42. SOUTH TASMAN BASIN AND BORDERLANDS: A GEOPHYSICAL SUMMARY

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ABSTRACT

New profiler and sonobuoy data are presented to supplement the existing geophysical data in the Tasman area. The tectonically disturbed western edge of the Campbell Plateau extends southward as a deep-sea fracture zone that separates 80 m.y. old sea floor to the east from the 30 m.y. old Emerald Basin (Site 278). A 600-meter regional depth change occurs at the boundary. The effectiveness of bottom currents on sedimentation is shown on the profiler sections from the Campbell Plateau and the western Tasman Sea. A possible marginal rift, now buried, can be inferred from profiler data taken from near Sites 275 and 276. A widespread reflector on the plateau has been identified as being in the region of the Cenozoic/Mesozoic boundary. A normally faulted erosion surface on the South Tasman Rise corresponds with the Oligocene-late Eocene unconformity.

A large east-west graben between the South Tasman Rise and Tasmania may represent an earlier rift that predates the rifted east-west margin drilled south of the rise (Site 280).

Sonobuoy refraction data reveal a somewhat atypical structure section in the Central Tasman, where a 7.1- to 7.4-km/sec layer at a depth of 7.5 km supplants the typical 6.8-km/sec oceanic layer.

INTRODUCTION

The most recent, complete summary of geophysical results in the Tasman area is Volume 19, Antarctic Research Series (Hayes, 1972). More recently new information has become available such as the identification of magnetic anomalies that show an early opening of the Tasman Sea (Hayes and Ringis, 1973), a sediment isopach map of the area (Houtz et al., 1973) and the availability of previously unpublished sonobuoy solutions and profiler data from a few selected ship tracks. This summary utilizes all this information in the discussions to follow.

The generalized bathymetry and geographic place names of the areas discussed appear in Figure 1, as well as marked profiler sections, and sonobuoy stations. The more reliable sonobuoy solutions from the regions are listed in Table 1.

BRIEF OUTLINE OF REGIONAL PLATE MOTIONS

The history of plate motions in the Tasman Sea area can be inferred from the magnetic lineations mapped in Figure 2, which are the work of Pitman, Larsen, and Herron (in preparation). The separation of Australia from Antarctica was accompanied by extensive transform faulting just to the west of Tasmania. The faulting largely destroyed the magnetic record, and apparently obscured the position of the mid-ocean ridge to the south of this region. These factors reduce the reliability of the reconstruction in the region of the South Tasman Rise as developed by Weissel and Hayes (1972). The lack of coherent magnetic lineations from the Emerald Basin also leads to doubtful interpretations and reconstructions. Drilling results may not solve the complex structural relationships in these areas, but they certainly will provide useful constraints on further speculations. The data in Figure 2 show that most of the Leg 29 drill sites were located in areas where the age of the sea floor is in doubt, especially at the Macquarie Ridge, and in the Emerald Basin. Similarly, the sites west and south of Tasmania are located in areas where the sea floor is of an unknown age.

The New Zealand Plateau separated from Antarctica and Australia about 80 m.y. ago (Hayes and Ringis, 1973). The separation from Antarctica has continued up to the present time, but the separation of the Tasman Sea Basin ceased about 60 m.y. ago. At that time, or slightly later, Australia detached from Antarctica; a separation that has continued up to the present time. The two stages of separation have produced a boundary (shown as a heavy dashed line on Figure 2) in the Tasman Sea (Hayes and Ringis, 1973). Across this boundary an age difference of at least 30 m.y. exists. An even larger time gap of about 50 m.y. exists between Site 278 and sea floor to the east. This requires a similar boundary or fracture zone (Figure 2).

SEDIMENT DISTRIBUTION

Sediment distribution in the region of the Leg 29 drill sites appears in Figure 3. Contours represent reflection time in tenths of seconds to 'basement' whether continental (e.g., Campbell Plateau) or oceanic basement. Due to the increase of velocity with depth in these sediments, a reflection time of 0.5 sec yields a thickness of 0.44 km, whereas a reflection time of 3.0 sec would indicate a thickness of 5.07 km (see fig. 2 and eq. 2 in Houtz, Chapter 41, this volume). Apparently a 6-fold increase in reflection time would indicate nearly a 12-fold increase in sediment thickness in this region.

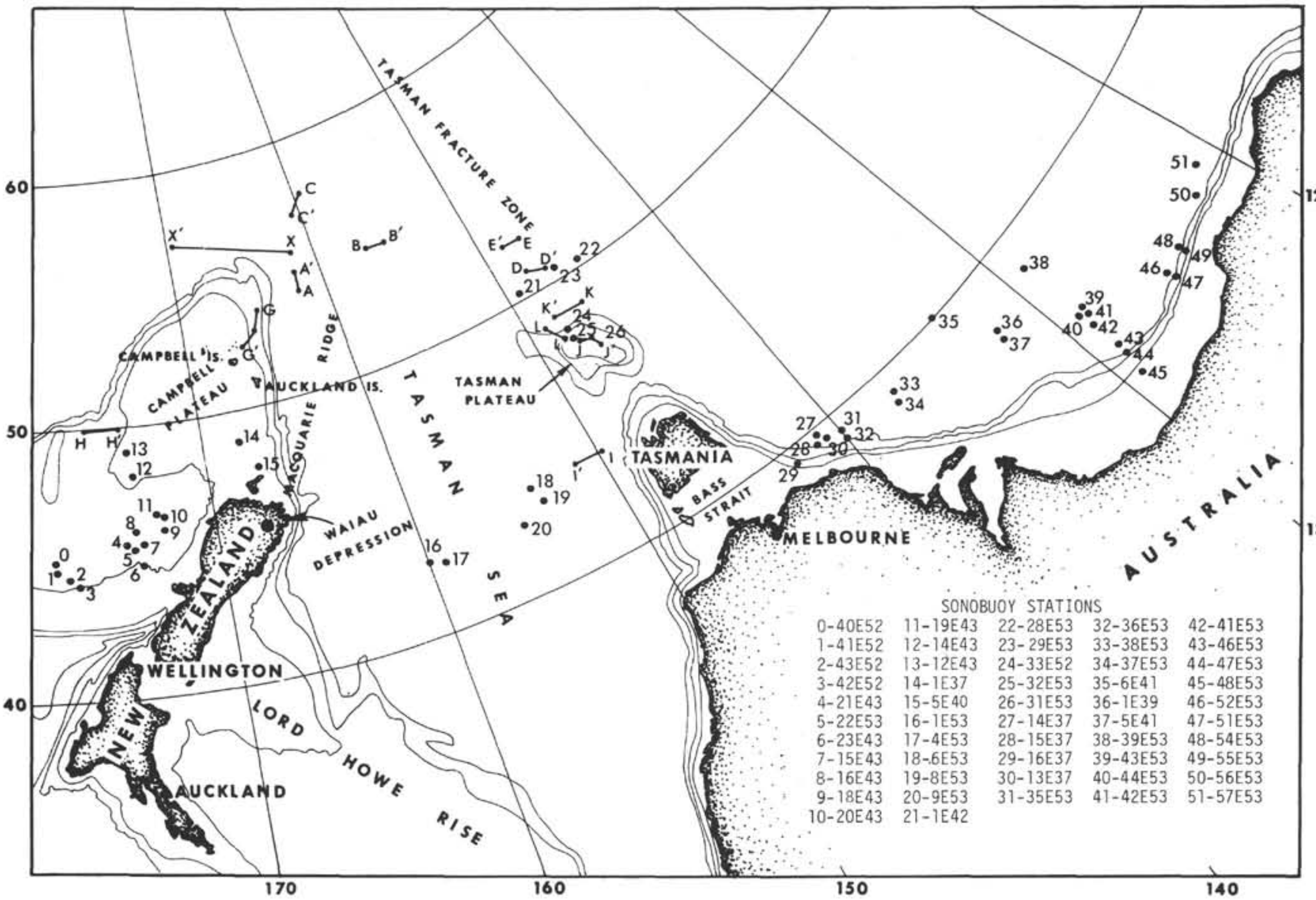

Figure 1. *Generalized bathymetry of the South Tasman borderlands. Profiler sections are discussed in the text, and all sonobuoy stations are shown.*

