Terra Antartica
2000, 7(3), 215-220

A Revised Correlation of the Seismic Stratigraphy at the Cape Roberts Drill Sites with the Seismic Stratigraphy of the Victoria Land Basin, Antarctica

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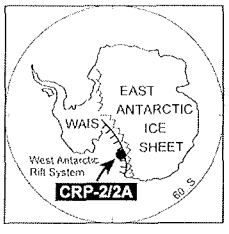
Received 30 July 1999; *accepted in revised form* 8 March 2000

Abstract - Newly available multichannel seismic profiles are used to correlate the previously defined seismic stratigraphy of the Victoria Land basin with that of western flank of Roberts Ridge (western McMurdo Sound), where the Cape Roberts Project drillsites are located and constraints on the ages of the seismic events can be derived. The older regional seismic events from two regional seismic stratigraphies (V series and the RSS series) have been compared for the southern Victoria Land basin and an age progression derived for the seismic reflectors interpreted as RSU6, V3/V4, and V4/V5. The new data permit a more robust correlation of these seismic events to the drill sites. A seismic reflector, previously interpreted to correspond to the Ross Sea wide RSU6 event in this region, is significantly younger (less than 17 Ma at the Cape Roberts drill site CRP-1 and CRP-2/2A) than the RSU6 event in the Eastern basin, where an age greater than 26 Ma is inferred, suggesting a miscorrelation of this event across basement highs between Eastern basin and the basins in western Ross Sea. Based on the drill core ages, a geological correlative at drill site CRP-2A of RSU6 in the Eastern basin could be the unconformity at 443 m bsf, inferred to correspond to the seismic sequence boundary V4/V5 (see below). A single V3/V4 event can be consistently correlated from the Victoria Land basin to all profiles west of the ridge. The velocity/depth data from CRP-1 and CRP-2 drill cores, indicates that the V3/V4 seismic event lies just below the base of CRP1 drill hole and at a depth of about 90 m at drill hole CRP2. The age data from these two drill sites indicate an age for V3/V4 of about 21 Ma. The V4/V5 event has been correlated to the drill sites from the Victoria Land basin by four independent routes, and intersects drill hole CRP-2/2A at a depth of about 440 m. This depth is close to a significant geologic unconformity in the drill core at a depth of 443 m bsf and an age of about 28-29 Ma (close to the late/early Oligocene boundary). Previous interpretations of the V4/V5 event correspond to a deeper seismic sequence boundary within unit V5. The revised interpretation indicates that there is a much thicker Oligocene and younger sedimentary sequence within the Victoria Land basin than previously thought.



INTRODUCTION

An important aspect of the Cape Roberts science programme is the correlation of the information obtained on the sediments cored by the Cape Roberts Project (CRP) drill holes (CRP-1 and CRP-2/2A to date) with the regional geology. The primary source of data for extrapolating the geology of the drill core to the SW Ross Sea region is via the comprehensive seismic reflection database for the region (*e.g.* Anderson and Bartek, 1992, Brancolini et al., 1995). The process of extrapolation of the data has two parts; i) the correlation of the geology sampled in the drill cores with the seismic data across the drill sites, usually by development of synthetic seismograms for the cores and matching to the observed seismograms (*e.g.* Bartek et al., 1996, Bucker et al., 1998; Henrys et al., this volume); and ii) the correlation of the seismic stratigraphy in the vicinity of the drill sites with the seismic stratigraphy developed and defined for the Victoria Land Basin (Cooper & Davey, 1985; 1987) or the Ross Sea in general (Brancolini et al., 1995).

