FINDING THE CONTINENTAL SHELF – EXAMPLES FROM THE NEW ZEALAND REGION

ABSTRACT

New Zealand has nearly completed the surveying phase of its Continental Shelf Project. Some surveys have been designed to fill gaps in the 2,500 m isobath and bathymetric foot of slope positions. Others have been designed to collect data to demonstrate natural prolongation and to determine sediment thickness beyond the foot of slope.

The seafloor around New Zealand is characterised by ridges and plateaus that reflect the complex tectonic history of the region. Rifting and subduction processes have resulted in continental fragmentation and continental growth by the accretion of terranes and the formation of island arcs. These complexities raise questions about how Article 76 should be interpreted in order to identify the edge of the Continental Shelf.

The geological and morphological connection of two large continental fragments, Gilbert Seamount and Bollons Seamount, with the New Zealand landmass are discussed. Consideration of their relationship with the landmass highlights a number of issues concerning natural prolongation.

The geological and morphological connection of the Hikurangi Plateau and the Resolution Ridge System with the New Zealand landmass are discussed. Their relationship with the New Zealand landmass shows that a subduction trench/plate boundary does not necessarily define foot of slope positions.

INTRODUCTION

New Zealand setting

New Zealand comprises two major islands and a number of smaller islands in the Southwest Pacific. The total land area is about 250,000 km^2. These islands are surrounded by large submarine plateaus, typically lying at depths of 500-2000 m. The present 200 M Exclusive Economic Zone (EEZ) covers an area of about 4,000,000 km^2.

New Zealand has had a dynamic geologic history, strongly affected by plate tectonic events for at least the last 160 Ma. As a result of this dynamic history the geology and bathymetry of the New Zealand region is complex, characterised by plateaus, ridges, troughs, seamounts, volcanic arcs, fracture zones and oceanic spreading centres (Figure 1). The continent is a complex amalgamation of rifted crustal plateaus, accreted terranes and volcanic arcs.

Several phases of plate convergence have affected the New Zealand region. A major period of continental growth took place along the Gondwana margin from the Triassic to the Early Cretaceous (230-115 Ma) and these rocks are a major component of the basement rocks of New Zealand (e.g., Mortimer & Tulloch 1996). Accretion of the Northland Allochthon, of the order of 100,000 km^3, took place about 25 Ma (Isaac, et al. 1994), and oblique convergence is occurring along the modern plate boundary east of the North Island and southwest of the South Island.

The New Zealand continental block has been fragmented by at least two major phases of rifting. The fragmentation of Gondwana began more than 80 Ma and resulted in the separation of New Zealand from Australia and Antarctica. The modern plate boundary began to develop through New Zealand about 40 Ma. Evolution of this margin has involved rifting, large-scale transform faulting, and oblique subduction. The submarine plateaus surrounding

New Zealand are geologically related to the land territory, the difference in elevation primarily reflecting distance from the present plate boundary.

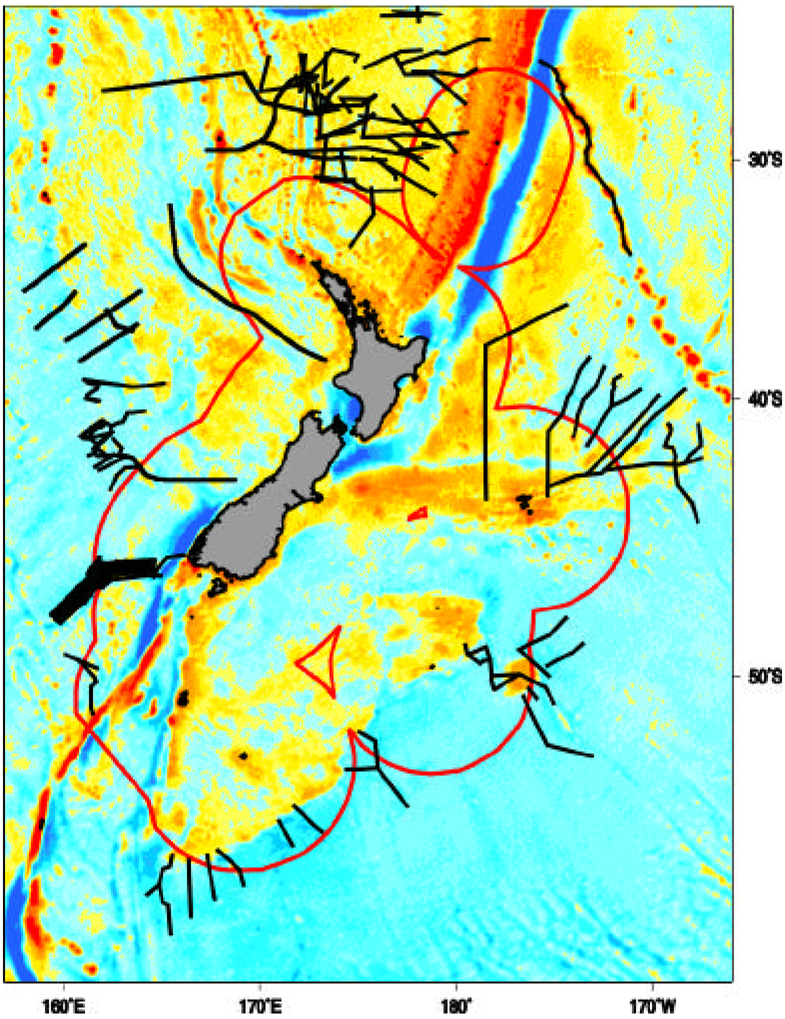

Figure 1. Satellite gravity map of the New Zealand region showing the 200 M EEZ and the location of surveys undertaken as part of the Continental Shelf Project.

