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The geology of the Kenn Plateau off northeast Australia:
results of *Southern Surveyor* Cruise SS5/2004 (Geoscience Australia Cruise 270)

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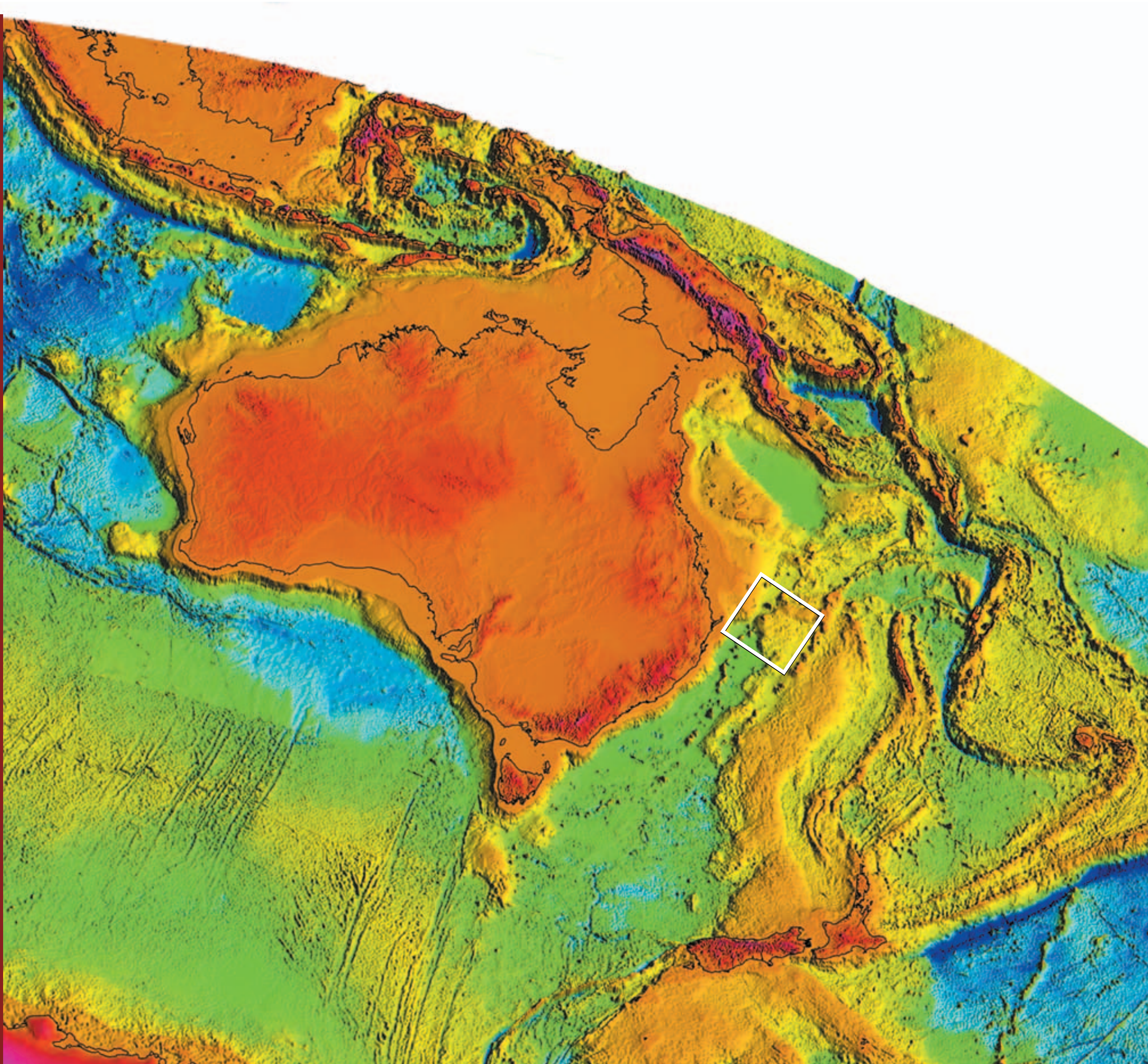
Record
2005/04



S P A T I A L   I N F O R M A T I O N   F O R   T H E   N A T I O N

Geoscience Australia

Petroleum and Marine Division

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The geology of the Kenn Plateau off northeast Australia: results of *Southern Surveyor* Cruise SS5/2004 (Geoscience Australia Cruise 270)

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Canberra 2004

Department of Industry, Tourism & Resources

Minister for Industry, Tourism & Resources: The Hon. Ian Macfarlane, MP
Parliamentary Secretary: The Hon. Warren Entsch, MP
Secretary: Mark Paterson

Geoscience Australia

Chief Executive Officer: Neil Williams

ISSN: 1448-2177
ISBN: 1 920871 29 2

GeoCat No. 61747

Bibliographic reference: Neville Exon, Peter Hill, Yves Lafoy, Georgina Burch, Alix Post, Christian Heine, Patrick Quilty, Richard Howe and Lydia Taylor. The Geology of the Kenn Plateau off northeast Australia: results of Southern Surveyor Cruise SS5/2004 (Geoscience Australia Cruise 270). Record 2005/04.

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ABSTRACT

The Kenn Plateau is a continental fragment that lies east of the Marion Plateau off Queensland. To the north is the Mellish Rise, to the west is the Cato Basin, to the south is the Tasman Basin, and to the east are the limestone banks of the Early Miocene Lord Howe hotspot chain. In the Late Cretaceous, the Kenn Plateau was adjacent to the Maryborough Basin to the west and the Capricorn Basin to the north. It separated from Australia during the earliest Paleocene to the Middle Eocene by moving northeastward overall along the Cato Fault Zone and rotating 45º anticlockwise. The West Bellona Fracture Zone splays off the Cato Fracture Zone and separates the western part of the plateau, with west to northwest trending structures, from the eastern part of the plateau, with northeast trending structures. The northeast trending structures correspond in trend to the fracture zones in the oceanic crust of the northern Tasman Basin, indicating that they have a common origin.

The Kenn Plateau consists of about 140,000 km² of thinned continental crust and it is surrounded by ocean basins, largely floored by oceanic crust, to the north, west and south. A geoscience survey by R.V. *Southern Surveyor* in 2004 showed that the plateau is highly complex, consisting of basement ridges, intervening troughs, and the Oligocene hotspot volcanoes of the Tasmantid chain in the west. On this survey, multibeam-sonar swath-bathymetry was recorded continuously, and 3090 km of multichannel seismic data and magnetic data were also recorded. In addition, twelve dredge hauls recovered sedimentary rocks, many of which have been dated micropaleontologically as Eocene and younger.

Rifting of the pre-existing continental basement rocks, and the overlying Mesozoic siliciclastic sedimentary rocks, thinned the crust and formed Late Cretaceous and Cainozoic rift basins that trend ENE overall. The thinning led to subsidence, but this was complicated by Early Oligocene and Early Miocene volcanic heating and build-ups, and Eocene compression. Overall, subsidence has averaged ~50 m/m.yr. since the Early Oligocene.

Three major sequences can be identified from the seismic profiles and other information. The lowermost is the most poorly understood, but appears to consist of up to 2500 m of Upper Cretaceous and Lower Paleocene siliciclastic sediments deposited in the troughs. These detrital sediments grade into marine limestones, both upward and into basinal areas. Unconformably

overlying the older sequence is a few hundred metres of Middle and Upper Eocene chalk, some of it highly siliceous, with the silica apparently derived from radiolarians. Compression during the Eocene formed anticlines in the troughs in places. Faults generally show major displacement only in the Cretaceous to Eocene sequences. Above another unconformity is a draped Oligocene to Recent sequence of chalk, containing few siliceous microfossils. It is relatively thin and often sits directly on basement on the highs, but is up to 700 m thick in the troughs. Virtually the entire area is blanketed in calcareous pelagic ooze.

The Oligocene volcanic edifices of the Tasmantid chain formed at 30-34 Ma, earlier than the calculated onset of carbonate build-up of about 15-30 Ma. Erosion had probably removed most of the volcanic edifices above sea level before build-ups started to form. Cool water carbonates apparently formed here first (30 Ma) and somewhat later on the Marion Plateau (25 Ma), perhaps because the Kenn Plateau seamounts subsided beneath the sea earlier than did the Marion Plateau with its thicker continental crust. Limestone ages suggest that average reefal growth rates were 40-110 m/m.yr. Reefal growth kept up on some seamounts until the present day, but not on others.

The Kenn Plateau, as expected, appears to have little petroleum resource potential. However, its varied environments – reefs, slopes of basement rocks, volcanics, limestone and soft sediments, and bathyal ridges and deepwater troughs – may well be significant environmentally.

Key words: northeast Australia, submarine plateau, Cretaceous rifting, Paleocene drifting, terrigenous rift sediments, Cainozoic chalk, Cainozoic reefs, hotspot volcanoes, seismic profiles, swath mapping, dredges, R.V. *Southern Surveyor*

1. INTRODUCTION

The Kenn Plateau (named after Kenn Reef, which forms the plateau's northwest corner) is a large submerged block off northeast Australia (Figure 1) which rifted from northeastern Australia 63-52 million years ago. Kenn Reef was discovered and named by Captain Kenn on 3 April 1824, in the vessel *William Shand*, on passage from Port Jackson towards Torres Strait. The Kenn Plateau is believed to be continental, contains presumed Cretaceous and younger rift basins, and lies in a critical position between seafloor-spreading terrains to the south, and ridge propagation and other terrains to the north. Geoscience Australia and Sydney University applied for ship time on the Australian National Facility R.V. *Southern Surveyor* in 2002 (Exon, Hill and Müller, 2002) and carried out research cruise SS5/2004 in May 2004, to test whether there were fundamental differences in pre-existing basement geology and margin development that may have localised the terrain change, and address other fundamental questions about the nature and tectonic evolution of the plateau. The methods employed were seismic, bathymetric and magnetic profiling to establish the broad plateau framework and setting, and dredging to obtain rocks and sediments.

1.1. Scientific objectives

The objectives of this research voyage were to help determine:

- The nature and distribution of acoustic basement (continental and/or volcanic?);
- The nature and tectonic styles of the plateau's margins to help constrain plate tectonic hypotheses;
- The geometry and age of the rift basins, and the nature of their Cretaceous and Cainozoic sediments, addressing geologic, climatic and oceanographic evolution;
- The controls on the initiation and development of east Australian carbonate platforms since the early Miocene;
- The nature and ideally the age of several Cainozoic volcanic pedestals, assumed to be parts of the Tasmantid volcanic chain;
- The nature of the modern surficial sediments on this remote marginal plateau because of their potential influence on benthic habitats.

The outcome would be a greatly improved understanding of the plateau's geology and palaeogeography, as well as its long-term resource potential, believed to be small.

1.2. Scientific background

This project was designed to improve our understanding of the geological evolution and modern environmental setting of the Kenn Plateau (Figure 1). It was envisaged as the first stage of an on-going investigation of the remote and poorly understood marginal plateaus that lie off Australia's northeast margin. The Kenn Plateau was targeted initially, because of its pivotal tectonic setting at the junction between the Coral and Tasman Seas, the presence of reefs and islands, and the presence of a buried basinal sedimentary succession more than two kilometres thick. The Kenn Plateau is an important part of the tectonic jigsaw of the Southwest Pacific (Figure 2), and is one of the few areas where one can study both rifted (southwest) and transform (northwest) margins. Existing knowledge suggested that it is a continental block (e.g. Willcox, 1981), but the existing seismic profiles were generally of low quality, and there were few sediment and no rock samples from the plateau.

We proposed to collect a series of seismic and magnetic lines, dredge samples and soft-sediment cores across the Kenn Plateau, largely within Australia's EEZ. Pre-existing BMR seismic tracks and ODP sites are shown in Figure 3. The new work would link to previous environmental and resource studies undertaken on the nearby Marion Plateau (McKenzie et al., 1993; Isern, Anselmetti, Blum et al., 2002), and the Capricorn and Maryborough Basins (Hill, 1994). The survey would also yield valuable knowledge to help us address both marine zone management and frontier petroleum issues in a remote, poorly known region - at 140,000 km² much larger than Tasmania. The plateau includes 50,000 km² of French/New Caledonian territory and this voyage furthered cooperative research, with a New Caledonian geologist (Yves Lafoy) aboard as a important member of the scientific team.

1.3. Previous geoscience studies and data

The Kenn Plateau region had seen only one systematic geophysical survey, BMR's Continental Margin (CMP) Survey (Figure 3), reported on in Mutter (1973) and Symonds (1973). Unfortunately, neither author focussed on the Kenn Plateau as such. However, the analogue reflection seismic, bathymetric, gravity and magnetic data, recorded at a spacing of 30 nautical miles, were valuable in planning and evaluating the results of the *Southern Surveyor* cruise. Almost all those lines were east-west, so we ran our seismic lines in complementary directions: northeast-southwest and northwest-southeast.

An interpretation of one of the CMP geophysical lines is shown in Figure 4 (after Willcox, 1981). This line (BMR 13/35) extends from the Aquarius No. 1 petroleum exploration well (Carlsen and Wilson, 1968) in the Capricorn Basin near the Queensland coast, eastward across the Marion Plateau and the rifted Cato Trough to the Kenn Plateau, and beyond into the northern extension of the Middleton Basin. It suggests that the Kenn Plateau is underlain by stretched and intruded Palaeozoic basement, and is cut by rifts/graben that are presumably related to the final earliest Paleocene break-up of this part of the Australian margin. As the motion of the block away from Australia was to the northeast (e.g. Gaina et al., 1999), related structuring should trend northwest, parallel to the southwest margin of the plateau, or northeast parallel to the spreading flow lines. Willcox (1981) interpreted the rift fill on the plateau as siliciclastic sediments of Cretaceous and Palaeogene age, draped by post-rift sediments of Eocene and younger age. On line BMR 13/35, the rift fill is a maximum of 1.5 seconds (2 km) thick, and the post-rift sediments are less than 1 second (1 km) thick.

While the age of the basinal succession and resource potential of the rifted depocentres on the Kenn Plateau remained speculative, tectonic reconstructions suggested former juxtaposition to the Capricorn and Maryborough Basins to the west. The conjugate Maryborough Basin contains some natural gas, supporting the idea that hydrocarbons might perhaps be present in the Kenn Plateau.

Very few seabed samples have been taken from the Australian part of the Kenn Plateau, to our knowledge only cores (Table 1). One *Kana Keoki* freefall core (FFC074), from high on the Kenn Plateau (1606 m), recovered 84 cm of calcareous biogenic mud or ooze. Two other *Kana Keoki* freefall cores, from 4630 m (FFC075 & 76), recovered 41 cm and 84 cm respectively of calcareous biogenic mud or ooze. One *Robert Conrad* piston core (RC12-109), from 2930 m on the southernmost plateau, recovered 704 cm of foraminiferal chalk. French samples from the shallow-water Bellona Plateau to the east, and from the crests of the seamounts south of the Bellona Plateau are listed in Appendix 6. They consist largely of carbonate sands and oozes, with occasional volcanics, volcaniclastic rocks and carbonate sandstones.

Table 1. Kenn Plateau and Cato Trough cores

Ship/cruise	Sample	Length (cm)	Latitude/ Longitude	Water Depth	Description
Marion Dufresne MD106	MD97-2127 (PC)	2713	18°06.31’S 152°06.01’E	27 m	
Robert Conrad RC12	109 (PC)	704	25°53.00’S 157°52.00’E	2930 m	Foraminiferal chalk (Pleistocene base)
Vema VM24	162 (PC)	439	17°22.00’S 152°33.00E	1328 m	Foraminiferal chalk (Pleistocene base)
Kana Keoki 71042604	FFC074	23	25°32.6’S 156°04.2E	4631 m	Nannofossil mud or ooze (Quaternary base)
Kana Keoki 71042604	FFC075	41	25°32.2’S 156°04.1’E	4630 m	Calcareous biogenic mud or ooze (Quaternary base)
Kana Keoki 71042604	FFC076	84	22°14.5’S 156°01.0’E	1606m	Calcareous biogenic mud or ooze (Quaternary base)
HMAS *Cook* 2/88	2GC2	123	22º37.68’S 155º03.53’E	3380 m	Greyish orange biopelagic mud; 65-69 cm bioclastic sand turbidite
HMAS *Cook* 2/88	3GC3	146	22º34.29’S 155º30.54’E	3068 m	Yellowish brown biopelagic ooze; 111-116 cm bioclastic silt turbidite
HMAS *Cook* 15/89	3GC3	136	19º43.3’S 154º59.3’E	3152 m	Pale orange bedded calcareous sandy mud, with six thin layers of sandy bioclastic turbidites

Walker (1992) concluded from evidence from cores, seismic and bathymetric profiles, and sidescan sonar images, that gravity flow processes have dominated sedimentation in the >3000 m deep Cato Trough west of Kenn Plateau. He maintained that turbidites, slumps and debris flows were characteristic from break-up through until the present day. Photographs from the narrow Cato Pass west of Cato Island showed symmetrical, sharp crested ripples, which indicate oscillatory current flow to both north and south. Sidescan sonar images showed that turbidites flow south through the pass. Three short sediment cores from the Cato Trough (Table 1) consist of young interbedded fine-grained carbonate turbidites and calcareous ooze. The carbonate turbidites were derived from pelagic sediments on the Marion Plateau.

Hill (1994) reviewed the geology of the conjugate margins of the Maryborough and Capricorn Basins. Symonds and Davies (1988) reviewed the Townsville Trough and the Marion Plateau, and Struckmeyer et al. (1994) provided a detailed assessment of the Townsville Trough. The most recent discussion of the Tasmantid Seamounts is by McDougall and Duncan (1988). Müller et al. (2000) modelled the subsidence history of the Queensland Plateau. Weissel and Hayes (1977), Shaw (1978), Mutter and Karner (1980), and Gaina et al. (1998a, b; 1999) established the overall tectonic setting of the region, whereby the Coral Sea Basin, the Louisiade Trough and the Cato Trough were arms of a triple junction of Paleocene age (Figure 5). Other tectonic papers that bear on the Kenn Plateau to some extent are Terrill (1975), Larue et al. (1977), Shaw (1990), Kroenke (1984), Veevers et al. (1991) and Walker (1992).

Deep Sea Drilling Project Leg 21 provided a great deal of information about the stratigraphic sequences in areas near the Kenn Plateau (Burns, Andrews et al., 1973). Representative sites from the abyssal Coral Sea Basin (Site 210), Queensland Plateau (Site 209) and northern Lord Howe Rise (Site 208) are summarised in Table 1. Basement was not reached at these sites. At Site 210, the lowermost 190 m consists of Eocene and Oligocene pelagic nannofossil chalk, which gives way in the Miocene to graded beds, which represent turbidite sedimentation through into the Pleistocene. Sites 209 and 208 were drilled in bathyal depths, and the Eocene and younger sequences tend to be similar in both. The Oligocene and younger sequences are calcareous ooze, and the Eocene sequences are chalk grading to radiolarite (with some chert). At Site 208 the Eocene is underlain by Paleocene radiolarian nannofossil chalk, and Maastrichtian nannofossil chalk. Thus, in these pelagic sites, deposition of radiolarians and other biosiliceous organisms is concentrated in the Paleocene and Eocene.

A very important discovery of DSDP drilling is that there are two very widespread regional unconformities in the region (Edwards, 1973). The younger is the regional Eocene-Oligocene unconformity, which spans at least the late Late Eocene and the early Early Oligocene. The older is the Paleocene-Eocene unconformity, which was recognised in DSDP Sites 206, 207 and 208, and spans at least all of the Late Paleocene and the early Early Eocene. This is the best dating of the regional unconformities present in our seismic profiles.

Davies et al. (1989) and Feary et al. (1991) used a variety of geological information, including Australia's movement northward, to outline climatic evolution and its control on carbonate deposition off northeast Australia. They postulated that sea surface temperatures for the Cainozoic were warm enough to support reef growth before 45 Ma and after 25 Ma. Later studies have generally corroborated their views.

Important comparative sedimentological information for the Neogene comes from ODP Leg 133 cores to the west on the Queensland and Marion Plateaus, and in the Great Barrier Reef (McKenzie et al., 1993). ODP Leg 194 on the Marion Plateau (Isern, Anselmetti, Blum et al.,

2002) drilled Neogene sequences to test the amplitude of the major middle Miocene sea level fall (Pigram et al., 1992), and studied many other aspects of carbonate and siliciclastic sedimentation on drowned reefs, reef slopes and in the basin. Carbonate platforms first formed in the early Miocene on the Marion Plateau (18-25 Ma) from cool subtropical calcareous faunas. There was extensive reefal growth by the middle Miocene. Acoustic basement was cored at five sites and highly altered lava flows and volcaniclastics were recovered. They have not been dated but are immediately overlain by early Miocene carbonates. The lack of deformation suggests that they may have been emplaced during the Late Cretaceous to Paleocene rifting in the region. Site 1198 is summarised in Table 1.

Table 2. Representative DSDP and ODP drill sites nearby

Character	**Site 210** **Coral Sea Basin**	**Site 209** **Queensland Plateau**	**Site 1198** **Marion Plateau**	**Site 208** **North Lord Howe Rise**
Location	13º45.99’S 152º53.78’E	15º56.19’S 152º11.27’E	20º57.93’S 152º44.00’E	26º06.61’S 161º13.27’E
Water depth	4643 m	1428 m	319.4 m	1545 m
Pleistocene	130 m graded beds with nannofossil ooze	20 m calcareous ooze	110 m outer neritic limestone with clay	40 m calcareous ooze
Pliocene	230 m graded beds with nannofossil ooze	20 m middle to late Pliocene calcareous ooze	90 m outer neritic limestone with clay	60 m calcareous ooze
Miocene	165 m total: 115 m late Miocene graded beds with nannofossil ooze; 50 m early and middle Miocene silty clay.	65 m foraminiferal ooze	315 m total proximal slope limestone: 200 m middle and late Miocene; 108 m early and middle Miocene; over basalt	330 m calcareous ooze: 130 m late Miocene; 85 m middle Miocene; 115 m early Miocene
Oligocene	20 m early to middle Oligocene clayey nannofossil chalk	40 m late Oligocene foraminiferal ooze		50 m late Oligocene calcareous ooze
Eocene	>170 m nannofossil chalk to nannofossil clay: 15 m late Eocene; 130 m middle Eocene; >25 m early Eocene	>200 m calcareous ooze with terrigenous detritus: 135 m late Eocene sandy foraminiferal ooze and chert; > 60 m middle Eocene outer neritic sandy foraminiferal limestone		50 m middle Eocene foraminiferal radiolarian nannofossil chalk to nannofossil bearing radiolarite
Paleocene				35 m early to middle Paleocene radiolarian nannofossil chalk
Maastrichtian				>20 m foraminiferal nannofossil chalk, variably cherty, with rare radiolarians
Total thickness	711 m	344 m	522.6 m	594 m

1.4. Regional setting

The northeastern region off Australia (north of 27°S) consists of a series of prominent, although poorly defined, very large bathymetric features (Figures 1, 6 & 8). Collectively, these features lie in water depths varying from less than 1000 m to more than 3000 m. Off Queensland, and west of the Coral Sea Basin, Cato Basin and Cato Trough, are the comparatively well known Queensland Plateau, Townsville Trough and Marion Plateau. East of these features, from north to south, are the Louisiade Plateau, Louisiade Trough, Mellish Rise, South Rennell Trough, Bampton Trough (new name), and Kenn Plateau. All trend northeast. Very little is known of their geological evolution, resource potential, or modern environments. Kroenke et al. (1983) shows the Kenn Plateau as being separated from the Marion Plateau to the west by the north-trending Cato Trough some 3000 m deep and, in part, extending north of the narrow, deep feature that many authors have named the Cato Trough. The Cato Trough grades northward into a broader deeper bathymetric depression, a bathymetric feature that we name ‘Cato Basin’. The Kenn Plateau is contiguous with the Bellona Plateau (carbonate caps on volcanic edifices) to the northeast and the Middleton Basin to the southeast (Figures 5 and 6). Stagg et al. (1999, 2002) named the north-south extending structural basin that flanks both sides of the seamount chain extending from Bellona Plateau to Capel Bank - the Capel Basin.

Rifting and seafloor spreading along the eastern Australian margin between 95 and 52 Ma created two major oceanic basins, the Tasman Sea and Coral Sea basins, along with a series of slivers of continental crust that detached from the Australia continent (Figures 2 and 5). The most recent study of the spreading histories of the northern Tasman Sea and Coral Sea Basins, that of Gaina et al. (1999), is based on reconstructions using seafloor magnetic lineaments, GEOSAT gravity data and present-day bathymetric images.

Various workers have suggested that the opening of the Tasman and Coral Sea Basins occurred in several stages and included a number of failed rifting events (see *Previous geoscience studies and data*). According to Gaina et al. (1999), rifting in the Tasman Sea propagated from south to north between 95 and 64 Ma. A change in the nature of rifting and the orientation of seafloor spreading occurred around 63 Ma, and the spreading ridge propagated northward from the northern Tasman Sea into the Cato Trough. At approximately the same time, seafloor spreading began in the Coral Sea, and presumably in the Louisiade Trough, resulting in the development of

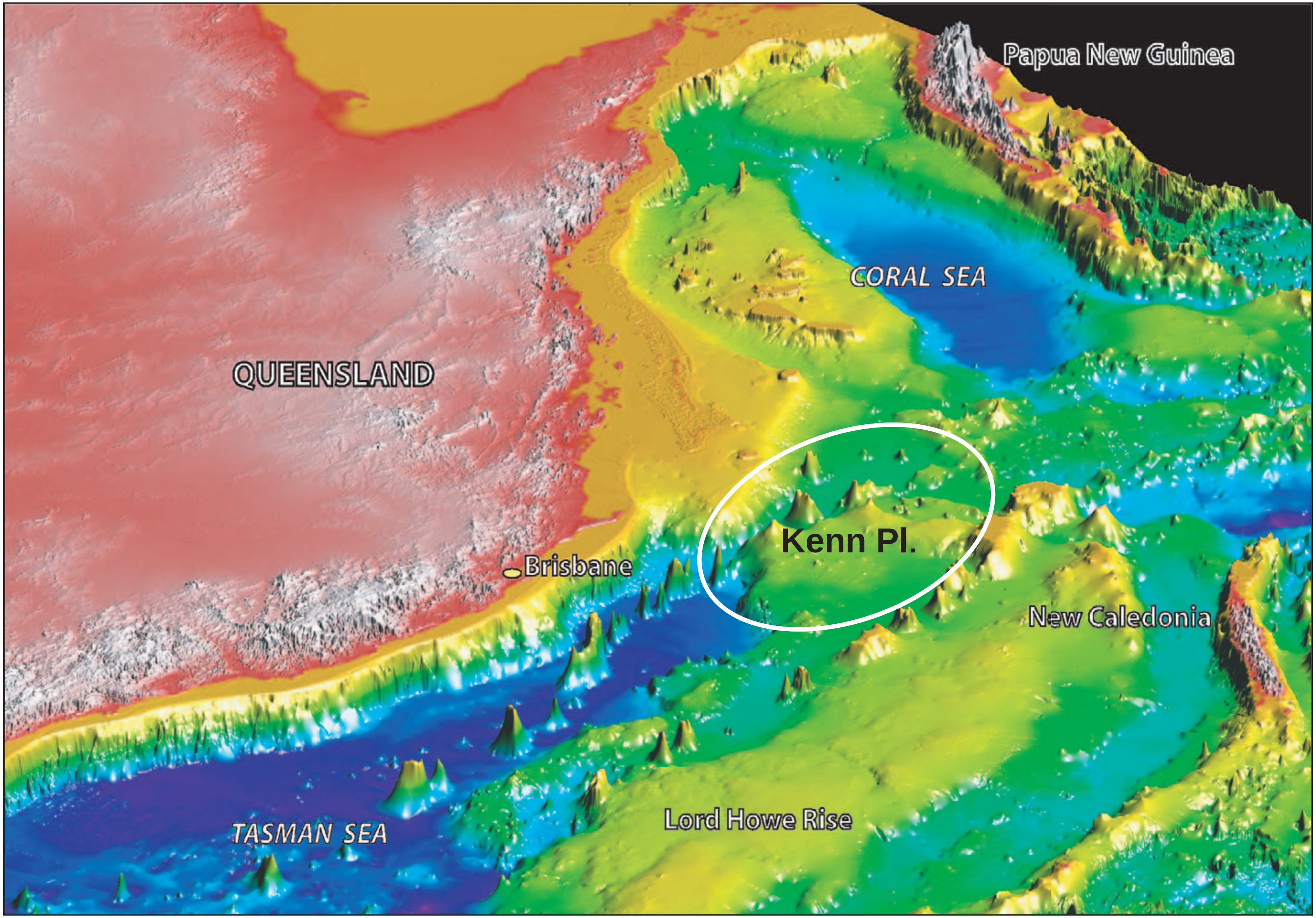

Figure 1. Kenn Plateau is a continental fragment located near northern Lord Howe Rise between the Tasmantid and Lord Howe hot-spot seamount chains; it covers an area twice the size of Tasmania.

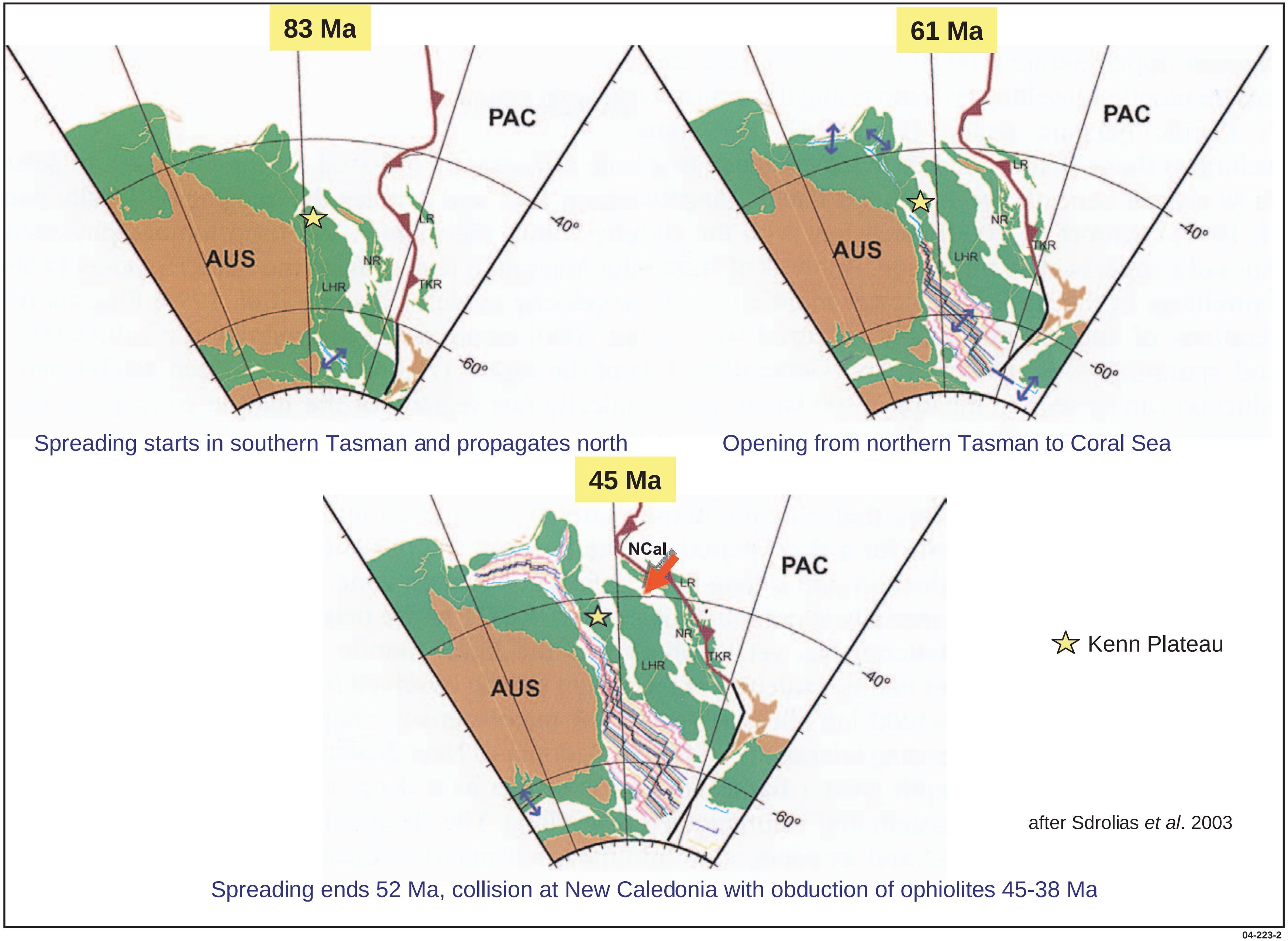

Figure 2. Plate tectonic evolution of the region, Late Cretaceous-Palaeogene (after Sdrolias et al. 2003). Kenn Plateau shown by star. Published with the permission of the Geological Society of Australia.

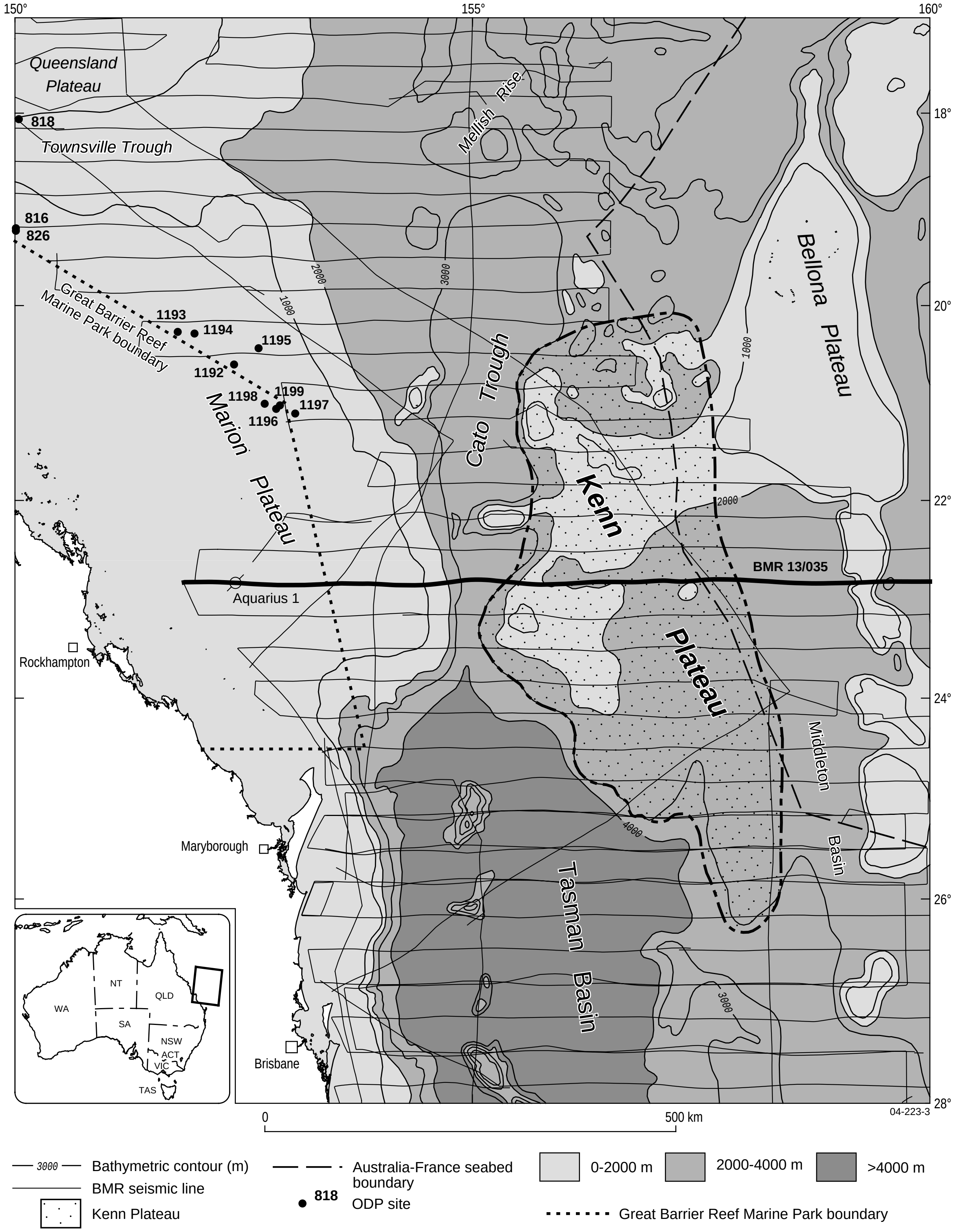

Figure 3. Regional bathymetric map including the Kenn Plateau and showing the regional coverage of pre-existing geophysical lines recorded as part of BMR Survey 13 in 1973. Reflection, seismic, bathymetric, magnetic and gravity data were recorded along the tracks. The heavy seismic line is 13/035, shown in Figure 4. (from cruise proposal Figure 1).

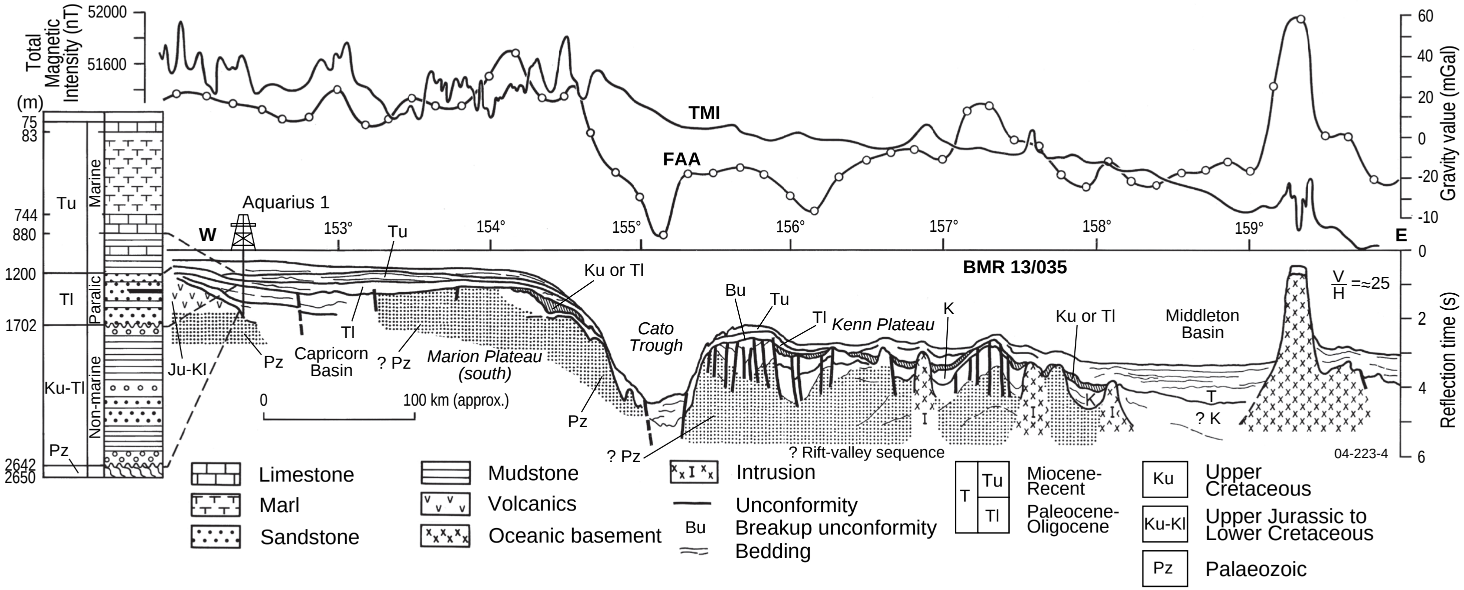

Figure 4. Interpreted east-west geophysical line BMR 13/035, extending 800 km from near the Queensland coast to the Middleton Basin. Seismic interpretation after Willcox et al. (1981). The location of this line is shown in Figure 3.

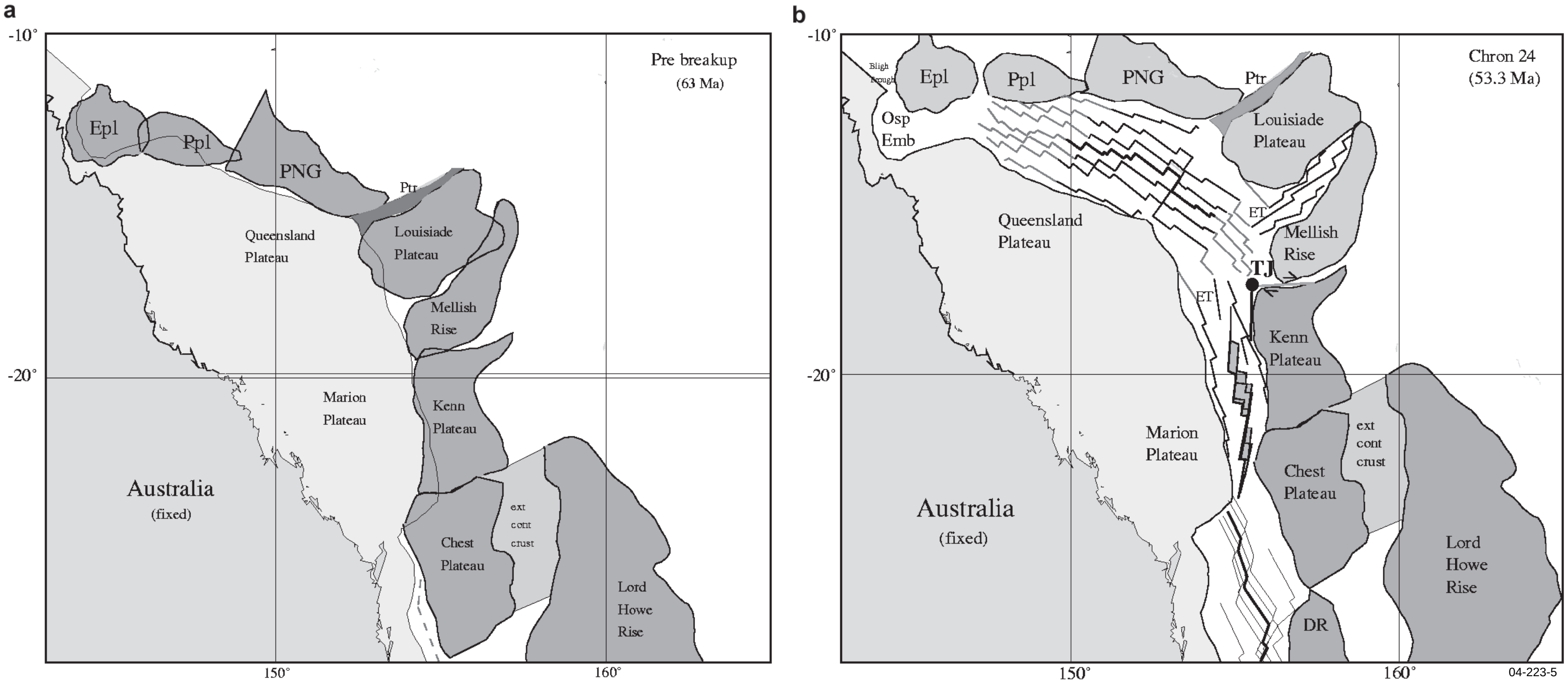

Figure 5. Reconstructions for the evolution of the Louisiade triple junction (TJ) after Gaina et al. (1999).
Figure 5a shows the pre-breakup reconstruction at 63 Ma (early Paleocene). Dark grey areas are tectonic blocks involved in the Coral Sea opening (Papuan Plateau (Ppl), Eastern Plateau (Epl), southern Papua New Guinea (PNG), Louisiade Plateau, and the Louisiade Trough formation (Mellish Rise), and the Cato Trough opening (Kenn Plateau and Chesterfield Plateau). Figure 5b shows reconstruction at chron 24 (53.3 Ma). The Louisiade triple junction (TJ) is located SE of the Louisiade Plateau. The active ridges in the Coral Sea, Cato and Louisiade Troughs, and northern Tasman Sea are thick black lines. The segments of isochrons in the Coral Sea that are unconstrained by magnetic anomalies are drawn in light gray. Gray areas highlight oceanic crust in the Cato Trough formed after chron 26, during roughly N-S oriented transtension between the Kenn and Marion Plateaus. ET is extinct transform fault. The direction of strike-slip motion between the Mellish Rise and the Kenn Plateau is indicated with arrows. The spreading system became extinct at 52 Ma (lower Eocene).

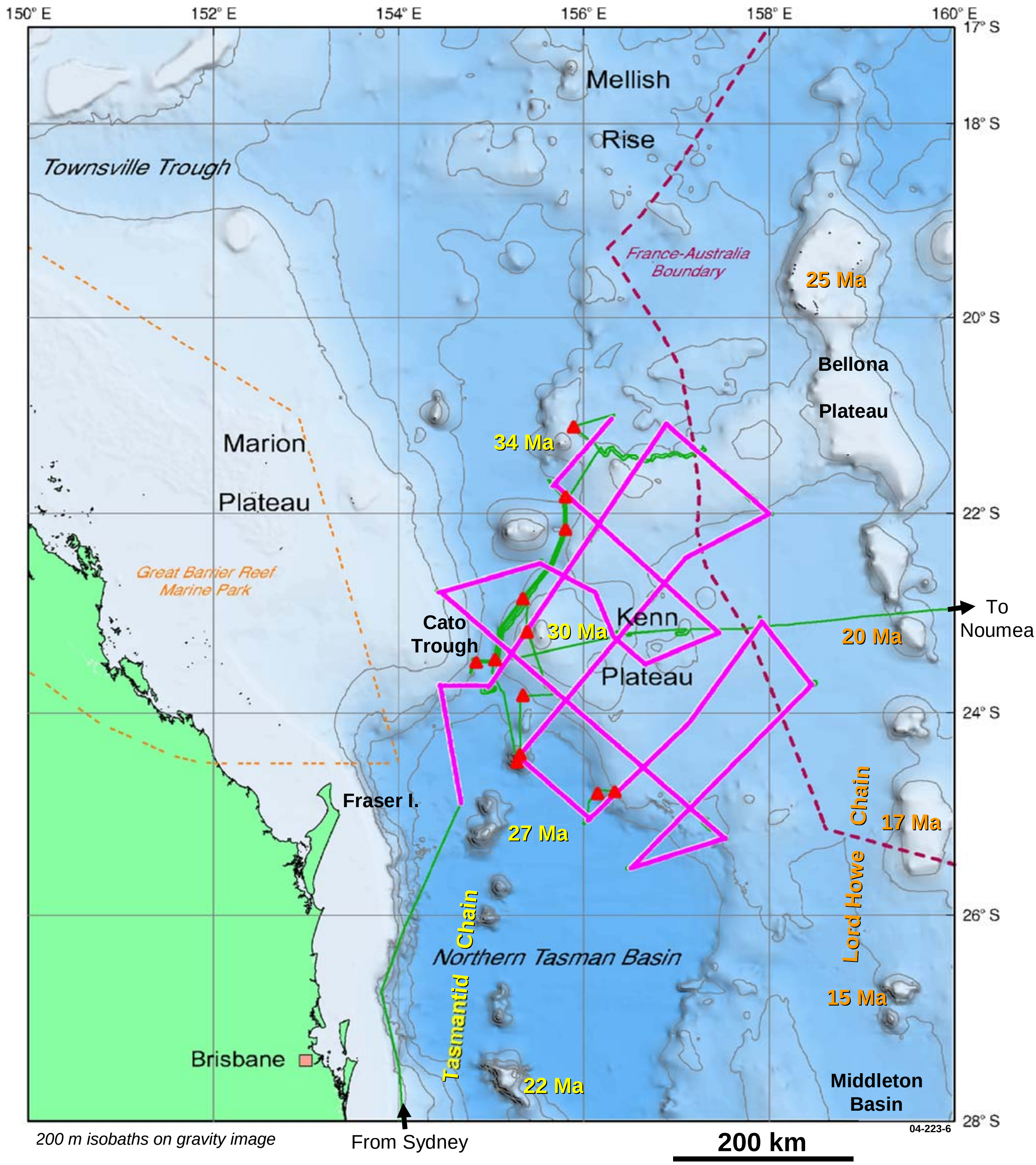

Figure 6. Location of Geoscience Australia Survey 270 on Kenn Plateau. The green line represents the track of *Southern Surveyor* and multibeam coverage; the dark pink lines are the multichannel seismic lines. Adjacent to Kenn Plateau, the volcanic pedestals of the Tasmantid chain to the west are Oligocene in age, while those of the Lord Howe chain to the east are Early Miocene (about 10 m.y. younger).

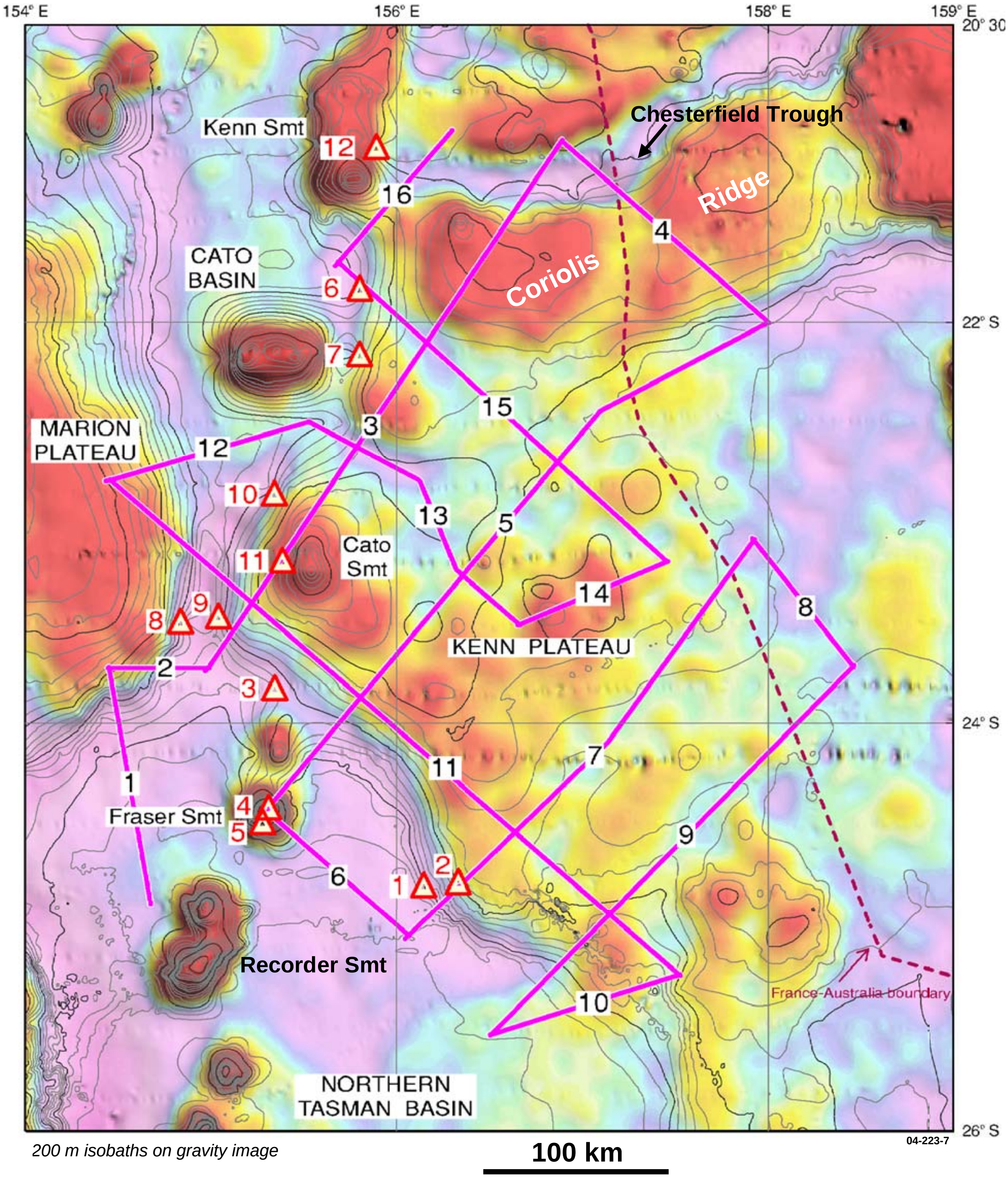

Figure 7. Detailed map of Geoscience Australia Survey 270 seismic lines and dredge sites on gravity image with bathymetric contours. Seamounts of the Tasmantid chain and the elevated basement block of the Coriolis Ridge show up as prominent highs in the gravity image. On Kenn Plateau, gravity lows correlate strongly with depocentres. Seismic shotpoints shown in Figure 50.

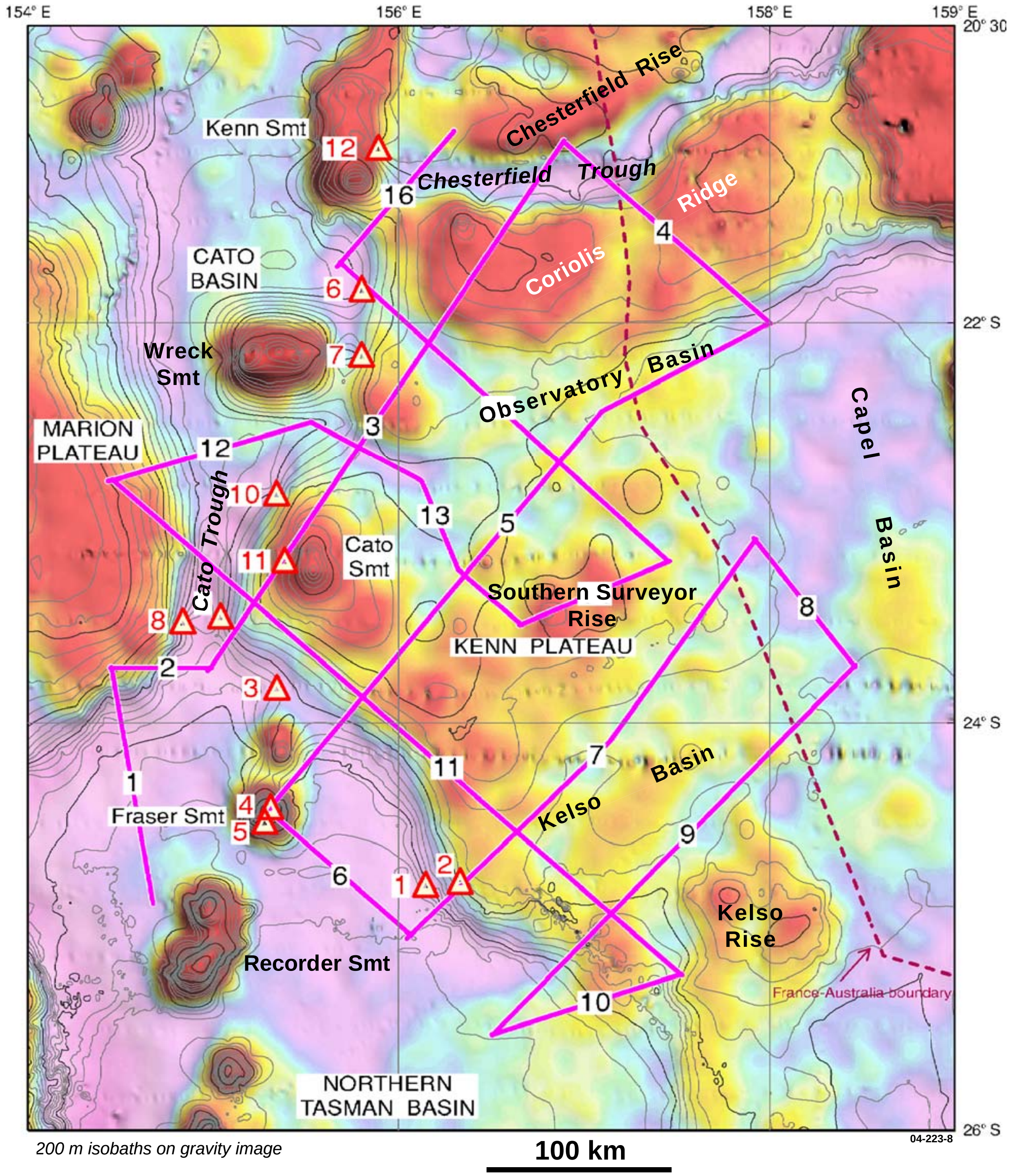

Figure 8. Map of Kenn Plateau structural features showing 200 m isobaths on gravity image (see Tables 6 and 7).

