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Norfolk Ridge to Three Kings Ridge Region: FAUST-2, Preliminary Results

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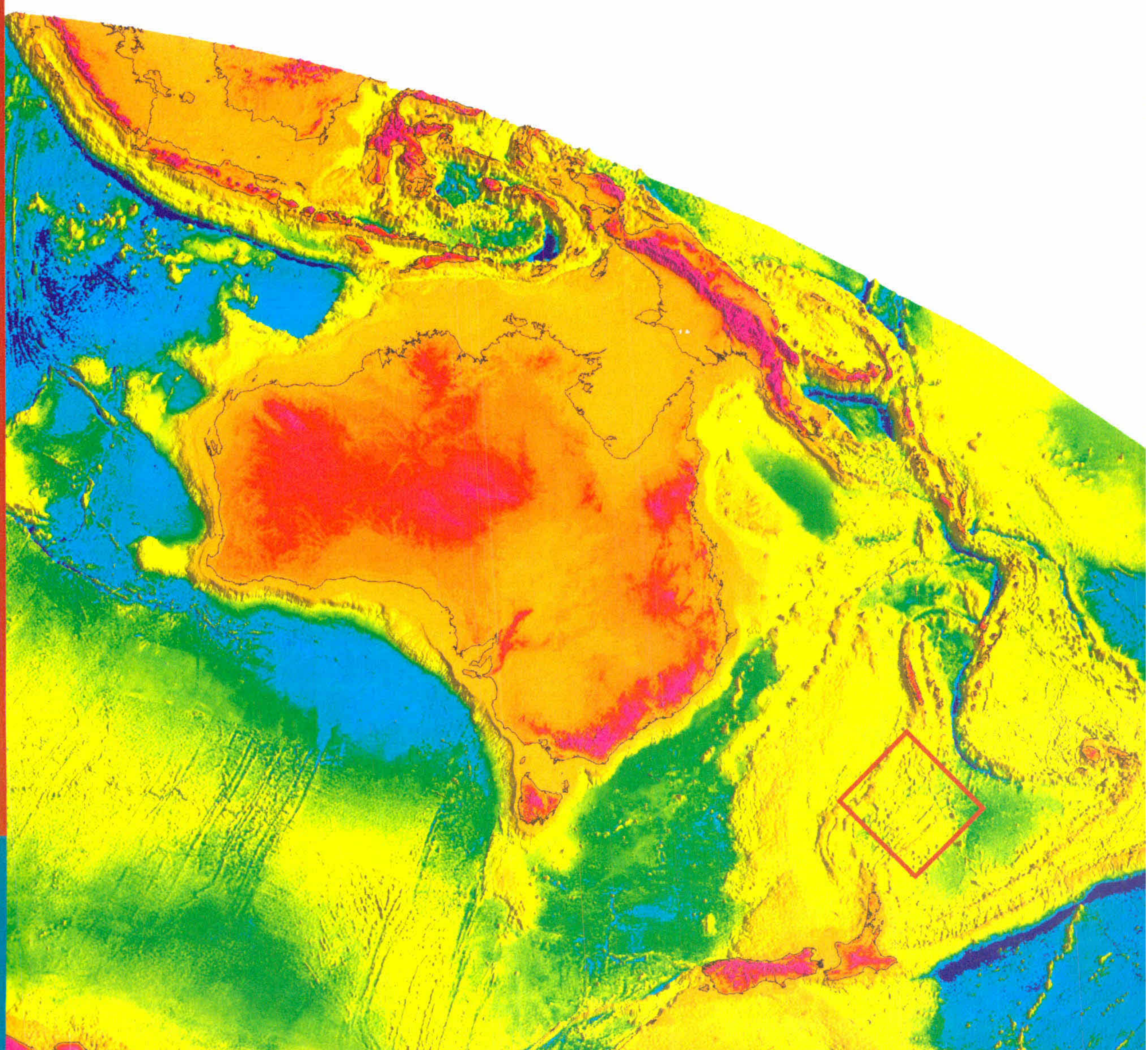

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Collaborative Australia/France Multibeam Seafloor Mapping Survey – Norfolk Ridge to Three Kings Ridge Region: FAUST-2, Preliminary Results

by

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Executive Summary

In November-December 1999, the second of two collaborative surveys involving Geoscience Australia (formerly the Australian Geological Survey Organisation) and the Institut Français de Recherche pour l'Exploitation de la Mer was conducted in the waters east of Norfolk Island towards the submerged Three Kings Ridge. Seabed swath-mapping and geophysical acquisition covered an area of approximately 186 000 km^2. The primary aims were to understand the complex seafloor morphology and the underlying geological framework and tectonic development. The interpretations derived would also clarify the respective Australian and French definitions of legal Continental Shelf under the provisions of the United Nations Convention on the Law of the Sea.

Swath and geophysical data collected included Simrad EM12D swath bathymetry and backscatter, 6-channel GI-gun high-speed seismic, 3.5 kHz sub-bottom profiling, and field gravity and magnetics. This was augmented by successful dredging at three sites and a suite of continuous oceanographic data, including seawater temperature and salinity depth profiles. Weather and sea conditions were mostly favourable resulting in excellent data quality.

The western section of the main survey area, directly east of Norfolk Island, reveals an eastwards-directed spur of the Norfolk Ridge into an area of moderate depth and highly variable seafloor covered by many small volcanoes and wide expanses of elevated basement or stacked lava flows. Several large seamounts trend approximately E-W and source many debris flows. The presence of a large sub-circular basinal depression is problematic.

The central section of the main survey area is characterised by a NNE-trending section of more subdued seafloor largely covered by deformed and undeformed bedded facies. This general trend is perpendicular to the Cook Fracture Zone and suggests extension parallel to fracture zone movement.

The eastern section of the main survey area reveals a prominent N-S trough flanked by seamounts and steep scarps sourcing large quantities of slump facies. It is separated from the main axis of the Three Kings Ridge, which is dominated by seamounts, by a broad terrace region over a deeply sedimented basin. The trough development suggests an E-W extensional phase.

The northern section of the main survey area is dominated by the central axis of the WNW-trending Cook Fracture Zone. This feature is bounded by steep flanks and in places is associated with perpendicular ridges that may represent seafloor spreading fabric. The general configuration of features along the fracture zone indicates left-lateral motion.

Three widely distributed dredges reveal the presence of a volcanic substrate with large amounts of silica, carbonate and manganese precipitation.

Introduction

Throughout the 1990s there have been many discussions between Australian and French scientists aimed at promoting collaborative geoscientific studies in areas of mutual national interest, particularly in the expansive northern Lord Howe Rise/Norfolk Ridge/New Caledonia region. In mid-1997 an informal agreement was reached initially to conduct two collaborative surveys in this large region involving an exchange of ship-time between AGSO (the Australian Geological Survey Organisation; now Geoscience Australia) seismic research vessel R/V *Rig Seismic* and the IFREMER (Institut Français de Recherche pour l'Exploitation de la MER) multibeam seafloor mapping vessel N/O *l'Atalante*. This arrangement was cemented by a formal agreement between the organisations signed in Canberra, Australia, in October 1998 by the President-Director General of IFREMER and the Executive Director (now Chief Executive Officer) of AGSO.

The first survey (French AUstralian Seismic Transect - FAUST-1) was operated by AGSO in April-May 1998 using R/V *Rig Seismic* to conduct a deep-seismic program mostly over the northern Lord Howe Rise, New Caledonia Basin and northern Norfolk Ridge to as far east as the New Hebrides Trench (Lafoy et al., 1998; Bernardel et al., 1999). Some 4600 km of deep-seismic, bathymetry, gravity and magnetic data were collected on four transects across the region. The broad objectives of this survey were to understand the geological framework and tectonic evolution of the submarine ridges and basins in the region; assess the hydrocarbon potential of the region's deep-water sedimentary basins; and to acquire data to enhance claims under the United Nations Convention on the Law of the Sea (UNCLOS, 1983) for extended Continental Shelf beyond the respective Exclusive Economic Zones (EEZs), which are adjacent to the agreed Australia-France seabed boundary.

The second survey of the collaborative program (FAUST-2) concentrated on the Norfolk Ridge - Three Kings Ridge region and the area of complex bathymetry that lies within the eastern part of Australia's 200 nautical mile EEZ around Norfolk Island (Fig. 1). It was operated by IFREMER in November-December 1999 using its multi-purpose seafloor-mapping vessel, the N/O *l'Atalante*. The FAUST-2 survey built upon the knowledge acquired during a 1996 R/V *Rig Seismic* deep-seismic survey (ie. AGSO Survey 177; Ramsay et al., 1997) in the region that was conducted for marine zone definition purposes in collaboration with the New Zealand Ministry of Commerce.

The broad objectives of the FAUST-2 seabed swath-mapping survey were:

- to obtain a clearer picture of the area of complex morphology to the east of the Norfolk Ridge and west of the Three Kings Ridge, as an aid to understanding its geological framework, tectonic evolution and resource potential, and to support environmental and resource management; and

- to examine the extent and nature of possible Australian and French extended Continental Shelf to the east and southeast, respectively, of their EEZs.

The FAUST-2 survey area covered a unique part of Australia's marine jurisdiction that contains evidence for convergent tectonism related to collision and subduction along the eastern margin of the Australia Plate. Several important tectonic features were examined in this area such as possible subduction-related island arcs and extensional back-arc basins lying between two major bounding fracture zones (the Cook and Vening Meinesz Fracture Zones). Apart from utilising N/O *l'Atalante's* standard range of swath-mapping, high-speed seismic and potential field acquisition and processing systems, a limited dredging program was also conducted on basement and seamount scarps distributed across the area. Scientists from IFREMER (Brest), AGSO (Canberra), CNRS-INSU Université Pierre et Marie Curie (Paris), Services des Mines et de l'Energie (Noumea), Université de Lille (Lille), Université de Perpignan (Perpignan), Institut de Physique du Globe de Paris (Paris), and the University of Sydney (Sydney) took part on the cruise.

The cruise began in Noumea, New Caledonia, on 12 November 1999, and ended in Noumea on 13 December 1999. A total of some 13 290 km of multibeam bathymetry (ie. at an average swath width of 14 km this equates to a seafloor coverage of about 186 000 km^2), 12 550 km of high-speed seismic and mostly continuous 3.5 kHz, gravity and magnetic data were acquired. In addition, three successful dredge hauls were made. Navigation was provided throughout by two independent GPS systems. Apart from a two-day period, the weather throughout the survey was fine with generally calm seas and only a slight swell.

This report[1] presents the preliminary results of the FAUST-2 survey[2] - the second survey of the two-part collaborative FAUST project. It is hoped that the data acquired and preliminary results presented herein will lead to further studies into the region as well as more general ideas on subduction-related processes and the tectonic processes forming large-scale ocean fracture zones.

Finally, as a result of the onboard data processing and map preparation techniques the entire data set was viewed at various compilation stages throughout the survey. For FAUST-2 this compilation was best achieved by artificially partitioning the study area into (see Fig. 11): a transit leg to the main area; a western portion of the main area dominated by volcanics; a larger eastern portion covering the Three Kings Ridge and adjoining terrace and trough to the west, as well as the southeastern extension of the Cook Fracture Zone; and a northern portion, on the return leg, over the northwestern Cook Fracture Zone. This partitioning is adhered to below in the section presenting the preliminary interpretations. Due to time constraints, the analyses of the northern portion are limited in scope and are non-existent for the return transit over the Norfolk Ridge to Noumea.

[1] The data, and the interpretations based on that data, contained in this report are preliminary only. It is not necessarily indicative or representative of the final information that might be used by Australia or France to support the location of the outer limit of the continental shelf beyond 200 nautical miles.

[2] For AGSO database purposes this survey will be known as AGSO marine survey 221.

Regional Setting

While this survey is directed at the Norfolk Ridge/Three Kings Ridge region, its geological framework and tectonic evolution cannot be understood in isolation from the regional geology of the wider area of the southwest Pacific and eastern Australian continental margin (Fig. 2).

The evolution of the southwest Pacific and eastern Australia region is extremely complex incorporating the full gamut of continental margin development, from crustal compression and accretion, through passive margin extension, breakup and seafloor spreading, to the present-day convergence and subduction setting (Symonds et al., 1996, 1999; Gaina et al., 1998). Following protracted Palaeozoic to early Mesozoic convergence, a vast extensional terrane developed through eastern Australia in the Late Jurassic-Palaeogene in response to the fragmentation and dispersal of Gondwana. The earliest (Late Jurassic - Early Cretaceous) episode of rifting occurred between Australia and Antarctica, and probably onto the Lord Howe Rise, in a convergent tectonic setting more than 1000 km behind the proto-Pacific plate boundary. The transition from convergence to divergence was characterised by extensive Barremian - Cenomanian extensional/transtensional magmatism near the locus of the future Tasman breakup. Intense volcanism, concentrated in the north and south of the rift zone, shed large volumes of volcanogenic sediment westwards into the developing Eromanga/Surat/Clarence-Moreton basin system in the north, and into the Otway/Bass/Gippsland system in the south. In the Cenomanian - Campanian a second major rift system developed along eastern Australia contemporaneously with slow seafloor spreading south of Australia. This extensional terrane, which was up to 1000 km in width, fragmented and dispersed during the Campanian - Eocene (84 - 52 Ma) period of seafloor spreading. Following breakup, most of the rift basin systems off eastern Australia received sag-phase sediments; however, many of these basins were also affected by significant episodes of compressional reactivation, which were probably the local expression of global plate boundary adjustments and changes in the intraplate stress field. Although these probably began in the Late Paleocene - Early Eocene, it was not until the Late Eocene - mid Oligocene that convergent tectonism (ie. collision, obduction, subduction and associated back-arc spreading) re-commenced along the eastern margin of the Australian Plate from New Guinea, through New Caledonia to New Zealand.

The end result of this tectonic history is a vast area of complex seabed lying 300 - 1500 km east of Australia, and extending north-south for over 2000 km from New Caledonia to New Zealand. It includes (Figs 1 & 2) relatively shallow-water elongate continental plateaus and ridges such as the Lord Howe Rise and the West Norfolk Ridge and Dampier Ridge, ridges of less certain affinity such as the Norfolk Ridge and Three Kings Ridge, and intervening deeper water basins such as the Lord Howe Basin, Middleton Basin and New Caledonia Basin. The narrow conjugate southeast Australian margin formed the western edge of a central Tasman extensional terrane prior to Campanian breakup and seafloor spreading in the Tasman Basin. The effects of the Late Eocene and younger convergent tectonism are apparent throughout the region, but are particularly well represented by local thrusting both on the eastern margin of and within the Lord Howe Rise; buckling and reverse faulting of the Paleogene section in the New Caledonia Basin; thrusting/compression beneath the northern Norfolk Ridge and the western margin of New Caledonia; significant compressional deformation to the east of the West Norfolk Ridge in the Reinga Basin province; and possible arc and back-arc formation along the Three Kings Ridge (TKR) and within the combined North Norfolk Basin (NNB) and South Norfolk Basin (SNB) area, respectively.

Regional Physiography

The major submarine features in the region are, from west to east: the Tasman Basin, the Lord Howe Rise, the New Caledonia Basin, the Norfolk/West Norfolk Ridge system, the NNB, the SNB, the TKR and the South Fiji Basin (Figs 1 & 4).

The Lord Howe Rise extends from the eastern Coral Sea, southwest of New Caledonia, in the north, to west of the North Island of New Zealand in the south. At about 2500 km in length (including its southern extension, the Challenger Plateau) with a width of 450 - 650 km and a total area of about 1 500 000 km^2 it is by far the largest feature in the region. The NW-trending northern segment of Lord Howe Rise merges with a region of complex topography, which includes features such as the Chesterfield Plateau, Kenn Plateau, Mellish Rise and a NW-trending feature named the Fairway Ridge (Dubois et al., 1974). The central segment of the rise trends N-S for some 1100 km within the latitudes 24^o - 34^oS. The southernmost segment of the rise again trends NW-SE and is almost contiguous with the Challenger Plateau adjacent to the New Zealand continental margin. The Lord Howe Rise and the Challenger Plateau are partly separated by the 3000 m deep, N-S trending Bellona Trough at about 39^oS. Excluding the isolated islands and banks of the N-S trending Lord Howe seamount chain on the western flank of the rise, the rise is shallowest in the east where crestal water depths generally range from 1000 - 1500 m.

The western flank of the Lord Howe Rise province is morphologically complex. Along the N-S trending, central segment of the rise, the Dampier Ridge (crestal water depths of 2000 - 2500 m) is separated from the rise by the 3000 - 4000 m deep Lord Howe and Middleton Basins. In the south, the western flank of the rise is formed by the NW-trending Monawai Sea Valley, at about 3000 m depth, and the slightly shallower Monawai Spur to the southwest.

The Lord Howe Rise is separated from eastern Australia by the Tasman Sea. This ocean basin is triangular in outline, narrowing from about 1100 km in the south, between Tasmania and New Zealand, to about 150 km in the north, southeast of the Marion Plateau. The floor of the basin lies at water depths of about 4800 - 5100 m, and varies from quite flat to extremely rugged, depending on the presence of fracture zones. The Tasman Sea is notable for the presence of the linear N-S trending Tasmantid seamount chain, which extends from the northern Tasman Sea to about 37^oS, where it appears to bifurcate. These seamounts have reliefs of up to 2500 m above the seabed with some being planated (guyots).

To the east of Lord Howe Rise, lies the sub-parallel New Caledonia Basin. This basin extends for about 2000 km from the continental margin of the North Island of New Zealand to west of New Caledonia. As with the Lord Howe Rise, there are NW-SE trending segments in the north and south, separated by a N-S trending central segment. The basin has strong linearity, with an average width of about 150 km. The seafloor is generally flat-lying, and lies at a depth of about 3000 m.

The eastern flank of the New Caledonia Basin is bounded by the Norfolk Ridge system, a complex series of ridges and basins that extends for some 1600 km from the northern tip of New Zealand to New Caledonia. In the south, it comprises the NW-trending West Norfolk Ridge, Wanganella Basin, Wanganella Ridge, Reinga Basin and both Reinga and South Maria Ridges, with water depths generally ranging from 300 - 1000 m on the ridges to 1500 - 2000 m in the intervening basins. This segment is bound to the northeast by the large-scale, NW-trending scarp of the Vening Meinesz Fracture Zone. The northwest extension of the Vening Meinesz Fracture Zon separates the southern part of the Norfolk Ridge system from the N-S trending Norfolk Ridge proper. This segment of the Norfolk Ridge is steep-sided and only about 70 km in width. Crestal water depths average 1000 m, and Norfolk Island is the only exposed portion of the ridge. The western flank of the ridge is punctuated by a chain of seamounts (Norfolk Seamount Chain) that are prominent in the satellite gravity and related predicted bathymetry data sets (Figs 4 & 5).

To the east of Norfolk Ridge lies the complex province that is the main focus of the FAUST-2 survey. This area will be discussed in more detail in a later section, but includes the NNB, SNB, TKR, South Fiji Basin, and, further to the east and beyond the survey area, the Tonga-Kermadec Trench and its associated volcanic ridges. Further north the main features are the NW-trending Cook Fracture Zone, and the Loyalty Basin and Loyalty Ridge, which separate New Caledonia from the active New Hebrides Trench. Most of these features are thought to have derived from complex processes related to the collision of the Australian and Pacific plates.

Regional Crustal Structure

Seismic refraction and gravity anomaly measurements (Officer, 1955; Dooley, 1963; Shor et al., 1971; Woodward & Hunt, 1971) and studies into seafloor spreading magnetic anomalies (Ringis, 1972; Weissel & Hayes, 1977; Shaw, 1978) indicate that the Tasman Basin is a normal oceanic basin. The crust beneath the New Caledonia, Middleton and Lord Howe Basins is commonly considered to be oceanic, though it is slightly thicker than typical oceanic crust. More recent studies (Etheridge et al., 1989; Symonds & Colwell, 1992) have suggested that at least parts of these basins may be floored with extended lower continental crust. Deep seismic data have indicated that the crustal reflection characteristics and structured Moho of parts of these basins are quite different from those of the Tasman Basin. On this basis Symonds et al. (1999) and Stagg et al. (in prep.) have suggested that the basins may be floored by extended lower continental crust and/or upper mantle formed by removal of all of the upper crust during extension above a regional detachment.

Seismic refraction surveys, gravity modelling and magnetic studies (Shor et al., 1971; Schreckenberger et al., 1992; Zhu & Symonds, 1994) over Lord Howe Rise indicate that its crust is 26 - 29 km thick and of continental origin. The Rise is largely composed of crust with a P-wave velocity of 6.0 km/s, which is similar to the values found for the Australian continent (Shor et al., 1971). The Dampier Ridge is thought to be a continental fragment altered by rifting and igneous intrusions, as supported by dredging of a Triassic (New England Orogen age) granitic rock from its western flank (McDougall et al., 1994).

The crustal structure of the northern sector of the Norfolk Ridge has been interpreted from refraction velocities by Shor et al. (1971), while Zhu and Symonds (1994) and Herzer et al. (1997) have carried out gravity modelling across the West Norfolk Ridge - Reinga Basin end of the ridge system. These studies indicated a crustal thickness greater than 20 km beneath the Norfolk Ridge in the north and as much as 30 km beneath the West Norfolk Ridge in the south, thinning to 16-25 km beneath the Reinga Basin, Taranui Sea Valley and Wanganella Trough. These crustal thicknesses are consistent with thinned continental crust.

Gravity modelling supported by seismic reflection and refraction data indicates that the crust of the southern Loyalty Basin has a relatively normal ocean velocity structure and thickness, and appears to be contiguous with the obducted peridotites of New Caledonia (Collot et al., 1987).

Seafloor Spreading History

Hayes and Ringis (1973) first identified seafloor spreading magnetic anomalies in the Tasman Sea, and interpreted a complete set of anomalies from 33o (33 'old') to 24. This work, and later revisions by Weissel and Hayes (1977) and Shaw (1979), described the opening of the Tasman Sea in terms of a two-plate model. Shaw (1979) argued that the morphology of the northern Tasman Basin could only be explained by strike-slip motion and not by a simple pull-apart mechanism as suggested by Weissel and Hayes (1977).

Gaina et al. (1998) have revised plate tectonic reconstructions for the opening of the Tasman Basin based on a compilation of all the available magnetic data and satellite gravity data. This interpretation of the breakup of the Tasman Basin is considerably more complex than that of previous authors as they identified 13 microplates that were active during breakup and spreading. Some of these microplate boundaries control the limits of major tectonic provinces in the region - for example, the Barcoo-Elizabeth-Fairway lineament and its influence on the form of the Middleton and Lord Howe Basins, the Capel, Faust and Fairway Basins, and possibly the West Caledonian Basin (Fig. 2). This complex microplate history, which was accompanied by several changes in spreading azimuth and involved several failed rifts, is important to the understanding of the Late Cretaceous plate kinematic evolution of the region.

Seafloor spreading was initiated in the southern Tasman Sea (84 Ma) as a result of rifting between the Challenger Plateau and the central Lord Howe Rise. Magnetic lineations identified between the Challenger Plateau and the Gilbert Seamount Complex (84 - 77 Ma) correspond to the next episode of spreading resulting in about 250 km of oceanic crust being emplaced between these structures. At about 77 Ma the spreading stopped and Gilbert Seamount, which was previously attached to the South Tasman Rise, transferred to the Challenger Plateau.

In the north, extension between northern Lord Howe Rise and the Dampier Ridge (then attached to Australia) led to the formation of Lord Howe and Middleton Basins, beginning at about 84 Ma. As mentioned previously, it is unclear whether these basins are floored by oceanic crust or by highly extended continental lithosphere. Prior to 79 Ma the southern Dampier Ridge became attached to the northern Lord Howe Rise following rift or ridge propagation from the Lord Howe Basin into the Tasman Sea.

At 72 Ma, after short-lived transtension between the northern Dampier Ridge and the fragment immediately to the south, the entire Dampier Ridge became attached to the Lord Howe Rise and rifting in the Lord Howe and Middleton Basins ceased. The last stage of rift propagation at about 62.5 Ma separated the Chesterfield Plateau from Australia and established a continuous spreading centre through the length of the Tasman Sea. At the same time, the central and northern Lord Howe Rise blocks became attached after 260 km of left-lateral strike-slip motion between them.
The Gaina et al. (1998) reconstructions indicate that spreading in the northern Tasman Sea was highly oblique. Tasman Basin spreading ceased between 56 and 52 Ma following a slowing of the spreading rate. This event reflects a major change in plate driving forces of the Australian Plate, which predates the beginning of India-Eurasia collision.

The opening history of other basins in the region is much less well understood. No seafloor spreading magnetic anomalies have been identified in the New Caledonia Basin; however, Willcox et al. (1980) suggested that it is somewhat older than the Tasman Basin, whereas Kroenke (1984) suggested that it began to open at about the same time, but finished somewhat earlier, in the early Palaeocene, rather than the Early Eocene as in the Tasman Basin.

The age of the NNB and SNB, to the east of the Norfolk Ridge, is also a matter of speculation. Launay et al. (1982) defined magnetic anomalies 34 and 33 in the limited data set over these basins, giving them a Late Cretaceous (Campanian) age like the Tasman Basin. Eade (1988) recognised that the depth to basement in the NNB and SNB supported a Late Cretaceous breakup age. Kroenke (1984), however, speculated that these basins formed during the Late Eocene. More recently, Herzer & Mascle (1996) and Herzer et al. (1997) argued for Early - Late Miocene backarc spreading in the SNB. Mortimer et al. (1998) further constrained this age by the radiometric dating of an intraplate seamount that indicates that the SNB was opening or opened by at least 18-20 Ma.

Magnetic lineations in the South Fiji Basin, which forms the eastern limit of the FAUST-2 survey area, indicate that seafloor spreading occurred between the latest Eocene (35.5 Ma) and the Late Oligocene (25.5 Ma) (Watts et al., 1977; Weissel et al., 1982; Malahoff et al., 1982) at a now extinct ridge-ridge-ridge triple junction that lies about 200 km northeast of the northern tip of the TKR. Further north, the northern Loyalty Basin is thought to have formed at a NE-SW trending spreading ridge, perpendicular to the Loyalty Ridge, between 55 - 42 Ma (Paleocene - Middle Eocene) in a backarc setting.

In addition to the episodes of seafloor spreading cited, that were mainly identified on the basis of magnetic lineations, there is also some evidence of older Gondwana breakup in the region along and to the east of the New Caledonia-Norfolk Ridge-New Zealand trend:

- The ocean floor to the west of the Loyalty Ridge in the South Loyalty Basin is thought to be continuous with the obducted ultramafic terrane of New Caledonia (Collot et al., 1987), and should therefore have been formed during the mid-Cretaceous (prior to 80 - 100 Ma; Prinzhoffer, 1981), or possibly even during the Early Cretaceous (130 Ma; Prinzhoffer,

1987) based on K-Ar and Nd-Sm dating of gabbros and associated rocks. It has been suggested that the ophiolite formed on the northern limb of an E-W trending spreading system (Prinzhoffer et al., 1980), or with a similar orientation to that of the Tasman Basin seafloor spreading system further west (Eissen et al., 1998).

- The Tangihua Complex of the Northland-East Coast Allochthon of New Zealand, is considered to be a disrupted ophiolite of probable Cretaceous (to Early Cenozoic?) age (Mortimer et al., 1998; ?Albian, ~102 Ma, R. Herzer pers. comm.). The adjacent Houhora Complex, a volcanic-hypabyssal igneous and volcaniclastic suite was considered to be a pre-100 Ma age, but recent Ar-Ar dating on rocks from this complex have given 60 Ma (Paleoecene) ages (Mortimer et al., 1998).

- The basaltic province of the west coast of New Caledonia that constitutes the thrust sheet of the Poya Terrane (Cluzel et al., 1995) has been biostratigraphically dated as forming from the Campanian-Late Paleocene, or possibly earliest Eocene (Cluzel et al., 1997) - a similar age to the Tasman Sea spreading further west. The geodynamic significance of this terrane has been variously described as: the volcanic carapace of the main New Caledonia ophiolite (Avias, 1967; Challis & Guillon, 1971); allochthonous crust of a Late Cretaceous backarc basin (Aitchison et al., 1995; Meffre et al., 1996); N-MORB basalts with arc affinities (Black, 1993); an oceanic plateau within a marginal basin to the east of New Caledonia (Cluzel et al., 1997); and as being genetically unrelated to the ophiolite and constituting a rift tholeiitic suite formed on the easternmost margin of Gondwana around the time of opening of related 'ocean' basins (Eissen et al., 1998).

This information, and other regional considerations and reconstructions such as Korsch and Wellman (1988), and that from deep-seismic data (Symonds et al., 1999), indicates that Late Cretaceous or older (perhaps of similar age to the Tasman Sea) oceanic crust probably lay adjacent to New Caledonia, Norfolk Ridge, West Norfolk Ridge and northern New Zealand (Eissen et al., 1998). If any of this crust is still present it could have important implications for our understanding of the FAUST-2 study area.

Survey Area Setting

The FAUST-2 survey area is shown in its regional context in Figures 1 and 2, and in more detail in the gravity and terrain data sets in Figures 5 and 6, respectively. The lines shown in Figure 3 are the proposed tracks designed before the cruise. These figures also show ZoNéCo-1 survey tracks, deep-seismic (16 second record length) lines recorded during the collaborative 1996 AGSO/New Zealand Survey 177 (Ramsay et al., 1997), and geological sampling locations along with Australia's 200 nautical mile Exclusive Economic Zone (EEZ) around Norfolk Island and other EEZs with respect to New Caledonia, New Zealand and Matthew/Hunter Islands.

The physiography and general geological framework of the area is poorly known, and its evolution has been the subject of considerable speculation. The main survey area lies to the south and east of the NNB, north of the SNB, and extends as far east as the TKR and its eastern flank with the South Fiji Basin (Fig. 6).

Physiography

The western part of the study area is bounded by the Norfolk Ridge system - a complex feature that extends from the northern tip of New Zealand to New Caledonia. The northern segment - the Norfolk Ridge - is N-trending, steep-sided and about 90 km wide. Its western margin is associated with a seamount chain - the Norfolk Island seamount chain (Rigolot, 1989). The southern, NW-trending segment to the south of the survey area is offset to the west and forms a complex triple-ridge system about 200 km wide. The western part of this southern ridge complex is generally referred to as the West Norfolk Ridge, the central part as the Wanganella Ridge (Eade, 1988), and the eastern part as the Norfolk-Reinga-South Maria Ridge system (Fig. 2; Eade, 1988; Herzer & Mascle, 1996; Herzer et al., 1997). The Norfolk/West Norfolk Ridge is quite rugged with crestal depths ranging from about 500 to 1500 m. The West Norfolk and Wanganella Ridges are separated by a narrow, 1500 m deep bathymetric trough, the Wanganella Trough. The Wanganella and Norfolk-Reinga-South Maria Ridges are separated by the poorly known Taranui Gap (Sea Valley), which lies on the eastern flank of the ridge system, near its point of offset, and the Reinga Basin (Eade, 1988).

Two small basins at about 3500 m water depth - the NNB and SNB - lie between the Norfolk Ridge and the TKR to the east. They are separated by a complex area at about 2500 m water depth, which appears to be an eastward prolongation of the Norfolk Island platform. The TKR is an approximate N-trending feature defined by the 2500 m isobath, and is surmounted by volcanic seamounts and guyots, which rise to less than 500 m depth. The TKR is about 100 km wide in the north, but broadens significantly to the south adjacent to the SNB, where it appears to take on a more NNE-trend, as shown by the predicted bathymetric data set (Fig. 1). In the south, the increased width of the TKR province is largely due to the presence of two terrace-like features on its western flank at about 3000 m and 2000 m depth - the Lower and Upper Three Kings Terraces (Herzer & Mascle, 1996), respectively.

An un-named terrace-like feature at about 2500 m depth also occurs in the north. It lies between a more subdued ridge on its western margin and the TKR to the east, and is flanked in the west by a 3000-3500 m deep N-trending trough. This double ridge system bounding a terrace, or basinal feature, has been commented on by several authors. Comparisons have long been made between the basin/terrace and adjacent TKR and the Loyalty Basin and Ridge to the north (Packham & Terrill, 1975; Launay et al., 1982). Meffre (1995) reinforced this similarity by using seismic data to compare the North/South d'Entrecasteaux Ridge system in the north, with the Loyalty Basin/Ridge and TKR systems further south. The similarities are further highlighted in the satellite gravity data set (see Fig. 5; Meffre, 1995; Symonds et al., 1999).

The terrain between the NNB and the northern TKR is poorly known, but includes some broad rises and highs at about 2500 m water depth and volcanic seamounts. This area is a main focus of the FAUST-2 survey (Fig. 4). The entire Norfolk Ridge -

North and South Norfolk Basins - Three Kings Ridge province is bound to the north and south by the NW-trending Cook and Vening Meinesz Fracture Zones, respectively. Some authors have also implied that the shallow region separating the NNB and SNB may be another fracture zone - the Norfolk Fracture Zone (new name) (Launay et al., 1982; Herzer & Mascle, 1996; Mortimer et al., 1998).

The 4000 m-deep South Fiji Basin lies at the eastern edge of the main FAUST-2 survey area. To the northeast of the TKR it is sometimes referred to as the Minerva Abyssal Plain, and to the east of the TKR as the Kupe Abyssal Plain (Kroenke & Eade, 1982). The margin of the South Fiji Basin adjacent to the TKR is very complex and contains numerous large seamounts that rise to less than 2000 m depth (eg. the Sarah Seamounts; Koenke & Eade, 1982; Ramsay et al., 1997).

Geological Framework and Evolution

There is general agreement that at least part of the Norfolk Ridge system was rifted and separated from Gondwana, probably during the Late Cretaceous (Willcox et al., 1980; Kroenke, 1984). However, several hypotheses have been advanced to explain the Tertiary development of New Caledonia and its marine continuation southward, the Norfolk Ridge, and the adjacent New Caledonia Basin and Norfolk Basins. These include the evolution of a complex arc system (Dubois et al., 1974; Kroenke, 1984), and arc migration and marginal basin development (Karig, 1971; Packham & Falvey, 1971). The pre-Permian metamorphic and sedimentary rocks forming the core of New Caledonia were once part of the ancient Australian (Gondwana) continent, so it is plausible that the core of the Norfolk Ridge is also continental. In support, granodiorite of Early Triassic age (247 Ma; Mortimer et al., 1998) and other continental rocks have been dredged from the West Norfolk/Wanganella Ridge system. The granodiorite may be similar to the New England-aged granodiorite dredged from the southwestern margin of the Dampier Ridge in the Tasman Basin (McDougall et al., 1994).

Launay et al. (1982) suggested that the Norfolk Basin-system was formed by backarc spreading in the Late Cretaceous, being associated with eastward-directed subduction beneath the western margin of the Norfolk Ridge. This spreading was envisaged as splitting the Norfolk/Three Kings arc into two N-trending fragments. Kroenke and Eade (1982) and Kroenke and Dupont (1982) used single channel seismic data across the Norfolk Basin/Three Kings Ridge province to define a west to east arrangement of trench (adjacent to northern Three Kings terrace), forearc basin (the terrace west of TKR), volcanic arc (TKR) and back arc region. They suggested subduction beneath a W-facing TKR arc in the north, with obduction along the same trend to the south. More recently, Herzer and Mascle (1996) interpreted the Vening Meinesz Fracture Zone as a dextral continent/back arc transform that operated during mid- to Late Miocene subduction beneath an E-facing TKR arc. Mortimer et al. (1998) analysed and dated a large range of dredge samples throughout the Norfolk/Three Kings Ridge region and further refined the westerly directed subduction model suggesting the SNB had opened as a backarc basin by 18 - 20 Ma.

Existing Data Coverage

Prior to 1996, the FAUST-2 survey area was sparsely covered by geoscience surveys, consisting of GEORSTOM, AUSTRADEC, Lamont-Doherty Vema and DSDP Glomar Challenger data (Launay et al., 1982; Kroenke & Dupont, 1982; Kroenke & Eade, 1982). In 1996, AGSO and the New Zealand Ministry of Commerce acquired over 4000 km of deep-seismic, gravity, magnetic and echosounder bathymetry data in the region, as part of a collaborative program to support marine jurisdictional claims (Ramsay et al., 1997). In 1998, during the collaborative France/Australia FAUST-1 survey of the northern Lord Howe Rise/Norfolk Ridge region (Lafoy et al., 1998; Bernardel et al., 1999), two deep-seismic lines and other geophysical data were collected to the north of the study area from the New Hebrides Trench, Loyalty Ridge and Basin system, Norfolk Ridge and into the New Caledonia Basin and over the Lord Howe Rise. These 1996 and 1998 surveys provide the first deep-seismic images of the area, and form an important tectonic framework for the FAUST-2 multibeam bathymetry and high-speed seismic data.

Direct information on the geology of the study area is sparse. Mortimer et al. (1998) summarises a large amount of geochemical, petrographic and age data from all rocks sampled in the region. The locations of sample sites occurring in the FAUST-2 survey area are shown in Figure 6, and information on the samples is given in Table 1.

Survey Objectives and Design

The broad survey objectives were outlined in the 'Introduction' to this report. Apart from the general marine jurisdictional, resource and environmental aspects of the survey, there are several important scientific questions to be examined and are as follows:

- What is the nature of the eastern margin of the Norfolk Ridge and the Norfolk Island platform?

- The origin of the NNB - is it a Miocene backarc basin as suggested by Herzer and Mascle (1996) and Mortimer et al. (1998), or is it older (?Late Cretaceous) ocean floor formed prior to the start of convergence?

- Is there any validity in the trough/forearc basin/volcanic arc model of Kroenke and Dupont (1982) and Kroenke and Eade (1982) to explain the arrangement of bathymetric features in the area from the NNB to the TKR, and its association with eastward subduction; or is the TKR the arc resulting from westward-directed subduction of South Fiji Basin crust (Herzer & Mascle, 1996; Mortimer et al., 1998)?

Sample	Latitude	Longitude	Depth (m)	Greatest Age	Lithology and Environment
U566 1-3	-35.08333	169.16666	979	?vL.Olig-lE.Mio	Bioclastic, bryozoan limestone, oceanic, shoal
RE9302-5-2	-34.01083	166.95833	1270-2250	EL.Cret	Coal measures, carbonaceous mudstone, lower coastal plain
RE9302-6-1	-33.90722	167.38138	700-735	VL.Olig-E.Mio	Bioclastic bryozoan limestone, bored and replaced by forminiferal limestone, bathyal (age and depth ranges common to both limestones)
RE9302-7-2	-33.56083	167.65527	650-900	VL.Olig-mE.Mio	
E-855	-33.16666	169.93333	742		Sandy limestone
RE9302-2-6	-33.12638	170.91416	1875-1950	ME.Mio	Micrite infilling cracks in basalt, oceanic bathyal, calm
RE9302-1 1-4	-33.01111	171.70694	2500-2700	?vL.Olig-E.Mio ?lE.-?eM.Mio	Calcareous volcanic sandstone, shoal, lapilli tuff, lower bathyal, rapidly deposited
G-1	-32.58333	167.38333	138	lE.Mio-?M.Mio	Algal ball, shallow photic zone, sheltered
RE9302-3-6	-32.36777	170.86722	3680-4160	mM.-lM.Mio	Calcareous ooze chalk, bathyal >1000m
GO350D-5	-32.36333	169.14166	1600-3400	L.Pal-E.Eo-M.Eo	?Argillaceous limestone, cataclasite, planktonic
GO349D	-32.15833	167.47500	1000-2000		Altered calcareous volcanic sandstone
GO351D-g	-31.88166	168.28666	900-2500	M.Eo	Mudstone breccia, bathyal >1000m (age and depth of matrix fauna only)
U579	-31.85833	171.95999	2109	late Paleogene? Olig?	Calcareous fine sandstone, oceanic, bathyal or deeper
GO347D	-30.47500	168.09000	1840-2300		Calcareous mudstone
GO348D-b	-30.12000	167.49666	900-1400	vL.Olig-vE.Mio	Coquina with volcanic lithics, shallow open marine, photic zone to >100m
GO357D	-35.62000	165.77999			Olivine basalt, gabbro, hyaloclastic breccia with mid-Miocene forams (from Willcox et al., 1980)
GO353D	-33.01666	167.84833	1870-1530	2.3 Ma for basalt	Hyaloclastic breccia, palagonite and 'bubble' lava, pyroxene, olivine inclusions
SO-36-57KD	-31.86500	157.37833	2400-2700	mid-Permian	Granite, gabbro, undated sandstone
GO345	-30.93333	168.81666	2260-3200	E. Mio	Altered olivine basalt
S565	-29.30833	169.77833	830-1350		Vesicular basalt
VE209	-28.18333	173.15000	1800-2200		Basalt
S573	-30.49499	172.70499	840-975		Aphyric vesicular basalt
S574	-30.83499	172.74000	1180-1290	E. Mio	Basalt

Table 1. Summary of sample information in the FAUST-2 study area (modified from Herzer et al., 1997, and Mortimer et al., 1998). Locations of some of the sample sites are shown in Figure 6.

- What is the tectonic significance of the volcanic seamounts and guyots that surmount the TKR?
- Is the shallow saddle-like area separating the NNB and SNB associated with an oceanic fracture zone, similar in trend to the Vening Meinesz and Cook Fracture Zones to the south and north, respectively?
- What is the tectonic significance of the Cook Fracture Zone? Are there any indicators for the relative motion along it, and does it link the Loyalty Ridge and TKR, as implied by the satellite gravity data (see Fig. 5)?
- What are the implications of the tectonic development of the FAUST-2 study area to an improved understanding of convergence in New Caledonia and the formation of the Norfolk Ridge system?

The pre-cruise plan for the FAUST-2 survey is shown in Figure 3. The multibeam survey tracks are largely oriented sub-parallel to the strike of the dominant structural grain as indicated by the TKR and adjacent crustal features; however, because of the bathymetric complexity of the area, some features are crossed nearly perpendicular to strike, such as the Cook Fracture Zone and the saddle area directly east of Norfolk Island. Areas of very shallow water over the summit of the TKR were not expected to be mapped with full 100% coverage due to the inherent variations in the width of the swath footprint with varying water depth. It was envisaged that line spacing would be adjusted during the survey to reflect our evolving understanding of the seafloor and changing priorities. Nevertheless, the overriding aim was to have continuous coverage from the eastern flank of the Norfolk Ridge across to the central N-S axis of the TKR.

The proposed east-west lines in the northwest of the survey area (Fig. 3) were designed to link the FAUST-2 data to the French ZoNéCo multibeam survey, and provide coverage up to and across the agreed France/Australia maritime boundary. These lines were also expected to provide information on the western extent of the Cook Fracture Zone.

The survey was also designed to link all pre-existing deep-seismic lines in the area, and locate suitable scarps on which to conduct up to two days of dredging.

Figures 6 and 11 highlight the actual survey path for the main part of the survey. Apart from the area of east-west mapping of seafloor to the northwest - to join with the ZoNéCo swath data - all objectives were met.

Preliminary Analysis

The descriptions that follow represent a first-pass onboard analysis of the data acquired. They are grouped according to an artificial partitioning of the survey area: the transit from Noumea to the main survey area over the Norfolk Ridge (*transit to area*); the western portion of the survey area between the NNB and SNB (*western portion*); the large eastern portion of the survey area leading up to and over the N-S trending TKR (*eastern portion*); and the northern portion over the NW-SE trending Cook Fracture Zone (*northern portion*).

The eastern portion of the survey area is defined by a box lying between latitudes 26^{o} and 30^{o}30'S and longitudes 171^{o} and 174^{o}E, and was mapped by NNE-SSW trending profiles 33 to 71 (Fig. 11).

The western portion of the survey area is defined by a box lying between latitudes 28^{o} and 30^{o}30'S and longitudes 167^{o} and 171^{o}E, and was mapped by NNE-SSW trending profiles 6 to 35 (Fig. 11).

The northern portion of the survey area extends from the western end of the eastern portion, at about longitude 171^{o}E, towards the west over the Cook Fracture Zone, to about longitude 169^{o}E, and was mapped by the, mostly NNE-SSW trending, profiles 71 to 103 (Fig. 11). Because of time limitations the description of this final part of the survey is limited.

Seafloor Morphology

Descriptions of seafloor morphology rely mostly on an interpretation of the multibeam bathymetry and, to a lesser degree, the multibeam backscatter signal component.

Transit to area

The FAUST-2 survey commenced with a transit line that extends from offshore the Dumbea Pass (22°25'S) to the northwestern edge of the western portion (see below) to the south (Figs 12a & 12b). This transit line, which parallels the TRANSNOR[3] swath track for part of its length, and lies to its east, successively crosscuts, from north to south:

- the western edge of the Norfolk Ridge that trends NW-SE north of 23°30'S and N-S down to 26°10'S. The western edge of the ridge is crosscut by a series of WSW-ENE trending canyons that descend into the New Caledonia Basin to the west. Two seamounts were swath-mapped during the transit. The northern seamount lies at 24°15'S and culminates at 500 m on its western edge, while that to its south, at 25°55'S, culminates at 1000 m;

- the Norfolk Ridge, the summit of which is characterised at 26°20'S by a N-S trending, eastward-tilted massive crustal block that culminates at 800 m. This feature, defined by a N-S trending fault at its western flank, is overlain on its eastern flank by bottom sediments marked by a large-scale ripple-like form evident on the backscatter; and

- the western edge of the NNB that mainly trends N-S in the north and NNW-SSE in the south. The northwestern edge is shaped by a series of NNW-SSE and NNE-SSW (en echelon?) trending scarps, while the southwestern edge is crosscut by two NE-SW trending canyons. A seamount that lies at 28°58'S culminates at 2300 m.

Western portion

The western part of the western box (Figs 11 & 13) crosscuts both the southern end of the NNB and the northern part of the SNB. The two basins are separated by an eastern 'spur-like' extension to the Norfolk Ridge, southeast of Norfolk Island, which we name the Nepean Saddle (ie. after a town on Norfolk Island). Five main geological provinces can be identified:

- the eastern Norfolk Ridge, delimited by the 2000 m-isobath and bounded to the east by a NNE-SSW trending fault scarp centred at 168°40'E. The eastern edge of the ridge culminates at 940 m at 29°25'S, and is structurally controlled by NW-SE and NE-SW trends to the north and to the south, respectively. To the south, the ridge is crosscut by a N-S

[3] Transit by N/O *l'Atalante* from Noumea to complete the TASMANTE survey south of Tasmania, via Auckland, in 1994.

trending canyon centred at 168°20'E that ends in an 8 km-wide fan. The canyon lies at the western edge of a NNE-SSW trending elongated ridge that rises up to 1400 m at 29°45'S;

- the eastern extension of the Norfolk Ridge. Delimited by the 2500m-isobath, this feature is divided into a southern arm trending NW-SE and a northern arm that extends along a NNE-SSW direction. The eastern extension of the ridge represents the Nepean Saddle that separates the NNB to the north and the SNB to the south. The saddle, dotted by numerous small volcanoes, widens eastward and is structurally controlled by four main trends. To the west, NW-SE and NE-SW faults flank the NNB and the SNB to the north and south, respectively. In the central part, near 169°E, the saddle is defined by NE-SW and NW-SE trends to the north and the south, respectively. The central southern part of the saddle is pierced by two lenticular, 15 km-long, volcanic massifs that culminate at 700 and 1000 m at approximately 29°42'S and 29°50'S, respectively. Trending WNW-ESE, these two volcanic features are dotted by numerous small-sized (2 km-wide) volcanoes. To the northeast, the eastern edge of the saddle shows two other lenticular-shaped seamounts that culminate at 1000 m at 29°19'S and 29°27'S. Well north of the saddle a NNE-SSW trending group of volcanic seamounts, delimited by the 2500 m isobath, culminates at about 2000 m at 28°35'S. To the west, centred at this latitude, this volcanic feature extends in an E-W direction that ends at 169°40'E, along a rhomboidal-shaped block (rifted feature?) centred aat 28°40'S and structurally controlled by N-S, NE-SW and NW-SE lineaments. This block is bounded to the west by a sigmoidal-shaped flat basin that deepens southward where it links to the northern edge of the SNB along a circular 3450 m deep basin centred at 29°30'S;

- the SNB, which deepens to the south, is bounded to the west by a major NNE-SSW fault. A NNE-SSW trending ridge that culminates at 2500 m near 30°S splits the western part of the basin. Its western part, west of 169°20'E and trending NNE-SSW, shows two WNW-ESE trending lenticular-shaped groupings of coalescent volcanoes. These 15 km-long volcanic features are centred at about 29°56'S and 30°02'S. The eastern part of the SNB, east of 169°20'E, is bounded to the west by the southeastern edge of the saddle, and is marked at 29°45'S by a guyot, which culminates at 550 m. The latter is offset from the 29°27'S massif along a NNW-SSE left-lateral fault. To the north, east of the guyot, the SNB abuts a NNE-SSW trending trough;

- the southern part of the prominent NNE-SSW trending flat-bottomed trough to the southeast. Its northern extension, swath-mapped on the adjacent eastern portion, links the SNB to the WNW-ESE trending Cook Fracture Zone; and

- the NNB, which deepens to the north, is flanked at its southern end by the main NW-SE trending Norfolk Ridge to Nepean Saddle spur (rifted feature?) to the west, a NE-SW trend to the south, and by a series of en echelon N-S and NNE-SSW scarps to the east. The basin is split by a N-S trending low-relief spur, centred at 168°52'E, which culminates at 2700 m.

