AGSO Cruise 147 Report - Tasman Rises geological sampling cruise of Rig Seismic: Stratigraphy, tectonic history and palaeoclimate of the offshore Tasmanian region

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TASMAN RISES GEOLOGICAL SAMPLING CRUISE OF *RIG SEISMIC*: STRATIGRAPHY, TECTONIC HISTORY AND PALAEOCLIMATE OF THE OFFSHORE TASMANIAN REGION

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1. SUMMARY

From 27 January to 27 February 1995, on the *Tasman Rises* cruise (AGSO Cruise 147), the R.V. *Rig Seismic* sampled the outer continental margin of Australia, west, south and east of Tasmania (see Figure 1), as part of a program of assessing resources within the 200 mile Exclusive Economic Zone (EEZ) and in potentially Australian territory beyond that zone. At the same time a major coring program was carried out for Late Pleistocene climatic studies. The cruise program concentrated mostly on the 200 000 km² of the South Tasman Rise south of Tasmania, about half of which is within the EEZ, and the rest of which should be claimable under the United Nations Law of the Sea Convention. However, important work was also done within the EEZ west of Tasmania and on the poorly known East Tasman Plateau that also lies within Australia's EEZ. This program follows AGSO's highly successful seabed mapping program of last year, which mapped much of the area in detail using the multibeam sonar system of the French research vessel *l'Atalante*. The South Tasman Rise generally lies 1000-4000 m below sea level, and the East Tasman Plateau 3000-4000 m deep.

Aboard the *Rig Seismic* were scientists from AGSO, the Antarctic and Southern Ocean Cooperative Research Centre in Hobart (in which AGSO is a participant), Woods Hole Oceanographic Institution (USA), and the Villefranche Geodynamic Laboratory in France, and students from the University of Tasmania and James Cook University. The interests of the participants are almost as diverse as their institutions, covering plate tectonic history, regional geology, petroleum potential, climatic history of the last glacial and interglacial periods, the living microplankton in the surface waters, and geophysical methods for predicting the nature of the sea bed.

In pursuit of these interests *Rig Seismic* successfully dredged rocks from the sea bed at 53 stations in depths of up to 4500 m, took 20 deepwater cores of young sediments that should record the climatic history, investigated surface and deep waters and their living content at 18 stations, and sampled the surface sediments on the continental shelf south of Tasmania at a dozen stations (see Table 1).

Table 1: Summary of all stations from AGSO Cruise 147

Station type	Total	Successful
Dredge stations	57	54 (85%)
Gravity core stations	37	20 (54%)
Vibrocore stations	8	4 (50%)
Grab stations	10	9 (90%)
Box corer stations	3	1 (33%)
Camera stations	6	5 (83%)
Free fall grab stations	7	7 (100%)
Hydrocasts (3 x 3500 m; 10 x 200 m) Temperature/pressure/salinity logging to 200 m (SDL)	10	10 (100%)
Surface water sample (often at hydrocast and SDL stations)	18	18 (100%)
Total	**166**	**128** (77%)

Both dredging and coring were concentrated largely on the South Tasman Rise (Fig. 1 & Table 2). About 15 tonnes of rocks were recovered and representative samples have been kept for future study. A total of 73 m of sediment cores were described and kept.

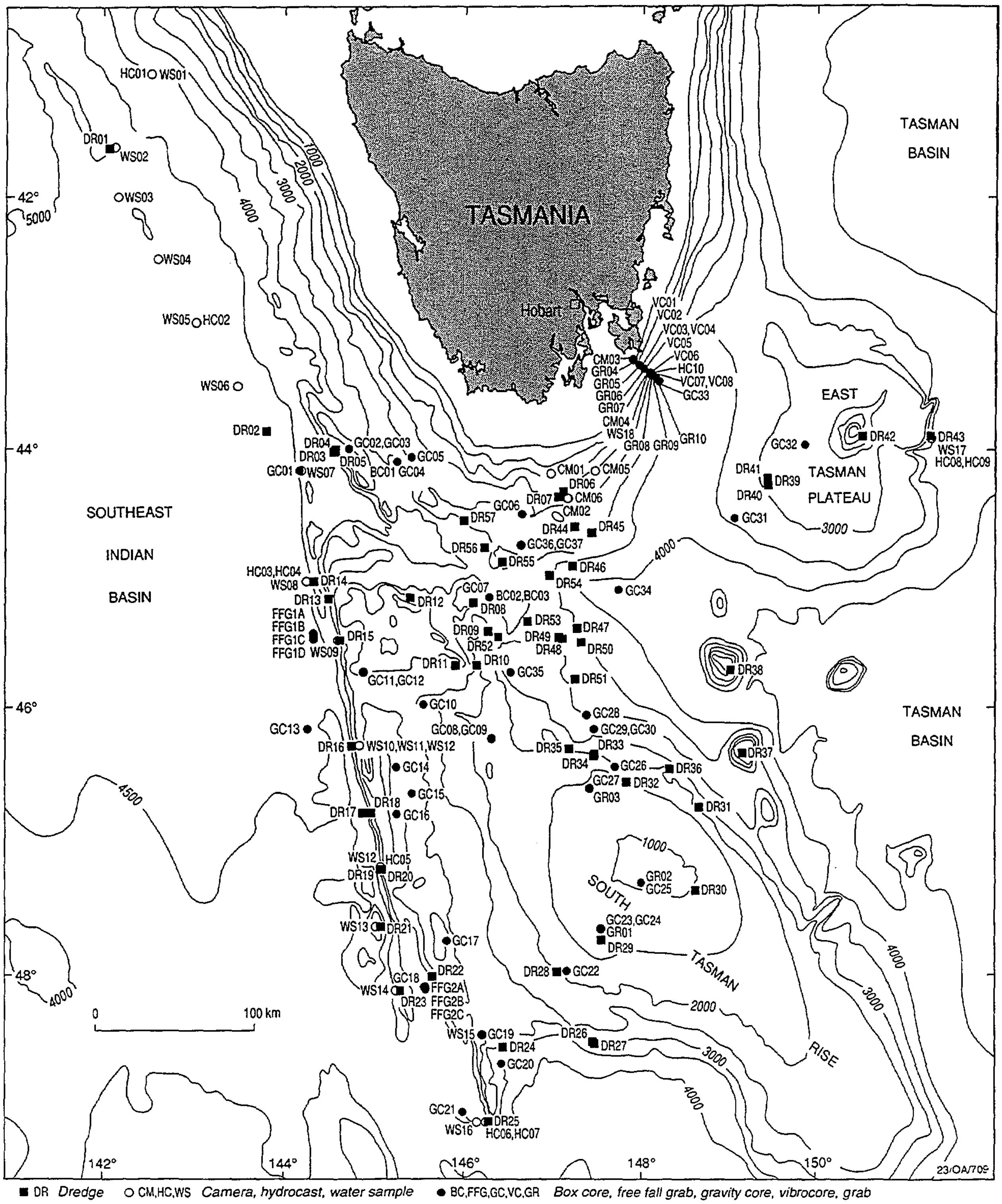


Figure 1. Bathymetric map of the study region showing all AGSO Cruise 147 stations. Based on l'Atalante swath-mapping and other data. DR = dredge, GC = gravity corer, VC = vibrocorer, BC = box corer, GR = grab, FFG = free-fall grab, HC = hydrocast, WS = surface water sample, CM = camera.

Table 2: Geographic distribution of bottom stations from AGSO Cruise 147

Location	Nos. of Stations	Nos. successful
Tasmanian margin	12DR, 7GC, 8VC, 7GR, 6CM	11DR, 4GC, 4VC, 6GR, 5CM
South Tasman Rise	36DR, 27GC, 3GR, 3BC	34DR, 13GC, 3GR, 1BC
East Tasman Plateau	5DR, 1GC	5DR, 1GC
Abyssal hills	4DR	4DR
Abyssal plains	7FFG, 2GC	7FFG, 2GC

DR = dredge, GC = gravity core, VC = vibrocore, GR = grab, CM = camera station, BC = box corer, FFG = free-fall grab

The area studied was once landlocked, deep within the supercontinent of Gondwana. This part of Gondwana started to break up in the Early Cretaceous (130 million years ago). We believe the western part of the *South Tasman Rise (STR)*, west of a major N-S fracture zone at 146°15'E, was attached to Antarctica until the Oligocene (30 million years ago), and slid with it slowly past western Tasmania. Thereafter, Antarctica and Australia completely separated, but the STR became attached to the Australian continent. Soon afterward the STR sank beneath the sea. The eastern part of the STR appears not to have moved very far.

The present studies have proven that the STR is underlain by a suite of continental igneous, metamorphic and sedimentary rocks. The western margin is underlain by gneiss and schist, granite, and basic plutonic rocks. The central STR is underlain by granitic rocks. The northeastern deepwater extension of the STR is underlain partly by high-pressure igneous rocks, unlike those on Tasmania, that are best matched with rocks in north Victoria Land in Antarctica. Fault blocks and other highs in the depression contain gneiss, granites, metamorphics of greenschist facies such as amphibolites, and gabbros.

The STR is cut by numerous NW-NNW trending strike-slip faults related to the break-up of Australia and Antarctica, and high-standing basement blocks are separated by deep, narrow sedimentary basins that geochemical studies of cores have indicated may contain petroleum. The age of the sedimentary rocks within these basins bears on their petroleum potential, and seismic results suggest that the basins may have formed later (Late Cretaceous) than the Gippsland and Otway Basins to the north (Early Cretaceous). The oldest basinal sediments recovered in this dredging program were Eocene.

Before this cruise, the nature of the *East Tasman Plateau* (ETP) was unknown, the possibilities being that it was either a volcanic buildup, or that it was a continental fragment like the STR. Our dredging of granitic gneiss and other metamorphic rocks, acid volcanics and quartz-rich sediments proves it to be continental, and hence suggests that it could have long-term petroleum potential. The ETP has high-pressure basement rocks (garnetiferous gneiss) unlike those on Tasmania, but like those in the northeastern deepwater extension of the South Tasman Rise. Exactly where it fitted before the break-up of Gondwana remains to be resolved. Two volcanic cones were dredged on the ETP. The large central Soela Seamount is believed to be a hotspot volcano and returned volcanic breccia and basalt. A small cone in deep water on the western plateau margin returned hyaloclastite and basalt.

The western and southern *continental margins of Tasmania* were dredged during the cruise and were confirmed to be underlain by gneiss, schist, granite, and related continental rocks. High-pressure garnetiferous gneisses from the southwestern scarp are much like those from the northeastern STR and the ETP. Although our dredging has shown that the western part of the large *sediment-filled depression* between the southern Tasmanian margin, the eastern South Tasman Rise and the East Tasman Plateau is underlain by thinned continental crust, and is part of the South Tasman Rise, seismic and magnetic evidence suggest that the central and eastern part of the depression is underlain by oceanic crust, but they are completely covered with sediment so could not be sampled.

The three continental masses (Tasmania, STR, ETP) are surrounded by the *deep ocean floor*, underlain by basalt that welled up as the Gondwanan fragments drifted apart. Cutting both the ocean floor and parts of the continental areas around Tasmania are extinct volcanoes whose rocks could help in timing plate tectonic movements in the region. Four have been sampled for studies of their composition and age to be carried out at the University of Tasmania's Geology Department. Two volcanoes, east of the South Tasman Rise, consist of basalt and hyaloclastite, and are part of a previously unsampled hotspot chain. The other two volcanoes, west of Tasmania, consist of basalt and were probably formed on oceanic fracture zones.

Basaltic volcanism proved to be widespread on the southern Tasmanian margin and also on the eastern STR. Cones on the Tasmanian margin and northernmost STR vary from a few hundred metres to more than 1000 metres high, and consist of volcanic breccia and basalt. Volcanic complexes on the eastern STR consist of basalt and hyaloclastite. The origin of these rocks may be related to stretching and thinning of the continental crust as the various blocks moved apart during Gondwanan break-up.

The *sediments* recovered from deep water in the three continental areas fall into four categories: metasediments in basement complexes; strongly lithified quartz-rich conglomerates and sandstones of probable Palaeozoic age; poorly lithified, greenish Palaeogene quartz-rich mudstones and sandstones; and altered Neogene limestones. The greenish mudstones frequently contain arenaceous forams, radiolarians and diatoms, and are probably all shallow marine in origin. They are common on the inner and outer ridges of the Tasman Fracture Zone that form the western margin of the STR, on the southern margin of Tasmania, and on the northern STR, and occur on the ETP, but were not found on the culmination of the STR. Similar rocks dredged on previous cruises on the west Tasmanian margin proved to be Late Cretaceous, Paleocene and Eocene in age. Several of the sediments dredged on the present cruise have been identified palynologically as Eocene, shallow marine, and glacial. Similar rocks cored during the Deep Sea Drilling Project (DSDP), on the west Tasmanian margin and the STR, are late Eocene to middle Oligocene in age. These results suggest that Triassic, Jurassic and Cretaceous sediments, if present at all, are confined to the deep basins on the STR.

Rocky outcrops are commonly coated in manganese crusts up to 20 cm thick, which is unusually thick compared to those in most parts of the world ocean, and manganese nodules are common in many places. The nodules are sometimes exceptionally large (up to 12 cm in diameter) and are frequently cored by granite or other basement rocks, which is very unusual. Previous work has shown both nodules and crusts to be generally of low grade, and this was confirmed for the bulk of the samples taken on this cruise. However, six analyses of crusts taken within the oxygen minimum zone (1000-2000 m water depth) average 0.79% cobalt, indicating that these shallow-water crusts may have possible long-term economic potential.

The *Tasman Manganese Pavement*, known from south of the South Tasman Rise, does not extend as far north as the area sampled during the cruise, and no manganese nodules were recovered at two multiple stations from the abyssal plain west and southwest of the rise. However, coring does suggest that that there may be a large area of buried manganese crusts on the southern STR, and that this may have formed a remarkably extensive dark pattern on *l'Atalante's* swath imagery.

The *climatic studies* of cores from this key region of the world's oceans, where two oceanic fronts are believed to have moved north and south with Pleistocene climatic changes, should reveal a great deal about those changes and their effects. The studies are being carried out on a collaborative basis by the Antarctic and Southern Ocean Cooperative Research Centre, Woods Hole Oceanographic Institution, and AGSO. The shipboard program was designed to provide both latitudinal and depth transects to document changes in both surface and bottom waters. One major problem has been the discovery that even very carefully targeted gravity coring is ineffectual in water depths of 1000-2500 metres on the current-swept STR, because of a blanket of winnowed foram sand. It may be that only deepwater vibrocoring or ODP hydraulic piston coring will obtain satisfactory cores in this depth range, so that a full depth transect can be examined.

An acoustic facies map, prepared on the basis of *l'Atalante's* data, was checked by coring, and this checking has confirmed much of the interpretation and will enable the map to be confidently finalised. Vibrocoring of bryozoal sands on the Tasmanian continental shelf did not recover cores of the length hoped for (several metres), but the cores still will be of use in studying the cool-water "carbonate factory" of Australia's southern margin. Camera studies and dredging of current-swept volcanic cones in water depths of 1000-1500 metres, in the orange roughy fishing grounds south of Tasmania, showed that there is another active carbonate factory there, based on colonial corals and barnacles, and making use of the nutrients carried in the deepwater currents rather than photosynthesis. The assemblage on one trawled cone apparently was no less rich than that on a cone that had not been fished at all, suggesting that in some cases the impact of trawling may not be as great as has been feared.

This cruise has and will advance both applied and pure scientific knowledge of a poorly known part of Australia. Among the fascinating finds of the cruise were the fossilised skulls of four different species of beaked whales, dredged at different locations during the dredging program. These whales appear not to be modern species, and the well-preserved skulls could well be important in understanding the evolution of this branch of moderate-sized whales.

The cruise was highly successful in all areas, and the completed program far exceeded the pre-cruise plans. For example, the number of dredges was almost twice what was planned, and far larger than on any previous deepwater BMR/AGSO cruise. Both dredging and coring efficiency were greatly improved by the existence of detailed maps, and seismic and echosounder profiles, from the previous year's *l'Atalante* cruise.

The weather included 50 knot gales and five metre swells, to be expected in the "Roaring Forties", but was never bad enough to stop operations. There were problems with the performance of some geological equipment, but hard work and *ad hoc* solutions from the mechanical and electrical technicians kept the winches and echosounder recorders going in difficult circumstances.

Immediately after this cruise was completed, *Rig Seismic* started related seismic profiling studies of the deep crustal structure around Tasmania and across the South Tasman Rise. Data from the two cruises and previous work will be brought together in major studies, which will bear on the mineral potential of onshore Tasmania and the petroleum potential of its offshore regions.

2. INTRODUCTION

The west Tasmanian margin and the South Tasman Rise have been the subject of a number of BMR/AGSO cruises over the years:

- BMR Continental Margins high-energy sparker seismic survey - 1972
- BMR low-energy sparker seismic survey of continental shelf - 1973
- BMR Cruise 40 Bass Basin contract seismic survey - 1982
- *Sonne* SO-36B & C cooperative seismic and sampling surveys - 1985
- BMR Cruise 67 *Rig Seismic* sampling survey - 1987
- BMR Cruise 78 *Rig Seismic* seismic and sampling survey - 1988
- AGSO Cruise 125 *l'Atalante* swath-mapping and seismic survey - 1994

These cruises have provided a great amount of morphological and geological information about the region. With the results of Cruise 147, AGSO will be able to carry out a full review of the geological framework and offshore resource potential of this part of the Australian margin, extending well beyond the Australian Exclusive Economic Zone.

2.1. Regional plate tectonic setting

This section is drawn directly from Royer & Rollet (1994). Their map of the present-day tectonic elements is shown in Figure 2. The South Tasman Rise (STR) is known from deep sea drilling and dredging to be of continental origin, and as such was part of the former East Gondwana continent. Reconstructions of Gondwana show that the STR was contiguous to several continental fragments that are now thousands of kilometres apart. Going counterclockwise, the STR was bounded by Victoria Land, Antarctica, to the west, by the Ross Sea shelf to the south, by the Campbell Plateau to the southeast, by the Challenger Plateau and Lord Howe Rise to the east, and by Tasmania and Australia to the north. The STR is certainly the smallest of these Gondwana fragments, and because of its central location in the plate boundary framework that developed within East Gondwana, it underwent all the major tectonic events that led to the dispersal of the Gondwanan fragments. These tectonic events span from the Late Jurassic to the Late Oligocene, after which the STR drifted passively northward along with the Australian plate. The STR is therefore a centre piece in understanding the complex tectonic history of this region.

Early extension between Australia and Antarctica started in the Late Jurassic along a NW-SE direction (relative to a fixed Australian plate; Willcox & Stagg, 1990). Extension in the Bass Strait, between Tasmania and the mainland, is contemporaneous and, in large part, in the same direction (Willcox et al., 1992). This extension phase lasted until the Late Cretaceous when seafloor spreading started in the Great Australian Bight (Cande & Mutter, 1982). The continent-ocean boundary is dated as 95 Ma old (Cenomanian; Veevers, 1986). Subsidence studies along the southern Australian margin, as well as the conjugate pattern of seafloor magnetic anomalies off Australia and Antarctica, suggest that the break-up between Australia and Antarctica propagated from the Great Australian Bight towards Tasmania (Mutter et al., 1985). Seafloor spreading started at a very slow spreading rate (< 1 cm/yr, full rate) until the Early Eocene, increasing somewhat to a slow rate (~ 2 cm/yr) until the Middle Eocene. The western margins of Tasmania and STR paralleled the north-south seafloor spreading direction and therefore behaved as a transform margin. It is possible that north-south extension initiated at this time between Tasmania and the STR (Veevers et al., 1991), as the STR might have still been attached to Antarctica.

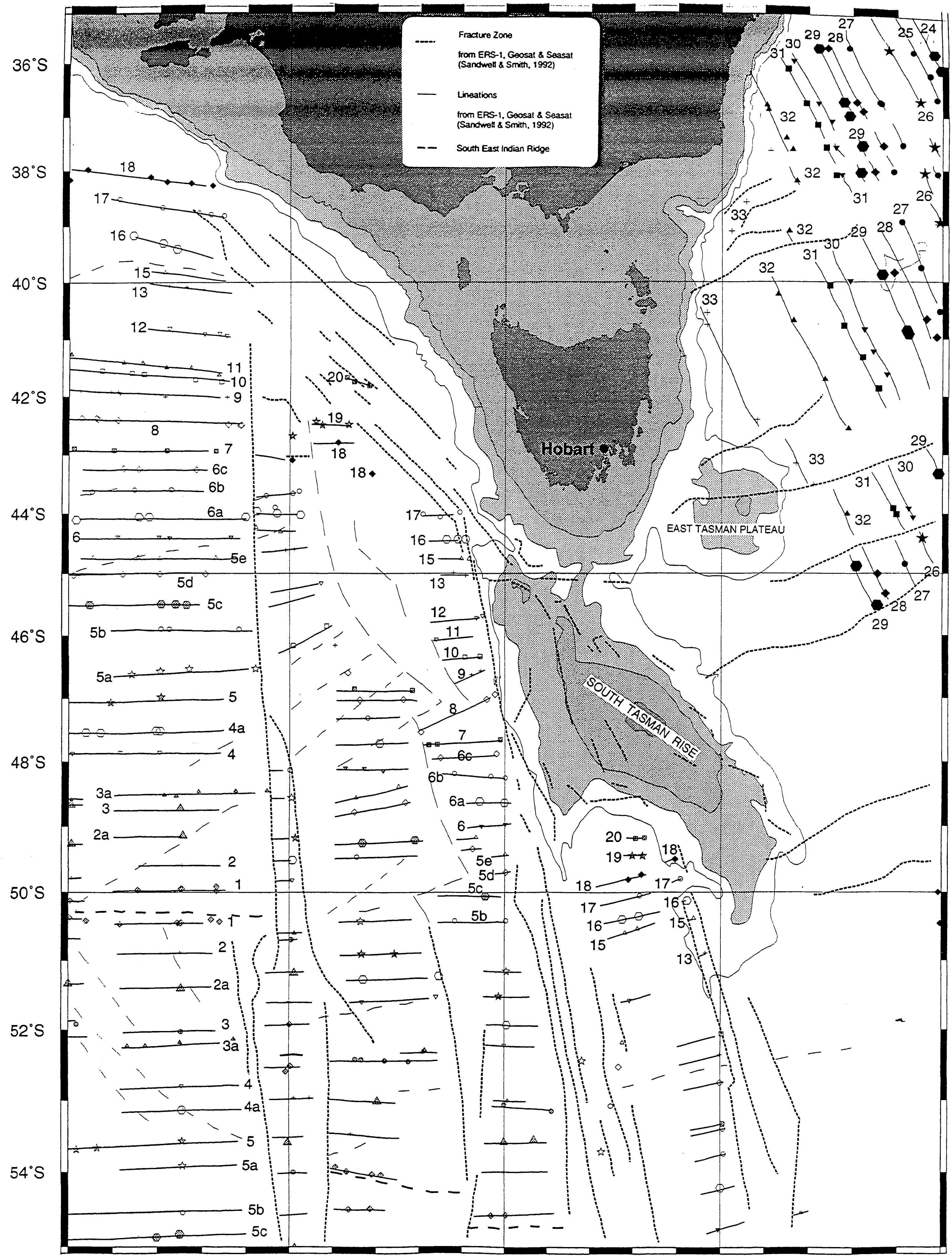


Figure 2. Tectonic map of southeast Australian region. Fracture zones and lineations interpreted from GEOSAT satellite gravity data. Magnetic anomaly pattern determined from all public data by J.-Y. Royer and N. Rollet (1994).

Seafloor spreading between Australia and Antarctica accelerated drastically (up to 4-5 cm/yr) in the Middle Eocene (~ Chron 18; 45 Ma); this event coincides with major reorganisations of the plate boundaries in the Indian Ocean. During this second stage, the STR remained attached to the Australian plate; but this does not preclude any further extension, if not early oceanisation, between the STR and Tasmania. At chron 13 (36 Ma; early Oligocene), the large transform offset of the Tasmanian and STR margins (~ 750 km long) was still preventing any deep water circulation between the Australian-Antarctic Basin and the Pacific Ocean. The Southeast Indian ridge axis remained in contact with the STR western margin until about chron 8 (30 Ma). As seafloor spreading continued, the transform margin of the STR gave birth to the large offset Tasman and Balleny oceanic fracture zones. The outstanding signatures of these fracture zones on the satellite gravity data provide major constraints to reconstruction of the relative motions of Australia and Antarctica (Royer & Sandwell, 1989).

Rifting along the eastern margin of Australia, Tasmania and the STR, probably began in the mid Cretaceous. The opening of the Tasman Sea, between Lord Howe Rise/Challenger Plateau and Australia, started in the Late Cretaceous (~ chron 33; 80 Ma), along an ENE-WSW direction (Hayes & Ringis, 1973; Weissel & Hayes, 1977). Seafloor spreading propagated from south to north along the eastern Australian margin. The oldest magnetic anomalies (chron 33) identified in the Tasman Sea are located just east of the East Tasman Plateau. Further south, lack of magnetic anomaly profiles prevents any exact dating of the oceanic crust lying east of the STR. However plate reconstructions at chron 33 bring the western slopes of Challenger Plateau next to the STR (e.g. Molnar et al., 1975). Seafloor spreading in the Tasman Sea stopped abruptly in the early Eocene (chron 24/23, 55-50 Ma), probably when the Australian-Antarctic and Pacific-Antarctic spreading systems connected south of the STR.

Seafloor spreading resumed south of the Tasman Sea almost at right angles to the former spreading ridge, leaving a prominent scar on the seafloor, extending from the southeastern tip of the STR to the South Island of New Zealand. The oldest magnetic anomalies, south of this boundary, roughly oriented east-west, are of middle Eocene age (chron 21-22; 45-50 Ma) and record the relative motion between the Antarctic and Australian plates. South of the STR, early Eocene to mid-Eocene basal sediments were recovered at DSDP site 280, suggesting that seafloor spreading, between Antarctica and the STR, started during this plate boundary reorganisation in the Tasman Sea. Such a discrepancy in age of initiation of seafloor spreading west (Late Cretaceous) and east (early/mid-Eocene) of the Tasman transform margin, favors the idea of a large amount of extension, if not oceanisation, between the STR and Tasmania.

The plate reconstruction of East Gondwana brings the southern boundary of the STR along the Ross Sea shelf and the western Campbell Plateau (e.g. Molnar et al., 1975; Weissel et al., 1977). The breakup of these continental pieces seemed to occur in the Late Cretaceous, and a triple junction developed in the vicinity of the STR. The three branches of this system being: to the north the Tasman spreading ridge between Tasmania-Australia and the Challenger Plateau-Lord Howe Rise, to the south the early Pacific-Antarctic Ridge separating the Ross Sea shelf from the Campbell Plateau, and to the east a transform boundary splitting the Challenger Plateau from the Campbell Plateau. An additional plate boundary is hypothesized between East and West Antarctica, across the Ross Sea.

2.2. The study region

The region of interest to us includes the area mapped by R.V. *L'Atalante* with the multibeam EM12D swath-mapping system, and extends from 40° to 50°S and 141° to 152°E. It lies west, south and east of Tasmania, extending from west of King Island to the crest of the South Tasman Rise, and east to the outer edge of the East Tasman Plateau, and from the outer edge of the continental shelf to the abyssal plain (Fig. 1). The continental shelf around Tasmania is generally less than 50 km wide and non-depositional at the present day (Jones & Holdgate, 1980), but bryozoal sands and gravel do accumulate on the outer shelf (Jones & Davies, 1983). The continental slope west of Tasmania is about 70 km wide, and falls fairly regularly from water depths of 200 m to 4000 m, so the average slope is 3-4°. The continental rise lies between about 4000 m and 4500 m, and below that is the abyssal plain, generally 4500-5200 m deep.

The South Tasman Rise is a large, NW-trending bathymetric feature that rises to less than 1000 m below sea level, and is separated from Tasmania by a WNW-trending saddle more than 3000 m deep (Fig. 1). The Deep Sea Drilling Project showed that it has a continental core, when quartz-mica schist was drilled in DSDP Site 281 (Kennett, Houtz et al., 1975A). The top of the rise is a gentle dome with low slopes, but slopes between 2000 and 4000 m on its eastern and southern sides are much like those in the Tasmanian continental slope, of the order of 3-4°. The western slope is not great to 3000 m, but below that there is a very steep scarp trending 350° and dropping away to 4500 m.

Several NNW to NW trending scarps and ridges, in the continental slope and on the edge of the deep ocean floor, west of the South Tasman Rise and Tasmania, and off the Otway Basin, mark tilt-blocks of continental rocks, necessarily overlying highly extended and thinned continental crust. Other ridges, off the west coast of Tasmania and oblique to the continental shelf edge, may lie on the continent-ocean boundary, or may be the trace of old transforms associated with the early stages of seafloor spreading between Australia and Antarctica.

The East Tasman Plateau is a nearly circular feature, separated from southeast Tasmania by a saddle 3200 m deep (Fig. 1). The area above 4000 m depth is about 60 000 km^2 and that above 3000 m is about 20 000 km^2. Slopes are generally 3-4° but they are considerably greater on the outer flanks. Atop the plateau is the Soela Seamount, a guyot that rises to 660 m below sea level. This guyot formed as the result of Eocene hotspot volcanism, and has yielded early Eocene shallow-water carbonates from its flanks (Drs. Pat Quilty & Chris Jenkins, pers. comm.). Prior to AGSO Cruise 147 it was uncertain whether the plateau itself, that has up to 1.5 seconds (TWT) of sedimentary section in places, was of continental or oceanic origin but the *Tasmante* results suggested that it was continental. The present sampling has proven its continental nature.

The mapping of seafloor magnetic anomalies starting with Weissel & Hayes (1972), and the interpretation of satellite altimeter data (e.g. Royer & Sandwell, 1989, repeat mission Geosat data; Veevers, 1990, Seasat data; Sandwell & Smith, 1992, 1994, Geosat and ERS-1 data) have shown that the abyssal plain west of Tasmania is characterised by fracture zones trending 350-335°, and that Late Cretaceous and Cainozoic magnetic anomalies are probably normal to the fracture zones. Tasman Sea spreading started east of Tasmania in the Late Cretaceous at about 80 Ma, and ended in the Eocene at about 55-50 Ma, according to Royer & Rollet (1994). The anomaly pattern and the Geosat data suggest that the associated fracture zones trend 70-80° (Fig. 2).

Satellite images of our study region define basement structure very well and provide excellent information on fracture zones. They confirm an older 320°-trending fracture direction (Jurassic-

Early Cretaceous) close to the west Tasmanian continental margin, and the younger 350-355° fracture direction further out on the abyssal plain. They also indicate that the South Tasman Rise is cut by major deep faults. An interpretation of the Geosat imagery is incorporated in Figure 3.

2.3. Acknowledgements

Our special thanks are due to the *Rig Seismic's* maritime crew, led by Ship's Master Trevor Walters, and to the AGSO data acquisition technicians (for full list see Appendix 1). With such a diverse scientific contingent, carrying out very diverse sampling operations, the load on both scientific and technical groups was very considerable. An additional problem was that the geological winches had not been used for some time, and proved to need electronic and mechanical repairs, before and during the sampling activities.

We are very grateful to Drs. Tony Crawford and Ron Berry of the University of Tasmania for their advice on the petrology of the basement and volcanic rocks dredged. We thank Peter Hill and Jim Colwell of AGSO for editing the manuscript, and the AGSO Cartographic Services Unit for producing most of the figures.

3. PREVIOUS STUDIES

Tectonic studies which have touched on this region include that of Falvey (1974), who produced a model of this margin as a typical Atlantic margin, with breakup between Australia and Antarctica in the late Paleocene, in line with the interpretations of magnetic anomalies by Weissel & Hayes (1972), and Deighton et al. (1976). Cande & Mutter (1982) revised the magnetic identification and concluded that margin formation commenced in the Santonian, with a period of slow spreading from 90 to 43 Ma, followed by more normal spreading rates until the present. Falvey & Mutter (1981) and Willcox (1982) included the region in general reviews of Australia's continental margins. Veevers (1985) has suggested that breakup started 95 Ma ago.

3.1. Early cruises

A great deal of seismic and sedimentological information, arising from cruises of R.V. *Vema*, R.V. *Robert D. Conrad* and USNS *Eltanin*, for the area between Australia and Antarctica, is presented in a synthesis volume edited by Hayes (1971). The basic data for five papers discussing the sediments of the southeast Indian Ocean come from a collection of about 300 cores taken on a number of cruises carried out in a very methodical manner. Conolly (1971) has written a brief and useful overview of the results, and he outlines the physiography, the sediment thickness above basement, the distribution of surface sediment types, and the Tasman manganese pavement south and southeast of the South Tasman Rise. Conolly & Payne (1971) mapped the manganese pavement largely by bottom photography. It consists of a pavement of nodules and/or reworked or relict foram and manganese sand that overlies firm grey siliceous ooze. Its distribution follows the deep troughs associated with the Tasman Fracture Zone between Tasmania and the mid-oceanic ridge, and spreads eastward onto the floor of the Tasman Abyssal Plain. The authors suggested that it was created by bottom water movement eastward around Tasmania and the South Tasman Rise. The manganese pavement coincides with an area of 3 000 000 km^2 of non-deposition or low deposition for at least the last 3 million years, documented by palaeomagnetic and faunal studies (Watkins & Kennett, 1971).

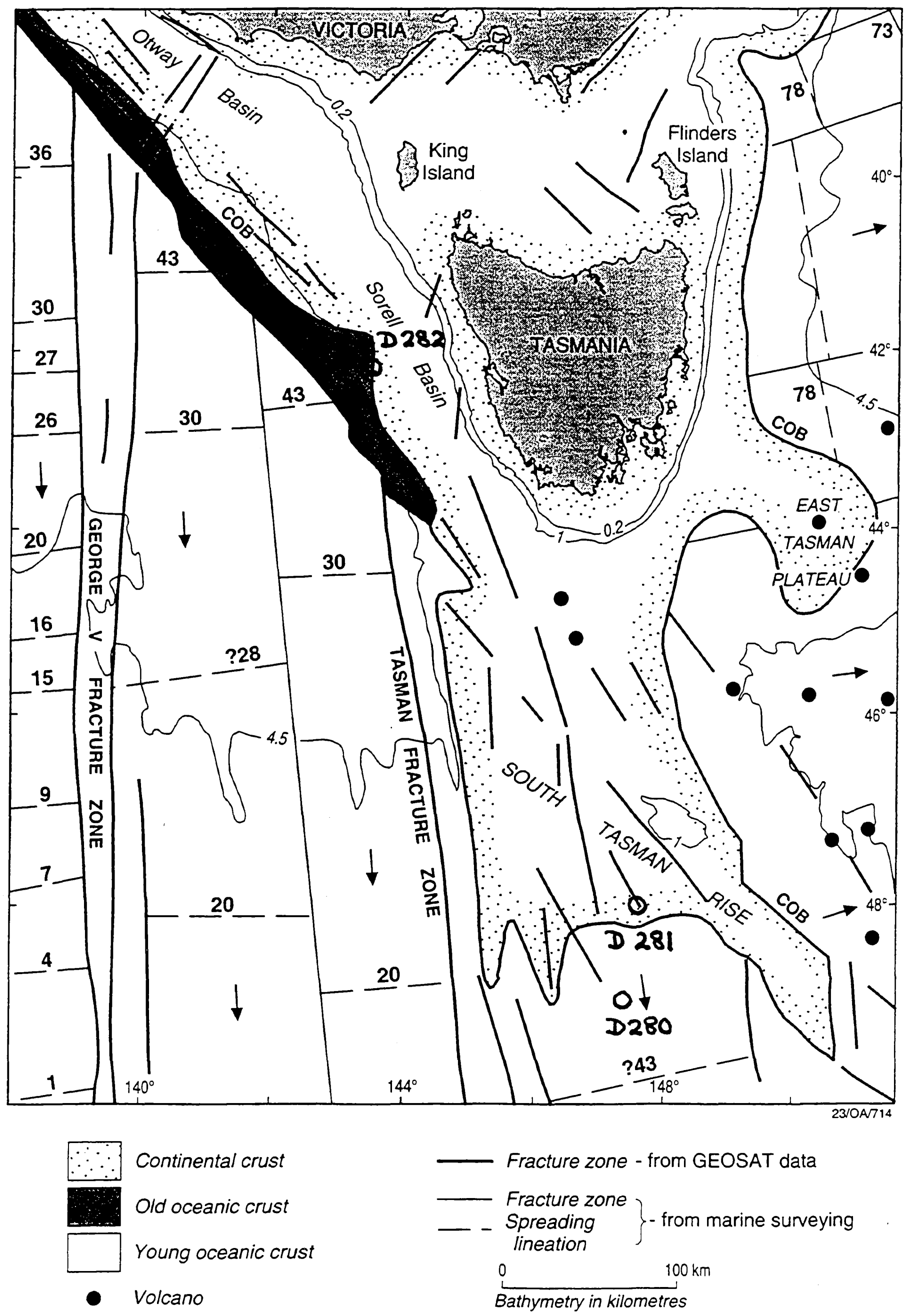


Figure 3. The tectonic elements of the offshore Tasmanian region. After Exon et al. (1994). Magnetic lineation ages in Ma, after CPCEMR (1991). DSDP Sites prefixed D.

A number of cores were taken by R.V. *Eltanin* in the region near Tasmania and the South Tasman Rise between 1966 and 1967 (e.g. Watkins & Kennett, 1971), and these are summarised below in Table 3, drawn from the US National Geophysical Data Center's Core Curator's File. Other cores taken by US institutions are listed in Table 4. All cores taken by US institutions are listed in considerable detail in Exon (1995, Appendix 3).

Table 3: Cores/dredge taken by USNS *Eltanin* near Tasmania (40-50°S, 138-154°E)

Station	Latitude (S)	Longitude (E)	Water depth (m)	Length (cm)	Primary lithology
38-18	40°03.0'	152°14.5'	4610	597	Mud, calc ooze, silic mud
36-01	40°51.6'	140°00.9'	5133	1205	Calc ooze & mud
53-20	41°26.0'	144°06.1'	1533	1179	Calc ooze
34-08	41°44.7'	152°15.0'	4854	1068	Silic ooze
53-19	42°32.0'	144°37.5'	1628	146	Calc ooze
36-02	43°32.3'	140°05.0'	4630	100	Calc ooze & mud
34-10	44°31.6'	149°58.4'	2853	1136	Calc ooze
27-30	45°04.0'	147°13.7'	3589	452	Calc ooze & mud
53-18	45°04.6'	144°28.3'	3690	80	Sandy mud
34-12	45°11.6	147°11.6'	3932	2262	Calc ooze
34-11	45°12.6'	147°48.2'	3932	440	Calc ooze
34-13	45°11.5'	145°04.2	4022	dredge	Mn nods
34-09	45°20.1	146°06.2'	2743	588	Calc ooze
39-64	45°33.6'	150°21.0'	4616	454	Calc ooze & minor mud
53-09	46°26.5'	152°39.8'	4371	726	Calc ooze & mud
39-62	46°56.9'	149°32.6'	3174	285	Calc ooze
27-29	47°00.0'	147°51.8'	925	405	Calc ooze
39-49	47°06.2'	142°36.3'	4649	423	Calc ooze
36-22	47°34.0'	148°03.0'	1099	506	Calc ooze
39-52	47°34.8'	142°59.7'	4610	463	Calc ooze & silic mud
36-23	47°53.2'	150°03.2'	2545	550	Calc ooze
39-57	48°15.0'	147°37.2'	2372	507	Calc ooze
39-53	48°49.0'	144°32.4'	3965	441	Calc ooze
53-16	48°53.0'	147°31.0'	4261	412	Mud & volc ash
53-17	48°59.0'	148°11.2'	4140	1534	Calc ooze & silic mud
53-10	49°00.0'	148°06.7'	4148	1175	Calc ooze & silic mud
36-21	49°28.0'	149°08.6'	3846	495	Calc & silic ooze
38-15	49°40.1'	152°34.1'	4324	bag	Mn nodules
38-16	49°43.9'	152°38.6'	4301	557	Silic mud & calc ooze
38-13	49°44.3'	152°36.8'	4333	308	Calc ooze & clay
38-14	49°45.0'	152°36.2'	4282	453	Silic mud & calc ooze
38-11	49°47.3'	152°30.6'	4333	1187	sandy mud
39-55	49°55.9'	145°55.8'	4782	911	Calc ooze & silic mud

Include both PC (piston core) and TC (trigger core) at each station

Table 4: Other seabed samples taken by US institutions near Tasmania (40-50°S, 138-154°E)

Core	Latitude (S)	Longitude (E)	Water depth (m)	Length (cm)	Comments
Eltanin 55/PC09	40°03.9'	140°23.2'	4703		
Eltanin 55/PC10	40°06.0'	139°41.8'	4996		
Robert Conrad 9/132	44°47'	152°48'	4709	1055	Pliocene
Robert Conrad 9/133	45°45'	148°22'	4082	1095	Pleistocene
Robert Conrad 9/134	44°05'	143°47'	4570	828	Miocene
Robert Conrad 9/135	42°12'	140°46'	5066	42	Pleistocene
Vema 16/114	49°36'	138°13'	3116	1080	Pliocene
Oceanographer 476/149	43°01.2'	145°13.2'	76	grab	
Oceanographer 476/179	40°48.2'	148°45.9'	121	grab	

Houtz & Markl (1971) summarised numerous seismic profiles from the area between Australia and Antarctica, and produced a general isopach map. They commented on a 1 second (TWT) thick sequence of predominantly transparent sediment that abuts the southern side of the South Tasman Rise and extends southward to about 56°S. They illustrate a profile south of the rise, running east-west at about 55°30'S, which shows about 0.5 second of transparent sediment east of the Tasman Fracture Zone, that is cut by the Balleny Fracture Zone but continues eastward beyond it into the Tasman Basin. The Tasman Fracture Zone on this profile is a ridge about 1000 m high that separates rough unsedimented oceanic crust to the west from the sedimented area south of the South Tasman Rise.

The 1972 BMR Continental Margins Survey was the first regional seismic survey that included the Tasmanian region (Tilbury, 1974). This survey used a 120 kilojoule sparker source, and extended from the shelf to the abyssal plain with a line spacing of about 50 km, and was the basis of a report on the Australian southern margin by Willcox (1978). The east-west lines in Figure 4 represent most of its profiles, and those off west Tasmania are identified in Figure 5.

In 1973, BMR recorded about 1000 km of low-energy sparker reflection profiles over the west Tasmanian shelf from M.V. *Sprightly*. These profiles gave penetration of up to half a second (two-way time), and showed that gentle faulting, uplift and erosion occurred during the late Miocene, and that Pliocene to Quaternary sediments unconformably overlie Miocene and older rocks (Jones & Holdgate, 1980). Much of the shelf consists of Miocene outcrop or subcrop below a veneer of younger sediments. Superficial sediments sampled on the same cruise showed that the inner shelf is covered by quartz sand with some shell debris, and the outer shelf by medium to coarse grained bryozoal sand and gravel (Jones & Davies, 1983). The shelf sands are mainly relicts from times of lower sea level.

In 1973, Shell International Petroleum conducted a reconnaissance survey off southern Australia using the M.V. *Petrel*. This included nine lines zig-zagging from the shelf to the abyssal plain in

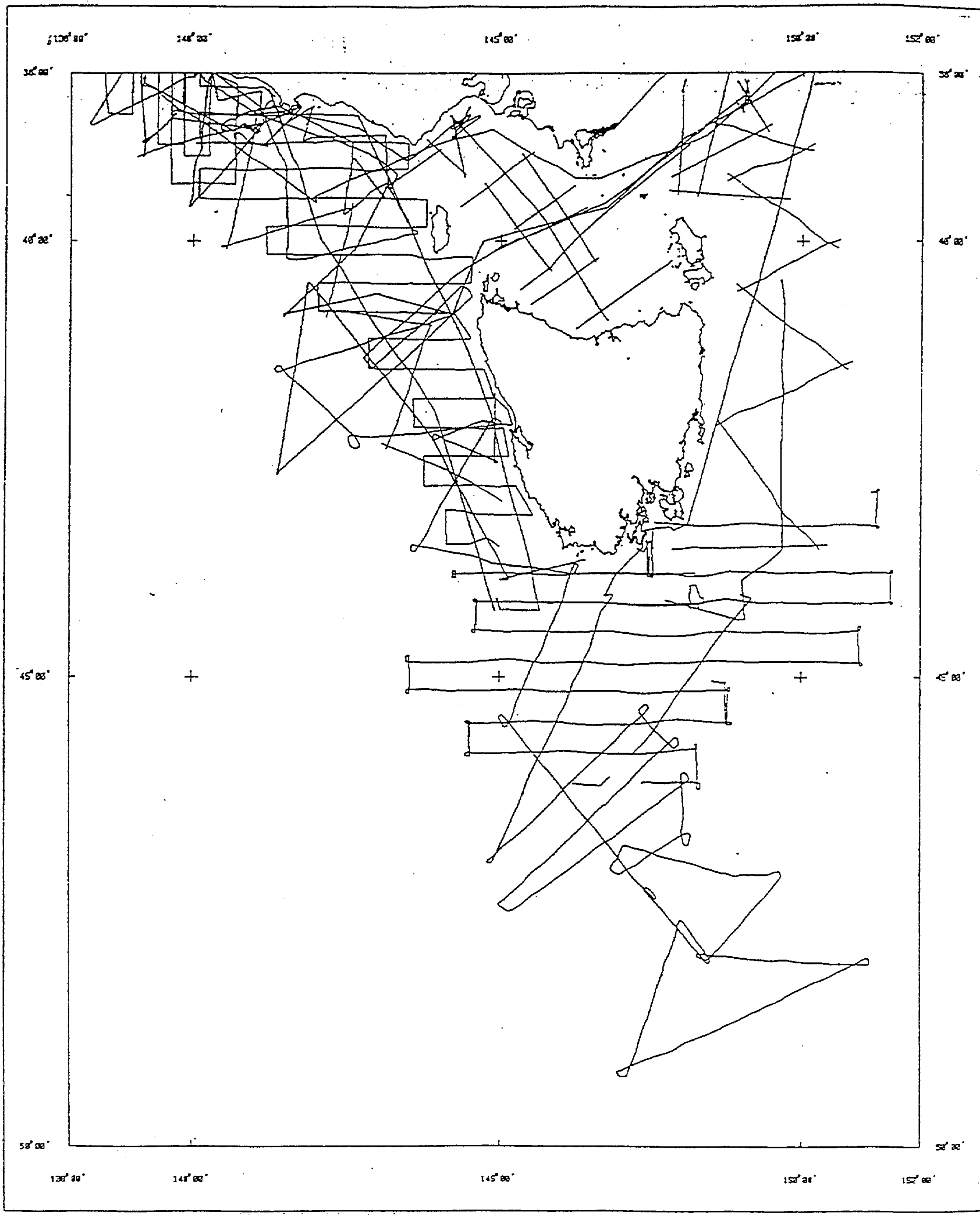


Figure 4. Map of selected pre-1994 multichannel seismic profiles in the Tasmanian and South Tasman Rise region.

the Otway Basin-West Tasmania region and included in Figure 4, and those off west Tasmania are specified in Figure 5. They showed 3 to 4 seconds (two-way time) of penetration. An interpretation by Boeuf & Doust (1975) showed that this was a passive margin, with a thick wedge of sediments that was bounded by oceanic crust on the edge of the abyssal plain. Beneath the continental rise, block-faulted continental basement was recognised.

In 1982, BMR contracted Geophysical Services International (GSI) to carry out a multichannel seismic survey of the Bass Basin (BMR Survey 40), which also included regional seismic lines extending on either side of King Island, from the Otway and Sorell Basins out to the abyssal plain. These lines are included in Figure 4.

3.2. Deep Sea Drilling Project (DSDP)

In 1973, Leg 29 of the Deep Sea Drilling Project (DSDP) drilled four partly cored holes in the Tasmanian region using the *Glomar Challenger* (Fig. 3 & Table 5), including Site 282 on the west Tasmanian margin which was some 310 m deep in 4202 m of water (Kennett, Houtz et al., 1973, 1975A). Site 282 lies 160 km west of Cape Sorell on *Sonne* line 36B-46, which shows it to have been on a basement high. The sequences drilled in it include much of the Cainozoic, but contain four major unconformities. The hole bottomed in pillow basalts of assumed middle Eocene age, which were overlain by Palaeogene siltstones and Neogene marls. The sedimentary sequence is presumed to be entirely abyssal, and includes 55 m of early Miocene to Pleistocene nannofossil ooze containing shelf-derived bryozoa and glauconite in part, 135 m of early and middle Oligocene silty clay, and 103 m of late Eocene silty clay, organic-rich and containing hydrocarbons.

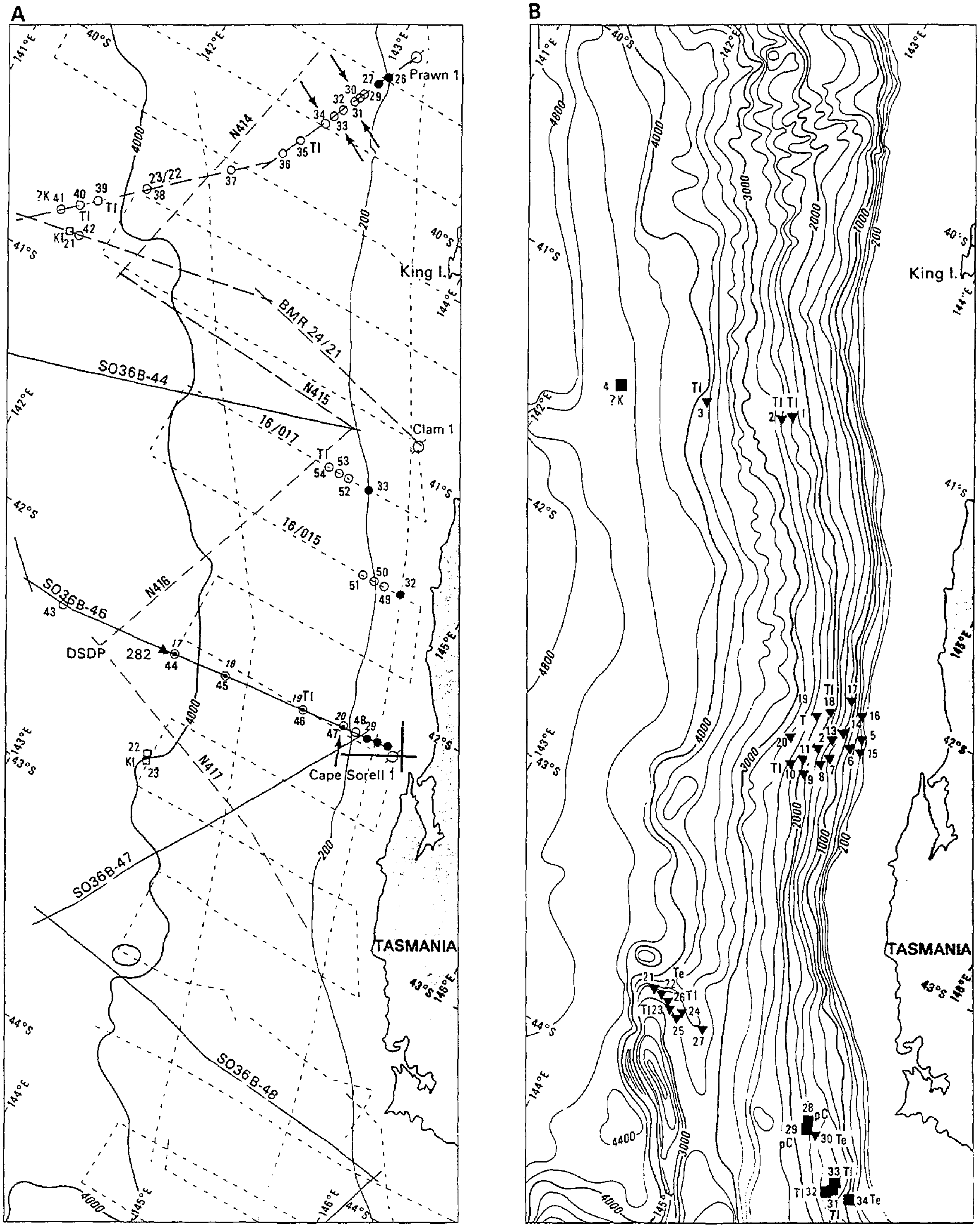
Table 5: Deep Sea Drilling Project (DSDP) sites off Tasmania

Site	Latitude (S)	Longitude (E)	Water depth (m)	Penetration (m)	Maximum age of sediments	Basement type
280	48° 57.44'	147° 14.08'	4176	524	Early to mid Eocene	Intrusive basalt
281	47° 59.84'	147° 45.85'	1591	169	Late Eocene	Late Carboniferous Palaeozoic schist
282	42° 14.76'	143° 29.18'	4202	310	Late Eocene	Pillow basalt
283	43° 54.60'	154° 16.96'	4729	592	Paleocene	Altered basalt

Reference: Kennett, J.P., Houtz, R.E. et al. (1975A)

DSDP Leg 29 also drilled Sites 280 and 281 in the South Tasman Rise region. Site 280 was drilled to 524 metres in water 4181 m deep on the southwestern slope of the rise, probably on oceanic crust, and bottomed in an "intrusive basalt". It penetrated a veneer of late Miocene to late Pleistocene clay and ooze underlain, beneath a sampling gap, by 55 m of siliceous early Oligocene sandy silt, and 428 m of middle Eocene to early Oligocene sandy silt, containing chert in the upper 100 m, and glauconite and manganese micronodules below that. The lower 200 m is rich in organic carbon (0.6-2.2 %). All sediments are presumed to be abyssal types.

Figure 5. Map of sampling and heatflow stations for 1985 *Sonne* (SO-36C) and 1987 *Rig Seismic* (BMR 67) cruises off west Tasmania. Shows bathymetry, petroleum exploration wells, key deepwater seismic lines, and major gas anomalies in surface sediments. After Exon et al. (1992).



- - - - *BMR Continental Margin survey 1970–73*

— — *Shell 'Petrel' survey*

— — *BMR Bass Strait survey*

—— *Amoco 'West Tasmania Basin' survey*

—— *BGR 'Sonne' Cruise SO-36, 1985*

▼ *Sonne core*

■ *Sonne dredge*

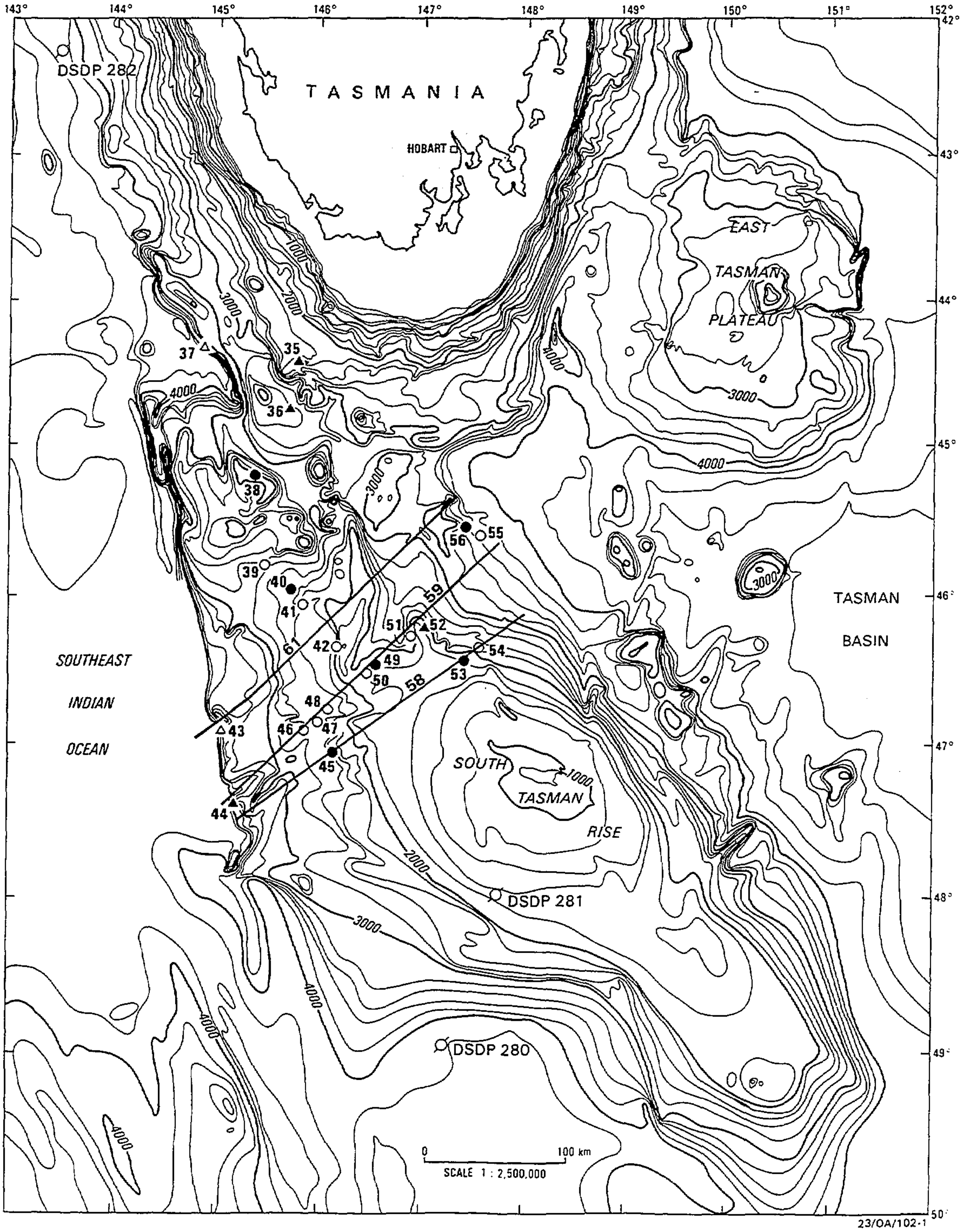
0 at 42°S 100km

1987 Rig Seismic stations

- ●17 *Grab*
- ○18 *Core*
- □19 *Dredge*
- •20 *Heatflow*
- ⟶ *Gas anomaly*

Age of oldest rock found

- Tl Late Tertiary (incl late Oligocene)
- Te Early Tertiary
- Kl Late Cretaceous
- Pz Palaeozoic
- p€ Precambrian



△ Dredge — no manganese
▲ Dredge — manganese
○ Core — no manganese
● Core — manganese
—— Seismic profile shown in figure 2

Figure 6. Bathymetric map of the study region. Shows *Sonne* South Tasman Rise sampling locations, and key seismic lines illustrated in Figure 9. After D. Jongsma and G. Wissmann (unpublished).

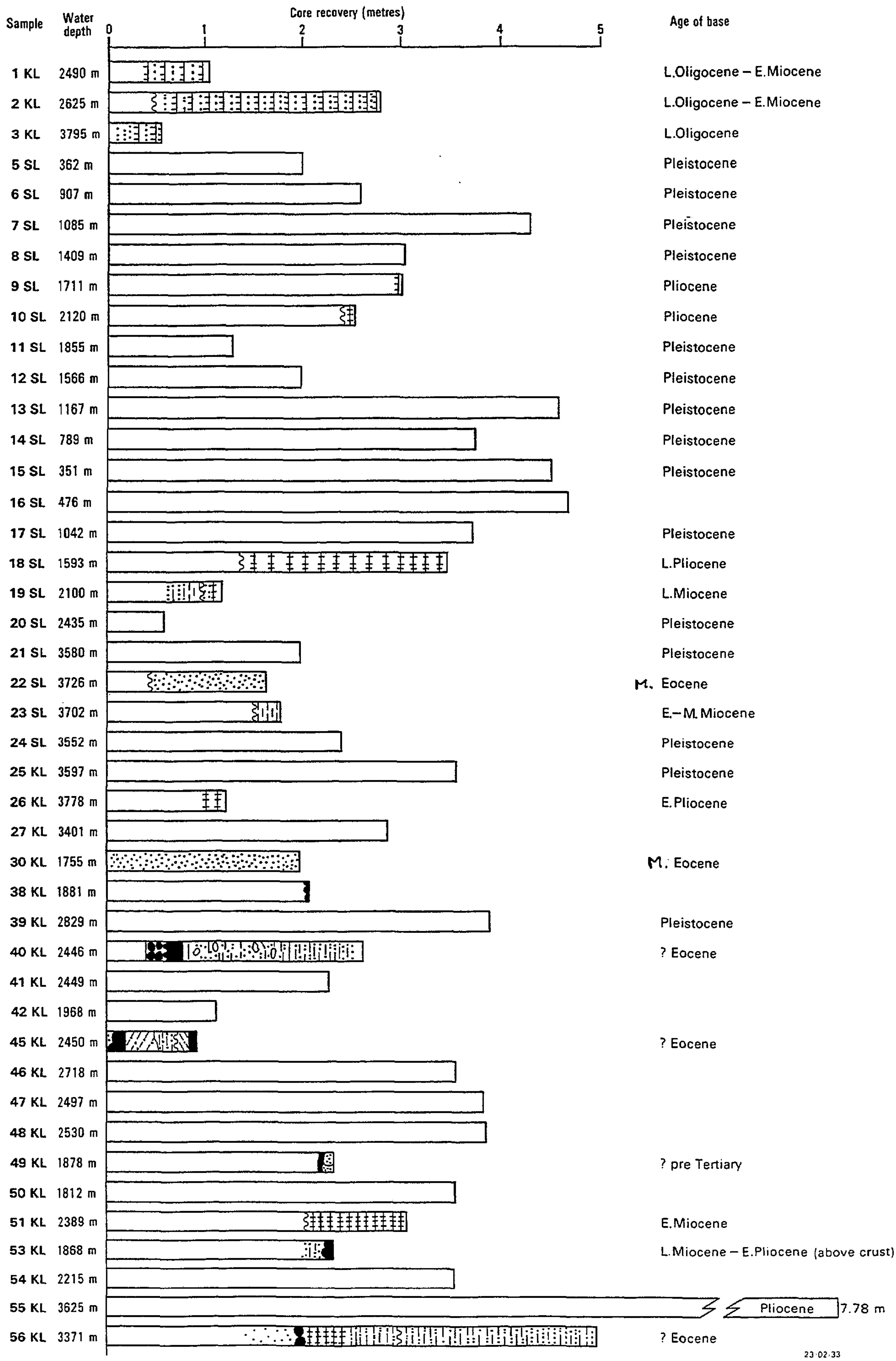


Figure 7. Simplified core logs for *Sonne* Cruise SO-36C. Modified from Hinz et al. (1985).

Unconform (Sequence)	Characteristics	Tectonic Significance	Facies Interpretation	Approx Thickness (m)	Proposed Age Identification: Stratigraphic	m.y.	Equivalent Mag Anom	Otway Basin Shelf Equivalent and Unconformities	Comment
	Low frequency, stratified and folded Floors Jurassic or Early Cretaceous rift beneath the lower continental slope	Pre–rift Tasman Geosyncline Crustal extension and first stage rifting at about U14 time	Varied metasediments and volcanics	Unknown	Palaeozoic and ? Precambrian				"Basement"
U14						? 140			
S(13–14)	Low frequency, stratified on rift shoulder Contorted fill in first stage rift	Lower rift–fill	Continental–? fluvial, lacustrine Alluvial fan and/or volcanics	1000 3000 +	Jurassic and Early Cretaceous		M Series	Casterton Beds and Otway Group Non–marine clastics and volcanogenic sediments	
U13						105			
S(12–13)	Bedded fill in first stage rift Now incorporated into tilted blocks beneath lower continental slope	Upper rift–fill, probably preceding marine transgression ? Development of shelf edge on U12	Fluvial–lacustrine possibly grading to marginal marine	0–?1000	"late" Early Cretaceous (? Albian)			Probably time equivalent to Eumeralla Formation (Otway Gp) Continental environments with volcanism	This sequence appears confined to the first stage rift
U12						95	34		
S(11–12)	Well stratified with onlap onto U12 U12/13 block–faulted beneath continental shelf	U12 (possibly U13) is main rift–onset unconformity in Otway Basin S(11–12) marine transgression	Marginal marine–marine (foram evidence from Ribis and Apthorpe, 1969)	0–?1000	Late Cretaceous (approx Cenomanian)		Slow spreading episode (Cande and Mutter, 1982)	Approximate Waarre Formation (Sherbrook Group) equivalent Shoreline facies	Wrenching and uplift of the tilted blocks beneath lower slope commenced (Willcox and Symonds, in preparation)
U11									
S(10–11)	Stratified sediment wedge with onlap onto U11 Basal channelling land ward of old shelf edge	U11 eustatic lowstand in ? Coniacian (Vail et al., 1977) S(10–11) basin transgr restricted by blocks below lower continental slope	Shallow marine (restricted basin)	0–1000 +	Late Cretaceous			Belfast Mudstone and Flaxman Formation (Sherbrook Group) Marginal marine–marine	1570 m Belfast Mudstone in Voluta 1
U10									
S(9–10)	Stratified sediment wedging out below lower slope Downlap onto U10	U9 and U10 relative falls in sea level U9–slowing or termination of movement of tilted blocks beneath lower slope	Shallow marine (regressive)	0–500 +	Late Cretaceous (approx Maastrichtian)			Curdies/Paaratte Formations (Sherbrook Group) Shoreline–continental	Slow spreading episode in southeast Indian Ocean has less influence on outer Otway Basin
U9						65	29		
S(8–9) U8 S(7–8) U7 S(6–7) U6 S(5–6)	S(5–6) to S(8–9) are distinctive, high frequency, downlapping sequences beneath lower continental slope Lower frequency, continuous, high amplitude beneath upper continental slope	A period of minimal subsidence in the outer Otway Basin due to contact between Australian and Antarctic plates in Tasmanian region Sedimentation influenced by elevated blocks beneath lower continental slope Outbuilding of fine clastics with minimal aggradation Unconformities largely reflect eustatic changes in sea level	Shelf clastics, grading into fine grained progradational wedges at palaeoshelf–edge (largely terrigenous)	200–1500	Paleocene—Middle Eocene		?	Age equivalent of the Wangerrip Group Shallow marine→shoreface→ continental (regressive)	Sequences S(5–6) to S(8–9) are believed equivalent to depositional cycles TP1, TP2, TE1 and ?TE2 of Vail et al., (1977)
U5						42	18	? ?	
S(4–5) U4 S(3–4)	Stratified, onlapping S(3–4) extends across outer tilted blocks	Accelerated movement along Australian–Antarctic plate boundary Major wrenching and development of flower structures in southeast Otway Basin and western margin of Tasmania	Shallow marine (largely terrigenous)	0–800	Late Eocene—earliest Oligocene			Nirranda Group (transgressive) — shallow marine	? Minor volcanism at U5 time
U3						35	13		
S(2–3) U2 S(1–2) U1	Stratified, channelled, shelf–edge progradation	U3 is widespread Early Oligocene unconformity marking clearance of Australian and Antarctic plates and establishment of open marine conditions	Shelf – open marine (largely carbonate)	0–600	Late Oligocene and Neogene		Southeast Indian Ocean spreading	Heytesbury Group (transgressive) marine carbonates	Main episode of seafloor spreading

23/K55/15

*For stratigraphy refer to BMR line 22/23 (Figure)
Tectonic events after Willcox and Symonds (in preparation)

Figure 8. Tabular representation of seismic stratigraphic sequences, with unconformities and tectonic events, for Otway and Sorell Basins. After J.B. Willcox in Hinz et al. (1986).

Site 281 was drilled to 169 metres in water 1591 m deep, southwest of the culmination of the rise, and bottomed in a quartz-mica schist, dated radiometrically as latest Carboniferous (305 Ma). This is overlain by a six metre thick basement conglomerate consisting of angular clasts, dominantly of schist, with lesser quartz, quartzite, glauconite, glauconitic sandstone and granite. The hole contains 36 m of Plio-Pleistocene foram-nanno ooze, 79 m of Miocene foram-nanno ooze, and 3 m of late Oligocene glauconite-rich detrital sand. Below a major unconformity there is about 33 m of shallow-marine late Eocene sediment: an upper 28.5 m of grayish-olive sandy silt and silty clay, a middle 3 m of detrital sand and nanno chalk, and the basal conglomerate.

One other DSDP Site relevant to the present study is Site 283, drilled on the abyssal plain east of the East Tasman Plateau in 4756 m of water to a depth of 592 m. It recovered entirely abyssal sediments above 4 m of pillow basalt. The sedimentary sequence consists of about 13 m of Plio-Pleistocene zeolitic clay, 163 m of late Eocene siliceous ooze, 139 m of middle Eocene silty clay, and 273 m of Paleocene silty clay with some chert.

3.3. R.V. *Sonne* cruises

In 1985, the West German Research Vessel *Sonne* carried out two co-operative cruises by the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) and BMR on the Tasmanian margin (*Sonne* Cruises 36B & C), during which four regional multichannel seismic lines and several short tie lines (1000 km long in all) were recorded off west Tasmania, and 34 sampling stations occupied (Fig. 5 & Table 6). During the same cruise, nine regional seismic lines were shot on the South Tasman Rise, and 19 sampling stations were occupied (Fig. 6). A detailed cruise report was produced by Hinz et al. (1985), and a discussion of the west Tasmanian results was published by Hinz et al. (1986). The core results for both west Tasmania and the South Tasman Rise are summarised in Figure 7. An interpretation of the west Tasmanian seismic lines, as well as that of BMR profile 40/22-23, showed that up to 5 seconds (two-way time) of section is present, and that up to 14 unconformities could be identified (Fig. 8). Sampling and well data from west Tasmania indicate that unconformity U3 represents the regional Oligocene unconformity, U9 the basal Tertiary unconformity, and U12 the basal Late Cretaceous unconformity. The relatively thin Tertiary sequences consist essentially of Neogene carbonates and Palaeogene terrigenous sediments. The Late Cretaceous sequence appears to subcrop along the foot of the continental slope, along with continental basement which was sampled at three stations.