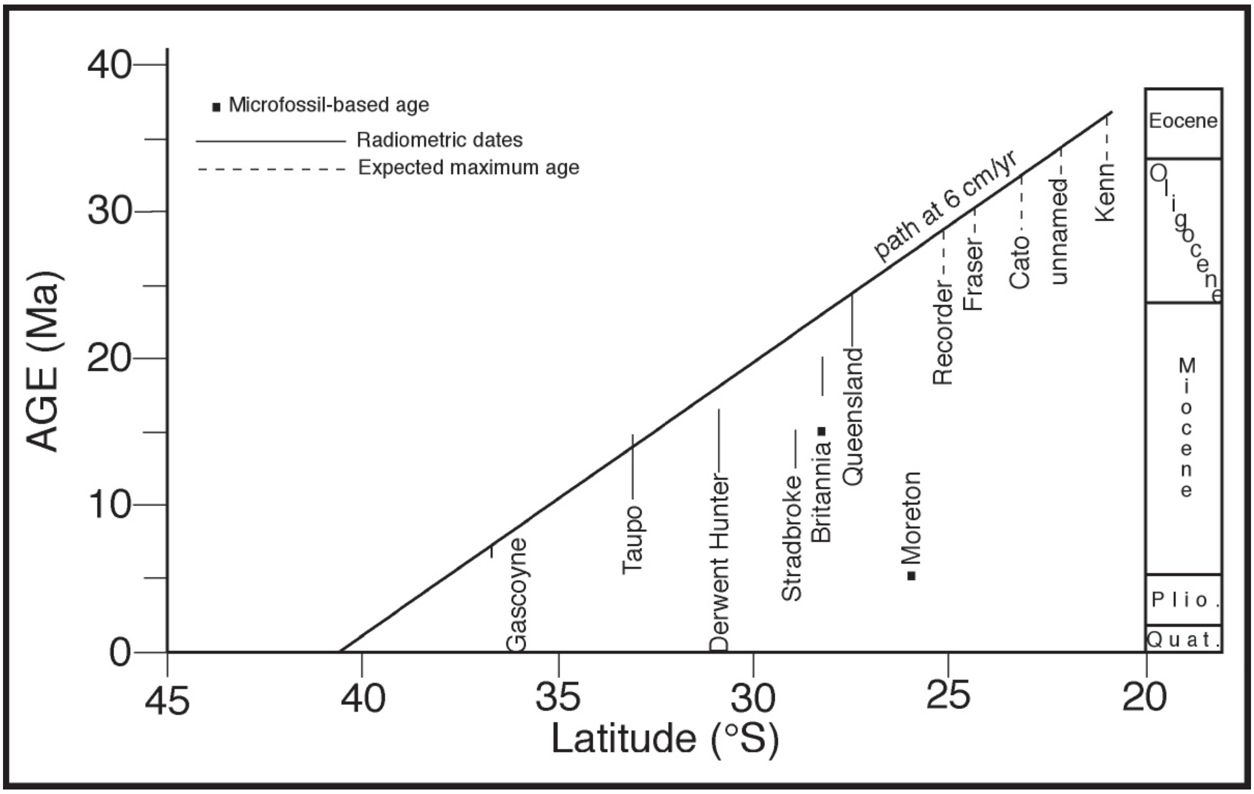

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Figure 9. The postulated ages of selected Tasmantid seamounts, based on movement northward of the Australian plate at @ 6 cm/year (prepared by Pat Quilty).

the Louisiade Triple Junction northeast of the Kenn Plateau. Beginning with a major plate reorganisation at around 60 Ma, and ending with the cessation of spreading at 52 Ma, the marginal plateaus off northeastern Australia were subjected to a complex regime of transpressional, transtensional and strike-slip movements controlled by the propagation and eventual abandonment of the triple junction in the Coral Sea.

Within the framework of Gaina et al. (1999), the Kenn Plateau occupied a pivotal position during the transition from seafloor spreading in the northern Tasman Sea, to ridge propagation in the Coral Sea basin. The plateau is the southernmost of a number of plateaus off northeast Australia, which contrast markedly with the simple large continental block of the Lord Howe Rise separated from Australia by the Tasman Basin. The cause of the north-south transition can be addressed best in the Kenn Plateau region.

The northwestern (Cato Fracture Zone) and southeastern boundaries of the Kenn Plateau apparently formed through strike/slip (or lateral) fault movement, while the southwestern boundary was formed through extensional rifting processes (normal faulting). Given the unique tectonic setting of the plateau, a better understanding of its overall basement geometry would help to constrain regional kinematics and plate reconstructions. Terrill (1975) and Gaina et al. (1999) suggest that the present-day bathymetric Kenn Plateau consists of two distinct continental fragments separated by a northeast-trending strike-slip fault. Determining whether or not this boundary exists, and its nature if it does, was one of the scientific objectives of the proposed seismic data acquisition program.

The plate reconstructions of Terrill (1975), Gaina et al. (1999 and Figure 5), and Sdrolias et al. (2003 and Figure 2) suggest that the continental fragment underlying the southern Kenn Plateau may contain the rifted extension of the Maryborough Basin, and the original southern extension of some sequences of the Marion Plateau and Capricorn Basin. If this is so, there could just conceivably be some petroleum potential in areas remote from the environmentally sensitive Great Barrier Reef Marine Park to the west.

1.5. The present expedition: data acquired

The present survey acquired 3090 km of multichannel seismic profiles, ~2000 km of magnetic profiles, and ~7600 km of multibeam sonar data (~25,000 km² of seabed mapping), plus 12 dredge hauls of rocks, to add to the existing geoscience data base (Exon, 2004). Multibeam sonar swath bathymetry was acquired on the transit northward along the middle of the continental slope from Sydney (Table 2), but not on the transit eastward to New Caledonia. Data acquired in the study area are located in Figures 6 and 7, and listed in Tables 3 and 4. More rocks will be dredged on the transit of *Southern Surveyor* to the nearby Mellish Rise late in 2004. Once the Mellish Rise survey is complete, all the major plateaus off Australia will have been geologically evaluated, at least to reconnaissance level.

Table 3. Transit way points on swath survey from Sydney to study area

Way point	Latitude (S)	Longitude (W)
1	33º48.50’	151º25.75’
2	33º15.50’	152º27.00’
3	33º09.50’	152º40.50’
4	32º48.00’	153º01.00’
5	32º27.50’	153º08.50’
6	31º51.00’	153º20.00’
7	31º40.00’	153º22.50’
8	31º01.75’	153º28.00’
9	30º50.75’	153º26.75’
10	30º10.50’	153º35.00’
11	29º37.00’	153º49.50’
12	29º15.50’	153º56.00’
13	28º21.00’	153º56.50’
14	28º06.50’	154º03.00’
15	27º29.92’	154º00.48’
16	26º45.09’	153º48.61’
17	26º07.78’	154º03.60’
18	24º53.33’	154º40.44’

Table 4. Data and samples gathered

Data type	Results
Seismic profiles	3090 km of 24 channel (3 fold) data
Magnetic profiles	
Multibeam sonar lines	7584 km of swath data
Bathymetric profiles	
Dredges	12 successful dredges
Grabs	1 successful grab

Table 5. Seismic line statistics

Line S270/	Direction	Start WP (lat S/long E)	End WP (lat/long)	Length (km)
1	north	24°53.3’S, 154°40.4’E	23°43.5’S, 154°27.0’E	132
2	east	23°43.5’S, 154°27.0’E	23°43.5’S, 154°59.0’E	55
3	northeast	23°43.5’S, 154°59.0’E	21°05.0’S, 156°53.3’E	351
4	southeast	21°05.0’S, 156°53.3’E	21°52.9’S, 157°36.0’E	152
5	southwest	21°52.9’S, 157°36.0’E	24°25.8’S, 155°17.6’E	390
6	southeast	24°25.8’S, 155°17.6’E	25°02.8’S, 156°03.8’E	104
7	northeast	25°02.8’S, 156°03.8’E	23°05.3’S, 157°55.3’E	292
8	southeast	23°05.3’S, 157°55.3’E	23°43.1’S, 158°27.3’E	90
9	southwest	23°43.1’S, 158°27.3’E	25°32.0’S, 156°30.4’E	285
10	east	25°32.0’S, 156°30.4’E	25°14.4’S, 157°31.2’E	109
11	northwest	25°14.4’S, 157°31.2’E	22°47.4’S, 154°27.6’E	414
12	east	22°47.4’S, 154°27.6’E	22°29.9’S, 155°31.2’E	116
13	southeast	22°29.9’S, 155°31.2’E	23°30.6’S, 156°39.6’E	168
14	east	23°30.6’S, 156°39.6’E	23°11.8’S, 157°27.3’E	90
15	northwest	23°11.8’S, 157°27.3’E	21°41.9’S, 155°41.0’E	244
16	northeast	21°41.9’S, 155°41.0’E	21°01.8’S, 156°17.8’E	98

Total = 3090 km

1.6. Acknowledgements

We are grateful to the National Facility Science Advisory Committee and Steering Committee for making *Southern Surveyor* ship time available for this expedition. We are very grateful to the Master, Ian Taylor, the Mates, Arthur Staron and Tim Sharpe, and all the maritime crew for their wholehearted support and professional seamanship throughout the cruise, and to the engineers for their support during our struggles with the recalcitrant compressor. The deck crew, led by bosun Tony Hearne, were efficient and helpful at all times. The excellent food helped keep spirits up. We thank the CSIRO Marine Division staff of Steve Thomas and Bernardette Heaney for ensuring that all the necessary scientific support was provided. The Geoscience Australia technical group did an excellent job aboard ship. Angie Jaensch is thanked for put putting the figures into their final form. Tony Stephenson and Alix Post are thanked for thorough reviews of an early version of this report. We thank Bev Allen, of the Geoscience Australia library, for finding out the origin of the name Kenn Reef - not a trivial task!

2. PLATE TECTONIC EVOLUTION

Christian Heine

The Kenn Plateau is a large submerged block of extended continental crust located between the northern Tasman and the Coral Seas. It is the northernmost part of a larger sliver of extended continental crust comprising the Lord Howe Rise, Dampier Ridge and Middleton Basin, which rifted off the eastern Australian margin in mid-Cretaceous to Early Tertiary times, associated with the seafloor spreading that formed the oceanic part of the Tasman Sea (Gaina et al., 1998a, b). During the opening process of the Tasman Sea between 95 Ma and 52 Ma, a number of ridge propagation events and changes in spreading direction disintegrated this continental sliver into several smaller blocks (et al., 1998a, b), which are offset by strike slip faults and failed rifts with a probably highly extended continental, probably partly oceanic basement. The tectonic reconstructions by Gaina et al. (1998a, b) are based on fracture zone analysis utilising satellite derived gravity, magnetic anomaly interpretation (including a statistical error analysis) and seismic data, thus providing a robust framework for the overall evolution of the eastern Australian margin.

Seismic data acquired during this cruise, and interpreted satellite derived gravity maps (Sandwell and Smith, 1997), suggest that the area of the Kenn Plateau itself is also composed of a number of smaller blocks underlain by extended continental basement, which are separated by larger graben structures. The basement of these grabens is probably made up of transitional crust and probably smaller segments of oceanic crust in the eastern part of the Observatory Basin/Capel basin. The region structurally inherits general trends associated with different phases of the breakup.

The following scenario is based largely on Gaina et al. (1998a, b), and is partly illustrated in Figures 2 and 5.

2.1. Early extension and seafloor spreading along the eastern Australian margin

The first stage of seafloor spreading started at ~95 Ma in the southern Tasman Sea, separating the southern Lord Howe Rise from southeast Australia. North of ~35°S the extension was largely taken up by the opening/rifting of the elongated Middleton Basin between the Dampier Ridge and the northern Lord Howe Rise, which is probably underlain by highly extended continental, probably transitional crust (Gaina et al., 1998a, b). In the Kenn Plateau area, this extension is probably expressed by normal faulting in the Observatory Trough/Capel Basin.

2.2. Seafloor spreading: 74–65 Ma

A second phase of seafloor spreading commenced at approximately 74 Ma, associated with a counter-clockwise change in spreading direction. Subsequently, blocks now comprising the Dampier Ridge, offset by fracture zones, were rifted off the eastern Australian margin while the ridge propagated further northward. In the Queensland section of the Australian margin, this rotation of the spreading direction resulted in a strike-slip/transtensional regime, which continued to extend the northern part of the Middleton Basin in a NNE-SSW direction. Steeply dipping faults in the Observatory Basin/Capel Basin area of the southeastern Kenn Plateau region may indicate that normal faults related to the first phase of extension have been reactivated by this event.

2.3. Seafloor spreading: 65–57 Ma

By the Cretaceous-Tertiary boundary (65 Ma), the spreading direction changed back to a more NE-SW orientation, and caused the rifting of the southern Kenn Plateau off the eastern Australian margin. This fixed the earlier rifted blocks of the Lord Howe Rise/Dampier Ridge relative to each other, as extension was largely taken up by seafloor spreading further west, along the present day eastern Australian margin. The Capricorn Basin of the southern Marion Plateau can, in this context, be regarded as a failed rift structure that developed when the spreading ridge tried propagating northward (Hill, 1994; Gaina et al., 1998a, b). Contemporaneously, the Louisiade triple junction in the Coral Sea north of the Kenn Plateau became active (~62 Ma; Gaina et al., 1999), subsequently opening the Coral Sea, the Louisiade Trough between Mellish Rise and the

Louisiade Plateau, and the triangle shaped, northward opening Cato Basin. The Kenn Plateau region occupies a pivotal position between these two spreading regimes, resulting in a diffuse gravity and topography signature.

2.4. Seafloor spreading: 57-52 Ma

Strike slip motions within the Cato Trough area mark the last phase of seafloor spreading (~57–52 Ma) which offsets Cato Seamount (western tip of southern Kenn Plateau) towards the northeast relative to the southeastern corner of the Marion Plateau. It is likely that the motion, which Gaina et al. (1998,a, b; 1999) related to transpression between the southeastern Marion Plateau margin and the western Kenn Plateau Blocks (Cato Seamount) is simple strike-slip without a compressional component, as the younger (after strike-slip motion) volcanic Cato Seamount occupies the western part of the southern Kenn Plateau. The true "break up" margin could be located a little further east, and might perhaps be correlated with small offsets visible in the gravity signature of the southern Kenn Plateau margin beneath the centre of the Cato Seamount.

2.5. Hotspot related volcanism

The seamount chain extending from the Coral Sea towards the south was caused by a hot spot and the Kenn and Cato Seamounts (30–35 Ma old) obscure some of the northwestern extent of the continental basement of the Kenn Plateau region. The younger volcanism in this area is likely to have used pre-existing zones of weakness in the crust, such as extinct seafloor spreading ridges, oceanic fracture zones and deep (strike-slip) faults.

2.6. Conclusion

The preliminary interpretation of the *Southern Surveyor* seismic data (see below) supports strongly the plate tectonic model and framework for this region formulated by Gaina et al. (1998a, b). It also supports the interpretations by Falvey (1972, 1974) and Mutter (1978) of the area east of the Cato Trough being a rift-valley region. Minor changes to the proposed tectonic model include the location of strike slip faults (see Section 10.3).

3. MORPHOLOGY AND STRUCTURE OF KENN PLATEAU

Neville Exon

In this chapter we have made a deliberate attempt to separate morphological (bathymetric) names from structural names to reduce confusion, because morphological names are used by all marine groups and should go through an official naming process, whereas structural names are usually used only by the geoscience community and are seldom officially named. The naming of undersea features is under the auspices of the International Oceanographic Commission and the International Oceanographic Commission and is explained under http://www.iho.shom.fr/publicat/free/files/B6efEd3.pdf. Furthermore, in the Kenn Plateau region the extent of bathymetric lows (for example) does not always coincide with the extent of structural troughs or basins. Also, feaures that are marked structural troughs may be overlain by insignificant depressions. Any approach to this problem is complicated by the existing names, in the naming of which varying approaches were taken. Among the most authoritative existing bathymetric names in this region are those of Kroenke et al. (1983), which were approved by the IOC/IHO process.

The Kenn Plateau (Figure 8), lies 200 km northeast of Fraser Island on the Queensland coast and is bounded:

- to the west by the Cato Basin (new name), beyond which lies the Marion Plateau;
- to the north by the Bampton Trough (new name), beyond which lies the Mellish Rise;
- to the east by the Capel Basin (Stagg et al., 1999, 2002) that joins the Middleton Basin to the West d'Entrecasteaux Basin, beyond which lie the guyots and reefs of the Chesterfield to Capel segment of the Lord Howe hotspot chain;
- and to the southwest by the Tasman Basin.

As defined above, the total area of the Kenn Plateau is about 140,000 km². The Australian part of the Kenn Plateau is about 100,000 km², and a strip of about 50,000 km² in the east is French territory. In the north and west about 40,000 km² is in water shallower than 2000 m. The plateau is shallowest in the north and northwest and generally deepens to the southeast. The major morphological features associated with the plateau, some named here for the first time, are tabulated below (Table 6). Many are the reflection of basic structural features (Table 7) that are better defined in the satellite gravity map (Figures 7 & 8) and corroborated by seismic profiles. Many trend ENE, suggesting that they are controlled either by transcurrent faults related to east Australian breakup, and/or to north-south rifting associated with the opening of the Coral Sea. The northern Kenn Plateau, a relatively high and coherent part of the plateau north of the Observatory Basin (new name), is distinct from the southern Kenn Plateau, a relatively low mosaic of small blocks. The northern Kenn Plateau is dominated by the Coriolis Ridge (earlier named after R.V. *Coriolis*).

Table 6. Morphological features of Kenn Plateau

Feature	Characteristics
Capel Depression	North-trending bathymetric depression overlying Capel Basin, 550 km long and 1500-3000 m deep, and forming the eastern margin of most of Kenn Plateau. Joins Middleton Basin in the south and extends from Coriolis Ridge to west of Capel Bank. West of banks extending from Chesterfield in the north to Capel in the south.
West D'Entrecasteaux Basin	Extension of the D'Entrecasteaux Basin west of the Chesterfield-Lord Howe seamount chain. Water depth 3400-3800 m.
Bampton Trough	Northeast-trending bathymetric depression 200 km long and ~3000 m deep, extending from the Cato Basin to the West d'Entrecasteaux Basin (west of Bampton Reef) and forming the northern margin of the Kenn Plateau.
Cato Basin	North-trending triangular bathymetric depression extending 500 km northward, from (and including) Cato Trough in the south to the southern margin of the Mellish Rise. Includes several seamounts including Wreck Seamount. Width increases northward from 20 km at Cato Trough to 250 km near Mellish Rise. Water depth 2500-3200 m.
Cato Trough	North-trending southernmost part of Cato Basin, 80 km long and 20 km wide, between Cato Seamount and Marion Plateau, and debouching into Tasman Basin in the south. Water depth 3000-3600 m.
Wreck Seamount	East-west elongated seamount in Cato Basin, 70 km long, consisting of a volcanic pedestal, overlying carbonates, and Wreck Reef and Bird Island. About 2000 km^2 is shallower than 3000 m.
Kenn Seamount	North-south elongated seamount 100 km long consisting of a volcanic pedestal, overlying carbonates and Kenn Reef. About 5,000 km^2 is shallower than 2000 m.
Chesterfield Rise	ENE-trending rise 100 km long, west of Chesterfield Reef and forming the northernmost block of Kenn Plateau, with ~5000 km^2 shallower than 2000 m
Chesterfield Depression	Depression 200 km long and more than 2000 m deep, extending from Kenn Reef to Chesterfield Reef and separating Chesterfield Rise and Coriolis Ridge. Overlies Chesterfield Trough. Western part oriented east-west; eastern part northeast.
Coriolis Ridge	Ridge 250 km long, extending from Bellona Plateau to Cato Basin. Like adjacent Chesterfield Depression, western part is oriented east-west and eastern part northeast. About 20,000 km^2 is shallower than 2000 m, and part shallower than 1000 m.

Observatory Depression	ENE-trending depression 350 km long and 2000-2500 m deep, extending from south of Wreck Reef to south of Observatory Cay, and overlying Observatory Basin.
Cato Seamount	Circular seamount consisting of a volcanic pedestal, overlying carbonates and Cato Island. About 4,000 km² is shallower than 1500 m.
Southern Surveyor Rise	Broad ENE-trending rise 150 km long that lies east of Cato Island. About 4,000 km² is shallower than 2000 m.
Kelso Rise	Circular rise 50 km in diameter, and 2000-2500 m deep, west of Kelso Bank

The Kenn Plateau lies between the reefs, seamounts and guyots of two north-south hotspot chains: the Lord Howe chain to the east, and the Tasmantid hotspot chain to the west. The Lord Howe seamount chain extends northward about 1000 km from Lord Howe Island to the Chesterfield Group of guyots. Basalts from Lord Howe Island (McDougall et al., 1981) were dated at 6.9-6.4 Ma by K/Ar dating. The Chesterfield Group, at the northern end of the chain, is interpreted as younger than Middle Eocene by Missegue and Collot (1987). If one applies a hotspot migration rate of about 70 km/million years, the pedestal of the Chesterfield Group should have formed at about 25 Ma (earliest Miocene).

The Tasmantid seamount chain (McDougall and Duncan, 1988) extends over 1800 km in and north of the Tasman Basin, from Gascoyne Seamount in the south to Kenn Reef in the north. Kenn Reef, and Bird and Cato Islands (atop similarly named seamounts in Figure 8), are part of the Tasmantid seamount chain. The seamounts increase in age northward. Queensland Seamount (26.5°S) is the oldest seamount basalt yet dated (24 Ma: K/Ar and 40Ar/39Ar). The results of McDougall and Duncan (1968), in conjunction with broader plate tectonic studies (e.g. CPCEMR, 1991) indicate that the associated hot spot migrated southward at about 70 km/million years, suggesting that the pedestal of Kenn Reef should have formed at about 35 Ma. Figure 9 shows the postulated ages of some Tasmantid seamounts assuming a migration rate of 60 km/million years.

Kenn Reef, and Bird and Cato Islands, lie near the western margin of the Kenn Plateau and each is about 130 km from the next. If hotspot migration was at the rate of 70km/million years, each volcanic build-up should be 2 million years younger that its neighbour to the north. Reefs and sand cays have developed on the relict topographic highs of the extinct volcanoes, probably since the early Miocene (~25 Ma) on the evidence of ODP sites on the Marion Plateau (Isern, Anselmetti and Blum, 2002). The shapes of the present shoals are completely controlled by those of the tops of their pedestals. Reefs are best developed on the windward side of any atoll, and these reefs are controlled by the Southeast Trade Winds. The pedestal of Kenn Reef straddles the boundary between Kenn Plateau and Cato Trough, rising 3000 m above the latter. Its shoals form an oblong 20 km long by 15 km wide and elongated NNW, with reefs on the southern and eastern side. Wreck Reef and Bird Island rise 4000 m above Cato Trough, their shoals forming an east-west oval 35 km long and 10 km wide, with reefs on the south side. The pedestal of Cato Reef and Island straddles the boundary between Kenn Plateau and Cato Trough, rising 3500 m above the latter. The shoals form a semicircle 20 km in diameter, with the straight side and the reefs on the south side.

Table 7. Structural Features of Kenn Plateau

Feature	Characteristics
Capel Basin	North-trending basin 550 km long, extending from Coriolis Ridge (west of Bellona Plateau) to Middleton Basin, and forming the eastern margin of most of Kenn Plateau. Sediment thickness of 3 seconds twt in places.
West D'Entrecasteaux Basin	Extension of the oceanic D'Entrecasteaux Basin west of the Chesterfield-Lord Howe seamount chain. Probably less than 1 second twt of sediment.
Bampton Trough	Northeast-trending depression 200 km long and ~80 km wide, extending from the Cato Trough to the West d'Entrecasteaux Basin (west of Bampton Reef) and forming the northern margin of the Kenn Plateau. Sediment thickness of 2 seconds twt in places.
Cato Basin	North-trending triangular, probably largely oceanic, basin extending 500 km northward, from Cato Trough in the south to the southern margin of the Mellish Rise. Includes several seamounts including Wreck Seamount. Width increases northward from 20 km at Cato Trough to 250 km near Mellish Rise. Sediment thickness of 2 seconds twt in places.
Cato Trough	North-trending southernmost part of Cato Basin, 80 km long and 20 km wide, between Cato Seamount and Marion Plateau, and debouching into Tasman Basin in the south. Water depth 3000-3600 m. Sediment thickness of 1.5 seconds twt in places.
Wreck Seamount	East-west elongated seamount in Cato Basin, 70 km long, consisting of a volcanic pedestal, overlying carbonates, and Wreck Reef and Bird Island. About 2000 km² is shallower than 3000 m.
Kenn Seamount	North-south elongated seamount 100 km long and 50 km wide, consisting of volcanic pedestal, overlying carbonates and Kenn Reef.
Chesterfield Rise	ENE-trending rise 100 km long and ~40 km wide, west of Chesterfield Reef and forming the northernmost block of Kenn Plateau, with ~5000 km² shallower than 2000 m
Chesterfield Trough	Trough 200 km long and ~30 km wide, extending from Kenn Reef to Chesterfield Reef and separating Chesterfield Rise and Coriolis Ridge. Western part oriented east-west; eastern part northeast.
Coriolis Ridge	High block, 250 km long and ~100 km wide, extending from Bellona Plateau to Cato Basin. Like adjacent Chesterfield Trough, western part is oriented east-west and eastern part northeast. About 20,000 km² is shallower than 2000 m, and part shallower than 1000 m.

Observatory Basin	ENE-trending basin 200 km long and 100 km wide, extending from the deeper Capel Basin southwest of Observatory Cay, to southeast of Wreck Reef. Sediment thickness of 2 seconds twt in places.
Cato Seamount	Circular seamount consisting of volcanic pedestal, overlying carbonates and Cato Island.
Southern Surveyor Rise	Broad ENE-trending rise, 150 km long and 100 km wide, that lies east of Cato Island. About 4,000 km^2 is shallower than 2000 m.
Kelso Basin	ENE-trending basin 150 km long and 100 km wide, extending from the deeper Capel Basin west of Kelso Bank to Tasman Basin. Sediment thickness of 1.5 seconds twt in places.
Kelso Rise	Circular rise 50 km in diameter, southwest of Kelso Bank

4. SWATH-MAPPING RESULTS

Peter Hill

The multibeam data collected during Survey 270 were mostly collected as single-line coverage, particularly along seismic lines, on transits between geological sampling sites, and on the transits from Sydney and to Noumea. Multiple-line coverage was obtained along the northern margin of the Coriolis Ridge (2-line coverage), and along the western and northwest margins of Kenn Plateau (4-line coverage on the Cato Trough margin; 3-line coverage to the north, on the Cato Basin margin).

Six key areas of swath coverage were selected for detailed display, analysis and discussion:-

1. Northern Kenn Plateau (Figure 10)
2. Northwest margin of Kenn Plateau, including dredge sites DR6 & 7 (Figure 11)
3. Western Kenn Plateau, including dredge sites DR9, 10 & 11 (Figure 12)
4. Central Kenn Plateau (Figure 13)
5. Fraser Seamount, including dredge sites DR4 & 5 (Figure 14)
6. Dredge site DR2, southwest margin of Kenn Plateau (Figure 15).

Enlargements of multibeam bathymetry at dredge sites DR6, 7, 9, 10 & 11 (Figure 16) provide details of local seabed morphology. Important aspects of Kenn Plateau geomorphology are illustrated in a series of 3-D images (Figures 17-26) of parts of the six key areas.

4.1. Northern Kenn Plateau

The slope at the northern margin of the Coriolis Ridge (Figure 10) is of varying character. In the east it is an irregular, fault-controlled escarpment about 500 m high (Figure 17). In the middle (where crossed by Seismic Line 3 – Figure 30), it is a gentle 2° smooth and sedimented slope. To the west, the slope is rugged (Figure 18) and cut by downslope canyons and gullies 50-200 m deep. Here the slope appears to be the base of a topographic high located just to the south. The rugged nature of the slopes suggests that this feature may be volcanic.

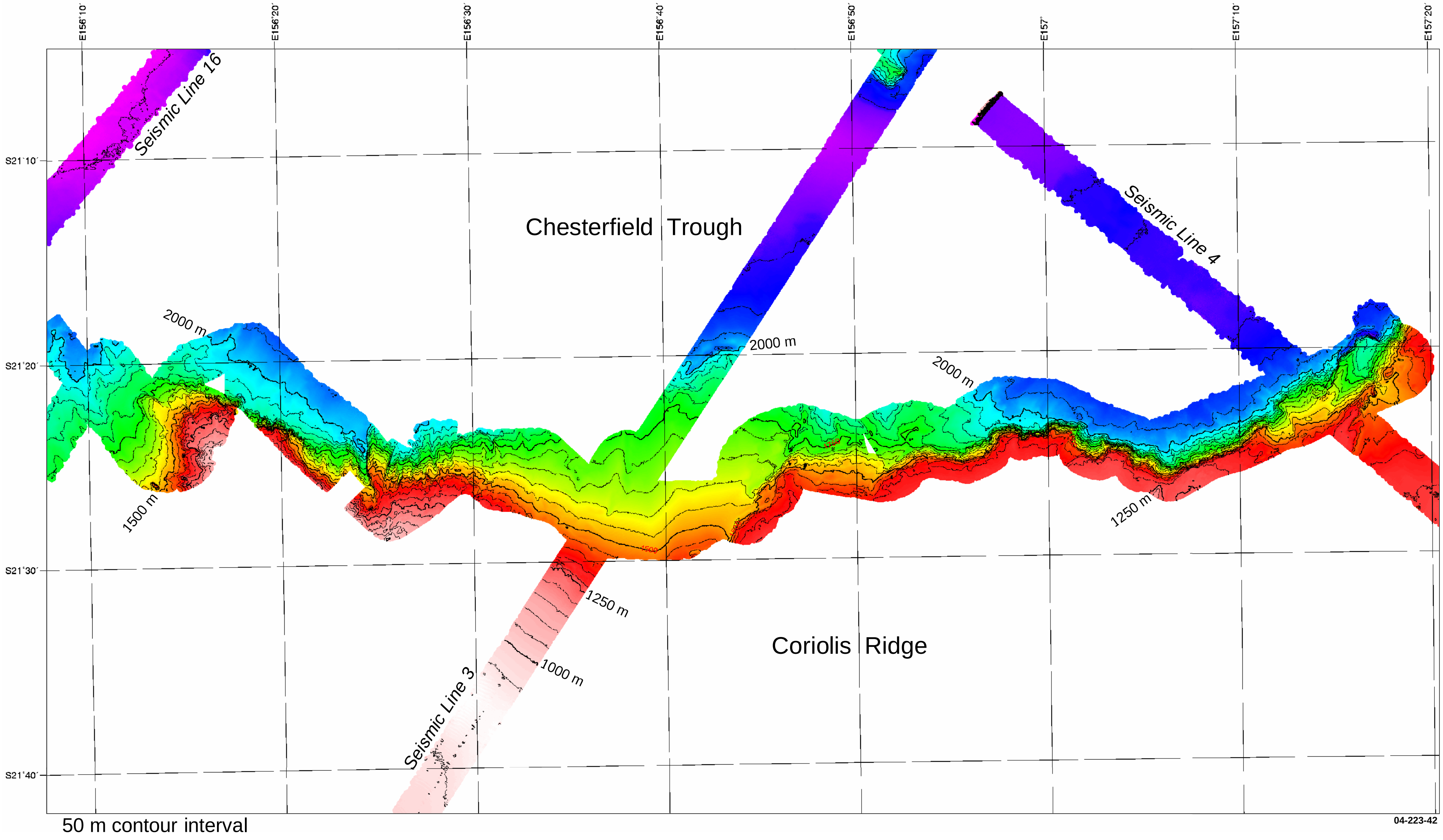


Figure 10. Northern Kenn Plateau multibeam bathymetry map.

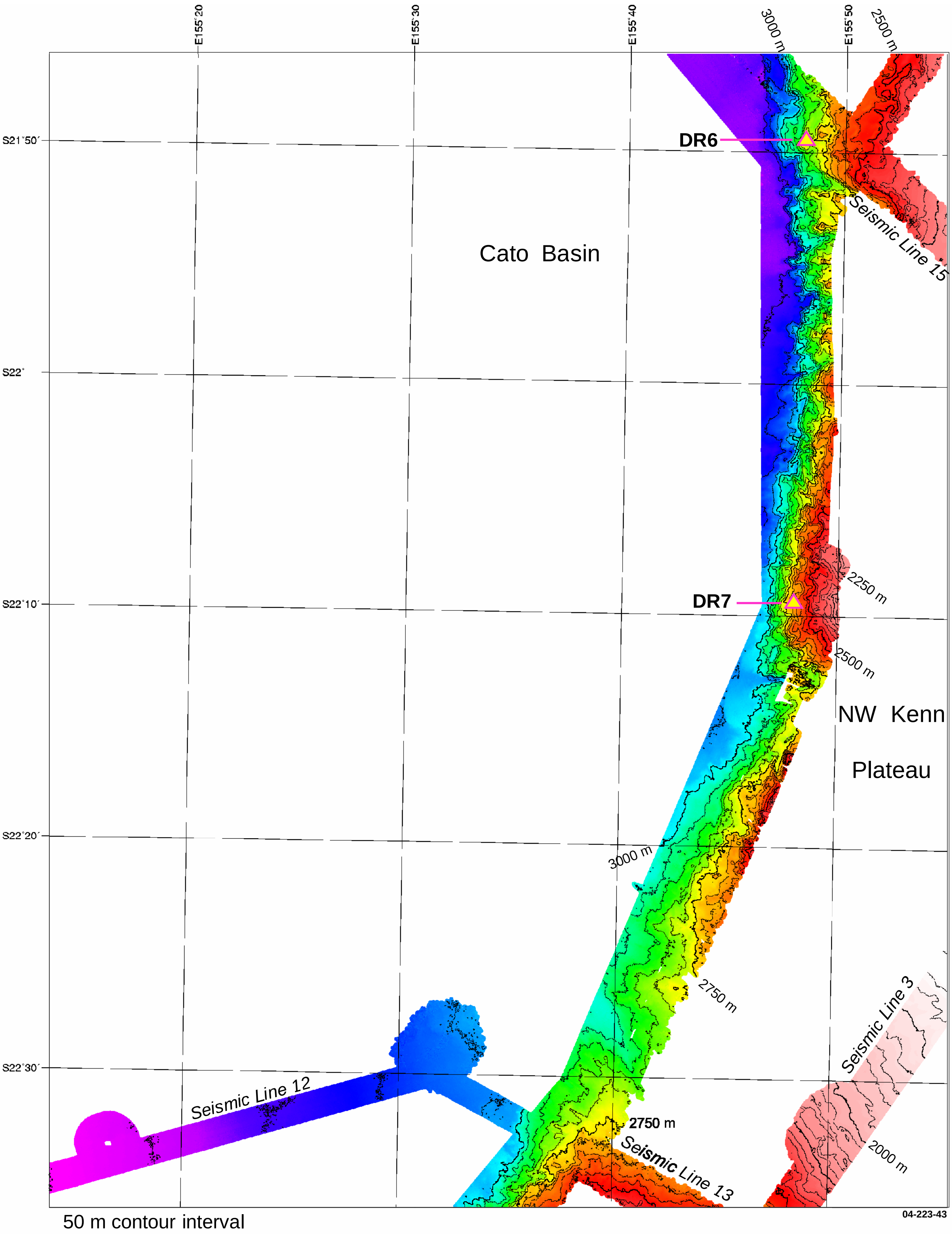


Figure 11. Northwest margin of Kenn Plateau (DR6 & 7) multibeam bathymetry map.

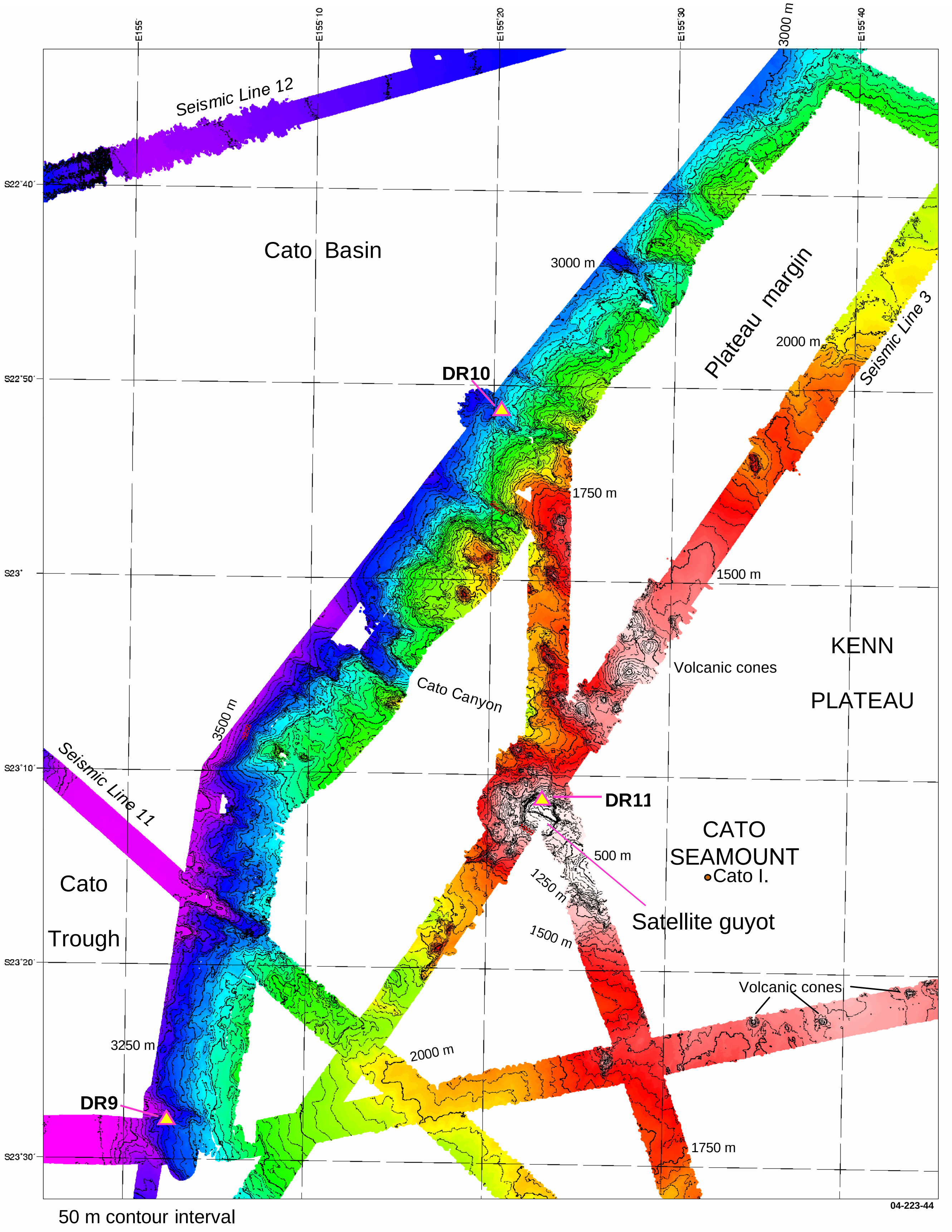


Figure 12. Western Kenn Plateau (DR9, 10 & 11) multibeam bathymetry map.

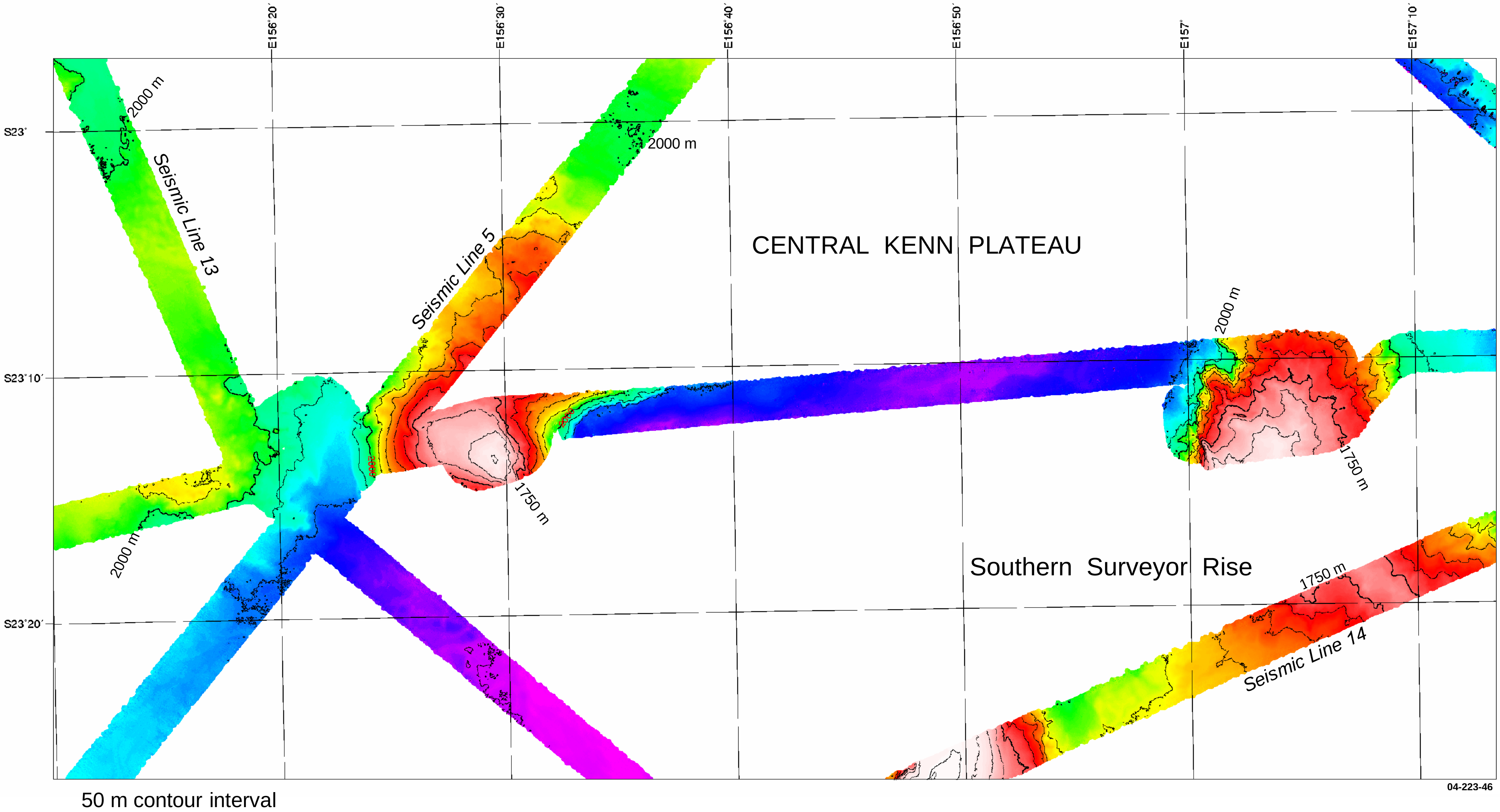
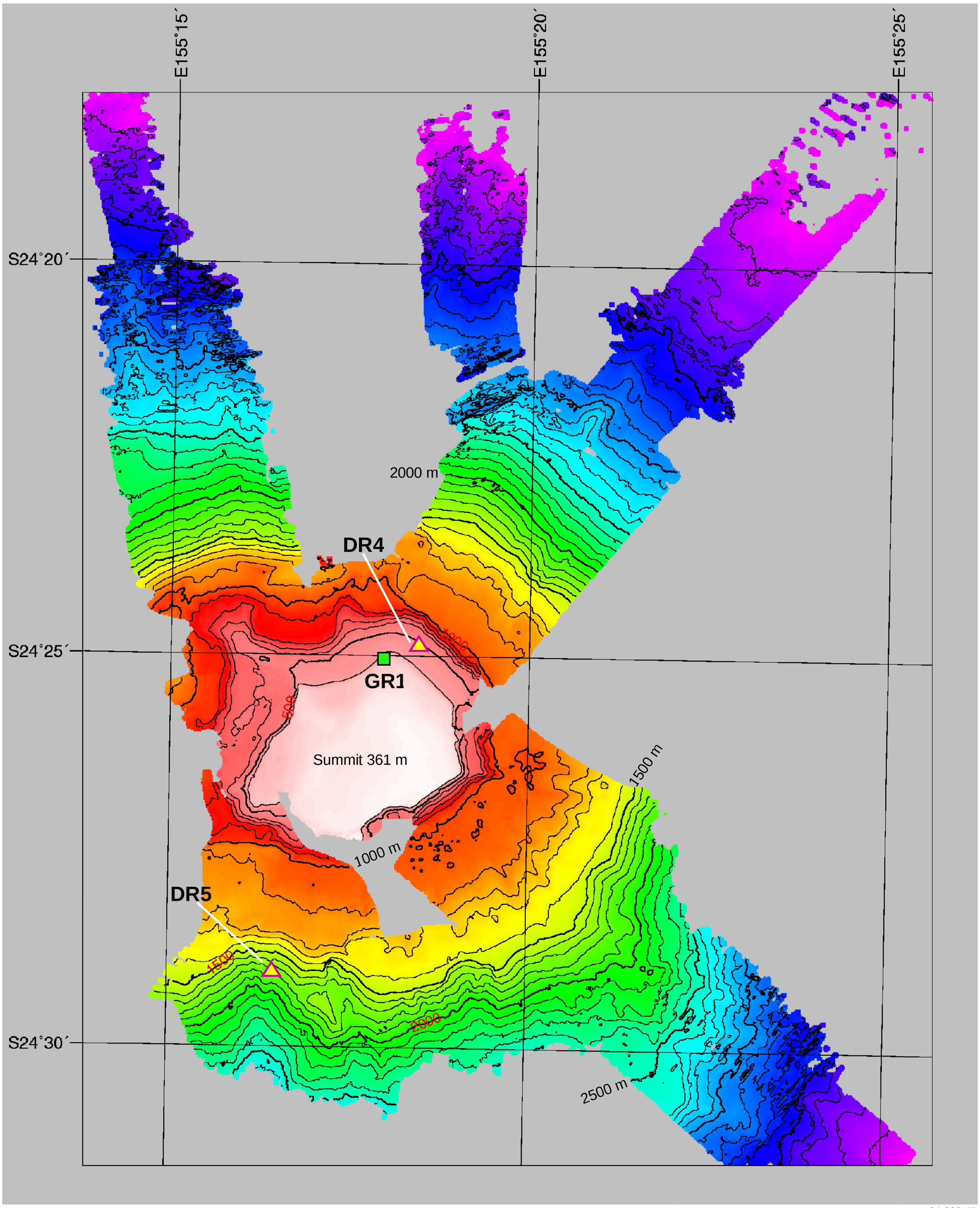


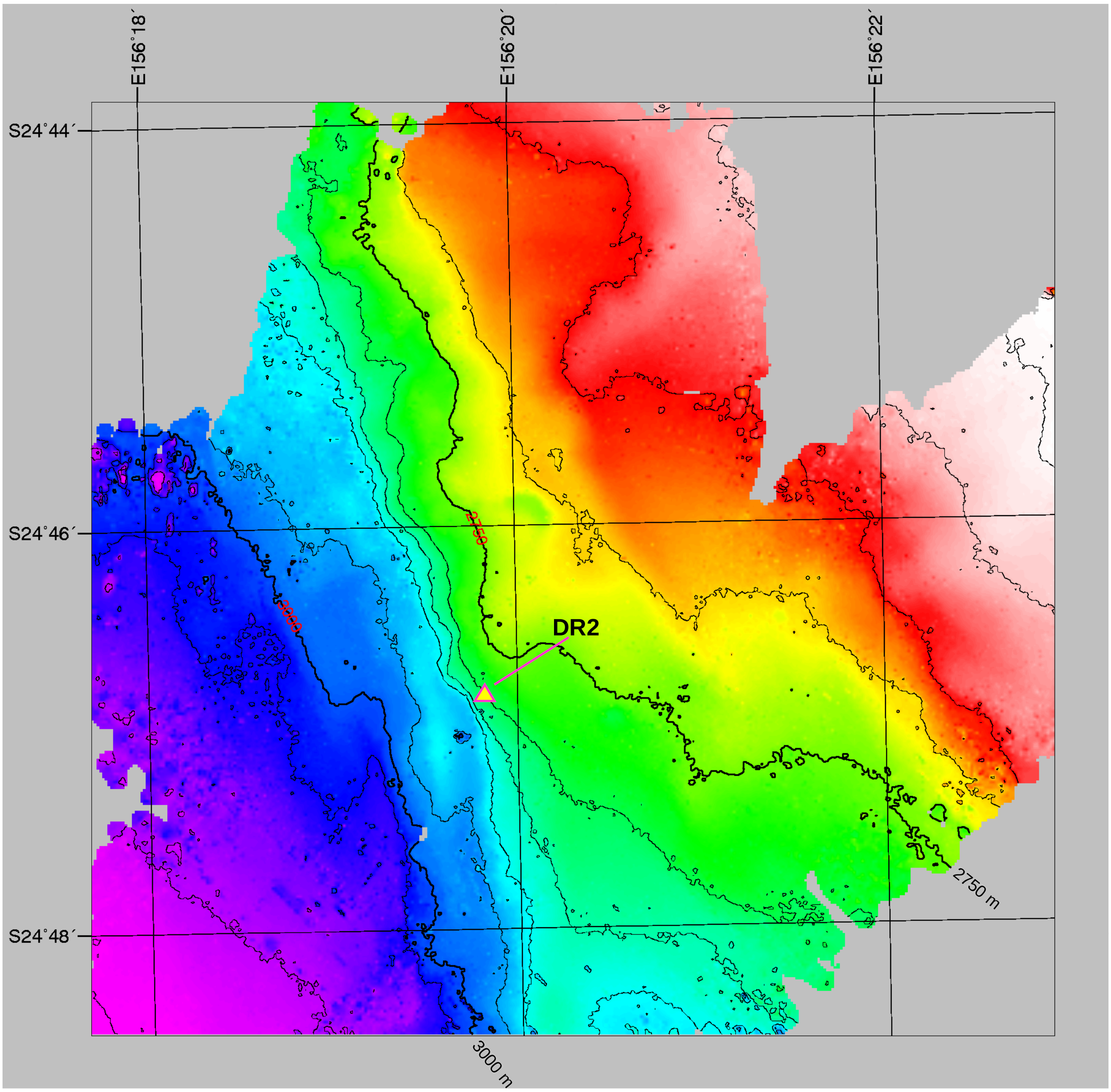
Figure 13. Central Kenn Plateau multibeam bathymetry map.



04-223-47

100 m contour interval

Figure 14. Fraser Seamount multibeam bathymetry map.



50 m contour interval

Figure 15. DR2, southwest margin of Kenn Plateau, multibeam bathymetry map..

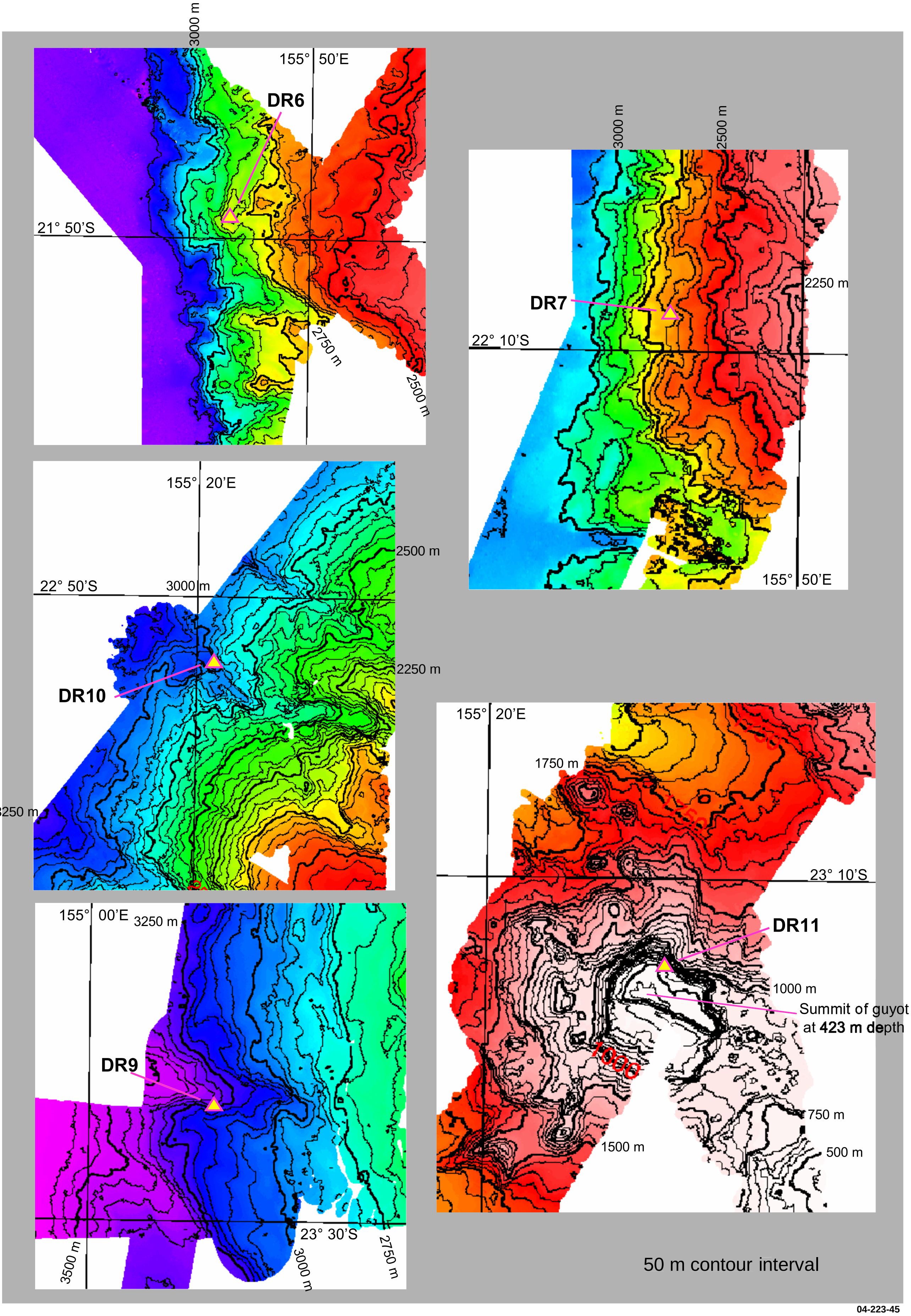


Figure 16. Detail of multibeam bathymetry at DR6, 7, 9, 10 & 11.

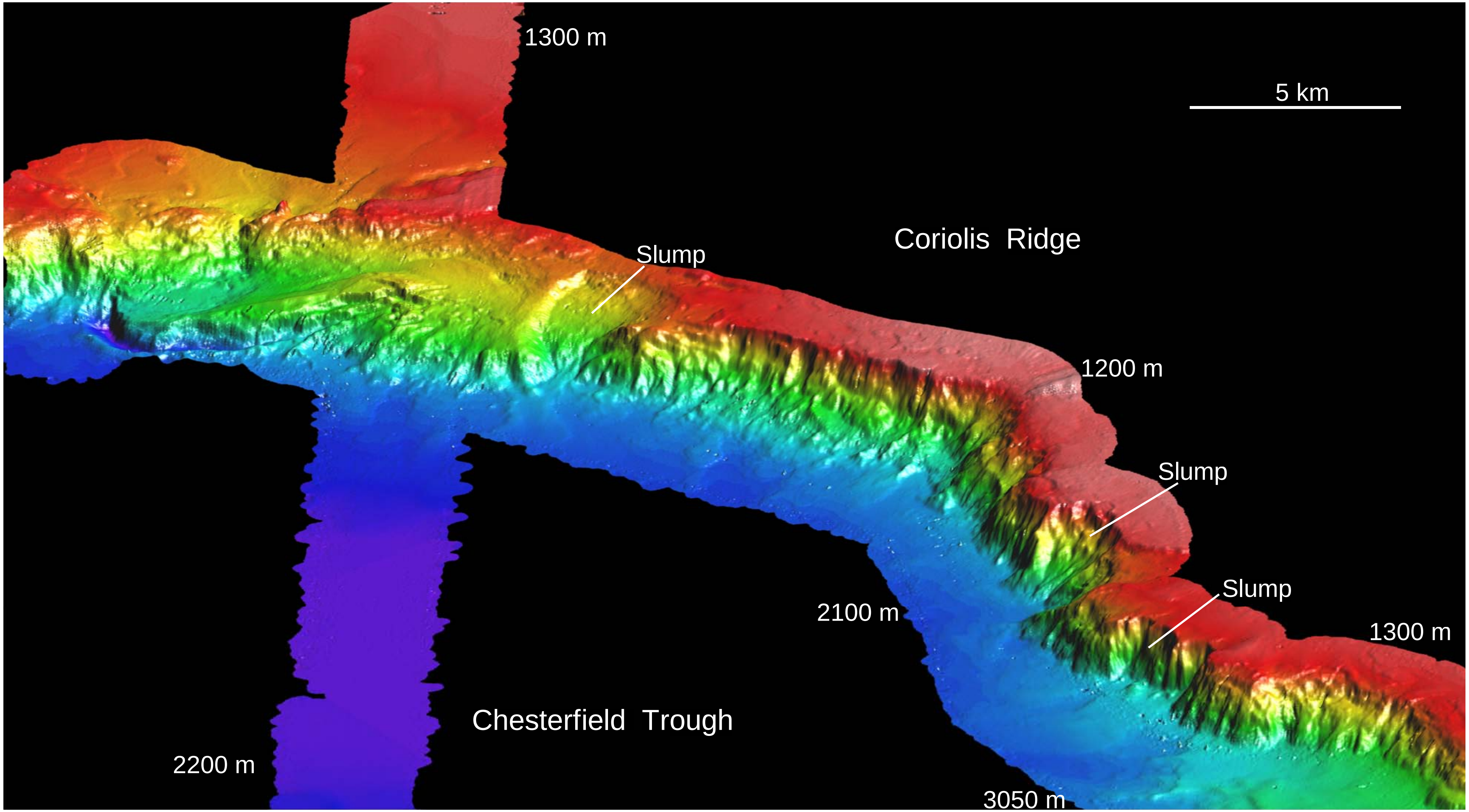


Figure 17. Central northern margin of Coriolis Ridge, 3-D multibeam image. View to southeast.

