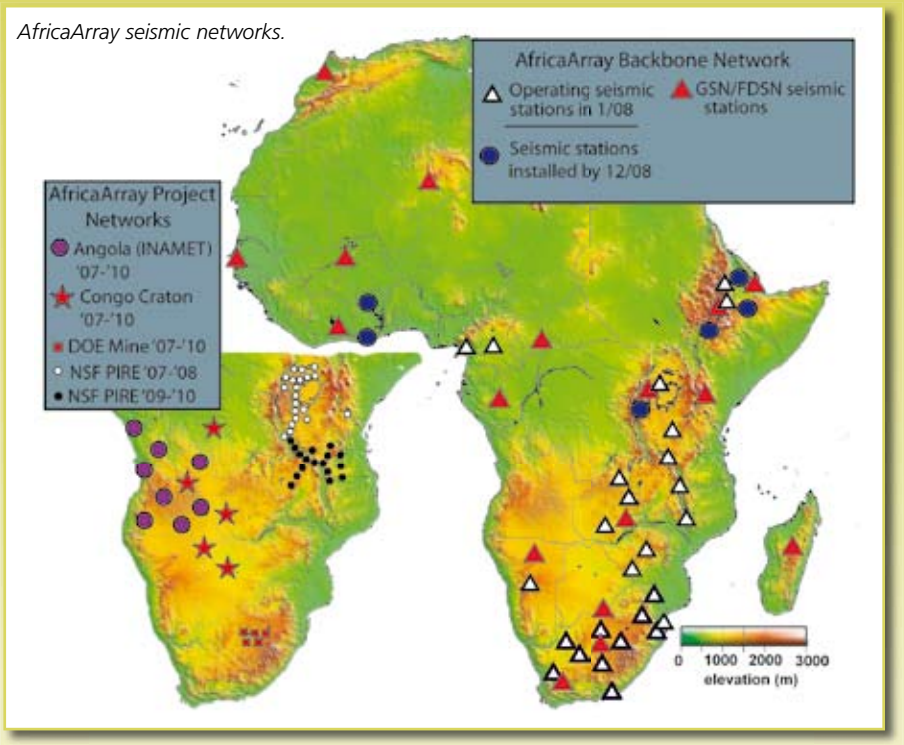


AfricaArray seismic networks.

Africa Array

Ray Durrheim describes a network of seismic stations and geoscientists across sub-Saharan Africa

AfricaArray[1] is a Pan-African geophysical and geological research initiative that was launched in July 2004 and is already starting to yield its first research results. Its network of monitoring stations records earthquakes occurring on the continent and worldwide.

The permanent network includes 27 broadband seismic stations spread across sub-Saharan Africa, and is supplemented by temporary deployments of seismographs for specific research projects. The AfricaArray facilities may also, in future, host other Earth observation instruments, such as those used for geodetic and climate studies.

What's being monitored

Large earthquakes shake the ground violently, creating seismic waves that spread through the Earth. Earthquakes can trigger landslides and tsunamis, and cause buildings to collapse (*see also pp. 37–39*).

Broadband seismographs are sensitive instruments that continuously monitor ground motion and can detect minute vibrations caused by a distant earthquake. The seismic waves from the earthquake are refracted and reflected when they encounter changes in rock properties[2].

The structure of the Earth's crust and mantle can be imaged from analyses of the waves produced by many earthquakes at different depths, distances, and directions, as recorded by an array of more-or-less evenly spaced seismographs. The AfricaArray seismographs are typically separated by distances of 500–1 000 km.