Table 6: West Tasmania and South Tasman Rise seabed samples from *Sonne* Cruise 36B

Stat No.	Latitude	Longitude	Depth (m)	Recovery (m)	Description
W Tasmania					
1/KL	41 03.789	143 25.120	2490	1.04	0.94 m L Oligo to E Mio nanno marl; 0.1 m Holo ooze
2/KL	41 06.246	143 21.872	2620	2.85	2.3 m L Oligo to E Mio nanno marl; 0.2 m calc sand turbidite; 0.35 m Pleist to Holo ooze
3/KL	41 12.505	142 53.599	3795	0.55	0.45 m L Oligo to E Mio nanno marl; 0.1 m ? Holo nanno ooze
4/KD	41 20.200	142 20.055	4216		Mn coated basalt & sandst; ooze

	41 20.550	142 20.135	4084		
5/SL	42 10.798	144 44.552	362	2	1.52 m Pleist shelly sandy mud; 0.48 m Holo foram sand
6/SL	42 14.449	144 43.648	907	2.6	2.45 m Pleist nanno-foram ooze, reduced; 0.15 m Holo ooze
7/SL	42 18.520	144 40.243	1085	4.3	4.16 m Pleist foram-nanno ooze, reduced; 0.14 m Holo ooze
8/SL	42 22.065	144 37.289	1409	3.05	3.0 m Pleist nanno ooze; 0.05 m Holo ooze
9/SL	42 25.909	144 34.004	1711	3	Tr Plio chalk; 2.94 m Pleist foram-nanno ooze; 0.06 m Holo ooze
10/SL	42 25.319	144 28.754	2120	2.57	0.1 m Plio chalk; 2.41 m Pleist nanno-foram ooze; 0.06 m Holo ooze
11/SL	42 21.814	144 31.452	1855	1.28	1.22 m Pleist nanno-foram ooze; 0.06 m Holo ooze
12/SL	42 17.991	144 33.945	1566	2	1.89 m Pleist nanno-foram ooze, reduced; 0.11 m Holo ooze
13/SL	42 14.320	144 37.357	1167	4.6	4.46 m Pleist nanno-foram ooze; 0.14 m Holo foram sand
14/SL	42 10.562	144 40.942	789	3.8	3.67 m Pleist nanno ooze with shell bed, reduced; 0.13 m Holo shelly ooze
15/SL	42 14.068	144 47.204	351	4.52	4.19 m Pleist shelly calc mud, reduced; 0.33 m Holo foram sand
16/SL	42 05.111	144 41.815	476	4	3.96 m Pleist shelly calc sand-mud; 0.04 m Holo ooze
17/SL	42 03.094	144 35.116	1042	3.75	3.65 m Pleist nanno-foram ooze; 0.1 m Holo foram sand
18/SL	42 08.741	144 32.272	1593	3.5	2.15 m L Plio chalk; 1.19 m Pleist nanno-foram ooze; 0.16 m Holo ooze
19/SL	42 11.156	144 28.290	2100	1.22	0.23 m L Mio chalk; 0.94 m ?Pleist foram-nanno ooze; 0.05 m Holo foram sand
20/SL	42 19.630	144 24.374	2435	0.61	0.33 m Pleist bryoz sand; 0.22 m ?Pleist nanno-foram ooze; 0.06 m ooze
21/SL	43 36.751	144 22.985	3574	1.8	1.73 m Pleist nanno-foram ooze; 0.07 m Holo foram sand
22/SL	43 36.866	144 25.124	3726	1.65	1.15 m M Eocene shallow marine carbonaceous mudst & siltst; 0.5 m ooze
23/SL	43 38.345	144 30.699	3702	1.7	0.3 m E-M Mio mud; 0.83 m Pleist nanno-foram ooze; 0.57 m Holo ooze
24/SL	43 38.761	144 35.474	3552	2.37	2.27 m Pleist ooze and shelly calc turbidites; 0.1 m Holo ooze
25/KL	43 39.277	144 34.992	3597	3.6	3.5 m Pleist ooze and shelly calc turbidites; 0.1 m Holo ooze
26/KL	43 37.495	144 29.336	3778	1.25	0.88 m E Plio chalk, ooze and shelly sandy turbidites; 0.37 m Pleist-Holo ooze
27/KL	43 40.137	144 40.433	3401	2.9	Pleist-Holo ooze and shelly turbidites
28/KD	43 46.621 43 46.345	145 37.853 145 37.540	1860 1830		Few small fragments of mica schist & phyllite; ooze
29/KD	43 46.693 43 46.320	145 37.656 145 37.130	1864 1800		Garnet-mica schist; calcarenite; rounded pebbles of quartz, chert ?basalt, schist; ooze

30/KL	43 47.094	145 42.016	1755	2	M Eocene carbonaceous shallow marine silty sand; trace foram sand
31/KD	43 49.060 43 49.050	145 56.275 145 56.375	530 500		L Oligo sandy shelly mudstone; bioclastic limestone; sand
32/KD	43 49.100 43 49.035	145 55.760 145 55.870	680 650		Pebbles of volcs, granitoids, metaseds; M Eocene bryozoan limest; phosphatic calcarenite/conglom; L Oligo mod consol bryozoan limestone
33/KD	43 48.690 43 48.700	145 56.505 145 56.670	510 460		L Oligocene mod consol bryoz limest (calcarenite), part phosphatic
34/KD	43 59.395 43 59.300	146 03.825 146 03.850	735 710		Fragment of lithified micritic bryoz limest with, gastropods, bivalves, corals
35/KD	44 26.234 44 25.223	145 50.238 145 51.561	2495 2009		Pebble of quartz sandstone; Mn/phosphatic conglom; Mn crust
36/KD	44 34.970 44 34.815	145 44.610 145 44.635	3250 3230		Mica schist & gneiss with quartz veins; phosphatic Mn crust breccia; thick Mn crust; ooze
37/KD	44 20.755 44 20.620	144 54.000 144 54.195	4050 3890		Fine well sorted micaceous quartz sandst; ooze
South Tasman Rise					
38/KL	45 12.286	145 22.870	1886	2.1	Mn crust; 1.7 m ?L Plio-Pleist shelly foram sand; 0.2 m foram sand
39/KL	45 48.208	145 30.142	2829	2.94	2.14 m Pleist foram-nanno ooze; 0.8 m Holo muddy ooze
40/KL	45 58.556	145 43.672	2446	2.34	0.72 m ? Eoc glassy zeolit mudst; 0.81 m muddy sand= ? palaeosol; 0.41 m Mn crust frags in clay; 0.4 m Holo ooze
41/KL	46 05.431	145 51.786	2449	2.3	2.24 m ?Pleist foram-nanno ooze; 0.06 m Holo foram sand
42/KL	46 22.338	146 13.308	1968	1.15	?Holo foram-nanno ooze
43/KD	46 54.253 46 53.861	145 02.837 145 05.618	3520 3086		Fragments of glassy feldspathic siltst; foram sand
44/KD	47 24.128 47 24.186	145 10.059 145 10.575	3968 3670		Garnetiferous schist & gneiss; granodiorite & pegmatite; glassy siltst with rads; fine breccia; Mn nodules
45/KL	47 04.005	146 12.867	2484	0.89	0.05 Mn crust; 0.11 m dipping ?Eoc siltst; 0.6m siltst with Mn nodules, sharks' teeth: 0.09 m Mn nods; 0.04 m Holo foram sand with nodules
46/KL	46 56.488	145 51.322	2718	3.56	Pleist-Holo nanno-foram ooze
47/KL	46 52.161	145 59.571	2497	3.88	Pleist-Holo nanno-foram ooze
48/KL	46 45.763	146 10.161	2540	3.9	2.75 m ?Pleist foram-nanno ooze; 1.15 m ?Holo ooze
49/KL	46 28.766	146 35.375	1878	2.3	Mn encrusted quartzose graywacke pebbles; 0.58 m foram sand; 0.53 m chalk; 1.19 Holo foram sand
50/KL	46 30.843	146 32.227	1812	3.6	Pleist-Holo foram sand

51/KL	46 17.661	146 52.059	2398	3.1	1.0 m E Mio chalk; 2.1 m ?Pleist-Holo foram sand with basal gravel of basement pebbles
52/KD	46 12.765 46 12.675	147 00.365 147 00.610	1810 1600		Blocks of glassy basaltic breccia in phosphatic matrix with 3 cm Mn crust
53/KL	46 26.355	147 27.078	1868	2.35	Mn crust frags & quartzite pebble; 0.4 m E Plio muddy ooze; 1.95 m ? Pleist- Holo foram sand
54/KL	46 22.836	147 33.792	2215	3.58	?Pleist-Holo foram-nanno ooze
55/KL	45 36.890	147 36.514	3625	7.78	L Plio-Holo ooze
56/KL	45 31.904	147 27.794	3371	4.98	2.1 m ?Eoc zeolitic mudst; 1.0 m ?Eoc volc-biogen mudst grading to chalk; Mn nodules; 0.29 m L Plio foram-nanno ooze; 1.65 m Pleist-Holo ooze

Palaeontological ages were modified after the cruise as shown here

West Tasmania

Hinz et al. (1985, 1986) briefly described the 37 stations occupied by *Sonne* (Fig. 5), of which sixteen recovered pre-Quaternary rocks. Foraminiferal dating aboard ship was by D. Belford (BMR), and he revised and published his results in Belford (1989). P. Cepek of BGR later identified coccoliths in selected samples after the cruise, and his ages are incorporated in Table 6. High grade metamorphic rocks were recovered from stations 28 KD, 29 KD and 32 KD, about 50 km southwest of Port Davey, and granitoids from 32 KD. Station 28 KD gave K/Ar ages of 344 and 349 Ma (Early Carboniferous) from muscovite; station 29 KD gave a K/Ar age of 355 Ma (Early Carboniferous). High grade metamorphic rocks were also recovered from 36 KD, about 100 km southwest of Tasmania and near the continent-ocean boundary, and K/Ar ages of 95 and 98 Ma (Cenomanian) were obtained from biotite. This young age may be related to re-heating just prior to Late Cretaceous breakup of the Tasman Sea.

Rocks of probable Mesozoic age were obtained at stations 4 KD (sandstone and basalt), 29 KD (pebbles of quartz, chert, ?basalt), 35 KD (quartz sandstone pebble) and 37 KD (micaceous quartz sandstone). Stations 4 KD and 37 KD lie very near the continent-ocean boundary. Middle Eocene sediments are present at four stations: moderately deep water bryozoal limestones 50 km southwest of Port Davey at stations 32 KD and 34 KD (Belford, 1989); and shallow marine to deltaic carbonaceous mudstones at stations 22 KL near the continent-ocean boundary, and 30 KL some 50 km north of 32 KD (age and palaeoenvironment determined by E. Truswell, AGSO, pers. comm., on basis of dinoflagellates). A major Oligocene unconformity separates the generally siliciclastic Palaeogene sediments from calcareous Neogene sediments. Late Oligocene and early Miocene bryozoal limestones are present at stations 29 KD, 32 KD, and 33 KD, and marls at stations 1 KL, 2 KL, 3 KL, and 31 KD. Younger chalks and oozes are widespread.

South Tasman Rise

The South Tasman Rise was discussed by Willcox et al. (1989) on the basis of the *Sonne* seismic profiles. It covers an area of 140 000 km^2 between 800 and 3000 m (Fig. 1). A continental origin is deduced from the schists drilled at ODP Site 281 and dredged by *Sonne*, from plate tectonic reconstructions, and from the relatively quiet magnetic and gravity (Fig. 9) profiles. Three of the *Sonne* profiles over the South Tasman Rise are illustrated as line drawings in Figure 9, which shows that there are basement highs separated by graben with several thousand metres of sedimentary fill,

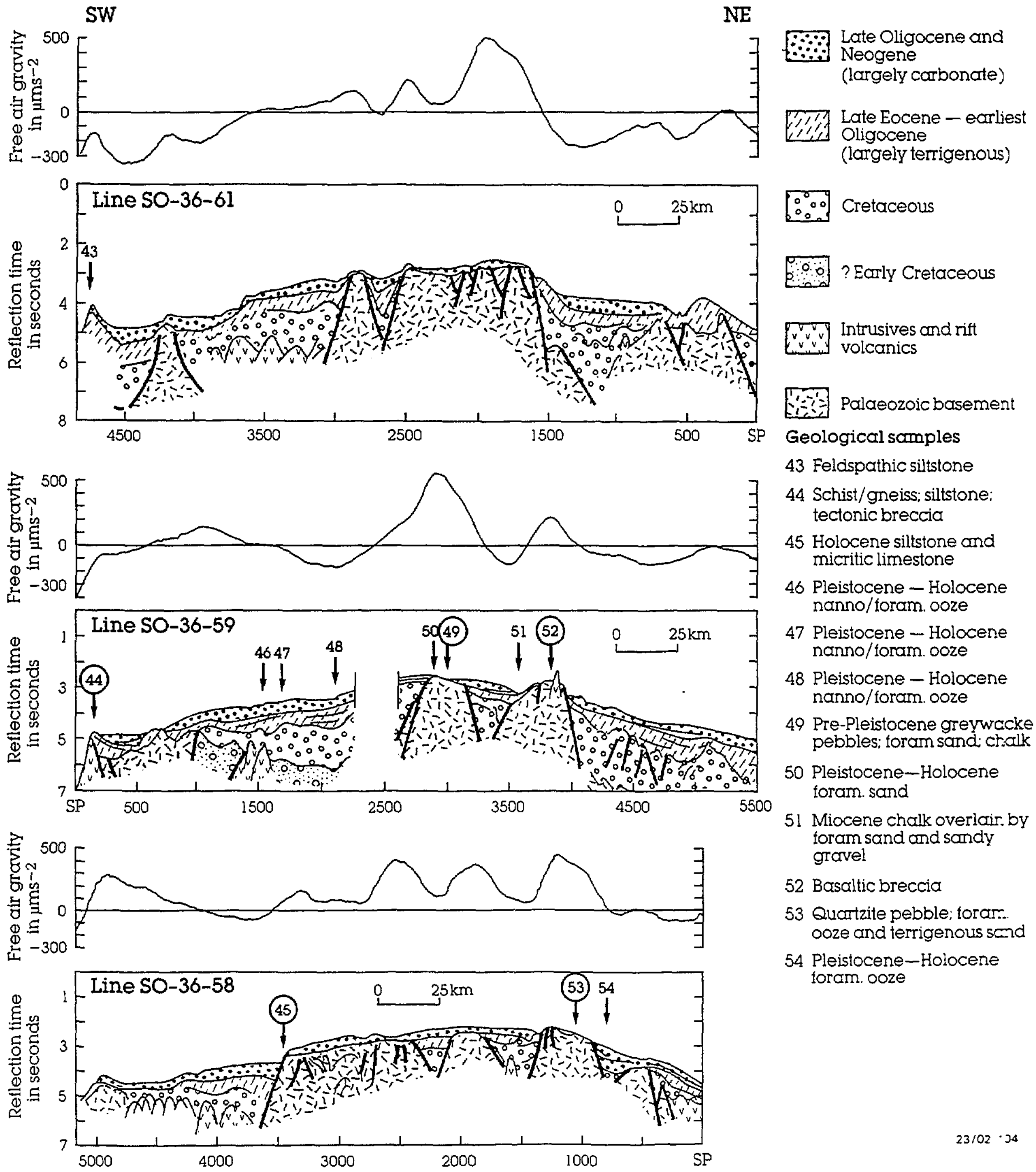


Figure 9. Line drawings of Sonne SO-36B seismic profiles from the South Tasman Rise, with free-air gravity values and the location of sampling sites. Locations in Figure 1. After Willcox et al. (1989) and Bolton et al. (1988).

most of it believed to be Cretaceous in age. Structurally, the culmination of the rise consists of a triangular core of basement, that is flanked on all sides by sedimentary basins (Figs. 9 & 10). The basement is extensively planated and its surface is continuous with the regional Oligocene unconformity.

The *Sonne* sampling results for the South Tasman Rise were outlined by Hinz et al. (1985) and are summarised in Table 6. Bolton et al. (1988) discussed manganese crusts and nodules, and their substrates. Basement rocks were recovered from dredge 44 KD (locations in Fig. 6): garnet-bearing schist and gneiss, granodiorite and pegmatite; K/Ar ages of 444, 457, 458, and 469 Ma (Late Ordovician) were obtained on micas. Dredge 52 KD recovered a basaltic breccia consisting largely of palagonitic basalt fragments in a collophane-bearing fine grained matrix, and encrusted with manganese. Pre-Tertiary basement rocks were recovered in cores 49 KL and 53 KL - fine grained graywacke and quartzite respectively. Eocene olive or grey-green mudstones were present in dredges 43 KD and 44 KD, and cores 40 KL, 45 KL and 56 KL, and Paleocene mudstone in core 56 KL. The mudstones contain zeolites, and are highly bioturbated with little evidence of bedding. They also contain poorly preserved radiolaria and arenaceous forams, and occasional glauconitic sands. Determinations on the basis of forams were carried out aboard ship by D. Belford, and some were published by Belford (1989). P. Cepek identified coccoliths in some samples after the cruise, and the ages are included in Table 6. Neogene sediments from above the Oligocene unconformity are nanno-foram and foram-nanno ooze and chalk.

Willcox et al. (1989) described a large extensional basin in the southwest, containing up to 6000 m of sedimentary fill, probably including syn-rift volcanics, and noted the presence of another basin in the northeast. The dominant structures were interpreted as being oriented either N-S or NW-SE, since indicated also by the GEOSAT imagery. The preliminary mapping suggested that the stratigraphy and structure of the rise was consistent with a common origin with the Otway and Sorell Basins, and hence that Early and Late Cretaceous sediments should be present at depth. Willcox suggested that major dislocations in the basins may represent the locations of transfer faults. He described the western half of the rise as characterised by northerly-trending slivers of basement, and intervening V-shaped basins, probably created by Eocene and early Oligocene transtensional movements. Wrench faults extend up to the Oligocene unconformity. The western margin (Figs. 1 & 10) is clearly a transform fault, with movement presumably ending in the Oligocene with the separation of Australia and Antarctica.

Salge (1989) presented an alternative history of the South Tasman Rise from a major study of the *Sonne* profiles. He concluded that the rise had always been adjacent to Tasmania, rather than transported with Antarctica southward from an original position west of the Otway Basin, as suggested by Willcox et al. (1989). He suggested that rifting in the Early Cretaceous formed NW-SE trending basins in basement rocks, characterised by listric and low-angled faults. Apparently in the mid or Late Cretaceous, when slow spreading between Australia and Antarctica started, there was left-lateral movement between Australia and Antactica to the west of Tasmania and the South Tasman Rise, and this resulted in wrench faulting of the basin-fill sediments. Major transcurrent fault zones caused the formation of transpressional features in the basins. An extensional zone developed between Tasmania and the rise. With the formation of oceanic crust in the adjacent Indian Ocean in the middle Eocene, subsidence and drift sedimentation began. Marginal marine detrital sediments were derived from high areas and show progradation or onlap in places. The continuing subsidence, the development of the Circum-Antarctic current as Antarctica cleared this southern prolongation of the Australian continent in the early Oligocene, and the fall in oceanic bottom water temperature as the Antarctic ice sheet developed in the latest Eocene and Oligocene (Kennett et al., 1972), led to major erosion that formed the regional Eocene-Oligocene unconformity, and to major changes in sediment type from detrital to pelagic. There was little Neogene sedimentation in high areas, because of current erosion and slumping into deeper water.

There is a major disagreement between Salge's (1989) view that the wrench basins of the South Tasman Rise formed in the Late Cretaceous, and the earlier view of Hinz et al. (1985) and Willcox et al. (1989) that they formed in the Eocene. Which interpretation is correct remains to be proven. The other open question is whether the South Tasman Rise was originally located northwest or south of Tasmania. The *Tasmante* swath and seismic mapping of the faults bounding the plateau to the west, north and east (Fig. 10), and oceanic magnetic lineations suggest movement from the northwest.

3.4. R.V. *Rig Seismic* cruises

BMR Cruise 67

In early 1987, R.V. *Rig Seismic* carried out a research cruise (BMR Cruise 67) over the Otway Basin and the Sorell Basin of the west Tasmanian margin, to provide new geological, geochemical and heatflow data, in an area with considerable petroleum potential (Exon & Lee, 1987; Exon et al., 1992). Altogether, 130 sampling stations were occupied using dredges, corers, grabs and a heatflow probe (Fig. 5). The dredge results for the Tasmanian region are summarised in Table 7, and the core results in Table 8. The rocks recovered were Late Cretaceous (Maastrichtian) sandstones and siltstones, dated by palynology at both localities. The depositional environment was marginal marine (M.K. Macphail, Appendix D *in* Exon et al., 1992). The samples were taken along seismic profiles, so that the results could be incorporated easily into the regional geological framework

A great variety of Quaternary sediments were recovered, and these have allowed a sedimentation model to be developed. Shelf areas are characterised by relatively high-energy deposits: shelly bryozoal sands and fine sandy oozes. These sediments are dominantly calcareous, and most likely sourced by a middle to outer shelf 'carbonate factory', dominated by bryozoa, pelecypods, gastropods and benthic foraminifera. There is extensive bioturbation by a relatively large infauna giving thick homogeneous units. Shelf sands periodically move downslope as turbidity currents or grain flows; their contribution to overall slope sedimentation is considerable (V. Drapala, pers. comm.). However, slope and abyssal areas appear to be dominated by pelagic and hemipelagic carbonates, typically olive-grey and greenish grey, foraminiferal and nannofossil oozes. Terrigenous clays and muds, sourced from coastal areas, are present only in small amounts. Variations in the terrigenous component appear to be cyclic, and may be climatically controlled. Bioturbation decreases downslope, and the cores are typically banded. More detailed studies on these and other cores from the Otway margin have since been made by Boreen et al. (1993) and Boreen & James (1993).

Table 7 : BMR Cruise 67 dredge stations from west of Tasmania (south of 40°S)

Stat.	Lat (S)	Long (E)	Water depth (m)	Seismic profile	Recov.	Description or comments
DR21	40o50.3' 40o49.5'	141o46.0' 141o49.0'	4580- 4155	40/24	20 kg	Yellowish brown, f-m, well-sorted quartz lithic sandstone. Some Maastrichtian restricted - marginal marine clayey sandstone containing clay clasts and lenses
DR22	42o40.4' 42o42.2'	143o43.4' 143o43.2'	4200- 3900	16/08	1 kg	Brown and grey v.f. micaceous sandstone and siltstone; tough, dark grey Maastrichtian restricted-marginal marine mud; white and pale olive-brown foram nanno ooze
DR23	42o39.0' 42o41.6'	143o43.1'1 43o42.8'	4257- 4000	16/08		Brown foram nanno ooze

Table 8: BMR Cruise 67 gravity core stations from west of Tasmania (south of 40°S)

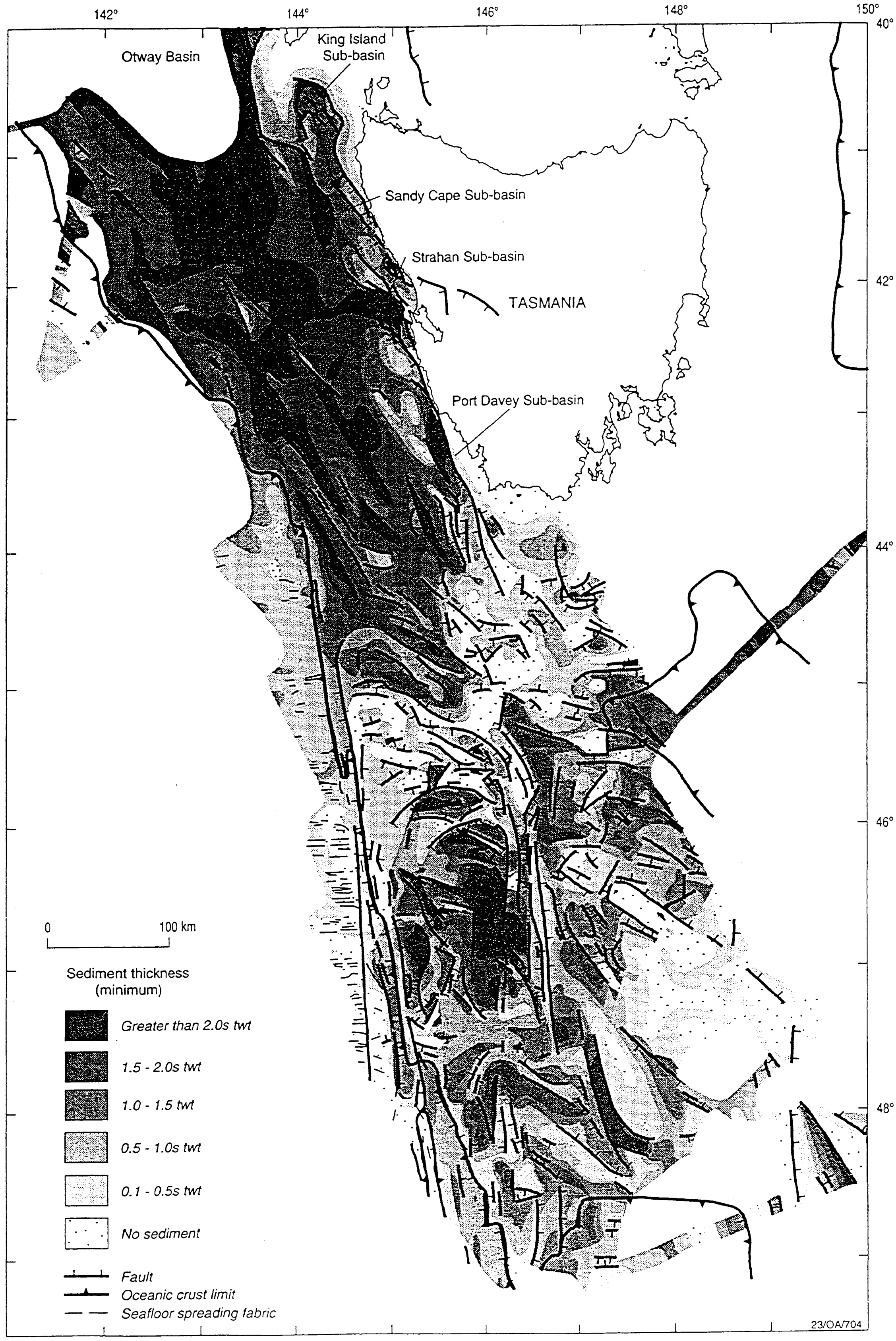
Stat.	Lat (S)	Long (E)	Water depth (m)	Seismic profile	Recov (cm)	Description or comments
GC36	40o00.9'	142o40.1'	2182	40/22	259	Grey and greenish grey foram nanno ooze; L. Pliocene at base
GC37	40o14.1'	142o25.2'	3090	40/23	275	Greenish grey foram nanno ooze, with three carbonate sand turbidites.
GC38	40o27.9'	142o04.9'	3850	40/23	194	Greenish grey foram nanno ooze, with two carbonate sand turbidites
GC39	40o37.9'	141o50.1'	4300	40/23	135	Olive-grey foram nanno ooze, with one sand turbidite, over L. Oligocene green clay
GC40	40o41.5'	141o46.4'	4370	40/23	62	Grey foram nanno ooze over E. Miocene olive-brown calcareous clay
GC41	40o43.8'	141o42.4'	4645	40/23	190	Two thick calcareous turbidite sequences, above multi-coloured pre-Quaternary clays
GC42	40o49.6'	141o48.8'	4161	40/23	84	Light grey foram nanno ooze, over yellow to reddish mottled pre-Quaternary gypsiferous clay (soil profile)

GC43 B	42o17.8'	142o51.7'	4830	SO36/46	2	Light olive-grey v.c. gritty bryozoal sand
GC44	42o14.8'	142o31.6'	4103	SO36/46	146	Greenish grey foram nanno ooze, with four calcareous sand turbidites; ?ash horizon 40 cm
GC45	42o13.6'	142o52.5'	3715	SO36/46	360	Grey and greenish grey foram nanno ooze, L. Pliocene at base
GC46	42o12.1'	144o24.8'	2360	SO36/46	176	93 cm greenish grey foram nanno ooze, over 7 cmcalcareous sand turbidite, over soft light greenish grey chalk
GC47	42o10.6'	144o40.9'	765	SO36/46	134	Grey foram nanno ooze, with four carbonate sand turbidites
GC48	42o10.8'	144o44.3'	377	SO36/46	190	Olive-grey mixed c. bryozoal sand and foram nanno ooze
GC49	41o31.4'	144o20.3'	838	16/015	294	Olive-grey bryozoal sand, foram sand and foram nanno ooze
GC50 A	41o30.5'	144o17.4'	1081	16/015	169	Olive-grey and greenish grey foram nanno ooze
GC51	41o31.2'	144o13.1'	1557	16/015	127	Greenish grey foram nanno ooze
GC52	41o10.9'	143o57.5'	1145	16/017	175	Olive foram nanno ooze
GC53	41o10.9'	143o55.4'	1367	16/017	166	Olive-grey foram nanno ooze
GC54	41o10.9'	143o50.2'	1634	16/017	97	Olive-grey foram nanno ooze, over L. Oligocene hard greyish olive mudstone

In the west Tasmanian region (Exon et al, 1992) there is a clear trend in Quaternary sediments from shelf to abyssal plain.

- In-situ lithology changes rapidly downslope, from outer shelf shelly sands and sandy oozes with more than 70% carbonate, to slope foram-nanno oozes with about 60-65% carbonate, and finally to rise and abyssal plain oozes with less than 50% carbonate. The sand fraction declines in parallel: about 60% in shelf sands, 10-15% in mid slope oozes, and less than 10% in rise oozes.
- Calcareous turbidites, generally absent on the shelf, are found in slope and abyssal plain cores. The coarser fraction of these turbidites contains 70-80% carbonate and is derived from the shelly shelf sands. A thin turbidite is tentatively correlated between cores along BMR profile 48/043, and is overlain by a decreasing amount of sediment downslope, suggesting slower rates of deposition towards the abyssal plain.
- A yellow-brown surface-oxidised layer, generally absent in the outer shelf cores, increases in thickness downslope. Its presence is related to oxygen-enriched cold bottom waters.
- A thin green or brown band present in many cores is probably a volcanic ash layer.
- Cores from the shelf consist of thick bioturbated, homogeneous units. Internal banding becomes more important downslope, as bioturbation decreases. Lithological variation between bands is generally slight (except in GC4), and is recognised by the alternation of light greenish grey and darker olive-green colours.The banding is probably cyclic and may be climatically related.
- The style of bioturbation changes with water depth. Outer shelf cores are extensively bioturbated and preserve little internal structure. Below about 1000 m, bioturbation

Figure 10. Structural and sediment thickness map of offshore Tasmanian region, based on interpretation of *L'Atalante* and *Sonne* reflection seismic data. Also takes account of *L'Atalante* swath maps and satellite gravity data. After Hill, Exon & Royer (1995).



decreases and internal banding becomes increasingly preserved. Sediments are generally mottled, and contain infilled horizontal *Zoophycos* and other burrows. *Zoophycos* seems restricted to 1000-2500 m. Below about 4000 m mottling is absent, and the only evidence of bioturbation is the presence of small (1 mm diameter), sulphide-filled burrows.

Heatflow calculations from 20 stations in the Otway and Sorell basin suggest that the present zone of thermal maturation of hydrocarbons is 2-4 km deep. Headspace gas analyses of many cores indicate that thermogenic hydrocarbons are widespread on the west Tasmanian margin. Thus, mature hydrocarbon source rocks must also be widespread.

BMR Cruise 78

In early 1988, R.V. *Rig Seismic* carried out BMR Cruise 78 on the Tasmanian margin (Exon, et al., 1989). Half of this cruise was devoted to multichannel seismic profiling (Fig. 11) and the other half to geological sampling (Fig. 12). Off west Tasmania, 1750 km of seismic data were recorded with a single airgun string (1600 cubic inches) and a 1200 m seismic cable (48 channels). Off southeast Tasmania, 265 km of seismic data were recorded near Hobart, with the airguns or an 80 cubic inch water gun as source, and a 600 m seismic cable (48 channels). The west Tasmanian survey better defined the King Island and Strahan sub-basins of the Sorell Basin, tested the structure from the continental shelf to undoubted oceanic crust, and provided a mid-slope tie through the thick sedimentary sequence of the Sorell Basin right along the Tasmanian margin. The survey showed that the area has tectonic complexities and that there is normally more than 3 seconds (TWT) of sedimentary section. The magnetic and gravity profiles, in conjunction with seismic reflection and sonobuoy refraction profiles, show that there is a transition zone about 50 km wide on the abyssal plain between the foot of the continental slope and undoubted oceanic crust (Fig. 13). The southeast Tasmanian survey was bedevilled by the presence of Jurassic sills, and is of little use.

During the geological work on the west Tasmanian margin, twelve dredge stations, 37 core stations, 9 grab stations, and 10 heat flow stations were occupied. The dredge stations (Table 9) were designed to sample basement and other relatively old outcropping sequences, in order to help elucidate the early history of the margin. The palynology of four samples showed that one was a Santonian-Campanian marginal marine mudstone, and the other three were Paleocene to early Eocene marginal marine mudstones (Exon et al., 1992). Younger sediments were cored (Tables 10 & 11), and grab samples obtained, to build on our model for Cainozoic sedimentation and to provide material for analysis for thermogenic gas. Sixteen cores were sampled for gas, and provided the first evidence that thermogenic gas is being generated in the Sandy Cape Sub-basin (Exon et al., 1989). Five stations gave thermal gradients which, when combined with conductivity measurements on three cores, suggest that heatflow may be lower (average 30 mW/m^2) than on the Otway Basin margin to the northwest. The sampling results from this cruise and its predecessors were combined in a map of surface sediments (Fig. 14).

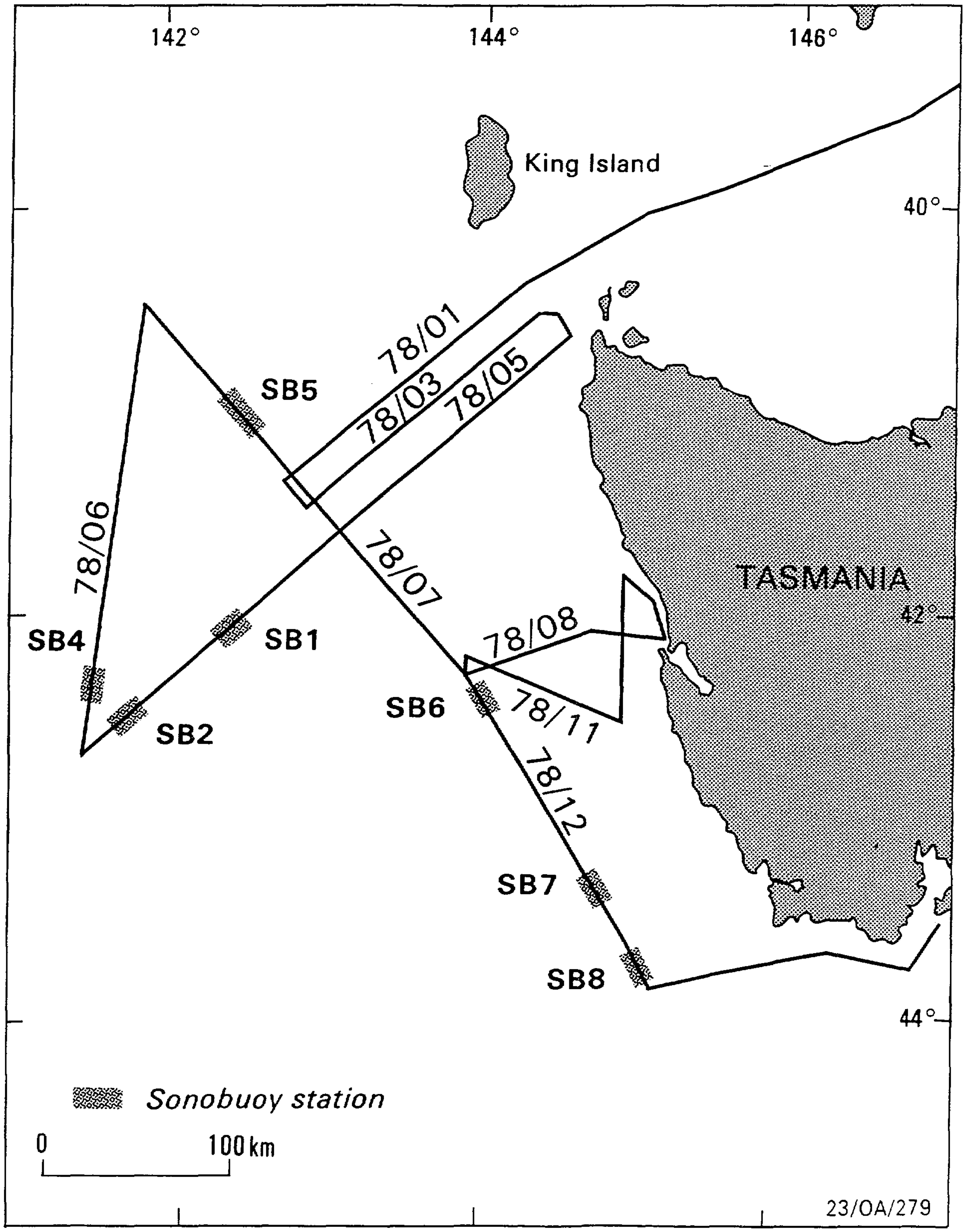
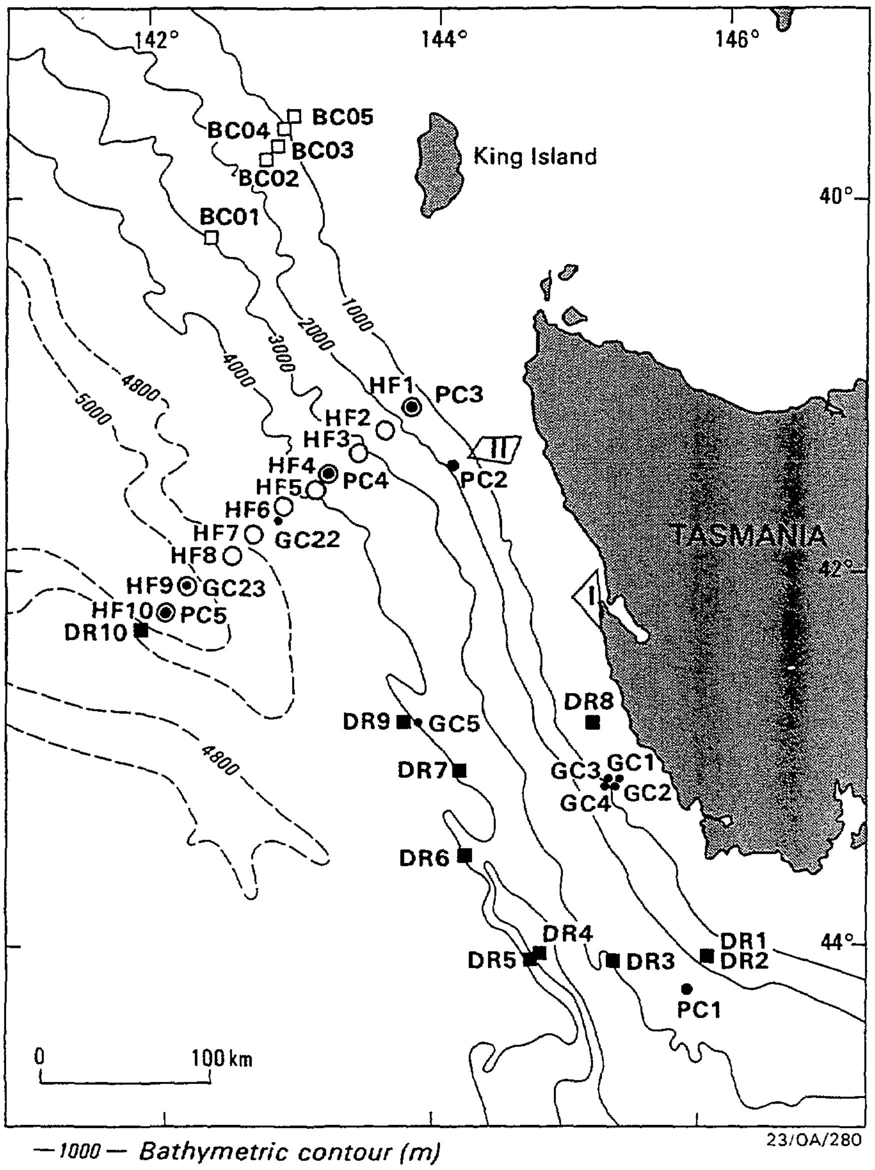


Figure 11. Map of west Tasmanian region showing 1988 BMR Cruise 78 multichannel seismic profiles 78/1-12, and sonobuoy locations. After Exon et al. (1989).

Figure 12. Map showing 1988 BMR Cruise 78 sampling and heatflow stations off west Tasmania. After Exon et al. (1989).



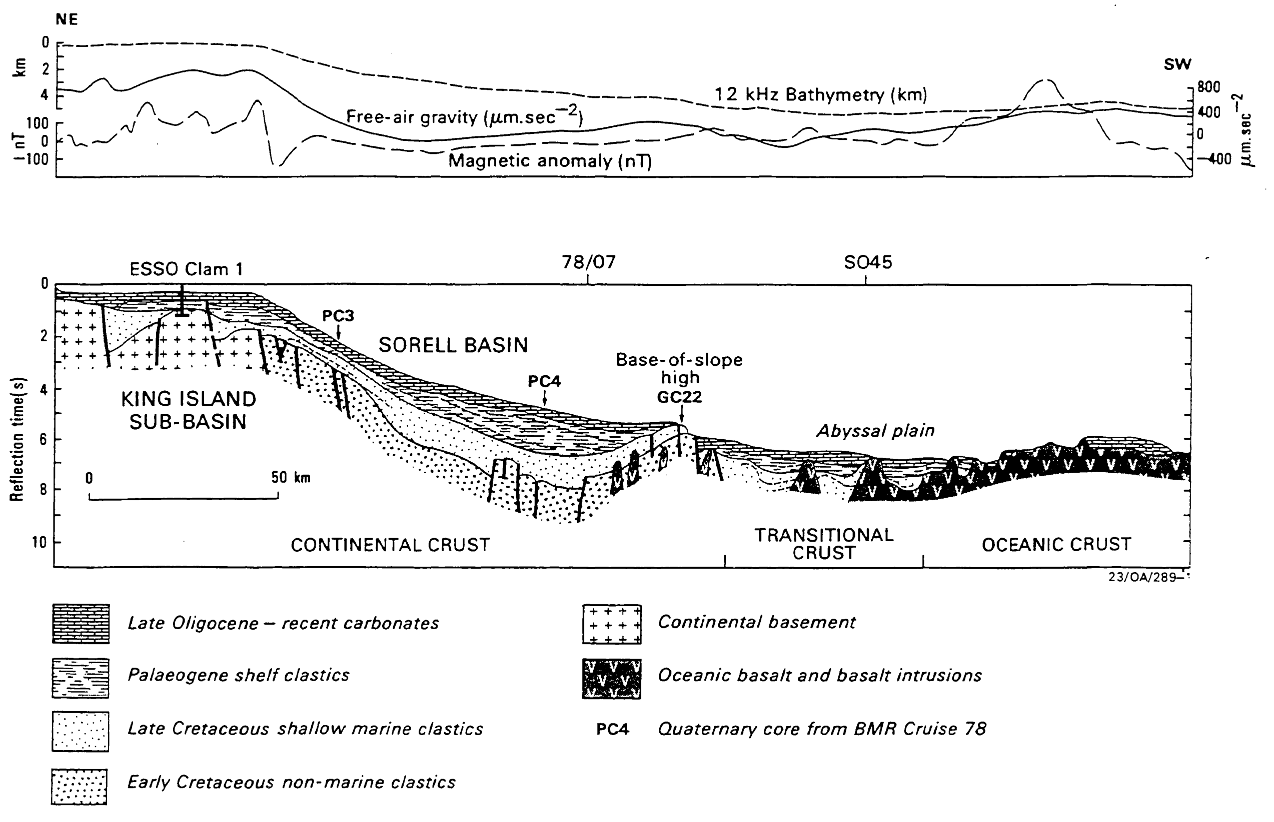


Figure 13. Line drawing of BMR seismic profile 78/05 on the west Tasmanian margin southwest from Clam No. 1 well to abyssal plain. Includes magnetic and gravity data. Location in Figure 11. After *BMR 1989.*

Figure 14. Map of surface sediment distribution off west Tasmania. Shows all dredges and cores that have recovered Lower Tertiary or older rocks, and location of BMR seismic profile 78/05 (see Fig. 11). After *BMR 1989*.

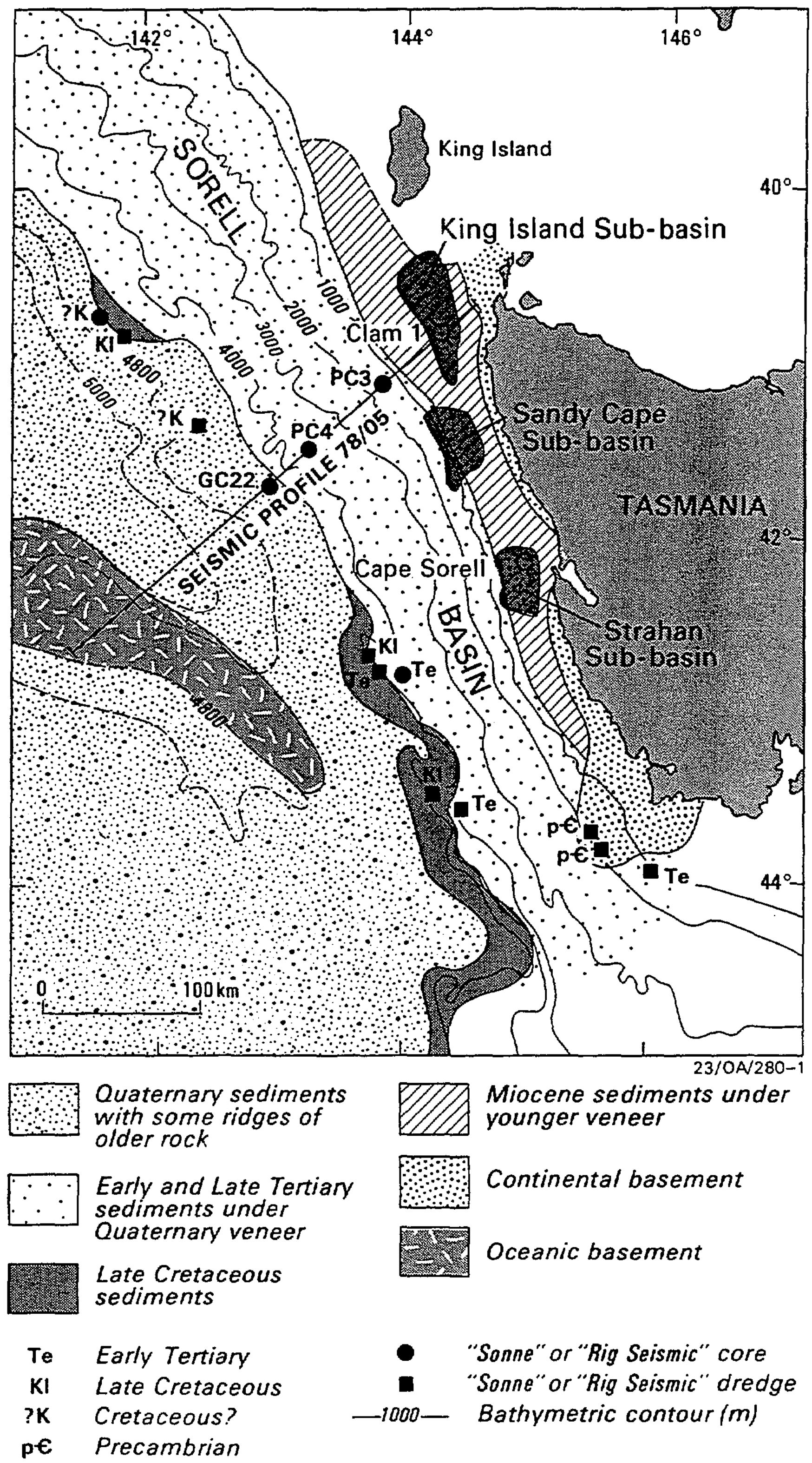


Table 9: BMR Cruise 78 dredge stations from west of Tasmania

Stat	Lat (S)	Long (E)	Water depth (m)	Seismic profile	Recov (hard rock)	Description or comments
DR01	44 09.5'	146 02.5'	1820	11/009	None	About 10 kg greenish grey Quaternary foram ooze in pipe dredge; 1 piece (1 cm) dark greenish grey ?metasiltstone with laminae, possibly volcanic.
DR02	44 09.4' 44 09.5'	146 03' 146 03.5'	1650- 1550	11/009	200 kg	Quartz muscovite schist, dark grey phyllite; probably Proterozoic. Quaternary grey foram ooze in pipe dredge, with small fragments of metamorphics.
DR03	44 10.2'	145 20.5'	3000	11/009	None	Quaternary light olive grey foram nanno ooze with arenaceous forams, fine worm burrows, ophiuroids, 1 piece basalt.
DR04	44 09.0' 44 08.8'	144 46.8' 144 47.6'	2800- 2600	11/009	200 kg	Manganese nodules, 4 cm to 15 cm diameter; manganese crusts to 25 cm thick.
DR05	44 10.2' 44 08.8'	144 41.7' 144 43.8'	3730- 3050	11/009	1 kg	Semi-indurated medium grey siltstone/mudstone with manganese crust (1 mm to 4 mm). Quaternary light olive grey nanno foram ooze with fragments of manganese crust, in pipe dredge.
DR06	43 36.2'	144 11.8'	3915- 3760	SO48	One pebble	Dark greenish grey Santonian indurated mudstone. Quaternary ooze.
DR07	43 10.4' 43 09.4' 43 08.9'	145 10.7' 145 11.7' 145 12.3'	1200 730 630	16/005	None, shear pin broke	In pipe dredge: A. Quaternary pale olive fine to coarse calcareous sand. B. Light olive grey foram ooze, slightly consolidated. C. Sticky greyish white foram nanno ooze, chalky. D. Fraction (>2 mm): bryozoa, gastropods, pteropods, corals, bivalves, larger forams, echinoid spines, calcareous lumps.
DR08	42 50.2'	145 07.2'	120		None	Large pipe dredge deployed; lost

DR09	42 50.0'	143 49.7'	3700-4370		None	In pipe dredge: A. Quaternary greyish orange (10YR7/4) foram ooze. B. 0.5 kg nannofossil-free, brownish grey (5YR4/1) Paleocene silty claystone. C. Granules of semi-lithified sandstone
DR10	42 22.2' 42 22.6'	141 52.8' 141 50.5'	4970 4820	78/005	None	Brown mud (?from deeper location). Grey mud (?from shallower location).

Table 10: BMR Cruise 78 - successful west Tasmanian regional cores

Station	Lat (S)	Long (E)	Water depth (m)	Seismic profile	Recov (cm)	Description or comments
GC01	43°09.9'	145°17.2'	307	16/05	282	Quaternary bryozoan shell hash; pink above 23cm, grey green below
GC02	43°10.9'	145°15.9'	478	16/05	2	Coarse shelly sand
GC03	43°08.9'	145°12.1'	643	16/05	20	Bryozoal ooze; greyish orange above 12 cm, bluish grey below. E-M Miocene at base
GC04B	43°09.8'	145°12.4'	793	16/05	383	Quaternary olive grey bioclastic sandy mud
GC05	42°50.1'	143°51.1'	3530	16/07	60	Quaternary pale orange nanno-foram ooze above E Eocene brownish black semi-plastic mud
GC22	41°45.3'	142°50.5'	3970	78/05	730	Quaternary light olive, light grey and light brown interbedded foram-nanno ooze, chalky toward base
PC01A	44°19.9'	145°53.0'	2270	SO/49	539	Quaternary interbedded light grey and greenish grey foram-nanno ooze and foram sand turbidites
PC02	41°30.0'	144°06.2'	1703	16/15	633	Not described; M-L Miocene at base
PC03	41°06.9'	143°50.0'	1265	78/05	494	Quaternary dusky yellow green foram-nanno ooze beneath 6 cm light olive grey muddy foram sand
PC04	41°30.3'	143°13.6'	3560	78/05	738	Quaternary greenish grey and light olive grey foram-nanno ooze with thin turbidite sands

Table 11: BMR Cruise 78 - successful cores from Sandy Cape Subbasin, west Tasmania

Stat	Lat (S)	Long (E)	Water depth (m)	Recov (cm)	Description
GC06	41°30.0'	144°25.0'	325	385	30 cm brown bryozoal shell hash above yellow green foram-nanno ooze. Quaternary
GC07	41°27.5'	144°24.3'	516	373	Olive grey sandy foram-nanno ooze
GC08	41°28.0'	144°28.0'	118	40	Bryozoal shell hash on chips of brown ?M Miocene calcarenite
GC09	41°26.0'	144°26.3'	131	10	Bryozoal shell hash on chips of brown Miocene calcarenite
GC10	41°23.0'	144°30.0'	127	5	Bryozoal shell hash
GC11	41°22.0'	144°33.1'	111	5	Bryozoal shell hash
GC12	41°19.7'	144°33.8'	119	2	Bryozoal shell hash
GC13	41°20.1'	144°30.0'	131	20	Consolidated muddy bryozoal shell hash; E-M Miocene at base
GC14	41°19.1'	144°27.2'	144	1	Bryozoal shell hash
GC15	41°21.4'	144°26.0'	159	1	Bryozoal shell hash
GC16	41°21.0'	144°24.0'	293	378	40 cm yellow to pale olive bioclastic sand, above yellow green calcareous silty mud containing Terebratulids. Quaternary
GC17	41°18.0'	144°20.0'	111	1	Bryozoal shell hash
GC18	41°23.1'	144°14.0'	814	410	15 cm yellowish grey foram-nanno ooze, above olive grey calcareous silty mud. Quaternary
GC19	41°24.8'	144°15.1'	910	394	37 cm pale yellow fine bioclastic sand, above light olive grey calcareous silty mud. Quaternary
GC20	41°24.0'	144°18.6'	641	20	Sandy bioclastic ooze. Quaternary
GC21	41°24.6'	144°21.7'	438	114	9 cm light olive grey bioclastic sand, above olive grey foram-nanno ooze. Quaternary

3.5. *Tasmante (L'Atalante)* cruise

The present offshore Tasmanian project commenced in early 1994 with AGSO Cruise 125, which used the French research vessel *l'Atalante* on an exchange basis. The following discussion is drawn largely from Exon et al. (1994). Some aspects of the results were published by Exon, Hill & Royer (1995) and Hill, Exon & Royer (1995). The French vessel was used, rather than *Rig Seismic*, because of its Simrad EM12D swath-mapping system, capable of mapping the sea bed in a swathe up to 22 km wide at 20 km/hour, and of producing final bathymetric contour maps and images of the sea floor aboard ship. The *Tasmante* (from Tasmania and *l'Atalante*) cruise started in Auckland and ended in Adelaide 45 days later. Data were recorded on the transits, as well as near Tasmania. The swath-mapping system, high speed seismic system, echosounder, magnetometer and gravity meter were deployed successfully throughout. Underway oceanographic data were also recorded. About 3200 km of geophysical data were recorded on the transit from New Zealand, 13 600 km on the South Tasman Rise (STR) and west Tasmanian margin, and 500 km on the transit to Adelaide, a total of about 17 300 km. All data were recorded digitally with the exception of the 3.5 KHz echosounder profiles. Seismic penetration of 2 seconds below sea bed was common. Total swath-mapping coverage in Australian waters exceeded 200 000 km² (Figs. 15, 16 & 17). The very accurate bathymetric maps and sonar images arising from this survey provide an unequalled source of structural information for AGSO and the petroleum exploration industry. Rollet (1994) integrated swath-mapping and Geosat satellite imagery to address the opening of this part of the Southern Ocean.

The maps defined bathymetry and surface texture with a degree of accuracy and rate of coverage unobtainable in any other way. This mapping of an area three times that of Tasmania helped to clarify the region's structural pattern and Cretaceous-Tertiary tectonic history, the latter strongly influenced by the final separation of Australia and Antarctica about 40 million years ago. Large-scale sedimentary structures and patterns were mapped to help elucidate Tertiary sedimentary history, and morphology to help define Australia's Legal Continental Shelf under the United Nations' Law of the Sea Convention.

The continental *South Tasman Rise* had been shown by satellite gravity maps to be a NW trending feature, cut by an older fault system trending NW, and a younger fault system trending almost north (Fig. 3). Both fault systems are clearly related to the break-up of Australia and Antarctica, starting 130 million years ago. Swath-mapping coverage was 150 000 km², or about two-thirds of the rise. Coverage of the sea bed was virtually 100 %, except in water shallower than 2000 m on the culmination of the rise. The results emphasise that the rise is bounded by steep scarps to the west and east, and less-marked scarps to the south (Figs. 16 & 17). The western fault scarp above the abyssal plain, north-trending and 2000 m high, is part of the Tasman Fracture Zone linking Australia to Antarctica. West of the fracture zone is Tertiary oceanic crust. A number of faults splay off the scarp toward the east, and the seismic profiles suggest abundant old volcanism. The basement blocks on the central plateau are either little sedimented or unsedimented, but are separated by transpressional or transtensional basins containing several kilometres of sediment and oriented N-S to NW-SE (Fig. 10).

The southern margin of the rise was shown to be delimited by south-dipping normal fault scarps beyond which is Tertiary oceanic crust. On the rise's culmination, north of the southern margin, NW-elongated magnetic anomalies over outcropping basement apparently represent magnetic intrusions. In the east the margin is heavily sedimented, but the continent may give way to Late Cretaceous oceanic crust immediately east of a major basement high trending NNE, south of Tasmania. In the northwest, a number of rotated fault blocks occur between major fault zones, and there are some thick sedimentary basins. In the deep saddle between the rise and Tasmania, sediment thickness varies greatly, with areas of basement outcrop, sedimentary basins, and volcanoes up to 1000 m high or more. One hundred kilometres south of Hobart, in water depths of 800-1500 m, there is a major fishing area for orange roughy and dory. The mapping shows that the individual grounds are the tops of about 80 volcanoes, most about 200-400 m high. The implications of the new maps for the fishing industry and biological conservation were outlined by Koslow & Exon (1995), and a conservation area over the southern volcanoes was agreed between the Australian Nature Conservation Agency and the Australian Fisheries Management Agency in August 1995.

The South Tasman Rise was probably largely above sea level until it started to subside when Antarctica cleared it in the Eocene, and much of it stayed near sea level until late Oligocene times. In the centre of the plateau the 3.5 kHz echosounder showed areas of apparent sediment waves in the Plio-Pleistocene that are about 4 km long and 70 metres high, and seem to be migrating upslope northwestward toward basement highs. They are commonly unconformably overlain by 10-15 m of

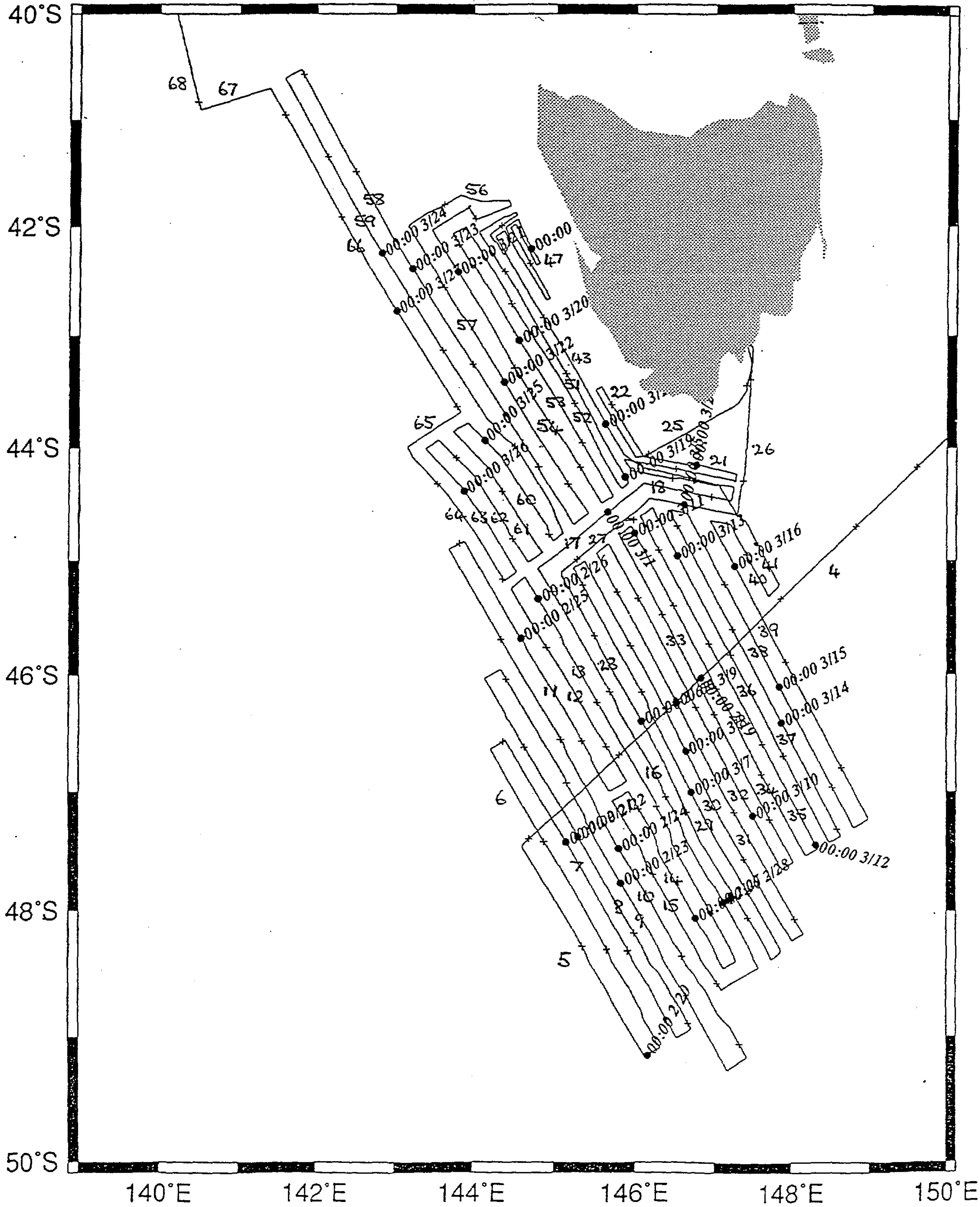


Figure 15. Track map for the detailed part of the *Tasmante* cruise off Tasmania. Position at beginning of each GMT day shown as dot with 00:00 Month/Day. Six-hourly positions shown with cross. After Exon et al. (1994).

Figure 16. Contour map of offshore Tasmanian region from merged conventional bathymetric data (ETOPO 5) and swath bathymetry. 5' x 5' grid for ETOPO5 and 1' x 1' grid for swath bathymetry. Swath bathymetry has precedence. Mercator projection. After Exon et al. (1994).

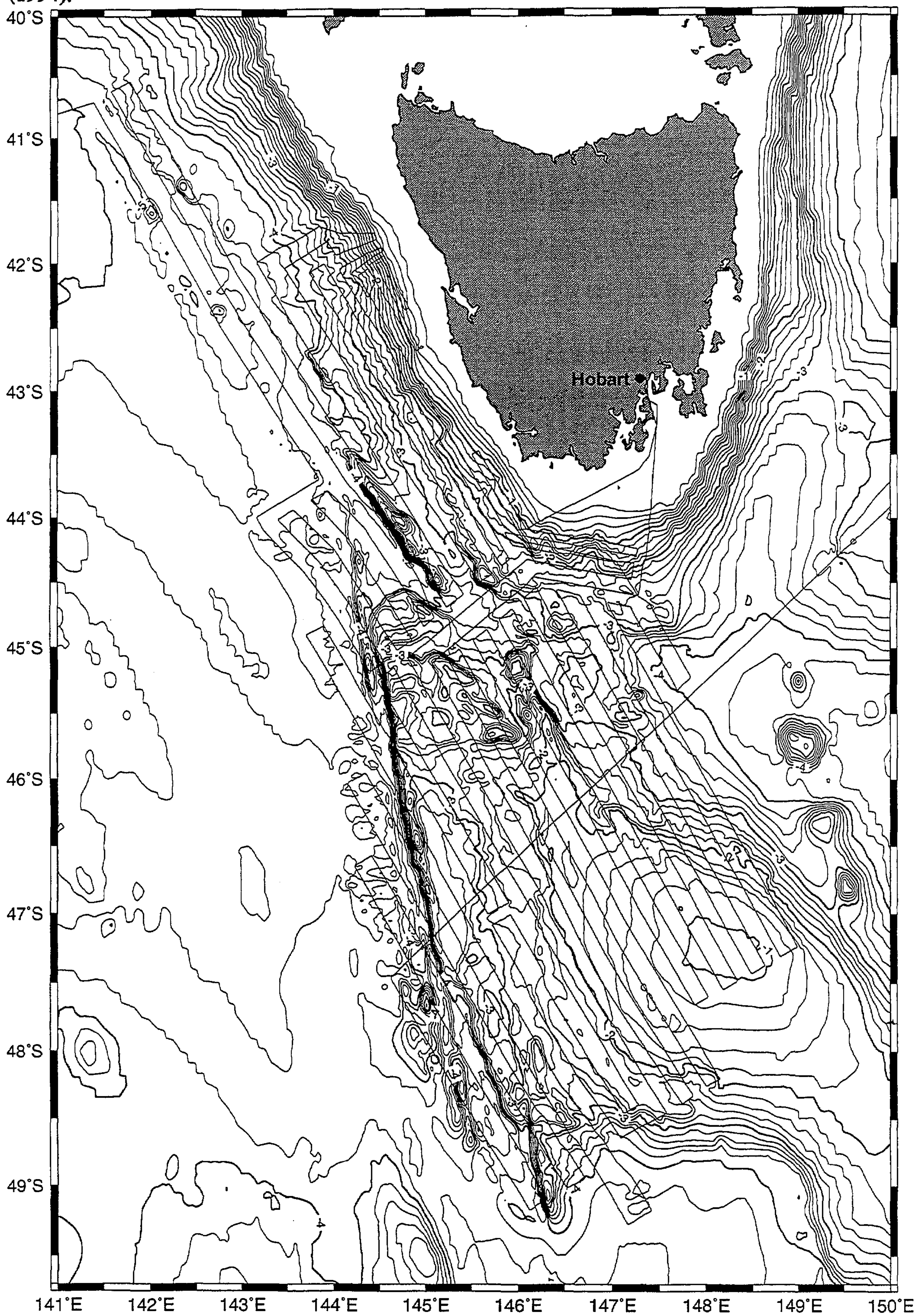
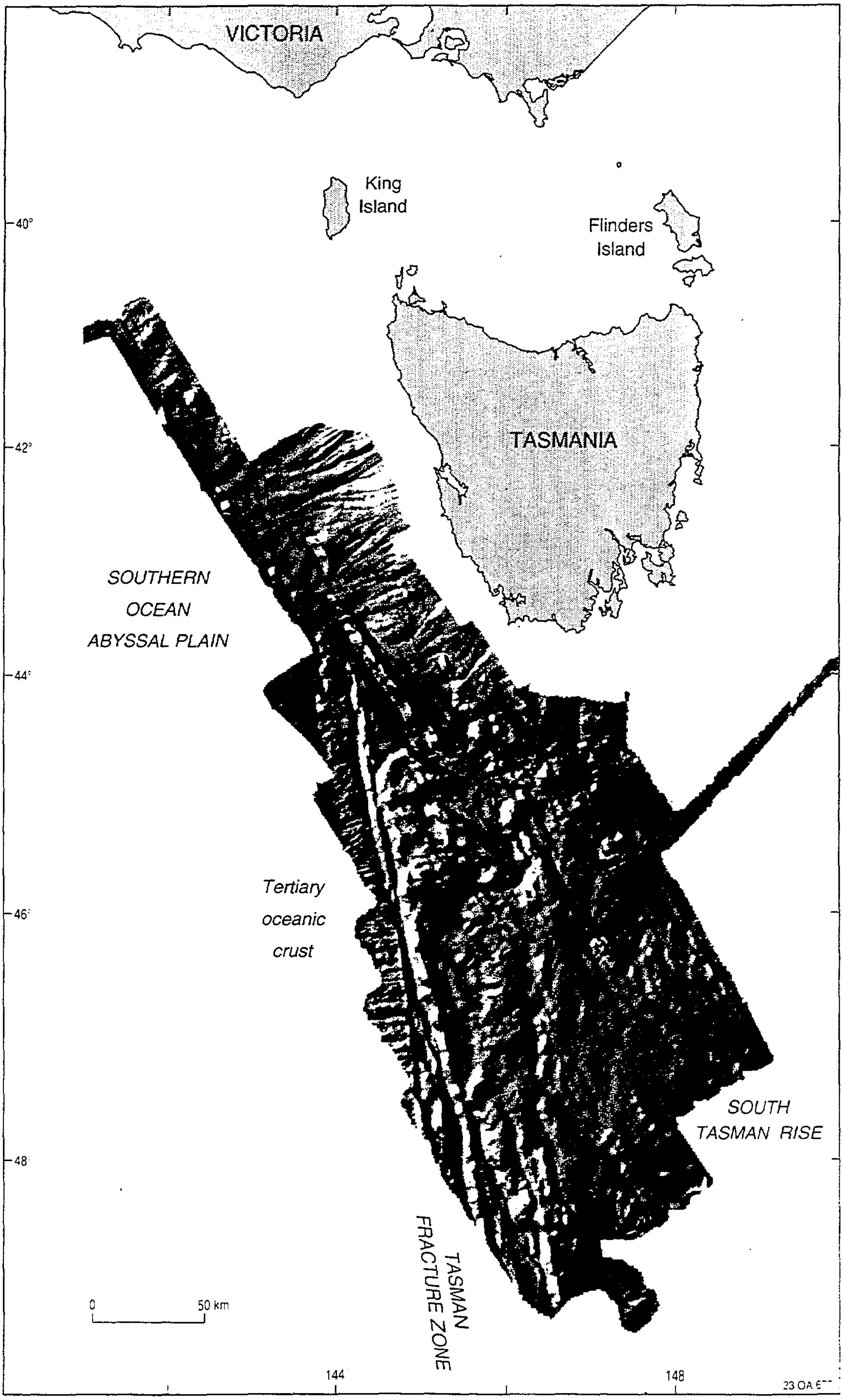


Figure 17. Relief diagram of the region surveyed off Tasmania from *Tasmante* data. Water depths are in the range 400-5000 m. Note the older 320° and the younger 345° fault directions, the deepwater volcanic cones west of Tasmania, the canyons on the western margin of Tasmania. The sea-floor spreading fabric is visible at the sea bed in the west as easterly trending ridges. After Exon et al. (1994).



draped pelagic sediments. These features clearly represent a major change in current regime. Future coring of these features would help elucidate the Southern Ocean's climatic history.

About 50 000 km² of the *west Tasmanian margin* was also mapped. The mapping showed that canyons are much more common on the slope than had been known (Fig. 17). Several of them are known fishing grounds for the bottom-dwelling blue grenadier. The seismic data show that the sedimentary sequence is almost everywhere more than 2.5 seconds (>3 km) thick, basement being visible only in some shelf areas. Suitable dredge targets for Cretaceous rocks have been found on the mid and outer slope.

On the outer west Tasmanian margin, large NW-trending fault blocks, up to 2500 m high and marking the last obvious continental crust, were mapped at the surface (Figs. 16 & 17). West of them is a transitional zone about 50 km wide, heavily sedimented and deep, with no obvious magnetic anomalies, and underlain either by Cretaceous oceanic crust or thinned continental crust. Beyond that is young, shallower Tertiary oceanic crust with only thin sediment cover, and volcanoes along the north-south fracture zones. The younger, north-south tectonism has disrupted the older northwest fabric along the margins in various ways. Southwest of Tasmania, at the junction with the South Tasman Rise, there is a triangular area 50 km across, where it appears that the movement past of Antarctica has dragged the older rocks around and southward, to form a series of arcuate outcrops on the northernmost South Tasman Rise. The triangle itself was apparently produced by the movement south of the older rocks, and is a depression that later seismic data from AGSO Cruise 159 show contains more than 3 seconds (twt) of sedimentary fill (Hill, Webber et al., 1995).

Acoustic facies mapping of the South Tasman Rise and the west Tasmanian margin (Whitmore, Belton & Wellington, 1994), based on the 3.5 KHz bathymetric profiles and the swath imagery, has allowed the patterns of Quaternary sedimentation to be mapped and interpreted. In general, sedimentation is more prevalent on the west Tasmanian margin, and erosion on the South Tasman Rise, but patterns change with basement structure, morphology, and current activity. Canyons presently cause starvation of much of the upper and middle slope off west Tasmania, and sedimentation on the lower slope.

The *East Tasman Plateau* lies southeast of Tasmania and is an equidimensional feature about 200 km across, from which rises the Eocene volcanic cone of Soela Seamount. A single *Tasmante* profile shows the rise to be bounded by scarps and probably of continental origin. The seamount is flat-topped, ten kilometres across and 1200 m high, and it culminates 650 m below sea level. The depression between the East Tasman Plateau and the South Tasman Rise is about 300 km wide, and gravity, magnetic and seismic data suggest much of it is oceanic. Basement is overlain by 1-1.5 seconds of sediment, this thickness explaining why the sea bed is not much deeper than 4000 m in the middle of a presumed oceanic basin. Our data indicate that the eastern side of the South Tasman Rise may be further west (see Fig. 3) than we had expected.

