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The Ogaden Dyke Swarm: Red Sea Rifting Continued in the Somalia Plate?

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Opening of the Red Sea started while the core of the lavas of the Ethiopian Large Igneous Province (LIP) was being erupted at ~30 Ma (Hughes et al., 1991) and has continued to the Present. In the southern Red Sea, oceanic spreading has occurred since 5 Ma (Cochran and Karner, 2007), with a possible precursory spreading event at 26-24 Ma (Almalki et al., 2012). The dated dykes along the Red Sea suggest that opening was accompanied by dyke emplacement along the Red Sea margins between 29.5 and 21 Ma (Sebai et al., 1991; Drury et al., 1994, Zumbo et al., 1995; Baker et al., 1996; Kenea et al., 2001). At the latitude of northern Afar, the spreading axis jumps inland where it ends at the junction with the East African Rift and the Gulf of Aden.

South of Afar, in southeast Ethiopia (Ogaden), field and high frequency aeromagnetic data reveal the presence of a 400+ km long mafic dyke swarm, the Ogaden Dyke Swarm (Mège et al., 2010), which is parallel to the Red Sea (Figure 1). It extends from the NW-SE trending Marda volcanic line in the north, at the contact with the southern Afar escarpment, to the Ethiopia/Somalia border in the south. The reported length of the dyke swarm is minimum, being limited by the extent of the high-frequency aeromagnetic coverage. We present $^{40}Ar/^{39}Ar$ ages in the southern part of the dyke swarm that indicate that the age of the swarm and associated basaltic flows is 27-24 Ma. In the north, no field evidence of fissure feeding of the Marda volcanic line was found, but at the Karamara Pass, the volcanic line overlies a subvolcanic complex of similar age, 23.5-25 Ma, and similar REE patterns. In general, the REE patterns of the Marda and Ogaden Dyke Swarm are similar. The lavas plot in the field of the high-Ti basalts that characterise many Ethiopian LIP lavas, and denote closer affinity to the Afar plume geochemical source than to the source of the Red Sea dykes. Therefore, the tectonic development of the dyke swarm appears to be controlled by the Red Sea system, whereas the composition of the magma is controlled by the LIP source.

Ogaden dyke swarm dilation may represent off-axis magmatism coeval with tectonic stretching in the Somalia grabens, and have been driven by the Zagros subduction slab pull (Figure 2). Starting of the Zagros collision (Mouthereau et al., 2012) and slowing of the Africa-Eurasia convergence at 25 Ma (McQuarrie et al., 2003), may have been the cause for dyke dilation to cease, and reorganised the plate boundaries in such a way that the Main Ethiopian Rift initiated (Mège et al., 2015).

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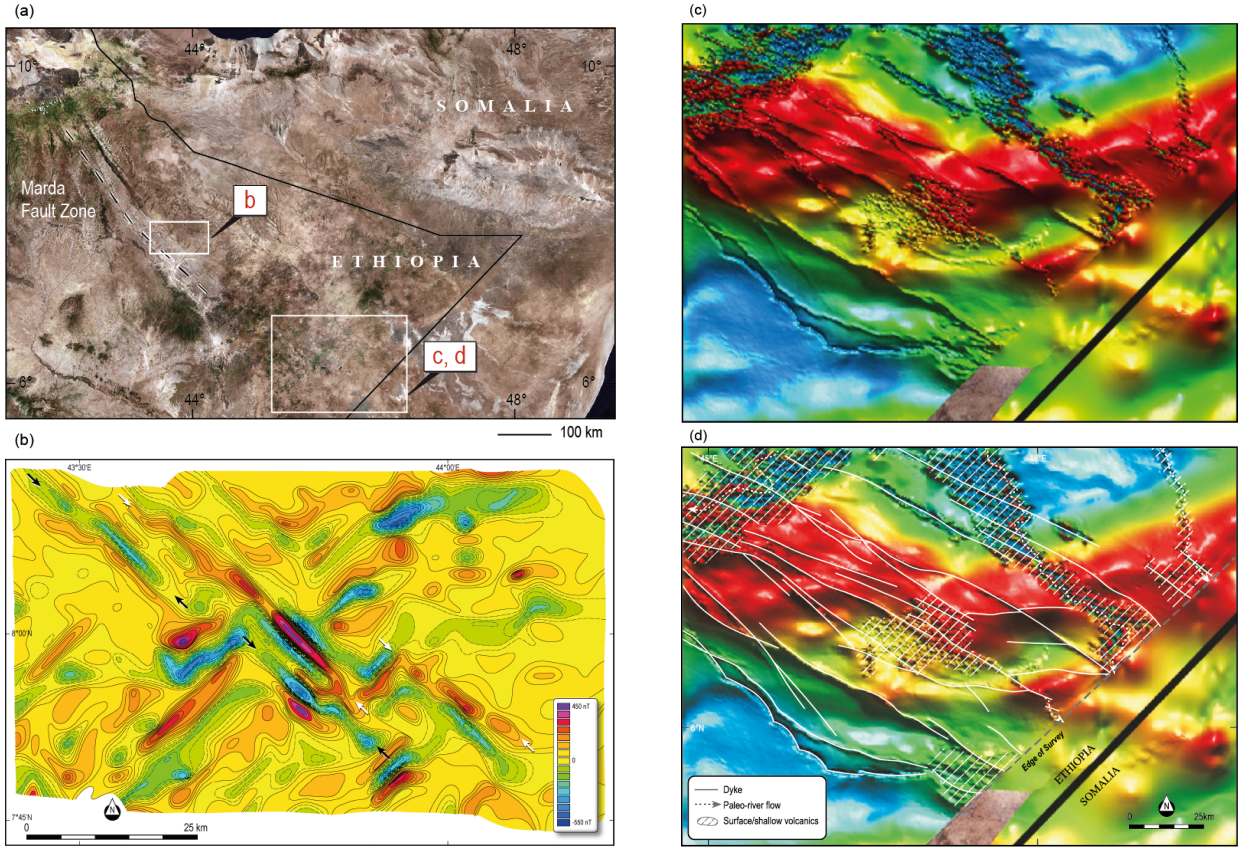

