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9th Annual AfricaArray Workshop

School of Geosciences
University of the Witwatersrand,
Johannesburg, South Africa

20-21 January 2014

REPORT

Annexure A: Participant List
Annexure B: Programme
Annexure C: Abstracts

9th Annual AfricaArray Workshop
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Introduction

The AfricaArray Workshop, held at the University of the Witwatersrand Johannesburg in January 2014, was the ninth workshop to be held since the research and capacity development program was established in 2004. AfricaArray continues to grow in scope and size. Notable developments since the eight workshop, held in January 2013, are:

- The deployment of new multi-sensor stations as part of the "backbone" network;
- The initiation of several new projects e.g. investigations of lithospheric structure in Botswana, and the seismic hazards and risk of eastern Africa;
- The award of MSc and PhD degrees

Participants

Seventy-four delegates attended the workshop. Forty delegates were sponsored. In selecting applicants, we considered various criteria:

- Scientific specialization, seeking a mix of disciplines;
- Age, seeking a mix of experience and youth;
- Nationality, seeking a wide geographic spread;
- Institutional affiliation; and
- Current or potential future involvement in AfricaArray programmes.

Twenty African countries were represented, and nine of the delegates received travel support from UNOOSA. The Participant List is appended to this report (Annexure A, p. 4)

Training and Scientific Programme

Two training programmes and three related workshop were offered on 19 and 22-31 January 2014, and attended by many of the sponsored delegates, as well as some local delegates:

- A training course on the operation of AfricaArray stations, presented by Professor Nyblade, Dr Delvaux and Dr Tokam Kamga.
- A training course on the use of the SEISAN code for locating earthquakes
- A workshop engineering seismology
- A workshop on the Global Earthquake Model (GEM)
- A workshop on developing a new seismotectonic map for Africa

Many Papers and posters were presented at the two-day Scientific Meeting held on 20 and 21 January 2014. Major themes were:

- Reports on the current status and future plans for the observational networks, research and educational activities
- Structure and tectonics of the African Plate
- African geodesy and stress
- Seismic monitoring and seismic hazard assessment
- Mining induced and engineering seismicity
- Initiatives allied to AfricaArray

The Workshop Programme and Abstracts are appended to this report (Annexure B and C)

Acknowledgements

We thank the following organizations for sponsorship of delegates: Department of Science and Technology, through the South African Research Chairs programme; the UN Office for Outer Space Affairs; and Penn State University.

We also thank the persons who provided administrative and technical support: Toni Mooney (Penn State), Sharon Ellis (Wits) and Matt Kitching (Wits).

Annexure A: Participant List

Full Name (Last, First)	Job Title	Company/Organization	Country
Abba, Mohammad J	Senior Scientific Officer	Centre for Geodesy & Geodynamics	Nigeria
Abdulhamidt, Nuhu	Senior Scientific Officer	Central for Geodesy and Geodynamics	Nigeria
Abiye, Tamiru A	Professor	University of Witwatersrand	South Africa
Afegbua Kadiri, Umar	Principal Scientific Officer	Centre for Geodesy and Geodynamics (CGG)	Nigeria
Akpan, Anthony	Senior Lecturer	Physics Department, University of Calabar , Cross River State, Nigeria	Nigeria
Akpan, Ofonime	HOD of Seismology	Centre for Geodesy & Geodynamics	Nigeria
Amponsah, Paulina	Manager, National Data Centre	Ghana Atomic Energy Commission	Ghana
Anakwuba, Emmanuel	Lecturer	Nnamdi Azikiwe University	Nigeria
Andeta, Biruk	Geophysicst	Addis Ababa University	Ethiopia
Andreoli, Marco	Consultant	NECSA	South Africa
Andriampenomananany Ony, Fenitra Sy Tanjona	Student Researcher	Institute and Observatory of Geophysics Antananarivo (IOGA)	Madagascar
Ayikwei, Abigail	Postgraduate Student	Department of Earth Science University of Ghana	Ghana
Bolaji, Segun	Teacher/Research	University of Lagos	Nigeria
Brandt, Martin	Seismologist	Council for Geoscience	South Africa
Brian Zulu	Seismic Hazard Analyst	Council for Geoscience	South Africa
Chibi, Anesu George	Seismic Analyst/Station Operator	Geotz Observatory	Zimbabwe
Chileshe, Mirriam	Seismogram Analyst	Geological Survey Government	Zambia
Chindandali, Patrick Rafik	Senior Siesmological Technician	Geological Survey of Malawi	Malawi
Chuma, Constant	PhD Student	National University of Science & Technology (NUST)	Zimbabwe
Daud Masungulwa, Ntambila Simon	Assistant Lecturer	ARDHI University, Tanzania	Tanzania
Dere, Joshua	Scientific Officer I	Center for Geodesy and Geodynamic Earthquake Seismology Department	Nigeria
Duncan, Dauda	Senior System Analyst	Earthquake Seismology Dept, Centre for Geodesy and Geodynamics Toro, Bauchi State, Nigeria	Nigeria
El-Sayed, Amr	Assistant Researcher/Seismologist	National Research Institute of Astronomy and Geophysics, Cairo, Egypt	Egypt
El-Sayed, Hany Mohammed	Researcher Assistant	National Research Institute of Astronomy and Geosphysics	Egypt
Essrich, Friedemann	Director	SiM Mining Consultants	South Africa
Gichini, Richard Kariuki	Seismic Data Analyst	University of Nairobi	Kenya
Gore, Gabriel Fonsiano	Civil Infrastructure Engineer/Project Manager	Ministry of Electricity, Dams, Water Resources and Iggigation	South Sudan
Gwaleba, Method Julius	Tutorial Assistant	ARDHI University, Tanzania	Tanzania

Hayola, Joseph	Senior Surveyor	ARDHI University, Tanzania	Tanzania
Inguane, Helio Filemone	Technician	National Directorate of Geology	Mozambique
Lupindi, Sergio Borralho Mayomona	Technician	Inamet	Angola
Maidala, Malla Abba	Scientific Officer	Centre of Geodesy and Geodynamics, Toro Bauchi	Nigeria
Makanjuola, Daniel	Assistant Lecturer	Salem University	Nigeria
Marimira, Kwangwari	Station Manager	Meteorological Service Department, Goetz Observatory	Zimbabwe
Mavazhe, Patricia	Seismic Analyst	Meteorological Service Department	Zimbabwe
Mavonga Tuluka, Georges	HOD of Seismology	Goma Volcano Oberservatory	DRC
Meghraoui, Mustapha	Professor	EOST - IPG Strasbourg	France
Midzi, Vunganai	Chief Scientist	Council for Geoscience	South Africa
Mosuro, Ganiyu Omotalo	Lecturer	Olabisi Onabanjo University	Nigeria
Moursi, Ahmed	Assistant Professor	National Research Institute of Astronomy and Geophysics, (NRIAG)	Egypt
Mphepo, Felix	Seismological Assistant	Geology Survey Seismological	Malawi
Msumba, Flemings	Seimological Assistant	Geological Survey Department	Malawi
Mulabisana, Thifhelimbilu Faith	Junior Scientist	Council for Geosciences	South Africa
Ngailo, Elly Gerson	Assistant Lecturer	ARDHI University, Tanzania	Tanzania
Nguiya, Severin	Lecturer	University of Douala/Industrial Engineering Faculty	Cameroon
Nyago, Joseph	Seismic Data Analyst	Dept of Geogolical Survey & Mines	Uganda
Nyblade, Andrew	Professor	Penn State University	United States
N'Yombo, Francois Lukaya	Researcher	Goma Volcano Oberservatory	DRC
Obiekezie, Theresa	Senior Lecturer/Cordinater Earth & Space Science Research Group	Nnamdi Azikiwe University	Nigeria
Obihan, Tfeanyi	Assistant Lecturer	Salem University, Lokota	Nigeria
Ohakwere-Eze, Michael	Graduate Assistant	Salem University	Nigeria
Okoyeh, Elizabeth	Lecturer	Nmamdi Azikiwe University Awka, Nigeria	Nigeria
Olayanju, Gbenga	Senior Lecturer	The Federal University of Technology, Akure, Ondo State, Nigeria	Nigeria
Oniku, Adetola	Associate Professor	Dept of Physics, Federal University of Technology, Yola, Nigeria	Nigeria
Osumeje, Joseph	Assistant Lecturer	Ahmadu Bello University, Zaria-Nigeria	Nigeria
Ozulu, George	Lecturer II	Salem University Lokoza	Nigeria
Rakotondraibe, Tsiriandrimanana	Student Researcher	Institute and Observatory of Geophysics Antananarivo (IOGA)	Madagascar
Ramarolahy Rina, Andrianasolo	Student Researcher	Institute and Observatory of Geophysics Antananarivo (IOGA)	Madagascar
Ramaselaga, Mpho	Geophysicist	Department of Geological Survey	Botswana
Raphael, Mukandila Ngalula	PhD. Student	University of Kinshasa	
Rouai, Mohamed	Professor - Research	Faculty of Science, My Ismail University	Morocco
Saria, Elifuraha	Lecturer	Ardhi University	Tanzania
Shaba, Pearson	Senior Seismology Technician	Geological Survey Department	Malawi
Singh, Mayshree	Lecturer	University of KwaZulu Natal (UKZN)	South Africa
Sinkonde, Christopher Chikaonde	Principal Mapping and Geospatial Officer	Department of Surveys and Mapping Services	Malawi
Tambulasi, Luciano	Seismology Analyst	Geological Survey Department	Malawi
Tessema, Tesfaye Temtime	Geophysicist	Geological Survey of Ethopia	Ethiopia
Tladi, Botune B	Chief Technician	Department of Geological Survey	Botswana
Tokam Kamga, Alain-Pierre	Post Doc	School of Geoscience, University of Witwatersrand	South Africa
Tonang Zebaze, Arnaud	Head of mines office of Adamawa Region	Ministry of Mines, Industry and Technology Development	Cameroon
Uzoegbo, Herbert	Associate Professor	University of Witwatersrand	South Africa
Wane, Oumar	Geologist Ingenner	Direction of Mines and Geology	Senegal
Wemegah, David Dotse	Lecturer/PhD. Student	KNUST/Aarhus University, Denmark	Ghana

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Programme

9th Annual AfricaArray Workshop

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19 January	*8h00-15h00*	*Training course for AfricaArray station operators*
20-21 January	*8h00-17h00*	*AfricaArray Scientific Meeting*
22 January	*9h00-12h30*	*Launch – IASPEI Seismological Commission for Africa*
22 January	*14h00-17h00*	*Engineering Seismology Workshop*
23 January	*9h00-12h00*	*Engineering Seismology Workshop (continued)*
23 January	*14h00-17h00*	*GEM Workshop*
24 January	*9h00-12h00*	*GEM Workshop (continued)*
25 January	*9h00-17h00*	*Seismotectonic Map for Africa Workshop*
26 January	*9h00-17h00*	*Seismotectonic Map for Africa Workshop (continued)*
27-31 January	*8h00-17h00*	*Seisan training (at Wits University)*

GLT Lecture Theatre, Geosciences Building, Wits **Monday 20 January 2014**

08:00 - 08:30 REGISTRATION

08:30 - 08:40 Welcome
Zeblon VILAKAZI (*DVC Research, 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 AfricaArray International Field School
Sue Webb (*University of the Witwatersrand, SOUTH AFRICA*)

09:15 - 09:30 Training and complementary activities
Ray DURRHEIM (*University of the Witwatersrand/CSIR, SOUTH AFRICA*)

