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AfricaArray: aims, achievements and future activities

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ABSTRACT

AfricaArray (www.africaarray.org) is a long-term programme to build geosciences capacity in Africa in support of the mineral, petroleum, groundwater and environmental sectors. It seeks to do this by establishing effective Africa-based education and research programmes and observational networks, initially focused on geophysics, but planned to include other geoscience disciplines. The seismic network comprises 37 broadband stations in 16 countries as well as three temporary networks. More than 20 papers reporting on research findings have been published or are in press. Five students have graduated with MSc or PhD degrees, and 26 are registered.

Key words: AfricaArray, capacity building, seismic network, Africa, geosciences.

INTRODUCTION

AfricaArray is a pan-African initiative that promotes linked research and training programmes to build professional geosciences capacity in support of the mineral, petroleum, groundwater and environmental sectors in Africa. The primary goal of AfricaArray is to address the problem of limited and shrinking training and human capacity in science fields allied to natural resource utilization in Africa by establishing effective Africa-based education programmes, initially focused on geophysics, but which will be expanded to other geosciences disciplines at a later stage.

AfricaArray is designed to achieve this goal over 20 years by tightly coupling education and research programmes in the geosciences with scientific data gathering through observational stations spread across Africa (Figure 1). The stations are positioned to provide data that can augment groundwater, oil, gas, and mineral exploration, and help the forecasting of natural hazards such as earthquakes and volcanic eruptions. Network capabilities are initially focused on seismic sensors, but expansions are planned to link AfricaArray facilities to other networks that include hydrologic, GPS, and climate change sensors. In detail, the objectives of AfricaArray are:

1. To work with the public and private sectors in selected African countries to ensure that high quality, long-term training capacity in the geosciences is developed and maintained.
2. To train a new generation of African geoscientists. They will earn BSc, MSc and PhD degrees, and be well-positioned to become leaders in government, industry and academic institutions.
3. To increase the number of locally trained geoscientists from historically disadvantaged groups (*viz.* black and female).
4. To develop a sustainable scientific community within Africa through education, research collaboration, and data exchanges.

AfricaArray was launched as a long-term initiative in July 2004 by the University of the Witwatersrand and the Council for Geoscience in South Africa, and Penn State University in the USA. It is supported by IRIS (Incorporated Research Institutions for Seismology) where AfricaArray datasets are stored and distributed.

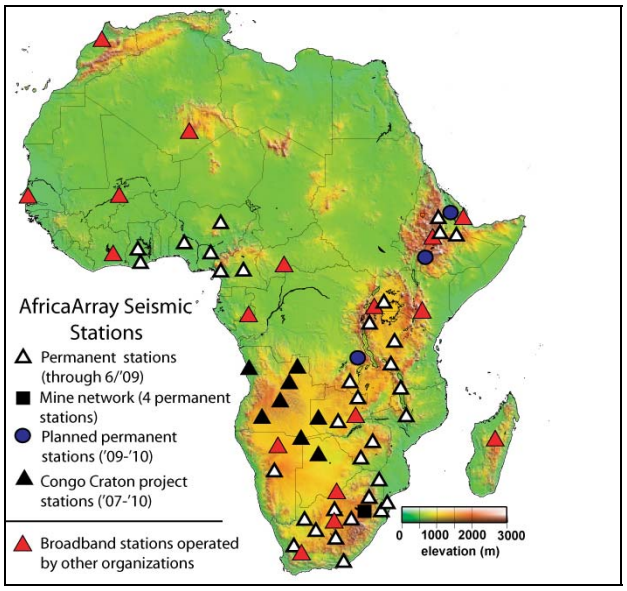

Figure 1. AfricaArray seismic stations and networks

TRAINING INITIATIVES

International Geophysics Field School

Geophysics is a science that studies the Earth and geophysicists need to learn how to collect accurate data under real field conditions. The AfricaArray Field School provides students with an opportunity to design, execute and interpret real geophysical surveys that address actual geological problems. The Field School has three distinct components:

1. In the first week students attend lectures about the various geophysical methods, geology of the field site and interpretation software. They then design a survey for a particular geophysical problem that will be encountered, such as using the seismic refraction method to determine overburden thickness. Students must determine the resolution, limits and cost of their proposed survey by producing forward models that predict the outcome of their design. This planning and costing component is crucial, as understanding the interplay between survey design, cost and resolution is essential to conducting any type of successful geophysical survey.
2. The second week is devoted to the collection, quality control and processing of data at the field site. Students spend time on each geophysical method including gravity, magnetics, differential GPS, resistivity, ground penetrating radar, electromagnetics and refraction seismic. This ensures that students are exposed to a wide variety of modern equipment.
3. The third week is spent on processing, interpreting and integrating the results from the different surveys into a comprehensive company-style report and culminates with presentations by the students.

The field school also functions as a two-tier training system. While the main objective is to train Honours level (4th year) students to plan, conduct and interpret a geophysical survey, a secondary objective is to provide graduate students with teaching and supervision experience. Thus several graduate student instructors participate by supervising a method in the field and provide lectures in the classroom both before and after the field work. This gives graduate students valuable exposure to lecturing and project management experience.

