

AfricaArray: Developing a geosciences workforce for Africa's natural resource sector

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Geoscientists from across Africa, the United States, and Europe are building a pan-African initiative, AfricaArray, to strengthen geoscience education and research programs in Africa and to create an Africa-to-Africa academic support system. Universities, government agencies, and exploration companies are benefiting from the establishment of AfricaArray training programs coupled to a network of geophysical observatories spanning the continent. The observatory network provides support to the training programs and fosters community building by catalyzing collaborative projects and encouraging data sharing.

AfricaArray (www.africaarray.psu.edu) is a 20-year initiative to meet the New Partnership for Africa's Development (NEPAD) requirements for continent-wide cooperation in human resources development and capacity building. The name "AfricaArray" refers to arrays of scientists working on linked projects across the continent; arrays of shared training programs and observational networks; and above all, a shared vision that Africa will retain capacity in an array of technical and scientific fields vital to the sustainable development of its natural resources. The initiative started in January 2005 with the arrival of 10 BSc honors students, from several African countries at the University of the Witwatersrand (Wits), Johannesburg. With generous in-kind support from many public and private partners, in just three years AfricaArray has become multifaceted, promoting a broad range of educational and research activities. AfricaArray has grown quickly because of grass-roots efforts from many people within a variety of African, U.S., and European institutions committed to the initiative's educational and research goals and its underlying philosophy of building support networks across the African continent. (Currently, 14 African universities participate in AfricaArray in collaboration with 19 government institutions in Africa, 18 companies, and many organizations outside of Africa.)

Vision

Africa's natural resource sector (in particular, petroleum, minerals, and water) is a major driving force for economic development. Africa is a primary source of strategic and base metals for the world market. Petroleum production from sub-Saharan African countries alone may provide 25% of U.S. oil imports by 2015. Water resources are needed to support sustainable livelihoods throughout the continent, and in some countries geothermal reservoirs provide an important energy source. AfricaArray has been designed to address demands for a well-trained geosciences workforce needed to develop and manage Africa's vast natural resource endowment by creating a pool of African professionals for employment in



Figure 1. Students in the geophysics field course collecting seismic refraction data (top left), gravity data (top right), and magnetic data (bottom).

industry, government, and academia. In addition, geoscientists in Africa are needed to monitor natural hazards, such as earthquakes, volcanoes, and tsunamis, which pose threats to parts of the continent.

AfricaArray has been established through a partnership of three organizations: the University of the Witwatersrand (Johannesburg, South Africa), the Council for Geoscience (Pretoria, South Africa; formerly known as the South African Geological Survey), and Pennsylvania State University (University Park, USA). These institutions have made a wide range of teaching, research, and data acquisition facilities available to AfricaArray. In order to store and manage the large quantity of data generated by AfricaArray, the Incorporated Research Institutions for Seismology (IRIS) has made available its data management and distribution facilities.

Although the long-term vision for AfricaArray is to support training in many geoscience fields, efforts during the initial three years have been focused on geophysics and seismology in particular, to:

- Maintain and develop existing geophysical training programs,
- Promote geophysical research, and
- Establish a network of geophysical observatories for obtaining data to investigate scientific targets of economic, societal, and academic importance.

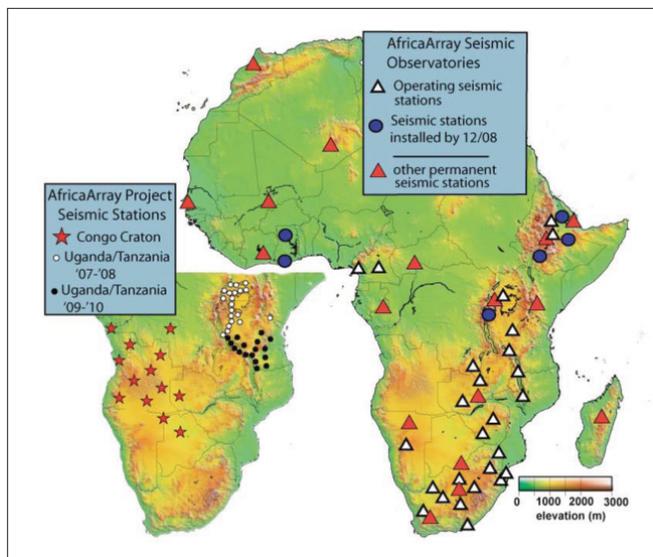


Figure 2. (right) Map showing the location of permanent AfricaArray seismic observatories (white triangles and blue circles) and permanent seismic stations operated by other organizations (red triangles). (left) Map showing the location of project-specific seismic networks that have been installed to image lithospheric structure along the southern margin of the Congo Craton (red stars) and mantle structure under the western side of the East African Plateau (white and black circles).