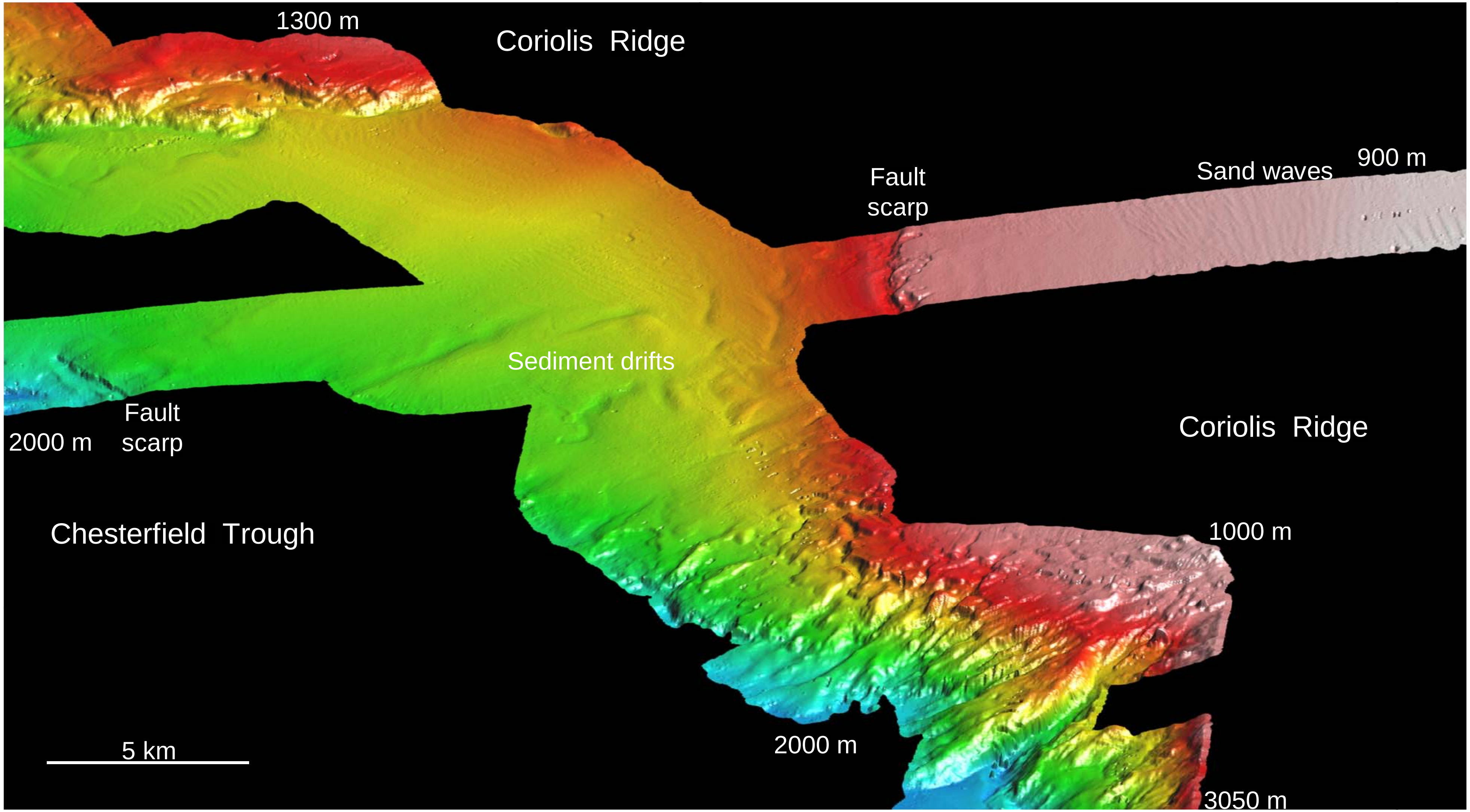


Figure 18. Northwest margin of Coriolis Ridge, 3-D multibeam image. View to southeast.

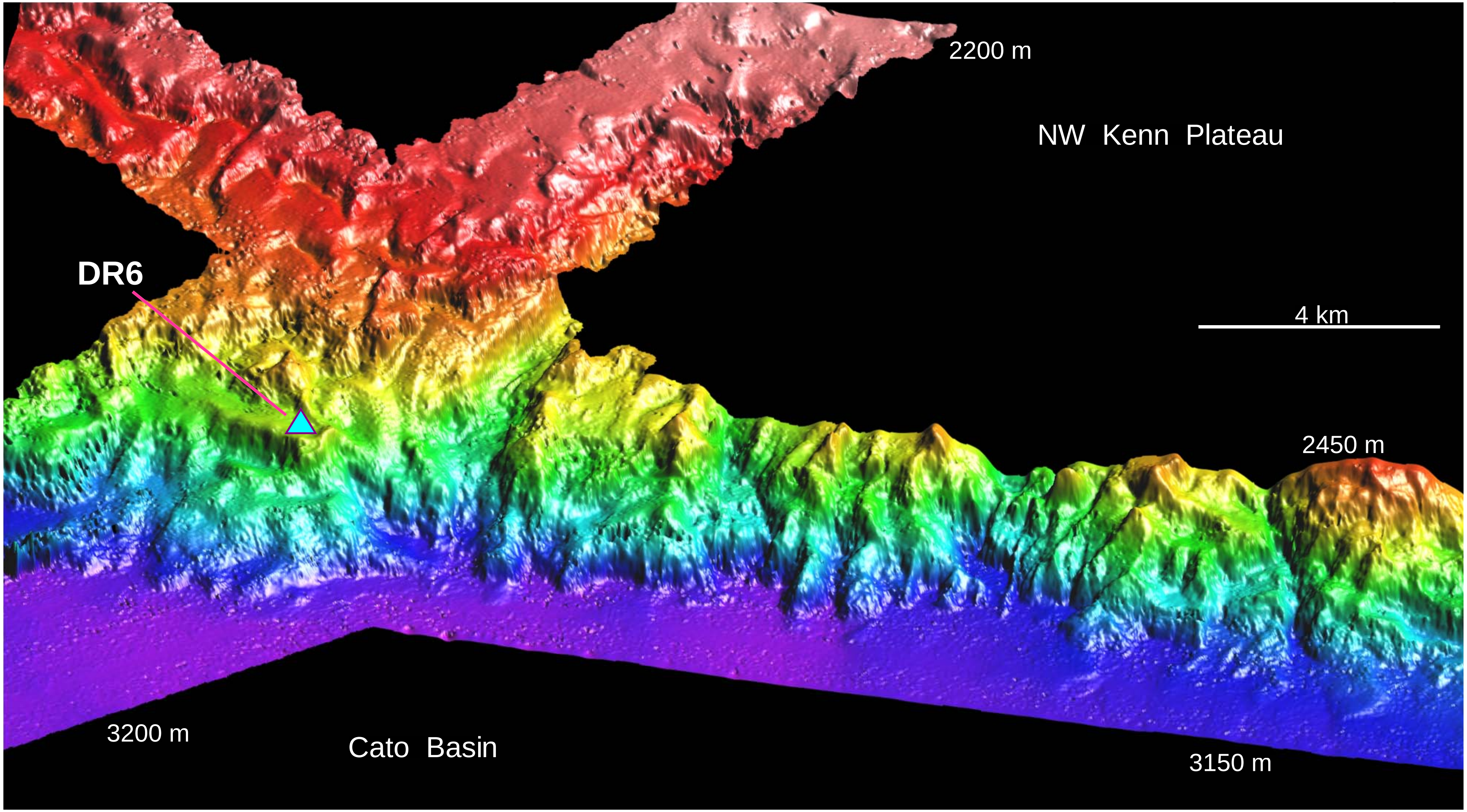
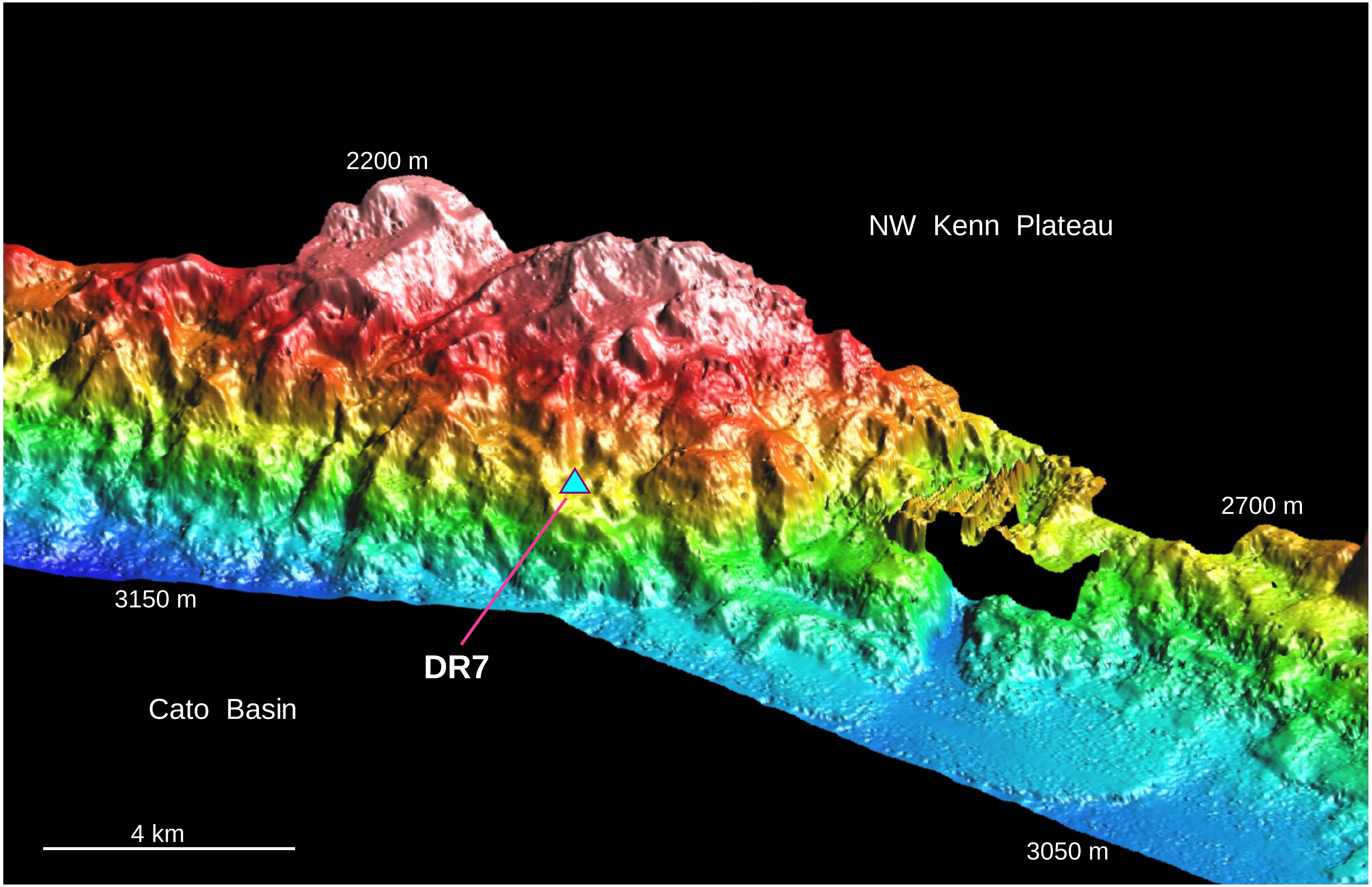


Figure 19. DR6, northwest margin of Kenn Plateau, 3-D multibeam image. View to ENE.



04-223-52

Figure 20. DR7, northwest margin of Kenn Plateau, 3-D multibeam image. View to ENE.

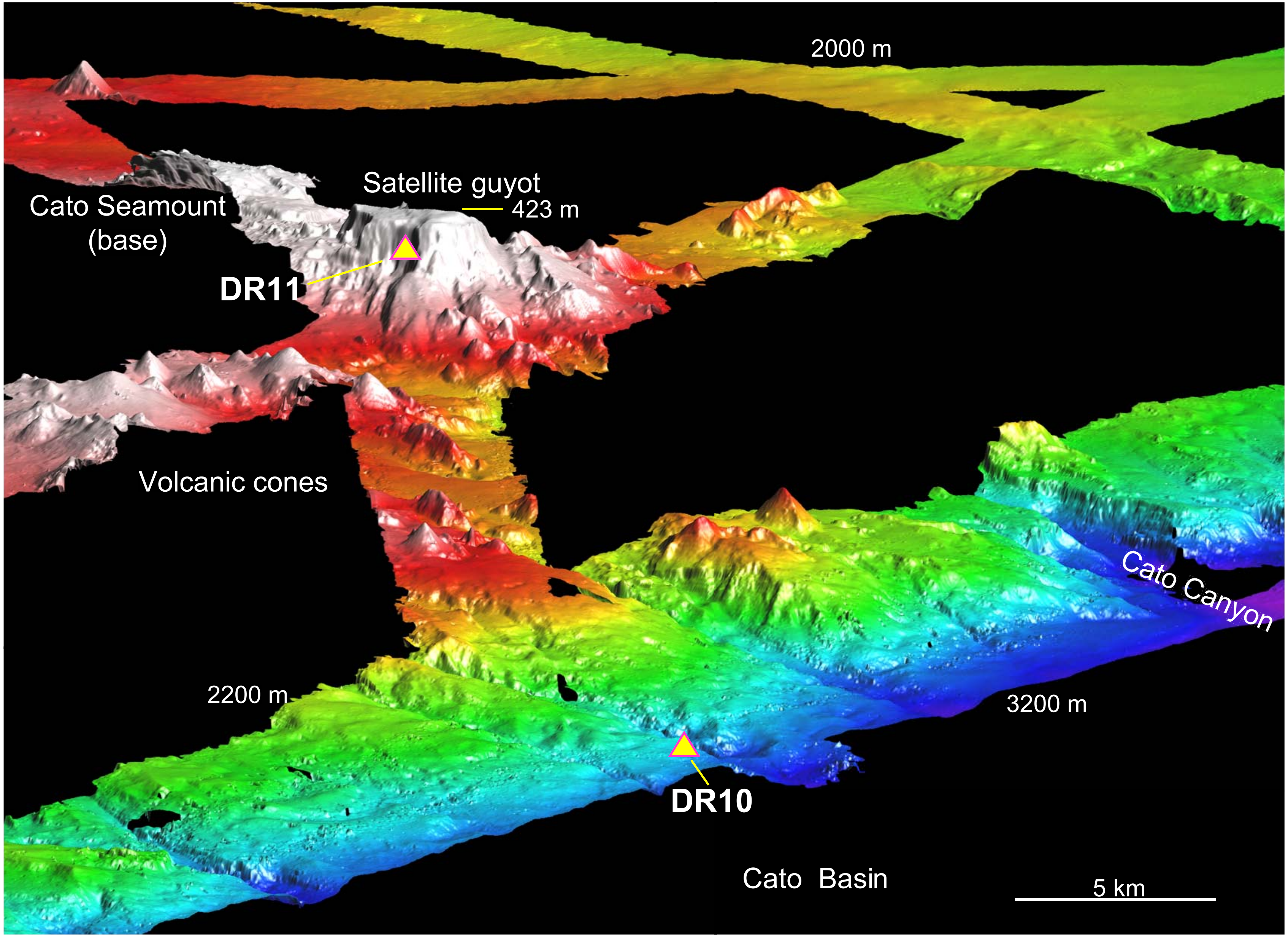


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Figure 21. Western margin of Kenn Plateau (DR10 & 11), 3-D multibeam image. View to south.

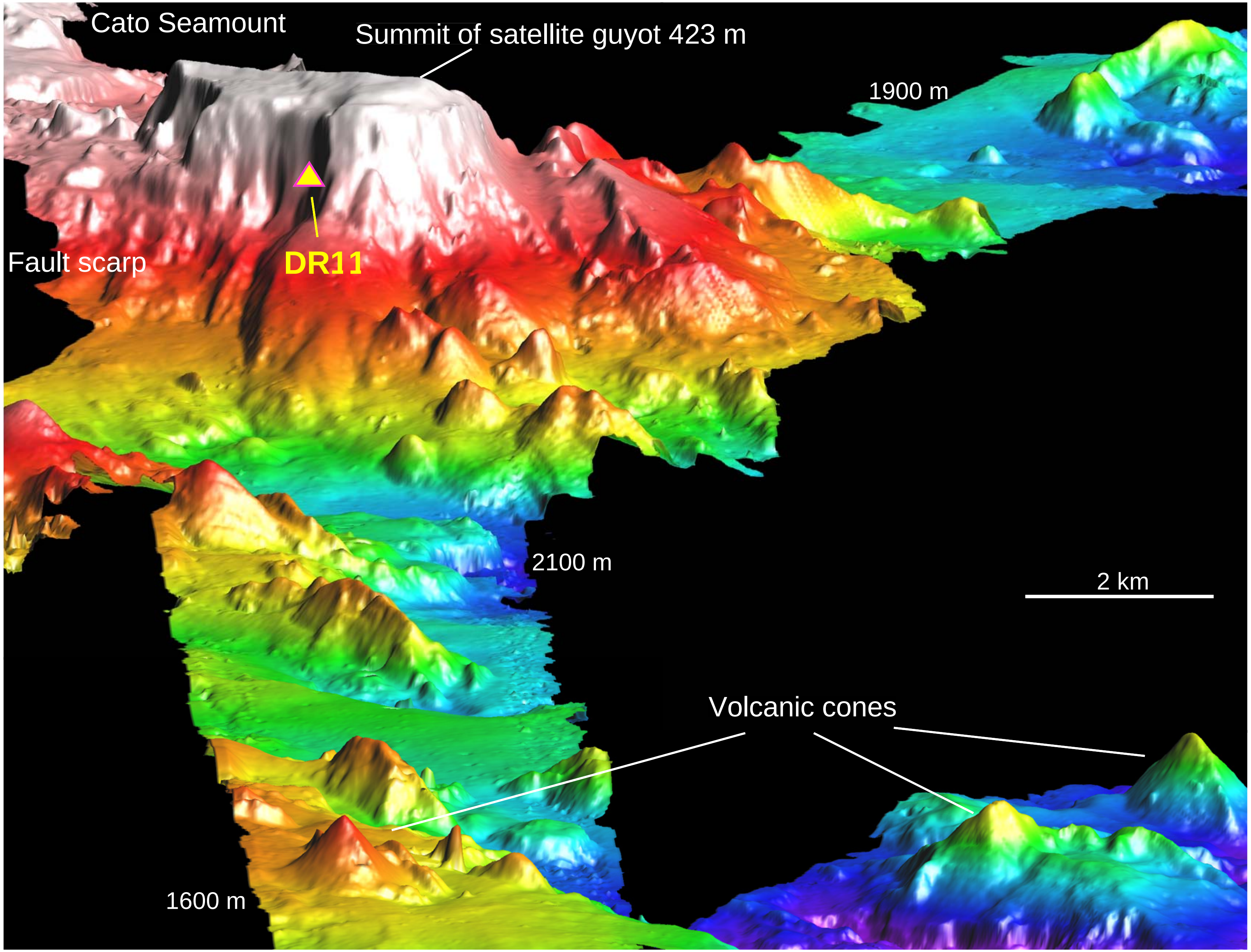


Figure 22. Satellite guyot, Cato Seamount area (DR11), 3-D multibeam image. View to south.

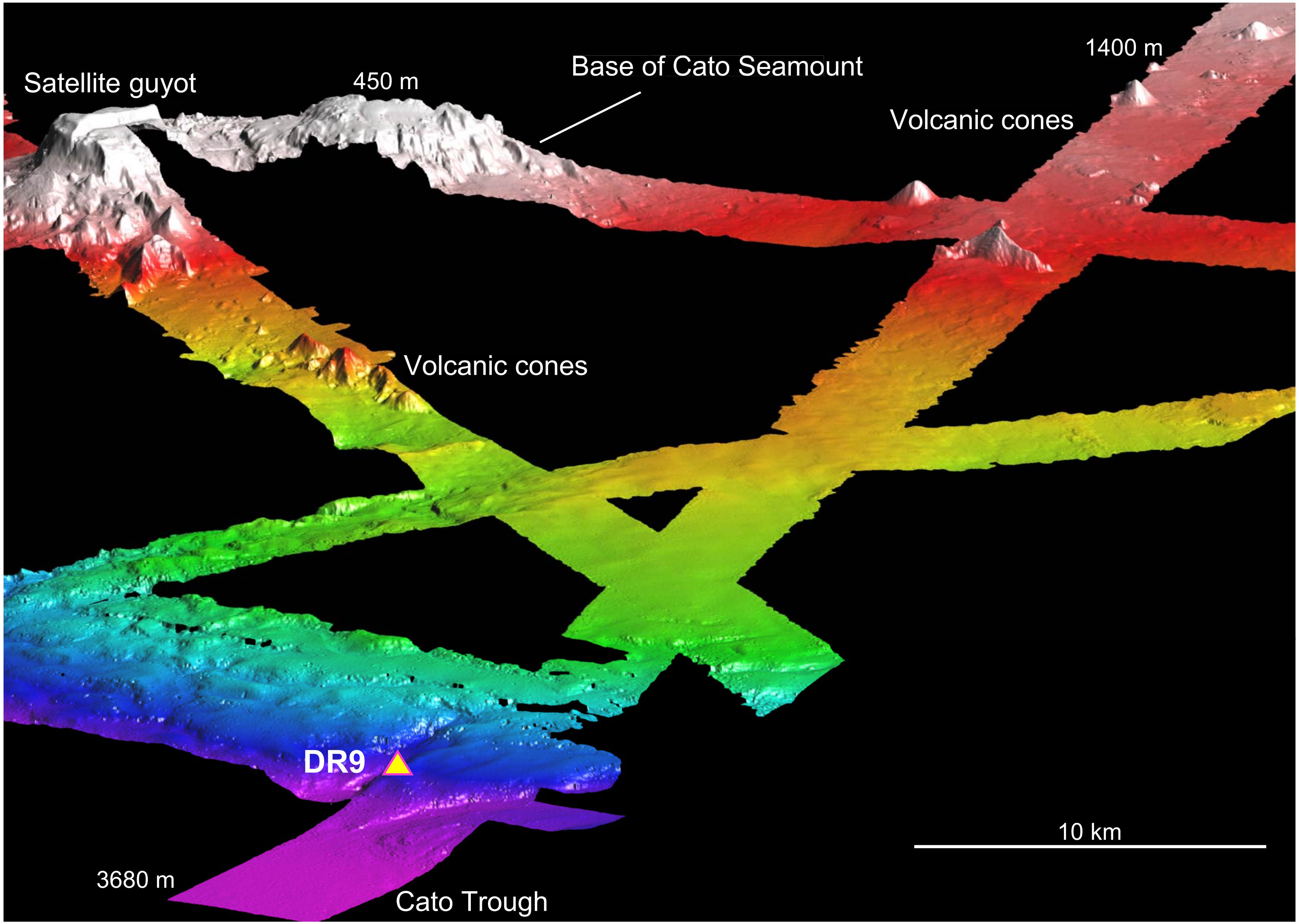


Figure 23. Western margin of Kenn Plateau (DR9), 3-D multibeam image. View to northeast.

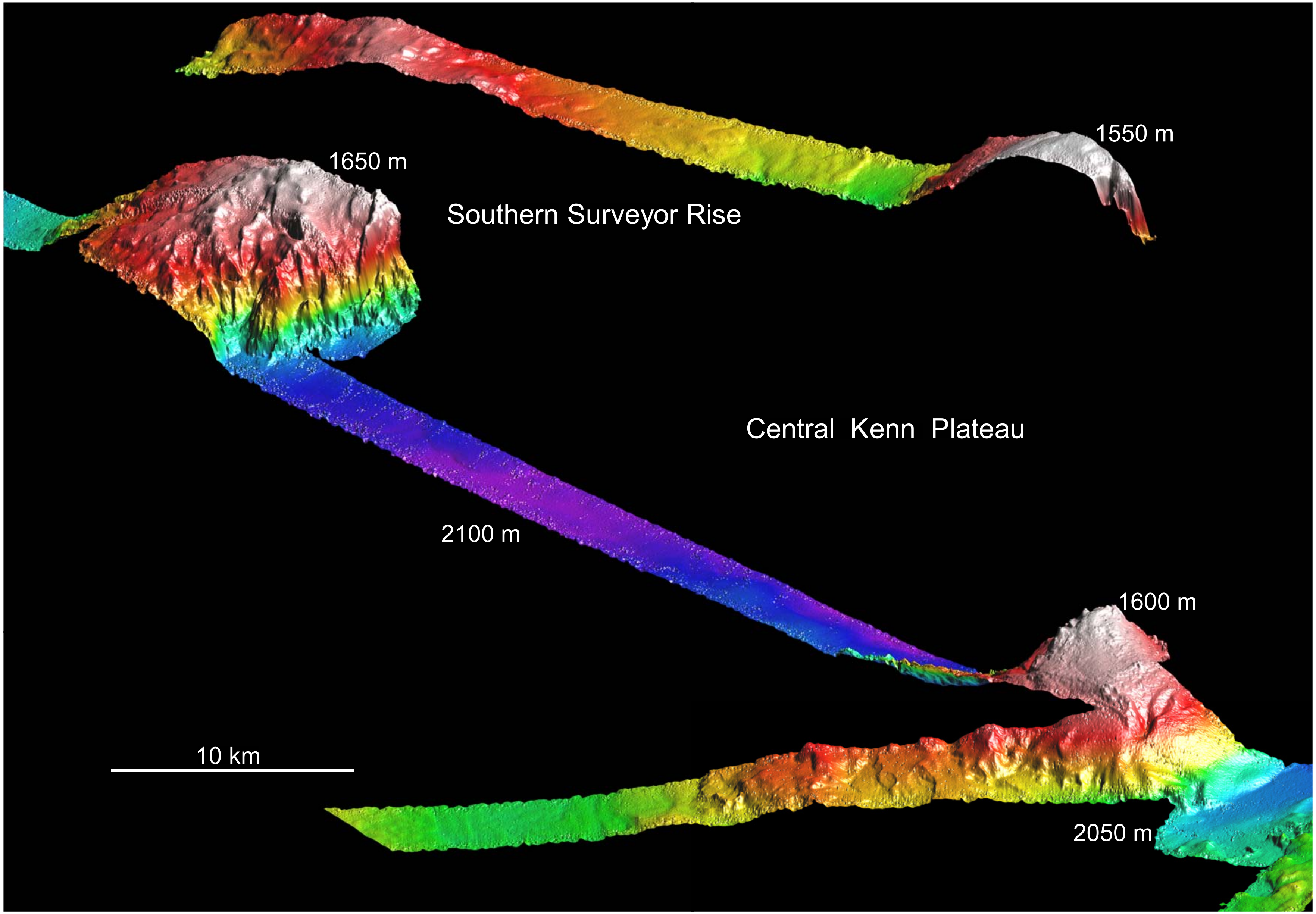
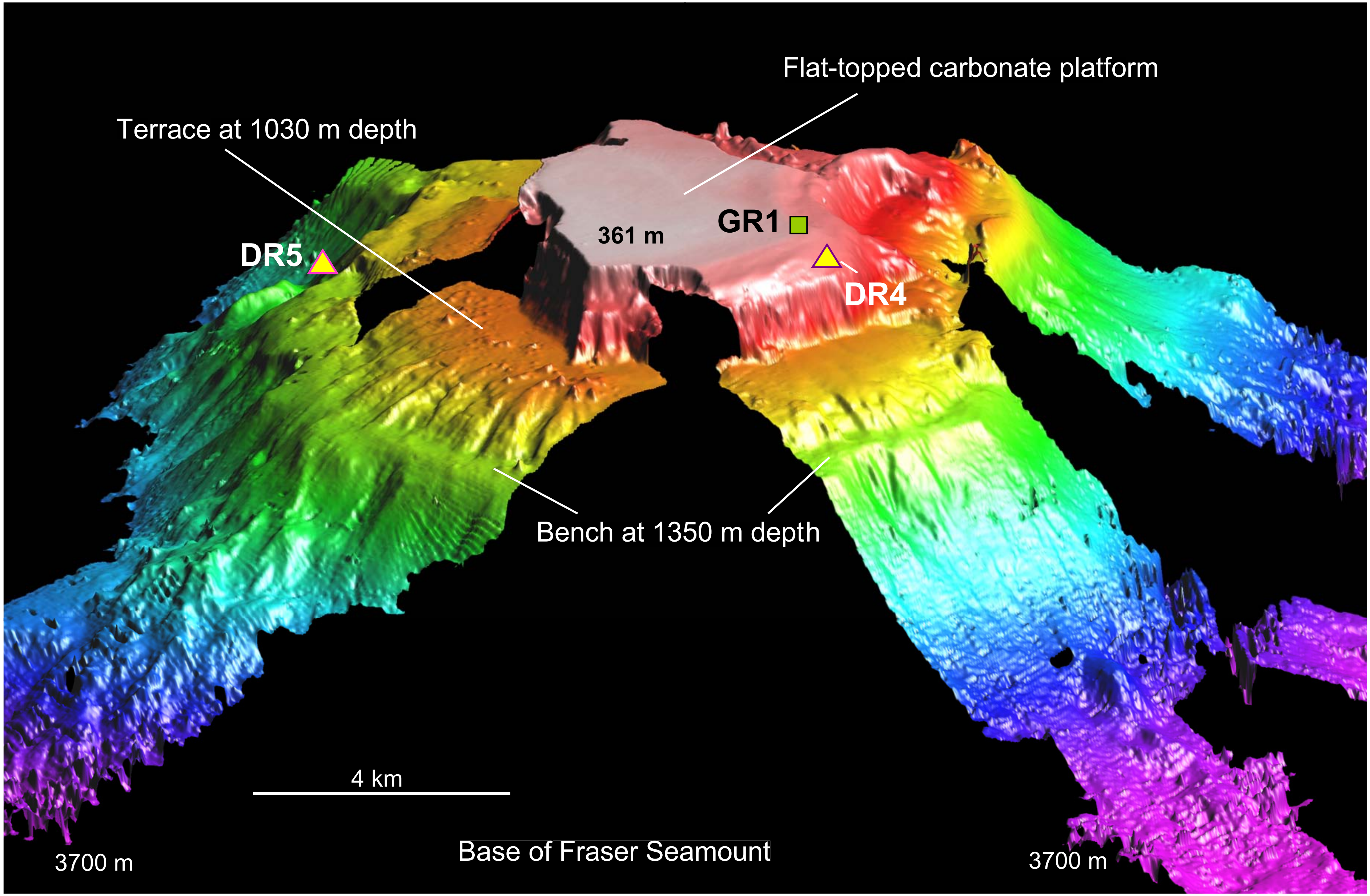
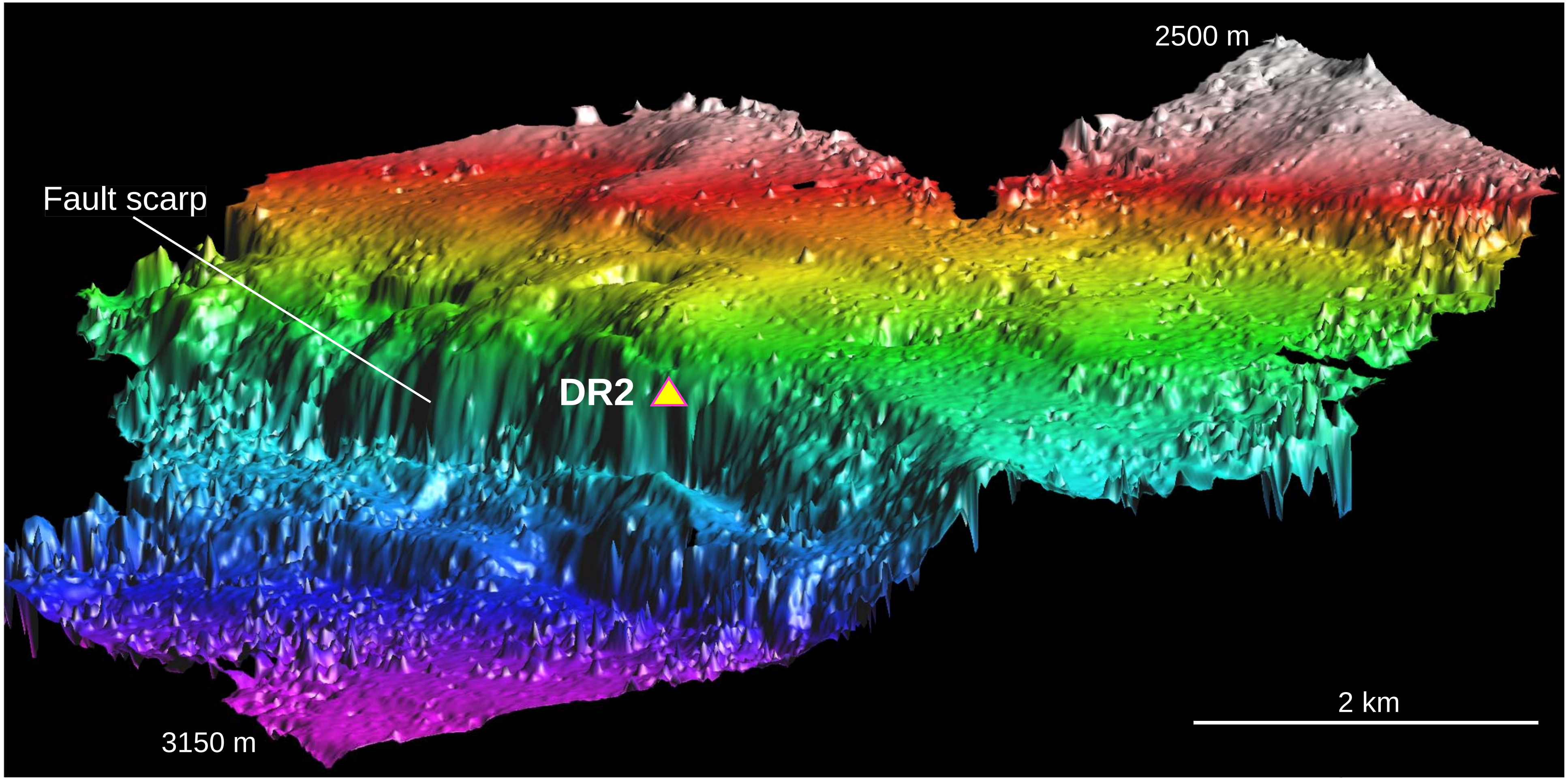


Figure 24. Central Kenn Plateau, 3-D multibeam image. View to southeast.



04-223-57

Figure 25. Fraser Seamount (DR4 & 5; GR1), 3-D multibeam image. View to west.



04-223-58

Figure 26. DR2, southwest margin of Kenn Plateau, 3-D multibeam image. View to northeast.

The Chesterfield Trough, adjacent to the margin, is floored by a flat sedimented seabed 2100-2200 m deep. Except for the high at the western end (Figure 10), the Coriolis Ridge in this area is a broad E-W trending dome that culminates at about 900 m depth.

The morphology of the eastern escarpment (Figure 10) suggests structural control by NE, ENE and WNW-trending fault sets. The steep slopes are marked by numerous slump scars, some 1-2 km wide (Figure 17). The sedimented central slope is mostly gently undulating, with minor relief due to sediment drifts and shallow channels, plus small fault scarps (<50 m high) (Figure 18). Low-amplitude WNW-trending sand waves on the crest of Coriolis Ridge indicate moderate bottom current activity in a NNE-SSW direction.

4.2. Northwest margin of Kenn Plateau

The 3-line swath survey mapped the lower slope of the northwest margin of Kenn Plateau from the adjacent Cato Basin, about 3000-3150 m deep, to roughly the 2500 m isobath on the slope (Figure 11). The basin floor and marginal slope exhibit sharply contrasting surface texture. The basin floor is very flat, with basin fill probably mainly aggradational turbidites derived from the slopes above, while the adjacent marginal slope is irregular and rough, with minor canyon development. Dredging (DR6 & 7; Figures 11, 16, 19 & 20) shows that the slope is underlain by calcareous ooze and chalks as old as Middle Eocene. The lower marginal slope is relatively steep, typically with a gradient of about 7°. The rugged nature of the lower slope is attributed to slumping of carbonate deposits, with erosion by bottom currents and neotectonic faulting (Cato Basin is tilted westward – see Seismic Line 12, Figure 43) possibly contributing to the nature of the erosional and depositional features.

4.3. Western Kenn Plateau

The western corner of the Kenn Plateau is complex structurally and morphologically, having evolved as a transform margin and also being the site of extensive 30 Ma hot-spot volcanism that produced the 20-km diameter Cato Seamount plus numerous surrounding volcanic edifices (Figure 12). The 4-line swath survey mapped the lower and mid slope of the margin adjacent to Cato Trough and Cato Basin. Swath coverage in this area is augmented by a number of criss-crossing single-swath lines. A large satellite guyot west of Cato Seamount was almost fully mapped. Dredge site DR11 is located on the northern flank of this guyot which has a diameter of 10 km at the base and is 1300 m high (Figures 12, 21, 22 & 53). Dredge sites DR10 and DR9 are located on canyon walls on the lower marginal slope (Figures 12, 21 & 23).

The upper part of the satellite guyot is 3.7 km in diameter and rises steeply from about 1000 m water depth. Its shallowest point is 423 m deep (Figures 12 & 22). DR11 recovered reefal framework limestone from 1000-800 m depth, and a seismic profile (Figure 53) indicates that it is at about 1000 m depth. As the base of the carbonate platform is at about 1000 m depth, about 1000 m of subsidence has occurred since 30 Ma, and the thickness of the carbonate platform is about 580 m. A 100-m high, WNW-trending scarp divides the summit area into an elevated northern half and a deeper southern half (Figure 13). The offset could be fault related, but it appears that the final phase of carbonate growth was restricted to the northern half. A number of parasitic cones 50-200 m high are located on the lower slopes of the guyot. Scattered volcanic peaks, rising as much as 300 m above the sediment surface, surround Cato Seamount to a distance of 40 km (Figure 12).

The marginal slope is relatively steep, with typical slopes being 7°-14°. A number of large canyons incise the slope and debouch onto the flat floors of the Cato Trough and Cato Basin. Several are 2 km wide and at least 10 km long. The largest of these, with steep walls 400 m high, is located northwest of the satellite guyot, and is here named Cato Canyon (Figures 12 & 21). Many of the canyons trend WNW-NW, probably reflecting underlying structure.

4.4. Central Kenn Plateau

A number of single-swath lines provide detail on the seabed topography of parts of the central Kenn Plateau (Figure 13). A local topographic high on the Southern Surveyor Rise was partly mapped by a short 3-line swath survey. This high, which is dome-shaped and 15-20 km across, rises steeply from a relatively flat sediment plain about 2100 m below sea level (Figure 24). The shallowest point mapped on the crestal area of the high is 1650 m deep, making this feature about 450 m high. Two similar highs, with summit areas 1550 m and 1600 m below sea level, are located in the area (Figure 24). Seismic profiles suggest that the highs represent diapiric structures, probably cored by intrusive volcanics. The surface texture of the highs varies from smooth to moderately rough, signifying that some erosion by bottom currents has occurred.

Small-scale faulting associated with the diapirism, and subsequent tectonic movements, may have facilitated erosion locally and contributed to seabed relief.

4.5. Fraser Seamount

The swath survey of Fraser Seamount (Figures 14 & 25) showed it to be a guyot, with a 4-km diameter flat top. The shallowest point is 361 m deep. Apart from the flat top, the seamount is roughly conical in shape, with steep gullied flanks commonly inclined at 16°-24°. A bench, presumably cut by wave-base erosion when the volcano was emplaced ~28 Ma, is present at 1350 m depth (Figure 25). Above this is a larger terrace, about 1030 m deep, which may represent the original subaerial erosion surface of the volcano, possibly modified by wave-base erosion as the edifice subsided. Above this terrace, the seabed rises steeply to the flat upper surface of the guyot. DR5 recovered basaltic volcanics from 1600 m depth on the steep southern flank of Fraser Seamount (Figures 14 & 25); DR4 recovered reefal limestone from 450 m just below the platform rim on the northern side of the seamount. These results suggest that the steep-sided platform above about 1000 m water depth is a carbonate platform constructed on a subsiding volcanic edifice. The carbonate platform would be about 600 m thick, which is almost identical to the interpreted thickness of the platform on the Cato satellite guyot. The similarities in depth, thickness and morphology of these platforms imply similar post-eruption subsidence histories of the seamounts.

4.6. Dredge site DR2, southwest margin of Kenn Plateau

As shown by Seismic Profile 7 (Figure 39), dredge site DR2 is located on the upper part of the Kenn Plateau continental slope. On this part of the margin, the continental slope rises steeply from the abyssal plain 4600 m deep to the top of the slope at 2400 m depth. It has a fairly uniform incline of 4°. The seismic profile also shows that DR2 is located close to a major, 200-m high fault scarp. The swath map of the local area (Figure 15) indicates that the fault scarp trends NNW, and that the mid-point of dredge haul DR2 is located on the upper part of a 120-m high fault scarp (Figure 26) that forms part of the fault system. The reddish-brown sandstone within the breccia recovered at DR2 may be a correlative of the thick Late Cretaceous-Paleocene redbed sequence intersected in the Aquarius 1 well in the Capricorn Basin (Hill, 1994).

5. PRELIMINARY INTERPRETATION OF SEISMIC PROFILES

Yves Lafoy

5.1. Geological setting - former studies

The Kenn Plateau is a broad high area to the east of the Cato Trough off eastern Australia, and is mostly shallower than 2250 metres below sea level. It is divided into the northern and southern Kenn Plateau by a WSW-trending depression that lies east of Wreck Reef (Observatory Basin; Figure 7). To the south is the Tasman Basin, and to the west are the Cato Basin and Trough and the Marion Plateau (Figures 27-30).

The Kenn Plateau lies within the “rift and valley province” described by Falvey (1972). This province is made up of several dissected blocks of stretched continental lithosphere, including the Kenn Plateau. According to Walker (1992), the Kenn Plateau consists of two distinct structural blocks: northern and southern. Their tectonic and sedimentary history is related to regional events of rifting, seafloor spreading, volcanism and plateau subsidence. According to Willcox (1981), the interpretation of BMR seismic line 13/035 over the southern extremity of the Kenn Plateau (Figure 4) strongly suggests that a rift-valley sequence, at least 2000 m thick, underlies a post-breakup sequence. According to the same author, the considerable water depth of the Kenn Plateau (1000 to 2000 m) may be a further indication of thinning caused by its rift-valley origin.

Multichannel seismic line WNC 118, from the Ouest Nouvelle-Calédonie (WNC80) survey carried out in 1981, cross-cuts the southwestern edge of the Chesterfield-Bellona Plateau, east of Kenn Plateau. This NE-SW-trending line shows that the plateau is underlain, at water depths of 1800-2100 m, by an eastward-tilted block with sedimentary deposits 2500 m thick (Guignard and Ravenne, 1982). According to these authors, the tilted block probably results from the late expansionary/accretionary phase of the Tasman Sea. However, it is difficult to know if such Tasman Sea sedimentary deposits extend beneath the Chesterfield-Bellona Plateau, the latter being capped by a reefal bank.

More recently, the eastern part of Coriolis Bank (Ridge) located west of the Chesterfield-Bellona Plateau at the eastern side of Kenn Plateau, has been investigated during the ZoNéCo 4 geophysical (multibeam bathymetry, gravity, magnetic and 6-channel seismic) survey (Le Suavé

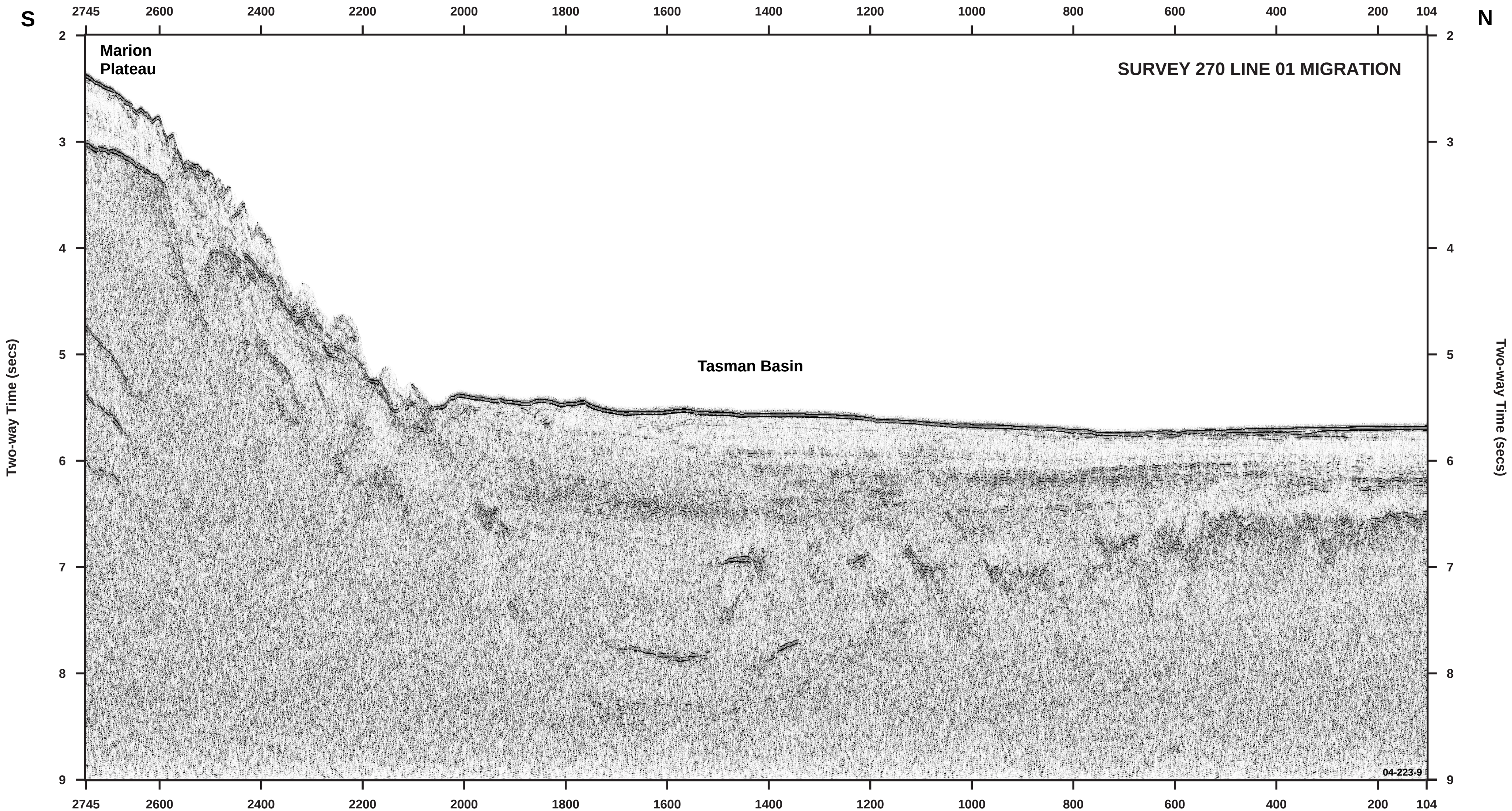


Figure 27. Seismic profile 270-1

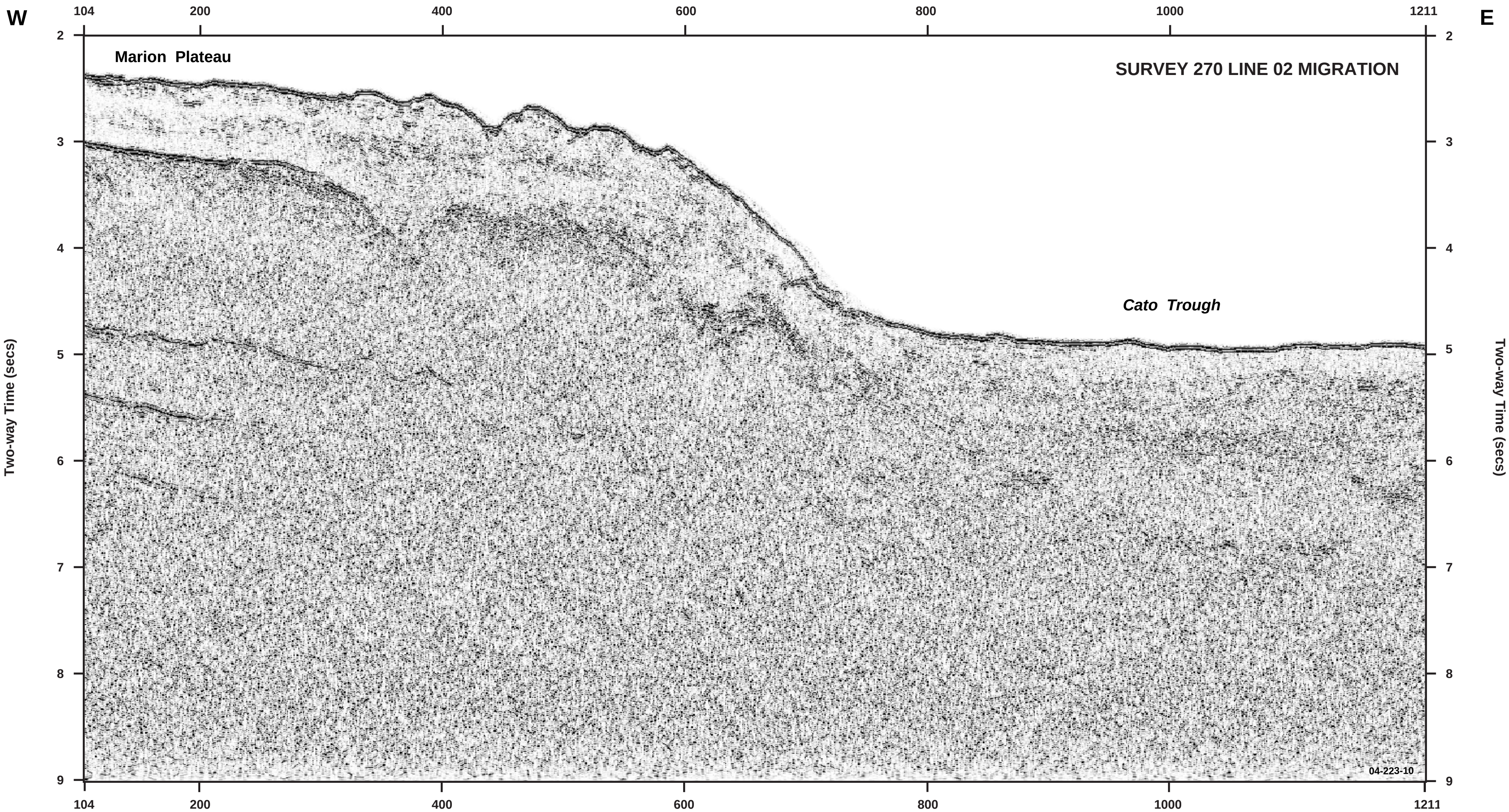


Figure 28. Seismic profile 270-2

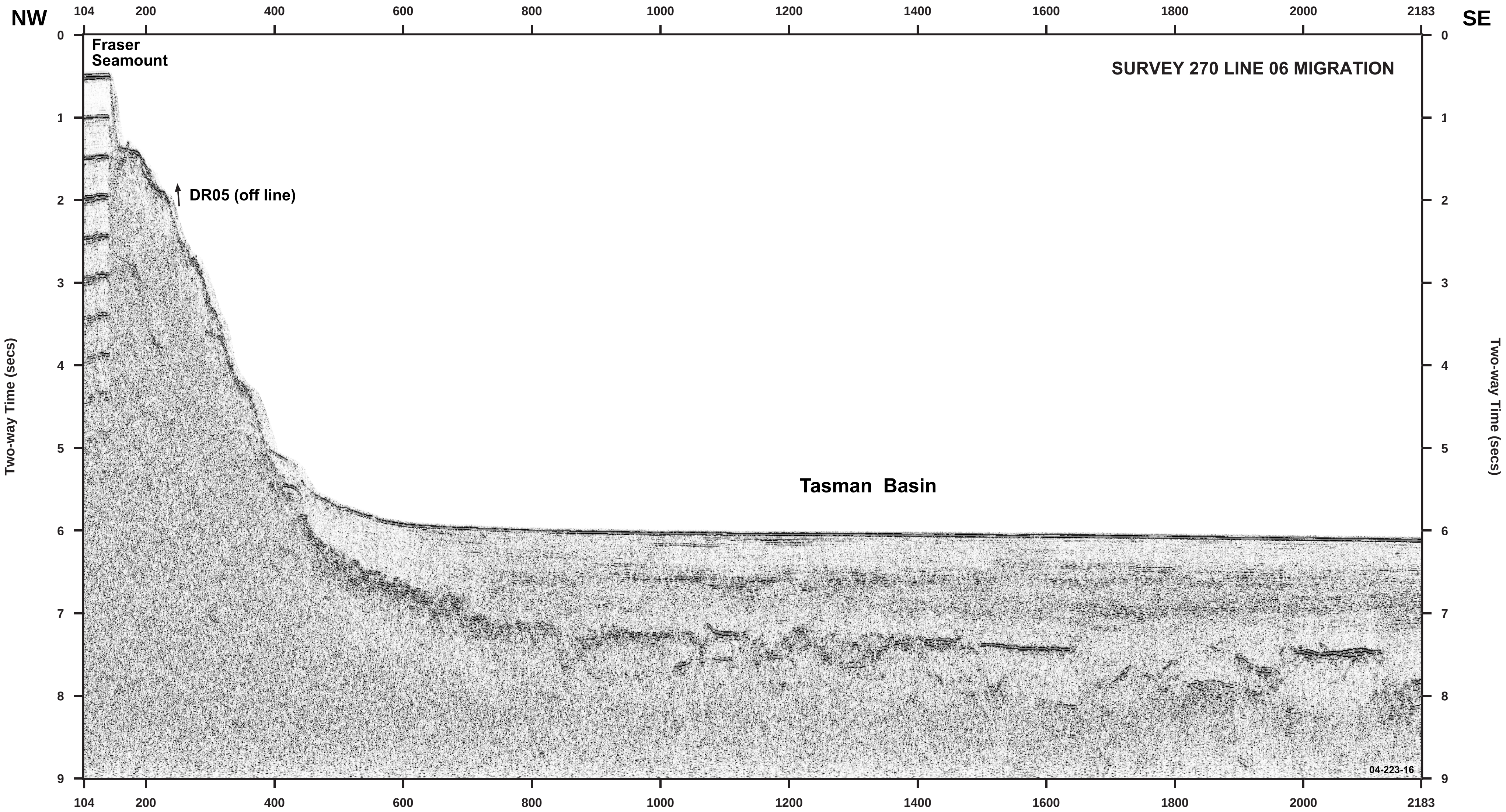


Figure 29. Seismic profile 270-6

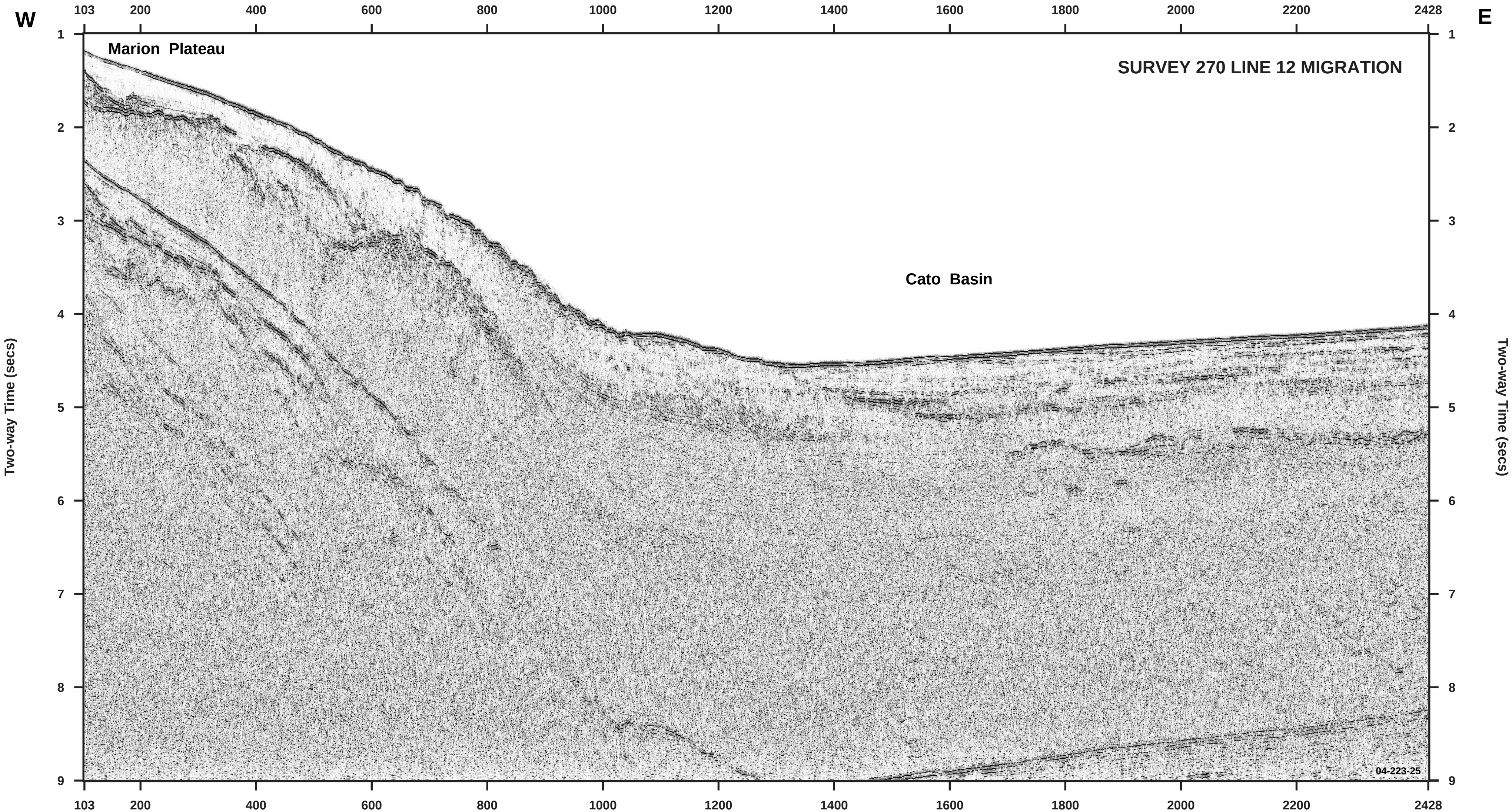


Figure 30. Seismic profile 270-12

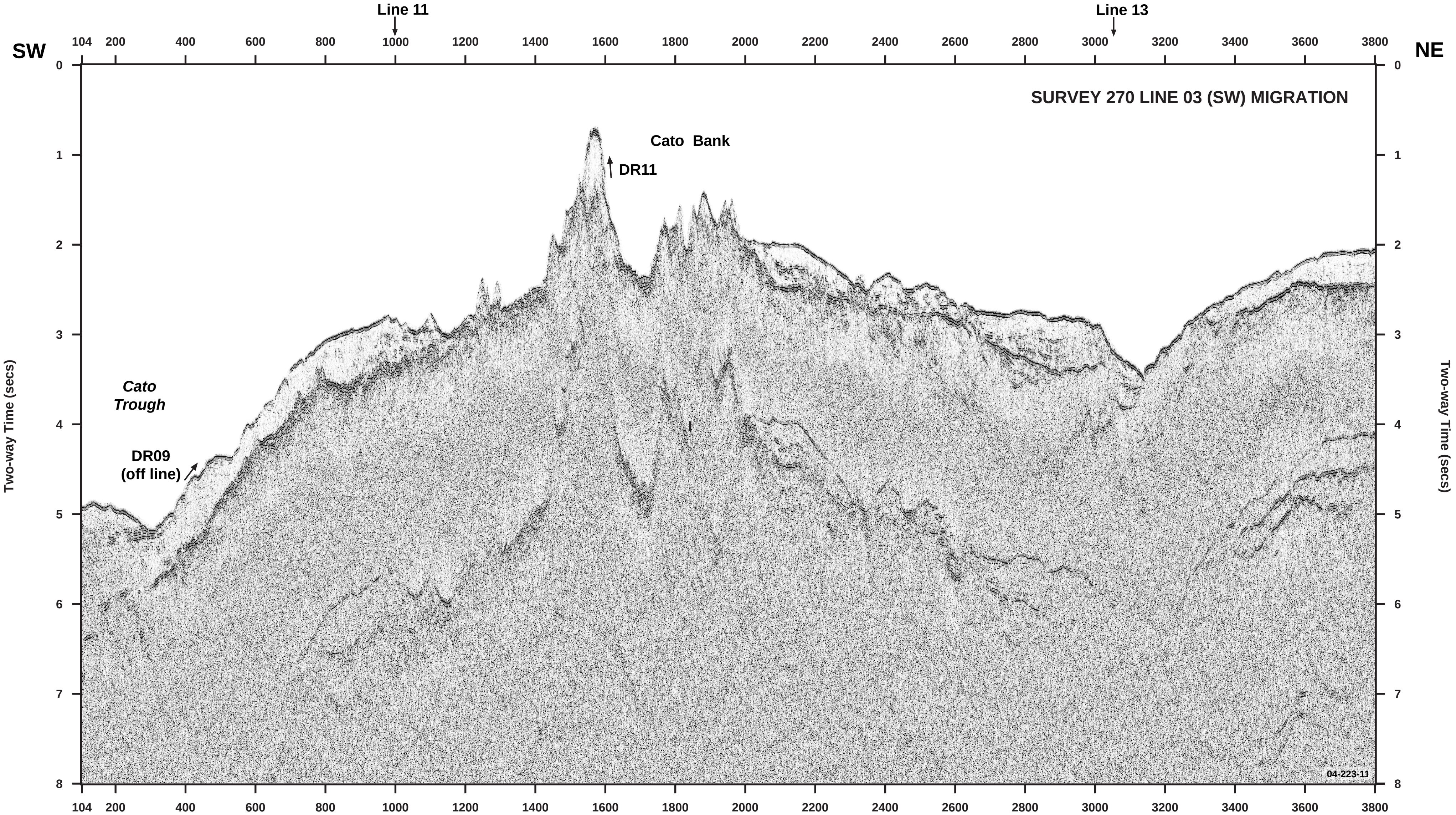


Figure 31. Seismic profile 270-3 (southwest part)