Theme: Structure and tectonics of the African Plate

09:30 - 10:00 KEYNOTE: Seismotectonic along the plate boundary in North Africa
Mustapha MEGHRAOUI (*University of Strasbourg, FRANCE and leader of the IGCP Seismotectonic Map of Africa project*)

10:00 – 10:20 The P and S wave velocity structure of the mantle beneath eastern Africa and the African superplume anomaly
Andy NYBLADE (*Penn State University, USA*) & **Gabriel MULIBO** (*Nelson Mandela-African Institute of Science and Technology, Tanzania*)

10:20 - 10:40 Crustal structure beneath the Precambrian basement in Nigeria
Ofonime AKPAN (*Centre for Geodesy and Geodynamics, NIGERIA*)

10:40 – 11:10	***Tea break***
11:10 - 11:30	Neotectonic setting and seismotectonics of the of the Kivu rift region **Damien DELVAUX**(*Royal Museum for Central Africa, BELGIUM*)
11:30 - 11:50	Recent felt M5.7 earthquakes (3 July 2013) in the region of Lake Albert and their significance to seismic hazard assessment **Georges MAVONGA TULUKA** (*Goma Volcano Observatory, DR Congo*)
11:50 - 12:10	Global seismicity in the east of DR Congo **Francois LUKAYA N'YOMBO** (*Goma Volcano Observatory, DR Congo*)
12:10 - 12:30	S-wave receiver function studies of African basins **Helio INGUANE** (MSc candidate, *University of the Witwatersrand, SOUTH AFRICA & National Geology Directorate, MOZAMBIQUE*)
12:30- 13:30	***Lunch break***
13:30 - 14:00	KEYNOTE: Challenges of intraplate seismicity: an example from Mozambique **Joao FONSECA** (*Instituto Superior Técnico, PORTUGAL*), **Jose CHAMUSSA** (*National Geology Directorate, Mozambique*) **& A DOMINGUES** (*University College, UK*).
14:00 - 14:20	Seismotectonic model for the KZN Province, South Africa **Mayshree SINGH** (*University of KwaZulu Natal, SOUTH AFRICA*)
14:20-14:40	Geophysical study of south Cameroon: structural and tectonic implications **Severin NGUIYA** *(University of Doula, CAMEROON*)
14:40 - 15:00	Structure of the lithosphere beneath the Cameroon Volcanic Line **Alain-Pierre TOKAM KAMGA** (*Post-doctoral Fellow, University of the Witwatersrand, SOUTH AFRICA*)
15:00 - 15:30	***Tea break***
15:30 - 15:50	Geophysical mapping of the inland extension of the Chain and Charcot Fault zones, southwestern Nigeria **Gbenga OLAYANJU** (*Tarkwa University of Technology and Mines, GHANA*)
15:50 - 16:10	Shear wave velocity model of El-Minya area, central Egypt, from the joint inversion of receiver functions and surface wave dispersion **Amr EL SHARKAWY** (*National Research Institute of Astronomy & Geophysics (NRIAG), EGYPT*)
16:10 - 16:30	Estimation of the attenuation of seismic waves in South African mining districts **Artur CICHOWICZ** (*Council for Geoscience, SOUTH AFRICA*)
16:30 - 16:50	Interpretation of 3D reflection seismic data from the Witwatersrand basin, South Africa, to assess the risk posed by inrushes of water and flammable gases **Musa MANZI** (*University of the Witwatersrand, SOUTH AFRICA*)
16:50 - 17:10	Interpretation of potential field and seismic data in the Karoo basin, South Africa, for shale gas potential **Stephanie SCHEIBER-ENSLIN** (*PhD candidate, University of the Witwatersrand, SOUTH AFRICA*)
17:10 - 17:30	The Automatic Determination of Magnetic Source Parameters **Gordon COOPER** (*University of the Witwatersrand, SOUTH AFRICA*)
17:30 - 19:30	**POSTERS & Finger *Supper in the Bleloch Museum***

GLT Lecture Theatre, Geosciences Building, Wits **Tuesday 21 January 2014**

Theme: African geodesy and stress

08:00 – 08:30 KEYNOTE: Refined kinematic model for the EAR / Progress towards defining the Geodetic Reference frame for Africa (AFREF)
Elifuraha SARIA (*Ardhi University, TANZANIA*)

08:30-08:50 The present velocity field of Africa
Rui FERNANDES (SEGAL, *PORTUGAL*)

08:50-09:10 Gravity-derived crustal thickness models: Is improved data adding more than different techniques? Examples for Africa
Mark VAN DER MEIJDE (*ITC, University of the Twente, THE NETHERLANDS*)

09:10-09:30 Reducing non-uniqueness in satellite gravity inversion using 3D object-oriented image analysis techniques
Islam FADEL & Mark VAN DER MEIJDE (*ITC, University of the Twente, THE NETHERLANDS*)

09:30-09:50 Further progress in mapping the South Africa regional stress: seismological implications
Marco ANDREOLI (*NECSA & University of the Witwatersrand, SOUTH AFRICA*)

09:50 - 10:10 Reactivation and rheology of Western Cape Faults
Ake FAKARENG (*University of Cape Town, SOUTH AFRICA*)

10:10 – 10:40 ***Tea break***

Theme: Seismic monitoring and hazard assessment

10:40 - 11:00 Processing earthquakes catalogues: critical issues and declustering algorithms
Ganesh RATHOD (*Council for Geoscience, SOUTH AFRICA*)

11:00 - 11:20 Seismic data quality assessment
Mohamed EL GABRY (*National Research Institute of Astronomy & Geophysics (NRIAG), EGYPT*)

11:20 - 11:40 Extension of the Parametric-Historic approach for seismic probabilistic hazard analysis
Petrus VERMEULEN (*PhD candidate, University of Pretoria, SOUTH AFRICA*)

11:40 - 12:00 Earthquake intensity in South Africa
Vunganai MIDZI *(Council for Geoscience, SOUTH AFRICA)*

12:00 - 12:20 The curious incident of the 1919 Swaziland earthquake
Brassnavy MANZUNZU *(Council for Geoscience, SOUTH AFRICA)*

12:20 - 12:40 Seismic monitoring in Malawi and seismic hazard assessment in Zomba
Winstone KAPANJE & Pearson SHABA (*Geological Survey Department, MALAWI*)

12:40- 13:50 ***Lunch break***

Theme: Mining-induced and engineering seismicity

13:50 - 14:20	KEYNOTE: Observational studies in South African gold mines to mitigate seismic risks – What do Japanese seismologists hope to learn? **Hiroshi OGASAWARA** (*Ritsumeikan University, JAPAN*)
14:20 - 14:35	Rockmass deformation associated with the extraction of the shaft pillar at Cooke #4 **Siyanda MNGADI** (*MSc candidate, University of the Witwatersrand, SOUTH AFRICA*)
14:35 - 14:50	Seismic hazard analysis in the gold mining regions of South Africa **Brian Sibunelo ZULU** (*Council for Geoscience SOUTH AFRICA*)
14:50 - 14:05	Late-stage rift seismicity in central Afar and the Tendaho Dam Safety, (Ethiopia): Downstream risk implications. **Atalay AYELE** (*University of Addis Ababa, ETHIOPIA*)
15:05 - 15:30	***Tea break***

Theme: Initiatives allied to AfricaArray

15:30 – 16:00	KEYNOTE: Assessing earthquake hazard in Europe and the Middle East **Domenico GIARDINI** *(ETH, SWITZERLAND)*
16:00 – 16:20	GEM regional programme for Sub-Saharan Africa and progress towards developing an earthquake risk model **Atalay AYELE** (University of Addis Ababa, *ETHIOPIA)*
16:20 – 16:40	IASPEI & the African Seismological Commission **Michelle GROBBELAAR** (*Council for Geoscience, SOUTH AFRICA*)
16:40 – 17:00	American Geophysical Union (AGU) & Society of Exploration Geophysicists (SEG) **Sue WEBB** (*University of the Witwatersrand, SOUTH AFRICA*)
17:00 – 17:15	IUGS Resourcing Future Generations initiative **Ray DURRHEIM** (CSIR & *University of the Witwatersrand, SOUTH AFRICA*)
17:30 - 19:00	**POSTERS & Finger *Supper in the Bleloch Museum***

Posters on display in the Bleloch Museum from 19-21 January 2014

Structure and tectonics of the African Plate

Structural style of major rift fault systems in the Turkana region, north Kenya
Valeria BILANCIA (*University of Cape Town, SOUTH AFRICA*)
Spatial analysis of the regional structural lineaments and regional tectonics of southwestern Zimbabwe
Constant CHUMA (*National University of Science & Technology, ZIMBABWE*)
Towards a new subsurface structural map for the Congo basin
Etienne KADIMA KABONGO (*University of Lubumbashi, DRC*)
Fractal temporal clustering in the aftershocks of the Al Hoceima (Morocco) earthquake of 24 February 2004.
Mohamed ROUAI (*My Ismail University, MOROCCO*)
Seismotectonic model for the KZN Province, South Africa
Mayshree SINGH (*University of KwaZulu Natal, SOUTH AFRICA*)
A broadband experiment in Botswana: setup and implementation
Mark VAN DER MEIJDE (*ITC, University of the Twente, THE NETHERLANDS*)

Geodesy

Pre-analysis at early stages of AfricaArray and Malawi-Tanzania project GPS time series
Ntambila Simon DAUD MASUNGULWA, Elly Gerson NGAILO & Joseph HAYOLA (ARDHI University, *TANZANIA*)
Deformation measurement in Central Afar, Ethiopia, using InSAR and GPS
Tesfaye Temtime TESSEMA (*Geological Survey of Ethiopia, ETHIOPIA*)

Seismic monitoring and hazard assessment

Radon measurements in soils along the cost of Accra from Teshie to Nyanyano, southeastern Ghana
Sylvanus AHULU (*Geological Survey Department, GHANA*)
Radon measurements in soils along the cost of Accra from Teshie to Nyanyano, southeastern Ghana
Paulina AMPONSAH (*Ghana Atomic Energy Commission, GHANA*)
Assessment of seismic hazard for West and Central Africa using an incomplete catalog
Bekoa ATEBA (*Institute of Geological and Mining Research, CAMEROON*)
Active faulting and folding along the Maghreb region in the framework for the seismotectonic map of Africa
Abdelhakim AYADI (*Centre de Recherche en Astronomie Astrophysique et Géophysique, Algeria*)**, Mustapha MEGHRAOUI, Said MAOUCHE, Farida OUSADOU, Youcef TIMOULALI, Nacer Djabour & Samir BOUAZIZ**
Seismology in Zambia
Mirriam CHILESHE (*Geological Survey Department, ZAMBIA)*
Seismicity and tectonics of Malawi
Patrick Rafik CHINDANDALI (*Geological Survey, MALAWI)*
The national satellite seismic networking system, seismicity of Angola.
Bernardo Manuel EBO & Sérgio LUPINDI (*National Institute of Meteorology and Geophysics (INAMET), ANGOLA*)
Seismic research in Madagascar
Fenitra ANDRIAMPENOMANANA, Tsiriandrimanana RAKOTONDRAIBE & Rina R. ANDRIANASOLO *(Institute and Observatory of Geophysics of Antananarivo (IOGA), MADAGASCAR)*
Status of environmental sustainability in Rwanda as one of the MDGs between 2000 and 2013
Jules KAZUNGU (*Regional Research Centre for Integrated Development RWANDA*)
New seismic hazard map for Zimbabwe
Victor MAPURANGA (*MSc candidate, University of Pretoria, SOUTH AFRICA*)
Seismic hazard assessment for southern Africa
Thifhe MULABISANA (*MSc candidate, University of the Witwatersrand & Council for Geoscience, SOUTH AFRICA*)
The importance of residuals of PGA for PSHA
Vasily PAVLENKO (*PhD candidate, University of Pretoria, SOUTH AFRICA*)
Signal to Noise ratio for Kaduna and Toro stations in Nigeria from noise and earthquake events
Kadiri UMAR AFEGBUA (*Centre for geodesy & Geodynamics, NIGERIA*)
Seismic hazard assessment of Cameroon
Ariane WETIE (*MSc candidate, University of Pretoria, SOUTH AFRICA*)

ABSTRACTS

Crustal structure beneath the Precambrian basement in Nigeria

O.U. AKPAN[1,3], A. A. Nyblade[2], C. S. Okereke[3] and M. I. Oden[3]

1. Department of Earthquake Seismology, Centre for Geodesy and Geodynamics, Toro, Nigeria.
2. Department of Geosciences, Pennsylvania State University, University Park, U.S.A.
3. Department of Geology, University of Calabar, Calabar, Nigeria.