Eastern portion

The eastern portion of the main FAUST-2 survey area extends largely over the TKR and adjoining western terrace and trough region and north over the eastern half of the Cook Fracture Zone (Figs 11 & 14). Five main geological provinces can be identified in this area:

- the NNE-SSW trending broad trough, the southern part of which has already been discussed (western portion), reaches a maximum depth of 3500 m near 28°20'S, and links the northern part of the SNB to the WNW-ESE trending Cook Fracture Zone. The trough is bounded to the east by an additional deeper N-S trending depression situated south of 27°15'S, and is herein named Cagou Trough. The main NNE-SSW trough, with a series of volcanoes lying on its floor between 28°35'S and 29°10'S, shows a sigmoid morphology between 27°10'S and 28°S. At 27°10'S, the trough curves toward the west and is flanked by two northward-dipping parallel ridges that both narrow to the north. The eastern ridge shallows along its eastern edge where it is defined by a series of highs centred around 171°40'E along a general N-S alignment. The eastern ridge ends to the north, at 27°25'S, along a narrow, sigmoidal, N-S trending ridge. East of this ridge, the NNE-SSW trending trough and the N-S trending Cagou Trough merge together. The latter, bounded by steep N-S trending faults, shallows to the south. It reaches a maximum depth of 4250 m along a NNE-SSW trending depression centred at 27°20'S. Between 27°30'S and 28°S, the N-S trending depression reaches its maximum width (about 40 km) and shows a gently dipping eastern flank crosscut by a NE-SW trending fault. Between 27°50'S and 28°10'S, the bathymetric axis of the N-S trending depression is shifted to the east. To the north, the northern end of the depression trends NNW-SSE and merges with the Cook Fracture Zone. To the east, the N-S trending depression, which is flanked by a parallel discontinuous ridge centred near 172°10'E, shallows southward. This discontinuous ridge separates the N-S trending depression from a perched basin to its east;

- the perched basin located west of the TKR, trending NNE-SSW and characterised by an average depth of 2750 m. This basin is defined in the north by an eastward curve to the seamount chain defining the central N-S axis of the TKR;

- the main TKR lineament, centred approximately along 173°E, comprises a series of volcanic highs aligned along a general N-S trend. It culminates at 350 m between 28°30'S and 28°50'S along two guyots. North of the two guyots, the ridge is slightly offset to the east and ends at approximately 27°30'S, where it abuts the Cook Fracture Zone;

- the WNW-ESE trending Cook Fracture Zone, which is characterised by a maximum depth of 4350 m between 27°S and 27°10'S. The fracture zone reveals a complex morphology comprising a series of NNE-SSW trending abutting ridges and troughs along its flanks. North of the fracture zone, the general NNE-SSW trending fabric shows a more parallel form. To the east, the overall Cook Fracture Zone complex widens, shallows, and bends to the NE, north of the northern tip of the TKR. However, the axial trough generally deepens towards the east; and

- The South Fiji Basin, extending north from the Cook Fracture Zone and east from the TKR, is characterised by minor highs and basins generally trending NNE-SSW. Several of these basins extend directly southwards where they coalesce with the Cook Fracture Zone floor.

Northern portion

The bathymetric map (Figs 11 & 15) shows the northern part of the NNB, the Cook Fracture Zone, the South Fiji Basin, the southern end of the Loyalty Ridge, the Loyalty Basin and the southern extension of the New Caledonia Plateau. The Cook Fracture Zone is particularly well traced, but disappears along the eastern flank of the New Caledonia Plateau. The Loyalty Ridge is characterized by several crowning small guyots. Figure 15 shows clearly the end of the Loyalty Ridge along a small protruding finger-like feature parallel to the Cook Fracture Zone and the prominent escarpment along the Cook Fracture Zone. There is no evidence for the extension of the fracture zone into the New Caledonia Plateau region.

Seafloor Character

Descriptions of seafloor character rely mostly on interpretations of the acoustic facies visible on the 3.5 kHz echsounder records and multibeam backscatter, as well as bathymetry where it can provide additional information on the likely environmental setting.

Transit to area

Seven acoustic facies types have been recognised off the echosounder records along the transit from the Dumbea Pass to the northwestern edge of the western portion of the main survey area (Figs 16 & 17):

Facies 1 (Fig. 26)
Facies 1 (F1) is defined by a uniformly bedded echo character with conformable sub-bottom reflectors. Near 26°30'S the facies is well developed along an area of moderate slope, where it shows a uniformly bedded echo type marked by a continuous sharp bottom with continuous sharp parallel sub-bottom reflectors. However, further downslope the bedding character becomes slightly undulating, whilst weakly stratified and marked by the interposition of a transparent facies in places (eg. 24°52'S and 25°15'S).

Facies 2 (Fig. 25)
Facies 2 (F2) is defined by a series of large irregular imbricated hyperbolae of widely varying relief and lacking internal reflection character. It represents the surface expression of steep and highly irregular topography, and is typically

located over seamounts and ridges. Along the transit line facies F2 correlates with seamounts identified on the bathymetry: at latitudes 24°15'S, 25°55'S, 26°20'S and 28°58'S.

Facies 3
Facies 3 is subdivided into facies types a and b. Facies 3a (F3a) is characterised by non-overlapping hyperbolae (unlike Facies 2) usually along the slopes of seamounts and other high-relief structures. It may include areas of more stratified reflectors corresponding to flat portions. Typical examples are found at latitudes 25°34'S, 25°44'S and 26°00'S.

Facies 3b (F3b) is also characterised by a series of moderate-sized hyperbolae and generally correlates with the base of slope, where slumped sediments are likely to accumulate. Typical examples are found at latitudes: 23°28'S, 23°48'S and 23°51'S.

Facies 4
Facies 4 (F4) is marked by a fuzzy bottom echo with small regular overlapping hyperbolae corresponding to the floors of canyons or wider valley-like developments. This signature is interpreted as being due to the presence of coarse-grained sediments. Between 23°55'S and 24°04'S a 7 km wide irregular floor of a broad valley is bordered on either side by small levees that host the facies.

Facies 5 (Fig. 25)
Facies 5 (F5) is identified by the presence of an opaque zone underlying a highly reflective bottom over sharp morphology, which are interpreted as areas of bedrock with little or no sediment cover. A typical example is found between 26°17'S and 26°27'S.

Facies 6
Facies 6 (F6) is marked by the development of a series of highly reflective sediment waves along the seafloor. Its extent is restricted to areas about 26°31'S and 26°37'S. The sediment waves may be formed by gravity sliding down the slope or by the shaping effects of current flow along the slope strike.

The multibeam backscatter signal reveals a series of approximate E-W trending bands of high reflectivity crosscutting a series of approximate N-S trending fault scarps along the eastern edge of the Norfolk Ridge, which are revealed by the bathymetry to be canyons (Figs 12b & 24). Lighter zones indicate slope wastage deposits.

The flanks of the seamounts crossed are dissected by radial gullies and provide evidence of debris flows at their base (Figs 12a & 16). The areas of high reflectivity are interpreted as volcanic substrate, which contrasts with the less reflective areas of probable muddy sedimentation.

The Norfolk Ridge between 26°20'S and 26°33'S is marked by a N-S trending fault and the presence of a highly reflective and ripple-like facies zone on its eastern flank, which is probably sand or mud (Figs 16 & 17).

The western edge of the NNB seafloor is marked by a set of N-S trending faults. At about 28°30'S, 168°E the scarp developed has a throw of some 1000 m with the rugged area at its base being well imaged on the backscatter, which may represent accumulations of talus breccias. Numerous reflective gullies perpendicular to the fault are also revealed.

Western portion

The acoustic facies recognised in the western portion of the study area (Fig. 18) are similar to those identified along the transit line. However, facies 1 can be subdivided into two subfacies: a bedded subfacies (1a) characterised by well-defined, regular and undeformed sub-bottom reflectors; and a second subfacies (1b) where the well-bedded reflectors are undulated and/or deformed by flexures, resulting in a hummock-like shape. Facies 1 may correspond to fine-grained material accumulated by turbidity currents, especially on levees of canyon banks, but may also result from pelagic or hemipelagic sedimentation.

Facies 2 is defined as an overlapping hyperbolic response to seamount and ridge morphologies where the bedrock is outcropping or covered by pelagic sediment.

The subfacies 3a associated with the steeper slopes shows the characteristic hyperbolic form occasionally interrupted by flat sections or slump material. In contrast, the subfacies 3b corresponds to mass wasting processes characterised by fuzzy bottom echoes, lack of internal reflection character and/or a transparent acoustic response.

The bottom of canyons and zones of sediment transport are characterised by a fuzzy bottom echo facies 4, which corresponds to coarse-grained turbidites subject to strong erosional processes.

Facies 5 includes the areas where sub-bottom reflectors are absent or very weak with a transparent facies developed under a hummocky morphology. This facies is found in the interchannel areas and may correspond to sediment waves or dunes generated by contour currents. It grades into subfacies 1b where internal reflections are better developed.

The distribution of the 3.5 kHz echo facies is marked by the predominance of the bedded facies 1a and 1b, which are well represented in the central part of the area forming an approximate NNE-SSW oriented band of about 100 km width. The undisturbed bedded facies 1a is restricted to the flatter parts of the depressions while the facies 1b coincides with areas of gently sloping and/or undulating topography.

The distribution of echo facies 2 is strongly correlated with seamount and ridge distribution. Along the western portion's southern boundary with the SNB, two major and two minor seamounts are elongated in an E-W direction, and possess an approximate en échelon arrangement along a N50°E direction. The E-W elongation of the seamounts may be interpreted as a dextral shear band developed during their volcanic phase.

The slope facies are well developed along the eastern extension of the Norfolk Ridge forming a continuous band trending N50°E over a length of some 200 km. This facies is also found along the eastern border of the box, where it coincides with a general N20°E trend in the topography.

Facies 3b includes all types of slump-derived sediments, with the dimensions of these slump bodies being of limited extent (ie. several square kilometres) and generally at the bases of seamounts. In the southeastern corner of the area, and south of the large guyot centred at 29°45'S, 170°05'E this facies is found as two large zones of about 50 km length, along a general NNE trend, and of 20-25 km width. Near the seamounts, small areas of slump development are common, but the shape of the displaced masses are difficult to define due to the wide spacing of the survey lines.

Submarine canyons and valleys are scattered throughout the area, particularly to the north where a set of E-W trending canyons is observed. A large valley trending N60°E, with an extent of 50 km by 20 km, is an area of intense sediment transport towards the ENE sourced from a nearby large seamount.

Several areas of significant facies 5 development have been identified. The most important is located on the eastern part of the area and follows the general bathymetry corresponding to a large NNE-trending rounded ridge which separates two depressions characterised mostly by facies 3a and 1b.

More detailed observations were possible for the following profiles (positions are given in terms of UTC time found along the profiles, that is, hour then minute):

- *Profile 7*
  Between 12h00 (relief) and 14h50 (flat area) lies a typical example of a slumped slope showing debris flows (facies 3b) and bedded facies (facies 1a) on an adjacent flat-bottomed basin. A similar arrangement, with a more prominent extension southwards, is observed south of a seamount (06h50 to 09h00).

- *Profile 8* (Fig. 27)
  The bedded facies 1a is undeformed except at 23h45 where there is a break of slope marked at the seamount's base by an undulating facies (facies 1b). Between 22h40 and 22h50, a flat-bottomed canyon shows a fuzzy echo character typical of facies 4. Between 18h40 and 20h00, a hummocky facies develops with a highly reflective surface and weak sub-bottom reflectors. Between 19h20 and 19h40 a flat-bottomed valley does not show the usual fuzzy facies, but displays a thick well-bedded facies (facies 1a), which is interpreted as a small graben structure. Between 16h10 and 18h40, the slope is more chaotic showing slope facies, downslope slumps and bedded facies in the flat area from 15h30 to 16h45.

- *Profile 9*
  The slope from 00h20 to 00h55 is marked by disturbed sediments, between 00h55 to 01h15 by a small hill area with facies 1b continuing until 02h00, and is cut by two canyons at about 02h50. Facies 2 develops until 03h35 in

a region of hilly morphology, and is then followed by a flat area marked by a fuzzy echo facies corresponding to erosion.

- *Profile 17* (Fig. 27)
  This profile is characterised by debris flows along the south slope of the major seamount centred at about 29°50'S, 169°10'E, which forms the boundary between the Nepean Saddle and the SNB.

- *Profile 18*
  From 16h40 to 18h30 an area of rugged morphology is followed by well-bedded facies 1a (18h30 to 19h25) and a slump area (facies 3b). From 19h50 to 21h10 an undulating bedded facies (facies 1b) is flanked by a small canyon at 21h45 running along the base of an area of relief until 22h50. The slope is then cut by several canyons, followed by an undulating facies (facies 1b) and a connecting slope (facies 3a) to a seamount from 00h40 to 01h30.

- *Profile 19*
  A wide valley is marked by a fuzzy facies (facies 4) in the lower part and bedded facies on both sides (02h40 to 03h55). A canyon is visible at 04h10 and debris flows (facies 3b) from 04h40 to 04h50, which disturb the bedded facies 1 extending from 04h20 to 05h50. These facies then grade to a more hummocky form without sub-bottom reflectors, which is well developed from 07h00 to 09h00 and punctuated by a minor seamount at 08h20. The bedded facies continues from 09h35 to 10h40 with an increase in the number of sub-bottom reflectors in a small valley (09h50 to 10h05), which corresponds to a graben structure. South of a seamount (10h40-11h10) a rugged morphology predominates with a mix of hummocky facies to slope facies until 12h10 where slump (facies 3b) and slope facies (facies 1b) mark the profile end.

- *Profile 20*
  The hummocky facies (facies 5) is observed from 15h31 to 15h40, with a valley bottomed by a slightly undulating bedded facies (facies 1a) from 16h50 to 17h25. From 18h40 to 21h40 a facies of hummocky form is well developed with faint sub-bottom reflectors. From 21h40 to 22h05 sediments along the slope are widely slumped while the adjacent flat area displays erosion and debris flow facies between 22h05 and 22h40.

- *Profile 21*
  From 03h30 to 05h50, there is a succession of weakly bedded facies (facies 1) with strong reflective characteristics. From 07h00 to 07h50, a series of three canyons cut across rugged relief. Between 08h20 and 13h10, the facies 1b is widely represented, and is interrupted by a seamount. Facies 3b indicating slumping is localised between 13h20 to 13h30 adjacent to an area of hummocky facies, without reflectors, until 14h40. To the end of the profile undulating bedded facies 1b develops.

- *Profile 22*
  From 17h20 to 19h20, facies 1a/1b is interrupted by two bodies formed by debris flow (17h35 to 17h50 and 19h20 to 19h45), a canyon with fuzzy bottom reflections (22h10 to 22h30) and then by a hummocky facies (facies 5) with a highly-reflective surface (23h40 to 00h30). A bedded facies (facies 1) is observed in a valley (01h30 to 01h45) and along the adjacent slope base: slumps and debris flows. The same pattern is observed between 04h25 and 05h10. The profile ends towards 05h50 in a hummocky facies with some sub-bottom reflectors.

- *Profile 23* (Fig. 28)
  From 06h00 to 07h40, the echo facies corresponds to a rugged area dissected by a canyon (07h10 to 07h20) and extends until 10h20 where it is interrupted by an area of seamounts. From there, a hummocky-facies 1b combination extends until 11h30. From 13h35 to 13h45, a sharp contact is found between the slumped base of the slope and well-bedded facies (1a) in a 3 km wide flat area bounded by a small fault scarp (14h00), which suggests a graben structure. On the southern side of this structure the bedded facies vanishes progressively, becoming disturbed by debris flows at 14h45 near the base of a slope.

The western portion of the survey area covers both the southern part of the NNB and the northern part of the SNB. The two basins are partly separated by the eastern spur-like extension of the Norfolk Ridge, extending southeast from Norfolk Island. The basin floors are characterised by uniform low backscatter levels (Figs 8, 10 & 19), and are probably overlain by fine-grained sediments, except at the base of the slopes and at the ends of the canyons where slope deposits and deep-sea fans can be observed. To the south, the Norfolk Ridge is crosscut by a N-S trending canyon, centred at about 168°20'E, which is terminated by an 8 km-wide fan extending into the SNB.

The eastern protruding extension of the Norfolk Ridge is characterised by uniform backscatter of medium intensity levels, which is probably due to coarse-grained sedimentation. These are located between irregular-shaped zones of high intensity levels, and are interpreted to be hard exposed basement of volcanics or undifferentiated basement material. To the south, the coarse sediment probably feeds into the N-S trending canyon and becomes a source of sediment for the wide fan at its base.

The eastern protruding spur-like extension of the Norfolk Ridge represents a saddle that separates the SNB and the NNB. This area is dotted by numerous circular areas of medium to high backscatter levels that are locally coalescent and occasionally align along structural trends. The circular features are probably small volcanoes.

The central and southern part of this area, between 169°E and 170°10'E, is shaped by NE-SW scarp faults (Figs 22 & 23) and NW-SE lineations, which delimit two small depressions. Between these small basins there are two main E-W trending irregular zones of high backscatter centred at 29°42'S and 29°50'S, which are interpreted as hard rock exposed volcanoes: trachybasalts have been dredged on a flank of the northern volcanic high (Mortimer et al., 1998). At the south-eastern edge of the saddle is found a large NW-SE trending guyot, which is characterised by gullied flanks and bounded to the south by the deep SNB. However, the northern part of the saddle is marked by a series of N-S to NW-SE trending faults, which delimit small depressions characterised by uniform low backscatter levels. Finally, a major NNE-SSW broad flexure aligned along 170°30'E separates this area from the TKR and adjoining terrace region to the east.

Eastern portion

The eastern area surveyed during the cruise covers two major structural domains. The southern and central area is dominated by N-S and NNE-SSW trends defined by a succession of basins and ridges. The 3.5 kHz echo facies interpreted in the western portion (see above) are valid for this area (Figs 20 & 21).

The dominant echosounder signature is the slope facies (facies 3) developed in the western part of the area, while in the eastern part bedded (facies 1) and hummocky facies (facies 5) are prominent. These form N-S trending lineations. The hummocky facies is particularly well developed in the south of the area. Slumping and debris flows are also present and form elongate bands along N-S and NNE-SSW trends.

The bedded facies (facies 1) is not well represented except between latitudes 28° - 29°S where it is found on the bottom of a large depression. This area is disturbed at the foot of the seamount by slumps and debris flows (Fig. 29). The presence of a N80°E trending fault with associated pop-up and graben-styled structures (Fig. 29) indicates tectonic activity.

The northern part of the area is dominated by the presence of the Cook Fracture Zone, where the recent sedimentary cover is particularly disturbed. Along the fracture zone's southern border slumps and debris flows are particularly abundant and indicate significant recent activity along the fracture (Fig. 29). The fracture zone floor displays transparent or weakly bedded facies, which suggests an area of permanent sediment remobilisation.

The interpretation of the multibeam backscatter reveals uniform low levels on the basin floor while higher levels indicate the presence of coarse-grained sediments. These coarser grain facies appear to be restricted to the deep troughs (ie. Cagou Trough and Cook Fracture Zone; Fig. 8). The backscatter levels are also probably indicative of high-angle slopes and areas where basement outcrops. Higher backscatter levels generally characterise basement outcrops on the top of the highs.

Northern portion

The multibeam backscatter imagery correlates with the main observations derived from an analysis of the multibeam bathymetry (Fig. 15). Uniform low backscatter can be seen on the basin floor of the South Fiji Basin and NNB. The very high backscatter levels mark the basement outcrops on the high-relief structures of the Loyalty Ridge and the steep flanking slopes of the Cook Fracture Zone.

Subsea Structure

Descriptions of subsea structure relied largely on an interpretation of the partly processed (ie. 3-fold stack, deconvolution and filtering) high-resolution seismic sections produced onboard. Previous seismic interpretations in the area include those identifying gross tectonic elements, basement, major faults and strong continuous reflectors for the AGSO Survey 177 profiles (Ramsay et al., 1997 reproduced in Figs 30 - 35), as well as those interpretations further to the north for the profiles from the FAUST-1 survey (Bernardel et al., 1999).

Transit to area

The transit portion of the survey is bounded by latitudes 22°30'S and 29°S and longitudes 166°E and 168°E. It is composed of 5 high-resolution seismic profiles (1 to 5), which cross, successively, the western New Caledonia Basin (profile 1, from 22°30'S to 23°30'S), the western flank of the Norfolk Ridge (profile 2, from 23°30'S to 26°10'S), the Norfolk Ridge summit (profile 3, from 26°10'S to 26°40'S) and along the eastern flank of the Norfolk Ridge (profiles 4 and 5 from 26°40'S to 29°S).

Profile 2 ties with two lines of the FAUST-1 survey: 206/04 (SP 9700, Figs 36 & 37) at 12h33, and 206/03 (SP 14720, Figs 38 & 39) at 19h20, while AGSO line LHRNR-BA (SP 14420, Fig. 30) ties with profile 3 at 03h26. The two major structural elements identified are the western New Caledonia Basin and the Norfolk Ridge.

Basement in the western New Caledonia Basin is located at about 5 s TWT depth, but cannot be clearly identified on most of the FAUST-2 profiles, where it appears to be characterised by a more chaotic seismic facies. The western New Caledonia Basin is divided into two sub-basins by an acoustic basement high (profile 2 between 24°05'S and 25°05'S, Fig. 39). In contrast, basement on the Norfolk Ridge appears to be defined by a tilted crustal block deepening eastward (SPs 14500 - 15500, Fig. 30) which suggests an earlier extensional phase.

The thickness of the sedimentary cover varies from 1.6 s TWT in the western New Caledonia Basin to an average of 0.2 s overlying the Norfolk Ridge. This cover is defined by three seismic megasequences: the oldest seismic megasequence is characterised by a discontinuous reflector sequence showing evidence of syn-rift deposition; the intermediate megasequence is made up of continuous reflectors characterised at the top by a regional unconformity and is affected by compressive deformation; and the youngest megasequence is characterised by a transparent seismic facies topped by a series of high frequency continuous reflectors. The thickness of this younger sequence is relatively constant (~0.6 s) and covers most of the structures within the western New Caledonia Basin. The base of the sequence is locally marked by probable lava flows, which is topped by an erosional surface and characterised by internal discontinuous high-amplitude reflectors.

The intersection of the FAUST-2 high-resolution seismic lines with the AGSO Survey 177 deep-seismic lines may provide some evidence for the relative timing of the seismic sequences. The oldest sequence is contemporaneous with the Cretaceous rifting of the eastern margin of Gondwana. The intermediate sequence is contemporaneous with a regional compression phase, and is dated between the

Paleocene to the Oligocene. The youngest sequence lies between the upper Oligocene to the present, and is marked by some compression effects in the western New Caledonia Basin and on the top of the Norfolk Ridge.

Two forms of volcanism are distinguished. The first form is marked by the existence of a large volcano (profile 2, centred at 24°15'S, 166°55'E) located on the flank of the Norfolk Ridge, which probably formed during the Eocene. The shape of the volcano indicates a submarine formation. Several volcanoes of this type can be identified on the satellite gravity image (Fig. 5). A second form of volcanism is located atop the Norfolk Ridge and is more widespread.

Western portion

High-resolution seismic data were acquired in the western portion of the main survey area along 28 profiles (ie. profiles 6 to 36; Fig. 11) and are crossed by AGSO lines LHRNC-C and LHRNC-D of Survey 177 (1996, conducted in collaboration with the New Zealand Ministry of Commerce; Ramsay et al., 1997).

Four major tectonic features are imaged by the seismic: the eastern flank of the Norfolk Ridge, the southern part of the NNB, the northern part of the SNB and the Nepean Saddle.

Three types of acoustic basement are distinguished in the western portion: volcanic, undifferentiated and acoustic basement:

- Volcanic basement comprises volcanoes, structured lava-flows and volcanogenics and sills. The flows cover mainly the Nepean Saddle, concealing true basement, and probably comprise successive stages of volcanism (Fig. 41). In the NNB the thickness of the volcanic flows are about 0.6 s, with a top at about 4.8 s depth (Fig. 40), while in the SNB the same kind of feature is developed with the top of the lava-flows found deeper at about 5.4 s (Fig. 40).

- Undifferentiated basement is characterised by a 'blurred' seismic facies, and is identified in some places below the lava-flows. In the SNB the undifferentiated basement is structured in a step-like manner by normal faulting to the south (see profile 9). Volcanism took place along these faults and formed two E-W ridges centred at 29°50'S, 168°45'E and 30°S, 168°45'E. The undifferentiated basement on the Nepean Saddle is faulted and structured in blocks. Two closed basins centred at 29°25'S, 169°10'E (Fig. 42) and 29°30'S, 170°E (Fig. 43) are probably structured by NE-SW trending strike-slip faults and tilted blocks opening in a NW-SE direction.

- 'True' acoustic basement is only identified on the NNB between 5.8 s and 6 s TWT depth, where it is commonly characterised by irregular and chaotic hyperbola-type reflections typical of oceanic crust (eg. see profile 7; Fig. 40).

The thickness of the sedimentary cover varies from absent over the seamounts to about 1 s TWT within closed basins and about 1.6 s TWT in the NNB (Fig. 44). The main cover identified on the top of the lava-flows is characterised by a mostly transparent seismic facies with some continuous and low-amplitude reflectors. In the closed basins three major seismic sequences of equivalent thickness are recognised (see profile 6; Fig. 40). The deepest megasequence is characterised by relatively high-amplitude, discontinuous reflectors. No evidence of synrift sedimentation is seen. This suggests that the faults on the flanks of these closed basins are probably strike-slip in nature. The middle sequence consists of relatively high-amplitude and continuous reflectors. The upper sequence is characterised by relatively low amplitude and continuous reflectors.

The sedimentary cover in the mapped NNB averages 1.6 s TWT thickness and is made up of three major sequences of equivalent thickness (Fig. 40). These sequences are separated by unconformities, with the internal seismic facies made up largely of high-amplitude and continuous reflectors.

The sedimentary cover of the SNB is approximately 0.8 s TWT thick and consists of a succession of different sequences separated by unconformities (Fig. 40). It reveals the presence of a sediment apron derived from the southern part of the Nepean Saddle. The presence of the seismic sequences may be explained by variations in the sediment supply.

The isochron map of acoustic basement in the western portion of the main survey area (Fig. 45) supports the four-fold identification of major tectonic features: the eastern flank of the Norfolk Ridge, the southern part of the NNB, the northern part of the SNB and the Nepean Saddle. The eastern flank of the Norfolk Ridge is defined in the south by a N-S trending volcanic ridge.

The southern flank of the NNB is structured by NW-SE trending faults, which corresponds to the axis of the basin and suggests a NE-SW opening. The northern flank of the SNB is structured by NNE-SSW faults with the basin's depositional axis being probably parallel. The Nepean Saddle is divided into two parts: a southwestern part formed by the NE-SW closed basins and NW-SE trend of a relay fault; and an E-W trend that is outlined by a volcanic ridge. The structuring of the northeastern part of the Nepean Saddle is more complex and indicates a N-S trend. A basin situated between the two parts possesses both a N-S and an E-W orientation, which could explain separate deformation episodes.

Generally, the overall first-pass analysis of the seismic data highlights:

- the widespread presence of various stages of volcanic activity over the Nepean Saddle and within the NNB and SNB;
- the different axis orientations of the NNB and SNB, which are, respectively, NW-SE and NNE-SSW;
- the difficulty in estimating the age of the sedimentary cover by comparison with the seismic sequences identified during the transit over the western New Caledonia Basin. The western portion of the main survey area is made up of a succession of small closed basins, surrounded by large volcanic ridges and seamounts, which are major suppliers of sediments via

canyons. Mortimer et al. (1998) have dated a main volcanic phase on the southern part of the TKR of about 20 to 18 Ma (base of Mid Miocene). A possible estimate of the age of these seismic sequences relies on considering the main volcanic phase as contemporaneous with the spread of lava-flows into the western area. This suggests that the sediment covering the top of these flows is more recent, while those deeper in the NNB and SNB are older; and

- the presence of deep reflectors under the northeastern part of the Nepean Saddle, at around 5 s TWT depth, while several reflectors outlined in the southwestern part are at about 6 s TWT depth.

Eastern portion

High-resolution seismic data was acquired along profiles 33 to 71H in the eastern portion of the FAUST-2 survey area (Fig. 11). These lines tie with recent AGSO multichannel deep-penetration seismic data of AGSO Survey 177 (Ramsay et al., 1997).

Seven major tectonic features are interpreted from the seismic profiles: the eastern flank of the Nepean Saddle, a triangular-shaped plateau, the Cagou Trough, the transition zone, the northern TKR, the Cook Fracture Zone and the southwestern part of the South Fiji Basin. However, the nature of the acoustic basement within these provinces is difficult to interpret due to the widespread presence of lava flows.

The eastern flank of the Nepean Saddle
The acoustic basement of the northeastern part of the Nepean Saddle lies at about 4.5 s TWT depth. Several very deep and steeply-dipping reflectors are identified below basement. A depression, centred at about 28°S, 171°E, divides the Nepean Saddle in two parts and is covered by a 0.8 s TWT thick sedimentary cover. Small unconformities within the sedimentary cover indicate that the basin has probably undergone several periods of uplift.

The triangular-shaped plateau
A triangular-shaped elevated section of seafloor is centred at about 29°20'S, 171°20'E (Fig.14). This plateau is covered by a faulted sedimentary cover that thickens to the east from 0.6 to 0.8 s TWT. It is flanked to the west by a broad NE-trending basin and to the east by the Cagou Trough.

The Cagou Trough
The Cagou Trough (Fig. 14) is formed by a succession of N-S trending basins. Those basins are assymetric and deepen along the eastern edge. The sedimentary cover is thick and can reach from 1 to 1.5 s TWT. The basin centred at 28°45'S, 171°50'E is characterised by some fan-shaped features along its southwestern edge.

The transition zone
The transition zone is an elevated basin, which underlies the Three Kings Terrace region, containing sediment thickening westward from 1.6 to 2.4 s TWT (profile 41), with basement lying at about 5.2 s TWT. The deformation

of the sedimentary cover indicates a succession of uplifting phases. The folding may result from a compression event. Furthermore, deep reflectors are identified below acoustic basement.

The northern Three Kings Ridge
The northern TKR complex comprises tabular structures covered by a carbonate platform of 0.2 s TWT thickness. Profile 61 shows one of the largest guyots centred at 28°40'S, 172°55'E, whose size is comparable to those on the Loyalty Ridge.

The Cook Fracture Zone
The morphology of the Cook Fracture Zone is highly variable. The flanks are assymetric (see profiles 33, 36, 37, 38, 44) to symmetric (see profiles 34 and 35) and from very steep (see profile 33) to less steep (see profile 34). Widening of the zone, centred at about 26°50'S, 171°50'E, 27°S, 172°30'E and 27°20'S, 173°15'E is characterised by tilted-block structures on the southern flank (see profiles 36, 40 and 63). Furthermore, its flanks are largely covered by a thick succession of lava flows. The sedimentary cover is about 0.2 s TWT thick with the basement occasionally outcropping (see profile 33).

The southwestern part of the South Fiji Basin
The topography of the mapped South Fiji Basin represents a succession of blocks that are deeper or uplifted compared with the southern margin of the Cook Fracture Zone. The deeper sections are centred at 26°35'S, 171°25'E and 26°50'S, 172°20'E, and basement is usually masked by lava flows. The thickness of the overlying sedimentary cover varies from 0.2 to 0.4 s TWT.

Gravity

Descriptions of the local gravity field rely on the interpretation of a map of a contoured representation of the discrete gravity field values measured along-track.

Transit to area

The transit from Noumea to the western portion of the survey area is defined by profiles 1 to 5:

- *Profile 1 (22°30'S - 23°30'S)*
  Values range from -20 to +30 mgals. There is a moderate-strength positive anomaly at 23°25'S.

- *Profile 2 (23°30'S - 26°10'S)*
  Values range from -10 to +100 mgals. A large symmetric anomaly of +100 mgals correlates with the eastern flank of a major seamount at 24°15'S. A moderate broad symmetric low of -10 to 0 mgals is associated with flat-lying topography, but seismic data indicates a broad depositional axis with at least 2 s TWT of sediment. A strong positive symmetric anomaly of +60 mgals at about 25°54'S is associated with a seismic feature that is either a broad seamount or an uplifted basement block.

- *Profile 3 (26°10'S - 26°40'S)*
  Values range from +10 to +30 mgals. A high of +30 mgals at 26°36'S may suggest a fault lineament.

- *Profile 4 (26°40'S - 28°30'S)*
  Values range from 0 to +40 mgals. No significant anomalies are present.

- *Profile 5 (28°30'S - 29°S)*
  Values range from +10 to +50 mgals. A symmetric anomaly of +50 mgals at 28°30'S matches an intense magnetic anomaly over the eastern slope of Norfolk Ridge, which is correlated on the seismic with the edge of an elevated basement block.

Western portion

The western portion designates that portion of the survey area approximately between latitudes 28°S and 30°30'S and longitudes 168°E and 171°E, and includes profiles 6 to part of 33, 34 and 35 (Fig. 46).

The seamounts referred to below are centred at the following positions:

Seamount A -	29°45'S, 168°50'E
Seamount B -	29°50'S, 169°10'E
Seamount C -	29°45'S, 170°05'E
Seamount D -	29°21'S, 169°40'E (two adjoining seamounts)
Seamount E -	28°35'S, 169°50'E

The overall area shows strong cross-cutting NE-SW and NW-SE trends to the west and mostly NNE-striking trends in the east. This pattern is further characterised by large circular to elliptical positive anomalies over seamounts A to E.

The southern corner of the NNB, which is traversed by profiles 7, 8, 16 and 17, is defined as a broad low, split in two by a weak saddle trending NW-SE, which is sub-parallel to the Norfolk Ridge trend.

The northern part of the SNB is defined by a weak broad low, whose dominant axis strikes N-NW. Its eastern flank is characterised by contours with a strong NW-SE trend, which correlate with the trends evident to the north of seamount A along the eastern flank of the Norfolk Ridge. A strong low is positioned north of seamount C and east of seamount D where it overlies a circular bathymetric depression. A small high north of seamount B is associated with a NE-striking bathymetric spur covered by multiple small volcanic cones, and is associated with a strong magnetic anomaly.

The broad bathymetric platform to the east of seamounts D and E is associated with a moderate-intensity NNE-SSW trending gravity high. This platform extends to the west, between the seamounts, and is there defined by a fairly featureless gravity signature, except for two weak lows striking in a WNW direction.

It is to be noted that in this part of the survey area the contoured gravity agrees well with the trends imaged in the satellite gravity data set (Sandwell & Smith, 1997).

Eastern portion

The contoured gravity field for the eastern portion (Fig. 47) may be broadly distinguished into three zones:

- a northern zone of mostly WNW-ESE trending anomalies;
- a western quadrant of fairly featureless character; and
- an eastern quadrant of mostly N-S trending anomalies.

The northern zone of the area is taken as that part lying to the north of a line extending from about 27°S, 171°E to about 28°S, 173°30'E. The dominant WNW-ESE trending gravity contours, and associated anomalies, mostly parallel the trend of the Cook Fracture Zone. The gravity lows correlate well with the deep bathymetric depression that appears to define the main strike-slip lineament, while several northeast and southwest branching trends are probably related to deeper sedimentation in accommodation zones formed along a combination of Reidel shear components for left-lateral movement along and asymptotic bending of seafloor spreading fabric into the Cook Fracture Zone. A broad gravity high centred at approximately 27°30'S, 172°05'E is associated with a block of high-standing seafloor crowned by three minor seamounts.

The western quadrant of the area has a relatively featureless gravity signature. It is characterised by a general NNE-SSW trend that parallels a similar-trending long narrow, sinuous-like bathymetric depression (Cagou Trough). Anomalous highs centred at 28°40'S, 171°E, and 27°15'S, 171°20'E are localised over moderate-sized seamounts.

The eastern quadrant of the survey area strongly reflects the N-S structural grain of the TKR and adjoining Three Kings Terrace tectonic features. This broad trend is interrupted by anomalous highs centred at latitudes 28°35'S, 28°50'S, 29°10'S and 29°40'S, along longitude 171°40'E, and a series of four highs along longitude 173°E on the northern nose of the TKR. These eight gravity highs correlate with moderate to large seamounts. A broad high at the southern extremity of the quadrant, centred at 29°45'S, 172°10'E, is associated with what seismic data indicates as either a W-tilting basement block or a strongly planated large seamount. The western edge of the quadrant is defined by a series of N-S trending anomalous lows along the western edge of the Three Kings Terrace. These lows correlate with a series of N-S trending bathymetric depressions marked by a slight en-echelon offset to the west. The depressions are flanked to the east by a long N-S trending bathymetric high, which produces a similar trending gravity high. Continuing to the east, across the Three Kings Terrace, the gravity contours become more evenly spaced along a N-S trend and increase in value and density up the western flank of the TKR. The ridge axis is itself defined by a series of strong highs, which are associated with large seamounts and guyots to its north. Along the eastern extremity of the area the contour density and values decrease as the ridge descends into the South Fiji Basin, where the gravity trends lack a consistent form.

Northern portion

The main observation made is the strong trend of the contours parallel to the Cook Fracture Zone in the northwest, whereas this trend is weaker in the southeast. This is related to the topographic contrast between the higher relief Loyalty Ridge and Loyalty Basin system with the more subdued NNB.

Magnetics

Descriptions of the local magnetic field rely on the interpretation of a map of a contoured representation of the discrete magnetic values measured along-track.

Transit to area

The transit from Noumea to the western portion of the survey area is defined by profiles 1 to 5:

- *Profile 1 (22°30'S - 23°30'S)*
  Values range from -200 to +50 nt. An anomaly of +50nt at 23°20'S correlates with a zone of NE-SW trending canyons evident on the swath bathymetry. It may indicate the presence of volcanics underlying the slope west of the W-facing Norfolk Ridge scarp (see shot points 14600 - 14800 on AGSO Survey 177 line LHRNR-BA)

- *Profile 2 (23°30'S - 26°10'S)*
  Values range from -300 to +50 nt. A broad anomaly high of +50 nt at about 26°S lies just north of shot point 14800 on AGSO line LHRNR-BA, where volcanics in the section are associated with a positive magnetic signature. A seamount, evident on the swath bathymetry at 24°15'S, has a strong satellite gravity signature and line gravity reading, but no prominent magnetic anomaly. The absence of a magnetic signature may be related to a long period of episodic volcanism resulting in overall cancellation of the magnetic field, or volcanism of largely non-basic geochemistry.

- *Profile 3 (26°10'S - 26°40'S)*
  Values range from 0 to -100 nt. No significant anomaly is present.

- *Profile 4 (26°40'S - 28°30'S)*
  Values range from 0 to -150 nt. No significant anomalies are found down the east-facing flank of Norfolk Ridge.

- *Profile 5 (28°30'S - 29°S)*
  Values range from -250 to +150 nt. An intense symmetric positive anomaly of +150 nt is found at about 28°33'S on a steep planar scarp. This part of the line is located close to an elevated basement platform evident on the seismic, and may suggest down-slope volcanism. Positive anomalies at 28°36'S and 28°45'S are associated with an incised lobate-like northeast protrusion of the eastern slope of Norfolk Ridge. These anomalies may be related to possible young lava flows descending into a

deep NNB from volcanic features to the southwest, about the present-day Norfolk Island.

Western portion

The western portion designates that portion of the survey area between latitudes 28°S and 30°30'S and longitudes 168°E and 171°E, and includes profiles 6 to part of 33, 34 and 35 (Fig. 48).

The seamounts referred to below are centred at the following positions:

Seamount A -	29°45'S, 168°50'E
Seamount B -	29°50'S, 169°10'E
Seamount C -	29°45'S, 170°05'E
Seamount D -	29°21'S, 169°40'E (two adjoining seamounts)
Seamount E -	28°35'S, 169°50'E

The overall area shows strong cross-cutting W and NW trends. This pattern is further characterised by intense circular to elliptical positive anomalies, some as dipole fields. Of note is that only seamount C is characterised by a very intense magnetic high - it being the largest and shallowest of the seamounts. Of the others seamount A has a moderate E-W dipole-like signature, seamount B has a strong magnetic low at its southeast end, seamount D is marked by a +100 to -200 nt ENE-WSW trending dipole and seamount E is associated with no defining anomaly.

The NE-SW trending bathymetric spur to the north of seamount B is associated with a NW-SE trending symmetric anomaly of, successively, 100 nt to 50 nt to 100 nt. The large field of seafloor volcanoes on this feature may explain the overall signature. Furthermore, a large anomaly of greater than 300 nt is located to the north of NE-trending contours, which is also reflected in the gravity map.

As expected, the NNB and SNB are generally associated with fairly featureless and broad magnetic lows, respectively. The eastern edge of the SNB, however, is characterised by a strong magnetic high that trends NNW. This correlates with a broad southwards plunging bathymetric platform into the basin. No seafloor spreading-type anomalies are evident.

The bathymetric platform area to the west of seamounts D and E is characterised by a series of strong NW-striking weak lows and highs, while the complex bathymetric depression north of seamount C is not associated with any distinct anomalous pattern. A strong positive circular magnetic anomaly centred at 29°10'S, 170°15'E correlates with no particular submarine feature.

Eastern portion

The machine-contoured magnetic field for the eastern zone of the survey area (Fig. 49) may be broadly distinguished into three zones:

- a northern zone of high-amplitude magnetic anomalies;
- a western quadrant of low-amplitude magnetic anomalies; and

- an eastern quadrant of moderate-amplitude magnetic signature interspersed with high-amplitude magnetic features.

The northern zone of the eastern portion of the main survey area can be considered to sub-parallel the Cook Fracture Zone, and extends part-way into the South Fiji Basin. Most of the magnetic anomalies are centred over seamounts that have formed along the fracture zone. An intense dipole of –200 to +200 nT is centred just north of a seamount at 27°12'S, 172°E.

The western zone of the area is taken as lying westward of a major sinuous-like N-S bathymetric depression along the western flank of the Three Kings Terrace (Cagou Trough). It is relatively featureless with several broad low- to moderate-amplitude anomalies being centred on, or near, seamounts. These anomalies are slightly more intense along the western rim of the indicated depression (along longitude 171°40-45'E) where they are associated with seamounts. A strong dipole is found over the southern-most seamount at about latitude 29°30'S.

The eastern zone of the area represents the terrain extending from the eastern edge of the Cagou Trough over the Three Kings Terrace and TKR axis to the east. As with its western flank, several moderate anomalies are developed along the eastern flank of the depression, and although not associated with seamounts may signal buried lava or volcanic bodies. Along the eastern edge much of the TKR is weakly magnetic. However, up onto the central ridge axis the magnetic character becomes more locally intense along a N-S trend, which reflects the development of volcanic seamounts. In particular, a series of intense dipoles are localised about several seamounts centred at about 28°35'S, 172°55'E. This signature becomes more diffuse and weakly magnetic further east into the South Fiji Basin.

Northern portion

The main trend of the magnetic contours in the northern portion of the survey area is parallel to the Cook Fracture Zone. However, to the southeast some anomalies strike normal to this trend and appear to be related to NE-SW directed seafloor ridging in the NNB.

Refractions

After two unsuccessful attempts with sonobuoy deployments a third try proved successful on the return transit over the Norfolk Ridge into Noumea. Some two hours of data were recorded and awaits analysis.

Dredge Samples

Three dredge sites (Fig. 11) were attempted with three successful recoveries. The first dredge site was situated at approximately 28°50'S, 171°45'E, on the flank of a large seamount, and recovered about 1.5 kg of manganese-coated carbonate, calcareous silicate and volcanic rock (Fig. 50). The second dredge site was situated at approximately 29°48'S, 172°16'E, on the eastern flank of a large ?uplifted ?oceanic crustal block, and recovered about 200 kg of mostly manganese-coated volcanic rock (Figs 51 & 53). The third dredge site was situated at approximately 27°13'S, 172°39'E, along the southern wall of the Cook Fracture Zone, and recovered 400 kg of mostly basaltic lava flow rock (Fig. 52). A descriptive analysis of sample composition and geological environment is found in Appendix 6, with a more detailed analysis of the petrography for dredge 2 in Appendix 7.

Cruise Narrative

The following represents a brief narrative of the operational aspects of the FAUST-2 survey. All quoted times are given in New Caledonian local time (ie. aboard the vessel). UTC times are plotted along track in Figure 11.

Friday, November 12
Departed Noumea 10h00 in low swell and overcast conditions. Headed north to deploy 600 m streamer, then south for first transit line. Shifts commenced at 12h00 and profile 1 at 14h15. Seismic system stopped recording for about 1 hour at 22h00.

Saturday, November 13
Clear skies, moderate swell and breezy. Commence with profile 2 and end day on profile 4. One gun firing from 04h20 to 08h00. At 09h50 change direction slightly E of S to skirt shallow seamount indicated by Royal Australian Navy charts. At 22h45 problem developed with Bridge autopilot producing large cross-course errors - back on line at 23h07. Deviation not significant given swath width of about 13 km on a transit leg.

Sunday, November 14
Low swell and clear skies. Commenced profile 5

Monday, November 15
Very low swell and clear skies. Started profile 8 at 03h50. Several test were conducted by the technicians into noise levels on the outside beam with the 3.5 kHz echosounder operating - preference was given to maintaining it in operation as it provides very useful bottom profiling and shallow sediment penetration. Profiles 9, 10, 11, 12 and 13 commenced at 12h30, 16h45, 18h40, 21h00 and 21h56, respectively. Profiles 10-13 constructed to fill in some major gaps over elevated seamounts. This deviation has added about 12 hours to the survey time and was considered justified given the complexity of the subsurface. Profiles 14 and 15 commenced at 22h45 and 23h30.

Tuesday, November 16
Low swell and clear skies. Profiles 16 and 17 commenced at 01h00 and 07h35, respectively. Several tests on the beam width were conducted during the night - it appears that the 140° beam width is giving the better results for the dominant bathymetry in the area (ie. water depths > 2500 m). Profile 18 commenced at 19h00. Loss of Uninterrupted Power Supply (UPS) power at 21h01 has meant the end of acquisition - mulitbeam coverage was lost so we have dropped speed and looped back to rectify the problem and recommence swath coverage.

Wednesday, November 17
Moderate swell and slightly rough seas. Profile 18 was recommenced at 00h30. UPS power was lost again at 02h15 and the profile recommenced, after another loop, at 05h15. Sightings of whales (sperm?) at 02h00 towards end of profile 18. Commenced profile 19 at 14h30. During day the gravity meter stopped recording twice, but only for short periods.

Thursday, November 18
Low swell conditions. Profile 20 commenced at 01h30. The decision has been made not to fill in the swath gaps left about the large seamount at 29°45'S,169°E - time constraints for the rest of the survey dictate our current agenda. Clearly, on a large-scale image the smaller holes should be adequately handled by an interpolation routine. Profile 21 commenced at 15h13.

Friday, November 19
Low swell with fine weather, becoming more rough in the evening. Profile 22 commenced at 05h13 and profile 23 at 18h00.

Saturday, November 20
Moderate swell with a slightly rough sea. Short profiles 24 and 25 began at 04h30 and 05h37, respectively. Profile 26 and 27 began at 06h46 and 16h42, respectively. At 18h45 a change in the orientation of profile 27 was taken to close the gap existing between the outer starboard beam and the adjoining line's swath coverage.