The *maps* produced of all the areas are mostly at 1:250 000 scale, and for the detailed survey off Tasmania (C1-C7) include ship tracks, sonar imagery, detailed and less detailed contour maps (25 and 50 m contours), and an overlay of sonar imagery on the less detailed contours. In addition, 1:1 000 000 scale maps of the entire Tasmanian survey area were produced of bathymetry (50 m contours) and imagery. Finally, 1:100 000 scale maps were provided of two fisheries areas off Tasmania: 20 m contours and imagery in the south, and 20 m contours only in the west. Both sets of data have sold steadily to the fishing industry.

This cruise showed the tremendous value of wide angle swath-mapping on the Australian margin, and that Australia should move toward acquiring such a system for itself. An area of Australia more than three times the size of Tasmania was mapped in considerable detail in 34 days of ship time (Fig. 17). The results provide tectonic information in plan view on areas that have petroleum potential, with thick sedimentary sequences and evidence of thermogenic hydrocarbons in surface sediments. They will also be valuable in establishing Australia's claim for the large area of the South Tasman Rise beyond the 200 mile limit, under the provisions on the UN Law of the Sea.

3.6. Other sedimentological studies

Boreen et al. (1993) studied the sedimentology of the shelf and slope of the Otway Basin, an area sedimentologically similar to the west Tasmanian margin. They used *Rig Seismic* and R.V. *Franklin* cores: vibrocores on the shelf and gravity cores on the slope. The shelf is a high-energy, open, cool temperate environment, partitioned hydrodynamically into three: ultimate abrasion depth (70 m), swell wave base (130 m), and storm wave base (250 m). They concluded that there are five depth-related zones of carbonate production and sedimentation. The shallow shelf is characterised by production of carbonate particles like molluscs, red algae and encrusting bryozoans, and these are abraded and swept away. The middle shelf consists of sand shoals formed largely of branching bryozoans. The outer shelf accumulates burrowed and storm-bedded fine bioclastic sands. The shelf edge and upper slope is relatively nutrient-rich, and bryozoans and sponges flourish. Muddy carbonate sand is deposited and moved down slope. The lower slope accumulates well-bedded pelagic carbonate, and is largely bypassed by other sediment.

Boreen and James (1993) discuss the Holocene sediment dynamics in the same area, on the basis of radiocarbon dated vibrocores and gravity cores. The Otway shelf has a patchy Holocene carbonate sand cover, less than 1.5 m thick, over Tertiary and late Pleistocene limestone. The Holocene slope deposits are bryozoan muds 0.5-3 m thick, over similar late Pleistocene deposits. The shelf edge and upper slope is a zone of carbonate production, accumulation of fines, and redeposition. The deep slope is dominated by pelagic and hemipelagic sediments, with climatically driven carbonate and terrigenous cycles. The authors develop a model that covers sedimentation in four phases: highstand and shallow flooding at 60-26 ka, lowstand at 20-18 ka, transgression at 18-6.5 ka, and highstand and deep flooding from 6.5 ka to the present. They discuss accumulation rates in detail, and conclude that differential accumulation rates, high in shallow protected waters, and low at the shelf margin, lead to the formation of a carbonate ramp. The shelf-margin bryozoan community is little affected by eustatic changes of 50-100 m, so there is continuous platform progradation.

Bolton et al. (1988) described eighteen samples of ferromanganese crusts and nodules dredged and cored by R.V. *Sonne* on the South Tasman Rise, and related them to the rocks or sediments with which they were associated. The samples came from four dredge hauls and six cores. These slowly-forming deposits formed largely on current-swept outcrops. They overlie a variety of basement rocks, and also frequently occur at the major hiatus above the Eocene mudstone and siltstone. The chemical composition of all samples is broadly similar, but subsurface samples are more contaminated and hence show lower metal values. Average values of the metals of economic interest are: Mn 15%, Fe 19%, Ni 0.39%, Cu 0.16%, and Co 0.33%. These are quite unexceptional values, although one deposit had high Co values of 0.8-1.0%.

3.7. Summary of sedimentological knowledge

The situation on the west Tasmanian margin (40-45°S) is rather different from that on the South Tasman Rise (45-50°S), so this section treats the two areas separately.

West Tasmanian margin

Well stratigraphy is summarised in Figure 18. The Upper Cretaceous Sherbrook Group is thickest, 1590 m, in Prawn No. 1 well, north of King Island. It consists of marginal marine to fluviatile sandstone, siltstone, mudstone and conglomerate. The Tertiary sequence is probably disconformable on the Upper Cretaceous sequence. Non-marine to shallow marine, Paleocene to lower Eocene fining upwards sequences are present in all four exploration wells, and are by far the thickest in Cape Sorell No.1, about 2250 m! The middle Eocene to lower Oligocene sequence is more calcareous, consisting of shallow marine sandstone, marl and limestone, and is thickest, 375 m, in Cape Sorell No.1. Above a major unconformity, the upper Oligocene and younger sediments are dominantly shelfal marl and limestone. They are thickest, 617 m, in Prawn No. 1.

In DSDP Site 282, located deep on the continental slope (Fig. 3), 240 m of late Eocene to middle Oligocene sediments rest on a basalt flow of presumed Tertiary age. The basal, late Eocene unit is 103 m thick. It consists of a glassy and zeolitic mudstone laid down in reducing conditions, with appreciable organic carbon, but contains shallow-water benthic forams at some levels, as well as shallow water coccoliths and sponge spicules. Thus the conclusion of Kennett, Houtz et al. (1975A), that the sequence was laid down in deep water, remains in doubt. The conformably overlying early to mid Oligocene sediments are olive grey mudstones and are 78 m thick. They contain nannofossils, sponge spicules and glauconite stringers. The next unit up is a dark olive grey, organic carbon bearing, nannofossil-rich mudstone, 9 m thick. It contains shelly fossils and a possibly shallow-water benthic foram assemblage. The uppermost middle Oligocene unit is 50 m of grey, glauconite and micronodule bearing, quartz rich mudstone, rich in nannofossils and sponge spicules, and containing a shallow-water benthic foram assemblage in one core. Above the Oligocene unconformity is 42m of early Miocene foram and glauconite bearing nannofossil marl. Late Miocene nannofossil ooze, 7 m thick, disconformably overlies the early Miocene sequence, and is overlain by a veneer of Pleistocene ooze. There is little in this well to suggest that it was in deep water until the margin started to subside in the Oligocene, and it may be that the basalt is not an oceanic basalt at all.

Grab, vibrocore, core and dredge samples from the west Tasmanian margin have provided a great deal of valuable information. They are listed in Tables 6-11 and discussed in Hinz et al. (1985, 1986), Exon, Lee & Hill (1989), and Exon et al. (1992). A general summary of the results is given in Table 12. All the Late Cretaceous, Paleocene and Eocene siliciclastic sediments are interpreted as shallow or restricted marine, and the Eocene limestones are also shallow marine. Above the Oligocene unconformity, the effect of the collapse of the margin westward is evident in the sediments, with those near Tasmania generally being shallow marine, but those further west being deposited in increasingly deep water.

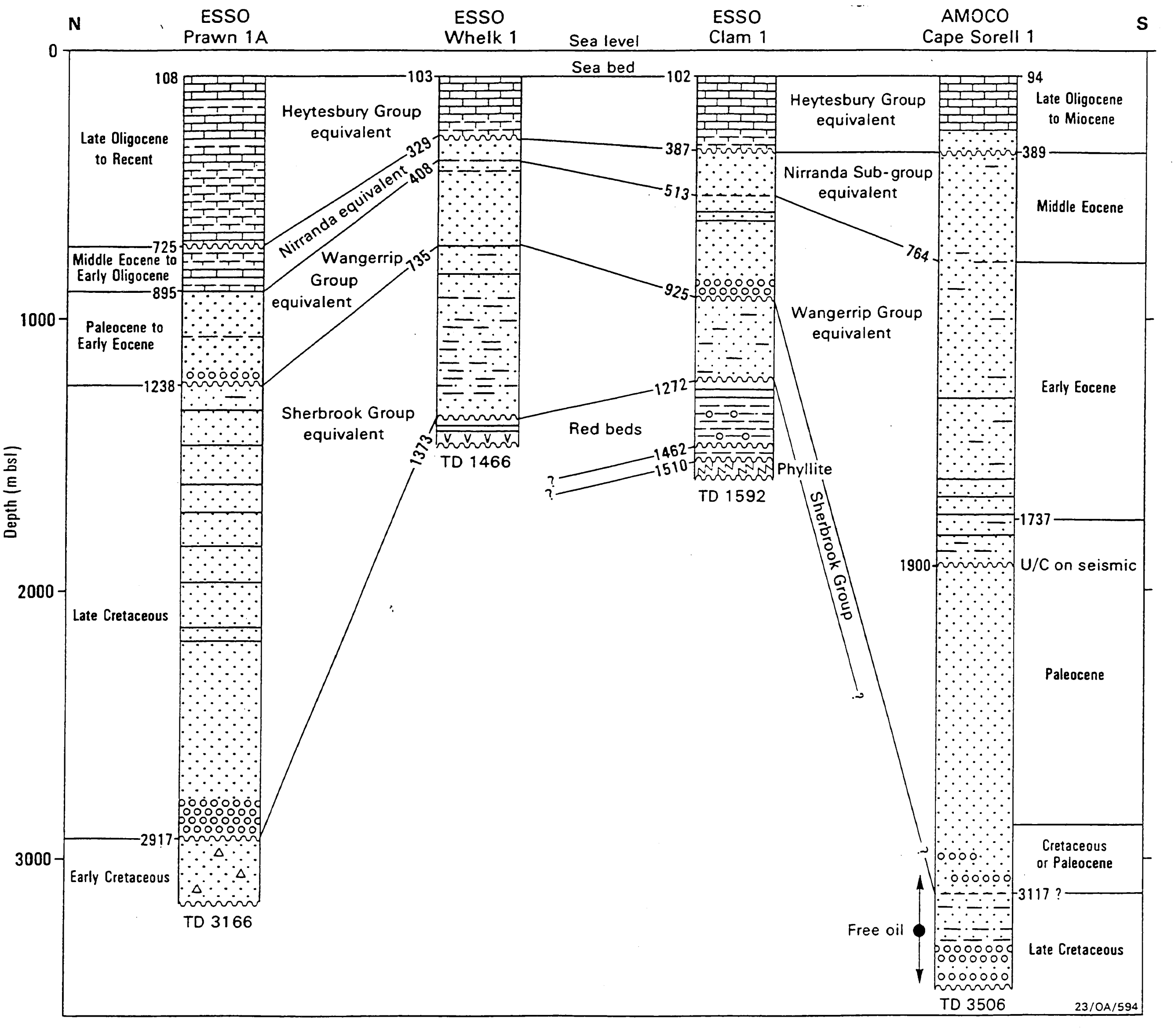


Figure 18. Well correlation diagram for four petroleum exploration wells west and northwest of Tasmania. Locations of southern three in Figure 18. Note the great thickening of the Paleogene in Cape Sorell No. 1, caused by its proximity to a fault scarp active at that time. After Moore et al. (1992).

Table 12: Character & age of west Tasmanian seabed samples (south of 40°S)

Sequence	Stations
Pleistocene to Recent bryozoal shelf sands and muddy sands	67/GS 28-31; 78/GS1-9; 78/VC 1 & 2; 78/GC 8-17
Pleistocene to Recent oozes and turbidites	23 *Sonne* cores, 18 BMR Cruise 67 cores, 16 BMR Cruise 78 cores
Miocene to Early Pliocene limestone, chalk, marl, ooze and mudstone	9 *Sonne* cores, 2 BMR Cruise 67 cores, 5 BMR Cruise 78 cores
Late Oligocene shelf limestone	2 *Sonne* dredges
Late Oligocene marl and mudstone	2 BMR Cruise 67 cores
M Eocene shelf limestone	2 *Sonne* dredges
E-M Eocene nearshore marine mudstone	2 *Sonne* cores, 1 BMR Cruise 78 core
Paleocene restricted marine mudstone	1 BMR Cruise 78 dredge
Late Cretaceous shallow marine mudstone and sandstone	2 BMR Cruise 67 dredges, 1 BMR Cruise 78 dredge
Basalt	1 *Sonne* dredge, 1 BMR 78 dredge
Palaeozoic or Mesozoic sandstone, grit or metasiltstone	3 *Sonne* dredges, 1 BMR 78 dredge
Schists and related rocks	3 *Sonne* dredges, 1 BMR 78 dredge

South Tasman Rise

Two DSDP wells were drilled on or near the South Tasman Rise (Kennett, Houtz et al., 1975A). Site 281 was drilled in water 1591 m deep, southwest of the culmination of the rise (Fig. 3), and bottomed in a quartz-mica schist of latest Carboniferous age. This is unconformably overlain by a six metre thick, late Eocene, basement conglomerate consisting of angular clasts, dominantly of schist, with lesser quartz, quartzite, glauconite, glauconitic sandstone and granite. This contains a battered assemblage of benthonic forams, and was a locally derived, shallow-water, high-energy deposit, laid down during the initial transgression across the subsiding South Tasman Rise. It is overlain by 3 m of detrital sand and nanno chalk. The upper 28.5 m of late Eocene sediment consists of greyish-olive glauconitic sandy silt and silty clay, with abundant forams, radiolarians, diatoms and sponge spicules. Neritic nannofossils and benthic forams in older strata point to deposition in outer shelf or upper bathyal depths, whereas the presence of shallow-water benthic forams points to shelf deposition later. Unconformably overlying the late Eocene sequence there is 3 m of late Oligocene glauconite-rich detrital sand, unconformably overlain by 79 m of Miocene foram-nanno ooze and 36 m of Plio-Pleistocene foram-nanno ooze.

Site 280 was drilled to 524 metres in water 4181 m deep southwest of the rise (Fig. 3), and bottomed in an "intrusive basalt", almost certainly oceanic crust. It penetrated a veneer of late Miocene to late Pleistocene clay and ooze underlain, beneath a sampling gap, by 55 m of siliceous early Oligocene sandy silt, and 428 m of middle Eocene to early Oligocene sandy silt, containing chert in the upper 100 m and glauconite and manganese micronodules below that. The lower 200 m is rich in organic carbon (0.6-2.2 %). All sediments are presumed to be abyssal types, and a brown organic stain suggests reducing conditions in parts of the late Oligocene and early Miocene.

Most of the sea bed samples from the South Tasman Rise were taken by R.V. *Sonne* in 1985, and have been described by Hinz et al. (1985) and Bolton et al. (1988). They are listed in Table 6, and have been discussed earlier in this report under "R.V. *Sonne* cruises". The main results are summarised in Table 13.

Table 13: Character and age of *Sonne* South Tasman Rise seabed samples

Sequence	*Sonne* Stations
Pleistocene to Recent carbonate ooze or foram sand	16 cores
Pliocene carbonate ooze	4 cores
Miocene chalk	1 core
Eocene glassy zeolitic mudstone with radiolarians	2 dredges, 3 cores
? Eocene palaeosol	1 core
Tertiary basaltic breccia	1 dredge
Palaeozoic graywacke	1 core
Schist, gneiss, pegmatite	1 dredge

The sampling results show that the early history of the two areas, west Tasmanian margin and South Tasman Rise, was probably similar. Clearly there were major differences in the Eocene, when the northern area saw the deposition of shallow marine deltaic sediments and limestones, while the southern area saw the deposition of glassy radiolarian-bearing glauconitic mudstones in a shallow sea that was restricted on occasions. As Antarctica cleared Australia there was a period of erosion in both areas, forming the Oligocene unconformity, and both areas subsided steadily. However, the southern area sank vertically as a block, whereas the west Tasmanian margin rotated downward from a hingeline near the coast, so that the further from Tasmania, the deeper the water. In the south, the Circum-Antarctic Current scoured most sediments away, whereas thick late Oligocene to Recent carbonate sediments are present in depocentres off west Tasmania.

3.8. Southern Ocean palaeoceanographic studies - clues for changes in atmospheric CO_2 content

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The Subtropical Convergence (STC) is a major boundary between surface ocean water masses. It is the northern limit of the Southern Ocean and is marked by a strong temperature gradient of about 4°C (from 14-18°C in the summer [Tchernia, 1980]). The Polar Frontal Zone (PFZ) is also marked by a temperature gradient of about 4°C (from 2-6°C: Nemoto & Terasaki, 1985; Tchernia, 1980), and it is also the site of formation of a major deep water mass, AAIW (Tchernia, 1980). The Southern Ocean is known to have a large influence on global deep ocean circulation, and is believed to have had a major influence on atmospheric CO_2 changes that occurred during the major climatic changes (glacial to interglacial) of the late Quaternary. Consequently, understanding changes in the surface properties (such as sea surface temperature: SST) and productivity of the Southern Ocean across its boundaries is of great interest in reconstructing the influence of the Southern Ocean on global climate change (eg. Mortlock et al., 1991; Howard & Prell, 1992).

Ice core records have revealed that the atmosphere underwent a 1/3 increase in CO_2 between glacial and Holocene climate regimes (eg. Neftel et al., 1982). What controls this natural change in atmospheric CO_2 content is a puzzle whose answer must lie in ocean circulation because the ocean contains the world's largest exchangeable carbon reservoir (about 50 times that in the atmosphere, [Broecker et al., 1980]). The most important waters in the ocean for this exchange are the Southern Ocean and the northern North Atlantic which are the two main sites for deep water formation today.

However, during the last glaciation northern source water was significantly reduced (Boyle & Keigwin, 1985, 1986) and northern source water sank only to intermediate depths (Boyle & Keigwin, 1987), greatly increasing the southern ocean influence on the deep ocean (Curry & Lohman, 1983; Oppo & Fairbanks, 1987; Duplessy et al., 1988; Curry et al., 1988, Charles & Fairbanks, 1992).

Many theories have been put forward as to how changes in the ocean's composition and circulation could change the atmospheric CO_2 content by about 90 ppm (see Broecker & Peng, 1989 for a review), but the one proposed by Boyle (1988) and modified by Broecker & Peng (1989) satisfies the geological data most closely. They proposed that shifting the nutrient sink from intermediate depth waters in the interglacial ocean (present conditions) to deep waters in the glacial ocean, changed carbonate dissolution conditions sufficiently, due to the reorganisation of nutrients, to account for the entire glacial-interglacial change in atmospheric CO_2 content. Recent work on Southern Ocean sediments by Howard & Prell (1992) on planktonic foraminiferal parameters, and Francois & Altabet (1992) on sedimentary Nitrogen 15, strongly indicate that changes in surface processes in the sub-polar waters of the Southern Ocean in the last glaciation were important in controlling atmospheric CO_2 content, and thus global climate.

The East Tasman Plateau and the South Tasman Rise are ideal locations oceanographically to investigate these interrelated topics. The STC overlies the South Tasman Rise today and the Polar Front is only a few degrees to the south. Both topographic features have bathymetric depths as shallow as 1000 m so that most deep ocean water masses impinge on their flanks. An investigation of SST and other surface water parameter changes across both the STC and the PFZ will be able to determine not only if there were changes in SST and the position of the PFZ and the STC over the last glacial cycle, but also if there were significant and long term changes in upper water column properties during this cycle. This study will complement work Dr Sikes has begun in looking at changes in the STC on the Chatham Rise, and work that Dave Heggie and Dan McCorkle have begun on cores from the Perth Basin.

3.9. Petroleum potential

Any assessment of the petroleum potential of this frontier region depends partly on analogy with the Cretaceous-Cainozoic Otway Basin to the north, which has a number of small gas fields onshore, and two large undeveloped gas fields offshore, the La Bella and Minerva discoveries. These two discoveries (Luxton et al., 1995) are in Cenomanian-Santonian fluvial to marginal marine sandstones of the lower Sherbrook Group (BHP Petroleum's informal 'Shipwreck Group'), sealed by Cretaceous claystones, with the gas sourced by coals and shales in the Early Cretaceous Eumeralla Group. Gas reserves are estimated at 575 BCF at Minerva and 210 BCF at La Bella, and development awaits markets. Other hydrocarbon accumulations are found in sandstones throughout the Cretaceous sequence.

The best researched hydrocarbons in the Otway Basin were generated in the Neocomian rift-infill Crayfish Group (Padley et al., 1995), and were derived from a range of lacustrine, fluvial, marginal marine, and even perhaps playa lake deposits. The orientation of the early rift depocentres varies from NNW to E-W to NE across the basin (Perincek & Cockshell, 1995). Sand box modelling (Cockshell et al., 1995) suggests that in the western basin at least, rifting was controlled by north-south extension.

West Tasmanian margin

Organic-rich late Eocene silty clays at DSDP Site 282 west of Tasmania have considerable petroleum source rock potential (Hunt, 1975; 1984). In Cape Sorell No. 1 (AMOCO, 1982) extensive traces of oil were found in the latest Cretaceous/earliest Paleocene. A shipboard study of 27 *Sonne* cores (Whiticar & others, 1985) indicated that wet gas of thermogenic origin is abundant in surface sediments on the west Tasmanian margin, indicating the presence of mature source rocks. Fourteen cores were analysed for gases on the South Tasman Rise and most were relatively poor in hydrocarbons. However, three stations in the east gave higher yields with a thermogenic signature. More than 20 exploration wells have been drilled in the offshore Otway and Sorell Basins.

The petroleum prospects of the continental margin of western Tasmania were reviewed by Moore et al. (1992) and this section is drawn from their work. The margin is underlain by the southern Otway Basin and the Sorell Basin (Fig. 8). The latter lies mainly under the continental slope, but it includes four sub-basins (the King Island, Sandy Cape, Strahan and Port Davey Sub-basins) underlying the continental shelf (Fig. 19). In general, these depocentres are interpreted to have formed at the 'relieving bends' of a major left-lateral strike-slip fault system, associated with 'southern margin' extension and breakup (seafloor spreading). The sedimentary fill could have commenced in the Jurassic.

Maximum known sediment thickness is about 4300 m in the southern Otway Basin, 3600 m in the King Island Sub-basin, 5100 m in the Sandy Cape Sub-basin, 6500 m in the Strahan Sub-basin, and 3000 m in the Port Davey Sub-basin. Megasequences in the shelf basins are similar to those in the Otway Basin, and are generally separated by unconformities. There are Lower Cretaceous non-marine conglomerates, sandstones and mudstones, which probably include the undated red beds recovered in two wells, and Upper Cretaceous shallow marine to non-marine conglomerates, sandstones and mudstones. The Cainozoic sequence often commences with basal shallow marine sandstones, mudstones and marls, and grades up into Eocene shallow marine limestones, marls and sandstones, and Oligocene and younger shallow marine marls and limestones. The sequences in four unsuccessful petroleum exploration wells, west and northwest of Tasmania, are summarised in Figure 18.

The presence of active source rocks has been demonstrated by the occurrence of free oil near the base of Cape Sorell No.1 well (Strahan Sub-basin), and thermogenic gas from surficial sediments recovered from the upper continental slope and the Sandy Cape Sub-basin (Exon et al., 1992). Geohistory maturation modelling of wells and source rock 'kitchens' has shown that the best locations for liquid hydrocarbon entrapment in the southern Otway Basin are in structural positions marginward of the location of Prawn No. 1 well. In such positions, basal Lower Cretaceous source rocks could charge overlying Pretty Hill Sandstone reservoirs. In the King Island Sub-basin, the sediments encountered by the Clam No. 1 well are thermally immature, though hydrocarbons generated from within mature Lower Cretaceous rocks in adjacent depocentres could charge traps, providing that suitable migration pathways are present. Whilst no wells have been drilled in the Sandy Cape Sub-basin, basal Cretaceous potential source rocks are considered to have entered the oil window in the early Late Cretaceous, and are now capable of generating gas/condensate or oil. Upper Cretaceous rocks appear to have entered the oil window in the Paleocene. In the Strahan Sub-basin, mature Cretaceous sediments in the depocentres are available to traps, through considerable migration distances would be required.

Moore et al. (1992) concluded that the west Tasmania margin, which has five strike-slip related depocentres and the potential to have generated and entrapped hydrocarbons, is worthy of further

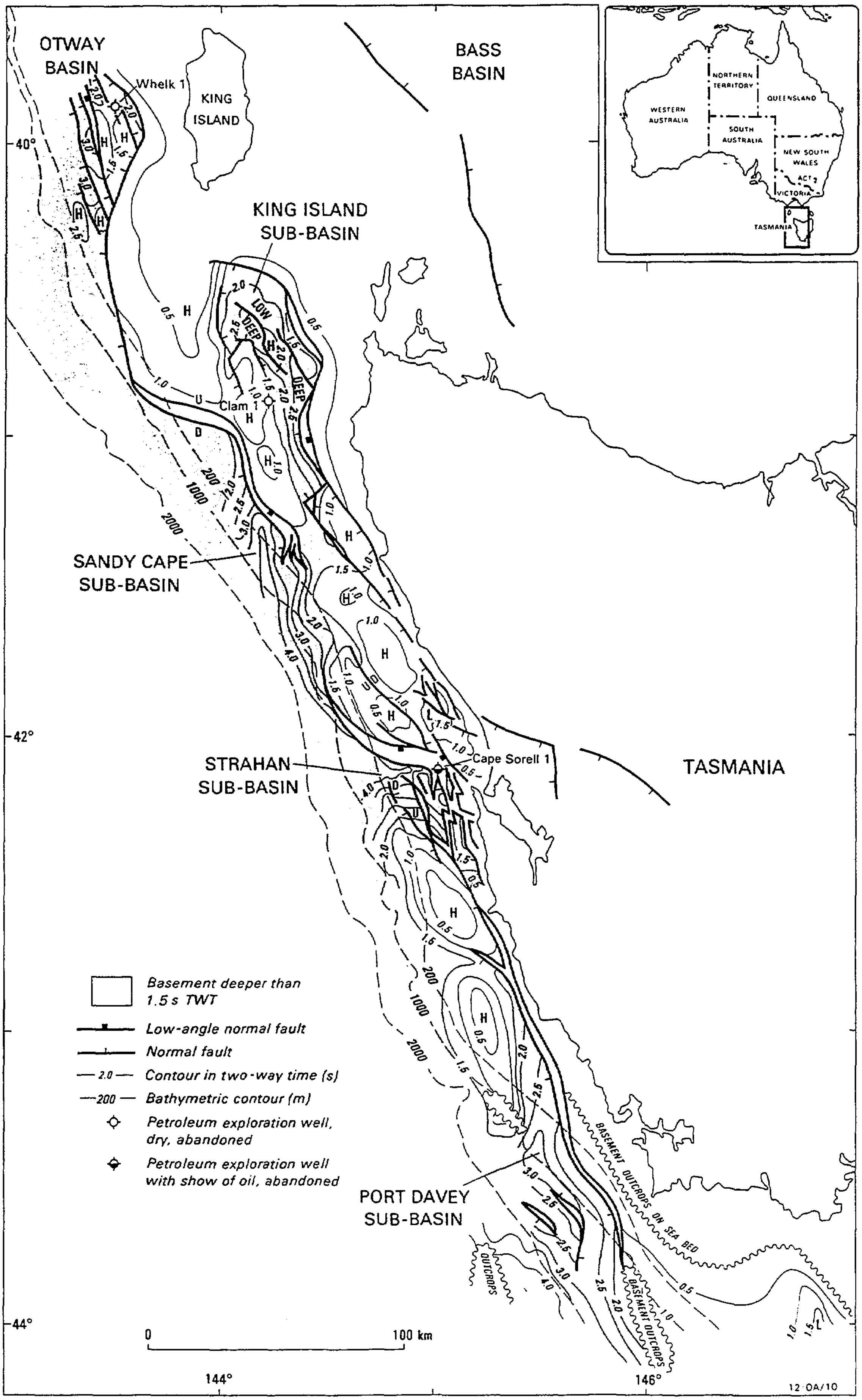


Figure 19. Map of basement structure off west Tasmania. Shows basins and sub-basins in water shallower than 1000 m. After Moore et al. (1992).

consideration by the exploration industry. The more prospective areas are the southern Otway Basin, and the Sandy Cape and Strahan Sub-basins of the Sorell Basin.

South Tasman Rise

The submerged continental block of the South Tasman Rise has not been the subject of any activity from petroleum exploration companies, probably because of the limited regional geological information, and especially because it lies more than 800 m below sea level. An additional factor is that it lies in the unfavourable climatic belt of the "Roaring Forties".

Willcox (1982), briefly reviewed its geology on the basis of two BMR sparker lines and noted the presence of sedimentary rift basins. The *Sonne*-36 cruise (Hinz et al., 1985) recorded a number of multichannel seismic profiles across the rise, and showed that it has a triangular central core of basement rocks, surrounded by sedimentary basins. Mapping by J.B. Willcox (Willcox et al., 1989) and Salge (1989) indicated that the western half of the rise consists of northerly-trending deep wrench basins more that 2 seconds (TWT) deep, between slivers of basement. The age of the sedimentary fill is unknown, but was assumed to be Cretaceous and Cainozoic.

Whiticar et al. (1985) reported that three shallow *Sonne*-36 cores from the northeastern basinal area of the rise contained substantial concentrations of thermogenic hydrocarbons. In contrast, yields from nine cores from the western basins and the central basement area were low.

With this encouragement, AGSO planned the *Tasmante* cruise (Exon et al., 1994) to obtain a good regional grid of seismic and swath-mapping data to provide more information about the surface and deep structure. Figures 10 and 17 show the complexity of the rise; only when the seismic data are fully interpreted can the hydrocarbon potential of this frontier area be properly assessed.

4. CRUISE OBJECTIVES

We planned to use R.V. *Rig Seismic* for this major sampling cruise in order to upgrade our understanding of the evolution of the Australian southern margin and the Southern Ocean, particularly the way in which it may have affected the age and formation of petroleum source rocks and the development of migration paths, to map sedimentary structures and patterns, and to work toward an understanding of Neogene sedimentary processes and their variations with time. On the basis of all existing data including the recent swath-mapping data from R.V. *L'Atalante* (Exon et al., 1994), *Rig Seismic* was to carry out targeted sampling of the area off southeastern Australia (38-50°S 138-152°E) as follows:

- ❑ Sample older sequences in the west Tasmanian continental slope for geological information, to be assessed together with seismic information, in order to help establish stratigraphy and assess petroleum potential.
- ❑ Sample older sequences on the South Tasman Rise to establish its stratigraphy and help establish its petroleum potential.
- ❑ Sample East Tasman Plateau to establish whether it is all volcanic, or whether the Soela Seamount forming its crest is a volcano built on continental crust. If it is continental, to help establish its stratigraphy and petroleum potential.
- ❑ Sample tectonically controlled features (defined by swath-mapping) to provide a better tectonic history.
- ❑ Sample outer shelf and upper slope sediments off southeast Tasmania for palaeoclimatic purposes.

- Sample typical sedimentary features (defined by swath-mapping) on the continental margin to help establish its Cainozoic history.
- Take cores in undisturbed sediments, for studies of Southern Ocean palaeoclimate, on the South Tasman Rise and East Tasman Plateau.
- Use free-fall grabs to assess manganese resources in the known manganese nodule fields on the abyssal plains around Tasmania.
- Sample and photograph volcanic cones on the slope south of Tasmania for geological and fisheries information.
- Sample surface and bottom waters for chemical analysis and plankton composition

5. CRUISE PLAN

The cruise was scheduled to depart from Melbourne on 27 January 1995, and berth in Hobart on 27 February, a total time at sea of 31 days and, in fact, that schedule was adhered to. The broad plan was to sample southward down the western side of Tasmania and the South Tasman Rise, northeastward across the South Tasman Rise, cross eastward to the East Tasman Plateau, and then sample south and southeast of Tasmania. The estimate for long transits, on which we were to deploy echosounder, magnetometer and gravity meter (if available), was 5 days. The components to be fitted together logistically included:

1. Twenty-one stratigraphic dredges of older sequences on the plateau margins and of major scarps within the plateau (10 days).

2. Up to 5 dredges of igneous features on and near the plateaus (2-3 days).

3. Up to 10 gravity cores and 5 vibrocores for various stratigraphic and sedimentological purposes (5 days).

4. Fifteen gravity and box cores, and associated bottom water sampling, to investigate Quaternary palaeoclimatic changes (5 days).

5. Five stations of freefall grabs (three grabs at each station) to investigate Mn nodule concentrations (2 days).

6. Two camera stations on volcanic cones 100 km south of Tasmania (0.5 day).

7. Five water sample strings in top 200 m on an opportunity basis (0.5 day).

Details, particularly of the coring program, were to be finalised aboard ship by the interested parties, but the general areas traversed were regarded as unlikely to change very much.

6. CRUISE NARRATIVE

S. Dutton, AGSO

Nomenclature

BC	Box Core
CM	Underwater Camera
DR	A dredge with chain bag and two pipe dredges attached One pipe for mud and one for smaller rocks
FFG	Free Fall Grab
GC	Gravity Core with varying core lengths. (Most with a 6 metre barrel)
GR	Grab Sample
HC	Hydrocast with Niskin Bottles — Shallow ~ 200 metres; Deep ~ 3500 metres
VC	Vibrocore
WS	A bucket of water taken from the surface

All times are in AESST (-11)

Friday 27 January

Cast off and departed No 4 Victoria Dock, Melbourne at 1815. We were delayed 15 minutes due to traffic in the Yarra River.

Saturday 28 January

Arrived at the first sampling site at 1605. Sampling for the day consisted of HC1 (Shallow), WS 1 & 2 and DR1.

Sunday 29 January

Completed DR1 and then sampled WS 2, 3, 4 & 5 and HC2 (Shallow).
Magnetometer was initially deployed and operated satisfactorily until late Sunday night when it had to be recovered for investigation as there was too much noise on the record.

The weather has been kind to us since departure. It was moderate on entering Bass Strait late on Friday night but eased on Saturday morning and we have had slight seas and winds for the weekend.

All of the geology equipment is functioning well except that we are unable to drive the hydrographic winch with the winch room controls. This is being investigated. All sampling stations to date have been successful.

Monday 30 January

Sampling during the day consisted of WS 6 & 7, DR 2 & 3 and GC1.

Today has been another successful day of sampling. A weather front moved through about midday and we experienced 45 knot winds and a slightly rough sea. However, it had settled to 25 knots at sunset and the seas had also abated a little. Conditions remain comfortable.

The magnetometer problem mentioned yesterday was due to bad connections at one end of the deck leader. It was reterminated and the mag is again operational.

Tuesday 31 January

Sampling for the day saw the completion of DR3, then DR 4 &5, GC 2, 3 & 4, and BC1 which was still underway at midnight.

The results were reasonable, GC2 &3 did not return samples nor did DR3.

The EPCs which display our bathymetric information have been breaking down. We have 7 on board, one of which has been cannibalised for spares. Currently there are only three working and there is a requirement for three. The electronics technicians are putting a major effort into fixing the three unserviceable units.

At 1700 we lost the trace on the 3.5 kHz echo sounder. Repair of this has a second priority to the EPCs as we still have the 12 kHz echo sounder operating.

Wednesday 1 February

Today we completed BC1 which gave no return and then we did GC5, CM1, DR6 & 7. All were successful although the camera triggered in the water column many times.

The wind was steady at 25 knots with attendant seas which made it difficult for Box Core and Camera operations.

Thursday 2 February

Work today comprised CM2, GC 6 & 7, DR8 and the commencement of BC2. All stations were successful with GC7 yielding a 5.33M core in a 6M barrel.

Strong winds up to 35 knots made conditions a little uncomfortable but did not hamper sampling operations. By late evening the wind had dropped to 10 knots and the seas were abating.

Friday 3 February

BC 2 was a no-recovery, but later in the day BC 3 gave 20 cm of ooze which was pleasing. Four sub-cores were taken from it. DR 9 & 10 were also successful, returning 20 and 500 Kg respectively.

The wind speed picked up on Friday night and with it the swell which was running at 3 to 4 metres. Undaunted by the weather, sampling continued.

The operational EPCs now number 5 and we are working on the sixth unit.

Saturday 4 February

Three gravity cores, GCs 8, 9 and 10, gave no recoveries except for some small sand samples. DR 11 yielded a 500 Kg bag.

The weather eased a little but continued at 25 knots for the remainder of the weekend.

The winch house EPC stopped and had to be replaced. Since the winch house replacement, we have fixed all of the unserviceable units. We now have six operating and one cannibalised. Further, we have no take up motors and only one spare stepper motor.

The 3.5 Khz echo sounder is working again and giving a reasonable picture.

Sunday 5 February

Today's sampling comprised DR 12 and 13 and a deep Hydrocast to 3,500 metres. All stations were successful. DR13 contained part of a whale skull. A sketch and description of the skull was sent to Ewan Fordyce at the University of Otago, New Zealand who is confident it is an almost complete rostrum (snout) of a ziphiid or beaked whale, a family in the Order Odontoceti (toothed whales).

The Festo controller equipment for measuring wire out is not operational and Jack's box only seems to be accurate for the coring winch. Consequently we are having some difficulty knowing the amount of wire out on the hydrographic winch.

Monday 6 February

A good day's sampling, two dredges returning 100 Kg each, one FFG deployment using 4 grabs returning small amounts in each grab, and one gravity core with a 2.64 metres sample.

The weather was a little worse than the weekend and we are expecting a front through tomorrow.

Tuesday 7 February

Three gravity cores, one dredge and two water samples. GC 12 had no return, GCs 13 &14 giving 5.3 metres and 6.3 metres. The 6.3 metre core was in a six metre barrel and the corer must have "pogoed" oncee or twice to have filled the liner. The dredge returned 250 Kg and the water samples, as usual, were successful.

The expected weather front passed through yesterday with 45 knot winds and attendant seas. The sea state was such that we cancelled an FFG series as we had doubts about recovering the grabs because of the weather.

During the day we spotted a pod of 40+ pilot whales that were feeding. They swam to within 50 metres of the ship.

Wednesday 8 February

Sampling today was GCs 15 & 16 and DRs 17 & 18, all successful. We recovered 4.04 metres in a 4 metre barrel and 3.58 metres. The dredges returned 50 and 40 Kg of rock.

Life has become uncomfortable with big seas and strong winds prevailing. Fortunately we are still able to continue with the sampling program.

Thursday 9 February

Today's sampling consisted of DRs 19, 20 and 21. We also did shallow HC 5 and WS 12. The dredge was lost during DR19, and DR20 was a repeat of the station; it returned 50 Kg of rocks. DR21 also recovered 50 Kg of rock, mainly mudstone.

The wind has eased and with it the sea, but the large swell which has developed over the last few days remains. As we go further south, currently at 47° 45' S, the air temperature is dropping and is often less than 10° C, especially at night.

Friday 10 February

Two GCs, one DR, a FFG series and one WS. Recovery in all but the FFGs. We put three FFGs in the water and recovered three, but with no result. Weather still moderate, 25 - 30 kt winds and big swell.

Saturday 11 February

Two dredges, two GCs, a shallow HC and a WS. All except one GC gave recovery. Weather abated today, 20 knots and a slight sea on a 2 metre swell. Working conditions relatively comfortable.

Sunday 12 February

One GC, two DR and a deep HC. All gave recovery, but one dredge was mud only in the pipe. We moved 2 miles along the scarp and tried again.
At 0600 this morning we reached the southernmost point of the survey, 49° 04.90 S, 145° 59.00 E.

Monday 13 February

Three DR, two GC and our first Grab Sample. Both GCs, using a 6 metre barrel, were unsuccessful, so we are rigging a 4 metre barrel to see if we can do any better. The sandy bottom is not conducive to good GCs. The weather has eased considerably, light breezes and a long 2 metre swell. We had a most pleasant sunny morning followed by an afternoon of fog and a beautiful sunset.

Tuesday 14 February

Two GCs, one Grab and one Dredge. The GCs once again failed to recover sample, probably due to the nature of the bottom.

Wednesday 15 February

One GC, four DRs and a GR. No recovery from the GC, all other stations were successful. However one DR was damaged and only yielded 2 Kg of rocks. That station was repeated nearby and on the second attempt gave 200 Kg. The wind picked up to 40 knots and with it, the sea and swell.

Thursday 16 February

Three GCs and one DR. All gave recovery except for one GC which was repeated, giving a 5.19 metre core on the second attempt. The strong winds are continuing at 40+ knots and the big seas make life a little uncomfortable, however the sampling goes on.

Friday 17 February

Two DRs, both successful. The second dredge gave 500 Kg of rocks and a fossilised rostrum from a whale thought to be from the beaked whale family.
A front moved through early on Friday morning and we experienced 50 knot winds (force 10) with big swells and big seas. The 3.5 kHz echo sounder has been repaired. After two frustrating weeks of trying to fix the unit the problem was traced to a faulty power supply.

Saturday 18 February

Two GCs and three DRs - all successful. The weather eased considerably after the front moved through yesterday, and tonight we have light airs and a glassy sea on a 2 to 3 metre swell. Today was also election day in the ACT. *Rig Seismic* had been appointed as a polling booth and ten of the science crew were able to vote as Antarctic voters having registered prior to sailing. The votes were passed to Canberra by telephone at 1815 that evening.

Sunday 19 February

Two DRs, one deep HC, one shallow HC and a WS - all successful. Unbelievably a third whale rostrum was recovered in DR 43 which was on the East Tasman Plateau.

Monday 20 February

Monday was a beautiful day with the wind dropping to very light airs giving a glassy sea on a 2 metre swell. This was fortunate as it was time to commence the vibrocore program which needs a reasonably stable platform.
The sampling site was in sight of land and all onboard enjoyed the spectacular views of the southern end of the Tasman Peninsula. Sampling comprised four GRs, one CM, and six VCs. All stations gave some recovery, except for two VCs, but the other four VCs only yielded short cores. This was probably due to the sandy bryozoan bottom. We had a problem with the brakes on both the hydrographic and coring winches when they would not release. This was finally overcome by increasing the oil pressure in the system.

Tuesday 21 February

Sampling consisted of three GRs, one with no recovery, two VCs, one deep HC, one WS, one GC and two CM stations. The two VCs and the last GR station gave no recovery. This was the last of the original programmed sites, and we are now moving to the south to continue coring and dredging in an area between the South Tasman Rise and the East Tasman Rise to try and define the line between the oceanic crust and the continent.

Wednesday 22 February

One CM and three DRs all with good recovery. We moved back into the 40 to 50 knots winds with attendant seas and the ever present big swell. However, with all the work being scheduled for the coring winch, sampling operations proceeded without any problems. The ship movement in the big seas is making life uncomfortable and we are all very tired.

Thursday 23 February

One GC and two DRs. During the third dredge, which was not completed and went on to Friday's records, the coupling to the servo pump on the AWH power pack failed. We had no spares but the mechanics onboard were able to rebuild the coupling and sampling continued.

At 1730 we sighted a pod of ~ 15 pilot whales 20 metres off the stern of the ship. They stayed with us for about 30 minutes before moving away.

Friday 24 February

Three DRs and one GC all giving good results. Weather continues to be moderate.

Saturday 25 February

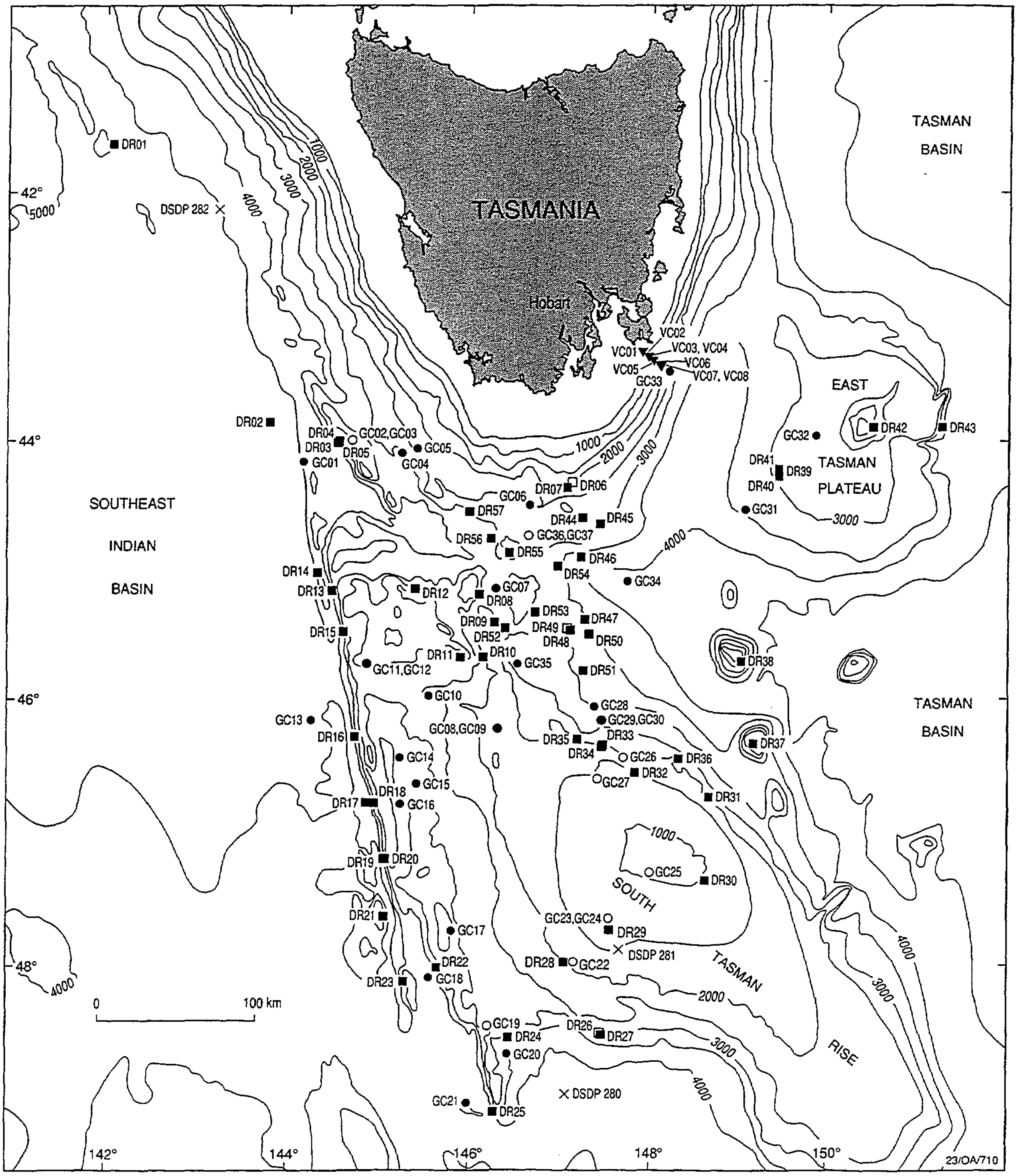
Three DRs and two unsuccessful GCs. On the second GC the barrel was separated at the bomb. We lost both the barrel and collar, which is unusual as the GC is designed to shear at the barrel-retaining bolt.

Sunday 26 February

Three DRs, all successful. During the breakfast dredge the coupling to the servo pump on the AWH power pack failed again. This time it was too far gone to repair, and the mechanics had to machine up a new part using the drill mill. Sampling for the survey finished at 1603 but we took about two hours to recover the cable as it was lubricated on the way in. At 1730 a self-serve bistro on the BBQ deck gave a relaxed ending to a most successful geology survey. 1830, all finished, en route to Hobart for an 0800 arrival on Monday morning.

Monday 27 February

Arrived Hobart 0800. Met by Tony Yeates, TASGO Co-ordinator. Press conference at 1000 to report on the South and East Tasman Rises survey and also to introduce the following TASGO project. At 1130 a group of VIPs arrived for lunch, after which they were given a presentation of the completed survey, a preview of the TASGO project, and a tour of the ship.



DR = *Dredge* ■ *successful* □ *unsuccessful* GC = *Gravity core,* ● *successful* ○ *unsuccessful* VC = *Vibrocore,* ▼ *successful* ▽ *unsuccessful* × DSDP

Figure 20. Bathymetric map of the study region showing all AGSO Cruise 147 dredge and core stations. Bathymetry from *l'Atalante* swath-mapping and other data.

7. INTRODUCTION TO CRUISE RESULTS

The work carried out greatly exceeded the expectations in the Cruise Plan, and *Rig Seismic* successfully dredged rocks from the sea bed at 53 stations in depths of up to 4500 m, took 20 deepwater cores of young sediments that should record the climatic history, investigated surface and deep waters and their living content at 18 stations, and sampled the surface sediments on the continental shelf south of Tasmania at a dozen stations (see Tables 1, 2 & 14 & Fig. 1). Both dredging and coring were concentrated largely on the South Tasman Rise (Fig. 20). Much more work was done on the central and northern South Tasman Rise, and the southern Tasmanian margin, than had been anticipated. About 15 tonnes of rocks were recovered and representative samples have been kept for future study. A total of 73 m of sediment cores were described and kept.

Table 14: All stations occupied on AGSO Cruise 147 off Tasmania

Station	Latitude	Longitude	Depth (m)	Station time in hrs (& date)	Notes
HC01/ WS01	41° 00.3'S	142° 31.0'E	4060	1.1 (28.1)	200m hydrocast + SDL + water sample
WS02	41° 35.8'S	142° 07.6'E	4850	0.1 (28.1)	200 m SDL + water sample
DR01	41° 36.0'S 41° 36.9'S	142° 06.2'E 142° 02.5'E	4800-4100	9.5 (28.1)	Basalt, Mn nodules and crusts on abyssal rise. *L'Atalante* profile 66
WS03	42° 00.0'S	142° 09.8'E	5003	0.1 (29.1)	Surface SDL + water sample
WS04	42° 30.1'S	142° 36.0'E	4905	0.1 (29.1)	water sample
HC02/ WS05	43° 00.0'S	143° 02.0'E	4760	0.5 (29.1)	200 m hydrocast + SDL + water sample
WS06	43° 30.0'S	143° 29.0'E	4613	0.5 (30.1)	water sample
DR02	43° 51.5'S 43° 51.4'S	143° 48.0'E 143° 48.1'E	4250-4770	5.5 (30.1)	Basalt, Mn nodules and crusts on abyssal hill. *L'Atalante* profile 66
GC01/ WS07	44° 10.3'S	144° 10.8'E	4238	2.5 (30.1)	3.78 m recovery: 40 cm ooze above green clay and claystone (Eocene?). *L'Atalante* profile 61 (0432). Water sample and surface SDL
DR03	44° 01.8'S 44° 00.5'S	144° 32.5'E 144° 34.6'E	4400-3800	4 (30.1)	Ooze only
HC03/ HC04/ WS08	45° 02.0'S	144° 15.1'E	4815	5 (5.2)	200 m SDL + hydrocast + water sample. 3500 m hydrocast

DR04	44° 0.8'S 44° 0.7'S	144° 34.0'S 144° 34.4'E	4000-3000	6 (31.1)	Gneiss and other metamorphic basement rocks
GC02	44° 00'S	144° 43'E	1957	1.5 (31.1)	No recovery. *L'Atalante* profile 58
GC03	44° 00'S	144° 43'E	1957	1.5 (31.1)	1 cc foram sand. *L'Atalante* 58
DR05	44° 0.5'S 44° 0.2'S	144° 34.5'E 144° 35.4'E	3000-2300	4 (31.1)	Gneiss, schist and other metamorphic basement rocks, Mn crusts
GC04	44° 06.0'S	145° 15.0'E	2981	2 (1.2)	2.57 m ooze. *L'Atalante* profile 54
BC01	44° 06.0'S	145° 15.0'E	2986	3 (1.2)	Box corer. No recovery. Pinger/EPC failure.
GC05	44° 04.0'S	145° 25.0'E	2334	1 (1.2)	1.8 m ooze. *L'Atalante* profile 53
CM01	44° 11.6'S 44° 11.6'S	146° 58.9'E 146° 58.7'E	640-720	3 (1.2)	Camera station with bottom photos
DR06	44° 19.7'S 44° 19.5'S	147° 7.2'E 147° 7.1'E	1400-1200	2.5 (1.2)	Corals etc, rare basalt pebbles
DR07	44° 22.7'S 44° 22.7'S	147° 6.1'E 147° 6.5'E	1550-1100	3.5 (1.2)	Breccia of basalt & limestone clasts, basalt, Mn crusts
CM02	44° 23.4'S	147° 10.2'E	1350	3 (2.2)	Camera run aborted with pinger problem
GC06	44° 31.5'S	146° 42.5'E	2609	2 (2.2)	86 cm foram ooze. *L'Atalante* profile 27
DR08	45° 12.0'S 45° 12.0'S	146° 07.4'E 146° 05.8'E	3000-2450	3.5 (2.2)	Volcanic breccia, minor basalt & Mn crust. *Sonne* profile 62
GC07	45° 09.5'S	146° 17.5'E	3307	2 (2.2)	5.3 m of ooze. *L'Atalante* profile 34
BC02	45° 09.5'S	146° 17.5'E	3307	2.5 (2.2)	Box corer did not trigger. No pinger fitted
DR09	45° 24.5'S 45° 25.9'S	146° 17.2'E 146° 15.8'E	3300-2200	4.5 (3.2)	"dolerite" and related igneous rocks of greenschist facies (?Jurassic)
BC03	45° 09.5'S	146° 17.5'E	3307	3.5 (3.2)	20 cm surface ooze. Pinger fitted
DR10	45° 41.0'S 45° 41.0'S	146° 08.1'E 146° 09.4'E	2800-2100	4 (3.2)	Labile sandstone (?Eocene), breccia, Mn crusts, minor tuff. *L'Atalante* profile 31
GC08	46° 14.0'S	146° 19.0'E	1813	1 (4.2)	No recovery. Not to bottom. *L'Atalante* profile 30
GC09	46° 14.0'S	146° 19.0'E	1813	1 (4.2)	10 cc foram sand. *L'Atalante* profile 30

GC10	45° 58.9'S	145° 33.4'E	2369	1.5 (4.2)	1cc foram sand. *L'Atalante* profile 66
DR11	45° 41.3'S 45° 40.6'S	145° 54.3'E 145° 54.3'E	2200-1940	4 (4.2)	Granite, diorite, Mn crusts, minor silicified limestone, conglomerate. *Sonne* profile 62
DR12	45° 09.0'S 45° 10.2'S	145° 25.1'E 145° 23.8'E	3000-2100	5 (5.2)	Schist, Mn crusts, minor Cainozoic chert (silicified limestone) and conglomerate. *Sonne* profile 49
DR13	45° 07.7'S 45° 07.4'S	144° 30.3'E 144° 32.8'E	3900-2700	5 (5.2)	Quartzose sandstone (?Palaeozoic), muddy sandstone (Late Cretaceous to Early Tertiary palynomorphs) Mn nodules & crusts, minor chert (silicified limestone) and breccia. *L'Atalante* profile 64
WS08	45° 02.2'S	144° 15.0'S	4800	5 (5.2)	Water sample
DR14	45° 02.2'S 45° 02.2'S	144° 19.2'E 144° 20.8'E	4400-3800	4 (5.2)	Marine mudstone with varves (late Eocene palynomorphs), rads, diatoms, siliceous forams; glass; Mn nodules
WS09	45° 29.4'S	144° 35.9'E	3800		Water sample
FFG1A FFG1B FFG1C FFG1D	45° 26.0'S 45° 27.3'S 45° 28.0'S 45° 29.0'S	144° 20.0'E 144° 20.0'E 144° 20.0'E 144° 20.0'E	4772 4833 4701 4678	5 (6.2)	Clayey nanno ooze. *L'Atalante* profile 11
DR15	45° 29.3'S 45° 29.2'S	144° 36.8'E 144° 37.1'E	3400-3000	4 (6.2)	Leucodiorite, silicified limestone, Mn crusts, minor slate
GC11	45° 44.0'S	144° 53.0'E	2387	2 (6.2)	2.64 m ooze. *L'Atalante* profile 12
GC12	45° 44.0'S	144° 53.0'E	2387	2 (6.2)	1 cc ooze. Core catcher collapsed. *L'Atalante* profile 12
GC13	46° 10'.0S	144° 16.0'E	4452	3 (7.2)	5.3 m clayey ooze. *L'Atalante* profile 8
WS10	46° 17.4'S	144° 50.4'E	4000	0.2 (7.2)	Water sample
DR16	46° 17.5'S 46° 17.5'S	144° 44.7'E 144° 45.9'E	4250-3700	5 (7.2)	Granite, Cainozoic breccia of igneous rocks, Mn crusts. *L'Atalante* profile 16
WS11/ WS12	46° 17.4'S	144° 50.4'E	2930	0.5 (7.2)	Water samples

GC14	46° 27.0'S	145° 14.5'E	3360	3 (7.2)	6.29 m ooze (some repetition). *L'Atalante* profile 11(0510)
GC15	46°39.0'S	145° 25.1'E	3260	3 (8.2)	4.04 m ooze). *L'Atalante* profile 11(0630)
GC16	46° 48.0'S	145° 15.0'E	3523	2 (8.2)	3.58 m ooze. *L'Atalante* profile 10(0430)
DR17	46° 47.4'S 46° 47.4'S	144° 47.4'S 144° 58.1'E	4500- 3400	4.5 (8.2)	Microgabbro, "dolerite", Cainozoic breccia, Mn nodules and crusts
DR18	46° 47.5'S 46° 47.5'S	144° 57.6'E 144° 58.5'E	3700- 3200	4 (8.2)	Sandstone & siltstone (late Eocene palynomorphs), conglomerate, microgabbro, Mn crusts and nodules
DR19	47° 13.0'S 47° 13.0'S	145° 3.8'E 145° 5.5'E	4200- 3300	5 (9.2)	Lost dredges, 7 tonne shear pin broke
DR20	47° 13.0'S 47° 13.0'S	145° 5.0'E 145° 5.1'E	3600- 3500	3 (9.2)	Gneiss, granite, tonalite, mudstone, Mn crusts
HC05	47° 11.9'S	145° 4.3'E	3096	1 (9.2)	200 m hydrocast + SDL
DR21	47° 38.5'S	145° 04.8'E	3400	4 (9.2)	Soft mudstone (?Eocene)
GC17	47° 45.0'S	145° 49.0'E	3001	1.5 (10.2)	2.29 m ooze
WS13	47° 38.6'S	145° 01.4'E	3500	0.2 (10.2)	Water sample
DR22	48° 01.4'S 48° 00.8'S	145° 38.3'E 145° 39.5'E	3750- 3350	5 (10.2)	Granite, microdiorite, Mn nodules and crusts, minor claystone (?Eocene)
GC18	48° 05.5'S	145° 34.0'E	4368	2.5 (10.2)	2.5 m of brown and white clay above Mn crust
FFG2A FFG2B FFG2C	48° 05.3'S 48° 06.0'S 48° 06.6'S	145° 34.8'E 145° 34.9'E 145° 34.9'E	4383 4390 4403	5 (10.2)	No recovery
WS14	48° 07.0'S	145° 14.4'E	4600	0.2 (10.2)	Water sample
DR23	48° 07.0'S 48° 07.0'S	145° 15.2'E 145° 19.0'E	4600- 3600	3.5 (10.2)	Mn nodules, minor mudstone (?Eocene)
GC19	48° 26.5'S	146° 13.0'E	2578	2 (11.2)	No recovery, core catcher inverted
WS15	48° 26.5'S	146° 13.0'E	2578	0.2 (11.2)	Surface SDL + water sample

DR24	48° 32.0'S 48° 31.3'S	146° 27.0'E 146° 27.0'E	2600-2250	4 (11.2)	Waterworn cobbles of granite and metamorphosed sandstone and mudstone; Mn crusts
GC20	48° 39.0'S	146° 26.0'E	3300	2 (11.2)	3.53 m foram ooze
GC21	49° 0.0'S	145° 59.0'E	4132	3 (12.2)	3.71 m foram-nanno ooze
HC06 HC07 WS16	49° 04.5'E	146° 15.0'E	3650	3650	3500 m hydrocast, water sample
DR25	49° 04.3'S 49° 04.0'S	146° 16.0'E 146° 17.4'E	3300-2420	4 (12.2)	Mudstone (?Eocene), metasediments, Mn crusts nodules, minor granite and trachyte
DR26	48° 29.9'S 48° 29.6'S	147° 27.2'E 147° 27.8'E	2980-2600	3.5 (12.2)	Ooze only
DR27	48° 30.8'S 48° 30.6'S	147° 28.2'E 147° 28.6'E	3000-2700	4 (13.2)	Granite, metasediments, sedimentary rocks, Mn crusts
GC22	47° 58.5'S	147° 10.0'E	1914	1 (13.2)	No recovery apart from a little foram sand
DR28	47° 58.5'S 47° 58.6'S	147° 03.3'E 147° 03.4'E	2100-1800	3.5 (13.2)	?Palaeozoic polymictic conglomerate, foliated metasiltstone, schistose argillite, sandstone, Mn crusts
DR29	47° 44.2'S 47° 44.6'S	147° 33.7'E 147° 32.8'E	1170-1070	3.5 (13.2)	?Palaeozoic polymictic conglomerate
GC23	47° 39.6'S	147° 33.0'E	1300	1 (13.2)	No recovery
GR01	47° 39.6'S	147° 33.0'E	1311	1 (13.2)	8 cm coherent foram sand
GC24	47° 39.6'S	147° 33.0'S	1310	1 (13.2)	Little recovery
GR02	47° 19.0'S	148° 00.0'E	922	1 (14.2)	10 kg foram sand
GC25	47° 19.0'S	148° 00.0'E	923	1 (14.2)	Little recovery
DR30	47° 22.7'S 47° 22.8'S	148° 37.3'S 148° 36.9'E	900-800	2 (14.2)	Granite, conglomerate; corals, barnacles etc
DR31	46° 45.4'S 46° 45.0'S	148° 40.0'E 148° 39.5'E	2230-2080	3 (14.2)	Diorite, quartzite, Cainozoic polymictic conglomerate, muddy sandstone (?Eocene)

GC26	46° 27.0'S	147° 42.0'E	2001	1.5 (14.2)	50 cc foram sand
GR03	46° 37.0'S	147° 25.2'E	1583	1 (15.2)	6 cm foram sand
DR32	46° 33.7'S 46° 34.0'S	147° 47.7'E 147° 47.0'E	1600-1200	4 (15.2)	Weathered basalt, Mn crusts
GC27	46° 36.6'S	147° 25.2'E	1580	1 (15.2)	Few cc foram sand
DR33	46° 21.4'S 46° 21.6'S	147° 28.5'E 147° 28.4'E	2350-2250	2 (15.2)	Few cobbles of weathered basalt, Mn crusts
DR34	46° 21.9'S 46° 22.2'S	147° 28.2'E 147° 28.1'E	2200-2100	2 (15.2)	Weathered basalt, Mn crusts
DR35	46° 18.6'S 46° 19.1'S	147° 12.2'E 147° 11.4'E	2300-1950	3 (15.2)	Calcalkaline ?Tertiary volcanics, hyaloclastites, Mn crusts
GC28	46° 03.5'S	147° 23.0'E	3065	1.5 (16.2)	2.68 m ooze
GC29	46° 10.0'S	147° 28.0'E	2931	1.5 (16.2)	No recovery. Catcher inverted
GC30	46° 10.0'S	147° 28.0'E	2968	1.5 (16.2)	5.19 m ooze
DR36	46° 27.7'S 46° 28.1'S	148° 19.7'E 148° 19.3'E	2400-2350	4 (16.2)	Rounded Palaeozoic cobbles of metasediments, minor granite, vein quartz, conglomerate, red sandstone; Mn nodules and crusts.
DR37	46° 21.3'S 46° 21.2'S	149° 08.2'E 149° 10.1'E	2450-2200	4 (16.2)	Weathered vesicular basalt, Mn crusts
DR38	45° 43.0'S 45° 43.0'S	149° 00.0'E 149° 01.0'E	2300-2050	4 (17.2)	Hyaloclastites, vesicular basalt, Mn crusts, minor silicified chalk. One cobble ?ice-rafted gneiss.
GC31	44° 32.8'S	149° 03.8'E	3440	2 (17.2)	5.23 m clayey ooze
DR39	44° 16.0'S 44° 16.0'S	149° 24.7'E 149° 27.0'E	3150-2900	4.5 (18.2)	Mn crusts, minor pebbles of quartz sandstone, quartzite, quartz

DR40	44° 17.3'S 44° 17.1'S	149° 26.3'E 149° 26.8'E	2950-2515	4.5 (18.2)	Mn crusts, hyaloclastites, minor basalt, metasediment, marble/amphibolite
DR41	44° 14.0'S	149° 26.0'E	2850	3 (18.2)	Quartzose ferricrete, Mn crusts
GC32	43° 57.9'S	149° 52.2'E	2650	2 (18.2)	2.64 m ooze
DR42	43° 54.0'S 43° 54.1'S	150° 34.1'E 150° 33.0'E	1620-1280	4.5 (19.2)	Volcanic breccia/hyaloclastite, basalt, Mn crusts
DR43	43° 54.0'S 43° 54.0'S	151° 19.2'E 151° 17.8'E	3600-3030	5 (19.2)	Granite, rhyolite, mudstone and sandstone, Mn crusts
HC08/9 WS17	43° 54.4'S	151° 22.0'E	3365	4 (19.2)	Deep 3500 m hydrocast, shallow 200 m hydrocast, water sample
GR04	43° 17.8'S	147° 53.7'E	131	0.2 (20.2)	Light olive grey foram ooze
CM03	43° 17.7'S	147° 53.7'E	131	1 (20.2)	Bottom photos taken
VC01	43° 17.8'S	147° 53.7'E	129	0.2 (20.2)	34 cm olive grey bryozoal sand
GR05	43° 20.2'S	147° 58.0'E	135	0.2 (20.2)	Pale yellowish brown bryozoal sand
VC02	43° 20.2'S	147° 58.0'E	135	0.2 (20.2)	No recovery. Equipment failure
VC03	43° 20.2'S	147° 58.0'E	135	0.2 (20.2)	No recovery. Equipment failure
VC04	43° 20.2'S	147° 58.0'E	133	0.2 (20.2)	24 cm bryozoal sand
GR06	43° 21.9'S	148° 01.2'E	137	0.2 (20.2)	bryozoal sand
VC05	43° 21.9'S	148° 01.2'E	137	0.2 (20.2)	27 cm bryozoal sand
GR07	43° 23.9'S	148° 05.5'E	145	0.2(20.2)	Pale yellowish brown coarse bryozoal sand
VC06	43° 23.9'S	148° 05.5'E	145	0.2 (20.2)	94 cm
GR08	43° 24.5'S	148° 06.2'E	141	0.2 (21.2)	Light olive grey bryozoal sand
VC07	43° 24.5'S	148° 06.2'E	141	0.2 (21.2)	No recovery
VC08	43° 24.5'S	148° 06.2'E	142	0.2 (21.2)	No recovery

CM04	43° 23.9'S 43° 23.9'S	148° 05.4'E 148° 05.3'E	140-135	1 (21.2)	Bottom photos taken while drifting
HC10/ WS18	43° 24.5'S	148° 06.2'E	141	0.3 (21.2)	Hydrocast of bottle near bottom + SDL + surface water sample
GR09	43° 26.4'S	148° 09.6'E	804	1 (21.2)	Light olive grey sandy bryozoal grit
GR10	43° 27.7'S	148° 11.8'E	1285	1 (21.2)	No recovery. Contacted bottom
GC33	43° 27.7'S	148° 11.8'E	1285	1 (21.2)	10 cm light olive grey foram sand with bryozoa and echinoderms
CM05	44° 10.4'S 44° 10.4'S	147° 28.4'E 147° 28.5'E	1150-1220	2 (21.2)	Bottom photos of corals, other biota, outcrop
CM06	44° 23.6'S 44° 23.4'S	147° 10.6'E 147° 10.4'E	1280-1420	4.5 (22.2)	Bottom photos of corals, other biota, outcrop
DR44	44° 36.3'S 44° 36.0'S	147° 14.7'E 147° 14.8'E	2400-2250	4 (22.2)	Granite gneiss, bioclastic limestone, Mn crust and nodules
DR45	44° 39.2'S 44° 39.5'S	147° 26.4'E 147° 26.5'E	2800-2600	3 (22.2)	Granite and granite gneiss, altered basalt or metasediment, minor Cainozoic conglomerate and siltstone, Mn crusts
DR46	44° 55.0'S 44° 54.1'S	147° 14.1'E 147° 13.9'E	3500-3250	4 (22.2)	Schist, quartzite, metasandstone, Cainozoic bioclastic limestone, Mn crusts
GC34	45° 06.0'S	147° 44.5'E	4202	2 (23.2)	5.16 m grey silty clay
DR47	45° 23.2'S 45° 21.8'S	147° 16.5'E 147° 17.5'E	2650-2250	5 (23.2)	Greenschist/amphibolite, marble, gabbro, quartzite, Cainozoic bioclastic limestone, Mn crusts
DR48	45° 28.4'S 45° 27.5'S	147° 07.2'E 147° 07.8'E	2800-2720	3 (23.2)	Granite, schist, muddy sandstone, Mn crust and nodules
DR49	45° 27.8'S 45° 26.9'S	147° 04.3'E 147° 05.4'E	3170-2700	6 (23.2)	No recovery. May not have reached bottom. Winch problems

DR50	45° 30.4'S 45° 31.4'S	147° 20.6'E 147° 20.3'E	3100-2950	7 (24.2)	Granite, gneiss, ribbon chert, Mn crusts and nodules
DR51	45° 47.3'S 45° 46.0'S	147° 14.2'E 147° 14.0'E	3180-2500	4 (24.2)	Basalt, Mn crusts
GC35	45° 44.0'S	146° 32.0'E	2720	2 (24.2)	2.05 m ooze over quartz rich clay
DR52	45° 38.0'S 45° 38.2'S	146° 25.0'E 146° 24.4'E	2370-2200	4 (24.2)	Metasediment, dolerite, conglomerate, Mn crusts
DR53	45° 21.8'S 45° 21.1'S	146° 43.2'E 146° 43.7'E	3000-2770	4 (25.2)	Mn crusts
DR54	44° 58.2'S 44° 57.5'S	146° 57.8'E 146° 58.0'E	3050-2700	2.5 (25.2)	Chlorite schist/mylonite, metasediment, ?Eocene muddy siltstone, Cainozoic siliceous limestone
GC36	44° 45.0'S	146° 39.0'E	2650	2 (25.2)	No recovery. Did not reach bottom
GC37	44° 45.0'S	146° 39.0'E	2650	2 (25.2)	No recovery. Barrel torn off
DR55	44° 52.6'S 44° 52.2'S	146° 27.6'E 146° 27.6'E	2650-2400	4 (25.2)	Cainozoic silicified limestone and limestone breccia, Mn crusts
DR56	44° 47.1'S 44° 47.3'S	146° 13.6'E 146° 13.3'E	3050-3000	4.5 (26.2)	Rounded pebbles of quartzite, metasediment, sandstone
DR57	44° 32.8'S 44° 31.7'S	146° 00.4'E 146° 00.6'E	2850-2300	6 (26.2)	Phyllitic schists, basalt, concretionary ironstone, Mn crusts

8. DREDGE RESULTS

The dredging program was designed to elucidate geological history and to sample any Mn crusts in order to assess their economic potential. A chain bag dredge and two small pipe dredges were dragged up the slopes targeted. The dredge material was studied aboard ship in hand specimen, with the aid of sawn material and a few thin sections. It was then classified into various groups for each dredge haul before specialist sampling began. Each group in each dredge was assigned a letter, and individual samples were given a suffix in the form of a number; further subsamples were designated by another suffix in the form of letters. Thus a typical number for a subsample from group 3, from

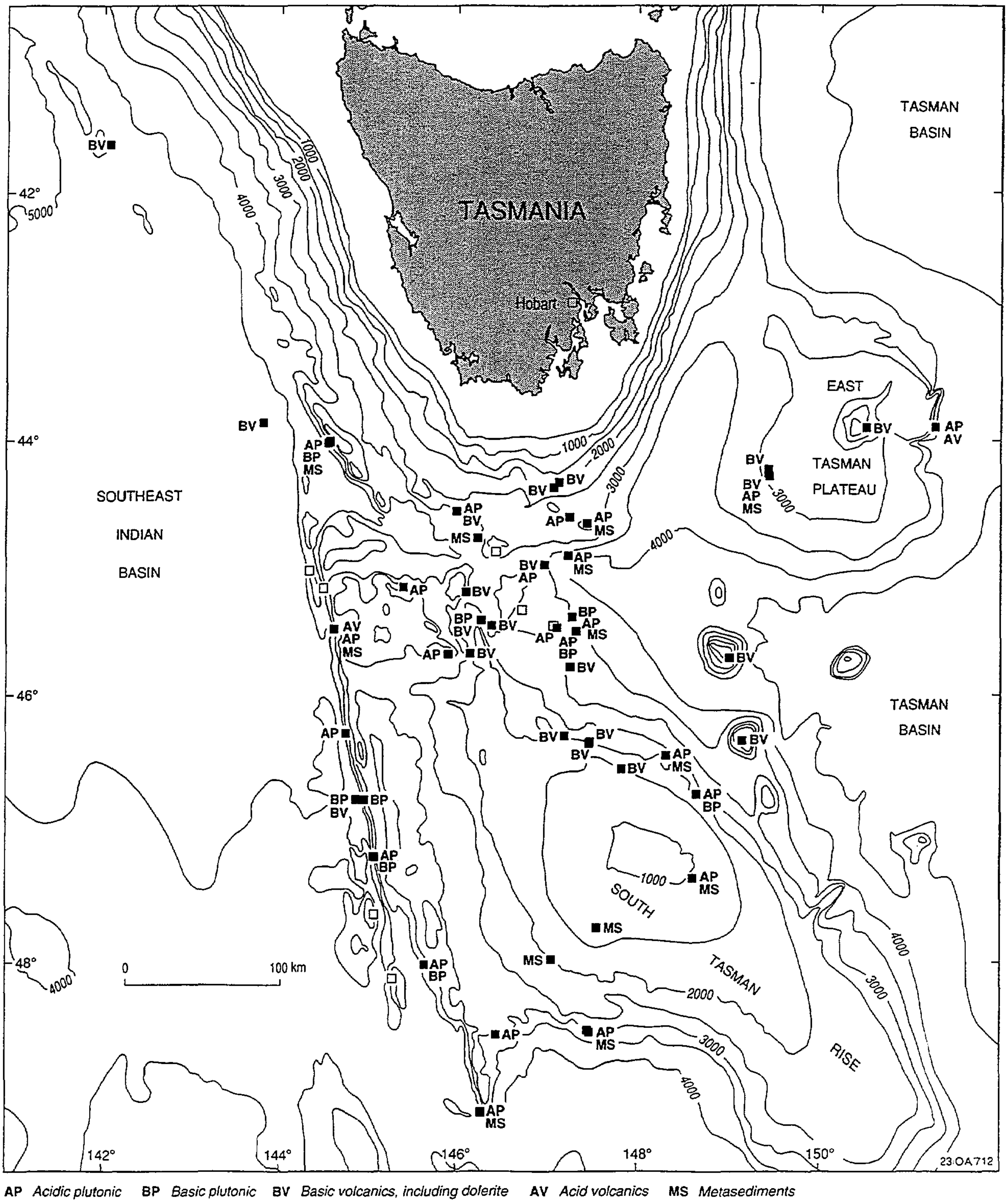


Figure 21. Bathymetric map of the study region showing distribution of AGSO Cruise 147 basement and volcanic rocks from dredge stations. Map based on *l'Atalante* swath-mapping and other data. AP = acid plutonic, BP = basic plutonic, BV = basic volcanics, AV = acid volcanics, MS = metasediments.

