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EAST–WEST ANTARCTIC BOUNDARY IN McMURDO SOUND

L.D. McGINNIS, R.H. BOWEN, J.M. ERICKSON, B.J. ALLRED and J.L. KREAMER

Department of Geology, Louisiana State University, Baton Rouge LA 70803-4101 (U.S.A.)

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ABSTRACT

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Common-depth-point seismic reflection profiling indicates that the crust beneath western McMurdo Sound is capped by a thin veneer of layered reflectors. The absence of deep, layered reflectors suggests the crust beneath the coast is made up primarily of intrusions which we associate with plutons generated during the Ross Orogeny. The layered reflectors dip and thicken to the east, away from the coast, where they are found at two-way reflection times of 7 s, corresponding to depths of 14–16 km. Reflection data support earlier refraction, gravity, and magnetic interpretations that indicate fundamental differences in the crust beneath McMurdo Sound and the Transantarctic Mountains. Differences may be due to early Paleozoic subduction of the Ross Embayment crust beneath the Transantarctic Mountains during the Ross Orogeny. Orogeny has produced an over-thickened crust beneath the Ross orogenic belt which was followed by several periods of reactivation including the Jurassic thermal event and the uplift of the present-day Transantarctic Mountains in early Tertiary time. The presence of the McMurdo Volcanics and preliminary interpretations of reflection data suggest that the Sound is now being thinned by processes of extension.

INTRODUCTION

Since the early 1970's a series of magnetic, gravity, and seismic refraction studies extending from Ross Island to the dry valleys have been used to define the regional characteristics of the crust underlying McMurdo Sound (McGinnis et al., 1983). The studies were undertaken to permit the construction of a crustal model which could then be used to define the tectonic history of the margin separating East from West Antarctica. Although potential field methods have been useful in providing some constraints on the geology of the crust, they provide little information on horizontal layering or vertical boundaries. For example, magnetic data (Pederson et al., 1981) have been interpreted to indicate the absence of rocks of high magnetic susceptibility beneath western McMurdo Sound, thus eliminating Ferrar dolerites from considera-

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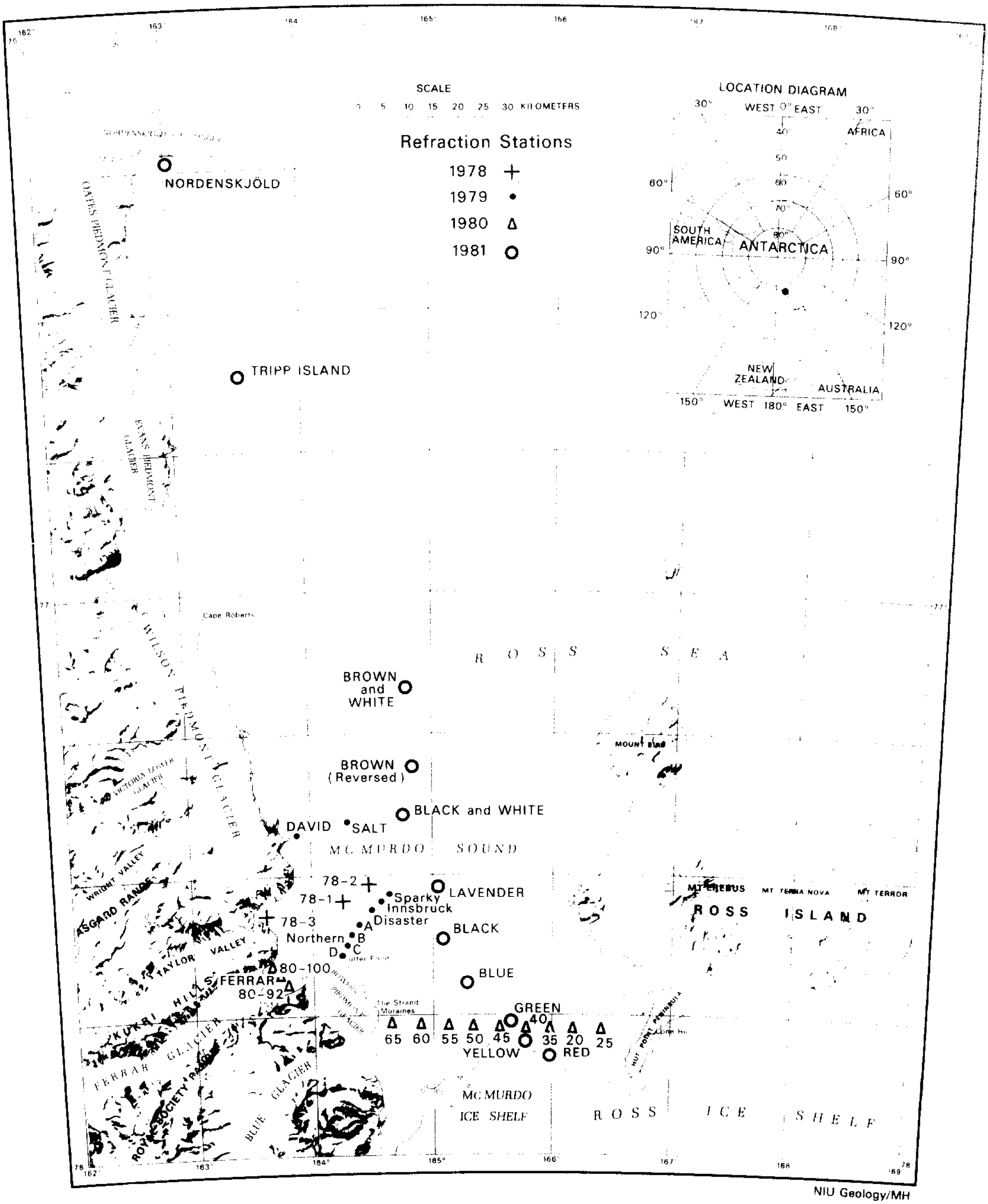