Emerald Basin

The isopach map shows the thick accumulation of sediments within the Emerald Basin. These sediments are densely stratified and for the most part, have a gentle dip. Submarine canyons are prominent, so the sediments are at least partially composed of terrigenous turbidites. A typical profiler section of these sediments appears in Section A-A′, of Figure 4. Sediments that are layered less densely have significant accumulations west and southeast of Macquarie Island. Reflectors in these sediments can be absent (Section B-B′, Figure 4), or delicate and variable (Section C-C′, Figure 4). The layering tends to be nonhorizontal, and is occasionally parallel to basement. These isolated patches of thick (pelagic) sediment are probably the result of deposition of very fine materials under the influence of bottom currents. Past changes in the speed or direction of the currents near the Macquarie Ridge may account for the unconformities, and erosional outcrops seen near Site 278 (Section C-C′ in Figure 4).

Tasman Basin

In the Tasman Basin, west of the Macquarie Ridge, a pronounced sediment thickening occurs north of a line between 50°S, 150°E, and the southern tip of South Island (Figure 3). The thicker sediments were laid down on a sea floor that is as much as 30 m.y. older than that to the south. The sediment distribution clearly reflects the early opening of the Tasman Sea (Hayes and Ringis, 1973). This is enhanced by the prevalence of pelagic deposition, whose continuity would have been disrupted if turbidite deposition has occurred.

Turbidites are rather scarce in this part of the world, and are confined to a narrow strip along-shore and west of Tasmania, in the Emerald Basin, and in a small abyssal plain in the central Tasman Sea. Elsewhere, pelagic sediments, modified by bottom current activity, are the predominant deep-sea sediment type. A region of pelagic deep-sea deposits, unaffected by bottom currents, is present about 300 km south of the South Tasman Rise. Profiler sections from this region (Figure 5) show the remarkable parallelism of the sea floor and sediment section upon the rough basement surface (morphologically an east-west ridge); however, the parallelism abruptly disappears (near the arrows shown in Figure 5). Although major changes in the sedimentation and current regimes must have occurred as the continents separated, this region has clearly remained isolated from significant bottom current activity. Any

TABLE 1
Sonobuoy Solutions in Vicinity of Leg 29 Drill Sites

Sono-buoy	km						km/sec						Lat S	Long W	
	h_1	h_2	h_3	h_4	h_5	h_6	v_2	v_3	v_4	v_5	v_6	v_7			
4E44	3.52	0.75	0.40	0.57	0.98		1.69	2.12	3.06*	(4.00)	(4.71)		50°00.1′	164°43.4′	Solander Trough
7E42	4.64	0.46	0.22				1.82	1.74	(4.60)*				54°08.5′	163°05.2′	
9E42	4.66	0.27	0.36	0.30			1.97*	3.06	3.05*				54°25.4′	163°05.0′	Emerald Basin
10E42	4.71	0.46	0.40	0.91			1.82	2.38	2.90				54°33.6′	163°02.6′	
14E42	5.35	0.37	1.42				((1.8))	(5.49)	(6.67)				57°31.0′	170°30.2′	
15E42	5.40	0.23	1.23				((1.8))	(5.38)	(6.85)				57°31.3′	170°40.6′	
16E42	5.22	0.50	1.53				1.94	(5.40)	(6.62)				57°32.4′	170°00.5′	South Pacific
9E43	4.91	0.95	1.82				2.41	(5.82)	(6.61)				51°38.0′	178°27.2′	
10E43	4.83	1.34					1.64	(5.41)					51°12.0′	177°32.9′	
11E43	4.50	1.02	1.04	0.63			2.34	(5.60)	(6.57)	(7.17)			50°51.1′	176°54.5′	
31E53	1.56	0.35	1.36				1.66	(5.34)	(6.61)				47°58.1′	147°48.4′	
32E53	1.61	0.31	0.82	0.78	1.11	1.42	1.60	2.56	3.28	(4.85)	(5.80)	(6.86)	47°58.8′	148°02.3′	South Tasman
33E53	1.62	0.84					2.21	(5.69)					47°59.5′	148°45.2′	Rise (continental)
34E53	1.45	0.27	0.57				((1.8))	(4.70)	(5.48)				47°55.1′	148°32.8′	
27E53	4.20	0.53					((1.8))	(5.12)					51°09.8′	147°57.2′	
28E53	4.24	0.50	0.65	1.04			1.69	3.13	4.43				51°09.1′	147°40.6′	Southeast Indian
29E53	4.03	0.62	2.26				1.95	((5.00))	5.95				51°23.0′	147°49.7′	
30E53	4.14	1.05	1.94				2.67	(5.50)	(6.23)				49°04.7′	148°20.8′	
1E53	5.00	0.67	2.11				1.86	(5.15)	(7.10)				43°07.0′	160°03.2′	
2E53	4.94	1.09	1.50				2.60	(4.65)	(7.05)				43°09.6′	159°50.1′	
4E53	4.93	0.37	0.46				1.84	1.99	(4.90)				43°19.6′	159°15.1′	Central Tasman
6E53	4.87	0.63	2.04				1.75	(5.19)	(7.37)				44°02.5′	154°26.3′	
8E53	4.71	0.52	0.40				1.73	((2.20))	(5.50)				43°44.1′	154°04.3′	
9E53	4.47	1.04	2.15				2.05	(4.80)*	(6.20)				43°11.2′	155°13.5′	

Note: * = poorly determined values; ( ) = refraction velocities; (( )) = assumed velocities; unbracketed velocities based on T^2/X^2 data.