Sunday, November 21
Moderate swell, clear skies with a strong breeze. Short profiles 28 to 32 were run over the large guyot, at the southern end of profile 27, to attempt as much swath coverage as possible. Profile 33 commenced at 06h40 and represents start at western end of large tract of seafloor over North Norfolk Basin towards the Three Kings Terrace region.

Monday, November 22
Fine day, low swell and moderate sea. Profile 34 commenced at 04h45. At 08h30 the CHEOPS system (i.e. controlling the 3.5 kHz echosounder) was stopped and restarted to correct data and tracking errors.

Tuesday, November 23
Fine day, calm seas and slight breeze. Profile 35 commenced at 03h45. Several changes were made during the day to the beam width, but noise on the outside beams dictated a 140° setting. Profile 36 commenced at 01h50.

Wednesday, November 24
Fine day and very calm seas. Only one gun in water for most of the morning. Profile 37 commenced at 22h24 and has commenced too far to the west with a slight overlap on adjoining swath coverage.

Thursday, November 25
Fine day with slight breeze. Profile 38 commenced at 18h06, with several beam width changes throughout day to obtain maximum swath coverage versus noise levels.

Friday, November 26
Overcast day with moderate swell and choppy seas. Profile 39 commenced at 14h47.

Saturday, November 27
Fine day with moderately rough sea. Profile 40 commenced at 11h23. Several problems during the day with operation of the CHEOPS 3.5 kHz echosounder.

Sunday, November 28
Overcast day with moderate-rough swell. Profile 41 commenced at 07h27. Slight change in survey design has meant that we will run profiles 41 and 42 in an ESE direction across to the western flank of the TKR and back again. This is done to target some possible dredge sites. Profile 42 commenced at 16h30. An hour of swath coverage was lost at the initiation of profile 42 - to be filled in by a later line from the north. Multibeam data was being re-acquired at 21h45.

Monday, November 29
Moderate to high swell with rough sea causing high levels of noise on seismic data. General NNE strike of survey lines was recommenced with profile 43 at 05h15. This profile was begun after a decision was made to postpone dredging a seafloor high on profile 42 as a result of unfavourable wind conditions for dredging operations.

Tuesday, November 30
Seas abating with moderate swell. Profile 44 commenced at 00h13. From 06h45 to 09h00 only one gun in water. Profile 45 commenced at 15h24. At 16h30 pulled off profile to commence dredging at about 28°49.5'S, 171°45'E - a seamount on the western edge of a major N-S trending bathymetric depression (Cagou Trough). Dredge was brought on board at 20h19 with 3 samples - total recovery about 1.5 kg. At 23h20, after returning from the dredge site, profile 45 was recommenced.

Wednesday, December 1
Seas calm with low swell. Profiles 46 and 47 commenced at 03h54 and 06h10, respectively. From 07h15 to 23h15 conducting dredge operations at dredge site 2 (approximately 29°48.2'S,172°12.8'E) - this is a seafloor feature that seismic data seems to indicate is an elevated basement block or strongly planated seamount. Total recovery was about 200 kg. Profiles 48, 49 and 50 commenced at 14h15, 16h00 and 22h44, respectively. During the day one of the seismic streamer's 6 channels went dead.

Thursday, December 2
Slight breeze with calm seas and low swell. Profiles 51, 52 and 53 commenced at 04h51, 11h15 and 18h51.

Friday, December 3
Calm seas and low swell. Profiles 54 - 58 were run down the axis of the Three Kings Ridge and used to fill in the swath gap from the previous profile 42.

Saturday, December 4
Calm seas and low swell. Profile 59 and 60 commenced at 04h50 and 18h50, respectively.

Sunday, December 5
Calm seas and low swell. Series of short profiles 61A-D commenced at 02h20 and ended at 10h29 to fill gaps in previous swaths tracks taken over seamounts. Profiles 62 and 63 commenced at 10h29 and 17h55, respectively.

Monday, December 6
Calm seas and low swell. Profiles 64, 65 and 66 commenced at 00h44, 03h45 and 13h22. At 19h30 a series of short profiles 66A-C run to complete coverage over western flank of Three Kings Ridge. As remaining survey time now stands this will leave a large gap in the middle of the survey area, over the North Norfolk Basin.

Tuesday, December 7
Calm seas and low swell. Profiles 67, 67A, 68 and 69 commenced at 01h34, 05h22, 09h58 and 18h53. Loss of 3.5 kHz data from CHEOPS at 11h00 for about 10 min.

Wednesday, December 8
Calm seas and low swell. Cable brought aboard at 02h18 for traverse to dredge site 3 - dead channel 2 replaced. Arrived at site at 03h38 and completed at 07h10. Series of short profiles from 70 to 71 carried out over northern flank of survey area.

Thursday, December 9
Calm seas and low swell. Survey now moves into New Caledonia phase - extend ZoNéCo5 coverage over Cook Fracture Zone to complete join with FAUST-2 survey area. Short profiles 72-78 run on a series of NW and adjoining NNE trajectories to complete coverage from Loyalty Ridge to northern North Norfolk Basin, over the Cook Fracture Zone. At 22h30 lost 10 mins of swath coverage due to a system failure.

Friday, December 10
Calm seas and low swell. Profiles 79-88 continue coverage to west to cover southern extension of Loyalty Ridge.

Saturday, December 11
Calm seas and low swell. Profiles 89-100 continue coverage over southern extension of Loyalty Ridge.

Sunday, December 12
Calm seas and low swell. Profiles 101-103 continue coverage over southern extension of Loyalty Ridge.

Monday, December 13
Calm seas and very low swell. N-striking profile 104 continues as transit to Noumea along the Norfolk Ridge - parallel and extending width of initial transit and TRANSNOR swath track. Survey data acquisition stopped at 11h30.

Conclusions

It is too early to present a complete synthesis of the FAUST-2 survey data. However, considerable work has been performed onboard, and we find that an initial interpretation of the data does not fully agree with previous hypotheses presented for the area.

During the survey only three dredges were carried out with all having successful recoveries. The first was the most puzzling due to the small number and variability of the rock types. The second was more successful in recovering some 200 kg of different rock types from a slope indicated by the bathymetry to be at about 6°. The third and final dredge, along the inner southern wall of Cook Fracture Zone, was also very successful in recovering a large suite of some 400 kg of mainly basaltic rock, where some evidence of tectonism in a breccia suggests strike-slip styled rotations and faulting (see description in Appendix 6). This work results in the first investigation of the Cook Fracture Zone, and it is hoped that future Ar/Ar dating of the basalts will provide more information into its evolution. Further investigations using a submersible would provide much insight into the tectonic development of this major oceanic feature.

In the western part of the survey, the Nepean Saddle separates the North and South Norfolk Basins. These basins are elongated in a somewhat N-S direction, which is compatible with an approximate E-W extension. However, these basins are different in shape and in the style of their respective sedimentary fill. Moreover, the volcanic features which mark the boundary between the Nepean Saddle and the South Norfolk Basin trend somewhat E-W. These recent volcanoes and the adjacent small basins may be related to current N-S extension.

The Cagou Trough shows a N-S orientation along with the Three Kings Ridge to its east and the intervening perched basin on the adjoining terrace region. The Cagou Trough has been interpreted as a subduction zone with a benioff zone dipping to the east (Kroenke & Eade, 1982; Kroenke & Dupont, 1982) whereas the Three Kings Ridge is generally understood to be an island arc complex. This arrangement suggests compression in an E-W sense with subduction beneath the ridge to be from the east as argued by some authors (eg. Mortimer et al., 1998). The limited coverage of the data over the eastern flank of the Three Kings Ridge does not afford a clear response to the debate. However, the deep-seismic profiles (ie. AGSO Survey 177) that cross the eastern flank of the Three Kings Ridge give weak evidence of reflectors dipping to the west. For the Cagou Trough itself we are relatively confident that it is an extensional feature and not a trench. However, some recent compression may have occurred along the western side of the trough, but the N-S orientation of the seismic profiles acquired are not favourable for providing clear evidence.

From the satellite gravity and derived bathymetry maps (Smith & Sandwell, 1997) it is possible to observe the difference between the North and South Norfolk Basins. The more northern basin is less uniform than the southern basin and is affected by the eastern prolongation of the Nepean Saddle. The NNE-SSW trending broad ridge and basin features, the adjoining Cagou Trough, the perched basin on the Three Kings Terrace, the Three Kings Ridge and the Cook Fracture Zone are all evident. The Norfolk basin system is situated between the Veining Meinesz Fracture Zone to the south and the Cook Fracture Zone to the north, which according to Mortimer et al. (1998) were both opened during the Miocene behind the Three Kings island-arc system as a pull-apart basin with right-lateral motion. This hypothesis is mainly based on previous works on the Veining Meinesz Fracture Zone (eg. Herzer & Mascle, 1996), a few seismic profiles in the South Norfolk Basin and rocks dredged in the same basin and dated by the Ar/Ar method. However, no rocks have been sampled from the North Norfolk Basin and seismic profiles therein have limited coverage, nevertheless we suggest that a similar striking fracture zone may separate the two basins (ie. Norfolk Fracture Zone).

Previously, the Cook Fracture Zone was supposed to connect, with right-lateral strike-slip motion, the Norfolk basin system with the Loyalty Basin to its north. Rather, it is now apparent that the motion of the fracture zone is probably left-lateral, and that this fracture may link two compression-generated features: the Loyalty and Three Kings Ridges (Fig. 4). However, this hypothesis needs to be tested. Moreover, although work (Van de Beuque et al., 1998) on the recent FAUST-1 data suggests that the Loyalty Basin is Cretaceous in age and that the South Norfolk Basin is probably younger (ie. Miocene; Mortimer et al., 1998) a conclusive age for the North Norfolk Basin is still lacking.

The FAUST-2 data indicates that the Cook Fracture Zone is a very young feature and that several recent earthquakes (Tajima & Okal, 1995) located at the northern tip of the Three Kings Ridge prove continued movement. The depth of the major event was 17.4 km, which is explained by a thickened volcanic crust beneath an island arc system. The shallow depth of the ridge also suggests a thick crust. Tajima and Okal (1995) explain the activity of the fracture zone by a decoupling within the South Fiji Basin; the northern part (Lau Basin) having a faster spreading rate than the southern Havre Trough. From an analysis of the FAUST-2 data we do not see any evidence for the extension of the Cook Fracture Zone into the South Fiji Basin and, therefore, we prefer to invoke the effects of intraplate tectonics. In addition, the NE-SW compressional stress-field is distant from the subduction zone, and is also found on the Norfolk Ridge.

Acknowledgments

The successful completion of FAUST-2 was a fine example of collaboration and cooperation between the Australian and French scientific teams.

The authors would like to thank commandant Philippe Guillemet and the IFREMER and GENAVIR crew of the N/O *l'Atalante* (see Appendix 4) for their professionalism in meeting all aspects of the FAUST-2 objectives.

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Appendix 1

1982 United Nations Convention on the Law of the Sea (UNCLOS)

Article 76: Definition of the continental shelf

1. The continental shelf of a coastal State comprises the seabed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance.

2. The continental shelf of a coastal State shall not extend beyond the limits provided for in paragraphs 4 to 6.

3. The continental margin comprises the submerged prolongation of the land mass of the coastal State, and consists of the seabed and subsoil of the shelf, the slope and the rise. It does not include the deep ocean floor with its oceanic ridges or the subsoil thereof.

4. (a) For the purposes of this Convention, the coastal State shall establish the outer edge of the continental margin wherever the margin extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by either:

   (i) a line delineated in accordance with paragraph 7 by reference to the outermost fixed points at each of which the thickness of sedimentary rocks is at least 1 per cent of the shortest distance from such point to the foot of the continental slope; or

   (ii) a line delineated in accordance with paragraph 7 by reference to fixed points not more than 60 nautical miles from the foot of the continental slope.

   (b) In the absence of evidence to the contrary, the foot of the continental slope shall be determined as the point of maximum change in the gradient at its base.

5. The fixed points comprising the line of the outer limits of the continental shelf on the seabed, drawn in accordance with paragraph 4 (a) (i) and (ii), either shall not exceed 350 nautical miles from the baselines from which the breadth of the territorial sea is measured or shall not exceed 100 nautical miles from the 2,500 metre isobath, which is a line connecting the depths of 2,500 metres.

6. Notwithstanding the provisions of paragraph 5, on submarine ridges, the outer limit of the continental shelf shall not exceed 350 nautical miles from the baselines from which the breadth of the territorial sea is measured. This paragraph does not apply to

submarine elevations that are natural components of the continental margin, such as its plateaux, rises, caps, banks and spurs.

7. The coastal State shall delineate the outer limits of its continental shelf, where that shelf extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by straight lines not exceeding 60 nautical miles in length, connecting fixed points, defined by coordinates of latitude and longitude.

8. Information on the limits of the continental shelf beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured shall be submitted by the coastal State to the Commission on the Limits of the Continental Shelf set up under Annex II on the basis of equitable geographical representation. The Commission shall make recommendations to coastal States on matters related to the establishment of the outer limits of their continental shelf. The limits of the shelf established by a coastal State on the basis of these recommendations shall be final and binding.

9. The coastal State shall deposit with the Secretary-General of the United Nations charts and relevant information, including geodetic data, permanently describing the outer limits of its continental shelf. The Secretary-General shall give due publicity thereto.

10. The provisions of this article are without prejudice to the question of delimitation of the continental shelf between States with opposite or adjacent coasts.

Appendix 2

Informal Terms relating to UNCLOS Article 76

Application of Article 76 of United Nations Convention on the Law of the Sea (UNCLOS) raises several concepts and terms, which will be referred to frequently in interpretations of seismic/bathymetric survey lines for the purposes of 'legal' Continental Shelf (CS) definition. Following are simplified definitions of the more important terms that we commonly use. Some aspects of the application of Article 76 remain unclear, and will only be resolved following further deliberation by the Commission on the Limits of the Continental Shelf.

Firstly, a *Hedberg arc* may be drawn, with a radius of 60 n miles, from an interpreted foot-of-slope (FoS) position. The location at which this arc intersects the seaward extension of the survey line is called the *Hedberg point.* With a series of FoS positions established around a continental margin, at a spacing of less than 120 n miles, a series of intersecting Hedberg arcs may then be constructed. Clearly, as the spacing between survey lines (and therefore, the FoS positions) decreases, the envelope of the intersecting Hedberg arcs approaches a 60 n mile buffered locus of the FoS, except in some cases where the latter contains embayments. This is part of the reason for AGSO's 'safe minimum' approach, where we aim to space survey lines ~30 n mile apart, where logistically possible. The final outcome, the true *Hedberg Line* (the informal name for the line that defines the outer edge of the 'legal' continental margin, as contained in Article 76, paragraph 4(a)(ii), of UNCLOS), is constructed by joining selected points on the Hedberg arcs by straight lines, not more than 60 n mile long. This would normally be done in a manner so as to maximise the size of the enclosed 'legal' continental margin. This true Hedberg Line will normally only intersect the survey line at the Hedberg point where the locus of the FoS points is a straight line. Such situations are unusual in the context of CS beyond 200 n mile, since it is normally associated with irregularly shaped marginal plateaus.

Secondly, a *Sediment Thickness Point* may be determined, by interpretation of a seismic survey line (or possibly by drilling), where the 1% sediment thickness criterion is satisfied. That is, the point at which the thickness of sedimentary rocks is at least 1% of the shortest distance from such point to the FoS. In contrast to the Hedberg arc, this is strictly a single point, which may be joined to adjacent Sediment Thickness points to form the *Sediment Thickness Line* (the informal name for the line that defines the outer edge of the 'legal' continental margin, as contained in Article 76, paragraph 4(a)(i), of UNCLOS), or to selected points on Hedberg arcs, again by straight lines, not more than 60 n mile in length.

Finally, the fixed points (not more than 60 n mile apart) comprising the line which defines the outer limits of the CS, may not lie beyond one or other of two cut-offs. The first cut-off is 350 n mile from the baseline (informally called the *350 n mile cut-off line*), and the second is 100 n mile beyond the 2500 m isobath (informally called the *isobath cut-off line*). The former is purely a geometrical construction from the Territorial Sea baselines, whereas the latter depends on definition of the 2500 m isobath.

Appendix 3

Description of N/O *l'Atalante*

The research vessel N/O *l'Atalante* is owned and equipped by the Institut Français de Recherche pour l'Exploitation de la MER (IFREMER), and is dominantly owned by the French Government. It is a multi-purpose research vessel able to undertake research in marine geosciences, physical oceanography and marine biology, and to navigate all seas excepting those in the polar regions. It was constructed in France in 1990 by Ateliers et Chantiers du Havre, and is registered in Brest, France.

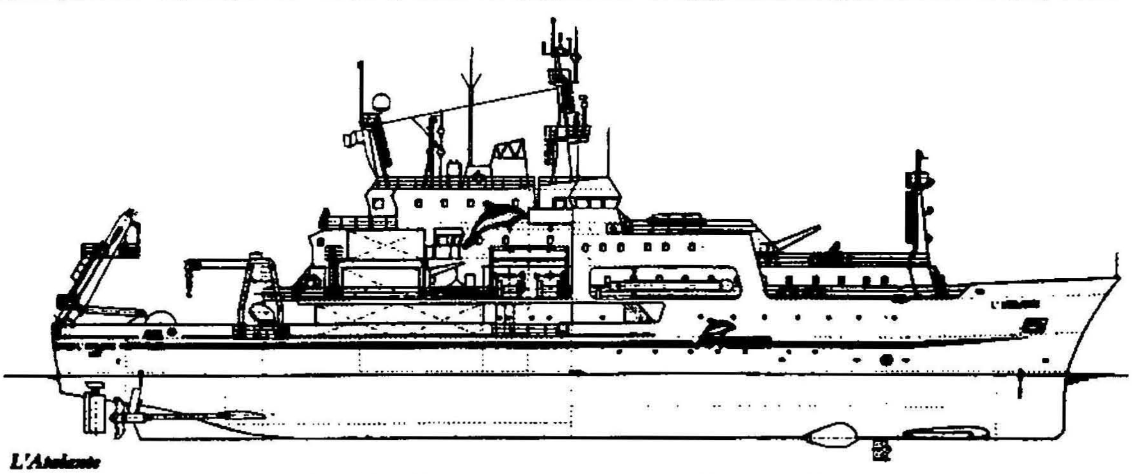
Gross tonnage:	2355 tonnes
Length:	84.60 metres
Breadth:	15.85 metres
Draught:	5.05 metres
Cruising speed:	13 knots
Maximum speed:	14.5 knots
Endurance (12 kts):	60 days
Call sign:	FNCM
Port of registry:	Brest, France

Engines:

Main:	2 electric engines DC 1000 kW operating off 3 diesel 1570 kVA alternators
Propellers:	2, each running off an engine
Side Thrusters:	1 retractable bow 370 kW DC

Accommodation:

Total complement of 59, all in single or double cabins
- officers and crew 17 to 30
- scientists and technicians 25 to 29



L'Atalante

Construit en 1989 par les Ateliers et chantiers du Havre. Longueur : 84,60 m. largeur : 15,85 m. déplacement : 3550 t. équipage : 30 p. scientifiques : 25 p.

Appendix 4

Ship Crew and Scientific Personnel

Ship Crew

Philippe Guillemet	Commandant
Serge Marcade	Chief Mate
Jean François Le Bloas	Mate
Elodie Scholla	Mate
Guy Milliner	Crew Supervisor
Michel Gac	Deck Supervisor
Patrick Paugam	Chef de Bordée
Guy Cordon	Chief Mechanic
Jean Luc Jaouen	Second Mechanic
Olivier Bass	Mechanics Officer
Bruno Callac	Mechanic
Yvon Squiban	Machine Master
Philippe Plouhinec	Electrician
Alain Creach	Carpenter
Frédéric Jourdain	Cadet Officer
Gilles Le Bris	Seaman
Kelekolio Tuataane	Seaman
Fernand Le Bousse	Seaman
Yann Floch	Seaman
Guy Rocher	Seaman
Laurent Floc'h	Cleaner
Thierry Jouneau	Chief Cook
Laurent Le Gros	Second Cook
Gwenaël Le Bot	Chief Steward
Philippe De Beauvais	Second Steward
Jean Paul Riou	ADC
Stephane Ascoet	Steward
Mikaele Tuugahala	Steward

Technicians

André Le Bot	Technician
Antoine Collet	Electronics Officer
Yvon Jaouen	Electronics Officer
Bruno Meneur	Seismic Technician
Christian Nicolas	Technician
Christian Prud'homme	Seismic Technician
Henri Serve	Technician

Scientific Personnel

Australian	George Bernardel	AGSO
	Cameron Buchanan	AGSO
	John Ryan	AGSO
	Nick Smith	Sydney University
	Phil Symonds	AGSO
French	Jean Benkhelil	Université de Perpignan
	Elia D'Acremont	Université de Paris
	Christian Gorini	Université de Lille
	Yves Lafoy	Services de Mines, Nouméa
	Alain Mauffret	Université de Paris
	Alexandre Nercessian	Université de Paris
	Sabrina Van De Beuque	IFREMER, c/o AGSO

Appendix 5

Weather Diary

Note: Temperature is in °C; wind direction in azimuthal degrees and speed in knots; pressure in hectopascals; and wave/swell height in metres; Lat is latitude and Long is longitude; Hour is based on New Caledonian local time.

				Wind		Temperature			Sea-height	
Date	Hour	Lat	Long	dir	speed	dry	sea	Pressure	wave	swell
Nov 14	0300	29.7	168.4	150	8	19.2	21.0	1017.6	0.5	2
	0900	29.8	168.6	130	13	19.5	20.7	1015.0	0.5	
	1500	28.9	168.9	120	12	19.0	21.2	1017.6	0.5	
	2100	29.7	168.7	120	15	20.8	21.1	1019.8	0.5	0.5
Nov 15	0300	29.8	168.9	100	13	20.0	21.3	1017.5	0.5	1
	0900	29.7	168.9	080	15	20.0	20.8	1018.0		
	1500	29.2	169.1	100	12	20.0	21.6	1016.3	1	
	2100	28.7	169.3	120	11	22.0	20.5	1017.0	1	
Nov 16	0300	29.7	169.0	090	10	20.8	21.5	1014.5	1.5	
	1500	29.6	169.2	090	20	19.8		1011.4	1.5	
	2100	29.2	169.3	080	12	22.0	21.2	1012.2	1.5	2.5
Nov 17	0300	28.6	169.7	040	7	21.8	21.5	1010.1	0	2
	0900	29.5	169.4	190	16	20.0	21.9	1010.0		
	1500	29.9	169.4	210	5	20.8	21.8	1004.8	0	
	2100	29.0	169.7	200	4	23.0	20.9	1012.0	0	1
Nov 18	0300	28.1	170.1	170	5	21.9	22.6	1010.7	0	1.5
	1500	30.0	169.5	220	10	20.1	21.9	1011.1		
	2100	29.7	169.8	200	6	21.0	21.5	1011.2	0	1
Nov 19	0300	28.7	170.1	200	10	21.5	21.2	1009.0		
	0900	28.7	170.2	190	22	18.5	20.3	1010.0	2	
	1500	29.6	170.0	200	20	18.3	20.4	1010.3	1.5	2
	2100	29.4	170.2	190	20	18.5	20.3	1013.3	1.5	
Nov 20	0300	28.4	170.5	190	13	19.0	20.5	1013.4	1.5	
	0900	28.9	170.5	230	12	18.5	20.0	1015.5		
	1500	29.8	170.1	270	18	18.6	20.0	1012.6	1.5	
	2100	29.4	170.5	260	18	19.5	19.9	1015.5	1.5	
Nov 21	0300	28.4	170.8	250	13	20.7	20.7	1015.5	1	
	0900	27.4	171.1	210	11	20.5	21.8	1018.0		
	1500	26.5	171.4	180	5	20.3	22.5	1016.8	0	
	2100	27.0	171.4	200	7	20.8	22.4	1018.8		1
Nov 22	0300	28.0	171.1	200	7	20.0	22.0	1018.6	0	1.5
	0900	28.8	170.8	170	7	18.5	19.8	1019.2		
	1500	29.8	170.5	190	5	18.3	20.0	1018.2	0	
	2100	28.9	170.9	180	2	19.8	20.6	1019.4	0	1.5
Nov 23	0300	28.0	171.2	120	11	20.7	21.9	1017.0	0.5	1
	0900	27.1	171.5	120	8	20.5	22.8	1018.0	0	
	1500	26.7	171.8	100	5	20.2	22.8	1015.5	0	1
	2100	27.6	171.5	070	7	22.2	21.9	1016.5	0	1
Nov 24	0300	28.6	171.2	050	3	20.0	21.9	1014.6	0	1
	0900	29.5	170.9	350	6	19.8	19.9	1014.8	0	
	1500	28.4	171.3	010	13	20.1	21.0	1012.2	0.5	
	2100	27.9	171.5	340	9	23.3	22.0	1012.8	0	
Nov 25	0300	27.0	171.9	360	8	22.2	23.5	1012.0	0.5	
	0900	27.1	172.0	360	1	19.5	22.7	1012.6		
	1500	28.1	171.7	210	10	19.7	22.1	1010.9	0.5	2
	2100	29.1	171.3	200	16	20.8	20.8	1012.0	1.5	2
Nov 26	0300	29.7	171.3	210	17	19.8	20.9	1011.5	1.5	2
	0900	28.2	171.6	200	14	20.3	20.8	1011.5		
	1500	27.9	171.9	220	22	19.2	21.7	1010.6	1.5	2

	2100	26.9	172.2	220	19	23.0	23.1	1010.7	1	1.5
Nov 27	0300	27.3	172.1	230	20	21.3	22.2	1007.4	2	
	0900	28.1	171.9	200	17	20.5	21.8	1007.5		
	1500	29.1	171.7	230	28	19.7	21.8	1000.4	2	
Nov 28	0300	29.9	172.8	230	18	19.8	20.5	1006.1	2	
	1500	29.6	171.8	260	28	18.2	21.0	1004.6	3.5	
	2100	28.9	171.8	240	22	19.5	21.6	1007.8	2	3.5
Nov 29	0300	28.1	172.1	230	20	20.0	21.5	1008.7	1.5	4
	0900	27.3	172.4	210	14	20.3	21.8	1011.5		
	1500	27.3	172.6	240	17	19.4	21.8	1010.8		
	2100	28.1	172.3	210	15	18.6	21.6	1013.4	1	2
Nov 30	0300	28.9	172.0	190	12	19.3	21.4	1012.7	1	3
	1500	29.5	171.8	200	13	18.7	20.7	1015.2		
Dec 1	0300	29.5	172.2	170	10	19.4	20.9	1017.8	0.5	1.5
	0900	28.6	172.3	130	6	19.6	21.7	1019.5		
	1500	29.2	172.3	190	5	19.2	20.7	1019.0		
	2100	20.7	172.5	150	6	20.4	21.1	1021.4	0	1
Dec 2	0300	29.1	172.6	180	8	19.4	20.8	1020.3	0.5	1.5
	0900	29.3	172.6	140	11	19.6	20.2	1021.5		
	1500	28.5	173.0	160	18	20.1	21.6	1019.6		
	2100	29.4	172.7	120	9	20.6	20.3	1022.0	0.5	1
Dec 3	0300	29.5	172.9	140	7	20.0	20.8	1020.8	0	1
	0900	28.7	173.2	100	7	20.0	21.6	1021.0		
	1500	29.8	173.1	180	7	19.2	20.4	1019.2		
	2100	28.7	173.3	130	9	21.4	21.5	1020.5		
Dec 4	0300	27.8	173.7	140	18	21.1	22.2	1017.7	1	
	0900	27.6	173.5	130	11	21.5	22.1	1019.0		
	2100	28.4	173.9	130	16	20.5	21.6	1017.7	1	
Dec 5	0300	27.6	173.4	140	10	21.5	22.5	1015.9	0.5	1
	0900	27.7	173.2	130	15	21.4	21.8	1015.4		
	1500	27.9	173.0	110	10	21.0	21.7	1014.3		
	2100	27.0	173.3	100	12	21.2	22.6	1014.5	1	
Dec 6	0300	26.8	173.2	100	12	21.4	23.2	1011.8	1	
	0900	27.6	172.9	120	11	21.5	21.8	1013.5		
	1500	28.1	172.8	130	12	21.1	21.5	1012.6		
	2100	27.2	172.9	140	18	23.5	22.5	1013.5	1.5	
Dec 7	0300	27.9	172.6	130	15	21.0	21.9	1013.3	1.5	
	0900	27.9	172.5	140	17	21.0	21.8	1014.7		
	1500	27.2	172.7	140	15	20.6	22.3	1013.2	1.5	
	2100	27.1	172.7	160	20	22.4	22.6	1014.0	1.5	
Dec 8	0300	26.5	172.1	120	15	22.2	23.2	1013.0	1.5	2
	0900	26.2	172.1	140	19	21.6	22.9	1013.2		
	1500	26.3	171.1	140	15	21.3	22.4	1012.2		
	2100	25.9	170.9	150	14	22.8	22.1	1013.6	1.5	
Dec 9	0300	26.6	170.7	110	15	21.8	22.4	1012.2	2	
	0900	25.7	170.5	120	9	22.0	22.9	1012.8		
	1500	26.6	170.4	100	10	21.3	22.1	1012.8		
	2100	25.7	170.4	110	10	23.0	23.2	1013.5	1	
Dec 10	0300	26.5	170.1	100	13	23.9	22.9	1012.7	1	
	0900	25.5	170.3	70	15	23.0	23.5	1013.5		
	1500	26.2	169.8	80	12	22.4	22.3	1012.9		
	2100	25.7	169.8	30	4	24.5	23.6	1013.6	0.5	1
Dec 11	0300	25.7	169.7	80	5	24.0	24.5	1012.2		
	0900	26.0	169.2	60	5	23.0	23.5	1013.0		
	1500	25.9	169.2	50	8	22.4	22.6	1012.1		
	2100	25.6	168.7	50	10	24.0	23.7	1013.0	0.5	
Dec 12	0300	25.6	167.7	40	10	24.5	24.3	1011.2	0.5	
	0900	25.1	167.1	360	13	24.0	24.3	1011.6		
	1500	24.6	167.0	100	10	23.8	24.1	1011.2		

Appendix 6

Dredge details and onboard sample descriptions

Note: all positions are actual vessel positions; T refers to wire strain in tonnes.

FAUST-2 Dredge 1

The first dredge is located in the southern end of the Cagou Trough to the west of profile 40 (Fig. 11). The scarp dredged is relatively steep (22°, Fig. 50).

Date:	November 30, 1999
Deploy:	28°49.81'S, 171°44.71'E. 3270 m. 16h45.
End:	28°50.43'S, 171°43.60'E.
Distance:	2.7 nautical miles
Direction:	220°

Bottom at 17h30. 28°49.72'S, 171°44.76'E. 3159 m. Length of cable: 3313 m.
Beginning of dredging at 17h40. 28°49.95'S, 171°44.51'E. 2930 m. Length of cable: 3600 m.

Important hits:

18h29. 28°50.78'S, 171°43.65'E. 7.5T.
18h40. 28°51.00'S, 171°43.52'E. 15T. 36 minutes.
19h20. 28°50.54'S, 171°43.71'E. 15T. 12 minutes.
19h35. Beginning of recuperation of wire. 19h35. 2250 m.
19h42. The dredge leaves the bottom 28°50.42'S, 171°43.49'E. 2237 m.

Sample description

Note: not all samples have been transcribed from the original log sheets, as not all samples were retained. For a full description of all samples refer to the original rock descriptions. Also, some sample numbers have been omitted because they were not retained.

SERIES A

A1 Size: 16 x 13 x 4 cm. Shape: Flattened oval-shape with sharp edges and fresh broken surface. A conchoidal surface indicates fine-grained material. One face is Mn coated, the other is fresh. Density: Average. Colour: One face orange with small black spots and dendrites (Mn). White veins and a white patch are present. Texture: Cryptocrystalline (very fine-grained) with no minerals visible to either naked eye or hand-lens. Structure: Irregular breaks suggest microstructures of 2 types. Grey-white irregular veinlets (mm scale) and microfractures (lens-visible) filled with grey crystallisation (quartz) forming a regular set. A second set cross-cuts the first one and is filled with microcrystalline Mn. On a fresh break, a concave surface bears linear features (striations?), which are observed in a small plane too. Other Features: The rock reacts strongly with HCl (10%), but vein material does not react. Rock type: carbonate.

SERIES B

B1 Size: 11 x 8 x 4 cm. Shape: Triangular piece with a thickening in its wider part. The borders are rounded and the surface is smooth and semi-regular. Breaks across the general fabric are irregular. Density: Average. Colour: Two distinct parts, one a black Mn coating, and the other a fresh greenish colour with a red-brown fringe at the Mn contact. Colour of breaks is light brown. Texture: No well-formed mineral can be identified by naked eye. Grey-green material forms the bulk of the sample with orange-brown carbonate material as infilling. Veins of grey-white translucent material are also visible in rare patches. Structure: The fabric of the rock is clearly oriented, but may be due to fractures filled with feldspar. Some striations are visible on planar surfaces. Rock type: calcareous silicate.

SERIES C

C1 Size: 7.5 x 5 x 5 cm. Shape: Sub-rounded pebble with triangular shape. The surface is smooth and regular except for one broken face. Density: Low. Colour: Grey, but variable due to Mn coating. One dark grey face, one light grey, with some orange and black colouration. Texture: Highly vesicular, with vesicles coalescent rather than spherical. Vesicles range from < 1 mm to 5 mm (1 mm average). Some vesicles contain fibrous structures, and quartz crystallisation is observed in two cases. Structure: No macrostructure or oriented features are visible. Rock type: volcanic pumice.

FAUST-2 Dredge 2

The second dredge is located on a block in the southern part of the eastern portion of the survey (Fig. 11). The scarp is very smooth and of low gradient (6°, Fig. 51).

Date: December 1, 1999
Deploy: 29°47.23'S, 172°16.11'E. 3270 m. 16h45.
End: 29°48.05'S, 172°12.97'E.
Direction: 269.6°

Bottom: 08h03. 29°48.2'S, 172°16.1'E. 2508 m. Length of the cable: 2563 m.
Beginning of the dredge: 08h08. 29°48.2'S, 172°15.9'E. 2448 m. Length of the cable:2811 m.

Important hits:

09h22. 28°48.2'S, 172°13.8'E. 6T.
10h06. 29°48.2'S, 172°12.6'E. 9T.
10h21. 29°48.1'S, 172°12.36'E. 12T.
10h25. 29°48.15'S, 172°12.4'E. 12.5T. 18 minutes.
10h45. 29°48.15'S, 172°12.4'E. 12.5T. 13 minutes.
11h00. The dredge leaves the bottom 29°48.0'S, 172°13.0'E. 1621 m.
11h32. Dredge on board. 29°48.2'S, 172°12.7'E.

Sample description

Note: not all samples have been transcribed from the original log sheets, as not all samples were retained. For a full description of all samples please see the original rock descriptions. Also some sample numbers have been omitted because they were not retained. See Figure 53 for some photographs of both raw and sectioned samples.

SERIES A

A1 (2) Mn encrusted pebbles, sub-rounded, up to 10 cm diameter. Basaltic, olive-green colouring with vesicles containing weathered olivine and pyroxene crystals.

A2 (2) Very few vesicles, fine cracks with Mn in a grey-green matrix.

A3 (2) Very fine Mn crust. Brown-green, vesicular with some vesicles filled with grey-cream coloured material, possible crystal ghost.

A4 (2) Large pebble up to 100 mm, vesicular, dense and olive-green in colour. Brown patches (altered phenocrysts?) and Mn crust.

A5 (2) Orange coloured, very altered, weathered, phenocrysts, possibly ferromagnesian.

A7 (2) Dense, green coloured, without phenocrysts. Fine-grained microcrystalline rock (basalt/ andesite?).

A8 (1) Green coloured, vesicular, crystal. Dense, fine-grained matrix (volcanic?).

A9 (2) Big altered phenocrysts and one olivine crystal. Fine matrix (glass?).

A10 (2) Unknown.

A11 (1) Grey-green. Highly vesicular fine-grained rock, with spots of alteration, quite distinct from other A series.

A12 (2) Grey-green dense rock with olivine and pyroxene crystals.

A14 (2) Dense, fine-grained matrix with very large crystals and no vesicles (basalt?).

A15 (2) Grey matrix, no vesicles, with feldspathic phenocrysts (volcanic?).

A16 (2) Vesicles and crystal ghosts. Big phenocrysts, in very altered, yellow matrix.

A17 (2) Large altered green crystals and phenocryst ghosts.

A18 (2) Vesicles with recrystallisation. Very weathered volcanic rocks with possible amorphous quartz in vesicles.

A20 (1) Rich in green minerals (olivine?) with altered recrystallisations.

A23 (2) Fine-grained green matrix. Very weathered with no vesicles (altered volcanics?).

A24 (2) Green coloured, with vesicles in a fine-grained matrix.

A25 (2) As A24.

A26 (2) As A24.

A27 (3) As A24, but with thick Mn crust.

A28 (2) As A24.

A29 (2) As A24.

A30 (2) Grey-green, dense, with few visible minerals in a microcrystalline matrix.

A31 (2) Brown-green, dense rock with some prismatic green minerals(amphibole/pyroxene?).

A32 (2) Dense, fine-grained rock, grey-green colour, with few vesicles. No visible minerals.

A33 (2) Grey-green, fine-grained rock. Volcanic with no visible minerals, low density and few vesicles.

A34 (2) As A33.

SERIES B

B1 (Bits) Yellow-orange-rock, very fine-grained with some prismatic, elongated green crystals (amphiboles). Showing twinning (1 family visible) volcanic.

B2 (1) Yellow rock with a lot of vesicles, some big crystals of feldspar. Recrystallisation visible (amorphous silica).

B3 (2) As B2.

B4 (7) As B2.

B5 (Bits) As B2.

B6 (Bits) As B2 with big vesicles, volcanic.

B7 (3) As B2 with quartz.

B8 (2) As B2.

B10 (2) As B2, very weathered.

B11 (2) Yellow colour. Very weathered, some clastics of olivine.
B12 (2) As B11.
B13 (2) Orange fine-grained. Large crystals of green round shape (olivine?). Few ghosts of crystals.
B15 (1) As B2.
B16 (2) As B2.
B17 (1) As B2.
B18 (2) As B2.
B19 (2) As B2.
B20 (3) As B2.
B21 (2) As B2.
B22 (2) As B2.
B23 (2) As B2.
B24 (2) As B2.

SERIES C

C1(1) Size and colour: greenish with diffuse reddish patches at fresh section. Surface is Mn coated. Texture: The rock is massive and weathered, it is loosely cemented. The texture is coarse-grained with a green matrix formed by quartz and debris mixed with clay. The elements are pebbles and biogenic material. The pebbles are mostly a few mm in size but greatly vary. They are dark brown (oxidised) or black and the shape is subrounded and sometimes elongated and/or flat. Biogenic material is abundant including broken shells of lamellibranch, gastropod, worm tubes and some internal moulds. Structure: no visible bedding or other laminar structure. Rock Type: Biogenic coarse-grained sandstone.

C2(1) Size and colour: grey-greenish with white patches and localised red-yellow oxidation. Texture: The rock is massive and the particles are fine and the texture is homogeneous. Elements are mainly broken shells, briozoa, worm tubes. The rock is loosely cemented and it reacts with diluted HCl. Rock Type: loose cemented bioclastic sandstone

C3(1) Size and colour: grey-greenish with small white patches and white yellowish veins or coating. Texture: Massive rock with a fine-grained texture. The elements are broken shells less than 1mm, larger shells are common lamellibranch, worm tubes, bryozoa. Reaction to diluted HCl not very strong. Structure: No visible bedding or other structure except in one piece at a fresh break where there is a weak lamination possibly indicating bedding.

C4(bits) Size and colour: rounded block grey-greenish. Texture: The sample is heterogenous due to white coating or veining. The matrix is very fine-grained and mainly argillacesus containing small shell debris. HCl reaction present. Structure: no bedding or other structure. Rock type: calcareous biogenic clay.

C5 (1) Size and colour: 2 pieces 20 x 10 x 7 cm green-yellow with oxidisation. Texture: Loosely cemented fine-grained rock with small pieces of shell. Biogenic elements are recognised briozoa, worm tubes, etc. Structure: no bedding or flow structure visible. Rock type: calcareous biogenic clay.

C6 (4) Size and colour: 25 x 10 x 7 cm greenish at fresh section and black Mn coating in two facies. Red oxidisation between the coating and fresh rock. Texture: coarse-grained texture with numerous mm-sized pebbles. A weak oxidisation is worked by alignment of biogenic debris. Matrix is clayey and the pebbles have various sizes and shapes, rounded, oval, elongated. The colours are dark green, grey, brown. Biogenic clasts are formed by lamillibranch, shells, bryozoa and tiny green spicules.

C7(2) Size and colour: 6 pieces, 10 x 6 x 1 cm, from a single block, with greenish to yellowish colour, with numerous clay spots and white coating. Texture: rock is formed by a clay matrix with abundant biozoic elements and pebbles, which may reach 3mm in size. They are rounded and elongated while some are more angular. The biogenic part is dominated by numerous bryozoa and other small debris. Structure: no layer structure is visible except weak bedding mobilised by alignment of the debris. Rock type: clay calcareous biogenic sandstone.

C8(bits) Size and colour: several pieces yellow and slightly reddish. Texture: loosely cemented fine-grained with scattered small pebbles. The clay matrix is abundant. Shape of the pebbles is variable from subrounded and elongated to rectangular. Some very angular (quartzite) with a vein about 2 cm wide cross cuts the sample. It is formed by a very fine-grained grey-brown material. It includes a hole filled with white mineral (clay) with some brown material in the vein.

D SERIES

D1 (2) Size and colour: 4 pieces of same block reddish to pinkish in section, the facies are black and Mn coated. Texture: made up of two facies: (1) coarse-grained sandstone with white gravel loosely cemented. The gravel includes rounded, oval and subangular shapes with the colours of the elements varying from dark grey to green. The surface may be polished, or iron coated; and (2) calcareous grainstone is formed by a fine-grained pinkish carbonate material including clasts (gravel and quartz) and recrystalised calcite with banded intervals, which may form veinlets cutting across the carbonate. Clasts embodied within the carbonate are not abundant. Biogenic fraction occurs in both facies including foraminifera, bryozoa, green spicules, coral debris. Structure: no visible bedding, veinlets cutting across the rock filled with a whitish calcareous material. Rock type: calcareous coarse-grained sandstone.

D2 (2) Size and colour: pieces of the same block are pinkish to greenish-yellow with black crust. Texture: same as D1. The carbonate is more abundant and some clasts of sandstones are included in the carbonate. Locally there is a concentration of green gravel and foramanifera. Rock type: calcareous coarse-grained sandstone.

D3 (5) Size and colour: pinkish with pieces of yellow to light brown inclusions. Texture: almost entirely carbonate with numerous clasts, pebbles and microfossils. Large pieces of sandy material are included within the carbonate mass. Pebbles are varied in size, colour and texture. Their shape varies from subangular to oval. Pieces of volcanics. Structure: no visible bedding, pinkish calcite veins (1mm). Karstic dissolution and ferruginised surface within the holes. Mn crust coats the karstic surface. Rock type: gravel and sandy limestone.

D4 (2) As D1. In addition the rock is weathered and affected by a set of irregular filled joints. Fresh subautomorphic white mineral present (feldspar).

SERIES E

E1 (1) Size and colour: 4 pieces of a single block. Dark red samples with small white dots. One surface comprises a 1 cm thick crust. Texture: rock is medium, locally coarse-grained sandstone including clasts (shells, pebbles). The grains are formed by quartz, which is grey, subrounded and poorly sorted. A vein 1 to 2 cm wide cuts across the sandstone, and is filled by a white pink carbonate matrix including shells and pebbles. Structure: a weak alignment marked by shells and parallel to the bedding. The carbonate vein cuts across the bedding at right angles. Rock type: calcareous sandstone.

E3 (4) Size and colour: the rock is reddish to locally pinkish on fresh faces with black Mn coating on exposed surfaces. Texture: heterogeneous of two facies: (1) a medium- to coarse-grained sandstone formed by lighter coloured grains (quartz, biogenic clasts) and red to brown elements up to 1 mm in size; and (2) a facies formed by a fine, pinkish-white carbonate material including numerous coarse grains (various clasts, pebbles, brown patches, shell debris). The carbonate seems to have occurred as veining within the sandstone, and the boundary between the two facies is not sharp but gradational. The rock also supports holes (+1 cm) filled with a white chalky material. The surface of the rock shows traces of karstic dissolution in reaction with the carbonate. Rock type: calcareous sandstone.

F SERIES

F1 (2) Size and colour: Pale greenish to yellow with a black Mn coat and numerous white patches. Texture: fine-grained and clay rich, poorly lithified. It contains some carbonate in the ground mass (HCl reaction) and as infilling of worm tubes. The rock displays several Mn inclusions generally following joints. Structure: no visible bedding but a form of fabric may correspond to it. The holes (worm tubes) are up to 1 cm in diameter and abundant. They have either circular or flattened section where their path coincides with the bedding. This may suggest formation in poorly consolidated sediment with subsequent flattening during diagenesis. Other: no trace of shell debris, most of the worm holes are coated by a thin red ferrigenous crust. Rock type: calcareous claystone.

F3 (3) Size and colour: grey greenish in fresh section, a black Mn crust on a face, and red coating along a fracture surface. Texture: a claystone identical to F4. Structure: in section the rock displays fractures of two types. The first one is formed by a joint filled with a thin Mn coating, while the second is an open fracture with a thin (1 mm) whitish to red crust (in section) - red at the surface of crust. A reaction to HCl indicates the presence of calcite (at least). A fracture forms a 2 cm-wide zone. Traces of worm tubes are present, but are restricted at the interface with the Mn crust (1 cm). Whitish clay-like material is present within the fracture. Rock type: claystone.

F4 (1) Size and colour: grey-greenish colour, the sample hosts white spots and ferruginised worm holes. Texture: rock is formed by a clay matrix containing a finer fraction. Structure: no bedding. The rock is affected by numerous holes corresponding to tubes 1 mm to 2 mm in diameter, coated with iron oxides or filled with a whitish clay-like fraction. The length of the tubes may exceed 5 cm. The density of the tube increases near the boundary with the Mn crust. Rock type: claystone.

F5 (2) As F1 / F3.

F6 (2) Size and colour: greenish to light brown. Texture: the rock hosts carbonate in the groundmass. A white chalky powder occurs as infilling to fractures. Structure: no visible bedding, but irregular network of small joints filled with Mn, one infilled with chalky material. Rock type: calcareous claystone.

G SERIES

G1 (2) Size and colour: white to reddish pieces of the same block. Texture: microconglomeratic, the matrix is white carbonate-bearing pebbles and biogenic clasts (shells, foraminifera). The microconglomerate is polygenic with subrounded and some subangular elements. Among the many rock types forming pebbles are: fine-grained basic rock with dark minerals (gabbro), fine-grained dark green rock, grey microlithic lava, and olive green lava with phenocrysts. Structure: none visible, and the surface is affected by dissolution. The pebbles are iron-coated and red/yellow oxidation is abundant. Rock type: calcareous conglomerate. Also a brown pebble of a vesicular lava containing phenocrysts.

G2 (2) Size and colour: conglomerate with red to white ground mass made of limestone. Pebbles are made of yellow lava, dark grey fine-grained rock, and greenish amorphous rock. Rock type: calcareous conglomerate.

G3 (1) Size and colour: 3 pieces of same block with various colours but generally clear. Texture: conglomeratic with a coarse-grained matrix, formed by a mixture of gravel and carbonate cement. Pebbles up to 5 cm across formed by a dark, fine-grained rock (brown microlithic texture with small (1 mm) green nodules. The matrix contains some biogenic clasts. The surface of the pebbles bears a ferruginised coating. Rock type: calcareous conglomerate.

G4 (2) Size and colour: conglomerate with large yellow pebbles (11 cm) of lava with inclusions and some olivine patches.

G6 (1) Large piece of conglomerate similar to G1. Red pebble half broken (chert or radiolarite?). Grey pebble, sub-rounded, very fine-grained texture.