Central to the AfricaArray initiative is the network of scientific observatories across Africa designed to create an integrated geoscience capacity-building program. Such a network, linked through common instrumentation, data access, and operation, builds on many aspects of the community-based facility model pioneered by IRIS in the U.S. With broad-based support, this community facility can underpin an extensive training and research support system through data sharing and collaborative projects.

Implementation: Phase 1

AfricaArray is being implemented in four phases. During Phase I, which ran through December 2007, the geophysics program at Wits was expanded and improved, an international geophysics field course was established, a network of permanent seismic observatories was built, and a multi-project research program was initiated.

Geophysics at Wits. Geophysics degrees at Wits are offered at the BSc honors (a one-year specialized degree following a three-year BSc degree), MSc, and PhD levels. At the undergraduate level, students interested in geophysics enroll in the BSc program and take a concentration of courses in geology, physics, and math.

To increase Wits' training capacity at the MSc and PhD levels, an AfricaArray "sandwich" program was set up that allows students to spend up to six months each year studying and conducting research with a professor

at an affiliated university in the U.S. or Europe. The students are co-supervised by faculty at Wits and at the affiliated institution, but degrees are granted by Wits only. Since 2005, 34 BSc honors, 13 MSc, and 10 PhD students, as well as five postdocs, have been supported in the program. The MSc and PhD students have been co-supervised by professors at Penn State, the University of Texas-Austin, the Dublin Institute for Advanced Studies in Ireland, and the International Institute for Geo-information Science and Earth Observation (ITC) in Enschede, The Netherlands.

The geophysics program at Wits has also been strengthened through the addition of a research chair in seismology and an IT technician, and procured seismic equipment (48-channel seismograph and three broadband seismometers) and computers, all supported by the South African National Research Foundation.

Geophysics field course. In 2006, the practical geophysics field course, patterned after the SAGE program (<http://www.sage.lanl.gov/>), was expanded by opening participation to students from outside of Wits and to employees of companies and government agencies. The 42 students who have participated in the field course during 2006–2008 have come from 12 different African countries and the U.S. Six of the African students have been supported by funding from the SEG Foundation. The three-week long course is part of the BSc honors curriculum at Wits and involves practical application of a variety of geophysical methods (differential GPS, GPR, gravity, magnetics, electrical resistivity, and seismic refraction) to image faults, dikes, and overburden thickness at mining prospects in the Bushveld Complex of northeastern South Africa (Figure 1). Industry support for the field school, including accommodation and gravity meters, has been provided by Anglo Platinum, Anglo American, African Rainbow Minerals, and CSIR.

Permanent seismic observatories. The AfricaArray observatory network (Figure 2) consists of 26 broadband seismic stations in 11 countries, and the Council for Geoscience plays the lead role in maintaining the network. Six additional stations will be added to the network by the end of 2008. The various components of a station are illustrated in Figure 3. Some of the seismic stations belong to national networks, and



Figure 3. A permanent AfricaArray seismic observatory in Tanzania. (top) Security fence and metal lid covering a vault whose depth is 4 m. (bottom) Interior of the vault.

others have been constructed using equipment provided by AfricaArray and donated by external organizations such as IRIS and the Royal Museum for Central Africa (Belgium). Data from a number of stations are downloaded daily, while at other stations the data are retrieved every month or two. Unrestricted access to the data is permitted three years after acquisition, giving AfricaArray students, postdocs, and faculty time to use the data for thesis research and sponsored projects.

Research projects. Two research projects are highlighted

to illustrate the linkage between the AfricaArray educational programs and seismic observatory networks. Descriptions of other projects can be found on the AfricaArray Web site. In the first project, sponsored by BHP Billiton, De Beers, and Rio Tinto, seismic data from earthquakes are being used to image lithospheric structures across Angola, which cover the southwestern section of the Congo Craton. To accomplish this, data from the permanent seismic observatories are being combined with data from temporary seismic stations deployed in D. R. Congo, Zambia, Angola, Botswana, and Namibia (Figure 2). PhD and MSc students supported by the project are using the data in a variety of ways to investigate the seismic velocity and attenuation structure of the crust and uppermost mantle beneath the western half of southern Africa.

In the second project, funded by the U.S. National Science Foundation, seismic data from earthquakes are being used to image crust and mantle structure beneath eastern and southern Africa for improving our understanding of the largest seismic anomaly in Earth's mantle, the so-called African Superplume. The African Superplume is best imaged in the lower mantle beneath southern Africa and appears to be a thermochemical structure extending upwards from the core mantle boundary well into the midmantle and perhaps even into the upper mantle beneath eastern Africa. There is no consensus on the interpretation of the African Superplume, what role it plays in large-scale mantle circulation, whether or not it extends to Earth's surface beneath southern or eastern Africa, or how it may have influenced surface uplift and the development of Africa's distinct topography and basin architecture.