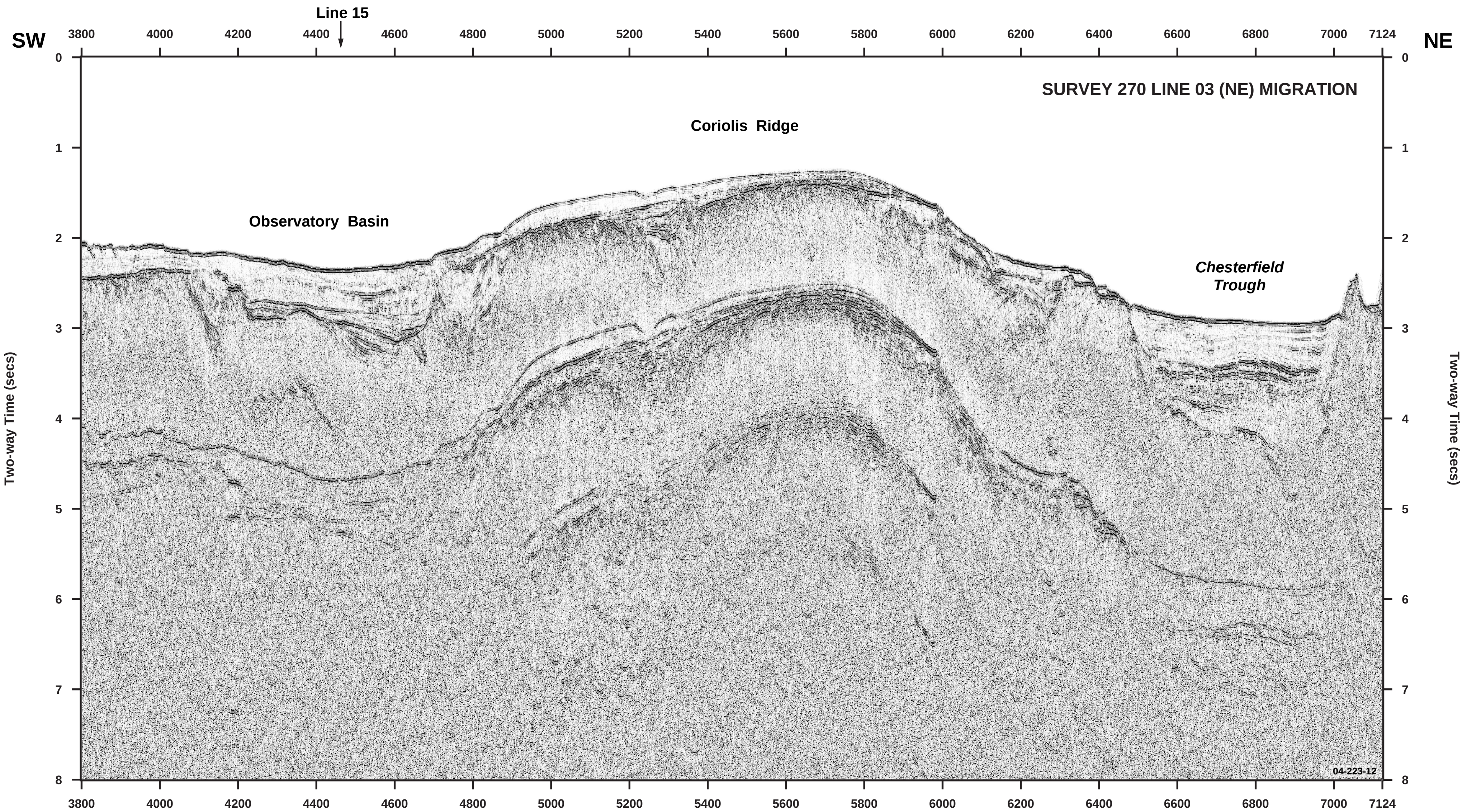


Figure 32. Seismic profile 270-3 (northeast part)

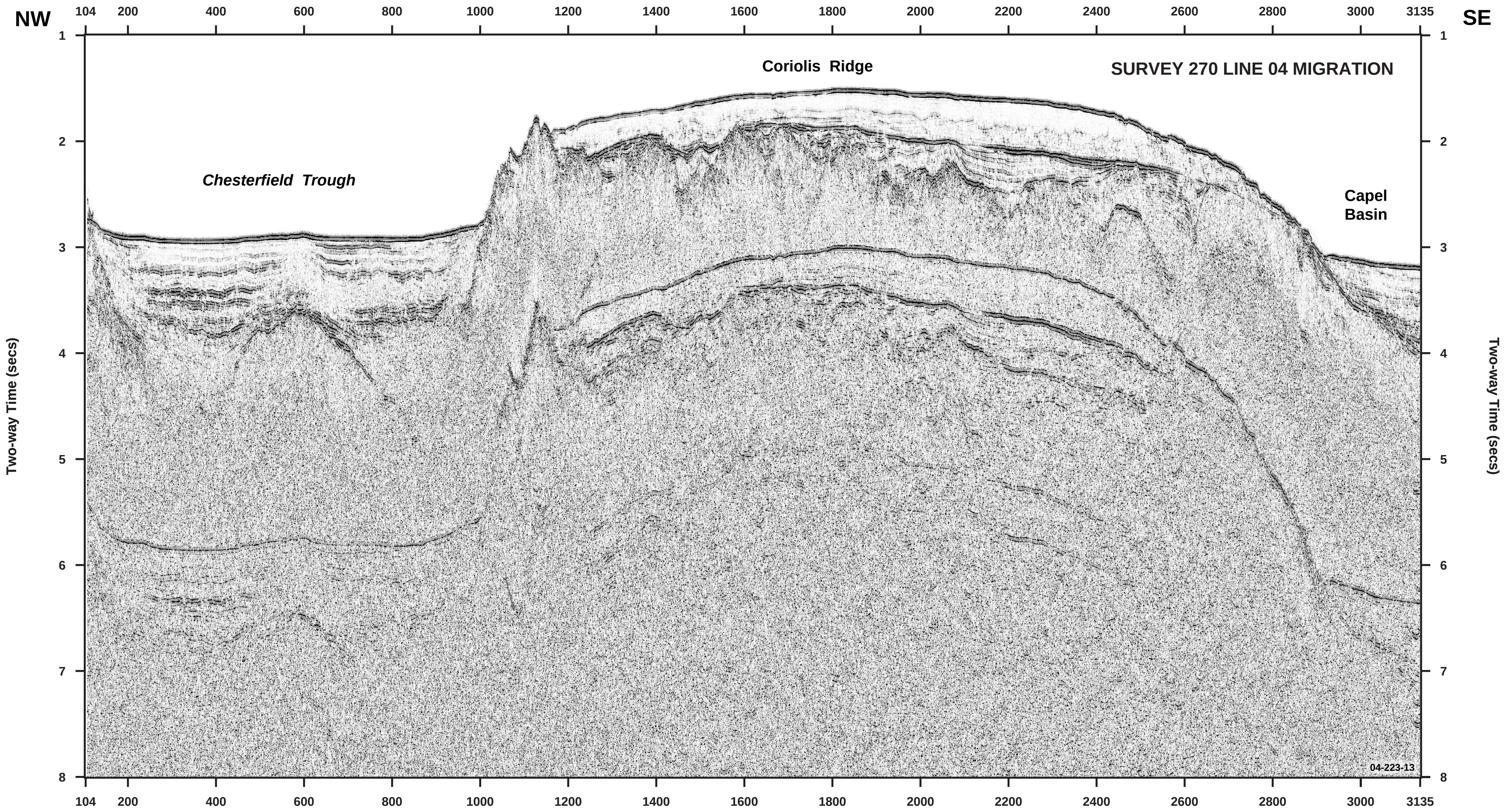


Figure 33. Seismic profile 270-4

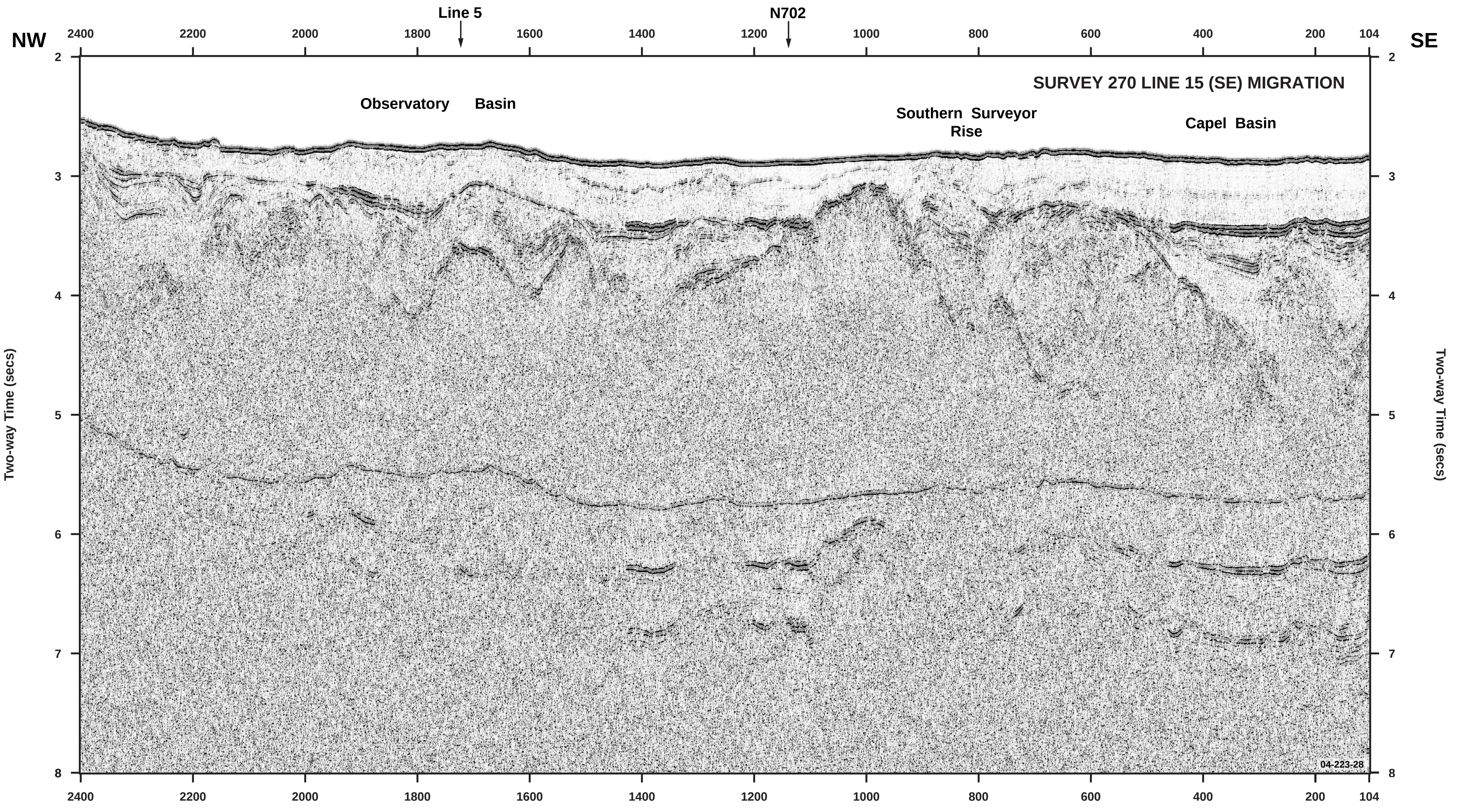


Figure 34. Seismic profile 270-15 (southeast part)

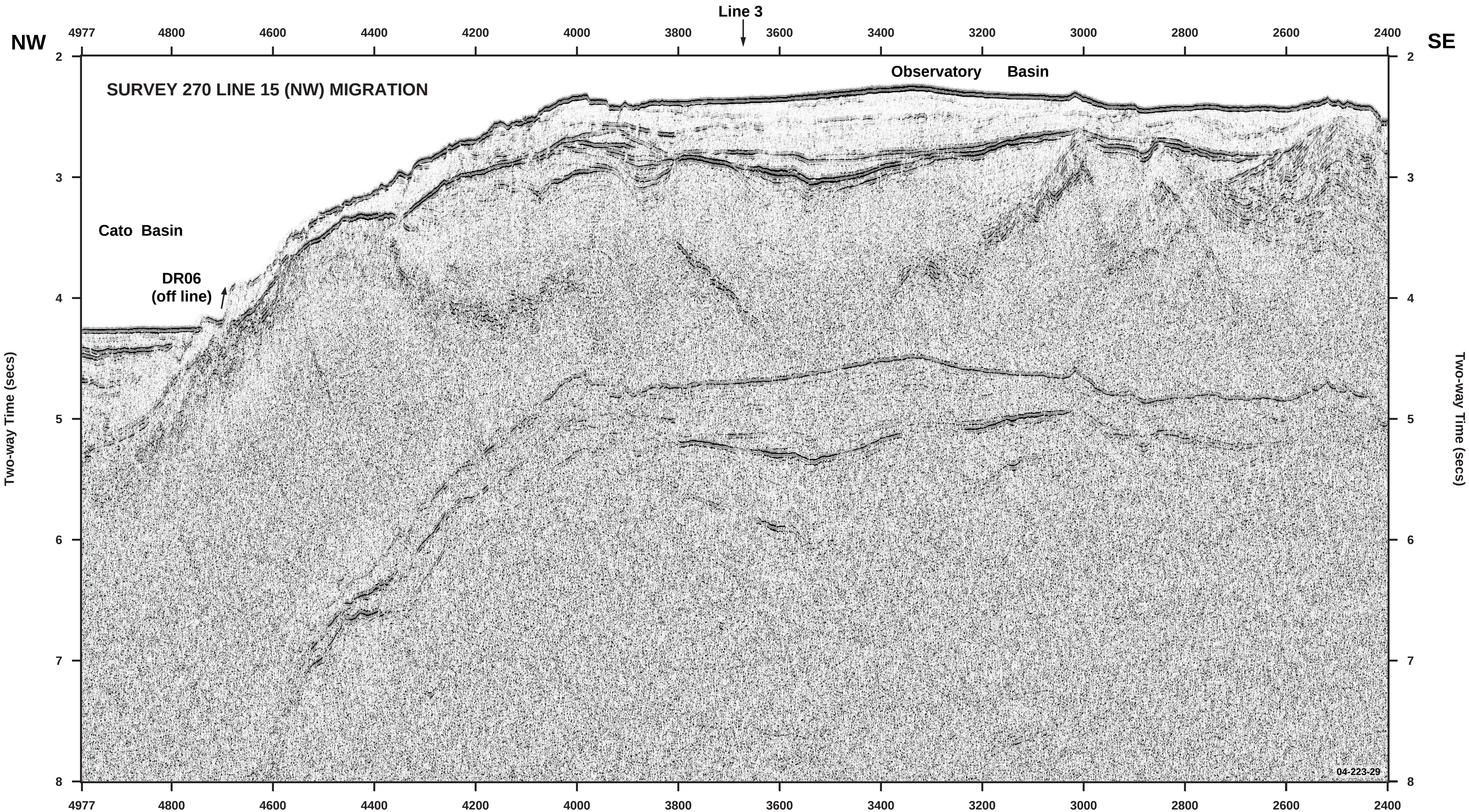


Figure 35. Seismic profile 270-15 (northwest part)

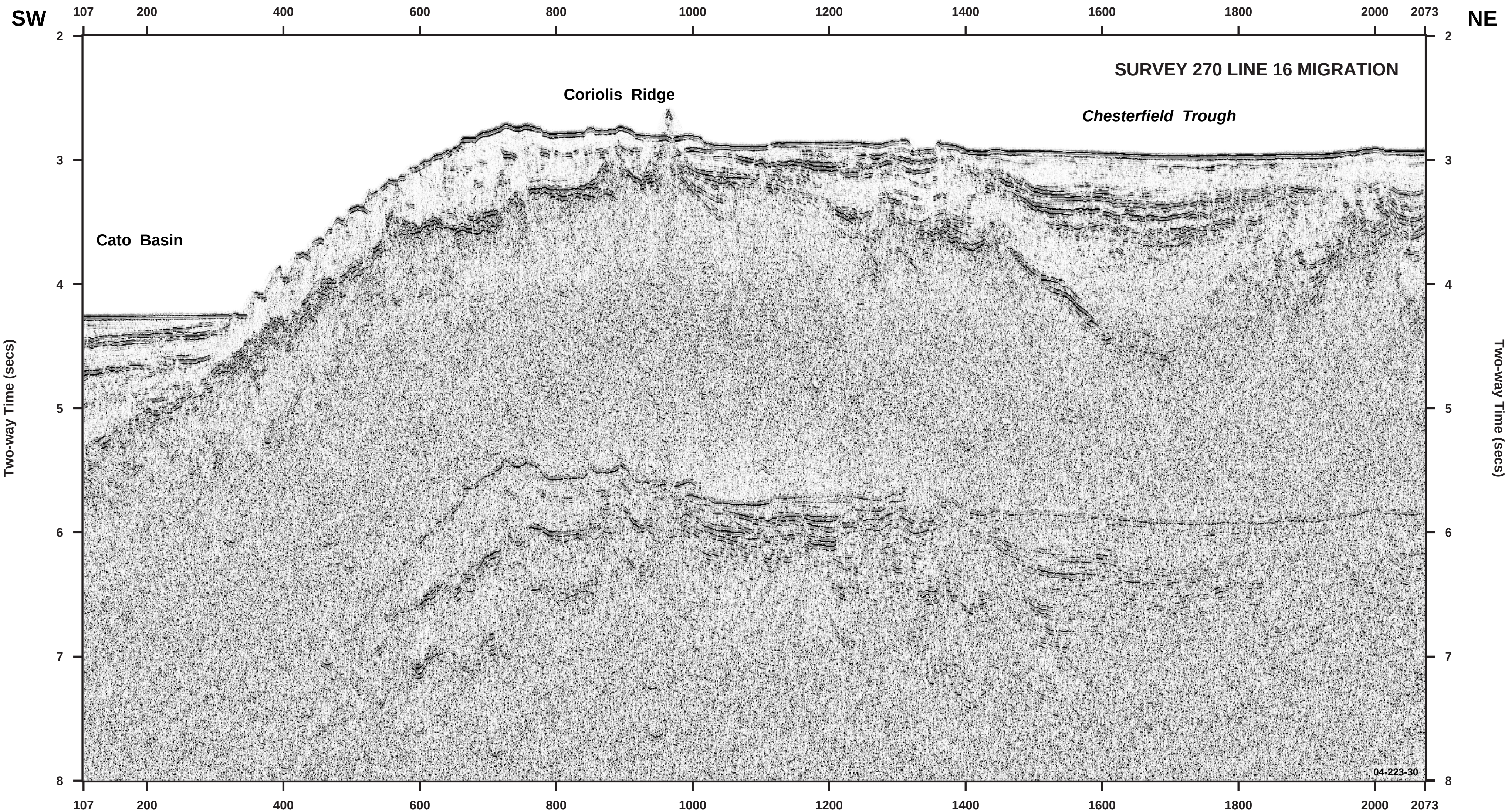


Figure 36. Seismic profile 270-16

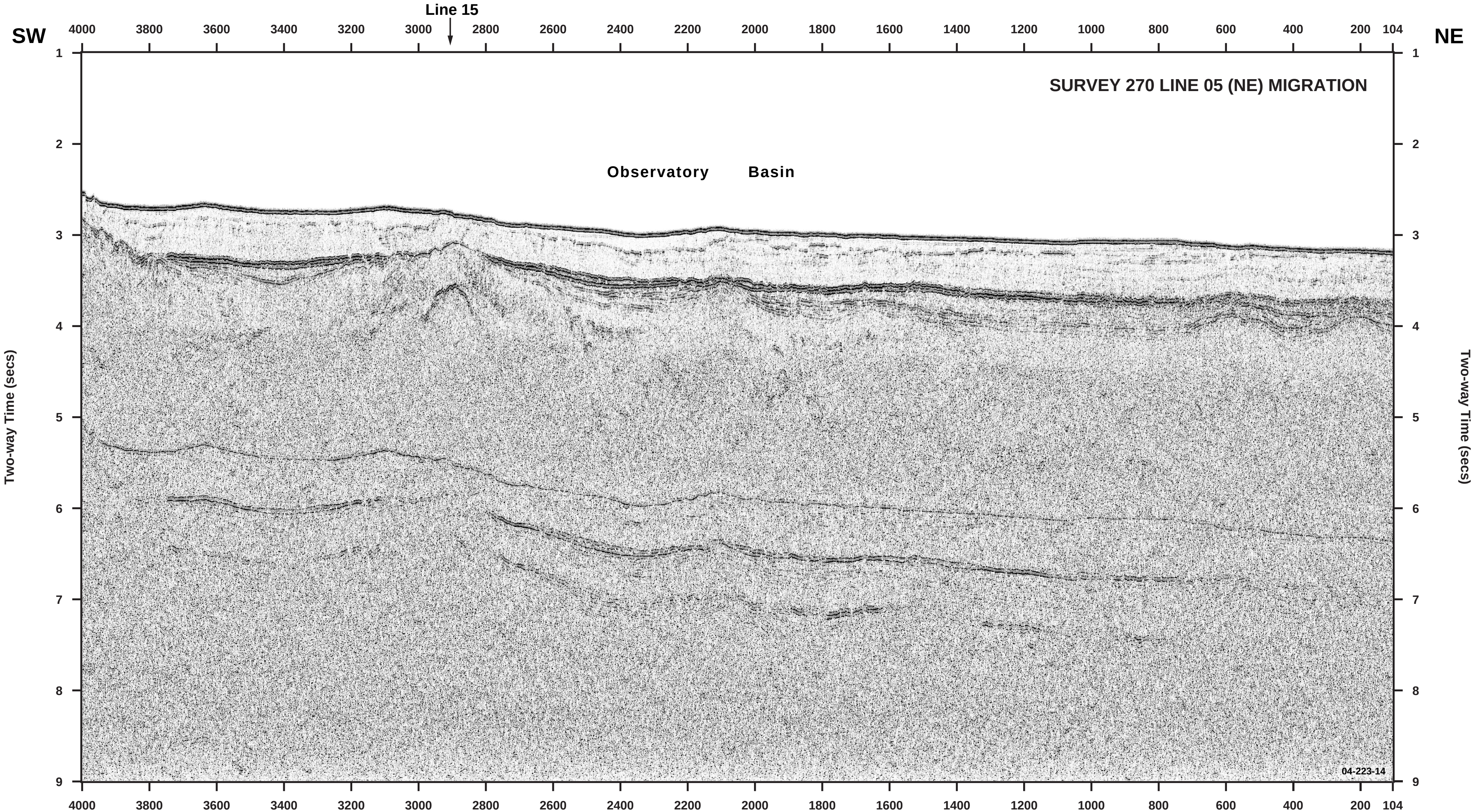


Figure 37. Seismic profile 270-5 (northeast part)

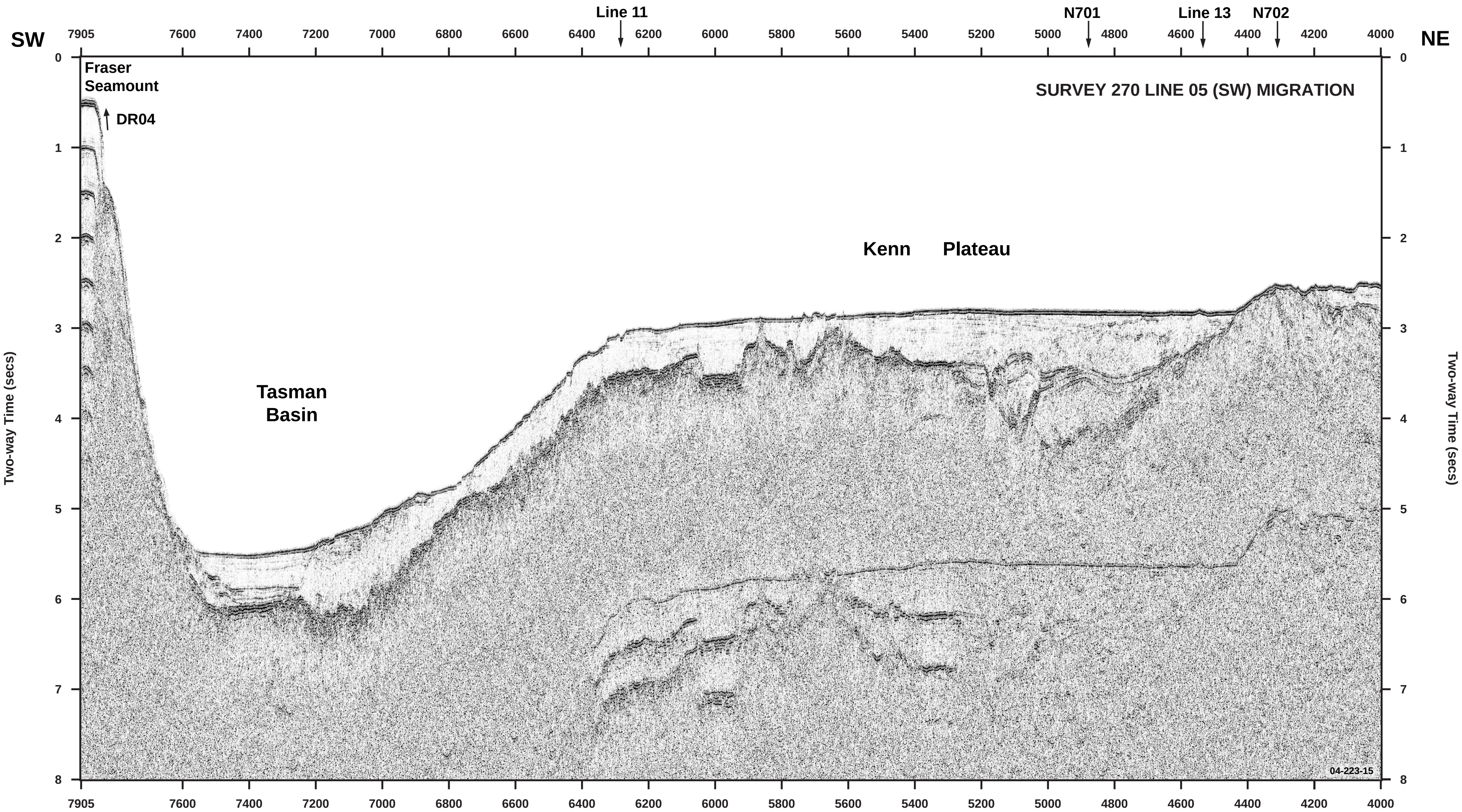


Figure 38. Seismic profile 270-5 (southwest part)

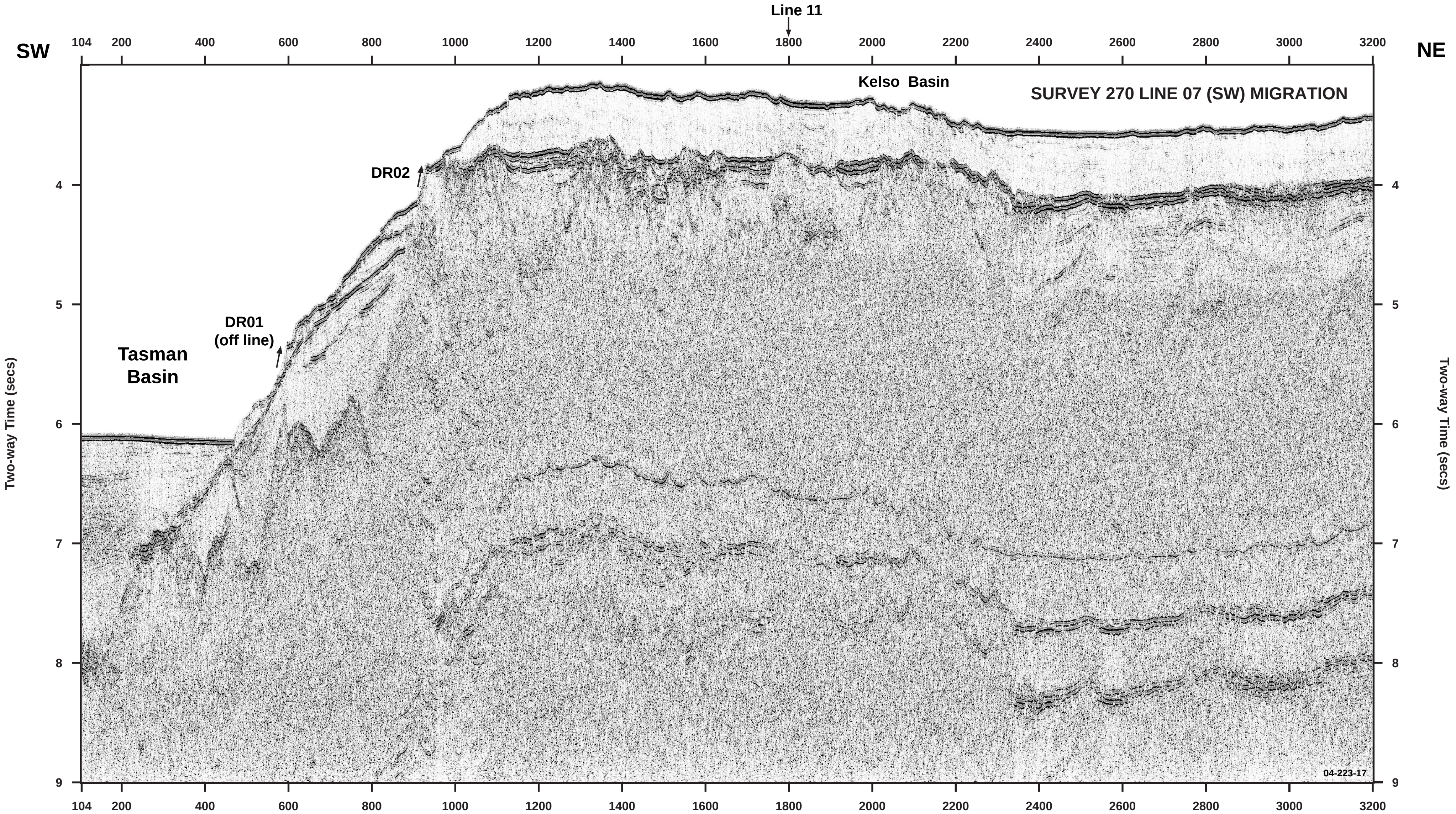


Figure 39. Seismic profile 270-7 (southwest part)

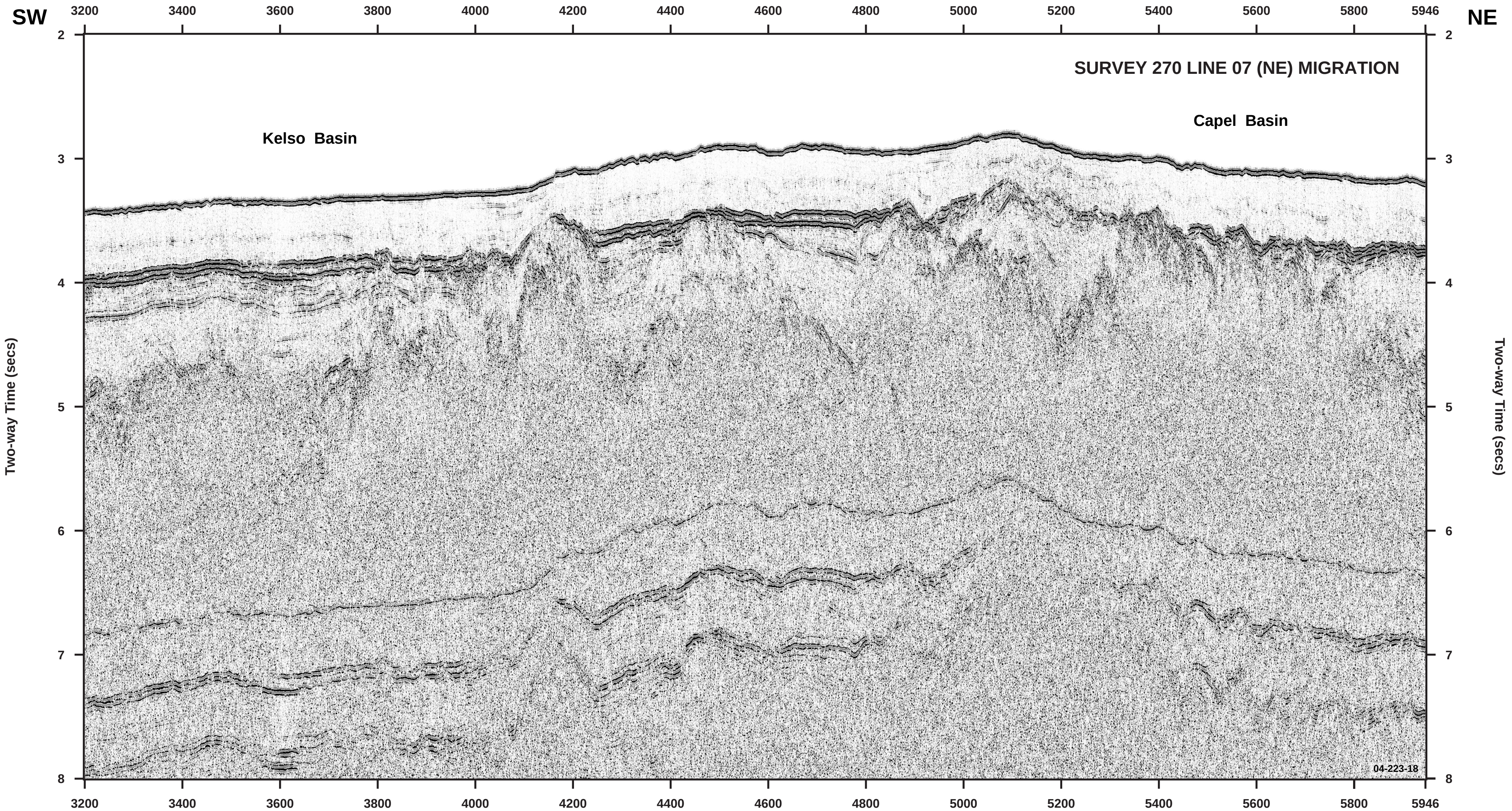


Figure 40. Seismic profile 270-7 (northeast part)

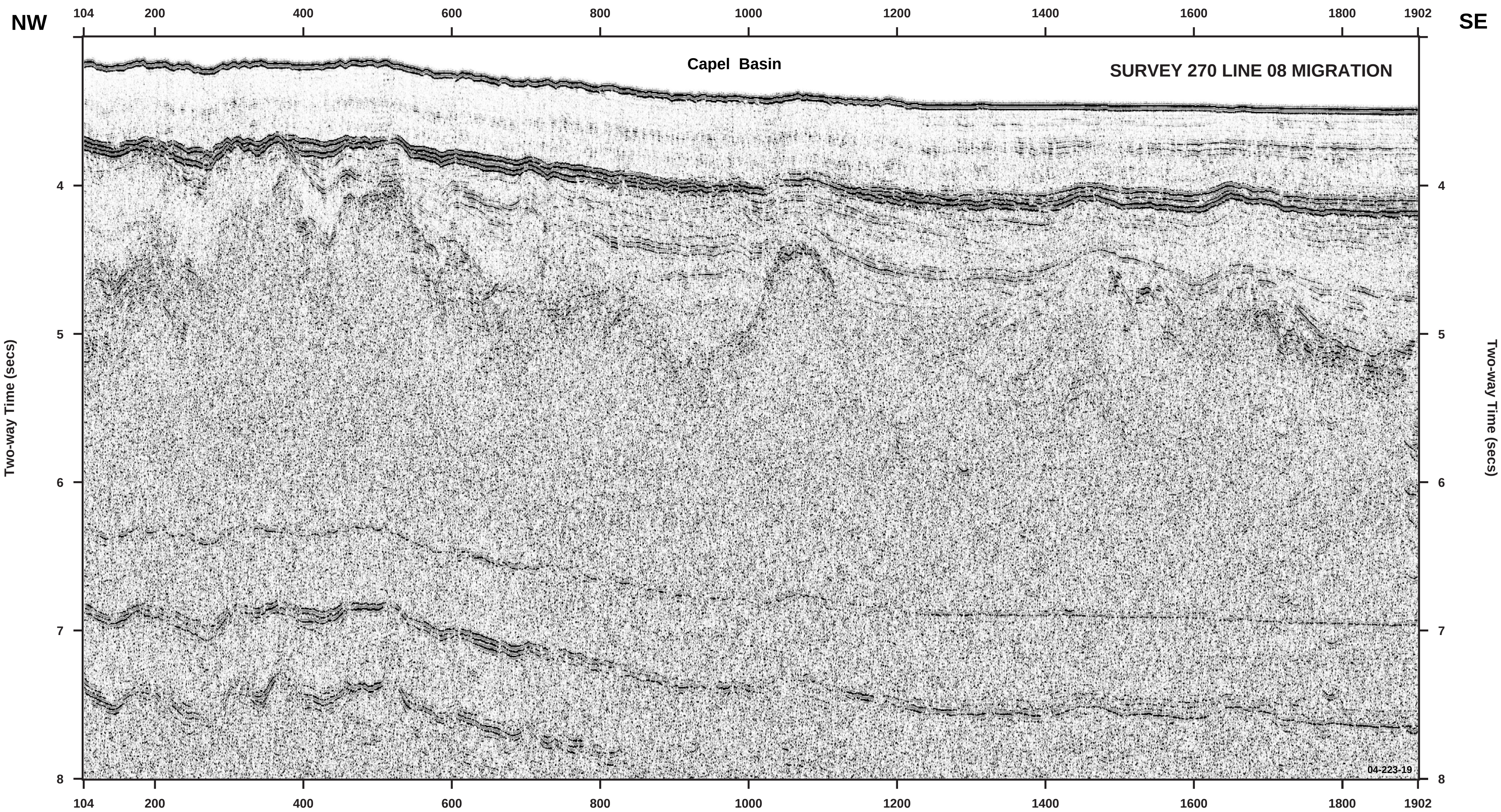


Figure 41. Seismic profile 270-8

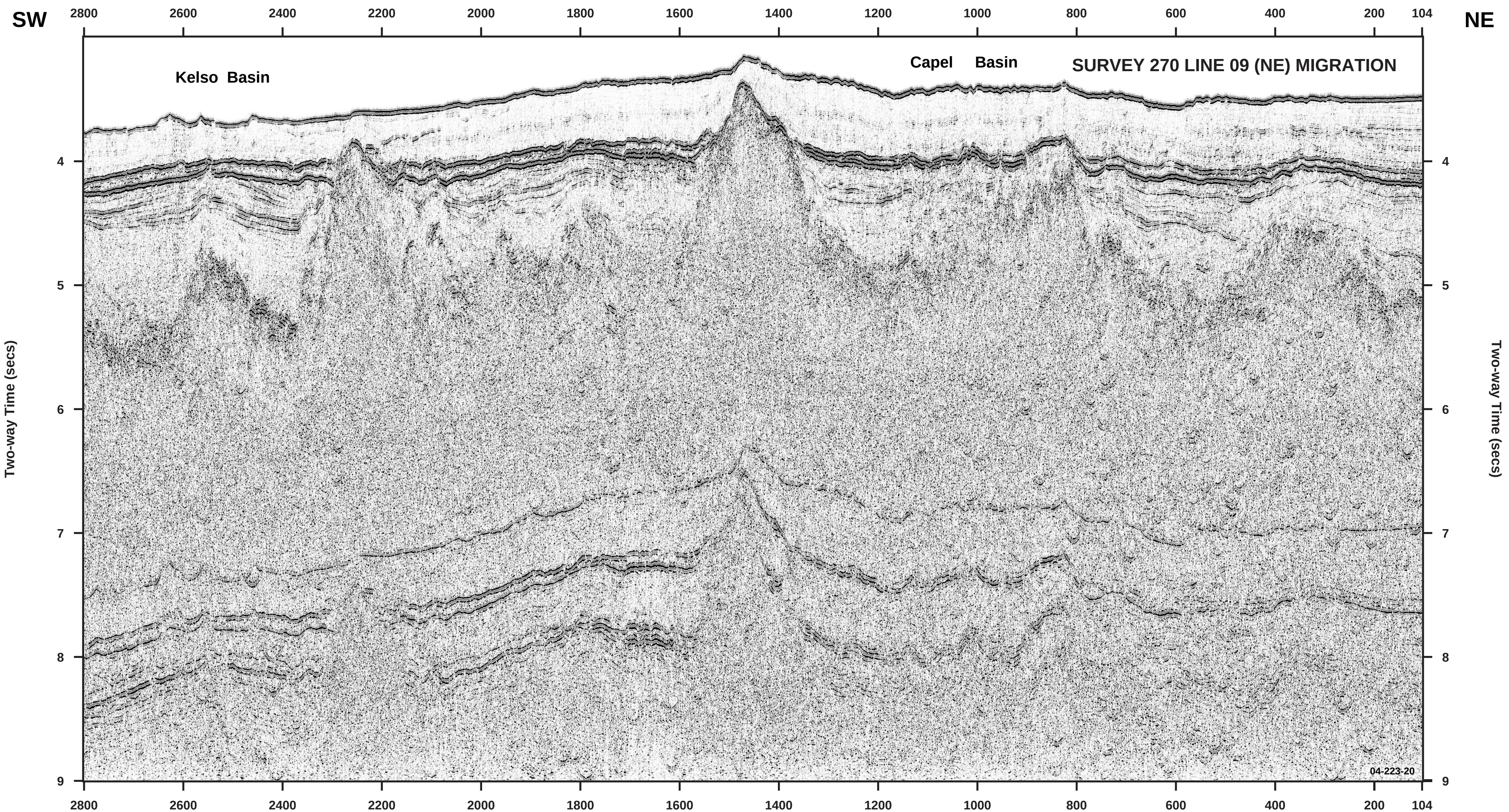


Figure 42. Seismic profile 270-9 (northeast part)

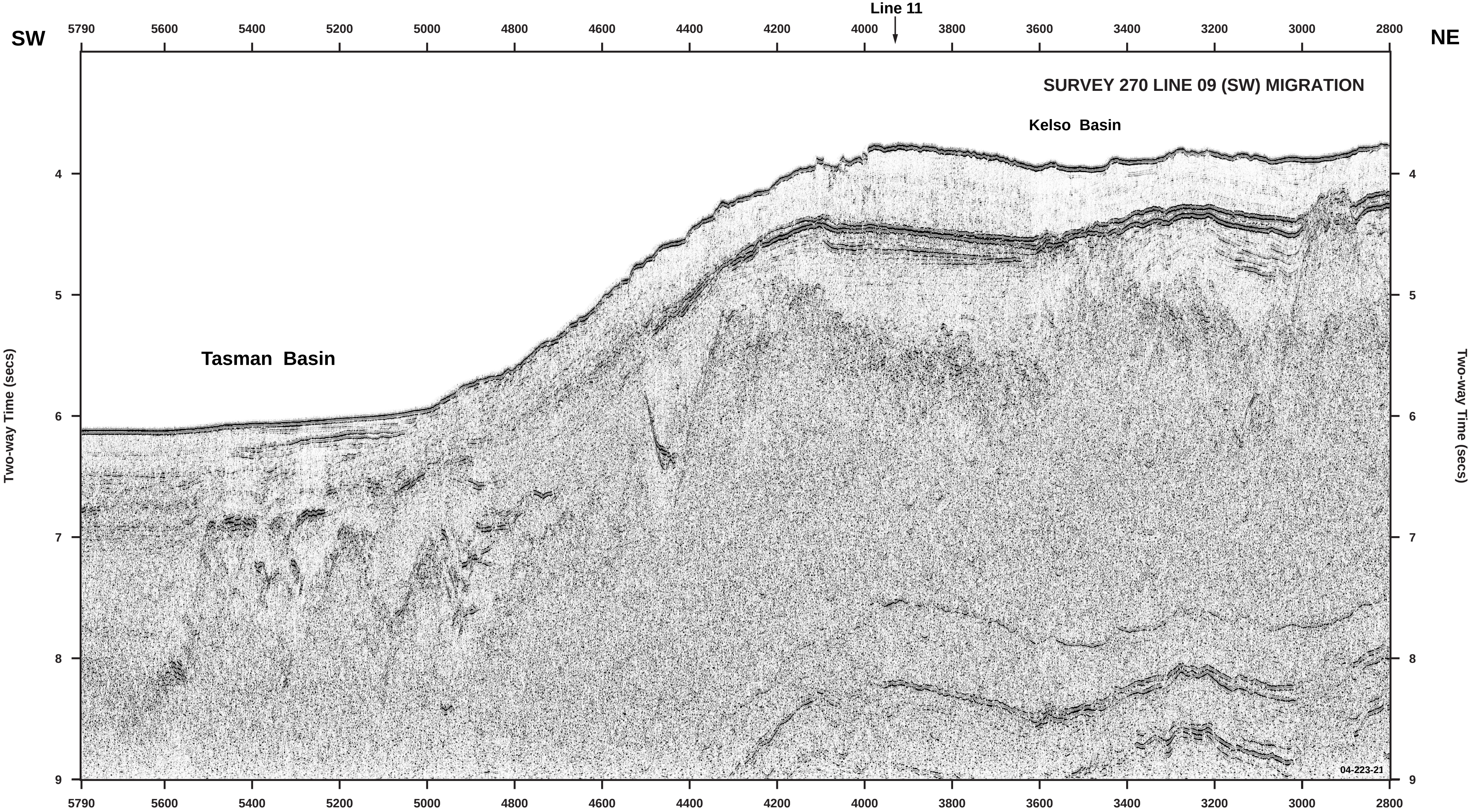


Figure 43. Seismic profile 270-9 (southwest part)

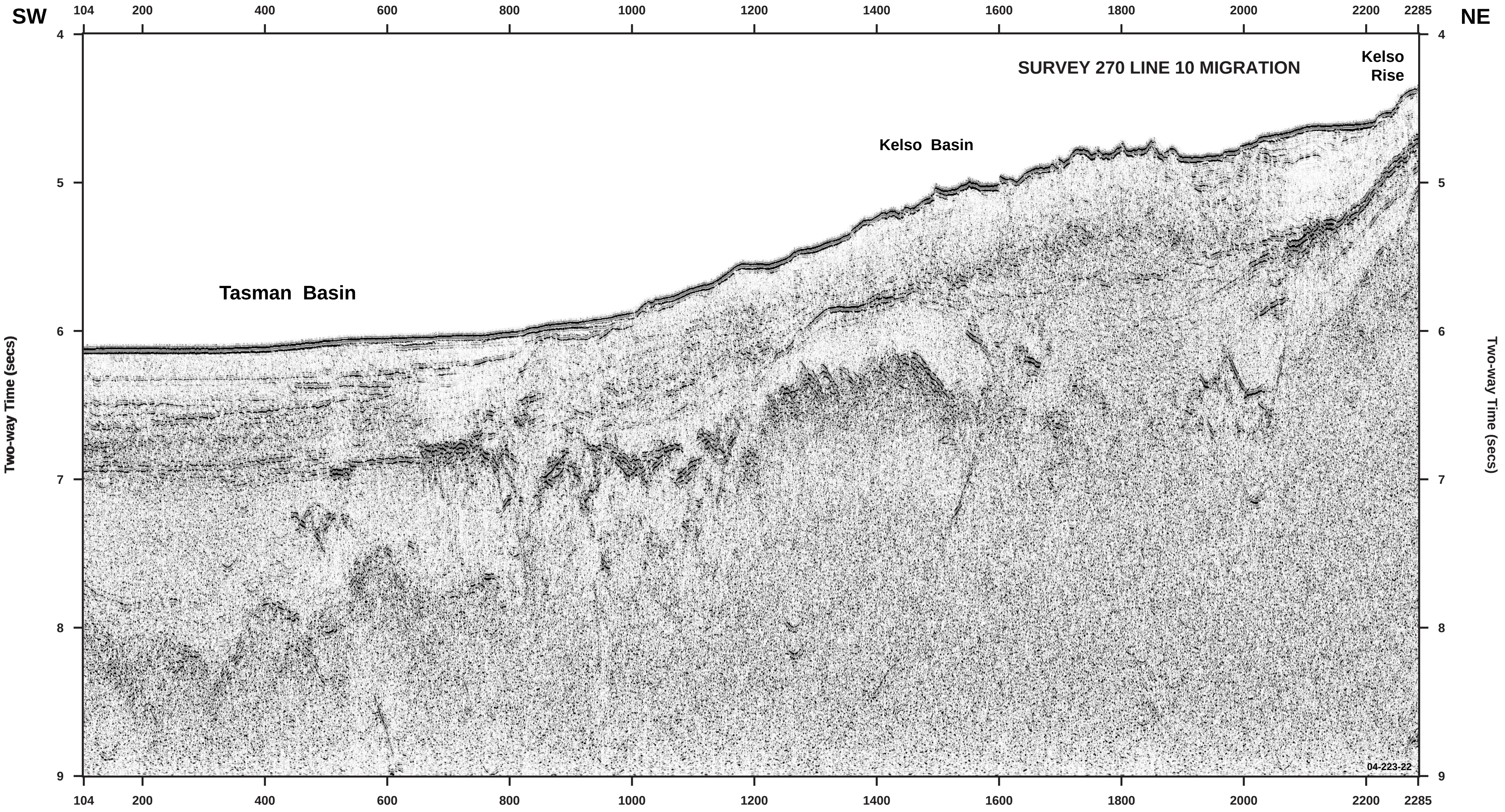


Figure 44. Seismic profile 270-10

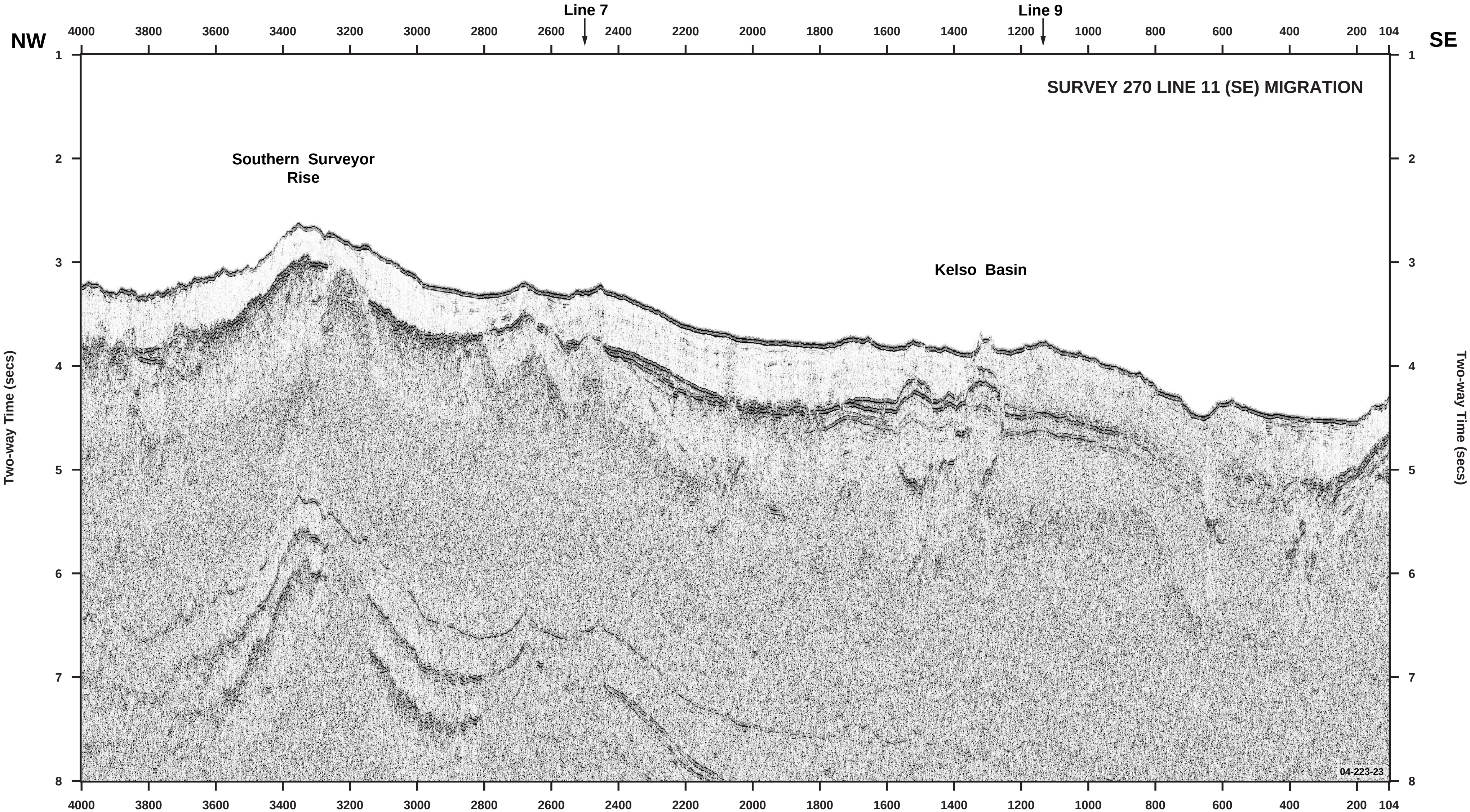


Figure 45. Seismic profile 270-11 (southeast part)