G7 (2) Size and colour: pieces of conglomerate with a white calcareous groundmass, which contains debris of lamellibranch, corals, and bryozoa. The pebbles are either ovoid or subangular. They are iron-coated at the surface. The rock types identified are: gabbro; ?dolerite; vesicular, light brown lava, and; a green colored sample (metamorphic?). A single piece (1 cm) of very fresh olivine. Rock type: calcareous conglomerate.

H SERIES

H1 (2) Very similar to type B, the groundmass is darker grey, but contains the same minerals.
H2 (2) As H1.
H3 (2) As H1.
H4 (2) As H1.
H5 (2) Full of big vesicles. Very fine-grained grey matrix (volcanics?).
H6 (2) As H1 with lots of white (feldspathic?) minerals.

H7 (2) Grey matrix, with vesicles and white patches.
H8 (2) As H7.
H9 (2) As H7.

I SERIES

I1 (2) Grained rock with very weathered ferromagnesian minerals and some garnets. Probably igneous rock (peridotite?).
I2 (2) Possibly belongs to a different group. Very large weathered crystal in a fine-grained matrix.
I3 (2) As I1.
I4 (2) As I1.
I5 (1) As I1.
I6 (1) As I1.
I7 (3) As I1.

J SERIES

J1 (3) Size and colour: piece of a yellow-green weathered medium-grained rock. It is a claystone without any amount of carbonate in the groundmass. The rock shows several holes corresponding to worm tubes, often coated with a white concretion containing carbonate. Red oxidation is common along joints and inside holes. Rock type: claystone.

K SERIES

General: yellow/orange heterogeneous rock. Texture: an agglomerate of volcanic lava blocks cemented by a groundmass of deeply-weathered volcanic ash and debris. The individual pieces may reach 12 cm (at most) in size. These are lavas containing crystals of grey/white quartz, and olivine crystals in a microlithic or weathered glassy groundmass. Some elements consist exclusively of weathered green/yellow material with fresh green components (olivine?). Amorphous silica forms small white/grey patches around the elements. In sample K3, the elements are orange and blue (olivine?), and are cemented by a network of amorphous silica. Holes are filled with a very pure white calcareous powder. Rock type: volcanic agglomerate.

K1 (2) Greenish to yellow agglomerate with elements (to 5 cm) and light brown fine material that formed the groundmass with small angular pieces of lava.
K2 (2) As K1.
K3 (5) As K1.
K4 (1 + bits) As K1.
K5 (2) As K1.
K6 (1) Includes angular pieces of weathering lavas (yellow to orange) and a piece of volcanic lava.
K7 (1) As K1.
K8 (1) Rounded pieces of lava. Light brown to orange.
K9 (1) Mn crust.
K10 (bits) As K1.
K11 (1) As K9.
K12 (1) Greenish-yellow volcanic agglomerate with pieces of lava, not exceeding 1 cm.
K13 (2) As K1.

L SERIES

L1 (1) Grained rock, minerals visible, black subautomorphous crystal and white mineral species between these crystals. Plutonic (gabbros with white feldspar and black pyroxene).

L2 (1) As L1.

L3 (2) Grained rock, mineral visible. Lots of weathered ferromagnesian with green mineral species.

L5 (1) Grained rock, minerals visible. White crystals and black subautomorphous ferromagnesian. Plutonic rock (gabbro with white feldspar and black pyroxene).

L6 (2) As L5.

M SERIES

M1 (2) Dolerite? Fine- to very fine-grained texture. Very rich in ferromagnesian crystals (pyroxene). White coloured crystals (feldspar). Some visible recrystallisation. Doleritic texture.

M2 (1) As M1.

M3 (1) As M1.

N SERIES

N1 (1) Size and colour: whitish with Mn crust and red oxidisation. Texture: Very fine-grained (micrite) with discrete layers formed by small gravels (yellow/light brown). A sutured surface (almost rhyolitic) separates a fine micritic material from a gravel-like part of the rock. The rock contains a dendritic network of Mn. Structure: the bedding is faint and only shown by the irregular surface between different parts of the rock. The surface is rich in dissolution holes, some filled with white "chalky" powder (reacts with HCl). Rock type: gravelly biomicrite.

O SERIES

O1 (1) Coarse conglomerate (see R series) with Mn crust.

P SERIES

P1 (2) Quite dense, purple colour, few vessicles, very fine-grained rock. Dispersion of volcanic fragments and volcanoclastics (ignimbrite).

P2 (2) As P1, some white mineralisation (polymorphs silica). Ignimbrite.

P3 (1) As P1, plenty of white small mineral disseminated into the matrix. Ignimbrite.

P4 (1) Very fine-grained matrix with phenocrysts of quartz and feldspar. Ignimbrite.

Q SERIES

Q1 (2) Fine-grained grey siltstone. No sand/pebbles. No carbonate (no reaction with HCl).

Q2 (2) As Q1.

R SERIES

R Manganese crusts.

S SERIES

S1 Pink dense fine-grained rock with some veins, probably metamorphic.

S2 As S1.

FAUST-2 Dredge 3

The third dredge is located on the southern high-relief flank of the Cook Fracture Zone to the east of the northern extremity of profile 44 (Fig. 11). The scarp is moderately steep (10°, Fig. 52). The samples are abundant but less varied than those for the second dredge (see above).

Date: December 8, 1999
Deploy: 27°13.00'S, 172°39.00'E. 3270 m. 16h45.
End: 27°12.29'S,'172°38.95 E.
Direction: 120°

Station: 03h35 dredge at sea surface. 03h48 27°12.3'S, 172°38.93'E. 4050 m.
Bottom: 04h44. 27°12.6'S, 172°39.4'E. 3900 m. Length of cable: 4000 m.
Beginning of dredge: 05h07. 27°12.7'S, 172°39.9'E. 4400 m.

Important hits:
05h10. 27°13.0'S, 172°38.9'E. 7.5T. 1 minute.
05h37. 27°13.4'S, 172°39.0'E. 10-15T. 20 minutes.
05h58. 27°93.0'S, 172°39.0'E. 10-14T.
06h00. Beginning of recovery of the wire. 3380 m.
06h16. Dredge leaves the bottom 27°13.16'S, 172°39.05'E. 3380 m.
07h10. Dredge on board. 27°13.3'S, 172°39.2'E.

Sample description
Note: not all samples have been transcribed from the original log sheets, as not all samples were retained. For a full description of all samples please see the original rock descriptions. Also, some sample numbers have been omitted because they were not retained.

A SERIES
A1 Fine-grained rock with some vesicles. Dense and grey colour rock. Seems to be rich in feldspars. Probably dolerite structure.
A2 As A1.
A3 As A1.
A4 As A1.
A5 As A1.
A6 As A1.
A7 As A1.

B SERIES
B1 Very fine-grained rock with lots of big vesicles. Large basaltic lava flow.
B2 Fine-grained rock, small vesicles. Weathered basaltic lava.
B3 As B1.
B4 As B2.
B5 As B1.
B6 As B1.
B7 As B1.

C SERIES (number of samples not numbered)

C1 Some pillow lava (basalt similar to B series) interbedded in sediment (white and breccia matrix). The interface between sediment and pillow lava is quite glassy and very weathered. Chilled effect on the edge of the pillow lava.

D SERIES (number of samples not numbered)

D1 Volcanoclastic-rich breccia, broken pieces of Series C type pillow lavas. Evidence of syntectonic breccia with strike-slip rotation, faulting and thrusting.

D2 Dark breccia with small basaltic angular elements in a weathered matrix.

D3 Dark grey breccia with a subrounded vessicular basalt.

E SERIES (number of samples not numbered)

E Lava flows similar to A series - cooking of sediment between the blocks, chilled effect. Pieces have been rolled.

Samples sent to UPMC and IFREMER

One slice from each of the samples taken in dredges 1 and 3.
Samples from dredge 2 listed below.

A SERIES
A1 A2 A3 A4 A5 A7 A8 A9 A10 A11 A12 A14 A15 A16 A17 A18
A20 A21 A23 A24 A25 A26 A28 A29 A30 A31 A32 A33 A34

B SERIES
B1 B2 B3 B4 B5 B6 B7 B8 B10 B11 B12 B13 B15 B16 B17 B18
B19 B20 B21 B22 B23 B24

C SERIES
C2 C3 C4 C5 C6 C7 C8

D SERIES
D1 D2 D3 D4

E SERIES
E1 E2 E3 E4

F SERIES
F1 F3 F4 F5 F6 F7

G SERIES
G1 G2 G3 G4 G6 G7

H SERIES
H1 H2 H3 H4 H5 H6 H7 H8 H9 H10

I SERIES
I1 I2 I3 I4 I5 I6 I7

J SERIES
J1 J2

K SERIES
K1 K2 K3 K4 K5 K6 K7 K9 K10 K11 K12 K13

L SERIES
L1 L2 L5 L6

M SERIES
M1 M2 M3

N SERIES
N1

O SERIES
O1

P SERIES
P1 P2 P3 P4

Q SERIES
Q1 Q2

R SERIES
R 1 BAG EACH

S SERIES
S1 S2

The balance of the samples were shipped to the Australian Geological Survey Organisation, Canberra, Australia.

Appendix 7

Detailed dredge 2 samples lithofacies description

Lithofacies C: Biogenic coarse-grained sandstone to biogenic sandy claystone

Petrographic description

This lithofacies type is a pale green to yellowish, poorly cemented sandstone. Detrital fragments form the major component of this generally massive sediment. It does not generally exhibit clear bedding, except in a few cases where it may be weakly defined by the alignment of flat shell pieces. The matrix of the rock is a mixture of clay and fine sand with a small amount of carbonate. Some diffuse veins filled with a white-pinkish clay-like material cut across the rock.

The components of lithofacies C include both mineral and biogenic phases. Inorganic clasts form the gravel component. The nature, shape, colour and size of the pebbles is extremely varied and includes several rock-types that will need to be identified under the microscope. Quartzite has tentatively been identified. The biogenic fraction is abundant and varied. The rock is very rich in bryozoa fragments and worm tubes, and includes, in lesser proportions, internal moulds of gastropods, lamellibranch shells, echinoids, debris from crustacea, crinoids, and corals, with foraminifera (*Globorotalia menardi*?) also identified.

Depositional history

Lithofacies C was deposited in a shallow-water environment as attested by the faunal association and the clastic component, which includes gravels. Further petrographic study of the pebbles will help to define the nature of the adjacent landmass. The abundant fine fractions of the rock indicate significant terrigenous input. Further analysis of the clay minerals may provide evidence on the climate and weathering conditions of the source area. After initial deposition the sediments were subjected to diagenetic processes including fluid circulation with precipitation and concentration of material in irregular veins within the poorly consolidated rock. Identification of the vein mineralogy will require X-ray analysis.

The age of lithofacies C cannot be constrained at this time, but its facies and faunal characteristics indicate that it could be Miocene, and that it subsided to its present depth during the Pliocene.

Lithofacies D: Sandy-gravelly limestone

Petrographic description

This lithofacies is a pink to red biosparite containing a high proportion of gravel and sand-grade detritus. The rock is similar to the calcareous red sandstone of lithofacies E, but the carbonate is dominant. The detrital fraction is the same: poorly sorted gravels and sand mixed with a variable amount of bioclastics. The gravel clasts vary from subrounded to subangular. The presence of a fresh sub-euhedral mineral, probably feldspar, indicates limited transport from the source area. The petrographic nature of the gravel is varied and the following rock/mineral types are present: volcanics, quartz, quartzite, and an unknown fine-grained magmatic rock.

The samples are massive, without apparent bedding, and commonly contain veinlets filled with a calcite and/or ?clay groundmass. All samples exhibit evidence of karstic dissolution on exposed surfaces, and the dissolution holes have an oxidised coating and are often sealed by manganese crusts.

The bioclastic component is mainly composed of shell debris, rare preserved shells are present. Bryozoa are the most common microfossil, but several sections of foraminifera have been observed on cut surfaces. Other bioclastic material includes coral debris and the green spines of ?echinoids.

Depositional history

The depositional history and evolution of lithofacies D is very similar to E - a very shallow water near-shore environment with an abundant supply of poorly sorted gravels (?beach material). The great variety of the rock types in the gravels indicates that the continental source area probably contained a diverse range of rocks, with a dominance of volcanics. The main characteristic of this lithofacies is the high carbonate content.

Lithofacies E: Calcareous red sandstone

Petrographic description

This lithofacies is mainly a medium to coarse-grained sandstone, which is crosscut by carbonate veins. The veins are generally at a high-angle to the bedding, which is defined by the preferential alignment of shell debris. The red calcareous sandstone consists of two subfacies: sandy and calcareous. The sandy facies includes poorly sorted grains and small pebbles of various sizes, shapes and colours. The pebbles mainly consist of a grey groundmass; green slightly glassy minerals; grey rock fragments with dark needles, (magmatic); and yellow ochre uniform grains (clay and/or volcanics). The red color of the sandstone is due to small oxidised particles or matrix in the sandy part of the rock. The calcareous subfacies is mainly composed of broken shell and other fragments that are difficult to identify; however, pieces of lamellibranch, bryozoa and arenaceous foraminifera can be identified.

The carbonate portions of lithofacies E are whitish to pinkish and composed of a micritic material including abundant clastic components. The gravel pebbles are more subangular than rounded, and composed of a uniform grey material with a pale-green to yellowish glassy mineral, but can also be brown, rounded and oxidised. The carbonate component appears to be secondary and to cut across the sandstone. The contact between the two subfacies is irregular, and can be sharp or progressive. Individual sand grains are not broken but are enveloped by the carbonate. This indicates that the emplacement of the carbonate occurred when the sediment was still water-saturated, but with sufficient fluid pressure to remobilise small pebbles.

A very consistent characteristic of samples of lithofacies E is that dissolution is commonly present where the carbonate occurs at the surface. It appears to be a karstic dissolution, with numerous holes, and solution fills (lapiez?), which can be manganese coated. Within some dissolution holes several round oxidised pebbles occur and are either covered with a yellow coating or sit directly on the dissolved surface of the hole.

Depositional history

Based on these preliminary observations, it is possible to define an event history that could have formed and shaped lithofacies E rock from its original depositional environment to its present state. The textural characteristics and faunal association indicate that deposition occurred in a shallow-water environment accompanied by abundant biogenic activity. The finely broken shells are an indication of a high-energy environment (longshore currents). The fine fraction reflects limited terrigenous input, but the pebbles forming the gravels reflect a variety of sources from an adjacent landmass. Quartz and volcanics are commonly present and may indicate a continental origin. During a second stage of development, carbonate-rich fluid impregnated the sediment that was already shallowly buried. This resulted in remobilisation of particles (pebbles, shell debris) forming an irregular network within the sandy matrix. A third stage in the evolution of lithofacies E occurred through emergence of the area and resultant weathering of the sediment in a hot oxidising climate producing the red oxides of the matrix and the iron-coated surface of the gravel pebbles. Evidence for karstic dissolution of the carbonate component of the lithofacies supports subaerial exposure of these rocks. At its present depth (2000 - 3000 m), the red sandstone is being subjected to a major phase of manganese precipitation resulting in crusts up to 10 cm thick. Several holes, filled with a whitish, clay-type material may indicate a further phase of fluid circulation and precipitation.

Lithofacies F: Claystone

Petrographic description

Lithofacies F is a grey-greenish to yellowish massive or weakly bedded claystone with carbonate and sandy fractions. The rock contains numerous worm tubes of various sizes that are concentrated near the boundary with the manganese crust. The walls of the tubes are lined by a calcitic crust coated with iron oxide and are filled with a white powder containing at least some calcite. In section, the shape of the worm tubes appears to be circular or oval depending on their orientation relative to the bedding. Some fractures were observed either as joints associated with thin manganese dentrites or as open and filled fractures. The walls of the fractures have a calcitic coating and contain broken fragments of the country rock as well as a white calcitic powder. No biogenic traces, except for the worm tubes, were observed, but the rock may contain microfossils (post-cruise analysis is necessary).

Depositional history

Lithofacies F is a claystone that contains both fine terrigenous and carbonate fractions. Its depositional environment was probably a quiet area protected from coarse river input, probably a restricted shallow mud-flat or estuarine environment. Biogenic activity is restricted to worm burrowing. Following the circulation of calcareous fluids and associated precipitation inside the worm tubes, the sediment underwent the first stage of diagenesis with compaction and deformation of the worm tubes. At some stage during or following this process the rock was near the surface and/or emergent as indicated by the iron oxidation products that have coated the calcitic mineralisation. The origin of the terrigenous fraction must await further work via clay content analysis. Later, the claystones subsided to their present water depth of 2000 - 3000 m, and were then subjected to an intense phase of manganese crust accretion.

Lithofacies G: Calcareous conglomerate

Petrographic description

Lithofacies G is a polygenic microconglomerate to conglomerate. It contains pebbles that vary in size from gravel up to 6 cm. The ground mass is a white to pinkish carbonate that also includes gravels and biogenic clasts such as lamellibranch shells, foraminifera, corals and bryozoa debris. The carbonate matrix displays evidence of karstic dissolution at exposed surfaces. The size, shape and nature of the pebbles are highly variable, but a common feature is the almost ubiquitous oxidisation of their surfaces. The shape of the pebbles ranges from ovoid to subangular, and they have a light-brown or yellowish vesicular texture with small olivine nodules indicating a probable volcanic origin. In one sample a 1 cm long fragment of fresh olivine was observed in the groundmass. One pebble was identified as a gabbro, however, other types could not be precisely identified but include lava-sourced phenocrysts, grey microlitic lava, and a red pebble with an amorphous texture (chert or ?radiolarite).

Depositional history

There are probably two origins for the pebbles and other components of the lithofacies G conglomerate. Some of the clasts have undergone considerable transport attested to by their roundness. However, others have only been transported for a shorter distance as indicated both by their subangular shape and the presence of fresh olivine nodules, which are easily weathered. The pebbles generally have a volcanic origin, probably from acid explosive activity, but some have been derived from basement (gabbroic and possibly metamorphic rocks). Possible chert or radiolarite pebbles are evidence of a deep-sea depositional environment, perhaps in the vicinity of a volcanic terrane. The carbonate matrix of the conglomerate contains biogenic material typical of a shallow-water environment. All the conglomerates show evidence of subaerial alteration - karstic dissolution in carbonates and oxidised pebble surfaces.

Lithofacies J: Claystone

Petrographic description

Lithofacies J is a homogeneous claystone without any carbonate content or identifiable clastic component; however, it is not a pure clay, and contains a fine to very fine sandy fraction. The rock is bored by numerous worm tubes, which are often coated with a white carbonate concretion. A red oxidation layer covers the surface of the carbonate coating and also occurs along joints and fractures. Overall, lithofacies J is very similar to lithofacies F except for the lack of carbonate in the matrix.

Depositional history

Refer to lithofacies F.

Lithofacies N: Gravel biomicrite

Petrographic description

Lithofacies N is a white fine-grained micrite-bearing variable accumulation of gravels surrounded by a fine matrix. The pebbles are subrounded and have various colours and origins. Traces of dissolution are present at exposed surfaces and there is secondary infilling of dissolution holes by a calcareous white powder. The biogenic fraction is not abundant but some foraminifera have been identified.

Depositional history

Lithofacies N carbonates were deposited in a calm shallow marine environment, which was occasionally disturbed by the sudden input of detrital continental discharges. The rock bears evidence of subaerial chemical alteration resulting in karstic dissolution.

Lithofacies K: Volcanic agglomerate

Petrographic description

Lithofacies K is an agglomerate containing various bright orange to yellow pebbles of lava whose sizes range from gravel up to 12 cm. The clasts are cemented by a matrix of volcanic ash and highly weathered detritus. The typical composition of the volcanic material is hyaloclastite or ignimbrite composed of a weathered ground mass that contains two different mineral types that are not normally associated with each other - quartz phenocrysts and olivine inclusions. The olivine can be fresh or weathered to a yellowish material. This preliminary analysis did not allow determination of the depositional environment for the volcanics.

Depositional history

The composition of this agglomerate indicates explosive volcanic activity with probable pyroclastic flows that contain pieces of lava ejected and mixed with the hyaloclasts. The presence of olivine in the agglomerate may be related to magmatic contamination by the country rock during the rising of magma prior to eruption.

Possible geological history

The rock samples dredged from the planated and tilted block on the western flank of the Three Kings Terrace appear to have two main origins - sedimentary and magmatic. If we consider this area as a possible southern equivalent of the Loyalty Basin, as mentioned elsewhere in this report, it would be interesting to make a comparison between the rocks dredged from the two areas.

A variety of rock types have been dredged from the southern part of the Loyalty Basin (Bitoun & Recy, 1982). Conglomerates were recovered from 1600 m water depth containing volcanic (tholeiitic basalt) pebbles in a calcareous matrix. These were interpreted to be the products of the erosion of an emergent tholeiitic volcanic series deposited in a shallow-water environment during the Early Miocene (19 Ma). Early-Middle Miocene biomicrites deposited in a shallow reefal environment contain benthic foraminifera, bryozoa, echinoid fragments and coral.

The sedimentary rocks of the FAUST-2 second dredge are mainly terrigenous but include a significant proportion of carbonate matrix grading to a pure carbonate. All the facies indicate shallow-marine to near-shore deposition with a continental source close by. Almost all rocks dredged exhibit evidence for subaerial alteration. Pebbles resulting from the erosion of a surrounding landmass are now at a minimum water depth of 2000 m. It appears that following the erosional phases, which may be dated using the volcanic material, the area has undergone a significant phase of subsidence.

The various lithofacies dredged were possibly deposited in the following order:

1. Polygenic conglomerate transported from a nearby continental source via rivers and deposited in a shallow-water environment (inner carbonate platform).

2. Sand and gravels deposited in a similar environment, but reflecting a decrease in clastic input, resulting in a sandy to gravelly limestone, and biogenic coarse-grained sandstone to biogenic sandy claystone. Evidence of subaerial alteration indicates that the rocks were exposed following deposition.

3. Carbonate sedimentation or deposition of claystone in a restricted environment reflecting periods of low clastic input.

4. Explosive volcanic activity in the surrounding areas.

A similar assemblage of sedimentary facies has been described in the southern Loyalty Basin and dated as Miocene and younger. The first occurrence of biogenic components appears to be in the Miocene, but this remains to be confirmed by detailed micropaleontological dating of the FAUST-2 dredge samples.

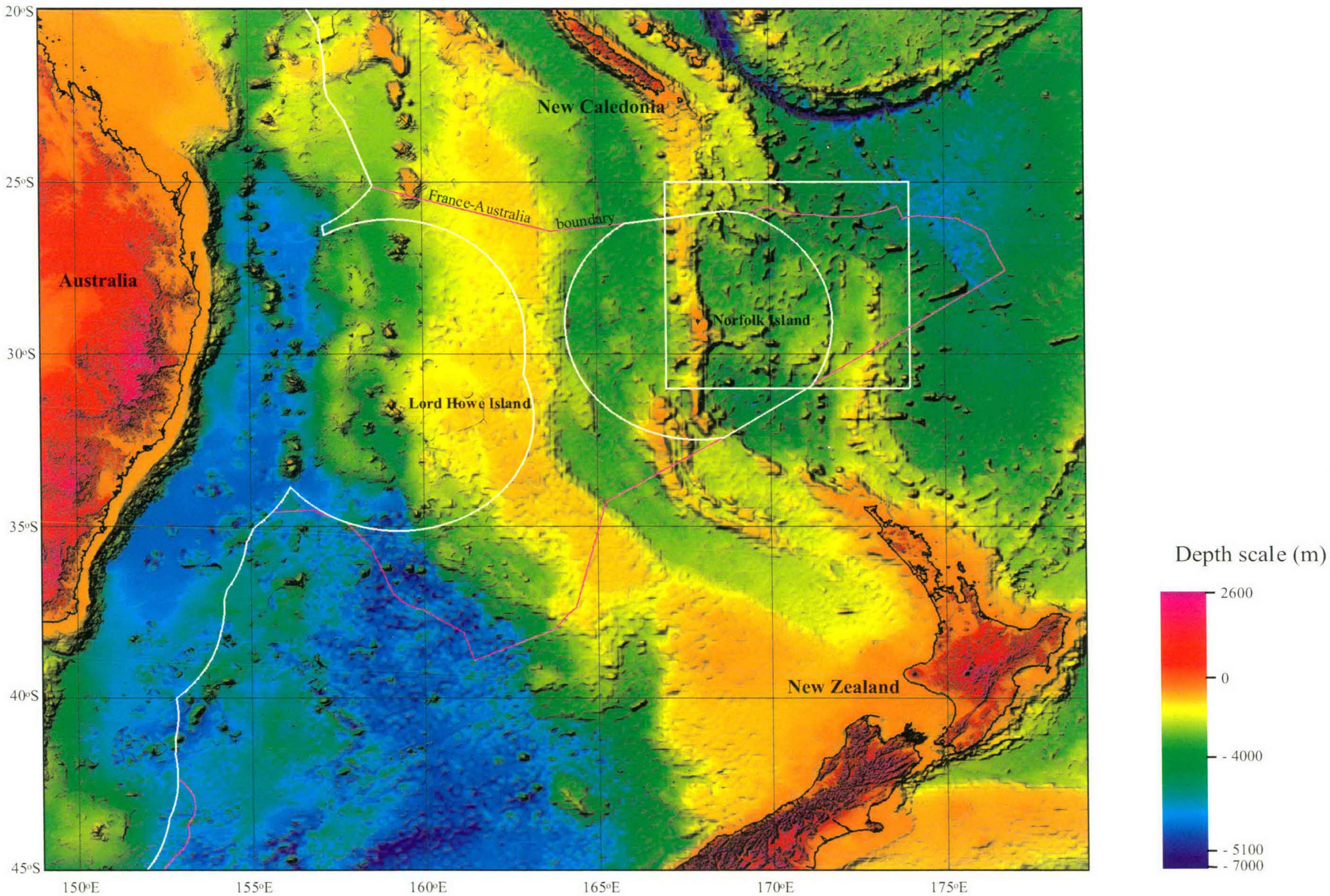


Figure 1. Hill-shaded image for part of the southwest Pacific terrain (see Fig. 2 for tectonic elements). White box outlines main FAUST-2 survey area, other white lines Australia's EEZ and magenta lines its extended Continental Shelf. Note that image is merge of predicted bathymetry (Smith et al., 1997), digital elevation models and interpolated ship track bathymetry. Projection is geodetic.

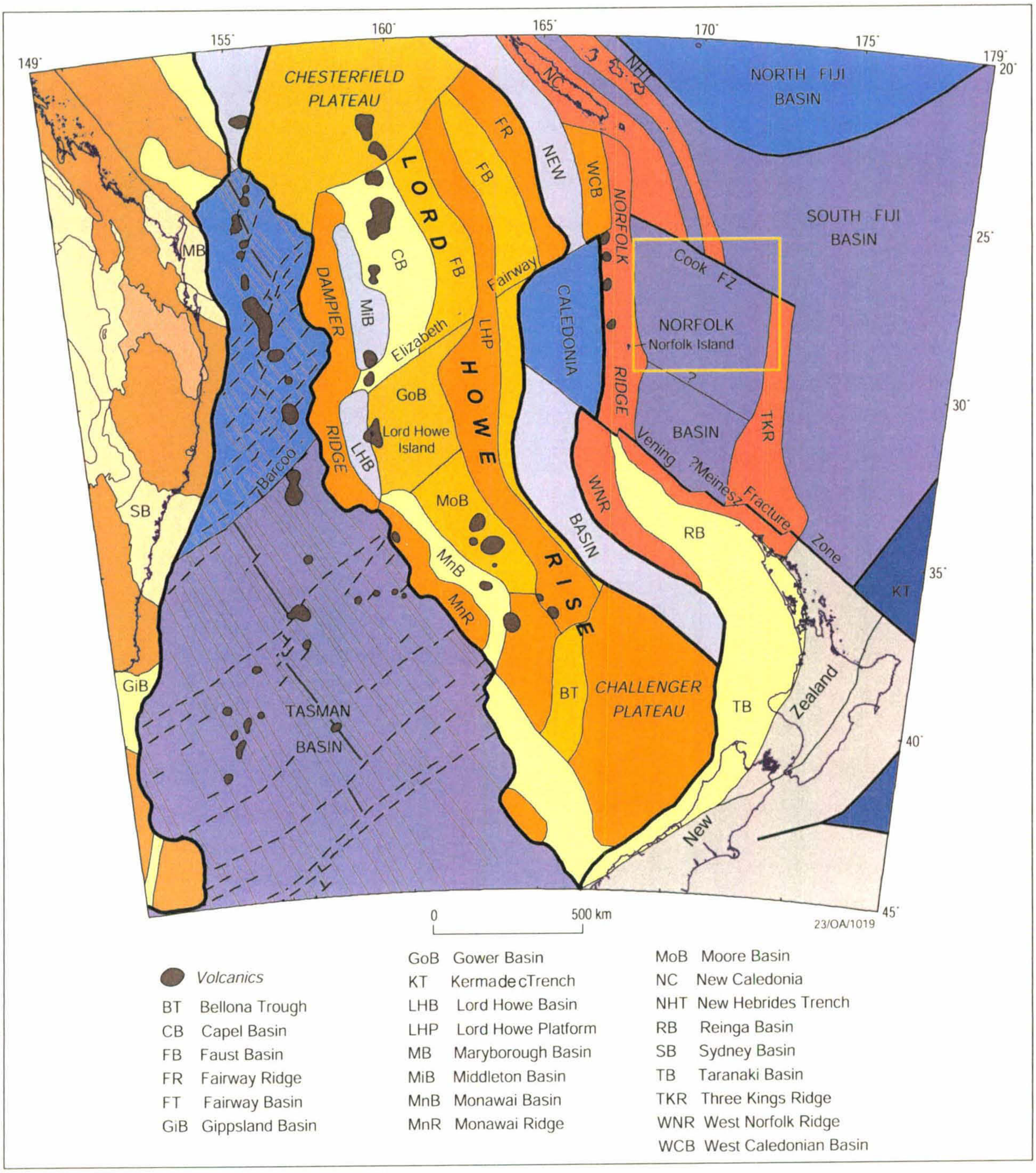


Figure 2. Tectonic provinces of the Lord Howe Rise/Norfolk Ridge region for part of the southwest Pacific (taken from Stagg et al., 1999). Main FAUST-2 survey area is outlined by the yellow box. Compare with Figure 1 for equivalent terrain expression. Projection is lambert conformal conic

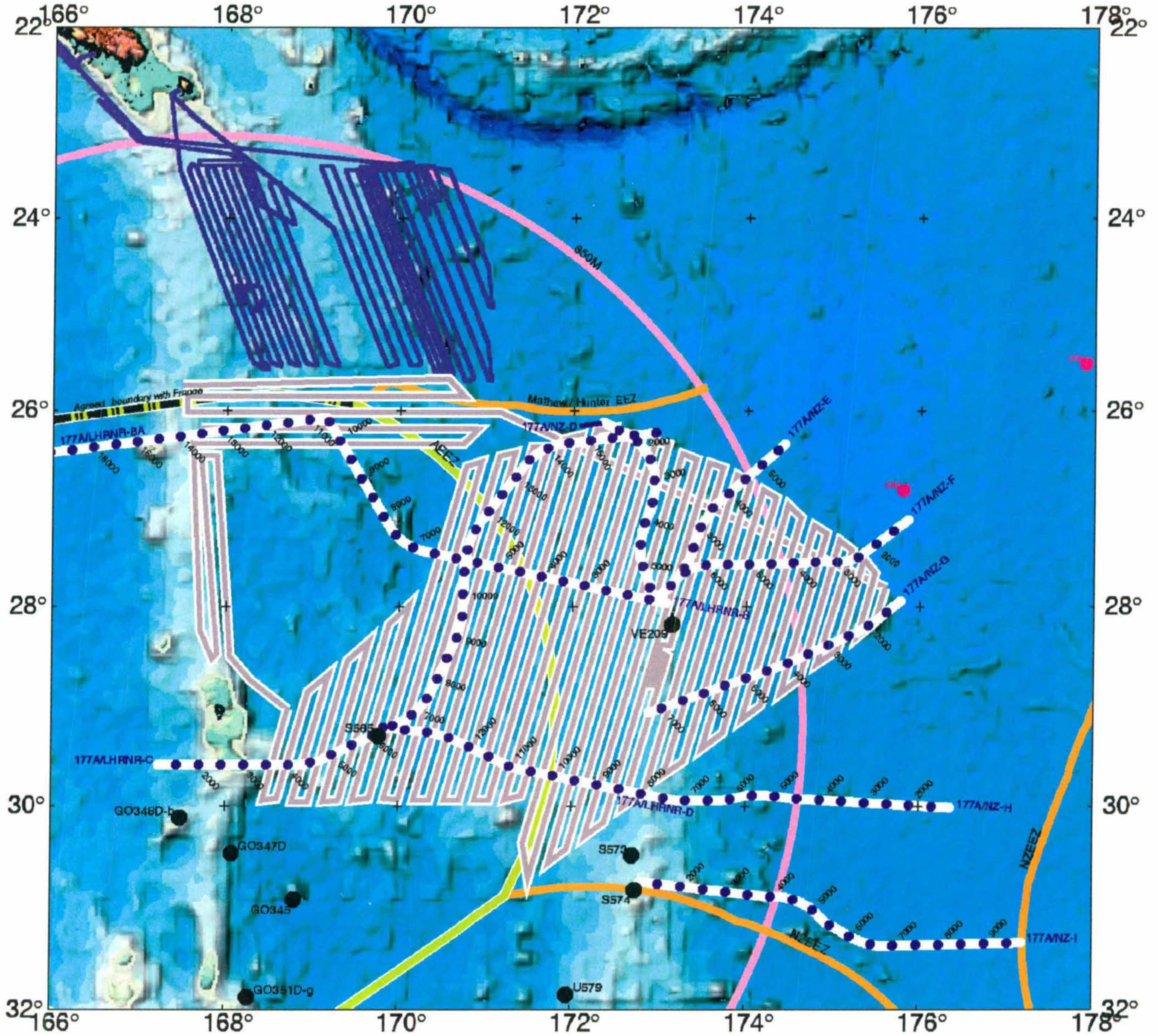


Figure 3. Hill-shaded image of predicted bathymetry showing proposed swath tracks for the main FAUST-2 survey area (grey lines) covering the area from east of Norfolk Island, across to the Three Kings Ridge and on into the South Fiji Basin. The proposed return leg includes some fill-in work over the southern Loyalty Ridge and Basin, adjoining the previous ZoNeCo-1 survey work (dark blue lines). Also shown are Australia's EEZ (green line), 350 nautical miles in respect to Norfolk Island (pink line), France's and New Zealand's respective EEZs (orange line), AGSO deep-seismic Survey 177 (white lines with shotpoints marked), DSDP sites (pink dots) and seafloor sample sites (black dots; see Table 1).

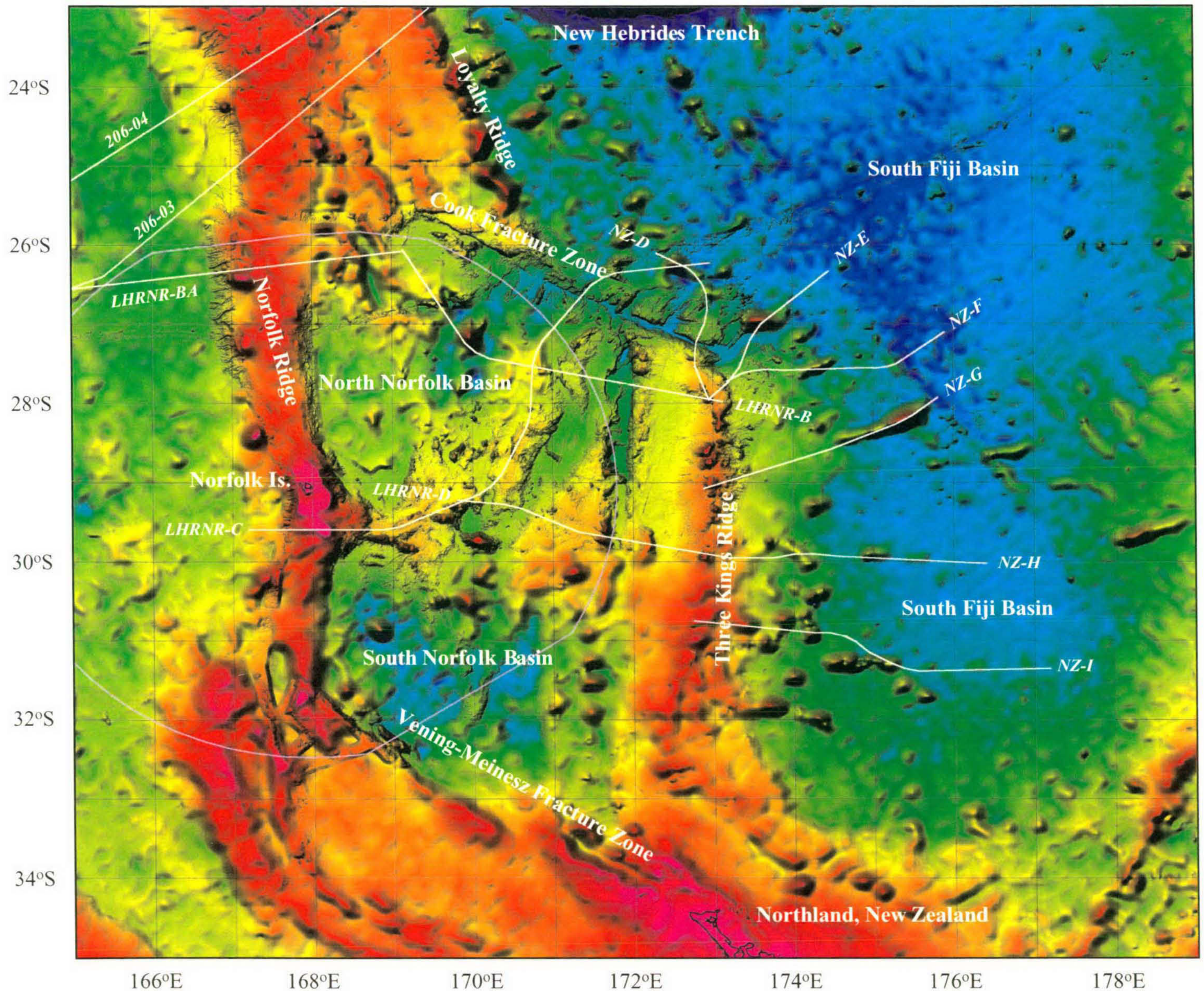


Figure 4. Hill-shaded image of merged terrain data sets over the wider Norfolk Ridge, Three Kings Ridge and South Fiji Basin region. Also shown are the Australian EEZ (grey line) and AGSO seismic surveys 177 (ie. LHRNR- and NZ- lines) and 206 (206- lines). See Figure 6 for a more detailed view of the main FAUST-2 survey area.

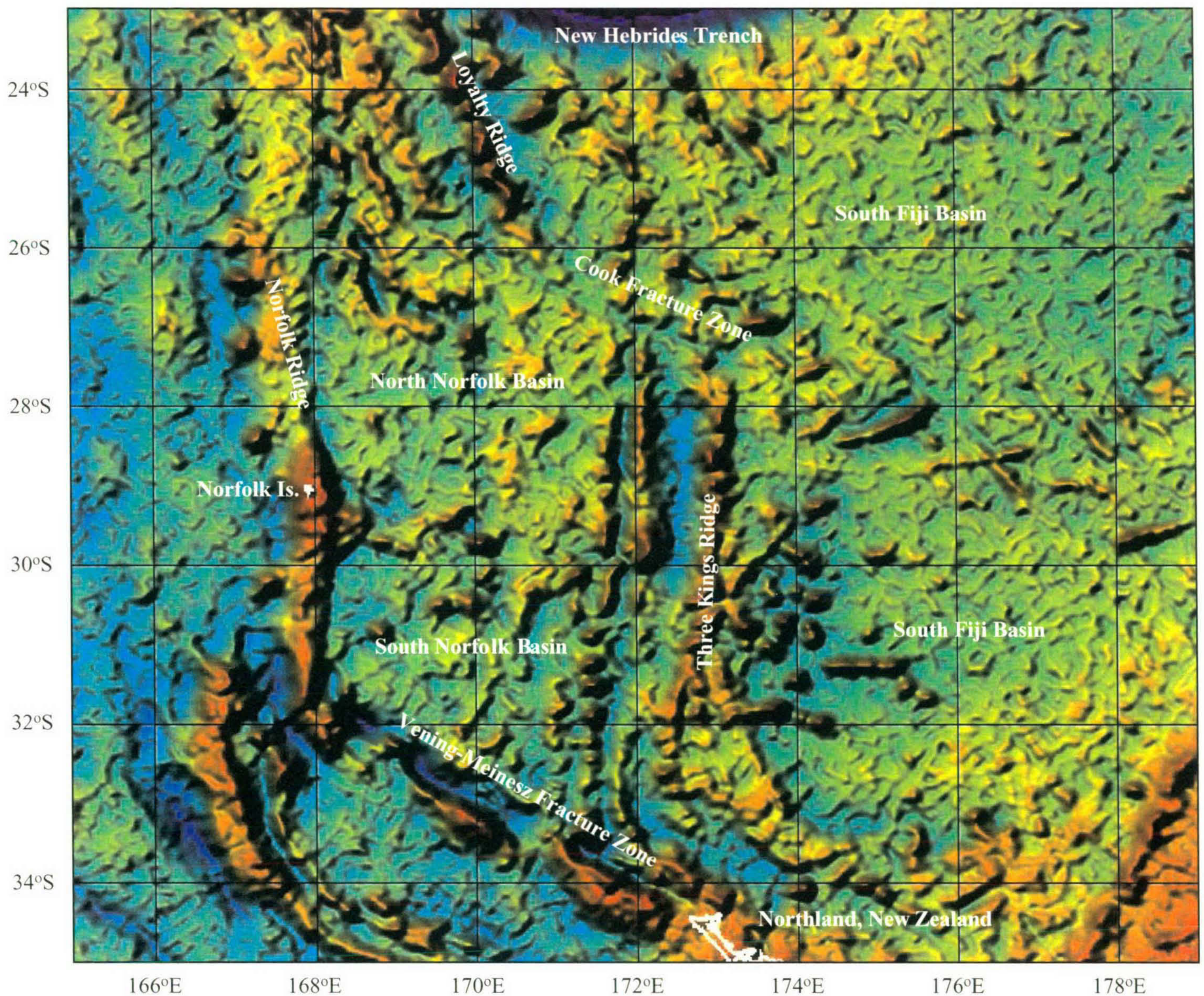


Figure 5. Hill-shaded image of satellite gravity (Sandwell & Smith, 1997) over the wider Norfolk Ridge, Three Kings Ridge and South Fiji Basin region.

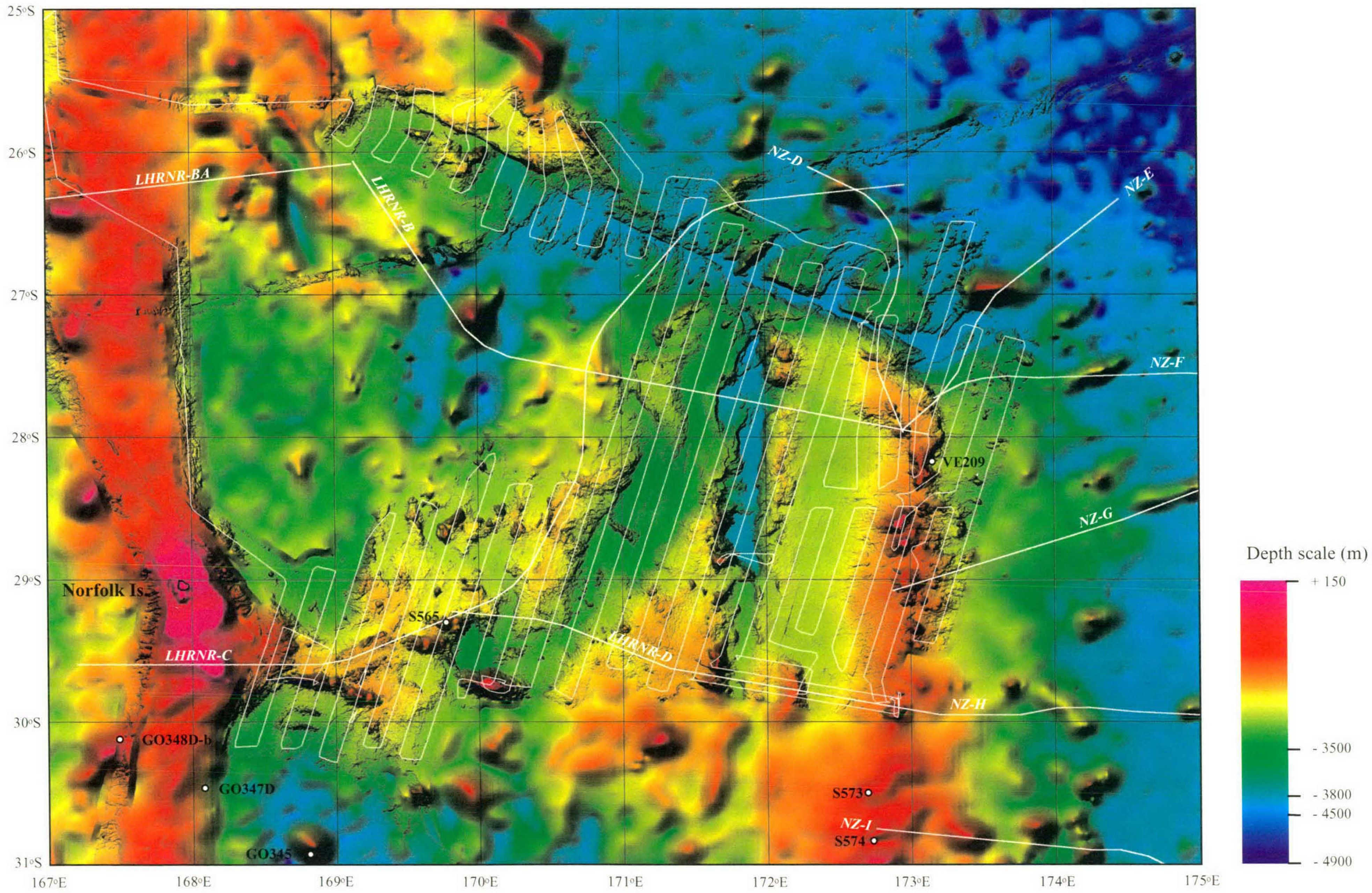


Figure 6. Hill-shaded image of merged swath and predicted bathymetry in the main FAUST-2 survey area. Also shown are FAUST-2 tracks (white) along with AGSO Survey 177 deep-seismic (labelled white lines). Dredge sites are also marked and labelled (see Table 1).