Continental margins similar to the simple cartoon model often used to illustrate the application of Article 76 are relatively rare in the New Zealand region. Planning of the surveys for the Continental Shelf Project required consideration of how Article 76 applies to complex margins.

Continental Shelf Project

New Zealand signed the United Nations Convention on the Law of the Sea and began its Continental Shelf Project in 1996. The project team has called on geological, geophysical, hydrographic and geodetic expertise as required. Most of the data collection phase of the project has been completed. We are just starting a major effort on data integration and analysis.

The project has had several phases, each focused on one or more geographic areas. Each phase started with a desktop study to compile and analyse existing data. The desktop studies collected the available data (bathymetry, seismic, gravity, magnetics, rock samples), determined the aspects of Article 76 that were relevant, assessed if the quality of the data was sufficient to delineate New Zealand's Continental Shelf, and finally identified where and what kind of additional data were required. Survey lines were designed to complete determination of the 2,500 m isobath and bathymetric foot of slope positions at intervals of less than 60 M. They were also designed to determine the relationship of the rocks on and beneath the sea floor to those onshore, and to find areas of significant sediment thickness beyond the foot of slope positions.

The diagrams presented in this paper show preliminary interpretations of bathymetry and geophysical data. Processing of these data is not complete and their interpretation may change following their integration with all the data in the regions.

CONTINENTAL FRAGMENTS FROM RIFTED MARGINS

Rifted margins are often characterised by a transition zone between continental and oceanic crust, sometimes containing large fragments of continental rocks. A major factor influencing the determination of the extent of the Continental Shelf is the nature of the connection between these fragments and the continental landmass.

Gilbert Seamount and Bollons Seamount are examples of elevated continental fragments, morphologically separated from the main body of the adjacent plateaus by the Cretaceous break-up of Gondwana (Figures 2, 4). The structure and morphology of these seamounts were relatively poorly known prior to the commencement of the Continental Shelf Project, and several surveys were conducted to determine their relationship with onshore New Zealand.

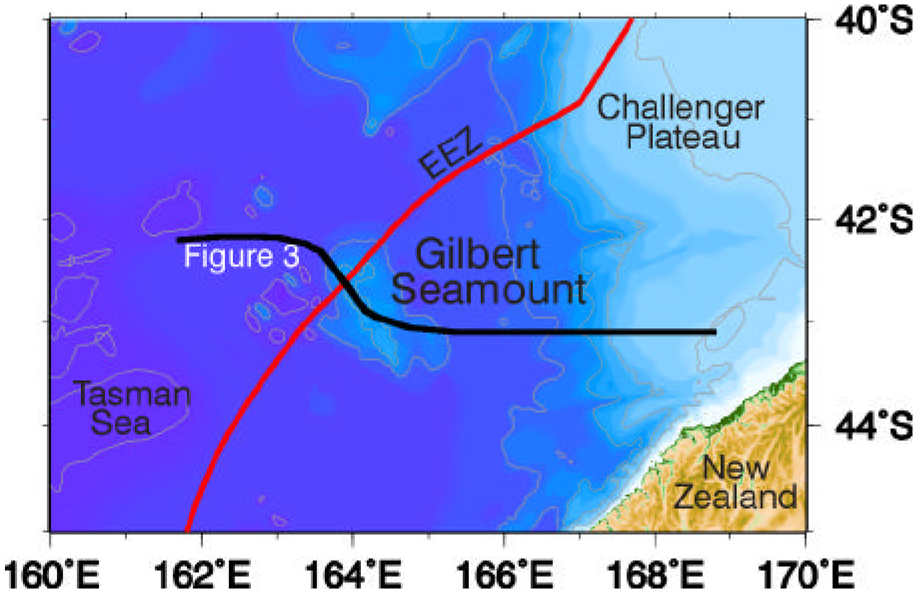

Figure 2. Bathymetry of the Gilbert Seamount region (CANZ 1997). The location of the EEZ and the profile in Figure 3 are indicated.

Gilbert Seamount

Description

Gilbert Seamount is located 450 km west of the South Island of New Zealand, and 250 km southwest of the Challenger Plateau (Figure 2). It has an area of about 11,500 km^2 and shallows to a depth of 2,400 m. It is elongated northwest-southeast, parallel to the rift margin along the Challenger Plateau. The seamount lies almost entirely within the EEZ.

Gilbert Seamount has been considered to be continental in origin, largely because of its elevation and proximity to the rift margin (Ringis 1972). Magnetic anomalies associated with seafloor spreading have been mapped in the Tasman Sea (e.g., Gaina et al. 1998), but have not been identified between Gilbert Seamount and the Challenger Plateau. Analysis of seismic, gravity and magnetic data indicates that crustal thinning has taken place along the margin, but that there is a continuous connection of continental rocks between the seamount and the New Zealand mainland (Figure 3; Wood and Woodward 1999, V. Stagpoole pers. comm. 2001). Basement structure shows half grabens extending across the Challenger Plateau margin and Gilbert Seamount, probably containing Cretaceous sediments.

