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The Ross Sea rift system, Antarctica: structure, evolution and analogues

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Abstract

Based on the combination of available geological and geophysical information it is concluded that the Ross Sea depression is a major continental rift system comparable to other important rift provinces in size, morphology, structure and magmatism. It shows a two-phase evolution: a first phase related to the Australia–Antarctica separation at around 95 Ma was amagmatic and characterized by diffuse crustal attenuation (Basin & Range-type crustal thinning). A second phase commenced at about 50 Ma and caused more focussed basin subsidence, shoulder uplift and rift-type magmatism from 25 Ma to the present. This second phase resembles the development of the East African rift system.

Introduction

Similarities of Mount Erebus kenytes with East African volcanics and block faulting of the 'horst of the Transantarctic Mountains' were noted by the geologists of Scott's expeditions. Extensional tectonism was postulated later for the Ross depression from observations in the following different fields:

(i) Bathymetric and seismic surveys carried out in the Ross Sea (Hayes *et al.*, 1975; Davey, Hinz & Schroeder, 1983; Cooper & Davey, 1987) indicated the existence of sedimentary basins and thin crust in the Ross Sea area
(ii) Gravity and aeromagnetic surveys in coastal regions (McGinnis *et al.*, 1983; Bosum *et al.*, 1989) further established the elongated basin structure and a shallow Moho
(iii) Volcanism in the Transantarctic Mountains and Marie Byrd Land (Kyle & Cole, 1974; LeMasurier & Rex, 1982; Wörner *et al.*, 1989) is of typical 'rift' character
(iv) The uplift history of the Transantarctic Mountains was derived from fission-track data by Fitzgerald *et al.* (1987)
(v) Stratigraphic information from drillholes in the Ross Sea area (Hayes *et al.*, 1975; Barrett, 1986) indicates the presence of thick Cenozoic sediments in the basin.

In this paper, we treat the Ross Sea depression and the Transantarctic Mountains as a tectonic entity and propose that both are parts of one large crustal feature, the Ross Sea rift system (RSR). We compare it to its closest analogues: the Basin & Range Province (B&R) and the East African rift system (EAR).

The Ross Sea rift system

Setting and structure

Continental break-up between Australia and Antarctica commenced at about 95 ± 5 Ma (Veevers, 1986). Whereas the larger western part of the two continents split fairly regularly, the break-up was more complicated in the east, where several microplates developed: Lord Howe Rise, Tasmania and South Tasman Rise, New Zealand and Chatham Plateau, and Marie Byrd Land (Grindley & Davey, 1982).

The Ross Sea depression (RSD) is located in this area of former microplates. It is about 1000 km wide and extends inland from the continental margin as a curved depression for more than 3000 km, between the Transantarctic Mountains (TAM) and Marie Byrd Land (MBL) (Fig. 1). The Transantarctic Mountains form a fault-scarp range up to 4000 m high parallel to the western border of the depression and display features of an uplifted and tilted rift shoulder. The lack of a comparable scarp in Marie Byrd Land indicates asymmetry of the depression. Along-strike it comprises three segments: (a) the sedimentary basins of the Ross Sea proper; (b) the morphological low under the Ross Ice Shelf; and (c) the Byrd Subglacial Basin.

In the Ross Sea, the depression is divided into three subparallel sedimentary basins (Fig. 2). The Eastern basin and the Central trough are 5–6 k m deep (Davey *et al.*, 1983), whereas the Victoria Land basin (VLB) immediately in front of the Transantarctic Mountains is 10–14 km deep (Cooper & Davey, 1987). The latter terminates in the north against an offshore basement block (Coulman high), but possibly has a northward