Fig. 1. Location of refraction recording stations in the McMurdo Sound region. The reflection profile shown in Fig. 5 was shot along the row of triangles between stations 45 and 50 at approximately 77°45′ south. Depth to basement was determined at all but the large open circles.

tion. Because of the inferred low susceptibilities, it was assumed that the lack of magnetic relief over the Sound could neither prove or disprove large scale, high-angle faulting between the Transantarctic Mountains and the Sound. In addition, gravity measurements at 1-km intervals crossing the Sound, are highly useful in describing the configuration of the Mohorovičić Discontinuity once complementary data are available from deep seismic refraction studies, but the gravity field by itself cannot be used to derive unique solutions with regard to layering in crustal or supracrustal rocks. In order to develop a unique record of the tectonic history along the proposed margin between East and West Antarctica, it was necessary to conduct an array of seismic measurements designed to determine the presence of faulting, layering, and folding. The study reported here offers a further refinement of deep refraction interpretations and presents for the first time reflection data from a processed segment of the McMurdo Sound reflection profile. The locations of the various data are shown in Fig. 1.

A summary of studies through the 1981–1982 field season has been reported by McGinnis et al. (1983). Since that time a 200 km-long reversed refraction profile paralleling the coast has been interpreted and a simple stack has been completed for 8 km of a 24 channel, Common Depth Point (CDP) reflection profile crossing McMurdo Sound. A total of 100 km of 24 channel seismic transects in McMurdo Sound has now been completed and most of the data are now being processed.

REFRACTION SEISMIC PROFILES

Refraction data were obtained with a Dresser SIE RS-4, 12 channel seismograph with a 5–125 H frequency response and 4 and 8 Hz geophones. An E–W, forward and reversed time–distance plot is shown in Fig. 2 with maximum shot to detector distances being approximately 40 km. These data were used to define the velocity distribution in the upper crust. A reversed, N–S profile, using shot sizes up to 900 kg, with shot to detector distances up to 200 km (Fig. 3), was obtained to provide depths to the Moho. It is assumed that the 5 km/s refractor is crystalline basement, the 6.5 km/s refractor is interpreted as a granulite facies, intracrustal unit, and the 8.2 km/s refractor is the upper mantle. The mean depth to the mantle below the N–S profile is about 21 km. This depth and the upper crustal depths from the E–W refraction data are used to constrain the depth to Moho derived from the gravity data.

GRAVITY PROFILE

Gravity data (Fig. 4) were obtained with a LaCoste-Romberg Model G gravity meter at 1-km intervals along the E–W profile. The profile was tied to a gravity base station in the USARP Garage at McMurdo Station. Because of oscillations of sea ice a resolution of only ± 1 mGal could be ensured. All velocity units derived from the

