A public-private partnership supporting training and research in earth, atmospheric and space sciences in Africa
http://africaarray.org

11th Annual AfricaArray Workshop

School of Geosciences
University of the Witwatersrand
Johannesburg, South Africa

17-23 January 2016

Programme

11th Annual AfricaArray Workshop

17-23 January 2016

University of the Witwatersrand, Johannesburg, South Africa

Sunday 17 January	*9h30-16h00*	***AfricaArray station operator course*** *Andy Nyblade, Joao Fonseca, Ranto Raveloson*
Monday 18 January and Tuesday 19January	*8h00-19h00* *8h00-17h00*	***AfricaArray Scientific Meeting***
Wednesday 20 January	*8h00-10h00*	***UNAVCO short course:*** Plug and Play system for accessing AfricaArray GPS data *Bill Hammond, University of Reno, USA*
Wednesday 20 January	*11h00-18h00*	***Field trip:*** Sterkfontein Cave *UNESCO World Heritage site famous for discoveries of 3 m.y. old Australopithecus fossils.*
Thursday 21 January to Saturday 23January		***Course:*** Measuring earthquakes from space using "Co-registration of Optically Sensed Images and Correlation" (COSICORR) *Mark van der Meijde & Harald van der Werff, University of Twente, The Netherlands*
Thursday 21 January	*08h30-17h00*	***Course:*** Procedures and pitfalls for mapping and interpreting trenches excavated across active faults *Marc Goedhart, KainosSA*
Friday 22 January	*08h30-16h00*	***Workshop:*** Using AfricaArray campaign data and OpenQuake Tools to assess seismic hazard along the East African Rift. *Georges Mavonga Tuluka, Ray Durrheim*

COURSE & WORKSHOP OUTLINES

Measuring earthquakes from space using "Co-registration of Optically Sensed Images and Correlation" (COSICORR)

Mark van der Meijde, University of Twente, The Netherlands

The course will focus on the use of online tools to process and analyse data. It will be a 50-50 mix of theory and practice. The number of participants is limited to 20. The training is composed of three elements. On the first day you will receive an introduction into remote sensing, the theory behind it, some practical tools for analysis and practical exercises. On day two you will be introduced to analysis of optical imagery, particularly using the COSICORR software. Through a few exercises you will learn how to apply it for extracting information on recent tectonic activity. The last day you will be applying the software yourself to obtain your own results of neo-tectonic activity in selected areas and derive information on active faults.

Procedures and pitfalls for mapping and interpreting trenches excavated across active faults

Marc Goedhart (KainosSA)

Using AfricaArray campaign data and OpenQuake Tools to assess seismic hazard along the East African Rift

Georges Mavonga Tuluka, Ray Durrheim

The US Office of Foreign Disaster Assistance is supporting an AfricaArray-GEM project to build capacity in Africa to mitigate the risk posed by earthquakes. Catalogue building, data processing and analysis methodologies will be discussed.

GLT Lecture Theatre, Geosciences Building, Wits **Monday 18 January 2016**

***Abstract appended**

08:00 - 08:30	REGISTRATION
08:30 - 08:40	Welcome **Helder Marques** (*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*)
09:30 - 10:00	Invited keynote address: Modelling climate change in sub-Saharan Africa **Francois ENGELBRECHT** (*CSIR, SOUTH AFRICA*)
10:00 – 10:30	***Tea break***

Theme: Structure, tectonics and resources of Africa

10:30 – 10:50	*Lithospheric structure in NW of African craton: case of the Moroccan Atlas Mountains **Youssef TIMOULALI** (*Mohamed V University, MOROCCO*)
10:50 - 11:10	*Crustal structure of Egypt from Egyptian National Seismic Network data **Ahmed HOSNY** (*National Research Institute of Astronomy & Geophysics (NRIAG, EGYPT*)
11:10 - 11:30	*Crustal structure of Nigeria and Ghana from receiver functions **Ofonime AKPAN** (*Centre for Geodesy and Geodynamics NIGERIA*)
11:30 - 11:50	*Tectonic activity of the mid-Atlantic Ridge and implications for seismicity in the West African region and/or *Estimation of thickness of the sediments and shear wave velocities in the Lower Benue Trough in Nigeria from seismic noise recordings **Umar AFEGBUA KADIRI** (*Center for Geodesy and Geodynamics, NIGERIA*)
11:50 - 12:10	S-wave Receiver Functions studies of African sedimentary basins **Helio INGUANE** (*MSc candidate, University of the Witwatersrand SOUTH AFRICA & National Geology Directorate MOZAMBIQUE*)
12:10 - 12:30	To be confirmed **Ranto RAVELOSON** (*Post-doctoral Fellow, University of the Witwatersrand SOUTH AFRICA*)
12:30- 13:30	***Lunch break***

13:30 - 13:50	*Mapping the Stress Field in Southern Africa: a tool to unravel the M5.5 Earthquake of 5 August 2014 near Orkney **Marco ANDREOLI** (*University of the Witwatersrand, SOUTH AFRICA*)
13:50 - 14:05	*The impact of dolerites and basin depth on shale gas exploration in the main Karoo basin **Stephanie SCHEIBER-ENSLIN** (*PhD candidate, University of the Witwatersrand, SOUTH AFRICA*)
14:05 - 14:20	Ambient noise tomography towards imaging the Eastern-Cape Karoo basin **Lucian BEZUIDENHOUT** (*PhD candidate, Nelson Mandela Metropolitan University, SOUTH AFRICA*)
14:20 - 14:35	Variations in isochore thickness of the Karoo sediments in the Eastern Cape Province of South Africa, as deduced from gravity models **Christopher BAIYEGUNHI** (*PhD candidate, University of Fort Hare, SOUTH AFRICA*)
14:35 - 14:50	*Shale Gas Exploitation, Karoo Basin: Anticipated Earthquakes and Micro-Seismicity **Shana EBRAHIM-TROLLOPE** (*Ph.D. candidate, Department of Geological Sciences, University of Cape Town*)
14:505 - 15:20	***Tea break***
15:20 - 15:35	*Fault structure for Madagascar **Tsitsi RAKOTONDRAIBE** (*PhD candidate,* University of Antananarivo, *MADAGASCAR & University of the Witwatersrand, SOUTH AFRICA*)
15:35 - 15:50	Crustal structure and mantle transition zone thickness beneath Madagascar **Fenitra ANDRIAMPENOMANANA** (*PhD candidate, University of Antananarivo, MADAGASCAR & University of the Witwatersrand, SOUTH AFRICA*)
15:50 - 16:00	The Reflection Seismology Research Centre at Wits University **Musa MANZI** (*University of the Witwatersrand, SOUTH AFRICA*)
16:00 - 16:15	*A possible impact structure in the offshore Orange Basin, South Africa **Ahmed ISIAKA** (*PhD candidate, Ahmadu Bello University NIGERIA & University of the Witwatersrand, SOUTH AFRICA*)
16:15 - 16:30	*Fault detection using seismic attributes in the West Wits Line Goldfield, Witwatersrand Basin, South Africa **Mbali MKHABELA** (*MSc candidate, University of the Witwatersrand, SOUTH AFRICA*)
16:30 - 16:45	*3D Geophysical modeling of the Bethlehem Sub-Basin, Free State, South Africa **Ansuya NAIDOO** (*MSc candidate, University of the Witwatersrand, SOUTH AFRICA*)
16:45 - 17:05	Crust and upper mantle structure beneath northern Lake Nyasa/Malawi and Rungwe volcanic province **Andy NYBLADE** (*Penn State University, USA*)
17:15 - 19:30	**POSTERS & SNACKS IN THE BLELOCH MUSEUM** **Visit to the Wits University Reflection Seismology Research Centre**

GLT Lecture Theatre, Geosciences Building, Wits **Tuesday 19 January 2015**

Theme: Geodesy and space science

08:30 – 09:00 *Invited keynote address: Uplift of the Sierra Nevada Mountain range in California and Nevada
Bill HAMMOND (*University of Reno, USA*)

09:00-09:20 A geodynamical model for Botswana based on traditional and satellite geophysics
Mark VAN DER MEIJDE (*University of Twente, THE NETHERLANDS*)

09:20-09:40 *Mapping earth structure from space: The future role of satellite gravity
Chikondi CHISENGA (*University of Science & Technology, MALAWI*)

09:40-10:00 *Variation of Total Electron Count (TEC) over the West Africa coast as observed from GPS and/or
*Stability Monitoring of the Africa Array GNSS reference Station Network
Joseph DODO (*National Space Research and Development Agency (NASRDA), NIGERIA*)

10:00 – 10:30 ***Tea break***

Theme: Seismic monitoring and hazard assessment

10:30 – 10:50 *The occurrence of disaster earthquakes in the Lake Kivu Basin
Mifunda Dieudonne WAFULA (*Goma Volcanic Observatory DRC*)

10:50 - 11:10 *Seismic Hazard Assessment in sub-Sahara using GEM OpenQuake software
Georges MAVONGA TULUKA (*Goma Volcanic Observatory DRC*)

11:10 - 11:30 Status of the Virunga-Kivu rift seismic network
Damien DELVAUX (*Royal Museum for Central Africa, BELGIUM*)

11:30 - 11:50 Seismic hazard results for the Northern Tanzania Divergence
Michael MSABI *(University of Dodoma, TANZANIA)*

11:50 - 12:10 Geophysical monitoring of African volcanoes: examples from Cape Verde and DRC
Joao FONSECA (*University of Lisbon, PORTUGAL*)

12:10 - 12:30 *Seismic Hazard Assessment of South Africa: seismic source model
Vunganai MIDZI (*Council for Geoscience, SOUTH AFRICA*)

12:30- 13:30 ***Lunch break***

13:30 – 14:10 Seismic Vulnerability Investigation of RDP homes in the city of Matlosana, North West Province, South Africa
Mayshree SINGH (*University of KwaZulu- Natal, SOUTH AFRICA*)-

14:10 - 14:30 *The March-April (2015) seismic unrest northeast of Fentale Volcano: an insight for a threat to block Ethiopia's commercial access
Atalay AYELE (*University of Addis Ababa, ETHIOPIA*)

