Crustal structure of the central basin, Ross Sea, Antarctica

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During the German Antarctic North Victoria Land Expedition (GANOVEX) V, which was jointly funded by the German Bundesanstalt für Geowissenschaften und Rohstoffe, the U.S. Geological Survey, and the National Science Foundation, ocean bottom seismometers (OBS) were deployed in the central Ross Sea to record shots from a tuned airgun array to image the crustal structure of the central basin. Existing near-vertical seismic reflection data had revealed a structural basin coincident with a 70-milligal (mGal) positive gravity anomaly (Hinz and Block 1984). The experiment was designed to discriminate between several possible explanations for this observation. The simplest model is that the gravity high is due to thinned crust and an elevated Moho beneath the basin (Davey and Cooper 1987). A second possibility is that the rift is underlain by a high-density rift pillow (Mooney et al. 1983) caused by magmatic underplating and/or intrusion during rifting. The third possibility, suggested by recent results from the midcontinent rift of North America (Tréhu et al. 1991), is that the basin is filled by high-density volcanic material rather than by low-density sediments and that the gravity high results from basin fill. Discriminating among these models is important for understanding the rifting process but is impossible with gravity and multichannel reflection data alone.

Figure 1 shows the location of large-aperture seismic profiles shot during GANOVEX V overlain on a simplified map of the regional gravity anomalies. In this paper, we present results from lines 2, 3, and 4. Data along line 6 are very noisy and are not included but are consistent with a structure similar to that determined for line 3. The data processing and analysis are discussed in detail by Tréhu et al. (1993).

The major sedimentary basins of the Ross Sea, identified on the basis of multichannel seismic and potential field data,

