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The August 2002 earthquake sequence in north Afar: Insights into the neotectonics of the Danakil microplate

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Abstract

In August 2002, there was high seismic activity in Afar concentrated at the plateau margin of the northern Ethiopian rift east of Mekele, near the western part of the Danakil microplate. The spatial and temporal distributions of this seismic activity over four weeks indicate the NNW propagation of the Gulf of Aden rift across the Afar Depression towards the western Ethiopian plateau. Fault plane solutions for six larger earthquakes from the August 2002 sequence are estimated from moment tensor inversion of local broadband waveform data. The results show only normal faulting on NNW trending and NE dipping faults, which agree with tectonics of the area and distribution of aftershocks. No strike-slip component is observed in any of our fault plane solutions or those of other workers including Harvard CMT solutions in the region. Such motion would be indicative of oblique-slip deformation between the Nubian plate and the Danakil microplate consistent with counter-clockwise rotation of the microplate. Hypocentral depths of well-constrained events are 5–7 km, which is the approximate elastic plate thickness in the Main Ethiopian rift, possibly indicating the depth to the brittle–ductile transition zone in this part of the Afar Depression. The shallowness of the depth estimates agree with the macroseismic reports available from a wide area in northern Ethiopia. Potential future shallow crustal deformation may cause significant loss of human life and damage to property in the densely populated highland region around Mekele unless measures are taken in improving building standards. The *b*-value for this sequence is estimated to be 0.66 using a least squares fit, while it is 0.67 ± 0.16 from a maximum-likelihood approach. This estimated *b*-value is low or the frequency of occurrence of relatively larger magnitude events is high indicating that it is a highly stressed region as evidenced by the recent increase of the seismicity in the area.

Keywords: Afar; Danakil microplate; Fault-plane solutions; Seismicity; *b*-Value

1. Introduction

The Afar Depression is a diffuse extensional province in the region where the Gulf of Aden, the Red Sea and the Main Ethiopian rift approach one another (Fig. 1a). The three extensional plate boundaries are different in age (Barberi et al., 1972; Cochran, 1981; Manighetti et al., 1998; Wolfenden et al., 2004) and divergence rate (Chu and Gordon, 1998; Bilham et al., 1999) but each tends to extend oblique to its strike (Joffe and Garfunkel, 1978; Boccaletti et al., 1994, 1998; Dauteuil et al., 2001; Huchon and Khanbari, 2003). Several studies show that the Red Sea and the Gulf of Aden oceanic rifts are propagating on land in Afar (e.g. Courtillot, 1980, 1982; Acton and Stein, 1991; Manighetti et al., 1997, 1998, 2001; Fig. 1a) as a result of the separation of Arabia from Africa and the quiescence of the Bab El Mandeb in geologically recent times (Barberi et al., 1975; Figs. 1b and 4). The rheology of the lithosphere beneath the Afar Depression is weakened by one or more mantle plumes (Ebinger and Sleep, 1998; White and McKenzie, 1989) though the origin and present day location

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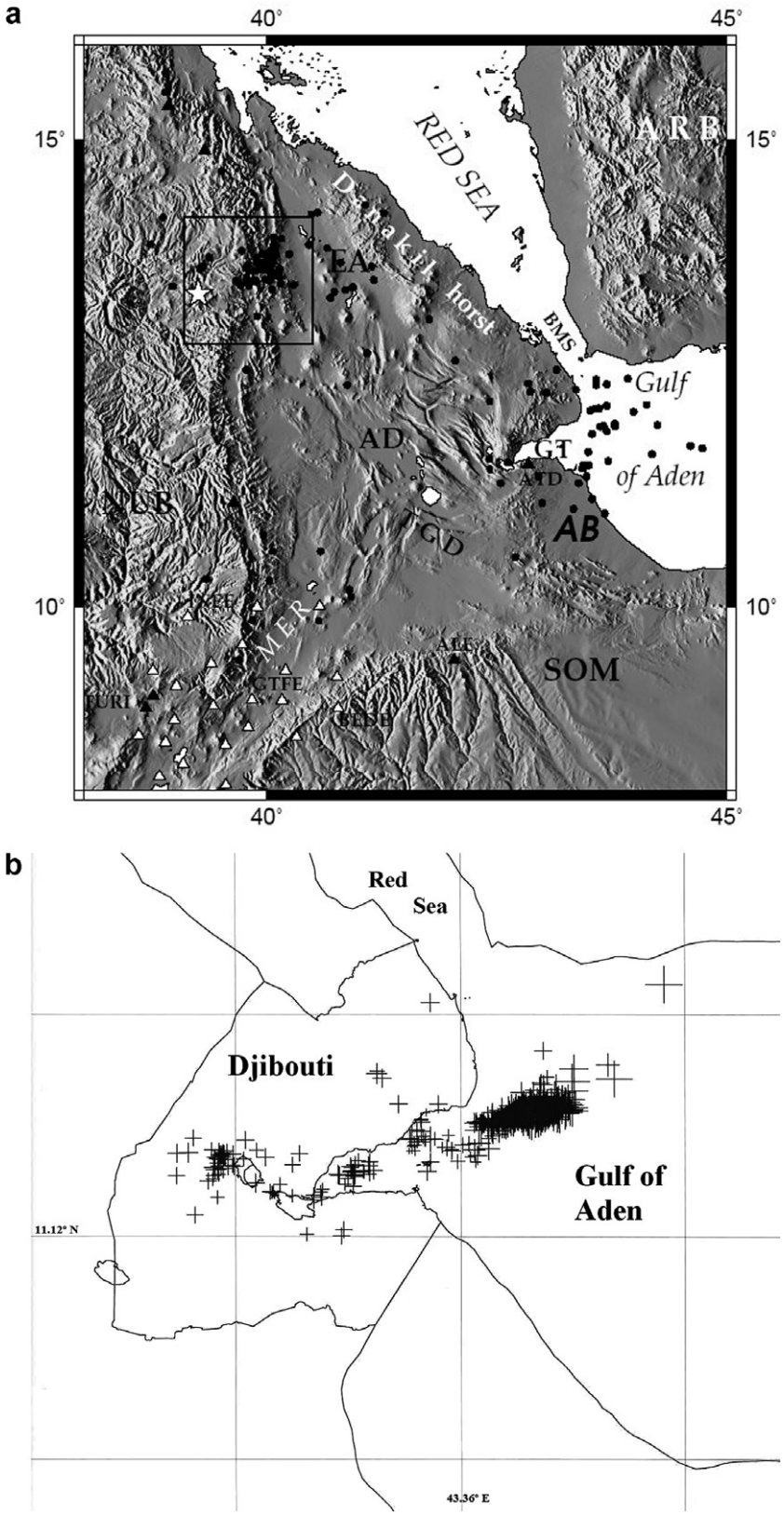

Fig. 1. (a) Gray color plot of the topography of the Afar triple junction. The white triangles represent the EAGLE temporary seismic broadband array and the black triangles show the permanent station locations in the region used in this study. The larger white star represents the location of Mekele town. AD, Afar Depression; GT, Gulf of Tadjoura; NUB, Nubia plate; SOM, Somalia plate; ARB, Arabia plate; MER, Main Ethiopian rift. The black circles show earthquakes distribution of the August 2002 activity located in this study. (b) Seismicity of the Djibouti and Gulf of Tadjoura area of August, 2002 as reported in the Arta seismic bulletin.