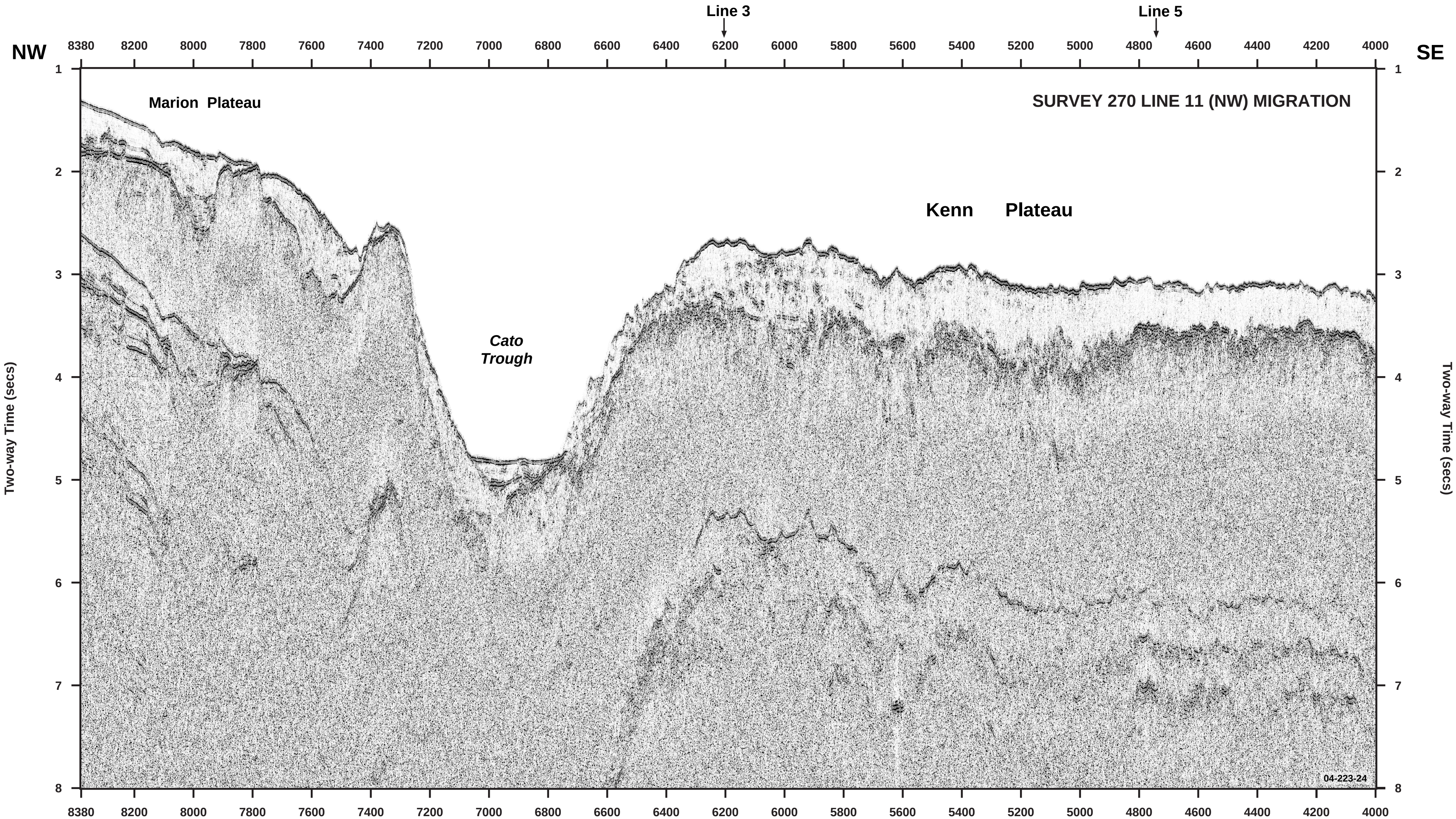


Figure 46. Seismic profile 270-11 (northwest part)

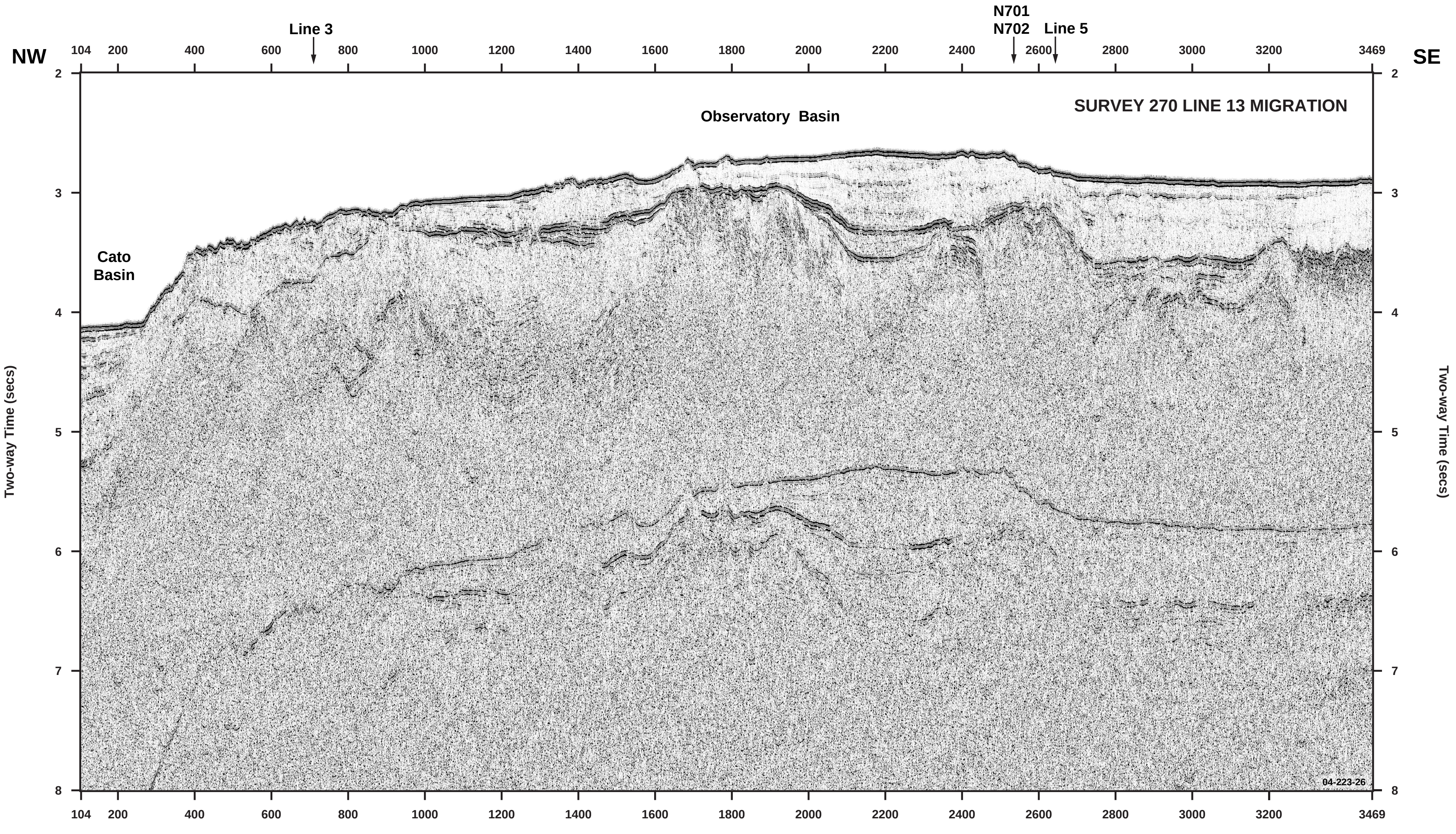


Figure 47. Seismic profile 270-13

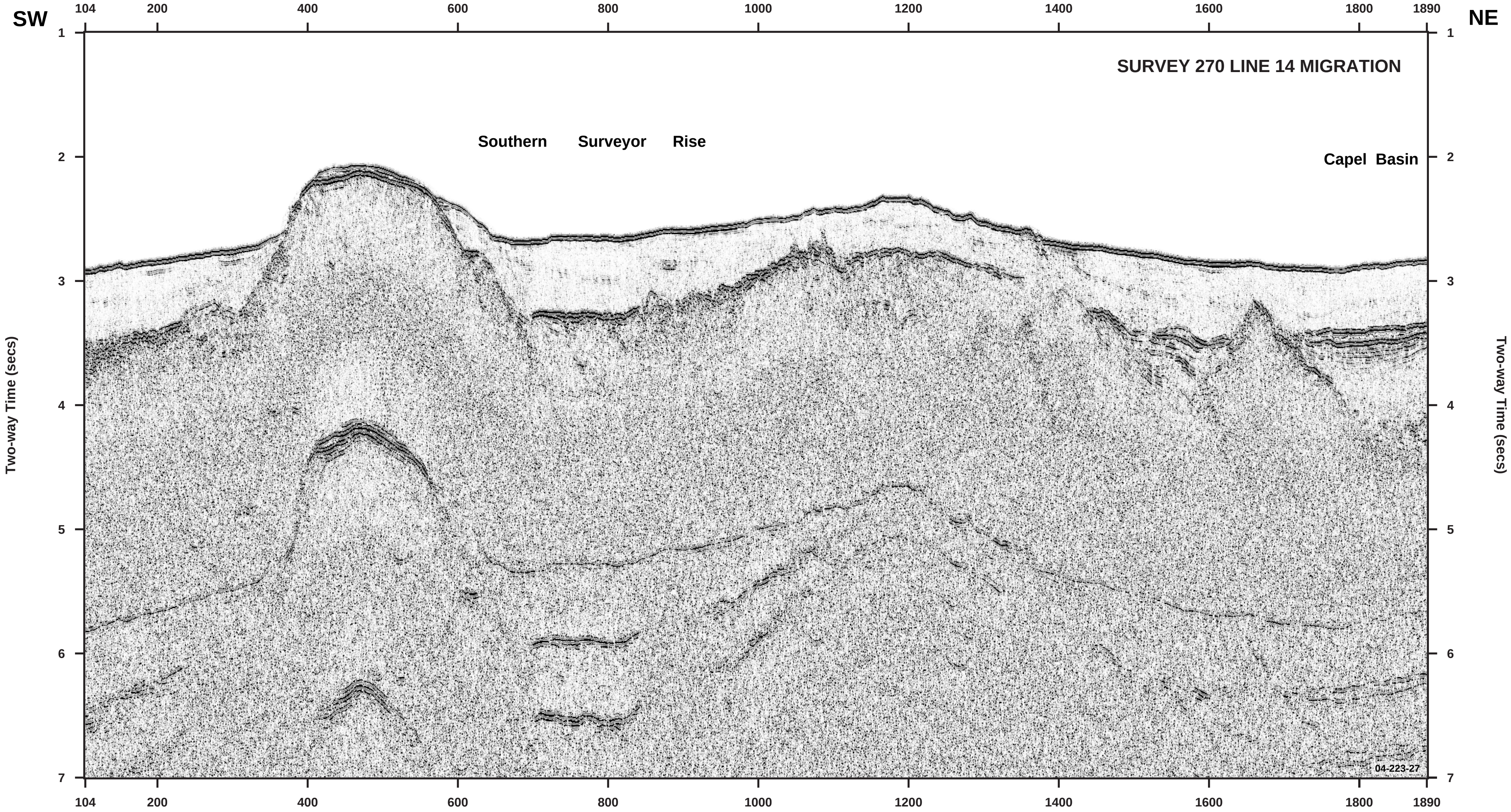


Figure 48. Seismic profile 270-14

et al., 1996). The Coriolis Bank culminates in a water depth of 960 m, and trends SW-NE. Its fractured basement shows a horst and graben morphology, with tilted half-grabens sealed by the Late Eocene – Oligocene unconformity, its age derived from DSDP Site 208 (Burns, Andrews *et al.*, 1973). To the northeast of a central basement rise, interpreted as the crest of a thinned, continental crust, the assumed thickness of the Cretaceous deposits reaches at least 1500 m (Lafoy *et al.*, 1996).

5.2. Main sedimentary sequences

The aim of *Southern Surveyor* Cruise SS5/2004 was to better understand the tectonic and sedimentary history of the Kenn Plateau, mainly through multichannel (24 channel) seismic data acquisition. Interpretation of the new seismic lines enables us to illustrate the structural style of the Kenn Plateau. It is divided into the northern and southern Kenn Plateaus by the WSW-trending, 2400 m-deep Observatory Basin.

Identification of seismic sequences and unconformities is based on broad correlation of our multichannel seismic data with DSDP Site 208 (Burns, Andrew *et al.*, 1973) located on the Lord Howe Rise (Table 2). Edwards (1973) showed that the younger unconformity is the regional Eocene-Oligocene unconformity, which spans at least the late Late Eocene and the early Early Oligocene. The older unconformity is the Paleocene-Eocene unconformity, which was recognised in DSDP Sites 206, 207 and 208, and spans at least all of the Late Paleocene and the early Early Eocene. Three main sedimentary sequences were established on board and dated from DSDP information and our dredge ages. The sedimentary sequence is as follows (from youngest to oldest sediments):

- Sequence I: Seismic Unit I can be directly correlated with DSDP borehole 208 that indicates that it postdates the Late Eocene - Early Oligocene regional unconformity. Seismic sequence I, characterised by low amplitude and continuity reflectors, is therefore dated as post-Eocene. Unit I is continuous throughout the whole study area as it represents a post-tectonic depositional event. Its thickness is relatively consistent and continuous and averages 0.6 s (twt).
- Sequence II: Seismic unit II, also sampled by DSDP borehole 208, is variable in thickness, probably due to the uplift and erosion of the summits of high-standing features as a result of Middle to Late Eocene compressive events in New Caledonia (Avias, 1967;

Paris, 1981). It is assumed to post-date the Late Paleocene to Early Eocene unconformity. In the basins, Unit II is more consistent in thickness, averaging 0.3 S (twt) and is believed to include Middle to Upper Eocene section. Within our study area, Unit II is interpreted as being deposited during the Eocene uplift phase of the ridges off eastern Australia, such as the Dampier Ridge and the Kenn Plateau.

- Sequence III: This seismic unit overlies acoustic basement and is bounded at its top by a strong reflector. This sequence, characterised by seismic reflectors of strong and continuous amplitude, thickens toward the central feature of the surveyed area, the WSW-trending Observatory Basin, where it can reach a maximum of 1.2 s (twt). Sills and lava flows can be identified within this sequence. On the grounds of tectonic history, the seismic sequence is thought to represent an accretion phase in the Late Cretaceous and Early Paleocene, in response to Early Cretaceous rifting throughout the area off the eastern Australian continental margin, and Late Cretaceous uplift and erosion in the Maryborough Basin (Hill, 1994) that shed sediments into what became the Kenn Plateau.

5.2.1. The Northern Kenn Plateau (north of the Observatory Basin)

This shallowest part of the northern Kenn Plateau reaches 1000 m deep along the WSW-trending Coriolis Ridge, which was cross-cut by lines 3 and 4, the northern part of line 15, and line 16.

Seismic line 3 (Figures 31 & 32) was SW-NE trending, and cross-cut the Cato Trough, the Cato Island seamounts, the Observatory Basin, the western edge of the Coriolis Ridge, and the Chesterfield Trough.

From the southwest to the northeast the following units were encountered:

a) The Cato Trough, 3600 m-deep, flanked on its eastern side by a series of stepped normal faults (SP 500-800) with a throw that offsets the basement from 6 s (twt) to 3.2 s (twt).

b) A series of intruding seamounts at the northwestern side of Cato Island, the main one, 10 km-wide (SP 1400-2000) shoaling to 525 m deep.

c) The 65 km-wide Observatory Basin (SP 2000-3300), characterised by a gentle northeast-dipping western flank and a steep western edge. Sedimentary deposits underlying the western flank thicken to the northeast to reach 0.7 s (twt).

d) The 40 km-wide southwestern spur of the Coriolis Ridge (SP 3300-4100), reaches its maximum height at 2 s (twt), and is covered by thin (0.4 s (twt) sedimentary deposits. It is isolated from the Coriolis Ridge by a sedimentary basin (SP 4100-4850). This 8 km-wide basin is an eastward-tilted half-graben within which the total sedimentary infilling reaches a maximum thickness of 1.4 s (twt). The assumed thickness of the Cretaceous deposits, identified between the Paleocene unconformity and the acoustic basement, is 0.9 s (twt).

e) The WSW-trending Coriolis Ridge (SP 4900-6500), 80 km-wide and tilted toward the southwest, is characterised by thin sedimentary deposits that reach a maximum thickness of 0.6 s (twt) at SP 5300.

f) The 75 km-wide Chesterfield Trough (SP 6500-7050) has sedimentary deposits which thicken toward the east to reach 1.5 s (twt), with an assumed thickness for the Cretaceous series of 0.8 s (twt). At its northern edge the trough is intruded by a seamount.

Seismic line 4 (Figure 33) trends NW-SE and cross-cuts the northern Kenn Plateau across its central rise, the Coriolis Ridge. This bank is bounded to the west by the Cato Basin, to the north by the Chesterfield Trough, to the south by the Observatory and Capel Basins, and to the east by the Bellona hot spot chain.

From northwest to southeast, the following three main geological features were encountered:

a) The Chesterfield Trough, appearing as a 45 km-wide basin (SP 101-1100). This basin shows a basement rise in its central part (SP 550) that isolates two sub-basins and disturbs the overlying post-Paleocene seismic sequences. Within the eastern sub-basin the assumed thickness of the Cretaceous series is 1.8 s (twt) thick (SP 850).

b) The WSW-trending Coriolis Ridge (SP 1100-2900) is 90 km wide. The junction with the Chesterfield Trough occurs along a basement outcrop at shotpoint 1100. This main tectonic lineament is visible in the gravity anomaly map of Sandwell and Smith (1997). West and east of this lineament, the Coriolis Ridge trends E-W and WSW-ENE, respectively. The lineament is interpreted as a strike-slip fault, trending NNE-SSW and extending to the north into the Chesterfield Trough. Southeast of this major fault, the Coriolis Ridge is made of stretched, probably continental basement, characterised by extensional horst and graben structures. The Coriolis Ridge shows a transverse asymmetry as the sedimentary deposits thicken toward the southeast. The maximum thickness reaches 1.2 s (twt) at shotpoint 2600 within an eastward-tilted half graben, which is structurally controlled at its eastern edge by a westward-facing normal fault. To the east of this fault, the eastern edge of the Coriolis Ridge is made of a main horst, 5 km wide, which lies between shotpoints 2650 and 2750.

c) The northern end of the Capel Basin, where it joins the northern flank of the E-W trending Observatory Basin (SP 2750-3135).

Seismic line 15 (Figures 34 & 35) trends SE-NW and crosscuts the North Kenn Plateau between shotpoints 2400 and 4976. From the southeast to the northwest, the North Kenn Plateau consists of:

a) The Coriolis Ridge southern edge (SP 2400-3000), 30 km wide, characterised by gently folded sediments and deposits that reach a maximum thickness of 1.6 s (twt).

b) The Coriolis Ridge sedimentary basin (SP 3000-4600), 80 km wide, that underlies the ridge's southwestern spur. The basin is made of thick deposits that reach at least 2 s (twt).

c) The Cato Basin (SP 4600-4976), 3150 m deep, intruded by a volcano at SP 4600.

Seismic line 16 (Figure 36) trends SW-NE and successively crosscuts:

a) The Cato Basin (SP 104-550), 3150 m-deep.

b) The western edge of the E-W trending Coriolis Ridge (SP 550-1200), intruded in its central part (SP 950) by a volcanic feature.

c) The E-W-trending western Chesterfield Trough (SP 1200-1950), 40 km-wide, characterised by a migration of depocentres toward the northeast, with a maximum thickness reaching 2 s (twt) (SP 1700).

d) The southern flank of the Chesterfield Rise (SP 1950-2073).

5.2.2. Southern Kenn Plateau (Observatory Basin and southward)

The southern Kenn Plateau reaches 1600 m depth at its shallowest, along the WSW-trending Southern Surveyor Rise, and was cross-cut by lines 5, 7, 8, 9, 11, 14 and the southern part of line 15.

Seismic line 5 (Figures 37 & 38) trends NE-SW, and cross-cuts the northern part of the southern Kenn Plateau. The following units were encountered:

a) The WSW-trending Observatory Basin (SP 102-2900) is 140 km wide and is characterised by thick sedimentary infillings, although the depth of the acoustic basement is difficult to define. The assumed maximum thickness averages 2 s (twt).

b) The northern flank of the Southern Surveyor Rise (SP 2900-3800) culminating at a water depth of 2100 m. The northern flank of the rise, 45 km wide, is underlain by a 40 km-wide basin filled up by sediments 1.4 s (twt) thick.

c) The WSW-trending Southern Surveyor Rise (SP 3900-4600) culminates at a water depth of 1900 m, here is 35 km wide, and is tilted toward the southwest. The underlying acoustic basement, although hardly identifiable, is visible at a depth of 3.8 s (twt) at shotpoint 4200, suggesting a thickness of 1.2 s (twt) for the sedimentary cover beneath the rise.

d) The Cato Seamount's southeastern extension is 90 km wide (SP 4600-6450) and is made of sedimentary deposits that thicken toward the northeast, to reach 1.8 s (twt) within a basin that lies at the southwestern edge of the Southern Surveyor Rise. At shotpoint 5100, the spur is underlain by a deep fault, overlain by a pop-up block that offsets both the Late Paleocene-Early Eocene and the Middle Eocene-Early Oligocene unconformities.

e) The northern end of the Tasman Basin (SP 6500-7600).

f) The Fraser Seamount (SP 7800-7900) that culminates at 370 m below the sea surface.

Seismic line 7 (Figures 39 & 40) trends SW-NE, and runs south of the Southern Surveyor Ridge. From southwest to northeast, the following main features were encountered:

a) A southwest-facing normal fault (SP 900) that links the Tasman Basin to the southwestern side of the southern Kenn Plateau.

b) The southeastern subdued extension of the Southern Surveyor Ridge (between SP 900 and 2200), characterised by underlying domes (volcanic or intra-sedimentary?).

c) The Kelso Basin (SP 2200-4200), 100 km wide near 24°S, is characterised by a sedimentary basin slightly tilted toward the southwest. The sedimentary infilling reaches a maximum thickness of 1.6 s (twt) with assumed Cretaceous deposits 1 s (twt) thick.

d) The northeastern edge of the Southern Surveyor Ridge (SP 4200–5946) is made up of a series of underlying horst and graben structures. At shotpoint SP 4750, a half-graben tilted to the northeast is filled by sediments 1.7 s (twt) thick, with an assumed thickness of 0.8 s (twt) for the Cretaceous deposits.

Seismic line 8 (Figure 41), that trends NW-SE, was shot at the eastern side of the southern Kenn Plateau, where it links with the Capel Basin. The plateau is characterised by a system of horst and graben structures typical of extensional tectonics over a continental basement. At shotpoint SP 1050 a basement rise shoals up to 4.4 s (twt). To the east of this feature, within a westward-tilted half-graben, the sedimentary deposits reach a maximum thickness of 2.2 s (twt), with an assumed Cretaceous series 1.2 s (twt) thick.

Seismic line 9 (Figures 42 & 43), trending NE-SW, obliquely crosscuts the WSW-trending Kelso Basin and successively encountered:

a) The eastern edge of the Kelso Basin, 65 km wide (SP 102-1400) at its junction with the N-S-trending Capel Basin. The underlying basement of likely stretched-continental origin is intruded by a volcanic massif at shotpoint SP 800. The maximum thickness of the sedimentary deposits at the eastern edge of the basin reaches 1.8 s (twt) (SP 600), with Cretaceous deposits averaging 1 s (twt).

b) The northern edge of the Kelso Rise that lies at a water depth of 2500 m. This N-S trending, less than 10 km-wide feature is underlain by a basement rise (SP 1400-1500), slightly tilted toward the northeast, and interpreted as being of stretched-continental origin,

c) The southwestern part of the Kelso Basin, 135 km wide (SP 1500-4200). This is likely to be stretched continental basement. It is characterised by horst and graben morphology, and is intruded by a series of volcanic massifs (SP 2250, 2950, 3450, 4150). The summits of these features affect the Paleocene-Eocene (and the Eocene-Oligocene?) unconformity. The maximum thickness of the sediments reaches 1.6 s (twt) (SP 2700 and 3600) with assumed Cretaceous deposits averaging 1 s (twt).

d) A probably transitional, i.e. continent–oceanic boundary, zone between shotpoints SP 4300 and 4800, characterised by southward-facing, stepped normal faults.

e) The northern end of the Tasman Basin (SP 4900-5790) is characterised by a basement of probable oceanic origin, with a series of intrusions overlain/covered by an average sedimentary blanket of 1.4 s (twt).

Seismic line 10 (Figure 44) trends SW-NE on the southeast margin of the Kenn Plateau and successively encountered:

a) The Tasman Basin (SP 104-1000) is characterised by probable oceanic basement, overlain by 2 s (twt) of sedimentary deposits. Near the margin of Kenn Plateau is a series of intrusions (sills and dykes) nearly 1 s (twt) above basement, and overlain by a sedimentary blanket of almost 1 s (twt).

b) The Kelso Basin on the slope of Kenn Plateau (SP 1000-2020), underlain by a coherent intrusion and a possible mid-sequence flow to SP1600, and sills and dykes to SP 2020. Sediment thickness varies from 1 to 1.5 s (twt).

c) The Kelso Rise on the slope of Kenn Plateau (SP 2020-2285), shows rapidly rising basement shallowing from 1.5 to 0.5 s (twt) below sea floor. A major flow dissects the sediment cover, and correlates with the flow from SP 1000 to SP 1600.

Seismic line 11 (Figures 45 & 46) trends SE-NW and successively encountered:

a) The Kelso Basin (SP 102-2800), 135 km wide, is characterised by sedimentary deposits that thicken to the southeast to reach a maximum of 1.8 s (twt) at SP 600. The basin is underlain by a fractured basement that shows a horst and graben morphology, likely of thinned-continental origin. The basement is locally intruded by a few volcanic features.

b) The Southern Surveyor Rise and the Cato Seamount, 180 km wide (SP 2800-6400), intruded by a main volcanic massif at SP 3200. The maximum sedimentary deposits beneath the Southern

Surveyor Rise reach 1.4 s (twt) at its southeastern edge. Between shotpoints 4500 and 4800 a 15 km wide horst culminates at 3.6 s (twt) beneath the rise. This feature could represent the southern extension of the lineament identified on lines 4 and 5 (see above).

c) The Cato Trough (SP 6400-7200), 40 km-wide, has a sedimentary infilling of 1 s (twt).

d) The eastern edge of the Marion Plateau (between SP 7200 and 8380) is intruded at shotpoint 7400 by a seamount that culminates at 1875 m below the sea surface.

Seismic line 12 (Figure 30), which trends SW-NE, cuts across:

a) The faulted eastern edge of the Marion Plateau (between SP 103 and SP 900), which has basement lying 0.3-1 s (twt) below Cainozoic sediments.

b) The floor of the Cato Basin (between SP 900 and 2428), for about 80 km. The basin consists of Cainozoic sediments that onlap the Marion Plateau, with a maximum thickness of about 1.2 s (twt) farthest from the plateau.

Seismic line 13 (Figure 47), which trends NW-SE, successively cross-cuts:

a) The Cato Basin, between shotpoints 101 and 350.

b) The western part of the WNW-trending Observatory Basin (SP 350-1600), 60 km-wide. The sedimentary deposits within the basin are notably thick (2.5 s twt). The assumed Cretaceous series is gently folded within the basin. At shotpoint SP 900, above a local basement rise, the post-Oligocene sediments have been almost eroded out, suggesting that the site should be a good candidate for a core site of older sediments.

c) The northeastern edge of the Cato Seamount (SP 1600-2000) and the northwestern flank of the Southern Surveyor Rise (SP 2300-2700) are separated by a 65 km-wide basin (SP 2000-2300) characterised by a maximum sedimentary thickness of 1.8 s (twt). The assumed Cretaceous deposits are 1 s (twt) thick within the basin. The northwestern edge of the Southern Surveyor Rise overlies an intensively fractured horst that could well correspond to the northern extension of the lineament pointed out on seismic lines 4 and 5 (see above).

d) The 40 km wide Southern Surveyor Rise (SP 2700-3469) underlain by 1.8 s (twt)-thick sedimentary deposits.

Seismic line 14 (Figure 48) trends WSW-ENE and cross-cuts the WSW-ENE summit of the Southern Surveyor Rise. Between shotpoints SP 400 and 550 the rise is underlain by a planated, slightly eastward-tilted horst 8 km-wide. The horst is overlain by a very thin sedimentary blanket (less than 0.1 s twt), the post-Lower Oligocene sediments having been eroded at its western side (SP 350). This could make a good candidate for a dredge site in order to unveil the nature (either thinned-continental or oceanic?) of the horst. To the east, a volcanic rise (SP 1700) intrudes the Southern Surveyor Rise.

Seismic line 15 (Figure 34 & 35) cross-cuts the southern Kenn Plateau and enters the Cato Basin. From southeast to the northwest, the southern Kenn Plateau is made of:

a) The westernmost part of the Capel Basin (SP 1-500) that reaches a maximum thickness of 2.2 s (twt) (SP 200)

b) The northern end of the Southern Surveyor Rise (SP 500-1100). A subdued, 20 km wide, northwestward-tilted horst lies at SP 1000.

c) The Observatory Basin (SP 1100-4000) shows horst and graben morphology and is characterised by gently folded sediments. The 120 km wide southern branch of Observatory Basin (SP 1100-2400) has a likely strike-slip fault at SP 2200, which could correspond to the extension of the faults pointed out on lines 4 and 5B (see above). The southern edge of the Coriolis Ridge (SP 2400-3000), 30 km wide, is clipped by the seismic line and is characterised by gently folded sediments and deposits that reach a maximum thickness of 1.6 s (twt). The northern segment of the Observatory Basin (SP 3000-4600), 80 km-wide, is made of thick deposits that reach at least 2 s (twt),

c) The Cato Basin (SP 4600-4976), 3150 m-deep, is intruded by a volcano at SP 4600.

5.3. Preliminary conclusions

From our preliminary analysis of seismic data, the following observations can be made:

a) **The Kenn Plateau** consists of two distinct structural blocks separated by the WSW-trending, 2400 m deep, Observatory Basin.

b) The northern block, called the **Northern Kenn Plateau**, lies north of the WSW-trending Observatory Basin. This block, 150 km-wide, includes the Chesterfield Rise (not surveyed), the Chesterfield Trough and the Coriolis Ridge. It is shaped by three main structural directions, N-S, E-W and WSW-ENE. This fractured block is globally tilted toward the south. The maximum sediment thickness reaches 2 s (twt) in the Observatory Basin.

Near its junction with the Coriolis Ridge, the Chesterfield Basin shows a basement bulge, west of a major fault (Seismic Line 4, SP 1100) visible in the gravity anomaly map of Sandwell and Smith (1997). This bulging is interpreted to be the result of compressive constraints associated with the functioning of the NNE-trending fault. West and east of the fault centred at 157°15’E, the Chesterfield Basin and the Coriolis Ridge trend E-W and WSW-ENE, respectively. We interpret this main NNE-SSW tectonic lineament as a major NNE-SSW left-lateral strike-slip fault that also offset the Observatory Basin to the north.

The seismic lines shot over the northern Kenn Plateau reveal that, in the Chesterfield Trough, a rift-valley sequence, at least 1.2 s (twt) thick (about 2000 m) underlies a post-breakup sequence made of post-Paleocene sediments 0.8 s (twt) thick (about 800 m). The western part of the northern Kenn Plateau is intruded by volcanic features dated, from seismic data interpretation to be of probable Late Eocene – Late Oligocene age.

c) The southern block, called the **Southern Kenn Plateau** is 380 km wide. It terminates south of the Coriolis Ridge to the north, and north of the Tasman Basin to the south. Within our study area, the southern plateau is made up of the Observatory Trough, Cato Seamount, Southern Surveyor Ridge, Kelso Basin and Kelso Rise. The southern Kenn Plateau is dominated by SW-NE, NW-SE and north-south directions. This intensively fractured block, that shows “scissor fault-type” morphology, is globally tilted toward the northeast. The sediment thickness reaches a maximum of 2 s (twt) in both the Observatory and Kelso Basins.

At about 156°10’E, the southern Kenn Plateau is affected by a main fault (Seismic Line 5, SP 5100) clearly visible on the gravity map derived from satellite altimetry (Sandwell and Smith, 1997). West and east of this NNE-trending fault, the southeastern extension of the Cato Seamount trends NW-SE, and the Southern Surveyor Rise trends NE-SW. This major tectonic lineament, aligned with the parallel fault identified to the north at 157°15’E, is interpreted as the southern extension of the left-lateral strike-slip fault that affects the northern Kenn Plateau.

In its central part, across the WSW-trending Kelso Basin, the South Kenn Plateau shows a horst and graben morphology. This basement signature, typical of stretched continental crust, is intruded by a series of volcanic massifs of likely Eocene-Oligocene age.

In its southwestern part, the Southern Kenn Plateau links with the Tasman Basin through a probably transitional, continent–oceanic boundary zone characterised by southward-facing, stepped normal faults.

d) In conclusion, both the Northern and the Southern Kenn Plateaus are made up of several faulted and dissected blocks. A main NNE-trending tectonic lineament, interpreted as a major strike-slip fault, offsets eastern and western parts of the two plateaus. It extends northward to form the northwest margin of Bellona Plateau (CPCEMR, 1991) and is here named the West Bellona Fault Zone.

Both the northern and southern Plateaus underwent regional events such as rifting, with a rift-valley sequence overlain by post Paleocene deposits from the post-breakup phase, volcanism of likely Eocene-Oligocene age, and plateau subsidence.

6. RESULTS OF GEOLOGICAL SAMPLING

Neville Exon

The geological sampling had been planned to include a number of basement sites, but the early failure of the winches curtailed the work, leaving us with twelve dredge sites and one grab sample (Table 8). The dredge sites were all successful in recovering lithified material, but no basement rocks were recovered. The dredge material was studied aboard ship in hand specimen, with the aid of sawn material. It was then sorted into various groups or lithotypes (e.g. A, B, C) for each dredge haul before specialist sampling began. For each dredge, each group was assigned a letter, and individual samples were given a numerical suffix; further subsamples were designated by another numerical suffix. Thus a typical designation for Cruise 270 for the first subsample from the first sampled rock in group A, from dredge 4, might be 270/4/DR4A1.1. The '4' before DR indicates that this was the fourth station (dredge or grab) occupied on the cruise.

Post-cruise micropalaeontological information from Pat Quilty (Section 7), nannofossil information from Richard Howe (Section 8), as drawn together in Table 9, thin section examination by Neville Exon (Table 10), and bathymetric information from Peter Hill (Section 4) are included in this summary. The dredge results for lithified material can be conveniently separated into three categories: siliciclastic sediments, Cainozoic calcareous sediments, and Cainozoic seamount limestones. Location information is given in Table 8 and on a map (Figure 7).

Table 8. Dredges and grab from GA Cruise 270

Station/ Dredge	Lat (S) Long (E)	Location	Depth (m)	Recov (kg)*	Description and age	Seismic Line
01/DR1	24°47.8’ 156°08.6’	SW Kenn	4000	10	Calcareous claystone. E. Miocene forams. Late and middle Early Oligocene nannos.	BMR 15/37
02/DR2	24°46.8’ 156°19.8’	SW Kenn	2800	10	Breccia of sandstone in ironstone, with thick Mn crust	GA 270/7
03/DR3	23°49.4’ 155°20.5’	W Kenn	3280	30	Chalk, calcareous ooze. Late E. Miocene & L. Miocene forams. Middle M. Miocene and middle L. Miocene nannos	BMR 12/23
04/DR4	24°24.8’ 155°18.5’	Fraser Seamount	450	4	Reefal biostromal limestone. E. Pliocene & younger forams. Middle middle Pliocene nannos.	GA 270/5
05/GR1	24°25.01’ 155°18.0’	Fraser Seamount	390	handful	Biogenic sand and gravel	GA 270/5
06/DR5	24°29.1’ 155°16.6’	Fraser Seamount	1600	5	Basaltic hyaloclastite breccia	GA 270/5
07/DR6	21°49.6’ 155°48.0’	NW Kenn slope	2800	20	Pelagic foraminiferal limestone, chalk, calcareous ooze. Early M. Eocene, latest Eocene & M. Miocene forams. Early to early M. Eocene, early E. Oligocene, and middle E. Miocene nannos.	BMR 13/42
08/DR7	22°09.5’ 155°47.9’	NW Kenn slope	2700	50	Pelagic foraminiferal chalk, semi-lithified chalk, calcareous ooze. Middle M. Miocene forams. Early M. Miocene nannos.	BMR 13/40
09/DR8	23°29.6’ 154°50.1’	SE Marion slope	3050	80	Foram nanno chalk, foram nanno claystone, calcareous ooze. Earliest Miocene & M. Miocene forams. Middle E. Miocene, early and late M. Eocene nannos.	BMR 13/29
10/DR9	23°27.7’ 155°02.4’ 23°28.4’ 155°02.6’	W Kenn slope	3300-3100	100	Highly and weakly lithified foram nanno chalk, yellow claystone, calcareous ooze. M. Miocene forams. Middle and late M. Miocene nannos	BMR 13/29
11/DR10	22°51.3’ 155°20.4’	W Kenn slope	3100	5	Highly and weakly lithified foram nanno chalk, calcareous ooze. Latest E. Miocene forams. Early M. Miocene nannos.	BMR 13/35
12/DR11	23°11.35’ 155°23.0’	Cato satellite guyot	1000-800	10	Reefal framework limestone. E. & M. Miocene, L. Pliocene forams.	GA 270/3
13/DR12	21°06.8’ 155°53.3’	Kenn reef east slope	1900	8	Calcarenite (packstone). E. Oligocene (possibly L. Eocene) forams	BMR 13/46

*Only lithified material considered

Table 9. Consolidated micropalaeontological ages from Kenn Plateau dredge samples

Location	Sample	Foram Zone	Nanno Zone	Preferred Age
NEOGENE SAMPLES				
Southeast Kenn Plateau	DR01B1	Lower Miocene		Lower Miocene
	DR01D	Oligocene-L. Miocene		Oligocene-L. Miocene
West Kenn Plateau	DR03A1	N16-18	CN8b, upper NN10	middle Upper Miocene
	DR03B1	N8	mid CN4, mid NN5	lower Middle Miocene
Fraser Seamount	DR04A1 (TS)	N18-20		L. Pliocene
	DR04A3 (TS)	N19-20		L. Pliocene
	DR04B1	N20	upper CN12a, middle NN16	middle middle Pliocene
Northwest Kenn Plateau	DR06C1	N4	mid CN1c, mid NN2	middle Lower Miocene
Northwest Kenn Plateau	DR07A1	N12	lower CN4, lower NN5	middle Middle Miocene
	DR07B1	N12	lower CN4, lower NN5	middle Middle Miocene
Southeast Marion Plateau	DR08A1	N9	lower CN4, lower NN5	lower Middle Miocene
	DR08B1	N4	mid CN1c, mid NN2	middle Lower Miocene
	DR08C1	N14	upper CN5b, upper NN7	upper Middle Miocene)
Northwest Kenn Plateau	DR09A1	N12-13	upper CN5a-lower CN5b, upper NN6-lower NN7	middle Middle Miocene
	DR09B1	N10-12	lower CN5b, lower NN7	upper Middle Miocene
Northwest Kenn Plateau	DR10A1	N8	lower CN4, upper NN4	lower Middle Miocene
	DR10C1	N8-9	lower CN4, upper NN4	lower Middle Miocene
Cato Seamount satellite	DR11A1(TS)	?L-M Miocene		?L-M Miocene
	DR11B1(TS)	L. Miocene; N21-22		L. Miocene; U. Pliocene/Pleistocene
	DR11C1(TS)	N9-12		Lower M. Miocene
PALAEOGENE SAMPLES				
West Kenn	DR01A1.1		lower CP19a, lower	upper Lower

Plateau			NP24	Oligocene
	DR01B1	Early Miocene	lower CP18, mid NP23	middle Lower Oligocene
Northwest Kenn Plateau	DR06A1	P10-11	mid CP9b-mid CP12b, mid NP11-mid NP14b	Lower to lower Middle Eocene
	DR06B1	P17	CP16b, upper NP21	lower Lower Oligocene
Kenn Seamount	DR12A1(TS)	M. Eocene-L. Oligocene		? Lower Oligocene

Table 10. Thin section rock descriptions from GA Cruise 270

Sample number/ GA lab number	Description and age
270/DR2B1 1419738	Brown to black, variably ferruginised clayey, fine quartz-rich sandstone. Sand (70%) is fairly even grained. It consists of angular fresh quartz, and subordinate feldspar and fine grained sedimentary grains
270/DR4A1.1 1419751	Grey reefal biostromal boundstone containing carbonate mudstone containing forams including a few larger forams, molluscs and algae. Cavities filled with pale micrite. Impregnated with ferromanganese.
270/DR4A3.1 1419752	Grey cavernous algal boundstone consisting of carbonate wackestone with abundant forams, bound by algae, and cut by calcite veins.
270/DR5A1.1 1419759	Brown basaltic breccia consisting of altered glassy basalt containing plagioclase laths, pyroxene, and some glass fragments, cemented by clay and recrystallised calcite veins containing no forams [Tony Crawford has sample]
270/DR5A1.2 1419760	Brown basaltic breccia as above, with some vesicular glassy clasts.
270/DR6A1.2 1419767	White pelagic foraminiferal micritic packstone, with some algae, minor clay infillings, and very minor feldspar.
270/DR8E 1419785	Pale grey highly-lithified, dense, burrow filling of radiating calcareous bodies.
270/DR11A1 1419816	White algal boundstone, about 90% framework algae, but with calcareous micrite infillings containing abundant smaller algae and some forams.
270/DR11B1 1419817	White pelagic foraminiferal micritic wackestone infilling, in a cavernous biostromal boundstone. Wackestone dominated by well-preserved forams, but contains some calcareous spicules and rare molluscan fragments, and is separated from boundstone by ferruginous crust.
270/DR11B2 1419818	White pelagic foraminiferal micritic wackestone infilling, in a cavernous biostromal boundstone as above. Wackestone contains more molluscan fragments than 11B1, and some of the associated rock (not in thin section) is algal.
270/DR11C1 1419819	White algal boundstone, containing variably recrystallised micritic wackestone. The wackestone contains larger forams, algae and some molluscan fragments.
270/DR12A1 1419824	White packstone consisting of sand-sized biogenic grains of algae, and lesser molluscs and forams, set in a recrystallised calcite matrix.

6.1. Siliciclastic sediments

One small haul of siliciclastic sediment (Dredge DR2) was made from the southwest margin of Kenn Plateau in a depth of 2800 m (Figure 26). It consists of a brown to black breccia of sandstone in ironstone, with a variably thick manganese crust. In thin section, the material is heavily altered but one can identify a variably ferruginised clayey, fine quartz-rich sandstone. Sand makes up 70% of the sandstone and is fairly even grained. It consists of angular fresh quartz, and subordinate feldspar and fine grained sedimentary grains. The ironstone breccia may be a Mesozoic weathering product, on which the marine manganese oxide has been deposited later.

6.2. Cainozoic chalks

Eocene and younger chalks and related deepwater limestones were dredged at a number of locations in the Kenn Plateau region. The following descriptions draw on shipboard descriptions and the micropaleontological Sections 7 and 8. The micropaleontology shows that the foraminifera lived in the tropical realm. Quilty notes in Section 7 that the benthic foraminiferal assemblages are dominated by elongate and tuberculate forms, unique in his experience, and suggests that they may be a concentration of particularly solution-resistant species. Dissolution of foraminifera indicates that the Carbonate Compensation Depth (CCD) has varied around 3000 m through time. Most samples have an admixture of modern foraminifera.

The oldest sample is DR6A1, a light grey, manganese encrusted, bored, recrystallised foraminiferal limestone, from a depth of 2800 m on the northwest slope of Kenn Plateau (Figures 11 & 19). Its age is Middle Eocene (P10-11) on the basis of poorly preserved planktic foraminifera. It contains common benthic foraminifera, and some echinoid spines and plates, bryozoans and ostracods. The presence of bryozoans, and one species of attached foraminifera, suggests deposition in an upper benthic environment, before the Cato Basin and Kenn Plateau slope subsided to their present depths.

DR6B1 is light yellowish brown, bored, silty calcareous mudstone containing well preserved planktonic foraminifera of latest Eocene (P17) age. Other components are volcanic fragments, radiolaria, sponge spicules, echinoid spines and fish bone. The water had deepened during the Eocene, since the deposition of DR6A1.

An unusual sample is DR1D, a dusky yellow, foram-bearing calcareous clay, from a depth of 4000 m on the southwest slope of Kenn Plateau. It is glauconitic and contains rare subrounded and frosted quartz grains, volcanic fragments, teeth and fish bone fragments, and planktic and benthic forams. Dissolution has largely removed the older foraminiferal microfauna, which may have been Oligocene to Early Miocene, but a full modern assemblage of planktic foraminifera is present. The clay is probably of the older age, and the glauconite suggests that it may have been deposited in an upper benthic environment.

The remainder of the variably lithified sediments are chalks of Miocene age, from the northwest slope of the Kenn Plateau (DR6, 7, 9 & 10: Figures 19, 20, 21, 23), the southeast slope of Marion Plateau (DR8), and the southwest slope of Kenn Plateau (DR3).

Those from the northwest Kenn Plateau are variably lithified, sometimes finely bored and manganese encrusted, deep ocean, foram-bearing chalks, with planktic foraminifera dominant over benthics. They lie in broadly comparable water depths of 2700 m to 3300 m. Dissolution is absent or minor, except in DR9A1. Other organic remains include ostracods, echinoid spines, fish bones, and occasionally sponge spicules. The oldest sample is DR6C1 of earliest Miocene (N4) age and with excellently preserved foraminifera. DR10A1 and B1 are of latest Early Miocene (N8) age and also contain well preserved foraminifera. DR9A1 and B1 are of Middle Miocene (N12-13 and N10-12) age and contain glauconite rods, probably replacing benthic foraminifera. Foraminifera in DR9A1 are highly dissolved, whereas those in DR9B1 show only minor dissolution. DR7A1 and A2 are also of mid Middle Miocene (N12) age. Foraminifera are well preserved and glauconitic rods are present.

DR8 from the southeast Marion Plateau, in water about 3050 m deep, contains finely bored, deep ocean chalks of three Miocene ages. The oldest is the most clayey and the youngest is the least lithified. All contain planktic and benthic foraminifera. The oldest sample is DR8B1 of Early Miocene (N4) age. It shows obvious dissolution and contains echinoid spines, ostracods, and fish bones and teeth. DR8A1 is of Middle Miocene (N9) age, shows severe dissolution, and contains the same components plus glauconitic rods. DR8C1 is of Middle Miocene (N14) age, shows considerable dissolution and, apart from foraminifera, the residue contains only fish vertebrae.

DR3 from the southwest Kenn Plateau, in water about 3300 m deep, contains bored, manganese coated, deep ocean chalks, whose residue is dominated by Quaternary foraminifera. DR03A1.1 also contains reworked Late Miocene (N16-18) foraminifera.

In general, water depths of deposition increased from upper benthic in the Eocene to open ocean in the Miocene. Some terrigenous and volcanic grains occur in the Eocene but not in the Miocene. The lack of Oligocene chalks suggests that the regional Oligocene unconformity is present. As regards the Miocene chalks, there is little apparent difference across the area. Dissolution is rather randomly variable, probably because some of it occurred fairly recently following early burial and later erosion. Glauconitic rods, replacing benthic foraminifera, are not present in the older samples (Early Eocene: N4 and N8) but are commonly present in the younger samples (Middle and Late Eocene: N9 to N14). It is unclear what this means in terms of dissolution and replacement.

6.3. Cainozoic seamounts

Three volcanic Cainozoic seamounts near or on the western Kenn Plateau were dredged on this survey: Fraser Seamount (just south of Kenn Plateau), a satellite cone to Cato Island, and the slope of Kenn Reef. All are flat-topped, with the two southern ones now guyots. They are part of the Tasmantid hotspot seamount chain, and their probable ages can be calculated from dated seamounts to the south, their location, and the rate of movement (6 cm/year) of the Australian Plate northward over the hotspot. Pat Quilty has done this (Figure 9) and he calculated the age of Fraser Seamount as ~30 Ma (Early Oligocene), the Cato satellite guyot as ~32 Ma (Late Eocene), and Kenn Reef as ~36 Ma (Late Eocene). By dredging, we hoped to confirm or disprove these postulated ages. Unfortunately, we dredged no datable volcanics, but did dredge datable limestones from the overlying reefal build-ups, which give a minimum age for the volcanic edifices. Information on the rocks is provided in Tables 8 and 9, on the foraminifera in Section 7, and on the seamount morphology in Section 4.

One of the fastest growing reefs in the Australian region is Scott Reef, which has built up 2000 m in the last 16 million years (Stagg and Exon, 1981), a rate of ~130 m/m.yr. ODP Leg 194 on the Marion Plateau (Isern, Anselmetti, Blum et al., 2002) showed that, at three drill sites, carbonate platforms first formed in the early Miocene (Site 1198 ~18 Ma, 1197 ~19 Ma and Site 1196 ~25 Ma) from cool subtropical calcareous faunas. It is reasonable to presume that similar times of onset prevail on the adjacent Kenn Plateau, and that is our working hypothesis. This suggests that the major volcanic edifices would have been subject to long periods of subaerial erosion (5-10 m.yr.) before fringing or capping reefs formed. Of course, some volcanism may have persisted after the 2 million years during which a typical hotspot volcano develops. The growth rates at the three ODP sites, through to the present day, vary from 27 to 34 m/m.yr. The growth rates, through to late in the Miocene, vary from ~28 to 45 m/m.yr. For the Kenn Plateau seamounts we initially assumed a growth rate of 40 m/m.yr. to calculate ages of onset and end of carbonate deposition from spot ages. This did not work well for Fraser Seamount, so we now assume that the earliest carbonates formed there at 25 Ma (c.f. Isern, Anselmetti, Blum et al., 2002, for the Marion Plateau), and calculate from that.

Fraser Seamount (Figures 14 and 25) is a guyot that rises from the Tasman Abyssal Plain, 4000 m deep, to a flat summit culminating at a depth of 360 m. It is about 30 km in diameter at its base and its flat cap is about 3.5 km in diameter. There is a bench at 1350 m depth and a terrace at 1030 m depth. In Section 4, the bench is described as cut by wave-base erosion, and the terrace as perhaps the original subaerial erosion surface of the volcano. An alternative is that the bench is the upper surface of the volcanics, and the terrace is the top of a carbonate debris apron. In the first case, the base of the limestones would be at 1030 m and in the second case at 1350 m. Two dredge hauls were carried out, DR5 to the southwest and DR4 to the north. DR5 recovered volcanic rock from below the bench (1600 m), and DR4 recovered limestone from above the terrace (450 m).

DR5, from 1600 m depth, contained one angular, weathered cobble of basaltic hyaloclastite breccia. Thin section examination of two subsamples (DR5A1.1 and 1.2) showed them to consist of altered glassy basalt containing plagioclase, pyroxene and some relatively fresh volcanic glass. Professor Tony Crawford of the University of Tasmania will examine the glass geochemically.

DR4, from 450 m depth, contained grey reefal limestone, which was largely algal boundstone and wackestone, with pelagic carbonate cavity fillings. A thin section of DR4A1, an algal boundstone, showed that it contained an older undatable phase, and a younger pelagic carbonate phase of Early Pliocene (N19-20) or possibly latest Miocene (N18) age. A thin section of a pelagic carbonate infilling in DR4A3.1 contained foraminifera that indicated an Early Pliocene (N19-20) age and an outer shelf depth or greater. The residue from the less-lithified DR4B1 contained echinoid spines, molluscs, brachiopods, ostracods, and abundant poorly preserved planktonic foraminifera.

The oldest foraminiferal assemblage from Fraser Seamount indicated an age on the Early/Middle Miocene boundary (N8). Thus the oldest limestone age (N8) is about 16 Ma, about 14 million years younger than the theoretical age of the volcanic edifice. The sample came from 450 m, and the base of the limestones could be as deep as 1350 m. If we assume that the oldest carbonates are 25 m.yr. old (c.f. Isern, Anselmetti, Blum et al., 2002), this would give an average growth rate of 100 m/m.yr. The surface of Fraser Seamount is ~90 m above the dredge location, so the reef may have died at ~15 Ma. Most likely its demise coincided with a major sea level fall, two of which approximate the Middle/Late Miocene boundary (Haq, 1991).

The **satellite guyot** to Cato Island (Figures 12 and 21) rises from the general volcanic mass of the Cato edifice. Its top is 423 m deep and the base of its independent steep slope is at ~1000 m. Its flat top is about 4 km across and its base about 5 km across. In Section 4 it is suggested that the base of the carbonate platform lies at 1000 m; and it is noted that a scarp 100 m high cuts the guyot top, trends WNW, and separates a higher northern half from a lower southern half. This may be a fault scarp, related to movement within the edifice.

One dredge haul (DR11) was carried out on the northern side of the guyot, near the base of the scarp, and recovered a number of cobbles of reefal framework limestone. Thin section examination of three samples (Table 9) indicates that we are dealing with various parts of an algal boundstone, containing micritic wackestone. The older wackestone contains well-preserved foraminifera, including larger benthic foraminifera, along with algae and molluscan debris. Examination of the foraminifera indicates that there appear to be at least two phases involved: a younger Late Pliocene (N21; ~3 Ma) phase; and an older Miocene phase, perhaps as old as Early Middle Miocene (N9-N12; 15-12 Ma). This compares with a calculated age of ~32 Ma for the edifice as a whole.

