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Seafloor Magnetic Patterns

Seafloor spreading and magnetization in the Southern Ocean

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An extensive network of magnetic survey lines now extends over the Southern Ocean (Fig. 1). Measurements of total field have been made by ship, aircraft, and at high altitude from satellites. However, because of the vastness of the region, coverage is mostly at reconnaissance level, with some areas such as the Antarctic continental margin very sparsely mapped. Exploration by oceanographic institute research vessels equipped with towed magnetometers began in the early 1960s. The first surveys providing systematic coverage were made between 1968 and 1972 by the *Eltanin*, generally along north-south oriented lines spaced at 5°C of longitude. From these data, Weissel and Hayes (1972) were able to map the overall magnetic anomaly lineation pattern of the Southern Ocean seafloor, develop a tectonic framework for the region, and outline the development of the Australia–Antarctica separation. They placed the onset of seafloor spreading at Magnetic Anomaly (MA) 22. Cande and Mutter (1982) have since produced a revised interpretation, putting the initiation of spreading at about MA 34 (85 Ma) with much slower spreading rates prior to MA 18 time. Veevers (1986), in an analysis of all available data, concurs with Cande and Mutter's interpretation of an early phase of slow spreading, but has refined the time of initiation to 96 Ma.

The Bureau of Mineral Resources (BMR) has been active in the acquisition of magnetic and other geophysical data over the Southern Ocean. Between 1971 and 1973, the southern continental margin of Australia was surveyed at a line spacing of about 50 km. More recently, digital data acquisition systems were installed aboard the Danish polar supply ship *Nella Dan* for survey work during the ANARE summer programs of 1979–82. About 110 000 km of magnetic data were collected during Southern Ocean transits between eastern Australia and the Australian Antarctic bases of Mawson, Davis and Casey, and during voyages out to sub-Antarctic Macquarie Island (Stagg *et al.* 1983a). More extended coverage was achieved in the region of the southern Kerguelen Plateau and offshore from the Antarctic stations while participating in multidisciplinary scientific programs, and during a dedicated geophysical survey of the Prydz Bay area (Stagg *et al.* 1983b). Earlier in 1980 BMR used the *Cape Pillar* to conduct a significant magnetic/bathymetric survey of waters around Heard Island and along the Heard–Western Australia transits (Tilbury 1981). BMR activity in the Southern Ocean will continue in 1985 with a major geophysical/geological investigation of the Kerguelen Plateau. This cruise, to begin in March, will be aboard the *Rig Seismic*,

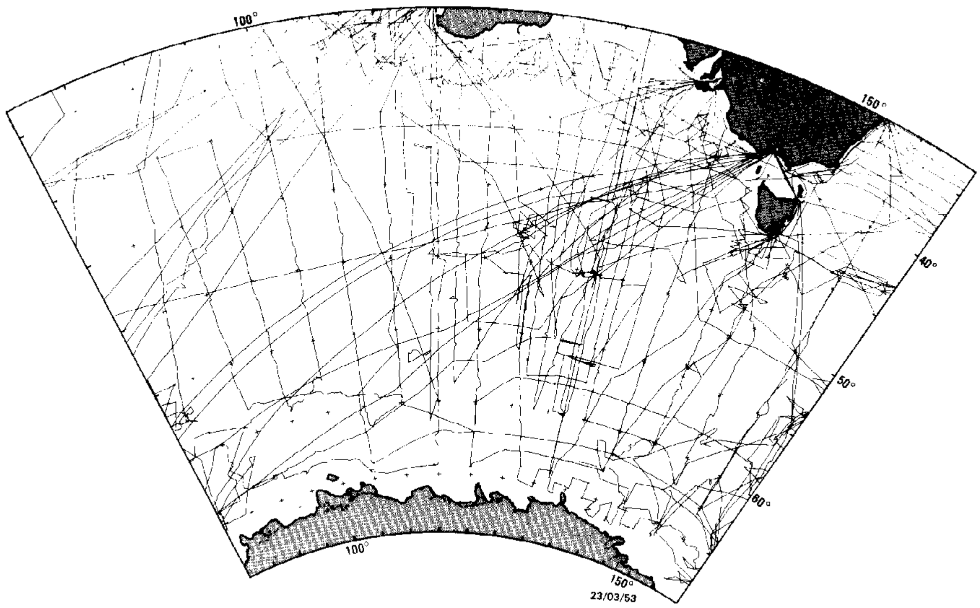

Fig 1 Southern Ocean research vessel tracks. Magnetic data are available over almost the entire network. BMR continental margin survey lines are omitted for clarity.

a new 72 m research ship. It is hoped to acquire a better understanding of the origin of the plateau and its basic structure and stratigraphy. Is it underlain by oceanic or continental crust? What crustal differences are there between the northern and southern parts of the plateau? Is there any further evidence for a ridge crest jump at MA 24 time? How does the Kerguelen Plateau fit into the India/Australia – Antarctica reconstructions? The magnetic data may help to answer some of these questions.