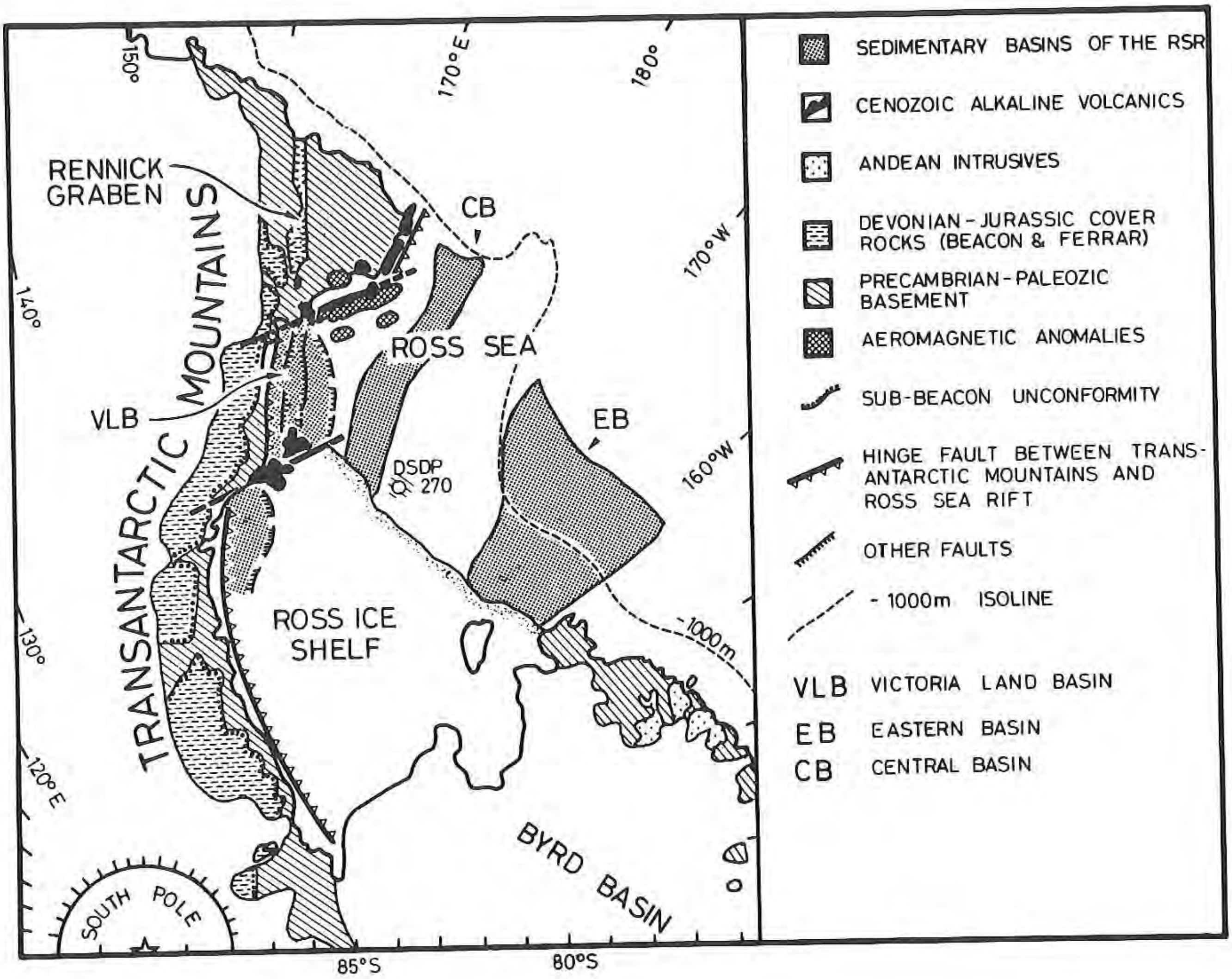

Fig. 2. The Ross Sea rift system RSR based on geophysical and geological evidence. See text for discussion.

to date at present. It may be related to back-arc tectonism associated with the Andean arc (Fig. 2) as well as to the continental break-up between Antarctica and Australia at around 90 Ma (Veevers, 1986);

(2) The second rift phase is characterized by uplift and tilting of the TAM from 50 Ma to the present (Fitzgerald *et al.*, 1987), asymmetric subsidence of the RSR with the particularly deep VLB, and the onset of alkali magmatism at about 25 Ma. Tectonic and magmatic activity are now focussed along the main fault between TAM and VLB where the maximum vertical displacement reaches 15–20 km.

Related continental rifts

Continental extensional provinces share many common features (Bosworth, Lambiase & Keisler, 1986). However, every single system has its own characteristic evolution and tectonic setting. The best analogues of the Ross Sea rift system appear to be the East African rift (EAR), with its deep and very pronounced rift valleys, and the Basin & Range province (B&R) in the western USA, with its contrasting tectonic style of tilted blocks and asymmetrical basins.

Both the EAR and the B&R rift provinces are of similar size to the RSR (Fig. 3). However, the former are related to broad regional *uplift* on the order of thousands of metres (Baker & Wohlenberg, 1971; Eaton *et al.*, 1978) whereas the RSR has *subsided* on a similar scale. The regional separation into three individual subparallel basins resembles the EAR whereas the overall topography, with a wide central depression and two uplifted shoulders (although at different elevations), relates to the B&R province.

Sengör & Burke (1978) defined *active* rifts as characterized by a rising mantle plume which causes the initial updoming through lithospheric heating, magmatic intrusion and volatile metasomatism (Bailey, 1974; McKenzie, 1978). Large volumes of magma are produced prior to the main phase of lithospheric extension. In a *passive* rift, thinning and asthenospheric uprise predates magmatism or may involve no magmatism at all.

The EAR represents an example of an active rift. As Bailey (1974) pointed out the determining factor for its long lifetime, extreme alkalinity of magmas and unsuccessful continental separation, may be that the African plate has remained stationary relative to the asthenosphere. In contrast, the B&R is considered a passive rift. The RSR is also a passive rift in the

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