Theme: Mining-related seismicity

14:30 - 14:50 *Observational studies in South African mines to mitigate earthquake risks (2010-2015) – key findings and outputs
Ray DURRHEIM (*University of the Witwatersrand & CSIR, SOUTH AFRICA*)

14:50 - 15:10 *Probabilistic seismic hazard assessment for Johannesburg
Brassnavy MANZUNZU (*PhD candidate, University of the Witwatersrand & Council for Geoscience, SOUTH AFRICA*)

15:10 - 15:30 *Integrated petrographic, geomechanical and seismological studies of rockmass behaviour during the extraction of the Cooke 4 shaft pillar
Siyanda MNGADI (*MSc candidate, University of the Witwatersrand SOUTH AFRICA*)

15:10 - 15:30 ***Tea break***

15:30 - 15:50 *Investigating the seismic signal of elephants: using seismology to mitigate elephant-human conflict
Susan WEBB (*University of the Witwatersrand SOUTH AFRICA*)

Theme: Initiatives allied to AfricaArray

15:50 - 16:10 Hazard models, datasets and tools developed within the Global Earthquake Model initiative
Valerio POGGI (Global Earthquake Model Foundation, *ITALY*)

16:10 – 16:25 IASPEI & the African Seismological Commission
Ataly AYELE (*Council for Geoscience SOUTH AFRICA*)

16:25 – 16:40 IUGS Resourcing Future Generations initiative, ICDP DSeis
Ray DURRHEIM (CSIR & *University of the Witwatersrand, SOUTH AFRICA*)

16:40 – 16:55 American Geophysical Union (AGU) & Society of Exploration Geophysicists (SEG)
Susan WEBB (*University of the Witwatersrand SOUTH AFRICA*)

16:55– 17:10 35th International Geological Congress, 27 August – 4 September 2016, Cape Town

17:15 - 19:00 **POSTERS & SNACKS IN THE BLELOCH MUSEUM**

Posters on display in the Bleloch Museum, 18-21 January 2015

Earth Structure, Tectonics & Mineral Resources

*Characteristics of Mount Cameroon seismicity for the period 2005-2015
Bekoa ATEBA (*Institute of Geological & Mining Research, CAMEROON*)

Full waveform moment tensor inversion of local earthquakes in Egypt
Hazem BADR EL-DIN (*National Research Institute of Astronomy & Geophysics, EGYPT*)

Title still to be provided
Etienne KADIMA KABONGA (*University of Lumbumbashi, DRC*)

*Observations of the Vredefort Dome using 2D Seismics
Marcello MOLEZZI (*MSc candidate, University of the Witwatersrand, SOUTH AFRICA*)

*Lithospheric structure in southwestern Zambia from magnetotelluric observations
Daniel MUTAMINA (*Geological Survey Department, Ministry of Mines, Energy & Water Development, ZAMBIA*)

Seismicity of Botswana
Onkgopotse NITBINYANE (*Geological Survey, BOTSWANA*)

Contribution of seismology to the understanding of Cameroon tectonics
Evariste NGATCHOU HEUTCHI (*University of Younde 1, CAMEROON*)

Title still to be provided
Severin NGUIYA (*University of Douala, CAMEROON*)

Seismicity studies of the Okavango Delta Region and the environs
Bokani NTHABA (*Botswana Institute of Science & Technology, BOTSWANA*)

*Structural Development of the Potchefstroom Fault, Witwatersrand Basin, South Africa
Matt TERRACIN (*PhD candidate, University of the Witwatersrand, SOUTH AFRICA*)

Surface wave tomography of Botswana
Mark VAN DER MEIJDE (University of Twente, THE NETHERLANDS)

Mining in Senegal
Oumar WANE (*Directorate of Mining and Geology, SENEGAL*)

Earthquakes, Volcanoes & Geohazards

Seismicity of Ghana
Sylvanus Tetteh AHULU (*Geological Survey Department, GHANA*)

*A hundred years of earthquake monitoring in Ghana (1914-2014)
Paulina AMPONSAH (*Atomic Energy Commission, GHANA*)

Localized occurrence of earthquakes within the Thunduwike-Vwaza area, Northern Malawi
Patrick CHINDANDALI (*Geological Survey of Malawi, MALAWI*)

Status of AfricaArray stations in Uganda
Lawrence KABENGE (*Ministry of Energy & Mineral Development, UGANDA)*

*Reservoir-induced seismicity potential at Tokwe Mukorsi Dam, Zimbabwe
Robin MASHINGAIDZE (*National University of Science & Technology, ZIMBABWE*)

*Active lineaments within the Chitipa-Karonga area, northern Malawi
Felix MPHEPO (*Geological Survey, MALAWI)*

Status of AfricaArray stations in Zambia
Annie MULOWEZI (Geological Survey Department, ZAMBIA)

*The Seismological Network of Namibia
Mako SITALI (Geological Survey, NAMIBIA)

*Seismic activity associated with the 2014 lava lake apparition at Nyamulagira volcano
Josue SUBIRA MUHINDO (*Goma Volcanic Observatory, DRC*)

ABSTRACTS

Tectonic activities of the mid-Atlantic ridge and implication of seismicity in West African region

Umar AFEGBUA KADIRI[1], F.O. Ezomo[2] and Ansie Smit[3]

[1]Centre for Geodesy and Geodynamics, Toro, Bauchi State, Nigeria
Email: umakad@yahoo.com, Tel: +2348037122784
[2]Dept. of Physics, University of Benin, Benin City, Nigeria
[3]University of Pretoria, South Africa

The tectonic activities of the Mid-Atlantic Ridge (MAR) have been investigated with respect to earthquake occurrence in the West African region in more than 300 years. The result clearly showed a trend of an increasing seismicity along the MAR bordering West African region in terms of number of earthquake occurrence and magnitudes. Statistical and probability Seismic Hazard Assessment (PSHA) techniques were employed in this research. The PHSA carried out along the MAR and West African region respectively revealed that increasing number of earthquakes have occurred in the last 20 years closer to West Africa, especially along the mega oceanic fracture zones linking with fractures on mainland in West African region. The statistical technique involved Regression Analysis, Focal Depth & Frequency Distribution analysis of observed events to establish distinct trend, using a decade-long each of earthquake catalogs at different completion levels in each case spanning 1963-2014 for MAR and 1618-2014 for the West African region. On the other hand, the b-values and activity rates were computed for both MAR and West African region using different sub-catalogs with different levels of completeness. Finally respective annual probability of exceedance and return period (years) were iteratively computed for each earthquake magnitudes, 4.0 being the threshold magnitude and up to a maximum of 7.1. Although, West African is not an active region compared to regions of high seismicity like EAR, Japan, California, Turkey, etc., a trend that showed an increasing earthquake occurrence with magnitude as high as 6.9 to 7.1 is now gradually appearing.

Keywords: MAR, tectonic activity, earthquake occurrence, seismicity of West Africa.

Estimation of thickness of the sediments and shear wave velocities in the lower Benue trough in Nigeria from seismic noise recordings

Umar AFEGBUA KADIRI[1] and Friday.O. Ezomo[2]

Email: umakad@yahoo.com, Tel: +2348037122784
[1]Centre for Geodesy and Geodynamics, Toro, Bauchi State, Nigeria
[2]Dept. of Physics, University of Benin, Benin City, Nigeria.

The thickness of sediments and average shear wave velocities have been determined in parts of the Anambra basin of Lower Benue Trough, South-East Nigeria, using seismic noise recorded at Awka, Nsukka and Abakaliki stations and noise recorded at different points with a short period sensors (16Secs.). The results showed a good fit to results earlier obtained by other studies using different techniques in the region. This straightforward method involved the collection of borehole data and data from previous research works in the area with published known thickness of sediments. The resonance frequencies were computed using Matlab programme from the noise recordings at the three stations and other points closed to the areas with known thickness of sediments. Using the values of resonance frequencies determined and known thickness of sediments, a nonlinear regression of power function was used to establish a relation between the resonance frequency and the depth of sediments for the area. The second phase of the work involved the determination of shear wave velocities for each point where the thickness of sediments is known, using the computed resonance frequency values. Finally, the Short Period sensor (16-period) was used to record noise at selected points in Abakaliki where the thickness of sediments was not known. The depth of sediments and shear wave velocities for the respective points were computed using the derived model.

Keywords: Lower Benue Trough, Resonance Frequency, Sediments Thickness, Shear Wave Velocity

Crustal Structure of Nigeria and Southern Ghana, West Africa from P-wave receiver functions

Ofonime AKPAN[1,2], Andrew Nyblade[3,4], Chiedu Okereke[2], Michael Oden[2], Erica Emry[3] and Jordi Julià[5]

[1] Centre for Geodesy and Geodynamics, Toro, Nigeria.
[2] Department of Geology, University of Calabar, Calabar, Nigeria.
[3] Department of Geosciences, Pennsylvania State University, University Park, PA 16802, U.S.A.
[4] School of Geosciences, The University of the Witwatersrand, Johannesburg, South Africa.
[5] Departamento de Geofísica & Programa de Pós-Graduação em Geodinâmica e Geofísica, Universidade Federal do Rio Grando do Norte, Natal, Rio Grande do Norte, Brazil
Email: ofonua@yahoo.com

New estimates of crustal thickness (Moho depth), Poisson's ratio and shear-wave velocities for eleven broadband seismological stations in Nigeria and Ghana are reported. Data used for this study came from teleseismic earthquakes recorded at epicentral distances between 30º and 95º and with moment magnitudes greater than or equal to 5.5. P-wave receiver functions were modeled using the Moho Ps arrival times, H-*k* stacking, and joint inversion of receiver functions and Rayleigh wave group velocities. The average crustal thickness of the stations in the Neoproterozoic basement complex of Nigeria is 36 km, and 23 km for the stations in the Cretaceous Benue Trough. The crustal structure of the Paleoproterozoic Birimian terrain, and Neoproterozoic Dahomeyan terrain and Togo Structural Unit in southern Ghana is similar, with an average Moho depth of 43 km. Poisson's ratios for all the stations ranges from 0.24 to 0.26, indicating a bulk felsic to intermediate composition crust. The crustal structure of the basement complex in Nigeria is similar to the average crustal structure of Neoproterozoic terrains in other parts of Africa, but the two Neoproterozoic terrains in southern Ghana have a thicker crust with a thick mafic lower crust, ranging in thickness from 12 to 17 km. Both the thicker crust and thick mafic lower crustal section are consistent with many Precambrian suture zones, and thus we suggest that both features are relict from the collisional event during the formation of Gondwana.