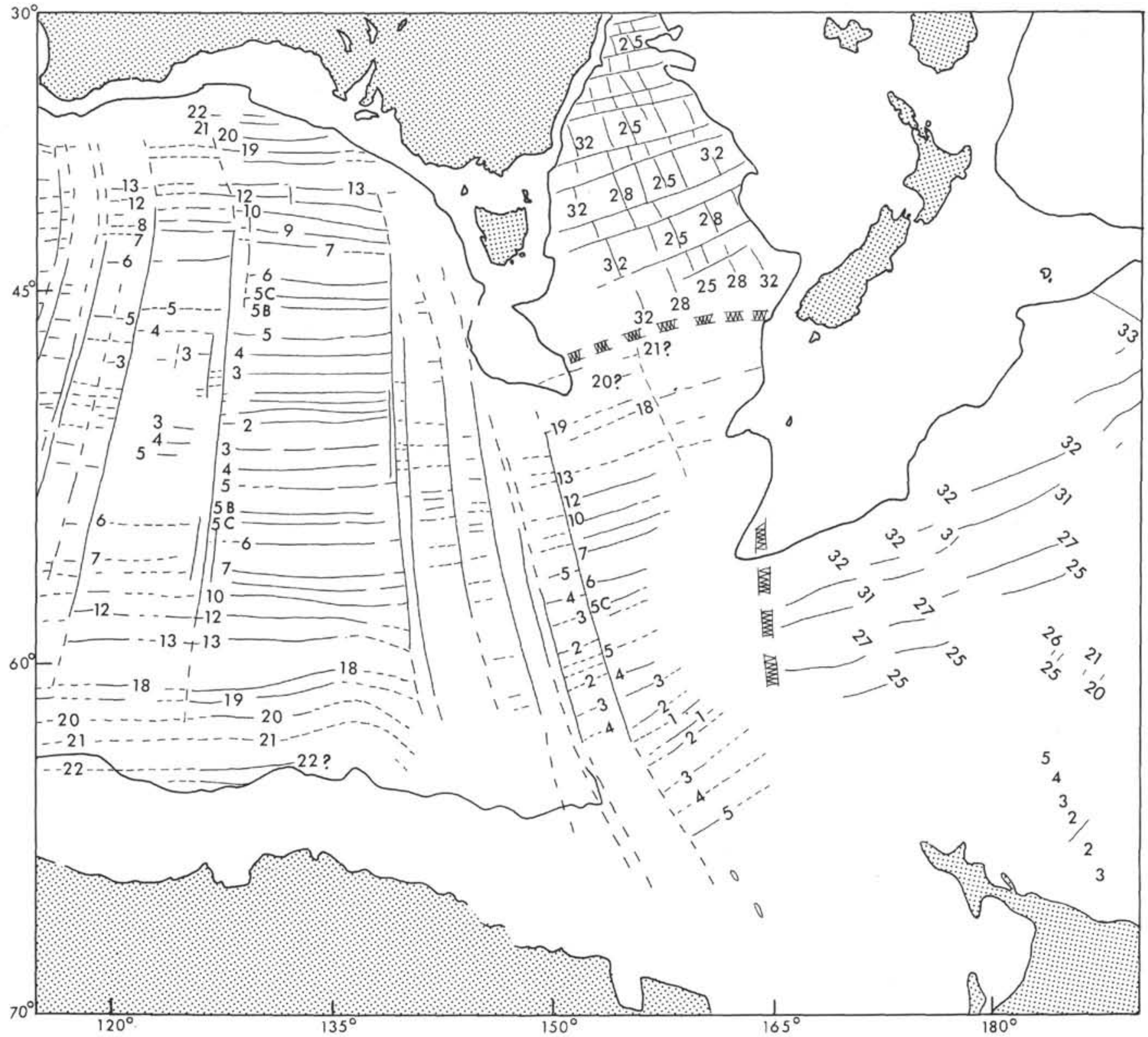

Figure 2. *Selected portion of world magnetic anomaly map used in this volume through the courtesy of W. Pitman, R. Larsen, and E. Herron.*

observable disruption could be due to very recent faulting; however, this does not explain the unique and local parallelism, unless the basement was quite flat before the faulting began.

Campbell Plateau Region

The effectiveness of intense bottom currents as erosional agents can be seen in a *Challenger* profile from the southern edge of the Campbell Plateau (Figure 6). Here the upper 200-300 meter of unconsolidated sediments appear to have been removed. The zone of intense scour along part of the southern edge of the Campbell Plateau is about 150 km wide, and has been observed in other profiler sections to the west. The outlier (marked by the arrow in Figure 6) strongly suggests that the scoured areas were formerly covered by sediment, and are not the result of nondeposition. Submarine canyons could also produce the profile (Figure 6); however, the widespread evidence for regional scour (perhaps combined with submarine canyon erosion) seems to outweigh alternative modes of sediment removal.

Other Bottom Current Activity

Less severe bottom currents may result in the formation of giant ripples on the sea floor. This seems to have

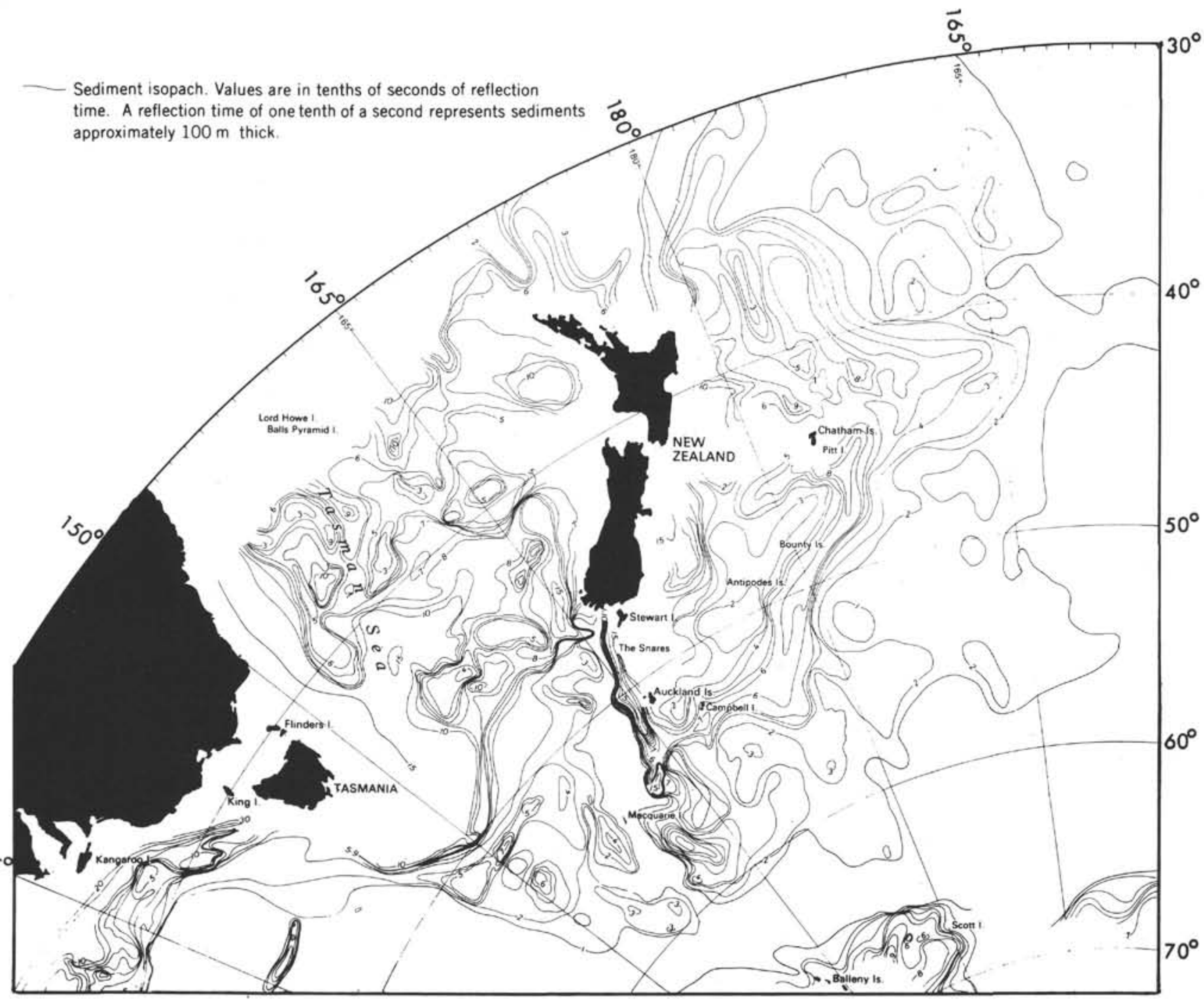

Figure 3. *Selected portion of sediment isopach map by Houtz et al. (1973). Contours are in units of seconds of reflection time.*

occurred at Site 283 in the western Tasman Sea (Figure 7). The reflection hyperbolas appear to be tangent to the sea floor, which would be unlikely if they emanated from random points of reflection. The tails of the hyperbolas are parallel, indicating that the ripples have uniform strike, and have an aperiodic distribution shown by a similar distribution of the hyperbolas.