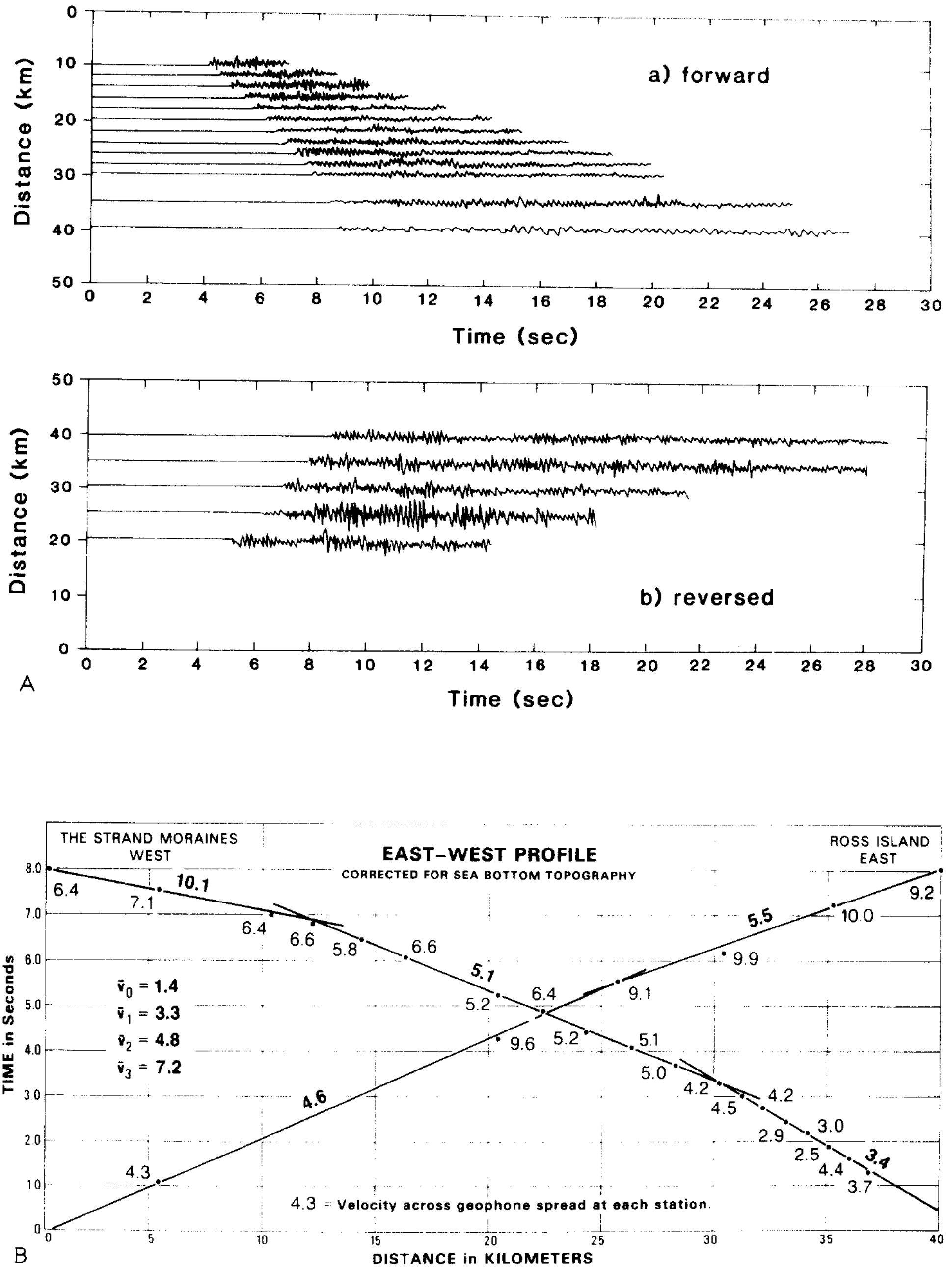

Fig. 2. Time–distance curves of east–west refractions along the profile of triangles shown in Fig. 1. B. Bold-faced numbers above the lines are apparent, uncorrected velocities. Lighter numbers at each data point indicate the apparent velocity sweeping across a 12-geophone array. An unusually high velocity of 7.2 km/s is derived for the intracrustal refractor for this profile and the 6.5 km/s refractor is missing. In all other refraction spreads out to distances of 20 km and the 6.5 km/s refractor was always observed.