Keywords: Nigeria, Ghana, Neoproterozoic, Paleoproterozoic, crustal structure, suture zones.

Hundred years of earthquake monitoring in Ghana (1914-2014)

Paulina AMPONSAH[1] and Solomon Anum[2]

[1]National Nuclear Research Institute, Ghana Atomic Energy Commission, P.O.Box LG 80, Accra, Ghana
[2] Geological Survey Department, P.O.Box M 80, Accra, Ghana
Email:pekua2@yahoo.com

Ghana is located in the Western part of Africa and is far from the major earthquake zones. The country, however, has adversely been affected by damaging earthquakes as far back as 1615. Major earthquakes occurred in 1615,1636,1862,1906 and 1939. Historical earthquakes of magnitude greater than 6.0 and current local events with magnitudes ranging from 1.0 to 4.8 on the Richter scale have been recorded since the establishment of the seismograph stations. Earthquakes in Ghana are concentrated in the southern part of the country where we have the seismic network. Instrumental recording of earthquakes in Ghana began in 1914 with the installation of a Milnes's single-boom seismograph. In 1973 a seismograph observatory equipped with a World-Wide Standard Seismograph Network (WWSSN) system with three component short and long period seismometers was established at Kukurantumi in the Eastern region of Ghana. At present earthquake recording is done using a digital seismic network operated by the Geological Survey Department. Most of the events recorded are located at the intersection of the Akwapim fault zone and Coastal boundary fault, the two major fault systems in the country. The epicenter distribution indicates that the two major fault systems are the probable source of the seismic activity in the country. In this study, we review the outcome of hundred years (1914 -2014) of seismic monitoring in Ghana and its relevance in seismic hazard assessment.

Keywords: Ghana, Earthquake monitoring, fault systems, Instrumental records

---

The March-April (2015) seismic unrest northeast of Fentale Volcano: an insight for a threat to block Ethiopia's commercial access

Atalay AYELE

Institute of Geophysics Space Science and Astronomy
Addis Ababa University

Fentale is a large stratovolcano located in south Afar at latitude 8.975ºN and longitude 39.93ºE with summit elevations 2007 meters. The latest eruption is known to occur in 1820 where basaltic lava flows were extruded onto the rift floor. A colossal seismic activity occurred in January and February 1981 while another moderate earthquake activity occurred in June 1989. Both swarms were recorded by the AAE seismic station which was one of the best functioning WWSSN type in Africa.

A recent swarm of earthquakes occurred from March 22 to April 20, 2015 with a maximum magnitude of 3.5 ML. This activity was captured by the Ethiopian Seismic Station Network (ESSN) with additional installation of temporary SABU station very close to the activity. Few events are located and all clustered northeast of the volcano while analysis of the whole data from other stations of ESSN is still underway. SABU was installed in the middle of the activity and collected high quality data but the whole range of the swarm is captured by ANKE and other stations. There was neither sub-areal magmatic manifestation nor signature of subsurface volcanic movement from the seismic record.

This nearly 30 days long seismic unrest could have been potential threat to block the country's economic lifeline had there been associated volcanic eruption as the main road passes by the foothill of the Fentale Volcano.

Mapping the Stress Field in Southern Africa: a tool to unravel the M5.5 Earthquake of 5 August 2014 near Orkney

M.A.G. ANDREOLI[1], A. Bumby[2], S. Coetzee[3], D. Delvaux de Fenffe[4], R.J. Durrheim[5], A.O. Heidbach[6],
A. Kjiko[7], A. Logue[8], A. Lourens[9], V. Midzi[10] and I. Saunders11

1. University of the Witwatersrand, South Africa Marco.Andreoli@wits.ac.za
2. University of Pretoria, South Africa, Adam.Bumby@up.ac.za
3. University of Pretoria, South Africa, Serena.Coetzee@up.ac.za
4. Royal Museum for Central Africa, Belgium, damien.delvaux@africamuseum.be
5. University of the Witwatersrand, South Africa, Raymond.Durrheim@wits.ac.za
6. GFZ Potsdam, Germany, heidbach@gfz-potsdam.de
7. University of Pretoria, South Africa, Adam.Bumby@up.ac.za
8. University of Cape Town, South Africa, Andrew.logue@hotmail.co.za
9. University of Pretoria, South Africa, Annerie.laurens@gmail.com
10. Council for Geoscience, South Africa¸ vmidzi@geoscience.org.za
11. Council for Geoscience, South Africa¸ ians@geoscience.org.za

The 5th August 2014 event with epicentre near Orkney, the strongest recorded in South Africa in 45 years, received much attention by the press and the seismological community; and the analysis of the seismic data, including those of the aftershocks, revealed some intriguing facts. Focal mechanism solutions computations provided evidence for a NW-oriented, sub-horizontal σ1 and a left-lateral, predominantly strike slip movement along a cryptic fault plane oriented NNW to N. Adding to the puzzle, the aftershock data also indicated that most of the seismogenic displacement happened below the gold-bearing reef [1]. Prompted by these results, an international effort is being planned to study in situ the slippage zone with an inclined borehole drilled from one of the adjacent mines [2]. Our companion approach aims to capture data on the tectonic stresses that acted on the southern African crust for the past 130 Ma and to model their effects on the Witwatersrand basin. For this, the more reliable stress data are computed from borehole breakouts measurements (mainly offshore exploration wells) [3] and fault plane solutions from seismic events recorded by multiple stations. Less reliable are instead stress and strain release structures in mines and tunnels as they may reflect in varying degrees anthropogenic influences. Further stress data were obtained from the structural analysis of fault displacing Late Cenozoic sediments; however, the difficulty to date the last age of movement severely constrains the applications of this technique. Available observations consistently indicate a NNW - N orientation of the maximum horizontal compressive stress (σH), named the Wegener Stress Anomaly [4], that prevails across most of South Africa, and in Namibia up to the Angola border. An early compilation of our data was adopted by Viola et al. [5] and Bird et al. [6] to produce kinematic models of stress and strain rate across southern Africa. In particular, Bird's best fit model (AF-SO-013) is based on realistic rates of remote boundary conditions and generates a belt of strike slip stress (strain rate tensor, E3-E1 = ~10-17units) that extends from the Northern Natal basin, through N Natal and the eastern side of the Witwatersrand region to Central Botswana. Given the coarseness of the AF-SO-013 model, minor changes in model input parameters would easily allow the strike slip belt to include the western sector of the Witwatersrand basin; whereas the orientation of the conjugate faults and their sense of movement already match within error those computed for the Orkney event. To conclude, the recognition of neotectonic activity in the Witwatersrand basin is consistent with other finds within 100km from Orkney, namely the undated thrust faults cutting calcrete at Bultfontein, and the proposed Late Pleistocene seismites in hot spring deposits at Florisbad [4]. The dearth of data precludes a quantitative assessment of the seismic hazard in the Orkney area, however greater insights might be obtained from more work at Bultfontein and Florisbad, and from a forensic scrutiny of the major tremors swarms in the wider Witwatersrand basins [4], starting from those between Orkney and Welkom with M >2 x the Standard Deviation of the area average.

[1] Midzi, V., et al., 2015. J. Seismology 19: 741 – 751
[2] Ogasawara, H., et al., 2015. AGU Assembly, 14 December 2015, San Francisco: S13B-2834
[3] Logue, A., 2015. M. Sc. Thesis, University of Cape Town.
[4] Andreoli, M.A.G., et al., 1996. Africa Geoscience Review 3: 1-16
[5] Viola, G., et al., 2005. Earth and Planetary Sci. Letters 231: 147– 160
[6] Bird, P., et al., 2006. J. Geophys. Res. 111, B08402: 14 pp

Keywords: Witwatersrand basin, Orkney, borehole breakouts, neotectonic stress, focal mechanism solutions

---

Characteristics of Mount Cameroon seismicity for the period 2005-2015

Bekoa ATEBA[1], Ferdinand E. Mbossi[2] and C.A. Tala Mougon[3]

1. Institute of Geological and Mining Research, Branch for Geophysical and Volcanological Research
2. University of Yaounde I, Faculty of Science, Department of Physics P.O. Box 812 Yaounde
3. University of Douala, Faculty of Earth Sciences, P.O. Box Douala, Cameroon

Mount Cameroon is an active volcano located in the Gulf of Guinea in West Central Africa. The last recorded eruptions in 1999 and 2000 were associated with swarms and felt earthquakes. From 2005 to 2015, the monthly frequency of earthquakes was in general less than 60 and no event with magnitude greater than 3 has been recorded. The seismic data have been compiled and successfully put in a SEISAN data base. Its facilities are used to determine b values which range between 1.0 and 1.3; and map active seismic zones. The seismicity is concentrated in 3 zones: one in the east flank where events are located under the crust (20 km); the second in the west flank, hypocentres are in the crust; the last group of events appears around the summit area (altitude ≥ 2000 m). Not directly associated with the volcano is the seismicity observed west of the city of Douala, along the Wouri estuary. These results are correlated with the tectonics and show that micro-seismicity can also help to delimit seismogenic zones for seismic hazards assessment studies.

Mapping active faults from space: The future role of satellite gravity

C. CHISENGA[1] and M. van der Meidje[2]

1. Malawi university of Science and Technology, P.O.Box 5196 limbe, Malawi, cchisenga@must.ac.mw
2. University of Twente, Faculty ITC, P.O box 6, 7500 AE, Enschede, Netherlands.

Botswana remains one of the least understood countries despite having diamond and other resources underneath its crust. The country comprises some of the interesting cratons e.g. Congo craton, Zimbabwe craton and Kaapvaal craton, cratonic margins and intra-cratonic boundaries. An incipient rift in the Okavango area which comprises the recent geodynamic activities of Botswana and numerous dyke swarms cutting across the country. These features represent tectonic activities that in some cases resulted in earthquakes and active faults formation. Important information like crustal thickness, Moho depth, and geodynamic of the crust as well as tectonic activities is still poorly understood in Botswana.