The hyperbola (at the arrow in figure 7) seems to be tangent to a subbottom reflector. This reflector may represent the original surface upon which the ripples formed and has since been buried by about 15 meters of sediment. The drilling results at Site 283 indicate that the postripple sediments are Pleistocene, and the giant ripples are in upper Eocene sediments.

CRUSTAL STRUCTURE

Campbell Plateau

Summerhayes (1969) has described the Campbell Plateau in some detail using data from bottom samples, soundings and information on the geology of Campbell and Auckland islands. He concluded that the plateau was eroded to about its present level during earliest Tertiary times. The plateau has not been severely deformed since then, except for gentle rises formed by late Tertiary volcanism. Profiler data also show evidence of a general lack of deformation throughout the central plateau.

However, the western edge of the plateau is deformed, at least locally, by what appear to be normal faults (Figure 8). The outcrops of the disturbed sediment, if sampled, would cause a wide range of sediment ages to be reported. Summerhayes (1969) reported this type of age span (Pleistocene to Eocene) from his study of bottom samples taken from along the western margin of the plateau. In view of the approximate 50 m.y. discrepancy between the sea floor at Site 278 (Oligocene), and the sea floor just to the east (Late Cretaceous), it is likely that the zone of normal faults extends southward beyond the southern edge of the plateau.

The southern extension of the proposed ancient boundary between the western edge of the Campbell Plateau, and the Emerald Basin is shown in the reflection profile

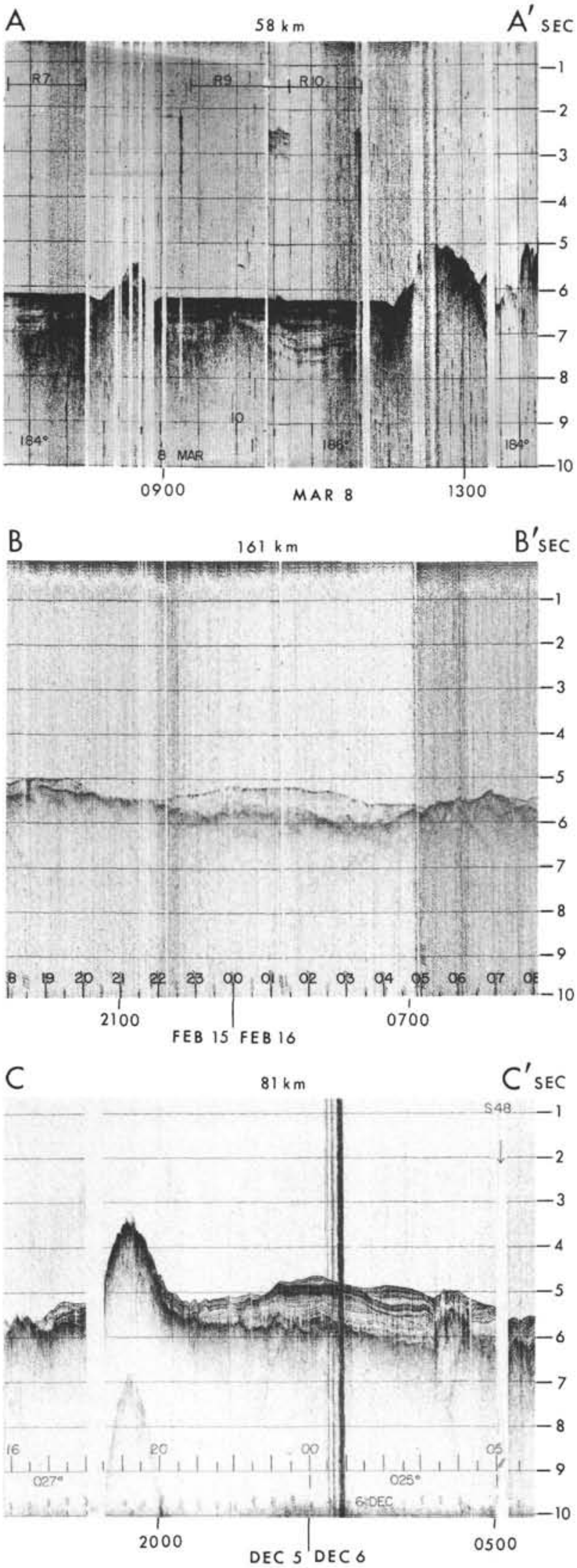

Figure 4. *Profiler sections from Solander Trough (A-A'), Southeast Tasman (B-B'), and Emerald Basin (C-C'), illustrating a variety of sediment types (vertical × 30).*

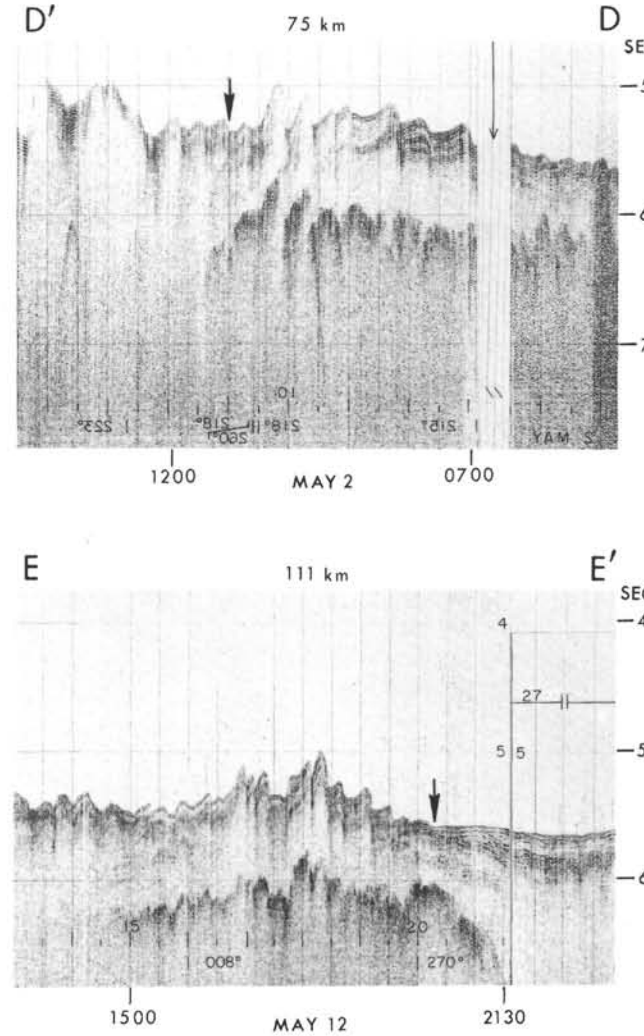

Figure 5. *Profiler sections from south of the South Tasman Rise showing a localized zone of undisturbed pelagic sediments (vertical × 30).*

(Figure 9). The fracture zone (arrow in Figure 9) separates the older, deeper sea floor to the east from the younger sea floor to the west.

