RAS. These results confirm that the roughness coefficient cannot be assumed to be constant throughout different seasons as had been assumed widely when applying hydrological modelling. Throughout the study innovative approaches and methods (e.g. back-calculating from Manning's equation and calibrating HEC-RAS based on observed water levels) are used in order to determine the consequences of ignoring the variability of the roughness coefficient. Due to the study, one can

derive that vegetation needs to be considered in having an important impact on the varying roughness coefficient value and it cannot be left as a constant value within hydrological models.

Keywords: Manning's roughness coefficient, vegetation, HEC-RAS, uncertainty, rating curve

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Preliminary study on Probabilistic Seismic Hazard for Madagascar

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Seismic hazard for Madagascar based on Probabilistic seismic hazard analysis (PSHA) method is carried out. Earthquakes catalogue data from the combined bulletin by the MACOMO stations and NDC stations between 1975 and 2016 were arranged, adapted to MW magnitude scale and declustered in order to remove dependent earthquakes. Seismotectonic map from recent studies is used for area source zonation. The study area is formed by seven source zones and divided into small grid of size 0.5o x 0.5o for performing the hazard map. Hazard parameters were determined at the center of the introduced grid by taking to account the contributions from all seismic sources. The hazard values from 10 % and 2 % probabilities of exceedance for 50 years are estimated with the spectral accelerations for periods 0.3 s and 1.0 s. Resulted contour maps that show the variation of the PGA and spectral acceleration values are presented. Results show spatial variation of PGA values for the two return period 475 and 2475 and the uniform hazard response spectrum for 10% and 2% probability of exceedance in 50 years.

Keywords: Earthquake catalogue, Madagascar, Probabilistic Seismic Hazard

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3D Structure of the Congo Basin from Surface Wave and Gravity Joint Inversion

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We simultaneously inverted the Rayleigh-wave group velocity measurements and gravity observations in order to investigate the structure of the lithosphere beneath the Congo basin. The seismic dataset used in this study consists of a large number of regional seismic events with magnitudes greater than 4.5 and shallower than 100 km recorded by many stations belonging to various permanent and temporary networks. We measured group velocities of fundamental mode Rayleigh waves using narrow band filters and the phase matching method and inverted them to obtain maps of group velocities. The gravity observation was extracted from the dataset of the global Earth Gravitational Model (EGM2008) free-air gravity field. To combine these two datasets, we use a relationship between seismic velocity and density governed by two empirical relations. The Nafe and Drake relationship is most appropriate for sedimentary rocks; while the linear Birch's law applies to denser rocks. An iterative, damped least squares inversion including smoothing is used to jointly model both datasets, using shear velocity variations as the primary model parameters. Results show that the sedimentary strata in the Congo basin are about 9 km thick. Slower mantle velocities are found beneath the south-eastern and north-western portions of the Congo basin.

Keywords: Rayleigh waves, group velocity, gravity, joint inversion, Congo basin.

An ultra-high resolution, satellite-derived DEM to map the distribution of slip on the Hebron Fault, Namibia

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Access to high-definition satellite imagery has increased in the last few years, making it possible to produce high-quality topographic datasets for anywhere on earth. Using stereoscopic image pairs, the stereo-photogrammetry method is able to estimate the three-dimensional coordinates of points for an area, producing a point cloud dataset on which an analysis of landform displacement can be made. Worldview 3 satellite imagery, with a panchromatic resolution 0.31 m, was used to construct a high-resolution digital elevation model (DEM) of the Hebron Fault, south of Sossusvlei, Namibia. The Hebron Fault exhibits a 4-6 m high, 40 km long scarp that strikes NE-SW and is a part of a larger (300 km long) structure running subparallel to the coastline and the Great Escarpment. The arid nature of the region has led to excellent scarp preservation and there is very little vegetation to complicate DEM extraction. This makes the area an ideal location to further test the capabilities of the satellite-derived DEMs for tectonic geomorphology. The number and size of the seismic events that formed the Hebron scarp is not currently known. If the scarp formed in a single event it would represent an earthquake of Mw >7 in an area that is considered to have negligible earthquake hazard. There is significant debate about the expected slip-history of faults in such stable intraplate regions, and there is a lack of well-studied African examples. Detailed tectono-geomorphic interpretations were made for the length of the fault. In particular, the vertical offset and lateral offset values were measured and used to investigate the potential rupture history of the fault.

