Birth of an ocean Africa splits apart

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The Earth's surface is not quite as stable or permanent as you may think. The tectonic plates that form our planet's outer crust are constantly moving around, bumping past each other along fault zones, crashing to create mountain belts and being pulled apart to create ocean basins. Normally these movements are pretty slow, a few millimetres per year, but in 2005 in the remote Afar desert in Ethiopia a 60 km long section of a plate boundary cracked open by 8 metres in only a few days. ***David Ferguson*** *of Oxford University has been there.*

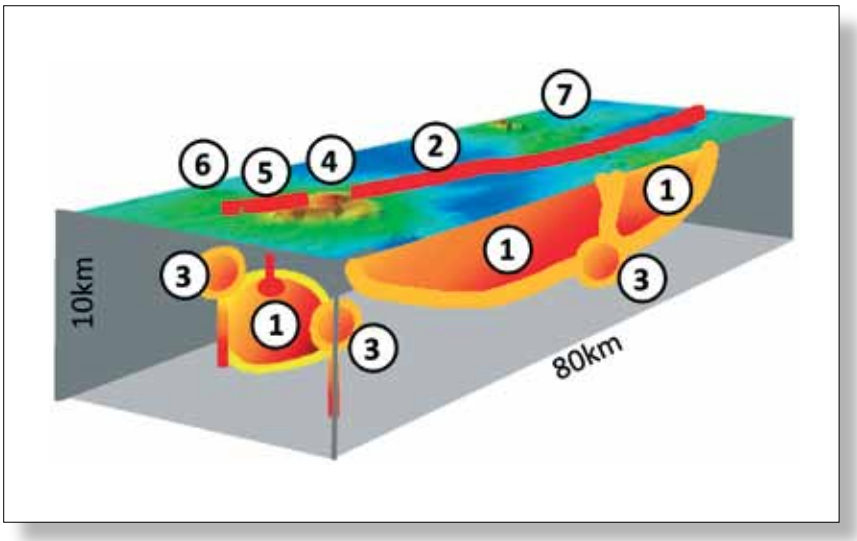
Iam one of an international team of scientists who are using the latest technologies available to geoscientists to probe deep into the Earth in Afar to discover what happens when the crust is rifted apart and a new ocean is born. In this article, I will describe some of the techniques currently being used to study Afar and what they are telling us about the formation of Africa's new ocean.

The importance of magma

When the Earth's crust is stretched it becomes thinner and thinner until eventually it fractures and breaks up. As the crust becomes stretched hotter material from below moves upwards to fill the space. When this hot rock rises it starts to melt, generating magma.

There is currently a lot of magma under Afar and it is this that is ultimately responsible for the amazing geological activity going on today. However, this magma is not spread evenly beneath the surface. Rather, it is concentrated along the fracture zones where the tectonic plate is being broken apart (i.e. where the new plate boundary is forming). Periodically a batch of magma will surge upwards, wrenching apart the crust as it tries to reach the surface. These episodes are called intrusions and they are accompanied by lots of earthquakes as the magma cracks open an upward path.

Sometimes the magma makes it all the way to the surface, erupting new lava flows on to the desert floor from long volcanic fissures. These lava flows will one day form the part of the floor of the new African ocean. Since 2005 there have been 14 separate intrusions of magma and 4 volcanic eruptions in Afar.



Below the ground –
the 'plumbing' of the Afar region.

1. September 2005 dykes
2. Trace of dyke on surface
3. Magma chambers
4. Dabbahu volcano
5. Da'Ure vent
6. Gab'ho volcano
7. Ado'Ale volcanic complex

Afar
The Afar region covers the northeastern part of Ethiopia. It is a desert scrubland with saline lakes and long chains of volcanoes. It is one of the hottest and also least populated places on the Earth. In summer the tempertaure reguarly gets above 50°C. As the crust in Ethiopia has been streched the ground surface has sunk lower and lower, so much so that many parts of Afar are now below sea level, though not yet under water. The geological processes we wtiness there are similar to those that occur beneath the oceans where two tectonic plates that form the sea floor are moving apart. The amazing thing about Afar is that we can observe this happening on (very) dry land! Afar is also where the earliest hominid fossils have been discovered, the most famous of which is 'Lucy', an *Australopithecus afarensis* who lived in Afar about 3.2 million years ago.

Catalyst

www.sep.org.uk/catalyst

A volcanic fissure, several metres wide, formed as underground magma pushed upwards. Photographed in the Afar region of Ethiopia by Julie Rowland, University of Auckland.