The 600-meter depth difference between the older, eastern sea floor and the younger, western sea floor, is less than the 1000-meter difference predicted by Sclater et al. (1971). Their 1000-meter calculation is predicted for cooling slabs with ages of 30 and 80 m.y., respectively.

Additional information on the crustal structure of the Campbell Plateau can be derived from the results of sonobuoy profiles (Table 1). Sonobuoy 11E43 (and Sonobuoys 9E43 and 10E43 to the south) recorded refractions from 5.6-km/sec material that is clearly associated with acoustic basement. A deeper, 6.9-km/sec refraction confirms that a normal deep-sea structure section exists at the foot of the southern edge of the Campbell Plateau. The remarkable abrupt transition from oceanic to continental structure seems to have occurred without the development of a marginal rift (Figure 10). Houtz and Markl (1972) tentatively

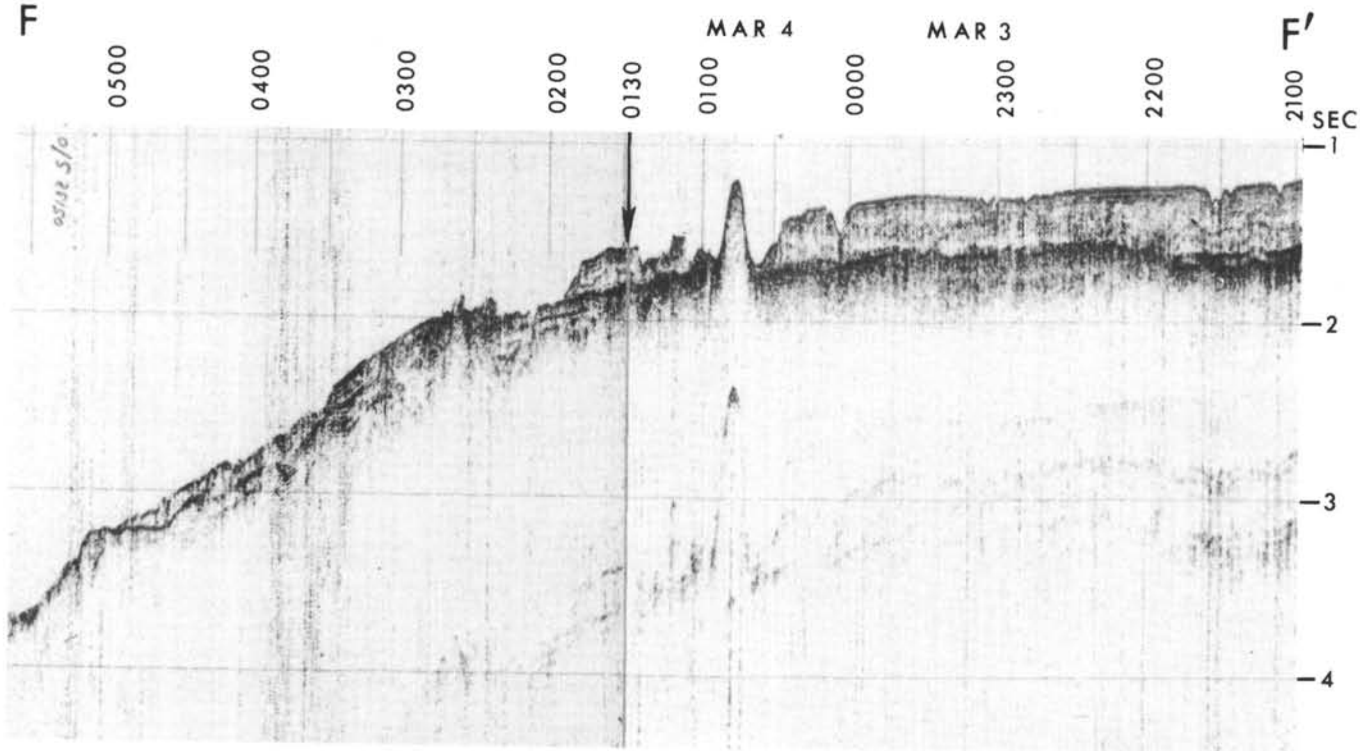

Figure 6. *Profiler section along southern edge of Campbell Plateau, showing effects of boundary current scour (vertical X30).*

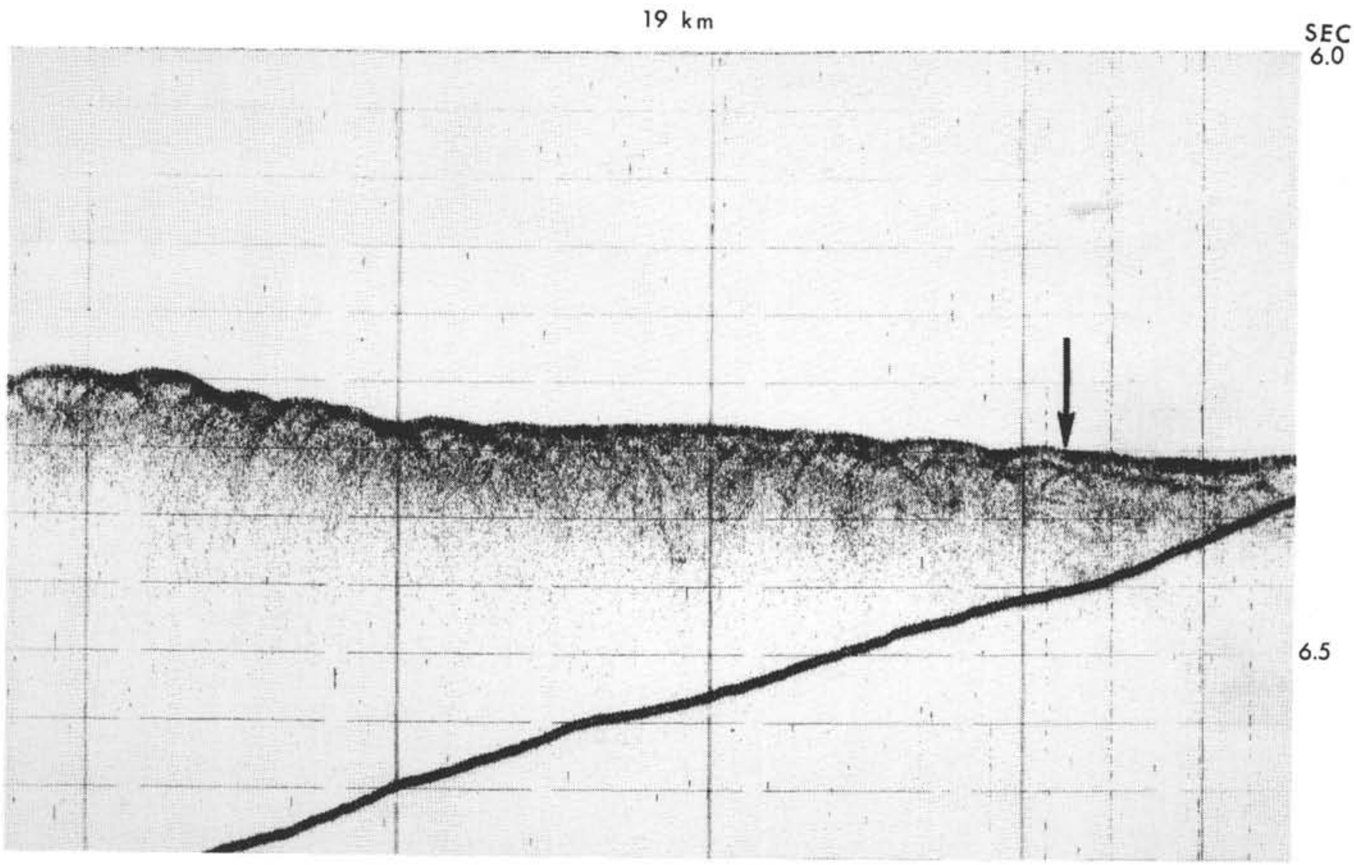

Figure 7. *3.5-kHz record of giant ripples or dunes near Site 283. Rippled surface may be about 15 meters below sea floor near the arrow.*