Correlation of the major seismic sequences between the deeper part of the Victoria Land basin and the dipping seismic units which crop out on the western margin of the Roberts Ridge (the focus for sampling by drilling by the Cape Roberts Project) has been simple in general terms but equivocal in detail. The ages derived from the drill core sediments have been much younger than the ages inferred for these sediments from correlation using seismic data to dated sequences (sometimes poorly constrained) elsewhere in the Ross Sea. Detailed correlation of the older sequences has proved difficult as the reflections of interest pass across the Roberts Ridge, or to the north of the Roberts Ridge, at travel times below the seafloor multiple reflection. Multiple energy severely limits the usefulness of the single channel seismic data across the area - the largest available seismic data set. Correlation of younger sequences has proved difficult due to a lack of reflector continuity caused by erosion and faulting near the crest of Roberts Ridge. An analysis by Henrys et al. (1998) identified significant uncertainties in the seismic correlation. A good correlation of the drill site data to the Victoria Land Basin is critical for an analysis of the basin evolution.

The recent availability of several regional seismic reflection lines of high quality data suggest that some of

the uncertainties in correlation of the seismic sequences across Roberts Ridge to the main Victoria Land Basin beneath the seafloor multiple may be resolved. These data include the detailed processed 60 fold multichannel seismic (MCS) data from R/V Explora (the IT series of seismic profiles), and the processed 22 fold MCS data from the detailed survey of Roberts Ridge by R/V N B Palmer (the NBP9601 series of seismic profiles).

SEISMIC ANALYSIS

A preliminary review of the data set (Fig. 1) indicated that the crucial seismic profiles for connecting the seismic stratigraphy of the Victoria Land Basin with that for Roberts Ridge are i) RV Lee line USGS414, on which the seismic units V3, V4, and V5 have been defined (Cooper et al. 1987), and ii) RV Explora line IT69, that extends from line USGS414, across Roberts Ridge, and connects to the detailed NBP9601 survey. The interpretation of line IT69 used the revised seismic unconformities for the Ross Sea (RSU1-6) (Brancolini et al. 1995). In McMurdo Sound, Bartek et al.(1996) have further refined the seismic sequences into a local series A through T (see also Henrys et al., this volume).

The analysis of the seismic reflection data was based on a "type section" defined at the intersection of IT69 (SP 1590) and USGS414 (SP 5860) (Fig. 2):

Table 1. Section at intersection of lines IT69 and USGS414.

Unconformity	Depth (s twt)	comment
RSU6	1.1 s bsf*	defined by Brancolini et al 1995, line IT69
V3/V4	1.6 s bsf	defined by Cooper et al 1987, line USGS414
V4/V5	2.4 s bsf	defined by Cooper et al 1987, line USGS414 SP 6140 and interpreted by us to SP 5860

*bsf - below sea floor

The comparison of the stratigraphies interpreted for the two seismic sections (IT69 and USGS414) forming the "type section", demonstrates that the RS stratigraphy (Brancolini et al., 1995) interpreted in the Victoria Land basin cannot be solely used for the Roberts Ridge part of the Victoria Land basin as events of interest lay below the interpreted RSU6 unconformity, the deepest in the RS seismic stratigraphy. The "type section" also shows that the interpreted RSU6 unconformity in this region is at a shallower depth and hence younger age than both the V3/V4 and V4/V5 seismic unconformities, whereas the RSU6 unconformity where it is constrained in age (in Eastern Basin) and V4/V5 are expected to be of about the same age (Brancolini et al., 1995)

The seismic section for line IT69 (Fig. 3) used in our interpretation has greater continuity and detail at depth than previous available sections, and is the key line as it runs from the "type section", across the Roberts Ridge, to close to (north of) the drill sites (Fig. 1). This seismic section gave more confidence in following deeper, sub-multiple, seismic reflectors across Roberts Ridge. The interpreted events on line IT69 are shown in figure 3. The events were also traced into the Cape Roberts Project drill site area via three additional routes, two northern links (IT75, NBP9407-53 and NBP9601-97 to IT69, and IT75, NBP9601-93, NBP9601-94, IT68 to IT69) and a southern link (IT73, IT72, (1.5 km gap) to NBP9601-83) (Fig. 1). The NBP9601 MCS lines were concentrated in the region of Roberts Ridge (Fig. 1). They were used to trace individual reflections through a network of seismic profiles across Roberts Ridge. The redundancy in correlation paths compensated for areas on individual lines where, for example, structure, faulting, and erosion resulted in ambiguity in tracing events.