Morphologically, the saddle between Gilbert Seamount and the Challenger Plateau is about 4,400 m deep, significantly shallower than the 5,000 m depths in the Tasman Basin. The youngest sediments in the saddle are part of coalescing fans, deposited by the Haast and Hokitika canyons, that largely encompass the seamount.

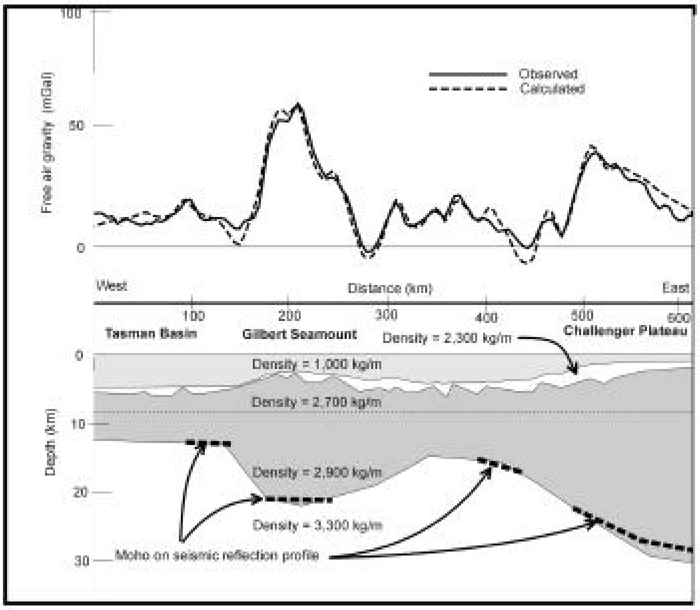

Figure 3. Interpretation of seismic and gravity data on line NZ-C across Gilbert Seamount and the Challenger Plateau margin (V. Stagpoole pers. comm. 2001).

Continental Shelf Discussion

Gilbert Seamount is separated by a saddle from the Challenger Plateau and the New Zealand landmass, but it is a natural prolongation of onshore New Zealand. Its continuous geologic and morphological connections with the landmass both support this conclusion. The seamount is therefore a natural component of the margin and not a submarine or oceanic ridge. Because it is a natural component of the margin, its 2,500 m isobath could be used to extend the cutoff of the Continental Shelf beyond 350 M (although it is not an issue in this case as the 2,500 m + 100 M cutoff lies inside the 350 M cutoff).

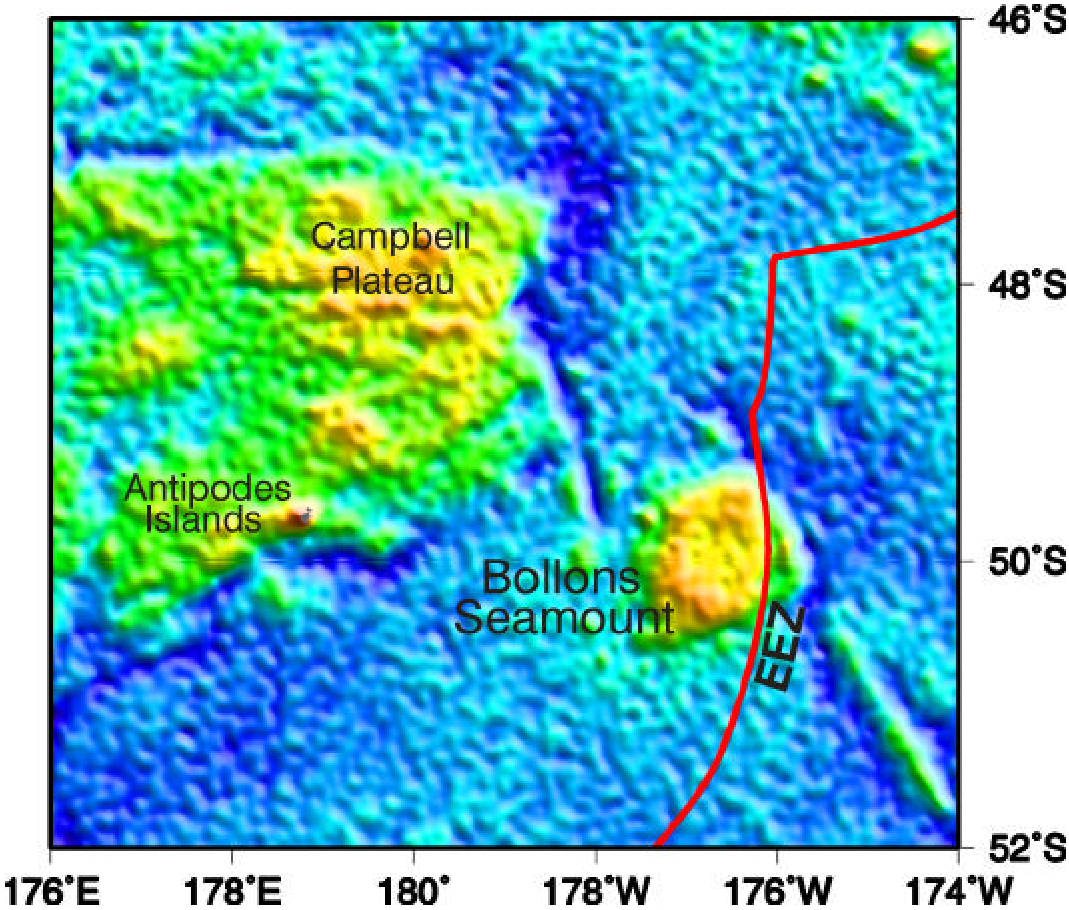

Figure 4. Satellite gravity map of Bollons Seamount and Campbell Plateau. The location of the EEZ is indicated.

