

# Tectonic implications of paleomagnetic results from Marie Byrd Land, West Antarctica

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Many questions have not been satisfactorily answered regarding the geologic history and tectonic motions of the crustal blocks that make up West Antarctica. Most previous work in West Antarctica was concentrated in the Antarctic Peninsula, Thurston Island, and Ellsworth-Whitmore Mountains blocks (figure 1). The Marie Byrd Land crustal block is a key element in several important problems but its history was the most poorly known. This study is a reassessment of the motions of the west antarctic crustal blocks resulting from the Jurassic and Cretaceous breakup of Gondwanaland as implied by paleomagnetic results from Marie Byrd Land.

To address the role of Marie Byrd Land within the framework of West Antarctica, a cooperative field program was launched by the U.S. Antarctic Program, the British Antarctic Survey, and the New Zealand Antarctic Program. The South Pacific Rim International Tectonics Expedition (SPRITE) visited Marie Byrd Land during three consecutive field seasons in the 1990-1991, 1991-1992, and 1992-1993 austral summers.

In addition to descriptions of field relations and sampling for geochemical and radiometric study (Weaver et al. 1994), over 1,000 oriented cores and hand samples were collected at 174 sites for paleomagnetic analysis. The largest part of the

collection comprises rocks of Cretaceous age. The results from these samples allow some important questions to be addressed.

It has long been suggested that the low-lying, apparently continental crust of the Ross Sea, Ross embayment, and Byrd Subglacial Basin has been the site of major extension between East and West Antarctica. In one view (Schmidt and Rowley 1986), it was presumed that this had largely occurred in the Jurassic at the time of east-west Gondwanaland rifting and separation and the emplacement of the Ferrar Dolerite and Kirkpatrick Basalt throughout the Transantarctic Mountains. It has become apparent from evidence gleaned from seismic studies of the Ross Sea crust (Cooper, Davey, and Hinz 1991, pp. 285-291), fission track dating of uplift in the Transantarctic Mountains (Stump and Fitzgerald 1992), and airborne geophysics over the Byrd Subglacial Basin (Blankenship et al. 1993) that the area has been tectonically active in the Cretaceous and Cenozoic up through the present time. Paleomagnetic results from mid-Cretaceous, approximately 100-million-year-old rocks in Marie Byrd Land (DiVenere et al. 1993; DiVenere, Kent, and Dalziel 1994) are consistent with similar age results from Thurston Island and the Antarctic Peninsula. The mid-Cretaceous paleomagnetic poles from

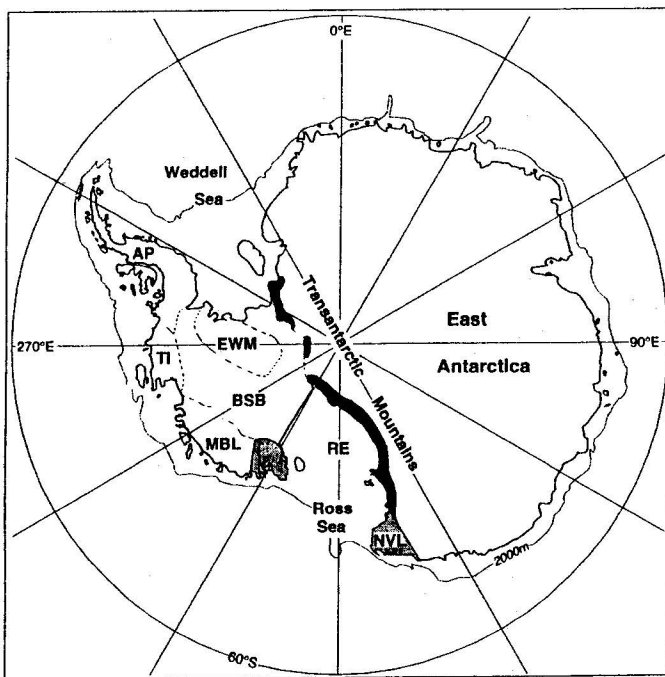


Figure 1. Map of Antarctica showing the crustal blocks of West Antarctica: MBL, Marie Byrd Land; TI, Thurston Island; AP, Antarctic Peninsula; and EWM, Ellsworth-Whitmore Mountains. Also shown are: RE, Ross embayment; BSB, Byrd Subglacial Basin. (NVL denotes north-eastern Victoria Land. m denotes meter.)

