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Miocene-to-Quaternary oblique rifting signature in the Western Ross Sea from fault patterns in the McMurdo Volcanic Group, north Victoria Land, Antarctica

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ABSTRACT

Mt. Overlord and Mt. Melbourne are part of the fossil-to-active eruptive centre belt of the McMurdo Volcanic Group, located along the western shoulder of the West Antarctic Rift System in north Victoria Land (Antarctica). The formation and localisation of these volcanic centres are intimately connected to the regional fault patterns associated with Neogene transtensional stretching in the West Antarctic Rift System. This study reports about 900 structural data of faults and fault-related joints affecting the Miocene–Pliocene deposits of Mt. Overlord and the Plio-Quaternary deposits of Mt. Melbourne. Fault surfaces strike along three main directions (NW–SE, NE–SW, and N–S) with high (>70°) dip angles. The reconstructed fault geometries and kinematics document a NW–SE strike-slip fault system having dextral motion in the Mt. Overlord area, which evolves into a more complex structural architecture characterised by transtensional deformations in the Mt. Melbourne area, where volcanism is still active. The fault array can be reconciled with principal and subordinate deformation structures developed at the termination region of NW–SE intraplate strike-slip fault systems inducing oblique rifting in the West Antarctic Rift System. The structural dataset, integrated with available geochronological constraints, gives rise to a two-step (Miocene-to-Holocene) tectonic scenario in which the spatial migration of the volcanic activity towards the eastern boundary of the Transantarctic Mountains occurred during the evolution of the West Antarctic Rift System.

1. Introduction

Crustal rifting zones represent tectonic-assisted environments where investigating the linkage between magmatism, volcanism, and faulting. Magma ascent and emplacement are intimately related to the magnitude and orientation of crustal stresses controlling the rifting process (e.g. Gudmundsson, 2006) and, thus, magma percolation benefits of major crustal weakness before feeding the volcanism at the surface. Fault networks and associated fracture zones play an important role in providing a pathway for large volumes of crustal magma propagation (e.g. Buck et al., 2006; Gudmundsson, 2011; Rowland et al., 2010). As such, different mechanisms of faulting have been documented to control the distribution and shape of volcanoes and volcano-related structures (e.g., dyke injections and caldera formation), and they include re-activation of pre-existing structural discontinuities (e.g., Acocella et al., 2002; Seebeck et al., 2010), nucleation and propagation of newly-formed segmented faults (e.g., Rowland and Sibson, 2004), and interaction between active (strike-slip and extensional) intersecting fault systems (e.g., Mouslopoulou et al., 2007). The style and pattern of deformation structures involving the volcanic deposits can be used to decipher the tectonic regime encompassing crustal magma accumulation in active rifting zones (e.g. Acocella et al., 2006; Ebinger et al., 1993; Gudmundsson, 2011; Lesti et al., 2008; Macdonald, 1998; Pollard et al., 1983; Rowland et al., 2007; Wright et al., 2006). Moreover, volcanic deposits can be radiometrically dated because of the occurrence of suitable minerals, thus providing temporal constraints to volcanic events relative to regional deformation. These aspects have great importance in case of volcanic deposits outcropping in rifting areas where very few geological constraints are available for unravelling the regional (neo)tectonic regime.

The Ross Sea region (namely the region that encompasses Victoria Land and the Ross Sea; Fig. 1) of East Antarctica provides a key area to study relationships involving magmatism and regional neotectonics. The evolution of the Ross Sea region is dominated by the Mesozoic–Cenozoic development of the West Antarctic Rift System (WARS) and the Transantarctic Mountains rift shoulder during continental breakup of the Gondwana Supercontinent (Fitzgerald, 2002). The WARS provides the unconventional case of an orthogonal Mesozoic wide rift overprinted on the landward side by Cenozoic oblique narrow rifting