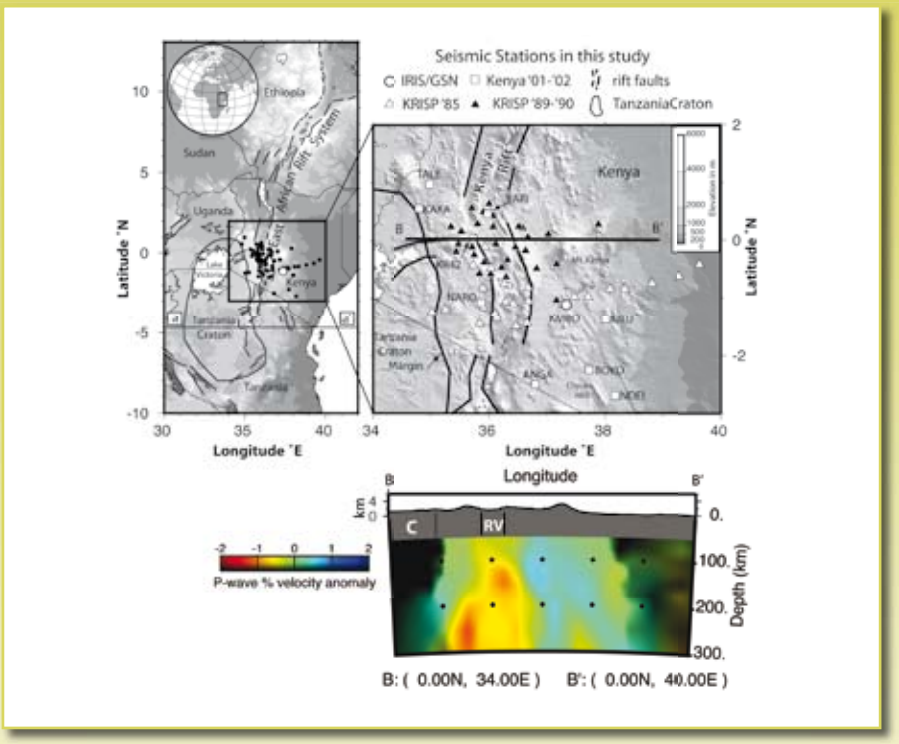
Seismologists analyse the seismograms to determine the location and size of an earthquake, and they use earthquake catalogues (histories) to determine the seismic hazard of a region.

Aims

Secure scientific monitoring sites with effective data communication facilities are difficult to establish and maintain. The AfricaArray collaboration aims to:

- *Provide high-level training for African geoscientists*: Already, 20 African students – representing Angola, Botswana, the Democratic Republic of Congo (DRC), Namibia, Nigeria, South Africa, Tanzania, and Uganda – are busy with postgraduate research; an annual international field school provides practical training in geophysical techniques.
- *Map the broad-scale geological structure of the African continent:* The seismic images of the planet's crust and mantle provide information

1. AfricaArray seeks to train the next generation of geoscientists to develop the continent's mineral resources and mitigate the effects of geohazards. Core partners are the University of the Witwatersrand, the Council for Geoscience, and Pennsylvania State University, with participating institutions from other African countries, Europe, and the USA. The data are archived and distributed by IRIS (Incorporated Research Institutions for Seismology), a US-based consortium of universities.
2. *Refraction* describes the way in which the waves are bent when the seismic velocity of the rocks through which they are travelling changes (owing to changes in composition, pressure, and temperature, for example). *Reflection* describes the way seismic waves bounce off boundaries where rock properties change suddenly, such as the crust–mantle and core–mantle boundaries. A *seismograph* simply measures the shaking of the ground. By analysing the seismograms, however, we can deduce which waves were refracted and which were reflected. From this information we can construct an image of the Earth's interior.



Left: 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 (2006), L07311, doi:10.1029/2005GL025605, 2006

that helps geoscientists to understand better the structure and evolution of the Earth, and that assists companies searching for deposits of minerals, oil, and gas. For example, seismic stations currently being established in Angola, Botswana, the DRC, and Zambia will be used to delineate the extent of the ancient block of crust known as the Congo Craton; this knowledge will help to guide diamond exploration.

- *Mitigate geohazards:* New seismic hazard maps are being developed for Angola and the DRC. Some AfricaArray stations also form part of the Indian Ocean Tsunami Early Warning System. Earthquakes are often precursors of volcanic eruptions, so seismic monitoring can help with the timely evacuation of people from areas at risk. The Nyiragongo volcano (DRC) and Mount Cameroon are right now being closely monitored. The most recent major eruption of Nyiragongo was in 2002, when lava flowed through the city of Goma, killing 147 people, destroying some 12 000 homes, and displacing hundreds of thousands of people.