The depth and ages of the events at the CRP drill holes were derived from the drill core velocity logs and age data (Cape Roberts Science Team, 1998; 1999; Henrys et al., this volume).

DISCUSSION

RSU6

The seismic reflection interpreted as RSU6 on line IT69 at its intersection with line USGS414 (Fig. 2) can be traced with confidence along line IT69 across Roberts Ridge, and lies above V3/V4. Comparison with CRP drill site data (Cape Roberts Science Team, 1998; 1999) shows that drillholes CRP-1 and CRP-2/2A would have penetrated this event close to the seafloor, corresponding to an age of less than about 17 Ma. This event is much younger than the age inferred for RSU6 in the eastern Ross Sea (>26.7 Ma (Busetti & Cooper, 1994), preferred age 30 Ma (De Santis et al., 1995)) and suggests that the correlation of the seismic sequence boundary RSU6 being traced through the Ross Sea and into the Victoria Land basin is incorrect. On the basis of age, the RSU6 reflector in the Eastern Basin may correspond to the V4/V5 event that would intersect CRP-2A drill hole at a depth of about 440 m bsf. This is consistent with Cooper et al. (1987) who defined V4/V5 as the same as the regional unconformity U6 of Hinz and Block (1984) which is equivalent of RSU6 in Eastern Basin (Brancolini et al., 1995).

V3/V4

Interpretation for V3/V4 and V4/V5 via four main routes give a consistent correlation of seismic events at the drill sites with the assumed "type section" at the intersection of lines USGS414 and IT69. We noted that the V4/V5 reflection on the eastern part of IT69, as defined from profile USGS414, appears to correspond to a peg-leg multiple. A slightly deeper low frequency reflector, considered primary, can be traced to western Roberts Ridge and is inferred to be V4/V5 event. At drill site CRP-1, event V3/V4 is just below the base of the hole, using velocity logs from the drill core (Cape Roberts Science Team 1998). Drill hole CRP2 intersected V3/V4 at a depth of about 90 m. Although there is some uncertainty in the

