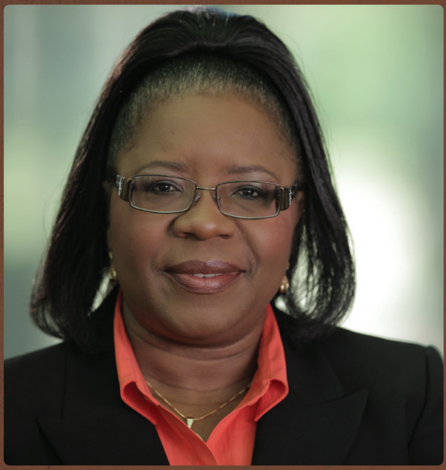
# Testing tectonics

**Drs Rob Evans** and **Estella Atekwana** discuss their work on new and recently developed continental rifts in East Africa. Their groundbreaking research promises to deepen our knowledge of the development of continental rifts on a global scale



**Could you outline your respective roles within the project?**

**RE:** I have expertise in electromagnetic methods and have been the lead scientist overseeing the collection of magnetotelluric (MT) data in Botswana and Zambia.

**EA:** I am an expert in potential fields (gravity and magnetic methods) and the Lead Principal Investigator of the project. I also oversee the collection of gravity and magnetic data in Botswana, Zambia and Malawi.

**From what context did your research into continental rifts emerge?**

**EA:** This worked stemmed out of research that I conducted while on a sabbatical at the University of Botswana in 1999. The Botswana Government had just completed a high resolution airborne magnetic survey for groundwater and mineral exploration purposes, but the data also provided an unprecedented view of the basement geology highlighting faults of the incipient Okavango Rift Zone.

We realised that geoscience literature contained a lot of information on older and more mature rifts, but very little information on incipient rifts. A number of the Principal Investigators involved in the project have experience looking at rifts from both observational and geodynamic angles understanding how rifts form and behave. With interest focused on the Okavango, we were able to put together an interdisciplinary team with the requisite expertise to tackle the problem. This team wrote a successful proposal to the National Science Foundation that is supporting our fieldwork.

**Why have you decided to focus on the Okavango Rift Zone and Malawi Rifts in particular?**

**RE & EA:** The East African Rift System (EARS) exhibits a strong gradient in rift evolution along its length. This provides a unique opportunity to investigate the processes that drive rift initiation and control early rift localisation. Our project focuses on the southwest branch of the EARS. This includes the very early stage Okavango Rift Zone, where classic geomorphic rift features are just beginning to emerge, and the Mweru, Luangwa (Zambia) and Malawi Rifts, where geomorphic features are fully developed but magma, if present, has yet to breach the surface.

**How important is collaboration to your work?**

**RE & EA:** Collaboration is essential to the project and in fact is a requirement of the programme which funded this research. Our project consists of scientists from several geophysical and geological disciplines who bring expertise in each of their areas to bear on the problem of rifting. No single technique alone is able to solve the problem. Additionally, international collaboration, working closely with African scientists is essential for the success of the programme. Local assistance with permits, siting instruments and communicating with local landowners has to be done by African scientists.

**Could you discuss some of the research and education opportunities you provide?**

**RE & EA:** Our project offers the opportunity for capacity building and workforce development through the training of scientists within the African nations where we are working. For students from the US, this provides them with hands-on international research experience and prepares them for jobs in academia and industry. Partnerships with local scientists are an essential component of the research programme and are vital to the success of the fieldwork. In Zambia, we have been able to train scientists to collect magnetotelluric (MT) data. By allowing them access to our equipment while it is not in use for the main programme, the Geological Survey Department has been able to collect data for their own needs. We have assisted in the processing and analysis of these data while training Zambian staff in how to carry these steps out themselves. We have also provided training for staff from the Malawi Geological Survey as well as students from the University of Botswana. We would very much like to expand this capacity building; both Zambia and Malawi suffer from a lack of trained geophysicists working in government departments and are actively seeking funding sources that can facilitate such training and infrastructure development.

**Do you have any exciting upcoming research trips?**

**RE & EA:** Later this year, a group from the US led by Drs Pablo Canales and Dan Lizarralde will travel to the Okavango to complete an ambitious active source seismic experiment adjacent to the Okavango delta. This will probably be one of the largest active source seismic projects in sub-Saharan Africa. These data will provide high resolution images of faults, crustal thickness variations and upper-mantle structure which can be combined with MT, magnetic and gravity data to give a detailed model of this section of the rift.

# Creating a rift

The **Project for Rift Initiation Development and Evolution** has been looking at incipient continental rifts across the East African Rift System to determine what factors affect rift evolution in its early stages. This information will contribute towards improved rift modelling systems

**CONTINENTAL RIFTING IS** the process by which the crust and upper mantle of the Earth, or lithosphere, is stretched as tectonic plates move away from one another. Through extensional deformation, this process forms long, narrow fissures which are known as 'rifts'. Rifting gives rise to a number of significant geological features, including continental growth through plate collision and the formation of ocean basins as plates move apart.

