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Crustal formation and evolution processes in the Natal Valley and Mozambique Ridge, off South Africa

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ABSTRACT

The evolution of seafloor spreading of Africa, South America, and Antarctica is key to understanding the initial break-up of Gondwana. Vector geomagnetic surveys were conducted in the Natal Valley and Mozambique Ridge, off South Africa. We summarize the nature of the crust using the results of dense vector geomagnetic anomaly data, as well as satellite gravity data. Based on both inversion and forward analytical results, we identified areas of stretched continental crust, with basaltic magma intrusion in parts, as the northern Natal Valley, north part of the Mozambique Ridge, and north part of the southern Natal Valley. Oceanic crust was identified in the south part of the southern Natal Valley and south part of the Mozambique Ridge. Magnetic isochrons M0–M10 were identified in the south part of the southern Natal Valley. Clear magnetic lineations were observed in the south part of the Mozambique Ridge, where some areas were distorted by hotspot volcanism. The location of the continental ocean boundary in the Natal Valley, along with a four-stage model of tectonic evolution of the study area since about 183 Ma, are newly proposed.

1. Introduction

The break-up of Gondwana is the most significant geological event to have affected the southern hemisphere in the past 200 Ma. A number of recent reconstruction models of Gondwana based on geophysical data have been reported (e.g., Cox, 1992; König and Jokat, 2010; Lawver et al., 1998; Eagles and König, 2008; Leinweber and Jokat, 2012; Reeves and de Wit, 2000; Reeves et al., 2016). Geophysical research around the continental margins that formed Gondwana is key to understanding fragmentation processes during the initial stage of break-up. The Natal Valley and Mozambique Ridge off South Africa (Fig. 1a and b) are considered to have formed as the result of separation between the South America-Africa-Madagascar and Antarctic continents during initial break-up (e.g., Tikku et al., 2002). The Natal Valley is separated into 2 areas along Ariel Graben (AG; Fig. 1b), the southern Natal Valley (SNV) and the northern Natal Valley (NNV). Magnetic isochrons M0–M10 associated with seafloor spreading were interpreted in the SNV (e.g., Goodlad et al., 1982). Mozambique Ridge (MOZR), located to the east of the Natal Valley, is an aseismic ridge. Precambrian rocks were obtained by dredging from the MOZR (e.g., Mougenot et al., 1991). The Explora Escarpment (Hinz et al., 2004) in the Lazarev Sea off Antarctica and the Falkland Plateau off South America (Fig. 1a) are considered a conjugate pair with the Natal Valley and Mozambique Ridge (e.g., König and Jokat, 2010). The detailed geological setting is described in Supplementary data (Appendix A).

The location of the continental ocean boundary (COB) is one of a number of features that can be used for solving the Gondwana reconstruction overlap problem, although there are many uncertainties about the definition of COB (Eagles et al., 2015). Two models of the COB have been proposed for the Natal Valley and Mozambique Ridge. The first model places the COB at the AG based on the geomagnetic, gravity, and seismic studies (e.g., Darracott, 1974; Martin et al., 1982; Scrutton, 1973), and it assumes the NNV and MOZR are continental or transitional crust. If this is the case, kinematic reconstruction models show a large overlap onto the Explora Escarpment and Dronning Maud Land in Antarctica (e.g., König and Jokat, 2010). This interpretation cannot explain the proposed volume of continental crust beneath the NNV and MOZR. To solve this overlap problem, it is necessary to understand the crustal nature of the Natal Valley and Mozambique Ridge, and the Explora Escarpment, and detailed geophysical data such as marine