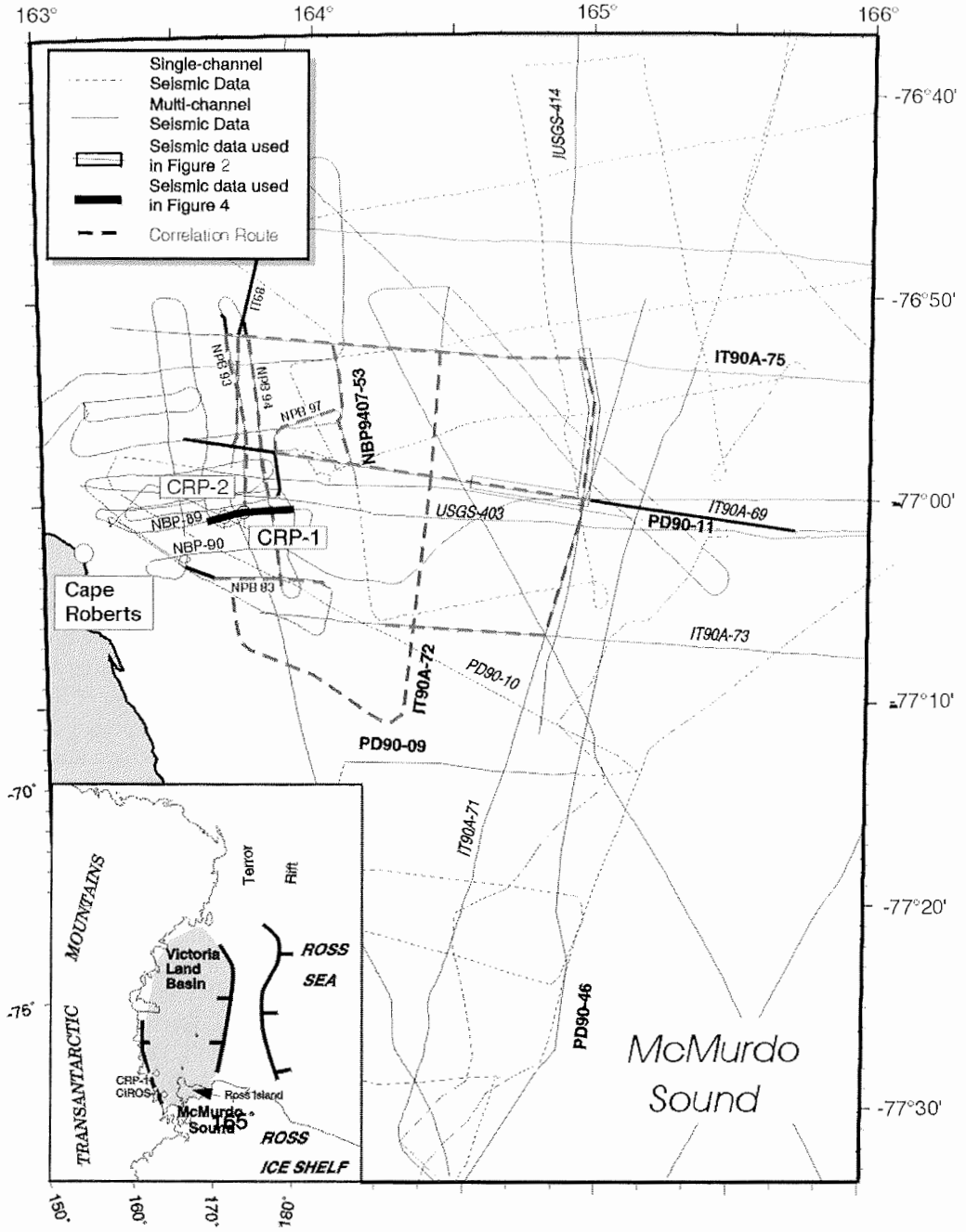


Fig. 1 - Location of study area, seismic lines and correlation paths (after Henrys et al. 1999).

precise age of the cores, an early Miocene age (21 Ma) is indicated for event V3/V4 at the drill sites. At CIROS-1, V3/V4 was interpreted to correspond to a major unconformity covering the period 30-34 m.y. at 366 mbsf (Bartek et al., 1996). However, the interpretation of seismic units over the basin flanks and below the sea-floor multiple at the CIROS-1 is difficult and remains uncertain (Henrys et al., 1998). Correlation of the seismic reflection data set with CIROS-1 has not been re-evaluated as no improved data set exists in the region. Between the V3/V4 and V4/V5 events at Cape Roberts, an intermediate event was correlated extensively across the western flank of Roberts Ridge. It corresponds to the alternate (lower) V3/V4 reflector of Henrys et al. (1998), and the V3/V4 of Hamilton et al. (1998). It is at a depth of about 220 m bsf at site CRP2A and corresponds to an age of about 24 Ma. This reflector is a subtle seismic unconformity in the area of CRP2A. A deeper, much more angular seismic unconformity correlates closely in depth to a geological unconformity at 307 mbsf in CRP-2A. The intervening seismic sequence appears to pinch out in all directions; highlighting the difficulty of mapping units in the region.