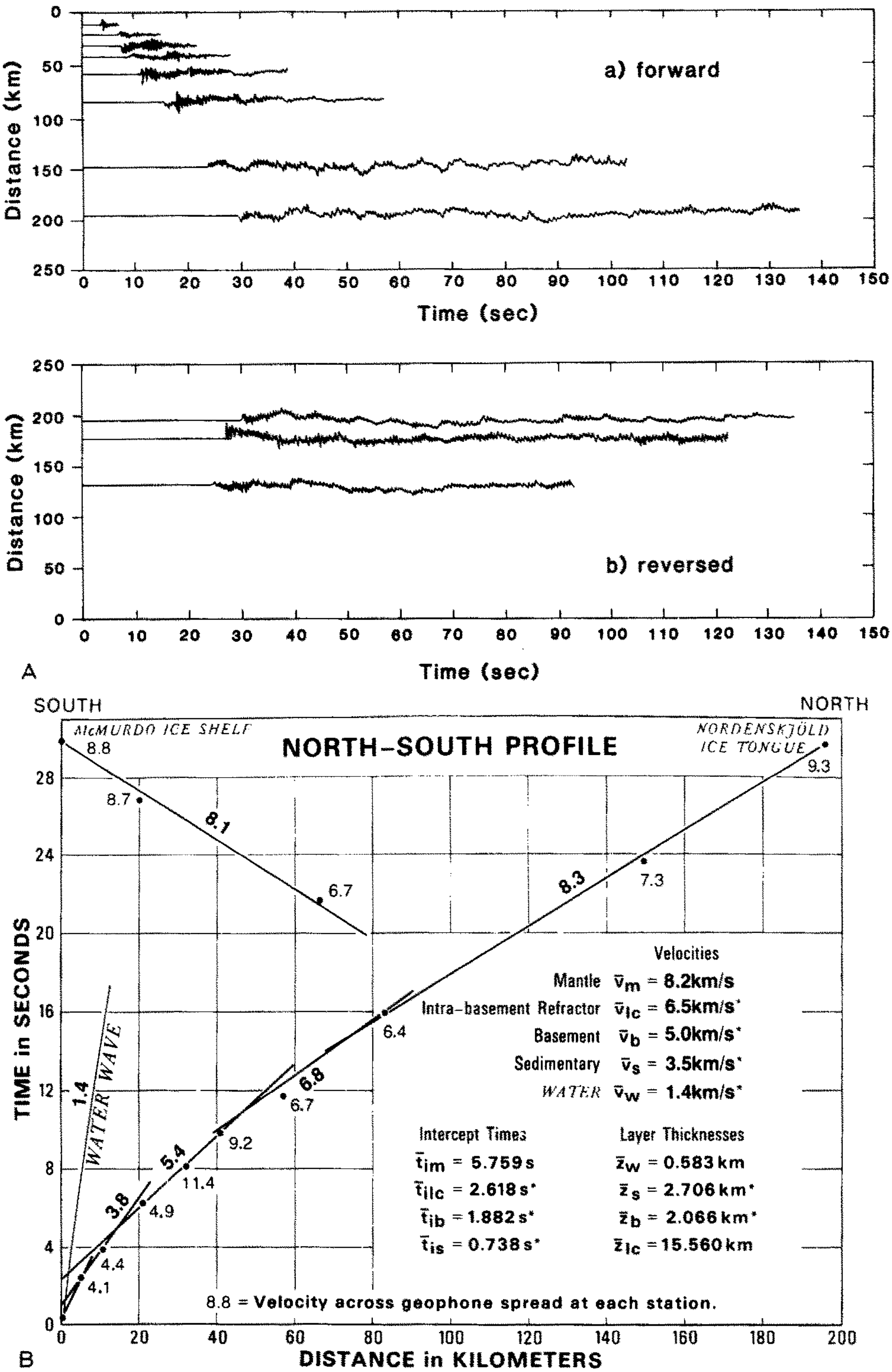

Fig. 3. Time–distance curves of north–south refractions along the profile of large open circles shown in Fig. 1.