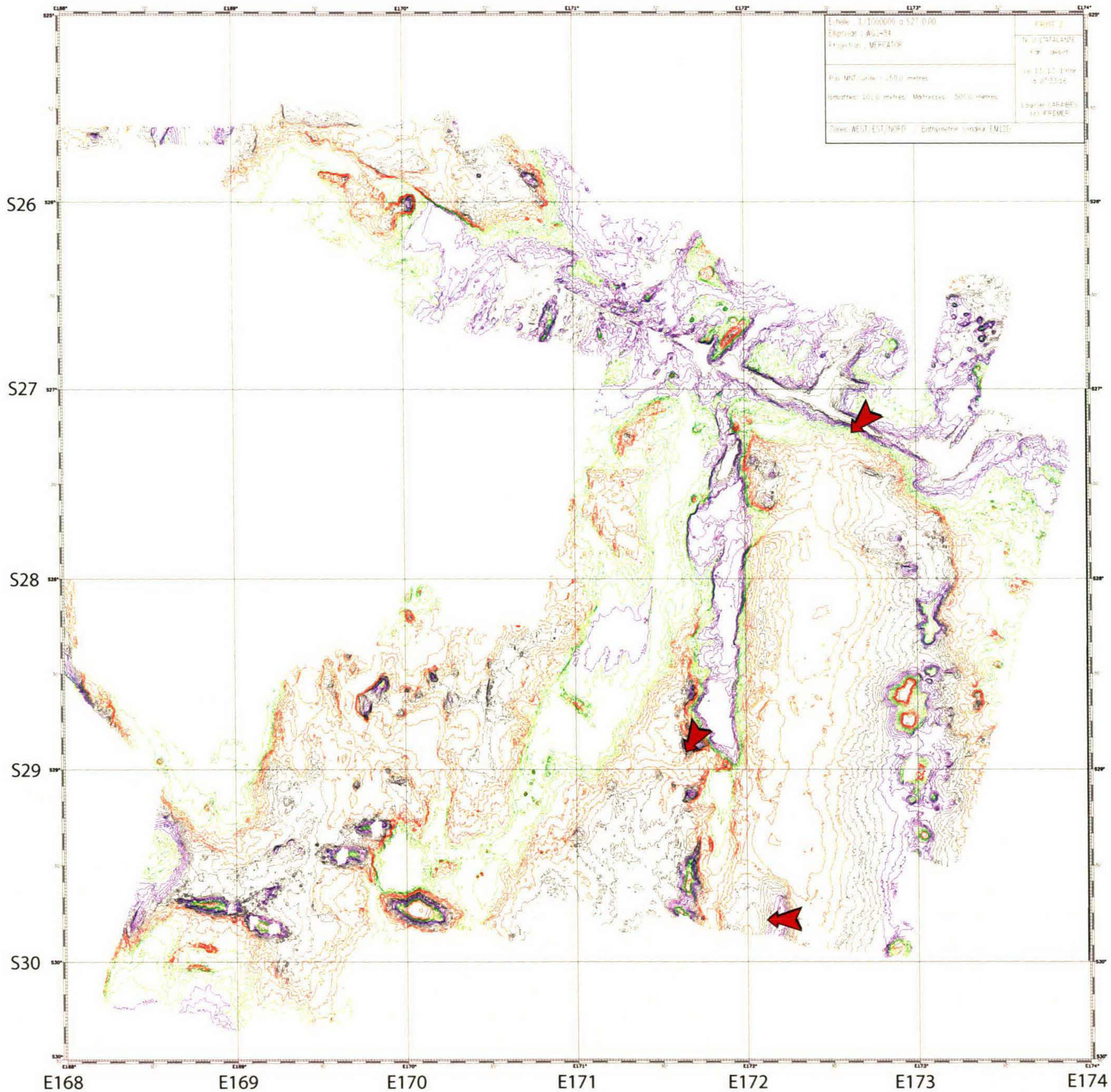


Figure 7. Colour-coded bathymetric contours for the main FAUST-2 survey area. Contour interval is 100 m in cyclic colour banding of red-black-blue-green for increasing elevation. Approximate dredge positions are shown by arrows.

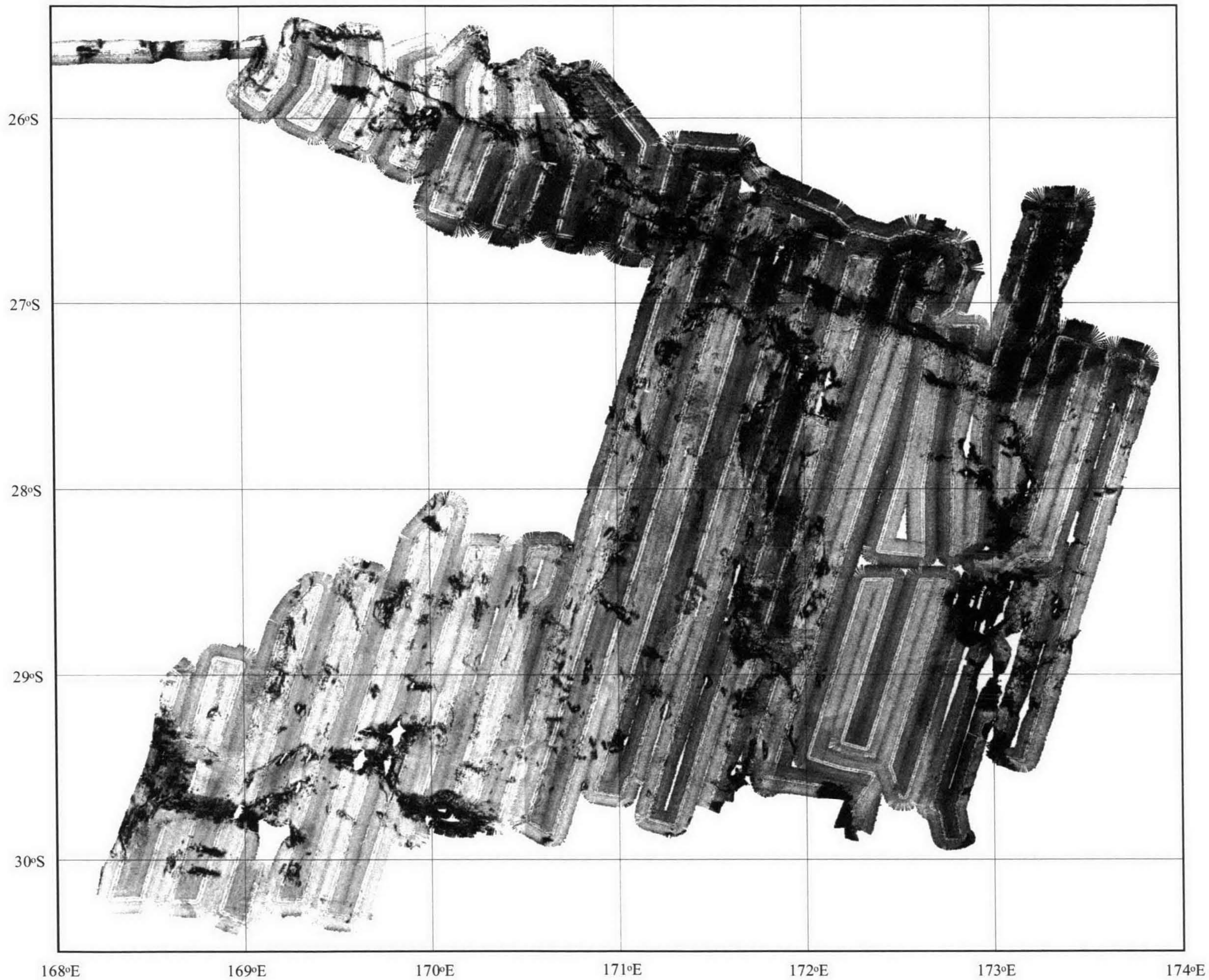


Figure 8. Multibeam backscatter coverage for the main FAUST-2 survey area.

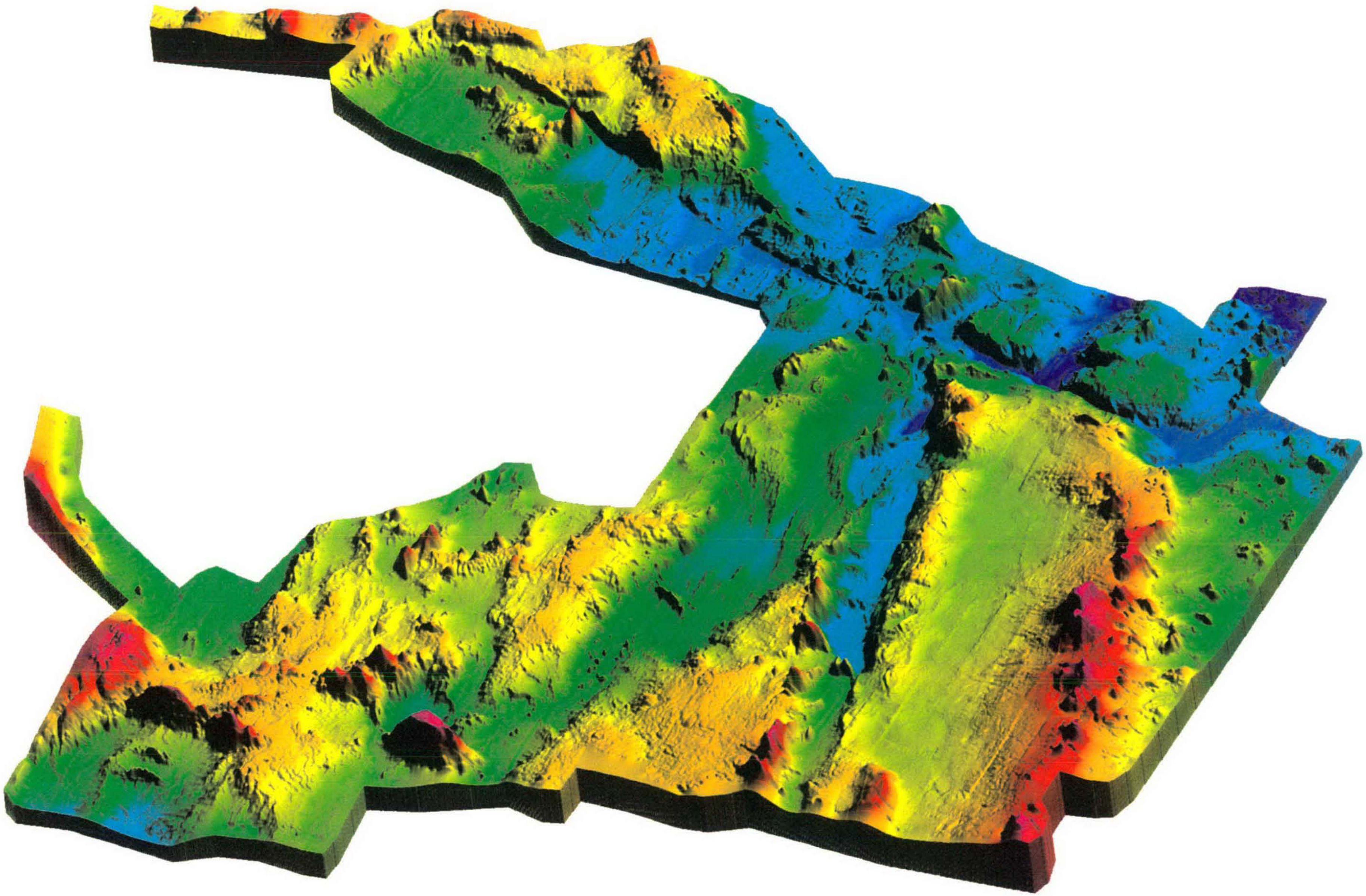


Figure 9. 3D perspective view from the south-southeast of the main FAUST-2 swath-mapped survey area between the Norfolk Ridge to the west, the Three Kings Ridge to the east and the Cook Fracture Zone to the north.

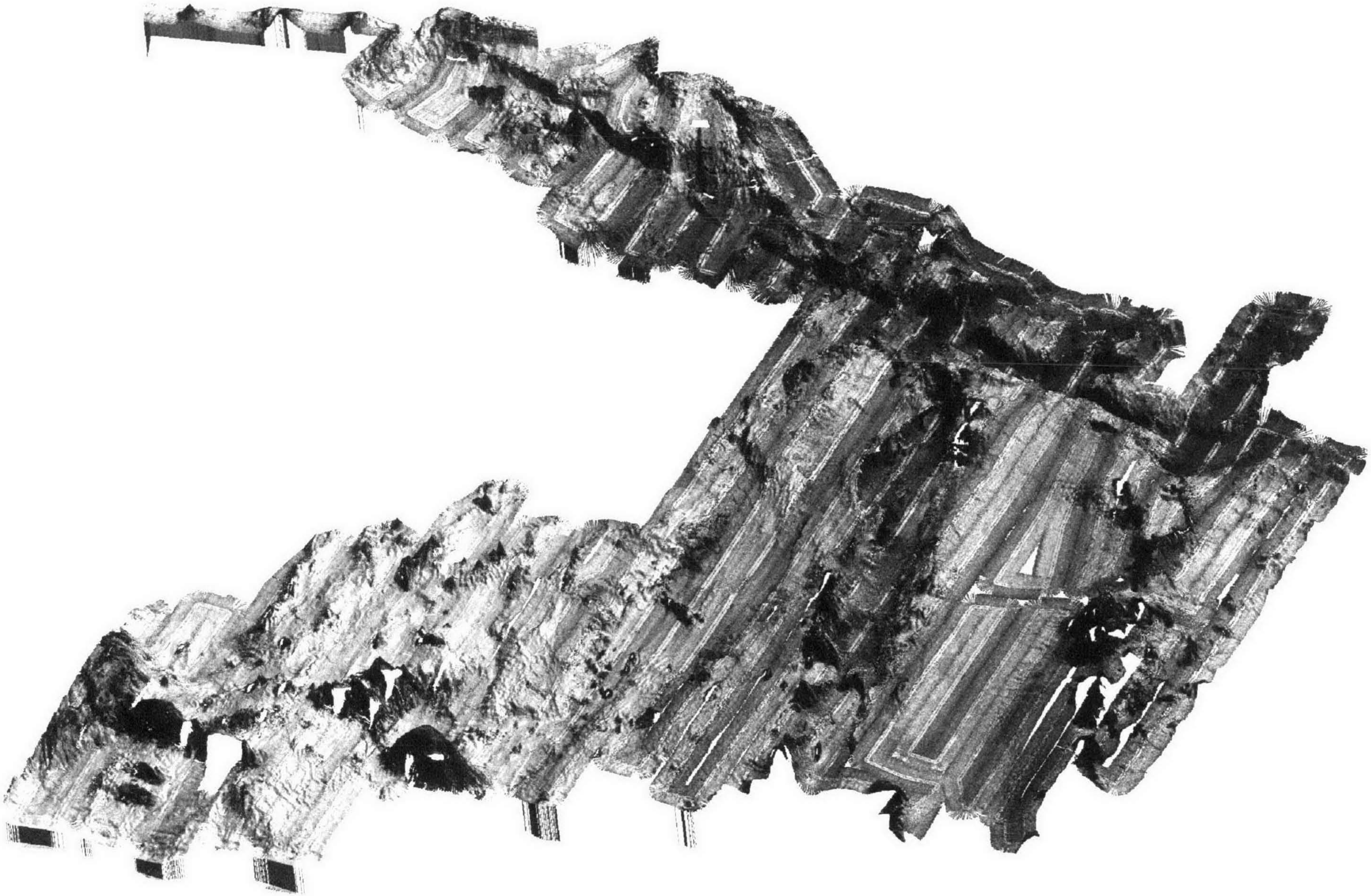


Figure 10. 3D perspective view from the south-southeast of the multibeam backscatter signal draped over the swath bathymetry for the main FAUST-2 survey area - compare with Figure 9.

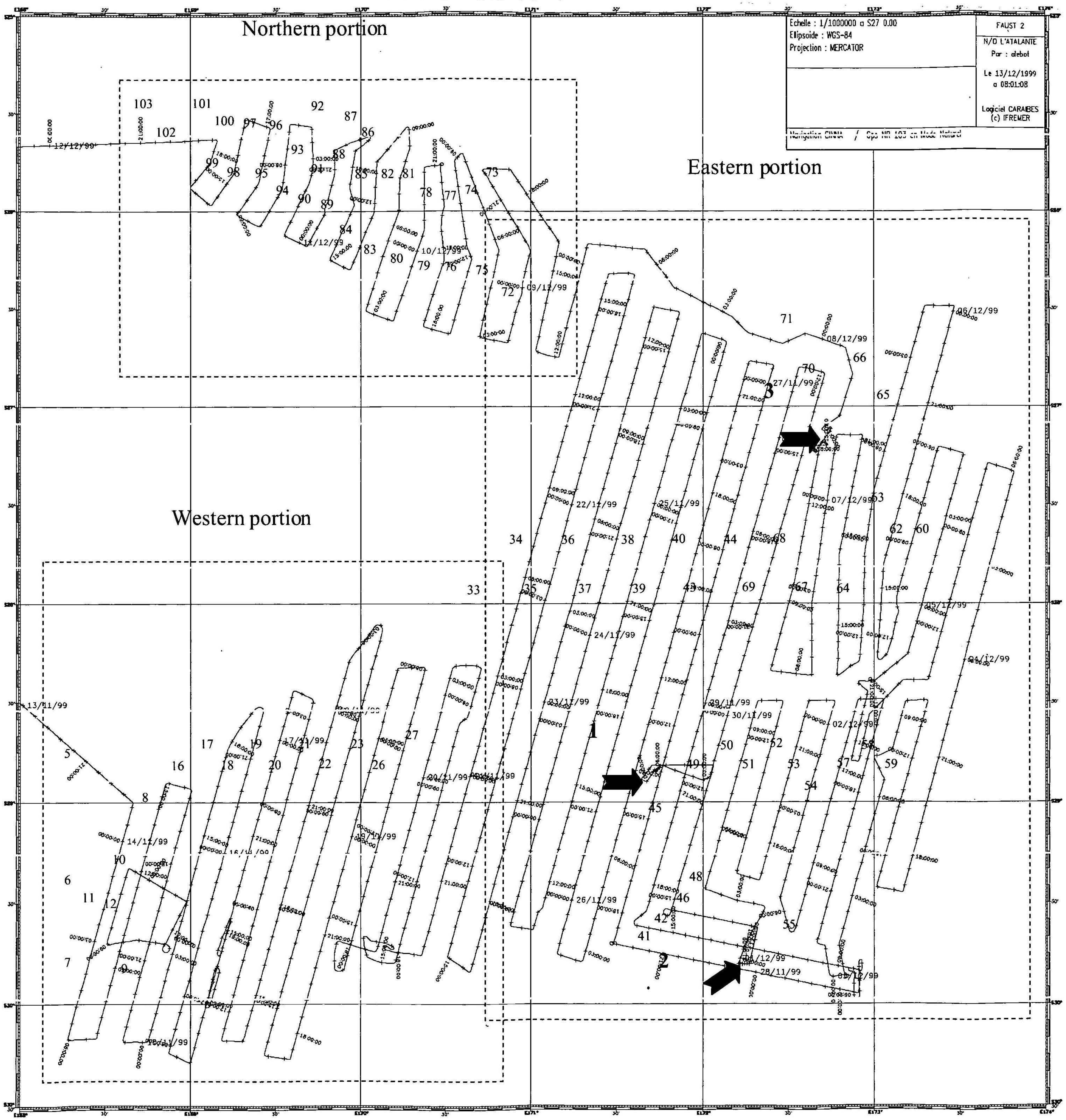


Figure 11. Track map of the main FAUST-2 survey area east of Norfolk Island. Dredge sites are marked with large arrows, seismic profiles are numbered and the dashed boxes outline the partitioning, for descriptive purposes, of the main FAUST-2 survey area (see text).

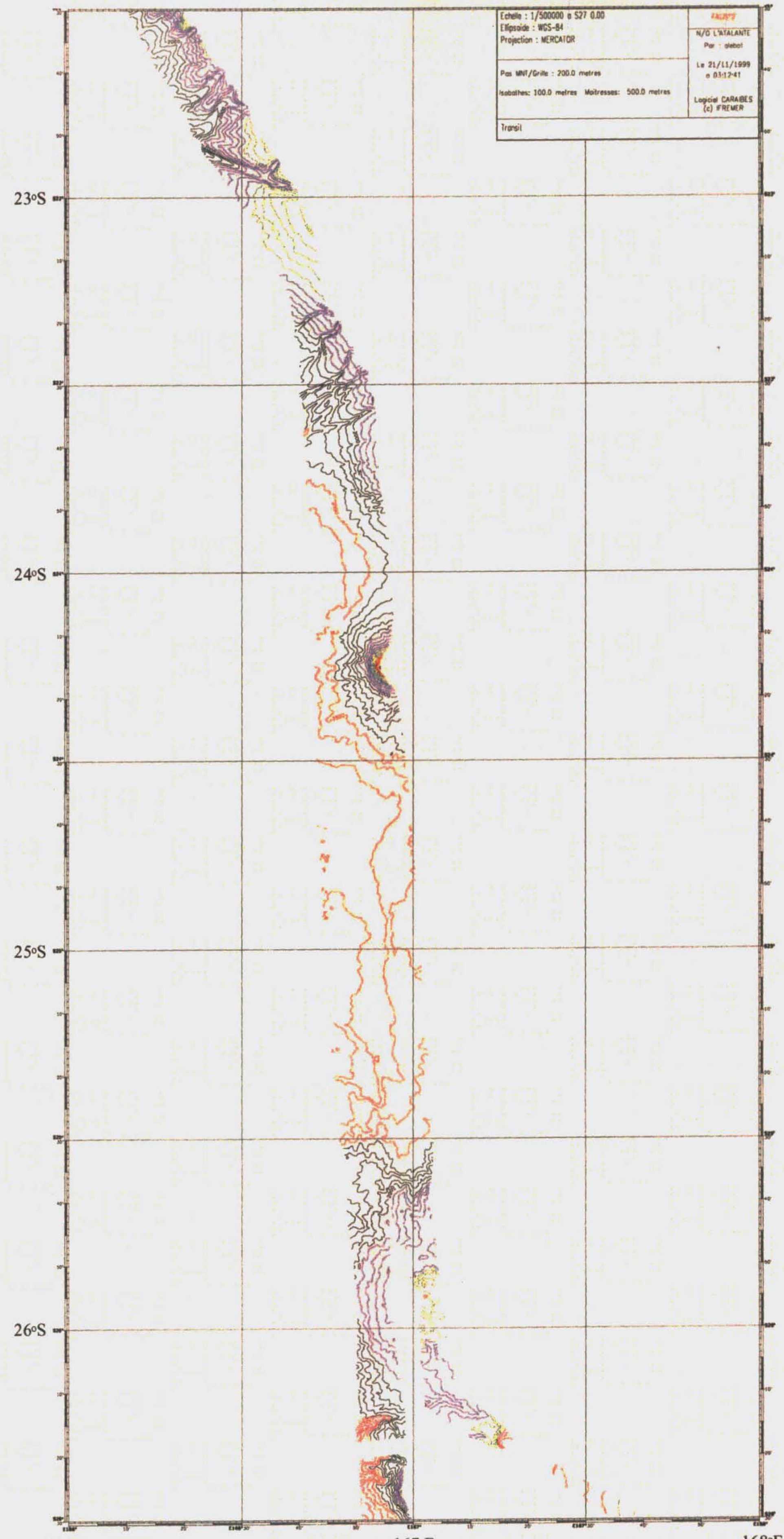


Figure 12a. Colour-coded bathymetric contours for the northern part of the transit to the main FAUST-2 survey area (east) run parallel with the TRANSNOR swath track (west), both over the Norfolk Ridge.

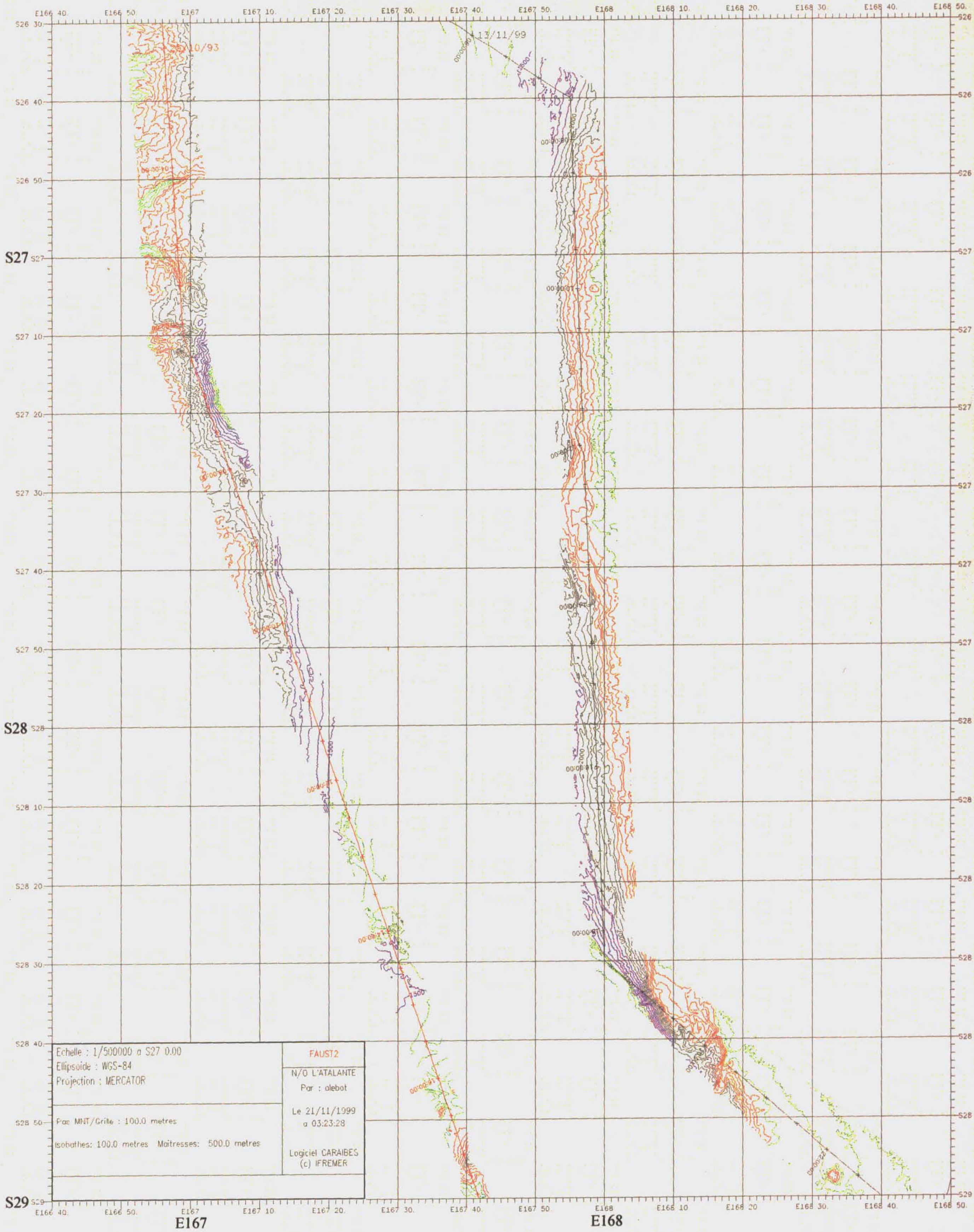


Figure 12b. Colour-coded bathymetric contours for the southern part of the transit to the main FAUST-2 survey area (east) with the TRANSNOR swath track (west), both over the Norfolk Ridge.

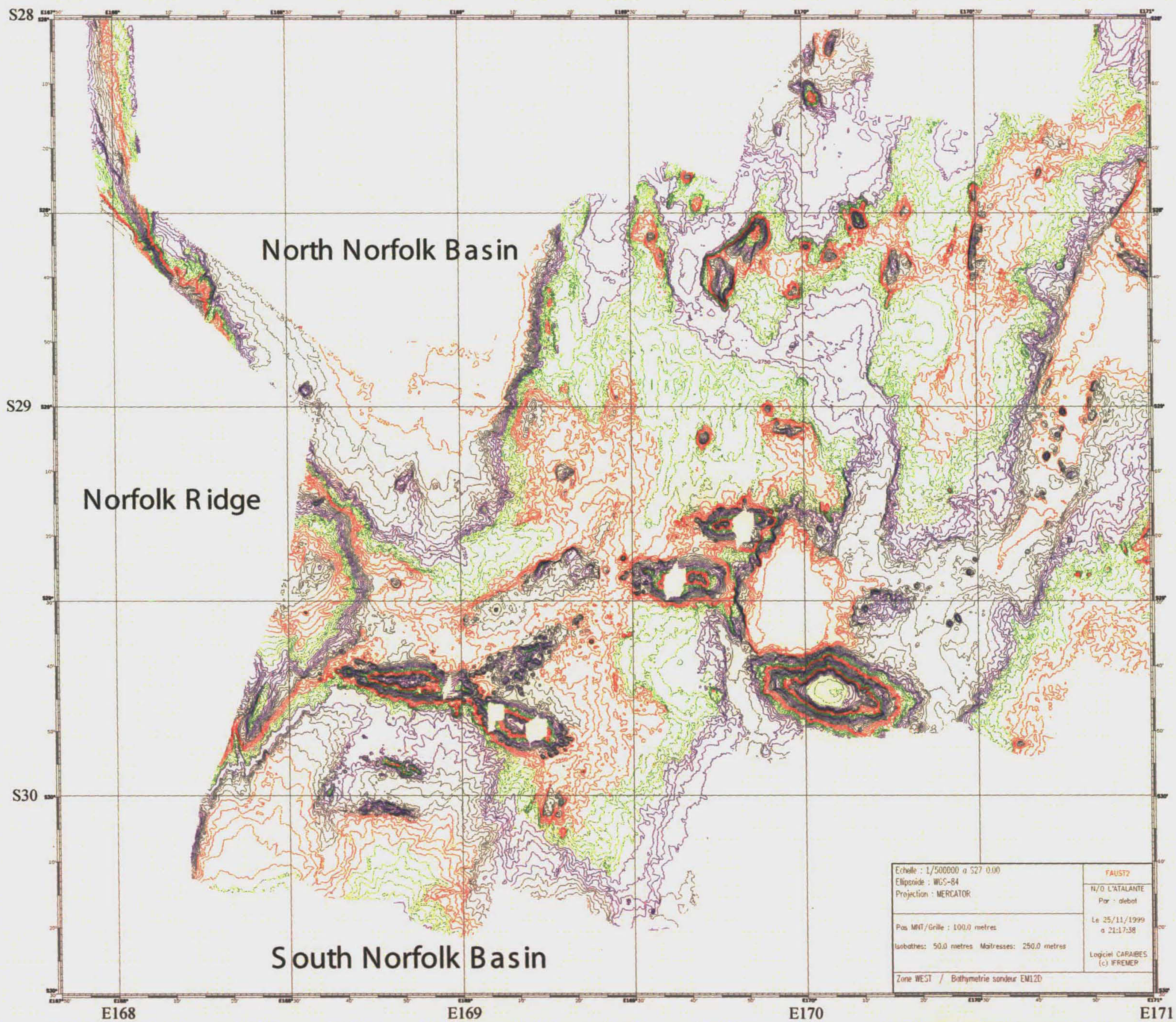


Figure 13. Colour-coded bathymetric contours for the western portion of the main FAUST-2 survey area. Colour interval is 100 m in cyclic colour banding of red-black-blue-green for increasing elevation.

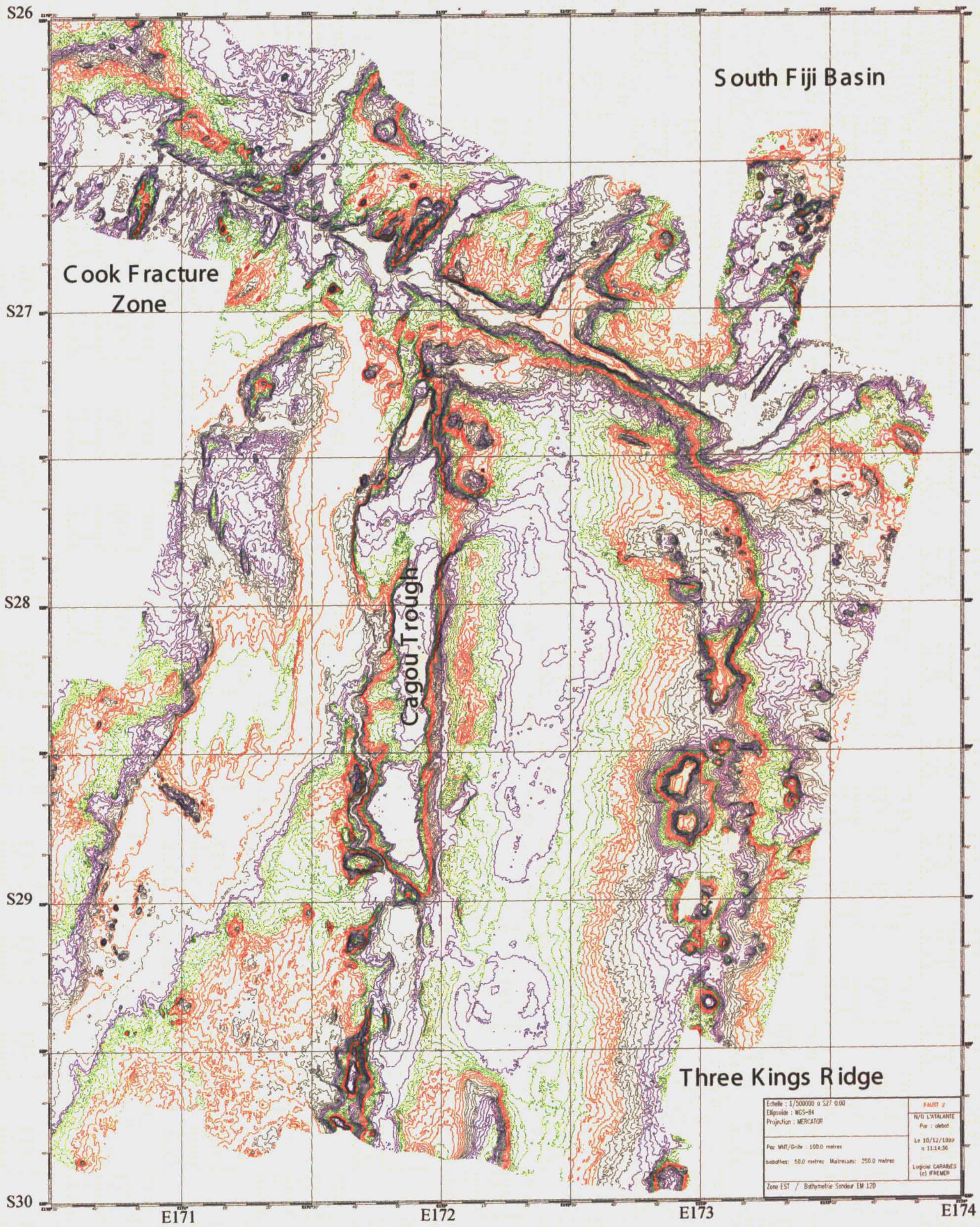


Figure 14. Colour-coded bathymetric contours for the eastern portion of the main FAUST-2 survey area. Contour interval is 100 m in cyclic colour banding of red-black-blue-green for increasing elevation.

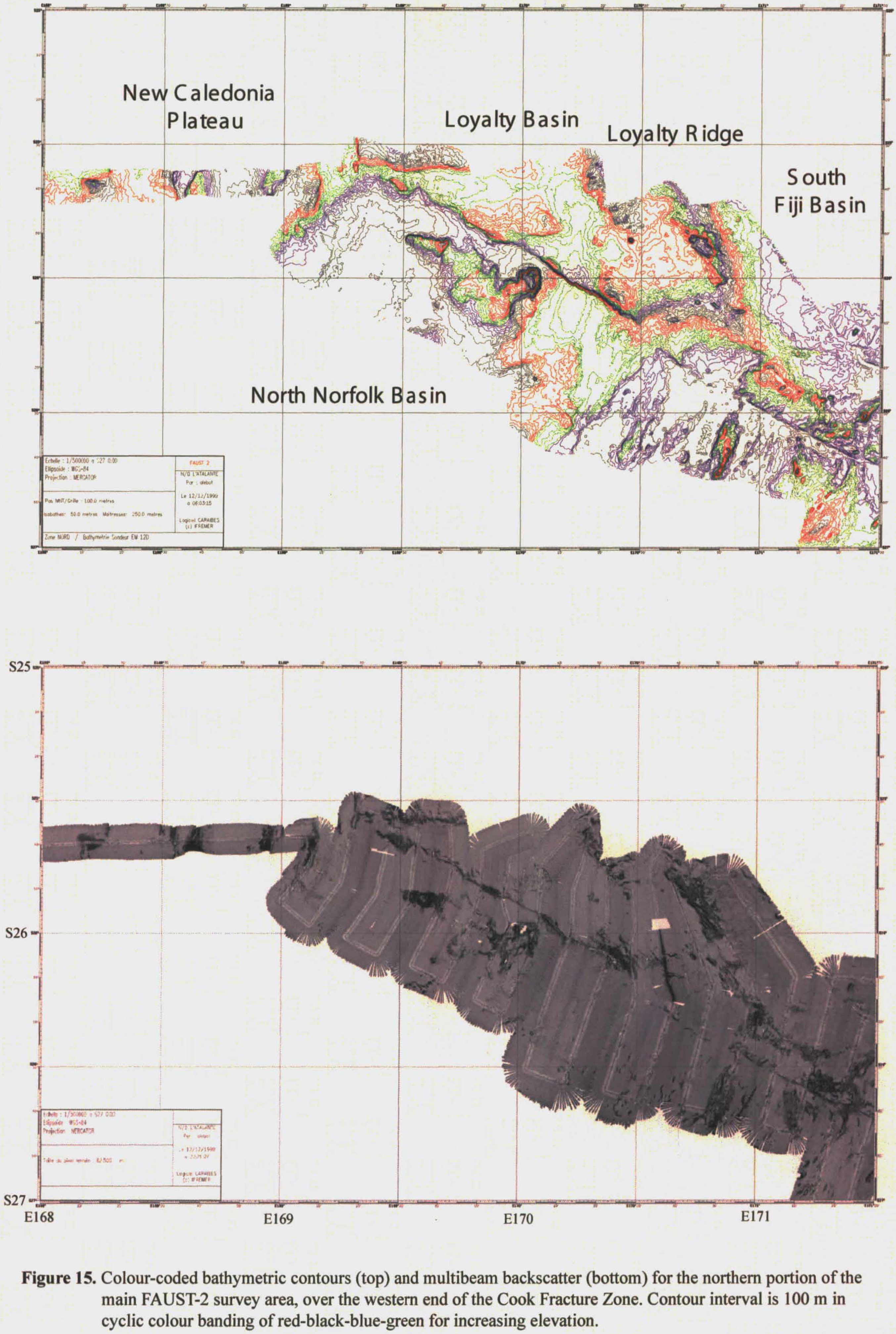


Figure 15. Colour-coded bathymetric contours (top) and multibeam backscatter (bottom) for the northern portion of the main FAUST-2 survey area, over the western end of the Cook Fracture Zone. Contour interval is 100 m in cyclic colour banding of red-black-blue-green for increasing elevation.

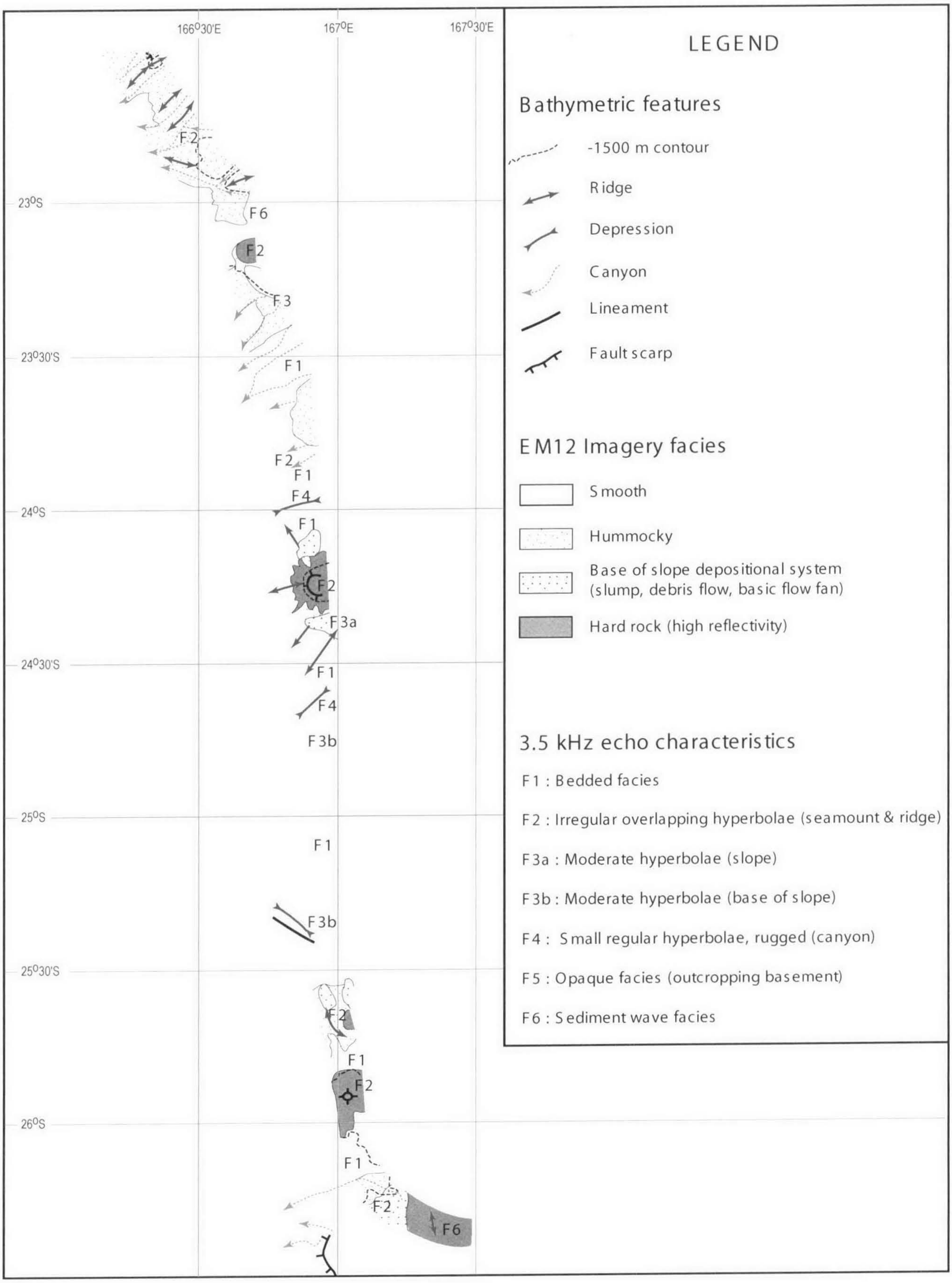


Figure 16. Interpreted bathymetric, backscatter and echosounder characteristics for the northern part of the transit to the main FAUST-2 survey area.

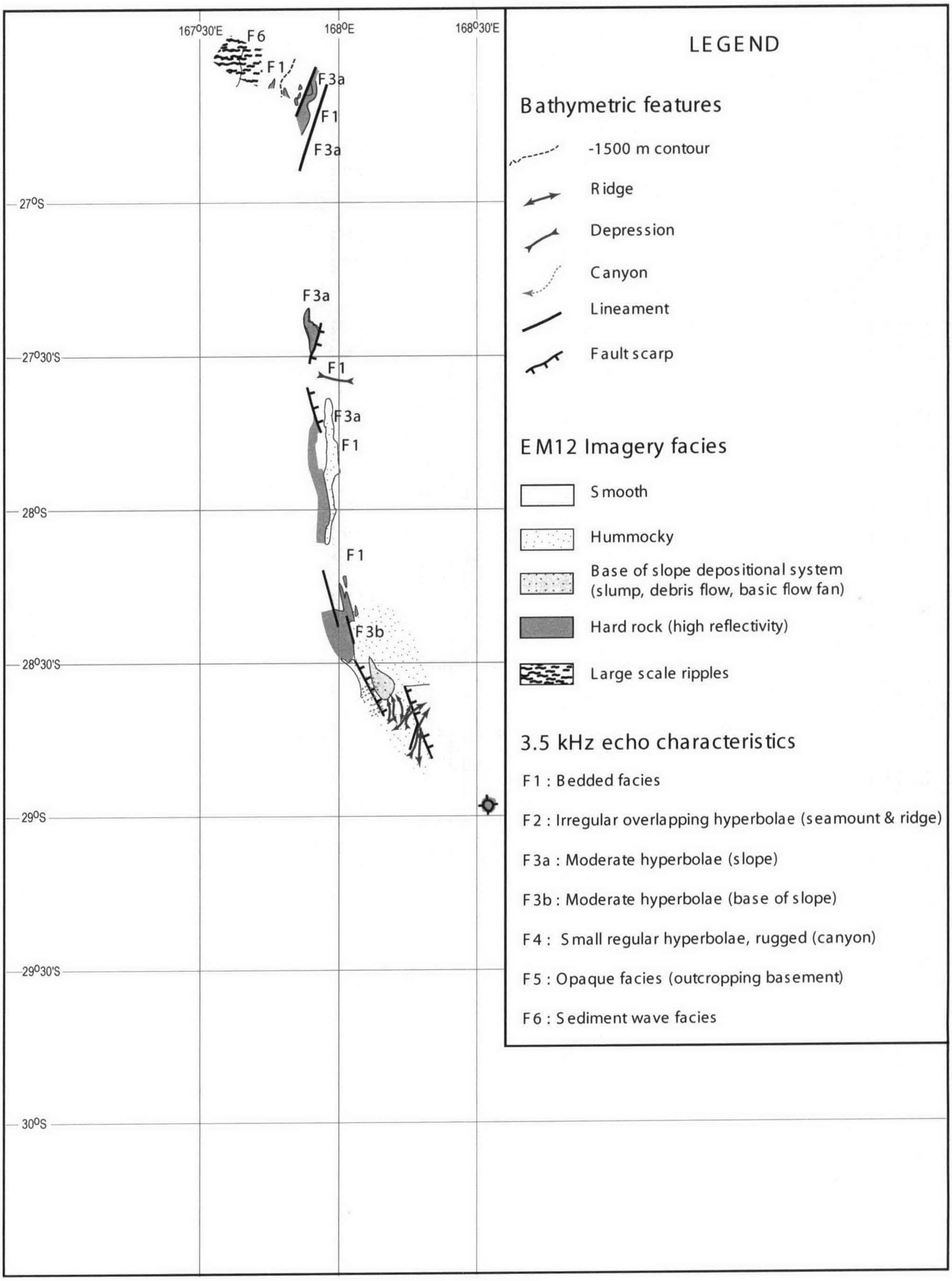


Figure 17. Interpreted bathymetric, backscatter and echosounder characteristics for the southern part of the transit to the main FAUST-2 survey area.

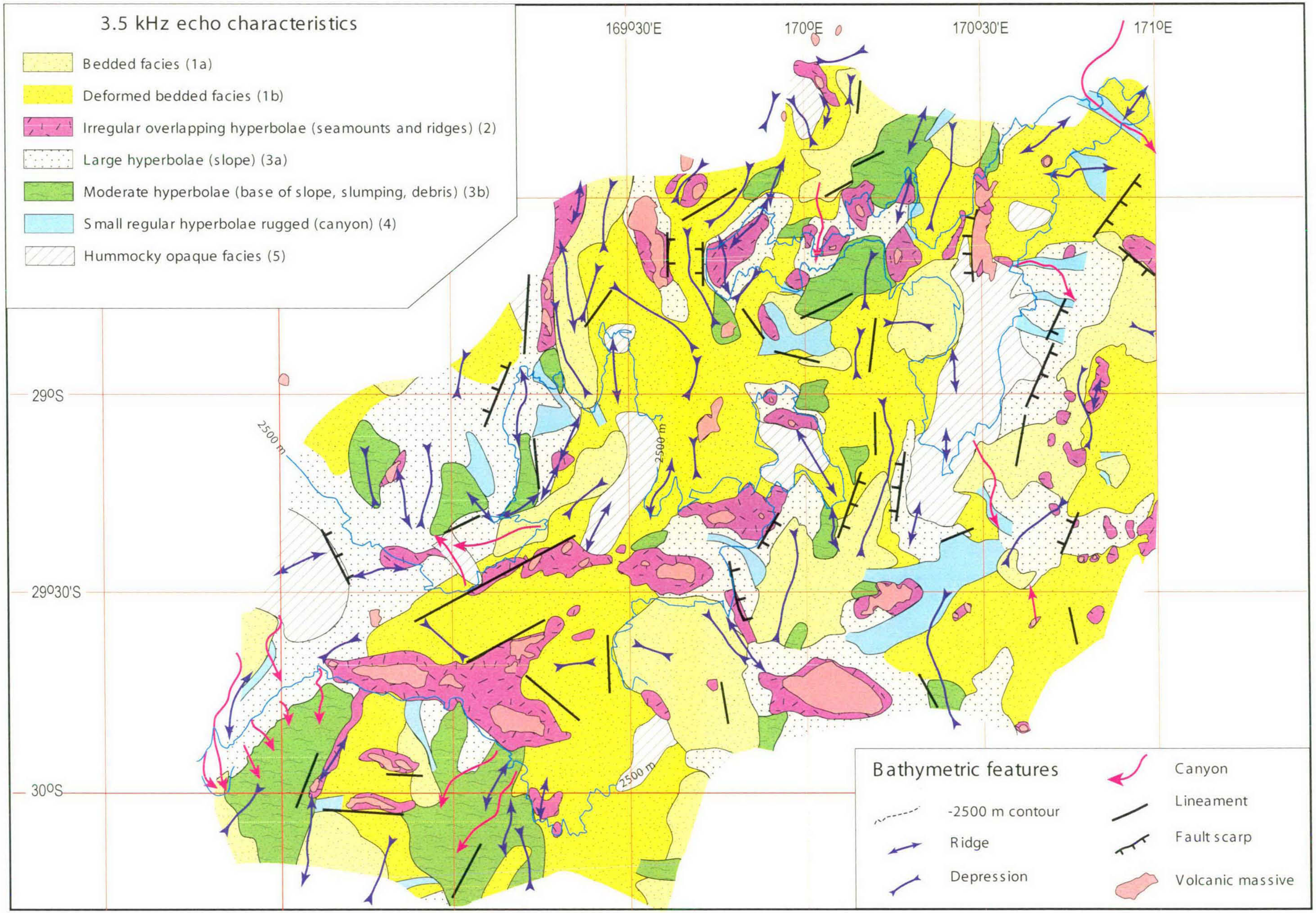


Figure 18. Morphostructure and acoustic facies map for the western portion of the main FAUST-2 survey area.