Project Investigator-1, a low-level aeromagnetic survey flown over the Australian–Antarctic Discordance (AAD) of the SE Indian Ridge, has added considerably to knowledge of the seafloor tectonics of this anomalous zone, characterized by relatively deep and disrupted seafloor topography (Figs 2, 3). The survey was a co-operative project between the United State's Naval Research Laboratory (NRL) and the Australian Defence Science and Technology Organization (DSTO). Two Orion aircraft were used to cover a 1000 km section of the ridge with north–south flight lines spaced about 20 km apart. Coverage extended north to MA 7 (25.5 Ma) and south to MA 6 (19.5 Ma). Vogt *et al.* (1983) have interpreted the crenulated geometry of the AAD as having developed from a combination of continuous asymmetric spreading and propagating rifts which caused sudden changes in transform offset. The propagators are postulated as having been driven by asthenospheric flow toward the AAD from adjacent parts of the spreading axis to the east and west. The observed change in transform trend between 7 and 4 Ma, indicating adjustment to a new plate rotational pole, may have initiated the propagating rifts. A series of six colour charts depicting the main results of Project Investigator-1 have been prepared, and will be published by BMR in the near future. The charts illustrate revised plate tectonics of the Southern Ocean region, interpreted magnetic lineations of the AAD, seafloor ages and structures, magnetic profiles, magnetic anomaly contours and bathymetry.

In 1974 the BMR derived an Australian Geomagnetic Reference Field (AGRF) for the Australian region which was intended primarily for reduction of marine magnetic data to residual (anomaly) values. This AGRF was adopted in preference to the existing 1965 IGRF because of obvious discrepancies between predicted and observed secular variation patterns, and the problems this was creating, particularly in margin magnetic data from different surveys. Examination of Southern Ocean magnetic data acquired during 1978–82 indicates major differences between the observed regional field and that calculated by the AGRF formula. The discrepancy is particularly severe in the region between Kerguelen Plateau and the AAD, where the AGRF is up to 1000 nT less than the observed regional total field. These differences are caused by extrapolation of the secular variation beyond the time interval for which the AGRF is applicable. For these more recent surveys, later models of the global field and its secular variation should be used for the reduction of marine magnetic data. For example, PGRF 1975–80 and IGRF 1980 models (Peddie 1982), which are

Fig 2 Revised tectonic map of the AAD, Southern Ocean (Vogt *et al.* 1983). The region bounded by the solid line was surveyed during Project Investigator-1.

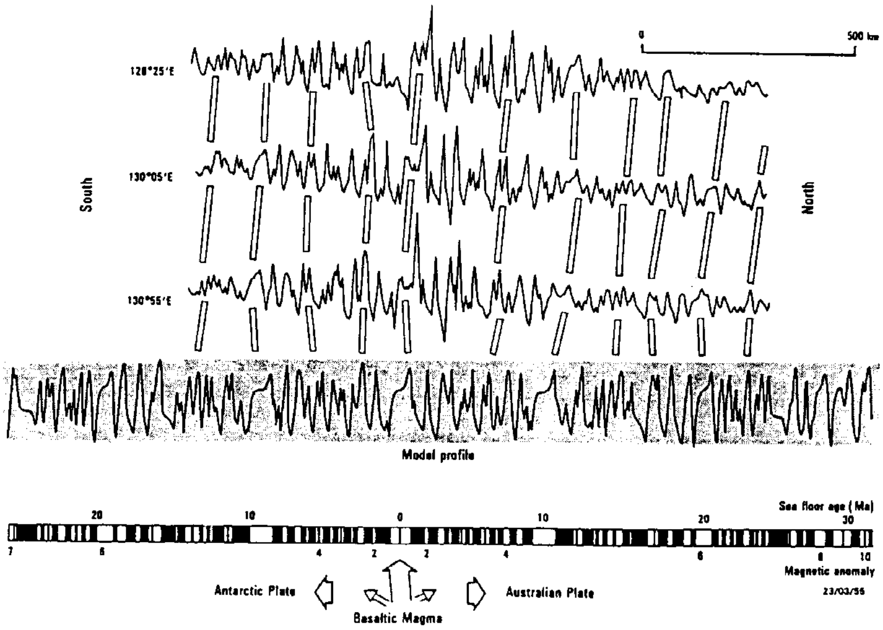

Fig 3 Aeromagnetic profiles across the AAD, showing strong correlation with the model based on the geomagnetic reversal timescale.

based partly on MAGSAT data, provide very good fits to the observed total-field marine data. Furthermore, definitive models of the global field (DGRF) have been defined for 1965, 1970 and 1975, based on retrospective analysis of a complete data set (Peddie 1982). These require evaluation of their suitability to replace the initial AGRF model for the reduction of early survey data.

The open ocean areas have always presented a problem in studying and modelling the global secular variation because of the lack of land-based magnetic stations and observatories. Magnetic data have been collected in the Southern Ocean for more than two decades over a network of criss-crossing tracks. By comparing magnetic values recorded at track intersections, useful estimates of secular variation over the region can be obtained. Statistical analysis would be required to take into account limitations imposed by navigational inaccuracies and geomagnetic diurnal/storm variations for which precise corrections cannot be made.

The *Rig Seismic* is equipped with a magnetic gradiometer, rather than the single sensor that has commonly been used for oceanographic research in the past. This equipment means that much of the short-term, time-varying component in recordings can be separated from anomalies of geological origin. This capability is a significant improvement in survey areas such as the Southern Ocean where nearby base stations cannot be set up. Removal of temporal variations, or direct use of magnetic gradients enhances the usefulness of automatic computer interpretational techniques such as Werner deconvolution. Furthermore, the isolated temporal data are available for the study of external fields, and induction effects over oceanic regions.

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