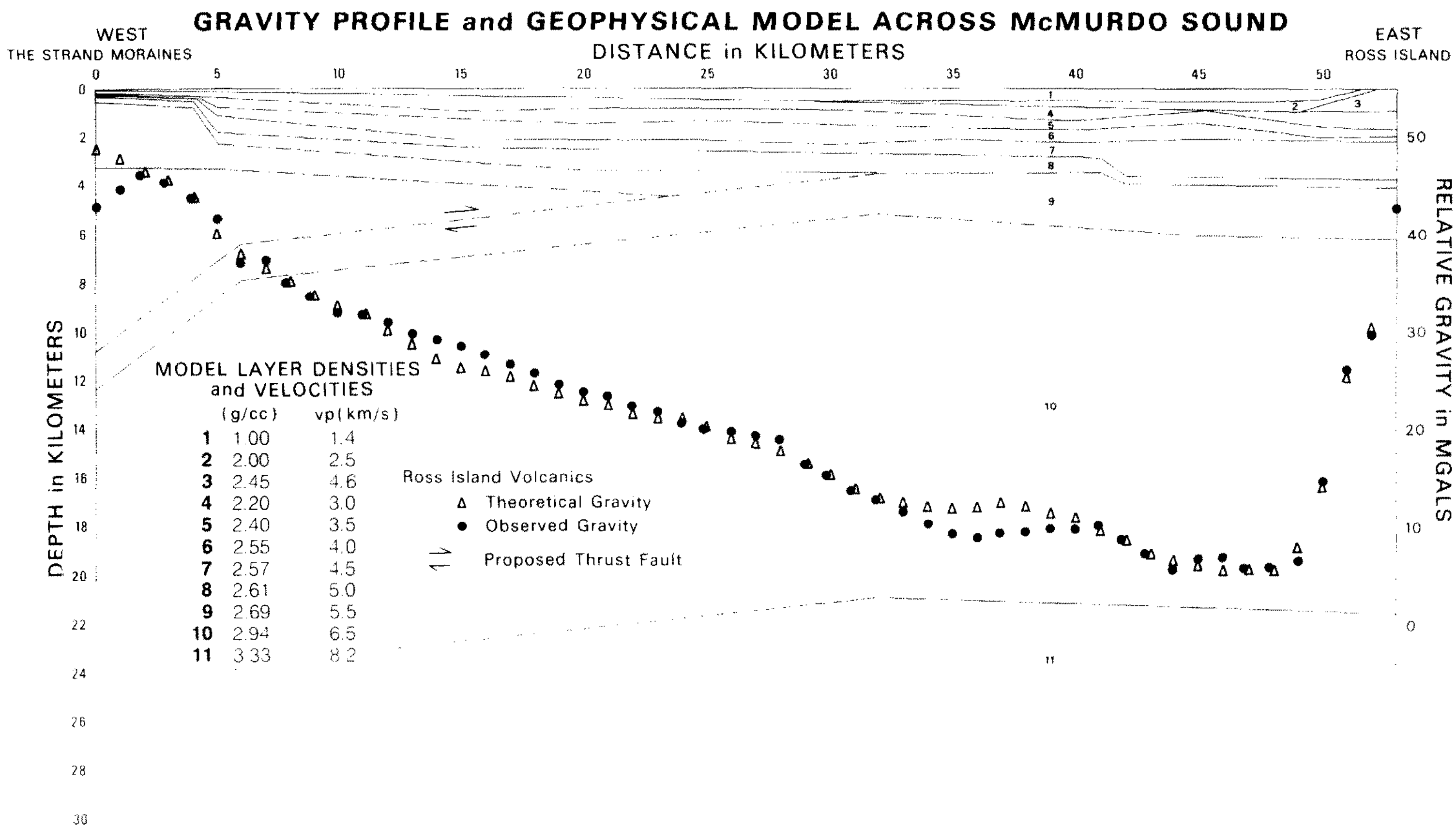

Fig. 4. East–west crustal model and depth to Moho based on seismic refraction and gravity data. Densities from Barett and Frogget (1978).

E–W profile in the upper crust were assigned densities based primarily on density–velocity relationships published by Barrett and Froggett (1978). Depths to upper crustal units are derived from the E–W, time–distance curves and the minimum depth to the Moho of 21 km is assigned from the N–S refraction profile. Using these various constraints the Moho configuration is derived from the gravity data after the two-dimensional procedure of Talwani et al. (1959). The geologic model derived from seismic refraction and gravity data is shown in Fig. 4.

REFLECTION SEISMIC PROFILE

A 24-channel, Texas Instruments DFS-III reflection seismograph was used to record the stacked, 12-fold section reproduced in Fig. 5. Data were recorded to 12 s. Layered reflectors, sloping down to the east, away from the coast, can be observed to at least 7 s. Assuming mean vertical velocities based upon horizontal velocities derived from refraction profiling, a 7-s reflector would lie at a depth of 14–16 km. A high-velocity, intracrustal refractor should lie between 3 and 4 s on Fig. 5 and the crystalline basement reflector should arrive at about 2 s. Reflectors lying above 3 s are poorly developed on the simple stacked profile and further processing, including filtering and migration, will be required to enhance reflection quality. The lineations lying between 4 and 7 s may be due to lower crustal layering or to sediments having velocities equal to or greater than 5.0 km/s. A reflection or diffraction pattern (?) dipping to the west toward the Transantarctic Mountains may be observed below 8 s on the west side of Fig. 5. This may mark the descending Moho beneath the mountains; however, further processing on this line and processing of new data collected with larger shots and greater offsets during the 1983–1984 field season will be required before a more definite interpretation can be made. Reflection lineaments are replotted in Fig. 6 for clarity.

DISCUSSION

Gravity, magnetic, and seismic refraction data provide a regional view of crustal structure and lithology beneath McMurdo Sound. Aeromagnetic data indicate crustal rocks beneath most of the Sound are relatively nonmagnetic or uniformly polarized except for the southern Sound where Pederson et al. (1981) have modeled a deep intrusion. Thus, the aeromagnetics do not display faulting or the presence of Ferrar dolerite sills, or submarine volcanics. The Dailey Islands are associated with the only area in McMurdo Sound displaying high intensity, short wave length magnetic anomalies.

Twenty one reversed seismic refraction stations provide a first approximation to the configuration of the basement, upper crustal layering, layer velocities, and a depth to Moho. Structure on the basement map is shown in Fig. 7. It is assumed from the refraction data that the 5 km/s layer is crystalline basement. The basement rises from a depth of 4 km below sea level beneath Ross Island to 2 km above sea level in the Transantarctic Mountains. Some of the displacement is certainly by faulting as shown on Fig. 7; however, reflection data suggest the major deformation may be due to downward flexure. An alternate interpretation of the reflection profile can be made if it is assumed that the layered reflectors are represented by sedimentary strata. If a lower mean velocity were assumed a basin containing approximately 10 km of sediment would rest in McMurdo Sound.

The gravity profile, through constraints provided primarily by refraction interpretations, is used to model depth to the Moho. The 200-km Moho refraction profile, parallel to the coast (see Fig. 1), gives a depth to the mantle of 21 km. With the upper crustal configuration given by shallow refraction studies, a shallow crust and sediment density distribution can be inferred and the remaining variation in gravity field is assumed to be due to change in mantle depth as shown in Fig. 4.