Bollons Seamount

Description

Bollons Seamount is located 1,000 km southeast of the South Island of New Zealand and 300 km west of the Antipodes Islands on the Campbell Plateau, the closest part of the New Zealand landmass (Figure 4). It lies almost entirely within the EEZ. Bollons Seamount has an area of about 22,000 km^2 and shallows to less than 1,000 m. It is roughly rectangular in shape.

Very little is known about Bollons Seamount, but the release of global satellite gravity data (Smith and Sandwell 1995) revealed south-southeast trending fracture zones on either side of it. These fracture zones and seismic data across the seamount show that Bollons Seamount is continental in origin. It was a contiguous part of the Campbell Plateau until about 83 Ma.

The structural and morphological connections of the seamount to the Campbell Plateau are inadequately surveyed, and are likely to be complex. The satellite gravity data suggest that the rifting between Bollons Seamount and the Campbell Plateau may be farther advanced than that between Gilbert Seamount and the Challenger Plateau. We do not yet know how much of a sedimentary apron surrounds the seamount. No magnetic anomalies have been identified between Bollons Seamount and the Campbell Plateau, but a clear connection of either continental rocks or seafloor morphology like that of Gilbert Seamount has not yet been identified.

Continental Shelf Discussion

Bollons Seamount is clearly a fragment of the New Zealand continent and therefore not an oceanic ridge. But a number of questions arise:

1. If a continuous geologic or morphological connection to the Campbell Plateau cannot be found, is Bollons Seamount a natural prolongation of the New Zealand landmass?
2. Is its location within the EEZ relevant?
3. Is Bollons Seamount a natural component of the margin or a submarine ridge (determining whether its 2,500 m isobath could be used to extend the cutoff of the Continental Shelf beyond 350 M, although it is not an issue in this case)?

ACCRETED TERRANES AT CONVERGENT MARGINS

As mentioned in the Introduction, several periods of plate convergence have resulted in the growth of the New Zealand continent by terrane accretion. In terms of determining the extent of the Continental Shelf, the biggest challenge is the same as for rifted margins: to understand the connection between these terranes and the continental landmass.

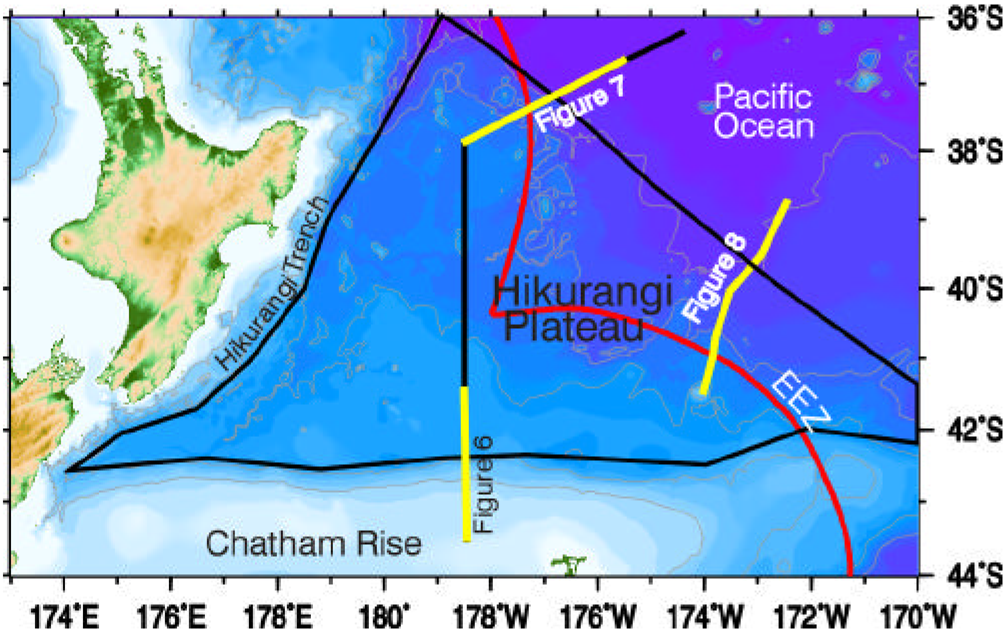

Figure 5. The black line indicates the extent of the Hikurangi Plateau large igneous province east of the North Island, New Zealand. The location of the EEZ and profiles in Figures 6-8 are also indicated.