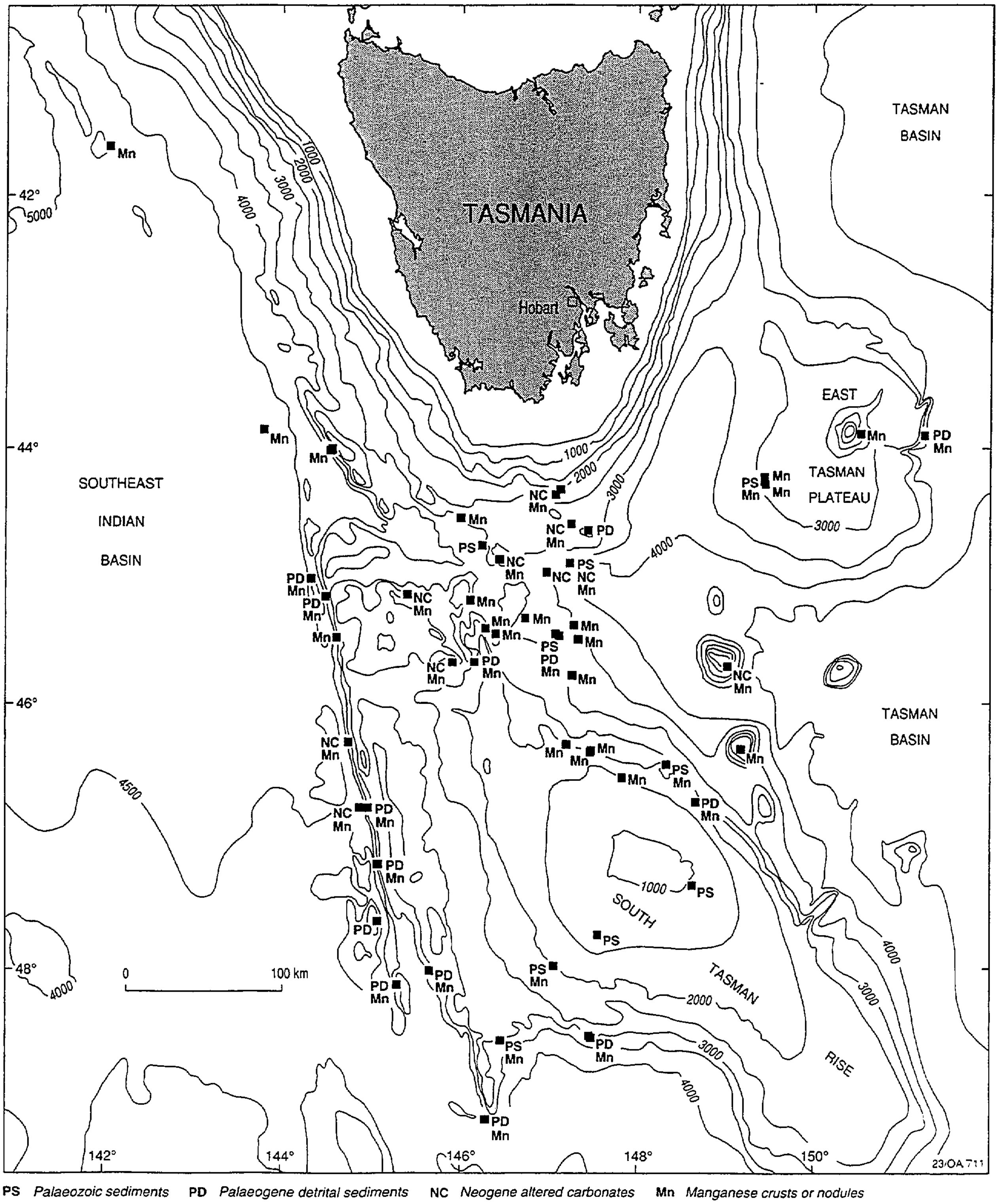


Figure 22. Bathymetric map of the study region showing distribution of AGSO Cruise 147 sedimentary rocks from dredge stations. Map based on *l'Atalante* swath-mapping and other data. PS = Palaeozoic sediments, PD = Paleogene detrital sediments, NC = Neogene silicified carbonates, Mn = manganese crusts and/or nodules.

dredge 2 might be 147/DR02/A2B. All the dredge results are summarised below in Table 15, the location and identification of all the dredges are shown in Figure 20, and the areal distribution of the various dredged rock types is shown in Figures 21 and 22. The descriptions have been modified to take account of post-cruise thin section examination.

Table 15: Dredge stations from AGSO Cruise 147 off Tasmania

Station, depth (m)	Latitude	Longitude	Notes (excludes modern sediments)
DR01 4800-4100	41°36.0'S 41°36.9'S	142°06.2'E 142°02.5'E	Aphanitic E-MORB pillow basalt with olivine pseudomorphs and glassy rims, Mn nodules and ?Eocene (forams) crusts on volcanic rise on abyssal plain west of Tasmania. *L'Atalante* profile 66
DR02 4250-4770	43°51.5'S 43°51.4'S	143°48'E 143°48.1'E	Largely aphanitic E-MORB pillow basalt with glassy rims, Mn nodules and crusts on abyssal cone southwest of Tasmania. *L'Atalante* profile 61
DR03 4400-3800	44°01.8'S 44°0.5'S	144°32.5'E 144°34.6'E	Ooze only from scarp SW of Tasmania.
DR04 4000-3000	44°0.8'S 44°0.7'S	144°34.0'S 144°34.4'E	Grey high and low temperature granite gneisses including garnetiferous gneiss, lesser schist, metasediments, metagabbro from 320° scarp SW of Tasmania.
DR05 3000-2300	44°0.5'S 44°0.2'S	144°34.5'E 144°35.4'E	Granite gneiss, quartz-mica schist, fault breccia, Mn crusts, lesser metasediment, metabasalt, phyllite from 320° scarp SW of Tasmania.
DR06 1400	44°19.7'S 44°19.5'S	147°7.2'E 147°7.1'E	Rare basalt pebbles, abundant modern corals and associated fauna from small volcano south of Tasmania. *L'Atalante* profile 20
DR07 1500-1100	44°22.7'S 44°22.7'S	147°6.1'E 147°6.5'E	Breccia of basalt & limestone clasts, vesicular basalt, Mn crusts, abundant modern corals and associated fauna from small volcano south of Tasmania. *L'Atalante* profile 21
DR08 3000-2450	45°12'S 45°12'S	146°07.4'E 146°05.8'E	Volcanic breccia, aphanitic vesicular alkali olivine basalt, and Mn crusts from large volcano on northern South Tasman Rise. *Sonne* profile 62
DR09 3300-2200	45°24.5'S 45°25.9'S	146°17.2'E 146°15.8'E	Metagabbro, diorite and ?metabasalt of greenschist facies, volcanic breccia, Mn crusts from 320° scarp on northern South Tasman Rise
DR10 2800-2100	45°41S 45°41'S	146°8.1'E 146°09.4'E	Moderately lithified yellowish feldspathic ?Eocene (forams) sandstone and olive bioturbated muddy siltstone, minor basaltic breccia and tuff, abundant Mn crusts from N-S anticline on northern South Tasman Rise. *L'Atalante* profile 31
DR11 2200-1940	45°41.3'S 45°40.6'S	145°54.25'E 145°54.25'E	Pink alkali granite, minor hornblende diorite, silicified late Oligocene to early Miocene (forams) bioclastic limestone, Mn-cemented polymictic conglomerate, abundant Mn crusts on 90° rotated block on northern South Tasman Rise. *Sonne* profile 62

DR12 3000- 2100	45°09.0'S 45°10.2'S	145°25.1'E 145°23.8'E	Quartz-mica schist, mica schist, feldspar schist, minor Cainozoic ?Eocene (forams) chert and conglomerate, abundant Mn crusts on 305° rotated block on northern South Tasman Rise. *Sonne* profile 49
DR13 3900- 2700	45°07.7'S 45°07.4'S	144°30.3'E 144°32.8'E	Olive muddy sandstone with ?Eocene arenaceous forams and Late Cretaceous to Early Tertiary sporomorphs, coarse quartzose sandstone, nodular sandstone with wood, minor hard cemented quartzose sandstone, chert and ferruginous breccia, abundant Mn nodules & crusts on main 345° scarp of western South Tasman Rise. *L'Atalante* profile 64
DR14 4400- 3800	45°02.2'S 45°02.2'S	144°19.2'E 144°20.8'E	Marine grayish, generally bioturbated silty mudstone with varves and Eocene radiolaria, diatoms, ?Eocene siliceous arenaceous forams, and late Eocene dinocysts; minor glass; abundant Mn nodules on outer westernmost 345° ridge of South Tasman Rise. *L'Atalante* profile 64
DR15 3400- 3000	45°29.3'S 45°29.2'S	144°36.8'E 144°37.1'E	Greenish grey leucodiorite, late Oligocene to early Miocene (forams) quartz-bearing silicified limestone, minor slate and vein quartz, abundant Mn crusts on main 345° scarp of western South Tasman Rise. *L'Atalante* profile 12
DR16 4250- 3700	46°17.5'S 46°17.5'S	144°44.7'E 144°45.9'E	Grey monzonitic granite, minor Cainozoic breccia of granite pebbles in siliceous matrix, abundant Mn crusts on main 345° scarp of western South Tasman Rise. *L'Atalante* profile 16
DR17 4500- 3400	46°47.4'S 46°47.4'S	144°47.4'S 144°58.1'E	Greenish grey pyroxene microgabbro and microgabbro, minor metabasalt at greenschist facies, ?Eocene (forams) volcanic breccia and grit with some radiolaria, Mn nodules and crusts on main 345° scarp of western South Tasman Rise. *Sonne* profile 62
DR18 3700- 3200	46°47.5'S 46°47.5'S	144°57.6'E 144°58.5'E	Brown laminated silty sandstone and siltstone with late Eocene dinocysts and ?Eocene arenaceous forams, mudstone conglomerate, olive microgabbro, abundant Mn crusts and nodules on main 345° scarp of western South Tasman Rise. *Sonne* profile 62
DR19 4200- 3300	47°13.0'S 47°13.0'S	145°3.8'E 145°5.5'E	Lost dredges, 7 tonne shear pin broke on main scarp of western South Tasman Rise. *L'Atalante* profile 4
DR20 3600- 3500	47°13.0'S 47°13.0'S	145°5.0'E 145°5.1'E	Grey granite gneiss/schist, grey mylonite gneiss, minor microgranite, yellowish bioturbated mudstone with ?Eocene arenaceous forams, ?radiolaria and ?diatoms, abundant Mn crusts on main 345° scarp of western South Tasman Rise. *L'Atalante* profile 4
DR21 3400	47°38.5'S	145°04.8'E	Soft olive bioturbated, possibly late Oligocene to early Miocene mudstone (forams) with radiolaria, lithified bioturbated olive mudstone with one planktonic foram on outer westernmost 345° ridge of South Tasman Rise. *L'Atalante* profile 6

DR22 3750-3350	48°01.4'S4 8°00.8'S	145°38.3'E 145°39.5'E	Pink feldspar porphyroblastic granite, feldspathic gneiss and pegmatite, grey amphibolite and microdiorite, minor olive claystone with fish teeth, moulds of ?Eocene arenaceous forams, and ?radiolaria, mudstone, arkose, common Mn nodules and crusts on linking 330° scarp of southwestern South Tasman Rise. *L'Atalante* profile 7
DR23 4600-3600	48°07.0'S4 8°07.0'S	145°15.2'E 145°19'E	Minor greenish grey mudstone, abundant Mn nodules from outer westernmost 345° ridge of southern South Tasman Rise. *L'Atalante* profile 5
DR24 2600-2250	48°32.0'S 48°31.3'S	146°27.0'E 146°27.0'E	Waterworn cobbles of metamorphosed grey sandstone and mudstone, minor foliated coarse pink feldspar granite, hornblende granite, conglomerate containing Mn nodules with ?Eocene arenaceous forams, abundant Mn crusts on south-facing 100° scarp within southwestern South Tasman Rise. *L'Atalante* profile 9
DR25 3300-2420	49°04.3'S4 9°04.0'S	146°16.0'E 146°17.4'E	Brown bioturbated mudstone with ?radiolaria, ?diatoms, ?Eocene arenaceous forams, metasediments, dominantly quartzose sandstone, minor grey granite and granite gneiss, very minor trachyte, abundant Mn crusts and nodules on main 345° scarp of southwestern South Tasman Rise. *L'Atalante* profile 6
DR26 2980-2600	48°29.9'S4 8°29.6'S	147°27.2'E 147°27.8'E	Ooze only on SW-facing scarp on southern South Tasman Rise. *L'Atalante* profile 15
DR27 3000-2700	48°30.8'S 48°30.6'S	147°28.2'E 147°28.6'E	Soft orange mudstone with ?radiolaria, ?diatoms and ?Eocene arenaceous forams, polymictic pebbly sandstone and conglomerate, minor granite, granodiorite, metasediments, Mn crusts on SW-facing 320° scarp on southern South Tasman Rise. *L'Atalante* profile 15
DR28 2100-1800	47°58.5'S4 7°58.6'S	147°03.25'E 147°03.4'E	?Palaeozoic polymictic conglomerate, foliated metasiltstone, minor schistose argillite, hard quartzose graywacke, abundant Mn crusts on west-facing 320° scarp on central South Tasman Rise
DR29 1170-1070	47°44.2'S4 7°44.6'S	147°33.7'E 147°32.8'E	?Palaeozoic siliceous polymictic conglomerate with rounded pebbles of quartz, metasediments, gneiss, pegmatite, diorite on 330° trending ridge on central South Tasman Rise. *L'Atalante* profile 30
DR30 900-800	47°22.7'S4 7°22.8'S	148°37.3'S 148°36.9'E	Granodiorite with zoned plagioclase phenocrysts, minor polymictic conglomerate; corals, barnacles etc. on 320° ridge on central South Tasman Rise. *L'Atalante* profile 35
DR31 2230-2080	46°45.4'S 46°45.0'S	148°40.0'E 148°39.5'E	Muddy bioturbated fine sandstone with planktonic forams, foliated and massive diorite, quartzite and vein quartz, Cainozoic polymictic conglomerate, Mn crusts in northern slope of canyon in 320° slope on northeast South Tasman Rise. *L'Atalante* profile 39

DR32 1600-1200	46°33.7'S 46°34.0'S	147°47.7'E 147°47.0'E	Weathered vesicular and non-vesicular picritic basalt, minor olivine bearing volcanics, Mn crusts on NE-facing 310° slope on northeast South Tasman Rise. *L'Atalante* profile 36
DR33 2350-2250	46°21.4'S 46°21.6'S	147°28.5'E 147°28.4'E	Few cobbles of weathered basalt, Mn crusts on NE-facing 320° slope on northeast South Tasman Rise. *L'Atalante* profile 35
DR34 2200-2100	46°21.9'S 46°22.2'S	147°28.2'E 147°28.1'E	Weathered picritic basalt, Mn crusts on NE-facing 320° slope on northeast South Tasman Rise. *L'Atalante* profile 35
DR35 2300-1950	46°18.6'S 46°19.1'S	147°12.2'E 147°11.4'E	Calcalkaline ?Tertiary alkaline dolerite, hyaloclastites with reaction rims around brown glass clasts averaging 1 cm in size, Mn crusts on NE-facing 300° slope on north South Tasman Rise. *L'Atalante* profile 34
DR36 2400-2350	46°27.7'S 46°28.1'S	148°19.7'E 148°19.3'E	Rounded Palaeozoic cobbles. Green metasediments, both fine sandstone and siltstone, Mn nodules and crusts, minor granite, vein quartz, polymictic conglomerate, red sandstone on NE-facing 300° slope on northeast South Tasman Rise. *L'Atalante* profile 39
DR37 2450-2200	46°21.3'S 46°21.2'S	149°08.2'E 149°10.1'E	Weathered vesicular picritic basalt, Mn crusts on seamount east of South Tasman Rise
DR38 2300-2050	45°43.0'S 45°43.0'S	149°00'E 149°01'E	Late Oligocene to early Miocene (forams) hyaloclastites of brown glassy clasts in creamy glass or silicified chalk matrix, fairly fresh vesicular alkali olivine basalt, minor silicified chalk, one cobble of quartz gneiss (ice rafted?), abundant Mn crusts on seamount east of South Tasman Rise
DR39 3150-2900	44°16.0'S 44°16.0'S	149°24.7'E 149°27.0'E	Mn crusts, minor pebbles of quartz sandstone, quartzite, quartz on western N-S scarp of East Tasman Plateau. *L'Atalante* profile 4
DR40 2950-2515	44°17.3'S 44°17.1'S	149°26.3'E 149°26.8'E	Hyaloclastites consisting of brown glass and vesicular basalt clasts in glass or silicified chalk matrix, minor alkali olivine basalt, metasediment, one cobble marble/amphibolite, abundant Mn crusts on volcanic cone on western 310° scarp of East Tasman Plateau. *L'Atalante* profile 4
DR41 2850	44°14.0'S	149°26.0'E	Quartzose ferricrete, Mn crusts on western N-S scarp of East Tasman Plateau. *L'Atalante* profile 4
DR42 1620-1280	43°54.0'S 43°54.1'S	150°34.1'E 150°33.0'E	Volcanic breccia/hyaloclastite with silicified chert matrix, fresh alkali olivine basalt, Mn crusts from Soela Seamount on central East Tasman Plateau. *L'Atalante* profile 3
DR43 3600-3030	43°54.0'S 43°54.0'S	151°19.2'E 151°17.8"E	Abundant Mn crusts, minor garnetiferous gneissic granite, flow-banded spherulitic rhyolite, black aphyric lava, olive mudstone and olive brown feldspathic sandstone on eastern N-S scarp of East Tasman Plateau. *L'Atalante* profile 3

DR44 2400-2250	44° 36.3'S 44° 36.0'S	147° 14.7'E 147° 14.8'E	Abundant granite gneiss, bioclastic limestone, Mn crusts and nodules, minor bedded Fe/Mn deposit on SSW-facing 300° scarp on southern Tasmanian margin.
DR45 2800-2600	44° 39.2'S 44° 39.5'S	147° 26.4'E 147° 26.5'E	Abundant granite, granite gneiss and schist, altered basalt or metasediment, pegmatite, minor Cainozoic conglomerate, siltstone, Mn crusts on northern slope of 300°-trending fault block on southern Tasmanian margin. *L'Atalante* profile 41
DR46 3500-3250	44° 55.0'S 44° 54.1'S	147° 14.1'E 147° 13.9'E	Abundant Mn crusts, minor hornblende-quartz schist, foliated muscovite quartzite, metasandstone, bioclastic limestone, pebbles of quartz, quartzite, conglomerate, chert etc. on south-facing E-W scarp on southern Tasmanian margin. *L'Atalante* profile 39
DR47 2650-2250	45° 23.2'S 45° 21.8'S	147° 16.5'E 147° 17.5'E	Abundant greenschist/amphibolite, minor garnetiferous biotite schist, bioclastic limestone, marble, pelitic schist, gabbro, quartzite, Mn crusts on southern slope of E-W rise in depression south of Tasmania.
DR48 2800-2720	45° 28.4'S 45° 27.5'S	147° 07.2'E 147° 07.8'E	Alkali granite, granite gneiss, mica schist, muddy sandstone with ?Eocene arenaceous forams, Mn crust and nodules on western slope of 300° block in depression south of Tasmania.
DR49 3170-2700	45° 27.8'S 45° 26.9'S	147° 04.3'E 147° 05.4'E	No recovery on SW-facing scarp in depression south of Tasmania. *L'Atalante* profile 37, *Sonne* profile 61. May not have reached bottom. Winch problems
DR50 3100-2950	45° 30.4'S 45° 31.4'S	147° 20.6'E 147° 20.3'E	Abundant Mn crusts and nodules, minor garnetiferous granite gneiss, gabbro, biotite granite, ribbon chert on north-facing E-W slope in depression south of Tasmania. *L'Atalante* profile 38, *Sonne* profile 61
DR51 3180-2500	45° 47.3'S 45° 46.0'S	147° 14.2'E 147° 14.0'E	Abundant vesicular alkali olivine basalt with altered glass, Mn crusts on south-facing E-W slope in depression south of Tasmania. *L'Atalante* profile 36
DR52	45° 38.0'S 45° 38.2'S	146° 25.0'E 146° 24.4'E	Basalt or metasediment, dolerite, conglomerate, Mn crusts on NNE-facing 345°-trending slope on northeast South Tasman Rise. *L'Atalante* profile 33
DR53 3000-2770	45° 21.8'S 45° 21.1'S	146° 43.2'E 146° 43.7'E	Mn crusts on SW-facing 310°-trending slope in depression south of Tasmania. *L'Atalante* profile 35
DR54 3050-2700	44° 58.2'S 44° 57.5'S	146° 57.8'E 146° 58.0'E	Abundant multiply deformed quartz chlorite schist to mylonite, dolerite, chert, muddy siltstone, minor argillite, ferruginized siltstone, silicified limestone on SW-facing 320°-trending slope in depression south of Tasmania. *L'Atalante* profile 38
DR55 2650-2400	44° 52.6'S 44° 52.2'S	146° 27.6'E 146° 27.6'E	Abundant Mn crusts, silicified fine grained limestone and limestone breccia on SW-facing slope on 320°-trending rise on southern Tasmanian margin. *L'Atalante* profile 36
DR56 3050-3000	44° 47.1'S 44° 47.3'S	146° 13.6'E 146° 13.3'E	Rounded pebbles of quartzite, fine grained metasediment or basalt, quartz-rich sandstone on SW-facing slope on 320°-trending rise on southern Tasmanian margin. *L'Atalante* profile 35

DR57 2850-2300	44° 32.8'S 44° 31.7'S	146° 00.4'E 146° 00.6'E	Abundant Mn crusts, phyllitic schists, concretionary ironstone, basalt on SSW-facing slope on E-W scarp on southern Tasmanian margin. *L'Atalante* profile 27

Note that lithotypes are arranged in order of abundance

Further information on selected sites is provided below, and this incorporates preliminary thin section studies by Nadege Rollet (Section 8.1 below) and Michele Elmes (Section 8.2 below), and Neville Exon (Sections 8.3 & 8.4 below; Appendix 4).

Station 147/DR/04

This station was located at the base of a tilted block with a trend of 130° which belongs to the south-west Tasmanian margin. The samples recovered are gneiss including garnetiferous gneiss (90% : DR/04/A1&A2), dark metamorphic rocks (DR/04/B1-B5), angular pebbles in the pipe dredges (DR/04/C) and yellowish grey foram ooze(DR/04/D).

Station 147/DR/05

This station was located at the top of the escarpment of DR/04. The samples include gneiss (55% : DR/04/A), schist (20% : DR/04/B-C), metasediment (5% : DR/04/D), metabasalt (1% : DR/04/E), actinolite chlorite phyllite (1% : DR/04/F), a breccia (10% : DR/04/G) and manganese crust (10%

Station 147/DR/09

This station was located on a NW South Tasman Rise escarpment aligned with the tilted block dredged at station DR/04-05. The samples recovered are gabbro (95% : DR/09/A1-A4; 2% : DR/09/B), metasomatic rock (1% : DR/09/C), leucodiorite (trace : DR/09/D), volcanic breccia (2% : DR/09/E), Mn crust (trace : DR/09/F).

Station 147/DR/10

This station was located on the northern South Tasman Rise, on an escarpment with a north-south trend. Rocks recovered include: coarse feldspathic sandstone (1% : DR/10/A), massive, poorly-sorted, immature with 40% feldspar, 40% quartz, 5% biotite, 15% grey yellow clay; muddy siltstone (3% : DR/10/B); olive green, bioturbated, poorly lithified and massive; feldspathic tuff (trace : DR/10/C); hard, weakly bedded, medium sand-sized grains; manganese-encrusted breccia (1% : DR/10/D); dark grey to black, composed of angular basalt fragments; manganese crust (95% : DR/10/E) 5 to 10 cm thick; and yellowish nannoforam ooze (DR/10/F).

Station 147/DR/11

This station was located on the escarpment of a rotated block situated on the northwestern side of the South Tasman Rise. The samples recovered are coarse alkali granite (15% : DR/11/A), diorite (5% : DR/11/B), variably silicified limestone (5% : DR/11/C), igneous rock clasts in coarse conglomerate (3% : DR/11/D); Mn crust to ~10 cm thick (72% : DR/11/E).

Station 147/DR/12

This station is located on the northernmost rotated block at the northeastern part of the South Tasman Rise. All the rocks recovered in this dredge are strongly foliated, and include mica schists (45% : DR/12/A); schist (trace : DR/12/B) with shear zones; mulitply-deformed schist (10% : DR/12/C) with syntectonic granite veins transecting biotite-rich layers; a quartz vein in feldspathic schist (1% : DR/12/D) ; fossiliferous silified fine-grained limestone (1% : DR/12/E); siliceous conglomerate with a pale yellow siliceous matrix (11% : DR/12/F); Mn crust ~6 cm thick (40% : DR/12/G) ; yellowish foram ooze, (DR/12/H).

Station 147/DR/13
This station was located on the northern extremity of the western escarpment of the South Tasman Rise, which follows the Tasman Fracture Zone. Most of the samples recovered are diverse non-calcareous sandstones (62% : DR/13/A-B-C-D), along with a ferruginous chert (1% : DR/13/E), and a breccia with siliceous cement (1% : DR/13/F), Mn crust (30% : DR/13/G), Mn nodules (1% : DR/13/H).

Station 147/DR/14
This station is located on the most northwestern offset of the Tasman Fracture Zone. The samples recovered are silty mudstone (49% : DR/14/A) with flat worm tubes parallel to bedding. Palynology reveals that they are late Eocene glacial sediments. One cobble (DR/14/A6) composed of light and dark varves shows an oblique lineation into which the worm tubes are flattened. Such sediments are typical of estuarine deposits subject to annual cycles, with the dark varves forming during reduced conditions. These sediments are similar to Palaeocene marine sediments found in New Zealand, on the east coast of the South Island. The Mn nodules (50% : DR/14/B) are from 5 to 10 cm diameter; also present are ooze with mudstone fragments (DR/14/C) and a very weathered glassy volcanic rock (1% : DR/14/D).

Station 147/DR/15
This station is located further south than Station 13 on the same escarpment. The samples recovered include a very weathered leucodiorite (30% : DR/15/A), greenschist facies leucodiorite (40% : DR/15/B), a light grey slate (trace : DR/15/C), a quartz vein (trace : DR/15/D), silicified limestone (trace : DR/15/E), and Mn crust ~10 cm thick (trace : DR/15/F).

Station 147/DR/16
This station is located still further south on the same Tasman Fracture Zone escarpment. The samples recovered are micrograntes (15% : DR/16/A), a breccia with a siliceous matrix (5% : DR/16/B), Mn crust (80% : DR/16/C), and yellowish nanno ooze (DR/16/D).

Station 147/DR/17
This station is located even further south on the Tasman Fracture Zone escarpment. The samples recovered are altered microgabbro (45% : DR/17/A), microgabbro (30% : DR/17/B-D), olivine gabbro (5% : DR/17/C), a volcanic breccia (15% : DR/17/E), and Mn crust and nodules (5% : DR/17/F).

Station 147/DR/18
This station is located at the same location as dredge DR/17, but at the top of the escarpment. The samples recovered are silty sandstone and siltstone (10% : DR/18/A), conglomerate (5% : DR/18/B), weathered microgabbro (5% : DR/18/C), Mn crust ~20 cm thick (75% : DR/18/D) and Mn nodules to 5 cm diameter (2% : DR/18/E).

Station 147/DR/20
This station is located on the souhern edge of the same Tasman Fracture Zone escarpment. The samples recovered include a quartz-biotite schists with quartz veining (40% : DR/20/A), mylonite-gneiss (10% : DR/20/B), monzonitic granite (10% : DR/20/C), dark microgabbro (5% : DR/20/D), weathered and bioturbated mudstone (5% : DR/20/E), and Mn crust and nodules (30% : DR/20/F).

Station 147/DR/21
This station is located on an elongated block situated slightly to the southwest of the main escarpment, with a similar trend. The samples recovered are semi-lithified to lithified, bioturbated, non-calcareous mudstone (DR/21/A-B).

Station 147/DR/22
The Tasman Fracture Zone is divided into at least two parallel segments. This station is located on the south-west South Tasman Rise, on an offset escarpment separating those two segments. The samples recovered are pink feldspar granite (40% : DR/22/A), gneissic granite (30% : DR/22/B), pink feldspar pegmatite (1% : DR/22/C), amphibolites and microdiorites (5% : DR/22/D), arkose (trace : DR/22/E), a buff coloured sandy mudstone with an arkosic composition in a silicified clay matrix (trace : DR/22/F), pale olive claystone (3% : DR/22/G), Mn nodules 5 -12 cm diameter and a variable core (granite, diorite, claystone) (10% : DR/22/H), and Mn crust up to 6 cm thick (10% : DR/22/I).

Station 147/DR/23
This station is located on a 160° trending elongated block aligned with the north Tasman Fracture Zone segment to the south. The samples recovered are small greenish grey mudstone fragments (1% : DR/23/C-D), numerous Mn nodules (99% : DR/23/A), and foram nanno ooze (DR/23/B).

Station 147/DR/24
This station is located on a small escarpment situated on the southwest flank of the South Tasman Rise. This escarpment has a similar offset escarpment trend to that on which dredge DR/22 was taken. The samples recovered include pink feldspar granite similar to that in DR/22/A (5% : DR/24/A), hornblende granite (5% : DR/24/B), greenish metasandstone/mudstone (40% : DR/24/C), biotite granodiorite (trace : DR/24/D), silicified conglomerate (trace : DR/24/E), and Mn crust up to 5 cm thick (50% : DR/24/F).

Station 147/DR/25
This station is located on the southern Tasman Fracture Zone segment. The samples recovered are deformed granite, with sightly stretched quartz (2% : DR/25/A); green granitic gneiss (trace : DR/25/B); metasandstone (10% : DR/25/C-D); and very minor trachyte (DR/25/G)

Station 147/DR/26
This station is located on the southwestern side of the South Tasman Rise. The samples recovered in the pipe dredge are yellowish-grey clastic foram-nanno ooze.

Station 147/DR/27
This station is situated at the same location as dredge DR/26. The samples recovered include granite (18% : DR/27/A), metasediment (2% : DR/27/B), conglomerate with a ferruginous matrix (80% : DR/27/C), Mn encrustations (DR/27/D), and foram nanno ooze (DR/27/E).

Station 147/DR/28
This station is located on a north-south trending escarpment situated on the southwest side of the rise. The samples recovered are conglomerate (30% : DR/28/B), olive to light brown metasiltstone (14% : DR/28/C), argillite (5% : DR/28/D), sandstone (1% : DR/28/G), Mn crust ~2 - 4 cm thick (50% : DR/28/A), pink grey nanno-foram ooze (DR/28/E), light orange calcareous infilling of fractures in Mn encrustations (DR/28/F).

Station 147/DR/29
This station is located on the west side of the South Tasman Rise close to its top. The samples recovered include siliceous polymict conglomerate (DR/29/A), and yellowish grey foram sand in the pipe dredge (DR/29/B).

Station 147/DR/30
This station is located on the east side of the South Tasman Rise, close to it's top. The samples recovered are granodiorite (95% : DR/30/A), and a conglomerate containing clasts of granite and metamorphic rocks (5% : DR/30/B).

Station 147/DR/31
This station is located on the west side of the South Tasman Rise close to its top. The samples recovered are feldspathic diorite (15% : DR/31/A), vein quartz (2% : DR/31/B), schistose diorite (10% : DR/31/C), foliated microgranite (35% : DR/31/D), polymict conglomerate (10% : DR/31/E), yellow-brown highly bioturbated muddy fine sandstone, (20% : DR/31/F), Mn crust up to 2 cm thick (10% : DR/31/G), grey foram sand (DR/31/H). The diorite and the microgranite are of types that are widespread in Tasmania.

Station 147/DR/36
This station is located on the east side of the South Tasman Rise close to the top. The samples recovered are granite (2% : DR/36/A), greenish grey metasediment (60% : DR/36/B), vein quartz (5% : DR/36/C), red purple to grey ferruginous sandstone (similar to Beacon Group redbeds in Antarctica (trace : DR/36/D), fine metasandstone (trace : DR/36/E), dark quartzite (trace : DR/36/F), purple grey metasediment with some reddish detrital quartz grains (trace : DR/36/G), conglomerate made of siltstone fragments in a sandy matrix (3% : DR/36/H), Mn crust up to 2 cm thick (20% : DR/36/I), Mn nodules with variable nucleii (siltstone, chert, porphyry, basalt) (10% : DR/36/J).

Station 147/DR/38
This station is located high on a seamount in the depression between the South Tasman Rise and the East Tasman Plateau. The samples recovered are weathered vesicular basalt (20% : DR/38/A), hyaloclastite (30% : DR/38/B), silicified chalk (5% : DR/38/C), Mn crusts (45% : DR/38/D), recent calcareous sediments (abundant : DR/38/E-F), and a cobble of quartz gneiss assumed to be ice-rafted (DR/38/G).

Station 147/DR/39
This station was located on the southwest side of the East Tasman Plateau. The samples recovered are brown quartzose siltstone (trace : DR/39/C), quartzite (trace : DR/39/D), quartz (trace : DR/39/E), Mn crust up to 10 cm thick (100 : DR/39/A) and yellowish grey foram-nanno ooze in the pipe dredge (DR/39/B).

Station 147/DR/40
This station was situated at the same location as dredge DR/39 on the East Tasman Plateau, but at a shallower depth. The samples recovered are hyaloclastite, with glassy basaltic clasts in an orange grey silicified ooze matrix (20% : DR/40/B), vesicular basalt (trace : DR/40/C), granitic gneiss/marble (trace : DR/40/D), dark grey metasediment (trace: DR/40/E), Mn crust up to 10 cm thick (80% : DR/40/A).

Station 147/DR/41
This station was also situated at the same general location as dredge DR/39 and DR/40 on the southwestern side of the East Tasman Plateau. The samples recovered are ferricrete (70% : DR/41/A), Mn crust up to 3 cm thick massive (30% : DR/41/B), and yellowish grey foram ooze (DR/41/C).

Station 147/DR/42
This station was on the slope of Soela Seamount on the crest of the South Tasman Rise. The samples recovered are volcanic breccia/hyaloclastite (65% : DR/42/A), basalt (25% : DR/42/B) and Mn crusts up to 4 cm thick (10% : DR/42/C).

Station 147/DR/43
This station was located on the eastern slope of the East Tasman Plateau. The samples recovered are gneissic granite (2% : DR/43/A), rhyolite (5% : DR/43/B-G), Tertiary trachybasalt (5% : DR/43/C), labile sandstone (3% : DR/43/D).

Station 147/DR/44
This station is located on an ESE trending fault block on the southern Tasmanian margin. The samples recovered are granitic gneiss (30% : DR/44/A), orange-grey shelly limestone (30% : DR/44/B), interbedded Mn/Fe deposits up to 4 cm thick (5% : DR/44/C), Mn crust up to 4 cm thick and also agglomerated Mn nodules (35% : DR/44/D) with composite nucleii including metasediment, shale, microconglomerate.

Station 147/DR/45
This station is located on the southern slope of an ESE trending fault block on the southern Tasmanian margin. The samples recovered are granitic gneiss (25% : DR/45/A-B); basalt (50% : DR/45/C1) and dolerite (DR/45/C2) of presumed Tertiary age, green yellow metasediment (5% : DR/45/D), yellow to yellow brown moderately clay-altered felsic pegmatite (10% : DR/45/E), volcanic fragments and metasediment conglomerate with a sandy clay matrix (4% : DR/45/F), orange grey siltstone (1% : DR/45/G), Mn crust up to 6 cm thick (5% : DR/45/H).

Station 147/DR/46
This station was located on the southern Tasmanian margin, on an the northern slope of an east-west trending escarpment. Samples recovered are hornblende-quartz schist (5% : DR/46/A), muscovite quartzite (trace : DR/46/B), breccia (trace : DR/46/C), light olive grey fine metasandstone rich in quartz (trace : DR/46/F), Mn crust up to 15 cm thick (95% : DR/46/D), Mn nodules (trace : DR/46/E).

Station 147/DR/47
This station was located on a rotated block situated on the northeastern side of the South Tasman Rise, close to the depression between the rise and the East Tasman Plateau. The samples recovered are greenschist to amphibolite facies metamorphosed ultramafic rocks (70% : DR/47/A), pelitic metasediment (trace : DR/47/B), quartzite (trace : DR/47/C), quartz-bioite pelitic sediment (5% : DR/47/D), marble (1% : DR/47/E), coarse bioclastic limestone (3% : DR/47/F), gabbro (trace : DR/47/G), and Mn crust up to 4 cm thick and Mn nodules (10% : DR/47/H).

Station 147/DR/48
This station was located a NW trending block southwest of the previous dredge. The samples recovered are alkali granites (35% : DR/48/A-B) which may be Devonian, hornblende-biotite schist

(5% : DR/48/C), light olive muddy sandstone (30% : DR/48/D), Mn crust up to 5 cm thick (20% : DR/48/E), and Mn nodules (10% : DR/48/F).

Station 147/DR/50
This station was located on an east-west block south of DR/47. Samples recovered are garnet-bearing granite-gneiss (5% : DR/50/A), Tertiary(?) gabbro (10% : DR/50/B), Paleozoic biotite granite (2% : DR/50/C), red ribbon chert (1% : DR/50/D), Mn crust up to 4 cm thick and Mn nodules (80% : DR/50/E), foram sand in the pipe dredge (DR/50/F).

Station 147/DR/52
This station was located on the northeast side of the South Tasman Rise, south of dredge DR/09, on the same east-facing and NNW trending escarpment. The samples recovered are greenish grey vesicular basalt (5% : DR/52/A), olive greenish grey sandstone (5% : DR/52/B), basalt (10% : DR/52/C), polymict conglomerate with a sandy to silicified clay matrix (5% : DR/52/D), Mn crust up to 10 cm thick (75% : DR/52/E).

Station 147/DR/53
This station was located on an block elongated along 130°, on the northeast side of the South Tasman Rise. No hard rocks were recovered, only Mn crust up to 10 cm thick, and yellowish grey foram-nanno ooze in the pipe dredge.

Station 147/DR/54
This station was located on a rise on the southernmost part of the Tasmanian margin. Samples recovered include dolerite (45% : DR/54/A1), multiply-deformed quartz-chlorite schist to mylonite (DR/54/A3); chert (30% : DR/54/B), greenish grey muddy siltstone (25% : DR/54/C), silicified limestone (trace).

Station 147/DR/55
This station is located on a broad rounded rise situated on the southern Tasmanian margin. The dredge did not yield hard rocks but various siliceous limestones (30% : DR/55/B), and Mn crust (70% : DR/55/A), with foram sand in the pipe dredge.

Station 147/DR/56
This station was located on a 130°-trending, SW facing escarpment northwest of DR/54. Numerous rounded pebbles of diverse origin, including quartzite, metasediment, sandstone (DR/56/A-B-C) and pale grey foram-nanno ooze were recovered from the pipe dredge (DR/56/D).

Station 147/DR/57
This station was located on the major east-west escarpment on the southern Tasman margin. The samples recovered are yellowish schist (30% : DR/57/A), brown olive basalt (10%: DR/57/B), ferruginous concretion rock (20% : DR/57/C), and Mn crust (40% : DR/57/D).

8.1. Basement rocks

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Fifty-seven dredge stations were occupied on the South Tasman Rise and on the East Tasman Plateau (Fig. 20); of these, two were empty, six had only young sedimentary rocks, and forty-five yielded hard rock material (Figs. 21 & 22). Most stations also yielded manganese crust (usually 5-6 cm thick) and many yielded manganese nodules (Fig. 22), and recent foram-nannofossil ooze was present in almost all the pipe dredges. A summary of dredging results is presented in Table 15. Notes on basement rocks from individual stations are provided below. Where the notes are expanded, they are on the basis of preliminary thin section examination.

Station 147/DR/04
This station was located at the base of a 320°-trending tilted block on the south-west Tasmanian margin. Basement samples recovered are gneiss (DR/04/A: 90% of total dredge haul), and dark metamorphic rocks (DR/04/B: 10%).

Sample type DR/04/A1 is a gneiss with quartz porphyroblasts to 1.5cm diameter in a grey matrix. It contains foliated muscovite, and also garnet. The metamorphic assemblage suggests a high metamorphic grade, with temperature at least 600°C. This metamorphic grade contrasts with that of other, lower-grade metamorphic rocks recovered in the same dredge.

Sample type DR/04/A2 is also a gneiss but less deformed, and with more quartz porphyroblasts (50%). The thin section shows quartz, alkali feldspar, plagioclase, biotite, and muscovite, a low greenschist facies (300°C) metamorphic assemblage.

Sample type DR/04/B1-B3 is syntectonic mylonite metamorphosed in the low greenschist facies. Such rocks are unknown in Tasmania (R. Berry, pers. comm. 1994).

Sample type DR/04/B2 is a metagabbro with plagioclase, amphiboles and garnet; it has been metamorphosed in the upper amphibolite to granulite facies. This amphibolite is similar to those on King Island, or at Nye Bay on the SW coast of Tasmania.

Sample type DR/04/B4 is a very weathered carbonated and chloritized metagabbro.

Sample type DR/04/B5 is a sillimanite gneiss with quartz, plagioclase, biotite, garnet and sillimanite; it has been metamorphosed in the amphibolite facies and shows strong retrograde alteration. This amphibolite can be compared with those at Nye Bay, although the former are more retrograded.

Station 147/DR/05
This station was located at the top of the same 320°-trending escarpment as DR/04. Basement samples include gneiss (55% : DR/05/A), schist (20% : DR/05/B-C), metasediment (5% : DR/05/D), metabasalt (1% : DR/05/E), actinolite chlorite phyllite (1% : DR/05/F).

Station 147/DR/09
This station was located on a 320°-trending NW South Tasman Rise escarpment. Basement samples recovered are gabbro (95% : DR/09/A1-A4; 2% : DR/09/B), metasomatic rock (1% : DR/09/C), leucodiorite (trace : DR/09/D).

Sample type DR/09/A1 is rock dominated by calcic amphiboles, and is derived from a clinopyroxene-rich metagabbro or clinopyroxenite by greenschist facies metamorphism.

Sample type DR/09/A2-A3-A4 is an amphibolitized gabbro in which pyroxenes have been replaced by dark green hornblende. Quartz and chlorite are subordinate minerals. This rock recrystallized at high greenchist facies or low amphibolite facies conditions.

Sample type DR/09/C is a quartz-epidote metasomatic rock probably derived by intense fluid activity in metabasalts in a fault zone.

Station 147/DR/11
This station was located on the escarpment of a 90°-trending rotated block on the northwestern South Tasman Rise. Basement samples recovered are coarse alkali granite (15% : DR/11/A), diorite (5% : DR/11/B).

Samples DR/11/A1-A2-A3 are granites composed of 60% weathered feldspars, 20% quartz, 5% plagioclases, 15% biotite. They look in hand specimen identical to typical Tasmanian Upper Devonian granites.

Station 147/DR/12
This station is located on the northernmost 305°-trending rotated block on the South Tasman Rise. All the rocks recovered in this dredge are strongly foliated, and include mica schists (45% : DR/12/A); schist (trace : DR/12/B) with shear zones; mulitply-deformed schist (10% : DR/12/C) with syntectonic granite veins transecting biotite-rich layers; and a quartz vein in feldspathic schist (1% : DR/12/D).

Station 147/DR/15
This station is located on the western 345°-trending escarpment of the South Tasman Rise. The basement samples recovered include a very weathered quartz arkosic sandstone or a microgranite (30% : DR/15/A), greenschist facies metadolerite/leucodiorite (40% : DR/15/B), a light grey slate (trace : DR/15/C), a quartz vein (trace : DR/15/D).

Station 147/DR/16
This station is located still further south on the same western 345°-trending escarpment. The basement samples recovered are microgranites (15% : DR/16/A).

Station 147/DR/17
This station is located even further south on the western 345°-trending escarpment. The basement samples recovered are dolerite/microgabbro (45% : DR/17/A), basalt (30% : DR/17/B-D), olivine gabbro (5% : DR/17/C).

Sample type DR/17/B1 is very weathered alkali olivine basalt with pink titanaugite, and can be correlated with Tertiary basalts in SE Australia.

Sample type DR/17/B3 is a more altered version of the same rock, metamorphosed to low greenschist facies, perhaps associated with fluid movement along the Tasman Fault Zone.

Sample type DR/17/D4 is a basalt metamorphosed in the prehnite-pumpellyite facies.

Station 147/DR/18
This station is located at the same location on the western 345°-trending escarpment as dredge DR/17, but at the top of the escarpment. The basement samples recovered are weathered microgabbro (5% : DR/18/C).

Station 147/DR/20
This station is located on the southern end of the western 345°-trending escarpment. The basement samples recovered include quartz-biotite schist with quartz veining (40% : DR/20/A), mylonite-

gneiss (10% : DR/20/B), monzonitic granite (10% : DR/20/C), dark tonalite/microdiorite (5% : DR/20/D).

Station 147/DR/22
The Tasman Fracture Zone is divided into at least two parallel segments. This station is located on the south-west South Tasman Rise, on an offset 330°-trending escarpment separating those two segments. The basement samples recovered are pink feldspar granite (40% : DR/22/A), gneissic granite (30% : DR/22/B), pink feldspar pegmatite (1% : DR/22/C), amphibolites and microdiorites (5% : DR/22/D).

Sample type DR/22/A is a granite similar to the Devonian Tasmanian granites.

Sample type DR/22/B is a feldspathic gneiss unlike any found in Tasmania.

Sample type DR/22/D1 is an amphibolite.

Sample type DR/22/D2 is a highly deformed and retrograded amphibolite with biotite, hornblende, chlorite, sericite, and quartz.

Sample type DR/22/D3 is similar to the preceding rock but has more quartz. It may be a xenolith in granodiorite.

Sample type DR/22/D4 is a microdiorite.

Station 147/DR/24
This station is located on a small 100°-trending escarpment situated on the southwest flank of the South Tasman Rise. This escarpment has a similar offset escarpment trend to that on which dredge DR/22 was taken.
The basement samples recovered include pink feldspar granite similar to that in DR/22/A (5% : DR/24/A), hornblende granite (5% : DR/24/B), greenish metasandstone/mudstone (40% : DR/24/C), biotite granodiorite (trace : DR/24/D).

Station 147/DR/25
This station is located on the southern 345°-trending Tasman Fracture Zone segment, offset 50 km to the east from the main scarp. The basement samples recovered are deformed granite, with slightly stretched quartz (2% : DR/25/A); green granitic gneiss (trace : DR/25/B); metasandstone (10%), and trachyte (trace: DR/25G)/

Station 147/DR/27
This station is located on a 320°-trending scarp on the southwestern side of the South Tasman Rise. The basement samples recovered include granite (18% : DR/27/A), and metasediment (2% : DR/27/B).

Station 147/DR/28
This station is located on a 320°-trending escarpment situated on the southwest side of the rise. The basement samples recovered are conglomerate (30% : DR/28/B), olive to light brown metasiltstone (14% : DR/28/C), and argillite (5% : DR/28/D).

Sample type DR/28/C1 is a recrystallized quartz-feldspar-muscovite metasiltstone with chlorite on cleavages.

Sample type DR/28/D1 is a weakly metamorphosed quartz-feldspar-muscovite graywacke. This rock can be compared with Silurian-Devonian rocks in Tasmania, although the latter are usually more deformed.

Station 147/DR/29
This station is located on 330°-trending ridge on the west side of the South Tasman Rise close to its top. The basement samples recovered are siliceous polymict conglomerate (100%: DR/29/A).

Station 147/DR/30
This station is located on a 320°-trending ridge the east side of the South Tasman Rise, close to its top. The basement samples recovered are granodiorite (95% : DR/30/A), and a conglomerate containing clasts of granite and metamorphic rocks (5% : DR/30/B).

Station 147/DR/31
This station is located on the 320°-trending northeast side of the South Tasman Rise close to its top. The basement samples recovered are feldspathic diorite (15% : DR/31/A), vein quartz (2% : DR/31/B), schistose diorite (10% : DR/31/C), foliated microgranite (35% : DR/31/D), polymict conglomerate (10% : DR/31/E). The diorite and the microgranite are of types that are widespread in Tasmania.

Station 147/DR/36
This station is located on a 300°-trending slope on the northeast side of the South Tasman Rise close to the top. The basement samples recovered are granite (2% : DR/36/A), greenish grey metasediment (60% : DR/36/B), vein quartz (5% : DR/36/C), red purple to grey ferruginous sandstone (similar to Beacon Group redbeds in Antarctica (trace : DR/36/D), fine metasandstone (trace : DR/36/E), dark quartzite (trace : DR/36/F), purple grey metasediment with some reddish detrital quartz grains (trace : DR/36/G).

Station 147/DR/38
This station was located on a seamount in the depression between the South Tasman Riseand the East Tasman Plateau. One cobble recovered is a granulitic feldspathic gneiss (1% : DR/38/G) with garnets, some reddish quartz and biotite aggregates in layers at a centimetre scale. This rock type is unknown in Tasmania. It may be ice-rafted.

Station 147/DR/39
This station was located on a 0°-trending scarp on the southwest side of the East Tasman Plateau. The basement samples recovered are pebbles of brown quartzose fine sandstone to siltstone (trace : DR/39/C), quartzite (trace : DR/39/D), and quartz (trace : DR/39/E).

Station 147/DR/40
This station was situated on a 310°-trending scarp just south of dredge DR/39 on the East Tasman Plateau, but at a shallower depth. The basement samples recovered are granitic gneiss/marble (trace : DR/40/D), and dark grey metasediment (trace: DR/40/E).

Sample type DR/40/D1 is a high grade marble with occasional blueish amphiboles. This rock is unknown in Tasmania.

Station 147/DR/43
This station was located on a 0°-trending scarp on the eastern margin of the East Tasman Plateau. The basement samples recovered are garnetiferous gneissic granite (2% : DR/43/A).

Station 147/DR/44
This station is located on a 300°-trending fault block on the southern Tasmanian margin. The basement samples recovered are granitic gneiss (30% : DR/44/A), and composite nucleii in Mn nodules (35% : DR/44/D) of metasediment, shale, microconglomerate.

Sample type DR/44/A1 is a very weathered quartz-albite-muscovite granite which is similar to the Devonian granites in Tasmania.

Station 147/DR/45
This station is located on the northern slope of a 300°-trending fault block on the southern Tasmanian margin. The basement samples recovered are granitic gneiss (25% : DR/45/A-B), green yellow metasediment (5% : DR/45/D), yellow to yellow brown moderately clay-altered felsic pegmatite (10% : DR/45/E).

Sample type DR/45/A1 is a deformed quartz-feldspar-biotite granite. A gradation in the intensity of deformation exists from granite/gneiss (DR/45/B1) to a mylonitised granite (DR/45/A1), to schists (DR/45/A2), and finally to (DR/45/B2) which is the most deformed of this series.

Station 147/DR/46
This station was located on the southern Tasmanian margin, on the southern slope of an east-west trending escarpment. Basement samples recovered are hornblende-quartz schist (5% : DR/46/A), muscovite quartzite (trace : DR/46/B), breccia (trace : DR/46/C), light olive grey fine metasandstone rich in quartz (trace : DR/46/F).

Station 147/DR/47
This station was situated on the southern slope of an east-west trending block on the northeastern side of the South Tasman Rise, close to the depression between the rise and the East Tasman Plateau. The basement samples recovered are greenschist to amphibolite facies metamorphosed ultramafic rocks (70% : DR/47/A), pelitic metasediment (trace : DR/47/B), quartzite (trace : DR/47/C), quartz-bioite pelitic sediment (5% : DR/47/D), marble (1% : DR/47/E), gabbro (trace : DR/47/G).

Sample type DR/47/A1-A8 is a very deformed, metasomatised greenschist with abundant epidote (feldspar-epidote).

Sample type DR/47/A7 is an amphibolite.

Sample type DR/47/B1 is a greenschist with the assemblage quartz-tremolite/actinolite-chlorite-epidote-carbonate-secondary sphene.

Sample type DR/47/D1 is a pelitic schist very similar to those in the Precambrian of SW Tasmania.

Sample type DR/47/G1 is a gabbro metamorphosed in mid-amphibolite facies, similar to rocks in the Port Davey region.

Station 147/DR/48
This station was located on the western slope of a 300°-trending block southwest of the previous dredge. The basement samples recovered are alkali granites (35% : DR/48/A-B) which may be Devonian, hornblende-biotite schist (5% : DR/48/C).

Station 147/DR/50
This station was located on the northern slope of an east-west trending block south of DR/47. Basement samples recovered are garnet-bearing granite-gneiss (5% : DR/50/A), Tertiary(?) gabbro (10% : DR/50/B), Paleozoic biotite granite (2% : DR/50/C), red ribbon chert (1% : DR/50/D).

Sample type DR/50/A1 is garnet-biotite-quartz granite-gneiss, similar to that from the East Tasman Plateau (DR/43/A1).

Station 147/DR/52
This station was located on a 345°-trending, east-facing scarp on the northeast side of the South Tasman Rise, on the same east-facing slope on which dredge DR/09 was located further north. The basement samples recovered are polymict conglomerate with a sandy to silicified clay matrix (5% : DR/52/D).

Station 147/DR/54
This station was located on a SW-facing, 320°-trending rise on the southernmost part of the Tasmanian margin. Basement samples recovered include multiply-deformed quartz-chlorite schist to mylonite (DR/54/A3); chert (30% : DR/54/B).

Station 147/DR/56
This station was located on a 310°-trending, SW facing escarpment northwest of DR/54. Numerous rounded basement pebbles of diverse origin, include quartzite, metasediment, sandstone (DR/56/A-B-C).

Station 147/DR/57
This station was located on the major east-west trending, SSW-facing escarpment on the southern Tasman margin. The basement samples recovered are yellowish schist (30% : DR/57/A), brown olive metasandstone (10%: DR/57/B).

Summary

The samples dredged on the South Tasman Rise confirm its continental origin. The East Tasman Plateau now has a confirmed continental origin, and is capped by a Tertiary volcanic cone (Soela Seamount). An important result of these dredge data is the strong similarity between garnetiferous, high-pressure gneissic basement rocks from the East Tasman Plateau (DR/43), the deepwater scarp off southwestern Tasmania (DR/04), and the deepwater northeastern South Tasman Rise (DR/50). This result provides a constraint for plate kinematic models.

The South Tasman Rise is limited on its western side by a steep escarpment which corresponds to the Tasman Fracture Zone. It is composed mainly of granitic and pelitic metamorphic rocks at stations DR/16, DR/20, DR/22 and DR/24. However, some microgabbros, dolerites, basalts and breccias were dredged at stations DR/17 and DR/18. These possible slices of oceanic crust may have been emplaced during strike-slip motion along this escarpment.

The N130°E trending escarpment, situated at 43.5°S to 44.5°S latitude and 144°E to 145.5°E longitude, on the southwest Tasmanian margin, exhibits highly mylonitised acid rocks and amphibolites at stations DR/04 and DR/05, possibly formed during crustal thinning in the early rifting stage.

A strong deformation is recorded along the southern Tasmanian margin at stations DR/44, DR/45, DR/46, DR/54 and DR/57, as well as on the northeast South Tasman Rise at stations DR/47, DR/48 and DR/50. In these dredges, some rocks are mylonitised, and others are higly metamorphosed (greenschist to amphibolite facies).

On the northwestern South Tasman Rise, strong deformation is recorded in rocks dredged from the rotated fault block at station DR/12. The blocks are located at the hinge between three principal directions : the N130°E trend outlined by the deep tilted block on the southwest Tasmanian margin, the N160°E trend expressed by the Tasman Fracture Zone, and the east-west strike-slip scarp separating the south Tasmanian margin from the South Tasman Rise. In this region, at least two deformation phases related to the rifting are recorded by the rock samples. This junction area is also the site of a big volcano dredged at station DR/08.

8.2. Volcanic and volcaniclastic rocks

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Described below are a selection of volcanic and volcaniclastic rocks (locations in Figures 20 & 21), making use of thin sections. More general descriptions of these and other volcanics are given in Table 15 and the section following that table. A more mature discussion of these rocks has been recently completed and is included in Elmes (1995).

DR01 : Samples were collected along a 330°-trending volcanic rise on the abyssal plain to the west of Tasmania between 41°36.0'S, 142°06.2'E and 41°36.9' S, 142°02.5'E. Water depths along the slope varied between 4800 and 4100 metres. The recovered samples are fragments of pillow basalts with preserved pillow rim glass. Small radial fractures have acted as fluid conduits and resulted in a core of altered material with a thin (<2 cm) outer rim of relatively unaltered material, including fresh, datable glass. Phenocrysts of olivine and feldspar increase in size and proportion inwards from the rim. This basalt possibly represents the oceanic crust of a small seamount on a fracture zone. Preliminary microprobe analyses of the glass show an E-(enriched) MORB composition.

DR02 : This site is located on a small abyssal hill west of the northernmost South Tasman Rise, between 43°51.5'S, 143°48'E and 43°51.4'S, 143°48.1'E, in water depths similar to DR01 (4770-4250m). The predominant rock-type is a vesicular olivine basalt. Vesicles range in size from micro-vesicles, observable only with a hand lens, to 5mm diameter. Olivine phenocrysts are not preserved, but are represented only by red alteration products after anhedral crystals <2mm diameter. Pillow lava fragments contain some fresh pillow-rim glass, and as for DR01, the glass has E-MORB affinities.

DR07 : This is located on a seamount cluster 100 km south of Hobart. This cluster contains approximately 80 volcanoes, each around 200-400 metres high; it forms an important fishing ground. Samples were dredged from the side of a small seamount between 44°27.7'S, 147°4.1'E and 44°22.7'S, 147°5.2'E in water depths of 1500-1100 metres.

The most abundant rock type is a volcaniclastic sediment composed of weathered volcanic fragments up to 5 cm in diameter, with rare pumiceous material. The clasts are highly rounded and oxidised, indicating a high degree of weathering prior to lithification in the host sediment. Limestone clasts are common and dominantly fine-grained, suggestive of formation in deepwater conditions. The sediment matrix, predominantly calcareous ooze, also contains mollusc, barnacle, bamboo coral and bryozoan fragments. Minor amounts of vesicular basalt were also recovered. These are relatively unweathered, with large feldspar phenocrysts preserved. Olivine phenocrysts are rare and apparently altered.

DR08 : Samples were recovered by dredging east to west up the slope of a volcanic rise between 45°12.0'S, 146°07.4'E and 45°12.0'S, 146°05.8'E. Water depths varied from 3000 to 2450 metres. Volcaniclastic sediment was the dominant rock type collected. Clasts are angular-subangular fragments of vesicular basalt, up to 2 cm diameter, in a siliceous matrix. The fragments are typically oxidised with poor preservation of phenocrysts, although isolated clasts of unweathered material are common. In hand specimen the samples exhibit crude grading. Vesicular alkali olivine basalts were also collected from this site. Olivine phenocrysts are not preserved and zeolitic infilling of vesicles is
common.

DR09 : Dredging was done up a 320°-trending and NE-facing scarp between 45°24.5'S, 146°17.2'E and 45°25.9'S, 146°15.8'E. Depths vary between 3300 and 2200 metres. Recovered samples are dominantly metagabbros, with minor locally derived sedimentary rocks. Abundant chlorite/actinolite and secondary quartz suggest that these rocks are low grade (greenschist facies) metamorphics. They are highly unlikely to be Tertiary intrusives. Further geochemical studies (in progress) will provide data to compare these with metagabbroic rocks of Cambrian age in Tasmania and north Victoria Land. The sedimentary material is composed of small, rounded metagabbro clasts in a calcareous ooze matrix.

DR32 : Samples were collected from a volcanic cone on the low-angled, 310°-trending slope of the northeast South Tasman Rise, between 46°33.7'S, 147°47.7'E and 46°34.0'S, 147°47.0'E. Dredging was between 1600 and 1200 metres below sea level. Samples are identified as picritic basalts, both vesicular and non vesicular. Vesicles constitute 15% of the basalt and are less than 5 mm in diameter. Zeolitic infilling of the vesicles is common. The non-vesicular picrite is probably holocrystalline, and may represent a dyke. One picrite shows a mylonitic fabric, with strong alteration due to fluid passage along the fracture network.

DR34 : This site was located further down the plateau slope than the preceding dredge, on a 320°-trending, NE-facing slope, between 46°21.9'S, 147°28.2'E and 46°22.2'S, 147°28.1'E. The water depths from which samples came were 2200-2100 m. The dominant sample recovered is a vesicular picritic basalt, though vesicles are only observable with a hand lens. Several large (1-2 cm) olivine phenocrysts have partially preserved cores, though generally they are completely altered. The lava also contains several large olivine crystal clots. Volcaniclastic sediment was also recovered but only in minor amounts.

DR35 : This site was northwest of DR34, on a 300°-trending, NE-facing slope. Dredging was done between 46°18.6'S, 147°12.2'E and 49°19.1'S, 147°11.4'E in depths of 2300-1950 metres. The dominant rock type recovered was a dolerite. In hand sample, this is a pale yellowish brown colour (10YR 6/2), with a fine grained groundmass of small (<1mm) feldspar laths and granular augite, observable by hand lens only. Preliminary thin section examination suggests it bears a textural resemblance to the alkaline Tertiary dolerites rather than Jurassic tholeiitic dolerites of Tasmania.

Hyaloclastites were also recovered. In hand samples these consist of reddish brown, altered glassy fragments, up to 5 cm in diameter, in a creamy siliceous matrix.

DR37 : This site was located on the western side of a seamount within the depression east of the South Tasman Rise, between 46°21.3'S, 149°0.8.2'E and 46°21.2'S, 149°10.1'E. Dredging was up-slope between 2450 and 2200 metres water depth. Samples recovered were identified in hand sample as weathered vesicular picrites or picritic basalts. Vesicles range in size from 0.5 to 3 mm in diameter and zeolitic infilling is common. Olivine phenocrysts are completely altered, although the groundmass appears to be relatively fresh, and occasional plagioclase phenocrysts are preserved.

DR38 : This was located on another seamount to the east of the South Tasman Rise and north of DR37, between 45°43.0'S, 149°00.0'E and 45°43.0'S, 149°01.0'E. Dredging was done eastwards up the side of the volcano between 2300 and 2050 metres water depth. The two dredged seamounts form part of the proposed Balleny plume seamount chain.

Recovered samples were identified in hand specimen as vesicular alkali olivine basalt and volcaniclastic sediment. The vesicular basalts are altered and phenocrysts are not preserved. The groundmass is relatively fresh. Vesicles vary between 1 and 3 mm in diameter and are infilled by zeolitic material. The volcaniclastic sediments are comprised of clasts of vesicular basalt, variably weathered, in a calcareous ooze matrix. Clasts are rounded to subrounded, up to 1cm in diameter. Limestone clasts are rare.

DR40 : Samples were recovered by dredging eastward up the western scarp of the East Tasman Plateau between 44°17.3'S, 149°26.3'E and 44°17.1'S, 150°33.0'E. Depths were between 2950 and 2515 metres. Igneous rocks comprise only a minor proportion of this dredge, with the remaining collected samples being gneiss and metasediments. The igneous rocks present are vesicular alkali olivine basalts. Vesicles are generally less than 1mm in diameter, with most less than 0.25mm. Samples are relatively fresh, though the olivine phenocrysts are altered. The larger vesicles exhibit zeolitic infilling. Volcaniclastic sediment was also recovered.

DR42 : Samples were collected from the eastern side of the Soela Seamount on the East Tasman Plateau between 43°54.0'S, 150°34.1'E and 43°54.1'S, 150°33.0'E. Water depths ranged from 1620 to 1280 metres. The dominant rock types recovered are vesicular and non-vesicular alkali olivine basalts, with minor volcaniclastic sediment. The latter is comprised of angular and rounded basalt clasts in a matrix of calcareous ooze. The clasts are typically weathered vesicular basalt but rare fresh clasts are present. Clasts are variable in size, ranging from several mm to 2-3 cm in diameter.

DR43 : This site was located on the eastern scarp of the East Tasman Plateau between 43°54.0'S, 151°19.2'E and 43°54.0'S, 151°17.8'E. Depths up the scarp varied between 3600 and 3030 metres. The dominant rock type was a flow banded, spherulitic rhyolite. Also recovered was a black, fine-grained, aphyric lava.

DR51 : Samples were recovered from an east-west trending ridge on the northeastern slope of the South Tasman Rise between 45°47.3'S, 147°14.2'E and 45°46.0'S, 147°14.0'E. Dredging was done between 3180 and 2500 metres. In hand sample the recovered samples are identified as vesicular alkali olivine basalts. Vesicles are generally less than 0.25 mm in diameter and only readily observable by hand lens. Olivine phenocrysts are highly weathered. A small amount of altered glass was detected.

DR57 : Samples were recovered from an east-west trending slope south of Tasmania between 44°32.8'S, 146°00.4'E and 44°31.7'S, 146°00.6'E. Dredging was done between 2850 and 2300 metres. In hand sample the volcanic rocks are olive brown, hard and massive. In thin section they are microcrystalline basalt with plagioclase laths in an altered groundmass.

Post-cruise sample analysis

Planned analyses of samples from the above mentioned dredges included:

a) thin section analysis and microprobe analysis of preserved glass from DR01 and DR02.
b) 9 thin sections, predominantly of the vesicular basalt, from DR07
c) 3 thin sections of vesicular alkali olivine basalt from DR08.
d) thin sections of all metagabbro samples collected in DR09.
e) thin sections of 3 of the weathered vesicular picrites and 1 thin section each from the metamorphosed and mylonitic lavas recovered in DR32.
f) 1 thin section each of representative hyaloclastite and dolerite samples from DR34.
g) 7 thin sections of weathered vesicular picrites from DR37.
h) 4 thin sections of picrites from DR38.
i) thin section from the 2 retained samples of vesicular alkali olivine basalt from DR40.
j) 9 thin sections and wholerock analysis of samples from DR42.
k) thin section analysis of the lava sample from DR43.
l) 3 thin sections from the lava blocks and possible microprobe analysis of the glass from DR51.
m) Representative, best-preserved samples from each dredge will be analysed for major and trace elements, including REE where appropriate.

8.3. Palaeogene detrital sedimentary rocks

N.F. Exon, AGSO

Poorly lithified, poorly sorted Late Cretaceous to Eocene detrital sediments had previously been recovered from the west Tasmanian margin and the South Tasman Rise on several research cruises (see "3. PREVIOUS STUDIES"). Those dredged, cored, and drilled (DSDP), from west Tasmania were dated palynologically or micropalaeontologically as Maastrichtian, Paleocene, early Eocene, middle Eocene and late Eocene. The characteristically greenish sediments dredged, cored and drilled from the South Tasman Rise were dated as Paleocene, Eocene and late Eocene.

On the present cruise, greenish sandstones and mudstones were recovered at 14 dredge locations, mostly on the South Tasman Rise, especially in the west, but also on the East Tasman Plateau (Table 15 & Fig. 22). Those from three dredges on the western scarp of the South Tasman Rise yielded dateable microfossils. DR14/A8 and DR18/A1&A2 contain late Eocene dinocysts of glacial character, and DR13/A1 contains a poor assemblage of Cretaceous to Early Tertiary palynomorphs (C. Foster, pers. comm.). DR14/A3 contains radiolarians of probable Eocene age (K. Romine, pers. comm.). Tweny-one other samples proved to be barren of palynomorphs, probably because of weathering at the sea bed (Appendix 8). Fourteen dredges contain arenaceous foraminiferal assemblages of low diversity and possible Eocene age (Chaproniere, Section 12.1). Fish teeth are present in many samples.

One core (GC01), 4262 m deep off southwest Tasmania, was taken on a ridge that showed cross-bedding characteristic of the Palaeogene on *L'Atalante* seismic profile 61. It contained geenish quartz bearing silty clay (Figure 28 & Appendix 9) and we assume it to be a shallow-water sediment laid down before the Oligocene unconformity was cut and the margin subsided. No nannofossils were found (Shafik, Section 12.2). The late Pliocene forams recorded intermittently down the core (Chaproniere, Section 12.1) are assumed to be contamination.

Hand specimen, thin section (Appendix 4), and palaeontological studies have shown that most of the dredged samples are remarkably similar poorly sorted sandstone and mudstone (Table 16). The sandstones commonly are immature and poorly sorted. The mudstones are usually carbonaceous. Most lithologies are massive and bioturbated, but some are laminated, and one is a varve (DR14/A6). Palaeontological evidence suggests that much of the sequence was laid down in shallow glacial seas. Colours vary from green, olive or grey when the rocks are fresh, to yellow or reddish when they have been heavily weathered at the sea bed.