Assuming a maximum dredge haul age of 14 Ma, that the dredge haul came from 900 m, and that the age of the limestone forming the guyot's top (423 m) is about 2 Ma, very close to the age of the youngest material dredged (~3 Ma), a growth rate of 40 m/m.yr. is calculated. With this growth rate, the age of the limestone at the base of the slope (1000 m) would be about 16 Ma, some 2 m.yr. younger than the youngest reef onset dated by the Marion Plateau ODP drilling, but quite possible.

Kenn Reef rises 3000 m above the Cato Basin, but we did not map it in any detail. A very steep slope starts on its eastern side at 2100 m, and we dredged a large slab of calcarenite from this slope at about 1900 m. Thin section examination shows this to be a recrystallised packstone containing algae, bryozoan, echinoid spines, pteropods, volcanic fragments and foraminifera. It is described by Quilty (Section 7) as a deposit that formed under moderately high-energy conditions in the photic zone. It is dated on foraminifera only as probably Early Oligocene (29-33 Ma). On this evidence, it could have formed soon after the calculated age of formation of the volcanic edifice of ~34 Ma, or much later. We arbitrarily assume the reef first formed at 30 Ma, giving an average growth rate of 70 m/m.yr.

6.4. Conclusions

On the basis of the above calculations, with their series of variably reliable assumptions, our understanding of reefal buildups on the Kenn Plateau is summarised in Table 11. We suggest that the volcanic edifices formed at 30-34 Ma, earlier than the calculated onset of carbonate buildup, at about 15-30 Ma. Erosion had probably removed most of the volcanic edifice above sea level before buildups started to form. It seems that cool water carbonates could form earlier here (30 Ma) than on the Marion Plateau (25 Ma), perhaps because the Kenn Plateau seamounts (on much thinner crust) subsided beneath the sea earlier than did the Marion Plateau. Average subsidence rates until the present day, as defined by the calculated limestone ages, are 50-100 m/m.yr. Average reefal growth rates (until the reef stopped growing) vary more, from 40-110 m/m.yr. Fraser Seamount limestones grew fastest until its demise at ~14 Ma, the Cato satellite guyot limestones grew slowest until its demise at ~2 Ma, and the Kenn Reef limestones apparently grew steadily until the present day. The figures suggest that Fraser Seamount subsided more slowly with time, as one would expect given its location on old oceanic crust. However, they suggest that the Cato satellite guyot has subsided more rapidly recently. Perhaps this is related to recent faulting as shown by the 100 m high scarp on its surface. Cato Reef itself has kept up with subsidence, but the satellite guyot (on an unstable flank of the volcanic edifice) has not.

Table 11. Proposed seamount history

Seamount	**Fraser**	**Cato satellite guyot**	**Kenn Reef**
Shallowest point	360 m	423	0 m
Inferred volcanic age	30 Ma	32 Ma	34 Ma
Carbonate thickness	1000 m (360-1350)	600 m (423-1000)	2100 m (0-2100)
Oldest limestone found	16 Ma (450 m)	15-12 Ma (900 m)	?33-29 Ma (1900 m)
Probable limestone ages	25-15 Ma	16-2 Ma	30-0 Ma
Avge. reefal growth*	100 m/m.yr.	40 m/m.yr	70 m/m.yr.
Subsidence	1300 m	1000 m	2100 m
Avge. subsidence rate**	55 m/m.yr.	60 m/m.yr.	70 m/m.yr.

* For period above
** Until present day

The foraminiferal ages of the carbonate rocks sampled are inexact (Section 7), and the dredging technique locates them only approximately. Furthermore, very few dredge hauls were made on the seamounts, so the times of growth and the calculated growth rates are very imprecise, and based partly on analogies to sequences from better known areas. This may explain some of the apparent differences between seamounts shown in Table 11. A more intense sampling program would give better results, although dating of the older limestones probably will continue to depend on thin section examination of foraminifera, a difficult technique that gives only broad ages. If fresh volcanics were dredged from the volcanic pedestals, they could be dated radiometrically and that would help constrain the seamount histories.

7. FORAMINIFERAL BIOSTRATIGRAPHY OF KENN PLATEAU DREDGE SAMPLES, GEOSCIENCE AUSTRALIA SURVEY 270

Patrick Quilty

7.1. Material and methods

Seventeen samples were sent initially by Dr Neville Exon of Geoscience Australia to cover dredges taken in basinal sediments. All are from chain dredge samples from Geoscience Australia Cruise 270 (*Southern Surveyor* SS05/2004). All had been processed in Canberra and each consisted of the >63 µm fraction in a single bottle. These were re-sieved at 125, 250 and 500 µm and examined fraction by fraction. Representative foraminifera and accompanying fauna were separated into standard micropalaeontological slides before identification and tabulation of results. No attempt has been made to separate species statistically even though the samples are of a quality that would warrant this approach. Following the initial examination, a further eight samples were sent in the form of thin sections to deal with the reefal build-ups dredged from three seamounts. Dredge 4 is from Fraser Seamount in the south, Dredge 11 from a satellite of Cato Seamount, and Dredge 12 from Kenn Seamount in the north.

The samples studied show that many dredges contain rocks of a variety of ages (Figure 49). The results listed below consist only of enough information to give the age of the sample, and they include some comment about the environment of deposition, a general 'Comments' section where warranted, and some judgement about the influence of dissolution on the quality of sample.

7.2. Features

An interesting aspect of the faunas is the general absence of a New Zealand influence in the Miocene faunas (except in samples from DR09), a contrast with the planktonic foraminiferal faunas of the SS03/01 cruise (Crawford *et al.* in prep.) from the Norfolk Ridge to Three Kings Ridge area, more than 1000 km to the southeast. The boundary between the tropical and southwest Pacific realms (which includes southern Australia) seems to lie between the areas covered by the two cruises, i.e. southeast of the Kenn Plateau.

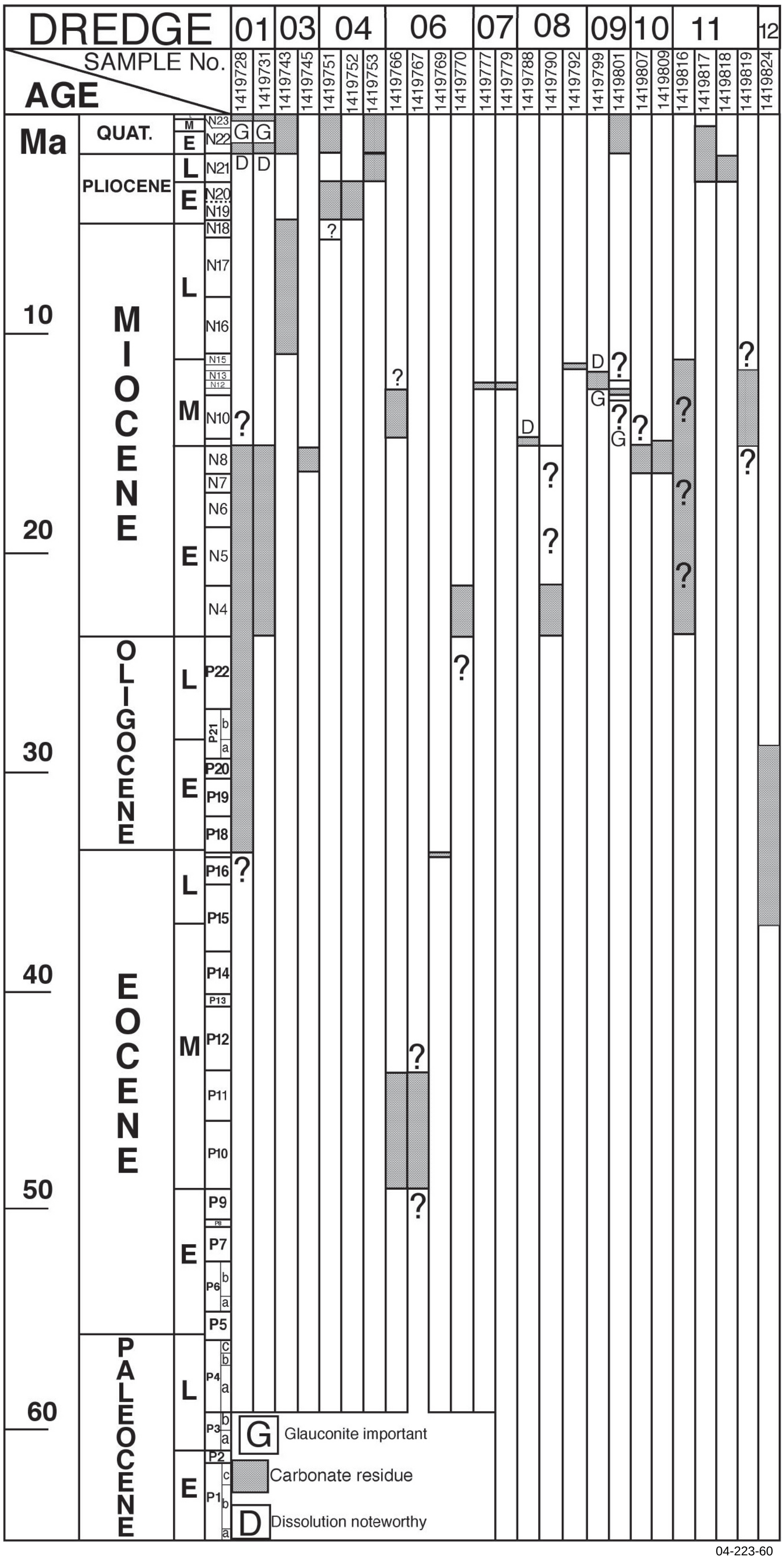


Figure 49. Age distribution of foraminiferal samples from Kenn Plateau dredges.

An unusual feature of the samples is the common occurrence of samples in which the benthic fauna is dominated by nodosariid and other foraminifera with elongate chambers, and those with tuberculate chambers. I have never encountered this before as such an obvious feature. Typical are *Nodosaria, Dentalina* and *Stilostomella*, and it may be that this is a result of concentration of solution resistant forms with imperforate, finely perforate or thick walls.

Samples from deeper than about 3000 m show the effects of dissolution. However, from depths near 3000 m, the effects vary markedly from sample to sample, suggesting regional variation in the CCD at about this depth and through time.

7.3. Relationship to Tasmantid/Lord Howe seamounts

Quilty (1993) reported on the age and significance of the Tasmantid and Lord Howe seamounts, based on studies of dredged samples. The Kenn Plateau seamount samples come from a northern extension of the Tasmantid seamount chain.

The oldest and most northerly seamount previously studied micropalaeontologically from the Tasmantid seamount chain was Recorder Seamount, at 25°12'S. Its age was indeterminate. The next to the south was Moreton Seamount at 26°S with the oldest age recorded (but not necessarily the age of formation of the seamount) of latest Miocene. Kenn Plateau samples are slightly to the north at 22-25°S.

Figure 9 is a plot of the ages obtained from the Tasmantid Seamount chain. The line linking them all is the line representing ages predicted by northward movement at 6 cm/year, starting from a point where the current hotspot is to be expected well south of Gascoyne Seamount and east of Tasmania. The extension of the line to the north (right hand side of figure) allows an estimate to be made of expected maximum age of the seamounts, on the assumption that they are part of the Tasmantid chain and that movement has been at a constant rate. The fact that foraminiferal ages are greater than expected for some samples is puzzling. It may possibly be an indication that the samples are not related to the history of the seamounts, but that the sediments accumulated as part of an earlier history. However, this is difficult to envisage.

7.4. Sample by sample results

Sample GA1419728

Dredge/Lithology: 270/01 DR01 D. Calcareous claystone.

Locality: Southeast Kenn Plateau

Latitude 24° 47.8'S; longitude 156° 08.6'E: Water depth: 4000 m.

Residue: >500 µm. Small amount, dominantly nodules of glauconite, a few planktonic foraminifera, minor benthic foraminifera, rare terrigenous and volcanic grains.

250 - 500 µm. Abundant glauconite, few terrigenous grains or pumice. Very few benthic foraminifera. Some dissolution evident on planktonic specimens. Fish teeth and bone concentrated.

125 – 250 µm. As above. Dissolution quite marked, teeth and bone more frequent; some glauconite in form of filled chamber lumina. Some unidentifiable fragments may belong to the older fauna.

Fauna:

Foraminifera:

Planktonic:

Modern *Globorotalia truncatulinoides* fauna with full diversity.

Older *Catapsydrax unicavus* (two small specimens).

Other: Teeth and bone.

Age: Dominantly Quaternary, N22/23 of Blow (1969) but also with a hint of Oligocene-Early Miocene.

Environment of deposition: Deep sea floor, now below the Carbonate Compensation Depth (CCD).

Comment: Dissolution more marked in finer fractions. Full diversity of modern warm water planktonic species. Dissolution has removed the older fauna and is affecting the modern fauna very strongly. Dissolution has concentrated insoluble residues.

Sample GA1419731

Dredge/Lithology: 270/01 DR01 B1.2. Calcareous claystone

Locality: South-east Kenn Plateau

Latitude 24° 47.8'S; longitude 156° 08.6'E: Water depth: 4000 m.

Residue: >500 µm. One planktonic foraminifer. Mainly rods of glauconite and Mn oxide linings of tubes.

250 - 500 µm. Dominantly hollow and solid rods of glauconite. Minor Mn oxide tube linings. One echinoid spine. A few teeth. Benthic foraminifera concentrated by dissolution but also affected by it. Planktonic foraminifera quite affected.

125 – 250 µm. Foraminifera dominate over glauconite. Planktonic species dominantly as fragments. Benthic foraminifera affected by dissolution but better preserved than planktonic species. Remnants of echinoid spines. Bone and teeth concentrated.

Fauna:

Foraminifera:

Planktonic:

Very little identifiable.

Quaternary:

Globorotalia truncatulinoides (or possibly *tosaensis*; preservation is very poor)

Hastigerina aequilateralis

Miocene

Globoquadrina altispira

Catapsydrax unicavus (several specimens)

Globigerina euapertura (one specimen)

Globorotalia cf. *continuosa*

Benthics:

Cibicides spp.

Other: Teeth, bone, echinoid spines.

Age: Quaternary fragments mixed with Early Miocene.

Environment of deposition: Modern deep sea floor. Below or at lysocline.

Comment: Dissolution very marked but more so in finer fractions; most carbonate is in the form of small unidentifiable residual fragments. Marked concentration of teeth and bone. Only highly insoluble forms of the earlier fauna remain. While much is taken to be of modern fauna, that identified as *G. truncatulinoides* is a poor fragment.

Tubes may be remnants of allogromiid foraminifera such as discussed by Gooday (2002) or as illustrated by Brady (Barker, 1960, pl. 29, figs. 1-4).

Sample GA1419743

Dredge/Lithology: 270/03 DR03 A1.1. Chalk

Locality: West Kenn Plateau.

Latitude 23° 49.4’S; longitude 155° 20.5’ E: Water depth: 3280 m.

Residue: >500 µm. Clean carbonate residue, dominantly planktonic foraminifera. Few benthic foraminifera, ostracods, echinoid spines.

250 - 500 µm. Same, no ostracods, dissolution more obvious.

125 – 250 µm. Same. Dissolution more marked. Few bone fragments, minor echinoid spines, sponge spicules. *Globigerina nepenthes* quite common, attesting to reworking of older into Quaternary.

Fauna:

Foraminifera:

Planktonic:

Modern:

Globorotalia truncatulinoides

Hastigerina aequilateralis

Orbulina universa

Older.

Globoquadrina altispira

Globigerina woodi

Globorotalia continuosa

Globigerina nepenthes

Benthic:

Other: Ostracods, echinoid spines, bone, teeth

Age: Quaternary with reworking of Late Miocene (N16-N18).

Environment of deposition: Modern sea floor abyssal plain conditions.

Comment: A mixed fauna, the older one represented best by the dissolution-resistant *G. nepenthes.* Dissolution is very active but apparently less so than in DR01 which is 720 m deeper.

Sample GA1419745

Dredge/Lithology: 270/03 DR03 B1.1. Chalk.

Locality: West Kenn Plateau.

Latitude 23° 49.4'S; longitude 155° 20.5' E: Water depth: 3280 m.

Residue: >500 µm. Clean planktonic foraminifera residue. Trace dissolution.

250 - 500 µm. Same. Mixed fauna. Minor dissolution.

125 – 250 µm. Same. Minor dissolution. *Globorotalia peripheroronda* stands out.

Fauna:

Foraminifera:

Planktonic:

Orbulina universa

Globoquadrina altispira

Globoquadrina dehiscens

Praeorbulina glomerosa glomerosa

Praeorbulina glomerosa curva

Praeorbulina transitoria

Globorotalia peripheroronda

Benthic:

Other:

Age: Latest Early Miocene (N8)

Environment of deposition: Modern deep sea floor conditions; abyssal plain.

Comment: A mixed fauna, including Quaternary and N8 of the Early/Middle Miocene transition.

Sample GA1419751

Dredge/Lithology: 270/04 DR04 A1.1. Lithified nanno/foram ooze in reefal biostromal limestone.

Locality: Fraser Seamount

Latitude 24° 24.8' S; longitude 155° 18.5' E: Water depth: 450 m.

Residue: Studied in thin section only. Highly fragmental with abundant calcareous algae and some larger foraminifera in the older phase. Younger phase (micritic ooze filling cavities) appears to be Pliocene and equivalent to GA 1419752 and 1419753. Description refers to "Grey reefal biostromal boundstone containing carbonate mudstone containing forams including a few larger forams, molluscs and algae. Cavities filled with pale micrite. Impregnated with ferromanganese". Grey mudstone component appears to be disturbed faecal pellets.

Fauna:

Older phase: Unidentifiable larger foraminifera (*Cycloclypeus*?), bryozoans.

Micrite:

Globorotalia cf. *puncticulata*

Globorotalia tumida

Orbulina universa

Globorotalia truncatulinoides

Globocassidulina sp.

Other: Pteropods

Age: Older phase undatable.

Younger phase – Early Pliocene (N19/20) (possibly oldest Miocene (N18). There may be more than one young phase (including Quaternary) as there appears to be *Globorotalia truncatulinoides.*

Environment of deposition: Older phase – shallow, photic zone. Younger phase – deeper water, probably outer shelf.

Comment: Ferromanganese coating is thick and penetrative, making differentiation of phases difficult. *Globoquadrina altispira* is present, but it is unclear to which phase it belongs. Study would benefit from thin sections cut parallel to equatorial plane of larger foraminifera.

Sample GA1419752

Dredge/Lithology: 270/04 DR04 A3.1. Lithified nanno/foram ooze in reefal biostromal limestone.

Locality: Fraser Seamount

Latitude 24° 24.8’ S; longitude 155° 18.5’ E: Water depth: 450 m.

Residue: Studied in thin section only. Ooze dominated by planktonic foraminifera with echinoid spines.

Fauna:

Orbulina universa

Globoquadrina altispira

Sphaeroidinellopsis seminulina seminulina

Globorotalia menardii

Globorotalia tumida

Globorotalia cf *puncticulata*

Turborotalita humilis

Globigerinoides spp.

Age: Early Pliocene, N19/20

Environment of deposition: Ooze depths, outer shelf or deeper.

Sample GA1419753

Dredge/Lithology: 270/04 DR04 B1. Lithified nanno/foram ooze in reefal biostromal limestone.

Locality: Fraser Seamount.

Latitude 24° 24.8’ S; longitude 155° 18.5’ E: Water depth: 450 m.

Residue: >500 µm. Clumps of non-disaggregated sediment. Trace echinoid spines, mollusc, brachiopod, abundant but very poorly preserved planktonic foraminifera, few large *Lenticulina*. No evidence of dissolution.

250 - 500 µm. Same. Ostracods. Mixed fauna.

125 – 250 µm. Same.

Fauna:

Foraminifera:

Planktonic:

Globoquadrina altispira altispira

Globigerinoides quadrilobatus fistulosus

Globororotalia tumida tumida

Globorotalia tosaensis

Globorotalia truncatulinoides

Globorotalia multicamerata

Globigerinoides spp.

Hastigerina aequilateralis

Sphaeroidinellids

Diverse keeled globorotaliids

Other: Ostracods

Age: Quaternary with admixture of Pliocene (N20).

Environment of deposition: Modern sea floor, well above any depth for dissolution.

Sample GA1419766

Dredge/Lithology: 270/07 DR06 A1.1. Chalk

Locality: Northwest slope of Kenn Plateau.

Latitude 21° 49.6' S; longitude 155° 48.0' E: Water depth: 2800 m.

Residue: >500 µm. White, largely recrystallised ooze, poorly disaggregated. Preservation very poor. Minor fragments Mn oxide. Echinoid plates.

250 - 500 µm. Mostly unidentifiable, poorly preserved foraminifera; benthic fauna significant and includes attached forms. Echinoid spines, bryozoan, ostracods.

125 – 250 µm. Poorly preserved *Globigerina/Globoquadrina* fauna.

Fauna:

Foraminifera:

Planktonic:

Globoquadrina sp.

Older:

Truncorotaloides rohri

Globorotalia broedemanni

Globigerina officinalis

Globigerina frontosa

Globigerina yeguaensis

"Globigerapsis index"

Pseudogloboquadrina primitiva

Benthic:

Common benthics, specially a small species of *Cibicides* with flat dorsal surface.

Other: Echinoid spines and plates, bryozoans, ostracods.

Age: Main body of residue is earlier part of Middle Eocene (P10/11) mixed with some (probably Early) Miocene.

Environment of deposition: Originally at mid shelf depths?

Comment: Sample deserves more work but preservation is not good. Major larger planktonic species expected in fauna of this age are rare or absent. '*Globigerapsis index*' is not true *G. index* but the species recorded by Bolli (1957) as this species. Is the absence of some expected species due to selective dissolution or to cooler conditions at the time?

The species of *Cibicides* suggests an environment in which such forms could exist in an attached form.

Sample GA1419767

Dredge/Lithology: 270/07 DR06 A1.2: Chalk; preservation poor.

Locality: Northwest slope of Kenn Plateau.

Latitude 21° 49.6' S; longitude 155° 48.0' E: Water depth: 2800 m.

Residue: Studied in thin section.

Fauna:

Chiloguembelina sp.

Truncorotaloides sp. (not *T. topilensis*)

Age: Probably as GA1419766 (main body of residue is earlier part of Middle Eocene (P10/11) mixed with some (probably Early) Miocene).

Comment: Very little is identifiable as the fauna lacks forms that are readily identifiable in thin section and is dominated by 'globigerinids'. What can be seen can be related to species identified in GA1419766. No *Globoquadrina* was observed.

Sample GA1419769

Dredge/Lithology: 270/07 DR06 B1.2. Calcareous silty mudstone

Locality: Northwest slope of Kenn Plateau.

Latitude 21° 49.6' S; longitude 155° 48.0' E: Water depth: 2800 m.

Residue: >500 µm. Very small residue. Mn oxide with pristine foraminifera. Single volcanic fragment.

250 - 500 µm. Small residue. Very well preserved, very dominantly planktonic foraminifera with minor Mn oxide. Few benthic forms, ostracods, echinoid spines, common nodosariid species with elongate chambers. Few modern foraminifera mixed in with older fauna.

125 – 250 µm. Main part of the residue; planktonic foraminifera, with a few sponge spicules, echinoid spines, bone, radiolarians.

Fauna:

Foraminifera:

Planktonic:

Pseudohastigerina micra (small and laterally compressed)

Chiloguembelina cubensis

Globorotalia cerroazulensis cerroazulensis

Globigerina gortanii gortanii

Globigerina 'winkleri'

Globorotalia gemma

Benthic:

Other: Radiolaria, sponge spicules, echinoid spines, bone.

Age: Latest Eocene, P17.

Environment of deposition: Ooze depths.

Comment: P17 determination is based on the characteristics of *Globorotalia cerroazulensis*, *Pseudohastigerina micra*, and *Globigerina gortanii*. It is a good fauna and worthy of detailed documentation (along with that from GA1419766). Eocene faunas are not well known from this region.

Sample GA1419770

Dredge/Lithology: 270/07 DR06 C1.1. Chalk

Locality: Northwest slope of Kenn Plateau.

Latitude 21° 49.6’ S; longitude 155° 48.0’ E: Water depth: 2800 m.

Residue: >500 µm. None

250 - 500 µm. Excellently preserved clean residue very dominantly of planktonic foraminifera; minor benthic foraminifera, echinoid spines, ostracods.

125 – 250 µm. Bulk of residue. Very dominantly planktonic foraminifera.

Fauna:

Foraminifera:

Planktonic:

Globigerina binaiensis

Globigerina sellii

Globigerina euapertura

Globorotalia kugleri

Globoquadrina dehiscens

Catapsydrax unicavus

Catapsydrax dissimilis

Other: Ostracods, echinoid spines.

Age: Earliest Miocene, N4.

Environment of deposition:

Comment: No evidence of dissolution. Minor admixture of modern contaminants. The presence of *Globigerina sellii* suggests some evidence of latest Oligocene (approximately N3)

Sample GA1419777

Dredge/Lithology: 270/08 DR07 A1.1. Chalk

Locality: Southeast slope of Marion Plateau**.**

Latitude 22° 09.5’ S; longitude 155° 47.9’ E: Water depth: 2700 m.

Residue: >500 µm. None

250 - 500 µm. Smaller part of residue. Planktonic foraminifera, ostracod, minor Mn oxide.

125 – 250 µm. Dominant part of residue. Planktonic foraminifera, minor benthic foraminifera, ostracods, echinoid spines.

Fauna:

Foraminifera:

Planktonic:

Orbulina universa

Orbulina suturalis

Biorbulina bilobata

Globoquadrina dehiscens dehiscens

Globoquadrina dehiscens advena

Globoquadrina altispira altispira

Globorotalia fohsi

Globorotalia peripheroronda

Globorotalia menardii praemenardii

Hastigerinella sp.

Other: Ostracods, echinoid spines.

Age: Mid Miocene, N12.

Environment of deposition: Deep sea ooze.

Comment: No evidence of dissolution. *Hastigerinella* sp. is represented by a few extremely elongate individual chambers with tuberculate distal ends. These chambers were described initially and erroneously as a benthic form *Bulava indica*.

Sample GA1419779

Dredge/Lithology: 270/08 DR07 B1.1. Chalk.

Locality: Southeast slope of Marion Plateau**.**

Latitude 22° 09.5' S; longitude 155° 47.9' E: Water depth: 2700 m.

Residue: >500 µm. Very small part of residue. Very dominantly planktonic foraminifera; very few benthic foraminifera. Ostracod. *Globoquadrina* and *Orbulina* fauna with very high-spired *Globigerinoides.*

250 - 500 µm. Larger fraction but still relatively small. Same as above. Very few benthic foraminifera. Ostracods.

125 – 250 µm. Dominant fraction. As above but with echinoid spines, ostracods, trace bone. Evidence of minor dissolution.

Fauna:

Foraminifera:

Planktonic:

Orbulina universa

Orbulina suturalis

Biorbulina bilobata

Goboquadrina dehiscens

Globoquadrina altispira altispira

Globigerinoides quadrilobatus subspp.

Globigerinoides with very high spire

Globorotalia peripheroacuta

Globorotalia peripheroronda

Globorotalia fohsi

Benthic:

Other: Ostracods, echinoid spines, bone

Age: Middle Miocene, N12.

Environment of deposition: Deep-sea ooze environment.

Comment: A fully diverse fauna with evidence of minor dissolution but more evident in finer fraction.

Sample GA1419788

Dredge/Lithology: 270/09 DR08 A1.1. Chalk.

Locality: Southeast Marion Plateau.

Latitude 23° 29.6’ S; longitude 154° 50.1’ E: Water depth: 3050 m.

Residue: >500 µm. Small part of residue. Dissolution obvious. Planktonic foraminifera plus some glauconitic rods (different from those in earlier samples). Great *Praeorbulina* fauna.

250 - 500 µm. As above. Larger part of residue. Dissolution more obvious with bone, nodosariid benthic foraminifera with elongate chambers, glauconitic rods.

125 – 250 µm. As above. Dissolution very obvious and bone and teeth noteworthy. Echinoid spines, ostracods, nodosariids with elongate chambers.

Fauna:

Foraminifera:

Planktonic:

Praeorbulina glomerosa glomerosa

Praeorbulina transitoria

Globoquadrina dehiscens

Globoquadrina altispira altispira

Globigerinoides cf. *sicanus* (slightly more elongate and less involute)

Diverse *Globigerinoides*

Globorotalia scitula

Other: Ostracods, echinoid spines

Age: Middle Miocene, N9, probably earlier part to account for absence of *Orbulina universa*.

Environment of deposition: Deep-sea ooze.

Comment: Dissolution very obvious, more so in the finer fractions. A very interesting *Praeorbulina* fauna.

Sample GA1419790

Dredge/Lithology: 270/09 DR08 B1.1. Calcareous claystone.

Locality: Southeast Marion Plateau.

Latitude 23° 29.6’ S; longitude 154° 50.1’ E: Water depth: 3050 m.

Residue: >500 µm. Minor part of residue. Mainly pale rods and clumps with Fe oxide interiors. Also a few large planktonic foraminifera and several nodosariids with elongate chambers. *Orbulina universa* and perhaps other planktonic foraminifera probably are contaminants in the light of observations below. Pale rods and clumps are carbonate.

250 - 500 µm. 60/40 foraminifera/rods and clumps. Ostracods, long-chambered nodosariids, echinoid spines, some evidence of dissolution. No keeled globorotaliids.

125 – 250 µm. 80/20 foraminifera/pale rods and clumps. No *Orbulina* or keeled *Globorotalia.* Obvious dissolution. Bone common, ostracods, echinoid spines.

Fauna:

Foraminifera:

Planktonic:

Globigerinoides spp.

Globorotalia kugleri

Globorotalia obesa

Globigerina ‘winkleri’

Globoquadrina dehiscens

Other: Ostracods, echinoid spines, bone/teeth.

Age: Early Miocene, likely to be restricted to N4

Environment of deposition: Deep sea ooze environment.

Comment: A difficult sample, lacking many diagnostic species. *Orbulina* in the coarse fraction is taken to be a contaminant. No keeled *Globorotalia.* Dissolution more prominent in finer fractions.

Sample GA1419792

Dredge/Lithology: 270/09 DR08 C1.1. Chalk.

Locality: West slope of Kenn Plateau.

Latitude 23° 29.6' S; longitude 154° 50.1' E: Water depth: 3050 m.

Residue: >500 µm. Minute residue. *Globoquadrina, Globigerinoides, Orbulina,* Mn oxide.

250 - 500 µm. Foraminifera; considerable dissolution. Fish vertebrae, trace Mn oxide.

125 – 250 µm. Foraminifera, considerable dissolution, minor bone, Mn oxide.

Fauna:

Foraminifera:

Planktonic:

Orbulina universa

Orbulina suturalis

Globorotalia mayeri

Globorotalia siakensis

Globorotalia menardii

Goborotalia limbate

Globorotalia scitula

Globoquadrina dehiscens

Globoquadrina altispira altispira

Globoquadrina altispira globosa

Globigerina nepenthes

Globigerina decoraperta

Globigerinita incrusta

Other: Bone (vertebrae)

Age: Middle Miocene (N14)

Environment of deposition: Deep sea ooze.

Comment: A very diverse fauna with much of it well preserved.

Sample GA1419799

Dredge/Lithology: 270/10 DR09 A1.1. Strongly lithified chalk.

Locality: Northwest slope of Kenn Plateau.

Latitude 23° 28.0' S; longitude 155° 02.5' E: Water depth: 3200 m.

Residue: >500 µm. Carbonate coated glauconite rods. Severe dissolution has enhanced benthic content. Nodosariids with elongate chambers.

250 - 500 µm. Mainly planktonic foraminifera; 5% glauconite rods. Considerable bone; few echinoid spines, sponge spicules, Mn oxide rods, enhanced benthic content.

125 – 250 µm. Considerable dissolution; bone, echinoid spines, sponge spicules, enhanced benthic foraminifera.

Fauna:

Foraminifera:

Planktonic:

Orbulina universa

Orbulina suturalis

Globoquadrina dehiscens

Globoquadrina altispira altispira

Globorotalia fohsi lobata

Globorotalia mayeri

Globorotalia siakensis

Globorotalia conoidea

Globigerinoides spp.

Hastigerinella aequilateralis

Benthic:

Small *Heterostegina* sp.

Other: Sponge spicules, echinoid spines, bone.

Age: Middle Miocene, N12/13.

Environment of deposition:

Comment: Small *Heterostegina* may indicate a local source of shallow input or may mean that the enhanced benthic content may be due to shallower water deposition. The presence of *Globorotalia conoidea* is unusual in this study and indicates the presence of a New Zealand biogeographic province influence in the Middle Miocene; this has not been obvious before in this set of samples.

Sample GA1419801

Dredge/Lithology: 270/10 DR09 B1.1. Chalk.

Locality: Northwest slope of Kenn Plateau.

Latitude 23° 28.0’ S; longitude 155° 02.5’ E: Water depth: 3200 m.

Residue: >500 µm. Minute residue. Dominantly planktonic foraminifera plus glauconitic rods. Mixed modern and *Globoquadrina* fauna.

250 - 500 µm. 95% foraminifera, very dominantly planktonic. Very minor dissolution.

125 – 250 µm. >95% foraminifera; occasional ostracods, echinoid spines, bone. Minor evidence of dissolution.

Fauna:

Foraminifera: Two faunas, modern and Miocene.

Planktonic:

Modern

Globorotalia truncatulinoides

Orbulina universa

Pulleniatina obliqueloculata

Miocene

Gloquadrina dehiscens

Globoquadrina altispira altispira

Globorotalia miozea

Globorotalia internec *peripheroacuta-praefohsi*

Hastigerninella aequilateralis

Globigerinita glutinata

Benthic:

Other: Ostracods, echinoid spines, bone.

Age: Modern, N22/23. Middle Miocene, N10-12, probably N11.

Environment of deposition: Deep sea ooze.

Comment: Many of the species dominating this fauna have long ranges and it is impossible to allocate, for example *Orbulina universa*, unambiguously to the modern or Miocene component. *Globorotalia* internec *peripheroacuta/praefohsi* suggests an N11 age but it could be +/- one zone. The presence of *Globorotalia miozea* reinforces the indication from GA1419779 (from the same dredge) of the influence of the New Zealand biogeographic realm.

Sample GA1419807

Dredge/Lithology: 270/11 DR10 A1.1. Chalk.

Locality: Northwest slope of Kenn Plateau.

Latitude 22° 51.3'S; longitude 155° 20.4' E: Water depth: 3100 m.

Residue: >500 µm. *Globoquadrina/Globigerinoides* fauna with glauconitic rods and a few elongate foraminifera.

250 - 500 µm. Same

125 – 250 µm. Same with minor glauconite, ostracods, echinoid spines, bone.

Fauna:

Foraminifera:

Planktonic:

Globigerinoides sicanus

Praeorbulina transitoria

Praeorbulina glomerosa curva

Globoquadrina dehiscens

Glovboquadrina altispira altispira

Benthic:

Bueningia creeki

Duquepsammia earlandi

Other: Ostracods, echinoid spines, bone.

Age: Latest Early Miocene, N8.

Environment of deposition: Ooze environment.

Comment: Little evidence of dissolution but perhaps a little stronger in the coarser fraction.

Sample GA1419809

Dredge/Lithology: 270/11 DR10 C1.1. Chalk

Locality: Cato Seamount satellite guyot.

Latitude 22° 51.3'S; longitude 155° 20.4' E: Water depth: 3100 m.

Residue: >500 µm. Small part of residue. *Praeorbulina/Globoquadrina* fauna; minor glauconite; elongate benthic species.

250 - 500 µm. As above.

125 – 250 µm. As above; minor bone.

Fauna:

Foraminifera:

Planktonic:

Praeorbulina glomerosa

Praeorbulina transitoria

Globoquadrina altispira

Globoquadrina dehiscens

Globigerinoides sicanus

Benthic:

Other: Bone.

Age: Latest Early Miocene, N8, earliest N9.

Environment of deposition: Typical ooze.

Sample GA1419816

Dredge/Lithology: 270/12 DR11 A1. Algal boundstone

Locality: Cato Seamount satellite guyot.

Latitude 23° 11.35'S; longitude 155° 23.0' E: Water depth: 800-1000 m.

Residue: Studied in thin section only. Slide dominated by one species of coral or calcareous alga. Minor foraminiferal fauna in small cavities. Rock described as 'White algal boundstone, about 90% framework algae, but with calcareous micrite infillings containing abundant smaller algae and some forms'.

Fauna:

Foraminifera:

Flosculinella cf. *bontangensis globulosa* (single equatorial section)

Amphistegina sp.

Other: Calcareous algae *Lithophyllum/Mesophyllum* and *Melobesia*.

Age: Indeterminate but if *F. b. globulosa* is correctly identified, Early to mid-Miocene.

Environment of deposition: Shallow water, photic zone, possibly sea grass.

Comment: While lithologically very different from GA1419807 (DR10 A1.1), the age is consistent but not as well defined.

Sample GA1419817

Dredge/Lithology: 270/12 DR11 B1. Algal boundstone.

Locality: Cato Seamount satellite guyot.

Latitude 23° 11.35'S; longitude 155° 23.0' E: Water depth: 800-1000 m.

Residue: Studied in thin section only. Very dominantly micritic ooze filling a cavity in older material which represented only by small corners of the slide. Cavity lined with ferromanganese. Ooze contains minor fragmental coral debris, pteropods and echinoid spines. Older phase severely recrystallised but with calcareous algae and large foraminifera.

Fauna:

Micrite

Foraminifera:

Planktonic (very diverse):

Goloborotalia menardii group

Globorotalia tumida

Globorotalia crassaformis

Globorotalia tosaensis

? *Globoquadrina altispira altispira*

Sphaeroidinella dehiscens

Benthic:

Globocassidulina sp.

Elphidium sp.

Older phase

Lepidocyclina (with equivalent sized proto- and deutero-conch, possibly *L. howchini praehowchini*)

Amphistegina sp.

Age: Young micrite – mid-Late Pliocene, N21/22, probably N21.

Older phase – Probably Early Miocene.

Environment of deposition: Early Miocene – shallow photic zone, possibly sea grass.

Pliocene – mid-outer shelf.

Sample GA1419818

Dredge/Lithology: 270/12 DR11 B2. Algal boundstone.

Locality: Cato Seamount satellite guyot.

Latitude 23° 11.35'S; longitude 155° 23.0' E: Water depth: 80-1000 m.

Residue: Studied in thin section only. Apparently identical with GA1419817; cavity-filling micrite in older severely recrystallised material. Older material contains no larger foraminifera in contrast with GA1419817.

Fauna:

Micrite

Foraminifera:

Planktonic (very diverse):

As for GA1419817

Benthic:

Older phase

Nothing identifiable

Age: Younger micrite – Pliocene, probably N21.

Older material – undatable.

Environment of deposition:

Sample GA1419819

Dredge/Lithology: 270/12 DR11 C1. Algal boundstone.

Locality: Cato Seamount satellite guyot.

Latitude 23° 11.35'S; longitude 155° 23.0' E: Water depth: 800-1000 m.

Residue: Studied in thin section only. Lithology as for GA1419816. Very highly porous reefal material dominated by calcareous algae (*Meso- and Litho-phyllum*) with gastropods.

Fauna:

Foraminifera:

Lepidocyclina sp. (abundant but vertical sections only)

Biarritzina proteiformis

Flosculinella bontangensis (equatorial section only)

Amphistegina sp.

Age: Early-Middle Miocene, probably early in the Middle Miocene (N9-N12 equivalent)

Environment of deposition: Shallow water, well within the photic zone.

Sample GA1419824

Dredge/Lithology: 270/13 DR12 A1. Packstone calcarenite.

Locality: Kenn Reef, east slope.

Latitude 21° 06.8'S; longitude 155° 53.3' E: Water depth: 1900 m.

Residue: Studied in thin section only. GA1419824 consists of very well sorted biocalcarenite with very diverse content. Bryozoa, calcareous algae (*Lithophyllum/Mesophyllum*), pteropods, echinoid spines, volcanic glass and other sand sized volcanic fragments. Planktonic foraminifera a minor component.

A second slide (University of Tasmania) is essentially the same but has a few forms not seen in GA1419824.

Fauna:

Foraminifera:

(1) GA1419824

Planktonic:

Pseudohastigerina micra

Chiloguembelina sp.

Globigerina of the *tripartita* group.

Benthic:

Biarritzina proteiformis

Operculina sp.(?)

Elphidium

Common simple agglutinates such as *Textularia*

Common simple miliolids

(2) University of Tasmania slide

As above, plus *Sphaerogypsina globulus* and initial chambers of a *Lepidocyclina* sp.

Age: Middle Eocene – Early Oligocene but not well defined. The absence of anything that would indicate a Late Eocene age makes me lean towards the Early Oligocene but it is very tentative.

Environment of deposition: Shallow water, photic zone, moderately high energy, inner shelf.

8. PRELIMINARY CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY OF KENN PLATEAU DREDGE SAMPLES, GEOSCIENCE AUSTRALIA SURVEY 270

Richard W. Howe

8.1. Summary

Table 12. Biostratigraphic summary of Survey 270 nannofossil samples

Sample No.	Sample	Stage	Zone
NEOGENE SAMPLES			
x1419744	270/03DR03A1.2	middle Tortonian (middle Upper Miocene)	CN8b, upper NN10
x1419746	270/03DR03B1.2	uppermost Langhian (middle middle Miocene)	mid CN4, mid NN5
x1419753	270/DR04B1	middle Piacenzian (middle middle Pliocene)	upper CN12a, middle NN16
x1419771	270/07DR06C1.2	upper Aquitanian (middle lower Miocene)	mid CN1c, mid NN2
x1419778	270/08DR07A1.2	mid Langhian (lower middle Miocene)	lower CN4, lower NN5
x1419780	270/08DR07B1.2	upper Langhian (lower middle Miocene)	lower CN4, lower NN5
x1419789	270/09DR08A1.2	upper Langhian (lower middle Miocene)	lower CN4, lower NN5
x1419791	270/09DR08B1.2	upper Aquitanian (middle lower Miocene)	mid CN1c, mid NN2
x1419793	270/09DR08C1.2	upper Serravallian (upper middle Miocene)	upper CN5b, upper NN7
x1419800	270/10DR09A1.2	middle Serravallian (middle middle Miocene)	upper CN5a-lower CN5b, upper NN6-lower NN7
x1419802	270/10DR09B1.2	upper Serravallian (upper middle Miocene)	lower CN5b, lower NN7
x1419808	270/11DR10A1.2	lower Langhian (lower middle Miocene)	lower CN4, upper NN4
x1419810	270/11DR10C1.2	lower Langhian (lower middle Miocene)	lower CN4, upper NN4
PALAEOGENE SAMPLES			
1419729	270/01DR01A1.1	upper Rupelian (upper lower Oligocene)	lower CP19a, lower NP24
1419731	270/01DR01B1.2	middle Rupelian (middle	lower CP18, mid NP23

		lower Oligocene)	
1419766	270/07DR06A1.1	middle Ypresian to lower Lutetian (lower to lower middle Eocene)	mid CP9b-mid CP12b, mid NP11-mid NP14b
1419768	270/07DR06B1.1	lower Rupelian (lower lower Oligocene)	CP16b, upper NP21

8.2. Introduction

Seventeen dredge samples from Geoscience Australia Cruise 270 (*Southern Surveyor* SS05/2004) to the Kenn Plateau in the southwest Pacific Ocean were analysed for calcareous nannofossils. Standard smear slides were prepared in the GA Palaeontology and Sedimentology Laboratory. The samples were analysed with a Zeiss Photomicroscope III, equipped with cross-polarising facilities, at a magnification of 1250x. This report uses the cosmopolitan NP (Palaeogene) and NN (Neogene) zonations of Martini (1971), and the CP (Palaeogene) and CN (Neogene) zonations of Okada and Bukry (1980). Correlation of the zonations to the geologic timescale follows Berggren (1995) and Young (1998). The zonal and stage assignments for the samples are summarised on Table 12.

Unlike many other dredge samples examined by the author, these samples are remarkably free of the mixing of different aged material that often occurs in dredge samples. Four of the samples are Palaeogene in age, with the oldest being Sample 270/07DR06A1.1, which is middle Ypresian to early Lutetian (early to early middle Eocene) in age. This sample has a poorly preserved, assemblage of very low abundance and diversity. The other three Palaeogene samples (270/01DR01A1.1, 270/01DR01B1.2, 270/07DR06B1.1) are all Rupelian (early Oligocene) in age, and have much higher abundances and diversities and much better preservation than the Eocene sample. The other 13 samples are all Neogene, with two samples (270/07DR06C1.2 and 270/09DR08B1.2) being Aquitanian (middle early Miocene) in age, six samples (270/03DR03B1.2, 270/08DR07A1.2, 270/08DR07B1.2, 270/09DR08A1.2, 270/11DR10A1.2 and 270/11DR10C1.2) being Langhian (early middle Miocene) in age, three samples (270/09DR08C1.2, 270/10DR09A1.2, 270/10DR09B1.2) being Serravallian (middle Miocene) in age, one sample (270/03DR03A1.2) being middle Tortonian (middle late Miocene) in age, and one sample (270/04DRB1) being middle Piacenzian (middle middle Pliocene) in age.

Semi-quantitative estimates were made of abundance of selected species (Tables 2 and 3), using the following scheme: VH = very high, >100 specimens per field of view (FOV); H = high, 50–100 specimens per FOV; M = moderate 10–50 specimens per FOV; L = low, 1–10 specimens per FOV; VL = very low, 1 specimen per 1–10 FOV's. Individual species abundances were recorded as follows: A = abundant, >100 specimens per FOV; C = common, 11–100 specimens per FOV; F = few, 1–10 specimens per FOV; R = rare, 1 specimen in 10 FOV's; S = single, only a single specimen observed. As the nannofossil assemblage in a sample can show overgrowth of some species, and dissolution of others, only the overall preservation state of the assemblage is recorded here as G = good, whole assemblage is well preserved, with the diagnostic features of most species preserved; M = moderate, with some dissolution and/or overgrowth, but most species still identifiable, P = poor, severe dissolution and/or overgrowth, with only a few species identifiable to species level.

Table 12a Distribution of selected Neogene nannofossil species

	GA Laboratory Number	Sample	Abundance	Preservation	SELECTED NEOGENE SPECIES	*Calcidiscus leptoporus* 1	*Calcidiscus macintyrei* 2	*Calcidiscus premacintyrei* 3	*Calcidiscus tropicus* 4	*Clausicoccus fenestratus* 5	*Coccolithus miopelagicus* 6	*Coronocyclus nitescens* 7	*Cryptococcolithus mediaperforatus* 8	*Cyclicargolithus abisectus* 9	*Cyclicargolithus floridanus* 10	*Discoaster brouweri* 11	*Discoaster challengeri* 12	*Discoaster deflandrei* 13	*Discoaster druggii* 14	*Discoaster exilis* 15	*Discoaster icarus* 16
1	1419744	270/03DR03A1.2	VH	P-M	.	F	R	.	R	.	.	.	R	.	.	F	R	.	.	.	R
2	1419746	270/03DR03B1.2	VH	P-M	.	R	.	R	.	.	F	R	.	.	F	.	.	R	.	R	.
3	1419753	270/04DRB1	H	P	.	.	F	.	.	.	.	.	.	.	.	F	.	.	.	.	.
4	1419771	270/07DR06C1.2	H	M-G	.	F	.	.	.	R	R	F	.	R	C	.	.	F	.	.	.
5	1419778	270/08DR07A1.2	H	M-G	.	.	.	R	R	.	R	R	R	.	C	.	.	R	.	F	.
6	1419780	270/08DR07B1.2	H	M-G	.	.	.	R	R	.	R	R	R	.	C	.	.	R	.	F	.
7	1419789	270/09DR08A1.2	H	M-G	.	.	.	R	R	.	R	R	R	.	F	.	.	R	.	F	.
8	1419791	270/09DR08B1.2	H	M	.	?S	.	.	.	.	F	F	.	.	C	.	.	C	?F	.	.
9	1419793	270/09DR08C1.2	H	M-G	.	.	F	.	F	.	.	.	.	.	.	F	.	.	.	F	.
10	1419800	270/10DR09A1.2	H	M	.	.	F	S	F	.	R	R	R	.	F	.	.	R	.	F	.
11	1419802	270/10DR09B1.2	H	M-G	.	.	R	.	F	.	F	.	R	.	F	F	.	R	.	C	.
12	1419808	270/11DR10A1.2	H	M-G	.	.	.	R	.	.	F	R	R	.	C	.	.	F	.	F	.
13	1419810	270/11DR10C1.2	H	P-M	.	.	.	R	F	.	F	F	R	.	C	.	.	C	.	F	.

	GA Laboratory Number	*Discoaster kugleri* 17	*Discoaster loeblichii* 18	*Discoaster moorei* 19	*Discoaster musicus* 20	*Discoaster neohamatus* 21	*Discoaster pentaradiatus* 22	*Discoaster petaliformis* 23	*Discoaster prepentaradiatus* 24	*Discoaster signus* 25	*Discoaster surculus* 26	*Discoaster tamalis* 27	*Discoaster triradiatus* 28	*Discoaster variabilis* 29	*Helicosphaera ampliaperta* 30	*Helicosphaera elongata* 31	*Helicosphaera euphratis* 32
1	1419744	.	R	.	.	R	F	.	R	.	.	.	.	F	.	.	.
2	1419746	.	.	.	R	.	.	F	.	.	.	.	.	F	S*	R	.
3	1419753	.	.	.	.	.	F	.	.	.	.	R	R	.	.	.	.
4	1419771	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F
5	1419778	.	.	.	.	.	.	.	.	.	.	.	.	C	.	.	F
6	1419780	.	.	R	R	.	.	.	.	.	.	.	.	C	.	.	.
7	1419789	.	.	R	R	.	.	.	.	F	.	.	.	C	.	.	.
8	1419791	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F
9	1419793	.	.	R	.	.	.	.	.	.	.	.	.	C	.	.	.
10	1419800	?R	.	R	.	.	.	.	.	.	.	.	.	C	.	.	.
11	1419802	?R	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
12	1419808	.	.	R	.	.	.	R	.	R	.	.	.	C	R	.	.
13	1419810	.	.	R	.	.	.	.	.	R	.	.	.	C	R	.	.

	GA Laboratory Number	*Helicosphaera perch-nielsenae* 33	*Helicosphaera recta* 34	*Ilselithina fusa* 35	*Minylitha convallis* 36	*Pseudoemiliania lacunosa* 37	*Reticulofenestra gelida* 38	*Reticulofenestra pseudoumbilicus* 39	*Sphenolithus abies* 40	*Sphenolithus heteromorphus* 41	*Tetralithoides symeonidesii* 42	*Triquetrorhabdulus carinatus* 43	*Triquetrorhabdulus challengeri* 44	*Triquetrorhabdulus milowii* 45	*Triquetrorhabdulus rioi* 46	*Triquetrorhabdulus rugosus* 47	*Zygrhablithus bijugatus* 48	Nannofossil Zone	Stage
1	1419744	.	.	.	R	.	.	.	F	.	.	.	.	.	R	R	.	CN8b, upper NN10	middle Tortonian (middle Upper Miocene)
2	1419746	R	.	.	.	.	.	.	.	C	.	.	R	.	.	.	.	mid CN4, mid NN5	uppermost Langhian (middle middle Miocene)
3	1419753	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	upper CN12a, middle NN16	middle Piacenzian (middle middle Pliocene)
4	1419771	R	F	.	.	.	.	.	.	.	.	R	R	R	.	.	.	mid CN1c, mid NN2	upper Aquitanian (middle lower Miocene)
5	1419778	R	.	.	.	.	.	.	.	R	R	.	.	S	.	.	.	lower CN4, lower NN5	mid Langhian (lower middle Miocene)
6	1419780	R	.	.	.	.	.	.	.	F	R	.	.	S	.	.	.	lower CN4, lower NN5	upper Langhian (lower middle Miocene)
7	1419789	R	.	.	.	.	.	.	.	C	R	.	.	.	.	.	.	lower CN4, lower NN5	upper Langhian (lower middle Miocene)
8	1419791	F	R	R	.	.	.	.	.	.	R	R	R	.	.	.	R	mid CN1c, mid NN2	upper Aquitanian (middle lower Miocene)
9	1419793	.	.	.	.	.	C	F	F	.	S	.	.	.	R	.		upper CN5b, upper NN7	upper Serravallian (upper middle Miocene)
10	1419800	.	.	.	.	.	C	F	.	.	.	.	.	.	R	R	.	NN6-lower NN7	middle Serravallian (middle middle Miocene)
11	1419802	.	.	.	.	.	.	C	.	.	.	.	.	.	R	R	.	lower CN5b, lower NN7	upper Serravallian (upper middle Miocene)
12	1419808	R	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	lower CN4, upper NN4	lower Langhian (lower middle Miocene)
13	1419810	F	.	.	.	.	.	.	.	C	R	.	.	.	.	.	.	lower CN4, upper NN4	lower Langhian (lower middle Miocene)

Table 12b Distribution of selected Palaeogene nannofossil species

	GA Laboratory Number	Sample	Abundance	Preservation	SELECTED PALAEOGENE SPECIES	*Chiasmolithus altus* 1	*Chiasmolithus* sp. 2	*Clausicoccus fenstratus* 3	*Coccolithus formosus* 4	*Coccolithus miopelagicus* 5	*Coccolithus pelagicus* 6	*Coronocyclus nitescens* 7	*Cruciplacolithus serraculoides* 8	*Cyclicargolithus abisectus* 9	*Cyclicargolithus floridanus* 10	*Discoaster calculosus* 11	*Discoaster deflandrei* 12	*Discoaster deflandrei* 5 ray 13	*Discoaster nodifer* 14	*Discoaster tanii* 15	*Helicosphaera bramlettei* 16	*Helicosphaera compacta* 17	*Helicosphaera recta* 18	*Helicosphaera reticulata* 19	*Helicosphaera wilcoxonii* 20	*Ilselithina fusa* 21	*Isthmolithus recurvus* 22
1	1419729	270/01DR01A1.1	H	P-M	.	C	.	F	.	F	.	R	.	.	A	R	F	.	R	.	.	R	R	.	.	R	.
2	1419731	270/01DR01B1.2	H	P	.	?R	.	F	.	F	.	F	.	F	C	.	R	R	R	.	.	?R	.	.	.	.	.
3	1419766	270/07DR06A1.1	VL	VP	.	.	R	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
4	1419768	270/07DR06B1.1	M-H	M-G	.	.	.	F	F	.	.	.	F	.	.	.	F	.	F	F	R	R	.	R	R	R	F

	GA Laboratory Number	*Lanternithus minutus* 23	*Pontosphaera spp.* 24	*Reticulofenestra bisecta bisecta* 25	*Reticulofenestra bisecta filewiczii* 26	*Reticulofenestra circus* 27	*Reticulofenestra hillae* 28	*Reticulofenestra stavensis* 29	*Reticulofenestra umbilicus* 30	*Rhabdosphaera tenuis* 31	*Sphenolithus akropodus* 32	*Sphenolithus ciperoensis* 33	*Sphenolithus dissimilis* 34	*Sphenolithus distentus* 35	*Sphenolithus predistentus* 36	*Sphenolithus pseudoradians* 37	*Toweius gammation* 38	*Toweius occultatus* 39	*Toweius pertusus* 40	*Transversopontis* spp. 41	*Triquetrorhabdulus carinatus* 42	*Zygrhablithus bijugatus* 43	Nannofossil Zone	Stage
1	1419729	.	.	C	C	.	.	F	.	.	.	R	.	F	R	R	.	.	.	.	R	R	lower CP19a, lower NP24	upper Rupelian (upper lower Oligocene)
2	1419731	.	.	C	C	C	.	F	.	.	F	.	.	F	R	.	.	.	.	.	.	.	lower CP18, mid NP23	middle Rupelian (middle lower Oligocene)
3	1419766	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	S	R	F	.	.	.	mid CP9b-mid CP12b, mid NP11-	middle Ypresian to lower Lutetian (lower to
4	1419768	R	.	C	C	F	F	.	F	R	.	.	S	R	.	S	.	.	.	R	.	F	CP16b, upper NP21	lower Rupelian (lower lower Oligocene)

8.3. Results

1419744 270/03DR03A1.2

Zone: CN8b, upper NN10.

Stage: middle Tortonian (middle Upper Miocene).

Key species: *Discoaster pentaradiatus, D. prepentaradiatus, Minylitha convallis,* very rare *Reticulofenestra pseudoumbilicus.*

1419746 270/03DR03B1.2

Zone: mid CN4, mid NN5.

Stage: uppermost Langhian (middle middle Miocene).