Hikurangi Plateau

Description

The Hikurangi Plateau is a large igneous province lying east of the North Island and north of the Chatham Rise (Wood and Davy 1994; Mortimer and Parkinson 1996). It has an area of about 350,000 km^2 and lies at an average water depth of about 3000 m. It has a complex structure, but most seismic lines show several kilometres of sediments overlying a sequence of volcanic rocks. Gravity modelling indicates that its crust is 10-15 km thick, compared to 5-7 km for the oceanic crust to the northeast (Davy and Wood 1994).

The age of the volcanic rocks of the plateau is unknown, but they are older than 70 Ma (Strong 1994). They may be similar in age to other large igneous provinces in the Pacific

(115-125 Ma; Mortimer and Parkinson 1996), or perhaps more than 160 Ma, the age of compressive deformation along the Chatham Rise which may have been associated with their collision with New Zealand (Davy 1992). The Hikurangi Plateau is currently being subducted beneath the North Island along the Hikurangi Trench.

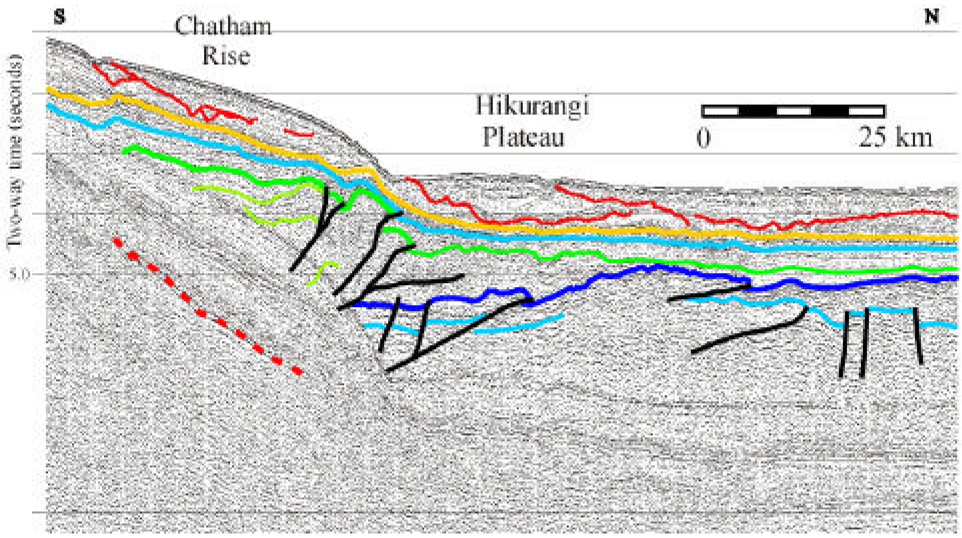

Figure 6. Seismic line OCR-5 across the Chatham Rise – Hikurangi Plateau margin showing deformation associated with subduction of the Hikurangi Plateau.

Figure 6 shows a seismic line recorded across the northern margin of the Chatham Rise and the Hikurangi Plateau. Volcanic basement of the Hikurangi Plateau can be traced beneath the Chatham Rise, and it appears that deformation of Mesozoic basement rocks on the flank of the rise can be related to subduction of the plateau.

Analysis is continuing, but there is no doubt that the Hikurangi Plateau has been part of the New Zealand continent for at least 70 Ma, and possibly more than 160 Ma. The basement rocks of New Zealand are characterised by a number of terranes accreted to the Gondwana margin during the period 230-115 Ma (Mortimer & Tulloch 1996). The Chatham Rise is part of the old Gondwana margin, and the Hikurangi Plateau is probably the last of these terranes to be accreted (Davy 1992).

There is a break in slope along the base of the Chatham Rise (Figure 6), but Figure 7 shows that this is only an intermediate drop to 2600 m before the final steep descent from the Hikurangi Plateau to the deep ocean floor, 5200 m below sea level. The morphologic foot of slope lies seaward of the scarp along the northeast margin of the Hikurangi Plateau.

The boundary of the Hikurangi Plateau, however, does not always coincide with a pronounced morphologic boundary such as the scarp in Figure 7. In Figure 8, the boundary between the Hikurangi Plateau and oceanic crust to the north is near the northeast end of the line, about 100 km beyond a prominent bathymetric foot of slope position.

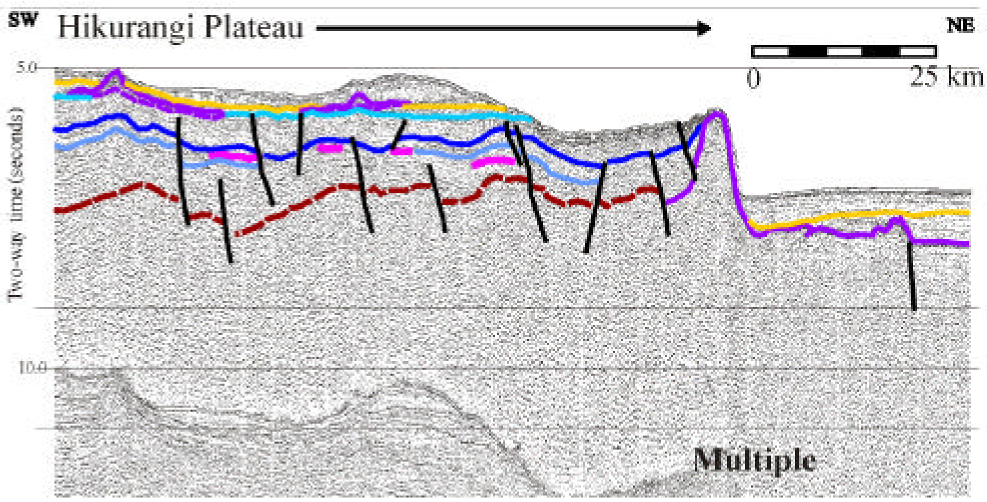

Figure 7. Seismic line HKDC-1 across the Hikurangi Plateau margin with oceanic crust to the northeast.