Reflection profiling provides the basis for refining the structural model. Twelve-fold stacking of 24-channel data gives the time–distance profile shown in Fig. 5. Figure 5 is an 8-km segment taken from the cross-sound traverse. Reflection data indicate a layered crust below basement. The layering extends into the crust to depths as great as 14 km where a diffraction pattern is observed at 7 s. This pattern

TABLE 1

Preliminary interpretation of tectonic units in the study area *

Age	Rock unit	Environment	Thickness (km)
Early Miocene–Recent	McMurdo Volcanic Group	Incipient Rift (?)	
Late Oligocene–Recent	Diamictite	Glacial Marine	
Late Cretaceous–Oligocene	Clastics/Diamictite	Marine/Glacial Marine Erratics	
Middle Jurassic	Ferrar Group–Dolerite/Tholeiitic Basalt	Incipient Plate Margin	2.6
Permian–Jurassic	Victoria Group (Beacon Supergroup)	Glacial to Coal Measures	
Late Carboniferous	Maya Erosional Surface	Uplift	
Devonian–Permian	Taylor Group (Beacon Supergroup)	Clastics Filled Basin near Sea Level	1.4
Silurian	Kukri Erosional Surface	Uplift	
Ordovician	Granite Harbor Intrusives	Pre-, Syn-, Post Tectonic	
Cambrian	Anthill Limestone (Skelton Group Marble-Schist)	Shallow Marine	7.0
Late Precambrian	Teall Greywacke (Skelton Group Gneiss)	Deep Sea	3.0
Precambrian	Granulite	Deep Crust	7.0

* Total Crustal Thickness 21.0 km

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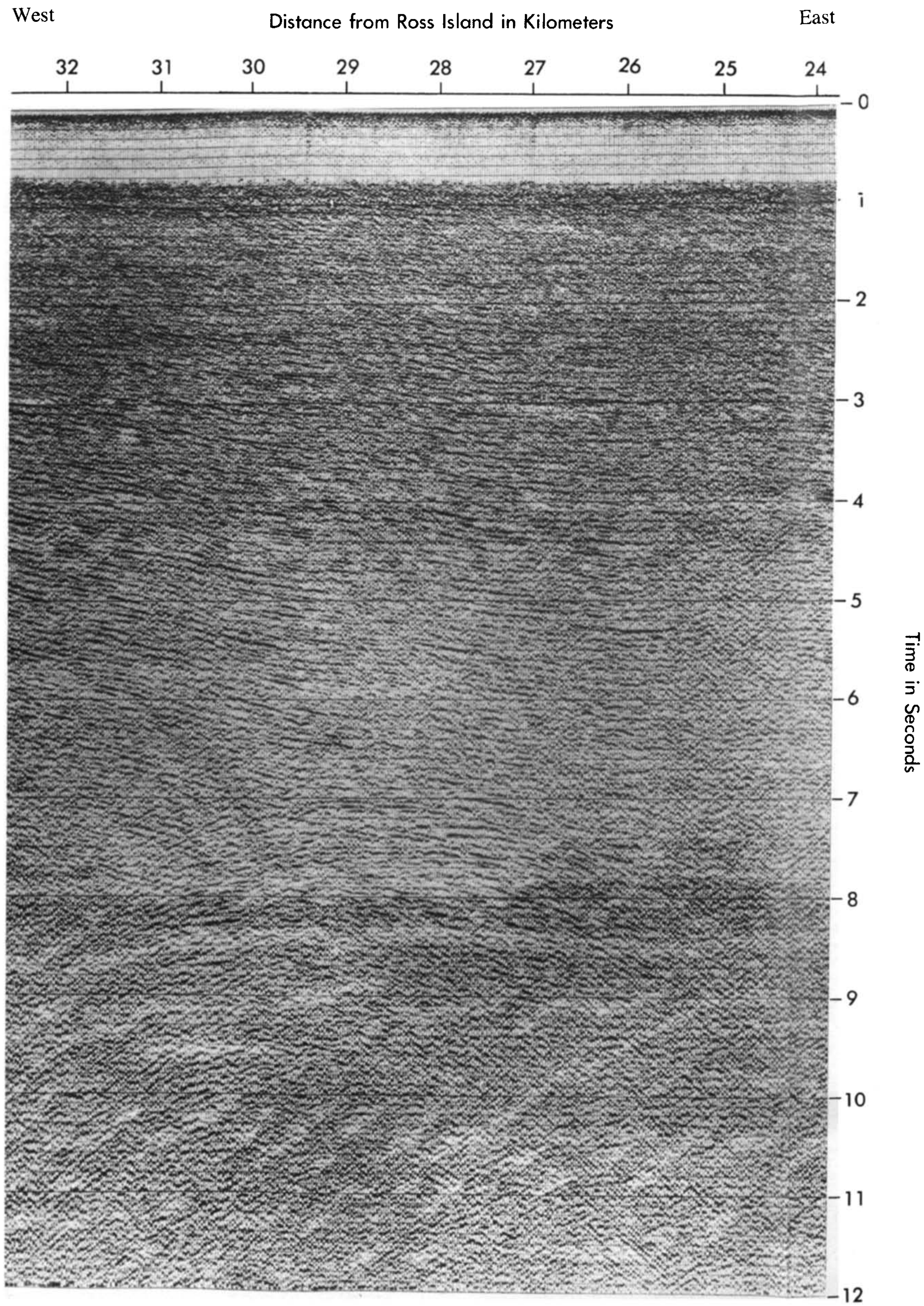