Key Species: *Discoaster signus, Helicosphaera perch-nielsenae, Sphenolithus heteromorphus.*

1419753 270/04DRB1

Zone: upper CN12a, middle NN16.

Stage: middle Piacenzian, middle middle Pliocene.

Key Species: *Discoaster tamalis, D. pentaradiatus, D. brouweri.* Absence *D. variabilis.*

1419771 270/07DR06C1.2

Zone: mid CN1c, mid NN2.

Stage: upper Aquitanian (middle lower Miocene).

Key Species: *Helicosphaera recta, Calcidiscus leptoporus.*

1419778 270/08DR07A1.2

Zone: lower CN4, lower NN5.

Stage: mid Langhian (lower middle Miocene).

Key Species: *Sphenolithus heteromorphus, Cyclicargolithus floridanus, Helicosphaera perch-nielsenae.* Absence *Helicosphaera ampliaperta, Discoaster signus/petaliformis, D. musicus.*

1419780 270/08DR07B1.2

Zone: lower CN4, lower NN5.

Stage: upper Langhian (lower middle Miocene).

Key Species: *Sphenolithus heteromorphus, Cyclicargolithus floridanus, Helicosphaera perch-nielsenae, Discoaster musicus, D. moorei.* Absence *Helicosphaera ampliaperta, Discoaster signus/petaliformis.*

1419789 270/09DR08A1.2

Zone: lower CN4, lower NN5.

Stage: upper Langhian (lower middle Miocene).

Key Species: *Sphenolithus heteromorphus, Cyclicargolithus floridanus, Helicosphaera perch-nielsenae, Discoaster musicus, D. moorei.* Absence *Helicosphaera ampliaperta, Discoaster signus/petaliformis.*

1419791 270/09DR08B1.2

Zone: mid CN1c, mid NN2.

Stage: upper Aquitanian (middle lower Miocene).

Key Species: *Helicosphaera recta, Ilselithina fusa.* Absence *Clausicoccus* spp., *Calcidiscus leptoporus.*

1419793 270/09DR08C1.2

Zone: upper CN5b, upper NN7.

Stage: upper Serravallian (upper middle Miocene).

Key Species: *Coccolithus miopelagicus, Calcidiscus macintyrei.* Absence *Cyclicargolithus floridanus, Catinaster coalitus, Discoaster signus, Coronocyclus nitescens.*

1419800 270/10DR09A1.2

Zone: upper CN5a-lower CN5b, upper NN6-lower NN7.

Stage: middle Serravallian (middle middle Miocene).

Key Species: *Calcidiscus macintyrei, Coronocyclus nitescens, Calcidiscus premacintyrei*

1419802 270/10DR09B1.2

Zone: lower CN5b, lower NN7.

Stage: upper Serravallian (upper middle Miocene).

Key Species: *Coccolithus miopelagicus, Calcidiscus macintyrei, Discoaster kugleri, Triquetrorhabdulus rugosus.* Absence common *Cyclicargolithus floridanus, Discoaster signus, Coronocyclus nitescens.*

1419808 270/11DR10A1.2

Zone: lower CN4, upper NN4.

Stage: lower Langhian, lower middle Miocene.

Key Species: *Helicosphaera ampliaperta, Discoaster signus, Calcidiscus premacintyrei, Discoaster moorei, D. calculosus.*

1419810 270/11DR10C1.2

Zone: lower CN4, upper NN4.

Stage: lower Langhian, lower middle Miocene.

Key Species: *Helicosphaera ampliaperta, Discoaster signus.*

8.3. Palaeogene Results

1419729 270/01DR01A1.1

Zone: lower CP19a, lower NP24

Stage: upper Rupelian (upper lower Oligocene)

Key Species: *Sphenolithus ciperoensis, S. distentus, S. pseudoradians, Chiasmolithus altus.*

1419731 270/01DR01B1.2

Zone: lower CP18, mid NP23

Stage: middle Rupelian (middle lower Oligocene)

Key Species: *Reticulofenestra circus, Sphenolithus distentus.* Absence *Lanternithus minutus, Reticulofenestra umbilicus.*

1419766 270/07DR06A1.1

Zone: mid CP9b-mid CP12b, mid NP11-mid NP14b

Stage: middle Ypresian to lower Lutetian (lower to lower middle Eocene)

Key Species: *Toweius gammation, T. pertusus.*

1419768 270/07DR06B1.1

Zone: CP16b, upper NP21

Stage: lower Rupelian (lower lower Oligocene)

Key Species: *Coccolithus formosus, Isthmolithus recurvus.* Absence *Cribrocentrum reticulatum.*

9. STRUCTURAL AND BASINAL GEOLOGY

Peter Hill

The structure/sediment thickness map of the Kenn Plateau region (Figure 50) was compiled from the following data sources:

- Survey 270 seismic
- Sparker seismic surveys 12, 13, 14 & 15 of the Continental Margins Survey, Bureau of Mineral Resources, 1970-73
- Shell *Petrel* airgun seismic survey 1972-73 (lines N701 & 702)
- Shell Coral Sea Roving airgun seismic survey 1973-74
- Satellite gravity imagery (Sandwell and Smith 1997)
- Magnetic anomaly map of the Australian region (Petkovic 2002)
- Structure/sediment thickness maps of the Capricorn, northern Tasman and Maryborough Basins (Hill 1992; Hill 1994).

9.1. Main structural features

Kenn Plateau is a thinned continental block bounded on its western side by an ocean-continent boundary (COB) that roughly coincides with the foot of slope in the adjacent Cato Basin, Cato Trough and northern Tasman Basin (Figure 50). Basement to the Cato Basin is interpreted as oceanic from a range of indirect evidence including gravity data and plate reconstructions. Existing seismic profiles shot with low-power sources do not image basement well because of the thick (>2 s twt) sedimentary fill and masking by extensive mid Tertiary hot-spot volcanics. The COB is interpreted to lie west of Kenn and Cato Seamounts. This differs from the interpretation of Gaina *et al.* (1999), who show the COB located to the east of these features and the western tip of Kenn Plateau underlain by oceanic crust. The southwest margin is a passive margin conjugate to SE Queensland, while the northwest margin between Coriolis Ridge and Cato Seamount is a transform margin conjugate to the southern Marion Plateau. Transform movement took place along the Cato Fracture Zone forming the southern margin of the Marion Plateau and the western margin of Kenn Plateau (Figure 51). The bend in the middle of this structure, at the Cato Trough, suggests that separation of Kenn Plateau from Australia (~63-52 Ma) was initially in a NE direction and finished in a NNE direction.

No basement rocks or dateable bedrock sediments have been recovered from Kenn Plateau as yet. Quartz sandstone dredged at DR2 on the southwest margin could not be dated, but was probably deposited before breakup in a continental setting. The conjugate southeast Queensland margin is underlain by Palaeozoic-Triassic basement of the New England Fold Belt. Several stacked and contiguous basins, which range in age from Late Triassic to mid Cretaceous and include the Ipswich, Nambour and Maryborough Basins (Stephenson and Burch 2004), overlie the basement rocks. Equivalent basement and Mesozoic sedimentary bedrock could be expected on the Kenn Plateau. Structural trends on the adjacent Australian continent (SE Queensland, Capricorn Basin and Marion Plateau) are predominantly NNW (Figure 50), probably reflecting the underlying structural fabric of the New England Fold Belt. Faults along the southwest margin of the Kenn Plateau and in the western Observatory Basin parallel this trend, when the Plateau is reconstructed against the Australian continent.

Northern Kenn Plateau largely comprises fault-bounded basement blocks of the Coriolis Ridge and the Chesterfield Rise, divided by the 20-40 km wide Chesterfield Trough (Figure 51) which broadly trends ENE, but is controlled by northwest-trending faults at its western end and northeast-trending faults at its eastern end. The shallow basement block that forms the core of Coriolis Ridge contains a number of small rift grabens. Its upper surface is 1100-1500 m deep, has been planated by erosion, and dips gently to the south and southeast (away from the Chesterfield Trough). Northwest-striking faults in the middle section of the Coriolis Ridge may be transform or transfer faults associated with extension in this direction during the Late Cretaceous-Palaeogene.

Apart from margin-parallel faulting along the southwest margin of Kenn Plateau, southern Kenn Plateau exhibits no distinct structural fabric. Its western end is dominated by a widespread Oligocene hot-spot volcanic terrain (now mostly covered by Neogene carbonates), including Cato Seamount, numerous surrounding cones, and extensive lava fields (Figures 52 & 53). The central and southern parts of southern Kenn Plateau are characterized by numerous diapiric structures and folding within the sedimentary section (Figures 53 & 54) and a seismic basement that appears to be largely volcanic (Figures 55 & 56).

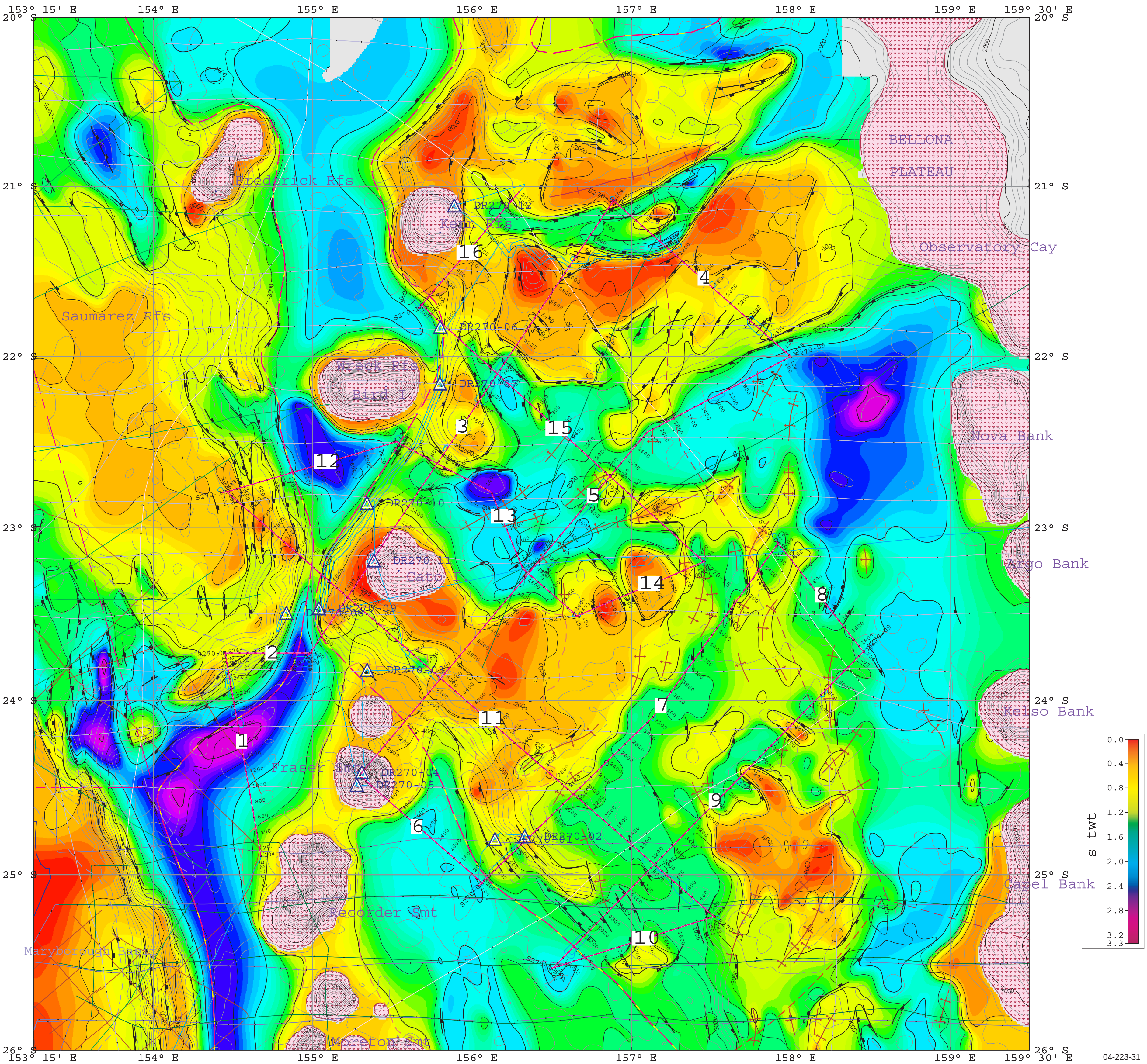


Figure 50. Structure and minimum sediment thickness map of the Kenn Plateau region. Black unannotated contours are isopachs at 0.5 s twt interval (thick contours are at 1.0 s twt interval). Fine black annotated contours are ETOPO2 isobaths at 1000 m interval; fine grey contours are intermediate ETOPO2 isobaths at 200 m interval. The continent-ocean boundary (COB) is shown as a thick dark pink and yellow dashed line. The thick dashed red line indicates the outer boundary of supra-basement volcanics which mask probable deeper sedimentary section. Areas outlined by a dashed dark pink line and filled with a triangle pattern on a light pink background are underlain by hot-spot volcanoes. The brown anticline symbols represent diapiric structures. An interpreted volcanic ridge on the Chesterfield Rise is indicated as a red line with crossbars.

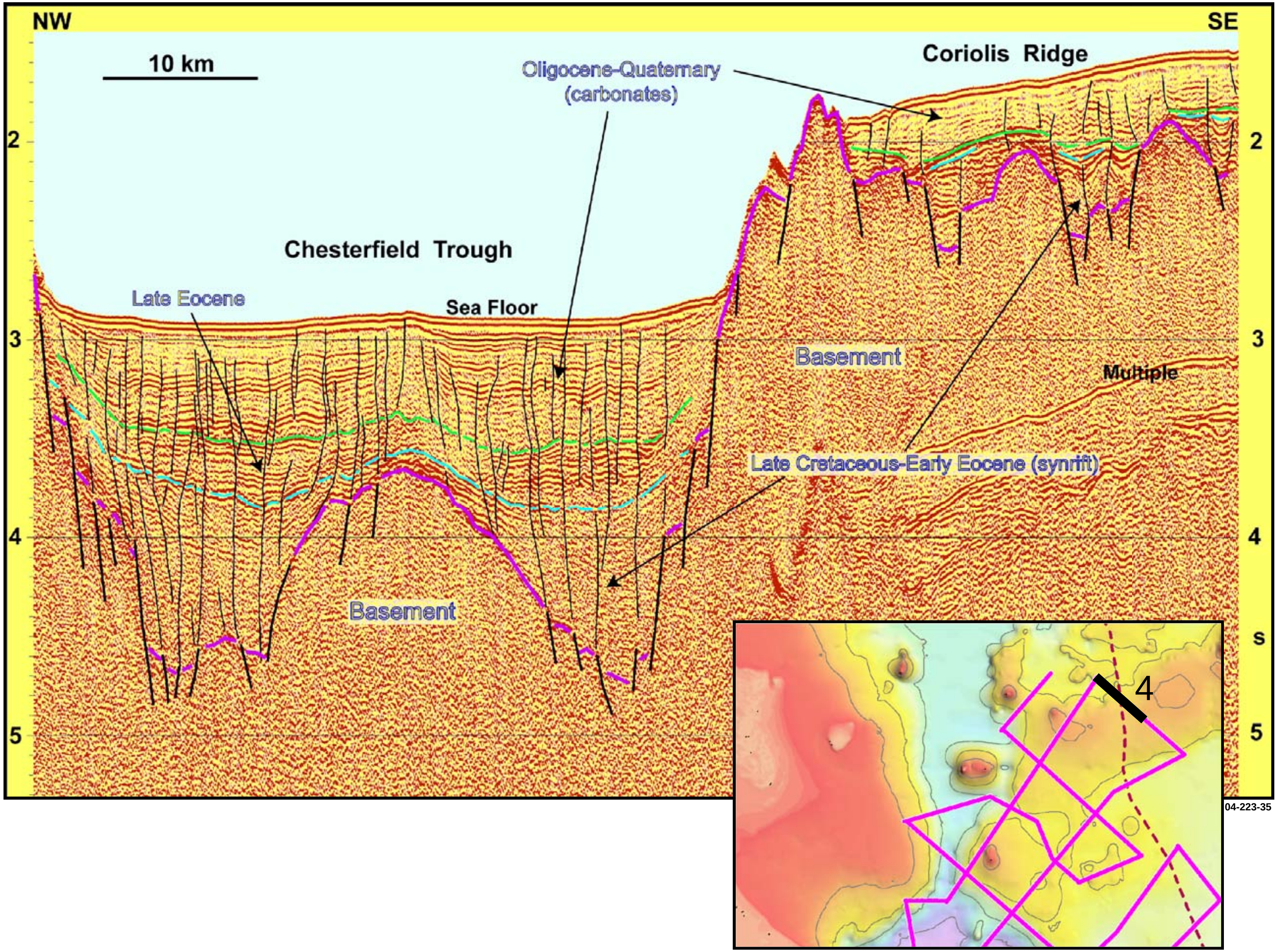


Figure 51. Seismic profile (Line 4) across the Chesterfield Trough on the northern Kenn Plateau. The Trough contains 2 s twt of sediment, comprising deformed synrift and early sag phase deposits, late Eocene fill, and a thick sequence of Oligocene-Quaternary carbonates. Pervasive small-scale faulting extends upwards into the late Neogene and, in places, the Quaternary.

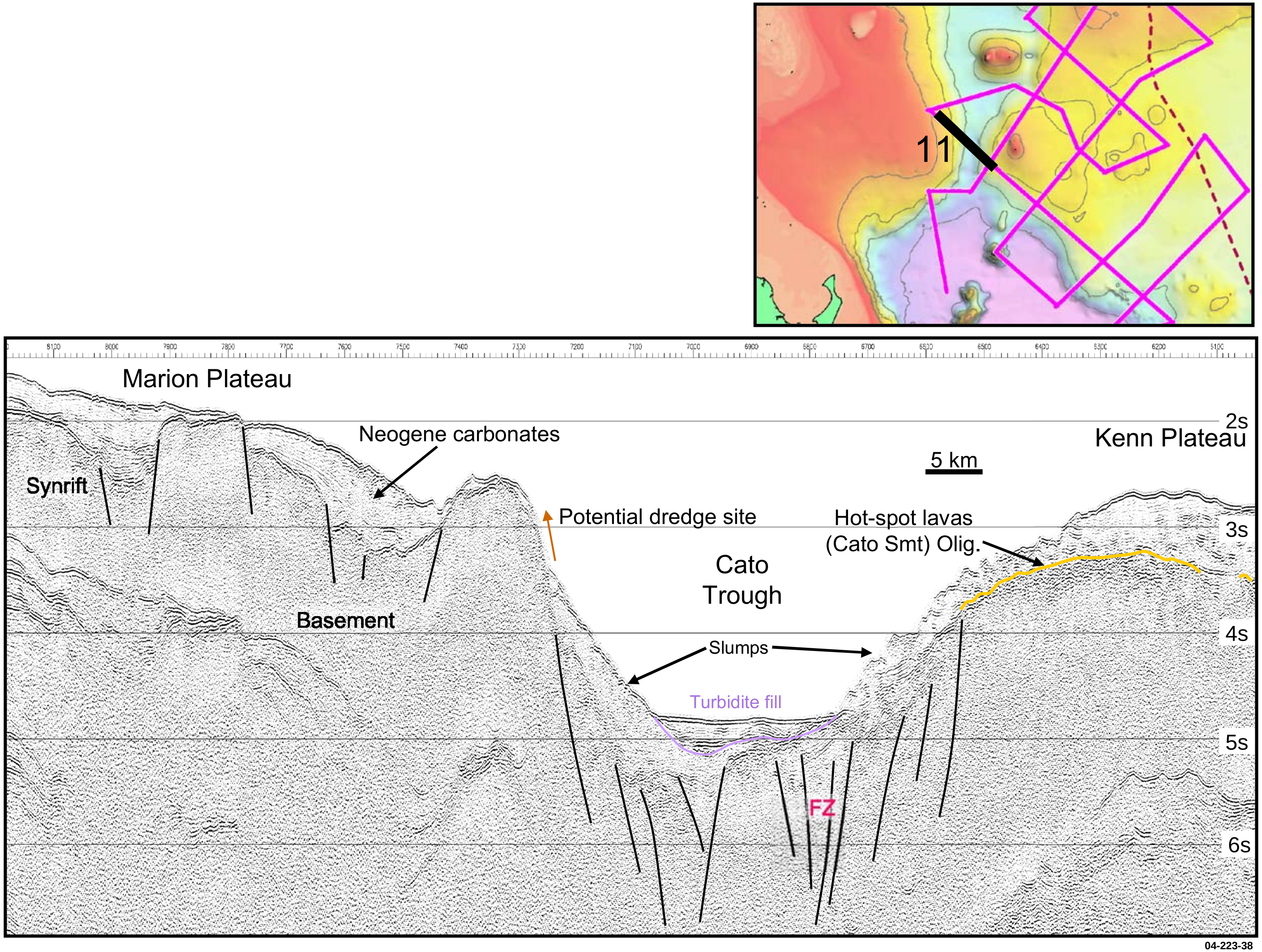


Figure 52. Seismic profile (Line 11) across Cato Trough, showing intense faulting at the Cato Fracture Zone, synrift graben fill on the Marion Plateau, Oligocene lavas associated with Cato Seamount, and late Neogene/Quaternary turbidites ponded within the Trough.

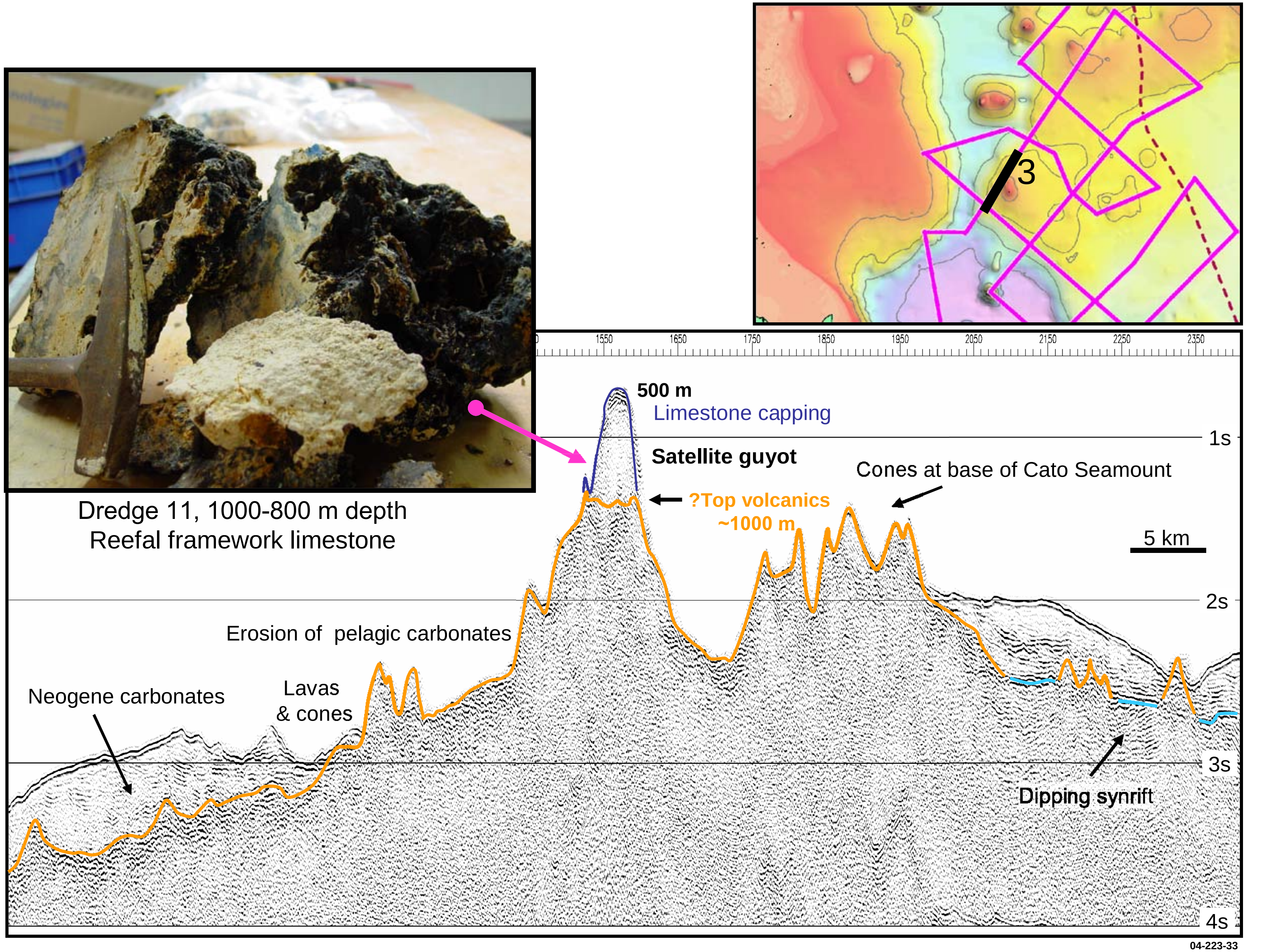


Figure 53. Seismic profile (Line 3) across volcanic terrain adjacent to Cato Seamount. Bottom currents have eroded Neogene carbonate cover and kept much of the 30 Ma volcanic terrain free of sediment. Reefal framework limestone dredged (DR11) from the upper flank of a satellite guyot indicates a carbonate capping many hundreds of metres thick and subsidence of ~1 km.

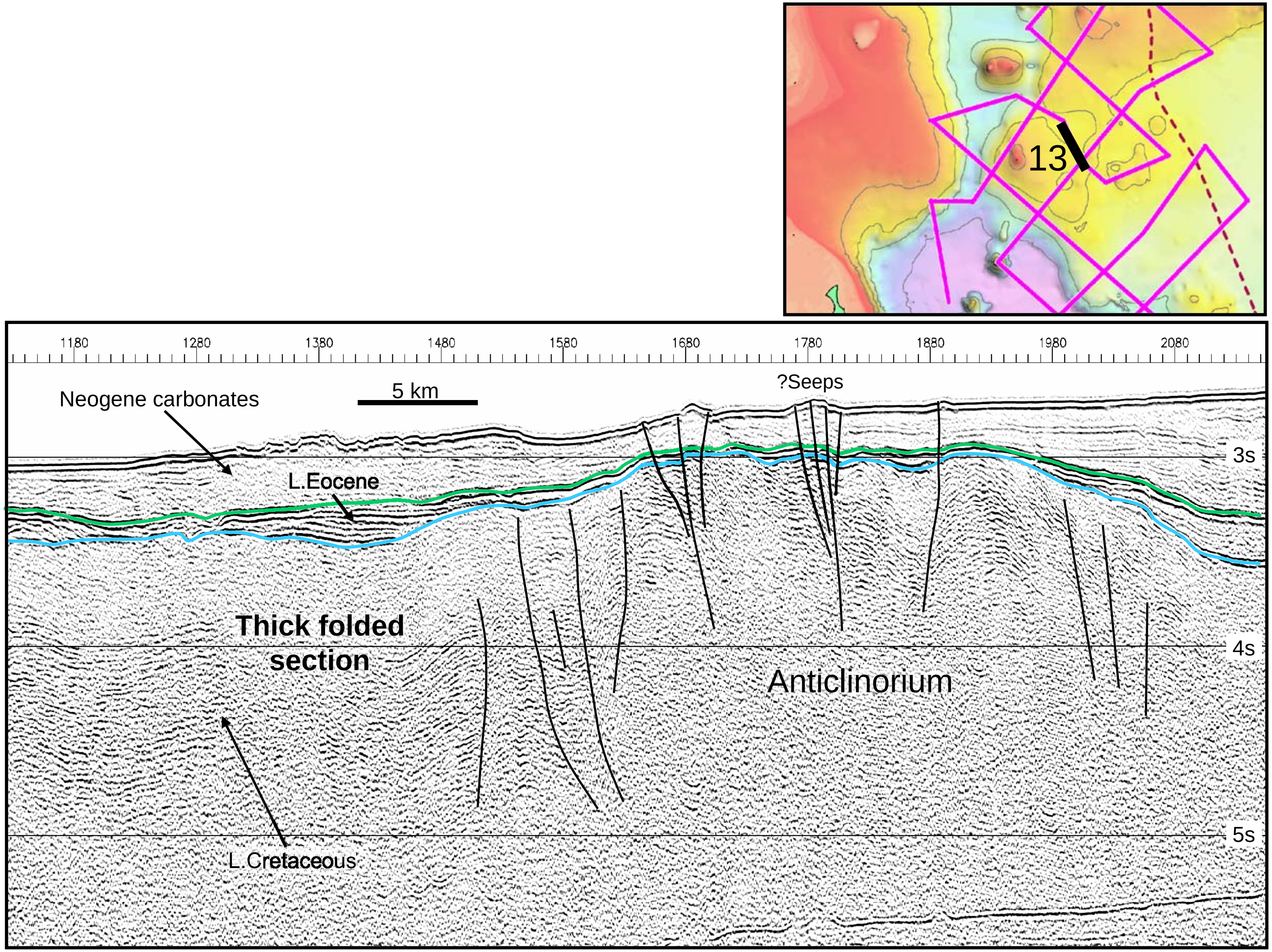


Figure 54. Seismic profile (Line 13) across the southwest Observatory Basin. The thick (2+ s twt) sedimentary section has been strongly folded during mid Eocene compression, producing a series of anticlinal structures that have had their tops partly removed by erosion. Young, small-displacement faults extend upwards to the seabed and may be seeping hydrocarbons.

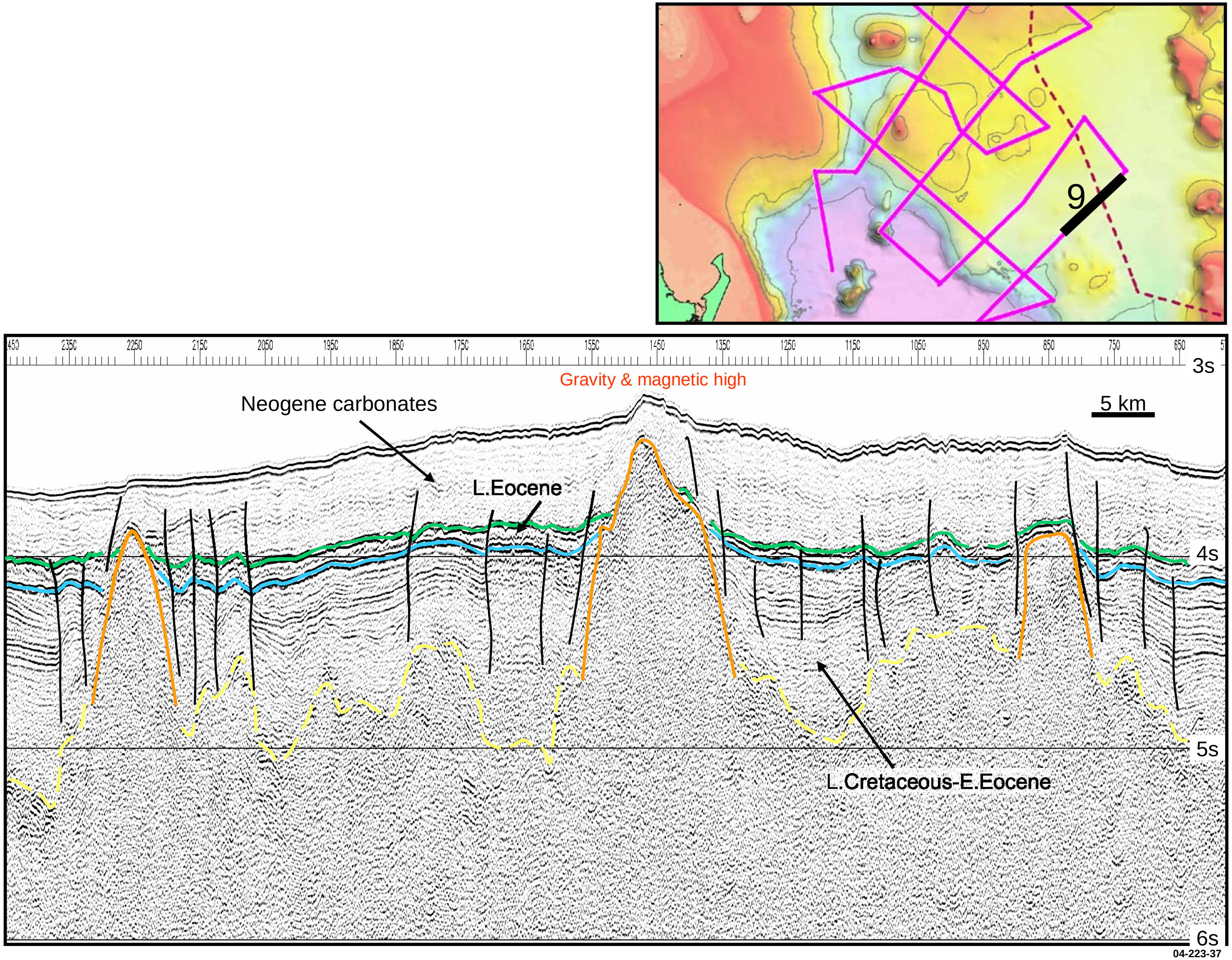


Figure 55. Major diapiric structures within thick sedimentary section of the southern Kenn Plateau (Seismic Line 9). Coincident gravity and magnetic highs over the largest diapiric structure suggest a volcanic core. Diapiric activity and folding appears to have peaked in the mid Eocene, though some deformation has continued into the Neogene.

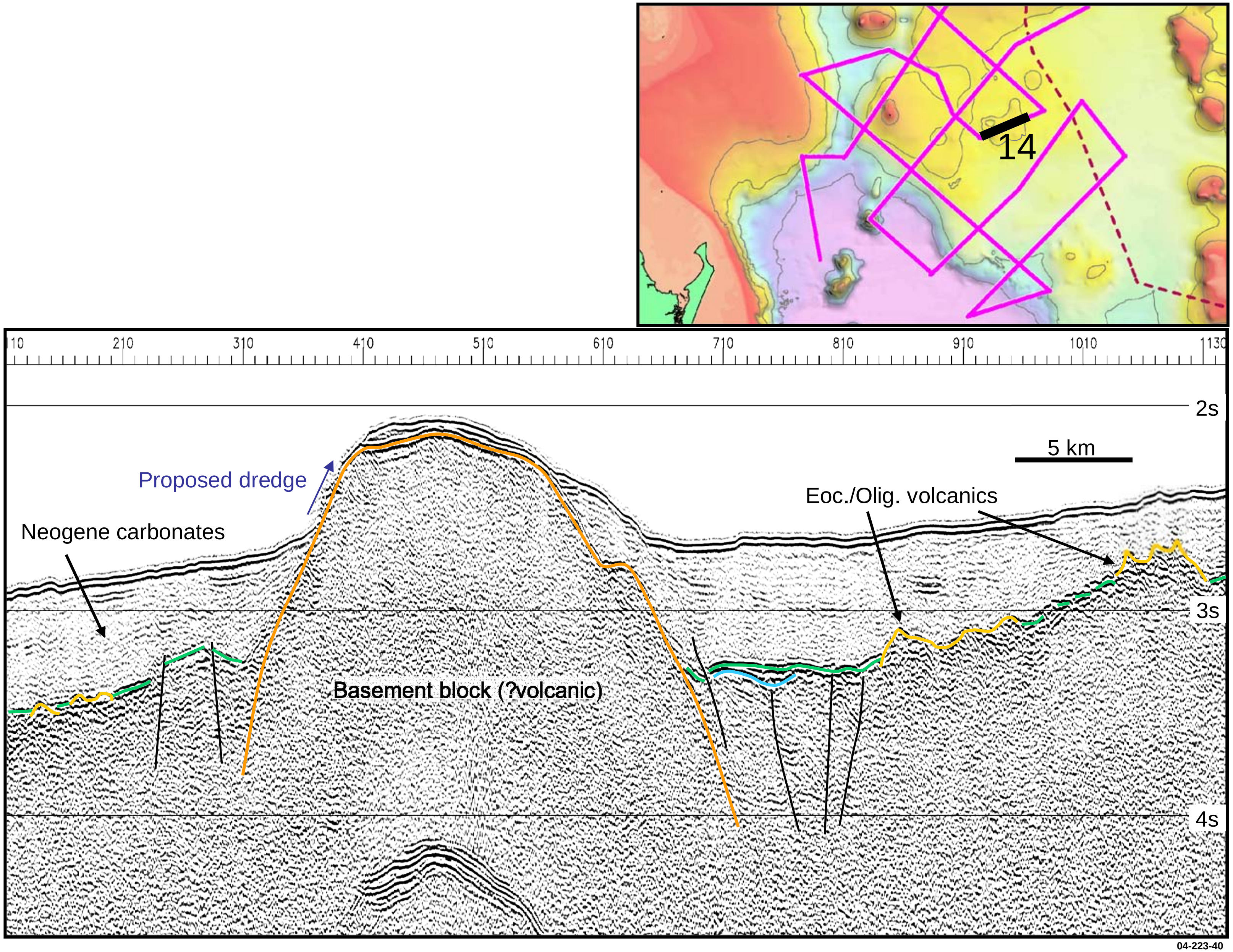


Figure 56. Large ?volcanic basement high, 15 km across, in the central Kenn Plateau (Seismic Line 14, Southern Surveyor Rise).

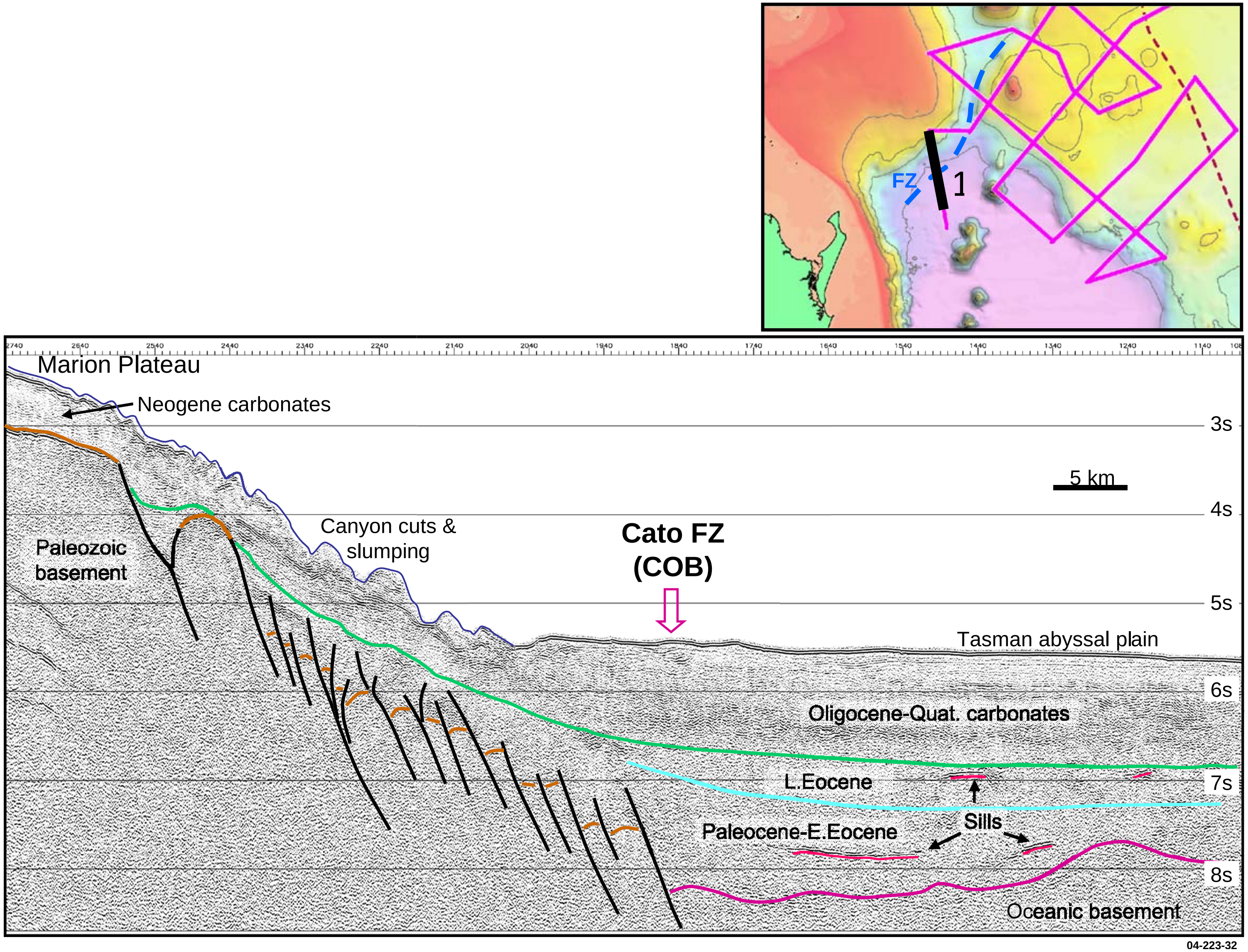


Figure 57. Seismic profile (Line 1) across the Cato Fracture Zone at the southern margin of the Marion Plateau, showing 3 s twt of post-breakup deposits on oceanic basement. Small grabens and complex faulting characterize this transform margin. Seabed relief of up to 200 m on the marginal slope is caused by canyon cutting and slumping within Neogene carbonates. Sills within the sediment pile beneath the abyssal plain may be related to hot-spot volcanism that constructed nearby Recorder Seamount 27 Ma.

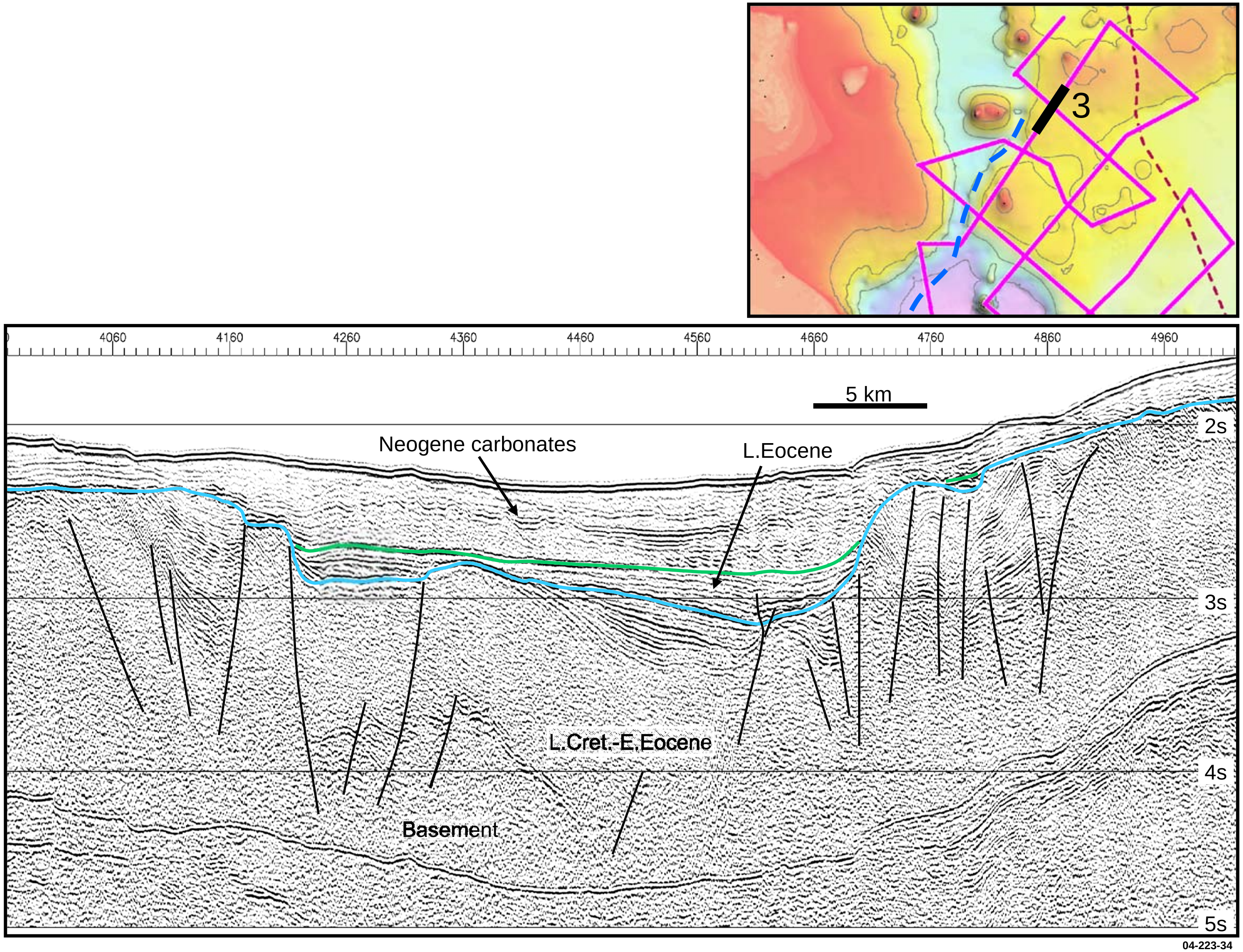


Figure 58. Complex structuring in thick pre-mid Eocene sedimentary section south of the western Coriolis Ridge and adjacent to the northern end of the Cato Fracture Zone (Seismic Line 3). The section has undergone folding, faulting, uplift and erosion due to rifting, possibly Paleocene strike-slip movement at the fracture zone, but mostly due to mid Eocene inversion. Post-tectonic infill occurred in the Late Eocene-Oligocene, followed by drape of pelagic carbonates in the Neogene.

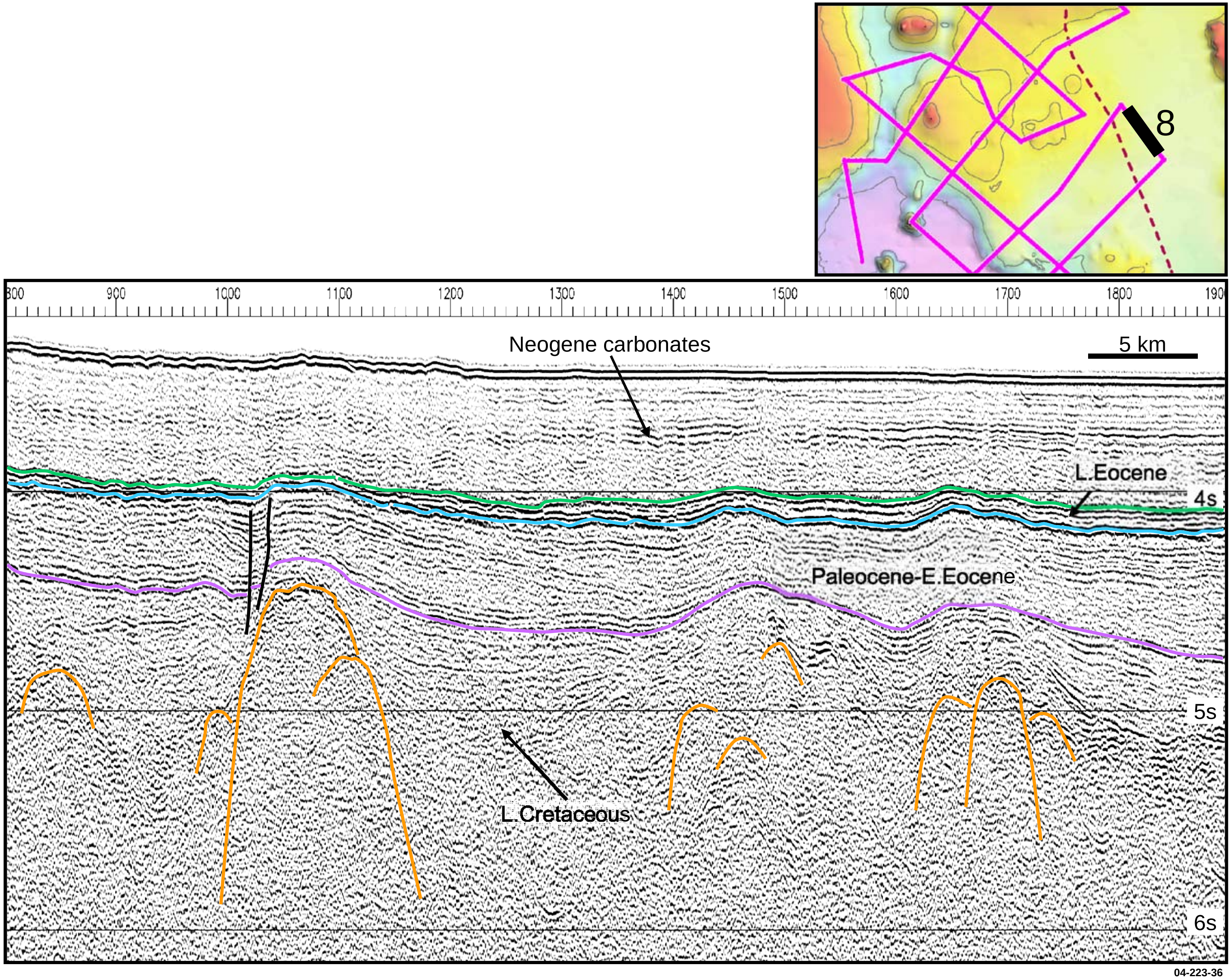


Figure 59. Diapiric structures deep within a basinal section at least 2 s twt thick, eastern Kenn Plateau (Seismic Line 8). The main deformation was in the mid Eocene (collision and obduction at New Caledonia), with minor reactivation since then.

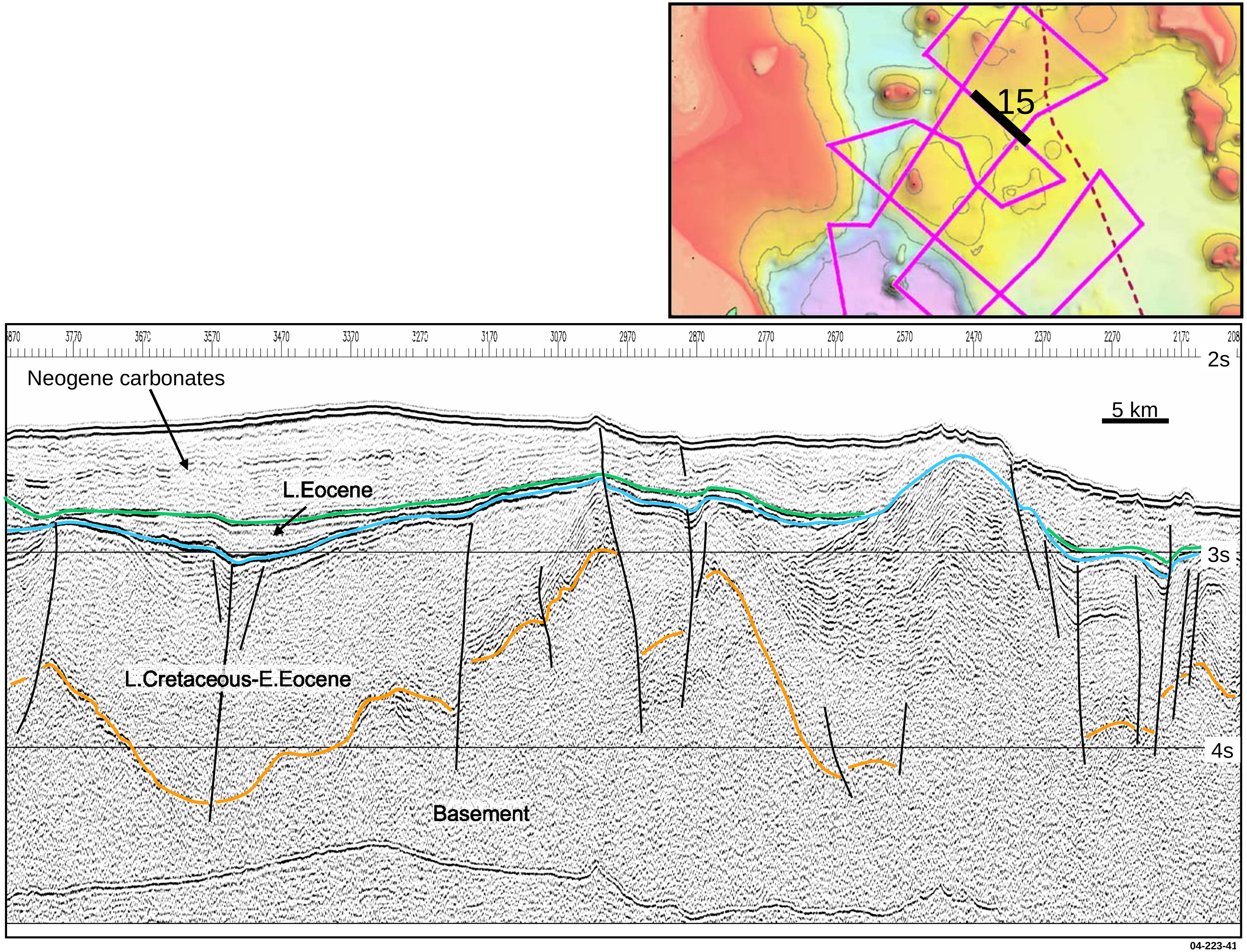


Figure 60. Seismic profile (Line 15) in the Observatory Basin, central Kenn Plateau showing a thick and strongly deformed sedimentary section. The section has undergone mid Eocene folding, faulting and erosion of uplifted blocks.

When Kenn Plateau is reconstructed against southeast Queensland, the southern arm of the western Observatory Basin may link with the Capricorn Basin. The combination of the Capricorn and Observatory Basins may have formed a basin similar in shape and orientation to the Queensland Trough, but of somewhat smaller scale. In such a reconstruction, the western end of Coriolis Ridge abuts the southeast Marion Plateau, and the western end of the Chesterfield Trough is roughly aligned with the eastern margin of the Marion Plateau, joining at a local complex graben on the Marion Plateau margin. However, the nature of the intervening small crustal block, on which Kenn Seamount is constructed and which extends just north of the seamount, is poorly known. Much of it is hidden by overlying Late Eocene hot-spot volcanics, and it may be allochthonous, with its eastern boundary a possible transform fault. Its northeast-trending northern margin is probably a fracture zone against which the northern Cato Basin opened.

Major morphological features on and adjacent to Kenn Plateau are edifices of the N-S oriented Tasmantid and Lord Howe hot-spot seamount chains (Figure 6). These chains are progressively younger to the south, with the larger seamounts typically spaced 70-80 km apart and up to 4 km high. Most of the larger seamounts are capped by carbonate platforms that grew upwards as their volcanic pedestals subsided. Inferred age progression in the Tasmantid chain adjacent to Kenn Plateau is roughly: Fraser Seamount 28 Ma, Cato Seamount 30 Ma, Kenn Seamount 34 Ma (CPCEMR 1991). Similarly, for the Lord Howe chain, age progression of nearby seamounts/banks is: Capel Bank 17 Ma, Argo Bank 20 Ma, northern Bellona Plateau 25 Ma (Figure 6). Aprons of volcaniclastic sediments and flows, now buried by post-eruption deposits, commonly extend 15 km or more from the bases of the hot-spot volcanoes (Figure 50). Our swath-mapping, seismic and sampling results (Figure 53) suggest that the carbonate platforms are commonly at least 500 m thick.

9.2. Basin development and stratigraphy

The distribution of basins and depocentres in the Kenn Plateau region is indicated in Figure 50. The mapped sediment thickness largely represents Late Cretaceous and younger deposits. The thicker depocentres contain more than 3 s twt (~4^{+} km) of sedimentary section. These include: (i) a north-trending graben in the southern, deep-water Capricorn Basin that represents a failed rift arm at the northern end of the Tasman rift system, (ii) post-breakup deposits on oceanic crust adjacent to the Cato Fracture Zone south of the Marion Plateau (Figure 57), and (iii) a broad depocentre in the northern Capel Basin just south of the eastern Coriolis Bank. Depocentres with at least 2 s twt (~2.5^+ km) of section include: (i) post-breakup deposits at the foot of the continental slope along the entire southeast Queensland and southern Marion Plateau margins, (ii) post-breakup deposits beneath the abyssal plain (and on oceanic crust) off the southwest Kenn Plateau margin, (iii) most of the Capel Basin, west of the Lord Howe seamount chain, (iv) the Observatory Basin (e.g. Figures 54 & 58), (v) Cato Basin, south and north of Wreck Seamount, (vi) a NNW-trending graben on the Marion Plateau margin west of Frederick Seamount, (vii) eastern Chesterfield Trough, and (viii) a small marginal basin at the far northeast corner of Kenn Plateau.

Areas with less than 200 m of sedimentary section visible in seismic profiles include: (i) the elevated parts of Chesterfield Rise and Coriolis Ridge on northern Kenn Plateau, (ii) volcanic terrain at the western end of southern Kenn Plateau, around Cato Seamount (Figure 53) and to the southeast, and (iii) presumed volcanic massifs on the Southern Surveyor Rise (Figure 56) and in the central southern Kenn Plateau. The flanks of the hot-spot seamounts appear to have little sediment cover.