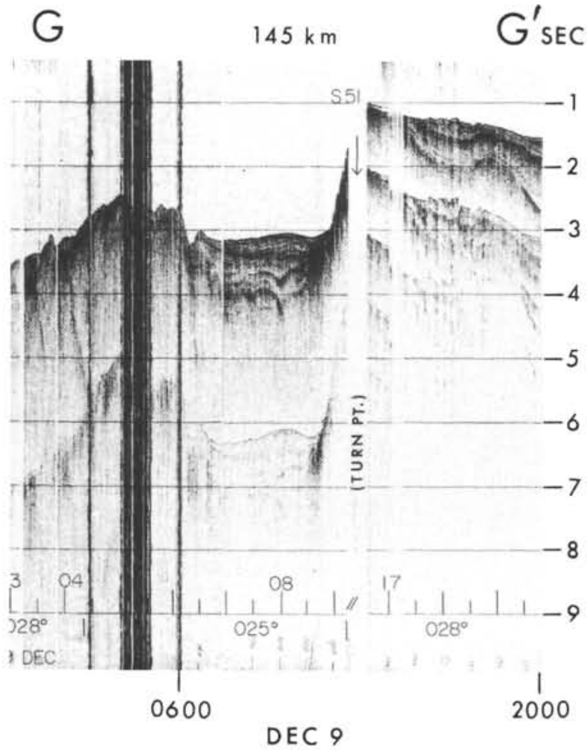

Figure 8. *Profiler section of disturbed sediments along western edge of the Campbell Plateau (vertical X30).*

suggested that the ancient boundary between New Zealand and Antarctica was sheared during the first stages of their separation. Separation of this sort need not produce marginal rifts. Cullen (1967) had suggested earlier that the eastern margin of the New Zealand Plateau (from the Chatham Rise to the southern margin of the Campbell Plateau) is a major shear zone.

The dashed lines in Figure 10 represent the extensions of features observed in the profiles, which suggest normal faulting in a small marginal rift contained within the continental slope. The gentlest dips seen are only about 10° near the surface. A 10° dip is hardly steep enough to be associated with normal faults. If a marginal rift is buried beneath the outbuilding slope, the dips would have to steepen with depth. Thus, it is possible that the 'fault faces' in the profile are in reality scree slopes at the base of much steeper (now buried) scarps. The outer basement 'peak' (shown at *A* in Figure 10), is probably a long-shore ridge, because the sediment has been dammed up behind it. Other areas along the southern and eastern edges of the Campbell Plateau may have a similar margin, but profiler penetration is insufficient to demonstrate a consistent marginal rift. At best the 'rift' may only occur locally.

The Upper Cretaceous clastic sediments drilled at Site 275 were from a layer of consolidated material, below which no bottom current erosion has been effective. (Figures 6, 10). These profiler sections show that this reflector of Upper Cretaceous age marks the base of the parallel stratified sequence, and the top of the layer that covers basement.

Solander Trough-Emerald Basin

It can be seen in Figure 1 that the Waiau Depression may be the landward extension of the Solander Trough (Brodie, 1958). Similarly, the Solander Trough seems to be a northerly continuation of the Emerald Basin. The three regions appear to be a single extensional feature (Hatherton, 1967). The Oligocene age for the onset of subsidence in the Waiau Depression (Fleming, 1962) is the same as that of the sequence cored at Site 278.

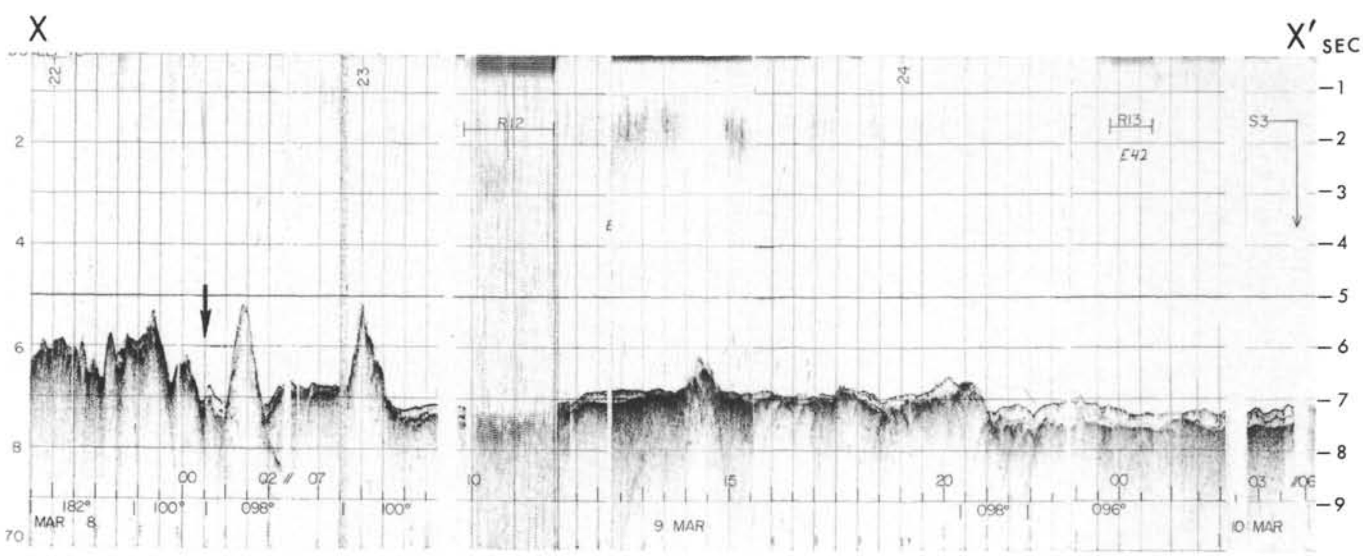

Figure 9. *Profiler section across southern extension of fault zone between the Emerald Basin and the Campbell Plateau (vertical X30).*