Keywords: photogrammetry, Namibia, geomorphology

Acoustic Impedance inversion and seismic frequency attributes in reservoir characterisation: the offshore Orange Basin case study

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A combination of genetic inversion (Seismic Impedance and Porosity) and Instantaneous Frequency attribute is used to characterise Albian and Cenomanian clastic reservoir targets in offshore, northern Orange Basin. Delineated reservoirs were mapped using an exploration well and 3D seismic volume (8-bit) after initial dip-steering coherency filtering had been performed on the 3D seismic volume to remove incoherent noise, improve data resolution and interpretability. Model-based seismic acoustic impedance inversion calibrated with porosity inversion was applied on the seismic volume in addition with RMS (Root Mean Square) amplitude to delineate possible reservoirs. Instantaneous frequency attribute was also applied for the likely presence of hydrocarbon-charged sediments. Acoustic impedance inversion reveals the presence of two fluvial channels within the Cenomanian sequence. These channels expectedly show high porosity along its geometry compared to its surrounding lithology while the presence of a meandering channel within the Albian sequence was equally resolved by the RMS. The application of Instantaneous Frequency (IF) attribute reveals the presence of hydrocarbon-charged Cenomanian reservoirs in close proximity to a listric normal fault, judging by the attenuation of frequency observed. This was achieved by using thirty–three seismic traces as an input in the Hilbert transform window, after which trace envelope and instantaneous phase were transformed into Instantaneous Frequency. This study demonstrates the effectiveness of Acoustic Impedance and Frequency attribute as a non-invasive approach in characterising clastic reservoirs.

Keywords: Acoustic Impedance, Frequency Attributes, Orange Basin

IsoSeismal Maps for the 2015 and 2016 Earthquakes in the KZN Province, SA

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Isoseismal Maps are provided for two local earthquakes that occurred in the KZN region in 2015 and 2016. These earthquakes occurred in the region of previously activated seismic sources. The 2015 earthquake occurred along the Tugela River. The 2016 earthquake was located offshore Umhlanga by CGS and located by the USGS at a striking unnoticed source in Mpumulanga Township near Hammarsdale. In both cases, people in the low cost housing in the region felt most of the ground shaking and a large crack was observed in a mall in Hammarsdale although no other significant damages and injuries were reported.

Keywords: earthquake; Mpumalanga Township

Is Active Tectonics on Madagascar Consistent with Somalian Plate Kinematics?

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The East African Rift System (EARS) actively breaks apart the Nubian and Somalian tectonic plates. Madagascar finds itself at the easternmost boundary of the EARS, between the Rovuma block, Lwandle plate, and the Somalian plate. Earthquake focal mechanisms and N-S oriented fault structures on the continental island suggest that Madagascar is experiencing east-west oriented extension. However, some previous plate kinematic studies indicate minor compressional strains across Madagascar. This inconsistency may be due to uncertainties in Somalian plate rotation. Past estimates of the rotation of the Somalian plate suffered from a poor coverage of GPS stations, but some important new stations are now available for a re-evaluation. In this work, we revise the kinematics of the Somalian plate. We first calculate a new GPS velocity solution and perform block kinematic modeling to evaluate the Somalian plate rotation. We then estimate new Somalia-Rovuma and Somalia-Lwandle relative motions across Madagascar and evaluate whether they are consistent with GPS measurements made on the island itself, as well as with other kinematic indicators.

Keywords: Kinematics, GNSS, Madagascar, Somalian Plate

Seismic Risk Awareness and Emergency Preparedness in Zimbabwe: A case study of Harare Metropolitan City

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This study sought to evaluate public understanding of seismic risk and earthquake emergency preparedness in Harare, to reveal which age group or gender is more knowledgeable and to point out the gaps that are there in the earthquake preparedness systems in place. The qualitative study was carried out in the city of Harare. The target subjects were the general public, working class and students at schools. Questionnaires were distributed and the data collected was sorted. Data analysis was done using excel and the results were represented using tables, bar graphs and pie charts. 79% of sample population had never been educated on how to be safe during an earthquake. 90% had no training on basic survival skills. 61% felt there was lack of information access points. Overally18% females were more educated and aware of the seismic risk, compared to males. Age group 13-18 were more knowledgeable on earthquake emergency preparedness and seismic risk than all the other age groups. It was discovered that generally the public is ill informed on seismic risk and earthquake emergency preparedness. Only 7% of the selected population had both knowledge and understanding of earthquakes in accordance to analysis of question 1 and 2 combined. There is a gap on preparedness systems in place and people have no access to information on earthquakes and seismic risk. Clearly the study shows there is a need for further raising seismic risk awareness and revisiting the earthquake emergency preparedness systems in place.

Keywords: Seismic risk, education, public awareness, questionnaire, preparedness.