Earthquakes related to deep-level mining for gold and platinum in South Africa sometimes shake the ground powerfully enough to damage the excavations. Deep mines provide unique opportunities for research, as the approximate location of tremors can be forecast reliably[3], making it possible to record many seismic events within a reasonably short period of time. These 'earthquake laboratories' attract seismologists from countries that experience natural earthquakes, such as Japan and the USA.

- *Investigate the African Superplume, the largest seismic velocity anomaly in the Earth's lower mantle:* The African Superplume occurs in the lower mantle, 1 500–3 000 km directly below South Africa. It may be associated with the elevated topography of south, central, and east Africa, known, in turn, as the African Superswell. Higher-resolution images of the seismic velocity structure of the mantle are required than are currently available, to explain the origin of the superplume and to understand its link to the superswell. For producing a sufficiently high-resolution seismic tomographic image, researchers need an extensive network of seismometers and a long period of observation, to be able to record sufficient earthquakes from different azimuths and distances. □

NOTE: With regard to the available network, the stations in the Sahara and Morocco (indicated by red triangles on the map on p. 14) are supplementary to the permanent backbone network of AfricaArray, and are operated by the Global Seismic Network (GSN) and the International Federation of Digital Seismograph Networks (FDSN). The data they record are in the public domain and therefore available to AfricaArray researchers.

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For more information and details, visit the AfricaArray website **www.africaarray.psu.edu/** and read L.M. Linzer *et al.*, "Recent research in seismology in South Africa", *South African Journal of Science*, vol. 103 (2007), pp.419–426.

3. Forecasts are particularly reliable in deep-mine conditions, as – because the tremors are triggered by the mining activity – seismometers can be installed close to the areas where mining is taking place, and in a closely spaced network around a geologically identified area (zone) of weakness.

Some definitions

Crust (of Earth): The planet's outermost rocky shell, typically 25–75 km thick in continental regions, comprising rocks that are chemically different from the *mantle*.

Geodesy: The science of measuring the shape or figure of the Earth and its gravitational field. The advent of satellite positioning systems, such as GPS and SPS, has expanded this field of study from topographic and astronomic surveying.

Mantle (of Earth): The main bulk of the Earth, extending from the base of the *crust* to the core/mantle boundary at a depth of about 3 000 km, composed of dense silicate rocks.

Seismic tomography: An imaging method that deduces the 3D structure of the Earth's interior by using seismic data from an array of seismographs distributed over the planet's surface.

Seismic waves: A general term for waves generated by earthquakes or explosions. There are many types, the principal ones being **body waves** and **surface waves**. Body waves travel through the interior of the Earth, whereas surface waves are guided by the surface of the Earth. The two basic types of body wave are the **P wave**, with compressional particle displacement, and the **S wave**, with shear particle displacement.

Seismic velocity is the speed of travel of seismic waves. The velocity of a seismic wave through a rock (medium) is mainly determined by its composition, but is also affected by pressure and temperature. The P wave is the fastest wave travelling away from a seismic event: it has a velocity typically 6–7.5 km/s in the crust, and 8–14 km/s in the mantle. In any given medium, the P wave travels more quickly than the S wave.

Seismic velocity structure is a generalized local, regional, or global model of the Earth that represents its structure in terms of P and/or S wave velocities.

Seismic velocity anomaly is a deviation from the average or typical seismic velocity structure of the Earth or of a region within the Earth.

Superplume: A large region in the mantle with anomalously low or high seismic velocities attributed to high-temperature upwelling and low-temperature downwelling, respectively.

Superswells: The surface expression of upwelling that may be related to superplumes.

Tomogram: An image (normally in the form of a slice through) the interior of a body (in this case the Earth), formed using tomography.

Tomography*: the science and technological art of creating images of the interior of bodies.

* Tomography is also used in medical examinations, to map tumors, for example, using X-ray tomography. The mathematics of tomography was developed by South African-born Allan McLeod Cormack (1924–1998), who, jointly with Godfrey Newbold Hounsfield, won the 1979 Nobel Prize for Physiology or Medicine for this work. He was posthumously awarded South Africa's Order of Mapungubwe on 10 December 2002.