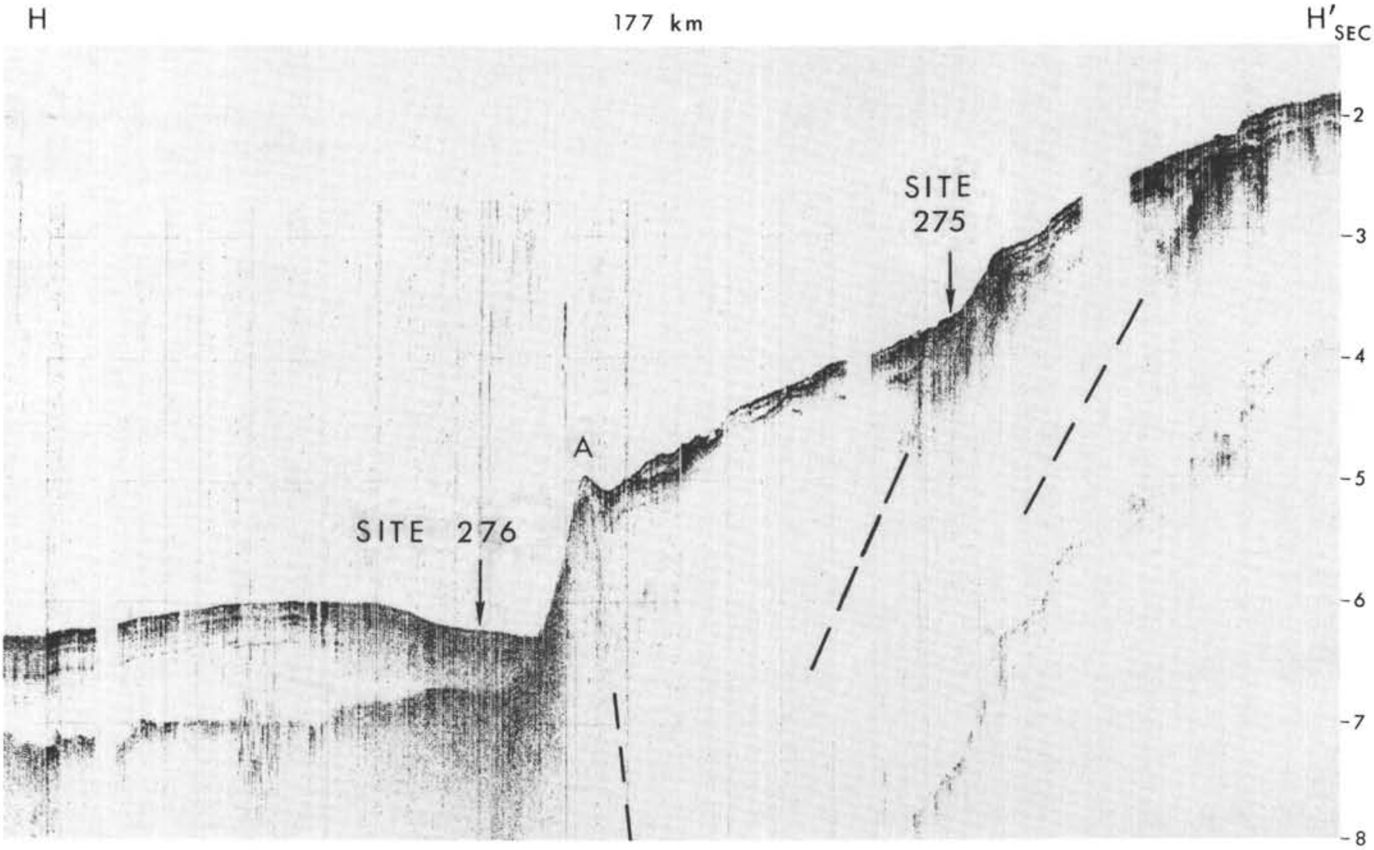

Figure 10. *Profiler section along southern edge of Campbell Plateau, showing longshore ridge at A, and possible structure of marginal rift (indicated by dashed lines).*

Sonobuoys 14E42, 15E42, and 16E42 are located east of the fracture zone (Figure 10) and reveal a thin cover of sediment on typical oceanic crust. These sonobuoy solutions were taken from a region south of New Zealand where the sea floor is about 75 m.y. old. West of the fracture zone (Figure 10), the sea floor is elevated about 600 meters, confirming that it is a younger feature. However, in the Solander Trough the sediment cover increases to 2.7 km (see Sonobuoy Station 4E44), and basement is depressed to a depth of 6.22 km. This depth is 500 meters below that of the much older crust, a result of overburden weight. The sonobuoy refraction data from the Emerald Basin and Solander Trough are not sufficiently reliable to claim that the 4.6- and 4.7-km/sec basement measured at 7E42 and 4E44 is really different from that measured within the older sea floor.

Tasmania and South Tasman Rise

The deep-sea margins of Tasmania and the South Tasman Rise appear in the profiler records as zones of major normal faulting. The western slope actually faces on a zone of complex shears (Weissel and Hayes, 1972), even though it appears as a normally faulted boundary in some of the profiler sections (Houtz and Markl, 1972). A profiler section of the East Tasman Plateau (Section I-I′, Figure 11) shows a very narrow zone of scoured sediment caused by a weak boundary current. This section is similar to the sections from the western edge of the Campbell Plateau (Figure 8). However, the sea floor at the foot of the western edge of the Campbell Plateau, judging by the drilling results at Sites 278 and 283, is much younger than the analogous sea floor near Tasmania.

The apparent lack of a marginal rift at the foot of the slope is evident (Section I-I′, Figure 11), as it is south of the Campbell Plateau. This contrasts sharply with the Otway Rift System to the northwest of Tasmania, and with the Bass and Gippsland basins to the north. Part of an east-west rifted zone between Tasmania and the South Tasman Rise appears in Section J-J′, of Figure 11. The depth to basement cannot be estimated here due to a lack of profiler penetration, but it is not likely to be as deep as 9 km below sea level. This depth was reported by Houtz and Markl (1972) for the Otway Rift south of Adelaide.

However, the rift may have been sufficiently deep to represent an early stage of rifting, predating the margin drilled at Site 280. This could account for the observation that the basement at Site 280, though poorly dated, is 10 m.y. younger than the oldest magnetic anomalies identified by Weissel and Hayes (1972). The width of the graben (J-J′ in Figure 11) would also account for some of the overlap of the South Tasman Rise onto the Iselin Bank in Antarctica. The initial rift occurred between

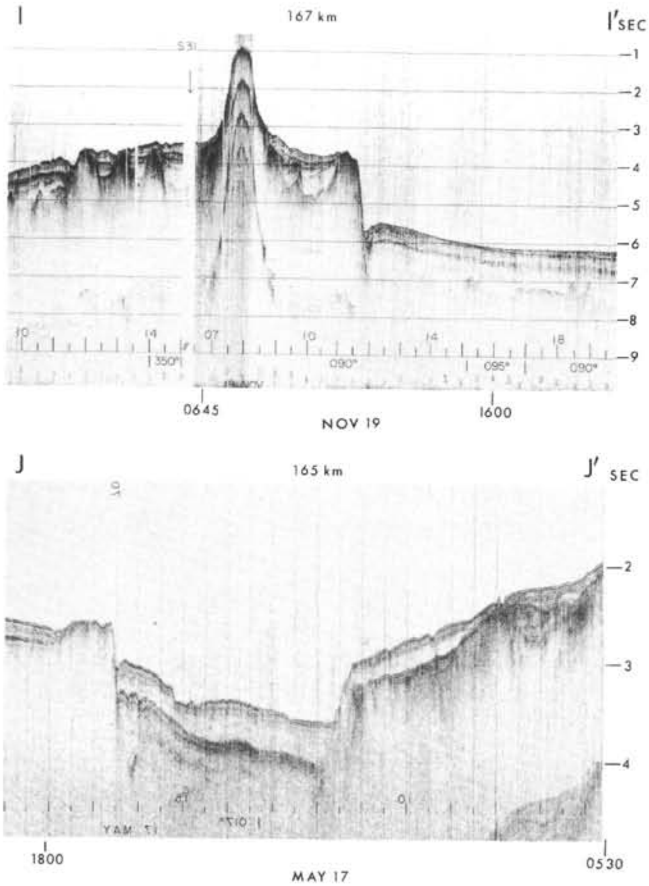

Figure 11. *Profiler sections from East Tasman Plateau and the South Tasman Rise, showing the dominant normal faulting.*

Tasmania and the South Tasman Rise during the early Eocene; then the rift opened up south of the rise in the late Eocene (Site 280), and continued opening up to the present.