Fig. 5. Segment of 12-fold, 12-second, Common Depth Point reflection profile crossing McMurdo Sound. The segment lies between triangles 45 and 50 at 77°45′ south as shown on Fig. 1.

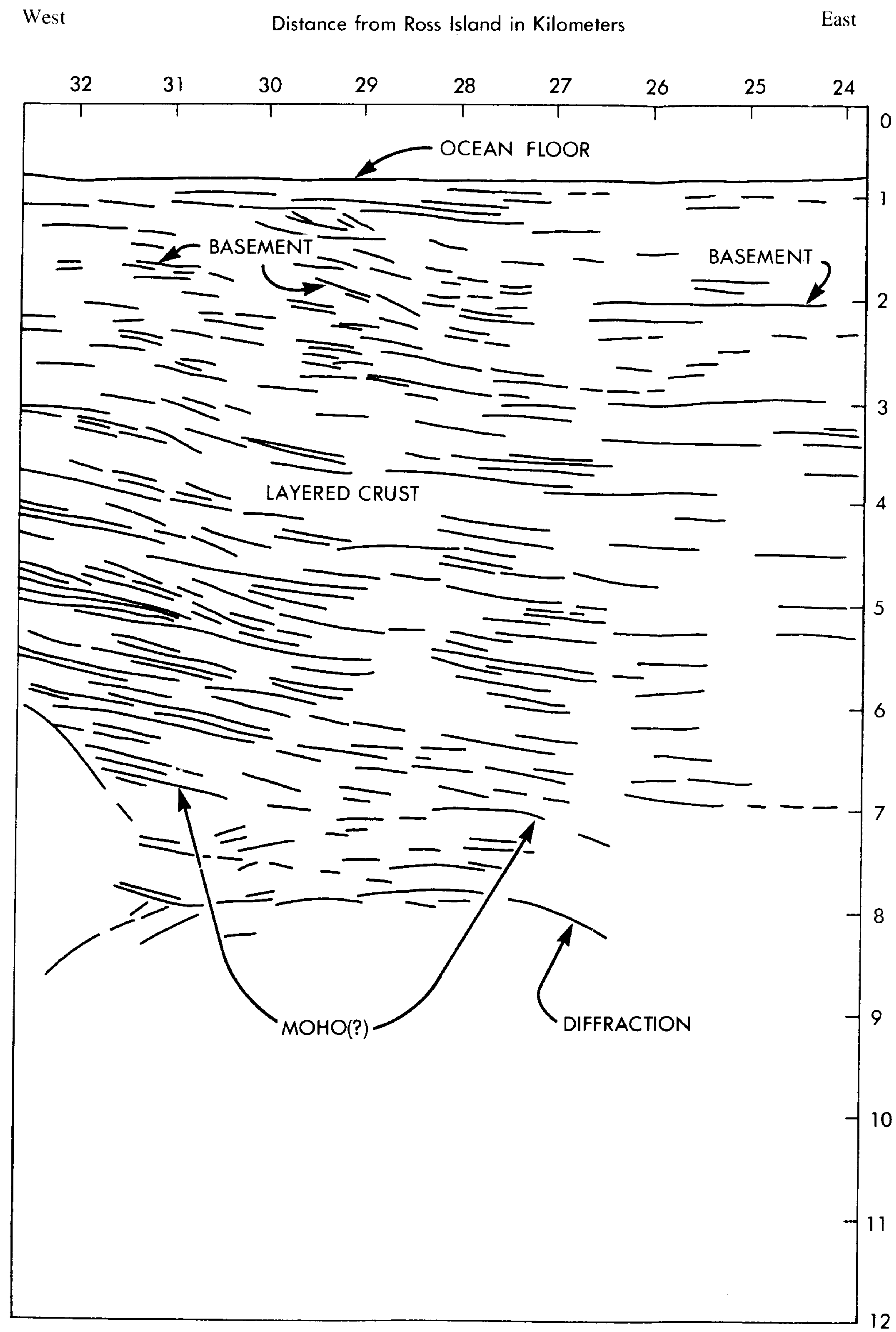

Fig. 6. Crustal layering plotted from reflections shown in Fig. 5.