A study was carried out at 3 stations of the Nigerian National Network of Seismographic Stations (NNNSS) using the H-k stacking of receiver functions to determine the crustal structure at these stations. The stations are located at Ile-Ife, Kaduna and Toro on the Nigerian Precambrian basement complex. The results showed that the Moho depths were 35 km, 32 km and 39 km at Ile-Ife, Kaduna and Toro stations respectively. Vp/Vs ratios of 1.76 were obtained at the 3 stations, which are equivalent to a Poisson's ratio of 0.26. This results indicates that the crust has a predominantly felsic to intermediate composition at these stations. This study is the first attempt to estimate the crustal structure beneath seismographic stations in Nigeria using teleseismic earthquake data.

Keywords: Nigeria, teleseismic earthquake, receiver functions, H-k stacking, Poisson's ratio.

Radon measurements in soils along the coast of Accra from Teshie to Nyanyano, southeastern Ghana

Paulina AMPONSAH[1,2], Aba Andam[2], Bruce Banoeng –Yakubo[3]

1. National Nuclear Research Institute, Ghana Atomic Energy Commission, Legon.
2. Graduate School of Nuclear and Allied Sciences, University of Ghana, Legon.
3. Department of Earth Science, University of Ghana, Legon.

A study has been undertaken along the coast of Accra (Teshie to Nyanyano) in the Greater Accra Metropolitan Area to investigate the emission of radon gas in the area using Lenin Resin (LR) - 115 cellulose nitrate detectors. Twenty seven sampling points were considered within a 500 m × 500 m spaced grid. A set of detectors were buried at a time and were replaced fortnightly for a period of two weeks. Three exposures were made at each location. Due to logistics constraints, the detectors were buried in phases over a period of fifteen weeks. After the exposure period the detectors were etched, air dried in the laboratory and the alpha tracks registered were counted using the Spark counter. The radon data obtained were analyzed and for each detector four counts were made and the average value was taken. The track density was calculated using the average tracks counted and the area of field of view of the electrode. The radon gas concentration was computed using the calibration factor (k = 0.29) obtained by the Ghana Atomic Energy Commission and verified in an inter-comparison exercise organized by the Environmental Protection Agency of the United States of America and the International Atomic Energy Agency. The radon concentrations range from 1.40 kBqm- 3 to 282.87 kBqm- 3 for the period of monitoring. The average soil radon concentration measured during the period of the survey was 24.41 kBqm-3.The background level of radon concentration increased before a magnitude 1.5 earthquake struck the area.

Keywords: Ghana; soil radon concentration; coastal boundary fault; seismic activity

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Seismic Research in Madagascar

Fenitra ANDRIAMPENOMANANA, Tsiriandrimanana RAKOTONDRAIBE & Rina R. ANDRIANASOLO

Institute and Observatory of Geophysics of Antananarivo (IOGA), MADAGASCAR

The seismology branch of the Laboratory of Seismology and Infrasound LSI at the Institute and Observatory has for main goal the study of the seismicity, the tectonic context and the velocity structure beneath Madagascar. The seismic activity affects the whole island but the epicenters are unevenly spread. Most of the epicenters are in the central part of Madagascar; by using appropriate seismological method for data from broadband seismic station like the joint inversion of receiver function and Rayleigh wave group velocities, the result is that at the Moho depth is between 33km to 48 km. Regarding the tectonics of Madagascar: the epicenter distribution indicates that the lower crust of Madagascar is still active and the seismic activities are mostly related to preexisting structures. We see that the normal faults exist with average dip of 55 degrees and reveal the main active faults. Our future works will deal about the studies of the local seismicity for the entire island, surface wave tomography, focal mechanism inversion and seismic hazard of Madagascar.

Progress in Mapping the South African Regional Stress Field: Seismological Implications

M A G ANDREOLI[1,2], A Bumby[3], Z Ben-Avraham[4 5], D Delvaux De Fenffe[2,6], M De Wit[3], R Durrheim[2,7], A Fagereng[8], A O Heidbach[8], M Hodge[8], A Logue[1,8], H Malephane[2], N v d Merwe[2], J Muoka[2], K Saalmann[2], I Saunders[10], K Tabola[3]

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2. University of the Witwatersrand, South Africa
3. University of Pretoria, South Africa, Adam.Bumby@up.ac.za
4. Tel Aviv University, Israel, zviba@tau.ac.il
5. University of Haifa, Israel
6. Royal Museum for Central Africa, Belgium, damien.delvaux@africamuseum.be
7. CSIR, South Africa, RDurrhei@csir.co.za
8. University of Cape Town, South Africa, Ake.Fagereng@uct.ac.za
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The intensity and orientation of the natural principal compressive stresses ($\sigma_1 > \sigma_2 > \sigma_3$), or the azimuth of the *maximum horizontal compressive stress* (σ_H), are key parameter that mining and civil engineers and seismologists should know to determine the reactivation potential of known faults or the behavior of large excavations. Unfortunately, much of the subcontinent is under-represented in the World Stress Map database, and this is a problem that our consortium is trying to rectify using a multidisciplinary approach. Our first step in this direction started with the monitoring of the Grootvloer seismic cluster in the Northern Cape – southern Namibia.

In 2012 we replaced two obsolete TELS seismic instruments that collected data for over twenty years at the Vaalputs site with a compact, broad-band Trillium seismic sensor at the same site. We also added two 1-sec sensors of the same make at Aggeneys and Koffiemeul (Bushmanland). All three stations are equipped with Reftek data loggers and powered by solar panels. Much of 2013 was plagued by technical problems related to the installation and transmission of data; these issues are now being rectified. When the data from these stations will be received, they will be integrated with data from the national network to obtain the focal mechanisms of the events. These stress tensors will be combined with σ_H parameters obtained from caliper logs of off-shore wells and from the geometry of neotectonic joints, faults and sheared fractures as found across South Africa. Areas currently investigated include Bushmanland (Vaalputs – Bosluis Pan), NW Free State (Bultfontein), West Griqualand (Douglas), and the southern Cape (Gansbaai). We also include underground rock engineering phenomenological observations and measurements, and data in the public domain.

Our observations consistently indicate a NNW-SSE oriented σ_H (Wegener Stress Anomaly or WSA) that prevails across most of central, southern and western South Africa, Namibia up to the Ruacana hydroelectric power plant at the Angola border. However, in the Congo basin, a few earthquake focal mechanisms suggest rotation of the regional σ_H to an E-W direction. Geological units affected by the WSA include the Cretaceous oceanic lithosphere (Walvis Ridge), the southern Angola-Kasai craton, the offshore Outeniqua and Orange Basins, the Cape Fold Belt, the Namaqualand metamorphic complex, and the Archaean Craton up to the Witbank coal field. Azimuths of σ_H in the NE-SW quadrants seem prevalent in E Mpumalanga, N Natal, and northern Limpopo.

Whereas the NE-SW stress orientations may be linked to the southerly propagation of the E African Rift System, the strike-slip to transpressional character of much of the WSA remain unexplained. The WSA is also puzzling as its intensity has waxed and waned over time spans of millions to tens of millions of years, with at least 7 successive tectonic regimes having affected Namaqualand in the past 130 Ma. The available evidence also suggests that the WSA was responsible for seismogenic reactivation of older faults and uplift along the Griqualand-Transvaal Axis in the past 20 Ma, and for a 3-fold increase in seismic events in the Grootvloer cluster in the past 20 years.

Keywords: South Africa, Grootvloer seismic cluster, stress tensors, neotectonics, Wegener Stress Anomaly

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Preliminary Seismic Hazards Assessment in West and Central Africa Based on Incomplete Earthquake Catalogues

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The monitoring of earthquake activity by local seismic arrays is quite recent (< 50 years) in Central and West Africa. Earthquake catalogues on that part of the continent are incomplete. In 1991, Bertil studied the seismicity of West and Central Africa based on networks of seismic stations in Ivory Coast and neighbouring countries. Results have been compiled and two sub-catalogues identified with a magnitude 3 level of completeness. We also used the reference work of Ambrasseys and Adams on the seismicity of West Africa to determine the period during which a complete catalogue is extracted for earthquakes of magnitude > 4. The Aki Utsu Extension (AUE) method implemented by Kijko and Smit is applied to the data set. The results give a *b*-value of 0.63 ± 0.06 for the whole period and preliminary seismic hazards curves are also plotted for return periods 50, 500 and 1000 years. This is a good and practical example showing that AUE method can be used for seismic hazards assessment in central and western Africa.

Keywords: Africa, earthquake catalogue, seismic hazards.

Active Faulting and Folding in the Maghreb Region: A framework for the Seismotectonic Map of Africa

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Most of the seismic activity in the Maghreb region took place along the Africa-Eurasia plate boundary. This area displays a complex pattern of active deformation mainly characterized by thrust or reverse faults. During the last decades many strong earthquakes have occurred in the Atlas Mountains of North Africa such those of: Agadir (1960), El Asnam (1980), Constantine (1985), Tipasa-Chénoua (1989), Mascara (1994), Al Hoceima (1994), Ain Temouchent (1999), Zemmouri (2003) and Al Hoceima (2004). For inland faults, surface ruptures and long–term active tectonics appear as a thrust escarpment and fold-related faulting visible in the field and using remote sensing images, or measured using space-borne geodesy (GPS or INSAR). For coastal faults, major uplifts of late Quaternary marine terraces and folding with steplike morphology are exposed indicating the incremental development of coastal active deformation. We have investigated the similarities and differences between different active fault-related folding along the Africa-Eurasia convergent plate boundary. These active structures are seismogenic and the striking case studies are the 1960 Agadir (Mw 5.9), the 1954 Orleansville (Mw 6.7), the 1980 El Asnam (Mw 7.3), the 1992 Gafsa (Mw 5.3), the 1999 Ain Temouchent (Mw 6.0), and the 2003 Zemmouri (Mw 6.8) earthquakes. From paleoseismic investigations the El Asnam active fold shows 0.6 to 1.0 mm/yr uplift rate. West of Algiers on the Sahel anticline, the levelling of uplifted successive coastal benches and notches document the incremental folding uplift with ~ 0.84 – 1.2 mm/yr uplift rate in the last 120-140 ka. The relatively fast folding growth during late Pleistocene and Holocene in the Atlas Mountains attests for the significance of earthquake activity and the importance of convergent movements between Africa and Eurasia in the Western Mediterranean. A stress map based on focal solutions inversion, Quaternary tectonic shortening

are presented for the study area. This work is prepared in the framework of the UNESCO (SIDA) - IGCP Project 601 "Seismotectonics and Seismic Hazards in Africa".

Late-stage rift seismicity in central Afar and the Tendaho Dam Safety, (Ethiopia): Downstream risk implications.