Results from Site 281 show that the South Tasman Rise is continental, so it seems reasonably certain that the East Tasman Plateau is another unit of rifted continental material that fragmented during the initial separation of Australia from Antarctica.

A structure section based on sonobuoy solutions (Table 1), and accompanying reflection profiles from the South Tasman Rise appear in Figure 12. The sonobuoy data reveal that a very rough basement surface near Site 281 has been covered by sediments to produce a relatively smooth sea floor. The variability in the basement velocities may be caused by excessive dip corrections, but they are not inconsistent with the variability expected in continental basement rocks. The basement peaks are flat-topped, and occur at about the same depth as the gently undulating sea floor. This is fairly convincing evidence for wave base truncation and later subsidence.

The dark reflector (arrows in Sections K-K′, L-L′, Figure 12) may represent the erosion surface, corresponding to the Oligocene-late Eocene unconformity described at Site 281. This surface appears to have been disrupted by normal faulting (Section K-K′, Figure 12).

Central Tasman

Structure columns based on sonobuoy solutions from the Central Tasman (near Site 283) appear in Figure 13. The 7.1- to 7.4-km/sec refraction lines appear in the records as first arrivals, apparently at the expense of a typical oceanic layer with a seismic velocity of about 6.75 km/sec. The top of the 7.1- to 7.4-km/sec layer is consistently at a depth of about 7.5 km. This is several kilometers shallower than typical depths measured from the 7.1- to 7.7-km/sec 'basal layer' reported by Sutton et al. (1971) in the South Pacific. A comparison of the Central Tasman sonobuoy results with those obtained south of New Zealand (Table 1, 'South Pacific') seems to reveal a genuine difference, but until more data are available, it should not be accepted as a demonstrated difference.

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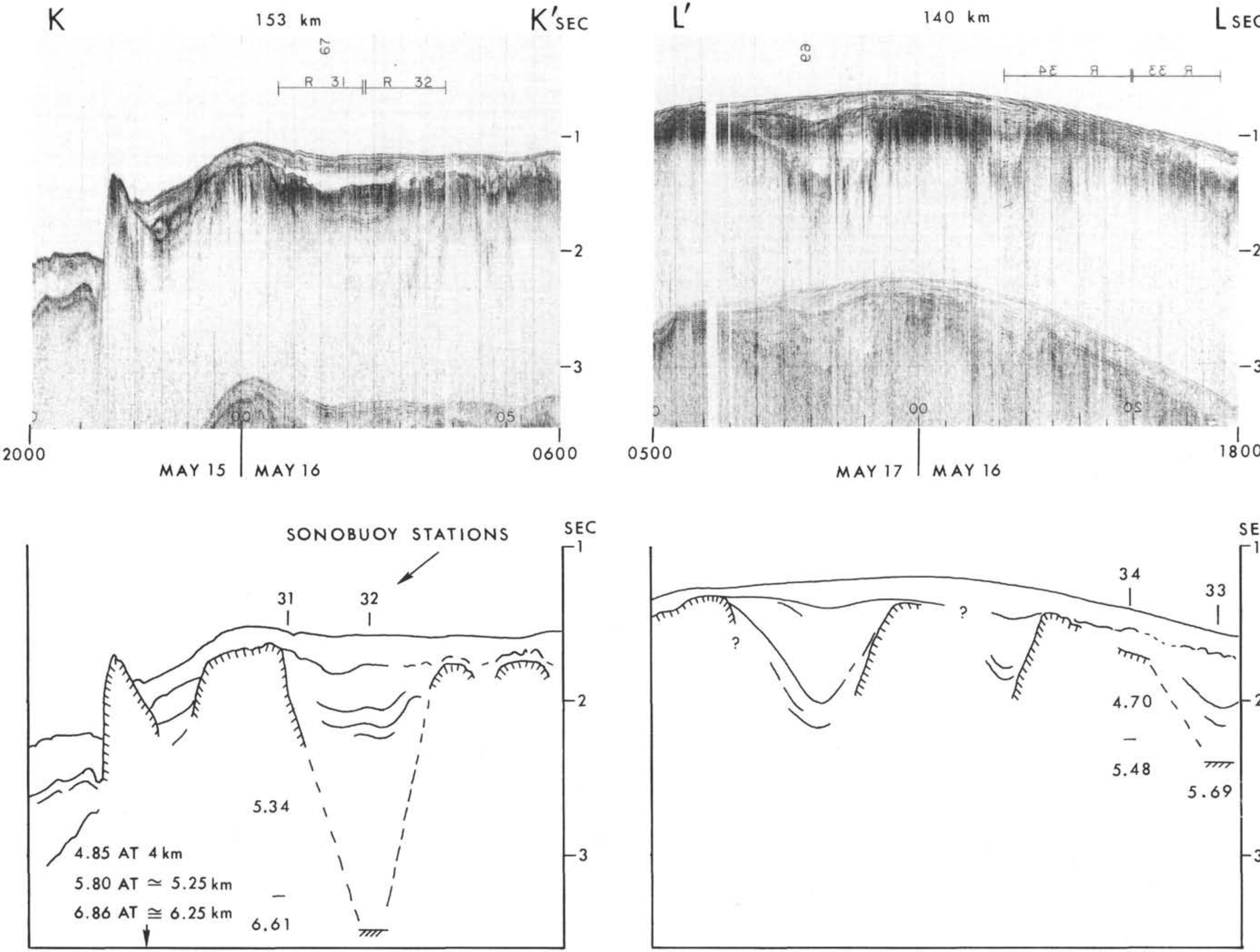

Figure 12. *Profiler sections from the South Tasman Rise. Sonobuoy data have been used in the lower sections to convert the sections to units of thickness. Hatched interfaces rest on basement.*

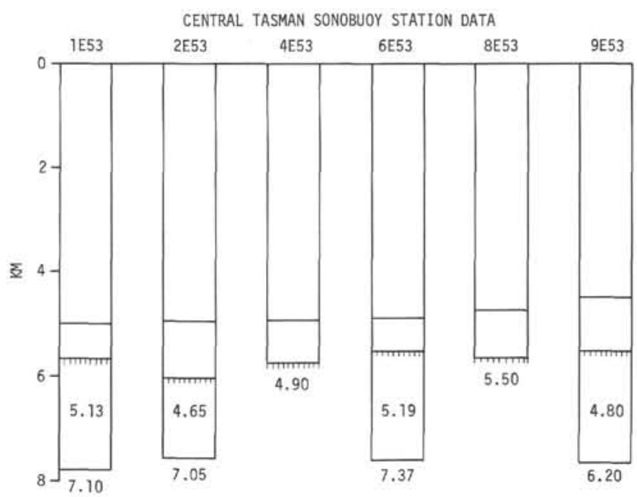

Figure 13. *Structural columns from Central Tasman sonobuoy data. Note the lack of a typical oceanic layer (6.8 km/sec).*