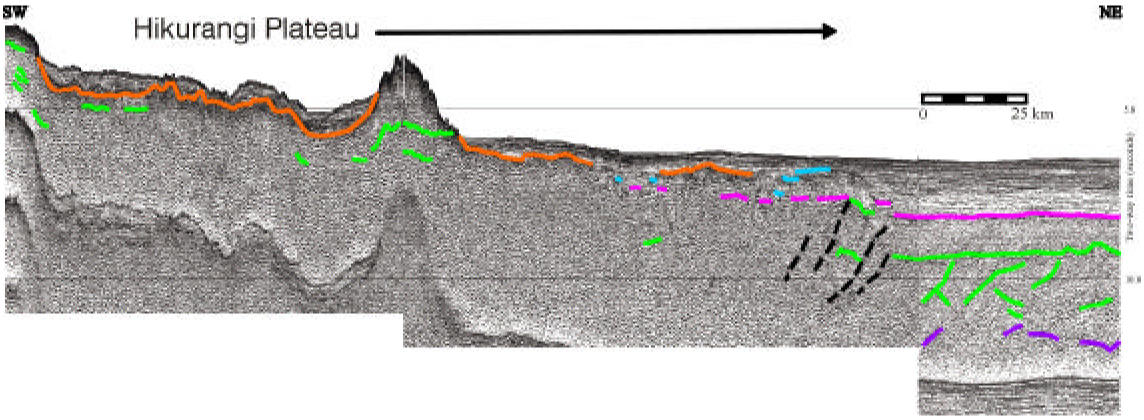

Figure 8. Seismic line HKDC-4 across the northeast margin of the Hikurangi Plateau. The boundary between the Hikurangi Plateau and oceanic crust to the northeast lies near the northeast end of the line.

Continental Shelf Discussion

The Hikurangi Plateau lies at an average depth of about 3,000 m and is being subducted beneath the North Island, but it is a natural prolongation of the New Zealand landmass. There is a continuous connection between the rocks of the Hikurangi Plateau and those of the Chatham Rise and onshore New Zealand. The plateau is therefore a natural component of the margin and not a submarine or oceanic ridge.

In the north, the boundary of the Hikurangi Plateau closely coincides with the morphologic foot of slope, and determining the extent of the Continental Shelf will be straightforward. In the east, the boundary of the Hikurangi Plateau is clearly identifiable but does not have a prominent morphologic foot of slope. Determining the extent of the Continental Shelf in this region may rely on 'evidence to the contrary.'

Because the Hikurangi Plateau is a natural component of the margin, seamounts that are part of the plateau and shallow to less than 2,500 m could be used to extend the cutoff of the Continental Shelf beyond 350 M.

Resolution Ridge System

Description

The Resolution Ridge System is comprised of a series of bathymetric ridges extending southwest of Fiordland for about 500 km (Figure 9; Wood et al. 1996). The eastern half of the ridge system lies within New Zealand's EEZ. The ridge system exhibits a segmented, right-stepping en echelon geometry. Resolution Ridge, the easternmost ridge of the system, is about 2,000 m deep. The ridges deepen to the southwest to about 3,500 m. The blocks are often separated by relatively flat seafloor at about 4,500 m depth.

The largest seamount in the system, Resolution Ridge, divides the Puysegur and Fiordland trenches along the Pacific-Australian plate boundary. Convergence across this boundary is very oblique.