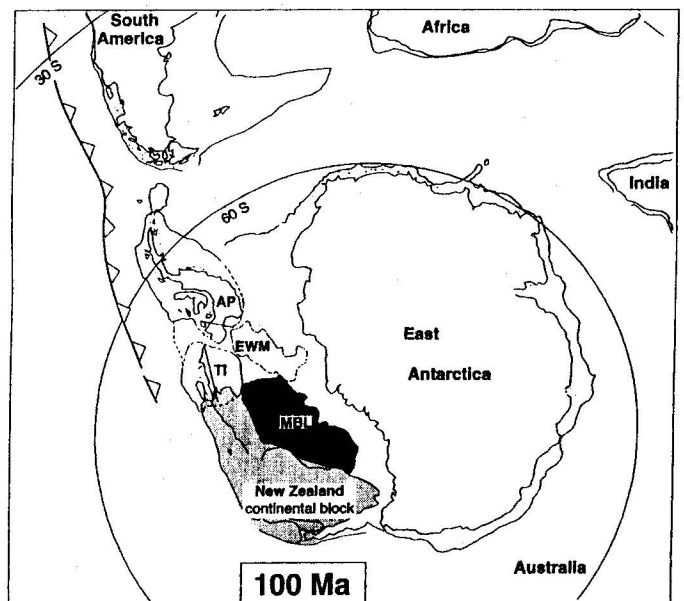


Figure 2. Reconstruction from approximately 100 million years ago (100 Ma) showing approximately 50 percent closure (Marie Byrd Land to East Antarctica) of the Ross Sea to satisfy the paleomagnetic data. (MBL denotes Marie Byrd Land. EWM denotes Ellsworth-Whitmore Mountains. TI denotes Thurston Island. AP denotes Antarctic Peninsula.)