Watching the Earth move

How do we know the Earth surface in Afar is being pulled apart? We know that the earthquakes and eruptions are probably being caused by the magma moving underground, but we need to be able to actually measure the movement of the surface. Geodesists use satellite radar measurements to detect very small changes in the height of the Earth's surface. Comparing measurements made at different times shows if the surface has changed during this time.

In Afar the intrusion of magma forces the ground apart and causes faults to move. This radar technique can be used to measure changes of just a few millimetres. However over the past five years the surface in Afar has been opened up by almost 10 metres!

Feeling the ground shake

When magma moves underground it needs a pathway, this means it has to break apart a lot of rock, thereby generating earthquakes. Like the ripples from a stone thrown into a pond, these waves travel outwards from the fractured rock and can be recorded with a seismometer at the surface.

The Afar team of seismologists (scientists who study earthquakes) have set up a network of stations to record the earthquakes caused by the magma. By comparing the different times that the seismic waves arrive at each station we can calculate the underground location of the earthquake and therefore the magma. During the current active phase in Afar there have been thousands of earthquakes, some very large. In 2005 when the first intrusion happened there were over 163 large earthquakes in a few weeks. Seismologists working in Afar have to travel to Ethiopia every few months to download the data from the seismic instruments.

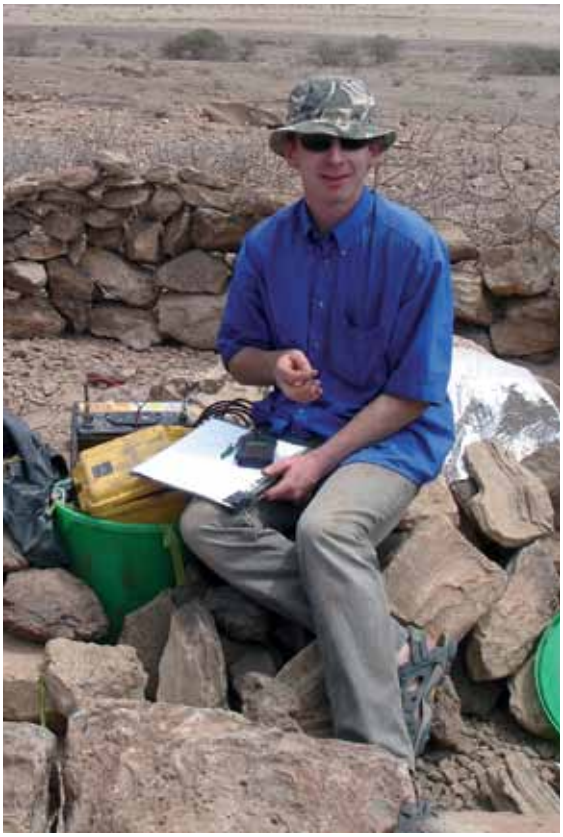
A new volcanic fissure in Afar which opened up in only a few days in 2005. It was formed as magma forced its way upwards pushing the ground apart. The light grey coloured material around the fissure is fresh volcanic ash. On the right are circular goat pens, used by nomadic herders.

Probing the Earth for magma

The satellite measurements show the ground surface is opening up along the new plate boundary; the seismic data suggests is caused by magma moving underground. But where is this magma stored? Magnetotellurics is a geophysical technique that can be used to look for an underground magma chamber. Just like a metal, liquid rock is highly conductive. Geophysicists using magnetotellurics make measurements of the electrical conductivity of the subsurface and try to find highly conductive bodies of molten rock. In Afar mangnetoelluric data has identified a large 'conductor' about 10 km below the new plate boundary. This is the magma chamber that is feeding the intrusions and eruptions.

Chasing volcanic eruptions

You might think a volcanic eruption is a pretty hard thing to miss, but how do you know when a remote volcano erupts and no one is around to see it? Satellite measurements can record the heat and gases emitted by a new eruption. Once we know an eruption is in progress the volcanologists (scientists who study volcanoes) in our group quickly travel out to Ethiopia to try and collect lava samples and to observe the eruption. Measuring the chemistry of the lava can give further clues to where the magma is stored underground, and also what the conditions were like when the magma was originally formed. Once the lava has cooled on the surface it looks very similar to other lava flows, however using infrared cameras allows us to 'see' the heat of the new eruption.



The author collecting lava samples

What have we discovered so far?