In this study we utilise the gravity data of Botswana to produce the crustal thickness map of Botswana. We assume a two layer model of earth crust and upper mantle, the lithospheric mantle, with a density contrast in between and model our crustal thickness using the parker-Oldenburg equation and constraints against seismic depth estimates. We then produced a tectonic boundary of Botswana based on the lineaments extracted using canny edge detection algorithm. The results of these two processes were combined with epicentre distribution data to identify active areas in Botswana. A new insight into the structure, tectonic and geodynamic underneath Botswana is understood. The failed incipient rift in the Okavango area, major faulting that resulted into dykes' swarms and tectonically active areas that represent recent dynamic activities of Botswana are well defined by the thickness and thinning of the crust underneath Botswana. Larger earthquake follow boundaries of thinner and thicker crust as well as tectonic boundaries. However, not all tectonic boundaries represent active faults but only those that coincide with boundary of crust thickness. Furthermore, active boundaries are found in shaped tectonic boundaries which coincide with boundaries of crustal thickness indicating recent geodynamic activities of Botswana.

Keywords: Active faults, gravity, inversion, lineament extraction

---

Variation of Total Electron Content (TEC) over the West African Coast, as Observed from GPS

Joseph D. DODO and T. Seun Oluwadare

Centre for Geodesy and Geodynamics,
National Space Research and Development Agency, Toro, Nigeria;
E-mail-jd.dodo@gmail.com;

The ionosphere is a dispersive medium for radio waves with the refractive index that is a function of frequency and total electron content (TEC). The Global Positioning System (GPS) has become a powerful tool for ionospheric studies. The ionospheric corrections are necessary for the augmentation systems required for Global Navigation Satellite Systems (GNSS). Dual-frequency carrier phase and code-delay GPS observations are combined to obtain ionospheric observables related to the total electron content along the satellite-receiver line-of-sight. The effects of the ionosphere can cause range-rate errors for GPS satellite users who require high accuracy measurement and the parameter of the ionosphere that affects the radio signals that propagate through this layer is known as Total Electron Content (TEC). This paper presents the variation of ionospheric total electron content on GPS stations over West Africa coast using GPS data collected over a period of one year. The analysis is presented for both seasonal and diurnal variation, the presented three seasons are; Equinox, summer and winter. For the seasonal variation analysis, the highest TEC is found during the winter months, followed by summer and lowest is found in equinox. The data was analyzed using Gopi GPS-TEC analysis software version 2.2 and MATLAB R2013a. The test data included measurements from a GPS station along the West African Coastal areas of Nigeria and Benin Republic. The result gives a significant daily and seasonal variation of TEC along the coastal areas of West Africa.

Keywords: Total Electron Content; ionospheric delay; West African coast; Global Positioning System; latitudinal difference; equatorial difference

---

Stability Monitoring of the Africa Array GNSS Reference Stations Network

Joseph D. DODO, Samuel Y. Tsebeje and Saturday E. Usifoh
y
Centre for Geodesy and Geodynamics,
National Space Research and Development Agency, Toro, Nigeria;
E-mail-jd.dodo@gmail.com;

Africa Array has over the years expanded its training model to include space geodesy for geodynamic research. This has led to the establishment of the network of Global Navigation Satellite System (GNSS) continuously operation reference station in Africa by the Africa Array initiative. The initiative has significantly increased the enthusiasm of African geoscientists in the utilisation of this infrastructure in making informed decisions on the basis of instantaneous positions derived from the GNSS. In utilising this service, the geodesist place increasing reliance on the network of Continuously Operating Reference Stations (CORS) that generate the real time information used to correct their GNSS receiver data, thereby enabling sub-meter levels of positioning accuracy. Theoretically, the overall quality of the solution obtained by the GNSS user should reflect a combination of the quality of the data collected within the CORS network and that measured by the roving receiver. However, in reality this is not the case and users often accept the overly optimistic quality estimates generated by GPS receivers. In order to accurately describe the quality of the Africa Array GNSS Station positional solutions, the Centre for Geodesy and Geodynamics has initiated a project to determine the stability of the Africa Array GNSS stations for geodynamics research. This paper presents the approach and results obtained from the first phase of this project, the continuous stability monitoring of the Africa Array GNSS reference station through the computation of daily network solutions. The paper discusses the role of stability monitoring within the existing Africa Array GNSS quality control activities.

Keywords: Continuously operation reference station, daily network solution, Africa Array GNSS reference Stations, coordinate repeatability,

---

Observational studies in South African mines to mitigate seismic risks

Raymond J. DURRHEIM[1,2,3] and Hiroshi Ogasawara[1,4] and the SATREPS[1] Research Group

1. JST-JICA Science and Technology Research Partnership for Sustainable Development (SATREPS)
2. The University of the Witwatersrand, South Africa
3. CSIR Natural Resources and the Environment Unit, South Africa
4. Ritsumeikan University, Japan

Mining-induced earthquakes pose a risk to workers in deep mines, while large earthquakes that occur near plate boundaries (and occasionally in stable continental regions) pose a risk to the public. A 5-year Japanese – South African collaborative project "Observational studies in South African mines to mitigate seismic risks" was launched in 2010. Acoustic emission sensors, accelerometers, strainmeters and controlled seismic sources were installed in three deep Witwatersrand gold mines to monitor the deformation of the rock mass, the accumulation of damage during the earthquake preparation phase, and the propagation of the rupture front. A surface array of accelerometers was installed in the Far West Rand mining district. These data are being integrated with measurements of stress, in-stope closure and strong motion, as well as data recorded by the mine-wide seismic networks. New insights into the physics of earthquakes have already been gained, and technologies have been developed or adapted to assess seismic hazard and mitigate rockburst risks.

Shale Gas Exploitation, Karoo Basin: Anticipated Earthquakes and Micro-Seismicity

R. EBRAHIM-TROLLOPE

Ph.D. candidate, Department of Geological Sciences, University of Cape Town

South Africa is an extensional intra-plate region that is tectonically stable by global standards with a typically low and shallow level of natural seismicity ($\approx$ 1 M_L > 5 event / 50 years, an M_{max} < 6.5 and depths of between 5 - 10 km). In contrast over 90 % of recorded seismicity locate within the Witwatersrand Basin with multiple M_L > 4 events annually and an $M_{max} \approx$ 5.4. Both agriculture and inhabitants of the Karoo are dependent on groundwater and waste-water contamination facilitated by fluid induced seismicity that might extend from the hydro fracturing depth up towards the primary aquifers is one of the primary concerns. Our technical preparedness and legislative framework in terms of monitoring, analysis, reporting, standards, best practice, data integrity, etc. need to be assessed. With over 100 years of experience in induced seismicity within the Witwatersrand basin, a wealth of experience and expertise has been accumulated. In conclusion it is noted that (a) the capacity of the national network to provide sufficiently detailed Seismic Hazard maps and other seismological services do not fulfil the requirements of advanced industry stakeholders, due to location and hypocentral depth uncertainty of over 5-10 km and limited knowledge about earthquake mechanisms, (b) inconsistencies between and within private networks, non-sharing of data, a current technical and service monopoly, lack of quality control measures, non- prescriptive standards and best practice, etc. hinders clarity,

(c) the lack of capacity, synergy and line of responsibility between government institutions has been persistent and d) seismicity 3-4 times higher than experienced within the Witwatersrand basin, an $M_{max} \approx 5.5$ and a possible triggered deeper M_{max} of ± 6.5 can be anticipated. It is strongly recommended that independence be developed via academic institutions and public research organizations; that government responsibilities in terms of monitoring, data preservation, regulations, etc. and legislative framework be clarified.

GPS Imaging of the Uplift of the Sierra Nevada Mountain Range, Western United States

William C. HAMMOND, Geoffrey Blewitt, Corné Kreemer

Nevada Geodetic Laboratory
Nevada Bureau of Mines and Geology MS178
University of Nevada, Reno
Reno NV, 89557
United States
whammond@unr.edu

Recent improvements in the scope and precision of GPS networks across California and Nevada allow for tectonic and anthropogenic vertical movements of the solid Earth to be observed directly. Many of these signals, in the range of 1 to 2 mm/yr, have been attributed to lithospheric scale rebound following massive groundwater withdrawal in the San Joaquin Valley in southern California, exacerbated by drought since 2011. However, natural long-term tectonic uplift of the Sierra Nevada may also contributes to the observed signals.

We have developed a suite of new analysis techniques called “GPS Imaging” and applied them to results of processing of data from over 14,000 stations, globally distributed. The techniques incorporate automatic, robust, and accurate non-parametric estimator of station velocity that is insensitive to step discontinuities, outliers, seasonality, and heteroscedasticity and advanced image processing techniques that create maps of vertical land motion. Median spatial filtering of the images using Delauney triangulation effectively despeckles the data while faithfully preserving edge features.

These new algorithms enhance the signal of Sierra Nevada uplift and improve our ability to interpret and separate natural tectonic signals from anthropogenic contributions. The resulting estimate of the vertical rate field are spatially comprehensive and insensitive to outliers and steps in the GPS time series, and omit isolated features attributable to unstable stations or unrepresentative rates. They show signals from the earthquake cycle including interseismic strain accumulation along the Cascadia subduction zone, postseismic relaxation of the mantle from recent large earthquakes in central Nevada and southern California, groundwater loading changes, and tectonic uplift of the Sierra Nevada and Coast Ranges.

Crustal structure of Egypt from Egyptian National Seismic Network data

Ahmed HOSNY[1] and Andrew Nyblade[2,3]

1. Seismology Dept., National Research Institute of Astronomy and Geophysics, (NRIAG), 11421 Helwan, Cairo, Egypt
2. Department of Geosciences, Pennsylvania State University, University Park, PA 16802
3. School of Geosciences, The University of the Witwatersrand, Johannesburg, South Africa.