Figure 1. (a) Satellite image mosaic of the Ogaden, showing the location of the Marda Fault Zone, on top of which is located the volcanic line, and the magnetic maps displayed in (b), (c) and (d); (b) Whitestone second vertical derivative magnetic map across the central Marda Fault Zone (Geosurvey, 1977). The survey was flown in 1977 at a constant barometric altitude of 1830 m using a Geometrics G803 proton procession magnetometer, with N/S-oriented lines 2.5 km apart and tie-lines at 10 km spacing. The normal and reversely magnetized dyke-related anomalies are shown by black and white arrows respectively; (c) Pexco first vertical derivative Reduced-to-Pole magnetic map in eastern Ogaden. Survey lines were flown in 2008 on a bearing of 045° on a 1 km spacing, with tie-lines flown at a 5 km spacing at a bearing of 135°. Average terrain clearance was 55 metres; (d) geological interpretation of (c). Dyke-related anomalies are marked in white and lava flows in white-dashed surfaces.

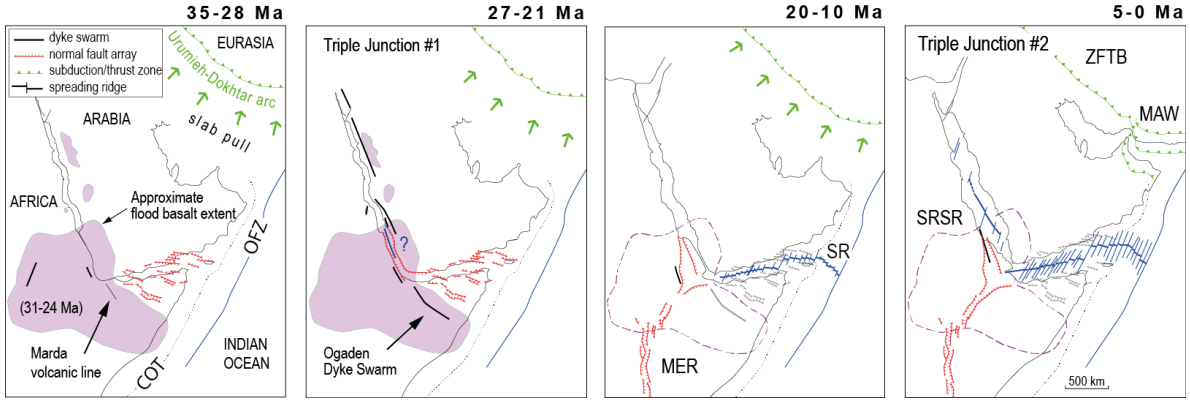

Figure 2. Schematic reconstruction of the evolution of the Afar Triple Junction, with emphasis on events occurring on the Somalia Plate. The base maps are modified from Bosworth et al. (2005). Flood basalt extent is approximate and based on the location of the outcrops described in the literature and, in eastern Ethiopia and Somalia, on geologic mapping and $^{40}Ar/^{39}Ar$ dating by the authors, oil- and water-well data (Faillace 1993), and vintage Esso and Elf aeromagnetic surveys (Bosellini, 1989). COT: continent-ocean transition; MAW: Makran Accretionary Wedge; MER: Main Ethiopian Rift; OFZ: Owen Fracture Zone; SR: Sheba Ridge; SRSR: Southern Red Sea Ridge; ZFTB: Zagros Fold-and-Thrust Belt. The inactive tectonic patterns are grey-coloured.

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