STRUCTURE AND EVOLUTION OF THE MAIN ETHIOPIAN RIFT

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The Ethiopia Afar Geoscientific Lithospheric Experiment (EAGLE) was undertaken in 2003 by an international team composed primarily of U. S., British, and Ethiopian scientists and students to provide a snapshot of lithospheric break-up at the transition between continental and oceanic rifting. In this transition, extensional strain is primarily taken up by mechanical failure of the lithosphere and oceanic rifting is accommodated by axial diking. Our focus is the Main Ethiopian Rift (MER) that extends from central Ethiopia into Afar towards the Gulf of Aden and Red Sea oceanic rifts. The MER cuts across the uplifted Ethiopian plateau, which is a major Oligocene flood basalt province associated with the impact of the Afar mantle plume. In addition to a large passive seismology effort led by the British group, EAGLE included a large controlled-source seismic experiment incorporating two ~400 km refraction lines along and across the rift and a two-dimensional array ~100 km in diameter spanning the rift at the intersection of the two profiles (Fig. 1). A total of 23 explosive sources were recorded by approximately 1000 “Texan” seismographs and ~100 broadband seismometers, requiring mobilization of the national seismic pools of the UK and Denmark as well as IRIS-PASSCAL. Our resulting crustal and sub-Moho P-wave seismic velocity model provides insight into the magmatic and structural processes occurring beneath the MER and identifies the rift architecture beneath the surface Tertiary-to-Recent volcanics and sediments. The most significant results relate to: (1) the variation in velocity within the mid and upper crust along the axis of the rift, from an average of ~6.2km.s-1 beneath the flanks to ~6.6km.s-1 beneath the axial magmatic segments (Fig. 2); (2) the emplacement of a high-velocity body (Vp ~7.4km.s-1) in the lower crust beneath the northwestern margin of the rift; (3) the dramatic variation in crustal thickness along the axis of the rift; and (4) the presence of a possibly continuous mantle horizon beneath both linear profiles. These are interpreted respectively in terms of: (1) the presence of cooled gabbroic bodies separated and laterally offset from one another and lying beneath the overlying Quaternary volcanic centers along the axis of the rift; (2) a ~10km thick mafic underplated layer emplaced at the base of the crust and associated with Oligocene flood basalt magmatism over the now uplifted northwestern Ethiopian plateau; (3) thinning of the crust from ~40km beneath the southwestern MER to ~26km in the northeast beneath Afar; and (4) the possible identification of a boundary in the mantle at a depth of ~60km caused by shearing due to stresses caused by lateral ‘spreading’ of the upwelling anomalous mantle beneath the rift and its surrounds.

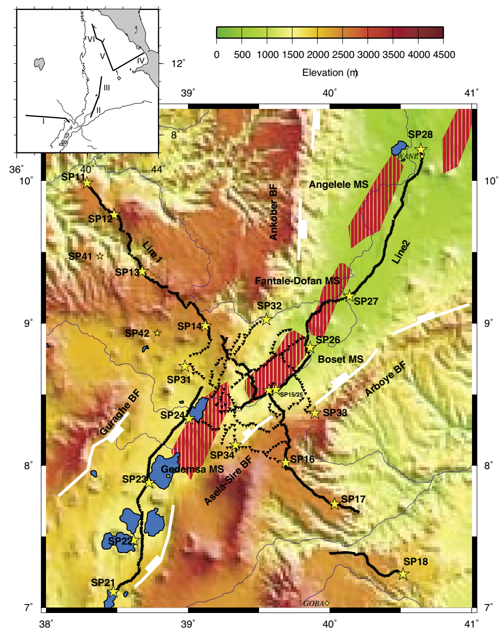

Figure 1: Index map of the EAGLE controlled source experiment. Line 1 crossing the rift valley; Line 2 follows the rift valley; and Line 3 is the array deployed in the region where Lines 1 and 2 cross. Yellow stars are shotpoints. Elongate areas shaded in red are magmatic segments that were targeted in this study. The inset shows the locations of previous studies in the region.

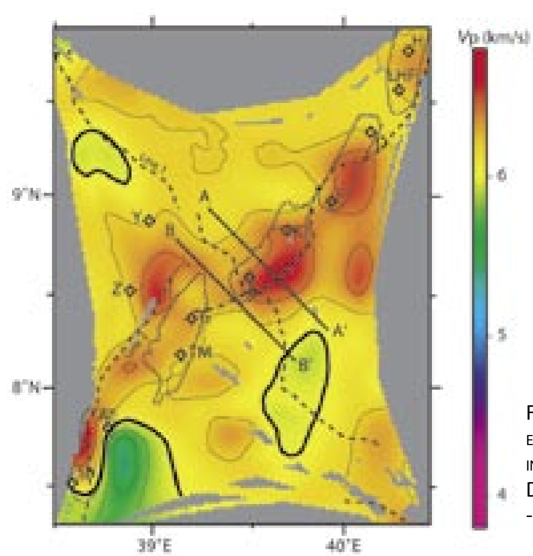

Figure 2: Horizontal slice through the 3-D tomographic model at 10 km below the surface (after Keranen et al. 2004). EAGLE Lines 1 & 2 dashed. High-velocity bodies (red) interpreted as solidified magmatic intrusions beneath the rift floor. Sections AA′ and BB′ are vertical slices shown in Keranen et al. (2004). Diamonds identify volcanoes: Al - Aluto, B - Boset, D - Dofan, F - Fantale, G - Gademsa, H - Hertale, K - Kone, LHF - Liado Hayk Field, TM - Tullu Moje, Sh - Shala, Y - Yerer, Z - Zikwala

Other EAGLE activities include complementary gravity and petrology studies (also funded by NSF-Continental Dynamics) and geology and magnetotelluric studies (funded by NERC, UK). Although we are at an