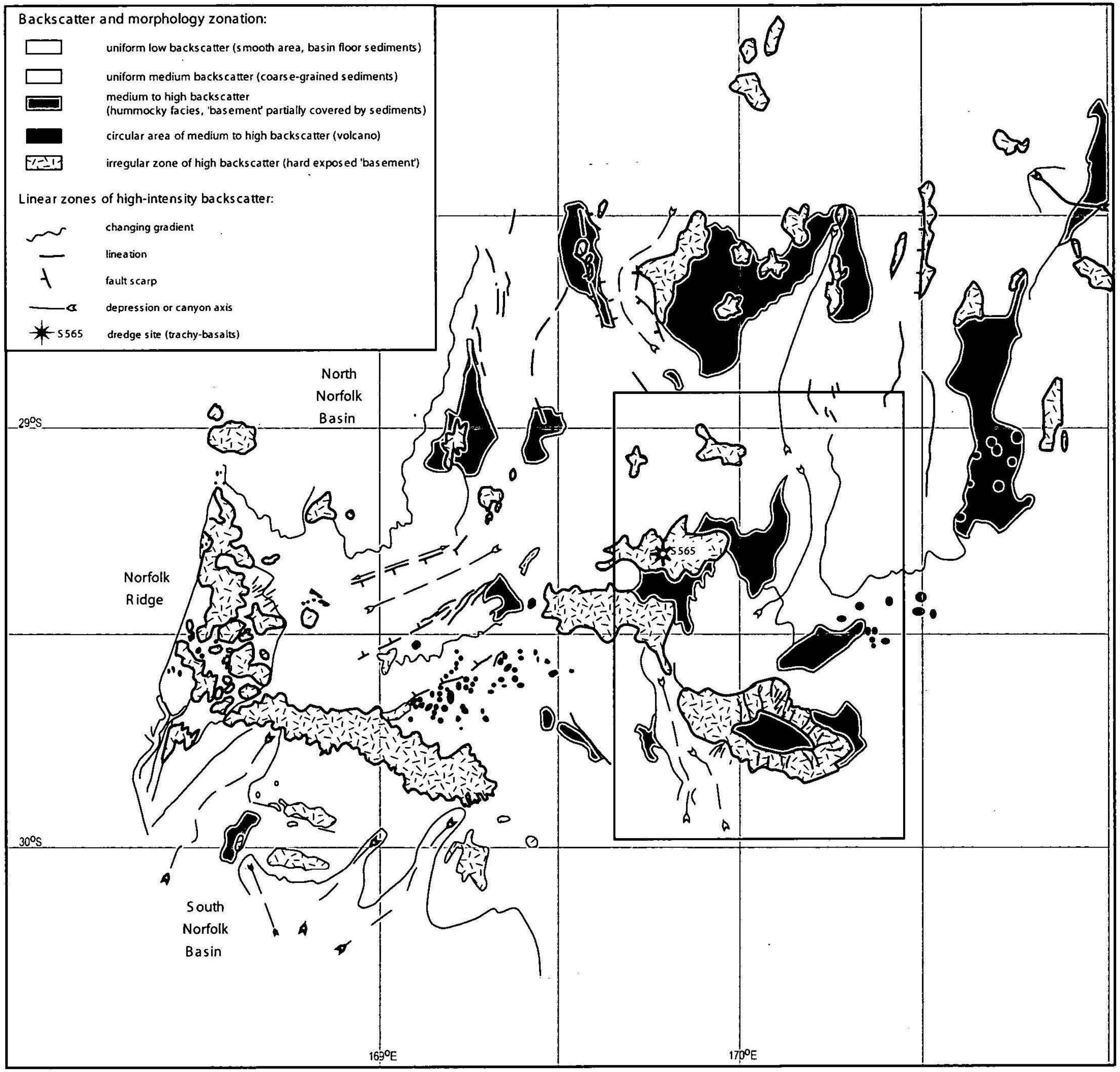


Figure 19. Multibeam backscatter interpretation for the western portion of the main FAUST-2 survey area. See Figure 22 for a detailed interpretation of the indicated box.

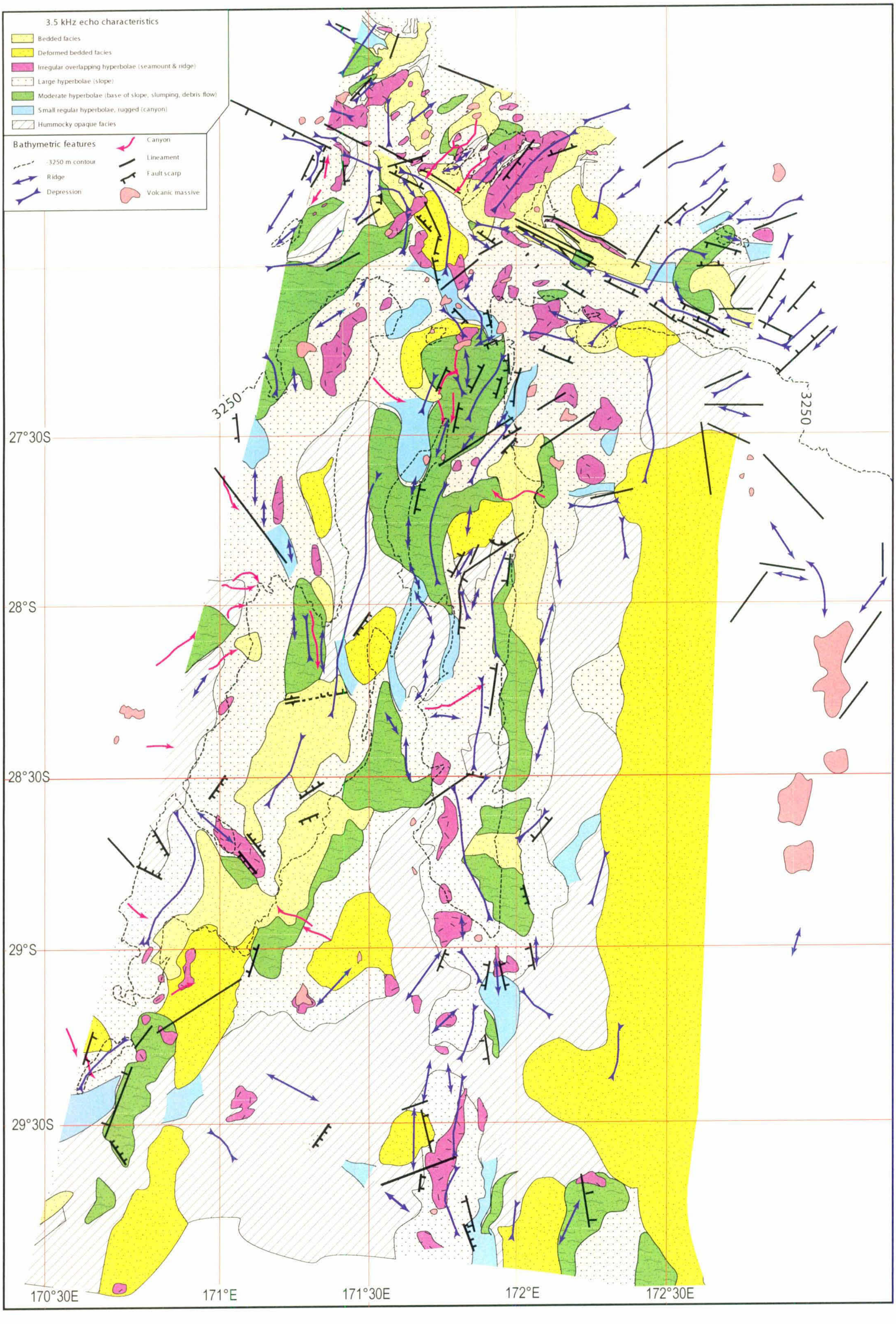


Figure 20. Morphostructure and acoustic facies map for the eastern portion of the main FAUST-2 survey area.

Figure 21. Multibeam backscatter interpretation for the eastern portion of the main FAUST-2 survey area.

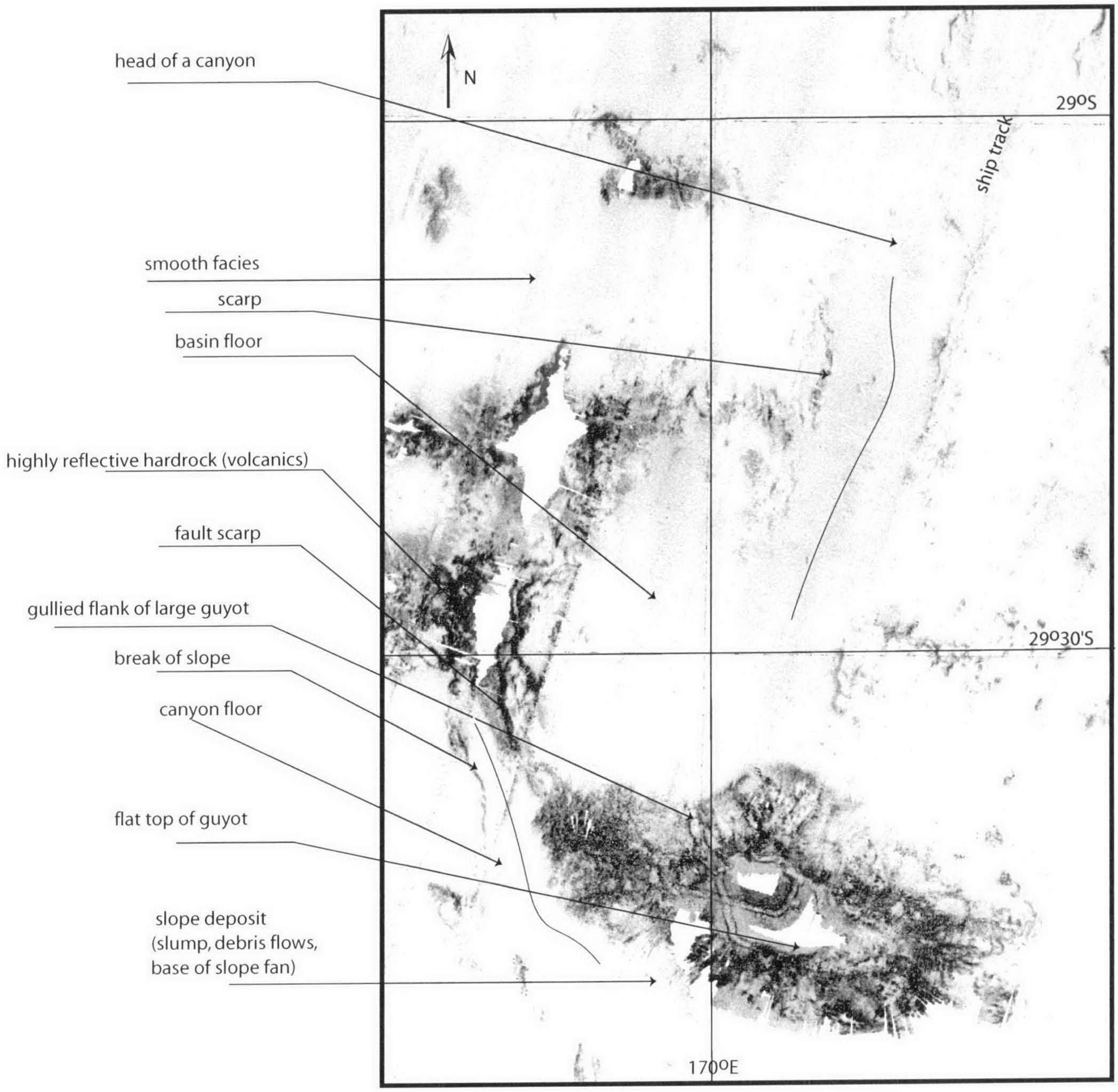
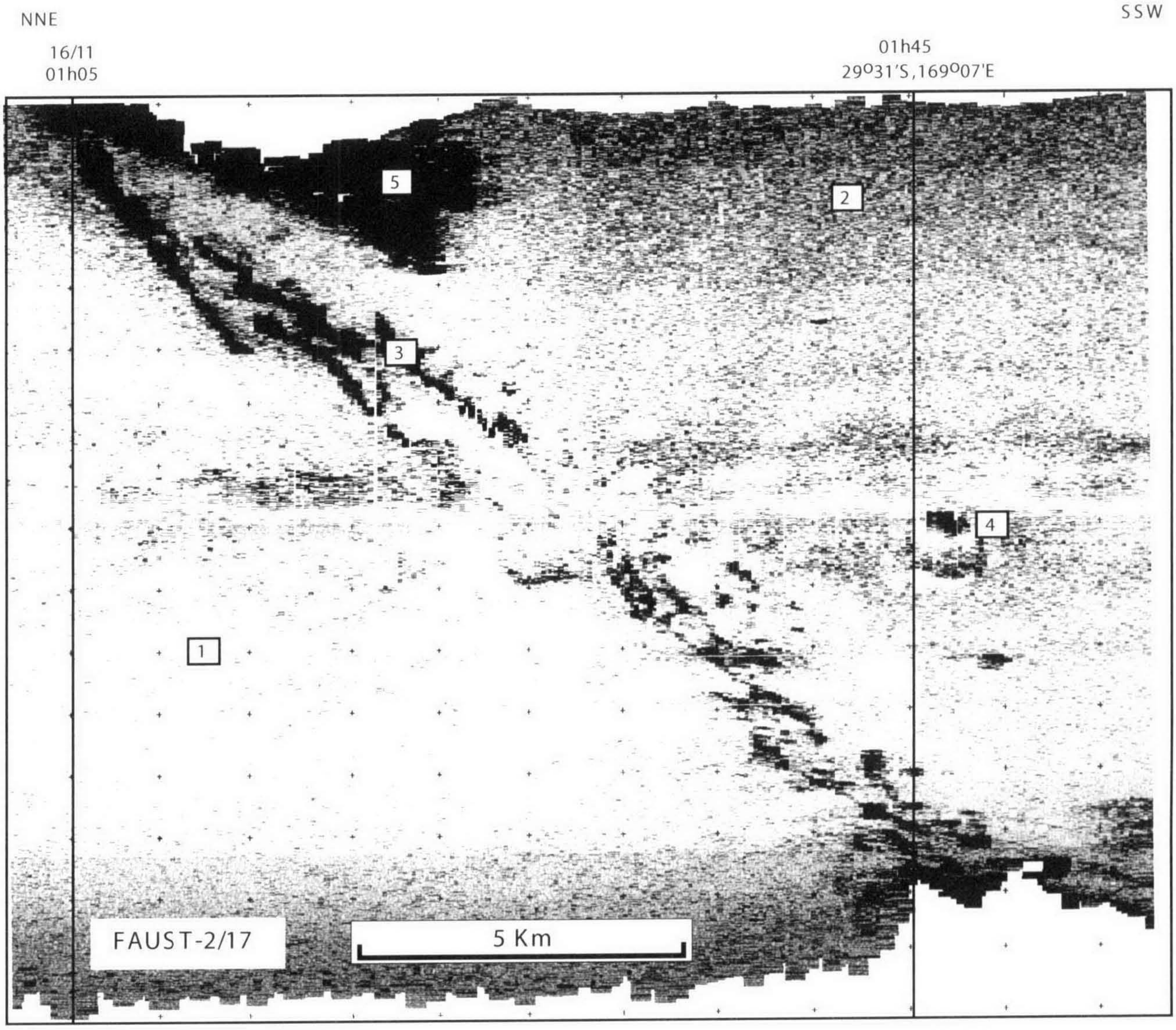


Figure 22. Analysis of backscatter and morphology for the area north of the major seamount centred at approximately 29°45'S,170°05'E in the western portion of the main FAUST-2 survey area.



1	uniform low backscatter (basin floor sediments)
2	uniform medium backscatter (coarse-grained sediments)
3	linear zones of high backscatter (fault scarp)
4	circular area of medium to high backscatter (volcano)
5	irregular zone of high backscatter (hard exposed 'basement')

Figure 23. Analysis of backscatter along FAUST-2 swath profile 17 - see Figure 11 for location.

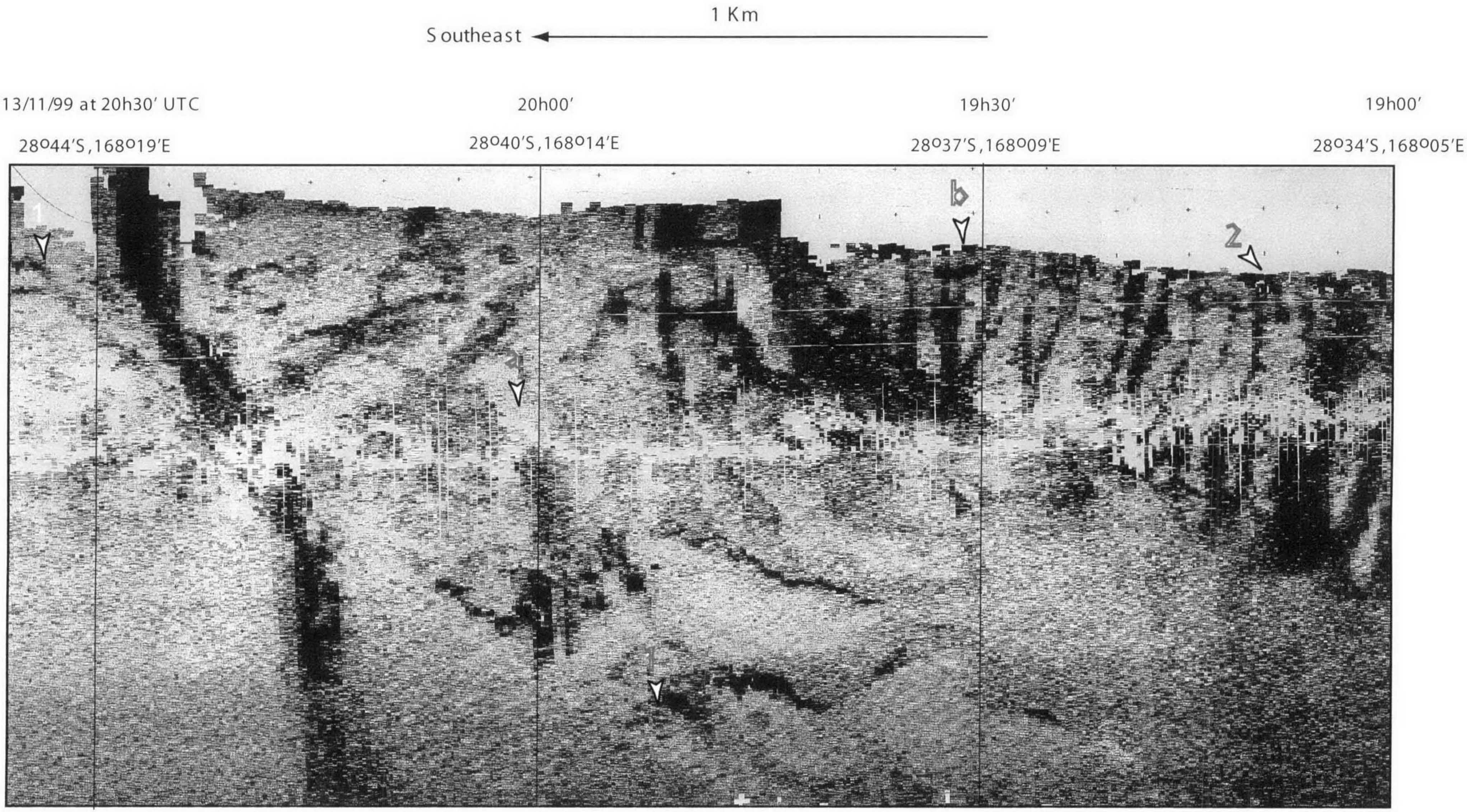


Figure 24. Backscatter interpretation adjacent to two approximate north-trending basin-bounding fault scarps (1 and 2) along the edge of the North Norfolk Basin (profile 5). 'a' indicates gullied scree slopes adjacent to the fault while 'b' indicates slope fan facies.

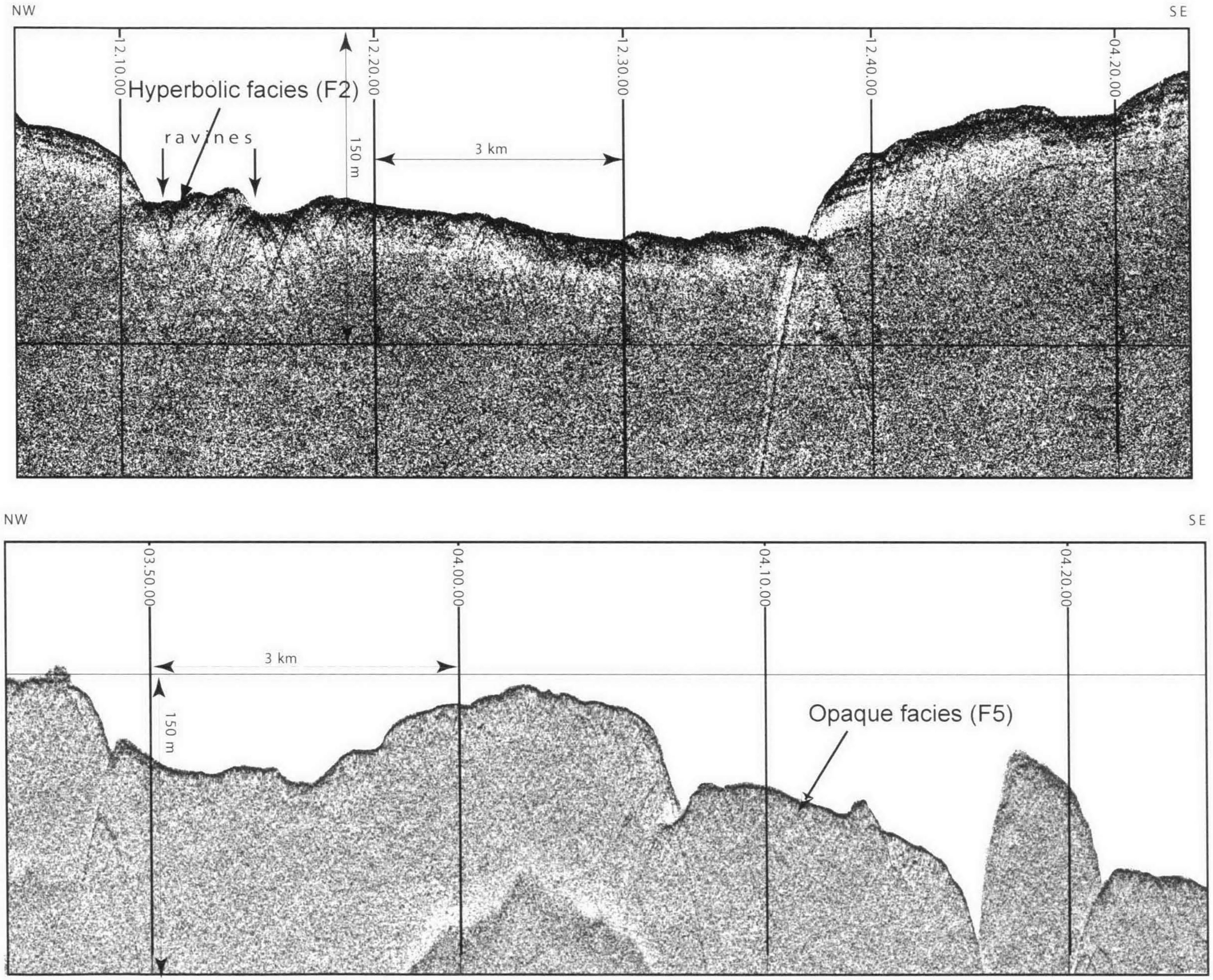


Figure 25. Echosounder examples along the transit to the main FAUST-2 survey area. Shown are small regular hyperbolae, indicating areas of sediment transport and weakly-bedded facies on levee banks (top), and opaque facies corresponding to areas of bedrock with little or no sediment cover (bottom).

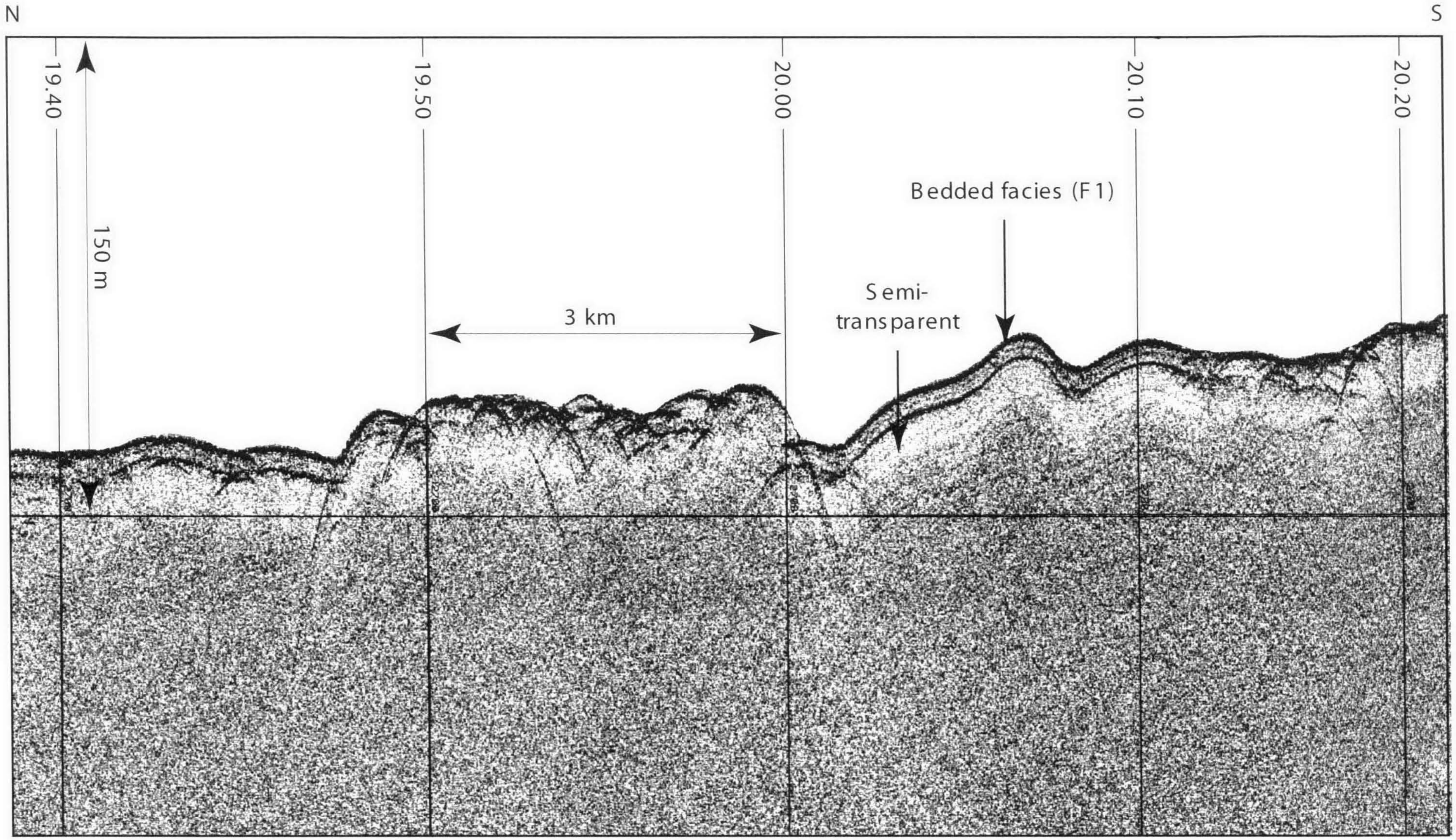
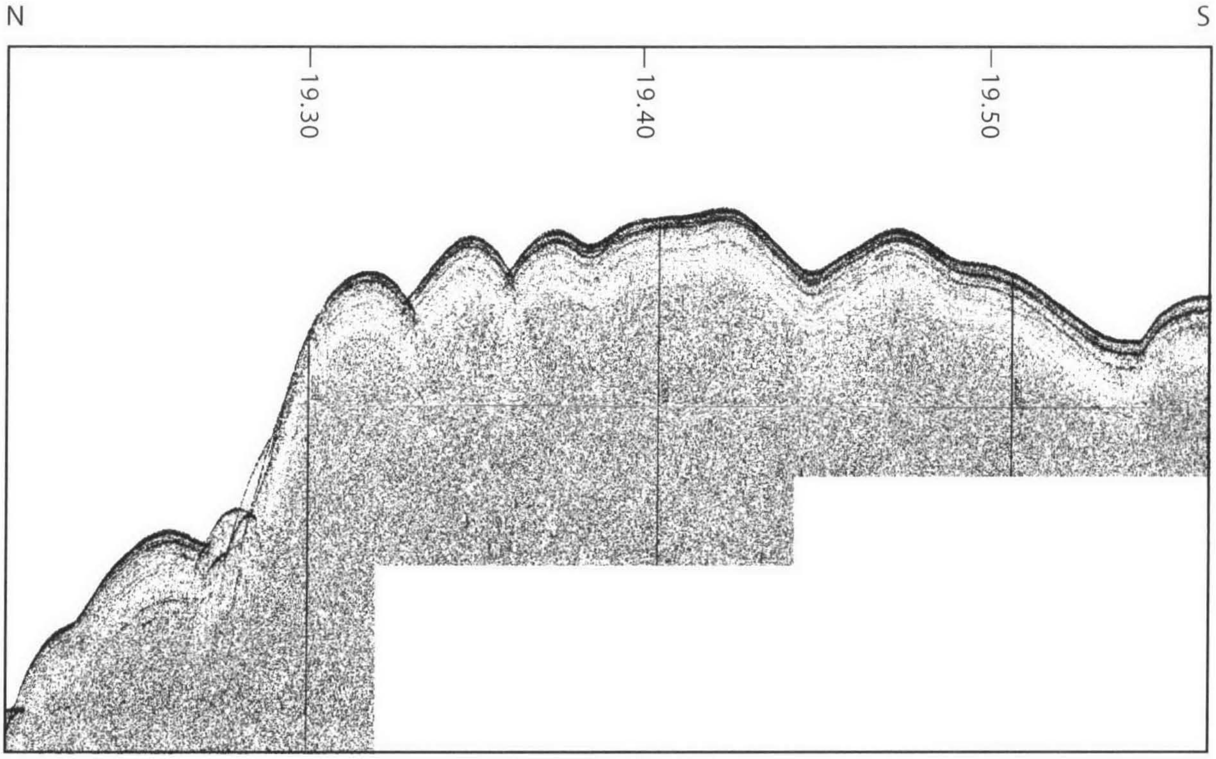
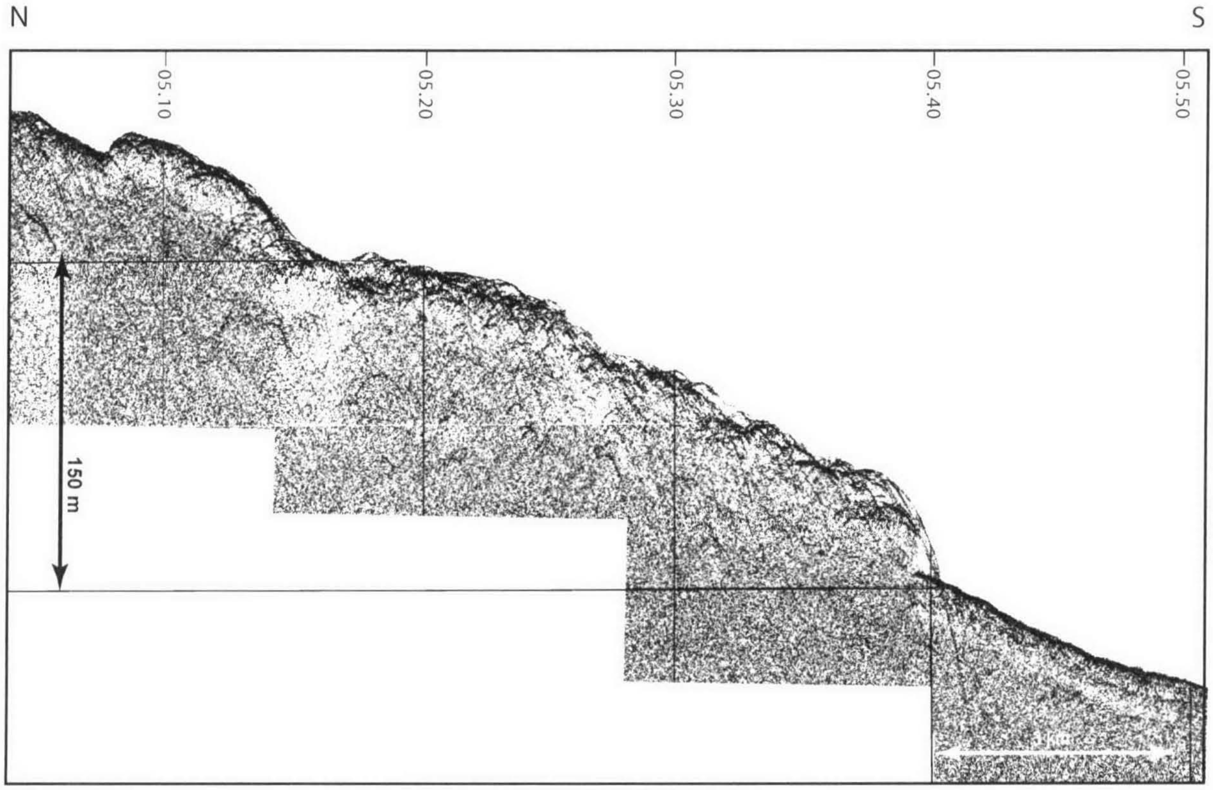


Figure 26. Example of echosounder record on the transit to the main FAUST-2 survey area showing bedded facies with sub-bottom reflectors overlying a semi-transparent facies with weakly expressed reflectors. The central part is dominated by hyperbolic facies which probably correspond to an area of erosion or thin sediment cover on uplifted basement blocks.



Part of profile 8.



Part of profile 17.

Figure 27. Examples in the western portion of the main FAUST-2 survey area showing hummocky morphology intermediate between bedded facies 1a and facies 5 in an interfluvial area (top) and a debris flow along the southern slope of the seamount centred at about 29°50'S,169°10'E (bottom).

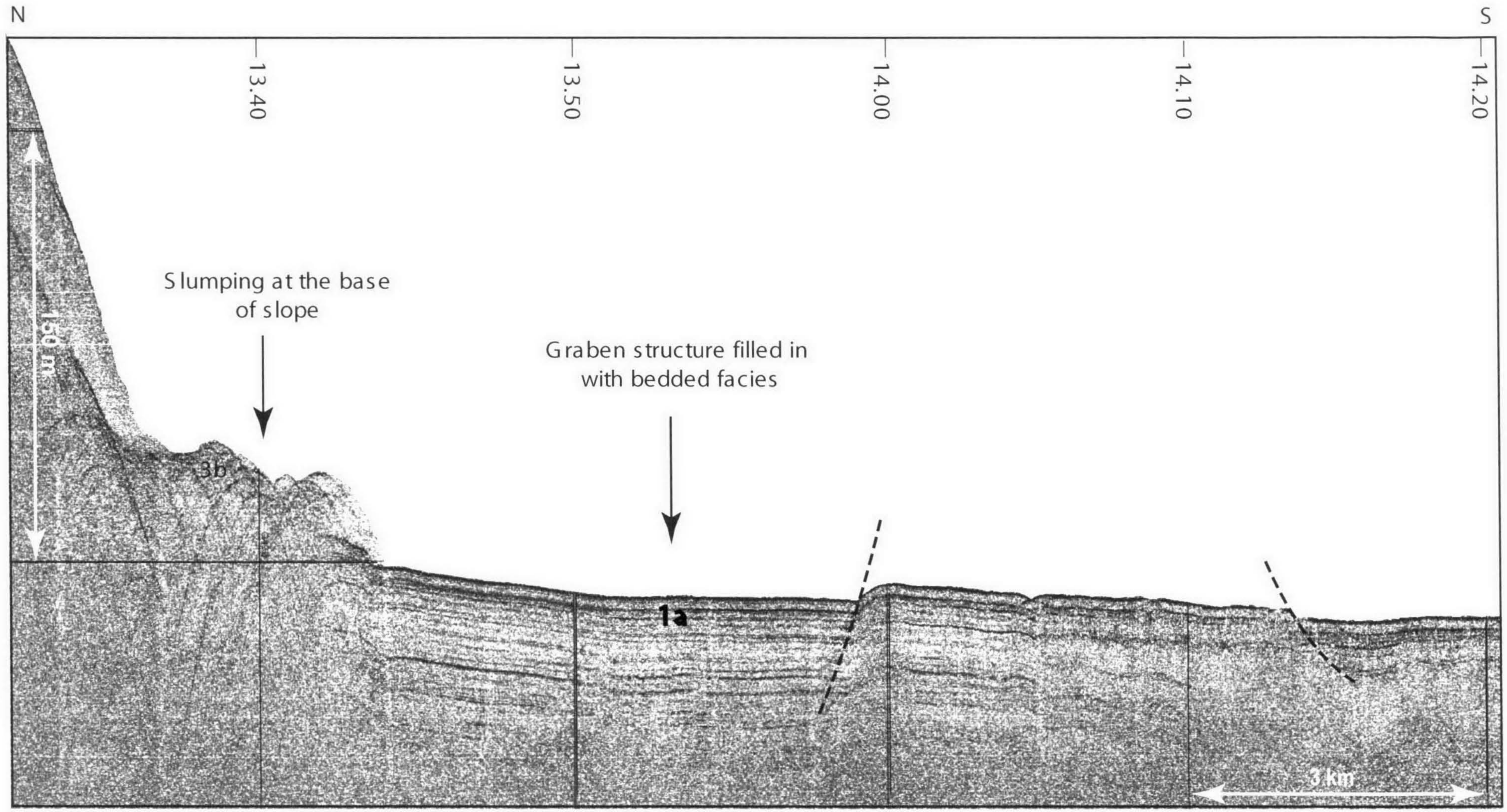


Figure 28. Example of bedded facies (1a) showing well-developed sub-bottom reflectors in a graben and disturbed sediment (facies 3b) resulting from slumping. Section is part of profile 23 in the western portion of the main FAUST-2 survey area from 29º24'S,170º02'E to 29º31'S,170º00'E.

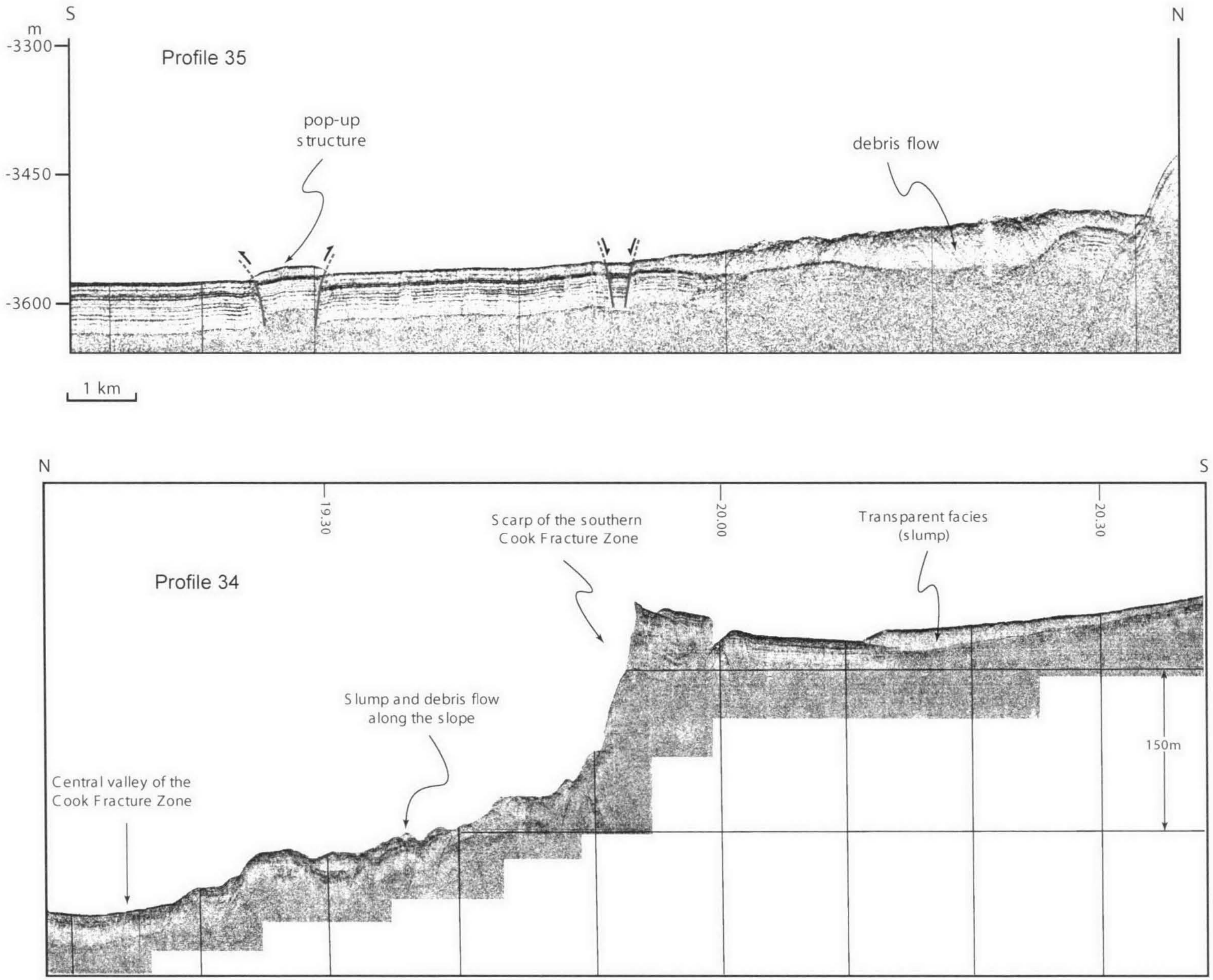
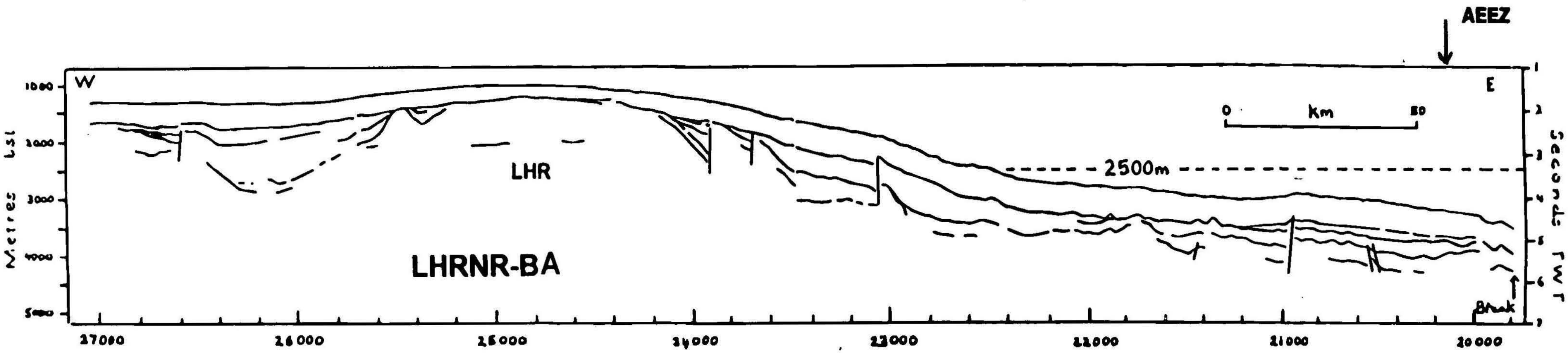


Figure 29. Examples of echosounder profiles in the eastern portion of the main FAUST-2 survey area across a debris flow at the base of slope with a pop-up structure indicating possible deep-seated transcurrent faulting (top) and across the southern boundary of the Cook Fracture Zone (bottom).



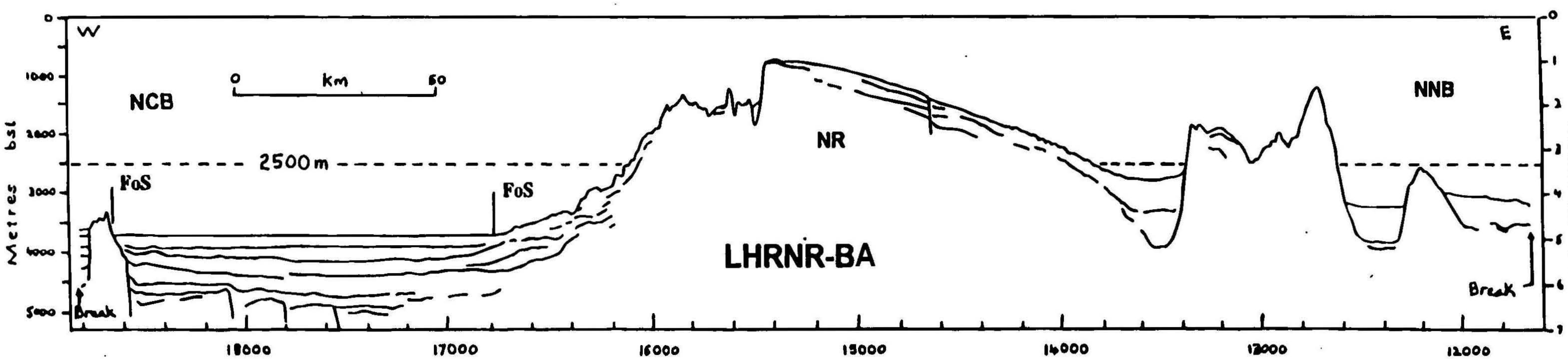
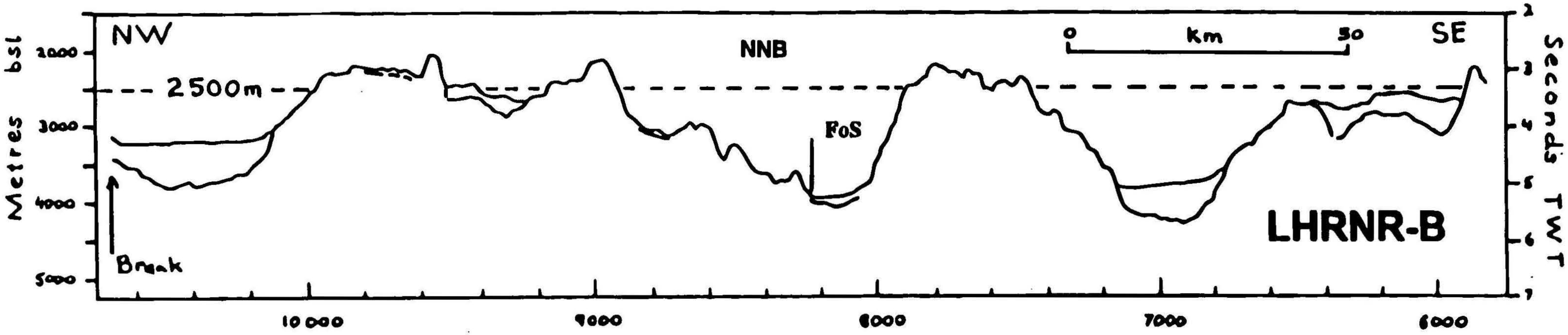


Figure 30. Line drawing interpretation of seismic profile LHRNR-BA (see Fig. 4). Taken from Ramsay et al. (1997). Shown are the Lord Howe Rise (LHR), Norfolk Ridge (NR), New Caledonia Basin (NCB), western part of the North Norfolk Basin (NNB) and relevant foot-of-slope picks (FoS).