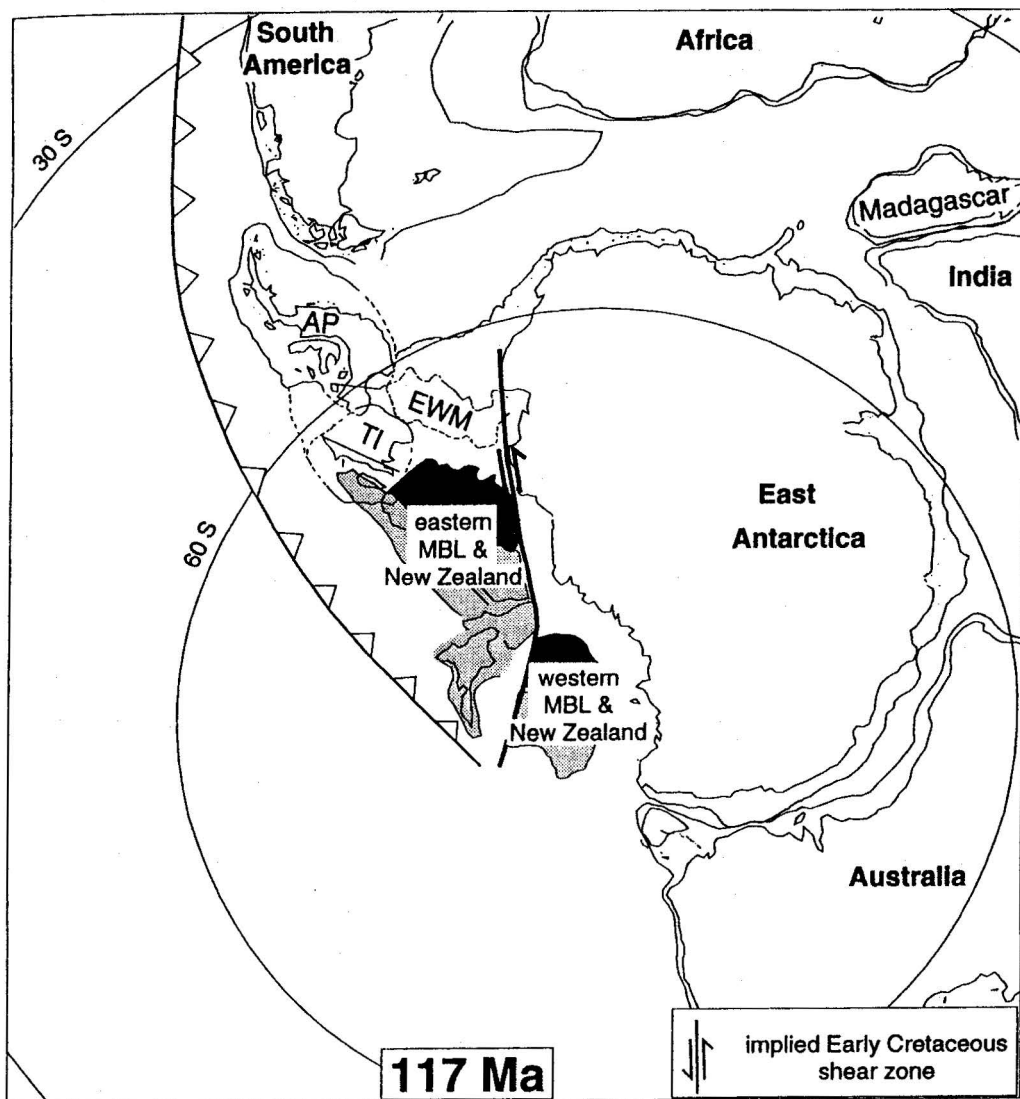


Figure 3. Reconstruction from approximately 117 million years ago (117 Ma) before implied motions of "Weddellia" away from the Weddell Sea and consolidation of the eastern and western portions of Marie Byrd Land and New Zealand. (MBL denotes Marie Byrd Land. EWM denotes Ellsworth-Whitmore Mountains. TI denotes Thurston Island. AP denotes Antarctic Peninsula.)

Marie Byrd Land, Thurston Island, and Antarctic Peninsula, however, are all significantly offset to the east from the east antarctic apparent polar wander path. We therefore conclude that paleomagnetically resolvable displacement of the Pacific-bordering blocks of West Antarctica with respect to East Antarctica has taken place since about 100 million years ago as a result of extension in the Ross Sea, Ross embayment, and Byrd Subglacial Basin (figure 2).

Interpretations of geophysical data in the Weddell Sea (LaBrecque and Barker 1981) and paleomagnetic data from the Antarctic Peninsula, Thurston Island, and the Ellsworth-Whitmore Mountains blocks have suggested that these west antarctic blocks (termed "Weddellia") have been displaced with respect to East Antarctica as a result of the opening of the Weddell Sea (Grunow, Kent, and Dalziel 1991). The interpretations of the geophysical and paleomagnetic data, however, are in conflict regarding the timing of the displacements. Early Cretaceous paleomagnetic data from approximately 117-mil-

lion-year-old rocks from eastern Marie Byrd Land (east of about 141°W longitude) and a reassessment of the earliest Jurassic pole from New Zealand imply that eastern Marie Byrd Land with the Eastern Province of New Zealand were part of Weddellia from at least the Early Jurassic through the mid-Cretaceous (figure 3) (DiVenere, Kent, and Dalziel 1995). The Early Cretaceous pole from eastern Marie Byrd Land, in conjunction with the Early Cretaceous pole from Thurston Island, places the constraint that the Ellsworth-Whitmore Mountains, Thurston Island, east Marie Byrd Land, and the Eastern Province of New Zealand did not attain their mid-Cretaceous positions (and consolidation with the western provinces of Marie Byrd Land and New Zealand) until after 117 million years ago. This motion is later than the estimated age of the initiation of spreading in the Weddell Sea. The Weddellia block motions that occurred less than 117 million years ago may therefore be the result of plate reorganization during the Cretaceous Quiet interval rather than due to the initial opening of the Weddell Sea.

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## Magnetotelluric profiling in central West Antarctica

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Earth structure and processes beneath central West Antarctica are thoroughly masked by the 2-kilometer (km) thick ice sheet of the Byrd subglacial basin and so must be inferred exclusively by geophysical means. To probe electrical resistivity structure below central West Antarctica, we collected 12 high-quality magnetotelluric soundings there (82°36'S 118°14'W, approximate) during the 1994–1995 austral summer field season (figure 1). Deep field deployment occurred from 6 December 1994 through 3 January 1995. Ten of the sites, acquired at 6-km intervals, constitute a profile off-

set 1 km from a seismic reflection line collected contemporaneously by other workers. One major purpose of our project was to demonstrate if magnetotelluric measurements are even feasible over the thick interior ice sheet.

