Geophysical Research Abstracts
Vol. 14, EGU2012-14089, 2012
EGU General Assembly 2012

Witnessing the birth of a new ocean? The first 6 years of the Dabbahu rifting episode, and other activity in Afar

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Intense earthquake activity and a small rhyolitic eruption in September 2005 heralded the onset of an unprecedented period of geological activity in the Afar Depression. The seismic activity accompanied dyke intrusion in the upper 10 km of crust along 60 km of the Dabbahu (northern Manda-Hararo) Magmatic Segment (DMS) of the Nubia-Arabia plate boundary, a nascent seafloor spreading centre. InSAR observations of the resulting deformation showed that the initial dyke was up to 8 m thick, with a total volume of 2-2.5 km3. Urgency funding from the UK Natural Environmental Research Council (NERC) and US National Science Foundation (NSF) enabled us to deploy a local array of seismometers in October 2005, continuous GPS instruments in January 2006, and to acquire a dense time series of satellite radar images. The medium-term viability of these instruments was secured with major follow-on funding from NSF and NERC; these projects supported the collection and analysis of additional unique data sets, including data from a broader array of seismic and GPS instruments, magneto-telluric transects of the rift, airborne LiDAR, petrological sampling and micro-gravity work. The combination of these data has allowed us to quantify the processes associated with crustal growth at divergent plate boundaries for the first time.

Here, we present a broad overview of geological activity in the Afar depression in the hyperactive 21st century. Activity in the DMS began after September 2000, when Gabho volcano at the north of the segment began uplifting, as its magma chamber, $\sim$3 km below the surface, was replenished. It is likely that the inflation at Gabho ultimately triggered the onset of the Dabbahu rifting episode. The rifting episode began with intense seismicity at the northern end of the DMS, before jumping to the Ado Ale Volcanic Complex at the segment centre. This initial dyking was fed from shallow ($\sim$3 km) chambers at Gabho and Dabbahu as well as a deeper ($\sim$10 km) source at Ado Ale. The initial dyke was followed by a sequence of smaller dyke intrusions, which began in June 2006. To date, there have been 14 dyke intrusions in total, with the most recent occurring in May 2010. These later dykes were typically 2-3 m thick and 10-15 km long, and have a cumulative volume approaching 1 km3. Three dykes broke the surface to produce basaltic fissural eruptions. Seismicity data show that they were all fed from the AVC and propagated at rates of 0.2 – 0.5 m/s. Overall, the locations of the dyke intrusions appear to be guided by tectonic driving stress, with the later dykes filling in areas that opened less in the initial dyke. However, the location of individual dyke intrusions is also influenced by their immediate predecessor.

Activity in the 21st century in Afar has not been restricted to the Dabbahu Magmatic Segment. In the Erta Ale Magmatic Segment (EMS), a large basaltic eruption occurred at the Alu-Dalafilla range in November 2008, and the Erta Ale lava lake itself overflowed in November 2010. In addition, we have recently identified a shallow dyke intrusion at the north of the EMS, which propagated south from Dallol in 2004. Further afield, Nabro volcano in Eritrea, near the border with Eritrea, began erupting explosively in June 2011. Many of the eruptions were first detected by satellite observations of SO_2 emissions and thermal hotspots, which enabled reliable alerts to be transmitted to local and national authorities, sometimes before eye-witness reports were communicated. Nabro was the 7th eruption in Afar in less than 6 years.

An intense and immense collaborative effort involving numerous Ethiopian and international scientists, with crucial support from local and national authorities, has enabled us to document and learn from this unique period of activity in Afar.