Seismic data from 26 stations in the Egyptian National Seismic Network have been used to characterize crustal structure in Egypt. Data from Teleseismic earthquakes with magnitudes > 5.5 were used to compute P-wave receiver functions, which have been modeled using the H-k stacking method and inverted jointly with Rayleigh wave group velocities. Stations along the Red Sea, Gulf of Suez, and Gulf of Aqaba have an average crustal thickness of 30 km, an average Vp/Vs ratio of 1.77, an average crustal shear-wave velocity of 3.6 km/s, and a mafic lower crust that is on average 5 km thick. Beneath stations located in northern and central Egypt, the average crustal thickness is 35 km, the average Vp/Vs

ratio is 1.79, the average crustal shear-wave velocity is 3.5 km/sec, and the average mafic lower crustal thickness is 3 km. Beneath the stations in southern Egypt, the average crustal thickness is 39 km, the average Vp/Vs ratio is 1.76, the average crustal shear-wave velocity is 3.7 km/s, and the average mafic lower crustal thickness is15 km. In comparison to previous published crustal structure studies in Egypt, our results shows good agreement. Similarly, our results compare favorably with crustal thickness along the Arabian side of the Gulf of Aqaba and northern Red Sea and in the Arabian Shield. In comparison to crustal structure in similar tectonic settings elsewhere in Africa, our results also show good similarity, except for southern Egypt, where the thickness of the mafic lower crust is substantially greater. We attribute the thickened mafic lower crust to modification of the crust during the collision of east Gondwana against the Sahara Metcraton along the Keraf Suture during the final assembly of Gondwana in the Neoproterozoic. For improving earthquake locations, average shear wave velocity models for the three geographic regions are also reported.

A Possible New Impact Structure within the Orange Basin, Offshore South Africa

Ahmed I. ISIAKA[1], Raymond J. Durrheim[1,2] and Musa S.D. Manzi[1]

1. School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS, 2050, South Africa
2. CSIR Natural Resources and the Environment Unit, South Africa

Email: Ahmed.Isiaka@students.wits.ac.za

We have interpreted a high resolution 3D reflection seismic data from the exploration Block 2A of the Orange Basin, offshore South Africa, using the 3D volume rendering technique, and have discovered a crater of approximately 5-7 km in size that is indicative of a possible impact structure preserved within the post-rift Cretaceous sediments. The comparison of this crater with other circular structures, such as pockmarks and mud volcanoes that occur within the exploration Block 2A of the Orange Basin, revealed lack of gas escape features below it, which supports an impact origin for the crater. The crater exhibits morphological characteristics similar to complex impact craters and transected by an approximately 400 m wide gully that probably developed as a result of resurge of water back into the crater after the impact. The association of the crater with sub-marine alluvial delta fans suggests the impact probably occurred in a shallow marine deltaic environment, where rapid sediment input was responsible for its rapid burial and eventual preservation. The crater is of Cretaceous age, based on its preservation within the post-rift Cretaceous sediments.

Key words: 3D seismic, impact crater, seismic interpretation, volume rendering.

Probabilistic seismic hazard assessment for Johannesburg

Brassnavy MANZUNZU[1], Vunganai Midzi[1], Brian Zulu[1], Tebogo Pule[1] and Thifhe Mulabisani[1]

1. Geophysics Competency, Council for Geoscience South Africa

Email: bmanzunzu@geoscience.org.za

A probabilistic approach was applied to estimate seismic hazard at bedrock level in terms of peak ground acceleration (PGA) for the city of Johannesburg. A detailed catalogue of historical and recent seismicity within 350 km radius around the city has been compiled and new seismotectonic map has been generated for the region. The completeness of the data was checked using cumulative visual interpretation technique before carrying out hazard analysis. Sixteen regional source zones were identified in the study area to account for local variability in seismicity characteristics. The seismicity parameters were estimated for each of these source zones, and the seismic hazard evaluation for the Johannesburg region has been performed using different attenuation relations. Probabilistic seismic hazard analysis has been performed with currently available data and their best possible scientific interpretation using appropriate instruments such as the logic tree to explicitly account for epistemic uncertainty by considering alternative models (source models, maximum magnitude, and attenuation relationships). The hazard maps for different periods have been produced for horizontal ground motion on the bedrock level. The new seismic hazard map prepared for Johannesburg specifies a 10% probability of exceedance of the given PGA values for bedrock conditions for an exposure time of 50 years.

Keywords: Seismic Hazard, Johannesburg, Peak ground acceleration.

Reservoir induced seismicity potential at Tokwe Mukorsi dam, south central Zimbabwe

Robin Tinavo MASHINGAIDZE[1], Lindiwe Nhlamba[1], Kwangari Marimira[2] and Patricia Mavazhe[2]

1. Department of Applied Physics, National University of Science and Technology, P.O Box AC 939, Ascot, Bulawayo, Zimbabwe.
2. Goetz Observatory, P.O Box AC 65, Ascot, Bulawayo, Zimbabwe.
Email: rtmashy@gmail.com

The Tokwe-Mukorsi Reservoir was created by the construction of a concrete faced rock fill dam on the confluence of the Tokwe and Mukorsi Rivers in the Tokwe terrain, a moderately active tectonic region in South Central Zimbabwe. The dam forms the biggest inland water reservoir in Zimbabwe with a dam wall of about 90 m and a back throw of over 35 km, with a total capacity of 1.8 billion m3. The primary function of the dam is to provide irrigation water to the Lowveld sugar estates and surrounding communal farmers. The dam also has the capacity to generate up to 15 megawatts of electricity. The Tokwe Mukorsi Reservoir lies in a region between the Archaean Zimbabwe Craton (ZC) and the Limpopo Mobile Belt (LMB). The Tokwe terrain is mainly composed of highly deformed and banded tonalitic gneisses and granodiorites rocks overlain by clastic sediments in some areas. The terrain is also characterized by a network of NNE trending structures, and cross cutting NW-trending faults and NNW-trending dykes.

Seismic data from June 2004 to January 2015 from a local seismic network are incorporated in this study in order to carry out an investigation of the Reservoir Induced Seismicity (RIS) potential at the Tokwe-Mukorsi Reservoir. The recorded event magnitudes ranged between Mc = 2.3 and 4.6. Information on the tectonic and geological structure of the area was mainly inferred from the published data sets available for the region. An average b value of 0.53 was determined for the whole period between 2004 and 2015, indicating that these earthquakes follow a recurrence rate normal for earthquakes of intraplate origin. The b-value also indicates that the frequency of earthquakes in the area is not likely to increase and will remain prone to small earthquake magnitudes, even with a reservoir being impounded in the area. The fault plane solutions suggest a mixture of normal faulting and strike-slip faulting which is consistent with the known faults in the area. The results show that at present there is a low level of seismic activity in and around the Tokwe-Mukorsi Reservoir. The limited data set analyzed in this study cannot confirm the potential of RIS at Tokwe Mukorsi. A more extended data set including micro seismic monitoring and in situ stress measurements in the area would help to provide more insight into the stress regime in the region and its relationship with the reservoir. Incorporation of the hydrological data from the area can also help to establish whether a relationship exists between the rate of earthquake occurrence at the reservoir and the fluctuations in water levels during various seasons throughout the year.

Keywords: Reservoir-Induced Seismicity, Tokwe-Mukorsi Dam, Earthquake, Tectonics, b Value.

Mitigating Earthquake Risk in Sub-Saharan Africa: a pilot project to assess the utility of AfricaArray data and GEM products and tools

R.J. Durrheim[1], **G. MAVONGA TULUKA**[2], M. Pagani[3], G. Weatherill[3], V. Poggi[3] and A. Nyblade[4]

1. University of the Witwatersrand & CSIR, South Africa, Raymond.Durrheim@wits.ac.za
2. Goma Volcanic Observatory, DR Congo, mavotulu@gmail.com
3. GEM Foundation, Italy, marco.pagani@globalquakemodel.org, graeme.weatherill@globalquakemodel.org, Valerio.Poggi@globalquakemodel.org
4 Penn State University, USA, aan2@psu.edu

Earthquakes pose a significant risk in tectonically-active parts of sub-Saharan Africa, especially as cities grow and many buildings are constructed without taking potential ground shaking into account. A significant impediment to the assessment of seismic hazard and risk in earthquake-prone areas of sub-Saharan Africa is the lack of high-quality seismic data from local and regional networks. The AfricaArray seismic network was launched in 2005 with a handful

of stations in eastern and southern Africa. Over the past decade the AfricaArray "backbone" network has expanded to include 51 permanent stations in 19 countries as well as several temporary deployments. These data may have the potential to improve greatly the seismicity catalogues for much of Africa. The Global Earthquake Model (GEM) Foundation was launched in 2009 with the vision of developing a uniform, independent standard to calculate and communicate earthquake risk worldwide. We describe a USAid-funded pilot project to ascertain the usefulness of the AfricaArray network and data and GEM products and tools for reducing seismic risk in regions affected by earthquakes associated with the East African Rift System.

Sub-Saharan Africa (SSA) encompasses the East African Rift System (EARS), the active divergent plate boundary between the Nubian and Somalian plates, which accommodates strain along the boundaries of at least three micro-plates. The delimitation of seismic sources within the SSA is facilitated with the recent publication of the Sub-Saharan Africa Geodetic Strain Rate Model 1.0 constrained by published geodetic data along the EARS and includes micro-plates between the Nubian and Somalian plates where they developed an improved strain rate field for sub-Saharan Africa that incorporates an expanded geodetic velocity field within the Nubia-Somalia plate system and along the EARS and redefined regions of deforming zones guided by seismicity distribution.

We assessed in the hazard using the GEM OpenQuake engine "Seismic Hazard" using seismicity, geology and geodetic tools. To reduce epistemic uncertainty due to the determination of b-value and maximum credible magnitude , a logic tree approach was used with 2 ground motion prediction Equation (GMPE) determined from shallow earthquakes occurring within active region, many source area (e.g. asrcv3.0 and asrcv4.0). Extended the ISC-GEM with AA catalogues showed that b-values obtained using ISC-GEM-AA catalogue were more close to those obtained with other authors (e.g Hodge et al., 2014) compared to those obtained with Extended ISC-GEM. PGA values obtained using asrcv4.0 are almost identical to those with asrcv3.0

Using separately the Extended-ISC-GEM and Extended-ISC-GEM-AA catalogues with different shaped source model for the Sub-Saharan Africa (asrcv3.0 and asrcv4.0), the highest PGA values are found in the region close to the Horn of Africa including the Ethiopian Main Rift, Gulf of Aden and Red Sea where the PGA values of 0.40g and 0.21 g, 0.44g and 0.23g, 0.43g and 0.23g are expected to be exceeded with probability 2% and 10% in 50 years, respectively. The next high value has been observed in South Sudan, Ruwenzori area, the Eastern Rift and Western Rift where PGA of 0.1g or more can be experienced with probability of 10% in 50 years.