V4/V5

The V4/V5 event crosses drill hole CRP-2/2A at 400 ms twt bsf, equivalent to a depth of about 440m using velocity logs from the drill hole (Cape Roberts Science Team 1999). A significant geologic unconformity occurs at 443 m in the drill hole, corresponding in age to the late/

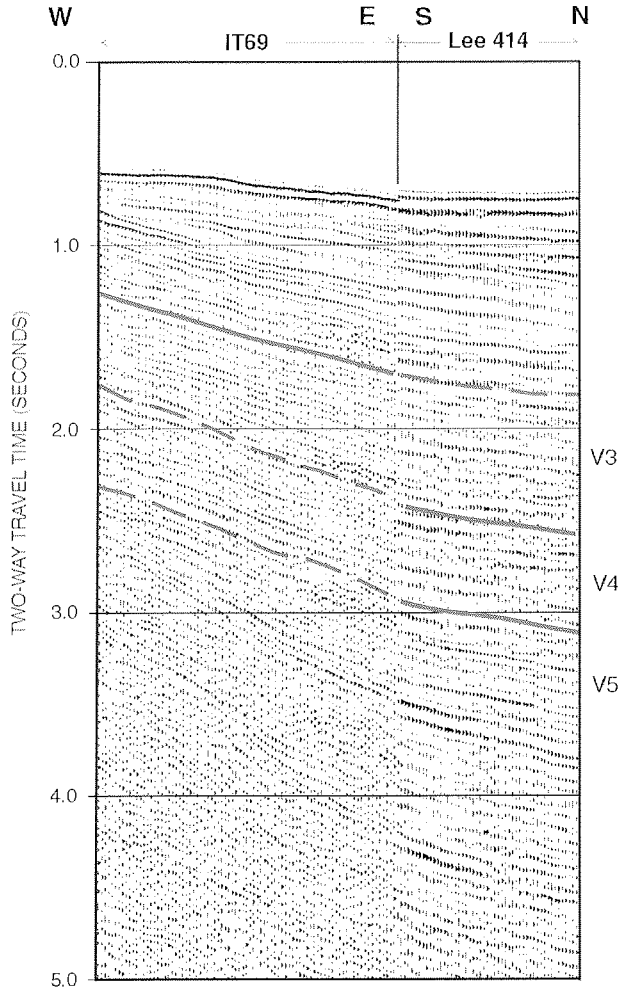


Fig. 2 - Seismic profile formed by joining line USGS414 and IT69 at their intersection (USGS414 to the north and IT69 to the west) - the "type section" - showing the seismic events RSU6, V3/V4 and V4/V5 used in this analysis (after Brancolini et al., 1995; Cooper & Davey, 1987). The profile is located on figure 1.

early Oligocene boundary at about 28.5 Ma (Cape Roberts Science Team, 1999). This corresponds to the strong V4/V5 reflector on the seismic data (NBP9601-89), and, on an age basis, we would suggest that this event may correspond to RSU6 in the Eastern basin. This correlation analysis indicates that a deeper seismic event (Fig. 4), previously identified as V4/V5 by Hamilton et al. (1998) and Henrys et al. (1998), lies within unit V5. These seismic unconformities can be also correlated to the detailed McMurdo Sound seismic stratigraphy, Q through T, of Bartek et al. 1996, (also Henrys et al., this volume).

CONCLUSION

Our study has indicated the difficulty of tracing major seismic events deep in the Victoria Land basin where seismic horizons are largely conformable, with problems arising apparently from peg-leg multiples. However, correlation of several regional seismic events interpreted for the Victoria Land basin can be carried onto the western flank of Roberts Ridge, and to the Cape Roberts drill sites (Fig. 4). Ages for these events can then be derived from the CRP drill core ages. The shallowest of these events has been correlated with the interpreted RSU6 seismic unconformity in the southern Victoria Land basin. Its age at the CRP drill sites is less than about 17 Ma, much younger than that inferred for the RSU6 in the eastern Ross Sea (>26.7Ma) and we suggest that the correlation of this seismic sequence boundary from the Eastern basin into the southern Victoria Land basin is incorrect. In this case, RSU6 in the Eastern basin may correspond closely to V4/V5 (approximately 440 mbsf in the CRP2A drill hole). The present study has resolved the ambiguity in correlation of V3/V4 with the seismic data in the Cape Roberts region noted by Henrys et al. (1998). The V3/V4 event (the upper