To improve images at all depths, but particularly at mid-mantle depths where anomalous lower and upper mantle structure might connect, data from the permanent seismic observatories are being combined with data from a network of temporary seismic stations in Uganda and western Tanzania (Figure 2). Students (BSc honors, MSc and PhD) are involved in field work and modeling the data to improve images of the superplume.

Implementation: Phases 2–4

The goals for the second development phase (2008–2010) are twofold: (1) to build regional centers of excellence in geophysics at several African universities, and (2) to expand into other geoscience fields, including the addition of new sensors to the observatory network for obtaining GPS, meteorological, and hydrological data.

Progress has already been made toward achieving these goals. AfricaArray has established a partnership with the Geophysics Department at Agostinho Neto University (ANU) in Luanda, Angola, and is training ANU geophysics staff through the Congo Craton project. The development of a geophysics field course at ANU is underway, similar to the one taught at Wits, and research projects are being planned to image details of crustal structure beneath the coastal margin of Angola for evaluating models of extension and rift evolution. In a paral-

lel effort, AfricaArray has established a partnership with the Geophysical Observatory at Addis Ababa University (AAU) in Ethiopia. AfricaArray is supporting the expansion of the seismic network run by AAU, and professors at affiliated universities in the U.S. have begun co-supervising students enrolled in a newly formed MSc seismology program at AAU.

The primary goal for phase 3 (2011–2013) is to expand the AfricaArray initiative into west and north Africa. The foundation for this expansion is now being laid. Several academic institutions in west Africa have become AfricaArray partners, and a number of seismic station operators have expressed an interest in joining the AfricaArray observatory network. By phase 4 (2014), the AfricaArray initiative will be fully implemented, supporting education and research projects throughout Africa in many geoscience fields, all linked through a multifunctional observatory network that serves to strengthen the science community through data exchanges and collaborative projects. The challenge for phase 4 and beyond will be to maintain and support the multifaceted educational and research program that has been created.

AfricaArray and diversity in the geosciences

Given that two of the three AfricaArray founding partners are institutions in South Africa, AfricaArray, from the outset, has had an explicit focus on assisting students from historically disadvantaged communities. Many efforts within the University of the Witwatersrand and the Council for Geoscience have been made to attract and support students from diverse backgrounds. With support from the U.S. National Science Foundation, AfricaArray has been able to expand this effort to include students from physics, math, engineering, and geoscience departments at Historically Black Colleges and Universities (HBCUs) in the U.S. The cornerstone of the U.S. effort is a summer field experience in which undergraduate students spend two weeks at Penn State for orientation and content training, four weeks in South Africa to participate in the AfricaArray geophysics field course at Wits, and two weeks back at Penn State to complete a project report. Over the past three years, 12 African-American students from North Carolina Agriculture and Technical State University (Greensboro) and Fort Valley State University (Fort Valley, Georgia) have participated in the program. Because the program has proven to be effective at motivating students, increasing knowledge and research skills, and in building leadership qualities, expansion of the program is planned to increase student participation and to add field courses in structural geology and sedimentology/paleontology.

AfricaArray and industry partners

Industry partners are providing support to AfricaArray in a variety of ways, in-

cluding both in-kind and direct financial contributions. A few illustrative examples include (1) Schlumberger's Faculty for the Future Program, which has provided support for two African female postdoctoral scholars to advance their careers through research using AfricaArray data and from mentoring by faculty at Penn State and Wits; (2) the Total Professors Association, an organization of retired professional employees from Total, which has provided short courses in 3D seismics, basin analysis and well logging to geoscientists at Wits and ANU; and (3) Anglo Platinum and its partner African Rainbow Minerals, which have made available to AfricaArray the use of an exploration camp as a base for the geophysics field course and prepared suitable field sites over exploration target zones. An example of a sponsored project that combines training of African students, research, and use of data from the observatory network is provided by the Congo Craton project described above.

Sponsors

Financial support from a diverse number of public and private partners is gratefully acknowledged, including African Rainbow Minerals, Anglo American, Anglo Gold Ashanti, Anglo Platinum, Belgium Technical Cooperation Agency, BHP Billiton, BP, Chevron, Council for Geoscience (South Africa), Council for Scientific and Industrial Research (South Africa), De Beers, Department of Energy (U.S.), Department of Minerals and Energy (South Africa), Department of Science and Technology (South Africa), ExxonMobil, Geosoft, Great Northern, ISS International, ITC, London Bullion Market Association, Marathon, Mineral Education Trust Fund (South Africa), National Science Foundation (U.S.), National Research Foundation (South Africa), Pennsylvania State University, Rio Tinto, Royal Museum for Central Africa (Belgium), Schlumberger, SEG Foundation, Sonangol, Total, Total Professors Association, University of the Witwatersrand, and the Jackson School of Geosciences at the University of Texas. A complete listing of partners, including contributors of financial and in-kind resources, can be found on the AfricaArray Web site. **TLE**

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