Very little stratigraphic information is available to control the seismic stratigraphy on Kenn Plateau. The nearest useful deep-sea drill site is Site 208 (Burns, Andrews *et al*. 1973) located on the northern Lord Howe Rise to the southeast. Here drilling finished in Maastrichtian chalk at 594 m sub-bottom. From DSDP Leg 21, Edwards (1973) showed that there is a regional Eocene-Oligocene unconformity, which spans at least the late Late Eocene and the early Early Oligocene, and a Paleocene-Eocene unconformity, which spans at least all of the Late Paleocene and the early Early Eocene.

The closest useful petroleum exploration wells are Capricorn 1A and Aquarius 1 in the northern Capricorn Basin (Hill 1994). Capricorn 1A reached a total depth of 1710 m in Cretaceous volcanics, while Aquarius 1 penetrated presumed Palaeozoic metasediments at 2643 m depth. The overlying sections in both wells were similar: Late Cretaceous-Paleocene continental conglomerates, sandstones and claystones unconformably overlain by an Eocene sequence comprising basal shallow marine sandstones and an upper unit of quartzose sandstones with interbedded lignite, which in turn is unconformably overlain by a marine sequence of Late Oligocene-Holocene limestones and marls. One of the important outcomes of the Survey 270 dredging program was the recovery of early Middle Eocene shallow marine chalk from the Cato Basin margin of the Kenn Plateau (DR6).

Two prominent regional seismic horizons are recognized on Kenn Plateau. These are interpreted as an Early Oligocene unconformity and a mid-Eocene unconformity. The Early Oligocene unconformity is attributable (in part at least) to changes in global ocean circulation and climate associated with development of the Antarctic Circumpolar Current (Kennett, 1977), i.e. development of erosive bottom currents and/or sea-level fall due to growth of glaciers on Antarctica. The mid-Eocene unconformity is attributed to compressional tectonics associated with collision of the Loyalty arc with New Caledonia and obduction of ophiolites. This collision occurred at 45-38 Ma (Sdrolias *et al.* 2003; Crawford *et al.* 2003 propose ~40-38 Ma), possibly triggered by increased convergence of the Australian and Pacific plates at about this time. The upper two megasequences correspond to Sequences A and B of Hill (1994) in the Capricorn Basin. Deeper seismic horizons are present in the Kenn Plateau succession (e.g. Figure 59), but mid Eocene deformation and widespread diapirism make mapping them over any distance difficult.

The upper, Late Oligocene-Quaternary megasequence is of consistent seismic character over Kenn Plateau and is believed to consist of pelagic chalks and calcareous oozes, based on our dredging results, and earlier coring and deep-sea drilling in the region. It is of variable thickness, but is commonly 300-700 m thick. The underlying (mid-)Late Eocene megasequence also varies in thickness, but is generally much thinner - typically 100-300 m. It probably consists mainly of shallow marine chalks and limestones, but is likely to locally include siliciclastic sediments eroded from uplifted blocks following mid Eocene inversion. The underlying synrift and early sag phase succession of Late Cretaceous-Early Eocene age is extensively deformed by folding, faulting or tilting (Figures 54, 58-60). The upper surface is commonly an erosional unconformity, that is highly angular in places – particularly on uplifted blocks (Figure 58). The lower part of this succession probably consists mostly of siliciclastic deposits, but the upper part may contain shallow marine carbonates. Its visible thickness in seismic profiles is commonly 1-2 km, but limited seismic penetration and masking by high-level volcanics could mean that it is actually much thicker in places.

9.3. Diapiric structures

Numerous diapiric structures occur within the Kenn Plateau section and are distributed over a large area of Plateau, particularly the central and southern parts (Figure 50). Many of the folded structures appear to be elongate in plan (i.e. are anticlines) but some are equidimensional in plan (i.e. are domes). There appears to be no clear pattern in the orientation of the structures, though there is a general ENE-NE trend in the Observatory Basin and a rough N-NNE trend along the middle of the Plateau to the south. In the Observatory and northwest Capel Basins, the diapiric structures are seen as anticlines within the thick sedimentary section (Figures 54, 59 & 60), while to the south the structures are more volcanic in character, with the diapiric structures possibly cored by volcanic intrusions (Figure 55) or appearing as volcanic basement blocks (Figure 56). In the Southern Surveyor Rise area and to the south, the presumed volcanic diapirism is expressed on the seabed as hills hundreds of metres high. The diapirism appears to be roughly coeval with the mid Eocene inversion, though there is some evidence that associated volcanic activity could be as young as Oligocene (Figure 56). Willcox *et al*. (2001), in their examination of seismic data across Dampier Ridge just south of Kenn Plateau, remark that (?similar) late-stage intrusions form part of the Ridge's basement and that these may have been emplaced at the same time as the Tasmantid seamounts or as late as Miocene.

10. DISCUSSION AND CONCLUSIONS

10.1. Morphology and structure

The morphology of the Kenn Plateau region reflects the structural geology, with the plateau limited to the north, west and south by oceanic basins that are underlain largely by oceanic crust, and to the east by the banks and guyots of the Lord Howe volcanic chain. The Kenn Plateau itself is a complex of thinned continental crust, consisting of basement ridges and troughs with a dominant grain of east-west to northeast, masked in places by mid Cainozoic hotspot volcanics. The troughs are filled by several kilometres of Cretaceous and Cainozoic sediments. The volcanics are either part of hotspot volcanoes like Kenn and Cato seamounts, or large diffuse aprons of material from unidentified vents.

The northern Kenn Plateau is a relatively high and coherent part of the plateau in water depths of 1000-2000 m. It consists, from north to south, of the Chesterfield Rise, Chesterfield Trough, and Coriolis Ridge. These trend broadly ENE, but are complicated by northwest-trending faults in the west and northeast trending faults in the east. The structure is further complicated by Kenn and Wreck Seamounts in the west, which culminate in reefs; the seamounts consist of volcanic pedestals overlain by carbonate build-ups. Kenn Seamount is believed to lie on continental crust, and Wreck Seamount on oceanic crust. To the east is Bellona Plateau, with Chesterfield Reef and Observatory Cay, of similar character to the western seamounts but generally larger.

The southern Kenn Plateau is relatively deep, mostly in water depths of 2000-3000 m. It consists, from north to south, of Observatory Basin, Southern Surveyor Rise, Kelso Basin, and Kelso Rise, with variable trends. The situation is complicated by Cato Seamount in the west, believed to lie on continental crust. To the east is the north-south Capel Basin, 2500-3000 m below sea level, beyond which lie various banks of the north-south Lord Howe volcanic chain. The load of the volcanic/limestone build-ups presumably has contributed to the sinking and formation of the Capel Basin.

10.2. General geology

Basement rocks have not been sampled, but they are believed to consist of continental rocks that will hopefully be dredged in early 2005, on the Mellish Rise *Southern Surveyor* SS1/05 survey. The troughs consist of three main seismic sequences that can be correlated in a general way with the sequences cored in DSDP sites in the region. They total more than 4000 m thick in some troughs, and are separated by Oligocene and Paleocene or Eocene unconformities. In these basinal areas, the water deepened with time. On high areas of the Chesterfield Rise and Coriolis Ridge in the north, and various areas in the south, the sequence is less than 200 m thick.

Numerous diapiric structures occur in the basinal lows, especially in the centre and south. In the central plateau they are anticlines in the sedimentary section, but in the south they appear to be cored by volcanic intrusions. The diapirism appears to coincide with the period of Eocene compression that is well documented in the New Caledonian region.

The lowermost seismic sequence (Unit III) is believed to be a rift sequence of Late Cretaceous and Early Paleocene age, and is more than 2500 m thick in places. The lower part of this sequence is completely unknown, but sits on basement and is presumed to be siliciclastic. On the basis of the sediments in DSDP Site 208, the upper part of the sequence is likely to consist partly of Maastrichtian chalk and Paleocene radiolarian nannofossil chalk.

The middle seismic sequence (Unit II) post-dates the Late Paleocene to Early Eocene unconformity. It is believed to be of Middle to Late Eocene age, and is of variable thickness, averaging 300 m. It shows evidence of being deposited during Eocene compression. DSDP cores and our dredges show it to consist of chalk, radiolarian-bearing chalk to nannofossil-bearing radiolarite, and some cherty horizons. Common components are nannofossils and planktic foraminifera, with lesser radiolarians, benthic foraminifera, echinoid spines and plates, bryozoans, ostracods, quartz and volcanic fragments. The only samples from this cruise dated as of this age are from Dredge 6: two samples are early Middle Eocene and one is latest Eocene. Altogether the assemblages suggest deposition in an upper benthic environment.

The uppermost seismic sequence (Unit I) postdates the Late Eocene to (?)Early Oligocene regional unconformity, and consists of reflectors of low amplitude and continuity. It is consistently about 500-700 m thick, and DSDP cores and our dredges show it to consist of calcareous ooze, grading downward to chalk. These pure pelagic carbonates consist largely of nannofossils and planktic foraminifera, and minor benthic foraminifera, ostracods, echinoid spines, fish bones and sponge spicules. Radiolarians and glauconite are also commonly present. Three of the basinal samples dated from this cruise, from Dredges 1 and 6, are of Early Oligocene age. Numerous samples are of Early and Middle Eocene age; one (Dredge 3) is of Late Miocene age; and numerous samples are of Pliocene and Quaternary age.

The western seamounts of the Tasmantid chain consist of volcanic pedestals of Early Oligocene age, overlain by Oligocene and younger carbonate build-ups up to 2000 m thick. Dredges from the build-ups show them to consist of reefal limestone, often algal boundstone, with finer grained cavity fillings that were dated on the basis of foraminifera. Plate tectonic considerations suggest that all of the seamounts should be Early Oligocene in age, and the limestones are younger. Dredge 12 (Kenn Seamount) contains foraminifera of probable Early Oligocene age. Dredge 11 (Cato Seamount satellite) contains foraminifera of Middle Miocene (one sample perhaps Early Miocene) and Late Pliocene ages. Dredge 4 (Fraser Seamount) contains foraminifera of Middle Miocene, Pliocene and Quaternary ages. The carbonate thickness varies from 600 m to 2100 m, and the oldest dated limestones vary from a maximum of 33 Ma to a minimum of 12 Ma. Some reefs have not kept up with subsidence, and guyot tops are hundreds of metres deep.

The eastern seamounts of the Lord Howe chain probably consist of volcanic pedestals of Early Miocene age, overlain by Miocene and younger carbonate build-ups of great thickness. The banks are far more continuous than those of the Tasmantid chain, suggesting that there may have been an earlier north-south fracture allowing more voluminous volcanism in the east.

As expected, the Kenn Plateau appears to have little petroleum resource potential. However, its varied environments – reefs, slopes of basement rocks, volcanics, limestone and soft sediments, and bathyal ridges and deepwater troughs – may well be significant environmentally.

10.3. Geological history

Early in its history this region was an integral part of eastern Australia, south of the present Marion Plateau and north of present Brisbane. It was presumably underlain by Palaeozoic to Triassic basement of the New England Fold Belt. Overlying basement there could have been stacked basins varying in age from Late Triassic to Late Cretaceous, corresponding to the

Ipswich, Nambour, Maryborough and Capricorn Basins. The structural grain would have been predominantly NNW. In the Maryborough Basin in the Late Cretaceous the transpressional Winton Movement (85-80 Ma: Lipski, 2001) caused widespread uplift, folding and erosion. Several kilometres of Maryborough Basin sediments were removed by erosion (Hill, 1994) and some of the detritus would have finished up in depocentres on what is now the Kenn Plateau. In the Late Cretaceous, the relevant structural features from west to east (after Hill, 1994, and Stephenson and Burch, 2004) were the Jurassic to Early Cretaceous Maryborough Basin, the Bunker Ridge, the Cretaceous Capricorn Basin, and the Swain Reefs High (Figure 61), and their eastern and southern extensions that are now beneath the Kenn Plateau.

The tectonic development of the Kenn Plateau can be reconstructed with the aid of a map of the main tectonic elements (Figure 62; based largely on Figure 50, a structural analysis of seismic profiles and gravity features discussed in Section 9). We postulate that, in the Late Cretaceous, the basement high of the southwestern margin of Kenn Plateau was contiguous to the eastern edge of the Maryborough Basin (i.e. rotated 45º clockwise from its present position), and a continuation of the NNW-trending Bunker Ridge beneath the Marion Plateau (Figure 61). This requires that there was considerable stretching of the Maryborough Basin and southwest Kenn Plateau margins before break-up, to allow the two highs to correspond. The western part of the Observatory Basin, now oriented northwest, may have been a southerly continuation of the NNW-trending Capricorn Basin. The western part of Coriolis Ridge, also now oriented northwest, was a southern continuation of the Swain Reefs High on the outer Marion Plateau (Figure 61). Sediment was being shed into the lows from the uplifted and eroding Maryborough Basin. The eastern parts of some of these features (and the Chesterfield Trough, Chesterfield Rise and Bampton Trough further north) are now offset and oriented northeast, suggesting that younger northeasterly strike-slip faults rotated them counter-clockwise (Figure 62).

Rifting started further south at ~95 Ma, and in this region it may have been taken up by east-west rifting in the Middleton Basin in the south and the Capel Basin east of Kenn Plateau. The Kenn Plateau region started to separate from Queensland at ~65 Ma (Cretaceous-Cainozoic boundary), and moved northeast, later NNE, and eventually north, along the concave-west Cato Fracture Zone (CFZ, Figure 62), a strike-slip zone that terminates the Capricorn Basin southward, and now forms the southeastern margin of Marion Plateau and the western margin of Kenn Plateau. This motion continued until ~52 Ma and amounts to more than 200 km of translation at the western end of the southwestern margin and 400 km at the eastern end, indicating an

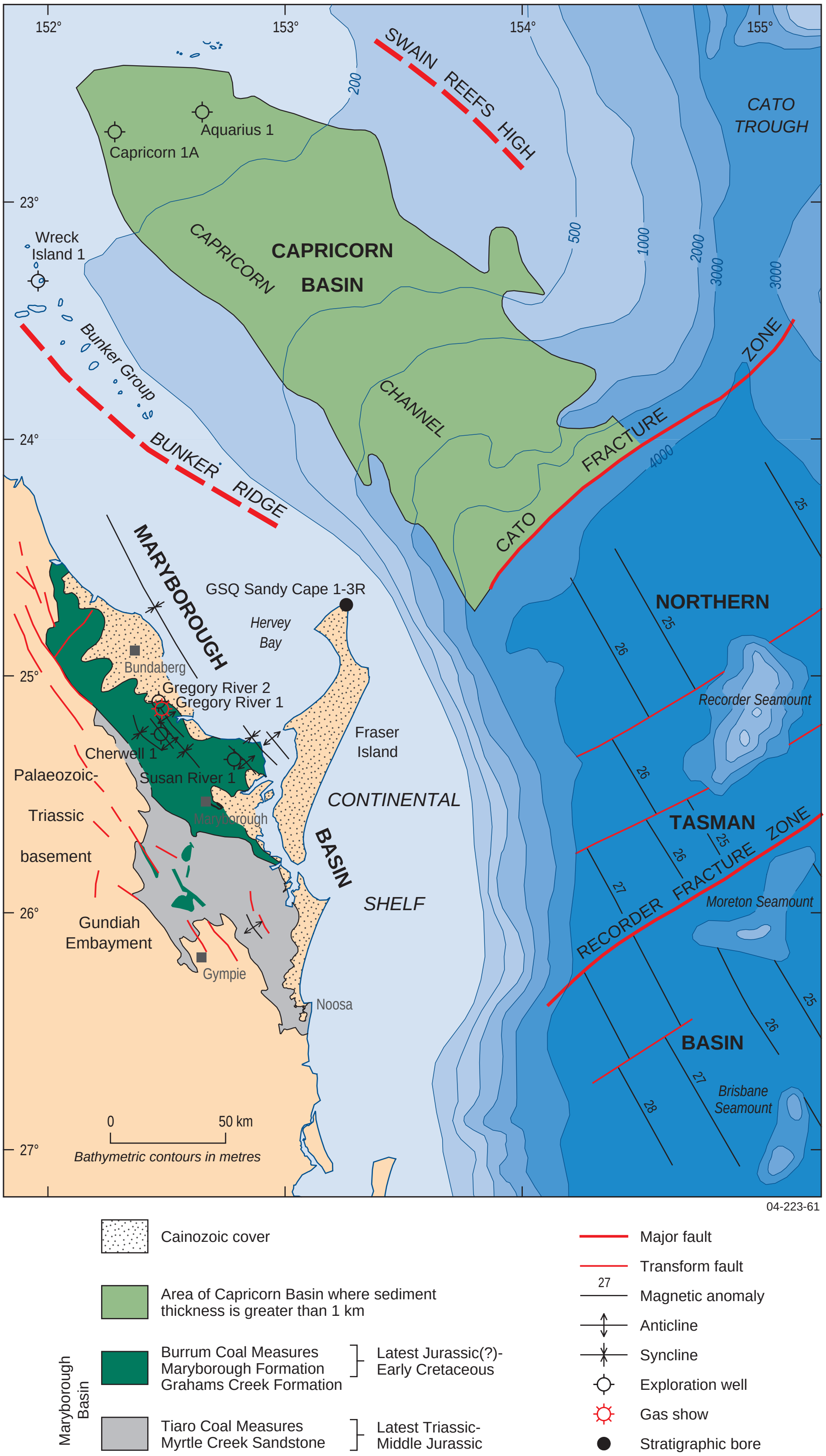


Figure 61. The basins that fitted against what is now the Kenn Plateau, before the oceanic crust of the Northern Tasman Basin formed and the plateau moved away to the northeast along the Cato Fracture Zone (after Figure 4 in Hill, 1994).

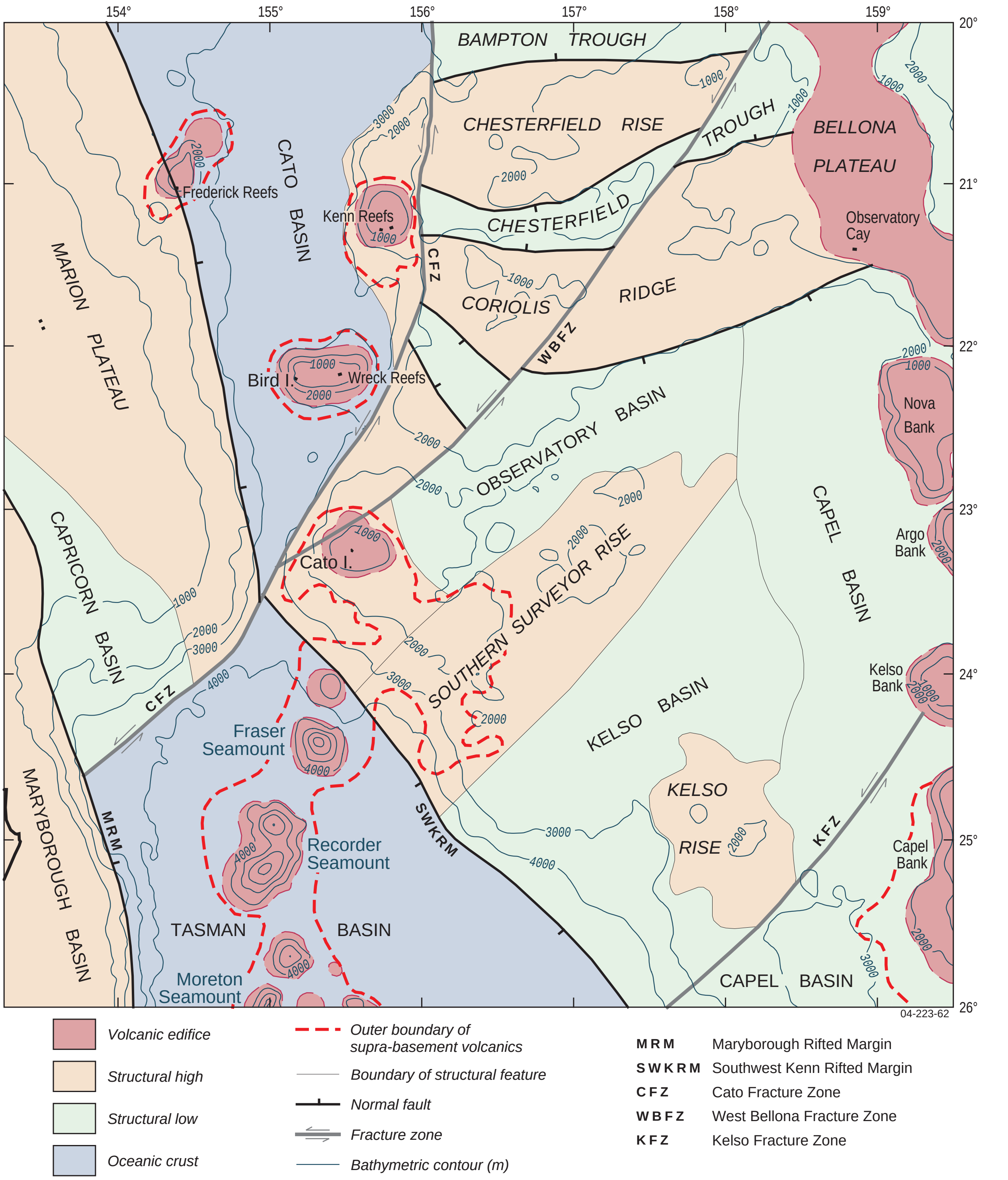


Figure 62. Tectonic sketch map of Kenn Plateau area, showing structural features. From 62 Ma to 52 Ma the basic structure of the region developed as the Kenn Plateau moved to the northeast. The SWKRM and the MRM separated by seafloor spreading, with the Tasman Basin filling with oceanic basalts. The motion was taken up along the CFZ, separating northwest Kenn Plateau from the southern Marion Plateau; and also along the WBFZ and the KFZ. The Cato Basin is floored with oceanic basalt or mixed crust. The ridges and troughs on the plateau may be in part pre-existing structures, heavily modified during spreading. The western volcanic edifices are part of theTasmantid hotspot chain and vary in age from about 25 Ma in the south to 35 Ma in the north. The eastern volcanic edifices are part of the Lord Howe volcanic chain and vary in age from about 18 Ma in the south to 25 Ma in the north.

overall anticlockwise rotation of 45º. During this period of motion the Kenn Plateau was cut by a strike-slip fault, the West Bellona Fracture Zone (WBFZ; new name, but identified by various authors and illustrated by CPCEMR, 1991) splaying off the Cato Fracture Zone.The WBFZ extends northward to form the northwest margin of Bellona Plateau and modified the Cretaceous structures in the Palaeogene. The WBFZ separates structures to the west, now trending northwest or west, from structures to the east, now trending northeast. The notheasterly trend corresponds to that of the oceanic fracture zones in the northern Tasman Basin (Figure 61), so the margins of the Southern Surveyor Rise and the Kelso Fracture Zone are presumably related to the oceanic fractures.

During the rifting and drifting phase in the Late Cretaceous to Early Paleocene, although continental stretching and thinning were taking place, and the region was subsiding, much of the Kenn Plateau was still above sea level and being eroded. Up to 2500 m of non-marine and shallow marine siliciclastic sediment, derived largely from the Maryborough Basin in the Cretaceous and local subaerial ridges in the Paleogene, were deposited in the various troughs and basins. By the latest Cretaceous, radiolarian chalks were being laid down in deepwater areas. In the marine areas, this phase of deposition was terminated by the regional Late Paleocene to Early Eocene unconformity. This unconformity coincided with the end of drifting at ~52 Ma, and was probably caused by the establishment of strong bottom currents as much of the area deepened, most of the ridges became submarine, and the region became susceptible to regional current patterns. These currents could have caused both physical erosion and dissolution of carbonates.

By the time that drifting ceased in the Early Eocene, the Kenn Plateau and its surroundings had taken up a modern tectonic configuration, with oceanic crust to the south in the Tasman Basin, and probably to the west in Cato Basin. Most of the thinned continental crust had subsided below sea level. Pelagic sedimentation returned to the basinal areas and a few hundred metres of Middle to Upper Eocene, radiolarian-bearing and sometimes cherty chalks were laid down. This was a period of compression in the New Caledonian and Fairway Ridge areas to the east, and there is some evidence of its effects in the Kenn Plateau region in the seismic profiles. There may have been associated uplift, as suggested by Middle Eocene upper bathyal limestone in Dredge 6 on the western margin of Kenn Plateau, more than 1500 m lower than the crest of Coriolis Ridge, which was presumably exposed. Anticlines formed in the Observatory Basin at that time.

The regional Late Eocene to Early Oligocene unconformity was caused largely by the onset of the circum-polar current system at 33 Ma, and the associated cooling of Antarctica and strengthening of thermohaline circulation provided cold, strong, acid bottom currents from the Antarctic margin that dissolved pelagic carbonates (Kennett, 1977). Locally, there were presumably tectonic complications. The unconformity is fully developed at nearby DSDP sites. However, in our samples the Middle and Late Eocene are missing, but Lower Oligocene chalks are present in Dredges 1 and 6.

In the Early Oligocene, as the Australian Plate moved northward at ~60 km/m.yr., the Tasmantid hotspot was crossed by the western margin of Kenn Plateau. The volcanic vent formed Kenn, Wreck, Cato and Fraser Seamounts, in that order. The seamounts were initially subaerial, but erosion and subsidence turned them into flat-topped guyots later in the Oligocene, and limestone reefs formed on their summits. Volcanic sills and dykes, presumably of this age, are visible in the seismic profiles. Average seamount subsidence rates have been 55-70 m/m.yr. - presumably more than for the plateau as a whole. Some reefs have not kept up with subsidence, and the guyot tops are now hundreds of metres deep. In the Early Miocene, another hotspot formed the Lord Howe chain in the east and associated sills and dykes, and it too subsided to allow carbonate banks to form.

From the Late Oligocene onwards pelagic carbonates, generally lacking radiolarians, were slowly deposited. Calcareous tests appear to have been swept from the shallow areas into the troughs, so that the thickness of the pelagic carbonates is ~200 m on Coriolis Ridge, but up to 700 m in the troughs.

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Appendix 1. Cruise Narrative

Neville Exon

The conversion of the *Southern Surveyor* from a fisheries configuration to a geoscience configuration took place in Sydney from 31 April to 2 May. This included the installation of the large seismic winch, the hydraulic core cradle and the compressor by Geoscience Australia's technical team. The scientific contingent arrived on 1-2 May. The vessel sailed from Sydney at 1000 local time on Monday 3 May (Julian Day 124 at 0000: 10 hours behind local time of 1000) in good conditions, and headed north up the New South Wales coast. The Simrad EM 300 swath-mapping system functioned satisfactorily in shallow water. The bridge agreed to warn the operations room if a whale were sighted ahead, so that the swath mapper could then be turned off in accordance with EPBC requirements.

At 1530 the seismic cable and the new airgun deployment system were both deployed. The steel deployment cable for the airgun system snapped when a sudden lurch of the ship in the high swell brought tension on it suddenly. Airgun recovery had to be made at very slow ship's speed, causing the seismic cable to sink and inflating the forward recovery device. Both airgun system and seismic cable were recovered at 1815, and further testing was deferred. Swath-mapping continued on the transit northward. At 2000 the vessel was at 33°20'S, 152°E on a course of 42°. Speed was 9.5 knots despite running into the south-flowing East Australian Current of 2.5 knots. Until 0900 on 4 May, swath-mapping continued on the transit to the north at speeds of 9.5 to 10.5 knots.

From 0900 to 1630 on 4 May, the seismic equipment was deployed and tested while the ship continued its course to the north in very good conditions, largely at 7.5 knots. The airgun array was deployed satisfactorily, with the failed cable replaced with high-tensile chain. Each gun was tested separately so that acoustic output was well below the level that triggers EPBC regulations. No whales were seen. The seismic cable was also deployed and ran satisfactorily at about 8-10 m. The various components of the seismic acquisition system were tweaked until everything was working properly, and 50 good shots from a single gun were recorded for experimental processing.

On 5 May, swath-mapping continued to the north in excellent conditions, but the ship was slowed by the East Australian Current. We ascertained that the seismic acquisition was satisfactory and that data could be read off the trial tape. However, it took time to get the new seismic processing system performing satisfactorily. Another problem was that the magnetometer developed an intermittent fault, which was more-or-less overcome later.

At 0400 of 6 May we started seismic profiling on Line 1, running north to the far southeastern corner of the Marion Plateau. Whale watching commenced. The 135 km of Line 1 was completed at 0400 on 7 May. There were numerous breaks in data acquisition, due to problems with the third stage of the compressor and unexplained glitches in the acquisition computers. Some of the seismic data recorded were processed and are of good quality. The swath-mapping data are of useful quality, although noisy, and on-board processing started. A humpback whale was seen during one period of downtime. Line 2, about 55 km long and running eastward, was completed in the middle of the Cato Trough at 0800.

Major problems with the compressor meant that Line 3 to the NNE, passing west of Cato Reef and crossing Coriolis Bank, was not started until 1515 on 7 May. There were further compressor problems on two occasions, but by 1040 on 8 May, 200 km of data had been acquired on the line, before a new armoured convoluted hose on the third stage blew out. After discussions with Canberra, the hose was replaced with another smaller diameter type, the airguns were checked, and the magnetometer was deployed for the first time after shipboard overhaul. The first shot as we restarted on Line 3 was at 1615. Despite two more loops to replace the same hose segment, the 350 km of Line 3 was completed at 0332 on 9 May. Data quality was good in the first three lines, with processing showing penetration of up to three seconds (twt).

The swath-mapper crashed at 0350 on 9 May during the turn into Line 4 and had to be rebooted. Seismic Line 4 to the southeast started at 0405. At 1000-1050 a hose leak caused a shut down. At 1415 the compressor was shut down, and leaky hoses were replaced. At the same time the guns were recovered and one was overhauled. We were back on line at 0903, and Line 4, 150 km long, was completed at 2028. Line 5 to the southwest, 390 km long, started at 2118. Seismic profiling stopped twice on 10 May, because of compressor and airgun problems, the latter stop requiring the fabrication of a part. At 0857 on 11 May we completed Line 5 at Fraser Seamount, which is a guyot whose flat top was measured to be 377 m below sea level. At 1001 we started Line 6 to the SE on the abyssal plain just south of Kenn Plateau, 110 km long, and completed it at 1726. While we were turning onto long Line 7 to the NE, two leaks were identified in the fourth stage heat exchanger on the compressor, and major repairs started. We pulled the seismic gear and magnetometer and headed toward Dredge Site 1 on the southern margin of Kenn Plateau.

The equipment was in the water for Dredge 1 at 2246 on May 11. Recovery from 4000 m was of calcareous claystone. Dredge 2, a few kilometres to the east, recovered some hard breccia of sandstone set in ironstone, plus manganese crusts, from 2800 m.

Once the repaired last stage heat exchanger on the compressor was re-installed, we headed back to the start of the 290 km long Line 7 to the northeast and were shooting again at 1548. The magnetometer winch was out of action and lacking a part, so we did not deploy the magnetometer. We looped at the change of direction on the line and replaced a pressure hose. Line 7 was completed at 1342 on May 13. During the loop for compressor checks before starting Line 8, several whales were sighted heading northwest on a reciprocal course while we were not shooting. At 1442 we started the 90 km long Line 8 to the southeast, which we finished at 2106. In the turn, repairs were made to compressor hoses and at 2215 we had started on the 285 km Line 9 to the SW. Line 9 was completed at 0342 on May 15, after three minor breaks, one for whales, one for hose replacements and one for a Stratavisor crash, and one major break for substantial compressor repairs.

We started the 110 km Line 10 to the ENE at 0433 on May 15 and completed it without incident at 1410. The 410 km long Line 11 to the northwest started at 1247 and stopped at 1433 to pull gear in preparation for bringing aboard compressor parts from fishing boat. Both airguns and seismic cable were aboard by 1530 and course was set to the WNW to successfully rendezvous with the fishing boat at 1645. A new third phase hose was added to the compressor and a new coupling was fitted to the magnetometer winch. Airguns, seismic cable and magnetometer were deployed by 1930, and we were shooting again on Line 11 at 2000. There was one short compressor repair, and then Line 11 continued until 1200 on May 16. After a compressor repair and a short period of seismic acquisition, the valve on the third stage failed at 1508. Very unfortunately, no spare valve was in the spares sent from Hurricane Compressors in the USA, and nothing could be constructed aboard ship, so the seismic program was terminated. About 260 km of data were acquired on Line 11.

At 1726 on May 16, we headed toward Dredge 3 on the western corner of Kenn Plateau. The seismic equipment and magnetometer were pulled in and secured by 2000. Dredge 3 recovered chalk and calcareous ooze from 3280 m. Dredges 4 and 5 and Grab 1 were all on Fraser Seamount, south of western Kenn Plateau. Dredge 4 recovered reefal biostromal limestone from 450 m depth, Dredge 5 recovered basaltic hyaloclastite breccia from 1600 m depth, and Grab GR1 recovered a handful of biogenic sand and gravel from the seamount top in 390 m depth.

At 1230 on May 17 we headed north for a swath survey of the foot of the slope (~3000 m) of the northwest margin of Kenn Plateau, trailing the magnetometer. We mapped a number of steep slopes and small canyons that are suitable dredge targets. At 0813 on May 18, at 21°39.9'S, 155°36.9'E we turned onto the reciprocal course to the southwest. Dredge 6 recovered foraminiferal limestone, chalk and calcareous ooze from 2800 m in a canyon. Dredge 7, on a steep slope further south, recovered foraminiferal chalk, semi-lithified chalk, and calcareous ooze from 2700 m on May 18.

We then continued swath mapping southward on the northwest margin of the plateau, before crossing to and surveying the area of Dredge 8 on the southeast Marion Plateau. The successful drop of a compressor valve by Fraser Air occurred at 1000 on May 19. Dredge 8, on a steep slope on southeast Marion Plateau, recovered foram nanno chalk and foram nanno claystone from 3050 m. Dredge 9, on a steep slope on the western corner of Kenn Plateau recovered highly lithified and weakly lithified chalk from 3200 m. Dredge 10, on a very steep slope on the northwest margin of Kenn Plateau, recovered highly lithified and weakly lithified chalk from 3100 m, early on May 20. Dredge 11 was taken on the flank of a satellite guyot to Cato Island whose flat top is at 450 m. The dredge recovered reefal framework limestone from 1000-800 m. The base of the limestone is at ~1100 m on seismic profile evidence. This was the end of this round of sampling.

At 0920 on May 20 we headed SE toward the restart point on seismic Line 11. The seismic gear and magnetometer were deployed from 1215, and shooting to the northwest commenced at 1430 after one third stage pressure hose failed. The remaining 210 km of Line 11 to the northwest across the Cato Trough to the southeast corner on Marion Plateau was completed at 0150 on May 21. We started the 115 km Line 12 to the ENE back across the Cato Trough toward the Kenn Plateau at 0255 and completed it, after 45 minutes of compressor down time, at 1151. The 70 km Line 13A to the ESE back across the Kenn Plateau margin started at 1248 and was completed at 1800. We went straight into the 55 km Line 13B to the SSE across the Kenn Plateau at 1800 and completed it at 2146. Then we commenced a turn for compressor repairs. The 40 km Line 13C to the SE started at 2309 and was completed at 0234 on May 22.

Time constraints meant that we had to cut off the eastern ends of the planned lines 13 and 15, and accordingly we designed a new Line 14 to the ENE for this purpose. This 90 km line was started at 0325 on May 22 and completed at 0949. The 240 km Line 15 to the NW started at 1041 and was completed in the Cato Basin at 0535 on May 23. The 90 km Line 16 to the NE started after compressor repairs at 0807 and ended on the Chesterfield Rise at 1350. This ended the seismic program. Productivity of 290 km/day on the second seismic leg was far better than the 210 km/day on the first leg. Overall we recorded 3090 km of seismic data.

By 1520, seismic and magnetic gear had been brought in and stowed, and we were heading WSW at 10 knots toward Kenn Reef. Dredge 12, on a very steep slope on the eastern flank of Kenn Seamount recovered unweathered calcarenite from 1900 m depth. It was on deck at 2000, when it was discovered that a hydraulic leak in the pipe work on deck was serious. We headed SSE toward the next dredge station while the engineers studied the problem. It was then realised that the hydraulic leak could not be fixed at sea and had put all winches out of action for this voyage. It seemed possible that some of the dredge sites could be picked up on the Mellish Rise cruise late this year. Accordingly, we swath-mapped the potential basement dredge sites on the northern margin of Coriolis Ridge, while we tried to find a way of deploying the seismic gear without the disabled winches. This proved to be impossible, so we decided to run a swath line right down the northwest margin of Kenn Plateau to southwest of Cato Island. This was completed at 0800 on May 25, and then we headed east across three potential basement dredge sites on the way to Noumea.

CSIRO staff and the ship’s personnel carried out a series of acoustic tests, at different speeds and with various pieces of ship’s equipment on and off, with the swath-mapper turned off but recording noise, between 1400 and 1600 on May 26. These suggested that the 28 kHz echosounder on the bridge could be interfering with the Simrad EM30 swath-mapper. Tests were then run with swath-mapper on, and bridge echosounder on and off, which further suggested that the poor performance of the swath-mapper was related to interference from the bridge echosounder. In particular, the major problem of central area mismatch (amplitude results different from phase) vanished with the bridge sounder off.

We berthed in Nouméa at night on Thursday June 27, two days early, allowing three days for winch repairs before the next voyage was to depart on Monday June 31. As Chief Scientist for the Mellish Rise voyage, I gratefully accepted the offer of an additional two days' ship time to allow some key Kenn Plateau dredges to be taken on the Brisbane-Mellish-Brisbane transits.

Appendix 2: Seismic Processing

Peter Hill

Introduction

The general aim of the reflection seismic acquisition program on S270 was to collect new stratigraphic and structural information on which to build a geological model of the Kenn Plateau. Similar surveys, with similar equipment, had been conducted on other parts of the Australian continental margin by GA in recent years using RV *Franklin* and RV So*uthern Surveyor*. Such surveys include S226 off Tasmania in early 2001 (Exon *et al*., 2002), S232 over the Fairway Basin in late 2001 (Exon *et al*., 2004a), and S265 over the Bremer Basin in early 2004 (Exon *et al*., 2004b). On this survey (S270) the geological setting is a continental plateau, with extended continental crust adjacent to an oceanic basin, and water depths generally ranging from a few hundred metres to about 4.5 km. As on the other similar surveys, S270 used a dual GI-gun source (2 x 45/105 cubic inch), with expected penetration of 2-3 s twt in basinal areas.

Onboard processing was required so that potential dredge and coring targets could be identified for the geological sampling component of the cruise.

Computer hardware

A Sun SunFire V240R with 20 inch LCD monitor, purchased and set up just before the start of the survey, was the field computer used. The V240R has a single 1 GHz Ultrasparc CPU, 2 Gb RAM, 76 Gb SCSI disk, DVD/CD reader drive, and was configured with a single DLT8000 tape drive. The operating system is Solaris OE 9.0 12/3. A second identical system was available as a backup in case of a major failure. The two systems were labelled Primary and Secondary. The equipment was set up in the Chemistry Lab on the ship.

Because the V240R had not been field tested, the old Ultra Sparc 1 seismic processing workstation (Conrad) was taken on the cruise in case of problems, but was not needed.

Software

The seismic processing software used was Paradigm Geophysical Disco/Focus version 5.1. Mapping of seismic lines and shot-point data was by Petrosys version 12.4. Larson Software Technology PlotLite Plotting System (Plite) software was used to convert the CGM+ plot files generated by Disco/Focus to HP RTL raster format suitable for the HP Designjet 1055 Cm Plus plotter on board, so that full-scale seismic sections could be produced.

Networking to CSIRO systems

At the start of the cruise the V240R was networked to the multibeam EM300 processing server Neptune and to the HP Designjet plotter - A0 paper roll (hp1055), and subsequently connected to the A4 HP LaserJet 4050N (hp4050) and A3 colour HP Business Inkjet 2600 (hp2600) printers.

Apparently related to this networking, a potentially serious problem developed with the Opterm (interactive tape operator interface utility program) facility of Disco/Focus. Because it could not be activated, it was not possible to read in the DLT field tapes. This corruption of Opterm was overcome by switching to the Secondary V240R as the main processing system (transferring the Paradigm and Petrosys licences). To avoid further problems, this system was run as a stand-alone unit, with no networking attempted. Data and file output was solely by DLT tape. The Primary system remained networked and was used for creating plotter and printer output, with data transfer between the two systems being by DLT.

Acquisition parameters

Streamer: 24-channel, 300 m active section (12.5 m groups) – Syntron Stealtharray, solid
50 m shot interval, giving 3-fold data
Mean towing depth of active section 10 m
Record length 9000 ms
Sampling interval 2 ms
Bandpass filters 10-250 Hz

Source: two 45/105 cubic inch GI guns suspended beneath a torpedo float at 6 m depth
Centre of group 1 (channel 1) behind stern 250 m

Middle of guns behind stern 30 m, thus offset = 220 m
Acquisition speed 7.5 knots

Magnetometer fish (sensor) towed 225 m astern, deployed while shooting seismic and on long transits.

The DGPS navigation reference point on the ship for the scientific equipment is the EM300 MRU (motion reference unit), located in the middle of the ship 38.13 m from the stern. The NMEA navigation data stream into the Navipac (and recorded in the Stratavisor logs) is referenced to this point.

Data quality

Weather conditions were generally good during the seismic survey, with winds mostly less than 15 knots. Sea state was generally 2-3, but at times the swell was up to 3 m in height. No major storms were encountered.

All 24 channels were recorded, but usually 4 or 5 channels were seriously affected by noise and were killed in the processing. Channels 2, 14, 17, 18 and 22 were the ones usually degraded by continuous high noise levels and/or spikes. Channel 3 had a high signal/noise ratio and was used for neartrace single-channel displays. Spectral analysis of the raw input to the Stratavisor showed sharp peaks at 50 Hz and harmonics (100, 150, 200 Hz) and minor peaks at about 75 and 125 Hz. This noise was obviously ship generated, but it was not clear whether the source was acoustic (from machine vibration on the hull) or electrical (mains pickup on the cable or electronics). The peaks were present with and without the guns firing. A 50 Hz notch filter in processing effectively removed this noise component. However, in the final displays a sub-50 Hz bandpass filter was applied instead, to avoid the slight smearing that a notch filter produces.

Breaks in acquisition were common during the survey, mainly due to failures of the Hurricane compressor, generally related to overheating of components. Some halts in acquisition were due to Stratavisor system crashes, while failure of the GI-guns was rare. Failure of a system during acquisition meant that the ship had to be looped back on line each time so that continuity of the seismic data was maintained. The survey was shot as 45 line parts.

Processing sequence (main elements)

- Read in SEG-D (8058) data from DLT tape and write to disk in Disco internal format
- Display neartrace gather (channel 3) and shot gathers for QC and shot/channel edits
- Define geometry and write to seismic trace headers
- Apply shot and trace edits
- Apply a time-variant gain function keyed to water depth and then apply a dip filter (F-K) in the shot domain to reduce noise travelling along the streamer (ship, bird, tug noise)
- Sort into CDP gathers
- Apply NMO correction using time-variant stacking velocity function keyed to water depth to create brute stack
- Join brute stacks for the various line parts to make complete line, rerunning geometry and resequencing shots (numerous failures of the compressor during the survey meant that many of the lines were acquired in parts)
- Do weighted merge of traces (9-trace running mix) and decimate to every 8th CDP (50 m)
- Digitise water bottom for cosmetic mute
- Apply time-variant filter, cosmetic mute and AGC to create 'final'stack
- Migrate brute stack (finite difference migration)
- Do 9-trace weighted running mix of traces and decimate to every 8th CDP (as for stack)
- Apply time-variant filter, cosmetic mute and AGC to create 'final' migration
- Produce full-scale plots and A3 plots (postscript)
- Create SEG-Y files of final migrated lines.

Navigation processing

Shot, date, time and navigation information was extracted from the Stratavisor log files. The DGPS navigation data were generally of excellent quality, and except for one incident near the end of Line 07 when navigation was momentarily lost and the ship veered 150 m off course, no post-acquisition manipulation was needed.

Line parts were displayed in Petrosys and join points determined for input to the seismic processing. Line parts were merged to produce final reformatted shot-point files, corrected for navigational reference point offset (from source) and mid-point reflection offset. Final shot-point maps were produced.

Processing summary

A total of 16 seismic lines (Lines S270-01 to S270-16) were acquired and processed. Processing was done to full record length of 9 seconds. Visible penetration was up to 3 seconds. Total final line length was 3090 km.

Seismic Line	Length (km)
S270-01	132
S270-02	55
S270-03	351
S270-04	152
S270-05	390
S270-06	104
S270-07	292
S270-08	90
S270-09	285
S270-10	109
S270-11	414
S270-12	116
S270-13	168
S270-14	90
S270-15	244
S270-16	98
TOTAL	3090

Recommendations

There was insufficient disk space to accommodate the complete survey, requiring periodic archiving of data to DLT tape. It is recommended that an additional 76 Gb disk be installed in the V240R (only one of the 4 internal bays is used at present), so that at least one complete survey can be accommodated and so that there is sufficient space for addition geophysical software (e.g. GMT, MB-System) and data sets required for planning and interpretation.

Apart from networking, data can only be extracted from the V240R via DLT tape. This is cumbersome for small files, such as text files, and also relies on the existence of a DLT drive on the system to which the data are to be transferred (generally not the case). It is recommended that a CD/DVD burner be installed.

Acknowledgements

The help of Mike Sexton (GA) pre-cruise in setting up processing routines and for sharing knowledge gained on S265 was greatly appreciated. Fred Kroh (GA) was responsible for purchasing the new SunFire workstations and arranging installation of software. Achieved just in time for S270, it was a major step forward since the new Sun proved to be far superior in performance to the outdated Ultra Sparc 1 Conrad workstation used on earlier surveys. Nathan Hand of Sun Microsystems did the installation on the V240Rs, and he is thanked for his friendly help and advice on the new system.

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Appendix 3: Shipboard data acquisition and data processing of EM300 multibeam sonar

Georgina Burch

The Kenn Plateau is located about 200 km northeast of Fraser Island, Queensland. Multibeam sonar data were acquired using the *Kongsberg Simrad* EM300 30 kHz multibeam sonar system. Data were collected throughout the transit from Sydney to the Kenn Plateau at speeds averaging around 11 kn. The transit data were not processed onboard. Data were acquired in the survey area during the seismic acquisition and geological sampling at speeds averaging around 8 kn. These data were successfully processed onboard using the Neptune software, and working maps were produced.

Data Acquisition

Data volumes:

Julian Day 124 20:00 to Julian Day 146 18:50
527 hours operation

Total track length (km):	7584
Total track length over survey area (km)	6753

Survey conditions were as follows: sea state 1 to 3 m; survey speeds 7 to 11 Kn.

System Performance

The EM300 system worked reasonably well during this survey with good to very good resolution of seabed features. However, the data acquired in deeper water were affected by high noise levels, which at times caused a reduction in the data coverage.

Prior to commencement of the survey the EM300 system was started and the built-in self-test was run as per *Kongsberg* recommendations. No errors were found during this testing.

There were 6 instances of EM300 system failure, 3 of which were not explained. The other cases included the real time display using up all the available memory; a .DAF contour file overloading the system; and the large size of the error log file. It should be noted that in future at the start of each cruise this log file should be reset.

Noise levels

Noise levels on the *Southern Surveyor* are moderate to high and appear to be mostly related to ship speed and water depth. At speeds exceeding 9 kn and depths beyond 2500 m, data quality was reduced resulting in a higher proportion of soundings being rejected in post processing.

A considerable amount of noise in the data was recorded in the central sector, specifically between beams 58 to 76, when the system appeared to be having trouble tracking the bottom. This noise was not evident in depths shallower than 1000 m and was most evident in regions of complex topography, at larger beam angle settings and at higher speeds. The outer beams sectors, specifically 28 to 41 and 95 to 108, also generated excessive noise at depths ranging between 2500 to 3500 m. The presence of the central sector and outer beam noise resulted in 10 to 50% data loss.

Error messages

Throughout the survey, P421 errors (communication problems between SPRX and BSP) were intermittently observed by the system. This error seemed to affect the ping received at the time of the error, but had no other obvious effects on the system performance. Previously, *Kongsberg* indicated that the P421 error message might be related to a problem with the raw data logger. As a result, a trial disconnection of the raw data logger was conducted from the 20^{th} May and remained disconnected for the remainder of the survey. This trial did not appear to have any affect on the performance of the EM300 system and the P421 errors continued intermittently for the remainder of the survey.

Coverage

The performance and coverage of the EM300 system during the survey was found to be optimal using the automatic mode and automatic angular coverage. This is believed to be a result of the flat lying topography of the sea floor over the region, average depth of 2000m and the average ship speed of 8 kn.

Automatic mode worked sufficiently well except when water depths exceeded 2500 m. When this occurred the data became increasingly noisy and the central sector noise prevented the system from automatically switching to extra deep mode, as the noise made the water depth appear shallower than in reality.

The maximum water depth during the survey was 4800 m in the Tasman Basin, at which point data were still being acquired using extra deep mode but was exceedingly noise. The shallowest water depth experienced was 257 m over the Fraser Seamount.

The cross track coverage achieved ranged from 1000 m to 4500m.

Processing

The EM300 system comes supplied with *Kongsberg's* post processing software NEPTUNE and this system was used to process the data during this survey. As a result of lack of operator training in NEPTUNE, the processing was initially slow due to self-training. Therefore, none of the transit data was processed onboard.

The bathymetry data acquired from the study area were successfully processed during the survey and assisted in the production of grids and contour files. The processed data were used to assist in locating dredge sites off hard copy maps and were tested interactively on the EM300 interface. However, the .DAF contour files that were imported into the EM300 display were large in size, which caused an overload on the system and subsequent failure. Therefore, this method was unable to be used for the remainder of the survey.

Conclusion

The Kenn Plateau survey was successful in the acquisition of 7584 km of swath data, 6753 km of which was processed onboard. This newly acquired information has provided high resolution bathymetric coverage of an area that was previously poorly known.

The four main issues encountered during the survey were:

1. The general flat topography of the seafloor over the Kenn Plateau allowed for the system to be run in automatic mode for the majority of the survey.
2. High data loss in the centre and outer beam sectors resulted in gaps in the coverage. Particularly at depths below 2500 m.
3. Failure to reset the log file at the start of the survey caused a system overload and subsequent failure.
4. Importing the processed bathymetric data as .DAF contour files into the EM300 acquisition interface caused on overload and failure of the system.

Recommendations:

- **In large survey areas it is not recommended to load .DAF contour files onto the EM300 system acquisition interface.**
- **The error log file should be reset at the start of each survey.**
- **The issue of the excessive data noise and the P421 error needs to be further investigated.**

Footnote: On the run to Nouméa at the end of the survey, a 27 kHz echosounder on the bridge was switched off, and the noise on the system decreased drastically. On all future swath-mapping surveys, this echosounder will not be used.

Appendix 4. Personnel Lists

Scientific personnel

Neville Exon	GA Chief Scientist
Peter Hill	GA Senior Geophysicist
Alix King	GA Geologist
Georgina Burch	GA Geologist
Yves Lafoy	New Caledonian geologist
Christian Heine	Sydney University geologist,
Lydia Taylor	Sydney University geophysicist,
Jon Stratton	GA science technician
Petar Vujovic	GA geophysical technician
Craig Wintle	GA mechanical technician
Franz Villagran	GA electronic technician
Stephen Thomas	National Facility electronics (cruise manager)
Bernadette Heaney	National Facility computing

Ship's Crew

Ian Taylor	Master
Arthur Staron	Chief Officer
Tim Sharpe	2nd Officer
John Morton	Chief Engineer
David Jonker	1st Engineer
Seamus Elder	Electrical Engineer
Tony Hearne	Senior Integrated Rating (Bosun)
Graham McDougall	Integrated Rating (seaman)
Bruce Noble	Integrated Rating
Fiona Perry	Integrated Rating
Philip French	Integrated Rating (engineering)
Andrew Goss	Chief Cook
Allan Sessions	2nd Cook
David Willcox	Chief Steward

Appendix 5. Key equipment

Kongsberg-Simrad EM 300 multibeam sonar swath-mapper

Scientific echosounder (12 kHz)

Charge-Air DC330/2000 diesel compressor of 2000 psi capacity for airguns

2 x GI airguns, each of capacity 45/105 cubic inches

Seismic winch

Stealtharray solid seismic cable 550 m long, with 300 m active section and 24 channels

Seismic processing work station

Plotter for seismic profiles and sampling locations

MMC *Seaspy Overhauser* magnetometer and towing winch

Gravity corer, 1 tonne, for 4-6m cores

Dredges, chain bag and pipe

Ship's winches and deck machinery

Coring cradle

DGPS navigation

Appendix 6. French samples from eastern seamounts

Identity	Cruise/Ship	Latitude (S)	Longitude (E)	Water depth (m)	Description
		19°11.9’	158°57’	65	
DW51	GEMINI	19°11.9’	158°55.8’	44	vesicular lava, volcanic breccia
		19°7.8’	158°48.1’	60	
DR52	GEMINI	19°6.73’	158°41.75’	60	vesicular lava, volcanic breccia
		19°11.6’	158°42.1’	67	
DW55	GEMINI	19°10.78’	158°37.1’	38	vesicular lava, volcanic breccia
		19°8.6’	158°31.8’	56	
DW59	GEMINI	19°17.15’	158°34.05’	67	basalt, sulfurous deposit, and basal.
		19°24.18’	158°31.4’	51	
DW60	GEMINI	20°28.9’	158°48.7’	40	basalt, sulfurous deposit, and basal.
		20°31.7’	158°50.9’	65	
		20°34.8’	158°47.3’	67	
	MUSORSTOM IV	20°38’	158°43.1’	67	
CC146		20°41.5’	158°38.4’	78	Oozy sand with turitellas
CC147		20°46.03’	158°33.73’	79	Oozy sand with turitellas
CP148		20°50.85’	158°36.03’	70	Oozy sand with turitellas
DW149		20°58.2’	158°35’	48	Coarse bioclastic sand
DW150		21°4.4’	158°40.7’	70	Coarse bioclastic sand
DW151		21°25.9’	158°59.5’	39	Fine sand
CP158		21°29.5’	159°16.4’		Sand with ptéropods
DW159		21°48.65’	159°27.95’	45	Coarse sand, blocks of sand
DW160		21°42.4’	159°29’	50	Sand with ptéropods
DW263		25°21.3’	159°46.44’		Shelly sand
DW265		25°21.1’	159°45.2’		Shelly sand
DW266		25°20.2’	159°45.7’	240	Shelly sand
DW270		24°48.85’	159°34.13’	223	Shelly sand
DW272		24°40.91’	159°43’		Shelly sand
DW282		24°11.55’	159°32.22’	230	halimeda sand
DW290		23°06.2’	159°26.3’	300	blocks of sand
DW294		23°10.98’	159°30.13’	272	blocks of sand
DW295		23°12.57’	159°32.31’	279	blocks of sand
DW296		23°12.61’	159°36.27’	178	blocks of sand
DW322		21°19’	158°0.4’	975	pumice
DW329		20°22.9’	158°46.5’		Coarse sand and coralline debris
DW330		20°19.8’	158°48.42’		Coarse sand and coralline debris
DW333		20°16.61’	158°49.02’		Coarse sand and coralline debris
DW334		20°16.61’	158°47.62’		Coarse sand and coralline debris
DW335		20°3.24’	158°45.35’	315	Coarse sand and coralline debris
DW336		19°55.8’	158°38.9’	350	Coarse sand and coralline debris
DW337		19°53.8’	158°38’		Coarse sand and coralline debris
DW338		19°51.6’	158°40.4’		Coarse sand and coralline debris
DW339		19°53.4’	158°37.9’		Coarse sand and coralline debris
DW340		19°48.5’	158°40.9’		Coarse sand and coralline debris
DW342		19°43.5’	158°47.72’	660	Coarse sand and coralline debris
DW343		19°41.39’	158°50.2’	760	Coarse sand and coralline debris
DW344		19°38.85’	158°34’	310	Coarse sand and coralline debris
DW346		19°39.77’	158°27.07’		Coarse sand and coralline debris
DW347		19°38.61’	158°28.03’	260	Coarse sand and coralline debris
DW348		19°36’	158°31.7’	260	Coarse sand and coralline debris
DW349		19°34.4’5	158°34.48’	275	Coarse sand and coralline debris
DW350		19°34’	158°35.3’	280	Coarse sand and coralline debris
DW353		19°26.5’	158°40.4’	290	Coarse sand and coralline debris
DW354		19°31.06’	158°42.56’		Coarse sand and coralline debris
DW355		1936.43’	158°43.41’	580	Coarse sand and coralline debris