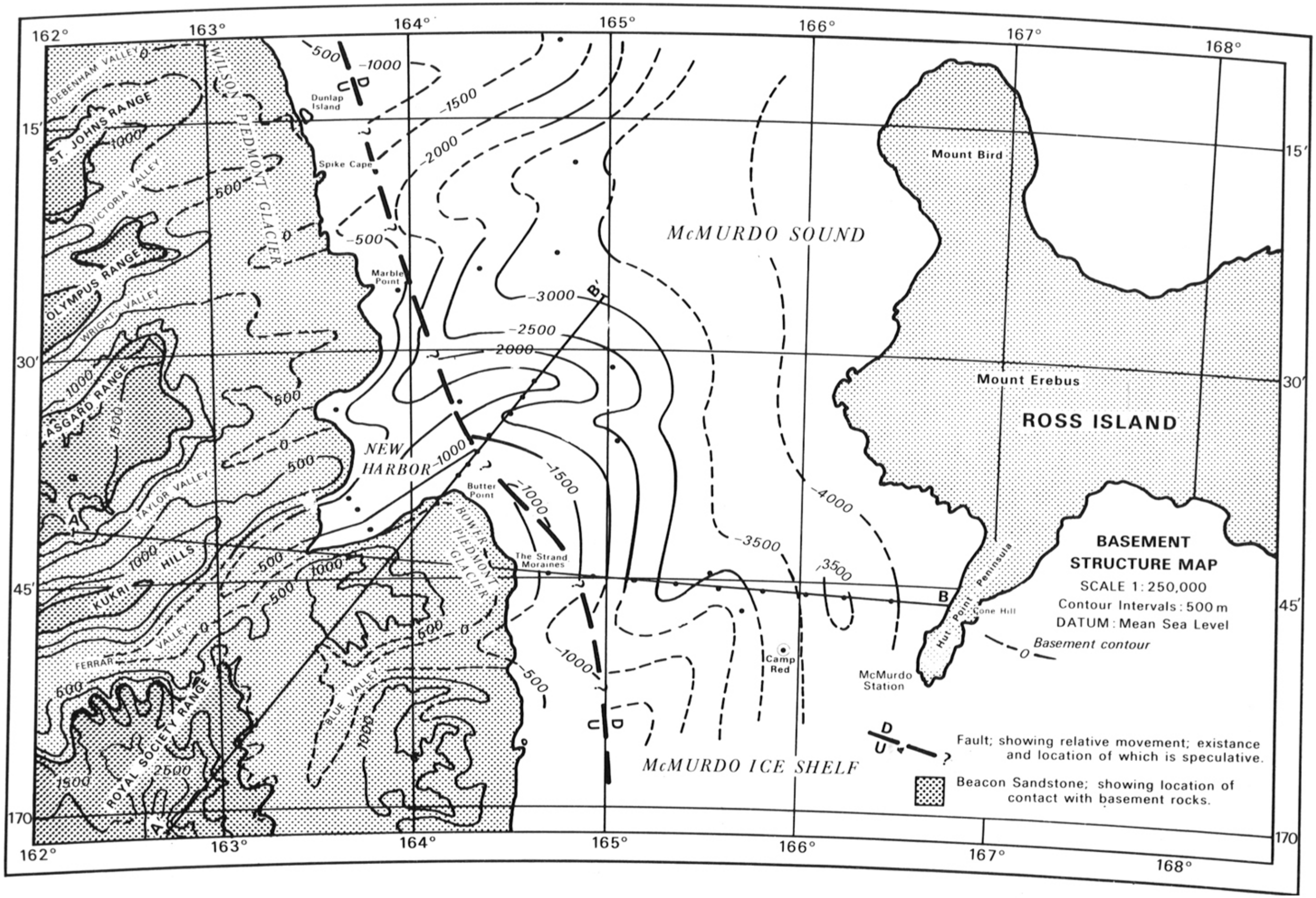

Fig. 7. Structure map on top of the 5 km/s refractor interpreted as basement.

is interpreted as being caused by crystalline intrusions in the lower crust that do not contain internal reflectors. Intracrustal reflectors bend downward from the coast to a point about 20 km offshore where they flatten out. The cause of the internal reflectors is unknown; however, they shallow toward the coast and may represent a continuation of high-grade metasediments found in the dry valleys. A preliminary interpretation of tectonic events is listed in Table 1, but will be further developed following final processing of reflection profiling completed in the 83–84 field season.

CONCLUSIONS

Data presented here may be summarized as follows:

(1) The Moho depth below sea level beneath McMurdo Sound is 21 km.

(2) The crust beneath McMurdo Sound is layered, whereas that beneath the Transantarctic Mountains is layered only in the upper few kilometers.

(3) Intracrustal layers dip away from the coast and the layered part of the crust extends to at least 14 km beneath the Sound.

(4) The crust along the Ross Orogenic belt has undergone two periods of reactivation, one a thermal event associated with Ferrar rocks in Jurassic time and the second with uplift in post-Cretaceous time. The crust beneath McMurdo Sound is presently being subjected to crustal thinning by extension.

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