Table 16: Palaeogene detrital sediments from AGSO Cruise 147

Sample	Lithology	Palaeontology	Colour	Bedding
SW Tasmania **GC01**	Quartz bearing silty clay**	No nannofossils; Pliocene forams assumed to be contamination	Pale green	Laminated in upper part; mottled in lower
North STR **DR10/A, B**	Immature sst, muddy siltst: quartz, K feldspar, muscovite, biotite, wood*	Arenaceous forams	Olive grey to yellowish	Massive, bioturbated
DR48	Muddy sandstone: quartz, feldspar, mica, clay clasts	Burrows with foram ooze	Light olive	Massive, bioturbated
West STR **DR13**	Muddy sandstone: quartz, mica	Late Cretaceous to Early Tertiary palynomorphs	Light olive grey	Massive to thick
DR14	Silty mudstone: quartz, lithics, mica, wood*	Late Eocene glacial dinocysts, siliceous arenaceous forams, radiolaria, calcareous worm tubes	Reddish fawn to grey	Thin to massive, bioturbated, 14A6 varved
DR18	Silty sandstone, mudstone: quartz, clay clasts, muscovite, opaques, wood*	Late Eocene glacial dinocysts	Dark yellowish brown	Laminated to thin
DR20	Mudstone	Radiolaria, diatoms	Dusky yellow	Laminated to massive, bioturbated
DR21	Mudstone	Planktonic forams	Pale olive	Massive, bioturbated
DR22	Claystone, sandy mudstone, arkose	No fossils	Pale olive, buff	Massive to thin
DR23	Mudstone, fine sandstone	No fossils	Greenish grey	Not determinable
DR25	Mudstone, sandy mudstone	Radiolaria, diatoms, arenaceous forams	Yellowish brown	Medium to thick
DR27	Carbonaceous silty mudstone	Radiolaria, diatoms, arenaceous forams	Orange	Massive
DR31	Muddy fine sandstone: quartz, muscovite, wood	Planktonic forams	Yellowish brown	Massive
East STP **DR43**	Labile sandstone, silty mudstone: quartz, lithics, two feldspars, mica, wood*	Woody fragments	Olive brown, olive	Massive

** Examined petrologically in thin section* *** Examined petrologically in smear slides*

8.4. Neogene altered carbonate rocks

N.F. Exon, AGSO

Calcareous Neogene rocks are widepread in the offshore areas around Tasmania, generally overlying terrigenous Palaeogene sediments disconformably or unconformably above the Oligocene unconformity, and have been dredged, cored and drilled (see "3. PREVIOUS STUDIES"). Calcareous rocks dredged, cored and drilled on the Tasmanian margin include middle Eocene, late Oligocene and early Miocene bryozoal limestone, and marls and oozes of most Neogene ages. On the South Tasman Rise, drilling and coring have shown that the Eocene mudstone sequence is overlain unconformably by a detrital Oligocene sequence, Miocene and Plio-Pleistocene foram-nanno ooze, and some Pleistocene foram sand.

On the present cruise, Pleistocene cores (Fig. 20) consist largely of carbonate ooze or foram sand (Figs. 27-47). However, many Neogene sedimentary rocks have been dredged from areas of basement outcrop, where sedimentation rates are low, and they consist of silicified limestones, with silica completely replacing the limestone in some cases. Eleven dredge hauls contain such sediments, all being on the southern slope of Tasmania or the northern South Tasman Rise (Fig. 22). All come from water shallower than 4000 m. Handspecimen, thin section (Appendix 4), X-ray diffraction (Appendix 10) and palaeontological information are summarised in Table 17.

Table 17: Neogene carbonate rocks from AGSO Cruise 147

Station	Lithology	Palaeontology	Colour
DR11/C	Micritic phosphatic limestone (mudstone, wackestone, packstone): bioclasts, glass, volcanics, quartz, pyroxene, biotite, feldspar*	Solitary corals, bivalves, echinoderms, bored. Possibly late Oligocene to early Miocene planktic and benthic forams	Pale yellowish orange to greyish orange
DR12/E	Micritic chalk with large lithic fragments set in micrite groundmass containing quartz and volcanic sand clasts*; conglomerate of siliceous clasts in micritic matrix	Calcareous shell fragments, fish bones, burrows. Possibly Oligocene or Miocene forams.	Yellowish brown
DR15/E	Micritic limestone (mudstone & packstone interbedded): bioclasts, quartz, lithics*	Possibly late Oligocene to early Miocene forams, bioturbated	Pale yellowish orange
DR16/B	Breccia of angular granite pebbles in micrite matrix	Pleistocene or younger forams, radiolarians	
DR38/C	Micritic phosphatic chalk: forams, glass, pyrite*	Possibly late Oligocene to early Miocene forams, and Pleistocene or younger forams, bioturbated	Very pale orange
DR44/B	Shelly limestone (packstone to wackestone): bioclasts, micrite clasts, quartz, peloids, pyrite, muscovite, feldspar, ferromagnesian crystals, carbonaceous wisps*	Colonial and solitary corals, barnacles, molluscs, echinoderms, Pleistocene or younger forams	Greyish orange
DR46/G	Shelly limestone	Bryozoa, echinoderms	Yellowish

DR47/F	Shelly limestone (packstone): bioclasts, minor basaltic clasts*	Coral, barnacles, bryozoans, bored	White to pale yellowish orange
DR54/D	Gritty calcilutite: lithics, chert, quartz, mica, ?glass grains*	None	Very pale orange
DR55/B	Micritic calcilutite: finely interbedded calcite/quartz and micrite laminae, pyrite, feldspar, lithics*	Forams & bioclasts only in cross-cutting micrite veins	White to very pale orange, with grey quartzose bands

* *Examined petrologically in thin section*

There is strong evidence that the fully altered (phosphatised) rocks, as well as the unaltered limestones and partially altered limestones, were originally deposited in varying water depths. Most contain bioclasts of calcareous organisms, and many dredge hauls contain similar rocks that are variably altered, with the micrite showing variable birefringence. The limestones are believed to have been altered variably at the sea bed, by phosphate-rich bottom waters of the oxygen minimum zone

The abundance in some samples of quartz, feldspar, lithic fragments and glass, suggests that quiet carbonate banks and slopes were sometimes inundated with such materials, perhaps in some cases during the eruptions that formed the many volcanic seamounts south of Tasmania. Cycles of erosion and redeposition are attested to by limestone breccia beds.

In order to determine the relative importance of calcite, dolomite, phosphate, and silica in the altered rocks six specimens were examined by X-ray diffraction (Appendix 10): DR11/C1 & C2, DR38/C2 &C3, and DR44/B2 & B3. The analyses show that dolomite is not significant, but that calcite, apatite, and secondary vein quartz, are present in variable amounts and combinations.

8.5. Fossil whale bones

C. Samson, Antarctic & Southern Ocean Cooperative Research Centre, Hobart

During AGSO Cruise 147, seven pieces of fossilised whale bone were recovered from four locations (147/DR13, 38, 43 & 50: Fig. 20) at the seafloor (2-4 km water depth) while dredging scarps and seamounts on the South Tasman Rise and East Tasman Plateau (Table 18). The most interesting specimens are of four beaked whale skulls and they are discussed below at greater length than the other specimens.

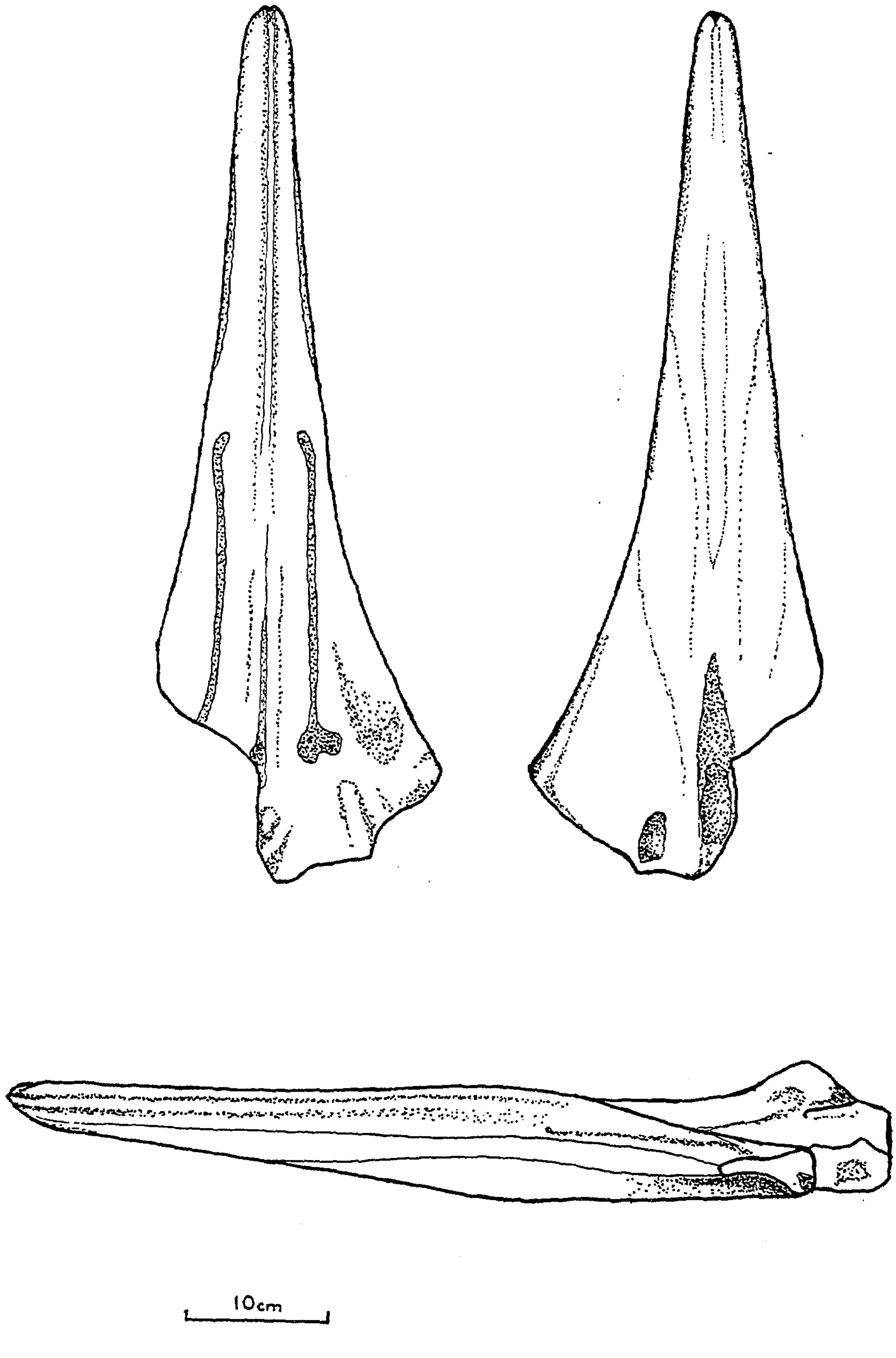


Figure 23: Rostrum of a fossil beaked whale (Ziphiidae), species unknown, from site 147DR13. From 2700-3900 m at the northern end of eastern Tasman Fracture Zone, SW of Tasmania (ca. 45°07'S, 144°31'E). Top left: dorsal view. Top Right: ventral view. Bottom: lateral view. Comments: Long narrow rostrum, very low profile. Tip of rostrum broken off but found.

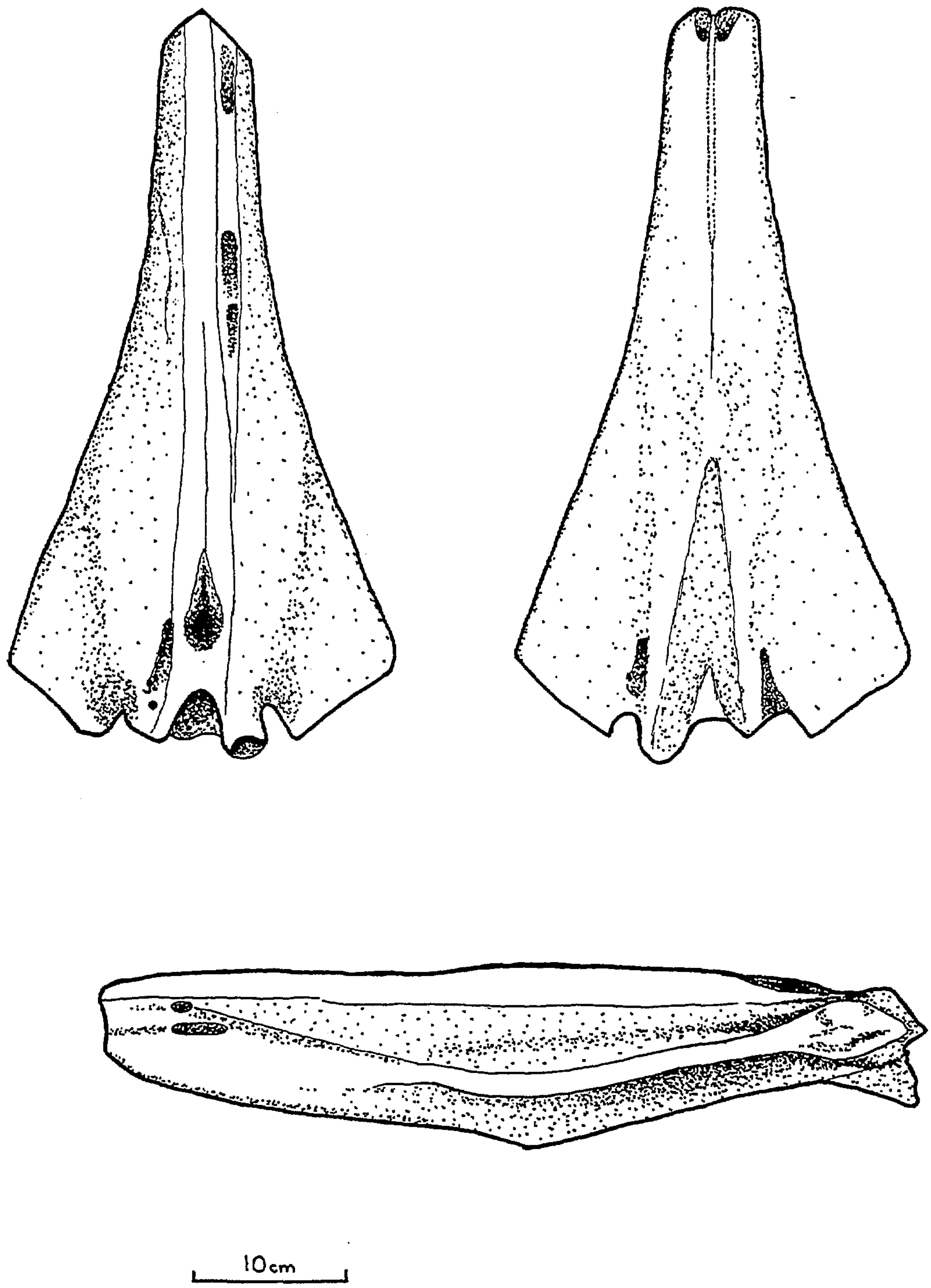


Figure 24: Rostrum of a fossil beaked whale (Ziphiidae), species unknown, from site 147DR38. From 2050-2300 m water depth on a seamount east of South Tasman Rise (ca. 45°43.0'S 149°00'E). Top left: dorsal view. Top Right: ventral view. Bottom: lateral view. Recovered in dredge 147DR038 on 17/2/95. Comments: Broad, robust low profile rostrum.

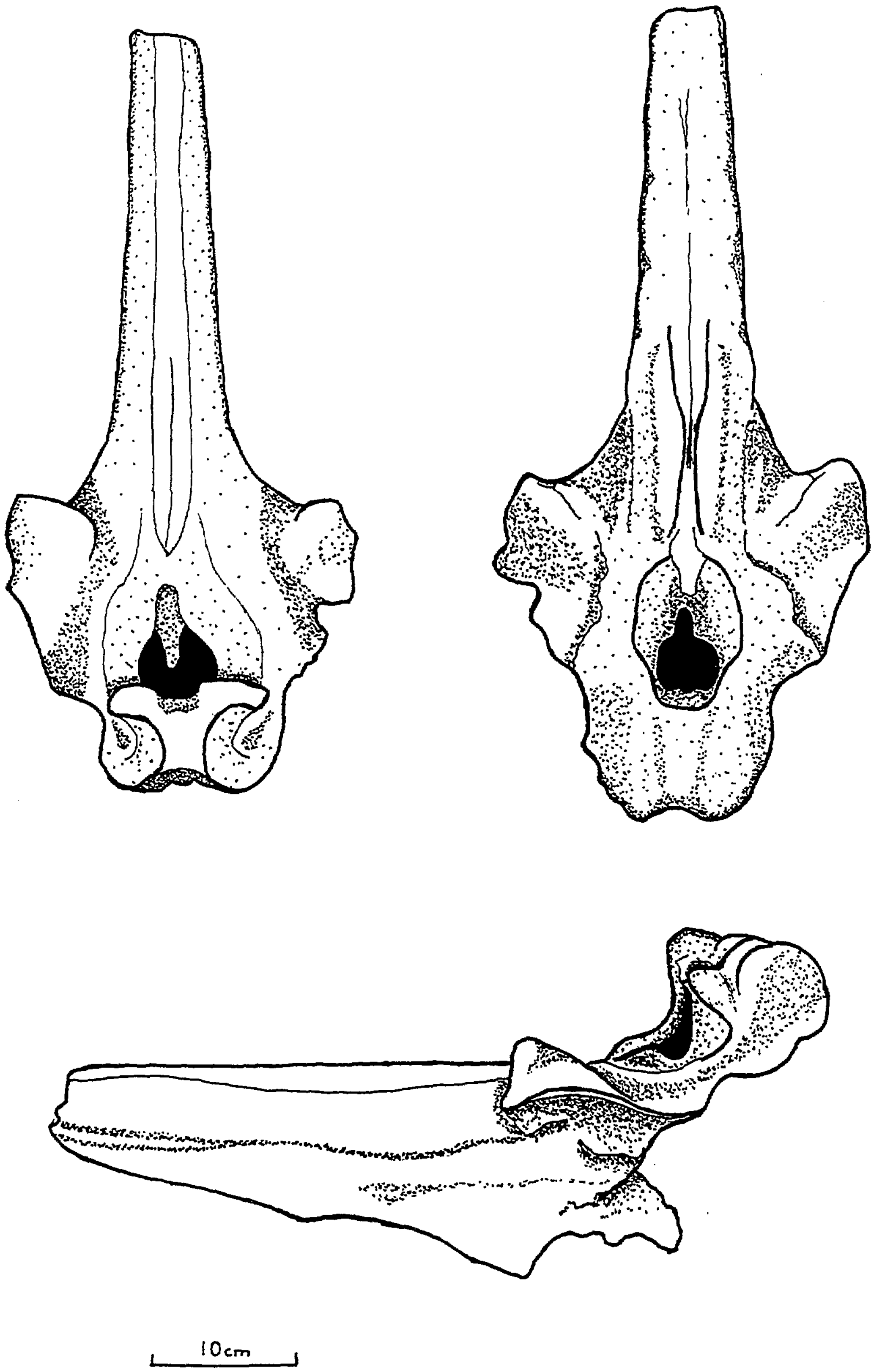


Figure 25: Rostrum and partial cranium of a fossil beaked whale (Ziphiidae), species unknown, from site 147DR43. From 3030-3600m water depth on the eastern scarp of East Tasman Plateau (ca. 43°54'S 151°18'E). Top left: dorsal view. Top right: ventral view. Bottom: lateral view. Comments: Rostrum and partial cranium. Very robust.

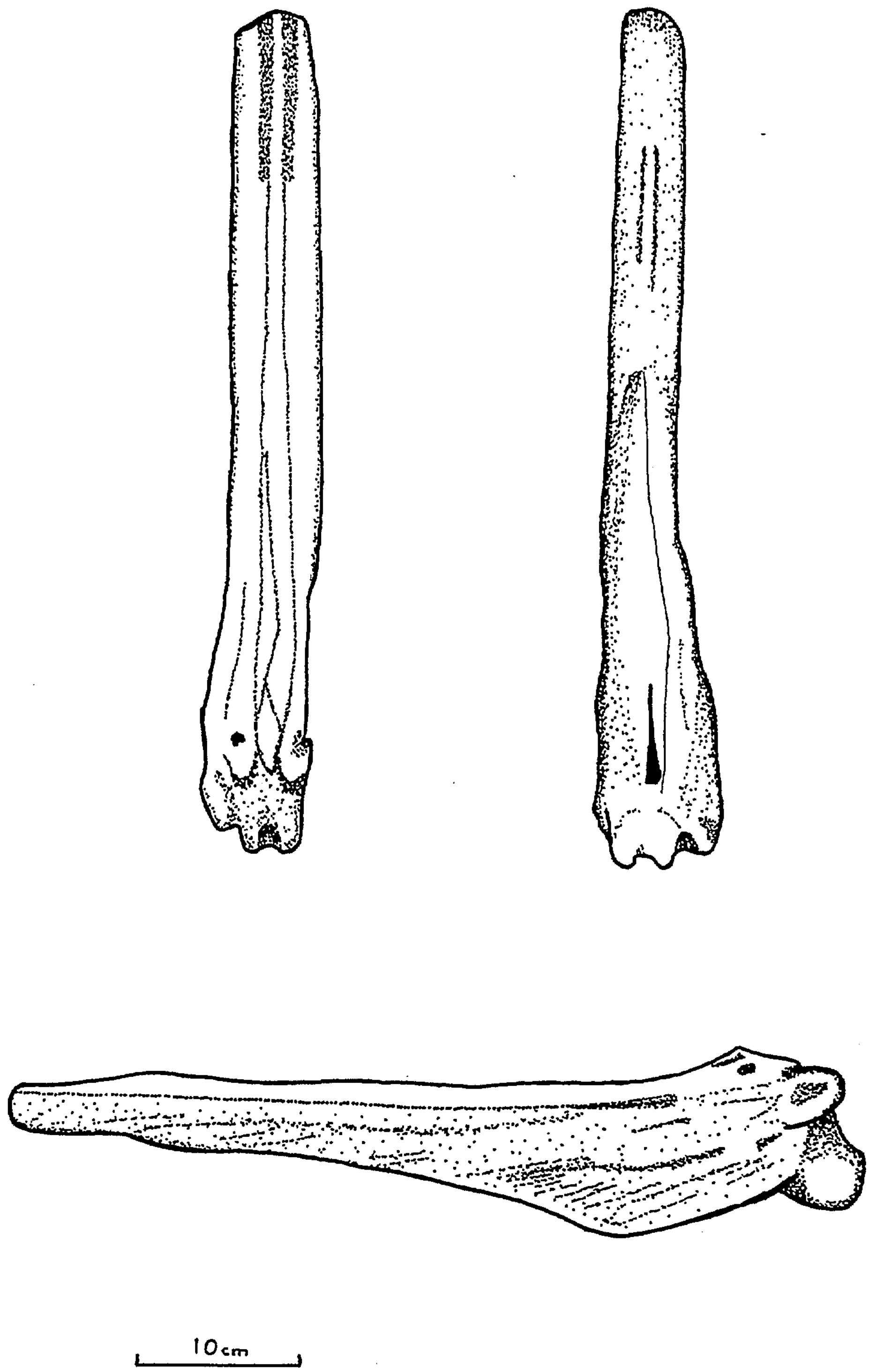


Figure 26: Rostrum of a fossil beaked whale (Ziphiidae), species unknown, from site 147DR50. From 2050-2300 m water depth from an east-west trending high on the eastern side of the South Tasman Rise (ca. 45°30'S 147°20'E). Top left: dorsal view. Top right: ventral view. Bottom: Lateral view. Comments: Very long narrow rostrum.

Table 18: Whale bone sites from AGSO Cruise 147

Whale skull 1 (Figure 23) Recovered in pipe dredge 147DR013 on 5/2/95. Location: northern end of eastern Tasman Fracture Zone, SW of Tasmania. First bite on seafloor: 45°07.7'S 144°30.3'E at 3900 m water depth Last bite on seafloor: 45°07.4'S 144°32.8'E at 2700 m water depth Comments: Long narrow rostrum, very low profile. Tip of rostrum broken off but found.
Whale skull 2 (Figure 24) Recovered in dredge 147DR038 on 17/2/95. Location: seamount east of South Tasman Rise First bite on seafloor: 45°43.0'S 149°00'E at 2300 m water depth Last bite on seafloor: 45°43.0'S 149°01'E at 2050 m water depth Comments: Broad, robust low profile rostrum
Whale skull 3 (Figure 25) Recovered in dredge 147DR043 on 19/2/95. Location: eastern scarp of East Tasman Plateau First bite on seafloor: 43°54.0'S 151°19.2'E at 3600 m water depth Last bite on seafloor: 43°54.0'S 151°17.8'E at 3030 m water depth Comments: Rostrum and partial cranium. Very robust.
Whale skull 4 (Figure 26) Recovered in dredge 147DR050 on 24/2/95. Location: east-west trending high on the eastern side of the South Tasman Rise First bite on seafloor: 45°30.4'S 147°20.6'E at 2300 m water depth Last bite on seafloor: 45°31.4'S 147°20.3'E at 2050 m water depth Comments: Very long narrow rostrum
Whale skull 5 Recovered in dredge 147DR050 on 24/2/95 Location: east-west trending high on the eastern side of the South Tasman Rise First bite on seafloor: 45°30.4'S 147°20.6'E at 2300 m water depth Last bite on seafloor: 45°31.4'S 147°20.3'E at 2050 m water depth Comments: Bizarre shaped skull? Perhaps baleen whale.
Bulla Recovered in dredge 147DR043 on 19/2/95 Location: eastern scarp of East Tasman Rise First bite on seafloor: 43°54.0'S 151°19.2'E at 3600 m water depth Last bite on seafloor: 43°54.0'S 151°17.8'E at 3030 m water depth Comments: Partially complete bulla probably of a baleen whale
Periotic Recovered in dredge 147DR052 on 24/2/95. Location: northeastern South Tasman Rise First bite on seafloor: 45°38.0'S 146°25.0'E at 2370 m water depth Last bite on seafloor: 45°38.2'S 146°24.4'E at 2200 m water depth Comments: Periotic of a small odontocete - probably delphinoid

Three of the four beaked whale skulls have only the rostrum preserved but the fourth also has the anterior section of the cranium preserved. In all four specimens the bone had been replaced by silica and then coated in a thin manganese crust up to 5 mm thick.

Fossils from the deep sea are potentially an important source of information about cetacean evolutionary history because cetaceans have been present in the oceans for the last 50 million years but most of the cetacean fossils known today are from shallow marine sequences now preserved on land rather than from deep ocean basins.

All four specimens have a long robust rostrum (upper jaw) which appears to be toothless. These features indicate the specimens found on the South Tasman Rise belong to the family Ziphiidae, more commonly known as beaked whales. Beaked whales belong in the Suborder Odontoceti (toothed whales).

Comparisons with skull material from modern species of beaked whales at the Tasmanian Museum and University of Tasmania Zoology Department suggest that the South Tasman Rise specimens are not living species of beaked whales. Instead they have strong similarities with fossil ziphiids from the Cameron Inlet Formation of Middle to Upper Pliocene age (4-2 million years ago) on Flinders Island (material held at the Tasmanian Museum). There have been no publications on the Flinders Island material to date because of difficulties in interpreting the material (pers. comm. Ewan Fordyce 1995).

Some of the problems associated with working with fossil ziphiids are described below.

1. Often the only material available are the remnants of rostra. The relationship between the bones in the rostra is extremely variable and is due not only to species differences but also ontogenetic (age) and sexual variation. As yet a method of differentiating these factors has not been established (Mead 1989).

2. Also many genera of fossil ziphiids are based upon fragments of skulls or postcranial material (Mead 1975) rather than entire specimens thus making comparisons difficult and sometimes impossible because there are no common elements.

3. Most of the material is quite worn/polished thus making identification to species level difficult.

4. Given the resistant nature of ziphiid rostra it is possible that the specimens are reworked into younger formations thus making it difficult to place the specimens in an evolutionary lineage (pers. comm., Ewan Fordyce, 1995).

Despite these problems there is hope that the specimens collected on this cruise may provide further information on the evolutionary history of ziphiids. Firstly, one of the specimens is more complete than most fossil material found previously. Secondly, the sutures between the bones and foramina for nerves and/or blood vessels are quite distinct. This fine detail will be important in determining the relationships between these specimens and other known species. Although the South Tasman Rise specimens share some features in common they are distinct enough from one another to be different species and possibly different genera. However, further detailed work is required to better determine the relationships between these specimens, living species and extinct species of this family.

Ziphiids have been recognised in the fossil record since the lower Miocene, about 20 million years ago. Today ziphiids are the second most diverse family of cetaceans, after Delphinidae. There are twelve species (five genera) of beaked whales in Australian waters today. They are of moderate size (4-9 m) and are deep diving squid eaters. Still very little is known about their biology because they aren't easily identified at sea. Species distribution is mainly known from records of stranded individuals. Modern day species have only a few rudimentary teeth, the rest having been secondarily lost. Adult males also have two large teeth (one on either side) which protrude from the anterior section of the lower jaw. In females and immature males these teeth remain buried beneath the gums. It is thought that these tusk-like teeth are used for display purposes.

As well as the four skulls a bulla (the largest earbone in cetaceans), a periotic (the second largest earbone of five in cetaceans) and two other pieces of bone were also recovered. From the number of specimens collected it seems probable that the area may provide further material if dredged in the future. However it is important to remember that the dredging sites were concentrated in nondepositional areas such as scarps and steep slopes which make up only about 10% of the area of the South Tasman Rise and East Tasman Plateau.

8.6. Biological collections

R. Connell, Antarctic & Southern Ocean Cooperative Research Centre, Hobart

Coincidental to the collection of geological data and samples on AGSO Cruise 147, was the photography and dredging of the seamounts, fished by the orange roughy trawlers, in order to document their biota. Photographs of the seamounts show a dense cover of colonial corals and other invertebrates. Two dredges, 147/DR06 and 147/DR30, retrieved large amounts of this coral and associated fauna (locations in Fig. 20). The fauna from these dredges were thoroughly picked over by ship-board biologists and representative samples of all species recorded, photographed and frozen in sea water for later examination. These collections and smaller collections from other dredges have been forwarded to Roger Buttermore, Curator of Invertebrates at the Tasmanian Museum, for identification and curation.

Biological samples were taken from 10 dredges. The dredges consist of a heavy steel mouth 85 cm wide and 50 cm high with a heavy, large mesh diameter, chain bag attached behind. Shackled to the rear of the chain mesh bag are two 22 cm diameter pipe dredges, one which has a solid bottom and the other a coarse mesh bottom. This whole apparatus is towed behind the ship, at very slow speed (< 1 knot), by a heavy steel cable. The chain mesh dredge contents are severely agitated as they are dragged along the sea floor, consequently all loose biota and the biota encrusting rock surfaces is destroyed except for specimens that survive in rock cavities or specimens robust enough to survive the pounding. Many rocks had the remains of the hold-fasts of encrusting organisms but very few had intact specimens. The pipe dredges recover samples in a less damaged condition but generally only collect small samples and specimens.

The ten collection sites are listed below in their order of collection, along with notes on the collections where appropriate.

147/DR06: Latitude 44° 20.0'S; Longitude 147° 07.4'E. Water depth: 1400m.

Notes: "Dory Hill", SW of Tasmania. The chain mesh dredge brought up approximately 150 kg of colonial calcareous corals, in and upon about 30 other species were found both free living and encrusting.

The pipe dredge retrieved approximately 20 kg of coarse biogenic sediment dominated by large barnacle plates. The only live organisms recovered were two species of gastropod but ~15 species of dead mollusc shells were recorded.

The combined fauna of the two samples are listed below according to their broad taxonomic classification (Table 19).

Table 19: Fauna from 147/DR06

Classification	Number of species
PORIFERA	2
COELENTERATA	
Scleractinia	3
Gorgonacea	6
Actiniaria	1
BRYOZOA	2
BRACHIOPODA	2
ARTHROPODA	
Malacostraca	3
Cirripedia	1
ANNELIDA	
Polychaeta	1
ECHINODERMATA	
Holothuroidea	2
Asteroidea	5
Echinoidea	2
Crinoidea	1
MOLLUSCA	
Bivalvia	4
Gastropoda	21
INCERTAE SEDIS	4

147/DR25: Latitude 49° 04.3'S to 49° 04.0'S; Longitude 146° 16.0'E to 146° 17.4'E. Water depth: 3300-2420 m.

147/DR29: Latitude 47° 44.2'S to 47° 44.6'S; Longitude 147° 33.7'E to 147° 32.8'E. Water depth: 1170-1070 m.

174/DR30: Latitude 47° 22.7'S to 47° 22.8'S; Longitude 148° 37.3'E to 148° 36.9'E. Water depth: 900-800 m.

Notes: The chain mesh bag from 147/DR30 retrieved approximately 50 kg of benthos dominated by colonial calcareous corals, in and upon which about 25 other invertebrate species were found both free living and encrusting. The pipe dredge retrieved approximately 20 kg of coarse biogenic sediment dominated by large barnacle plates in a ground mass of foraminiferal sand, small barnacle plates and echinoid spines. The only live specimens observed were rare examples of a small bysally attached bivalve.

The combined fauna of the two samples are listed below according to their broad taxonomic classification (Table 20).

Table 20: Fauna from 147/DR30

Classification	Number of species
PORIFERA	2
COELENTERATA	
Scleractinia	6
Gorgonacea	6
Actiniaria	2
BRYOZOA	1
BRACHIOPODA	3
ARTHROPODA	
Malacostraca	4
Cirripedia	3
ANNELIDA	
Polychaeta	2
ECHINODERMATA	
Holothuroidea	5
Asteroidea	3
Crinoidea	2
MOLLUSCA	
Bivalvia	2
Gastropoda	12

147/DR31: Latitude 46° 45.4'S to 46° 45.0'S; Longitude 148° 40.0'E to 148° 39.5'E. Water depth: 2230-2080 m.

147/DR36: Latitude 46° 27.7'S to 46° 28.1'S; Longitude 148° 19.7'E to 148° 19.3'E. Water depth: 2400-2350 m

147/DR40: Latitude 44° 17.3'S to 44° 17.1'S; Longitude 149° 26.3'E to 149° 26.8'E. Water depth: 2950-2515 m

147/DR45: Latitude 44° 39.2'S to 44° 39.5'S; Longitude 147° 26.4'E to 147° 26.5'E. Water depth: 2800-2600 m

147/DR47: Latitude 45° 23.2'S to 45° 21.8'S; Longitude 147° 16.5'E to 147° 17.5'E. Water depth: 2650-2250 m

147/DR51: Latitude 45° 47.3'S to 45° 46.0'S; Longitude 147° 14.2'E to 147° 14.0'E. Water depth: 3180-2500 m

9. CORE STUDIES

Climatic studies of cores from this key region of the world's oceans, where two oceanic fronts are believed to have moved north and south with Pleistocene climatic changes, are being carried out on a collaborative basis by the Antarctic and Southern Ocean Cooperative Research Centre in Hobart, Woods Hole Oceanographic Institution, and AGSO. The shipboard program was designed to provide both latitudinal and depth transects to document changes in both surface and bottom waters. Table 21 summarises the results for all gravity cores, box cores and grab samples.

Table 21: Summary of core and grab sites for AGSO Cruise 147 off Tasmania

						L'Atalante targets		
ID	Group/site	Date	Latitude	Longitude	Depth	Line	Time	Recovery
			(South)	(East)	(km)			(m)
GC-01	GW	1/30	44° 10.30	144° 10.86	4.238	61	0432	3.78
GC-02	DR site	1/31	44° 00.00	144° 43.00	1.957	58		none
GC-03	DR site	1/31	44° 00.00	144° 43.00	1.957	58		none
GC-04	CRC 1	1/31	44° 05.99	145° 15.00	2.981	54	1235	2.57
BC-01	CRC 1	1/31	44° 06.00	145° 15.00	2.986	54	1235	none
GC-05	CRC 2	2/1	44° 03.99	145° 24.99	2.334	53	0630	1.77
GC-06	GW	2/2	44° 31.51	146° 42.48	2.609	27		0.84
GC-07	CRC 3	2/2	45° 09.53	146° 17.51	3.307	34	0335	5.33
BC-02	CRC 3	2/2	45° 09.53	146° 17.51	3.307	34	0335	untripped
BC-03	CRC 3	2/3	45° 09.53	146° 17.51	3.307	34	0335	0.20
GC-08	CRC 4	2/4	46° 14.00	146° 19.01	1.813	30	2115	none
GC-09	CRC 4	2/4	46° 13.99	146° 18.97	1.813	30	2115	cc only
GC-10	CRC 5	2/4	45° 58.85	145° 33.35	2.369	16	1310	cc only
GC-11	CRC 6	2/6	45° 44.02	144° 53.05	2.406	12	1815	2.64 (dist)
GC-12	CRC 6	2/6	45° 44.02	144° 53.08	2.418	12	1815	none
GC-13	GW	2/7	46° 10.01	144° 15.99	4.452	8		5.3
GC-14	CRC B	2/7	46° 26.98	145° 14.47	3.360	11	0510	6.3 (2 hits)
GC-15	GW	2/8	46° 39.01	145° 25.06	3.260	11	0630	4.4 (4 hits)
GC-16	GW	2/8	46° 47.99	145° 14.99	3.523	10	0430	3.6 (4 hits)
GC-17	CRC 7	2/10	47° 45.04	145° 49.01	3.001	9	2350	2.29
GC-18	GW	2/10	48° 05.55	145° 34.11	4.368			2.5
GC-19	CRC 8	2/11	48° 26.50	146° 13.00	2.578	8	1545	none
GC-20	CRC A	2/11	48° 39.02	146° 26.02	3.306	8	1400	3.53
GC-21	GW	2/12	49° 00.05	145° 59.01	4.132			3.71
GC-22	CRC C	2/13	47° 58.48	147° 10.01	1.914	16	2340	cc only
GC-23	CRC 9	2/13	47° 39.60	147° 32.98	1.311	30/	0630/	none

GR-01	CRC 9	2/13	47° 39.60	147° 32.98	1.311	/31	/1500	0.08 sand
GC-24	CRC 9	2/13	47° 39.60	147° 32.98	1.311	30/31	"	cc only
GR-02	CRC S	2/14	47° 19.00	147° 59.99	0.922	34	2130	0.08
GC-25	CRC S	2/14	47° 19.00	147° 59.99	0.922	34	2130	cc only
GC-26	GW	2/15	46° 27.05	147° 42.00	2.001	-		cc only
GR-03	CRC 11	2/14	46° 36.59	147° 25.17	1.581	34	2130	0.08
GC-27	CRC 11	2/14	46° 36.59	147° 25.19	1.580	34	2130	cc only
GC-28	GW	2/16	46° 03.51	147° 22.94	3.065			2.68
GC-29	GW	2/16	46° 10.00	147° 28.00	2.931			none
GC-30	GW	2/16	46° 10.04	147° 27.98	2.968			5.2
GC-31	CRC ET1	2/17	44° 32.80	149° 03.81	3.403			5.23
GC-32	CRC ET2	2/18	43° 57.93	149° 55.18	2.645			2.7
GR-05	JM	2/20	43° 20.19	147° 58.00	0.135			sand
GR-06	JM	2/20	43° 21.89	148° 01.22	0.137			sand
GR-07	JM	2/20	43° 23.89	148° 05.51	0.145			sand
GR-08	JM	2/21	43° 24.48	148° 06.22	0.141			sand
GR-09	JM	2/21	43° 26.41	148° 09.58	0.805			trace
GR-10	JM	2/21	43° 27.67	148° 11.80	1.285			none
GC-33	JM	2/21	43° 27.67	148° 11.82	1.285			cc only
GC-34	GW	2/23	45° 06.00	147° 44.5	4.002			5.18
GC-35	GW	2/24	45° 44.0	146° 32.0	2.720			2.13
GC-36	GW	2/25	45° 45.03	146° 38.99	2.650			none
GC-37	GW	2/25	45° 45.04	146° 39.00	2.660			none

GR = gravity core, BC = box core, GR = grab sample
Group/site: CRC = palaeogeographic site; GW = acoustic facies site; JM = shelf or slope carbonate site
20/37 GCs (1/12 < 2.4km, 0<2.3km); 1/3 BCs; 3 deepwater grabs from shallow sites

One major problem has been the discovery that even very carefully targeted gravity coring is ineffectual in water depths of 1000-2500 metres on the current-swept South Tasman Rise, because of a blanket of winnowed foram sand. It may be that only deepwater vibrocoring or ODP hydraulic piston coring will succeed in obtaining satisfactory cores in this depth range, so that a full depth transect can be examined.

Another major problem we encountered with the coring was that the wire-out meter ("Jack's Box") overestimated the amount of wire out by roughly 3 to 4 percent in the 2 to 4 km range (based on comparison of wire out when the corer hit bottom with the echo sounder and precision depth recorder (EPC PDR) depth estimates).

9.1. Descriptions of gravity cores

G.P. Whitmore, James Cook University & R. Connell, Antarctic & Southern Ocean CRC, Hobart

The coring program is summarised in Tables 14 & 21. The following descriptions of deepwater cores were prepared by Connell, and the logs (Figs. 27-47) by Whitmore with help from others.

Core No. 147/GC001 length: 378 cm lat: 44° 10.30'S long: 144° 10.88'E
depth: 4262 m date: 30.01.95
location: S.W. of Tasmania
comments / description: Grey to green clayey biogenic ooze with distinct bedding. Top 40 cm is richly calcareous but decreases down core. (Below CCD)

Core No. 147/GC002 length: 0 cm lat: 44° 00.01' S long: 144° 43.01' E
depth: 1957 m date: 30.01.95
location: S.W. of Tasmania
comments / description: No recovery; uncertain if core barrel hit bottom.

Core No. 147/GC003 length: 0 cm lat: 44° 00.04' S long: 144° 42.98' E
depth: 1965 m date: 31.01.95
location: S.W. of Tasmania
comments / description: No recovery; uncertain if core barrel hit bottom.

Core No. 147/GC004 length: 257 cm lat: 44° 05.99' S long: 144° 15.00' E
depth: 2980 m date: 31.01.95
location: S.W. of Tasmania
comments / description: 257 cm greyish green, clayey foram-nanno ooze interbedded with ~4 thin, foram sand turbidites.

Core No. 147/GC005 length: 178 cm lat: 44° 03.99' S long: 145° 24.99' E
depth: 2334 m date: 01.02.95
location: S.W. of Tasmania
comments / description: 178 cm greenish grey, foram-nanno ooze interbedded with frequent foram sand turbidites.

Core No. 147/GC006 length: 86 cm lat: 44° 31.51' S long: 146° 42.47' E
depth: 2508 m date: 02.02.95
location: S of Tasmania
comments / description: 86 cm of mottled light olive grey clayey foram-nanno sand.

Core no. 147/GC007 length: 533 cm lat: 45° 09.52' S long: 146° 17.51' E
depth: 3300 m date: 02.02.95
location: Northern South Tasman Rise
comments / description: 533 cm light greenish grey, clayey foram-nanno ooze / foram-nanno clay with sparse foram sand turbidites.

Core No. 147/GC008 length: 0 cm lat: 46° 13.97' S long: 146° 19.01E
depth: 1813 m date: 04.02.95
location: Northern South Tasman Rise.
comments / description: No recovery.

Core No. 147/GC009 length: 0 cm lat: 46° 14.00' S long: 146° 19.01' E
depth: 1813 m date: 04.02.95
location: Northern South Tasman Rise.
comments / description: No recovery. Foram sand in the core catcher.

Core no. 147/GC010 length: 0 cm lat: 45° 58.93' S long: 145 33.40' E
depth: 2358 m date: 04.02.95
location: Northern South Tasman Rise.
comments / description: No recovery. Sand in the core catcher.

Core no. 147/GC011 length: 264 cm lat: 45° 44.02' S long: 144° 53.06' E
depth: 2387 m date: 04.02.95
location: NW South Tasman Rise.
comments / description: 264 cm firm to soupy light greenish grey clayey foram sand. Core top lost as very liquid, this was bagged separately. Suspect much of the core may be from turbidite gravity flow deposition.

Core No. 147/GC012 length: 0 cm lat: 45° 44.02S long: 144° 53.06E
depth: 2419 m date: 05.02.95
location: NW South Tasman Rise.
comments / description: No recovery. Core catcher failed, fingers inverted.

Core No. 147/GC013 length: 530 cm lat: 46° 10.01' S long: 144° 15.99' E
depth: 4452 m date: 06.02.95
location: Abyssal plain west of South Tasman Rise.
comments / description: 530 cm long core. Below CCD. Ranges at the core top from a yellowish grey to yellowish brown foraminiferal clay, to bluish green clays without forams from below ~3m. Core is moderately to strongly bioturbated in places.

Core No. 147/GC014 length: 629 cm lat: 46° 26.98' S long: 145° 14.47' E
depth: 3360 m date: 06.02.95
location: Western South Tasman Rise.
comments / description: Core is a double hit due to rough weather. About 40-50 cm of the uppermost sediments are probably missing as the core was longer than the core barrel, and the core top was extruded. 0-400 cm is Hit 1 and 400-629 cm is Hit 2. The 0-400 cm sequence is of very pale orange foram rich clay from the core top down to 40 cm and light grey green foram-nanno clayey ooze with frequent fine planar beds and parallel redox laminae. The 400-629 cm sequence is a repeat of the upper sequence except that the oxidised very pale orange core top section is 70 cm long.

Core No. 147/GC015 length: 402 cm lat: 46° 39.01' S long: 145° 25.06' E
depth: 3260 m date: 07.02.95

location: Western South Tasman Rise.
comments / description: Core is a multiple hit due to rough weather. Hit A = 0-123 cm, Hit B =123-289 cm, Hit C =289-345 cm., Hit D=345- 402 cm. Hit A has the core top missing. Hits B, C, D all have a thin 1-15 cm thick core top of very pale orange foram sand underlain by greyish brown "dirty looking sediments. Sediments range in ratio of foram sand / clay from clayey foram oozes to foram sands.

Core No. 147/GC016 length: 388 cm lat: 46° 47.99' S long: 145° 14.99' E
depth: 3523 m date: 08.02.95
location: Western South Tasman Rise.
comments / description: Core is a multiple hit due to rough weather. Hit A=0-29 cm., Hit B =29-246 cm., Hit C = 246- 327 cm, Hit D = 327 -388 cm.
4 m barrel used. Hit A is lacking the upper approximat 1.5 m of core top. Core top seen in hits A, B, C; all have the same sequence of soupy very pale orange white foram ooze underlain by a dark dirty mottled band of firm clayey foram sand and then underlain by grey clayey foram-nanno ooze.

Core No. 147/GC017 length: 228 cm lat: 47° 45.04S long: 145° 49.00' E
depth: 3001 m date: 10.02.95
location: SW South Tasman Rise.
comments / description: 228 cm long clayey foram-nanno ooze with numerous fine beds and redox laminae.

Core No. 147/GC018 length: 228 cm lat: 48° 05.37' S long: 145° 03.97' E
depth: 4410 m date: 11.02.95
location: Deep re-entrant in SW South Tasman Rise.
comments / description: 256 cm firm sticky, mid greyish brown, black speckled, foram, clayey manganese sand, overlying a firm to hard white clay which is deeply scoured and borrowed and coated with a ~2 mm thick manganese crust. The clay is underlain by the same overlying facies which in turn grades down into a hard crust of manganese nodule conglomerate.

Core No. 147/GC019 length: 0 cm lat: 48° 39.03' S long: 146° 13.00' E
depth: 2578 m date: 11.02.95
location: SW South Tasman Rise.
comments / description: No recovery.

Core No. 147/GC020 length: 353 cm lat: 48° 39.03' S long: 146° 26.02' E
depth: 3300 m date: 12.02.95
location: SW South Tasman Rise.
comments / description: Clean fresh foram sands with a high water content - soupy. The top 18 cm of the core appears to have been winnowed by swashing in the core barrel while aboard the vessel and comprises almost pure, massive homogenous foram sand with very little fine fraction. May be a multiple hit with a second hit occurring at 295 cm?!

Core No. 147/GC021 length: 369 cm lat: 49° 00.16S long: 145° 59.37' E
depth: 4132 m date: 12.02.95
location: Deep re-entrant in SW South Tasman Rise.

comments / description: Core is a multiple hit due to rough weather. Hit A = 0-216 cm. , Hit B = 216-369 cm. Both sections have core tops intact and have the same sequence down core from: Light grey foram-nanno sands--very mottled grey/brown extensively burrowed foram-nanno very clayey sands to very pale orange clay foram-nanno ooze.

Core No. 147/GC22 length: 0 cm lat: 47° 58.48' S long: 147° 10.00' E
depth: 1910 m date: 13.02.95
location: Southern South Tasman Rise.
comments / description: No recovery; a small quantity of foram sand from the core catcher.

Core No. 147/GC023 length: 0 m lat: 47° 39.60' S long: 147° 32.96' E
depth: 1399 m date: 13. 02. 95.
location: Central South Tasman Rise
comments / description: No recovery. Van Veen grab sent down at the same location yielded 8 cm of clean foram sand. Foram sands too hard to core.

Core No. 147/GC024 length: 0 cm lat: 47° 39.59' S long: 147° 32.99' E
depth: 1310 m date: 13.02.95
location: Central South Tasman Rise.
comments / description: No recovery.

Core No. 147/GC025 length: 0 cm lat: 47° 19.01' S long: 148° 00.02' E
depth: 923 m date: 14.02.95
location: Central South Tasman Rise.
comments / description: No recovery.

Core No. 147/GC026 length: 0 cm lat: 46° 27.00' S long: 147° 42 0' E
depth: 2001 m date: 15.02.95
location: NE South Tasman Rise.
comments / description: Recovered approximately 50 g of foram sand from the core catcher.

Core No. 147/GC027 length: 0 cm lat: 46° 36.62' S long: 147° 25.17' E
depth: 1580 m date: 15.02.95
location: NE South Tasman Rise.
comments / description: Recovered approximately 50 g of foram sand from the core catcher.

Core No. 147/GC028 length: 268 cm lat: 46° 03.48' S long: 147° 23.01' E
depth: 3065 m date: 16.02.95
location: NE South Tasman Rise.
comments / description: 268 cm pale olive grey, clayey foram-nanno sand. The ratio of clay to forams increases down section. Purple grey concentric redox laminae surrounding burrows (high organics?) are prominent.

Core No. 147/GC029 length: 0 cm lat: 46° 10.00' S long: 147° 28.00' E
depth: 2931 m date: 16.02.95
location: NE South Tasman Rise.
comments / description: No recovery . Core catcher failed, fingers inverted.

Core No. 147/GC030 length: 519 cm lat: 46° 09.99' S long: 147° 27.97' E
depth: 2968 m date: 16.02.95
location: NE South Tasman Rise.
comments / description: Core, grades from clayey foram sands with probable turbidite horizons in the upper part to foram-nanno clay in the lower part.

Core No. 147/GC031 length: 524 cm lat: 44° 32.79' S long: 149° 03.80' E
depth: 3402 m date: 17.02.95
location: Depression between South and East Tasman Rises.
comments / description: 524 cm greenish grey foraminiferal clays with faint cm-dm bedding; sparse large burrows, prominent redox laminae, rare thin foram sand beds (turbidites?).

Core No. 147/GC032 length: 264 cm lat: 43° 57.93' S long: 149° 55.18' E
depth: 2650 m date: 18.02.95
location: East Tasman Rise.
comments / description: 264 cm light greenish grey firm to soupy, clayey sands / sandy clays, with some large burrows, redox laminae, and 1 cm thick foram turbidite.

Core No. 147/GC033 length: 0 cm lat: 43° 27.67' S long: 148° 11.83' E
depth: 1285 m date: 21.02.95
location: East of Storm Bay on the continental slope SE of Tasmania.
comments / description: Small amount of sandy ooze recovered from the core catcher.

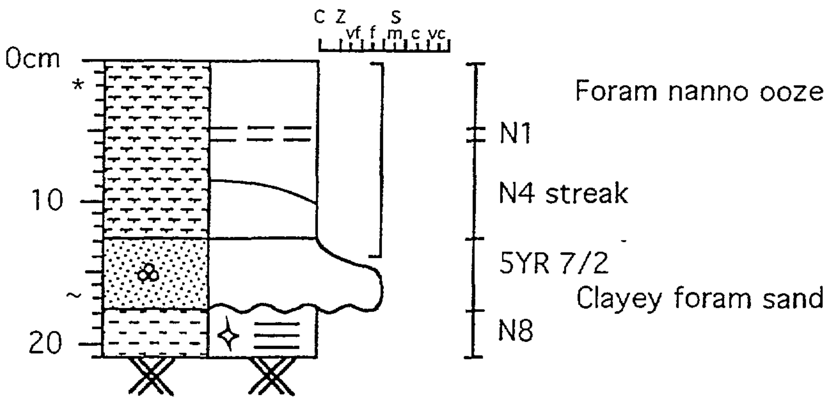
Core No. 147/GC034 length: 516 cm lat: 45° 06.00' S long: 147° 44.50' E
depth: 4002 m date: 23.02.95
location: Depression between Tasmania and NE South Tasman Rise.
comments / description: 516 cm of greenish grey to grey clay with sparse forams in the upper 2 m but absent in the lower part. Some large burrows and planar redox laminae. Two turbidites of medium -coarse mineral sands are present at 180-200 cm, and 430- 438 cm.

Core No. 147/GC035 length: 210 cm lat: 45° 44.00S long: 146° 32.0' E
depth: 2 720 m date: 24.02.95
location: NE South Tasman Rise.
comments / description: 210 cm of yellowish Gary foram sand with firm to very firm clayey sand / sandy clay over the bottom 15 cm. Core catcher had a coating of sticky firm yellowish brown, mineral sandy clay.

Core No. 147/GC036 length: 0 cm lat: 44° 44.98' S long: 146° 38.98' E
depth: 2650 m date: 25.02.95
location: Southern Tasmanian slope.
comments / description: No recovery. Device probably did not hit the bottom.

Core No. 147/GC037 length: 0 cm lat: 44° 55.0' S long: 146° 39.0' E
depth: 2660 m date: 24.02.95
location:. Southern Tasmanian slope.

Figure 27. Legend: South Tasman Rise core logs.



Sediment Composition
(left hand column)

- gravel
- foram ooze (40-59% forams)
- foram nanno ooze
- foram sand (>60% forams)
- clayey foram sand
- silty clay / clayey silt
- foram clay (<40% forams)
- clay
- distinct contact
- indistinct contact
- * smear slide description
- ~ texture from binocular mcrscp.
- *N22* foram microfossil zone

Sediment nomemclature follows the new ODP classification scheme. Lest abundant constituents are listed first (to the left). When used the term 'bearing' indicates a composition of 2-10%, and 'rich' upto 25%.

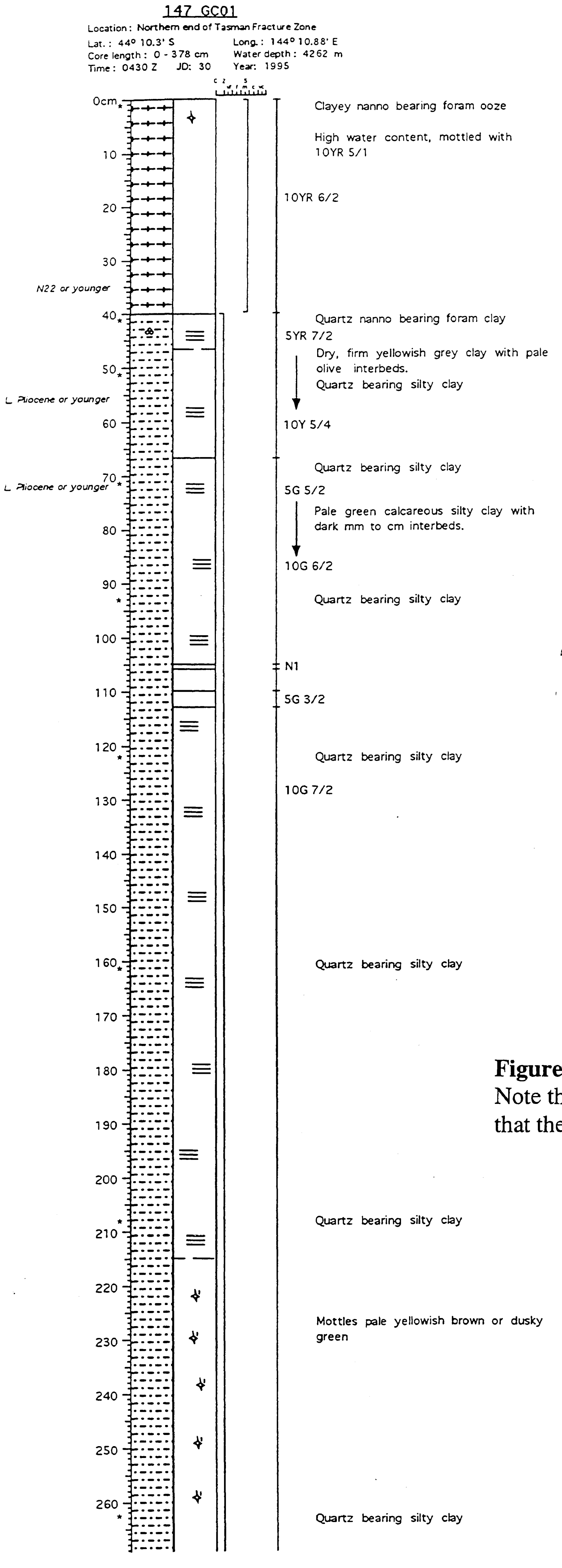
Sedimentary Structures
(right hand column)

- Distinct planar laminations
- Weak planar laminations
- Disrupted bed and apparent structure
- Distinct wavey contact
- No apparent structure
- Grain size of coarse fraction if bimodal
- Pyrite crust
- Sponge spicules
- Foraminifera
- Nannoplankton
- Bryozoan coral fragments
- Solitary coral
- Manganese micronodule
- Small manganese flake
- Burrow mottling / bioturbation
- Colour mottling (dark within pale)
- Inverse colour mottling (pale within dark)
- planar and circular laminae (redox fronts?)

C = clay, Z = silt, vf = very fine sand, f = fine sand, m = medium sand, c = coarse sand, vc = very coarse sand.

Colour Notation: Rock Color Chart. The Geological Society of America. 1991, 7th Ed.

N1 - Black
N2 - greyish black
N4 - medium dark grey
N5 - Medium grey
N6 - medium light grey
N7 - light grey
N8 - very light grey
2.5Y 5/2 - greyish brown
2.5Y 7/2 - light grey
5B 7/1 - light bluish grey
5G 5/2 - greyish green
5G 6/1 -greenish grey
5GY 5/1 - mod. greenish grey
5GY 6/1 - greenish grey
5GY 6/2 - pale yellow green
5GY 7/1 - pale greenish grey
5GY 7/2 - greyish yellow green
5PB 5/2 - greyish blue
5Y 5/1 - moderate olive grey
5Y 5/2 - light olive grey
5Y 6/1 - very light olive grey
5Y 6/2 - light olive grey
5Y 7/1 - light grey
5Y 8/1 - yellowish grey
5Y 8/2 - white
5YR 3/2 - greyish brown
5YR 5/1 - medium brownish grey
5YR 6/2 - dark pinkish grey
5YR 7/2 - greyish orange pink
5YR 7/3 - light orange pink
5YR 8/1 - pinkish grey
5YR 8/2 - pale orange pink
5YR 8/4 - moderate orange pink
10G 6/2 - pale green
10G 7/2 - very pale green
10Y 4/2 - greyish olive
10Y 5/3 - light greyish olive
10Y 5/4 - light olive
10Y 6/1 - very pale olive
10Y 6/2 - pale olive
10Y 7/1 - v.light greenish yellow
10Y 7/2 - light greenish yellow
10YR 5/2 - yellowish brown
10YR 5/3 - pale greyish brown
10YR 5/4 - mod. yellowish brown
10YR 6/1 - light grey
10YR 6/2 - pale yellowish brown
10YR 6/3 - pale brown
10YR 7/1 - very light grey
10YR 7/2 - pale greyish orange
10YR 7/3 - very pale brown
10YR 7/4 - greyish orange
10YR 8/1 - white
10YR 8/2 - very pale orange
10YR 8/3 - very pale brown
10YR 8/4 - very pale brown



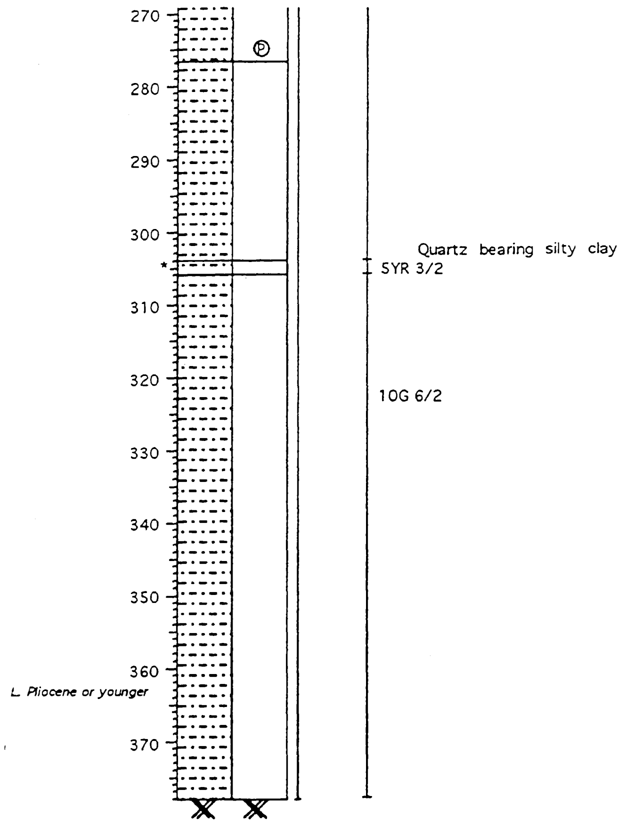


Figure 28. Log of Core 147/GC01.
Note that most (but not foram) evidence suggests that the sequence below 67 cm is Palaeogene.