Based on the Sub-Saharan Africa Geodetic Strain Rate Model 1.0, some trivial calculation of seismicity rate starting from deformation was made. A source model containing 19 supported shaped OpenQuake seismogenic source typologies, which was used. We simulated these seismogenic source zones as plate boundary and a single fault structure. We compute the rate of occurrence of earthquakes along these plates boundaries given their global horizontal divergence velocity and boundary length . The results obtained were consistent with those obtained with seismicity tools. In the last stage, we supplemented the area sources with fault sources.

Seismic Hazard Assessment of South Africa: Seismic Source Model

V. MIDZI, T. Mulabisana, B. Manzunzu, B. Zulu, T. Pule, S. Myendeki and G. Rathod

Geophysics Competency, Council for Geoscience, Private Bag X112, Pretoria 0001, South Africa

A reliable seismic source model is a key element of the inputs required when conducting probabilistic seismic hazard assessments. Such a model defines the seismogenic potential, locations, sizes, and rates of future earthquakes. Ideally the model gives a clear definition of the causative faults that give rise to the observed seismicity. However, information to identify such faults in South Africa is not available. The alternative is the creation of a source model made up of characterised area source zones that encompass the possible sources of earthquakes likely to contribute towards the seismic hazard of the region. Though limited in quantity and usefulness, available geological, geodetic, seismic and geophysical data was useful in demarcating the zones and in assisting with the evaluation of seismic source characteristics. An approach was taken that began with the consideration and collection of hazard-significant technical issues and data. Typical and important data that were obtained included a homogenised catalogue of earthquakes and information used in the compilation of the seismotectonic map of Africa. The seismic source characterisation process began with the identification of criteria that were used to define the seismic sources. These criteria were identified based on due consideration of the stable continental region tectonic regime and the types of seismic sources that might be present (e.g., fault sources and area source zones). Based on these considerations, unique seismic sources are defined to account for distinct differences in the following criteria: 1. Major geologic and tectonic boundaries 2. Earthquake recurrence rate 3. Maximum earthquake magnitude (Mmax) 4. Expected future earthquake characteristics (e.g., style of

faulting, rupture orientation, seismogenic thickness) 5. Probability that a fault is seismogenic. Application of these criteria helped in the preparation of a seismic source model made up of 22 area source zones and two fault sources (Kango and Hebron faults). The seismic sources were characterised in terms of their earthquake recurrence, (i.e. b value and activity rates), as well as the maximum magnitude for each source and their seismogenic depths.

Keywords: Seismic Source Model, catalogue, South Africa, Seismotectonic Map, Recurrence Parameters

---

Fault detection using seismic attributes in the West Wits Line Goldfield, Witwatersrand Basin, South Africa

Mbali MKHABELA[1], Musa S.D. Manzi[1], Grant M. Bybee[1]

1. School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS, 2050, South Africa
Email: mbali.mkhabela@students.wits.ac.za

The Booysens Shale is 65 to 125 m thick shale that is prevalent throughout the Archaean Witwatersrand Basin in South Africa. The Boosens Shale, a possible source rock for hydrocarbons, underlies one of the most economically significant gold-bearing ore-bodies (e.g., Ventersdorp Contact Reef) in the basin. 3D volumetric and instantaneous attributes were applied to horizons picked from pre-stack time migrated data and compared to conventional seismic interpretation to provide insight into structures that extend from the Booysens Shale into the overlying Ventersdorp Contact Reef.

Instantaneous phase, frequency and envelope applied to the Booysens Shale revealed the stratigraphic variability of the shale unit from the northeast to t the southwest of the goldfield. These attributes successfully mapped the sub-crop position of the Booysens Shale, second-order faulting and high seismic amplitude anomalies in the northwest area possibly associated with faulting as well as intrusions intersecting the horizon. Dip, azimuth and edge-detection displays provided a detailed structural representation of faults displacing both the Booysens Shale and VCR. The edge-detection attribute was particularly useful in delineating faults that lie below the seismic resolution limit (e.g., quarter of the dominant wavelength) that were not visible in the conventional seismic displays. The structural analysis of the Booysens Shale and Ventersdorp Contact Reef using seismic attributes gives new insight into the tectonic evolution of the basin as well as structures that may be responsible for methane gas found at mining levels at depth.

Keywords: Booysens Shale, Ventersdorp Contact Reef, Seismic Attributes, Witwatersrand Basin

---

Integrated petrographic, geomechanical and seismological studies of rockmass behaviour during the extraction of the Cooke 4 shaft pillar

S.B. MNGADI[1], R. J. Durrheim[2,3] and the SATREPS[4] Research Group

1. The University of the Witwatersrand, South Africa, siyanda.b.m@gmail.com
2. The University of the Witwatersrand, South Africa, Raymond.Durrheim@wits.ac.za
3. CSIR Centre for Mining Innovation, South Africa, rdurrheim@csir.co.za
4. JST-JICA Science and Technology Research Partnership for Sustainable Development (SATREPS)

Seismic events and rockbursts are prime worries in deep South African gold mines. Large seismic events often result in infrastructure damage and casualties. This paper examines the seismic and mechanical behavior of the rockmass during shaft pillar extraction operations at Cooke 4 mine, South Africa, by means of microscopic petrographic analysis, rock mechanics laboratory tests and pillar stability assessment; and to establish correlations with monitored microseismicity and underground mapping. The pillar composition observed underground is quartzite, pebbly quartzite and argillaceous quartzite, and four sedimentary precursors were identified from petrographic studies: quartz arenite, lithic arenite, quartz wacke and conglomerate. Mechanical laboratory tests revealed that quartzite (originally quartz arenite) had the strongest uniaxial compressive strength, followed by pebbly quartzite (lithic arenite), argillaceous quartzite (quartz wacke) and lastly, meta-conglomerate (conglomerate).

Over 90% of the microseismic events were found to be associated with the mining fronts. Some of the seismic clusters delineated Ortlepp shears forming ahead of the stope, these were associated with the excavation-induced stress field, and this correlates with the stress pillar analysis. High stresses ahead of the stope are also indicated by ubiquitous discing observed on core samples. The acoustic emissions (AEs) were also concentrated in the vicinity of service

excavations such as tunnels. Several AE clusters were located away from excavations, likely delineating faults, indicating that seismicity is largely influenced by structural discontinuities and mining activities, and not rock types.

Keywords: Seismic, mechanical response, rockmass, geomechanical, petrography

---

Observations of the Vredefort Dome using 2D Seismics

Marcello MOLEZZI[1], Kim A.A. Hein[1], Musa S.D. Manzi[1]

1. School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS, 2050, South Africa
Email: mgmolezzi@gmail.com

The principle objective of this research was to investigate the 3D strato-structural architecture of the Vredefort Dome using 2D seismics. The dome and associated rim strata represent the collapsed central uplift of a complex crater structure formed by a giant impact, accepted to be the oldest (2023±4 Ma) and one of the world's largest (250-300 km diameter) confirmed impact structures. The current land surface exposure is estimated to be 5-8 km below the original impact surface level. However, the concentric synform-antiform fold geometry of the crater is preserved. The 2D seismic lines show consistency of the reflectors across each line. The overlying subhorizontal Karoo Supergroup overlies the south-eastern half of this volume, but has been omitted for simplification. There is no seismic data for the northern part of the Dome; therefore grid constraints affect the accuracy of the model. The architecture identified is in agreement with published work as the model illustrates some key features; these include: 1) synform-antiform architectures around the central uplift, 2) apparent strata uplift in the south-east (the structural complexity in the south-eastern portion of the Dome is inconsistent with the rest of the Dome and needs refinement), and 3) apparent tilting of the Dome of approximately 10° plunging towards the north-west.

Keywords: Witwatersrand Basin; Vredefort Dome; 2D Seismics; Modelling

---

Active Lineaments with the Chitapa-Karonga Area

Hassan S. Mdala[1], Leonard S. Kalindekafe[2], **Patrick R.N. CHINDANDALI**[1], Chikondi Chisenga[2], and **Felix MPHEPO**[1]

1. Malawi University of Science and Technology, P.O. Box 5196, Limbe
2. Geological Survey of Malawi, P.O. Box 27, Zomba

The Karonga area is situated at the junction where the eastern and the western branches of the East African Rift System (EARS) cross into the Malawi Rift and the Luangwa Valley in Zambia respectively. As part of the rift system, Karonga has been the most seismically active area in the country. In order to understand the hazard resulting from such activity, we mapped the lineaments using satellite imagery. The source data used included SRTM DEM, existing geological and geophysical data in order to improve the characterization of the lineaments. Lineament extraction from SRTM DEM was achieved through Automatic Lineaments Extraction algorithm in PCI GeomaticaTM software. Predominantly, N-S, NW-SE, NE-SW, NNW-SSE and E-W trends of extracted lineaments were observed and buffered out for further analysis. When correlated, the source data with the mapped lineaments largely populated in the central and northern parts of Karonga area, coincided well with the current seismicity. This implies that the current seismicity is influenced by movement along some of the mapped or sub-surface structures which might have the potential of generating the seismicity experienced in the area. More geophysical methods need to be employed to identify these lineaments to fully understand their orientation, depth and how they interact at depth in order to qualify them as seismogenic lineaments.

Keywords: Active Lineaments, Automatic lineaments extraction, Seismicity of Malawi, SRTM DEM of Malawi.