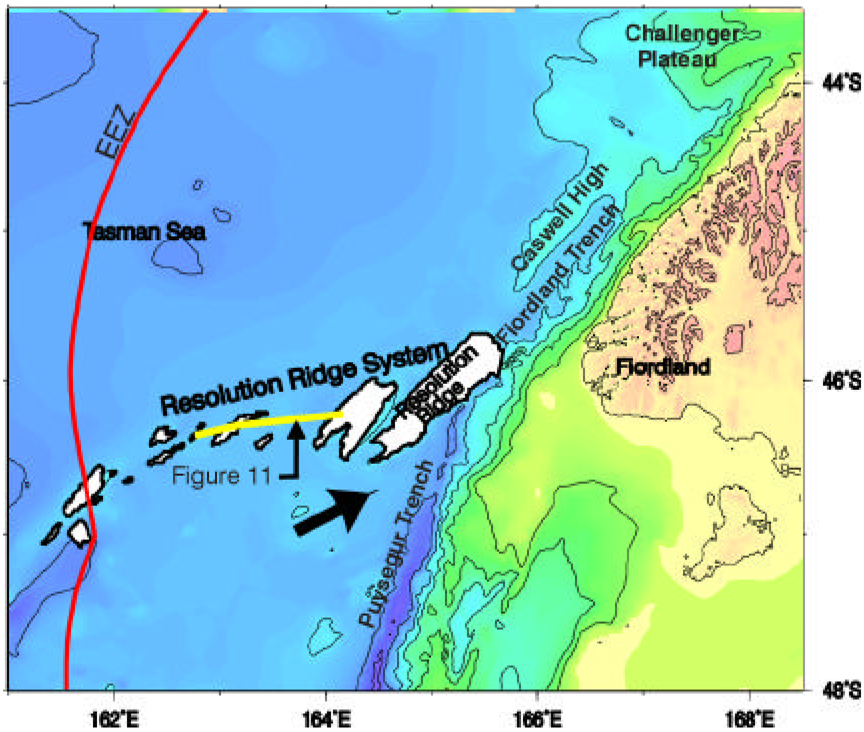

Figure 9. The Resolution Ridge System extends about 500 km southwest from Fiordland. The location of the EEZ and the profile in Figure 11 are indicated. The large arrow marks the direction of oblique convergence between the Pacific and Australian plates.

At least some of the blocks at the eastern end of the Resolution Ridge System are continental in origin (Wood et al. 1996), probably fragments of the western Campbell Plateau margin separated by rifting about 43 Ma (Sutherland 1995). It is likely that they are geologically connected to the Challenger Plateau and the South Island by continental rocks of the Caswell High (Wood et al. submitted). Magnetic anomalies and seafloor morphology indicate that blocks at the southwest end of the system are likely to be oceanic (Figure 10).

Analysis of the data is continuing, and the boundary between rocks of continental origin and oceanic rocks has not yet been identified. Figure 11 shows a seismic section along the eastern part of the ridge system. Block faulting of basement is evident in the basin between the high-standing ridges, and there is no sign of oceanic crust. Magnetic data in the southwest part of the area show clear correlations with magnetic sea floor spreading anomalies in the Tasman

Sea. There is no apparent correlation with these anomalies in the east part of the ridge system (Figure 10).

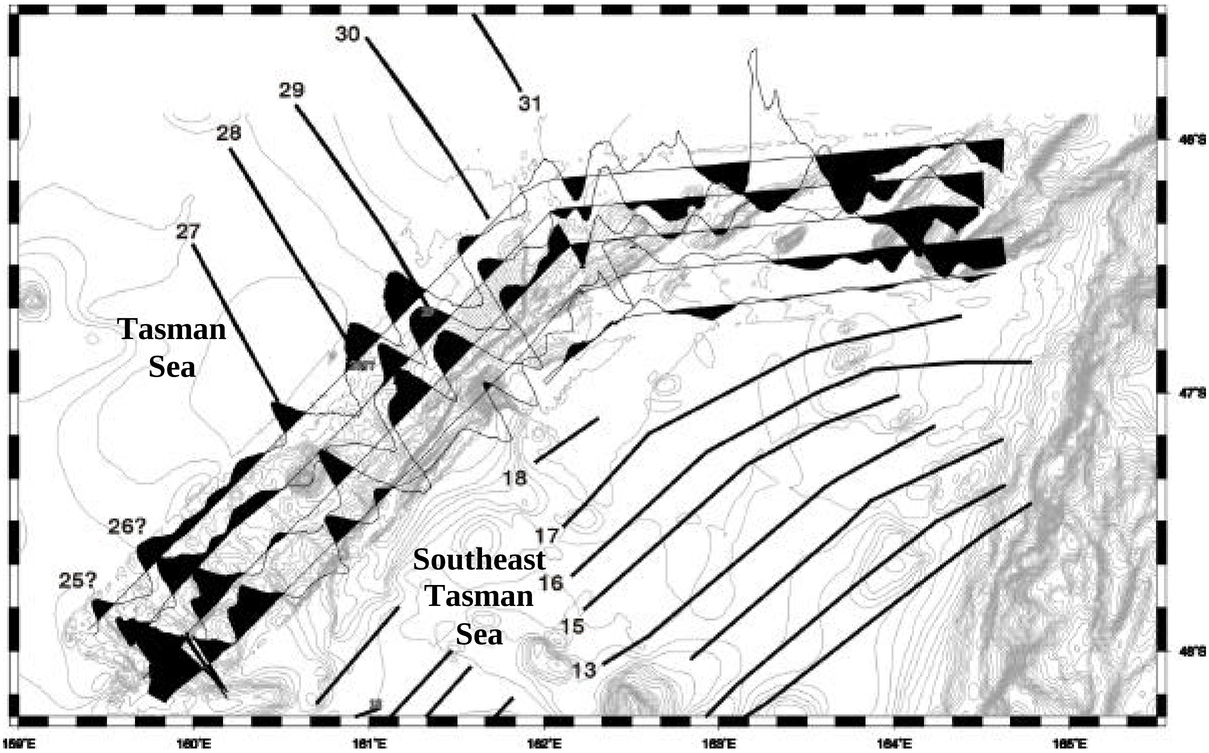

Figure 10. Magnetic anomalies along the Resolution Ridge system and seafloor spreading anomalies identified in the Tasman Sea (Cande et al. 1989) and Southeast Tasman Sea (Wood et al. 1996).