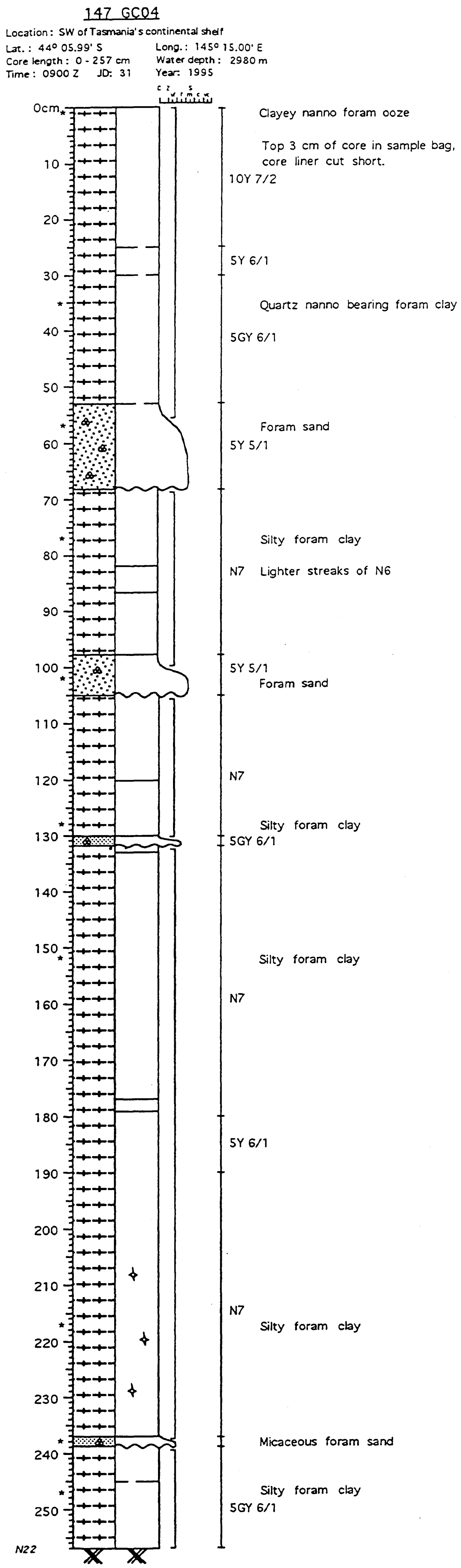


Figure 29. Log of Core 147/GC04

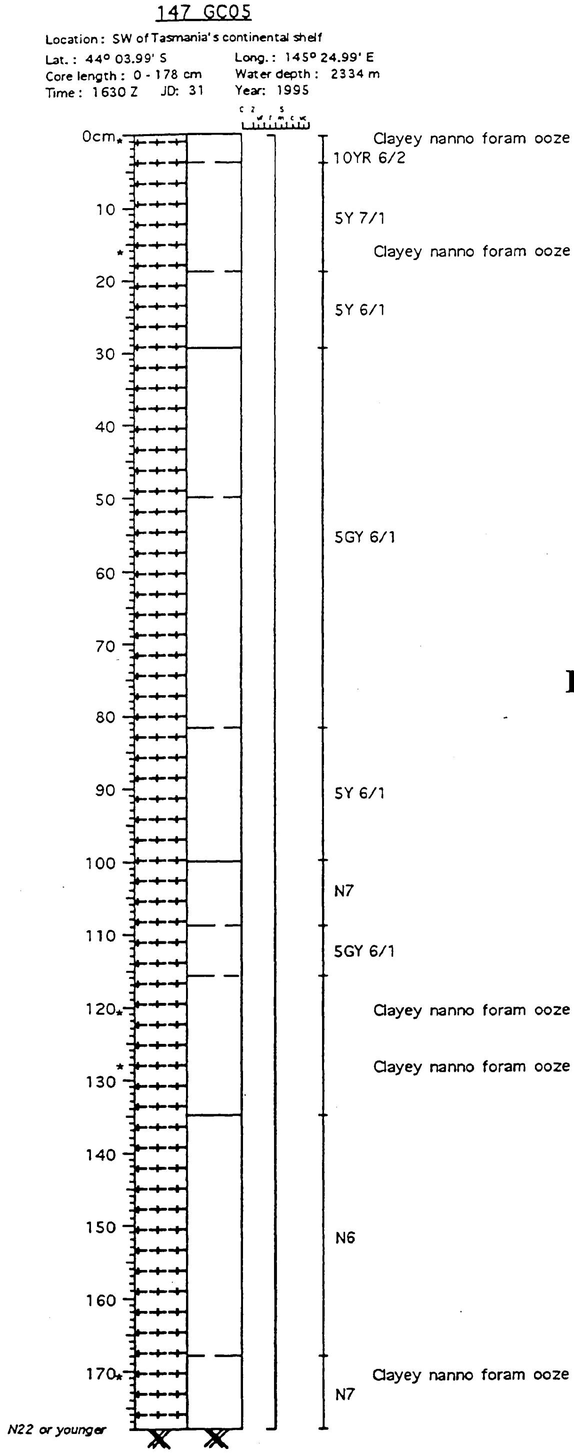


Figure 30. Log of Core 147/GC05

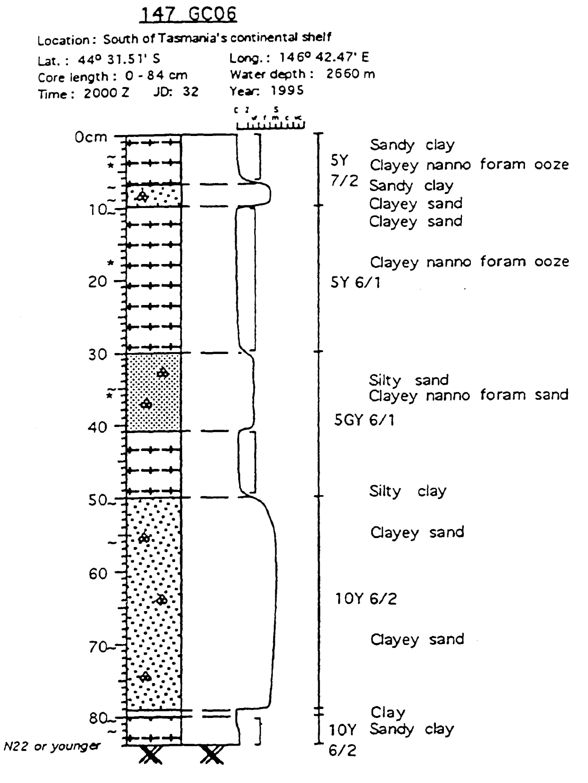
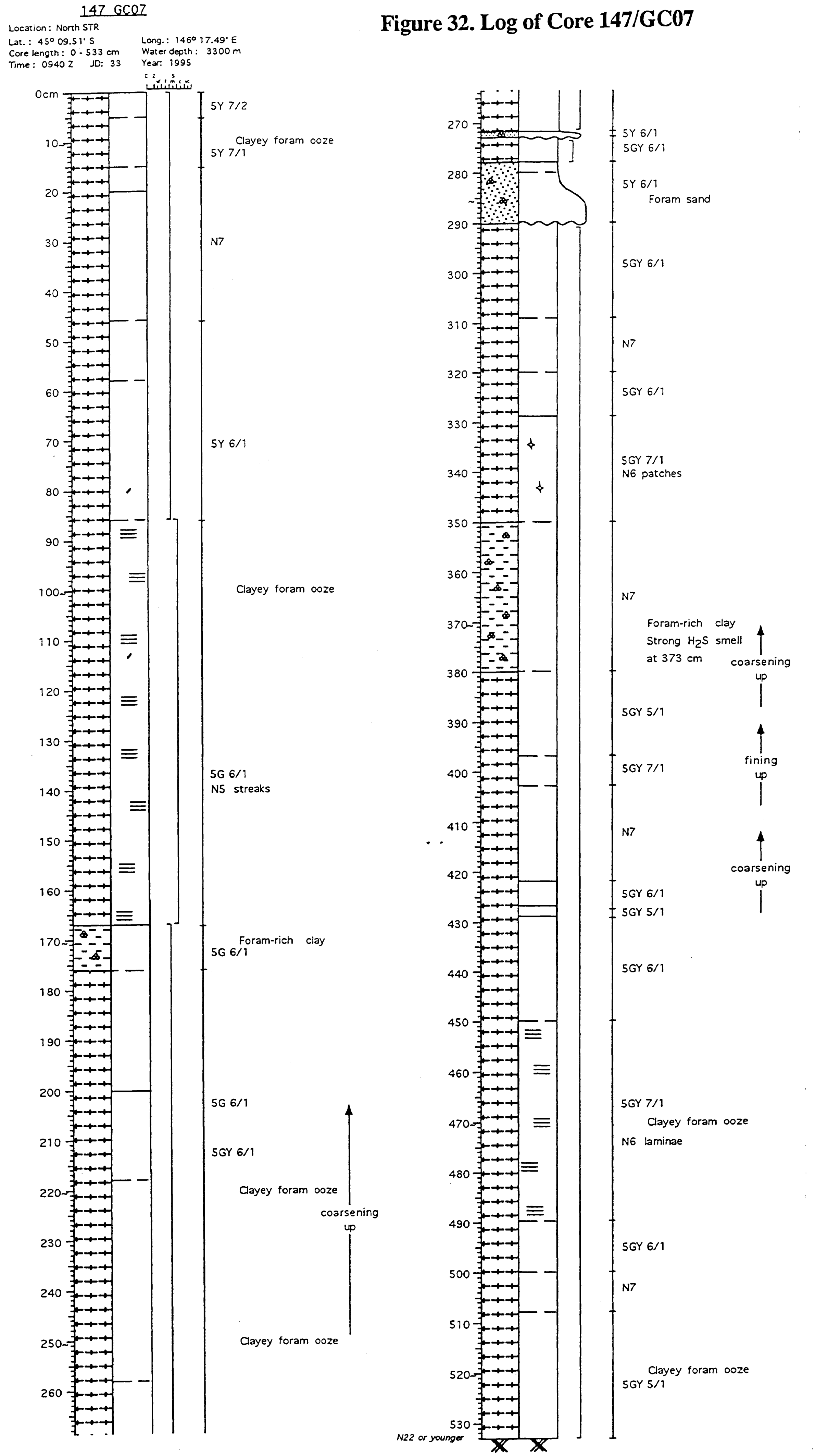


Figure 31. Log of Core 147/GC06

Figure 32. Log of Core 147/GC07



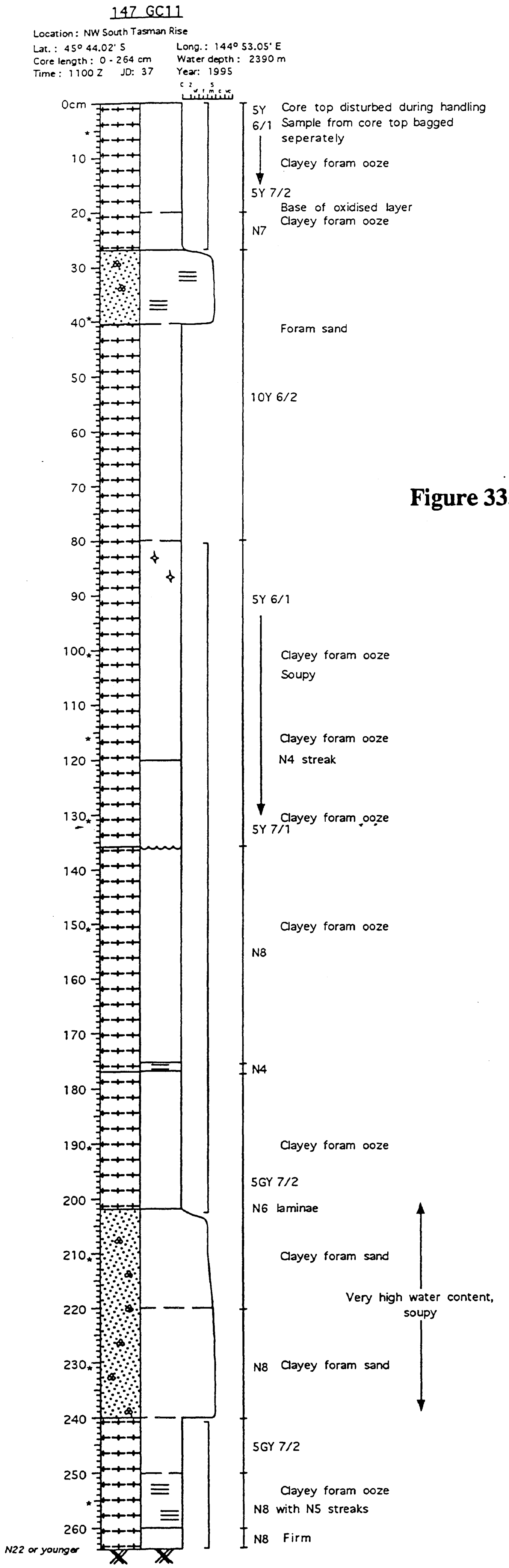
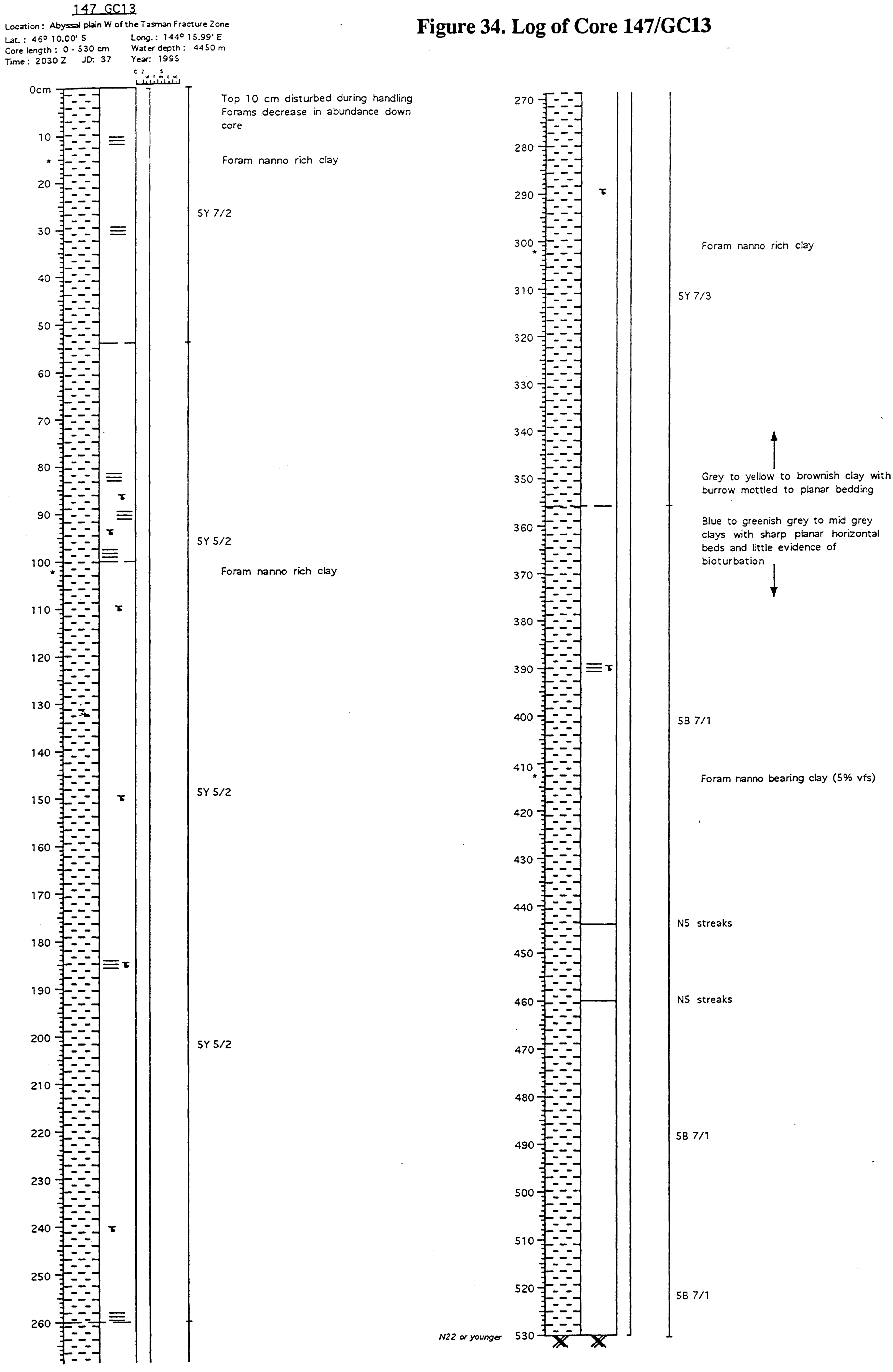


Figure 33. Log of Core 147/GC11

Figure 34. Log of Core 147/GC13



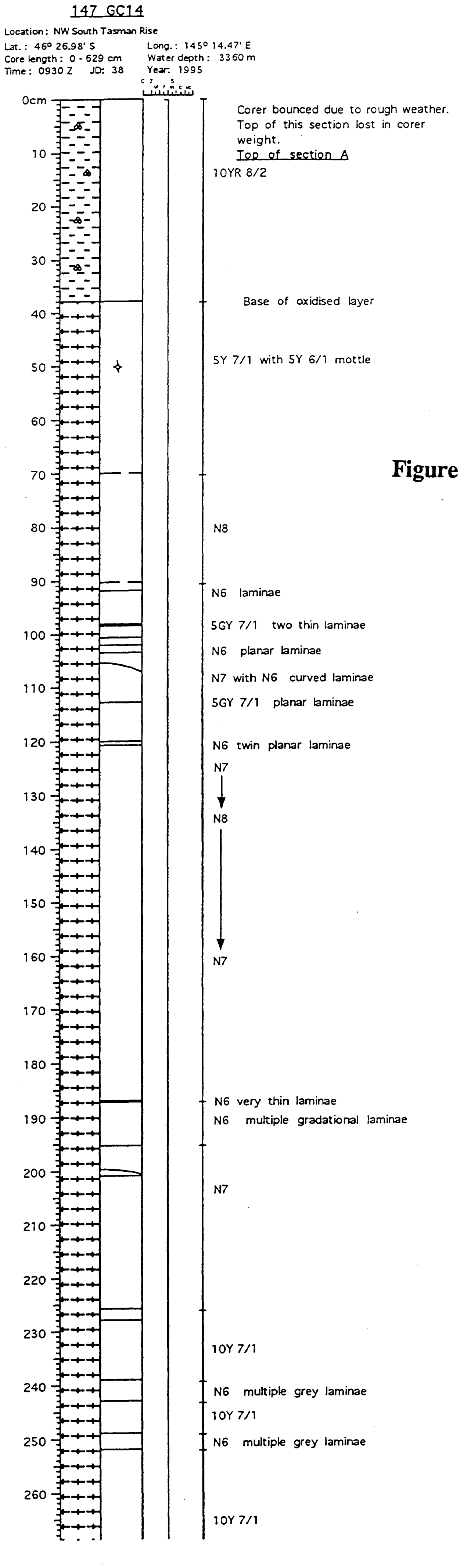
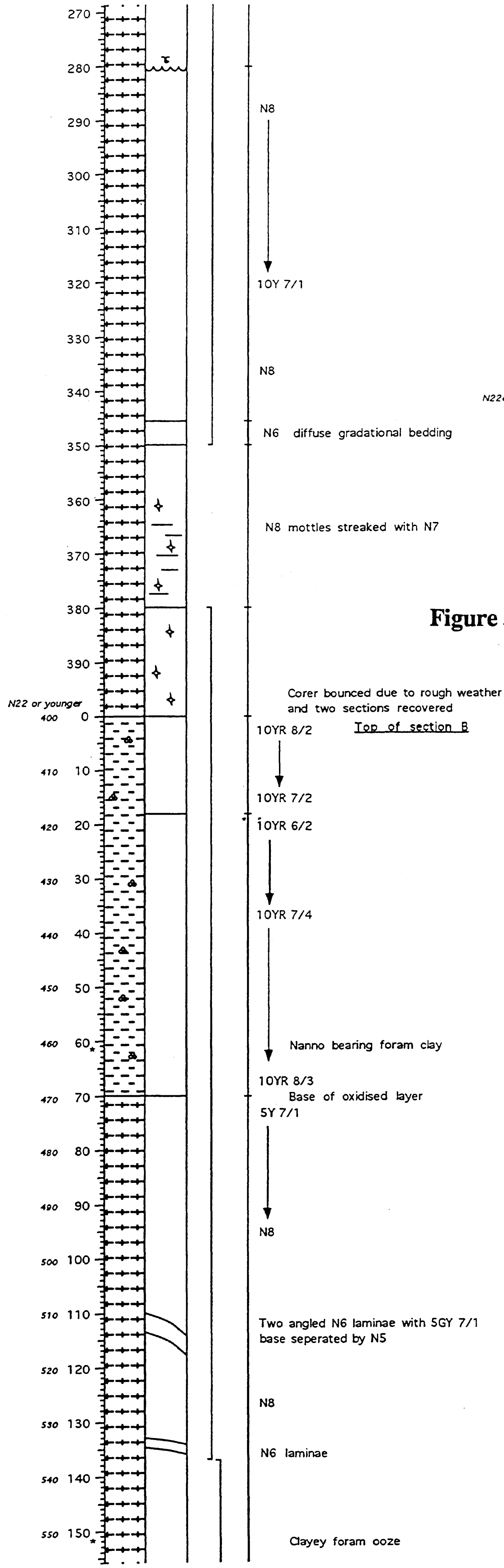


Figure 35. Log of Core 147/GC14 (upper part)



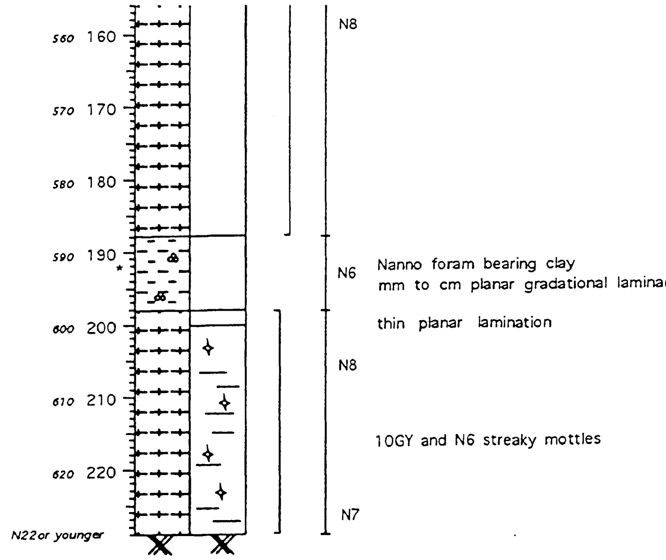


Figure 35. Log of Core 147/GC14 (lower part)

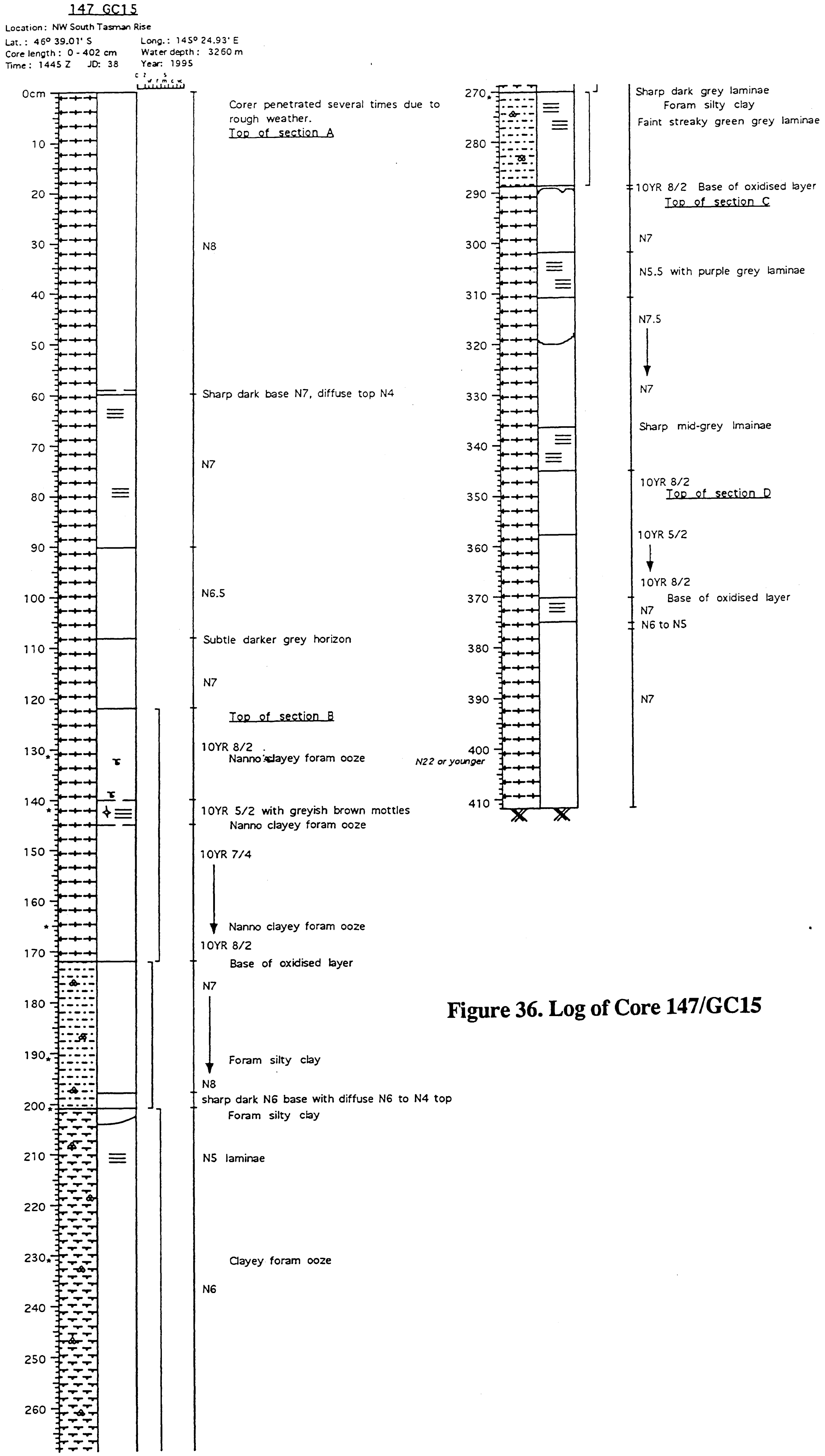


Figure 36. Log of Core 147/GC15

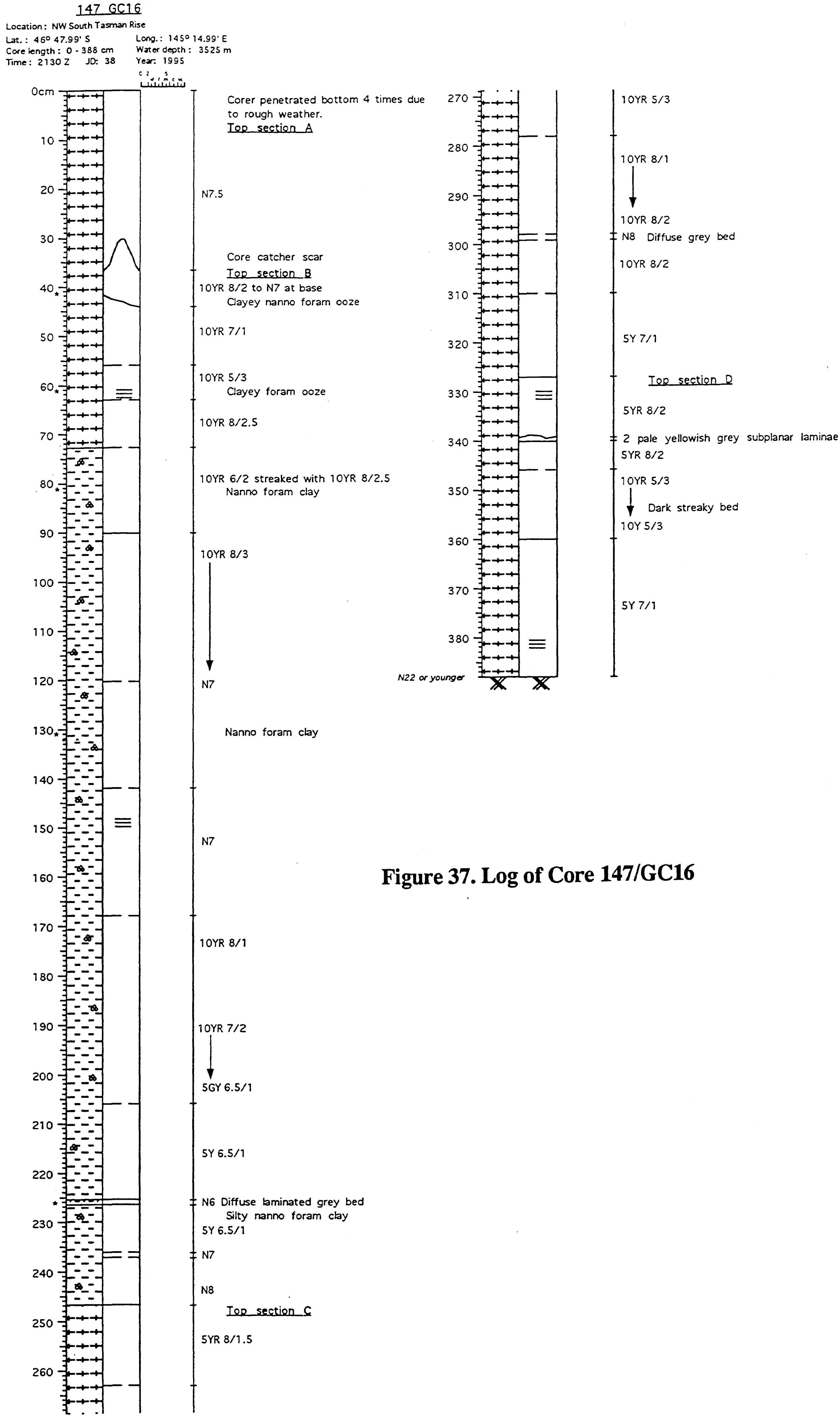


Figure 37. Log of Core 147/GC16

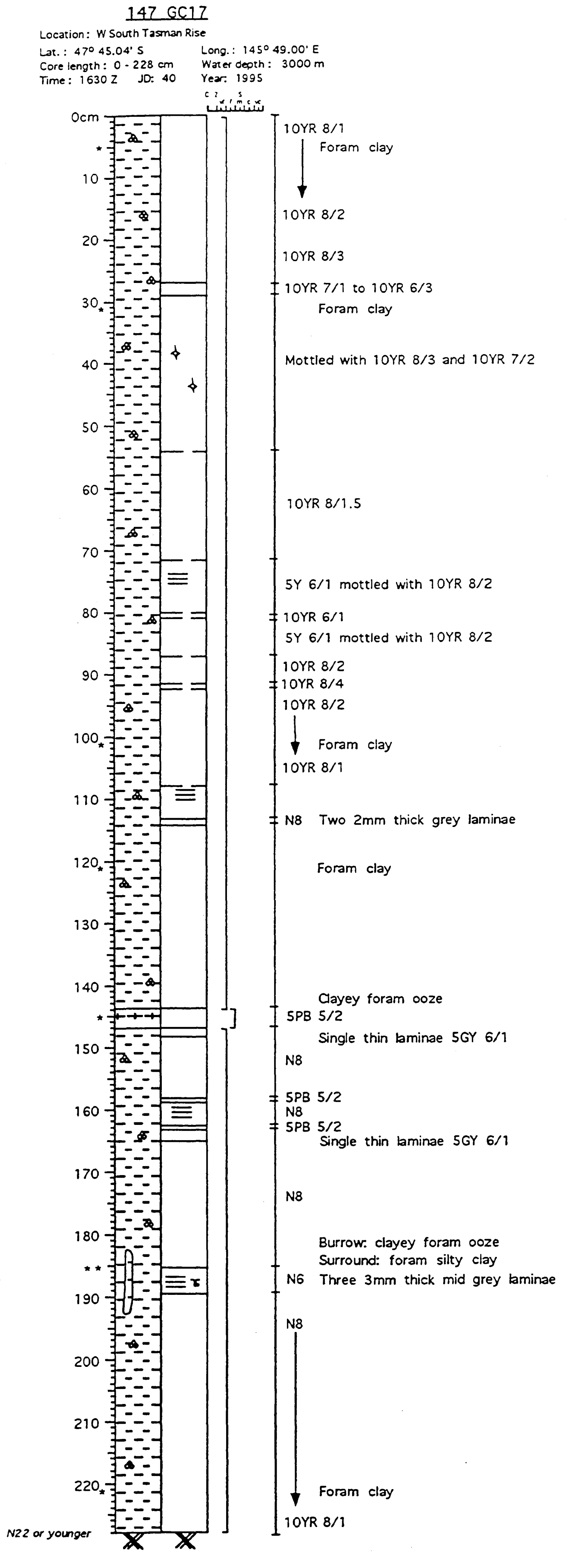


Figure 38. Log of Core 147/GC17

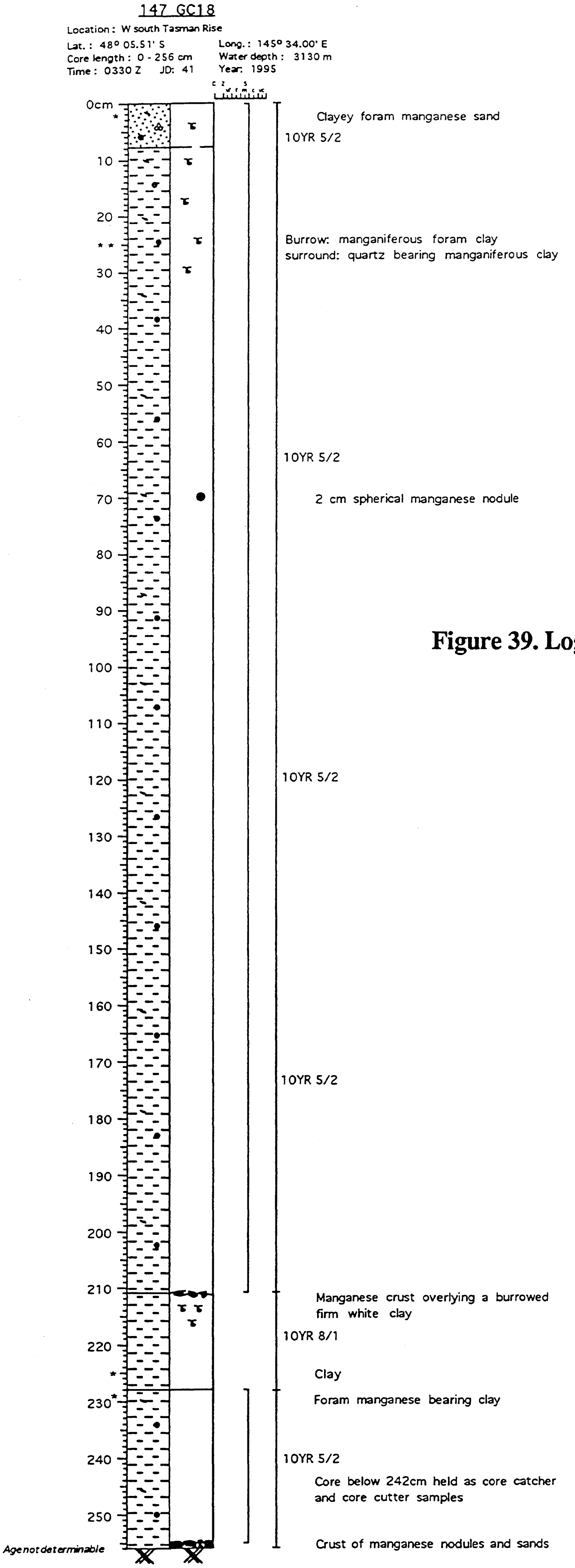


Figure 39. Log of Core 147/GC18

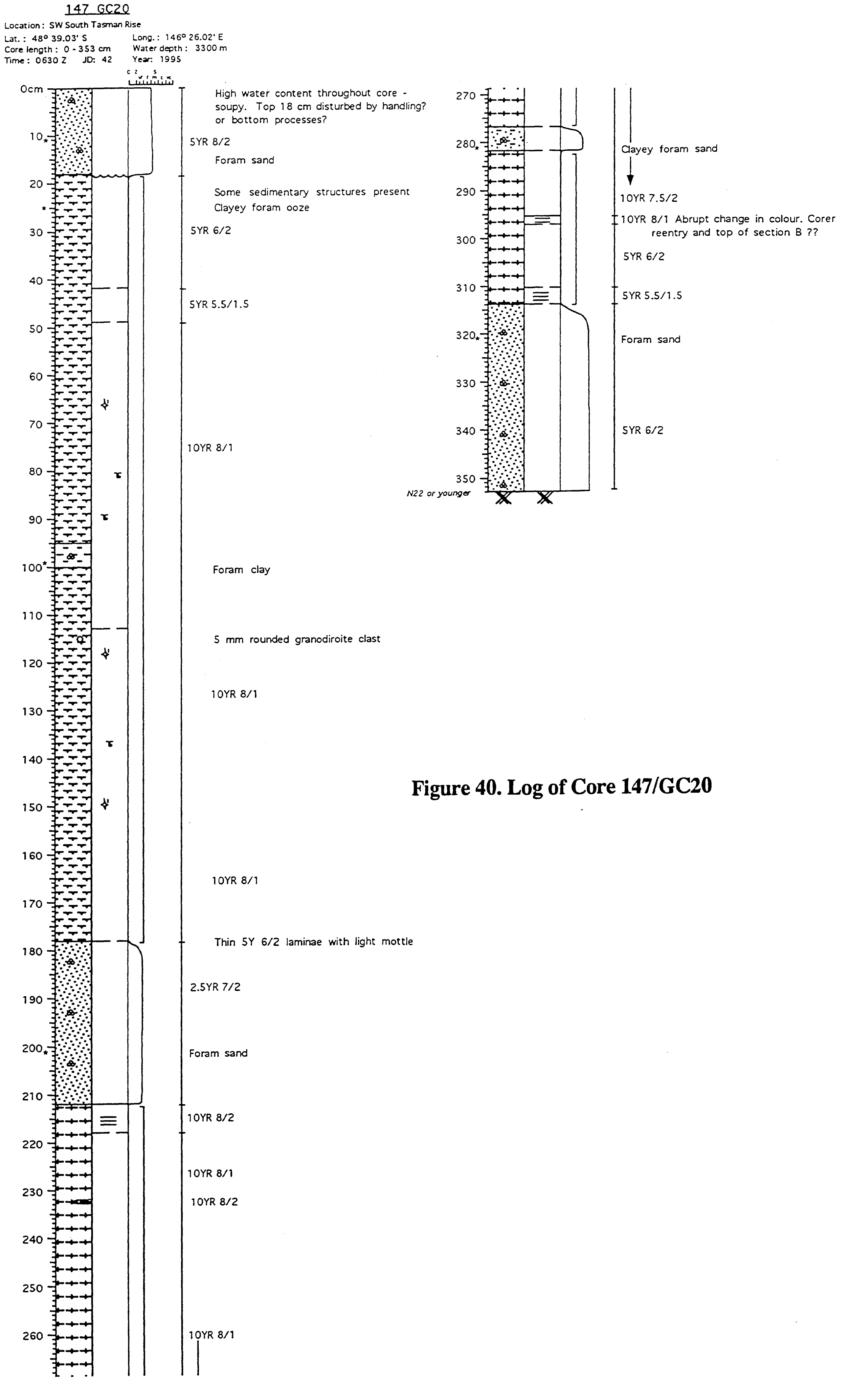


Figure 40. Log of Core 147/GC20

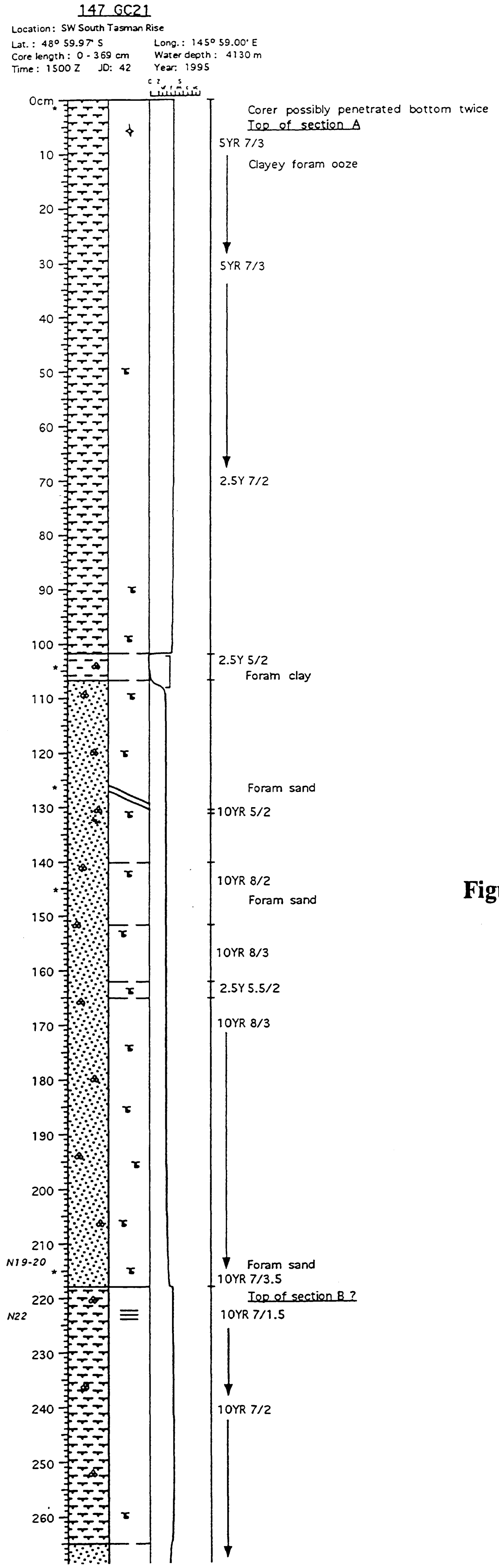


Figure 41. Log of Core 147/GC21

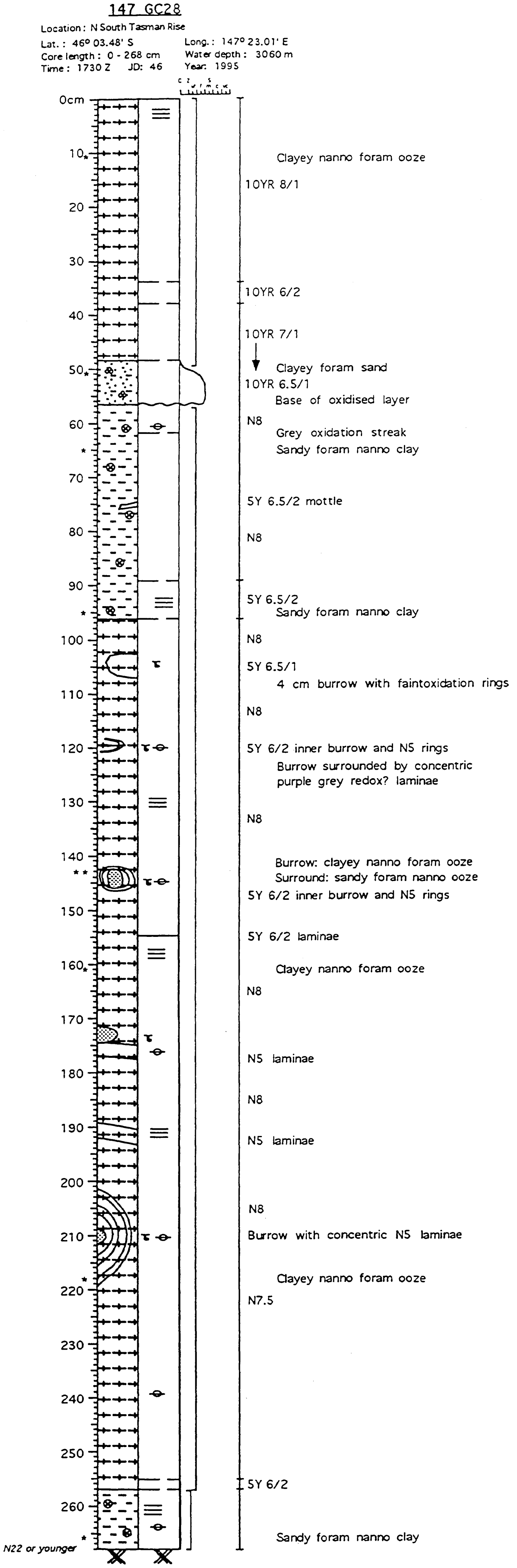


Figure 42. Log of Core 147/GC28

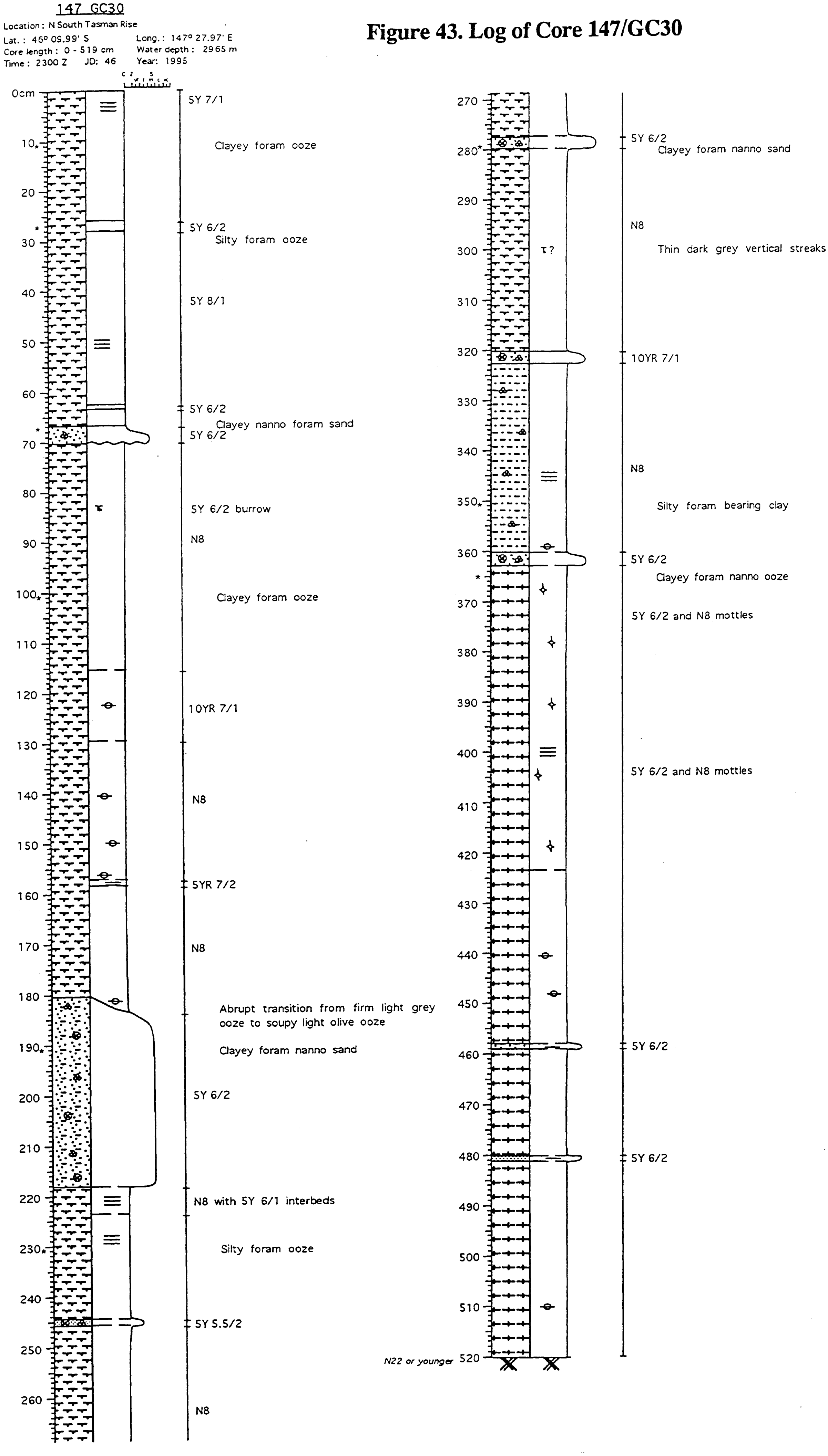
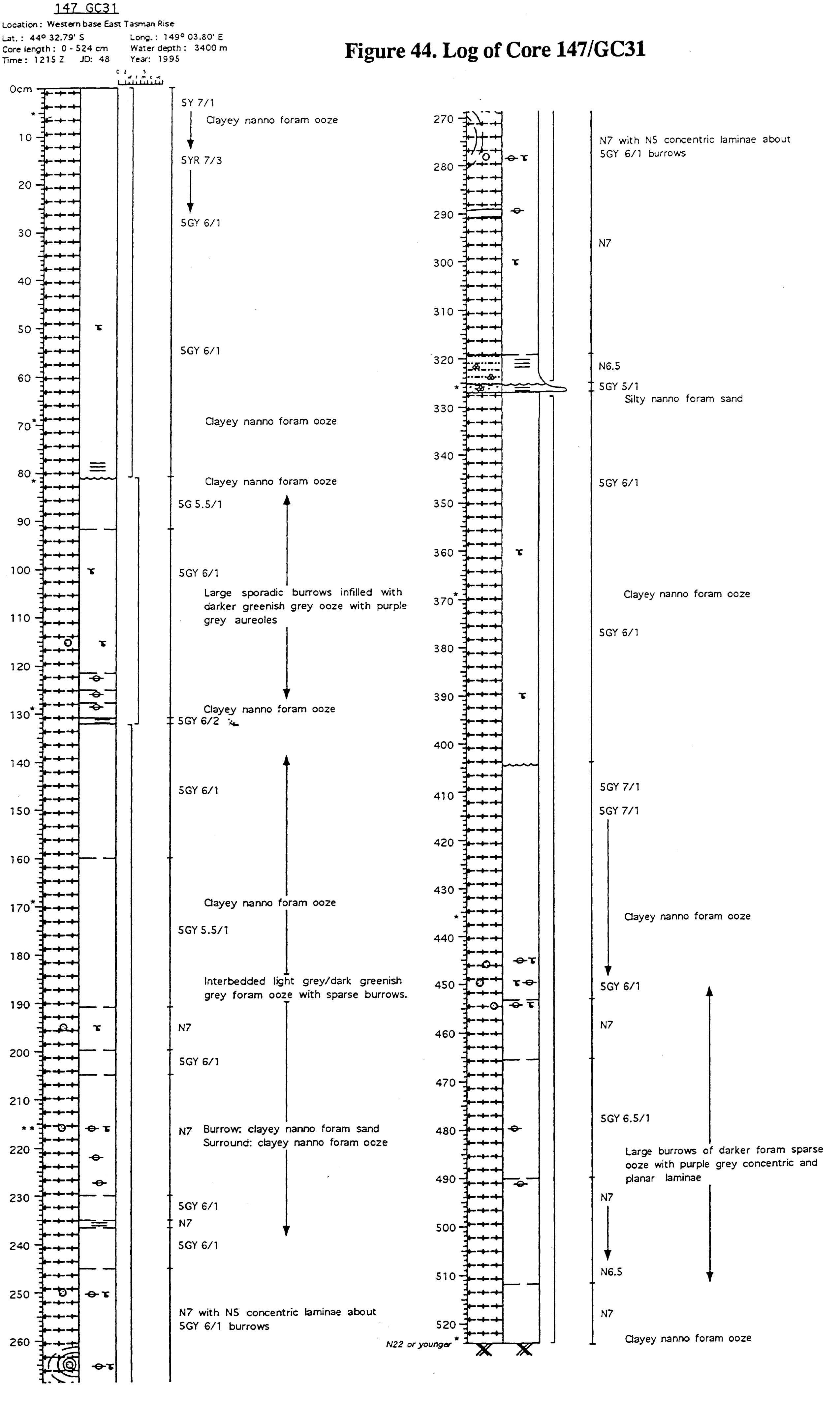


Figure 43. Log of Core 147/GC30

Figure 44. Log of Core 147/GC31



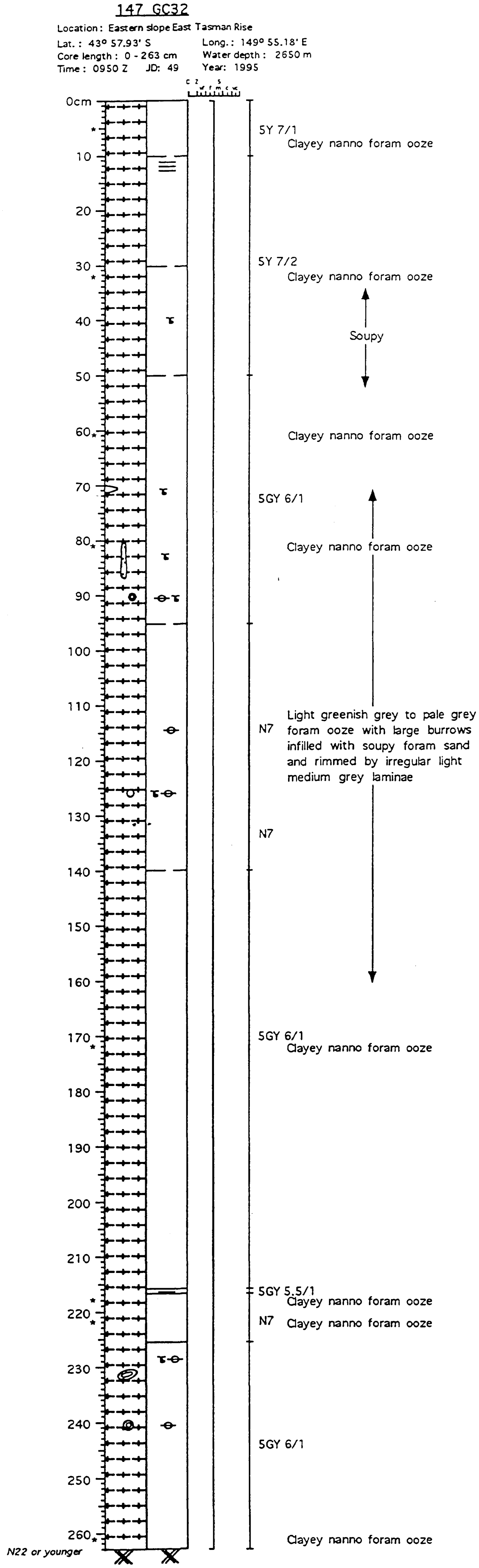


Figure 45. Log of Core 147/GC32

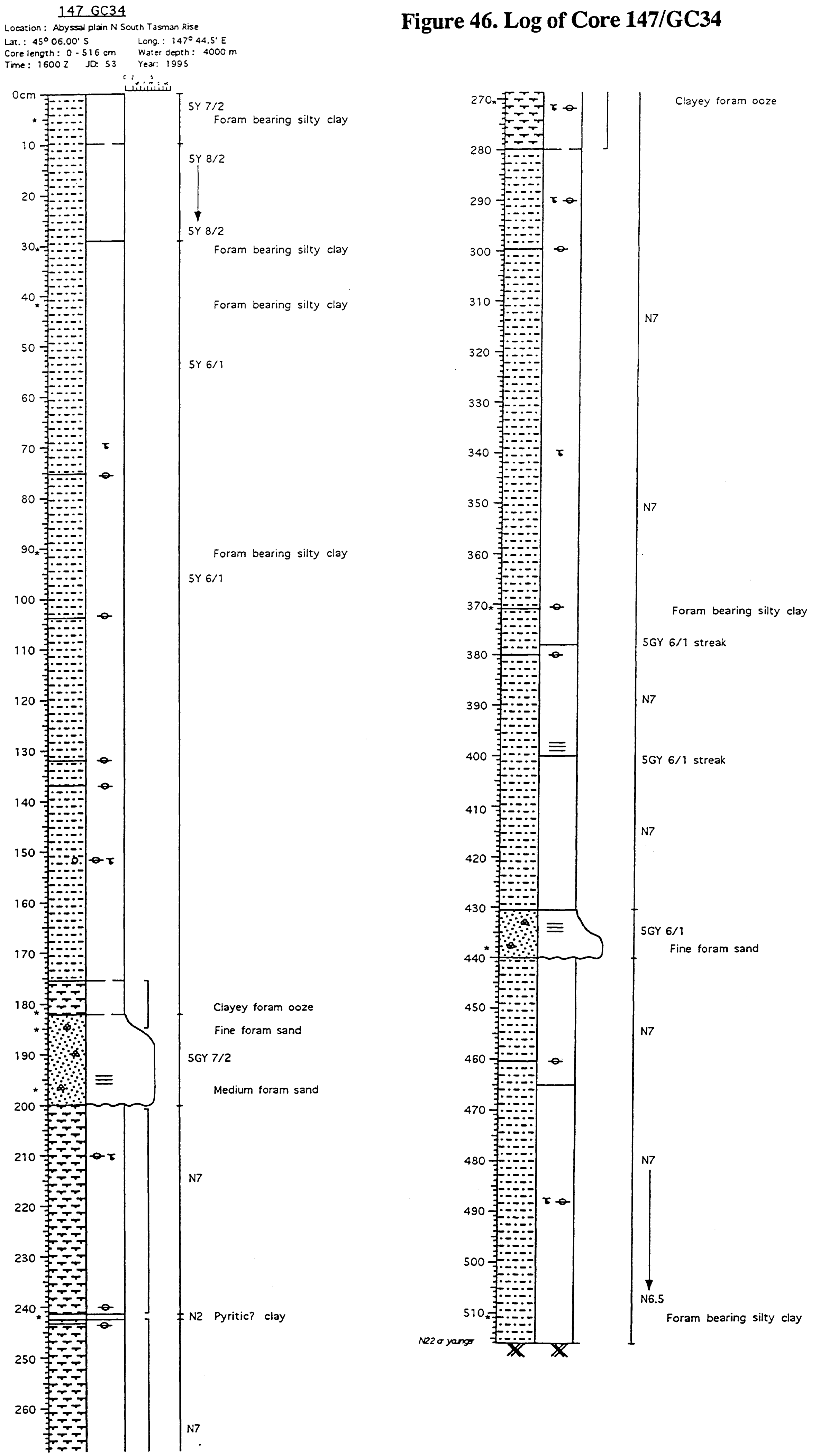


Figure 46. Log of Core 147/GC34

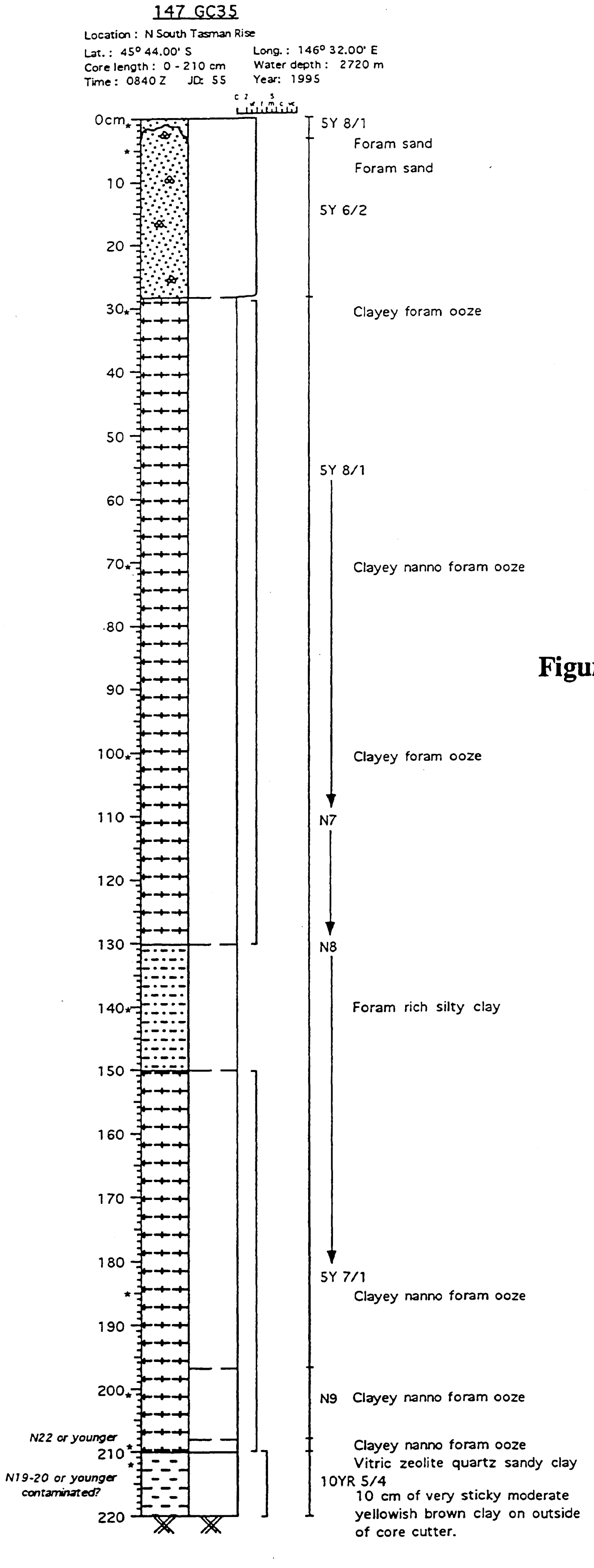


Figure 47. Log of Core 147/GC35

comments / description: No recovery. Lost core barrel!!!

9.2. Palaeoceanography

D. McCorkle, Woods Hole Oceanographic Institution

Overview

The basic goal of the paleoceanography group was to collect a set of cores and associated surface sediment and water column samples in order to document changes in Southern Ocean surface water and deep water properties (circulation, chemistry, and biology) on Glacial-Interglacial time scales. To accomplish this broad goal we hoped to collect:

1) a latitudinal transect of gravity cores from about 43°S to about 49°S (to monitor changes in the position of the Subtropical Convergence),

2) a set of gravity cores spanning the depth range of roughly 1.0 to 3.5 km (to monitor changes in the chemistry of intermediate and deep water masses),

3) box cores from a subset of the gravity core sites in 1) and 2) (to provide high-quality samples of the sediment-water interface, insuring good documentation of Holocene sedimentation and enabling us to carry out core-top calibration work on our paleoceanographic proxies),

4) a set of deep hydrocasts spanning the 1.0 to 3.5 km range (so we could document modern bottom water chemistry (oxygen, nutrients, $\delta^{13}C$, and trace metals) on the South Tasman Rise and East Tasman Plateau), and

5) a set of shallow hydrocasts (0 to 200 m) and surface water samples to investigate the modern assemblages of cocolithophores and diatoms (two groups of phytoplankton used in paleoceanographic studies) in this region.

Overall, this was a successful cruise in terms of the paleoceanographic studies. Though we were unable to collect a full depth transect of cores, we have 20 new deep-water cores which we hope will yield valuable new records of climatically-linked changes in surface ocean and deep water circulation, biology, and chemistry in the Southern Ocean. The surface water, water column, and surface sediment samples will be used for the proxy validation studies which provide an essential foundation for our paleoceanographic reconstructions.

Sample collection

The gravity coring work was fairly successful, particularly given the difficulties experienced in previous attempts to core the South Tasman Rise. Twenty gravity cores (Figs. 27-47) were recovered out of a total of 37 gravity corer casts. These cores ranged from 44° 06' S to 49° 05' S (see Table 22) and include sites on both the South Tasman Rise and the East Tasman Plateau. The successful gravity cores spanned a depth range of 4452 m to 2334 m; we were unsuccessful in eleven out of twelve casts in water depths less than 2.4 km, apparently because winnowing has left a relatively sandy sediment which gravity coring is unable to recover. Three of the successful cores had obviously penetrated more than once (147/GC-14: Fig. 35, 147/GC-15: Fig. 36, and 147/GC-16: Fig 37); all three were collected during a day of relatively bad weather which resulted in considerable pitching of the vessel. The top section of one other core (147/GC-11: Fig. 33) was noted as being strongly disturbed, but our attempt to collect another core at this site was unsuccessful.

Table 22 : Core sampling summary AGSO Cruise 147 off Tasmania

					Number of samples taken (approx.)					
ID	Group/site	Latitude	Longitude	Depth	Org	DBD/	$CaCO_3$	XRF	Mag /U	Forams/ Coccoliths/ Diatoms
		(South)	(East)	(km)		forams	TOC			
GC-01	GW	44° 10.30	144° 10.86	4.238	12	12	12	12	12	0/1/1
GC-04	CRC 1	44° 05.99	145° 15.00	2.981	30	30	29	29	27	0/1/1
GC-05	CRC 2	44° 03.99	145° 24.99	2.334	18	18	18	17	18	0/1/1
GC-06	GW	44° 31.51	146° 42.48	2.609		5	5		4	0/1/1
GC-07	CRC 3	45° 09.53	146° 17.51	3.307	47	47	47	47	47	0/1/1
BC-03	CRC 3	45° 09.53	146° 17.51	3.307	16		16			7 (LB)/1/1
GC-11	dist CRC 6	45° 44.02	144° 53.05	2.406	25	30	31	30	29	0/1/1
GC-13	GW	46° 10.01	144° 15.99	4.452	12	12	12	12	12	0/1/1
GC-14	2hitCRC B	46° 26.98	145° 14.47	3.360	32	35	65	33	9	22/1/1
GC-15	4 hit GW	46° 39.01	145° 25.06	3.260	not sampled					
GC-16	4 hit GW	46° 47.99	145° 14.99	3.523	13	19	39	19	8	14/1/1
GC-17	CRC 7	47° 45.04	145° 49.01	3.001	34	35	69	35	17	33/1/1
GC-18	GW	48° 05.55	145° 34.11	4.368	not sampled					
GC-20	CRC A	48° 39.02	146° 26.02	3.306	18	26	52	25	15	35/1/1
GC-21	GW	49° 00.05	145° 59.01	4.132			13			0/1/1
GR-01	CRC 9	47° 39.60	147° 32.98	1.311	*Grabs sampled for forams, cocoliths, diatoms, $CaCO_3$ /TOC, live benthics					
GR-02	CRC S	47° 19.00	147° 59.99	0.922	*					
GR-03	CRC 11	46° 36.59	147° 25.17	1.581	*					
GC-28	GW	46° 03.51	147° 22.94	3.065	27	28	51	25	19	15/1/1
GC-30	GChar	46° 10.04	147° 27.98	2.968		47	47			
GC-31	CRC ET1	44° 32.80	149° 03.81	3.403	15	23	47	24	18	30/1/1
GC-32	CRC ET2	43° 57.93	149° 55.18	2.645	13	18	36	18	18	0/1/1
GR-09	JM	43° 26.41	148° 09.58	0.805	forams only					
GR-10	JM	43° 27.67	148° 11.80	1.285	forams only					
GC-33	JM	43° 27.67	148° 11.82	1.285	forams only					
GC-34	GW	45° 06.00	147° 44.5	4.002		11	11	11	11	0/1/1
GC-35	GW	45° 44.0	146° 32.0	2.720		21	21	21	21	0/1/1

The gravity cores were each split, described, and photographed. The "working" half of each core was sampled at 5 cm intervals through the top 0.5 to 1.0 meter and at 10 and 20 cm intervals deeper in the core. Subsamples were collected for:

- percent $CaCO_3$ and percent organic carbon
- dry bulk density
- abundances and shell chemistry (stable isotopes and metal:calcium ratios) of planktonic and benthic foraminifera
- organic geochemistry (in particular, alkenone unsaturation ratios)
- x-ray fluorescence analysis of major and minor elements
- magnetic susceptibility
- uranium series dating
- coccolithophore and diatom abundances (surface samples only)

Initially all subsamples were collected from the same 3 cm depth interval, which used essentially all of the working half sediment in each sampled interval. Starting with 147/GC-014, we confined our sampling to one half of the working half; this meant that samples are from adjacent two- and three-centimeter intervals, but it preserved the opportunity to resample at closer spacing if our analytical results on the 5 and 10 cm samples suggest that this would be worthwhile.

Three box corer casts were attempted, one of which was successful. We did not make additional casts in order to maximize the time we could devote to gravity coring, and because we felt that the combination of relatively sandy sediments, the sea state, and the light weight of the AGSO box corer meant that our success rate was likely to be low. An archive subcore of the successful BC (147/BC-03) was set aside for the AGSO core collection. Subsamples of the other 147/BC-03 subcores were collected for:

- percent $CaCO_3$ and percent organic carbon
- abundances and shell chemistry (stable isotopes and metal:calcium ratios) of planktonic and benthic foraminifera
- organic geochemistry (in particular, alkenone unsaturation ratios)
- live (stained) benthic foraminiferal abundances and shell chemistry
- coccolithophore and diatom abundances (surface samples only)

At three of the shallower sites on the South Tasman Rise we collected surface grab samples when the gravity coring was unsuccessful. In each case the grab was successful in recovering about 6 to 8 cm of coarse, clean foraminiferal sand. In 147/GR-02 the sediment-water interface appeared to be particularly well-preserved - a flocculent greenish fluff was observed in small depressions in the sediment surface. Surface (0 - 1 cm) and subsurface sample from all three grabs were collected for:

- percent $CaCO_3$ and percent organic carbon
- abundances and shell chemistry (stable isotopes and metal:calcium ratios) of planktonic and benthic foraminifera
- organic geochemistry (in particular, alkenone unsaturation ratios)
- live (stained) benthic foraminiferal abundances and shell chemistry
- coccolithophore and diatom abundances (surface samples only)

9.3. Sedimentology of the South Tasman Rise from a 'groundtruthed' acoustic facies map

G.P. Whitmore, James Cook University

Introduction

Acoustic facies maps aim to accurately predict seabed geology in any given area of the seafloor using remotely sensed geophysical data. The interaction of sound waves with the seafloor can be used to predict seabed type much like mapping of soil types using satellite imagery is carried out on land. Modern acoustic facies maps rely on regular, closely spaced marine surveys with full swath imaging systems to produce accurate results. Reliable interpretation of acoustic facies maps for a particular area requires detailed 'groundtruthing' of the facies defined by the map. In this way predicted sedimentary facies, based on acoustic theory and past work in other oceans, can be tested and hopefully 'proved'.

A detailed definition, description and interpretation of the South Tasman Rise acoustic facies map (Fig. 48) and of the resultant sedimentary environments map (Fig. 49) is presented in the *Tasmante*

Figure 48. South Tasman Rise acoustic facies map. Prepared from *Tasmante* echosounder profiles and swath bathymetry. After Whitmore et al. (1994), and not modified in light of Cruise 147 results.

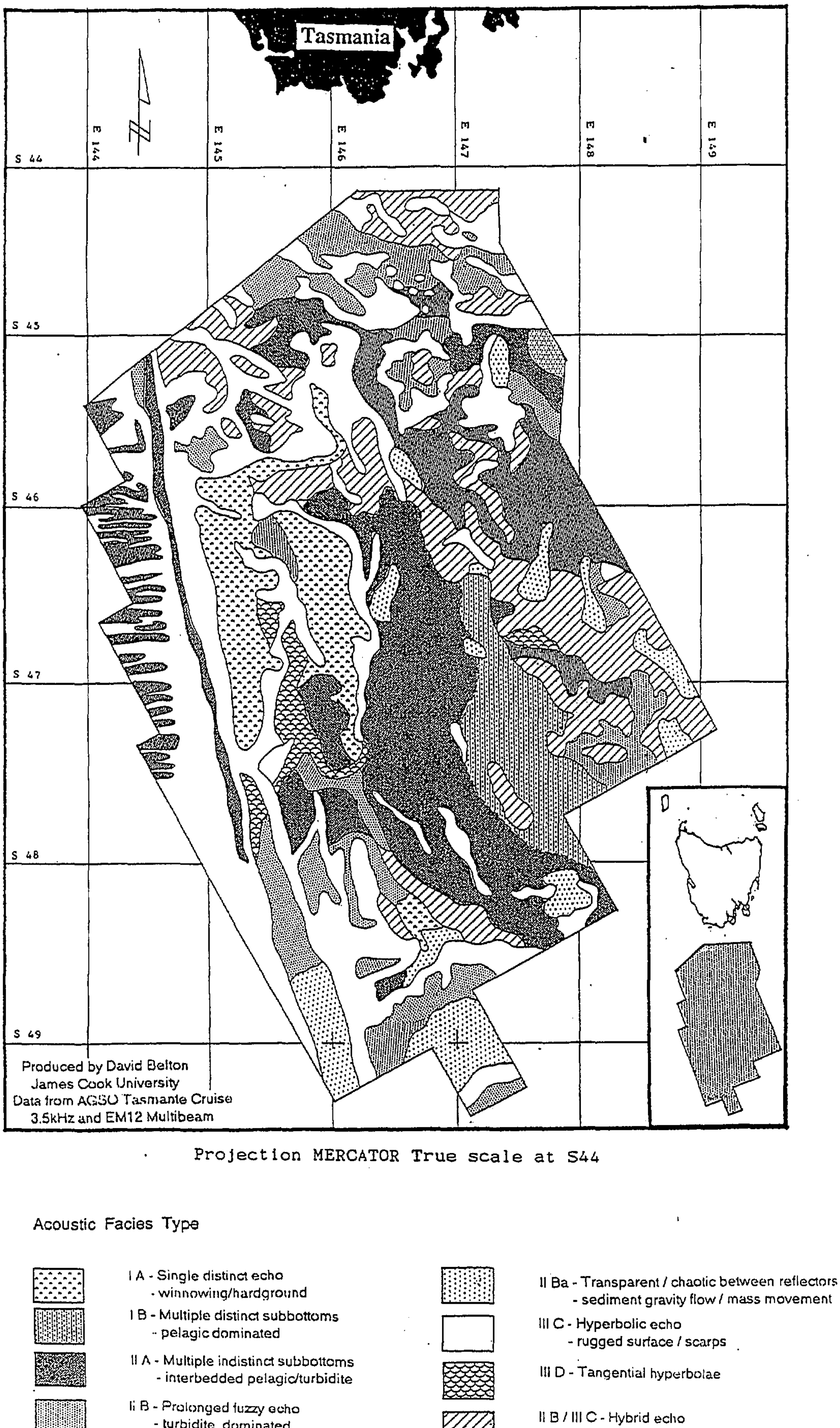
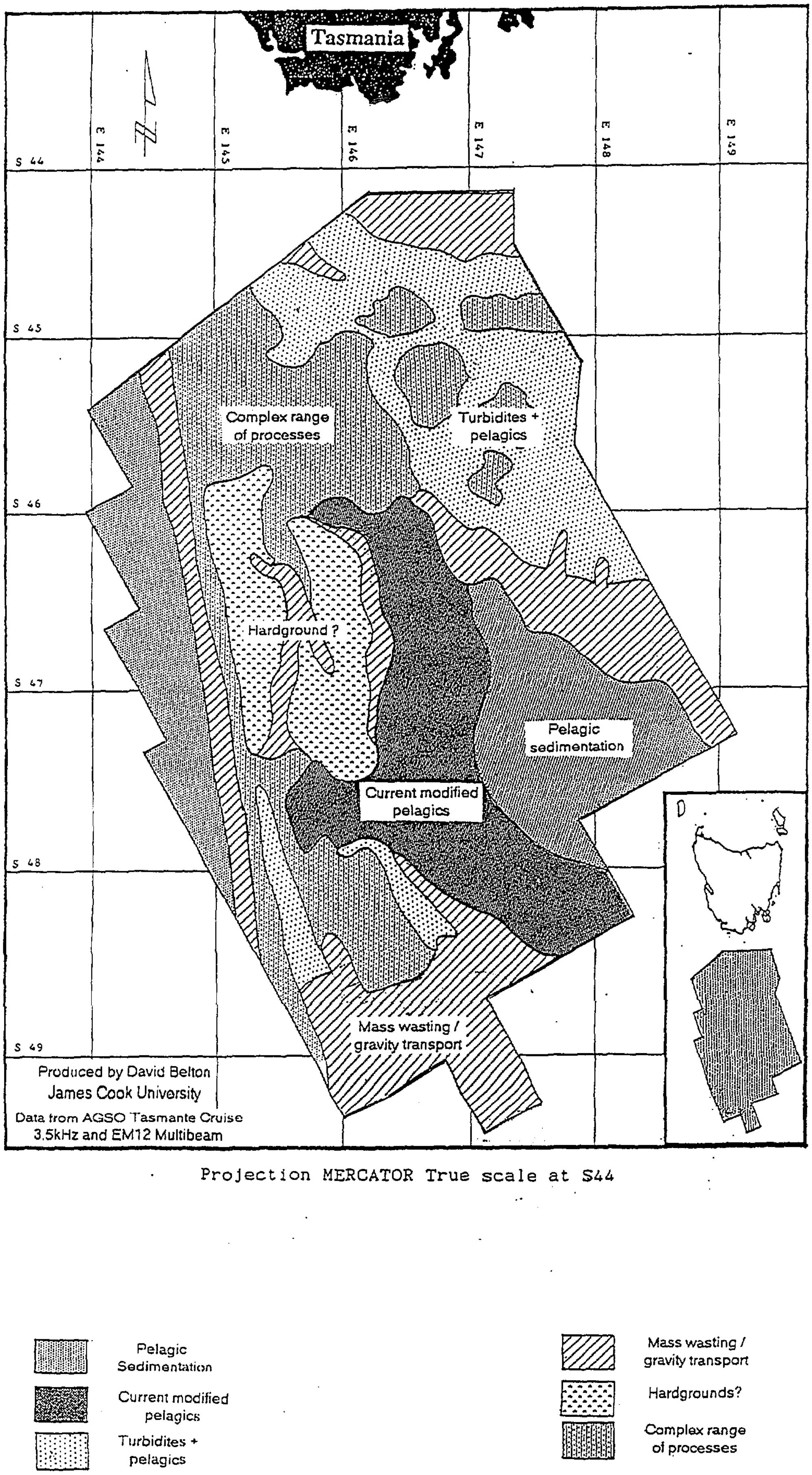


Figure 49. South Tasman Rise sedimentary environments. Derived from acoustic facies map (Fig. 49) and other information. After Whitmore et al. (1994), and not modified in light of Cruise 147 results.



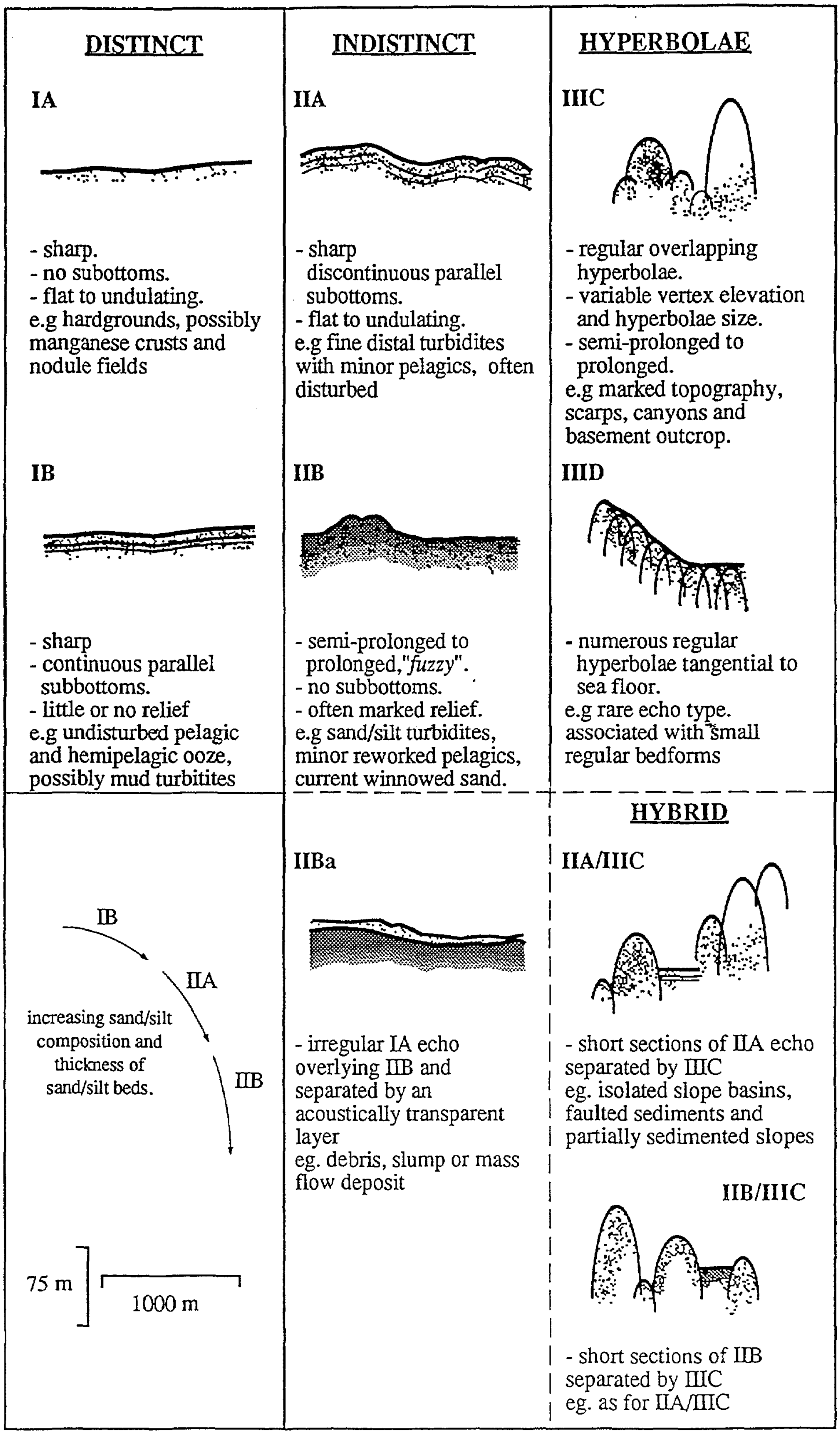


Figure 50. Acoustic facies types determined from 3.5 KHz echosounder profiles. Slightly modified from Damuth (1980). After Whitmore et al. (1994).