Lithospheric structure in southwestern Zambia from magnetotelluric observations

Daniel MUTAMINA[1], Jimmy Elsenbeck[2], Rob. L. Evans[2], Alan G. Jones[3]

1. Geological Survey Department, Ministry of Mines, Energy & Water Development, Lusaka, Zambia
2. Department of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA
3. Dublin Institute for Advanced Studies, 5 Merrion Square, Dublin 2, Ireland

The path of the East African Rift as it crosses through Zambia and into Botswana remains enigmatic. The Luangwa rift valley in Zambia is fully developed but there is no surface magmatism. The location of the Okavango Delta in Botswana, within the Damara mobile belt, supports the idea that rifting in this location takes advantage of pre-existing weaknesses in the lithosphere, as it does in other parts of the rift, but knowledge of the lithospheric structure through Zambia is poor making it harder to identify such zones.

As part of an ongoing program to study incipient rifting along the southwestern branch of the East African Rift, in 2011-2012 we completed a magnetotelluric (MT) survey in southwestern Zambia. The MT method is sensitive to the thermal structure of the mantle as well as to the presence of fluids such as partial melt or hydrogen (colloquially water) dissolved in olivine. MT data can be readily collected over large profiles making it an ideal method for characterizing continental lithosphere. Sixty sites were occupied using Phoenix MTU instruments providing data spanning periods from ~0.01 s to 2000 s. The data, augmented by existing data from the SAMTEX program, have been modeled through use of standard 2D and 3D inversion techniques. Preliminary models contain a highly conductive lower crust (between 20-40 km) at the western end of the survey region, consistent with the continuation of the Damara mobile belt northwards into this part of Zambia. The upper-mantle is also highly conductive over a broader region, with evidence for a thicker resistive lithosphere to the east. We are testing the limits of the conductive mantle and whether these conductivities require an additional contribution from a conductive phase such as melt and/or water or simply reflecting a raised geotherm as a result of the thinner lithosphere.

3D Geophysical modeling of the Bethlehem Sub-Basin, Free State, South Africa

Ansuya NAIDOO[1], Musa Manzi[1], Susan Webb[1] and Raymond Durrheim[1]

1. School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS, 2050, South Africa
Email: anaidoo18@gmail.com

Bethlehem is a small town situated in the Free State Province, South Arica. Geologically Bethlehem is situated on the Kaapvaal Craton and on the south eastern edge of the Witwatersrand Basin. The area is covered by Karoo sediments, which are Phanerozoic in age. The Bethlehem Sub–basin gravity anomaly was originally identified using Landsat images taken in 1972. The phenomenon was said to be caused by rain patterns due to its NW – SE trend. During gold and uranium exploration, boreholes drilled in the Bethlehem region intersected conglomerates, in Witwatersrand type sediments. This led to mining companies conducted other geophysical techniques such as seismic, magnetic and gravity surveys during mid-1980s to early 1990s. Their investigations revealed that the Bethlehem sub-basin is a structurally controlled remnant of a much bigger sedimentary sequence. However the investigations showed little potential for ore bodies and further study in the area was not conducted. Integrating 2D seismic data with magnetic, gravity and borehole data provided, a geological model of the Bethlehem region has been developed. The results showed a N-S trending normal fault, which may have uplifted the granite basement on the eastern side, with a maximum throw of 2.5 km. The Basement is covered by West Rand Group shales and Central Rand Group quartzites of the Witwatersrand Supergroup; this is overlaid by Klipriviersberg lavas of the Ventersdorp Supergroup which is followed by Dwyka and Ecca sandstones and shales of the Karoo Supergroup. The model shows two first order faults which have uplifted the granite basin, as well as subtle fault systems which have displaced the Central Rand Group Quartzites and Klipriviersberg lavas.

Keywords: Bethlehem, seismics, magnetics and gravity.

Contribution of seismology to the understanding of Cameroon tectonics

Evariste NGATCHOU HEUTCHI

University of Younde 1, CAMEROON

It is still difficult to picture how Cameroon develops its atypical present day tectonics. This is due to the complexity of the area and the fact that the tectonic settings of the structures are under much debate. Moreover, the past seismic investigations and structural model were analyzed in a limited area. So, no very accurate structural model of Cameroon was available, which highly hinders the proper earthquake location. Again, no study has been deeply conducted on the type of faulting triggering the events in Cameroon. A perfect interpretation of geodynamics and tectonics needs an accurate structural model, precise earthquake hypocenter locations and real focal mechanism solutions. The study represents thoroughgoing investigations focusing on the tectonic settings of Cameroon. The basic attack has been first to locate the earthquakes and use variety of techniques to describe the seismic activity. Then, the earthquake coordinates and structural models were used to compute the focal mechanism solutions. The analysis reveals an overall seismicity pattern characterized by the earthquakes at distinct localities with most of the activity in the Mt Cameroon area. The analyses together with some geological evidences have allowed to portray the Cameroon tectonics dominated by both dextral and sinistral mechanisms.

Seismicity studies of the Okavango Delta Region and the environs, Botswana.

B. NTHABA[1], R.E. Simon[2] and G. Ogubazghi[3]

Physics Department, University of Botswana, P/Bag UB 00704, Gaborone.
E-mail: nthabab@yahoo.com

The history of Botswana's major seismic events have been initiated by two earthquakes that occurred on the 11th of September and 11th of October 1952 with M_L Richter magnitudes of 6.1 and 6.7 respectively, in the Okavango Delta Region (ODR). Not much is known and documented about the seismicity of a larger coverage of Botswana primarily because of very limited seismological stations, with only nine in the existing network for national monitoring of earthquakes, which are biased on the north-western part of Botswana, the ODR. However, this study shows that micro-seismic activities are distributed not only on the northern part of Botswana, but also in other parts of the country such as the Kweneng west, Kweneng east and the southern part as well. Based on 327 events extracted from data compiled by the International Seismological Centre (ISC), the frequency-magnitude distribution (FMD) of earthquakes in Botswana from 1966 to 2012 was estimated, b-value and a-value for the entire interface catalogue were found to be 0.89 and 4.56, respectively, by the use of 'eye-fitting 'method. The completeness magnitude (MC) was found to be 3.7. The MC indicates the magnitude above which 100% of all earthquakes can be detected. The objective of this research project was to produce maps that show the spatial distribution of seismicity within Botswana, to assist in quest of hazard mitigation.

Keywords: Seismicity, b-value, Okavango Delta Region, Completeness magnitude

---

Fault Structures for Madagascar

Tsiriandrimanana RAKOTONDRAIBE[1, 3]**,** R.J. Durrheim[1], A. Nyblade[2], G. Rambolamanana[3]

1- School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS, 2050, South Africa
2- Penn State University, State College Pennsylvania, United States
3- Institute and Observatory of Geophysics in Antananarivo, University of Antananarivo, Madagascar
Email: tsitsikel@gmail.com

Madagascar's fault structures were established from previous work by inserting different field studies such as: aerial photographs, remote sensing, numerical field models and seismology studies. Predominant continental sedimentary rocks deposit occurred in the one-third of the island and a crystalline basement metamorphic rock (Precambrian rocks) formed with various igneous rocks that covers two-third of Madagascar throughout the central part .The second sequence in the central part is affected by normal faults due to the scarps, block tilting and opening of faulted basins, the most important of which being the Lake Alaotra Basin (Alain Pique, 1999).

Because of the scarcity of data only fault structures in the center part of the island were determined and interpreted. In this work, fault structure study in the whole part of Madagascar will be improved after using two years seismic data (2011-2013) from 26 temporary seismic networks deployed by the MACOMO project. About 400 localized seismic data with magnitude superior to 2.5.

Obtained results shows that focal mechanisms of clustered events occurred in the center , northern and southern part of Madagascar show respectively normal faulting with nodal planes having north- South orientation; strike slip faulting and almost reverse faulting. Orientation of each obtained faulting will be characterized. An extension of the main shear zone Bongolava Ranotsara can be interpreted and a new existing fault can be introduced in the Northern part and Southern part of Madagascar.

Keywords: Fault structures, Seismology, Focal mechanism, Madagascar

---

The impact of dolerites and basin depth on shale gas exploration in the main Karoo Basin

S.E. SCHEIBER-ENSLIN[1], S.J. Webb1 and J. Ebbing2

1. School of Geoscience, University of the Witwatersrand, South Africa, susan.webb@wits.ac.za
2. Department of Geosciences, Christian-Albrechts University, Kiel, 24118, Germany

The Main Karoo basin was deposited between approximately 300 and 180 Ma and covers a large portion of South Africa, including the high inland plateau. Smaller Karoo-type basins stretch up throughout southern Africa. Recent focus has been on the shale gas potential of the Whitehill Formation within the main basin. Initial estimates of the shale gas volume were around 485 trillion cubic feet (Tcf). This value was, however, downgraded to 30 Tcf after several factors were taken into account. These include depth of burial of the shale layer, thickness of the layer, later tectonic processes affecting the layer and proximity to dolerites that intruded the basin at 180 Ma. These factors in turn will affect the total organic carbon (TOC) and vitrinite reflectance (% Ro) values of the unit, which are a measure of the layers productivity. In this study we investigate the change in basin depth, as well as a change in dolerite concentration across the basin using borehole and seismic data. The basin deepens from on-craton in the northeast to the boundary with the Cape Fold Belt in the south, while the maximum concentration of dolerites is in the western and eastern part of the basin. These dolerites do not only have the potential to "burn off" gas within the layer, but can have the opposite effect of increasing the thermal maturity of the shale layer in places where there was previously no gas. The fracture networks associated with these dolerites can also provide storage for escaped gas. The optimum location for shale gas

exploration, therefore, is in the south-central basin. Seismic and Electromagnetic studies, however, will have to be done on a localised basis to understand the fracture networks associated with the few dolerites in this area to avoid contamination of groundwater.

The Seismological Network of Namibia

Mako SITALI

Ministry of Mines and Energy, Geological Survey of Namibia, Private Bag 13297, Windhoek
msitali@mme.gov.na

The Geological Survey of Namibia commenced the installation of a National Seismological Network (NSN) in 2000. The stations are located more than 500km apart from each other. Over the years, earthquakes have been widely reported in Namibia since in the early centuries by explorers and the first earthquake record occurred in 1910. Since then, hundreds of earthquakes have been recorded by regional and international seismic monitoring institution. Currently, there are eight seismological stations that form the national Seismological Network of Namibia, namely Windhoek, Rundu, Kamanjab, Aus, Ariamsvlei, Opuwo, Gobabis and Tsumeb.