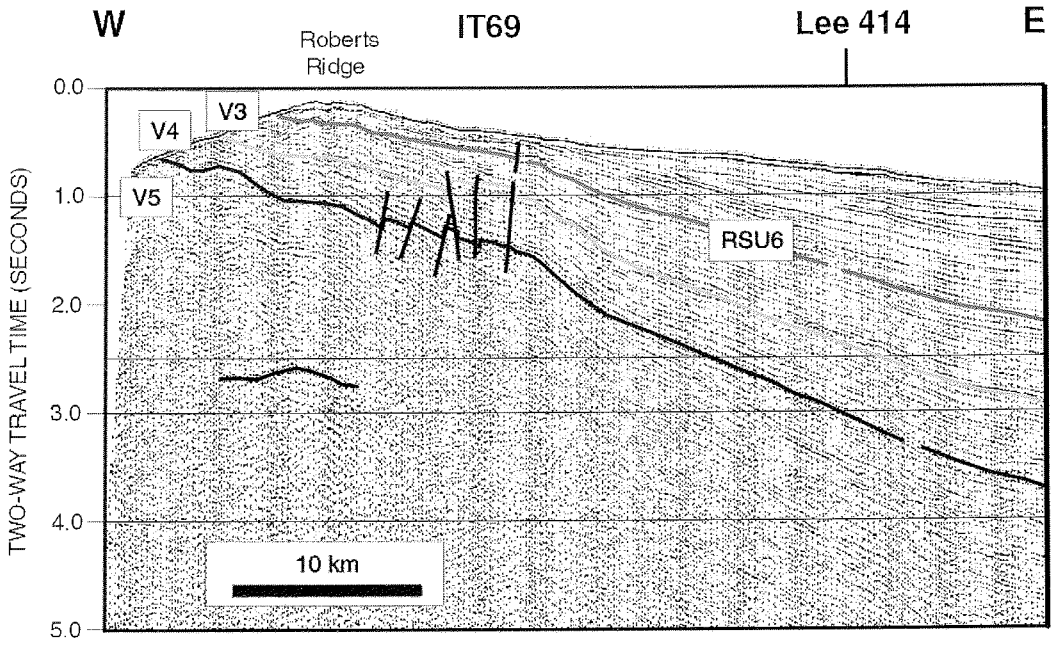


Fig. 3 - Seismic profile IT69 showing seismic event correlations from the published interpretations at the eastern end to the drill site area. The profile is located in Fig. 1.