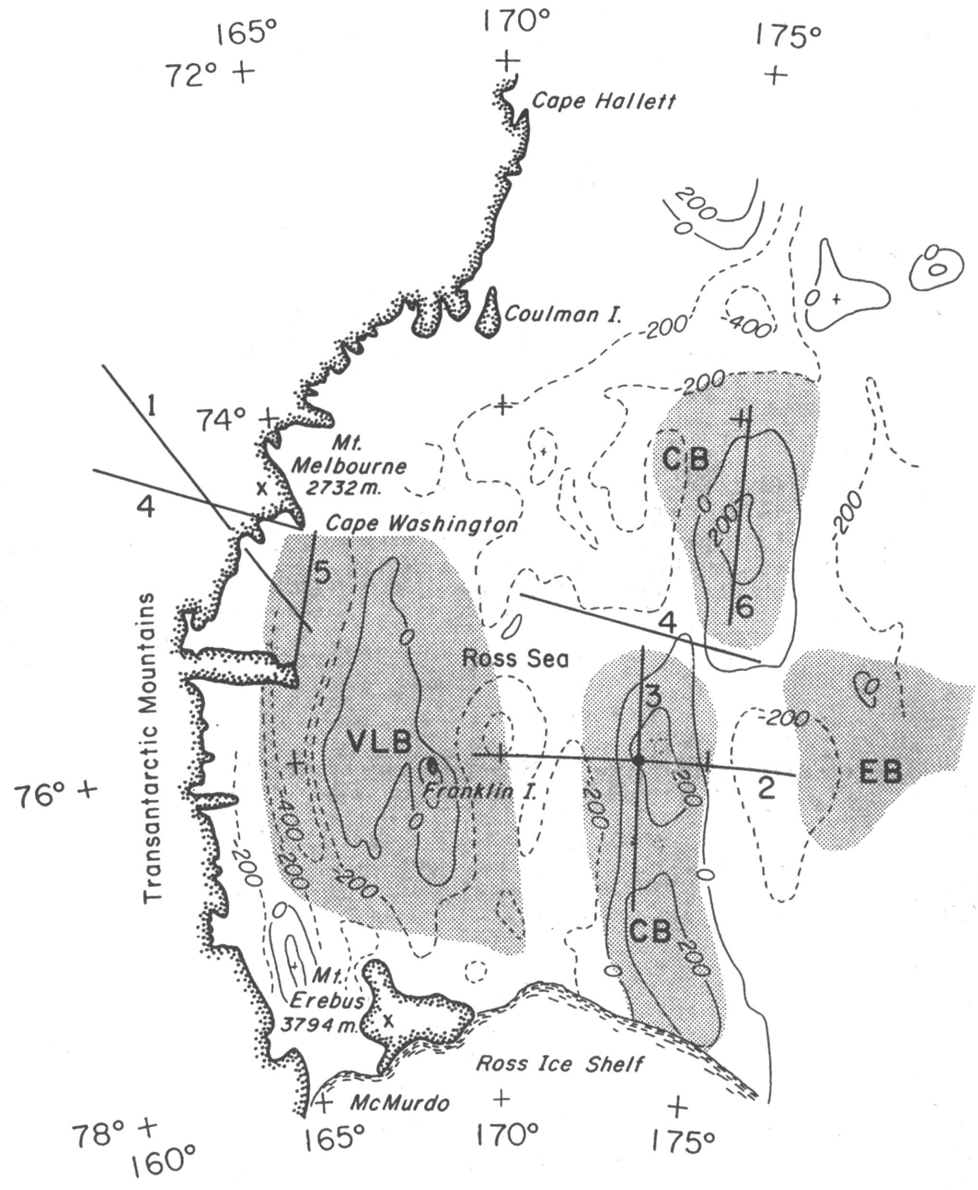

Figure 1. Schematic map showing the contours of gravity anomalies [in units of micronewtons per kilogram (μN/kg); from Davies and Cooper 1987], major sedimentary basins, and locations of large-aperture seismic profiles shot in the Ross Sea during GANOVEX V. (VLB denotes Victoria Land basin; CB denotes central basin; EB denotes eastern basin.)

are also shown in figure 1. The central basin is a long [approximately 50-kilometer (km)], narrow north-south basin that was probably formed during a late Mesozoic to early Tertiary rifting episode and may represent a failed arm of the rift that resulted in separation of Australia from Antarctica (Hinz and Block 1984; Cooper, Davey, and Hinz 1991). This region is part of a broad rift zone, known as the west antarctic rift system, that is currently active along its margins (LeMasurier 1990; Behrendt et al. 1991).

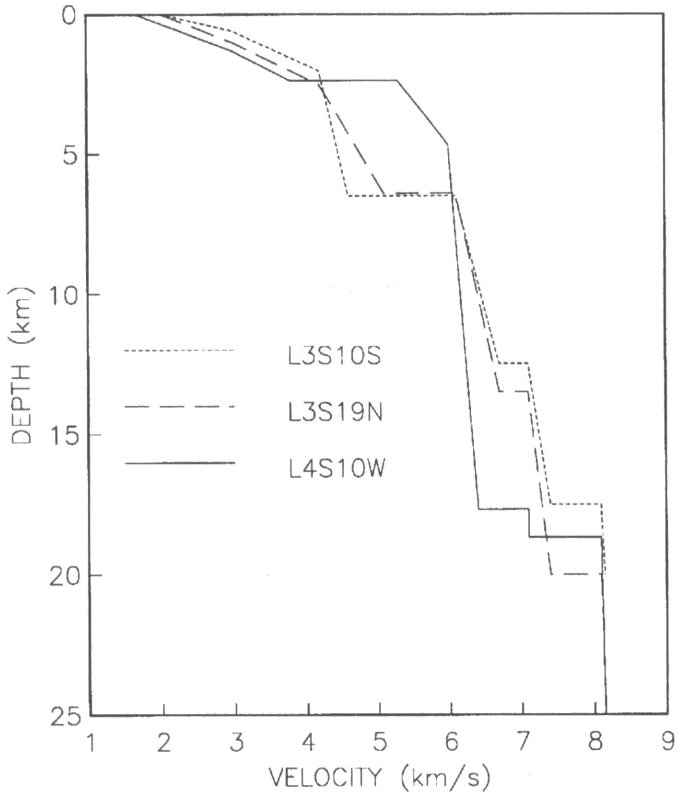

Figure 2. Velocity-vs.-depth profiles derived from data recorded along lines 3 and 4. These models do not include the water column because data were corrected for the effect of topography before modeling. LxSyN and LxSyS indicate the model for line x, recorded at station y, derived from shots to the north and south of the station, respectively.

Velocity-depth functions derived from the data recorded on line 3 and are shown in figure 2. A range of velocities, shown for line 3, qualitatively brackets the range of possible velocities. The velocity in the upper 2.5 km below the seafloor [approximately 1.35 seconds (s), two-way travel time, exclusive of water] increases sharply from about 2 kilometers per second (km s^{-1}) to 4 km s^{-1} along both profiles; this corresponds to sediments deposited since a regional unconformity of inferred Eocene (Cooper et al. 1991) or Oligocene (Hinz et al. 1990) age. Between 2.5 and 7 km below the seafloor on line 3, the velocity gradient decreases, and velocity is about 4.0–4.25 km s^{-1}, which is indicative of sedimentary basin fill. The data, thus, disallow the possibility that the gravity high is caused by layered high velocity/density volcanic rocks within the basin. Velocities in this depth range are much higher on line 4, which is indicative of crystalline rock. A high velocity (approximately 7.1 km s^{-1}) lower crustal layer extends from about 13 to 20 km depth on line 3 and is, at most, 1.5 km thick on line 4; total crustal thickness is similar on both profiles. The presence of this layer, which is necessary to model the data along line 3, indicates that simple crustal thinning also is not a viable explanation for the gravity anomaly.