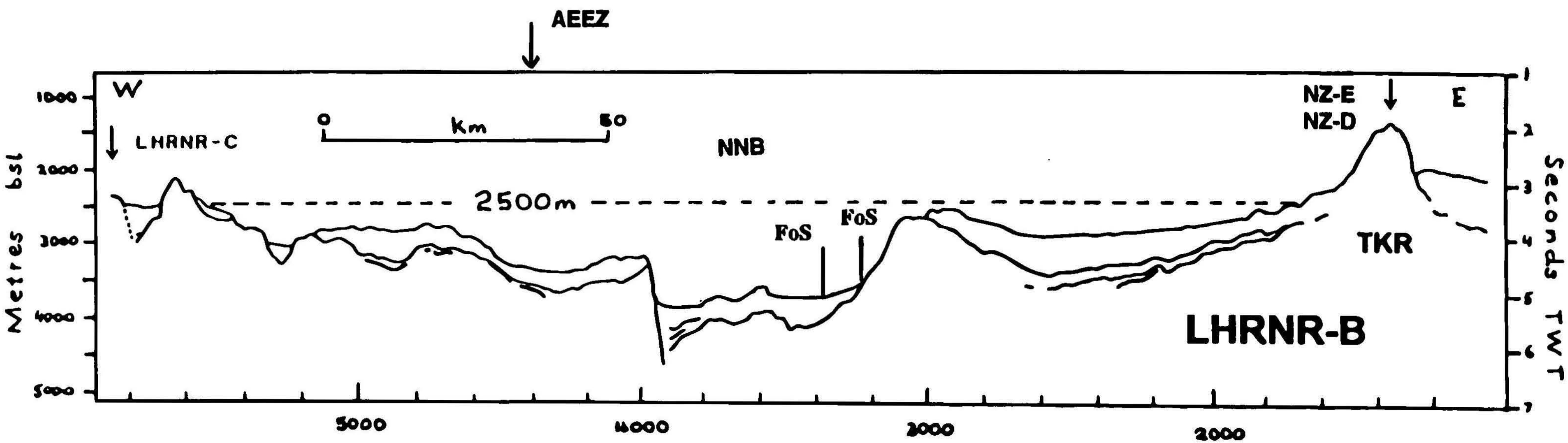


Figure 31. Line drawing interpretation of seismic profile LHRNR-B (see Fig. 6). Taken from Ramsay et al. (1997). Shown are the North Norfolk Basin (NNB), the Three Kings Ridge (TKR) and relevant foot-of-slope picks (FoS).

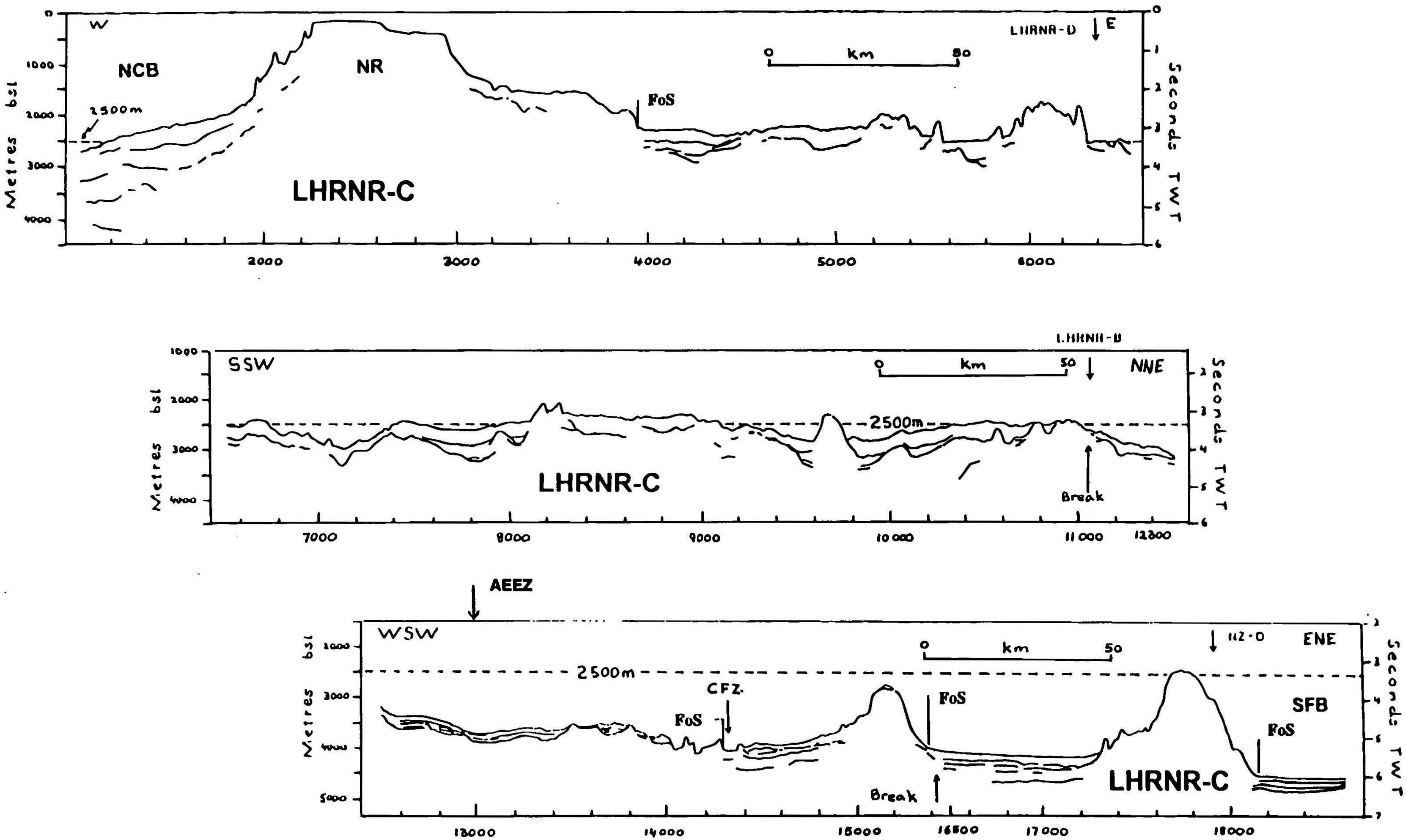


Figure 32. Line drawing interpretation of seismic profile LHRNR-C (see Fig. 6). Taken from Ramsay et al. (1997). Shown are the western edge of the New Caledonia Basin (NCB), Norfolk Ridge (NR), Cook Fracture Zone (CFZ), South Fiji Basin (SFB) and relevant foot-of-slope picks (FoS).

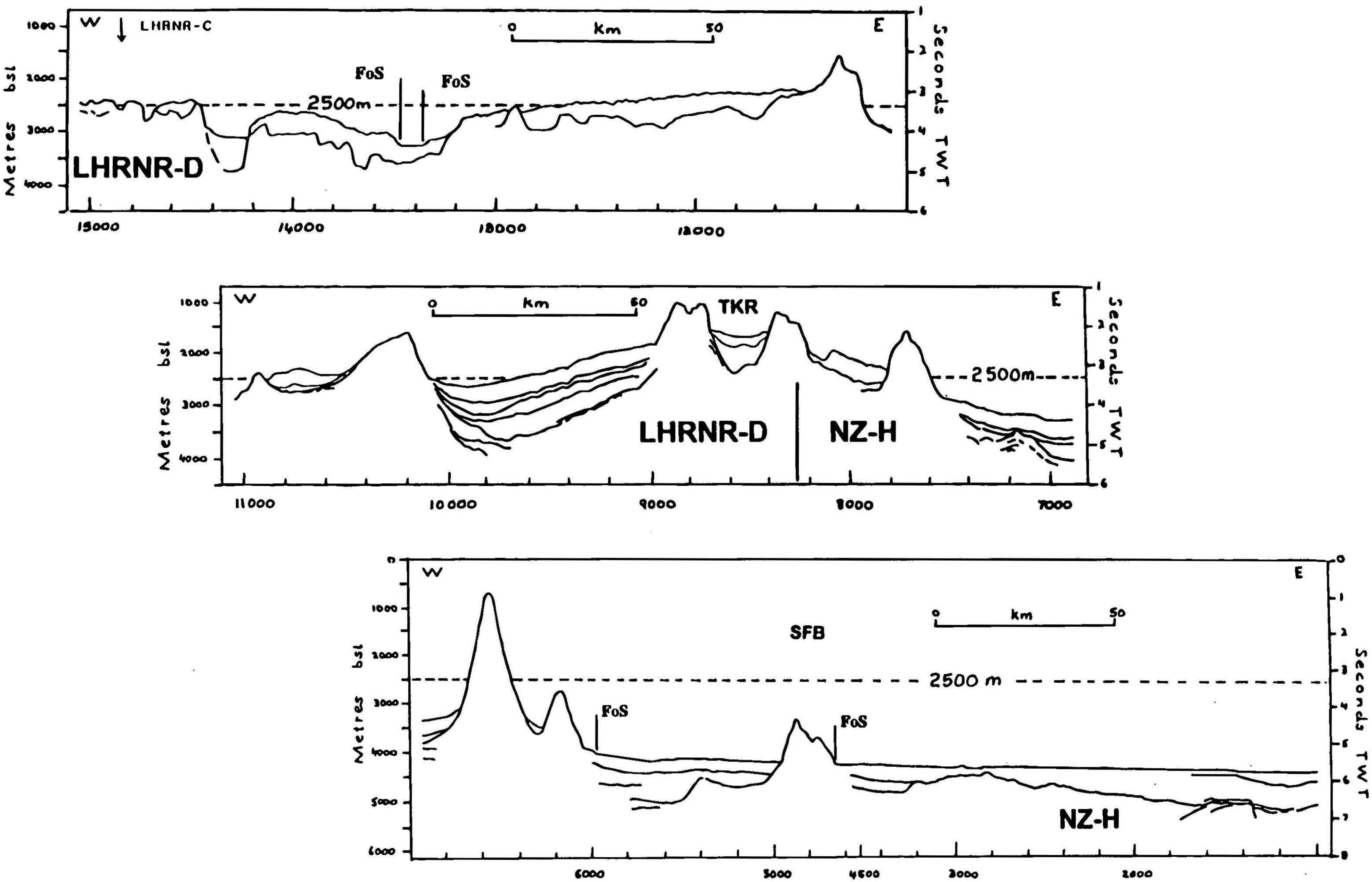


Figure 33. Line drawing interpretation of seismic profile LHRNR-D and NZ-H (see Fig. 6). Taken from Ramsay et al. (1997). Shown are the Three Kings Ridge (TKR), South Fiji Basin (SFB) and relevant foot-of-slope picks (FoS).

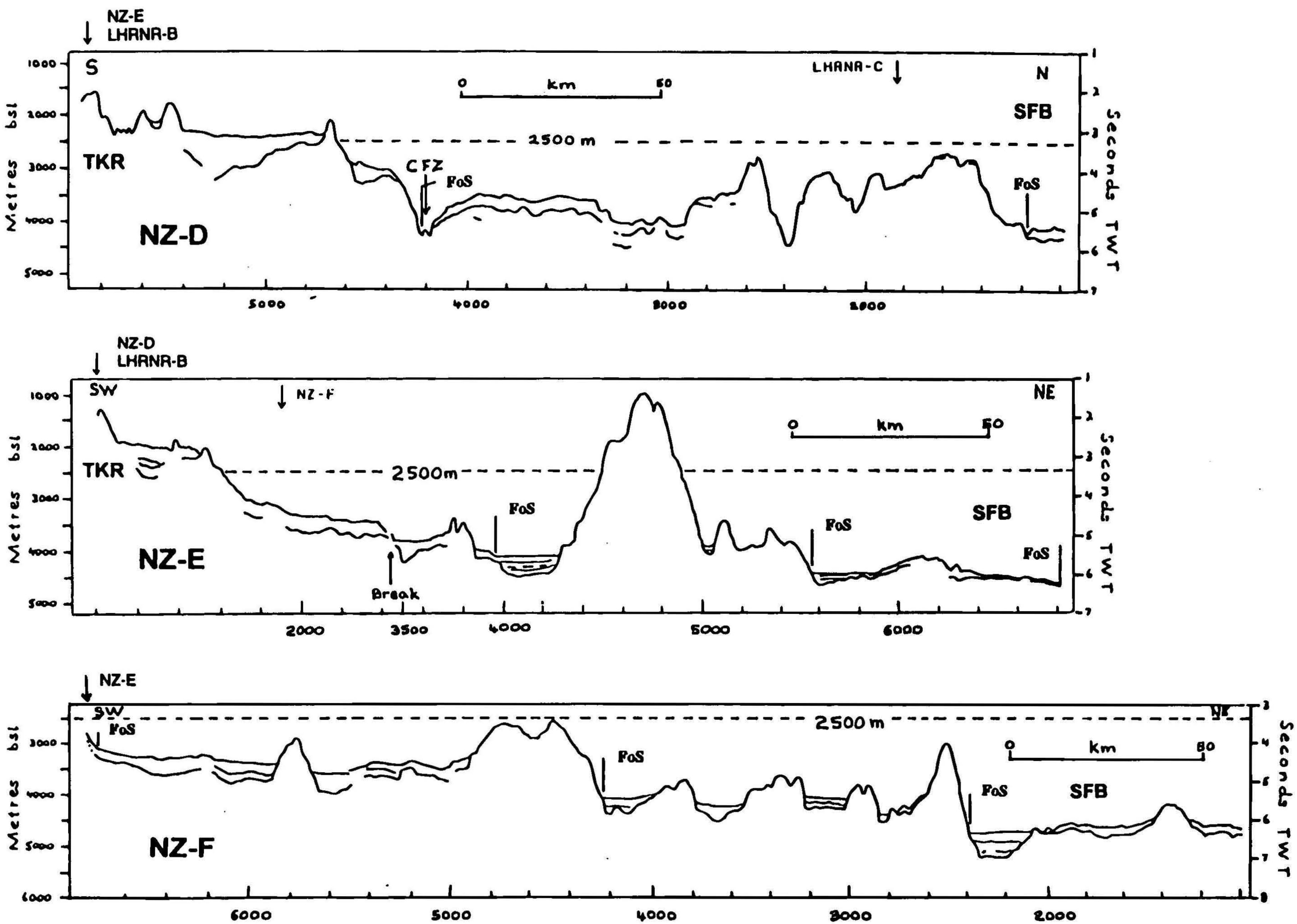


Figure 34. Line drawing interpretation of seismic profiles NZ-D, NZ-E and NZ-F (see Fig. 6). Taken from Ramsay et al. (1997). Shown are the Three Kings Ridge (TKR), South Fiji Basin (SFB), Cook Fracture Zone (CFZ) and relevant foot-of-slope picks (FoS).

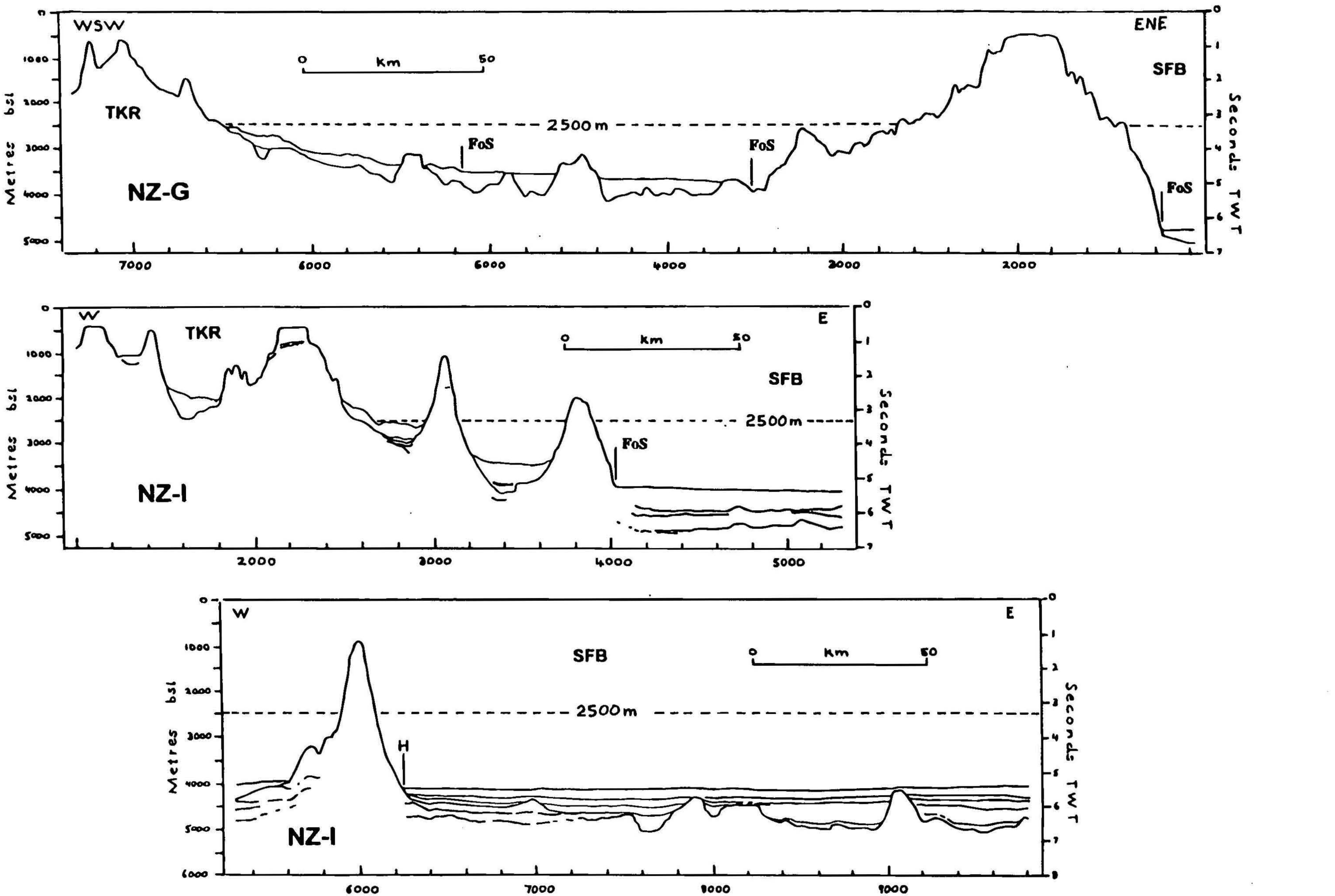


Figure 35. Line drawing interpretation of seismic profiles NZ-G and NZ-I (see Fig. 6). Taken from Ramsay et al. (1997). Shown are the Three Kings Ridge (TKR), South Fiji Basin (SFB) and relevant foot-of-slope picks (FoS).

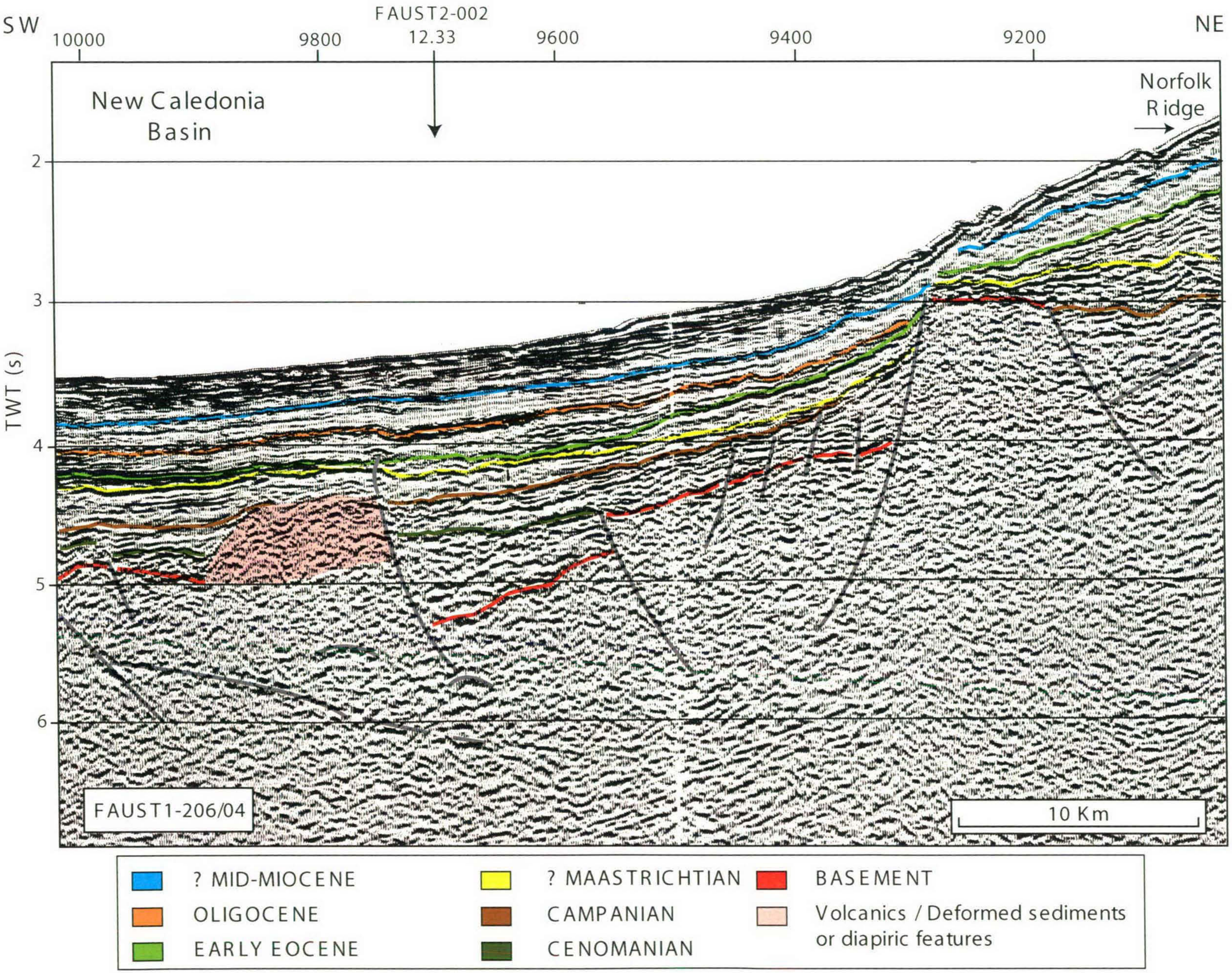


Figure 36. Interpretation of part of FAUST-1 line 206/04 over the western flank of the Norfolk Ridge into the New Caledonia Basin.

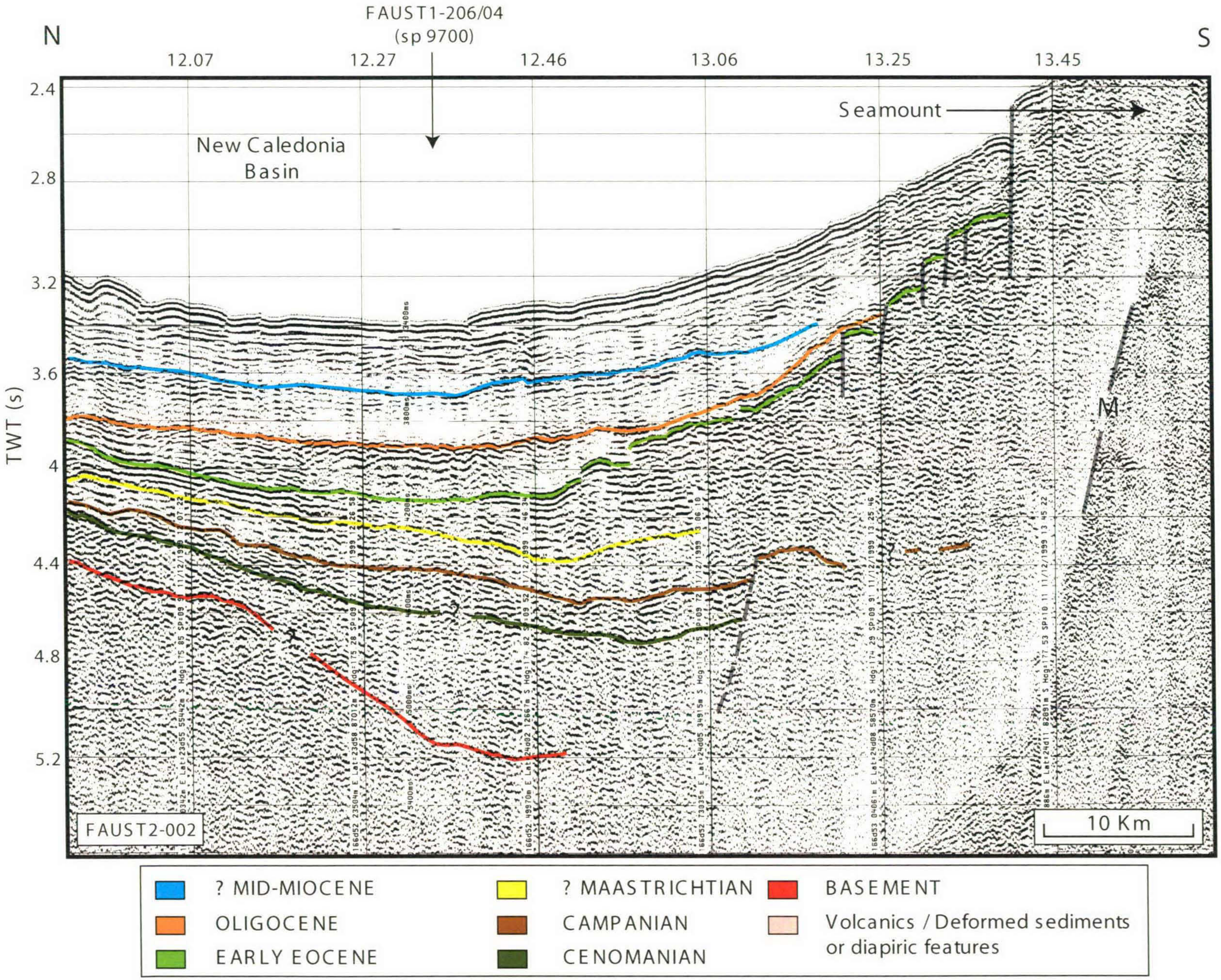


Figure 37. FAUST-2 seismic profile 2 with interpretation carried from FAUST-1 profile 206/04 in the New Caledonia Basin (see Fig. 36).

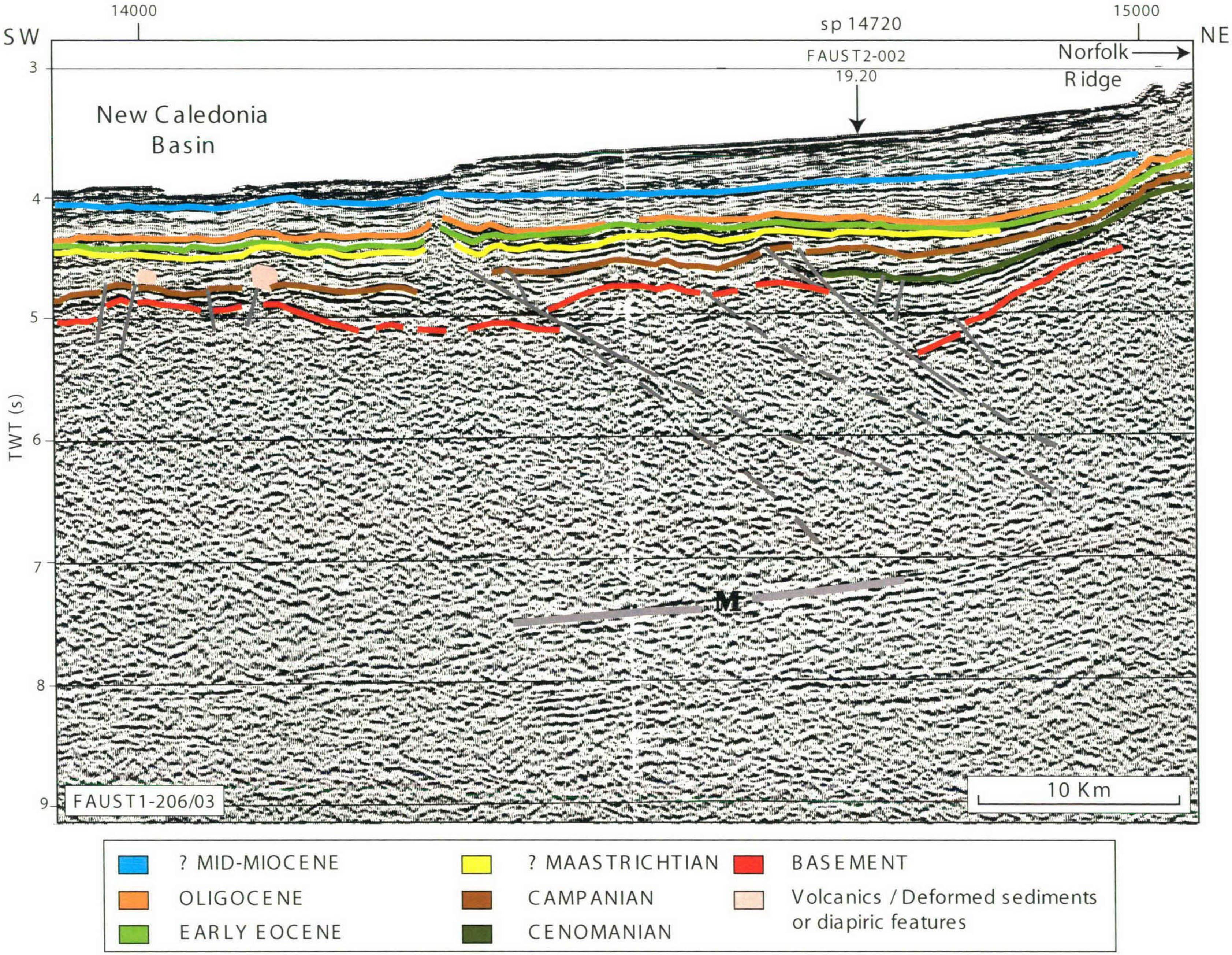


Figure 38. Interpretation of part of FAUST-1 seismic profile 206/03 in the New Caledonia Basin.

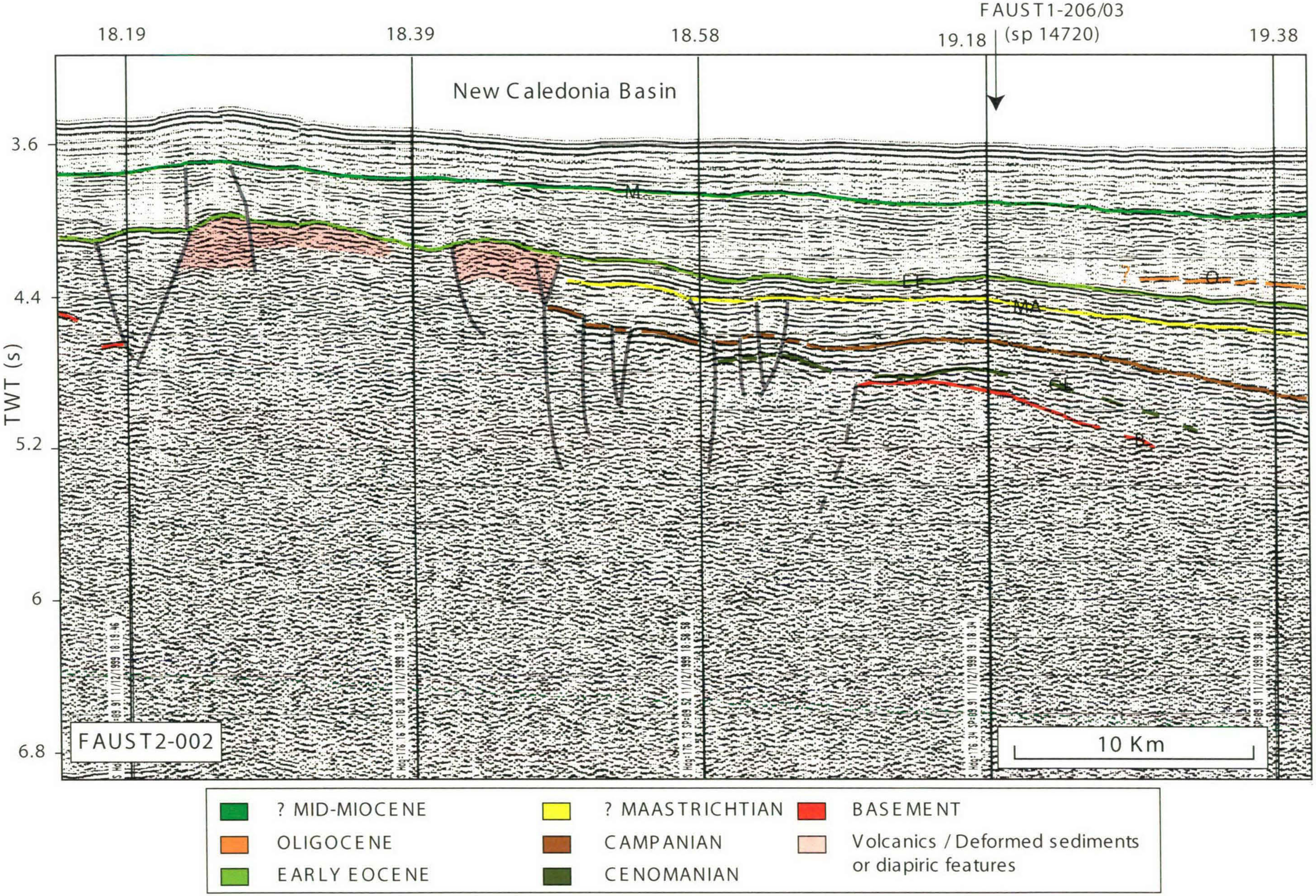
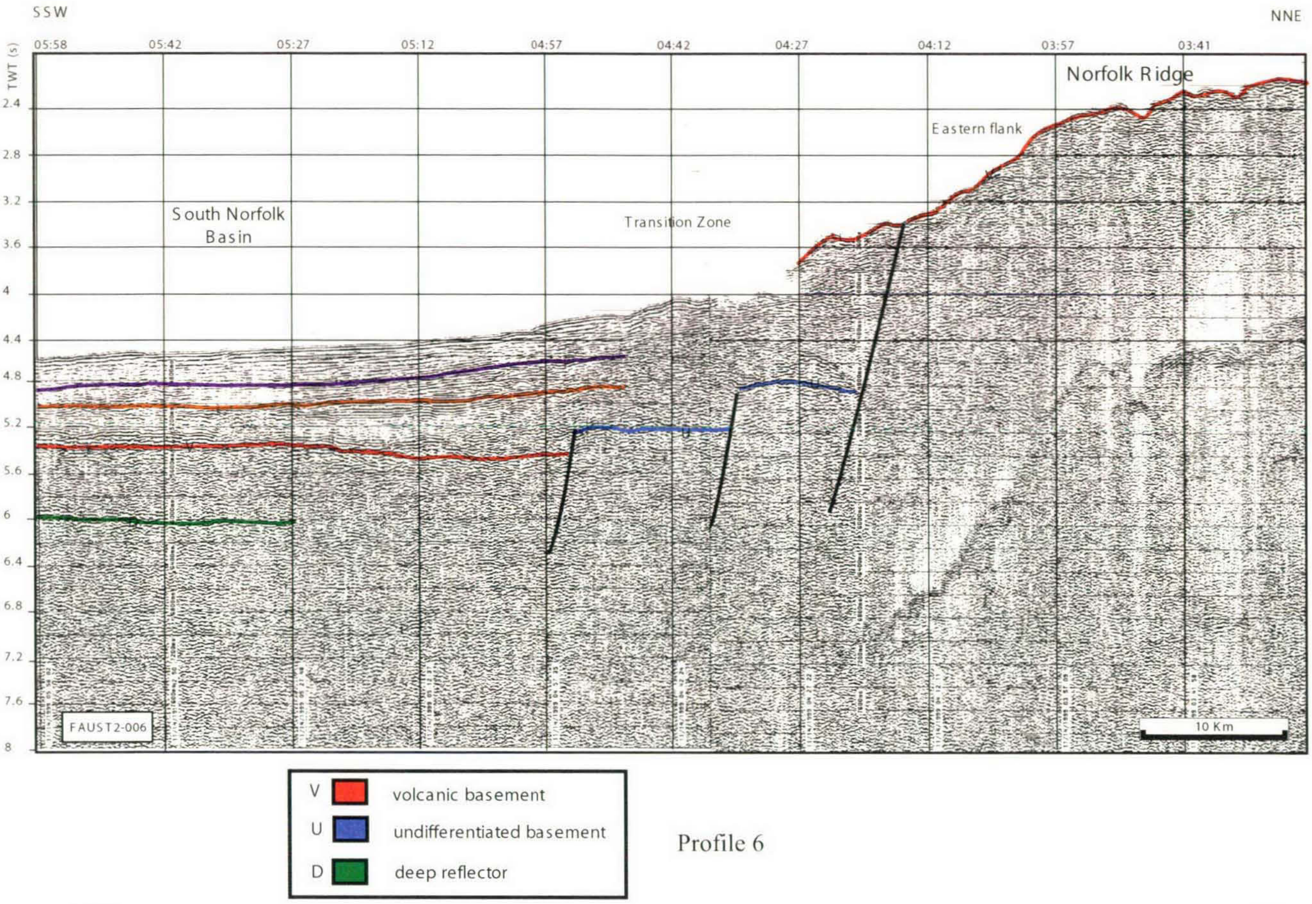


Figure 39. FAUST-2 seismic profile 2 with interpretation carried from FAUST-1 profile 206/03 in the New Caledonia Basin (see Fig. 38).



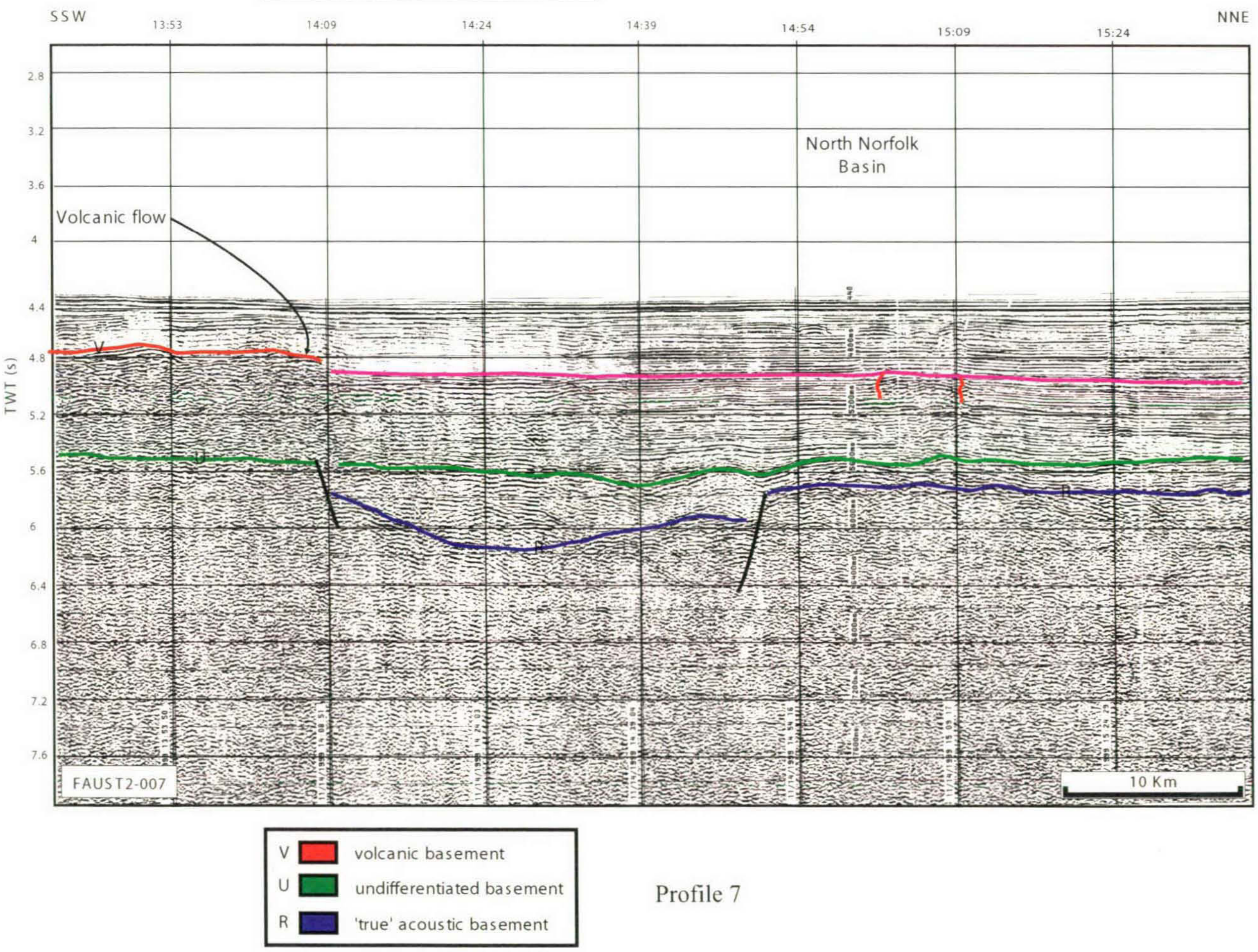


Figure 40. Interpretation of part of FAUST-2 seismic profile 6 (top), down southern flank of the Norfolk Ridge spur into the South Norfolk Basin, and profile 7 (bottom) into the North Norfolk Basin.

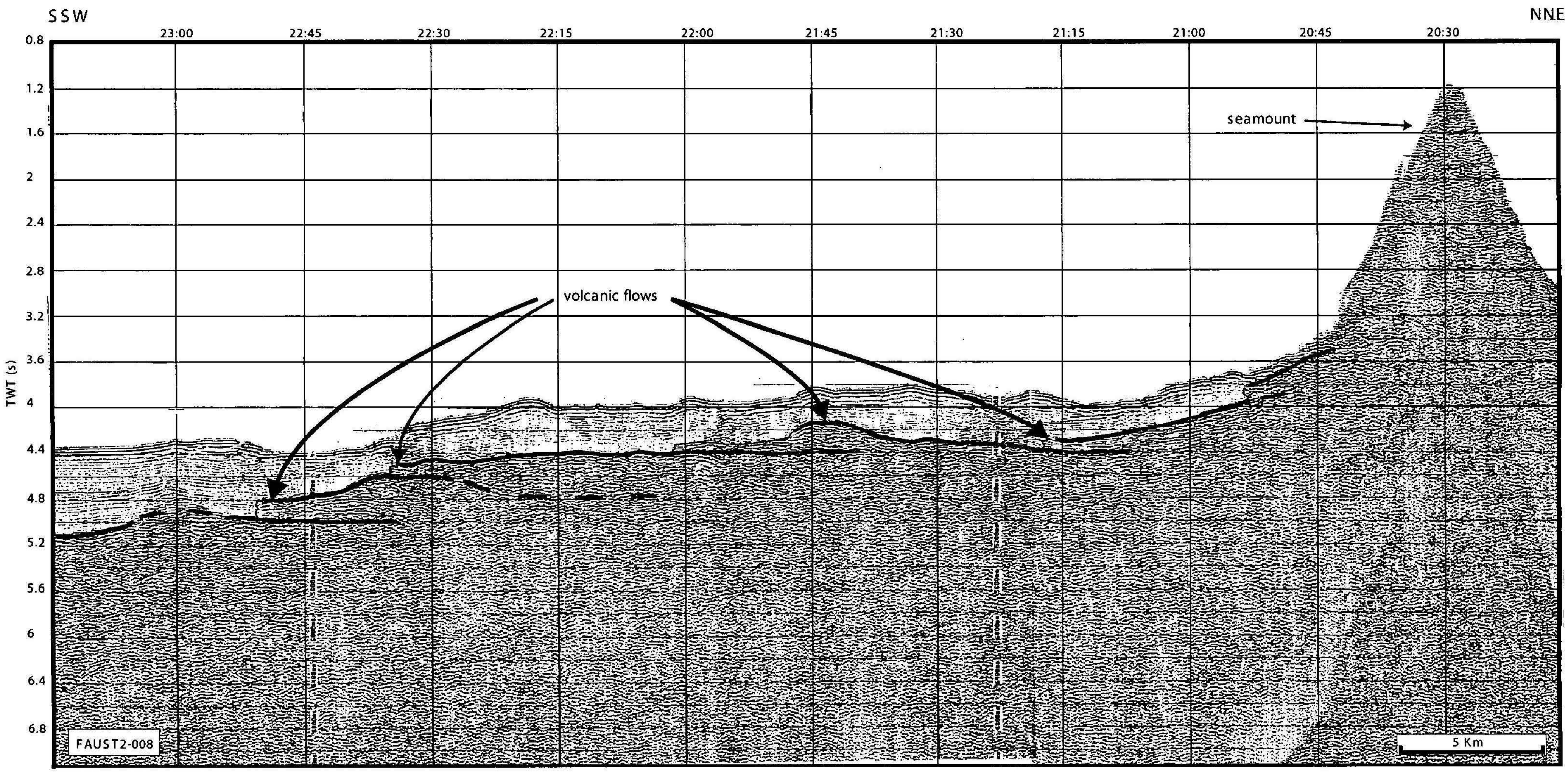


Figure 41. FAUST-2 seismic profile 8 showing an interpretation of stacked lava flows on basement over the northern end of the South Norfolk Basin.

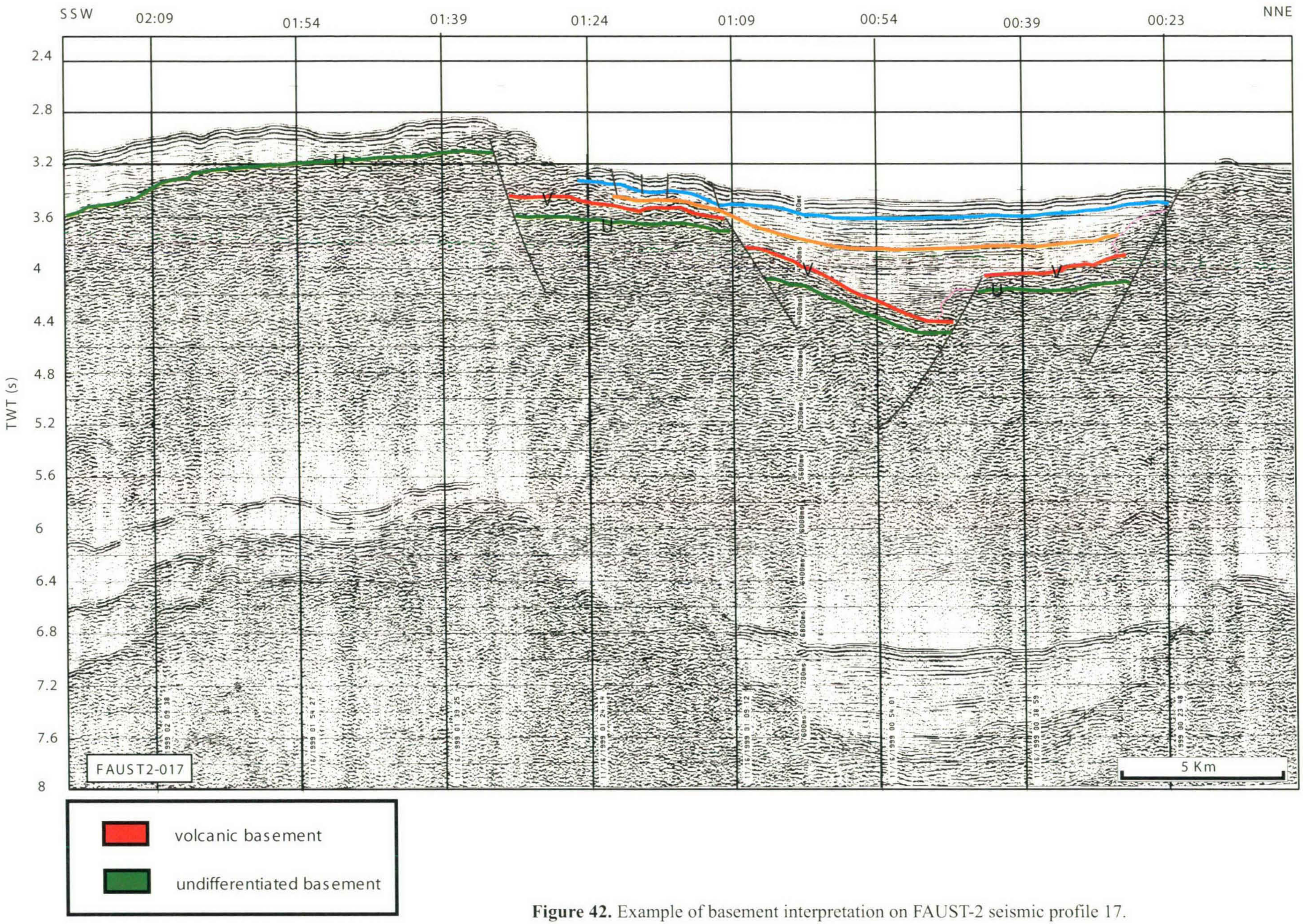


Figure 42. Example of basement interpretation on FAUST-2 seismic profile 17.