94 survey report (AGSO cruise 125: Exon et al., 1994), with references to similar work elsewhere. The *Tasmante* survey report also contains bathymetric maps, acoustic reflectivity imagery and line drawings of echo types used to construct the acoustic facies map. The acoustic facies identified on the *Tasmante* survey are illustrated in Figure 50. The *Tasman Rises* 95 cruise (AGSO cruise 147) was designed to recover samples from the area previously covered by *Tasmante* 94. Twenty successful gravity cores (Section 9.1) and 53 dredge hauls (Figure 1 and Tables 14 & 15) were recovered from the Tasman Rise and have been used to groundtruth the South Tasman Rise acoustic facies map, produced a year earlier from geophysical data alone. Initial results discussed below show that acoustic facies mapped on the South Tasman Rise are similar to facies mapped in other oceans (Figs. 51 & 52).

Of the 73 cores and dredge hauls recovered, none are markedly different from earlier predictions. Several cores, such as GC13 and 18, contain anomalously low concentrations of sand when compared to the acoustic facies from which the sample was recovered. In each case these apparent anomalies can be readily explained, and the map amended by incorporating new information into the description of each facies. This is very encouraging, as boundaries defined in 1994 remain unchanged, and the description of facies delineated by the acoustic facies map has become more precise.

Methods

Of principal interest to this study are the 20 successful gravity cores and 54 successful dredge hauls presented in Figures 27-47 and Table 14. Each rock type dredged was described on board and has been discussed in detail in Section 8 of this cruise report. The 20 gravity cores were split and described on board (Section 9.1). Initial construction of graphic logs for each gravity core relied on visual estimation of lithology and grainsize. All visual changes in lithology or grain size were sampled and smear slides prepared so that composition and texture could be more accurately assessed (see Appendix 9). The results from smear slide analysis were then used to revise the initial graphic logs. One method of displaying downcore textural data obtained by smear slide analysis is to present the data as percent sand for the total length of the core (Figures 51 & 52). As the quantity of interbedded sand within a core also represents a good indicator of sedimentary environment, and hence acoustic facies, it will be used to focus the remaining discussion.

Revised sedimentary facies interpretation

Distinct
IA : Sharp, continuous echo with no sub-bottom reflectors. Thin surficial ooze overlying pelagic clay with thin silty clay interbeds, possibly with hardground or manganese nodule pavement at depth.
IB : Sharp, continuous echo with up to 20 continuous parallel sub-bottom reflectors. Undisturbed interbedded pelagic clays, silts and oozes. Rare thin beds of foram sand, generally less than 2 cm thick, but up to 18 cm thick, comprise approximately 1% of the sediment and bioturbation is sparse.
Indistinct
IIA : Semi-prolonged echo with discontinuous parallel sub-bottom reflectors. Pelagic ooze with minor clays and silts. Bioturbation evident throughout. Foram sands form beds up to 40 cm thick and comprise approximately 7% of the sediment.
IIB : Prolonged to very prolonged 'fuzzy' echoes with no sub-bottom reflectors. Thick foram sands comprise greater than 50% of the sediment with minor ooze and clay. Manganiferous sands and crusts in areas with very high acoustic reflectivity.

Figure 51. Quantity of interbedded sand within successful *Tasman Rises* gravity cores showing acoustic facies from which each core was recovered.

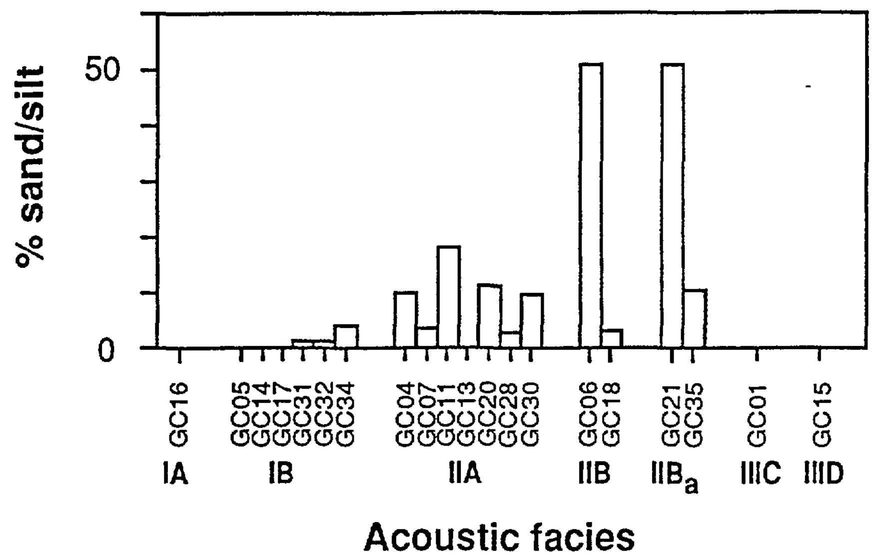
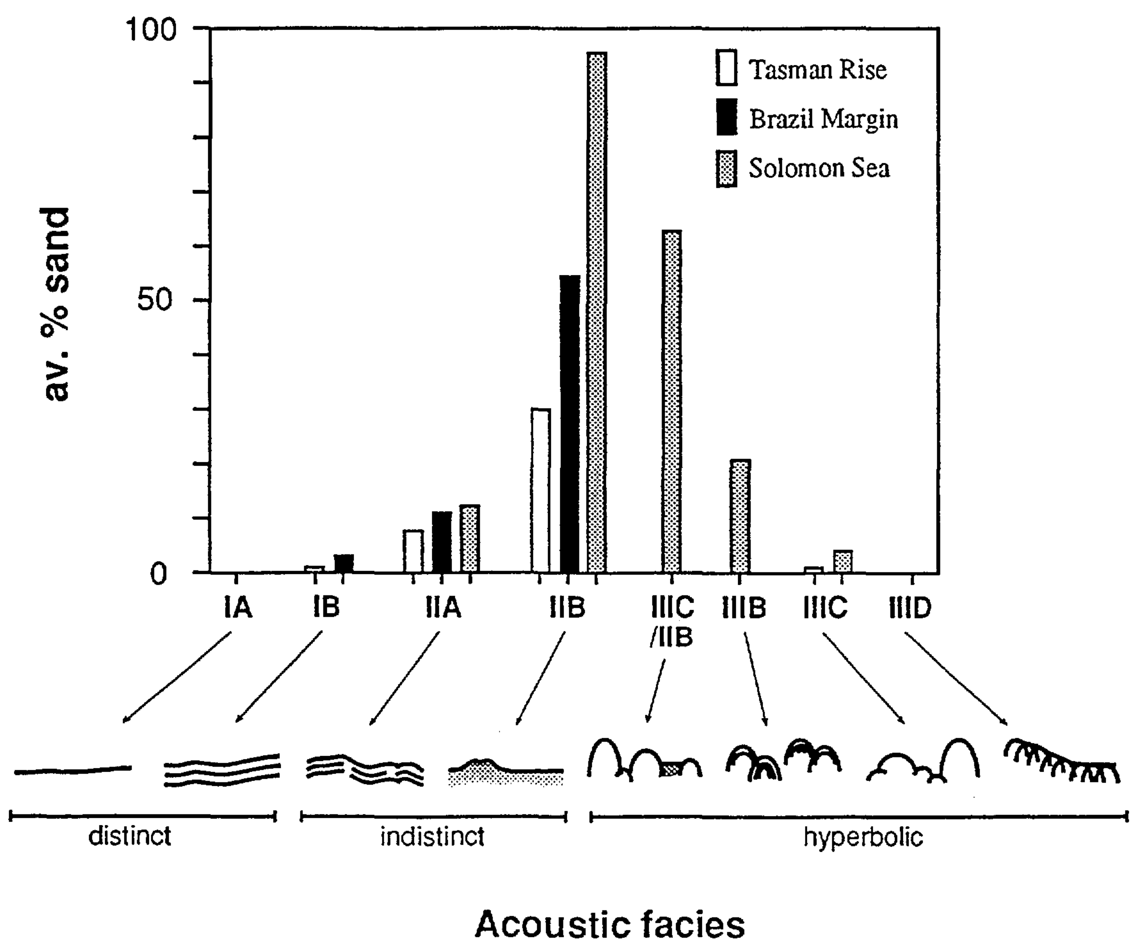


Figure 52. Average quantity of interbedded sand within cores from the South Tasman Rise (this study), Brazil Margin (Damuth, 1980) and Solomon Sea (Whitmore, in prep.), showing acoustic facies from which each core was recovered and line drawings of 3.5 kHz echo types used to define facies.



IIBa : Irregular sharp echo (IA) overlying a prolonged (IIB) echo with no sub-bottom reflectors and separated by an acoustically transparent zone. Pelagic ooze and clay with minor foram sand overlying an unconformity surface or pelagic ooze and clay overlying an extended section of foram sand more than one metre thick. Homogeneity could be due to gravity flow, slump or mass movement.

Hyperbolic

IIIC : Large, irregular, overlapping semi-prolonged to prolonged hyperbolae with varying vertex elevations. Rugged or erosional topography, canyons and scarps, with or without a thin veneer of pelagic ooze and clay.

IIID : Small, regular, overlapping hyperbolae, with vertices tangential to the sea floor. Pelagic ooze and clay possibly associated with small regular bedforms or erosional features suggesting current activity.

Discussion

IA

The acoustic facies comprising echo type IA is confined to two large perched basins immediately to the east of the Tasman Fracture Zone. Gravity core 16 (Figs. 37 & 51), recovered from this facies during a period of rough weather, returned 388 cm of thickly interbedded clayey nanno foram ooze and nanno foram clay with one thin silty clay bed. Close examination of this core revealed a core cutter scar at 35 cm and a repetitive pattern of lithology, sedimentary structures and colour below this. From this it is suggested that the corer penetrated the seafloor 4 times, possibly as the boat rode swells several metres high, and that the resulting core represents 4 stacked sections of the upper most sediments. Section B from 35 to 247 cm is interpreted to be the most complete section and has been used to characterise a dominantly pelagic setting, possibly with hardground or manganese nodule pavement at depth, for acoustic facies IA.

IB

Within the survey area, IB acoustic facies, characterised by multiple parallel sub-bottom reflectors, is limited to the upper part of the South Tasman Rise above 1500 m, the abyssal plain to the east of the Rise, and several other small basins. All six cores recovered from water deeper than 2000 m and areas of IB facies are long, and contain rare thin interbeds of sand. Of these six, five cores (GC05, 14, 17, 31, and 32) contain less than 1% interbedded sand as very rare sandy beds less than 2 cm thick or as rare sandy worm burrows. Core GC34 from the abyssal plain NE of the South Tasman Rise (Fig. 46) is the only core from this facies that contains sandy units greater than 2 cm thick. This core recovered 516 cm of clay and foram ooze with 2 sandy beds, 9 and 18 cm thick, giving it the highest percentage of interbedded sand for this facies at 5%. As these sandy beds have scoured bases and well developed fining-up features they are interpreted as turbidites.

Unfortunately, all gravity cores on the upper part of the rise failed, though small samples of well sorted, medium to coarse grained foram sand were recovered in core catcher and bottom grab samples. It is believed that the failure of gravity cores above 2000 m was due to a thick surficial accumulation of foram sand indicative of persistent bottom current activity. Acoustic facies IB below approximately 2000 m is interpreted as dominantly pelagic with rare thin sandy beds deposited by turbidity and possibly current activity. Above 2000 m this sediment type is believed to be overlain by a thick layer of current-winnowed foram sand.

IIA

Facies IIA, distinguished by multiple discontinuous sub-bottom reflectors, is the most common acoustic facies type in the survey area. It occurs in areas of little or no gradient surrounding the central rise, between seamounts and ridges, as a narrow sediment wedge marking the edge of the oceanic crust, and elsewhere as broad channel and basin features. DSDP site 281 is located in this facies type and shows laminated nanno-foram / foram-nanno oozes to a depth of 59m (Kennett et al., 1975). Fine scale examination of the 7 gravity cores recovered from this facies also reveals a dominantly pelagic depositional regime, but further identifies discrete beds of foram sand up to 40 cm thick that comprise, on average, 7% of the sediment. In comparison to IB facies this group has more frequent sandy interbeds, of greater thickness, giving the sediment a higher overall composition of sand. Either current or turbidite activity is believed to be concentrating coarse material in rare, yet comparatively thick, sandy beds. The IIA facies is interpreted as consisting predominantly of pelagic deposits that have been infrequently reworked by current or turbidite activity, disturbing original stratification or depositing discontinuous bedforms, and creating discontinuous sub-bottom reflectors.

Gravity core 13 (Fig. 34) is a notable exception to the average of 7% interbedded sand for IIA facies, containing no sandy interbeds within 530 cm of foram-nanno clay. Gravity core GC13 was recovered from a small elongate basin, approximately 4.5 km wide, between oceanic crustal highs. In this environment local tectonic stresses or downslope creep could have disrupted originally continuous reflectors, so that sediment normally indicative of IB acoustic facies can produce a IIA echo type. The sedimentary environment for IIA facies has been expanded, from dominantly pelagic with infrequent current and turbidite activity, to include wholly pelagic deposits in which originally continuous reflectors have been disturbed by tectonic activity or downslope sediment creep.

IIB

Acoustic facies IIB is generally restricted to areas of moderate topographic relief, especially those at the base of steep slopes and scarps and along the axes of submarine channels. While most efforts to core this facies failed, the two successful attempts highlight very different sedimentary environments capable of producing the characteristic fuzzy echoes of IIB facies. Gravity core GC06 (Fig. 31) contains greater than 50% foram sand interbedded with clayey nanno foram ooze. In this core the high proportion of porous sand is predicted to strongly attenuate sound and produce IIB type echoes. As GC18 (Fig. 39) contains only 5% interbedded sand, its IIB echo character cannot be attributed to attenuation of sound by thick sandy beds. This core does, however, contain up to 40% (Appendix 9) manganese micronodules within a quartz-bearing clay, a patchy manganese crust at 210 cm and a thick manganese crust at its base. Although manganiferous sediments are rare in the world's oceans, manganese crusts were recovered throughout the South Tasman Rise, and their presence in sediments would adequately explain the IIB echo type produced by this facies.

IIBa

Facies IIBa occurs at the base of steep slopes and scarps on the South Tasman Rise. On more moderate slopes, this facies starts on the upper reaches of the slope and extends out beyond the toe of the slope onto areas of lower gradient. The acoustically transparent zone overlying IIB echoes that characterises the IIBa facies is interpreted as homogenous sediment without sufficient impedance contrast to produce sub-bottom reflections. While gravity-induced mass flows occur on a range of scales throughout the South Tasman Rise and their deposits could theoretically produce such homogenous sediment accumulations, no evidence was found to indicate this process. Instead, the two gravity cores retrieved from IIBa facies show well preserved bedding and little evidence for bioturbation. While slumping and mass flow deposits cannot be discounted, the sedimentary environment for this facies has been expanded to include homogeneous pelagic oozes and interbedded oozes and clays with bedding less than 30 cm thick.

The suggested sources of IIB echoes for GC21 and 35, recovered from IIBa facies, are markedly different. GC21 (Fig.41) was recovered during rough weather and is interpreted to have penetrated the seafloor twice, returning two similar sections of surficial sediment. Section A of GC21 retains the most complete section, comprising 102 cm of foram ooze overlying a thin foram clay, overlying 101 cm of foram sand. It is this thick bed of sand at the base of GC21 (which could be thicker than the metre recovered) that is believed to produce IIB echoes.

While GC21 is in a prime locality to record gravity flows descending from the Tasman Fracture Zone, the thick sandy unit at its base is unlikely to result from a single turbidite as bioturbation is evident throughout the sand and organisms capable of burrowing 100 cm below the surface are rare (Wetzel, 1983). It is also unlikely that this unit formed due to gradual accumulation of thin turbidites, with burrowing between events, as sedimentary structures indicative of turbidites, such as cyclical grainsize variation, are not preserved. The base of GC21 is interpreted to represent a long period of current winnowing during which a thick accumulation of foram sand was deposited. This was followed by pelagic deposition, with low productivity and little current activity, to produce a thin clay with low foram abundance, and finally by increased productivity and accumulation of a thick foram ooze, devoid of acoustic reflectors and hence transparent on 3.5 kHz profiles.

Gravity core 35 (Fig. 47), recovered from IIBa facies, was targeted to sample the thin edge of an acoustically transparent layer estimated to be 3 m thick (Fig. 53) and to penetrate the underlying IIB facies. It comprises 210 cm of nanno foram ooze with interbedded foram sand and silty clay, overlying 10 cm of stiff yellowish brown clay with abundant sand sized quartz, glass and mica clasts, and no *in situ* carbonate. This lower sandy clay is interpreted to be terrestrial in origin and its contact with the overlying pelagic foram ooze is therefore a major unconformity surface. In this environment the acoustically transparent layer characterising IIBa facies is believed to be foram ooze with thin sandy and clayey units, while the fuzzy basal echo is caused by a major unconformity and a related change in lithology.

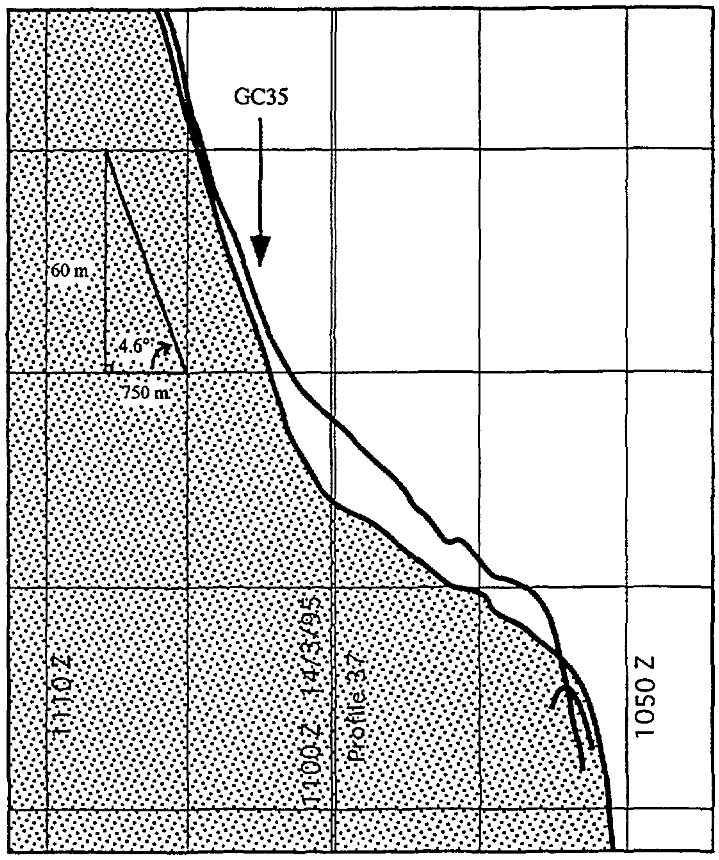
IIIC

Type IIIC acoustic facies is widespread throughout the South Tasman Rise. It occurs in areas of extreme topographic variation due to scarps, ridges and seamounts, as well as widespread areas of moderately graded, but rough, slopes. The erosional nature of these areas has exposed igneous, metamorphic and sedimentary basement rocks sampled extensively by R/V *Sonne* in 1985 and R/V *Rig Seismic* in 1995. Many of the slopes and scarps are also covered with manganese crusts and nodules discussed in Section 10. Gravity core GC01 (Fig. 28) was recovered from this facies. It contains 378 cm of silty clay and foram ooze, demonstrating that not all areas of this facies are erosional, and that moderately thick banks of sediment can be obscured by strong echos resulting from near surface basement rocks or nearby basement outcrop.

IIID

Acoustic facies IIID is restricted to similar geomorphological environments to IIIC. It is largely confined to a moderately steep slope dividing two elongate basins to the east of the Tasman Fracture Zone. The numerous small hyperbolae that characterise this facies are believed to be formed by small erosional gullies (Flood, 1980) running down the slope. Gravity core GC15 was the only successful core recovered from this facies. It contains no interbedded sandy units within 388 cm of nanno foram ooze and clay, and shows no sign of erosional sedimentary structures. As the core continued no evidence of the large-scale bedforms or gullies capable of producing the hyperbolae which distinguish this echo type, little can be added to the IIID facies description without further sampling.

Figure 53. Line drawing from Tasmante 3.5 kHz profile showing approximate position of GC35 and typical IIBa acoustic facies.



Hybrid
Hybrid acoustic facies are widespread and closely associated with areas of IIIC facies. They are common on the tops of ridges or seamounts and on intermediate slopes between IIIC and IIA or IIB facies. This group of acoustic facies was not targeted during the 1995 sampling program, as sedimentary facies in these areas are believed to vary between the constituent members already discussed.

Comparison with acoustic facies from other oceans

The echo types used to define acoustic facies on the South Tasman Rise are consistent with those used in other oceans. Comparison of sediment recovered from IB, IIA and IIB acoustic facies from the Brazil margin, Solomon Sea and South Tasman Rise (Fig. 52) shows that the South Tasman Rise sediments have a consistently lower percent composition of interbedded sand, yet produce the same echo types. This trend highlights the complex relationship between echo type and sediment insonification. While the quantity of interbedded sand within seafloor sediment is broadly diagnostic of echo type, other factors must also influence the echo type recorded on 3.5 kHz profiles. Changes in density caused by fluctuation in $CaCO_3$ content or differential compaction have been identified in the past (Damuth, 1980) as alternative influences on echo types.

Figure 52 shows that the average quantity of interbedded sand in facies IIA and IIB from the South Tasman Rise is half of that found within the same acoustic facies in the Solomon Sea. Given that the fundamental difference between seafloor sediments in the Solomon Sea and South Tasman Rise is that the former are terrigenous marine sediments and the latter biogenic $CaCO_3$, then both grainsize and $CaCO_3$ content must have an important interrelated influence on echo type. This information further suggests that, for facies IIA and IIB, the amount of interbedded sand required to produce their characteristic echo types is less if the sand is composed of $CaCO_3$ and not terrestrial minerals. However, this relationship is not straightforward, as the beds of carbonate sand thought to be generating sub-bottom reflectors for facies IIA and IIB on the South Tasman Rise are composed almost entirely of hollow foram tests which gives the beds a very high porosity / water content. So it may be a high water content within foram sands that generates sub-bottom reflectors and not the $CaCO_3$ content as such.

Conclusions

The major sedimentary processes acting on the South Tasman Rise are the primary deposition of pelagic sediments and the subsequent re-working of these by both bottom currents and gravity flows. Of these two processes, reworking by bottom currents appears to be the dominant factor producing thick sandy units by winnowing of fine material. The summit of the South Tasman Rise is blanketed by foram sand of unknown thickness that is indicative of widespread current activity. Its flanks are characterised by a range of deposits, dominantly pelagic but including slumps and mass flows initiated by slope failure. The change from IB to IIA to IIB facies has been interpreted to result from increased interbedded sandy units and the disruption of original stratification by sedimentary and tectonic processes. Results from this cruise confirm this interpretation, and also present rare anomalous examples that do not fit this trend. Areas of rugged topography defined by IIIC facies show a wide range of sedimentary environments, encompassing elements of all processes discussed thus far. West of the Tasman Fracture Zone, on oceanic crust, sedimentary processes are more limited. Here primary deposition of pelagic ooze is predominant, with disturbed bedding due to either tectonic activity or gravity-induced creep.

Manganese crusts and nodules are widespread throughout the South Tasman Rise in areas of steep topography where deposition of pelagic sediments is minimal. At abyssal depths they can also be found on flat plains where sedimentation is likewise minimal. Whereas manganiferous deposits on steep topography are defined by IIIC facies, the deeper water varieties are mapped as IIB and IIBa facies. Discriminating IIB and IIBa facies that contain manganese nodules and crusts from those composed of coarse pelagic sediment is tentatively possible, as the manganiferous varieties have a higher acoustic reflectivity.

Trends in the quantity of interbedded sand in cores from South Tasman Rise acoustic facies match those measured in other oceans. Comparison of sediment recovered from the same acoustic facies from the Brazil Margin, Solomon Sea and South Tasman Rise shows that the South Tasman Rise sediments generate the same echo type with a consistently lower quantity of interbedded sand. This indicates that factors other than quantity of interbedded sand must be influencing the echo type recorded on 3.5 kHz profiles. $CaCO_3$ content - and (perhaps) more importantly the water content in beds of foram sand - are identified as additional controlling factors.

9.4. Cool water carbonate production rates from Tasmanian shelf carbonates

J.F. Marshall, AGSO

The increase in atmospheric CO_2 during the last deglaciation, as detected in ice cores, is comparable to the recent industrial increase. The source of most of this CO_2 is considered to have been the oceans. However, one difficulty in understanding the oceanic origins of the deglacial increase in CO_2, and in calculating the CO_2 budget properly, is the unknown contribution by marine carbonates (Sundquist, 1993). While the calcium carbonate budget in the ocean represents only a small part of the global carbon cycle, some scientists believe that the deglacial buildup of CO_2 can be accounted for, more-or-less, by changes in carbonate depositional rates since the last eustatic rise in sea level (Berger, 1982; Keir and Berger, 1985; Opdyke and Walker, 1992; Sundquist, 1993). In particular, the "coral reef hypothesis" (Berger, 1982; Opdyke and Walker, 1992) maintains that the rate of coral reef growth by itself can account for this CO_2 variation.

Coral reefs are one of the most productive carbonate environments in the ocean, with estimated production rates for reef flats being of the order of 4 Kg m^{-2} yr^{-1} (Smith and Kinsey, 1976). However, as pointed out by Milliman (1993), these actively growing areas often account for only 20 percent, or even less, of the global coral reef area. If the production rate of lagoonal areas is taken into account, then reefs only produce at a rate of about 1 Kg m^{-2} yr^{-1}. However, while the production rates for coral reefs may have been underestimated, it is equally apparent that many of the world's continental shelves are mantled by carbonate sediments. While these shelf carbonates have been extensively studied by sedimentologists and geochemists, little is known about their production rates; estimates vary from 0.01-1.0 Kg m^{-2} yr^{-1}, but little work has been carried out to verify these figures.

One area of study that has received scant attention has been the so-called cool water or temperate carbonates. These cool water carbonates are particularly abundant along the southern margin of Australia (Wass and others, 1970; James and others, 1992; Boreen and others, 1993), and they tend to be dominated by Bryozoa, which commonly make up 20-50 percent of the carbonate fraction (Conolly and von der Borch, 1967). However, off Tasmania, bryozoans often exceed 60 percent of the sediment (Marshall and Davies, 1978).

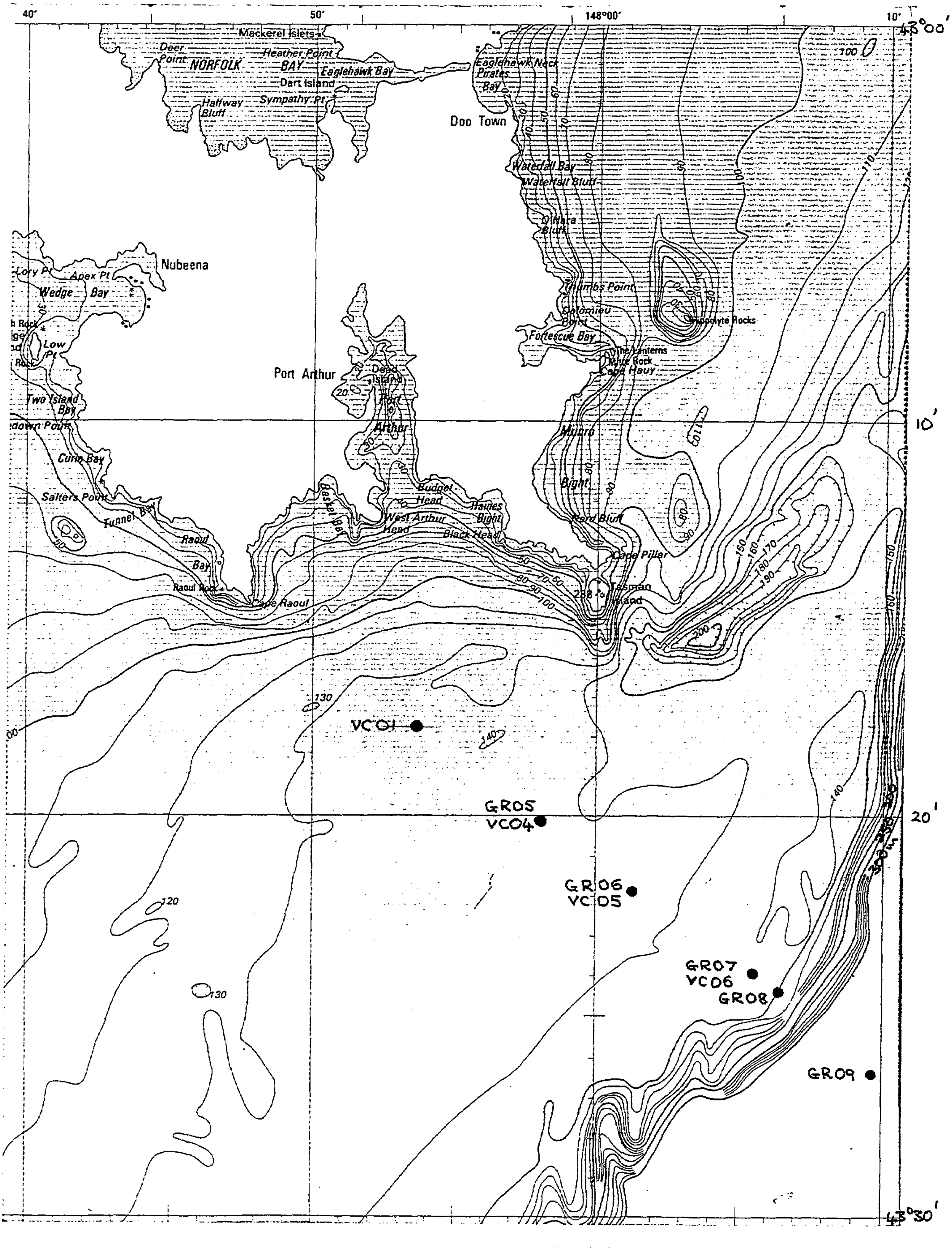


Figure 54. Map showing location of successful grab (GR) and vibrocore (VC) sites on the shelf off southeastern Tasmania. From *Bruny Island 1:250 000 Bathymetric Map*, Australian National Bathymetric Map Series Sheet SK 55-15, (1984).

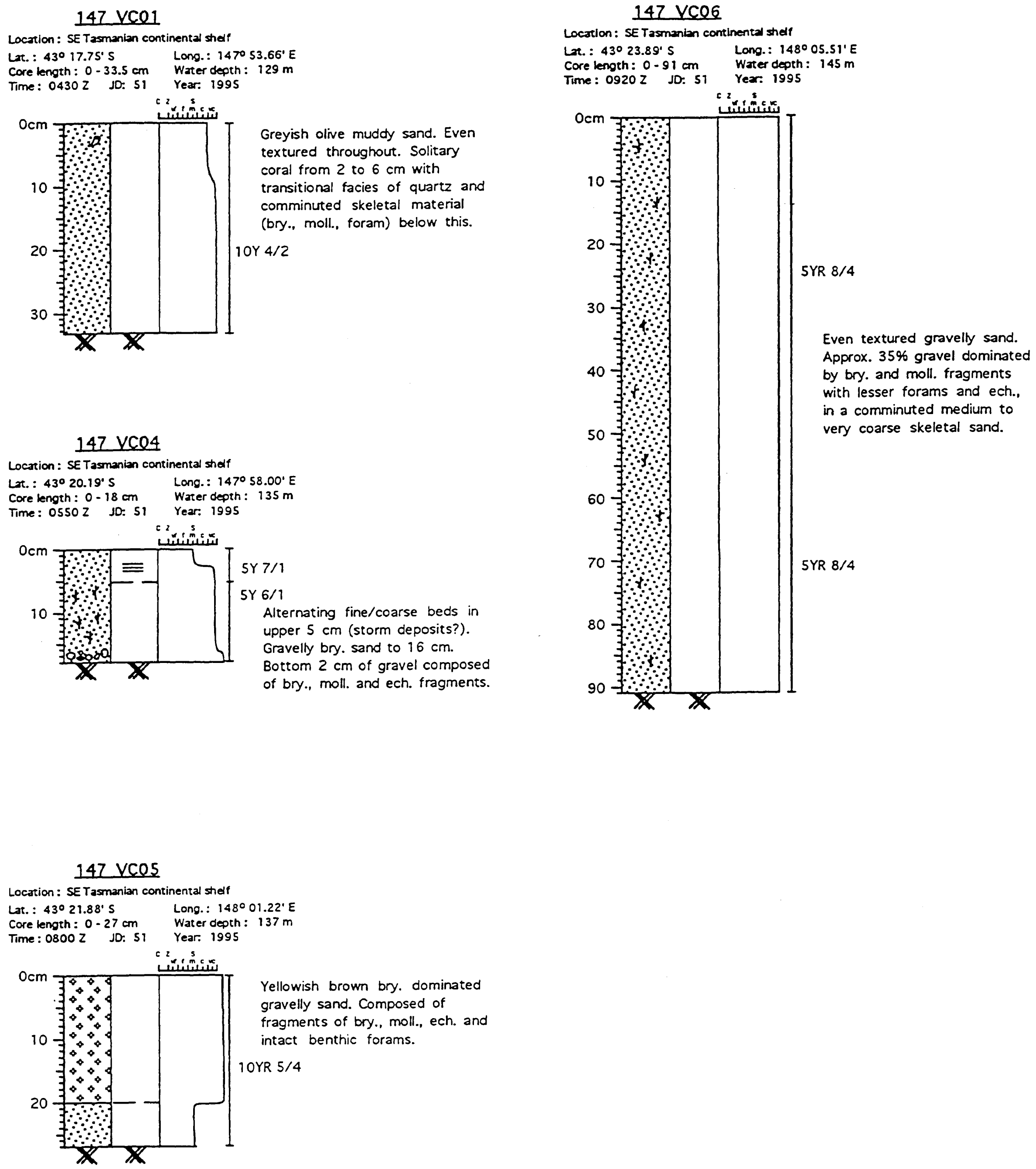


Figure 55. Core logs of vibrocores from the shelf off southeastern Tasmania. Legend in Figure 27.

The present study is an attempt to quantify the rate of bryozoan and cool water carbonate production on the outer shelf off southeastern Tasmania, in order to compare a high productivity cool water shelf with a tropical shelf. The shelf off southeastern Tasmania (Fig. 54) is dominated by a broad mid to outer shelf plain in 130-150 m water depth. The edge of the plain is marked by the shelf break, which occurs at around 165 m. The outer edge of the shelf has a slightly raised rim of about 4-12 m relief. This slightly raised shelf edge bank is considered to be the site of maximum bryozoan production on the shelf. Bryozoan-rich samples, both on the mid shelf and upper slope, are considered to be derived mainly from these banks.

A total of one gravity core and eight vibrocore stations were occupied on the shelf and upper slope, along with seven grab sample, two camera, one hydrocast and one water sample stations (Figs. 1 & 54); Table 14). Four of the vibrocore stations and the one gravity core station were unsuccessful, whereas recovery at the other vibrocore sites was small. Core recovery varied from 0.18 to 0.91 m (Fig. 55). Cores from the mid-shelf recovered slightly muddy sands consisting of quartz and comminuted skeletons of bryozoans, molluscs and forams. The outer shelf cores recovered a gravelly sand, with the gravel fraction (about 35%) being dominated by bryozoan and molluscan fragments set in a sand of similar composition, but more abraded. Fortunately, the longest core (147/VC/006) was taken from the area of high productivity, and should provide data on Holocene accumulation rates. Grab samples from the upper slope also recovered coarse bryozoan and mollusc debris, considered to have been derived from the outer shelf "carbonate factory".

10. MANGANESE CRUSTS AND NODULES

N.F. Exon, AGSO

The major previous study of manganese nodules and crusts from the South Tasman Rise was that of Bolton et al. (1988), based on *Sonne* sampling from water depths of 1800-4000 m. Eighteen samples of crusts and nodules from four dredges and six cores were analysed and shown to be dominantly ferruginous vernadite. Both crusts and nodules showed enrichment of Fe, Co and Pb, and depletion of Mn, Ni, Cu and Zn, to be expected of a vernadite-dominated lithology. The mineralogy, chemistry and physical appearance of the deposits indicate a hydrogenetic origin, apparently in a current-swept oxygenated environment.

Three nodules and one crust from the west Tasmanian margin, dredged by *Rig Seismic* (Exon et al., 1989) were analysed as an adjunct to other work and their full analyses are included in Appendix 2 in Exon et al. (1993). A summary of the chemistry of surface samples from these earlier studies is listed below (Table 23).

Table 23: Chemical analyses of Mn nodule and crust samples taken earlier off Tasmania

Samples	No. of samples	Mn %	Fe %	Ni %	Cu %	Co %	Zn %	Pb %	Ni+Cu+Co %	Mn:Fe
Sonne crusts	5	20.37	20.99	0.38	0.08	0.55	0.08	0.19	1.01	0.99
Sonne nodules	3	13.05	19.56	0.37	0.28	0.13	0.07	0.07	0.78	0.67
Rig Seismic crusts	3	11.59	21.58	0.37	0.10	0.25	0.10	0.09	0.72	0.54

Rig Seismic nodules	1	12.00	13.99	0.30	0.10	0.43	0.06	0.11	0.83	0.86

Values in percentages

The data base for manganese nodules and crusts in the area off Tasmania now is dominated by the samples gathered on BMR Cruise 147, with 45 dredges yielding nodules and/or crusts (list with locations in Table 15). Figures 20 and 22 are maps showing all the dredge stations that recovered nodules and crusts. Manganese was found near the base of gravity core GC018, but in none of the seven locations covered by two freefall grab stations on the abyssal plain (Table 14 & Figure 1).

Analabs of Welshpool, Western Australia, analysed 43 crust and nodule samples from 36 dredge stations for 30 components, using induction coupled plasma spectrometry or x-ray fluorescence on samples dried at 105° C and pulverised using chrome-free steel. The results are listed in full in Appendix 7. Figure 56 shows all the locations from this and previous cruises from which geochemical analyses have been obtained. Key nodule and crust geochemical data are summarised in Table 24, nodule data in Table 25, and crust data in Table 26.

Table 24: Key geochemical data from manganese nodules & crusts from AGSO Cruise 147 off Tasmania

Sample	Nature	Water depth (m)	SiO2 %	P (%)	Mn (%)	Fe (%)	Mn:Fe	Cu (%)	Ni (%)	Co (%)	Cu+Ni+Co (%)
147DR1B1	5 cm crust	4450	19.4	0	16.78	13.71	1.22	0.17	0.60	0.18	0.95
147DR1C1	6 cm nodule	4450	34.5	0.21	5.59	17.78	0.31	0.08	0.16	0.05	0.30
147DR2B1	6 cm nodule	4600	33.1	0.22	10.23	17.35	0.59	0.15	0.24	0.14	0.53
147DR2B2	0.5 cm crust	4600	45.4	0.22	2.32	8.34	0.28	0.05	0.09	0.03	0.17
147DR5H2A	4 cm outer crust	2650	28.4	0.13	11.98	15.60	0.77	0.06	0.19	0.21	0.45
147DR5H2B	3 cm inner crust	2650	21.7	0.28	11.49	19.41	0.59	0.08	0.18	0.20	0.45
147DR7DI	5 cm crust	1300	4.47	0.33	22.34	15.91	1.40	0.04	0.32	0.76	1.12
147DR10E1	7 cm crust	2450	13.0	0.49	14.73	17.36	0.85	0.07	0.24	0.23	0.53
147DR11E1A	4 cm outer crust	2050	10.4	0.52	15.49	18.94	0.82	0.06	0.23	0.33	0.62
147DR11E1B	6 cm inner crust	2050	13.4	0.37	14.27	19.99	0.71	0.09	0.23	0.23	0.55
147DR12G1	4 cm nodule	2550	25.1	0.38	13.62	14.29	0.95	0.14	0.39	0.21	0.74
147DR13G1	8 cm crust	3300	9.92	0.40	15.10	17.01	0.89	0.08	0.23	0.31	0.62
147DR13H1	2 cm nodule	3300	17.4	0.34	13.80	14.63	0.94	0.16	0.38	0.20	0.74
147DR14B1	7 cm nodule	4100	32.2	0.94	10.87	15.65	0.69	0.17	0.21	0.13	0.51
147DR14B2	7 cm nodule	4100	28.1	0.21	10.08	16.18	0.62	0.14	0.21	0.12	0.47
147DR15F1	8 cm crust	3200	36.6	0.25	9.37	14.00	0.67	0.17	0.26	0.09	0.52
147DR16C1	3 cm crust	4000	19.5	0.21	12.46	17.36	0.72	0.08	0.15	0.14	0.37
147DR18E1	5 cm nodule	3450	21.8	0.31	13.56	12.23	1.11	0.37	0.66	0.16	1.19
147DR20F1	5 cm nodule	3550	22.2	0.19	12.43	16.82	0.74	0.09	0.24	0.25	0.58
147DR22H1	6 cm nodule	3550	13.4	0.29	12.77	18.61	0.69	0.13	0.29	0.21	0.63
147DR23A1	6 cm nodule	4100	20.7	0.31	11.17	19.05	0.59	0.11	0.13	0.16	0.40
147DR24F1	5 cm crust	2400	5.55	0.41	18.16	17.17	1.06	0.09	0.31	0.41	0.81
147DR25H1	3 cm nodule	2850	33.4	0.35	10.15	12.98	0.78	0.10	0.22	0.19	0.50
147DR27D1	2 cm crust	2850	15.5	0.21	18.04	15.98	1.13	0.18	0.46	0.27	0.92
147DR28A1	3 cm crust	1950	2.87	0.24	24.1	14.81	1.63	0.05	0.38	1.00	1.43
147DR31G1	2 cm crust	2150	4.15	0.41	20.23	16.86	1.20	0.05	0.30	0.60	0.94

147DR32E1	2 cm crust	1400	3.5	0.45	23.95	16.46	1.46	0.04	0.38	0.87	1.29
147DR33B1	3 cm crust	2300	6.12	0.46	18.51	17.35	1.07	0.07	0.27	0.47	0.81
147DR36J1	3 cm nodule	2350	6.52	0.38	20.49	17.77	1.15	0.07	0.37	0.53	0.98
147DR36I1	2 cm crust	2350	9.11	0.41	20.00	16.08	1.24	0.01	0.51	0.45	0.97
147DR37B1	5 cm crust	2300	5.97	0.37	19.80	18.92	1.05	0.07	0.30	0.49	0.85
147DR38D1	5 cm crust	2150	7.15	0.42	20.10	18.24	1.10	0.04	0.29	0.43	0.76
147DR39A1	5 cm crust	3000	15.0	0.50	15.43	20.51	0.75	0.08	0.24	0.27	0.59
147DR40A1	5 cm crust	2700	19.8	0.41	14.01	19.53	0.72	0.06	0.24	0.20	0.50
147DR42C1	3 cm crust	1450	13.0	0.39	20.25	15.67	1.29	0.08	0.75	0.35	1.18
147DR45H1	5 cm crust	2700	19.6	0.38	14.69	17.41	0.84	0.11	0.48	0.17	0.75
147DR46D1	5 cm crust	3350	28.6	0.30	10.37	18.90	0.55	0.10	0.17	0.07	0.34
147DR47H1	4 cm crust	2450	14.3	0.29	14.42	19.86	0.73	0.12	0.26	0.31	0.69
147DR48E1	2 cm outer crust	2750	20.9	0.35	12.15	21.91	0.55	0.10	0.21	0.15	0.46
147DR50E1	5 cm crust	3000	10.4	0.39	19.97	16.15	1.24	0.16	0.67	0.34	1.16
147DR51B1	2 cm crust	2850	17.9	0.33	15.32	15.27	1.00	0.10	0.48	0.13	0.71
147DR53A1	5 cm crust	2900	8.3	0.82	17.06	18.92	0.90	0.08	0.25	0.35	0.67
147DR55A1	5 cm crust	2500	8.78	0.38	19.41	18.32	1.06	0.07	0.34	0.44	0.84
AVERAGE		**2910**	**17.37**	**0.38**	**15**	**16.9**	**0.90**	**0.10**	**0.31**	**0.30**	**0.71**

10.1. Manganese nodules on the abyssal plain

In both the Pacific and Indian Oceans, the same conditions seem to favour the formation of abyssal plain nodule fields of high grade (Ni & Co) and abundance (e.g Cronan, 1980; Mizuno et al., 1980, Pautot and Melguen, 1979; Exon, 1982; von Stackelberg and Beiersdorf, 1991). Abyssal plain nodule fields form predominantly on soft sediments, and the formation of high-grade nodules of this type depend on the following:

1) Low sedimentation rates, which are favoured by distance from major land masses and volcanoes and the dissolution of carbonate and silica below the CCD, favour the formation of manganese nodules, which grow at very slow rates and normally dissolve if buried.

2) High productivity of calcareous and especially siliceous plankton is needed, because these are the sources of the Ni and Cu found in high-grade nodules. Productivity is only moderate (50-100 gm/m^2/year) in this region (Dietrich and Ulrich, 1968).

3) Diagenesis is the only mechanism which can form high-grade nodules. This means that sediments should be fairly rich in Mn, Ni and Cu, and porous so that pore water can move through them. Furthermore the sediment pore water should be reducing to allow solution of these metals, and bottom water should be oxidising to force precipitation near the sediment-water interface.

4) Sediments with low sedimentation rates, high Ni and Cu content, and high porosity, where bottom waters are oxidising and pore water can be reducing, are exclusively deep-sea siliceous oozes. Only in such sediments can a combination of high grade nodules and high abundances be expected. Only in them have nodule mining sites been taken up (but it should be noted that even there nodule mining is unlikely in the medium term).

Previous work in the South Australian Basin to the west had suggested that the calcite compensation depth (CCD) lies at about 5000 m (Berger & Winterer, 1974; Mallett & Heezen, 1977), and that the most prospective areas for nodules off southeast Australia were south and southeast of the South Tasman Rise, where blankets of nodules and crusts were known from camera and core stations and called the *Tasman Manganese Pavement* (Payne & Conolly, 1972, Watkins & Kennett, 1977).

On this cruise, deepsea nodule sampling using freefall grabs was limited by time to two multiple stations, with 7 deployments of *Benthos* freefall grab samplers (Table 14). Sediment was recovered by a sampling tube included by us within the jaws of the grab, and a mesh provided by *Benthos*. Location was by means of radio (generally one per station), aided by flags or lights on all samplers, depending on whether recovery was to be in the day or night. The technique proved successful and no grabs were lost. The grabs were deployed along bathymetric and swath-mapping lines that been run by *l'Atalante*, and the deployments (four at FFG1 west of the rise, and three at FFG2, immediately southwest of the rise) were about a kilometre apart. The time spent at FFG1 was about four hours, and at FFG2 about 5 hours. Water depths varied from about 4680 m to 4830 m at FFG1, and from about 4380m to 4400m at FFG2. Pale yellowish brown clayey nannofossil ooze was recovered at FFG1, but nothing at FFG2. These stations showed that, although the acoustic pattern was dark, suggesting the presence of Mn crusts, they were almost certainly buried under a veneer of sediment if present at all. Core GC 18, taken at the same location as FFG 2, did contain a Mn crust beneath 2.5 m of young sediment.

10.2. Manganese nodules on marginal plateaus and seamounts

Manganese nodules on plateaus and seamounts tend to be relatively high in cobalt, and low in nickel and copper, and little emphasis has been put on their economic assessment apart from where they are associated with cobalt-rich manganese crusts.

On this cruise nodules were recovered only at dredge stations on rocky outcrops: west of Tasmania (2 stations), on the South Tasman Rise (8 stations) and in the depression south of Tasmania (3 stations). The locations are listed in Table 15 and shown in Figure 22. Geochemical data are summarised in Table 25. Most occurrences were of very large smooth mononodules (5-10 cm diameter), but in some cases these had grown together to form polynodules or indeed crusts. Nodules appear to be very abundant at some stations, but it is impossible to quantify abundance from dredge information, because one has no idea of the area of sea bottom actually sampled.

Table 25: Geochemical data from manganese nodules from AGSO Cruise 147 off Tasmania

Sample	Nature	Water depth (m)	SiO2	P (%)	Mn (%)	Fe (%)	Mn:Fe	Cu (%)	Ni (%)	Co (%)	Cu+Ni+Co (%)
147DR1C1	6 cm nodule	4450	34.5	0.21	5.59	17.78	0.31	0.08	0.16	0.05	0.30
147DR2B1	6 cm nodule	4600	33.1	0.22	10.23	17.35	0.59	0.15	0.24	0.14	0.53
147DR12G1	4 cm nodule	2550	25.1	0.38	13.62	14.29	0.95	0.14	0.39	0.21	0.74
147DR13H1	2 cm nodule	3300	17.4	0.34	13.80	14.63	0.94	0.16	0.38	0.20	0.74
147DR14B1	7 cm nodule	4100	32.2	0.94	10.87	15.65	0.69	0.17	0.21	0.13	0.51
147DR14B2	7 cm nodule	4100	28.1	0.21	10.08	16.18	0.62	0.14	0.21	0.12	0.47
147DR18E1	5 cm nodule	3450	21.8	0.31	13.56	12.23	1.11	0.37	0.66	0.16	1.19
147DR20F1	5 cm nodule	3550	22.2	0.19	12.43	16.82	0.74	0.09	0.24	0.25	0.58
147DR22H1	6 cm nodule	3550	13.4	0.29	12.77	18.61	0.69	0.13	0.29	0.21	0.63
147DR23A1	6 cm nodule	4100	20.7	0.31	11.17	19.05	0.59	0.11	0.13	0.16	0.40
147DR25H1	3 cm nodule	2850	33.4	0.35	10.15	12.98	0.78	0.10	0.22	0.19	0.50
147DR36J1	3 cm nodule	2350	6.52	0.38	20.49	17.77	1.15	0.07	0.37	0.53	0.98
AVERAGE		**3579**	**24.03**	**0.34**	**12.06**	**16.11**	**0.76**	**0.14**	**0.29**	**0.20**	**0.63**

The deepest deployment that returned nodules was at about 4600 m on a volcanic rise on the abyssal plain (DR02), and the shallowest about 2400 m on the northeast South Tasman Rise (DR36). Manganese crusts were found in much shallower water (see below). All successful deployments showed that nodules are associated with rocky outcrops. The key elements show averages of Mn 12.06%, Fe 16.11%, Ni 0.29%, Cu 0.14% and Co 0.20%. The average Mn:Fe ratio is a low 0.76. Average Ni+Cu+Co is a low 0.63%, partly because the nodules contain abundant detrital material as evidenced by the high average SiO2 content of 24.03%. Phosphorous is anomalously high (0.94%) in DR14 B1; nickel (0.66%), copper (0.37%), Ni+Cu+Co (1.19%) and the Mn:Fe ratio (1.11) in DR18E1; and cobalt (0.53%), Ni+Cu+Co (0.98%) and Mn:Fe in DR36J1.

None of these values are of even long-term economic potential as compared to abyssal nodules in parts of the Pacific and Indian Oceans (see Table 26). The values are similar to those from earlier sampling (Table 23).

Table 26: Manganese nodule analyses from AGSO Cruise 147 and elsewhere

Samples	Number	Mn (%)	Fe (%)	Mn:Fe	Cu (%)	Ni (%)	Co (%)	Cu+Ni+Co (%)
Cruise 147 nodules	12	12.06	16.11	0.76	0.14	0.29	0.20	0.63
Indian Ocean nodules	324	15.4	14.8	1.04	0.27	0.46	0.23	0.96
Wharton Basin nodules	39	17.5	11.9	1.47	0.41	0.55	0.18	1.14
Christmas Island nodules	24	19.7	4.6	4.28	0.49	0.51	0.12	1.12
CIB nodules (red clay)	44	22.2	10.7	2.07	0.68	0.92	0.21	1.81
CIB nodules (Si ooze)	45	26.1	7.7	3.39	1.19	1.22	0.14	2.55
NE Pacific nodules		22.4	8.2	2.73	1.02	1.16	0.25	2.43

CIB = Central Indian Basin

10.3. Manganese crusts on marginal plateaus and seamounts

Fifty-four of 57 dredge stations occupied on AGSO Cruise 147 yielded rocks, and 43 of the dredge hauls with rocks also contained manganese crusts. Thirty-one crusts obtained from tweny-nine stations were analysed for a wide range of metals. Four crusts came from seamounts west of Tasmania, four from the southern Tasmanian margin, thirteen from the South Tasman Rise, four from the East Tasman Plateau, and seven from the depression east of the South Tasman Rise. The analyses are summarised in Table 27 and detailed in Appendix 7. Brief descriptions for each dredge haul are provided in Table 15. The potential economic value of ferromanganese crusts depends on the thickness of the crusts and their grade of valuable metals, especially cobalt with preferred values of around 1%, and an aim of this work was to assess the economic potential of the crusts in the Tasmanian region.

Table 27: Geochemical data from manganese crusts from AGSO Cruise 147 off Tasmania

Samples	Nature*	Water depth (m)	SiO2 %	P (%)	Mn (%)	Fe (%)	Mn:Fe	Cu (%)	Ni (%)	Co (%)	Cu+Ni+Co (%)
147DR1B1	5 cm crust	4450	19.4	0.21	16.78	13.71	1.22	0.17	0.60	0.18	0.95
147DR2B2	0.5 cm crust	4600	45.4	0.22	2.32	8.34	0.28	0.05	0.09	0.03	0.17
147DR5H2A	4 cm outer	2650	28.4	0.13	11.98	15.60	0.77	0.06	0.19	0.21	0.45

	crust									
147DR5H2B	3 cm inner crust	2650	21.7	0.28	11.49	19.41	0.59	0.08	0.18	0.20	0.45
147DR7DI	5 cm crust	1300	4.5	0.33	22.34	15.91	1.40	0.04	0.32	0.76	1.12
147DR10E1	7 cm crust	2450	13.0	0.49	14.73	17.36	0.85	0.07	0.24	0.23	0.53
147DR11E1A	4 cm outer crust	2050	10.4	0.52	15.49	18.94	0.82	0.06	0.23	0.33	0.62
147DR11E1B	6 cm inner crust	2050	13.4	0.37	14.27	19.99	0.71	0.09	0.23	0.23	0.55
147DR13G1	8 cm crust	3300	9.9	0.40	15.10	17.01	0.89	0.08	0.23	0.31	0.62
147DR15F1	8 cm crust	3200	36.6	0.25	9.37	14.00	0.67	0.17	0.26	0.09	0.52
147DR16C1	3 cm crust	4000	19.5	0.21	12.46	17.36	0.72	0.08	0.15	0.14	0.37
147DR24F1	5 cm crust	2400	5.6	0.41	18.16	17.17	1.06	0.09	0.31	0.41	0.81
147DR27D1	2 cm crust	2850	15.5	0.21	18.04	15.98	1.13	0.18	0.46	0.27	0.92
147DR28A1	3 cm crust	1950	2.9	0.24	24.1	14.81	1.63	0.05	0.38	1.00	1.43
147DR31G1	2 cm crust	2150	4.2	0.41	20.23	16.86	1.20	0.05	0.30	0.60	0.94
147DR32E1	2 cm crust	1400	3.5	0.45	23.95	16.46	1.46	0.04	0.38	0.87	1.29
147DR33B1	3 cm crust	2300	6.1	0.46	18.51	17.35	1.07	0.07	0.27	0.47	0.81
147DR36I1	2 cm crust	2350	9.1	0.41	20.00	16.08	1.24	0.01	0.51	0.45	0.97
147DR37B1	5 cm crust	2300	6.0	0.37	19.80	18.92	1.05	0.07	0.30	0.49	0.85
147DR38D1	5 cm crust	2150	7.2	0.42	20.10	18.24	1.10	0.04	0.29	0.43	0.76
147DR39A1	5 cm crust	3000	15.0	0.50	15.43	20.51	0.75	0.08	0.24	0.27	0.59
147DR40A1	5 cm crust	2700	19.8	0.41	14.01	19.53	0.72	0.06	0.24	0.20	0.50
147DR42C1	3 cm crust	1450	13.0	0.39	20.25	15.67	1.29	0.08	0.75	0.35	1.18
147DR45H1	5 cm crust	2700	19.6	0.38	14.69	17.41	0.84	0.11	0.48	0.17	0.75
147DR46D1	5 cm crust	3350	28.6	0.30	10.37	18.90	0.55	0.10	0.17	0.07	0.34
147DR47H1	4 cm crust	2450	14.3	0.29	14.42	19.86	0.73	0.12	0.26	0.31	0.69
147DR48E1	2 cm outer crust	2750	20.9	0.35	12.15	21.91	0.55	0.10	0.21	0.15	0.46
147DR50E1	5 cm crust	3000	10.4	0.39	19.97	16.15	1.24	0.16	0.67	0.34	1.16
147DR51B1	2 cm crust	2850	17.9	0.33	15.32	15.27	1.00	0.10	0.48	0.13	0.71
147DR53A1	5 cm crust	2900	8.3	0.82	17.06	18.92	0.90	0.08	0.25	0.35	0.67
147DR55A1	5 cm crust	2500	8.8	0.38	19.41	18.32	1.06	0.07	0.34	0.44	0.84
AVERAGE		**2652**	**14.8**	**0.37**	**16.20**	**17.16**	**0.95**	**0.08**	**0.32**	**0.34**	**0.74**

**Thicknesses are those analysed, and are often considerably less than total crustal thicknesses*

The crusts occur as multiple layers, up to 20 cm thick, on any hard substrate. Individual layers are up to six cm thick. The crusts vary from heavily impregnated with sediment to massive ferromanganese. Finely laminated crusts are generally uncommon apart from the uppermost few millimetres. Their surface is frequently microbotrytoidal in character. If these crusts have formed at the average rate prevailing in the Pacific Ocean, of 4.7 mm/m.y. (Hein et al., 1990), the thickest crusts could be as much as 40 m.y. old. However, it should be noted that the known range of rates of formation in the Pacific Ocean is 1.5-16 mm/m.y., so the age of our crusts remains an open question.

Table 27 indicates that the average percentages for the main metals are 16.20% Mn, 17.6% Fe, 0.32% Ni, 0.08% Cu and 3.44% Co, and that Cu+Ni+Co averages 0.74%. The values are comparable to those obtained earlier (Table 23). The average Mn:Fe ratio is 0.95. Average Cu+Ni+Co is a low 0.74%, partly because of the high detrital content exemplified by the SiO2 content of 14.8% (45% in one case). Phosphorous is anomalously high (0.82%) in DR53A1; Mn:Fe (1.22%), Ni (0.60%) and Cu+Ni+Co (0.95%) in DR1B1; Mn:Fe (1.40%), Co (0.76%) and Cu+Ni+Co (1.12%) in DR7D1; Mn:Fe (1.63), Co (1.00%) and Cu+Ni+Co (1.43%) in DR28A1;

Mn:Fe (1.46%), Co (0.87%) and Cu+Ni+Co (1.29%) in DR32E1; Mn:Fe (1.29), Ni (0.75%) and Cu+Ni+Co (1.18%) in DR42C1; and Mn:Fe (1.24), Ni (0.67%) and Cu+Ni+Co (1.16%) in DR50E1.

The three anomalously high cobalt values are in water less than 2000 m deep, and are associated with very low Si02 values. In contrast, the three anomalously high nickel values show no clear relationship to water depth (1450-4450 m), and are associated with average Si02 values. Two thick crusts (DR5H2 and DR11E1) were sampled in two sections - outer and inner crust - to see whether there were changes in chemistry, because it is common for the outer part to be richer in Co than the inner part. In these cases there is no significant change with depth in the crust.

Compared to Pacific Ocean ferromanganese crusts (Table 28), which include the crusts with the most known economic potential, the average values for all valuable metals other than Ni are low.

Table 28. Manganese crust data from AGSO Cruise 147 and elsewhere

Samples	Number	Mn (%)	Fe (%)	Mn:Fe	Cu (%)	Ni (%)	Co (%)	Cu+Ni+Co (%)
Cruise 147 crusts	31	16.20	17.16	0.95	0.08	0.32	0.34	0.74
Christmas Island crusts	14	16.20	6.75	2.40	0.11	0.35	0.44	0.90
Pacific Ocean crusts	319	22	15.0	1.47	0.08	0.44	0.63	1.15
Central Pacific crusts	311	23	15.7	1.46	0.47	0.12	0.79	1.38
Central Pacific outer crusts	102	25.05	14.2	1.62	0.06	0.51	1.02	1.59
Marshall Islands crusts		20.3	12.5	1.64	0.04	0.39	0.85	1.28

According to Hein (1990) the commonly cited cutoff thickness for manganese crusts with economic potential is 4 cm, and many of the Tasmanian crusts are thicker than that. The commonly cited cutoff grade is 0.8% Co, and only two of the 31 analyses on crusts from this cruise have higher values (Table 23). Most crusts previously analysed from the region also generally have Co values well under the cutoff (Bolton et al., 1988). However, the oxygen minimum zone in the water column has been proven to coincide with the highest Co values in most parts of the world ocean, i.e. 1000-2000 m. Most of the crusts dredged in the Tasmanian region come from deeper than the optimum water depth of 1000-2000 m. Predictably, the highest Co values are in the shallowest water, i.e. less than 2000 m deep (Table 27).

Cobalt values of potential economic interest (exceeding 0.8%) are found in this area on the eastern and southern parts of the South Tasman Rise (Fig. 56), in 147/DR28A1 (1.00%), 147/DR32E1 (0.87%), and SO-36/52KD (1.02; Bolton et al., 1988). Altogether, six analyses have been made from crusts from dredge hauls in water less than 2000 m deep in the Tasmanian region (this survey plus Bolton et al., 1988). They average 0.79% cobalt, compared to the general average of 0.34%, and thus compare with the richer crusts in the world ocean (Table 28). This suggests that targeted sampling of shallow-water sites could yield deposits of long-term economic potential.

In summary, the cobalt analyses obtained to date have lower averages than those in more prospective areas elsewhere in the world. However, the thickness of the crusts is well above the assumed cutoff value of 4 cm, and two of the analyses are above the cutoff grade for cobalt of 0.8%. At face value, the results have not been particularly encouraging, but the samples have mostly come from deeper than the optimum water depths for high cobalt grades. Targeted sampling in water shallower than 2000 m on the eastern South Tasman Rise, in the area of high cobalt values shown in Figure 56, and on the Tasmanian continental slope, could reveal further cobalt-rich crust deposits.

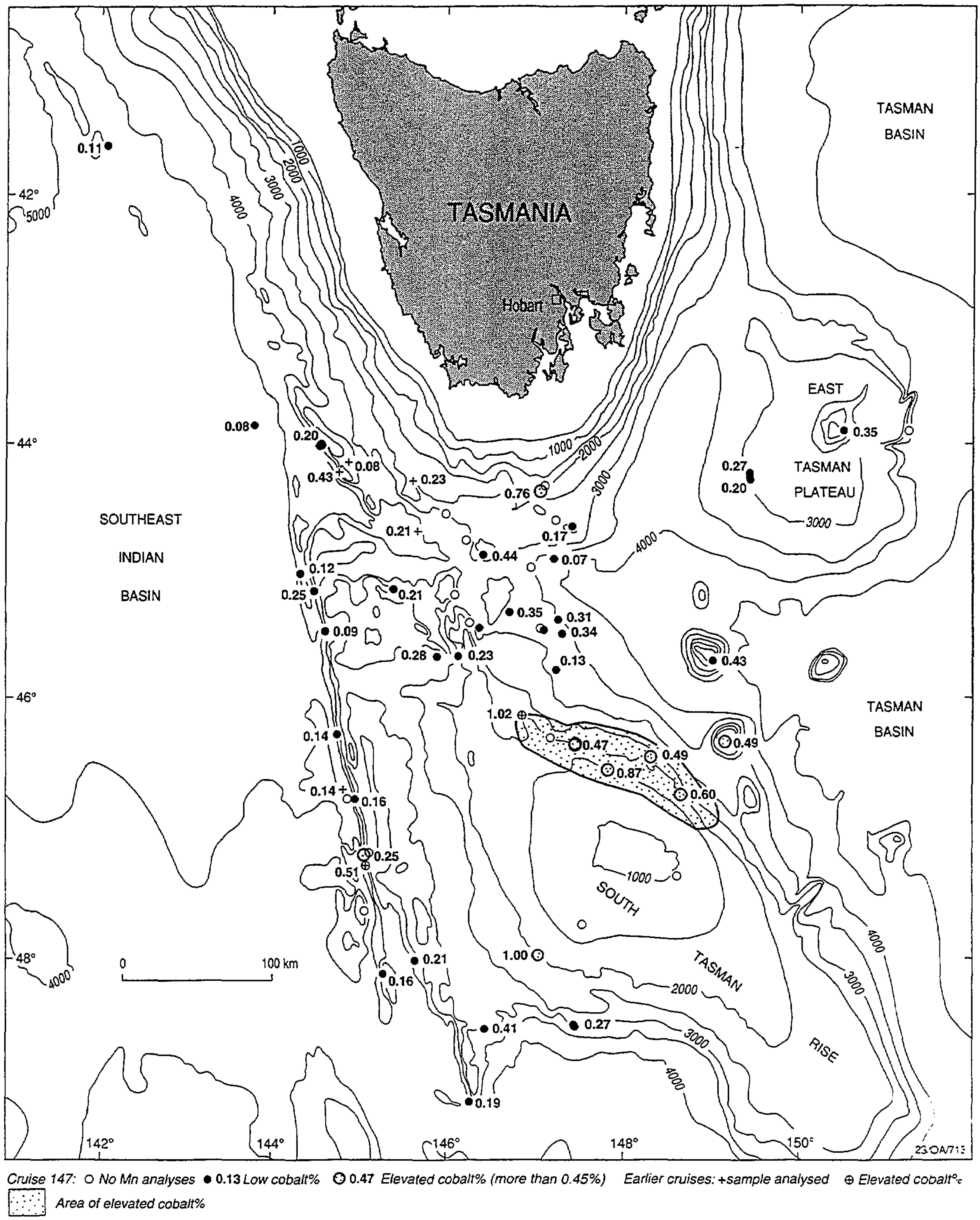


Figure 56. Map showing cobalt percentages from geochemical analyses of manganese nodules and crusts from stations from Cruise 147 and earlier cruises. The reference for the earlier *Sonne* cruise is Bolton et al. (1988), and the references for the earlier *Rig Seismic* cruise are Exon et al. (1989, field information) and Exon et al. (1993, analyses).

10.4. General discussion

Table 29 shows that there is little difference in the chemical characteristics of nodules and crusts dredged by us in the Tasmanian region, essentially because they have a similar hydrogenetic genesis and formed together in similar water depths on hard outcrops. The generally somewhat lower values of valuable metals in nodules as compared to crusts are related, in part at least, to the higher average detrital content of the nodules (as evidenced by the higher SiO2 content). This similarity contrasts to the results of studies of nodules and crusts elsewhere (e.g. Pacific Ocean), where nodule studies have concentrated on abyssal depths of about 5000 m, and crust studies on seamounts in water depths of around 2000 m. Because of the local similarity, we have lumped together all the nodule and crust data from Cruise 147, displayed in Table 24, and located in Figures 22 and 56, in the various cross-plots below (Fig. 57).

Table 29: Manganese nodule and crust data from AGSO Cruise 147

Samples	Number	SiO2 (%)	Mn (%)	Fe (%)	Mn:Fe	Cu (%)	Ni (%)	Co (%)	Cu+Ni+Co (%)
Crusts	31	14.80	16.20	17.16	0.95	0.08	0.32	0.34	0.74
Nodules	12	24.03	12.06	16.11	0.76	0.14	0.29	0.20	0.63

The water depth versus metal content plots show clear trends. Manganese, nickel and cobalt values fall off with water depth. Manganese averages about 22% in 1500 m of water and 4% in 4500 m of water (Fig. 57B). Nickel averages about 0.4% in 1500 m of water and 0.2% in 4500 m of water (Fig. 57A). These two trends are the reverse of those found in dealing with nickel-rich high grade abyssal nodules. Cobalt averages about 0.8% in less than 2000 m of water and 0.1% in 4500 m of water (Fig. 57C). This is a common trend around the world. Copper values are uniformly very low, so they have little effect on the Cu+Ni+Co plot which follows cobalt and nickel in dropping off with depth, from about 1.2% in about 1500 m of water to about 0.4% in 4500 m of water (Fig. 57D). The Mn:Fe ratio decreases with water depth (Fig. 57E), in line with the decrease of manganese with water depth, from about 1.4 in 1500 m of water to 0.4 in 4500 m of water. SiO2 increases with water depth, from about 7% in 1500 m of water to 32% in 4500 m of water (Fig. 57F), which helps to explain the decrease in valuable metals with depth.

The plots of one metal against another are also informative. Iron stays relatively constant at 15-20% while manganese varies, mostly in the range 10-25% (Fig. 58G). Higher cobalt values correspond to higher nickel values (Fig. 58H), an unusual situation. There appear to be two trends displayed, a steeper one and a shallower one, probably related to different genetic histories. The plot of copper versus nickel suggests that that they both increase together, but the trend is not strong (Fig. 58I).

The importance of SiO2 content as a controlling factor for metals is shown by plots of cobalt, nickel and Cu+Ni+Co percentages against it (Figs. 58J, K & L). There is an inverse relationship, with high SiO2 corresponding to low percentages of the other metals, indicating just how important silica is as a dilutant, in detrital form and perhaps in some cases as biogenic silica. The increase in silica with water depth may be related to declining current velocities with water depth. Where outcrops are exposed to fast currents, chemical precipitation of metals should predominate, but where currents are slow or intermittent more detrital or biogenic material can be incorporated into nodules and crusts.