Figure 3 shows a velocity model along line 2, which crosses the central rift basin. An initial model was constructed by using the velocities obtained for lines 3 and 4 to represent the crustal structure within the basin and beneath the flanks, respectively. The sediment/basement interface was determined from the coincident seismic reflection data using velocities determined from lines 3 and 4. Refracted arrivals observed on OBSs constrain the lateral variations in the velocity of the upper and mid-crust. Wide-angle reflections and gravity modeling constrain the geometry of the high-velocity lower crustal body. We interpret this body to represent magmatic material derived from the mantle that was underplated to the crust during the rifting process, as has been inferred for similar bodies observed beneath volcanic passive margin. The crustal velocity difference between the east and west flanks of the rift is well constrained by the data and suggests that concentrated rifting may have developed along a preexisting crustal suture. Alternatively, it may indicate the presence of high-velocity crustal intrusions east of the central basin.

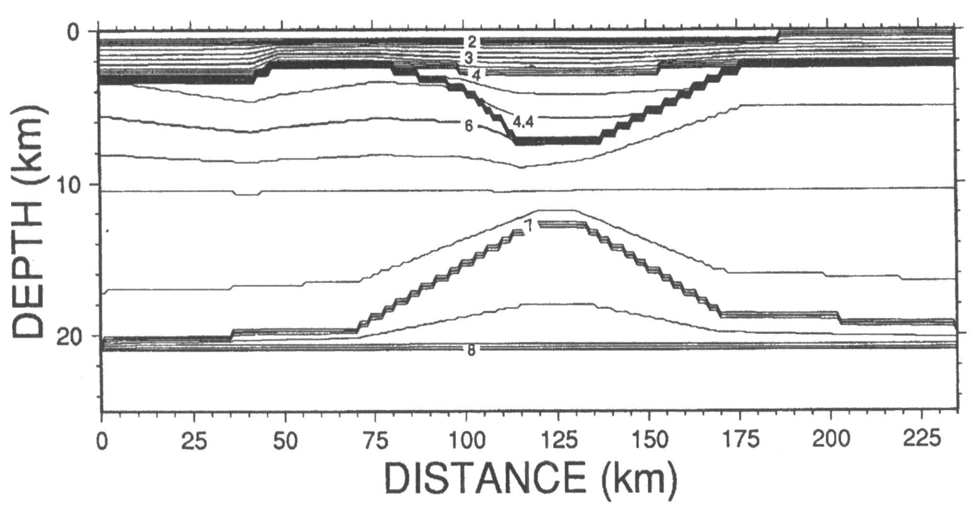

Figure 3. Velocity model of the central basin from modeling of seismic and gravity data. Contours are labeled in units of km s^{-1} and are plotted at 0.2 km s^{-1} intervals.

In summary, this study provides us with a detailed image of the lower crust beneath an extensional basin located within a large-scale continental rift zone. Assuming that the original crustal thickness beneath the Ross Sea was 30–40 km, the crust beneath the flanks of the central basin was uniformly stretched by a factor of 1.5–2.0. The absence of a thick, high-velocity, lower crustal layer beneath the flanks of the central basin suggests that significant extension occurred with only a small amount of melt generation. Beneath the central basin, the pre-rift crust was thinned by a factor of 5–8, and about 8 km of melt was added to the crust (including up to 1 km of extrusive material; Tréhu et al. 1993). This volume of melt is consistent with the mantle decompression melting model of McKenzie and Bickle (1988) for an upper mantle potential temperture anomaly of only about 50–75°C relative to normal oceanic upper mantle. Although the data do not place any firm constraints on the relative timing of extensional episodes, we assume that extension was broadly distributed at first and later localized beneath one or more rift basins, the locations of which may have been controlled by preexisting crustal structure. The balance between crustal thinning, volume of melt added, and postrift subsidence and sedimentation was such that the final crustal thickness is approximately constant.

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Late Glacial and Holocene history of the western Ross Sea: An initial survey of available cores

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As part of the west antarctic ice sheet initiative (Bindschadler 1991), investigators from Rice University, Hamilton College, and the University of Colorado at Boulder teamed up to develop an integrated approach to describing and dating the retreat of the west antarctic ice sheet across the Ross Sea during the last glacial/deglacial cycle. A knowledge of the glacial history and the paleoceanography of Antarctica is vital to resolving the large uncertainties about the global water budget during deglaciation (Tushingham and Peltier 1991; Andrews 1992) and is also important for assessing the potential global risk of rapid glacial ice recession and collapse. Productivity changes, as recorded by phytoplankton in the sediment, may provide information on global changes in Holocene deep-water circulation.

The research has two main phases: the first phase (1992–1994) involves a study of all existing cores, which are