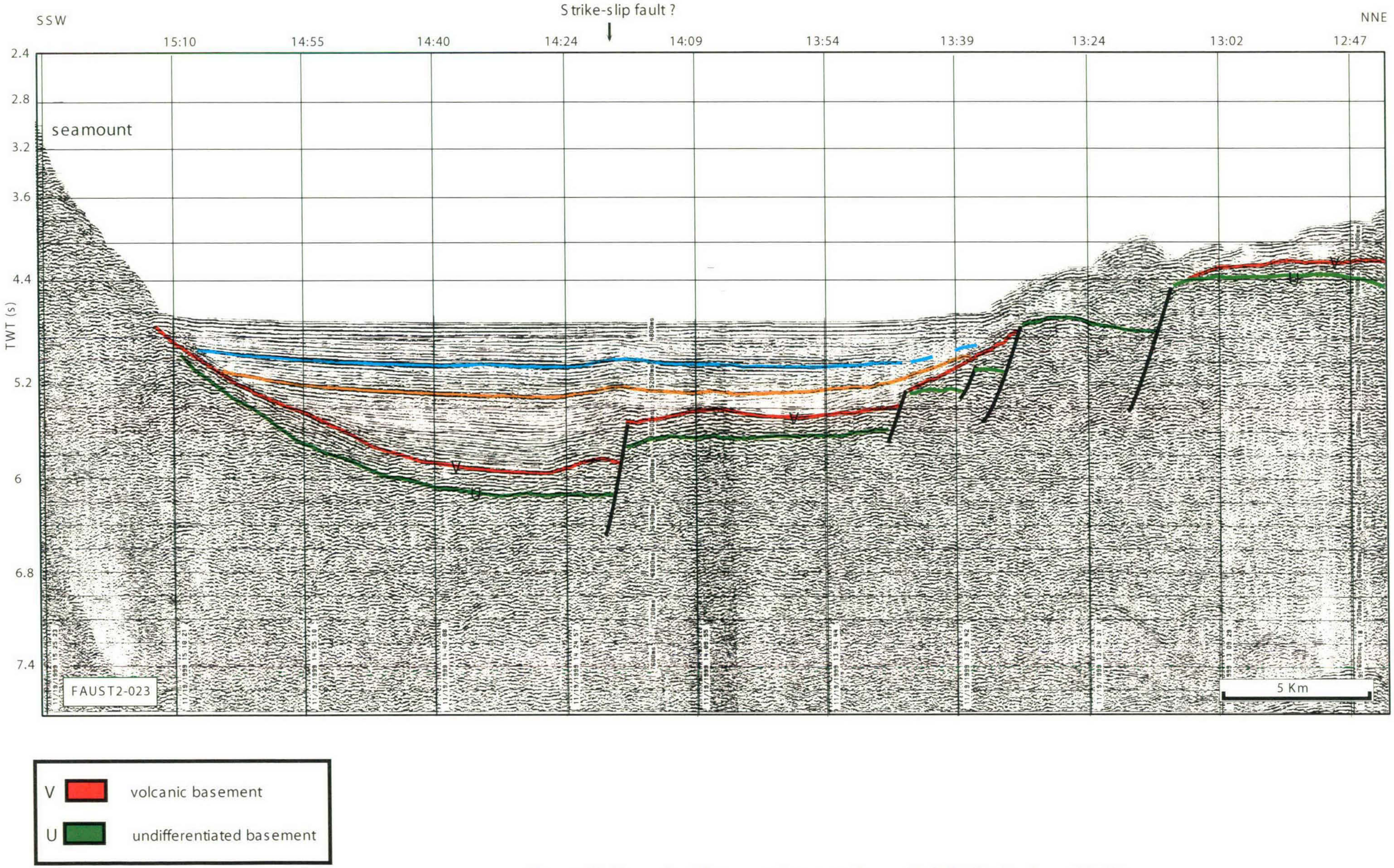


Figure 43. Example of basement interpretation on FAUST-2 seismic profile 23.

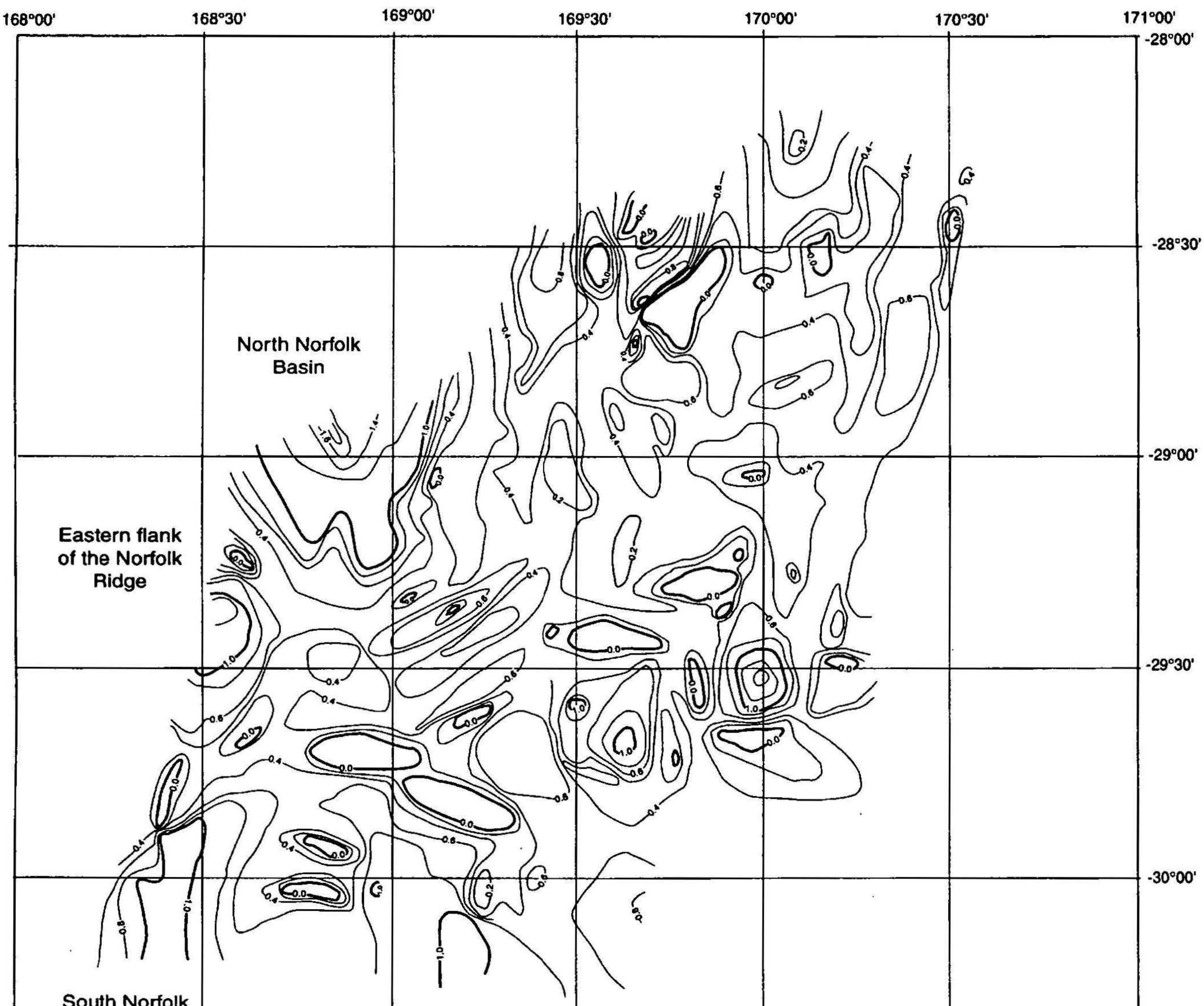


Figure 44. Sediment two-way time isochron map for the western portion of the main FAUST-2 survey area.

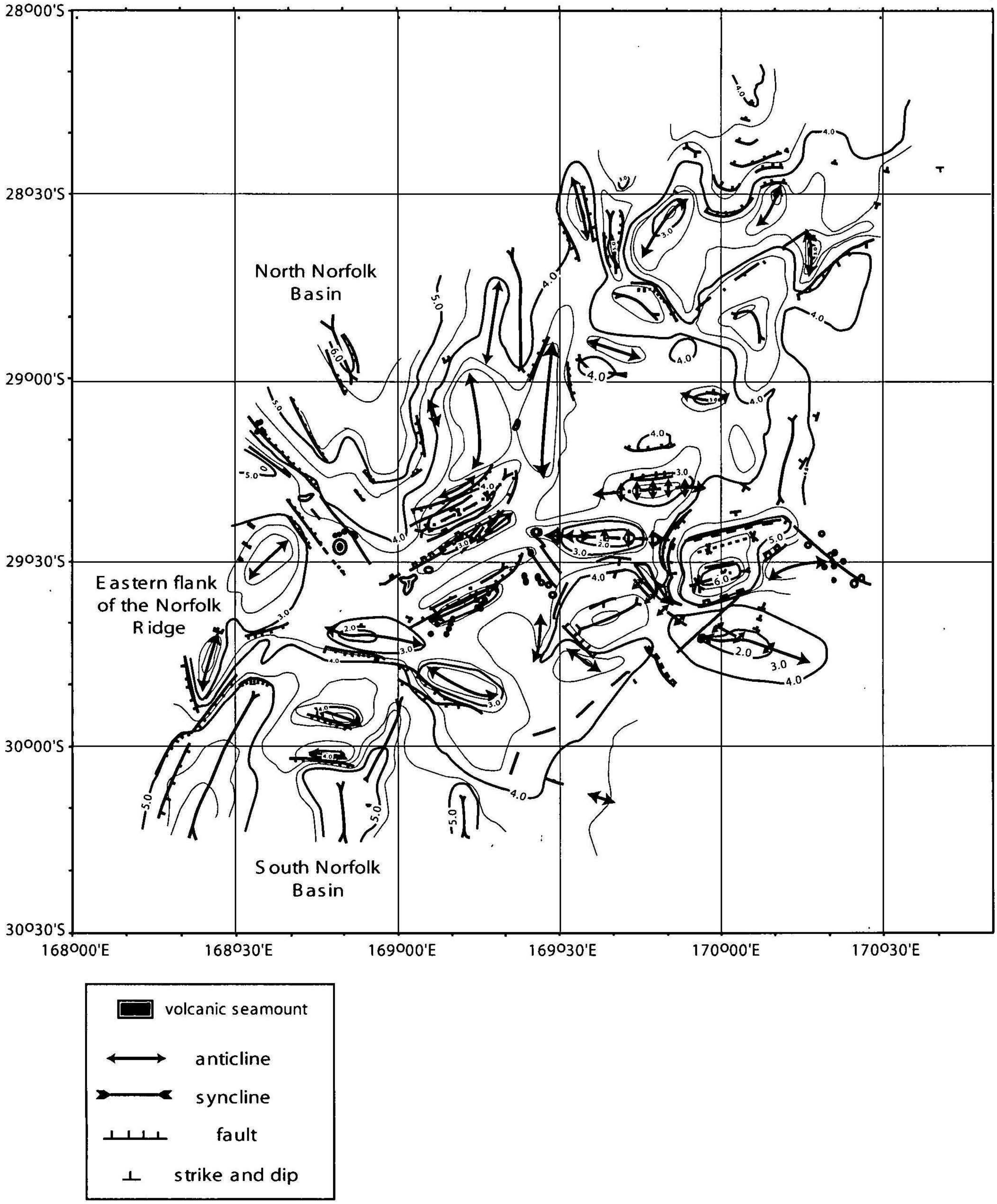


Figure 45. Basement two-way time structure contour map for the western portion of the main FAUST-2 survey area.

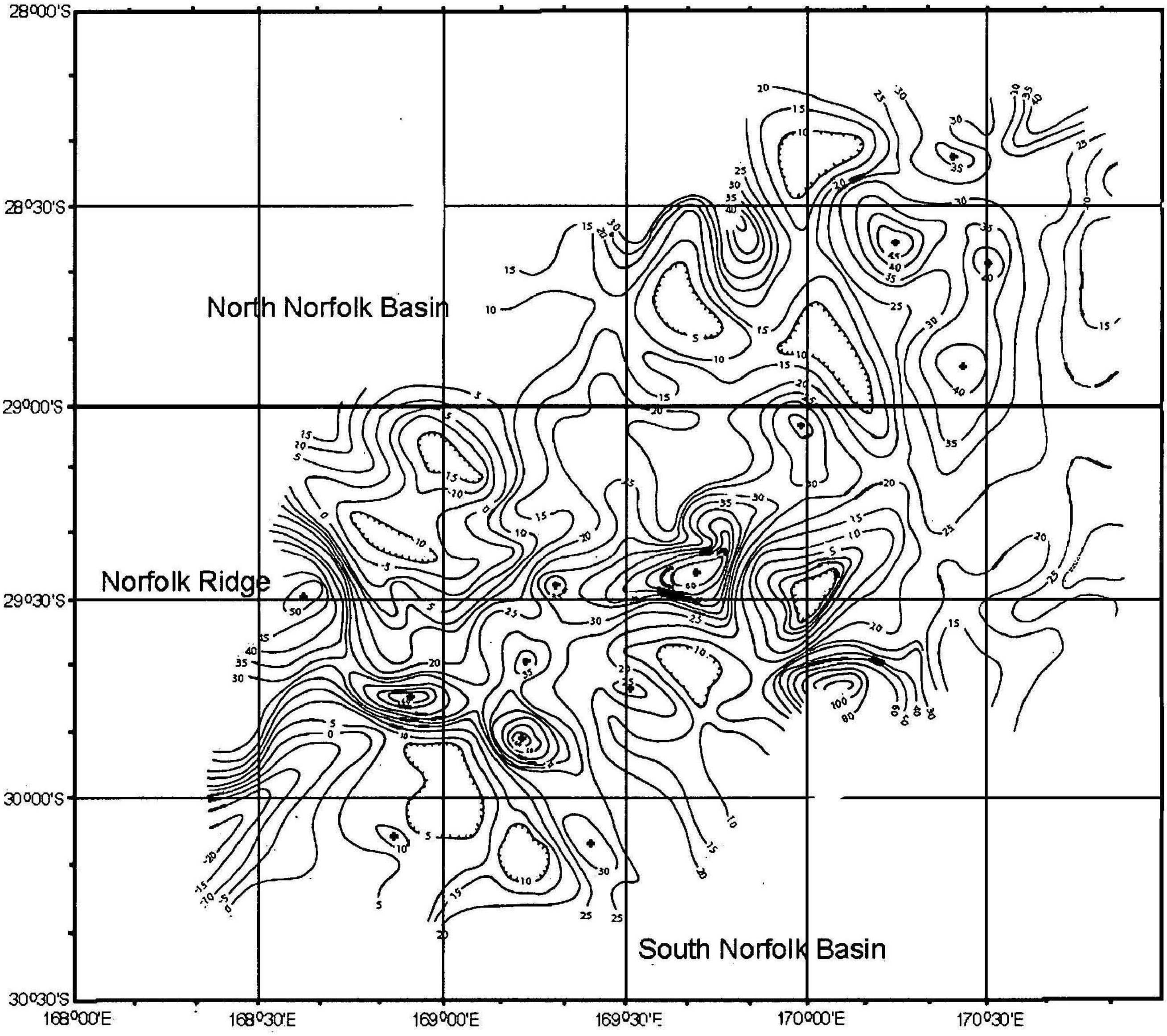


Figure 46. Contoured gravity for the western portion of the main FAUST-2 survey area. Contour interval is 5 mgals.

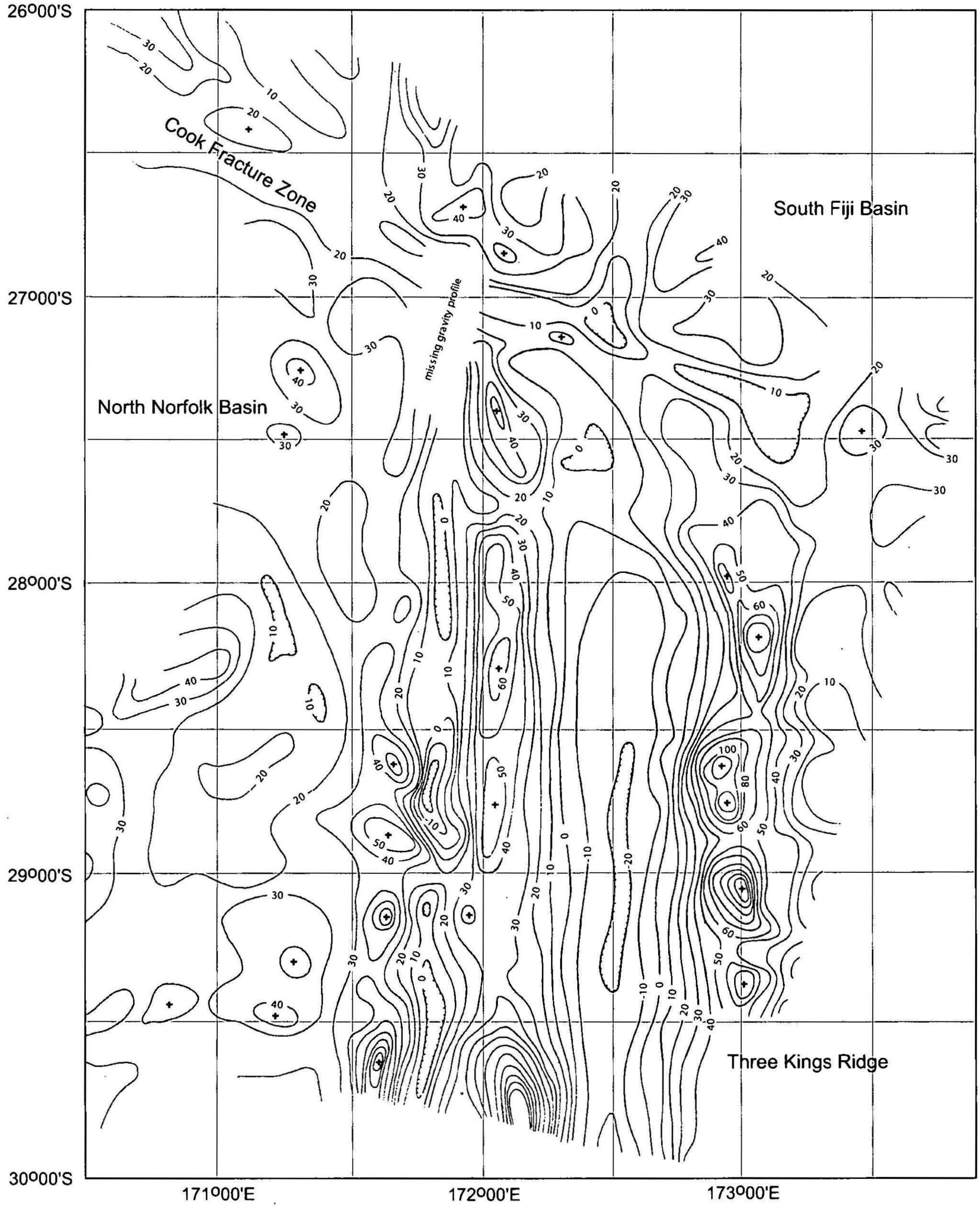


Figure 47. Contoured gravity for the eastern portion of the main FAUST-2 survey area. Contour interval is 10 mgals.

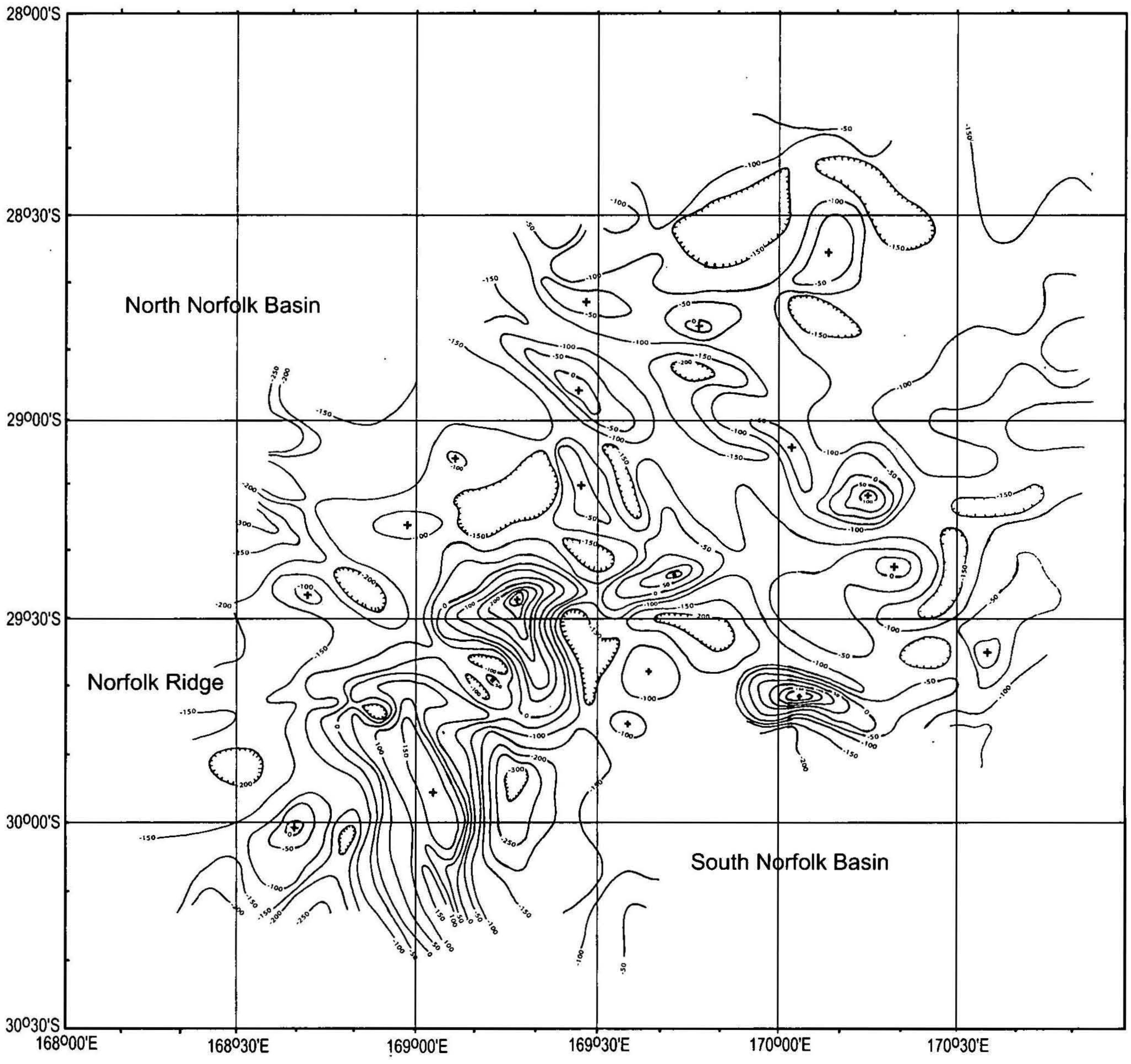


Figure 48. Contoured magnetics for the western portion of the main FAUST-2 survey area. Contour interval is 50 nT.

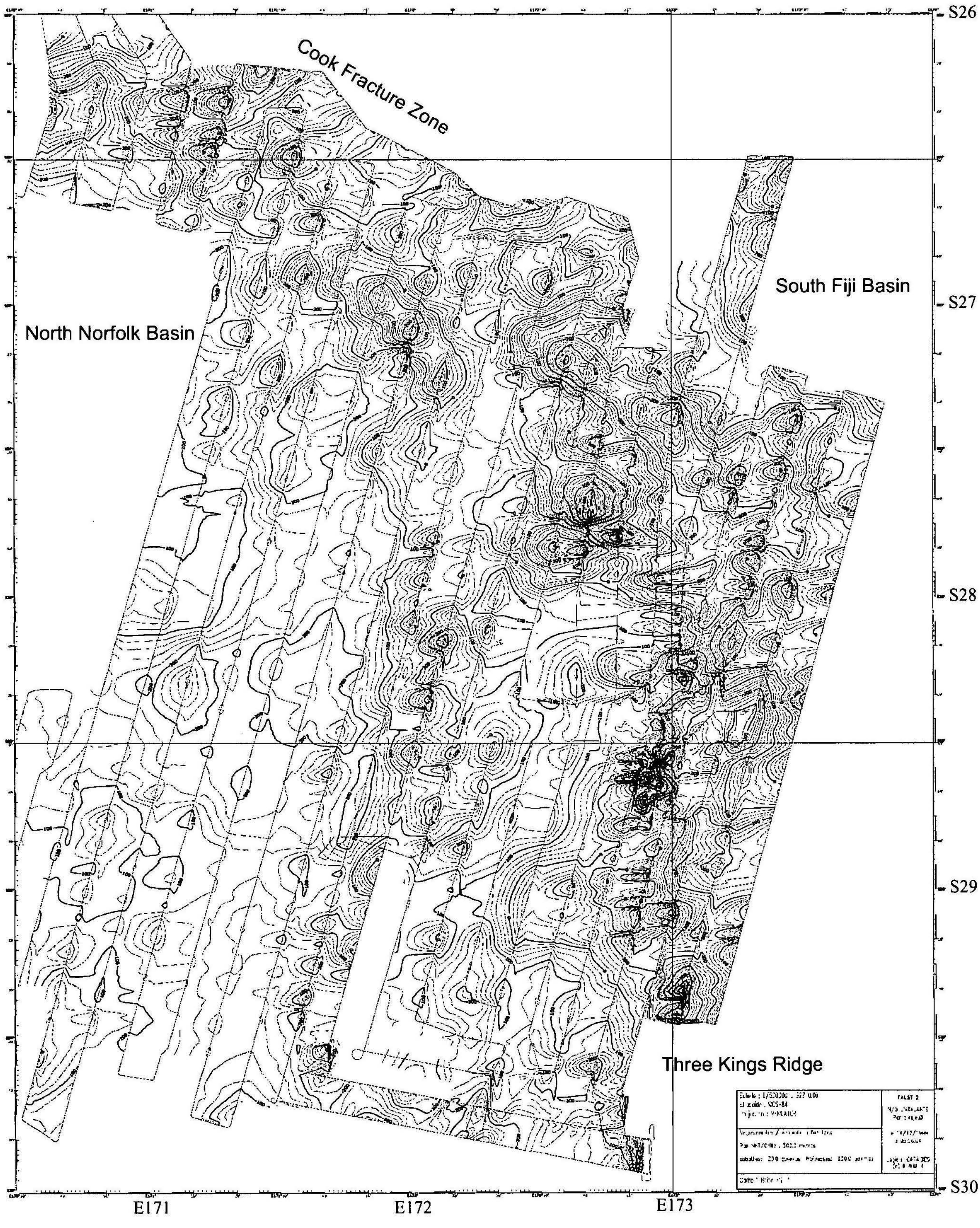
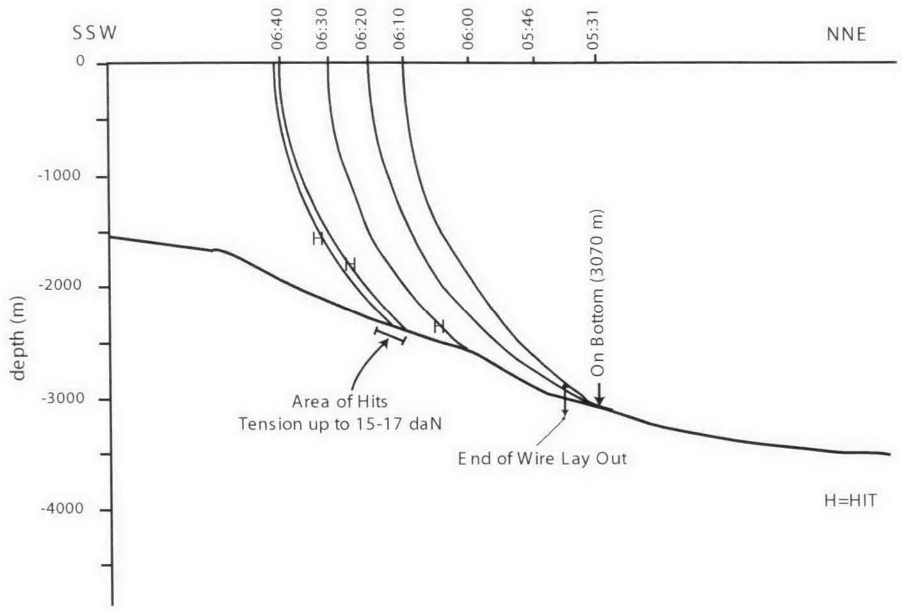
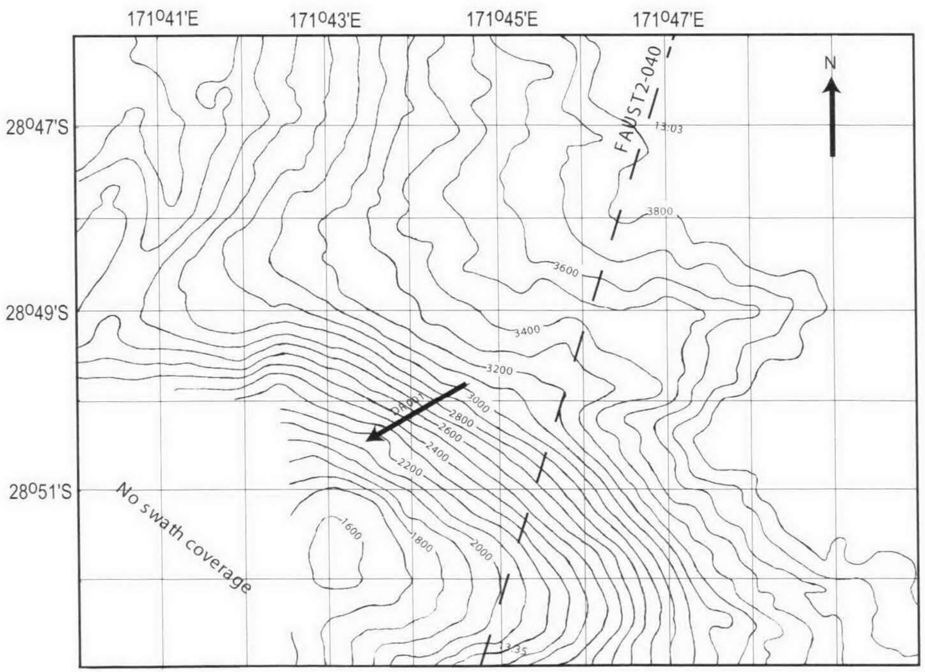


Figure 49. Machine-contoured magnetics for the eastern portion of the main FAUST-2 survey area. Contour interval is 20 nT.





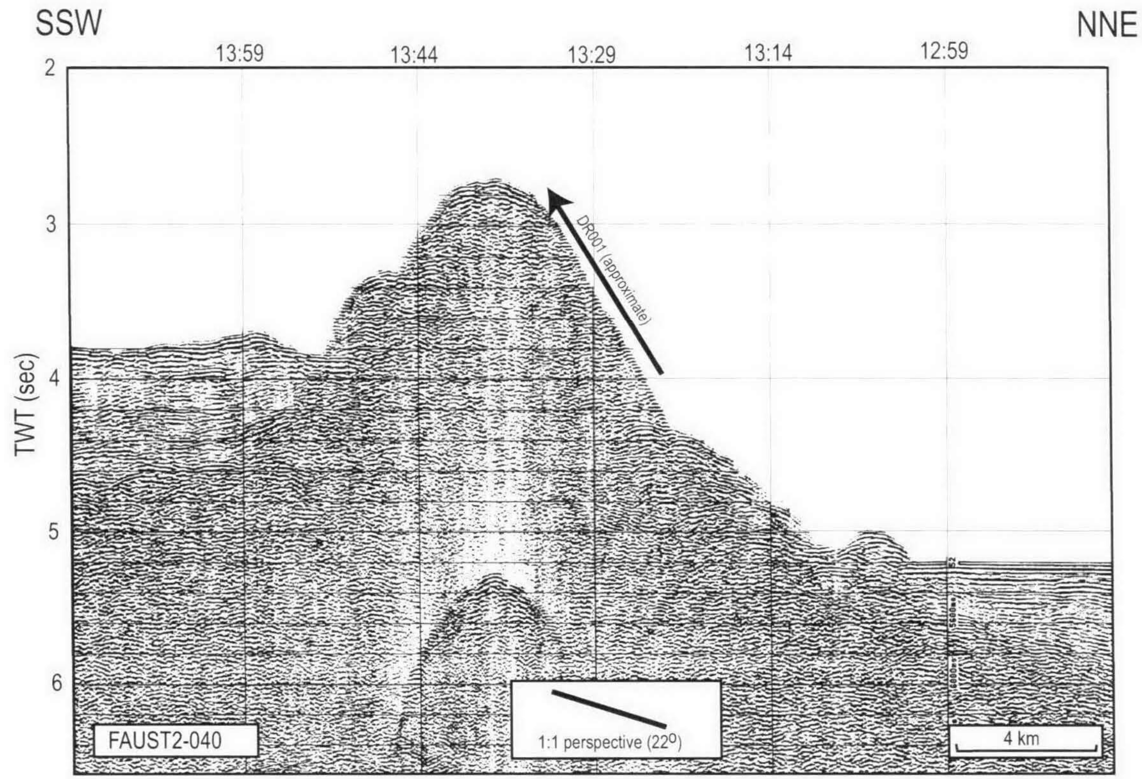
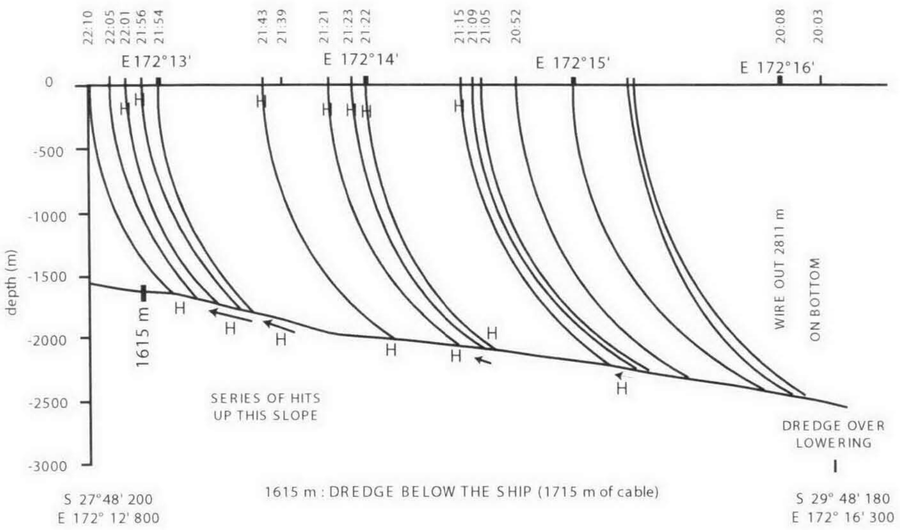
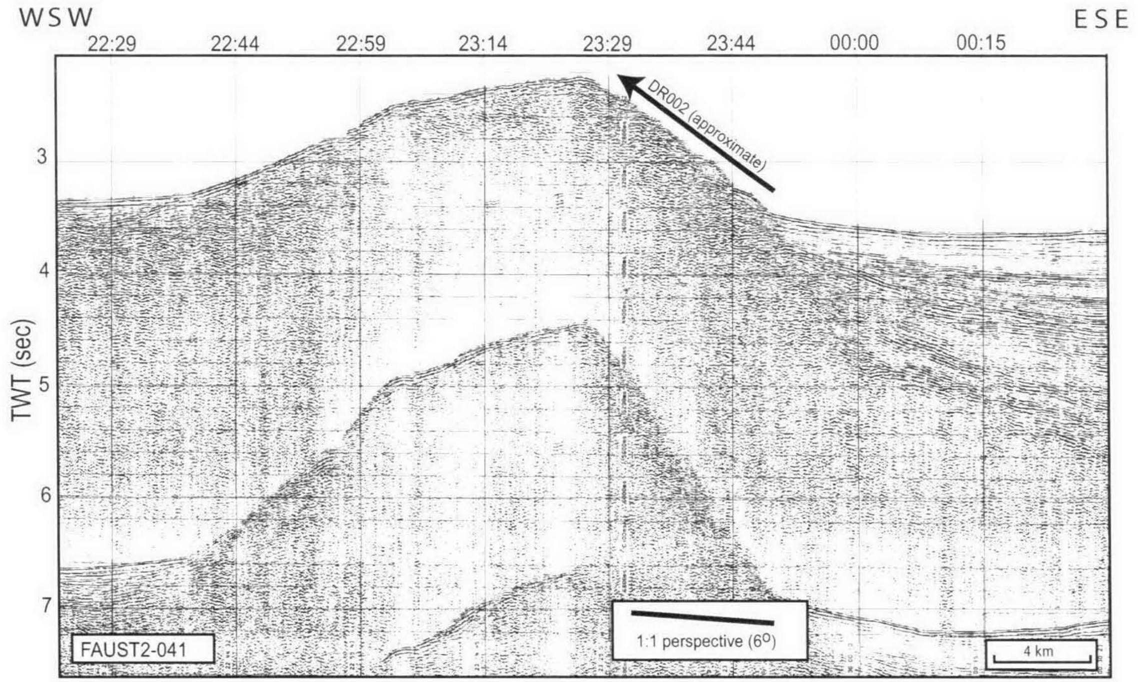


Figure 50. Details of the dredge at site 1 (see Fig. 11) near FAUST-2 profile 40. Shown are the event profile (top-left), the path over the contoured swath bathymetry (bottom-left) and a view of the closest seismic (top).





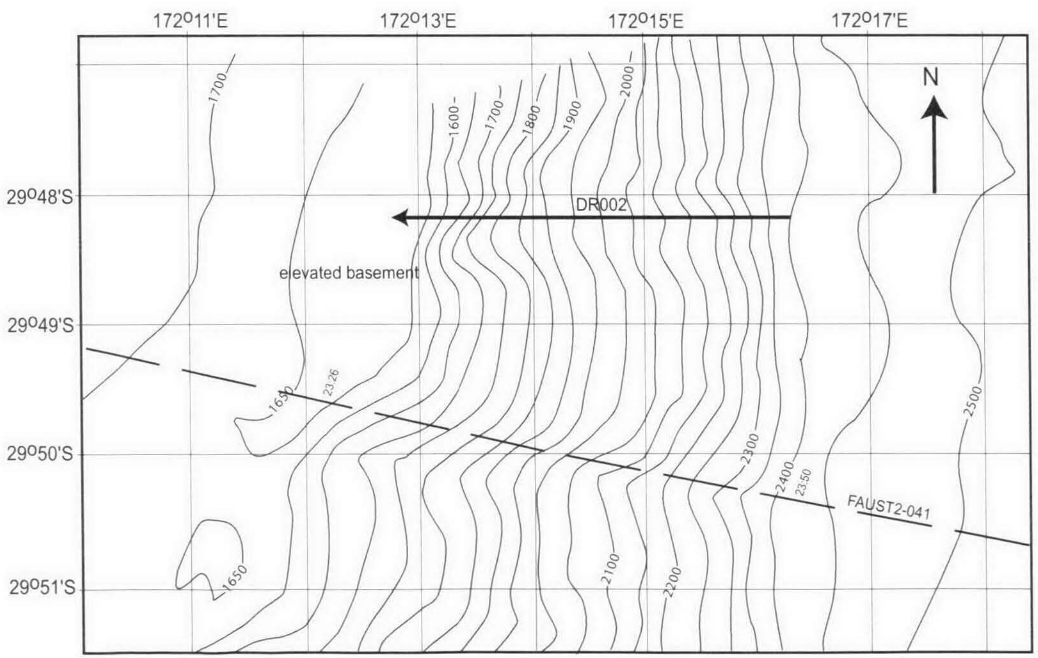
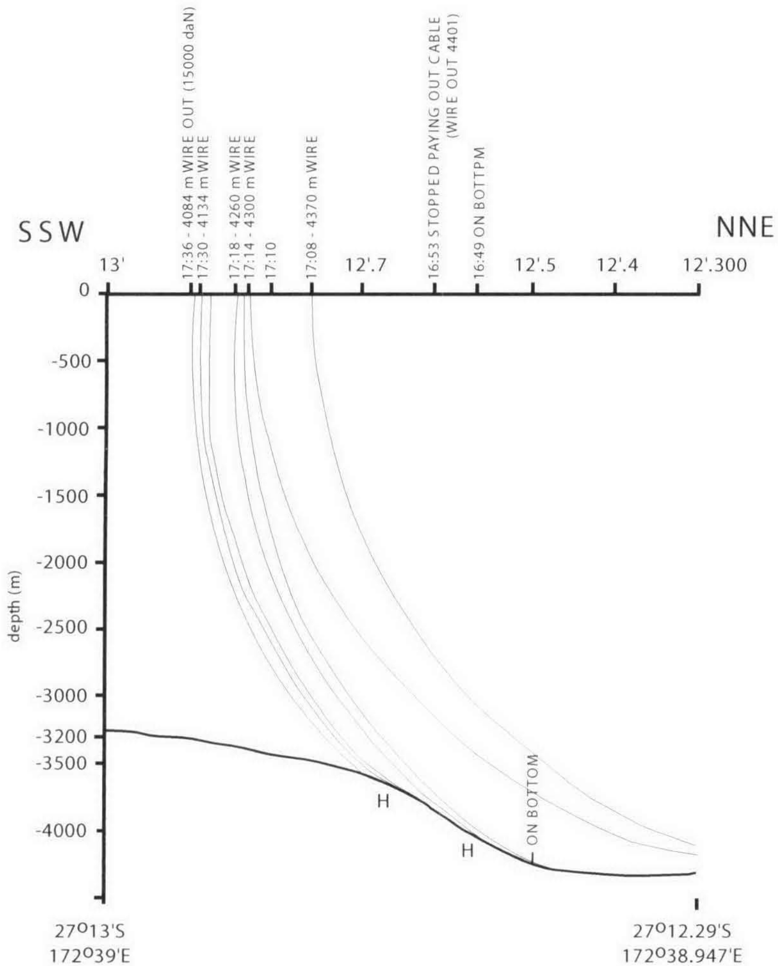
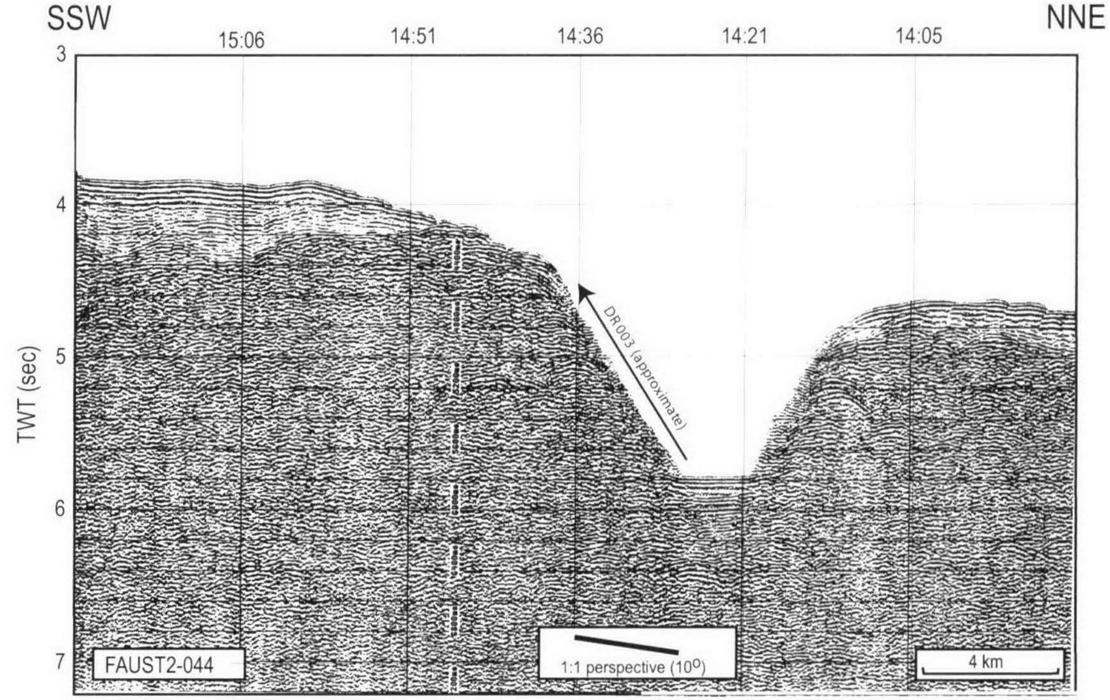


Figure 51. Details of the dredge at site 2 (see Fig. 11) near FAUST-2 profile 41. Shown are the event profile (top-left), the path over the contoured swath bathymetry (bottom-left) and a view of the closest seismic (top).





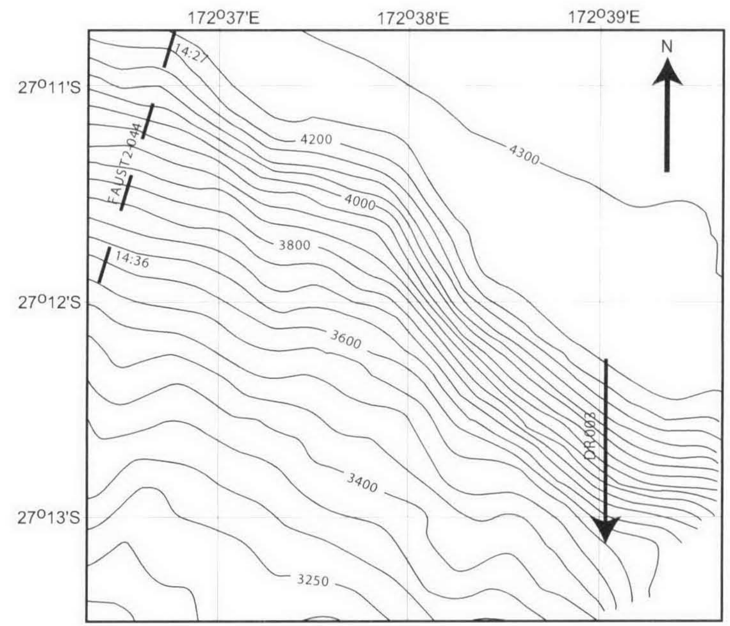


Figure 52. Details of the dredge at site 3 (see Fig. 11) near FAUST-2 profile 44. Shown are the event profile (top), the path over the contoured swath bathymetry (right) and a view of the closest seismic (top-right).

Figure 53. Photographs of samples taken from the dredge recovered at site 2 on the FAUST-2 survey. Refer to Figure 51 for a partial site description and Appendices 6 and 7 for an onboard sample and petrographic description.