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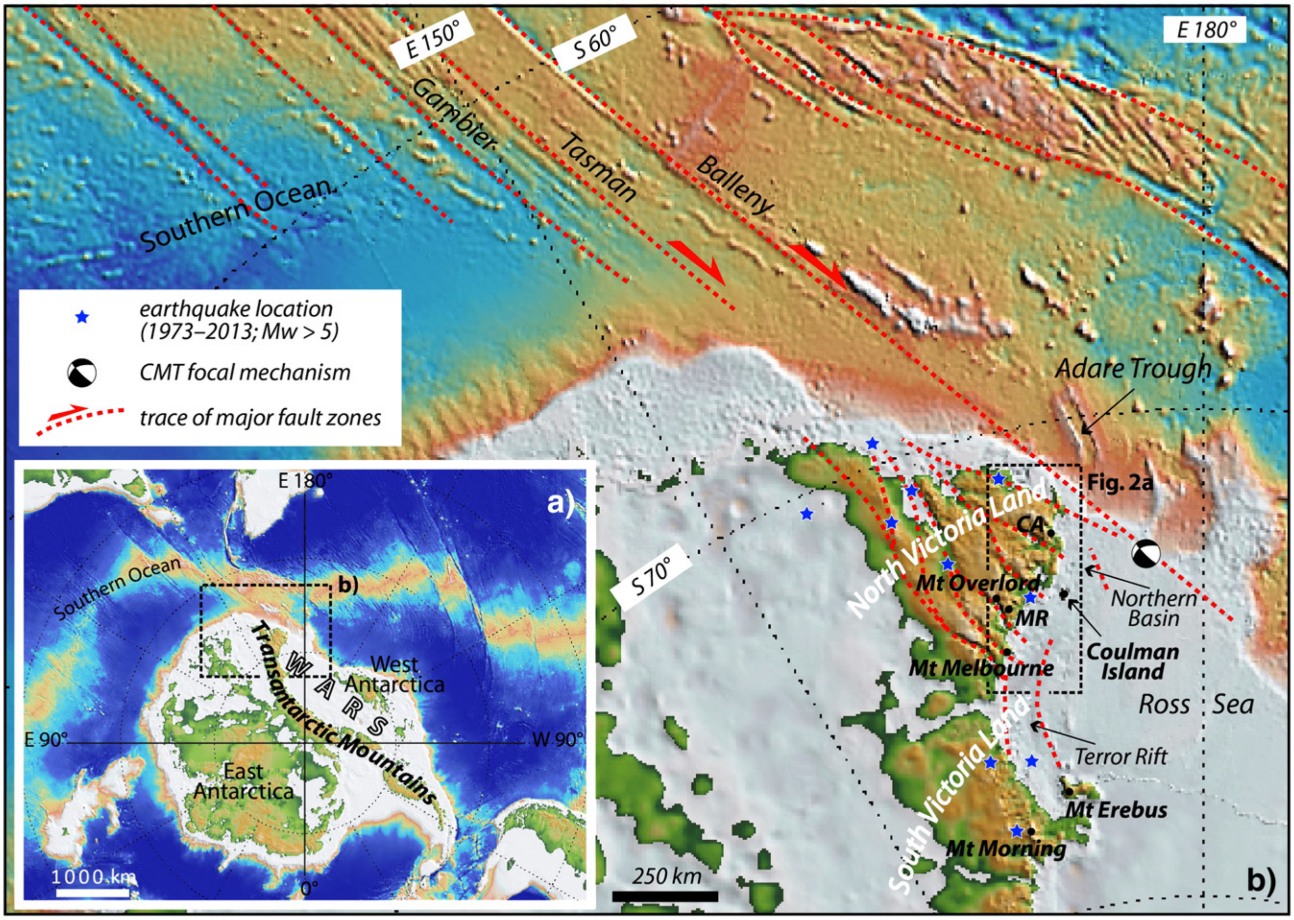

Fig. 1. (a) The Antarctica continent surrounded by the Southern Ocean to the north and the Ross Sea to the east. The trend of the Transantarctic Mountains and the localisation of the West Antarctic Rift System are shown; (b) tectonic map of Victoria Land and surrounding regions showing the trace of major fracture zones and their onshore prolongations. Onshore earthquake localisation and CMT focal mechanism are from Reading (2002) integrated with database extracted from GeoMappApp (http://www.geomapapp.org). The simplified tectonic pattern is from Salvini et al. (1997). Both images have been generated by managing the default basemap from GeoMappApp (Ryan et al., 2009). CA: Cape Adare; and MR: Mount Rittmann.