Diversity

AfricaArray is committed to enhancing the diversity of the geosciences workforce and is pioneering programmes both within Africa and the U.S. to provide new opportunities for students from diverse backgrounds. Supporting these innovative efforts is a broad coalition of industry, government and academic partners that understand the value and necessity of diversifying the geosciences for today's global environment.

As the field school is a distinct module within the Geophysics Honours programme, it is possible to include additional participants from within and outside South Africa. Funding from the NSF *Partnership in International Research and Education (PIRE)* programme and the Society of Exploration Geophysicists (SEG) Foundation has enabled us to fund additional international students and expert staff. These participants have included professionals from universities, geological surveys and mining companies interested in upgrading their field skills. In addition, African-American and Hispanic students from the USA participate in the field school as part of a geophysics experience aimed at attracting more U.S. minority students to a geosciences career.

Other AfricaArray-related initiatives to increase the number of both black undergraduate and black postgraduate students in the geosciences include:

- The establishment of the *South African Research Chair in Exploration, Earthquake and Mining Seismology* in 2007, funded by the Department of Science and Technology,
- The *Schlumberger Foundation* Faculty for the Future programme, which has provided support for three women (two postdocs and one Ph.D. student) to study seismology, and
- The *BHP Billiton Foundation* faculty development programme, which has provided support for several Ph.D. students, including a number of women.

In the U.S., the primary focus is on creating a preeminent and sustainable pipeline programme for increasing the representation of underrepresented minority students within the geosciences. The centrepiece of the programme is an educational alliance between North Carolina Agriculture and Technical State University, Penn State University, Fort Valley State University, University of Texas El Paso, and California State University Northridge. The program will contribute to the establishment of an Earth Systems Science Institute at North Carolina Agriculture and Technical State University, and will, by 2014, graduate up to 25 students per year with B.S. degrees in science, technology, engineering and mathematics fields. The students will be prepared to matriculate into geoscience graduate programmes across the U.S., and they will be able to compete for student support such as stipends provided by most research institutions.

RESEARCH GOALS

The main research goals of the AfricaArray programme are summarized below.

1. *Map the broad-scale geological structure of the African continent*

The crust and mantle can be imaged using seismic data (Figure 2). This information helps geoscientists to understand the structure and evolution of the Earth

better, and assists companies searching for deposits of minerals, oil and gas.

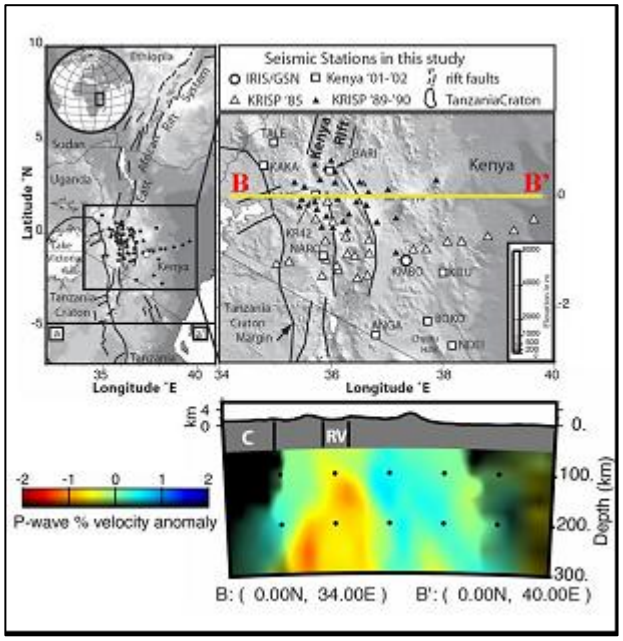

Figure 2. Tomogram of the P-wave seismic velocity in the upper mantle beneath the East African Rift System. The model shows that the velocity beneath the Kenya Rift is 0.5 – 1.5% lower than normal. Below a depth of about 150 km the anomaly broadens and dips to the west toward the Tanzania Craton. The anomalously low seismic velocities are attributed to the upwelling of hot rocks from the lower mantle. The geometry of the anomaly is consistent with models that show a low velocity anomaly (the African Superplume) extending upward from the core-mantle boundary beneath southern Africa to the middle of the mantle beneath southern and central Africa. For further information, see Y. Park and A. A. Nyblade, Geophysical Research Letters, vol. 33, L07311, doi:10.1029/2005GL025605, 2006

2. *Mitigate geohazards*

New seismic hazard maps are being developed for the DRC and Angola. Some AfricaArray stations also form part of the Indian Ocean Tsunami Early Warning System. Earthquakes are often precursors of volcanic eruptions, enabling timely evacuation. The Nyiragongo volcano (DRC) and Mount Cameroon are being monitored. The most recent major eruption of Nyiragongo was in 2002, when lava flowed through the city of Goma. 147 people died, approximately 12,000 homes were destroyed, and hundreds of thousands of people were displaced. Earthquakes are also related to mining at great depth for gold and platinum in South Africa. Sometimes the shaking is great enough to damage the excavations. The deep mines provide unique opportunities for research, as the approximate location of tremors can be forecast reliably, making it possible to record activity within a reasonably short time. These "earthquake laboratories" attract seismologists from countries that experience natural earthquakes such as Japan and the USA.