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Temporary broadband seismic networks deployed from 2007 to 2011 around the Afar triple junction of the East African rift system provide insights into space-time seismicity patterns of the actively deforming, comparatively mafic crust beneath and bounding the 1.86 km3 impounded lake system behind the Tendaho dam. The Tendaho dam region is characterized by a network of intersecting NNE-trending and NW-trending faults. Seismicity clusters indicate that both fault sets are active and are potential seismogenic hazards. The dam was completed and started filling in 2009. Though a water load of this size can trigger earthquakes in the area, the neighborhood is naturally active and it is not easy to evaluate whether the apparent increase in seismic activity reflects changing magmato-tectonic conditions or the influence of reservoir induced seismicity (RIS). However, it is clear that the dam region experiences high levels of tectonic and volcano-tectonic activity and the spatial distribution suggests that groundwater movement may also influence seismicity patterns. The spatial coincidence of narrow zones of crustal seismicity and upper mantle low velocity zones evident in S-wave tomography models suggests that melt production zones guide the distribution of strain during continental rupture. Given its volcanically and seismically active setting, the Tendaho dam site and the surrounding region require continuous monitoring for the safety of downstream population and to protect development infrastructures in the Afar Regional State.

Rift basin structure: examples from the Western Turkana basins, North Kenya

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The structural style of continental rifts depends on a combination of thermal, mechanic and kinematics parameters that control the deformation of the stretched lithosphere. When a number of factors interact concomitantly, such as long duration of rifting, strong structural inheritance, volcanic activity and changing stress field conditions, the structural complexity of the rift increases. This is the case of the Turkana basins in Northern Kenya, which represent a key area for understanding the evolution and the features of the Kenya Rift. This region is indeed characterized by a complex history of boundary fault propagation, activation and deactivation, influenced by pre-existing basement fabrics and showing a migration of the tectonic activity with time (Morley et al., 1999). On the basis of field work, geophysical and drilling results derived from hydrocarbon exploration in the past thirty years (Amoco, 1985-1989; Shell, 1990-1992; Tullow, from 2011), the level of knowledge of the geological features in the Turkana area has greatly improved. The dominant rift structures correspond to a series of west-thickening half-graben basins bounded by east-dipping major bounding faults. However, within the half-graben type depocentres, the bounding faults exhibit a wide range of characteristics such as low-angle to high-angle dips, linear to curved map view geometries, strongly uplifted rift flanks to minor uplift. These variations are in part related to inherited parameters (such as crustal thickness, Precambrian basement fabrics and lithologies) and in part to evolving patterns of magmatism and crustal temperatures. Understanding how and why these different factors affect fault patterns and their evolution is important for a better understanding of both the structural history of the rift and the way sedimentation has interacted with structures. The issues of fault development in the Western Turkana basins were addressed the study of the Major Bounding Faults:

sections across the basins (based on satellite images, geological maps, and seismic reflection data) were made to show the range of fault geometries. Besides, seismic data were used to investigate how the styles of major faults in map view develop with time, such as the along-strike changes in structural style and how the footwall uplift is affected by the lateral propagation and linkage geometries of the bounding faults. We are going to present here some of the key geological results derived from the analysis of 2D seismic datasets combined with outcrop studies carried in the Turkana area.

Keywords: Turkana, continental rift, half-graben basins, bounding faults.

Zambia's Seismic Network, its past participations in Africa Array and experiences encountered.

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The Zambian Seismic Network (ZSN) of five analogue seismic stations was established from 1983 to 1985 with assistance from the Finnish government with collaboration from the Finnish Institute of Seismology, University of Helsinki. The ZSN comprised one main station in Lusaka and four remote stations located in Isoka (IKZ), Kasempa (KMZ), Mansa (MZZ) and Petauke (PTZ). Since then to date there has been a number of upgrades from analog to digital seismometers in order to improve the quality of data detected.
The Analysis Centre was and is still located in Lusaka at Geological Survey Department. The records from LSZ are in near real time while those from the remote stations are collected by analysts. The Seismic Unit with one Seismologist, two senior Seismogram Analysts, four Seismogram Analysts and two station Attendants was established in the Geophysics section responsible for seismological matters. However, due to lack of personnel to fill up the established positions and as a way of integrating seismic activities within the Geophysics Section, all the members of the Geophysics Section were and are still required to fully get involved in seismological matters. This presentation describes the Zambian Seismic Network its past participations and goes on to describe various experiences encountered.

Keywords: Network, Seismic, Station.

Seismicity and Tectonics of Malawi

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Instrumental seismological observation in Malawi started in 1962 with two Z-component seismographs in Blantyre and Mzuzu. The stations remained in operation until they were replaced by five new analogue seismographs in 1989 by the Council for Geoscience of South Africa. Data recorded historically and instrumentally show earthquake distribution pattern in the Malawi Rift highly concentrated between latitudes 8.5000^{o}S and 13.5000^{o}S followed by latitudes 13.5000^{o}S and 14.5000^{o}S with a few clusters further south of latitude 14.5000^{o}S before seismicity picks up at latitude 17.0000^{o}S. Fault plane solutions on some major earthquakes have shown predominance of normal faulting with tension axes oriented perpendicular to strikes of faults which is consistent with the faulting mechanisms in the Western branch of the East African Rift System. Focal depths of <15 km on majority of earthquakes have been determined in this region although depths >15 km have been reported such as the 10th March, 1989 Salima earthquake whose depth was determined at 32±5 km. Seismicity in the South Rukuru Basin on the south-west of Nyika plateau shows high concentration within the Thunduwike-Kazuni area with a NW-SE trending pattern while it gets diffuse further NW in the Luangwa Valley. Generally, the distribution pattern in the Malawi rift suggests epicentres are closely related to rift structures without clear association to particular causal faults due to insufficient data and errors in locating events and recording gaps.

Keywords: Malawi rift, seismology in Malawi, instrumental data, Thunduwike-Kazuni area, focal depth

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Estimation of the Attenuation of Seismic Waves in Mining Districts, South Africa

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A study of regional attenuation contributes to the seismological and geological characterization of the region. The evaluation of the attenuation of ground motion amplitude is an essential for strong ground motion prediction. Accurate evaluation of attenuation is important to evaluate a magnitude for earthquakes, source dimension and seismic moment, prediction of ground motion and hazard assessment. Studies of attenuation in seismically active regions are very popular however; stable parts of continents around the world do not provide many opportunities to investigate attenuation. The only places in South Africa which guarantee excellent recordings of ground motion caused by seismic events are the mining districts. The attenuations of the P- and S-waves were estimated in the areas of mining districts in South Africa, using induced local events located in the distance range varied from 3 km to 120 km and the depths of events were less than 3 km. The body waves quality factors, Qp-1 and Qs-1 values are estimated by using coda normalization method. The strong observed frequency dependency of the quality factors is modelled using the Q-1 (f) = Qo-1 f -n parametric model. Coda amplitude was obtained from the root-mean-squared amplitude for a 5 sec time window at the lapse time 16 sec for events located closer than 30 km and a time window of 10 sec and lapse time 60 sec for events in the range 60 km to 120 km. The obtained values of Qp-1 vary from 0.017 to 0.0031 and of Qs-1 from 0.012 to 0.0013 in the frequencies ranging from 3 to 24 Hz. The frequency dependence of parameters are calculated for a set geometrical spreading constant, γ is fixed at unity for distances less than 60 km and at 0.75 for distances in the range between 60 km to 120 km. The ratio Qp-1/Qs-1 varies from 1.5 to 2.5.

Spatial Analysis of the Regional Structural Lineaments and Regional Tectonics of South-Western Zimbabwe

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The spatial variation of regional lineaments and tectonics of south-western Zimbabwe is presented. The significance of regional structural lineaments and regional tectonics cannot be overlooked when studying the regional seismicity and groundwater potential. Remote sensed data and other ancillary data were analysed using geospatial techniques. The regional lineaments are associated with faults, fracture zones, and lithological contrasts along fold belts, while the main direction of faulting and jointing is north-north-west to north, with several faults oriented to the north-north-east parallel to the Zimbabwe Great Dyke. Analysis of the lineaments in this region showed great potential to elucidate the possible regional seismtectonic activity of the area. This qualitative analysis need to be validated with the use of recent seismic data.

Keywords: Lineaments, tectonics, remote sensing, GIS, Zimbabwe

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The Automatic Determination of Magnetic Source Parameters

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Eulers equation for profile data is given by (Thomson, 1982); (1)

$$\Delta x \frac{\partial f}{\partial x} + \Delta z \frac{\partial f}{\partial z} = -N.f$$

where the known quantities are the field strength *f*, its horizontal and vertical gradients, and the structural index *N*. The unknown quantities are Δx and Δz, the distance from a given point to the source location in the horizontal and vertical planes. Cooper (2012) showed that this equation could be reformulated as; (2)

$$r = \frac{Nf}{As}$$

where *r* is the distance to the source and *As* is the analytic signal amplitude. Additionally (Cooper, 2013) it can be shown that; (3)

$$r = \frac{(N+1)As}{As_2}$$

where As_2 is the second order analytical signal amplitude. Equation 1 has been applied to the horizontal and vertical derivatives of the field, to the *As*, and to the Hilbert transform of *f, H(f).* In this work it is shown that applying equation 2 to the *As* is equivalent to the use of equation 3. Additionally, applying equation 3 to the horizontal or vertical derivatives of *f* gives identical results because they form a Hilbert transform pair, and similarly, the application of equation 3 to *H(f)* gives identical results to its application to *f.*

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Keywords: Potential fields, Semi-automatic interpretation.

Neotectonic Setting and Seismotectonics of the of the Kivu Rift Region

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The Kivu rift region forms a particular rift segment in the western branch of the East African rift system, between the northern termination of the Tanganyika rift and the southern extension of the Edward-George rift. It is however not isolated in the center of the African plate, but part of the intraplate deformation and influenced by its intraplate setting. We present also a new tectonic map for this region which lies in the northern portion of the Kabaran belt (Karagwe-Ankolean). A compilation of existing data on earthquake epicenters, focal depth, focal mechanisms, thermal springs and neotectonic faults has been performed. SRTM topographic data at 90 and 30 m resolution, river network extracted from the SRTM 90 m and bathymetric data have been used to better constrain the geographic locations, and also as a new topographic reference for analyzing the morpho-structural elements.

At the scale of the African plate, the western shoulder of the Kivu rift marks the transition between the Congo Basin, characterized by E-W horizontal compression, and the Kivu rift basin, characterized by E-W horizontal extension. This is expressed by a progressive rotation of the stress directions, together with a progressive change in stress regime. The basement structural fabric plays an important role in controlling the development of neotectonic structures. The general rift structure is marked by the interaction of two grabens systems that join in the Rusizi accommodation zone. A first system, formed by the NNE-SSW alignment of the Edward-George basin, the Virunga volcanoes and the Kivu basin, seems to continue south-westward into a tectonic depression that forms the upper part of the Elila river catchment. This rift valley alignment is bordered on its western side by the Lubero, Mitumba-North and Kahuzi-Biega chain of rift shoulder mountains. The Elila basin and south Kivu basins are flanked on their eastern side by the South-Mitumba Mountains in DRC and the Nyungwe massif in SE Rwanda. This eastern flank is dissected by the Rusizi basin which forms the northern termination of the N-trending Tanganyika rift basin. This complex architecture is controlled by basement structures and influence also the tectonic stress field. The distribution of seismicity and thermal springs shows that tectonic deformation is not limited to the central part of the rift valley but also affect its flanks. It is particularly well expressed for the western flank, which is affected up to 200 km away, i.e. up to the margin of the Congo basin. The eastern flank is also affected by neotectonic activity, in Burundi, Rwanda and NW Uganda. This area was strongly uplifted and tilted in response of rifting activity, as shown by the presence of river flow reversals and captures, inundation lakes, swamps and recent lacustrine deposits, as well as by seism epicenters and rare thermal springs.