Despite the important role continental rifting plays within the world of global tectonics and in resource exploration (hydrocarbon, groundwater and geothermal), parts of the process are not well understood and the extent to which some geological factors affect rift development is still unclear. Dr Estella Atekwana, Professor of Geophysics at Oklahoma State University, and Dr Rob Evans, of the Woods Hole Oceanographic Institution, are working to redress this knowledge gap. Atekwana has expressed the particular need for a closer look into earlier stages of the rifting process: "Continental rifting remains poorly understood, largely because it is a transient geodynamic process. Most rift systems provide only a snapshot in time of the entire process and existing studies have tended to focus on rift segments which are at or near completion. As a result, key processes which occur at the earliest stages of continental rifting remain largely unstudied in the field".

Our current understanding of continental rifting is based upon modelling systems which describe rifts as they mature, but these numerical models have been created exclusively from studies of older and relict rift systems. They do not take into account processes which occur solely at the onset of rift formation, such as strain localisation (the formation of narrow zones of intense shearing strain). It is therefore necessary to further investigate the mechanisms which drive rift initiation and the processes which occur in the early stages of rifting, in order to gain an accurate picture of rift development.

## THE EAST AFRICAN RIFT SYSTEM

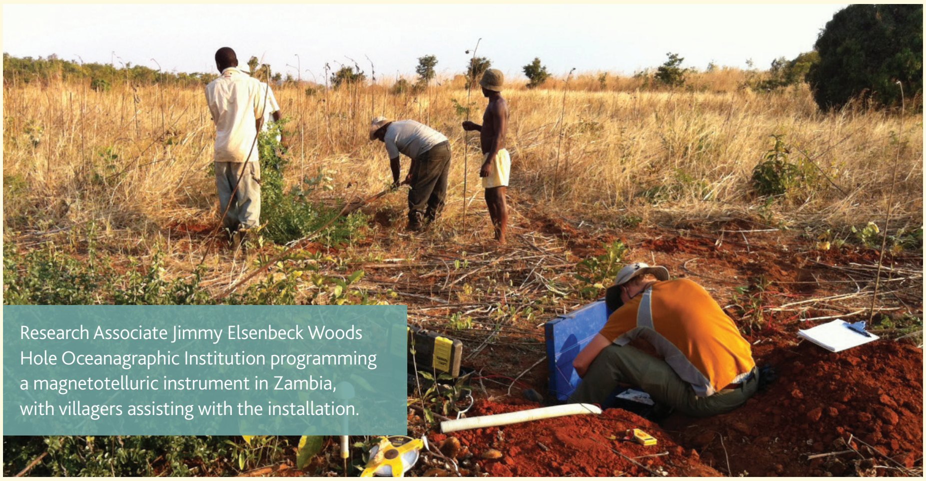
The East African Rift System (EARS) is a complex network of rift valleys which express active continental rifting throughout East Africa. The diverse range of rift valleys along EARS contain many examples of tectonic activity and provide an opportunity to observe the rifting process at multiple stages of evolution, from initiation to rupture.

EARS is an ideal example rift valley system for investigation as it contains a large variety of rifts at different points of development, as well as different types of rifts such as continental, intracontinental and oceanic. The Afar Triple Junction in the north of EARS is a site of great geological activity, as it contains the meeting point of three plates: the Nubian plate which carries most of the continent is diverging from the Arabian plate, and the Somali plate, which carries the Horn of Africa. This rifting has created the Afar depression, a well-developed rift basin which has been home to many geoscientific tests and experiments. Data from sites such as the Afar depression have led to the development of continental rifting modelling systems which, though accurate in depicting mature rift development, lack the depth of knowledge required to effectively model the rifting process in its earlier stages.

## PROJECT PRIDE

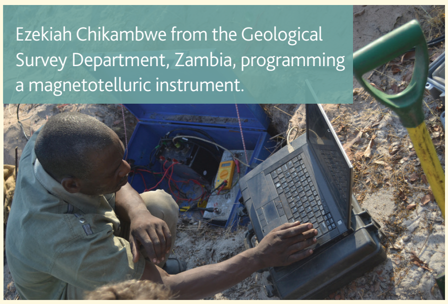
Atekwana is the Lead Principal Investigator for the Project for Rift Initiation Development and Evolution (PRIDE), a project which seeks to collect information on key processes that occur during the early stages of rifting. They ultimately hope to develop a better understanding of rift evolution and enable the fine-tuning of rift modelling systems to accommodate previously unincorporated factors that affect continental rifting.

PRIDE focuses on the southern extension of EARS, specifically upon the Okavango, Luangwa and Malawi rifts. The Okavango Rift Zone in Botswana is an incipient rift and is therefore ideal for studying the effects of various factors upon the earliest stages of rifting. Also, the Luangwa Rifts in Zambia and the Malawi Rift have yet to be affected by magmatism – the formation of igneous rocks



Research Associate Jimmy Elsenbeck Woods Hole Oceanagraphic Institution programming a magnetotelluric instrument in Zambia, with villagers assisting with the installation.

