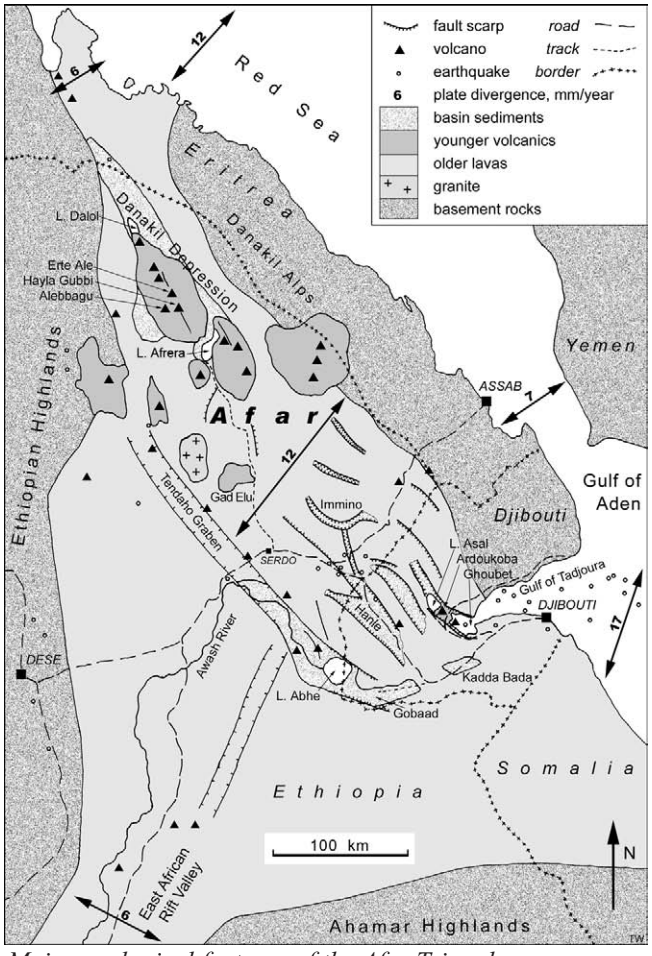
LECTURE

Extension tectonics in the Afar Triangle

Summary of lecture presented to the Society on Saturday 11th December 2004 by Dr Tony Waltham

Where the African Rift Valley meets the Red Sea, a triple junction of divergent plate boundaries has constructed the Afar Triangle, now forming parts of Ethiopia and Djibouti. Its terrain is a hot, barren, rocky desert. The African Nubian Plate forms the Ethiopian Highlands to the west, while the Danakil Microplate forms mountains between the Afar and the Red Sea. Within the Afar, the main rocks at outcrop are flood basalts, mostly < 2 Ma (see *Geology Today*, v.21, p.101-107, 2005, this author and title).

The largest of the grabens form splendid rift valleys across the waterless deserts, mainly within Djibouti. The Hanle graben is 3-10 km wide and 80 km long, with marginal scarps up to 800 m high flanked by smaller cylindrical faults on which blocks have rotated by up to 20°. The deepest graben contains the bay of Ghoubet and the saline Lake Asal (155 m below sea level), separated by the Ardoukoba volcano that has grown within the rift. The last eruption, in 1978, created a spatter ring, produced small lava flows from fissure vents, and left fresh fault scars along the margins of the subsided graben.



Major geological features of the Afar Triangle.

Travertine towers at Lake Abhe.

The most southerly graben contains Lake Abhe, fed by the Awash River and with no outlet, so that its level and extent fluctuate with climatic change. It is distinguished by hundreds of travertine towers that have grown over hot mineral springs when submerged by the lake waters. These stand up to 60 m tall, remnant from lake highs more than 1000 years ago that are also marked by terraces on adjacent hillsides.

All the Afar horsts and grabens are the result of active tectonic extension. Repeated surveying have shown that current divergence is more than 12 mm/year, and geological evidence shows that has been continuous for the last few million years. There is also up to 7 mm/year of extension on the Red Sea side of the Danakil Microplate. As the microplate moves eastwards, the horsts between the Djibouti grabens each have rotated about 11° in the last 1.8 Ma (measured by their basalts' paleomagnetism); this pattern of movement may be graphically described as bookshelf faulting. Accurate surveys indicate that about 80% of the crustal extension is accommodated by magmatic emplacement, as dykes and lavas, while 20% is expressed in the normal faults of the grabens.

Towards the northern apex of the Afar Triangle, the Danakil Depression descends to about 120 m below sea level, and is therefore especially hot and arid. It is inhabited by the tough and fiercely defensive Afar people, and is rarely visited by Europeans. A journey into it is a minor epic, requiring a pair of 4WD vehicles with a support team of Afar tribesmen. The floor of the Depression has salt lakes (exploited for their minerals) in basins fringed by Pleistocene reef limestones and underlain by 1000 m of evaporites, all formed when it was a subsiding and progressively desiccating arm of the Red Sea.

In the Depression centre, the active basaltic shield volcano of Erte Ale rises to 730 m above the salt lakes. Its summit caldera contains pit craters, one of which houses an active lava lake. One of the few long-lived lava lakes in the world, the lake's continued existence relies on heat flow from rising magma that only rarely overflows as lava, but is nearly all lost into active dyke swarms that underlie this constructive zone of plate divergence. For the last few years, the lava lake has been only 30 m across (see back cover), but it makes a fine climax to a journey into the Afar.