The network consists of broadband and single phase stations which are powered by a national grid and others by solar power. The recorded data is acquired in real time via the GPRS mobile network to the main server located in Windhoek. The eighth station, which is the Tsumeb station, is part of the Global seismological Network and Incorporated Research Institutions for Seismology (GSN/IRIS), the Tsumeb station contributes to worldwide earthquakes monitoring. It is also one of the CTBTO's IMS AS067 monitoring of worldwide nuclear explosion. The national seismic data are used to provide a monthly bulletin, monitors earthquakes countrywide and provides data for the Earthquake Hazard Map of Namibia.

Seismic activity associated with the 2014 lava lake apparition at Nyamulagira volcano

Josue SUBIRA MUHINDO

Goma Volcanic Observatory, DRC

Seismic activity remains a key component in monitoring volcanoes. The ascent of magma in volcanoes is usually accompanied by earthquakes. The spatio-temporal variation of these earthquakes in the Nyamuragira region was been examined for the period from May 5, 2013 to December 31, 2014. In this period, several swarms from which 9 majors (with number of volcanic earthquakes > 60) including mostly long period (LP) and hybrid earthquakes have been observed. The hypocenter location of these Low Frequency earthquakes have been made using SEISAN software, and all the activity has been observed in the North and Northeast flanks of the volcano. It was also noted that, after the April earthquake swarm, the seismicity decreased significantly, reference to the SAM (Seismic Amplitude Measurement) analyses. From this last swarm, a permanent eruption in the crater (lava lake), was been observed until now. In June 2014, a light (setting up of the new lava lake) was been observed in this Northeast part of the volcano, but without significant variation of the seismicity. This light remains active until now. A lava lake was been observed again at Nyamulagira volcano between 1921 and 1938, and many scientific discussions turn to describe similarity between the actual activity with this former one.

Keywords: Lava Lake, Nyamulagira volcano, volcanic tremors, Hybrid earthquakes, Earthquake swarm

---

Structural Development of the Potchefstroom Fault, Witwatersrand Basin, South Africa

Matt TERRACIN

University of the Witwatersrand, Johannesburg, South Africa.
Mterracin@gmail.com

This project examines a data set of 2 dimensional seismic lines acquired by Anglo Gold as part of the exploration of the Witwatersrand Basin. The project focuses on the area around the Potchefstroom fault and attempts to develop a 3 dimensional model of the development of this regional structure.

The various 2D seismic lines were gridded to develop pseudo- 3D surfaces of both the lithologies and sub-surface structures.

The resultant model of the area revises previous structural interpretations by demonstrating that there is no single "Potchefstroom Fault". Rather the area is the intersection of three major regional scale structures consisting of 2 south-easterly verging thrusts and a normal fault downthrown to the south-east. This has resulted in the complete removal of the Central Rand Group west of the normal fault and only partial deposition of the Ventersdorp Supergroup between the thrusts.

Lithospheric structure in NW of West African Craton: Case of the Moroccan Atlas Mountains

Youssef TIMOULALI[1] and Nacer Jabour[2]

1. Institut Scientifique, Mohamed V University, Rabat, Morocco
2. National Center of Research (CNRST), Rabat, Morocco

Email: ytimoulali@gmail.com

This study presents the outcomes of the local earthquake tomography applied in NW of West African Craton at the Moroccan Atlas domains. The arrival times data used in this study were obtained by the Moroccan seismic network. The seismic data (P and S wave arrival times) have been collected by 36 seismic stations located in the Atlas–Meseta domain for the period between 1988 and 2010. A linearized inversion technics and 3D modeling are used for determination of local velocity structure.

The interpretation of tomography images results emphasizes a new and detailed lithosphere structure presented by a high velocity body beneath the Souss Basin located from 20- to 45-km depth dipping to the North and interpreted as a body that marks the border between the Moroccan Anti-Atlas and the Meseta –Atlas domains. A second body with high velocity is detect beneath the Hercynian Tichka Massif from 10 to 50-km inclined away from Anti Atlas. This positive velocity anomaly can be interpreted as an old subduction making the limit between Meseta domain and West African Craton. In the eastern part of Anti Atlas, a high velocity body dipping northward from Jbel Ougnat at 15 to 40 km is detected. The occurrence of tholeiitic magmatic activity in the Hercynien Ticka massif zone and in the Jbel Ougnat leads us to conclude that a remains subduction zone exist in these zones

Keywords: Atlas Mountains; Seismic tomography; Crustal velocity; Lithospheric structure; Remains subduction

---

The Occurrence of Disaster Earthquakes in the Lake Kivu Basin, Western Branch of The East African Rifts System

M.D. WAFULA[1,2], K.T. Tambala[2] and B.S. Fiama

1. Department of Physics, Faculty of Sciences, University of Kinshasa.
2. Department of Geophysics, CRSN/ Lwiro, D.S. Bukavu.

Email: dmwafula@yahoo.fr

The Lake Kivu Basin is located in the Western Branch of the East African Rifts System consisting of two branches. The Western Branch includes the several great lakes namely: Albert, Edward, Kivu, Tanganyika, Rukwa and Malawi, with their lake basins presently very active. The tectonic conditions of the dome uplift, faulting, volcanism and shallow seismicity around the Lake Kivu (the highest 1462 m) are believed to be the indications of actual rifting and may represent a nascent stage in the development of plate boundary. Since 1997, it was observed in the Lake Kivu Basin the recrudescence of seismic activity. This seismic activity is mostly concentrated in the South-Western part of the Basin where earthquakes are regularly felt. Three large earthquakes associated with foreshocks and long duration aftershocks mostly confined around the epicenter areas were already recorded in the Basin: The October 24th event with magnitude m_b= 6.1, the February event with magnitude m_b=6,0 and the August 7, 2015 event with magnitude m_b= 5,8. Three events occurred at shallow depth around 10 km. It was observed small Tsunamis during these earthquakes reaching 5 m high and landslides on the shorelines near the epicenters. Many damages were recorded in the villages and towns mostly near the epicenters even in the big city of Bukavu with about 900.000 inhabitants. More than 50 persons were already killed. The mechanism solutions of these seismic events indicated the normal fault and the different epicenters are correlated with the local faults observed in the Basin. The occurrence of large earthquakes in the Lake Kivu may be dangerous because of the existence of dissolved gas; carbon dioxide (CO_2) and methane (CH_4) in the deep water of Lake Kivu, with the possibility of gas explosion.

Keywords: Lake Kivu Basin, recrudescence, epicenters, faults, damages.

Investigating the seismic signal of elephants: using seismology to mitigate elephant-human conflict

Susan WEBB, Musa Manzi, Ansuya Naidoo and Andriamiranto Raveloson

University of the Witwatersrand

Human interactions with wild elephants are often a source of conflict, as elephants invade inhabited lands looking for sustenance. In order to mitigate these interactions, a number of elephant defense systems are under development. These include electric fences, bees and the playback of warning calls recorded from elephants. With the discovery that elephants use seismic signals to communicate (O'Connell-Rodwell et al., 2006, Behav. Ecol. Sociobiol.), it is hoped that seismic signals can also be used to help reduce conflict.

Our current research project investigates the spectral content of the elephant seismic signal that travels through the ground using a variety of geophones and seismometers. Our experimental setup used a Geometrics Geode 24 channel seismic system with an array of 24 geophones spaced 1 m apart in an area of compact soil overlying weathered granites. Initially we used 14 Hz vertical geophones. The ground and ambient noise conditions were characterized by recording several hammer shots. These were used to identify the air wave, wind noise, and the direct wave, which had a dominant frequency of ~50 Hz.

Several trained elephants that 'rumble' on command were then deployed ~5 m perpendicular to a line of 24 (14 Hz) vertical geophones between the 1 and 10 m geophone positions. We recorded a number of different elephants and configurations, and digitally recorded video for comparison. An additional deployment of 20 (14 Hz) horizontal geophones was also used. For all data, the sample interval was 0.25 ms and the recording length was 16 s as the timing of the rumbles could not be precisely controlled.

We were able to identify the airwave due to the elephant's rumble with velocities between 305-310 m/s and the ground seismic signal due to the rumble with frequencies between 20-30 Hz. Our next experiment will include broadband seismometers at a further distance, to more fully characterize the frequency content of the elephant signal.

Building Geophysics Talent and Opportunity in Africa: Experience from the AfricaArray/Wits Geophysics Field School

Susan WEBB[1], Musa Manzi[1], Stephanie Scheiber-Enslin[1], Raymond Durrheim[1], Michael Jones[1] and Andy Nyblade[2]

[1]University of the Witwatersrand

[2]Pennsylvania State University

There are many challenges faced by geophysics students and academic staff in Africa that make it difficult to develop effective field and research programs. Challenges to conducting field work that have been identified, and that can be tackled are: lack of training on geophysical equipment and lack of exposure to field program design and implementation. To address these challenges, the AfricaArray/Wits Geophysics field school is designed to expose participants to a wide variety of geophysical instruments and the entire workflow of a geophysical project.

The AA field school was initially developed for the geophysics students at the University of the Witwatersrand. However, by increasing the number of participants, we are able to make more effective use of a large pool of equipment, while addressing challenging geophysical problems at a remote field site.

These additional participants are selected partially based on the likely hood of being able start a field school at their home institution. A good candidate would have access to geophysical equipment, but may not have knowledge of how to use it or how to effectively design surveys. These are frequently junior staff members or graduate students in leadership roles.

The three week program introduces participants to the full geophysical field workflow. The first week is spent designing a geophysical survey, including determining the cost. The second week is spent collecting data to address a real geophysical challenge, such as determining overburden thickness, loss of ground features due to dykes in a mine, or finding water. The third week is spent interpreting and integrating the various data sets culminating in a final presentation.

Participants are given all lecture material and much of the software is open access; this is done to encourage using the material at the home institution. One innovation has been to use graduate students as instructors, thus building a pool of talent that has developed the logistic and training skills necessary to implement field programs. Several geophysics field schools are being developed in Madagascar, Zimbabwe, Nigeria, Kenya, Uganda, Tanzania and Cameroon. We hope to enable some of our graduate students to help with these budding programs

---