The national satellite seismic networking system and the seismicity of Angola

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The poster provides a brief summary with maps and photos of the seismicity of Angola and its seismic network: the stations, instruments used, zones of high seismicity, largest recorded earthquake and the earthquake of 2013 (Chicomba e Cassongue).

Seismic Data Quality Assessment

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Noise analysis is useful for characterizing the performance of existing broadband stations and for detecting transients related to station operation and should be taken into consideration when selecting sites for new stations. The variation of seismic noise levels, as a function of geography, season, and time of day, can be characterized by applying the PSD technique on the seismic data observed by different stations. To estimate the true variation of noise at a given station Probability Density Functions (PDF) of seismic noise are generated from many PSDs. Estimates of PSDs and PDFs may be derived to form the basis for noise maps. The noise maps are useful for estimating the quality of seismic data, the performance of stations and optimizing the distribution of the network.

Reducing Non-Uniqueness in Satellite Gravity Inversion using 3D Object Oriented Image Analysis Techniques

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Non-uniqueness of satellite gravity interpretation has been usually reduced by using a priori information from various sources, e.g. seismic tomography models. The reduction in non-uniqueness has been based on velocity-density conversion formulas or user interpretation for 3D subsurface structures (objects) in seismic tomography models.

However, these processes introduce additional uncertainty through the conversion relations due to the dependency on the other physical parameters such as temperature and pressure, or through the bias in the interpretation due to user choices and experience.

In this research, a new methodology is introduced to extract the 3D subsurface structures from 3D geophysical data using a state-of-art 3D Object Oriented Image Analysis (OOA) technique. 3D OOA is tested using a set of synthetic models that simulate the real situation in the study area of this research. Then, 3D OOA is used to extract 3D subsurface objects from a real 3D seismic tomography model. The extracted 3D objects are used to reconstruct a forward model and its response is compared with the measured satellite gravity. Finally, the result of the forward modelling, based on the extracted 3D objects, is used to constrain the inversion process of satellite gravity data.

Through this work, a new object-based approach is introduced to interpret and extract the 3D subsurface objects from 3D geophysical data. This can be used to constrain modelling and inversion of potential field data using the extracted 3D subsurface structures from other methods. In summary, a new approach is introduced to constrain inversion of satellite gravity measurements and enhance interpretation capabilities.

Reactivation and Rheology of Western Cape Faults

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The Western Cape of South Africa is a stable continental region, which experiences little seismic activity relative to plate boundary regions. There is, however, a historical record of significant earthquakes, including an event of local magnitude (M_L) 6.3 in Ceres-Tulbagh in 1969. This earthquake accommodated sinistral strike-slip motion along a subvertical, north-west striking fault. In a 3 month long local microseismic study, we have observed microseismic activity, $-2.2 < M_L < 1.6$ (n = 168), localised to a zone ~ 4 km wide across strike, and subparallel to the aftershock zone of the 1969 Ceres-Tulbagh event. The microseismicity is detected to a maximum depth of 15 (+/- 2) km, indicating this is the depth of the seismogenic zone in this area.

In the Gansbaai area of the Southern Cape, subvertical joint systems in Plio-Pleistocene aeolianites indicate a subhorizontal least compressive stress oriented NE – SW. These joints are interpreted to be locally related to inferred blind normal faults, striking NW – SE, in the underlying sandstones. Breccias, kink bands, and minor normal faults within the aeolianites also indicate slip on NW - SE striking basement-hosted normal faults. In particular, the Blomerus fault is likely reactivated at least once since the Pleistocene. Depending on whether this fault slips in one rupture along its entire length, or in a number of segments, earthquakes on this fault may have magnitudes up to a maximum of moment magnitude (M_W) 7.3.

If the current greatest compressive stress is vertical, then the Blomerus fault is well oriented for reactivation as a normal fault, as it then strikes approximately parallel to the intermediate principal stress, and its surface trace is near perpendicular to the least stress as indicated by the joint systems measured in the Southern Cape. Thus, despite very long earthquake repeat times in a low strain regime, the Blomerus fault may be considered a potential seismic hazard.

The Ceres-Tulbagh region, on the other hand, shows a history of strike-slip faulting, requiring a subvertical intermediate stress. In addition, the strike of the currently microseismically active zone is subparallel to the greatest principal horizontal stress as determined from Southern Cape joints. It is possible that there is some stress rotation in the horizontal plane between Gansbaai and Ceres, or alternatively, the surface trace of the microseismic zone is indicative of the greatest horizontal stress. In the latter case, the strike-slip faulting in the Western Cape may represent transform faulting related to the extensional fault systems surrounding the Western Cape region. The location of faulting may relate to availability of well-oriented basement structures, within otherwise relatively strong crust. This interpretation requires further modelling, but could explain the presence of the Ceres-Tulbagh microseismic cluster, and the local inferred subvertical intermediate stress.

The present velocity field of Africa

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This work focuses on the analysis of the estimated velocity field for Africa derived using the existing network of cGNSS (continuous Global Navigation Satellite Systems) stations in Africa. It is being carried out in the framework of the IGCP Project 601 – "Seismotectonics and Seismic Hazards in Africa", which goal is the creation of a new thematic map of the seismic hazards of Africa.

Currently, the number of stations in Africa with sufficient information (time-series with more than 3 years of data-span and monument/equipment stability) already reaches more than 100. Although the network is spatially biased with significant gaps existing particularly on the Central and North (Sahara) Africa, its distribution already permits to compute an accurate velocity field that is able to sense the major tectonic units forming the African continent and to quantify their present-day kinematics.

The velocity solutions are computed with respect to the latest global reference frame, ITRF2008, using the existing temporal correlations between the daily solutions of the stations in order to properly estimate the velocity uncertainties and to detect any artifacts in the time-series.

We present new estimates for the present-day angular velocities of the major tectonic units in Africa, namely the Nubia and Somalia plates, and the tectonic blocks in the East Africa Rift. Additionally, we computed several estimates for several sub-regions coincident with the seismotectonic provinces defined in the framework of the IGCP Project 601 (when the data was sufficient). The results show that significant internal deformations are observed inside the considered stable part of several tectonic blocks that need to be understood.

Challenges of intraplate seismicity, an example from Mozambique

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Our understanding of earthquakes progressed through qualitative jumps, often related to major disasters. The Aristotelian notions dominated through time until the Lisbon earthquake in 1755, when modern seismology was born. Field observations in the wake of the San Francisco earthquake of 1906 led to the elastic rebound model of the earthquake process. Following pioneer work on continental drift by A. Wegener and A. duToit in the first decade of the 20th Century, the advent of plate tectonics in the 60's finally provided a rationale for most of the seismicity observed in the planet. Despite its great success, plate tectonics fails to account for the earthquakes that occur away from the plate boundaries, which, while corresponding to a small portion of the global seismic moment release, can make a strong contribution to seismic risk, because often they have epicenters directly underneath populated areas, combined with shallow depths. In addition, intraplate earthquakes reveal characteristics that are still poorly understood, such as temporal clustering and space migration. The recent M8.6 Indian Ocean earthquake of 2011 had a surprising effect on global seismicity in the following days. All these reasons warrant research into the driving mechanisms and controlling factors of intraplate earthquakes, and the African plate has the potential to provide clues into these poorly understood phenomena.

We present and discuss preliminary results from the MozaRT Project, a 2.5-year long deployment of very broad seismographic stations in Central and South Mozambique. Main goals include the investigation of the seismicity – on the wake of the M7 Machaze earthquake of 2006, in Central Mozambique – the characterization of crustal structure through tomography and receiver function analysis, and the understanding of the mechanisms behind the current deformation. The main result concerning the seismicity is the identification of a ~300 km long linear structure, seismically active down to depths of 30+ km, extending the known reaches of the East African Rift System from Northern Mozambique to the Machaze epicentral region. We relate the geometry of this seismicity belt to the strong contrast in crustal thickness through the Lobombo-Nuanetsi-Sabi monoclines, between the Kaapvaal and Zimbabwe cratons to the West and the Mozambican Coastal Plains to the East. We discuss the difficulties inherent to the characterization of the seismicity in slowly deforming regions, and highlight the importance of paleoseismological studies, still unavailable in the region.

Web-Based Geospatial Database for Management of Forest Ecosystems and Services: the Case of Pugu and Kazimzumbwi Coastal Forest Reserves in Kisarawe District, Tanzania

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Forest encroachment and Deforestation are major challenges to forest managers and other stakeholders who need reliable data and information for management. As in most of the forest reserve across the country Pugu and Kazimzumbwi forest reserve face a challenge of improper data management which results into poor forest management due to lack of effective and efficient Geospatial database for managing data from various projects, researches and studies. The research aim was to develop a Web based Geospatial Database for Forest Ecosystems and services data management. The requirement analysis and design of the system was conducted based on the nature of forest data. Forest data were reviewed to get an insight on how the use and usability can be effected. Also forest managers were interviewed to get more detail about forest management while looking upon the existing technology.
A Web based Geospatial database developed for management of Forest Ecosystems and services of Pugu and Kazimzumbwi forest reserve based on the open geo architecture comprised of three parts:- i) spatial database containing layers like Road, river, plot, Entropy, pixel_data, Pugu and Kazimzumbwi forest reserve boundaries was implemented using PostGIS, and non spatial database for these layers was implemented in PostgreSQL, both PostGIS and PostgreSQL being free and open source Database Management Systems (DBMS).
ii) Application logic was developed using MapServer by creating a configuration map file and the connection was made to the geodatabase. iii) User Interface was developed using Open layers for visualization and interactivity to the geodatabase. The Open layers were connected to the MapServer. A developed Web based Geospatial database was tested for its functionality by posing queries through interface. The geodatabase provided easier, faster access to spatial data, better data access control and versioning and more efficient data management and maintenance

Keywords: Tanzania, Geospatial Database, Coastal Forest, ecosystems and services.

Shear Wave Velocity Model of El-Minya, Central Egypt, from Joint Inversion of Receiver Functions and Group Velocity Dispersion

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A more accurate shear wave velocity model beneath El-Minya area is determined using the joint inversion of receiver functions and group velocity dispersion measurements. This study is conducted by using the teleseismic data recorded by Tal El-Amarna seismic station (TAMR, very broad band) within epicentral distances ranges from 30◦ to 90◦ from various azimuths. The joint inversion results reveal that the Moho depth is located at about 37±2 km. At this depth, the Vs = 4.4 km/sec and associated with a high Vp/Vs ratio (1.97). The depth to the basement is approximately 3 km from the surface. The shear wave velocity model delineates presence of a very shallow low velocity zone which represents the sedimentary cover and is underlined by another low velocity zone of thickness ranges from 5 to 8 km in the upper

crust (granitic layer) and can be observed at depths approximately from 7 to 15 km on the obtained model. The Conrad discontinuity is located at depth of 18 km with shear wave velocity is 3.6 km/sec. The observed low velocity zones may be attributed to the presence of zones of broken rocks due to faults with a possibility of fluids or water seepage from the Nile River through faults cut the upper crust of the area as this area very closed to the Nile.

Keywords: Velocity Model, Joint Inversion, El-Minya, Egypt.