The second purpose of our efforts was to ascertain if deep resistivity here is consistent with the hypothesis that central West Antarctica constitutes an active rift environment (LeMasurier and Rex 1991, pp. 249–284; Blankenship et al. 1993). One of the best-known mechanisms that determines deep resistivity in thermal regimes is the existence

of fluids, including melts (Wannamaker and Hohmann 1991). If interconnected, fluids can reduce deep resistivities dramatically and are detectable in quantities far smaller than can be detected using other techniques. Mappable resistivity structure also is produced, however, by juxtaposition of contrasting lithologies, whether in thermal regimes or not. In the crust, porous or graphite/sulfide-bearing sedimentary rocks are observable beneath crystalline or carbonate rocks in overthrust, suture, or basin environments that may not yield good seismic images.

For our magnetotelluric instrument, the very high impedance of the firm required custom construction of optically isolated, ultra-high-input impedance preamps (about 1 gigohm) to be placed at each contacting electrode. Provision was made in the apparatus for *in situ* calibration of the source

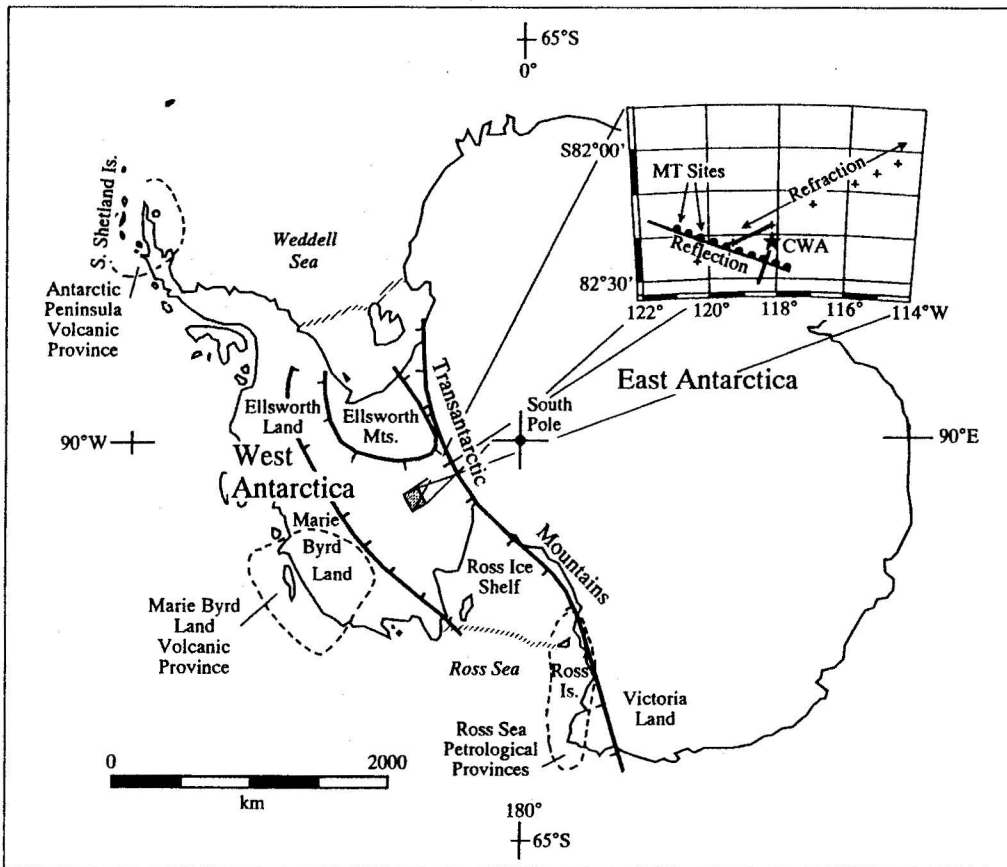


Figure 1. Field site map for magnetotelluric and other geophysical experiments at central West Antarctica. Modified from LeMasurier and Rex (1991). (CWA denotes central West Antarctica. MT denotes magnetotelluric.)