By piecing together all the different data from the various techniques we have begun to create a model of how the crust in Africa is being split apart.

- The new plate boundary in Afar is currently very active. Large volumes of magma are moving upwards, splitting apart the Earth.
- Satellite data shows us where the axis of the new plate boundary is and that over the last 5 years the plates have moved apart by up to 10 metres.
- Seismic data from earthquakes records the underground movement of magma as it travels along this new plate boundary.
- Magnetotelluric measurements allow us to 'see' the sub-surface magma chamber which is feeding the intrusions and eruptions.
- Volcanic eruptions confirm that is it indeed molten rock that is driving the activity in Afar and let us collect samples so we can analyse the chemistry of the magma.
- This activity is creating new oceanic crust that will one day form part of an ocean basin.

Africa's new ocean: the next 20 million years

The map shows what east Africa will look like in around 20 million years. A new ocean has appeared all along the eastern coast. This is where the crust is being pulled, stretched and fractured today. The floor of the ocean will be made of cooled lava flows erupted from the magmatic intrusions. The activity we are witnessing today along the plate boundary will still be happening, but will be hidden from view under the waters of the new ocean.

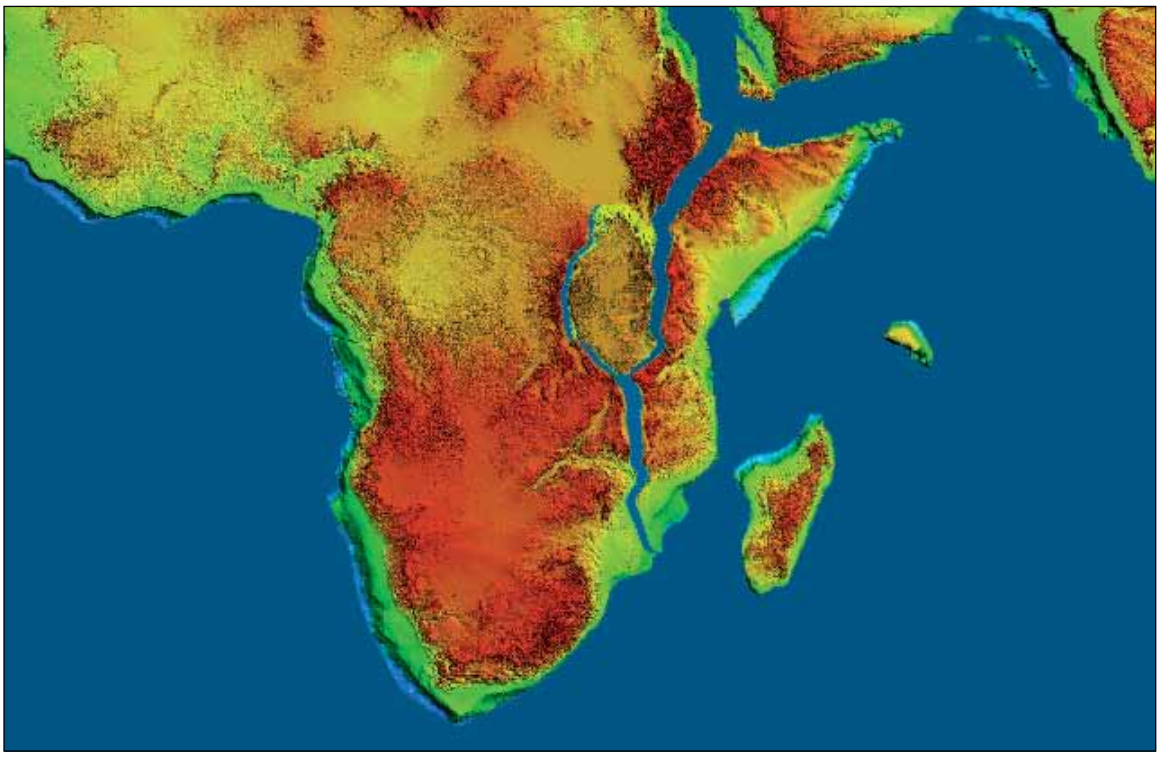
The Erta Ale lava lake

David Ferguson is a PhD student in volcanology at the University of Oxford. He is a member of an international research group who are studying plate tectonics in East Africa.

Look here!

This website has more details about the research in Afar:
www.see.leeds.ac.uk/afar

Check out the 'Day in the life of...' films to learn more about the work of geologists.



Africa 20 million years from now.