S wave Receiver Functions Studies of African Basins

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Basin system of Southern and Eastern Africa is not well known, therefore crustal studies were conducted using PRF (P wave Receiver Functions). We conducted SFR (S wave Receiver Functions) studies in eleven stations using data from ZP, YH, XV network located in sedimentary basins in Mozambique, Tanzania and Uganda. In this are temporary stations and results, Moho arrival is in between 4s and 5.9s. Using grid search were used to determine Moho thickness and Rayleigh group velocities. Moho thickness is 32 km ~ 40km, velocities average 3.4km/s and 3.8km/s.

Keywords: African basins, S-wave Receiver Functions, Grid search, Rayleigh velocities

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3D object-oriented image analysis in 3D geophysical modelling: Analysing the central part of the East African Rift System

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Non-uniqueness of satellite gravity interpretation has traditionally been reduced by using a priori information from seismic tomography models. This reduction in the non-uniqueness has been based on velocity–density conversion formulas or user interpretation of the 3D subsurface structures (objects) based on the seismic tomography models and then forward modelling these objects. However, this form of object-based approach has been done without a standardized methodology on how to extract the subsurface structures from the 3D models. In this research, a 3D object-oriented image analysis (3D OOA) approach was implemented to extract the 3D subsurface structures from geophysical data. The approach was applied on a 3D shear wave seismic tomography model of the central part of the East African Rift System. Subsequently, the extracted 3D objects from the tomography model were reconstructed in the 3D interactive modelling environment IGMAS+, and their density contrast values were calculated using an object-based inversion technique to calculate the forward signal of the objects and compare it with the measured satellite gravity. Thus, a new object-based approach was implemented to interpret and extract the 3D subsurface objects from 3D geophysical data. We also introduce a new approach to constrain the interpretation of the satellite gravity measurements that can be applied using any 3D geophysical model.

Keywords: Satellite gravity, 3D gravity model, Object-oriented image analysis, Inversion, Tanzania Craton, Seismic tomography

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Status of environmental sustainability in Rwanda as one of the Millennium Development Goals (MDGs)

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This paper seeks to highlight brought about by diverse techniques that have been adopted by Rwanda in order to achieve environmental sustainability, one of the eight Millennium Development Goals (MDGs). The Government has taken several policies and measures to ensure of environment sustainability. Land covered by Forest in Rwanda improved between 2000/1 and 20010/11 from 12.4 to 24.5 per cent and it seems likely that the 2015 target of 25 per cent will be met. This is coupled with an increase in percentage of land protected to maintain biodiversity from 8% in 2008 to 10.13% in 2012. Access to safe drinking water improved between 2005/6 and 20010/11 from 70.3 to 74.4 per cent but it seems unlikely that the 2015 for the MDG target of 82% will be met. Following a modest improvement in access to improved sanitation of eight percentage points between 2000/1 and 2005/6 there has been an accelerated increase between 2005/6 and 2010/11 of 16 percentage points. Despite this good achievement, Rwanda has historically suffered from periodic natural disasters, mainly in the form of droughts and floods impacting the agrarian economy. Vulnerability to periodic natural disasters, mainly in the form of droughts and floods is a long term concern. It is estimated that during 1974-2007, about 4 million Rwandans were affected by droughts and 2 million by floods. One of the main bottlenecks is the high population growth that results in a negative impact on the environment, including more pressure on Rwanda's natural resources such as seismic risk, forests, water, loss of biodiversity and other non renewable resources. This study seeks to present a holistic view of the problem and to suggest feasible ways of ameliorating the problem, such as strengthening capacity to mange public resources at the central or local level, and mitigating social risks reduction faced by vulnerable groups, will help reduce the risks from natural disasters.

Keywords: Rwanda, Environment, risk reduction, natural resources, Millennium Development Goal.

Global Seismicity of the East of D.R.Congo

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The territory of the Democratic Republic of Congo includes the Western branch of the East African Rift System. The seismicity of that area is predominant around the lake regions. Probably from the lake Tanganyika area , in south , to the lake Edouard, north area. In this study we will show interactions between active volcanoes with earthquakes occurred on the lake Kivu basin.

"The Curious Case of the 1919 Swaziland Earthquake."

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Location of seismic events during the early 19th century was marred by mislocations especially in Africa where there were a few seismographs. It is more common to find 'fake' earthquakes erroneously listed among true ones. Such mistakes have been disclosed for many events, and their nature revealed and discussed in quite a number of papers in the last thirty years. Some discoveries of fake earthquakes originated from the revision of national catalogs (e.g., for France, Vogt 1979; for Italy, Guidoboni and Ferrari 1986 and Bellettati et al. 1993; for Germany, see a summary in Grünthal 2004), and others come from projects dealing with European-wide catalogs (e.g., Stucchi and Camassi 1997). With the availability of early instruments on the continent some moderate to large events could be located with a bit of

accuracy. The combination of human effects and instrumental data has helped in relocation of some earthquakes and in some instances discarding located earthquakes. The case of the 1919 Swaziland earthquake (MS 6.5) is one good example of a 'fake' earthquake in the catalogue for Africa. The event was reported in the ISS bulletin with phases from more than 20 stations around the globe but was not felt even close to the epicentral location. With the presence of missionaries, British agents and many reporters in the region at that time, it raises the question "did the event really occur in Swaziland or was it a mislocation from instrumental data?" Another event which occurred in 1936 in the same area was felt around the Swaziland and as far as Durban. This event was only recorded at a seismograph in Johannesburg. An attempt to relocate the 1919 event resulted in alternative locations in the Indian Ocean and Atlantic Ocean. Another possible explanation for the mislocation is that the phase data could be from simultaneous multiple events recorded at the different stations. However, without access to the original records it is not possible to verify this. Considering the fact that the event was not felt in Swaziland, several alternative locations for the event or events were observed after relocating using phase readings in the ISS bulletin.

Interpretation of 3D reflection seismic data from the Witwatersrand Basin, South Africa, to assess the risk posed by inrushes of water and flammable gases

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Inrushes of ground water and the ignition of flammable gases pose risks to workers in deep South African gold mines. Large volumes of water may be stored in solution cavities in dolomitic rocks that overlie the Black Reef (BLR) Formation, while there are several possible sources for methane, namely, coal seams, kerogen found in some gold ore bodies, or methane introduced by igneous intrusions. Potential conduits that may transport water and methane to underground workings were mapped using 3D reflection seismic data. Edge detection attributes successfully identified many faults, some with displacements as small as 10 m. Faults that displace the Ventersdorp Contact Reef (VCR) and the BLR horizons were of special interest, as known occurrences of fissure water and methane in underground workings show a good correlation with faults that were imaged on the VCR and BLR horizons. Because there are uncertainties in determining the linkage of faults with aquifers and methane sources, it is considered prudent to assume that all structures that displace the VCR and BLR horizons are potential conduits.

Keywords: risks, faults, methane sources, water, Wits Basin.

New Seismic Hazard Maps for Zimbabwe

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In this study the seismic hazard of Zimbabwe is presented as maps showing the probabilistic peak ground acceleration (PGA). Seismic hazard maps of 10% chance of exceeding the indicated ground -acceleration over a 50 year period are prepared using a homogenized 101 year catalogue compiled for moment magnitude. Two approaches of probabilistic seismic hazard assessment are compared using four ground motion prediction equations developed for regions comparable to Zimbabwe. The procedure of probabilistic seismic hazard assessment compared are the classic Cornell-McGuire(Cornell, 1968) and the Parametric-Historic (Kijko and Sellevoll, 1998) procedures.

Keywords: seismic hazard, attenuation, parametric-historic, Zimbabwe.

The Bunia (DRC-Uganda) Earthquake sequence of 2-3 July 2013 and its implication to seismic hazard assessment in the Lake Albert region

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The Bunia earthquake sequence commenced on July 02, 2013 with an earthquake of magnitude 5,1 at 13:33 (UT). The main shock with magnitude about M=5.7 occurred on July 03, 2013 at 19:21 (UT). It was followed by the largest aftershock of magnitude M=5.1 at 22:22 (UT). These tremors were felt strongly mainly in Bunia (DRC) and Hoima (Uganda), distant from epicenter , respectively, at about 55 km and 67 km; according to the European-Mediterranean Seismological Center, and GFZ-Geofon program . This repeated occurrence was worrying. However, based on old events observed in the West rift Zone, such as the Karonga earthquake sequence in Malawi where main shock occurred on 20 December 2009, this earthquake sequence is a natural phenomena associated with active faulting on the West flank of the East Africa Rift.

The focal mechanism of these three moderate events provided by GFZ-Geofon program show normal faulting with probable nodal fault plane having the north-northeast orientation in agreement with the orientation of the rift axis in the region. Stress drop calculated for these events varied from 3 to 13 bars. There is no relationship between the Bunia earthquake sequence and the result of intensified oil and gas exploration activities in the Lake Albert region. Normally a 5.7 quake magnitude is capable of considerable damage, especially in built-up areas, however no major incidents were reported in the Lake Albert Region. Little damage was observed but this event raises concern about the quake-prone country's preparedness in the event of major seismic activity in the country. Population in Bunia City is estimated to about 76,000 inhabitants and will become soon the capital of Ituri province. With the increase of population and build up infrastructures, the seismic risk will increase. Seismic hazard assessment in the study area shows that the nominal peak ground acceleration value for a return period of 475 years equals or exceed 0.1 g. Therefore, it is recommended that structures be designed for seismic load in that area.

Seismotectonics along the plate boundary in North Africa

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We investigate the similarities and differences between seismogenic active tectonic structures along the Africa - Eurasia convergent plate boundary. These active structures are seismogenic and the striking case studies are the 1960 Agadir (Mw 5.9), the 1954 Orleansville (Mw 6.7), the 1980 El Asnam (Mw 7.3), the 1992 Gafsa (Mw 5.3), the 1999 Ain Temouchent (Mw 6.0), and the 2003 Zemmouri (Mw 6.8) earthquakes. Large earthquakes in the Atlas Mountains of North Africa are often generated on thrust or reverse faults. Neotectonic structures and significant shallow seismicity (with Mw > 5.0) indicate that coeval east-west trending right-lateral faulting and NE-SW thrust-related folding, result from the oblique convergence at the plate boundary, and form a transpressional system. Coseismic surface ruptures and long–term active tectonics often appear as thrust-related folding with coseismic deformation visible in the field or measured using space-borne geodesy (GPS or INSAR). The estimated 0.6 to 1.0 mm/yr folding growth during late Pleistocene and Holocene in the Atlas Mountains attests for the significance of earthquake activity and the importance of convergent movements between Africa and Eurasia in the Western Mediterranean. The strain distribution obtained from faulted-fold structures and P axes of focal mechanism solutions, compared with the geodetic (NUVEL1 and GPS) convergence shows that shortening and convergence directions are not coaxial. The transpressional strain is partitioned along strike and the quantitative description of displacement field yields a compression to transcurrence ratio varying from 33% near Gibraltar, to 50% along the Tunisian Atlas. The convergence between Africa and Eurasia is absorbed along the Atlas Mountains at the upper crustal level, by means of thrusting above decollement systems, controlled by subdued transcurrent faults. This work is prepared in the framework of the UNESCO (SIDA) – IGCP Project 601 “Seismotectonics and Seismic Hazards in Africa”.