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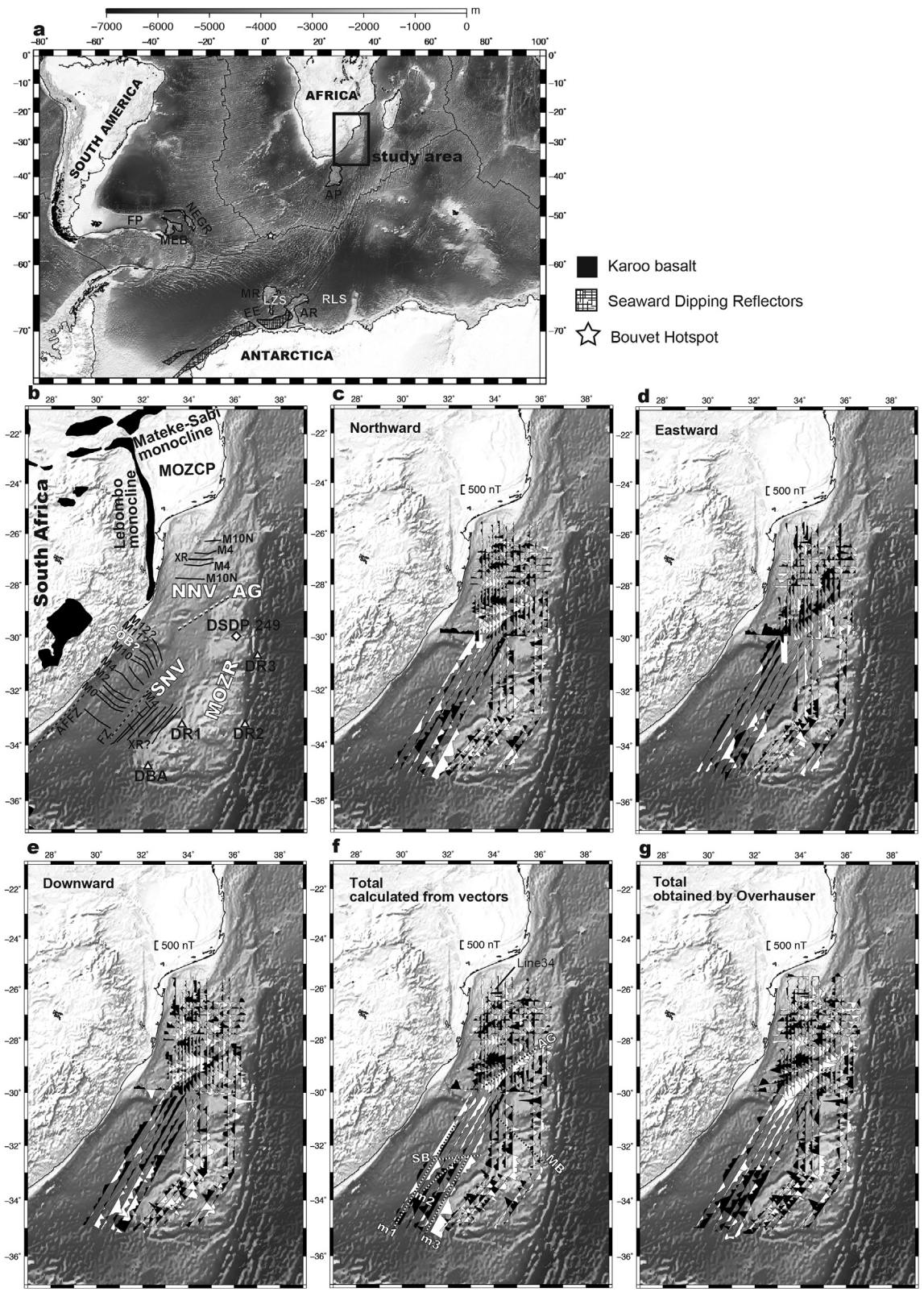

Fig. 1. (a) Overview of the study area (Natal Valley and Mozambique Ridge) and conjugate areas superimposed on topographic map (ETOPO1). Seaward dipping reflectors of Explora Escarpment (Hinz et al., 2004) are shown. Karoo: Karoo igneous province; FP, Falkland Plateau; MEB, Maurice Ewing Bank; NEGR, North East Georgia Rise; MR, Maud Rise; AR, Astrid Ridge; AP, Agulhas Plateau; EE, Explora Escarpment; LZS Lazarev Sea; RLS, Riiser Larsen Sea. (b) Study area superimposed with topographic map (ETOPO1), showing the Karoo basalt area and Ariel Graben (AG; dashed white line). NW-SE oriented longer solid black lines with M12-M0 and the COB indicate magnetic spreading anomalies proposed in Goodlad et al. (1982). The NW-SE oriented shorter solid black lines with M4 indicate magnetic spreading anomalies proposed in Reznikov et al. (2005). E-W oriented solid black lines with M10N, M4, and XR indicate magnetic spreading anomalies proposed in Tikku et al. (2002). The NNE-SSW oriented extinct ridge (XR?) and magnetic anomaly sequences of Leinweber and Jokat (2011) are also shown by solid black lines. The dashed black line (FZ) indicates the fracture zone identified by Reznikov et al. (2005). Dredge sites are indicated by triangles (DR1, DR2, DR3, and DBA; Ben-Avraham et al., 1995; Mougenot et al., 1991). The diamond (DSDP249) represents Deep Sea Drilling Project site 249. NNV, Northern Natal Valley; SNV,

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