The rift basins studied will create a framework for comparison and prove invaluable in understanding processes such as strain localisation and the role of magma in rift evolution



Ezekiah Chikambwe from the Geological Survey Department, Zambia, programming a magnetotelluric instrument.

caused by magma breaking surface of the lithosphere. Magmatism is present in mature continental rifts, and so the Malawi provides an opportunity for scientists to investigate the underlying lithosphere for other factors which affect rift development.

Eastern and western branches of the EARS show different types of rifting, suggesting that pre-existing geological conditions play a major part in rift development. Mantle plumes are currently thought to be the main geological feature that affects the development of continental rifts. The diverse locations of the Okavango, Mweru, Luangwa and Malawi rifts also allow the team to explore the possibility that edge driven convection (where the meeting of an older, thicker and a younger, thinner lithosphere causes instability) also has a significant effect upon rift formation.

## A MULTIDISCIPLINARY APPROACH

With the help of institutions such as Missouri University of Science and Technology, project PRIDE is able to conduct its research using an array of geophysical, geochemical, geological and geodynamic techniques. This approach will allow them to define the lithospheric structure beneath the three rift basins. The collection of passive seismic data across the rift basins will allow the team to determine upper mantle structure, and a wide angle P- and S-wave refraction experiment across the Okavango rift may enable the development of detailed velocity models of the lithosphere.

Magnetotelluric (MT) data allows scientists to model the Earth's electrical conductivity, facilitating the identification of temperature and the presence of fluids. It has been used extensively in southern Africa to map variations in lithospheric thickness. Project PRIDE will combine seismic data with MT and gravity readings to gain an understanding of the upper crust structure and density. Scientists will also use MT data to identify the presence of melts and fluids in order to ascertain the effect of magma flow upon rifting. Mantle activity will additionally be measured through geochemical sampling of helium and carbon isotopes in subsurface fluids and hot springs. Finally, remote sensing will enable the mapping of geomorphic-tectonic structures.

For the first time, scientists will be able to observe in detail transects from multiple young rift systems. The three rift basins are at different stages of development (from youngest to oldest, respectively) which will create a framework for comparison and prove invaluable in understanding processes such as strain localisation and the role of magma in rift evolution.

## IMPROVED GEODYNAMIC MODELLING

Project PRIDE hopes that their focus on early stage rifting processes such as strain localisation, the onset of magmatism and the effect which pre-existing lithospheric features can have upon rift evolution, will contribute towards creating a more accurate picture of rift evolution as a whole. The combination of multidisciplinary data with geodynamic modelling will enable scientists to determine the main drivers behind continental rift initiation and use this to develop the next generation of continental rifting models.

## INTELLIGENCE

### INTEGRATED STUDIES OF EARLY STAGES OF CONTINENTAL EXTENSION

### OBJECTIVES

To provide new insights into the mechanisms operative during the earliest stages of continental rifting.

### KEY COLLABORATORS

**Dr Eliot Atekwana • Dr Mohamed Abdel-Salam • Dr Pablo Canales • Dr Dan Lizarralde • Dr Mark Behn • Dr Steve Gao • Dr Kelly Liu • Dr John Hogan • Dr Roger Buck • Dr Dorsey Wanless • Dr Steven Harder • Dr Alan Jones • Dr Kevin Mickus**

### PARTNERS

**Geological Survey of Botswana • University of Botswana • Geological Survey Department, Zambia • University of Zambia • Geological Survey of Malawi**

### FUNDING

Continental Dynamics Program of the National Science Foundation, USA

Some funds to facilitate capacity building were provided by the Baylis Foundation

### CONTACT

**Dr Rob L Evans**
Senior Scientist, Department of Geology and Geophysics

Woods Hole Oceanographic Institution
Woods Hole, Maryland 02543, USA

**T** +1 508 289 2673
**E** revans@whoi.edu

**www.whoi.edu/profile.do?id=revans**

**Dr Estella Atekwana**
Professor of Geophysics

Boone Pickens School of Geology
Noble Research Center
Oklahoma State University
Stillwater, Oklahoma 74078-3031, USA

**T** +1 405 744 6358
**E** estella.atekwana@okstate.edu

**http://bit.ly/estellaatekeana**

**ROB EVANS** has a PhD from the University of Cambridge in Marine Geophysics. He is a senior scientist at the Woods Hole Oceanographic Institution where he has worked for the past 20 years. His expertise is in land and marine electromagnetic methods.

**ESTELLA ATEKWANA** has a PhD from Dalhousie University in Geophysics. She is currently the Regents Professor of Geology, the Sun Company Clyde Wheeler Chair in Hydrogeology and Department Head at the Boone Pickens School of Geology, Oklahoma State University where she has worked for more than eight years.