A Database of Intensity Data for South Africa

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A database of intensity observations from instrumentally-recorded earthquakes in South Africa has been compiled. The database contains just over 1,000 intensity data points (IDPs) that have been assigned from macroseismic observations retrieved from newspaper reports and questionnaires, and also digitised from previously published isoseismal maps. The database includes IDPs from 57 earthquakes with magnitudes in the range of MW 2.2 to 6.4 and based on observations at epicentral distances of up to 1,000 km for the larger events. For most of the earthquakes, there are very few IDPs. However, 16 events have 20 or more IDPs, with half of these events having more than 80 IDPs. The largest number of IDPs for a single event is 264 which were obtained for the 1st July 1976 Koffiefontein earthquake. The database is dominated by relatively low intensity values, mostly determined from human perception of shaking rather than structural damage. However, 19 IDPs have intensity values that are greater than VI. For each of the IDPs, the intensity value is reported – generally on the MMI-56 scale or another that may be considered equivalent – together with the epicentral distance and the moment magnitude. Using geological maps of South Africa, the location of macroseismic observations and published IDPs were correlated with surface geology to classify, where possible, IDPs as either on 'rock' or 'soil'. Such classifications were possible for 60% of the IDPs, with the uncertainty in locations precluding such a classification for the remaining data points. The number of IDPs classified as on 'soil' is rather small (~15%). A few soil IDPs do appear to show some site amplification, with some showing a strong influence. A final subset of the database was created and contains 15 earthquakes which have a minimum of five 'useful' IDPs. The 'useful' IDPs were identified after removing those IDPs that appeared to have been influenced by site conditions (or for other reasons are considered outliers), those with trivial intensity values (MMI = I), and those that were created using a single observation. A total of 436 useful IDPs were selected. These can be used in further studies such as selection of attenuation equations that are suitable for use in South Africa.

An investigation of the stress distribution in the rock mass during shaft pillar extraction

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The ultimate goal of the study is to determine the distribution of the stress around the stope at Cooke shaft 4. The shaft pillar is structurally unstable and highly stressed. The project integrates three fields of study: petrography, rock engineering and mining seismology. Firstly, the mineralogy and texture of the metamorphic rocks encountered in the shaft pillar were investigated. The second phase investigates the elastic properties, strength and behaviour of the lithologies via laboratory tests and finite difference numerical modelling. The last phase focuses on the mine seismicity in relation to the stress distribution around the stope during this pillar shaft extraction. Four sedimentary rock precursors were classified, *viz.* quartz wacke, quartz arenite, lithic arenite and conglomerate. They were all classified as one domain during the numerical modelling process. These rocks generally have quartz as a dominant mineral but it varies from each classified rock type from 50% to 92% content. The matrix is composed of very fine-grained clay minerals, mostly phyllosilicates such as pyrophyllite. The rock mechanics tests were carried out successfully in the laboratory at Wits University. Quartzite had the greatest uniaxial compressive strength, followed by pebbly quartzite, argillaceous quartzite, and the weakest being the conglomerate. The UCS of the weakest rock was 65.68 MPa, while the strongest was 199.21 MPa. Three numerical models were compared with the result predicted from the analytical equation (which was coded in Matlab). Elastic, Mohr Coulomb and Strain softening constitutive models were used. Seismic velocities and densities were measured in the laboratory: they showed maximum difference of 500 m/s in velocity and maximum difference in density of 0.1 g/m^3. The seismic data are yet to be processed and analysed.

Keywords: Wits basin, Cooke 4, petrography, experiments, numerical modelling, seismicity.

Pre-Analysis at early Stages of AfricaArray and Malawi-Tanzania Project GPS Time Series (Tectonic and magmatic processes during early-stage rifting: an integrated study of northern Lake Nyasa, Africa)

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The East African Rift (EAR), the divergent plate boundary between Nubia and Somalia, provides a rare natural laboratory to study continental rifting and breakup processes as they occur. The kinematic of EAR deformation are beginning to be revealed thanks to an increase in Global Positioning System (GPS) data in Africa and an increase in the number of well-determined centroid moment tensors. More GPS sites have been installed thanks to the SEGMENTS and AfricaArray projects that together have led to the installation of more than 20 continuous GPS sites in central and eastern Africa. This study provides the pre-analysis of the new time series of data from the 8-station SEGMENTS project that spans the northern Nyasa (Malawi) rift in Malawi-Tanzania-Zambia. At this stage time series of 5 stations with 15 months continuous observation period are analyzed. Although at this preliminary stage the velocities are not reliable (< 2.5years of continuous observations), the Malawi rift seems to open to the east relative to stable Nubia, as it has been predicted in previous studies. Our initial results indicate that in two years we will be able to resolve motion between the Nubia and Rovuma plates along the Malawi rift.

Determination of Local Magnitude Scale for Uganda using AfricaArray Data

Joseph NYAGO and Tatsuhiko Hara

We have derived a local magnitude ML scale for Uganda using waveform data recorded by a temporary broadband seismic network deployed in Uganda and a permanent broadband station. We used 54 earthquakes recorded between July 2007 and November 2008. First, we determined hypocenters of these earthquakes using P and S phase arrivals. Most of their locations are associated with the western rift of the East African Rift System. We compared the hypocenters of seven earthquakes determined by this study to those reported by NEIC's PDE catalog and IDC bulletins. They do not differ much, and they are roughly consistent with each other. To develop the ML scale, we removed instrument responses in the waveforms and then applied the frequency response of the standard Wood-Anderson torsion seismograph for amplitude measurements. We obtained 529 amplitude data from horizontal components of 52 earthquakes whose focal depths are up to 34 km. We performed simultaneous linear inversion to determine the coefficients of distance correction function and local magnitudes to obtain the formula $ML = \log A + 0.848\log(r/100) + 0.00116(r - 100) + 3.0$ where A is the maximum peak amplitude (mm) observed on the horizontal component seismogram, and r is the hypocentral distance (km). The coefficients of the above formula are smaller than those obtained for Southern California, and closer to those obtained for Tanzania.

Uganda, through the Department of Geological Survey and Mines (DGSM), is in the process of upgrading its seismological monitoring network with modern digital monitoring and data acquisition systems. Therefore, the result of this study and its application to data from the upcoming new seismic network will be useful for improving earthquake monitoring and seismicity study in Uganda.

Keywords: ML, amplitude, hypocenter, distance correction

The P and S wave velocity structure of the mantle beneath eastern Africa and the African superplume anomaly

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P and S relative arrival time residuals from teleseismic earthquakes recorded on over38 temporary AfricaArray broadband seismic stations deployed in Uganda, Tanzania and Zambia between 2007 and 2011 have been inverted, together with relative arrival time residuals from earthquakes recorded by previous deployments, for a tomographic image of mantle wave speed variations extending to a depth of 1200 km beneath eastern Africa. The image shows a low wave speed anomaly (LWA) well developed at shallow depths (100-200 km) beneath the Eastern and Western branches of the Cenozoic East African rift system and northwestern Zambia, and a fast wave speed anomaly at depths ≤ 350 km beneath the central and northern parts of the East African Plateau and the eastern and central parts of Zambia. At depths ≥350 km the LWA is most prominent under the central and southern parts of the East African Plateau and dips to the 47 southwest beneath northern Zambia, extending to a depth of at least 900 km. The amplitude of the LWA is consistent with a ~150-300 K thermal perturbation, and its depth extent indicates that the African superplume, originally identified as a lower mantle anomaly, is likely a whole mantle structure. A superplume extending from the core-mantle boundary to the surface implies an origin for the Cenozoic extension, volcanism and plateau uplift in eastern Africa rooted in the dynamics of the lower mantle.

Keywords: Tomography; low wave speed anomaly; eastern Africa, African superplume; Cenozoic rifting

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Observational studies in South African gold mines to mitigate seismic risks – What do Japanese seismologists hope to learn?

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We review how seismologist knew before the 2011 Mw9.0 Tohoku great earthquake, how seismology worked during the Mw9.0, and to what direction seismologists are orientated after the Mw9.0. In South African gold mines, Japanese seismologists have been learning the preparation and generation process of earthquakes at the closest proximity of hypocenters at depths of 1.0 – 3.4 km from surface since 1994. In particular since 2009, a largest JSPS 5-year project started, being followed by the 5-year SATREPS projects since August 2010, which aimed to deploy dense arrays to closely monitor the entire life of 100m-scale rock ruptures and to attempt to upgrade seismic hazard assessment by upgrading stress modelling and strong motion prediction. The SATREPS project also upgraded the CGS South African National Seismograph Network in Far West Rand area. We review what we have newly learned, some of which are being implemented in gold mining industries. We also introduce a potential future plan what Japanese seismologists can further learn, collaborating with rock engineers, in South Africa and other countries for seismic risk mitigation and natural resource development.

Keywords: seismic risk mitigation, Japanese seismological research plan, South African gold mines.

Geophysical mapping of the inland extension of the Chain and Charcot Fault zones, south-western Nigeria

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An extension of the Chain Fault zone has been traced inland of the south-western Nigeria using both satellite images and aeromagnetic intensity map over a 55 km by 55 km area of the Ifon Basement-Sedimentary area of the transition zone between the south-western basement complex and sedimentary basin of the eastern Nigeria. On the account of the qualitative and quantitative interpretation of the acquired Landsat-ETM+ multi-spectral bands and Digital Elevation Model (DEM) of the topography of the area, the evidence of inter-sedimentary tectonic events are recorded in the geomorphic characteristics of the study area's terrain in relation to the underlying influence of geology and structural

trends revealed by extracted lineaments. The observed geomorphic characteristics show three physiographical areas: the northern uplifted block (connection of a series of hills cut by deep-sided valleys), the central SW-NE trending subsided block (or graben) and the southern uplifted block. The geomorphic pattern of a series of flat and highly undulating terrain broken by a series of deep valleys and hills are due to rifting. These rift valleys are long, deep valleys bounded by parallel faults, or fractures. In addition, the geophysical analyses and interpretation revealed structural pattern showing predominant SW/NE, SE/NW and E-W linear structural trends were mapped as fracture/faults, which cut the basement and penetrated the overlying Cretaceous and Tertiary sediments in the study area. The main SW-NE trend which correlates with the general geologic strike suggest orientations of planes of rupture which are associated with fracture systems along these directions and represent the source of the deep-seated magnetic structures of approximately SW-NE orientation. The SE-NW trend can be attributed to relatively younger stress represented in the magnetic residual signature from shallow or near-surface magnetic bodies characterized by the SE-NW direction. The main SW-NE trending fracture/fault zones are traced to the inland extension of deep ocean Chain and Charcot fault zones. Although, the transition areas of Nigeria coastal areas have not experience any major seismic events, there have been series of inland tremors within the south-western parts of Nigeria. It is observed that the inland extensions of the Charcot and Chain fracture zones into the sedimentary-basement embayment of Nigeria might trigger seismic activities. This has corroborates the fact that the Nigeria section of the Gulf of Guinea continental margin is gradually becoming active as recorded within some inland areas of the county. It is therefore just a matter of time that the fracture zones of the Atlantic traced to the major SSW-NNE shear or fracture zones of the south-western Nigeria Embayment as displayed by Migmatite gneiss complex which form the basement rock in the study area, may induce seismic events of notable size and magnitude.

Keywords: Chain and Charcot Fault zones, inter-sedimentary tectonics, south-western Nigeria Embayment.