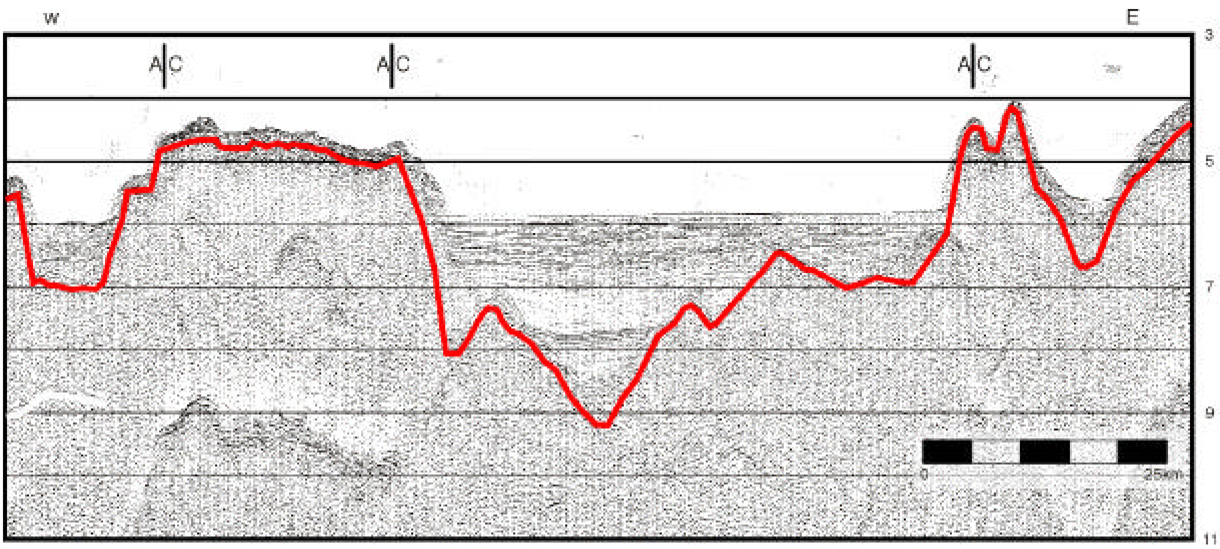

Figure 11. Seismic line along the eastern portion of the Resolution Ridge System. Preliminary interpretation of basement structure is shown in red. The west flank of Resolution Ridge is at the right of the diagram.

Motion along this plate margin has changed with time, with convergence beginning about 6.4 Ma (Walcott 1998). An inferred collapse structure on the inner trench wall south of the intersection with Resolution Ridge is thought to be evidence of collision of another en echelon ridge block (Delteil et al. 1996). Accreted pieces of the ridge system have not been identified on the inner trench wall, but large magnetic anomalies on the Pacific Plate east of Resolution Ridge (Delteil et al. 1996) could be associated with accreted material

Continental Shelf Discussion

The Resolution Ridge System crosses the Pacific-Australia plate boundary, but at least some of the ridges are natural prolongations of the New Zealand landmass. Farther north, the plate boundary bisects onshore New Zealand, and parts of the landmass are on each plate. The ridge system is geologically and morphologically connected with both parts of the landmass - across the trench to Fiordland, and north to the continental rocks of the Challenger Plateau and the western South Island. A subduction trench/plate boundary therefore does not automatically correspond with foot of slope positions.

Extending west from Resolution Ridge, the ridge system is not a simple morphological body. Rifting has produced deep basins between the high-standing blocks that are now filled with sediments (Figure 11). Determining the extent of the Continental Shelf in this region may rely on ‘evidence to the contrary.’

CONCLUSIONS

According to Article 76, paragraph 1, “The continental shelf comprises .. the natural prolongation of its land territory”. The key factor for determining the extent of the Continental Shelf, therefore, is the relationship of the seabed and subsoil to the landmass. This relationship can be demonstrated either on the basis of the geology of the rocks or the morphology of the seafloor.

Complexities associated with rifting, convergence and transcurrent plate motion along continental margins raise questions about how Article 76 should be interpreted in order to identify the edge of the Continental Shelf. Rifting can lead to the fragmentation of continental blocks. Convergence can lead to continental growth by the accretion of terranes and the formation of island arcs, and transcurrent margins can displace continental fragments great distances.

Two examples from rifted margins are discussed in this paper. They have different degrees of geological and morphological connection with the New Zealand landmass, and highlight questions about how natural prolongation of the landmass is determined. These questions include:

- ?? Is geological affinity by itself sufficient to demonstrate natural prolongation between elevated fragments of continental crust and the landmass?
- ?? If not, what degree of connection is required to demonstrate natural prolongation?
- ?? If these elevated fragments are all or partially within the EEZ, is it relevant to consideration of natural prolongation?
- ?? Are these elevated fragments natural components of the margin or submarine ridges?

Two examples from convergent margins are discussed in this paper. Both show terranes geologically and morphologically connected with the New Zealand landmass, both being obliquely subducted along the modern plate boundary. The relationship of these terranes with the New Zealand landmass shows that a subduction trench/plate boundary does not necessarily define foot of slope positions.

Determining the extent of the Continental Shelf will require identification of the outer margins of these terranes. In some areas the geological and morphological boundaries are clear and nearly coincident. In other areas, the relationship between the geological and morphological boundaries is more complicated, and determining the extent of the Continental Shelf may rely on ‘evidence to the contrary.’

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