(Wilson, 1995; Salvini et al., 1997; Hamilton et al., 2001; Rossetti et al., 2006; Storti et al., 2007). This intracontinental rifting is associated with diffuse Tertiary and Quaternary magmatism (e.g., Rocchi et al., 2011; Wörner, 1999). Within this context, regional topography (Faccenna et al., 2008), Neogene-to-Quaternary igneous activity of the McMurdo Volcanic Group (Harrington, 1958; Kyle and Cole, 1974; LeMasurier, 1990; LeMasurier and Thomson, 1990), seismicity (Bannister and Kennett, 2002; Reading, 2002) and GPS data (Dubbini et al., 2010) document neotectonic activity along the coastal region of Victoria Land, facing the Ross Sea embayment. In particular, development of several quiescent-to-active eruptive centres in both north Victoria Land (Mount Melbourne, Mount Overlord, Malta Plateau, Cape Adare, Mount Rittmann) and south Victoria Land (Mount Erebus and Mount Morning) is the most impressive on-shore evidence of present-day tectonics in the region (Fig. 1b).

Still debated are the mechanisms of Cenozoic rifting (orthogonal vs. oblique; e.g. Cande et al., 2000; Müller et al., 2007; Davey et al., 2006; Storti et al., 2007; Di Vincenzo et al., 2013; Granot et al., 2013) as well as the sources and geodynamic scenario for the volcanism in Victoria Land, referred either to a mantle plume (e.g. Behrendt et al., 1991; Hart et al., 1997; Kyle et al., 1992; LeMasurier and Rex, 1991; Storey et al., 1999) or lithospheric-scale strike-slip faulting (Rocchi et al., 2002, 2003; Salvini and Storti, 1999; Salvini et al., 1997). Lanzafame and Villari (1991) first provided a field based dataset for the tectonic structures affecting the Pliocene–Quaternary McMurdo volcanic deposits surrounding the Mt. Melbourne. Since then, volcanic deposits and volcanic-related features have been studied for documenting the neotectonic regimes within the WARS. In south Victoria Land, Martin and Cooper (2010) documented a strike-slip fault system producing dextral offset of a hawaiite dyke dated at 3.88 ± 0.05 Ma. Paulsen and Wilson (2009) reconstructed the Pleistocene stress direction from deformational structures concomitant with volcanism and oblique rifting. In the Admiralty Mountains, Faccenna et al. (2008) found evidence for tectonic control on the emplacement of the Neogene McMurdo Volcanics, which were localised by interference of NW–SE transtensional and NE–SW extensional fault systems in the Cape Adare area (see also Läufer et al., 2006).

This paper deals with the Miocene-to-Quaternary tectonics of the Ross Sea region by presenting the structural pattern (in terms of geometry, spatial distribution, internal architecture, and kinematics) of major fault zones and fault-related joint networks that affect the deposits of the Mt. Overlord and Mt. Melbourne volcanic fields, located in north Victoria Land (Fig. 1b). We performed field mapping and fault-slip analysis along the major fault zones in order to provide new constraints on the tectonic activity post-dating (and/or accompanying) the volcanism in this sector of north Victoria Land. We compare our results with evidence for active tectonics in the whole Victoria Land and we propose WNW–ESE-directed crustal stretching in a context dominated by oblique rifting as the tectonic scenario controlling Miocene–Quaternary volcanism along the western shoulder of the WARS. The structural dataset confirms evidence that tectonics and volcanism, and their space–time evolution, are primary sources of information for constraining the complex geodynamic framework of rifting in the Ross Sea region.