Processing earthquakes catalogues: Critical issues and declustering algorithms

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The compilation of a complete database of earthquake events is useful in understanding the recurrent behaviour of major earthquakes and helps to visualize the future events and their outcome. Earthquake catalogues are one of the most important products of seismology. They provide a comprehensive database useful for numerous studies related to seismotectonics, seismicity, earthquake physics, and hazard analysis. A critical issue to be addressed before any scientific analysis is to assess the quality, consistency and homogeneity of the data. A complete catalogue processed for foreshocks and aftershocks which is free from errors, plays a crucial role in assessing the recurrence relationship of the region. A complete and consistent catalogue of earthquakes can provide good data for studying the distribution of earthquakes in a region as a function of space, time and magnitude. A catalogue of events following the Poissonian distribution provides strength to seismic hazard analysis. However, most catalogues do not report the magnitude of earthquakes consistently over time, in addition to varying uncertainties in hypocenter locations. This may pose as an obstacle for delineating seismicity patterns or for assessing seismic hazards. It is important to convert the original magnitudes based on various scales in different time periods to a common magnitude scale throughout the whole period. Declustering attempts to separate the time-independent part of seismicity (background) from the time-dependent or clustered parts (aftershocks, foreshocks, and swarm type activity). For most hazard related studies, it is required that the seismicity behaves in a time independent fashion. It can be investigated whether or not the temporal distribution of events within the raw catalogue is stationary Poissonian, which would argue that declustering may not be necessary. There are many declustering algorithms available which were developed for specific seismotectonic regions. A decision on declustering algorithm to be used plays a crucial role in declustering the data. Magnitude range for the catalogue is of same importance. The completeness period and b value are also important and helps in assessing the quality of compiled data. There are many issues related to the processing of earthquake catalogue. Here an attempt has been made to discuss some of those issues with the help of procedures carried out on an earthquake database from north India.

Keywords: Earthquake catalogue, declustering, magnitude, completeness period, Poissonian process.

Fractal temporal clustering of aftershocks of Al Hoceima (Morocco) earthquake of February 24, 2004

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Al Hoceima region (northern Morocco) was struck by an important earthquake (Mw~6.1) on February 24, 2004; inducing a devastating damage and 629 victims. The time dynamics of the sequence following the main event (838 shocks) has been investigated by non-linear tools. The sequence of the occurrence times of the events with threshold magnitude M ≥ 3.2 is characterized by a time-clustering behavior, identified using different fractal methods (Korçak law, Hurst analysis, fractal correlation dimension, Fano Factor, Allan Factor, Count-based Periodogram, etc.), well suited to reveal scaling features in point processes. The presence of power-law behavior in the performed statistics indicates the existence of fluctuations on many timescales and therefore of fractal clustering. The obtained results not only show the presence of memory phenomena and correlation structures in the Al-Hoceima aftershocks, but also furnish quantitatively the estimate of the magnitude of such correlation by means of the estimate of the scaling exponents. This may put light on the rupture and fault geometry and to characterize the underlying pattern seismicity in the region.

Keywords: Fractal, earthquake, temporal clustering, Al Hoceima, Morocco.

Refined Kinematic Model of the East African Rift

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The kinematics of the East African Rift (EAR) is currently starting to be unraveled thanks to a recent augmentation of space geodetic data in Africa as well as the documentation of the earthquake slip direction. Here, we use a new data set combining episodic GPS measurements with continuous measurements on the Nubian, Somalian, and Antarctic plates, together with earthquake slip vector directions and geologic indicators along the Southwest Indian Ridge to update the present-day kinematics of the EAR. We find that the data is best fit with a model that includes three microplates embedded within the EAR, between Nubia and Somalia (Victoria, Rovuma, and Lwandle), consistent with previous findings but with slower opening rates. We find that earthquake slip vectors provide information that is consistent with the GPS velocities and helps to significantly reduce uncertainties of plate angular velocity estimates. We also find that 3.16 My MORVEL average spreading rates along the Southwest Indian Ridge are systematically faster than prediction from GPS data alone. This likely indicates that outward displacement along the SWIR is larger than the default value used in the MORVEL plate motion model.

The Malawi Seismic Network

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Malawi lies within EAST African Rift System (EARS) that starts from Rukwa through Lake Tanganyika Lake Malawi to Ulema graben in Mozambique. The country falls within the seismically active zones in the world. Historically Malawi has had a number of earthquakes, with some being so destructive e.g., between 9 th and 10 th, March 1989, in Salima, and Karonga on the 19th, December 2009, both within the Rift System, Historically Malawi had the first station in the early sixties, with the installation a station at Chileka (CLK) in Blantyre and later in the early seventies another one at Mzuzu (MZM). In 1989, three more Analog stations were donated by Council for Geo science, were installed; at Zomba (ZOM), southern Malawi, Lilongwe (LLIM) in central and Mzuzu (MZM), in the North. These stations had a fair share of operational difficulties, and the 2009, Karonga earthquakes another set of stations have installed in 2010

and 2012, making the total number to eleven , of these two are Africa Array stations, which are co located with weather stations, Mzuzu and Zomba.

Observations have clearly shown that the most active areas are in the northern Malawi, mostly along the lake areas and central Malawi, showing the same pattern of activity, along the coastal areas. But there have been minor seismic activity in upland areas, like Mchinji and Dowa in the central and Mpherembe/Kazuni (Mzimba) in the North. This shows that there was a gradual increase in the number of recorded earthquakes after the coming of WWSSN stations and later the inclusion of portacoder stations in the late 1980s. However, the pattern could not be maintained due to non-operation of some stations due to frequent breakdowns. While wishing to fulfill goals of reaching out to people and industry, operational challenges are a major stumbling block to this endeavor, a With good network coverage and greater regional cooperation good seismic maps, early preparedness would be easy, locally and the region as a whole, above all training is fundamental.

Seismo-Tectonic Interpretations of Seismic and Structural data for the KZN Province of South Africa

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A seismo-tectonic interpretation is made from analysing both the earthquake and structural systems. A methodology is designed from methods used in France and Italy. Geo-spatial data like geology, tectonics, regional geophysical anomalies, historical and instrumental seismicity are considered. Because of incomplete records and uncertain locations, efforts were made to improve the database. Additional historical epicenters and Intensity Data Points have been found from various sources. For recorded events, their location and magnitude were re-assessed and all the explosions due to coal mining were removed. A comprehensive geo-database has been created which contains all the original reports, shape-files and maps that can be revisited when re-testing or updating of the model is required. What once was considered as a diffuse seismo-tectonic region with low levels of seismicity and where insufficient, uncertain and incomplete data existed – we now have datasets that are more complete and have higher levels of accuracy. The province is composed of both the Kaapvaal Craton and the Namaqua Natal Mobile Belt which has distinctly different seismicity and geophysical signatures. Earthquake epicentres from both the historical and instrumental record as well as the occurrence of thermal springs correlate with old Jurassic faults. The seismo-tectonic interpretation is explained in a structured way where assumptions can be effectively tracked and recorded.

Keywords: seismotectonic model, KZN Province, seismicity, zonation

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Deformation Measurement in Central Afar, Ethiopia using InSAR and GPS

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This study is conducted to analyze the deformation pattern at a locality in the central part of Afar, northeast of Semera town, within the triple junction that is formed by the Arabian, Nubian and Somalian diverging plates. The study area is

bordered by Manda Harraro rift in the northwest and Tendaho rift in the south. Presently this dynamic process of earth's deformation in space and time can be accurately detected by satellite space geodetic observations. Global Positioning System (GPS) and Interferometric Synthetic Aperture Radar (InSAR) are used to study earth surface deformation. InSAR data from Envisat, image mode, with track 028 ascending and track 278 descending is used to detect surface deformation over the study area. To constrain the InSAR observations, continuously recorded GPS data obtained from DASM (2007-2012) and DASA (2008-2009) are used to investigate possible surface deformation changes in the area. The three dimensional position coordinates acquired from the DASM and DASA GPS stations over their period of observations have suggested a ground surface deformation rate of 48.5+0.2mm/yr North, 39.5+0.2mm/yr East and -9.5+0.7mm/yr Up; and 27.8+0.4mm/yr North, 43.9+0.5mm/yr East and -21.8+1.4mm/yr Up for DASM and DASA GPS stations, respectively in an absolute sense. The Up component of DASM shows two characteristics, 2.8 mm/yr upto doy 150, 2008 and -25mm/yr afterwards. The DASA shows also -10mm/yr up to doy 147, 2008 and -29mm/yr afterwards. The InSAR time-series shows -44mm/yr Line of Sight (LOS) rate in both tracks. The correlation between the DASM GPS and track 028 is 0.75 and it has a correlation of 0.79 with track 278. Generally, the result from this investigation suggested that there is an active subsidence in the area which needs further attention.

Keywords: Deformation, InSAR, GPS, LOS

Signal-To-Noise Ratio of Kaduna and Awka Stations in Nigeria From Seismic Noise and Teleseismic Earthquakes

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The signal-to-Noise-Ratio (SNRs) of Kaduna station sited on basement in the northern part of Nigeria and Awka station on sediments in the south, have been computed. The results obtained showed high values of SNR (above 3) for both stations in the lower frequency regions and lower values (less that 3) in the higher frequency bands. In addition, there was visible noise amplification on the Awka station which is likely due to effects from sub-soil features. To achieve these results, noise recordings spanning over six months (May -October, 2012) and teleseismic earthquakes recorded by the two stations in the same time window were used. In order to obtain reliable results, most stable parts of the noise trace from the North, East and Vertical components and clear earthquakes with distinct surface waves were selected, cut and computed. The noise traces were used to characterize the consistency of microseisms and hythropogenic noise while the noise region and surface waves from the events were subjected to FFT to obtain the SNR, after series of processing procedures. In carrying out this study, the natural period and sampling frequency of the time series were considered as well as well site condition. This study could well be adopted for best practices in station's siting and inference of sub-surface features like mineral deposits for further investigations. The results are relevant to correcting some anomalies that compromise data quality in these stations and can be extended to other existing stations as well as planned ones in the nearest future.

Keywords: Toro and Kaduna Seismic Stations, Seismic noise, teleseismic events, SNR, sub-surface soil.

Gravity-derived crustal thickness models: Is improved data adding more than different techniques? Examples for Africa

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Recently a range of new crustal thickness models have been published that are based on (satellite) gravity data. Some studies use models based on GOCE data or that have GOCE combined with other satellite gravity data and/or terrestrial gravity data. Although it is evident that GOCE data provides additional information in data sparse regions like Africa, South America en the Himalaya it is unclear how much this adds to the crustal thickness estimates derived from it.

Since most authors use different techniques and approaches the way the gravity data is treated differs for each study. How much they differ hasn't been studied in detail. It is very well possible that the use of different techniques and assumptions applied in the processing have a much stronger effect than the added value of GOCE has on the improvement of models. This study will explore the added value of GOCE data and compare this to the impact of different techniques used. Comparison will be made between various global and continental crustal thickness models based on gravity data.

AfricaArray Geophysics Field School: Practical training for Africans by Africans

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The AfricaArray geophysics field school is hosted by the School of Geosciences at Wits University and forms part of the core curriculum of the geophysics Honours program. By expanding the program to include additional participants, we are able to optimize the exposure to a large number of geophysical methods for a bigger group of people. Additional participants with an interest in geophysics and a strong background in math, physics, engineering, geology and geophysics from all over Africa are invited to apply. This includes participants from universities, government institutions and commercial companies. In addition, a number of participants from minority serving US based institutions are also hosted through a variety of NSF programs.

This field school runs for three weeks in June/July every year and exposes participants to survey planning, forward modelling techniques, data collection, and interpretation and integration of geophysical datasets. The most common geophysical techniques are covered and include: gravity, DGPS, magnetics, resistivity, refraction seismic and EM. All participants are provided the opportunity to familiarize themselves with the whole workflow. From determining the best technique to be used for a certain geological problem through planning the survey and the associated logistics to actually carrying out the experiments and familiarizing themselves with the equipment, to processing, modeling and integrating the different data sets as well as presenting on their findings, students are given an holistic introduction to geophysics in practice and should leave with a clear understanding of how geophysics can be used in mining, groundwater and oil and gas management and exploration. Graduate students from the University of the Witwatersrand and overseas are used as demonstrators, giving them an opportunity to supervise, learn quality control and logistics and is another way that the program enhances Africa's geoscientist resources. Contact Susan Webb (:susan.webb@wits.ac.za) to participate.

Keywords: Students, field school.