3. *Investigate the African Superplume, the largest seismic velocity anomaly in the Earth's mantle*

The African Superplume occurs in the lower mantle directly below South Africa. It may be associated with the elevated topography of south, central and east Africa, a feature dubbed the African Superswell. Higher resolution images of the seismic velocity structure of the mantle are required to determine the cause of the anomaly. An extensive network of seismometers and a long period of observation are required to record sufficient earthquakes from different azimuths and distances to produce a high-resolution seismic tomographic image.

The first research products are now emerging. Papers by AfricaArray researchers that have been published or are in press are listed at the end of this short paper. Five students have already graduated with MSc or PhD degrees, and a further 26 are working towards MSc or PhD degrees.

SEISMIC NETWORKS

Permanent network

The AfricaArray network records earthquakes occurring in Africa and worldwide by a permanent network that currently includes 37 broadband seismic stations spread across sub-Saharan Africa (Figure 1). In the last year new stations have been added in Ethiopia, Ghana, Nigeria, and Rwanda. The stations in Nigeria belong to the Nigerian National Network of Seismological Stations (NNNSS) and are operated by the Centre for Geodesy and Geodynamics within the National Space Research and Development Agency, located at Toro. The NNNSS will grow to seven stations when completed by the end of 2009. In the coming year and with continued support from the U.S. National Science Foundation, we anticipate upgrading the data loggers at many of the AfricaArray stations, and where possible, installing cell modems or Internet hookups to gain access to the data in near-real time.

Temporary networks

The permanent network is supplemented by several temporary deployments of seismographs for specific research projects (see Figure 1).

1. *Congo craton project*

Seismic stations have been deployed to delineate the extent of the ancient block of crust known as the Congo craton to assist exploration for diamonds. The temporary network for this project includes eight stations in Angola that are part of the Angola national seismic network, and one each in Zambia (Mongu), Botswana (Maun), Namibia (Rundu) and Angola (Lucapa) operated by AfricaArray. It is anticipated that most of the stations will become part of the permanent seismic network upon completion of the project in 2010. This project is supported by BHP Billiton, De Beers, and Rio Tinto.

2. *Uganda-Tanzania network*
The AfricaArray network in Uganda and Tanzania has been deployed in two stages. From August 2007-November 2008, 20 stations were deployed along the western branch of the East African Rift System. In December 2008 and January 2009, the stations were moved to new locations in western and southern Tanzania. Equipment for the project has been provided by the IRIS PASSCAL programme, and financial support by the U.S. National Science Foundation. The stations will be removed in July and August, 2010.

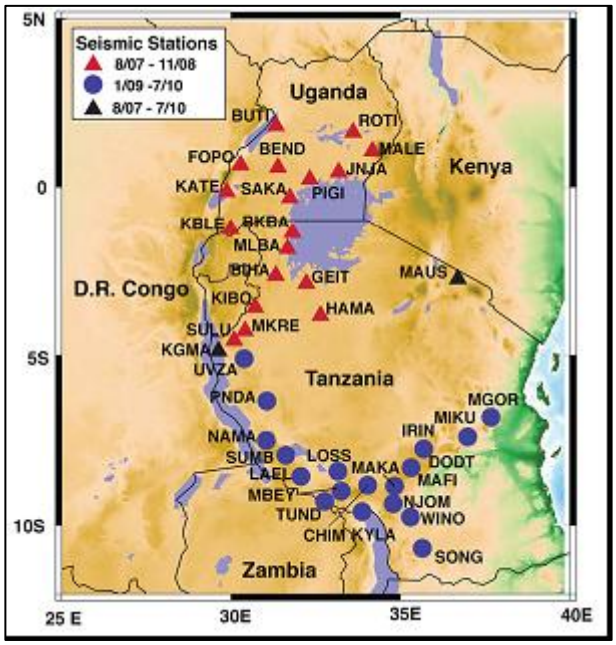

Figure 3. Uganda-Tanzania networks

3. *Mine network, Carletonville, South Africa*
Four stations were installed in 2006-2007 around three gold mines in the Carletonville mining region in South Africa as part of a project funded by the U.S. Department of Energy to study mining related seismicity. The stations have recently been upgraded by the Council for Geoscience and are now part of the permanent AfricaArray network.

ACKNOWLEDGEMENTS

AfricaArray is built on $3M of in-kind support from universities and government agencies in South Africa (mainly the University of the Witwatersrand and the Council for Geoscience, SA) and the U.S. (mainly Penn State and IRIS), and has garnered close to $6M in new funding from industry partners and government agencies in the U.S. and South Africa.

AA has grown quickly and been successful largely because of grass-roots support from many people within a variety of African institutions that are committed to AfricaArray's capacity building goals (currently 17 African countries actively participate in AfricaArray in collaboration with 11 private companies and many organizations outside of Africa).

Details about AA can be found on the AA website (www.africaarray.org).

AFRICAARRAY PUBLICATIONS

Special AfricaArray issue of the South African Journal of Geology (in press)

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