Lithospheric structure by seismic tomography and gravimetric data: case of the High Atlas (Morocco)

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We investigate sedimentological and tectonic processes at the Central High Atlas, in order to understand their functioning and to build a geodynamic model that placed the area in its current geological frame. The analysis used here is based on the numerical enhancement of a Landsat image where the main goal is to map surface sedimentary deposits throughout the central High Atlas in order to delimit the large geological structures. The sediment distribution throughout central High Atlas indicates that this one is a large tectonic subsiding basin, where the ongoing tectonic events and the geodynamical evolution remain to be explained by other prospecting techniques. 3-D structure velocities obtained by local seismic tomography and enhancement techniques of gravimetric anomalies are used to explore and define deep structure beneath the central High Atlas. The goal is to establish the spatiotemporal evolution of the deep structure related to the geodynamical processes. Modest crustal thickness variation beneath the central High Atlas (~20 to ~40 km) define by local tomography and gravimetric anomalies, confirms that, a major part of the lower crust is detached into the lithosphere by delamination. Gravimetric anomaly, local seismic tomography and vertical cross sections throughout the central High Atlas, suggest that the lower crust detached is related to the broken slab of remain northward subduction beneath High and Middle Atlas. Meanwhile, extrusions of heated Asthenosphere materials induce the rifting stage concomitant to tectonic subsidence of the basin.

Keywords: Subsiding basin, Seismic tomography, Gravimetric anomaly

Geophysical investigation of the Lithosphere beneath Cameroon and implications to the setting of the Cameroon Volcanic Line

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The structure and composition of the lithosphere beneath Cameroon and the origin of the Cameroon Volcanic Line (CVL) is still a matter of debate. Although many studies based on regional or global geophysical observations provide models for the setting of the CVL, none of them are strong enough to be considered as definitive. We used the joint inversion of Rayleigh wave group velocities and Rayleigh wave group velocities to derive 1D shear wave velocity profiles of the lithosphere beneath Cameroon and show that lithosphere is, on average, faster beneath the Congo Craton than beneath the Pan-African age crust. The inverted 1D models do not show any sharp discontinuity in the mantle that could be interpreted as the lithosphere-asthenosphere transition. Furthermore, there is no clear evidence of the existence of a low velocity zone beneath any geologic province within Cameroon, at least for our resolved depth of investigation of 100 km. The comparison of the lid structures beneath CVL, Main Ethiopian Rift (MER) and the Khartoum basin, other regions affected by the Cenozoic volcanism, shows significant differences. The upper mantle velocity beneath the CVL is higher (4.4 vs 4.1 km/s) and the Vp/Vs is lower (<1.74 vs >1.9) than found for the MER. The relatively low Vp/Vs indicates that there is little or no melt in the CVL crust. The higher upper mantle Vs indicates a different composition or lower temperature, or both. The temperature estimated from Vs clearly indicates a thermal anomaly within CVL with the highest temperatures found in the region .These findings are more compatible with small-scale convection in the asthenosphere and controlled by lithospheric fractures that are probably driven by the cold (and fast) edge of the Congo Craton, rather than plume material migrating from the Ethiopia/Afar region beneath thinned lithosphere.

Keywords: Cameroon Volcanic Line, shear wave velocities, Bouguer anomaly, lithosphere.

Uganda Infrasound Network Project and Analysis of Infrasound Data to Infer Lightning Signature

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Uganda is an earthquake prone country due the presence of tectonic structures associated with East African rift system (EARS) that bounds the country. The EARS is a modern continental rift system that represents early stages of continental break-up, with the western boarder of Uganda lying almost entirely in the Western branch of the Rift System, while the Eastern border is about a few hundred kilometres from the Kenya Rift; and there is more seismic activity in the Western than in the Eastern branch. The Kenya rift also is interconnected with the western rift through major faults.

The country too is prone to tropical lightning and thunderstorms, being one with the highest rates of lightning strike deaths among the countries in the world and its capital Kampala has more days of lightning per year than any other city, according to the World Meteorological Organization. These two phenomena present a natural geophysical laboratory for research in Uganda.

Besides other disasters namely- landslides, floods and earthquakes in the recent past, incidents of death of households, school children and adults killed by lightening flares are more frequently reported in the Media in Uganda. For instance on 29th June 2011, a lightning strike killed eighteen (18) children and their teacher at Runyanya primary school in Kiryandongo.

Using infrasound data at IS32 of International Monitoring System (IMS) installed by the Preparatory Commission of Nuclear Test Ban Treaty (CTBTO), it demonstrates that local lightening events analysed signatures can enable the generation of lightening flares risk maps. The maps are useful in informing policy on settlements designs and construction of safe houses in tropics where lightening flares are frequent.

The IMS infrasound network stations however need to be supported with setting up a local infrasound network arrays for such studies. In July 2016, we started working on our project to establish Uganda Infrasound Network. We are construction phase and procurement of the equipment for the first local Infrasound Station to be installed in Entebbe.

Keywords: Uganda Infrasound Network, Lightning