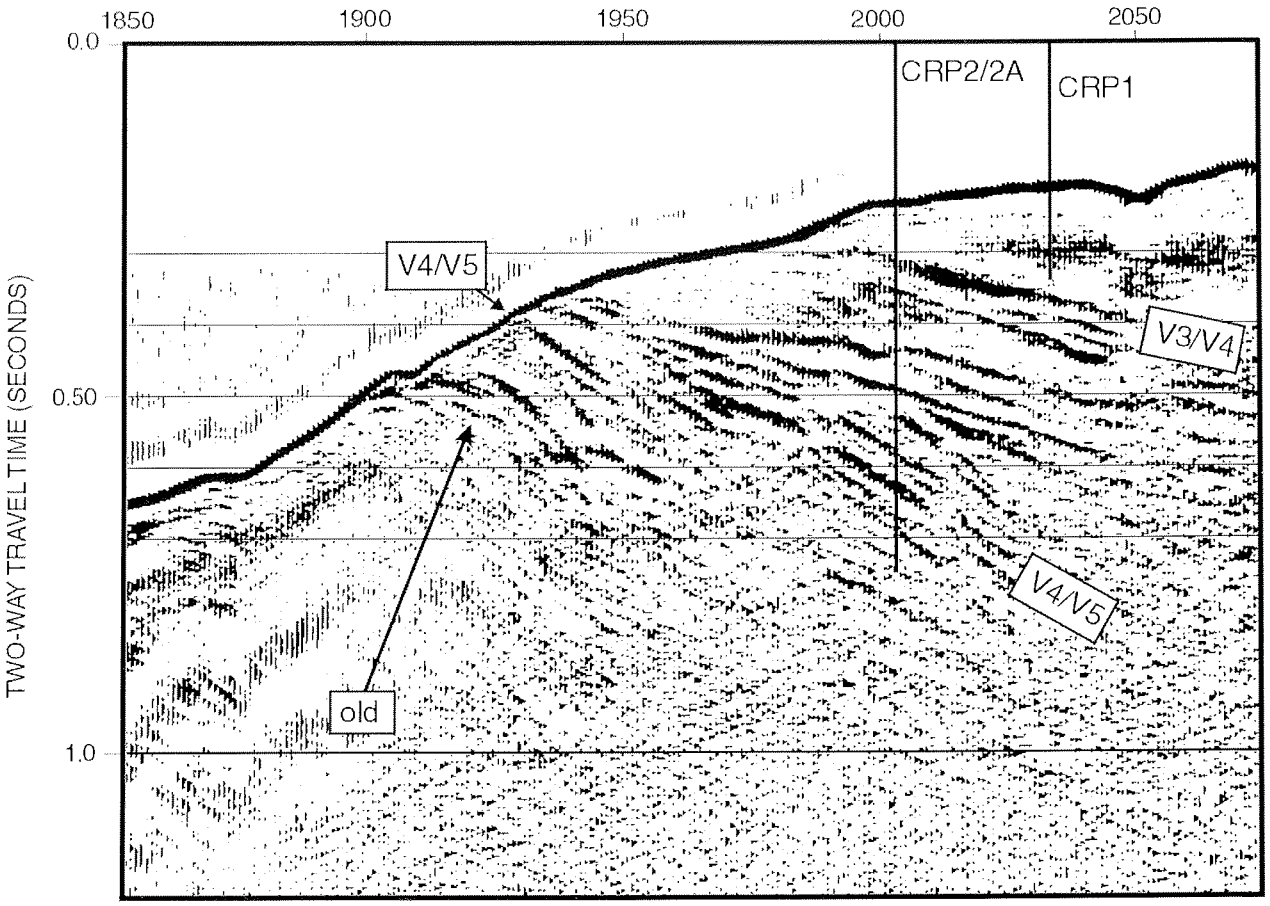


Fig. 4 - Seismic profile NBP89, showing seismic unconformities ("old" refers to the interpreted V4/V5 unconformity of Hamilton et al. 1998 and Henrys et al. 1998) and CRP2/2A drill hole location. The profile is located on figure 1.

alternative of Henrys et al., 1998) is at a depth of about 90 m bsf at site CRP-2A and has an age of about 21 Ma. An event between V3/V4 and V4/V5 (the lower V3/V4 unconformity of Henrys et al. (1998)) can be correlated extensively across the western flank of Roberts Ridge. It is at a depth of about 220 m bsf at site CRP-2A and has an age of 24 Ma. V4/V5 is at a depth of about 440 m bsf at site CRP-2A and corresponds closely to a geologic unconformity in the drill core at 443 m bsf with an age of about 28.5 Ma. A deeper sequence boundary, previously interpreted as V4/V5, lies within unit V5 and crops out at the seafloor close to a bench in the seafloor topography on line NBP9601-89.

Our results indicate that tectonic events in the western Ross Sea, based on the RS stratigraphy, may be significantly younger than originally inferred.

ACKNOWLEDGEMENTS

Dr Bruce Luyendyk (USCB) for hosting the meeting at which the correlations were made. This work was supported by the Office of Polar Programs grants 9316716 to L. Bartek and 9316712 to B. Luyendyk and by NZ Foundation for Research Science and Technology Grant C05815. Contribution 0343—95TC TC of the Institute for Crustal Studies. We greatly appreciated thoughtful reviews by A. K. Cooper and B. Luyendyk.

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