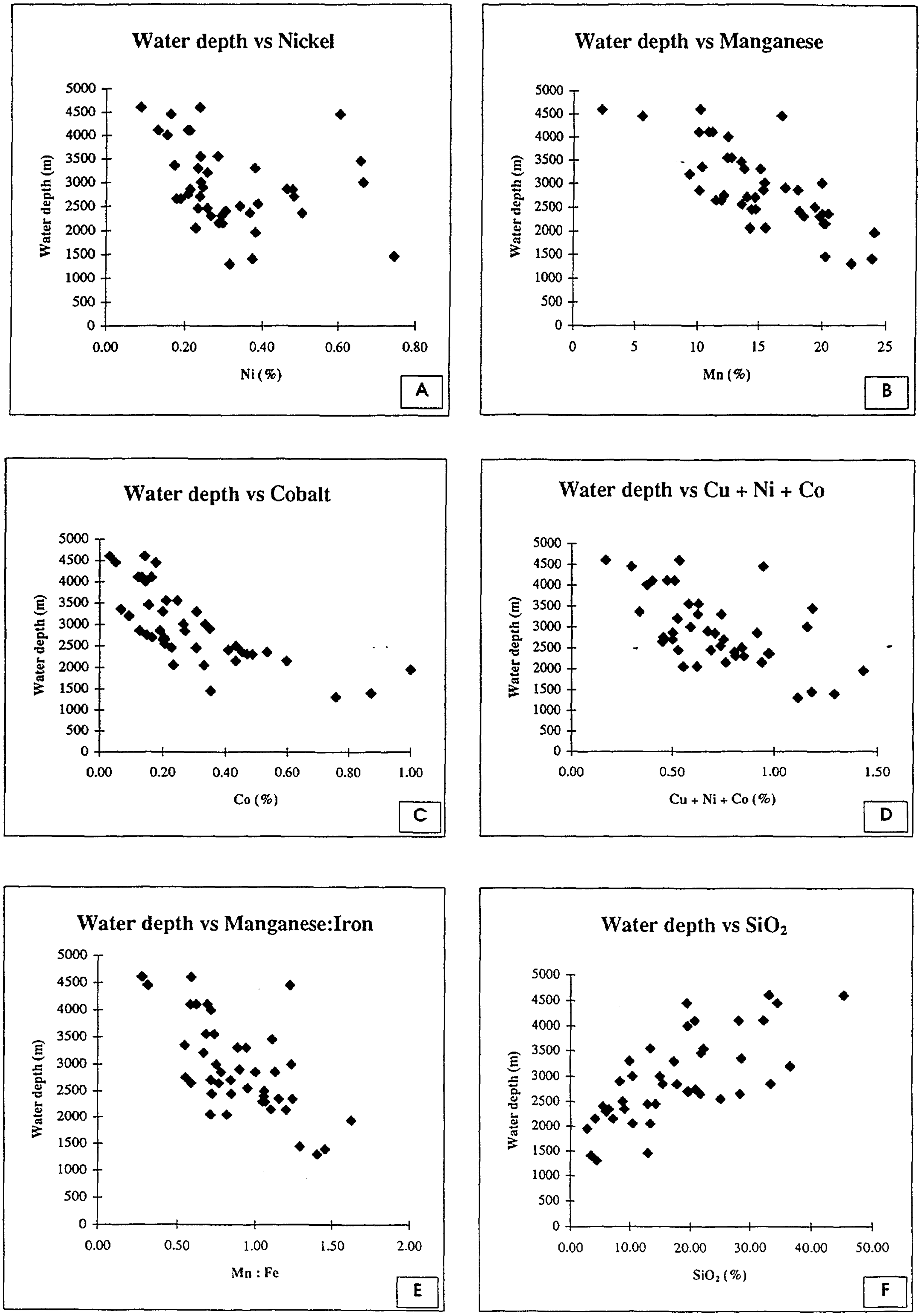


Figure 57A-F. Analyses of selected metals in manganese deposits recovered on Cruise 147 versus water depth (m).

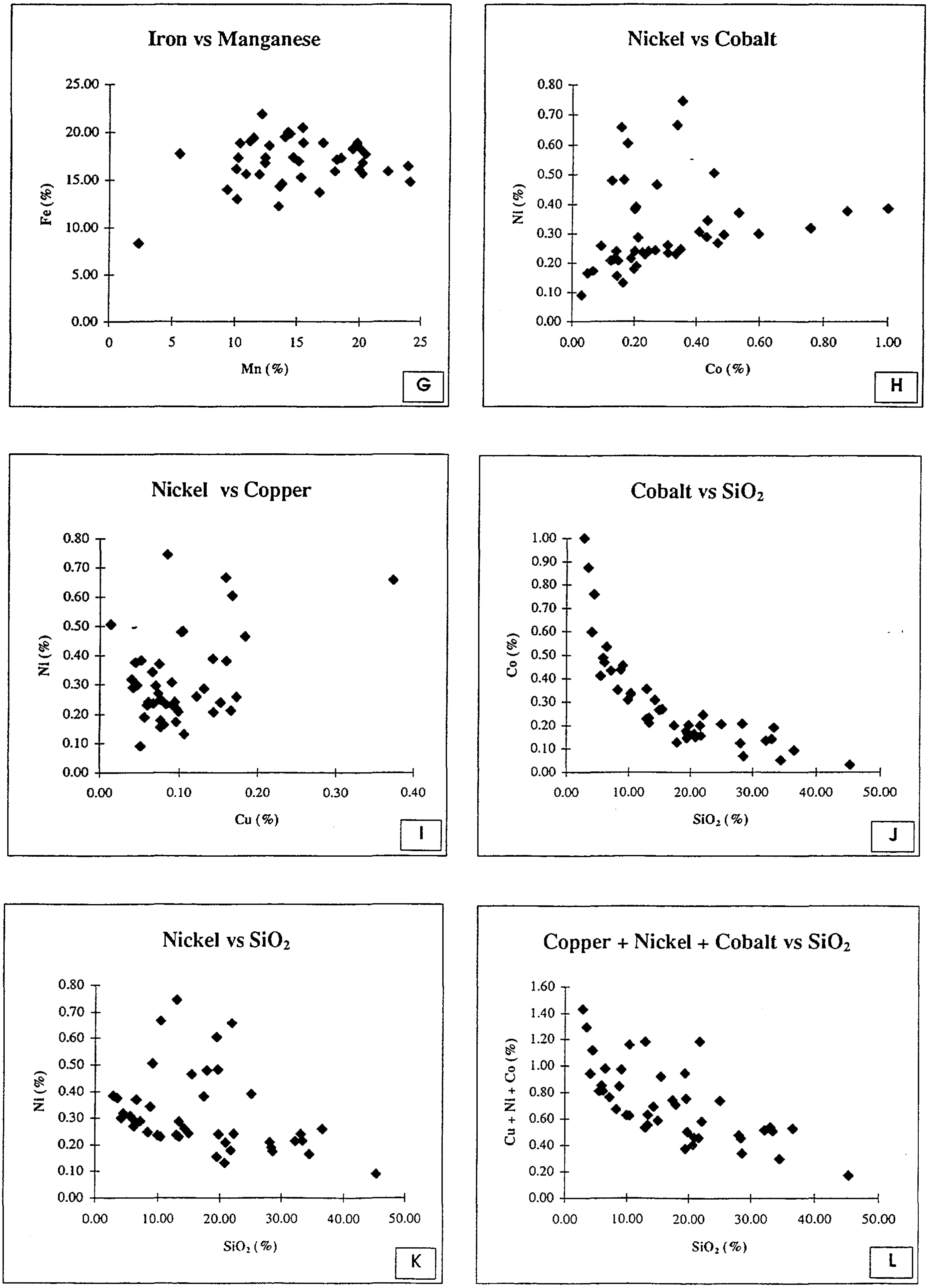


Figure 58G-L. Cross-plots of analyses of selected metals in manganese deposits recovered on Cruise 147.

Major points coming out of the above analysis are:

- Co, Ni, Cu and Mn percentages decrease with water depth, whereas SiO2 percentage increases, suggesting that it is a major dilutant. The relative importance of detrital and biogenic silica are not yet known, but either form is more likely to be incorporated into chemical deposits where currents are slower, that is at greater depths.
- Plots of Co and Ni percentages against SiO2 confirm the inverse relationship.
- Fe percentages remain roughly constant, but Mn percentages vary greatly. The valuable metals move with Mn, suggesting that they are being scavenged by it.
- Further prospecting for cobalt-rich crusts should concentrate on outcrops in water depths of 1000-2000 m, on the eastern South Tasman Rise and the southern Tasmanian margin
- Further AGSO sampling of the Tasman Manganese Pavement on the abyssal plain could be justified only once samples from earlier American cruises (Payne & Conolly, 1972) had been analysed and assessed.

11. WATER COLUMN STUDIES

11.1. Hydrocasts

D. McCorkle, Woods Hole Oceanographic Institution

Water column studies were carried out at a number of stations (Fig. 1). Three deep hydrocasts were carried out, on the western and southern boundaries of the South Tasman Rise (147/HC-03 and 147/HC-06, respectively), and on the east side of the East Tasman Plateau (147/HC-08). All three were successful, yielding sets of samples from six depths (1.0, 1.5, 2.0, 2.5, 3.0, and 3.5 km) for salinity, oxygen, nutrients, $\delta^{13}C/\Sigma CO_2$, trace metals, and deep-water temperature.

Six shallow hydrocasts were carried out, at approximately 41°, 43°, 45°, 47°, and 49° S on the west side of the South Tasman Rise, and at 44° S on the east side of the East Tasman Plateau. Each cast included samples from 10, 25, 50, 100, 150, and 200 m. Several litres from each bottle were filtered for cocolithophore abundance and distribution studies, and smaller water samples were collected for salinity, nutrients, oxygen, $\delta^{13}C/\Sigma CO_2$, and trace metals.

Seventeen bucket samples of surface water were collected, and at twelve of these sites the AGSO submersible data logger (SDL) was also used to profile the upper 200 m of the water column. The temperature of each bucket sample was measured, and subsamples were collected for salinity and for diatom abundance and distribution studies. The sensors on the SDL provided profiles of temperature and salinity (and also oxygen, pH, and turbidity) with roughly 2-meter vertical resolution. A 1.6°C offset was observed between the bucket thermometer and the SDL thermocouple. This discrepancy has not yet been resolved, though we suspect that the (higher) bucket temperatures may be incorrect since the bucket thermometer has not been calibrated. Comparison of the deep SDL temperatures with the reversing thermometer readings from the 200 m bottles on the shallow hydrocasts may help resolve this difference. All the water column sampling is summarised in Table 30.

Table 30: Summary of water samples and hydrocasts on AGSO Cruise 147 off Tasmania

ID	Latitude (South)	Longitude (East)	Bucket	SDL	Bottles	Temp (bucket)/ SDL-0	Temp SDL (deep)
WS-01	41° 00.17	142° 31.22	X			ND/15.8	
HC-01(S)	41° 00.17	142° 31.22		X	5		
WS-02	41°35.8	142° 07.6	X	X		17/15.7	
WS-03	42°0.04	142° 09.84	X	X		17.0/15.5	
WS-04	42° 30.07	142° 36.03	X	X		17.5/15.3	
WS-05	42° 59.95	143° 01.92	X			17.0/15.5	10.5
HC-02(S)	42° 59.95	143° 01.92		X	6		
WS-06	43° 30.00	143° 28.83	X	X		17.5/16.1	
WS-07	44° 10.18	144° 10.73	X	X		15.0/13.2	
HC-03(D)	45° 02.00	144° 15.01			6		
WS-08	45° 02.00	144° 15.01	X			15.8/14.3	10.2
HC-04(S)	45° 02.00	144° 15.01		X	6		
WS-09	45° 29.43	144° 35.87	X	no SDL		16.4/ND	
WS-10	46° 17.45	144° 50.42	X	no SDL		12.5/ND	
WS-11	46° 17.45	144° 50.42	X	X		ND/11.4	9.1
WS-12	47° 11.84	145° 03.86	X			13.2/11.8	9.6
HC-05	47° 11.84	145° 03.86		X	6		
WS-13	47° 38.56	145° 01.49	X	no SDL		12.2/ND	
WS-14	48° 07.04	145° 14.41	X	no SDL		12.0/ND	
WS-15	48° 26.49	146° 12.99	X	SDL data lost - File overwritten			
HC-06	49° 04.54	146° 15.01			6		
WS-16	49° 04.40	146° 14.62	X			11.5/9.4	8.5
HC-07	49° 04.40	146° 14.62		X	6		
HC-08(D)	43° 54.18	151° 21.39			6		
WS-17	43° 54.50	151° 22.15	X			20.0/18.4	12.2
HC-09(S)	43° 54.50	151° 22.15		X	6		
HC-10	43° 24.48	148° 06.22		X (sdl18)	1 (140m)		

Shallow hydro nominal depths[1]: 10, 25, 50, 100, 150, 200 m
Deep hydro nominal depths[1]: 1, 1.5, 2, 2.5, 3, 3.5 km
Bucket samples: Diatoms, temperature[2], salinity, nutrients.
Shallow hydro: Cocoliths, salinity, nutrients, oxygen, $\delta^{13}C$, trace metals.
SDL (submersible data logger) sensors logged depth, temperature[2], salinity, oxygen.
Deep hydro: Salinity, oxygen, nutrients, $\delta^{13}C$, trace metals, bottom temperature.

[1] *All depths require recalculation due to persistent problems with wire-out meter.*
[2] *There was a T offset between the bucket thermometer and the SDL thermocouple*

Thermometer = SDL + 1.65 °C (comparison in bucket in lab)

Thermometer = SDL + 1.58 °C ± 0.3 °C (mean of 11 surface water pairs)

3 deep hydrocasts; 6 shallow hydrocasts; 18 water samples/SDL profiles

We had problems analogous to those with the coring winch when using the hydrowire; on the shallow (200 m) SDL casts the meter underestimated the wire out by 10-20 percent (based on comparison with the depths recorded by the depth sensor (pressure transducer) on the SDL). [The meter reading was in reasonable agreement (i.e., within a few percent) of the true depth based on watching the PDR trace of the grab on the 3 1 km casts.] We don't have good independent estimates for the accuracy of the deep hydrocasts.

11.2. Studies of Recent calcareous nannoplankton

C. Findlay

The research project is divided into three parts:

1. The identification and quantification of calcareous nannoplankton (coccolithophorids) in water samples from the Southern Ocean between 10 and 200 m water depth from latitude 41°S to 63°S.

The first transect was covered by the WOCE-7 cruise between 48°S and 63°S, south of the Subtropical Convergence (Rosenberg et al., 1995). The second transect was covered by *Rig Seismic* Cruise 147, between 41°S and 49°S, north of, through and south of, the Subtropical Convergence.

I have completed examination of the WOCE-7 samples, identified and quantified the floral assemblage and have identified different morphotypes of *Emiliania huxleyi* (the most abundant species in all oceans at present), a cold water form and a polar form. Both these morphotypes increase in abundance with higher latitudes. Preliminary investigations of the *Rig Seismic* samples show a very different floral assemblage and a high percentage of a warm water morphotype of Emiliania huxleyi, which are not present in the WOCE-7 samples.

2. The identification and quantification of floral assemblages from sediment/surface interface samples, to compare with water column samples with particular reference to preservation properties (dissolution etc.) of different species.

Sediment/surface samples were collected on the *Rig Seismic* from cores, box cores and grabs to carry out the above analysis. At a later stage, I hope to obtain sediment/surface samples from higher latitudes, preferably to 63°S, for the same analysis.

3. Sampling of Quaternary cores at 10cm intervals down-core to assess the changes in morphotypes and overall floral assemblages with relation to temperature and salinity. This should provide a picture of the history of paleoceanography in the Southern Ocean with particular reference to the movement of ocean fronts.

12. PALAEONTOLOGY

12.1. Biostratigraphic report on samples from AGSO Cruise 147

George C.H. Chaproniere, AGSO

Introduction

One hundred and sixty-four samples from dredges (DR), box cores (BC), freefall cores (FFG), gravity cores (GC) and vibracores (VC) were examined for foraminiferids. The biostratigraphic summary is given in Table 31, and locality, lithologic and biostratigraphic data in Table 32. Most of these were Quaternary, but a few were from the Pliocene. A few samples of limestones (thin sections) contained faunas which were difficult to identify accurately, but had characteristics of species from the late Oligocene to Early Miocene. A number contained either very poor assemblages, or restricted arenaceous forms; the ages for these is listed as indeterminable, but as will be discussed below are probably Eocene. For five samples, barren of foraminiferids, the age could not be determined.

Table 31. Summary of pre-Quaternary samples recovered on Cruise 147.

Age	Sample
Quaternary	147DR01/E, 147DR01/F, 147DR02/1, 147DR02/2, 147DR02/3, 147DR02/4, 147DR03/1, 147DR04/1, 147DR05/1, 147DR06/1, 147DR07/1, 147DR08/1, 147DR09/1, 147DR10/1 147DR011/1, 147DR12/1, 147DR13/1, 147DR14/C, 147DR16/1, 147DR17/1, 147DR18/1, 147DR20/1, 147DR21/1, 147DR22/1, 147DR23/1, 147DR24/1, 147DR25/1, 147DR25/I1, 147DR26/1, 147DR27/1, 147DR28/1, 147DR29/1, 147DR30/1, 147DR31/1, 147DR32/1, 147DR33/1, 147DR36/1, 147DR37/1, 147DR37/D1, 147DR38/1, 147DR38/C1, 147DR38/C3, 147DR38/F1, 147DR39/1, 147DR38/1, 147DR41/1, 147DR42/1, 147DR43/1, 147DR44/1, 147DR44/B1, 147DR44/B2, 147DR45/1, 147DR47/F1, ?147DR47/F2, 147DR50/1, 147DR52/1, 147DR53/1, 147DR54/1, 147DR55/1, 147DR56/1, 147BC03/1, 147FFG1A, 147GC01/035, 147GC01/056, 147GC01/073, 147GC01/cc, 147GC04/cc, 147GC05/cc, 147GC06/cc, 147GC07/cc, 147GC09/kk, 147GC10/kk, 147GC11/cc, 147GC13/cc, 147GC14/cc, 147GC14/ccmid, 147GC15/400, 147GC16/cc, 147GC17/cc, ?147GC18/cc, ?147GC18/kktop, ?147GC18/kkbot, 147GC20/cc, 147GC21/220, 147GC22/cc, 147GC24/cc, 147GC25/cc, 147GC26/cc, 147GC27/cc, 147GC28/cc, 147GC30/cc, 147GC31/cc, 147GC32/cc, 147GC33/cc, 147GC34/cc, 147GC35/cc, 147GSO01/1, 147GSO02/1, 147GSO03/1, 147GSO04/1, 147GSO05/1, 147GSO08/1, 147VC01/250, 147VC01/cc, 147VC04/cc.
Late Pliocene	147DR28/F, 147DR35/D1, 147GC01/363, 147GC21/210, 147GC21/cc, 147GC35/kk.
Late Oligocene to early Miocene	147DR11/C1, 147DR11/C2, 147DR11/C3, 147DR11/C4, 147DR15/E, 147DR21/B1, 147DR38/C2.
?Eocene	147DR01/D1, 147DR10/B, 147DR12/B, 147DR12/E1, 147DR13/A, 147DR14/A1, 147DR14/A2, 147DR14/A3, 147DR14/A4, 147DR14/A5, 147DR17/E, 147DR18/A2, 147DR20/E1, 147DR20/E3, 147DR21/A1, 147DR22/G1, 147DR24/E1, 147DR24/G1, 147DR25/F1, 147DR27/C1, 147DR27/C2, 147DR48/D1, 147DR48/D2.
Age not determinable	147DR10/4A, 147DR10/6A.
Barren	147DR14/A6, 147DR31/E1, 147DR43/E2, 147DR54/C1, 147DR54/C2.

Previous studies (Jenkins, 1975 on DSDP Sites; Belford, 1989 on material from *Sonne* Cruise 36C) have recorded late Eocene to Quaternary assemblages in the area. DSDP Sites 281 and 282 produced the best sequences, with the most complete at Site 281, which was drilled on the South Tasman Rise. At Site 281 the late Eocene is overlain by an apparently continuous early Miocene to Quaternary sequence. At the deeper water and more northerly Site 282, there is an apparently nearly

TABLE 32: SUMMARY OF LOCALITY, LITHOLOGY AND AGE DATA FOR ALL MICROPALAEONTOLOGICAL SAMPLES EXAMINED FROM CRUISE 147.

Location	Water Depth	Latitude - Start	Latitude - End	Longitude - Start	Longitude - End	General Location	Date	Sample	Description	Age	Comments
Dredge 01	4800-4100	41° 36.0'S	41° 36.9'S	142° 06.2'E	142° 02.5'E	West Tasmania	1/28/95	D1		?Eocene	Very restricted fauna with fish teeth
Dredge 01	4800-4100	41° 36.0'S	41° 36.9'S	142° 06.2'E	142° 02.5'E	West Tasmania		E	grey ooze	N.22 or younger	Dissoln. More diverse than F
Dredge 01	4800-4100	41° 36.0'S	41° 36.9'S	142° 06.2'E	142° 02.5'E	West Tasmania		F	yellow ooze	N.22 or younger	Dissoln. Less diverse than E
Dredge 02	4250-4770	43° 51.5'S	43° 51.4'S	143° 48.0'E	143° 48.1'E	S.W. Tasmania	1/29/95	1	Light grn/yell plastic mud	N.22 or younger	Dissoln. moderate- many tests fragmented
Dredge 02	4250-4770	43° 51.5'S	43° 51.4'S	143° 48.0'E	143° 48.1'E	S.W. Tasmania		2	Light grn/or/yell plastic mud	?Quaternary	Dissoln. mod. severe
Dredge 02	4250-4770	43° 51.5'S	43° 51.4'S	143° 48.0'E	143° 48.1'E	S.W. Tasmania		3	yellow ooze	N.22 or younger	Dissoln. mod. severe
Dredge 02	4250-4770	43° 51.5'S	43° 51.4'S	143° 48.0'E	143° 48.1'E	S.W. Tasmania		4	Plastic mud from fines of PD	N.22 or younger	Dissoln. severe
Gravity Core 01	4238	44° 10.3'S		144° 10.8'E		S.W. Tasmania	1/29/95	350	cream-brown ooze	N.22 or younger	Dissoln. mod. severe
Gravity Core 01	4238	44° 10.3'S		144° 10.8'E		S.W. Tasmania		560	green-grey clay	Late Pliocene or younger	Dissoln. severe
Gravity Core 01	4238	44° 10.3'S		144° 10.8'E		S.W. Tasmania		725	green clay	Late Pliocene or younger	Dissoln. severe
Gravity Core 01	4238	44° 10.3'S		144° 10.8'E		S.W. Tasmania		3630	green clay	Late Pliocene or younger	Dissoln. severe
Gravity Core 01	4238	44° 10.3'S		144° 10.8'E		S.W. Tasmania		cc	mix of green clay & ooze	N.22 or younger	Dissoln. severe. Quartz & pellets present
Dredge 03	4400-3800	44° 01.8'S	44° 00.5'S	144° 32.5'E	144° 34.6'E	S.W. Tasmania	1/30/95	1	yellow ooze	N.22 or younger	Dissoln. moderate
Dredge 04	4000-3000	44° 00.8'S	44° 00.7'S	144° 34.0'S	144° 34.4'E	S.W. Tasmania	1/30/95	1	yellow ooze	N.22 or younger	Dissoln. moderate
Gravity Core 02	1957	44° 00.0'S		144° 43.0'E		S.W. Tasmania	1/31/95	No recovery		No recovery	No recovery
Gravity Core 03	1957	44° 00.0'S		144° 43.0'E		S.W. Tasmania	1/31/95	No recovery		No recovery	No recovery
Dredge 05	3000-2300	44° 00.5'S	44° 00.2'S	144° 34.5'E	144° 35.4'E	S.W. Tasmania	1/31/95	1	yellow ooze	N.22 or younger	Dissoln. minor. Reworked N.21?
Gravity Core 04	2981	44° 06.0'S		145° 15.0'E		S.W. Tasmania	1/31/95	cc	grey cream ooze	N.22 (Gr. viola Subzone)	Dissoln. very minor
Gravity Core 05	2334	44° 04.0'S		145° 25.0'E		S.W. Tasmania	1/31/95	cc	grey cream ooze	N.22 or younger	Dissoln. very minor
Dredge 06	1400	44° 20.0'S		147° 07.4'E		S.W. Tasmania	2/1/95	1	Grey brown gravel	N.22 or younger + rew N.21 or N.22	Dissoln. very minor; attached benthics.
Dredge 07	1500-1100	44° 22.7'S	44° 22.7'S	147° 04.1'E	147° 05.2'E	S.W. Tasmania	2/1/95	1	Grey brown gravel	N.22 or younger	Dissoln. very minor; attached benthics.
Gravity Core 06	2609	44° 31.5'S		146° 42.5'E		S.W. Tasmania	2/1/95		grey cream ooze	N.22 or younger	Dissoln. very minor
Dredge 08	3000-2450	45° 12.0'S	45° 12.0'S	146° 07.4'E	146° 05.8'E	South Tasmania Rise	2/2/95	1	grey cream ooze	N.22 or younger	Dissoln. very minor; attached benthics.
Gravity Core 07	3307	45° 09.5'S		146° 17.5'E		South Tasmania Rise	2/2/95	cc	grey cream ooze	N.22 or younger	Dissoln. very minor - some warm indicators
Dredge 09	3300-2200	45° 24.5'S	45° 25.9'S	146° 17.2'E	146° 15.8'E	South Tasmania Rise	2/3/95	1	grey cream ooze	N.22 or younger	Some dissoln. effects.
Box Core 03	3307	45° 09.5'S		146° 17.5'E		South Tasmania Rise	2/3/95	1	cream brown ooze	Recent	Dissoln. moderate; rads. present.
Dredge 10	2800-2100	45° 41.0S	45° 41.0'S	146° 08.1'E	146° 09.4'E	South Tasmania Rise	2/3/95	1	cream brown ooze	N.22 or younger	Some dissoln. effects.
Dredge 10	2800-2100	45° 41.0S	45° 41.0'S	146° 08.1'E	146° 09.4'E	South Tasmania Rise	2/3/95	A1	Cse. immature sandstone	Barren	T/S; barren.
Dredge 10	2800-2100	45° 41.0S	45° 41.0'S	146° 08.1'E	146° 09.4'E	South Tasmania Rise	2/3/95	B1	Muddy laminated siltstone	Barren	T/S; barren.
Dredge 10	2800-2100	45° 41.0S	45° 41.0'S	146° 08.1'E	146° 09.4'E	South Tasmania Rise	2/3/95	C	Mid brown burrowed sandst.	?Eocene	Very limited fauna
Gravity Core 08	1813	46° 14.0'S		146° 19.0'E		South Tasmania Rise	2/4/95	No recovery		No recovery	No recovery
Gravity Core 09	1813	46° 14.0'S		146° 19.0'E		South Tasmania Rise	2/4/95	kk	grey cream ooze	N.22 or younger	Dissoln very minor.
Gravity Core 10	2369	45° 58.9'S		145° 33.4'E		South Tasmania Rise	2/4/95	kk	grey cream ooze	N.22 or younger	Some dissoln. effects.
Dredge 11	2200-1940	45° 41.3'S	45° 40.6'S	145° 54.3'E	145° 54.3'E	South Tasmania Rise	2/4/95	C1	yellow-orange lst.	?N.8 to N.10?	T/S. Bioclastic packstone with rare planktics. Some red staining. Borings infilled by mud.
Dredge 11	2200-1940	45° 41.3'S	45° 40.6'S	145° 54.3'E	145° 54.3'E	South Tasmania Rise	2/4/95	C2	yellow-orange lst.	?P.22 or younger	T/S. ?Chert. Very recrystallised. Bioclasts are "ghosted" with vague boundaries. ?Phosphatic?
Dredge 11	2200-1940	45° 41.3'S	45° 40.6'S	145° 54.3'E	145° 54.3'E	South Tasmania Rise	2/4/95	C3	yellow-orange lst.	?P.22 or younger	T/S. ?Chert. Very recrystallised. Bioclasts are "ghosted" with vague boundaries. ?Phosphatic?
Dredge 11	2200-1940	45° 41.3'S	45° 40.6'S	145° 54.3'E	145° 54.3'E	South Tasmania Rise	2/4/95	C4	yellow-orange lst.	?Late Oligocene or younger	T/S. ?Chert. Very recrystallised. Bioclasts are "ghosted" with vague boundaries. ?Phosphatic?
Dredge 11	2200-1940	45° 41.3'S	45° 40.6'S	145° 54.3'E	145° 54.3'E	South Tasmania Rise	2/4/95	1	grey cream ooze	N.22 or younger	Some dissoln. effects. Rads. rare
Dredge 12	3000-2100	45° 09.0'S	45° 10.2'S	145° 25.1'E	145° 23.8'E	South Tasmania Rise	2/5/95	1	grey cream ooze	N.22 or younger	Some dissoln. effects.
Dredge 12	3000-2100	45° 09.0'S	45° 10.2'S	145° 25.1'E	145° 23.8'E	South Tasmania Rise	2/5/95	E1	??	?Eocene to ?Oligocene	T/S; Very recrystallised. Cyclammina sp. and very rare ?planktics.
Dredge 13	3900-2700	45° 07.7'S	45° 07.4'S	144° 30.3'E	144° 32.8'E	South Tasmania Rise	2/5/95	a	plastic green brown clay in PD		
Dredge 13	3900-2700	45° 07.7'S	45° 07.4'S	144° 30.3'E	144° 32.8'E	South Tasmania Rise	2/5/95	1	grey cream ooze	N.22 or younger	Some dissoln. effects.
Dredge 13	3900-2700	45° 07.7'S	45° 07.4'S	144° 30.3'E	144° 32.8'E	South Tasmania Rise	2/5/95	A	green brown fine sst. from PD	?Eocene	anomalous arenaceous tests?
Dredge 13	3900-2700	45° 07.7'S	45° 07.4'S	144° 30.3'E	144° 32.8'E	South Tasmania Rise	2/5/95	A1	green brown fine sst. from PD	Barren	T/S; barren.
Dredge 13	3900-2700	45° 07.7'S	45° 07.4'S	144° 30.3'E	144° 32.8'E	South Tasmania Rise	2/5/95	A2		Late Cretaceous to early Tertiary	Palynology
Dredge 13	3900-2700	45° 07.7'S	45° 07.4'S	144° 30.3'E	144° 32.8'E	South Tasmania Rise	2/5/95	B			
Dredge 14	4400-3800	45° 02.2'S	45° 02.2'S	144° 19.2'E	144° 20.8'E	South Tasmania Rise	2/5/95	A1	med brown mudst.	?Eocene	anomalous arenaceous tests?
Dredge 14	4400-3800	45° 02.2'S	45° 02.2'S	144° 19.2'E	144° 20.8'E	South Tasmania Rise	2/5/95	A2	laminated yell. brn. mudst.	?Eocene	Siliceous Ammodiscus?
Dredge 14	4400-3800	45° 02.2'S	45° 02.2'S	144° 19.2'E	144° 20.8'E	South Tasmania Rise	2/5/95	A3	mottled med brn. mudst.	?Eocene	Radiolaria & diatoms common.
Dredge 14	4400-3800	45° 02.2'S	45° 02.2'S	144° 19.2'E	144° 20.8'E	South Tasmania Rise	2/5/95	A4	Faintly lamin. brn mudst.	?Eocene	Radiolaria & diatoms common.
Dredge 14	4400-3800	45° 02.2'S	45° 02.2'S	144° 19.2'E	144° 20.8'E	South Tasmania Rise	2/5/95	A5	or. yell. mudstone	?Eocene	Siliceous Ammodiscus?
Dredge 14	4400-3800	45° 02.2'S	45° 02.2'S	144° 19.2'E	144° 20.8'E	South Tasmania Rise	2/5/95	A6	??	?Eocene	T/S
Dredge 14	4400-3800	45° 02.2'S	45° 02.2'S	144° 19.2'E	144° 20.8'E	South Tasmania Rise	2/5/95	A8	??	Late Eocene	Late Eocene dinocysts of Antarctic affinity
Dredge 14	4400-3800	45° 02.2'S	45° 02.2'S	144° 19.2'E	144° 20.8'E	South Tasmania Rise	2/5/95	C	PD, mix of ooze & mudst.	N.22 or younger	Dissoln. effects strong. Low diversity fauna.
Free Fall Grab 1A	4772	45° 26.0'S		144° 20.0'E		South Tasmania Rise	2/6/95	1A	Fine grey cream ooze	N.22 or younger	Dissoln. effects strong. Low diversity fauna.
Dredge 15	3400-3000	45° 29.3'S	45° 29.2'S	144° 36.8'E	144° 37.1'E	South Tasmania Rise	2/6/95	No mud		No recovery	No mud
Dredge 15	3400-3000	45° 29.3'S	45° 29.2'S	144° 36.8'E	144° 37.1'E	South Tasmania Rise	2/6/95	E	???	?P.22 to ?N.6	T/S. ?Chert. Very recrystallised. Planktics abundant but ghosted.
Gravity Core 11	2387	45° 44.0'S		144° 53.0'E		South Tasmania Rise	2/6/95	cc	Fine grey cream ooze	N.22 or younger	Dissoln. moderate; rads. present.
Gravity Core 12	2387	45° 44.0'S		144° 53.0'E		South Tasmania Rise	2/6/95	No recovery		No recovery	No recovery
Gravity Core 13	4452	46° 10.0'S		144° 16.0'E		South Tasmania Rise	2/7/95	cc	Fine grey cream ooze	N.22 or younger	Dissoln. effects strong. Low diversity fauna.
Dredge 16	4250-3700	46° 17.5'S	46° 17.5'S	144° 44.7'E	144° 45.9'E	South Tasmania Rise	2/7/95	D	Fine grey cream ooze	N.22 or younger	Dissoln. strong; rads. present.
Gravity Core 14	3360	46° 27.0'S		145° 14.5'E		South Tasmania Rise	2/7/95	cc	Fine grey cream ooze	N.22 or younger	Dissoln. moderate. Rare rads. This core was 2 hits.
Gravity Core 14	3360	46° 27.0'S		145° 14.5'E		South Tasmania Rise	2/7/95	cc mid	Fine grey cream ooze	N.22 or younger	Dissoln. minor. Rads present. cc from 1st hit!
Gravity Core 15	3260	46° 39.0'S		145° 25.1'E		South Tasmania Rise	2/8/95	400	Fine grey cream ooze	N.22 or younger	Dissoln. minor. Rads present. Orb. & Gl. nos. Warm??? Sev. hits
Gravity Core 16	3523	46° 48.0'S		145° 15.0'E		South Tasmania Rise	2/8/95	cc	Fine grey cream ooze	N.22 or younger	Dissoln. minor. Rads present.
Dredge 17	4500-3400	46° 47.4'S	46° 47.4'S	144° 47.4'S	144° 58.1'E	South Tasmania Rise	2/8/95	1	Fine grey cream ooze	N.22 or younger	Dissoln. moderate; rads. present.
Dredge 17	4500-3400	46° 47.4'S	46° 47.4'S	144° 47.4'S	144° 58.1'E	South Tasmania Rise	2/8/95	E	Mn. muddy grit.	?Eocene	A few radiolaria and mud tubes.
Dredge 18	3700-3200	46° 47.5'S	46° 47.5'S	144° 57.6'E	144° 58.5'E	South Tasmania Rise	2/9/95	1	PD. Fine grey cream ooze + Mn.	N.22 or younger	Dissoln. moderate; rads. present.
Dredge 18	3700-3200	46° 47.5'S	46° 47.5'S	144° 57.6'E	144° 58.5'E	South Tasmania Rise	2/9/95	A2	??	Late Eocene	Antarctic dinocysts with low diversity
Dredge 18	3700-3200	46° 47.5'S	46° 47.5'S	144° 57.6'E	144° 58.5'E	South Tasmania Rise	2/9/95	A2a	??	?Eocene	T/S. Fine carbonaceous sst. ?Benthis foram.
Dredge 18	3700-3200	46° 47.5'S	46° 47.5'S	144° 57.6'E	144° 58.5'E	South Tasmania Rise	2/9/95	A3	??	Late Eocene	Antarctic dinocysts with low diversity
Dredge 19	4200-3300	47° 13.0'S	47° 13.0'S	145° 03.8'E	145° 05.5'E	South Tasmania Rise	2/9/95	Dredge lost		No recovery	Dredge lost
Dredge 20	3600-3500	47° 13.0'S	47° 13.0'S	145° 05.0'E	145° 05.1'E	South Tasmania Rise	2/9/95	1	PD. Fine grey cream ooze + Mn.	N.22 or younger	Dissoln. strong; rads. present.
Dredge 20	3600-3500	47° 13.0'S	47° 13.0'S	145° 05.0'E	145° 05.1'E	South Tasmania Rise	2/9/95		mottled med brn. mudst.	?Eocene	Ferrugenised ?rads & ?diatoms?
Dredge 20	3600-3500	47° 13.0'S	47° 13.0'S	145° 05.0'E	145° 05.1'E	South Tasmania Rise	2/9/95		Faintly lamin. brn mudst.	?Eocene	Ferrugenised ?rads & ?diatoms?
Dredge 21	3400	47° 38.5'S		145 04.8'E		South Tasmania Rise	2/9/95	1	PD. Fine grey cream ooze + mudst.	N.22 or younger.	Large rads. similar to those of grn mudstones.
Dredge 21	3400	47° 38.5'S		146 04.8'E		South Tasmania Rise	2/9/95	A1	mottled med brn. mudst.	?Eocene	Many rads.
Dredge 21	3400	47° 38.5'S		147 04.8'E		South Tasmania Rise	2/9/95	B1	Faintly lamin. brn mudst.	?L. Eocene or Late Oligocene??	One small specimen of Globigerinatheka or G. woodi group.
Gravity Core 17	3001	47° 45.0'S		145° 49.0'E		South Tasmania Rise	2/10/95	cc	Fine grey cream sandy ooze	N.22 or younger	Dissoln. moderate to strong. Rads may be contaminents.
Dredge 22	3750-3350	48° 01.4'S	48° 00.8'S	145° 38.3'E	145° 39.5'E	South Tasmania Rise	2/10/95	G1	manganiferous med brn. mudst.	?Eocene	Fish teeth, pellets & internal moulds of forams & ?rads.
Dredge 22	3750-3350	48° 01.4'S	48° 00.8'S	145° 38.3'E	145° 39.5'E	South Tasmania Rise	2/10/95	1	Fine grey cream sandy ooze	N.22 or younger.	Dissoln. moderate; rads. very rare.Orb. & Gl. rare.
Gravity Core 18	4368	48° 05.5'S		145° 34.0'E		South Tasmania Rise	2/10/95	kk bot	manganiferous med brn. mudst.	?Eocene	Fish teeth, pellets, rads & internal moulds of ?forams.
Gravity Core 18	4368	48° 05.5'S		145° 34.0'E		South Tasmania Rise	2/10/95	kk top	Dark brn fine mudstone	?Eocene	Fish teeth, pellets, rads & internal moulds of ?forams.
Gravity Core 18	4368	48° 05.5'S		145° 34.0'E		South Tasmania Rise	2/10/95	cc	Dark brn fine mudstone	?Eocene	Fish teeth, pellets, rads & internal moulds of ?forams.
Dredge 23	4600-3600	48° 07.0'S	48° 07.0'S	145° 15.2'E	145° 19.0'E	South Tasmania Rise	2/11/95	1	Drk brn and creamy mud from PD	N.22 or younger	N.22 fauna with fish teeth and few rads. Grn mudst present!
Gravity Core 19	2578	48° 26.5'S		146° 13.0'E		South Tasmania Rise	2/11/95	No recovery		No recovery	No recovery
Dredge 24	2600-2250	48° 32.0'S	48° 31.3'S	146° 27.0'E	146° 27.0'E	South Tasmania Rise	2/11/95	E1	Yellow matix of Mn conglomerate	?Eocene	Frags. of echinoids and non-calc. moulds of planktic forams.
Dredge 24	2600-2250	48° 32.0'S	48° 31.3'S	146° 27.0'E	146° 27.0'E	South Tasmania Rise	2/12/95	G1	Mn conglomerate	?Eocene	T/S. Small, simple planktic forams in yell. matrix are leached and N.D. Other clasts are recryst. and barren.
Dredge 24	2600-2250	48° 32.0'S	48° 31.3'S	146° 27.0'E	146° 27.0'E	South Tasmania Rise	2/11/95	1	Piece of white ?coral fragment with adhering sediment from PD	N.22 or younger	Dissoln. minor. Rads present.
Gravity Core 20	3300	48° 39.0'S		146° 26.0'E		South Tasmania Rise	2/11/95	cc	Cream foram sand	N.22 or younger	Dissoln. moderate; rads. very rare.Orb. & Gl. rare.
Gravity Core 21	4132	49° 00.0'S		145° 59.0'E		South Tasmania Rise	2/12/95	cc	Or. cream foram mud.	Gr. inflata Zone; N.19-20.	2 hits? Gr. ronda & Gr oceanica, without Gr. tosaensis or Gr. truncatulinoides. Many rads. Fish tooth.
Gravity Core 21	4132	49° 00.0'S		145° 59.0'E		South Tasmania Rise	2/12/95	210	Or. cream foram mud.	Gr. inflata Zone; N.19-20.	2 hits? Gr. ronda & Gr oceanica, without Gr. tosaensis or Gr. truncatulinoides. Many rads. Fish tooth.
Gravity Core 21	4132	49° 00.0'S		145° 59.0'E		South Tasmania Rise	2/12/95	220	Or. cream foram mud.	N.22 (?Gr. viola Subzone)	2 hits? Dissoln mod to strong. Gr. truncatulinoides, with Gr. tosaensis (1 only). Glla. absent.

TABLE 32 (CONTINUED): SUMMARY OF LOCALITY, LITHOLOGY AND AGE DATA FOR ALL MICROPALAEONTOLOGICAL SAMPLES EXAMINED FROM CRUISE 147.

Location	Water Depth	Latitude - Start	Latitude - End	Longitude - Start	Longitude - End	General Location	Date	Sample	Description	Age	Comments
Dredge 25	3300-2420	49° 04.3'S	49° 04.0'S	146° 16.0'E	146° 17.4'E	South Tasmania Rise	2/12/95	I1	Cream foram mud on rock sample in dregde.	N.22 or younger	Some dissoln. effects. No rads or Orbulina or Globigerinella.
Dredge 25	3300-2420	49° 04.3'S	49° 04.0'S	146° 16.0'E	146° 17.4'E	South Tasmania Rise	2/12/95	F1	Faintly lamin. brn mudst.	?Eocene	Ferrugenised ?rads & ?diatoms? with ?Haplophragmoides sp.
Dredge 25	3300-2420	49° 04.3'S	49° 04.0'S	146° 16.0'E	146° 17.4'E	South Tasmania Rise	2/12/95	1	PD. Cream foram sand	N.22 or younger	Dissoln. strong. No rads. Orbulina & Globigerinella. rare. Cyclammina reworked?
Dredge 26	2980-2600	48° 29.9'S	48° 29.6'S	147° 27.2'E	147° 27.8'E	South Tasmania Rise	2/12/95	1	PD. Cream foram sand	N.22 or younger	Dissoln. minor. Orb. common. Gl. rare. Rads common in -125um.
Dredge 27	3000-2700	48° 30.8'S	48° 30.6'S	147° 28.2'E	147° 28.6'E	South Tasmania Rise	2/13/95	1	PD. Cream foram sand	N.22 or younger	Dissoln. minor. Orb. common. Gr. crassformis & Gl.absent. Rads common.
Dredge 27	3000-2700	48° 30.8'S	48° 30.6'S	147° 28.2'E	147° 28.6'E	South Tasmania Rise	2/13/95	C1	Dark brn grn fine mudstone	?Eocene	Ferrugenised ?rads & ?diatoms?
Dredge 27	3000-2700	48° 30.8'S	48° 30.6'S	147° 28.2'E	147° 28.6'E	South Tasmania Rise	2/13/95	C2	Dark brn grn muddy grit, bedded	?Eocene	Flat, coiled then uncoiled arenacous forms.
Gravity Core 22	1914	47° 58.5'S		147° 10.0'E		South Tasmania Rise	2/13/95	cc	Cream grey foram sand	N.22 or younger	Dissoln. minor. Rads rare. Some coral thicket fauna present. Gl. rare.
Dredge 28	2100-1800	47° 58.5'S	47° 58.6'S	147° 03.3'E	147° 03.4'E	South Tasmania Rise	2/13/95	1 (=E)	PD. Cream foram sand	N.22 or younger	No dissoln. Orbulina v. common, Globigerinelle v. rare.
Dredge 28	2100-1800	47° 58.5'S	47° 58.6'S	147° 03.3'E	147° 03.4'E	South Tasmania Rise	2/13/95	F	Cream-yell. foram mud on white lst.	N.21; Late Pliocene.	Gr. tosaensis; a unique benthic fauna. Needs T/S.
Dredge 29	1170-1070	47° 44.2'S	47° 44.6'S	147° 33.7'E	147° 32.8'E	South Tasmania Rise	2/13/95	1	PD. Cream foram sand	N.22 or younger	No dissoln. Orbulina v. common, Globigerinelle v. rare.
Gravity Core 23	1300	47° 39.6'S		147° 33.0'E		South Tasmania Rise	2/13/95	No recovery		No recovery	No recovery
Grab Sample 01	1311	47° 39.6'S		147° 33.0'E		South Tasmania Rise	2/13/95	1	Cream brn. foram sand	N.22 or younger	No dissoln. Orbulina common, Globigerinelle v. rare. Fauna seems worn.*
Gravity Core 24	1310	47° 39.6'S		147° 33.0'E		South Tasmania Rise	2/14/95	cc	Cream brn. foram sand	N.22 or younger	No dissoln. Orbulina common, Globigerinelle v. rare. Fauna seems worn.*
Grab Sample 02	922	47° 19.0'S		148° 00.0'E		South Tasmania Rise	2/14/95	1	Cream brn. foram sand	N.22 or younger	No dissoln. Orbulina common, Globigerinelle v. rare. Fauna seems worn.*
Gravity Core 25	923	47° 19.0'S		148° 00.0'E		South Tasmania Rise	2/14/95	cc	Cream brn. foram sand	N.22 or younger	No dissoln. Orbulina common, Globigerinelle v. rare. Fauna seems worn.*
Dredge 30	900-800	47° 22.7'S	47° 22.8'S	148° 37.3'E	148° 36.9'E	South Tasmania Rise	2/14/95	1	PD. Brown v. cse sand	N.22 or younger	No dissoln. No rads. Many coral thicket species present. Gl. rare.
Dredge 31	2230-2080	46° 45.4'S	46° 45.0'S	148° 40.0'E	148° 39.5'E	South Tasmania Rise	2/14/95	1	PD. Brown v. cse sand	N.22 or younger	Dissoln. slight. No rads. Globigerinelle v. rare. Gr. crassaformis common.
Dredge 31	2230-2080	46° 45.4'S	46° 45.0'S	148° 40.0'E	148° 39.5'E	South Tasmania Rise	2/14/95	E1	Grey brn, burrow mottled mudst.	Barren	Barren!!
Gravity Core 26	2001	46° 27.0'S		147° 42.0'E		South Tasmania Rise	2/15/95	cc	Cream brn. foram sand	N.22 or younger	Dissoln. slight. No rads. Globigerinelle v. rare. Gr. crassaformis rare.
Grab Sample 03	1583	46° 37.0'S		147° 25.2'E		South Tasmania Rise	2/15/95	1	Cream brn. muddy foram sand	N.22 or younger	No dissoln. Rads rare. Some coral thicket fauna present. Gl. v.rare.
Dredge 32	1600-1200	46° 33.7'S	46° 34.0'S	147° 47.7'E	147° 47.0'E	South Tasmania Rise	2/15/95	1	PD. Cream brn. muddy foram sand	N.22 or younger	Dissoln. slight. No rads. Globigerinelle v. rare. Gr. crassaformis present.
Gravity Core 27	1580	46° 36.6'S		147° 25.2'E		South Tasmania Rise	2/15/95	cc	Grn cream muddy foram sand	N.22 or younger	No dissoln. Rads rare. Globigerinelle v. rare. Gr. crassaformis rare.
Dredge 33	2350-2250	46° 21.4'S	46° 21.6'S	147° 28.5'E	147° 28.4'E	South Tasmania Rise	2/15/95	1	PD. Cream brn. muddy foram sand	N.22 or younger	No dissoln. Rads rare. Some coral thicket fauna present. Gl. v.rare.
Dredge 34	2200-2100	46° 21.9'S	46° 22.2'S	147° 28.2'E	147° 28.1'E	South Tasmania Rise	2/15/95	No mud		No recovery	No mud
Dredge 35	2300-1950	46° 18.6'S	46° 19.1'S	147° 12.2'E	147° 11.4'E	South Tasmania Rise	2/16/95	D1 (no mud)	Cream, semi lithified ooze	Gr. inflata Zone; N.19-20	Gr. ronda & Gr oceanica, without Gr. tosaensis or Gr. truncatulinoides. No rads.
Gravity Core 28	3065	46° 03.5'S		147° 23.0'E		South Tasmania Rise	2/16/95	cc	light grn grey fine ooze	N.22 or younger	Dissoln. minor. More Gnita. & Neogl. +250 fraction. Orb. v.rare; no Gl.
Gravity Core 29	2931	46° 10.0'S		147° 28.0'E		South Tasmania Rise	2/16/95	No recovery		No recovery	No recovery
Gravity Core 30	2968	46° 10.0'S		147° 28.0'E		South Tasmania Rise	2/16/95	cc	light grn grey fine ooze	N.22 or younger	Dissoln. mod. Rads rare. Gr. crassaformis & Gl. more common; no Gr. hirsuta.
Dredge 36	2400-2350	46° 27.7'S	46° 28.1'S	148° 19.7'E	148° 19.3'E	South Tasmania Rise	2/16/95	1	PD. orange grey sandy ooze.	N.22 or younger	Dissoln. minor. No rads. Some coral thicket fauna present.Gr.hirsuta more common.
Dredge 37	2450-2200	46° 21.3'S	46° 21.2'S	149° 08.2'E	149° 10.1'E	South Tasmania Rise	2/17/95	D1	Cream fine foram ooze	N.22 or younger	Dissoln. minor. No rads. Some coral thicket fauna present.Gr.crassaformis rare; Gl. v. rare.
Dredge 37	2450-2200	46° 21.3'S	46° 21.2'S	149° 08.2'E	149° 10.1'E	South Tasmania Rise	2/17/95	1	PD. Cream brn foram sand	N.22 or younger	Dissoln. minor. No rads. Some coral thicket fauna present.Gr.crassaformis rare; Gl. v. rare.
Dredge 38	2300-2050	45° 43.0'S	45° 43.0'S	149° 00.0'E	149° 01.0'E	East of South Tasman Rise	2/17/95	1	PD. Cse Cream brn sand with echinoid spines	N.22 or younger	Dissoln. minor. No rads. Some coral thicket fauna present.Gr.crassaformis v.rare.
Dredge 38	2300-2050	45° 43.0'S	45° 43.0'S	149° 00.0'E	149° 01.0'E	East of South Tasman Rise	2/17/95	C1	T/S. White fine grained foram lst.	N.22 or younger	T/S. Gr. truncatulinoides, Gr. crassaformis.
Dredge 38	2300-2050	45° 43.0'S	45° 43.0'S	149° 00.0'E	149° 01.0'E	East of South Tasman Rise	2/17/95	C2	T/S. White fine grained foram lst.	?P.22 or younger	T/S. ?Chert. Very recrystallised. Forams small and fragmentary; ghosted.
Dredge 38	2300-2050	45° 43.0'S	45° 43.0'S	149° 00.0'E	149° 01.0'E	East of South Tasman Rise	2/17/95	C3	T/S. White fine grained foram lst.	N.22 or younger	T/S. ?Chert. Minor recrystallisation. Planktic ooze; forams common. Gr truncatulinoides, Gr. inflata.
Dredge 38	2300-2050	45° 43.0'S	45° 43.0'S	149° 00.0'E	149° 01.0'E	East of South Tasman Rise	2/17/95	F1	Cse cream brn sandy ooze.	N.22 or younger	Dissoln. minor. No rads. Rare coral thicket fauna. Orb., G. falc., & Gl. more common.
Gravity Core 31	3440	44° 32.8'S		149° 03.8'E		West of East Tasman Rise	2/18/95	cc	light grn grey fine ooze	N.22 or younger	Dissoln. moderate. No rads. Orb.& Gl. common. Gr. crassaformis rare. Fish tooth.
Dredge 39	3150-2900	44° 16.0'S	44° 16.0'S	149° 24.7'E	149° 27.0'E	East of South Tasman Rise	2/18/95	1	PD. Cream brn. foram ooze	N.22 or younger	Dissoln. minor. No rads. Orb. v. common; Gl. near as common as 5-chambered megastoma.
Dredge 40	2950-2515	44° 17.3'S	44° 17.1'S	149° 26.3'E	149° 26.8'E	East Tasman Rise	2/18/95	No mud		No recovery	No mud
Dredge 41	2850	44° 14.0'S		149° 26.0'E		East Tasman Rise	2/18/95	1	PD. Cream brn. foram ooze	N.22 or younger	Dissoln. moderate. 1 rad. Orb.& Gl. common. Gr. crassaformis rare. Fish tooth.
Gravity Core 32	2650	43° 57.9'S		149° 52.2'E		East Tasman Rise	2/19/95	cc	light grn grey fine ooze	N.22 or younger	Dissoln. moderate. No rads. Orb.& Gl. rare. No G. falconensis or Gr. crassaformis.
Dredge 42	1620-1280	43° 54.0'S	43° 54.1'S	150° 34.1'E	150° 33.0'E	East Tasman Rise	2/19/95	1	PD. Cream brn foram sand	N.22 or younger	Dissoln. minor. Rare rads. Some coral thicket fauna present.Gr.crassaformis v.rare, Gl., G.falc., & Gds. elong. more common.
Dredge 43	3600-3030	43° 54.0'S	43° 54.0'S	151° 19.2'E	151° 17.8'E	East Tasman Rise	2/19/95	D2	Grn brn fine sandst.	Barren	T/S. Barren!!
Dredge 43	3600-3030	43° 54.0'S	43° 54.0'S	151° 19.2'E	151° 17.8'E	East Tasman Rise	2/19/95	E2	Grn brn med. sandst.	Barren	Barren!!
Dredge 43	3600-3030	43° 54.0'S	43° 54.0'S	151° 19.2'E	151° 17.8'E	East Tasman Rise	2/19/95	1	PD. Cream grey barnacle ooze.	N.22 or younger	Dissoln. minor. Orb., Gdes. elongatus mor common; Gr. crassaformis rare. Some barnacles.
Grab Sample 04	3600-3030	43° 54.0'S	43° 54.0'S	151° 19.2'E	151° 17.8'E	Shelf off Raoul Point, Tasmania	2/20/95	1	Cream brn foram sand	N.22 (Gr. viola Subzone)	No dissoln. Some worn bryozoa and Fe-staining. Possible contam. from GS03?? Gr.crassf. more variable though!
Vibra Core 01	131	43° 17.8'S		147° 53.7'E		Shelf off Raoul Point, Tasmania	2/20/95	cc	Grey brn sandy ooze	N.22 or younger	Bryozoa rich. Planktics rare; Gr. all thin-walled. Gdes. rare.
Vibra Core 01	131	43° 17.8'S		147° 53.7'E		Shelf off Raoul Point, Tasmania	2/20/95	0-2.5cm	Green grey sand	N.22 or younger	Bryozoa rich. Planktics rare; Gr. all thin-walled. Gdes. rare.
Grab Sample 05	129	43° 17.8'S		147° 53.7'E		Shelf off Raoul Point, Tasmania	2/20/95	1	Med brn bryozoan sand	N.22 or younger	Bryozoa rich. Planktics rare; Gr. all thin-walled. Gdes. rare.
Vibra Core 02	135	43° 20.2'S		147° 58.0'E		Shelf off Raoul Point, Tasmania	2/20/95	No recovery		No recovery	No recovery
Vibra Core 03	135	43° 20.2'S		147° 58.0'E		Shelf off Raoul Point, Tasmania	2/20/95	No recovery		No recovery	No recovery
Vibra Core 04	135	43° 20.2'S		147° 58.0'E		Shelf off Raoul Point, Tasmania	2/20/95	cc	Med brn bryozoan sand	N.22 or younger	Bryozoa rich. Planktics rare; Gr. all thin-walled. Gdes. rare; Gr. trunc. v.rare.
Grab Sample 06	133	43° 20.2'S		147° 58.0'E		Shelf off Raoul Point, Tasmania	2/20/95	1	Med brn bryozoan sand		
Vibra Core 05	137	43° 21.9'S		148° 01.2'E		Shelf off Raoul Point, Tasmania	2/20/95	cc	Med brn bryozoan sand		
Grab Sample 07	145	43° 23.9'S		148° 05.5'E		Shelf off Raoul Point, Tasmania	2/20/95	1	Med brn bryozoan sand		
Vibra Core 06	145	43° 23.9'S		148° 05.5'E		Shelf off Raoul Point, Tasmania	2/20/95	cc	Med brn bryozoan sand		
Grab Sample 08	141	43° 24.5'S		148° 06.2'E		Shelf off Raoul Point, Tasmania	2/21/95	1	Cream brn bryozoan sand	N.22 or younger	Bryozoa rich. Planktics rare; Gr. all thin-walled.Gr. hirsuta & N. humerosa. Gdes. rare.
Vibra Core 07	141	43° 24.5'S		148° 06.2'E		Shelf off Raoul Point, Tasmania	2/21/95	No recovery		No recovery	No recovery
Vibra Core 08	142	43° 24.5'S		148° 06.2'E		Shelf off Raoul Point, Tasmania	2/21/95	No recovery		No recovery	No recovery
Grab Sample 09	804	43° 26.4'S		148° 09.6'E		Shelf off Raoul Point, Tasmania	2/21/95	1	Med brn bryozoan sand		
Gravity Core 33	1285	43° 27.7'S		148° 11.8'E		Shelf off Raoul Point, Tasmania	2/21/95	cc	Med brn bryozoan sand	N.22 or younger	Planktics numerous. Bryozoa and shelly fossils still present. Gr. crassaformis & scitula rare.
Dedge 44	2400-2250	44° 36.3'S	44° 36.0'S	147° 14.7'E	147° 14.8'E	South Tasmania Rise	2/22/95	1	PD. Cse Cream brn sand with barnacles	N.22 or younger	Planktics numerous. Dissoln. moderete. Barnacles present. Coral thicket fauna. Orb. & Gl. not common.
Dedge 44	2400-2250	44° 36.3'S	44° 36.0'S	147° 14.7'E	147° 14.8'E	South Tasmania Rise	2/22/95	B1	Grey mud from cavities in lst. (-B2)	N.22 or younger	Planktics numerous. Some internal casts from lst. Orb. v. common; Gl. common.
Dedge 44	2400-2250	44° 36.3'S	44° 36.0'S	147° 14.7'E	147° 14.8'E	South Tasmania Rise	2/22/95	B2.	Yell. shelly lst.	?N.22 or younger	T/S. Recrystallised muddy sst. with shallow water bioclsts, some Fe-stained. ?Gr. truncatulinoides. Coated in modern ooze (-1)
Dredge 45	2800-2600	44° 39.2'S	44° 39.5'S	147° 26.4'E	147° 26.5'E	South Tasmania Rise	2/22/95	1	PD. Cse Cream brn sand with barnacles	N.22 or younger	Dissoln. minor. No rads. Orb. & Gl. not as common. Gr. crassaf. & Gdes. v. rare.
Dredge 45	2800-2600	44° 39.2'S	44° 39.5'S	147° 26.4'E	147° 26.5'E	South Tasmania Rise	2/22/95	For T/S	?		For T/S
Dredge 46	3500-3250	44° 55.0'S	44° 54.1'S	147° 14.1'E	147° 13.9'E	South Tasmania Rise	2/23/95	No mud; T/S	Yell. bryozoal/echinoid lst		For T/S; no mud.
Gravity Core 34	4202	45° 06.0'S		147° 44.5'E		South Tasmania Rise	2/23/95	cc	Grey grn foram ooze	N.22 or younger	Dissoln. strong. Orb., Gl., & Gr. crassaformis v.rare. No Gr. hirsuta, Gds.
Dredge 47	2650-2250	45° 23.2'S	45° 21.8'S	147° 16.5'E	147° 17.5'E	South Tasmania Rise	2/23/95	No sed. mat.		No sed. mat.	No sedimentary material.
Dredge 48	2800-2720	45° 28.4'S	45° 27.5'S	147° 07.2'E	147° 07.8'E	South Tasmania Rise	2/23/95	1	PD. Cse Cream brn sand with barnacles	N.22 or younger	
Dredge 48	2800-2720	45° 28.4'S	45° 27.5'S	147° 07.2'E	147° 07.8'E	South Tasmania Rise	2/23/95	D1	Brn grn bored calcareous fine sst	?Eocene	A few spherical fossils, ?Orbulina or ?Radiolaria. Ech. spines. ?Glauconite
Dredge 48	2800-2720	45° 28.4'S	45° 27.5'S	147° 07.2'E	147° 07.8'E	South Tasmania Rise	2/23/95	D2	Brn grn bored calcareous fine sst	?Eocene	T/S; ?Sponge spicules, ?glauconite.
Dredge 49	3170-2700	45° 27.8'S	45° 26.9'S	147° 04.3'E	147° 05.4'E	South Tasmania Rise	2/24/95	No recovery		No recovery	No recovery
Dredge 50	3100-2950	45° 30.4'S	45° 31.4'S	147° 20.6'E	147° 20.3'E	South Tasmania Rise	2/24/95	1	PD. Cse Cream brn sand with Mn nodules	N.22 or younger	Dissoln. moderate. Orb. common; Gl. & Gr. crassformis v.rare; no Gr. bermudezi.
Dredge 51	3180-2500	45° 47.3'S	45° 46.0'S	147° 14.2'E	147° 14.0'E	South Tasmania Rise	2/24/95	No sed. mat.		No sed. mat.	No sedimentary material.
Gravity Core 35	2720	45° 44.0'S		146° 32.0'E		South Tasmania Rise	2/24/95	cc	Cream brn sandy ooze	N.22 or younger	Dissoln. mod to severe. Gr. crassaformis v. common; Orb. & Gr. trunc. rare; Gl. & G.falc. v. rare. No rads.
Gravity Core 35	2720	45° 44.0'S		146° 32.0'E		South Tasmania Rise	2/24/95	kk	Med brn fine ooze	Gr. inflata Zone; N.19-20 or younger	Very poor fauna, which is most probably contamination from younger levels.
Dredge 52	2370-2200	45° 38.2'S	45° 38.0'S	146° 24.0'E	146° 25.4'E	South Tasmania Rise	2/25/95	1	PD. Med cream brn sand with Mn nodules	N.22 or younger	Dissoln. minor. Orb., & Gr. hirsuta common, Gl., rare, Gr. crassaformis & Gdes. v.rare.
Dredge 53	3000-2770	45° 21.8'S	45° 21.1'S	146° 43.2'E	146° 43.7'E	South Tasmania Rise	2/25/95	1	Cream brn foram ooze	N.22 or younger	Dissoln. minor. Orb., & Gr. hirsuta common, Gl., rare, Gr. crassaformis & Gdes. v.rare.
Dredge 54	3050-2700	44° 58.2'S	44° 57.5'S	146° 57.8'E	146° 58.0'E	South Tasmania Rise	2/25/95	D2	Cream, gritty limestone.	Barren	T/S. Very recrystallised. No fauna.
Dredge 54	3050-2700	44° 58.2'S	44° 57.5'S	146° 57.8'E	146° 58.0'E	South Tasmania Rise	2/25/95	C1	Grn brn faintly laminated mudstone	Barren	No fossils
Dredge 54	3050-2700	44° 58.2'S	44° 57.5'S	146° 57.8'E	146° 58.0'E	South Tasmania Rise	2/25/95	C2	Grn brn faintly laminated mudstone	Barren	No fossils
Dredge 54	3050-2700	44° 58.2'S	44° 57.5'S	146° 57.8'E	146° 58.0'E	South Tasmania Rise	2/25/95	F - T/S	Light orange lithified muddy grit	T/S	
Dredge 54	3050-2700	44° 58.2'S	44° 57.5'S	146° 57.8'E	146° 58.0'E	South Tasmania Rise	2/25/95	1	PD. Med cream brn sand with Mn nodules	N.22 or younger	Dissoln. severe. Gr. hirsuta & Orb., common. Gl., G. falc., Gr. crassaf. & Gds. v.rare. Rads. v. rare.
Gravity Core 36	2650	44° 45.0'S		146° 39.0'E		South Tasmania Rise	2/25/95	No recovery		No recovery	No recovery
Gravity Core 37	2650	44° 45.0'S		146° 39.0'E		South Tasmania Rise	2/25/95			No recovery	Corer Lost
Dredge 55	2650-2400	44° 52.6'S	44° 52.2'S	146° 27.6'E	146° 27.6'E	South Tasmania Rise	2/26/95	1	PD. Med cream brn sand with Mn nodules	N.22 or younger	Dissoln. moderate. Orb. common; Gl., Gds Ga. falc. & Gr. crassf v.rare; no Gr. bermudezi. No rads.
Dredge 55	2650-2400	44° 52.6'S	44° 52.2'S	146° 27.6'E	146° 27.6'E	South Tasmania Rise	2/26/95	B2	?Silicified micritic limestone	Barren	T/S; barren. Cross cutting ?burrow with ostracode.
Dredge 55	2650-2400	44° 52.6'S	44° 52.2'S	146° 27.6'E	146° 27.6'E	South Tasmania Rise	2/26/95	B3	?Silicified micritic limestone	Barren	T/S; barren. Very recrystallised.
Dredge 55	2650-2400	44° 52.6'S	44° 52.2'S	146° 27.6'E	146° 27.6'E	South Tasmania Rise	2/26/95	B4	Calcareous mudstone	Barren	T/S; barren. Very recrystallised.
Dredge 56	3050-3000	44° 47.1'S	44° 47.3'S	146° 13.6'E	146° 13.3'E	South Tasmania Rise	2/26/95	1	PD. bot. Med cream brn foram sand	N.22 or younger	Dissoln. minor. Orb., & Gr. hirsuta common, Gl., rare, & Gdes. v.rare.No Gr. crassaf. or Gr. berm. No rads.
Dredge 56	3050-3000	44° 47.1'S	44° 47.3'S	146° 13.6'E	146° 13.3'E	South Tasmania Rise	2/26/95	2	PD. top. Fine cream foram ooze.		
Dredge 57	2850-2300	44° 32.8'S	44° 31.7'S	146° 00.4'E	146° 00.6'E	South Tasmania Rise	2/26/95	No sed mat.		No sed mat.	No sedimentary material.

continuous late Eocene to late Oligocene section, with a discontinuous and thin Neogene sequence, but low core recovery precluded detailed study. Belford (1989) did not attempt to tie his results to those of Jenkins (1975).

Wherever possible the lowest sample of each core was examined, as well as samples from the chain-bag and pipe dredges. Most samples from the dredges were able to be desegregated, picked over and specimens examined. A few samples could be studied only in thin section.

?Eocene

A number of samples contained very low diversity foraminiferal faunas made up only of arenaceous species. Many contained fish teeth. The sediments were generally non-calcareous, green grey, muddy fine sandstones and mudstones, which are often micaceous. Most of these lithologies were collected along the western margin of the South Tasmania Rise in water depths greater than 3000m, where any calcareous fossils may have been leached. In some samples arenaceous benthic foraminiferids were recorded, such as *?Ammodiscus, Cyclammina, Haplophragmoides,* flattened specimens of *?Bathysiphon*, and a flattened, initially planispiral, becoming rectilinear form, similar to the Holocene *Glaphyrammina.* Some of these appear to be siliceous. Two samples (147DR14-A3, -A4) contained only radiolaria which are probably Eocene (Dr. K. Romine, pers com., May, 1995), and three samples (147DR14/A8, 147DR18/A1, 147DR18/A2) were found to be late Eocene, and another (147DR13A2) was late Cretaceous to early Tertiary, on palynological evidence (Dr. C.B. Foster, pers com.). On this basis all of the green to green-grey, fine sandstones and mudstones found in the dredge samples are believed to be probably Eocene.

Within the area studied, Belford (1989) recorded similar arenaceous forms to those found on the present cruise, in a dredge sample (SO-36-44KD) between 3670 to 3968m on the western side of the South Tasman Rise, south of 147DR12. Of the DSDP holes drilled in the area, only at DSDP Site 280 (located south of the South Tasmania Rise, near dredge sites 147DR26 and 147DR27) have similar arenaceous faunas to those from Cruise 147 been found (in grey and olive grey silty claystones); these yielded a mid to late Eocene palynoflora dominated by dinocysts (Shipboard Scientific Party, 1975). The overlying sediments contained a low diversity planktic assemblage which suggests a late Eocene or early Oligocene age.

Similar arenaceous assemblages have been recorded from land-based sections in southern Australia. Ludbrook (1971) recorded arenaceous faunas from the Eocene Knight Group. Also a similar fauna was recorded from the Joanna River Formation at the base of the late Eocene section at Browns Creek (McGowran, 1978; Shafik, 1983, 1995).

The sediments recovered suggest that depositional conditions during the Eocene were dominated by marginal marine environments, although there is evidence for normal marine sedimentation during the latest part of the early Eocene. Most of the ?Eocene samples were recovered from present-day water depths below the CCD, where calcareous components could have been selectively removed. Such depths may have been in existence since the splitting of Australia from Antarctica during the Eocene

?Late Oligocene to Early Miocene

Samples of either a phosphatised or silicified limestone were found in three dredges (147DR11, 147DR15 and 147DR38); these were well lithified and could only be studied in thin section. All were recrystallised, so limiting the study of the contained faunas. Nevertheless *?Catapsydrax* *dissimilis, ?Globigerina praebulloides, ?Globigerinita glutinata, ?Paragloborotalia* sp., *?Subbotina* spp., and *?Tenuitella* sp. were identified, together with ?radiolarians. This assemblage is typical of the late Oligocene and early Miocene (Zones N.22 to N.5). One sample was able to be disaggregated (147DR21/B1), but again the fauna was recrystallised and difficult to identify; however a single specimen of a small reticulate globigerine, similar to the *Globigerina woodi* group, was found together with ?radiolaria, and this also is questionably referred to the Late Oligocene or early Miocene

Sample 147DR11/C1 (a thin section) contains solitary corals with *?Dentoglobigerina baroemoensis, ?Globigerinoides subquadratus, Globorotalia (?Globoconella) ?praescitula* and *?Praeorbulina bispherica*. This assemblage has been questionably referred to the zonal interval N.8 to N.10 (late early to early middle Miocene).

Jenkins (1975) has recorded faunas of this age from DSDP Sites 281 and 282 in the area covered by Cruise 147. Belford (1989) recorded late Oligocene planktic foraminiferal faunas from cores and dredges from the west Tasmania area and South Tasmania Rise, but he did not find any early Miocene to early middle Miocene assemblages.

Late Pliocene

Samples from two dredges (147DR28/F, 147DR35/D1 and three gravity cores (147GC01/363, 147GC21/210, 147GC35/kk) contained *Globorotalia (Truncorotalia) crassaformis, Gr. (Globoconella) inflata*, sometimes *(Gr (Gc.) puncticulata*, without either *Gr. (Tr.) tosaensis* or *Gr. (Tr.) truncatulinoides*. This faunal association has been referred to the late Pliocene *Globorotalia inflata* Zone of Jenkins (1971, 1985), which is roughly equivalent to Zone N.19-20. The faunas are of low species diversity and the proportion of fragmented tests is high, with many specimens damaged by dissolution.

Quaternary

The majority of samples from the dredges and gravity cores contain the zonal marker for Zone N.22, *Gr. (Tr.) truncatulinoides*. It is not possible to recognise Zone N.23 in temperate and polar areas because the zonal index, *Bolliella calida calida*, is a tropical and subtropical form, and is not found in these colder water masses. For this reason all samples with *Gr. (Tr.) truncatulinoides* have been referred to as Zone N.22 or younger. *Neogloboquadrina pachyderma* which is present in all samples, has been used to subdivide this interval by Jenkins (1967) based on changes in coiling dominance from dextral to sinistral. This method has not been attempted on these assemblages.

Age Not Determinable

A number of samples were either barren or lacked foraminiferids. Most of these are green grey fine mudstones, and as noted above, are probably Eocene in age.

12.2. Calcareous nannofossils in cores from AGSO Cruise 147

S. Shafik, AGSO

Thirty two samples from the bottoms (mostly kk or cc) of gravity cores, vibrocores and box cores, and also from grab samples, were examined for calcareous nannofossils. Assemblages recovered (Table 33) date most of the cores as Quaternary -- younger than the last appearance datum (LAD) of

Table 33: Distribution of selected calcareous nannofossil species in AGSO Cruise 147 cores

Sample	Braarudosphaera bigelowii	Calcidiscus leptoporus	Calcidiscus macintyrei	Coccolithus pelagicus	Cyclicargolithus abisectus	Cyclicargolithus floridanus	Dictyococcites productus	Dictyococcites sessilis	Emiliania huxleyii	Gephyrocapsa aperta	Gephyrocapsa caribbeanica	Gephyrocapsa muellerae	Gephyrocapsa oceanica	Gephyrocapsa protohuxleyii	Helicosphaera burkei	Helicosphaera carteri	Oolithotus fragilis	Pontosphaera japonica	Pontosphaera plana	Pseudoemiliania lacunosa	Reticulofenestra minuta	Reticulofenestra pseudoumbilicus	Reticulofenestra scrippsae	Reticulofenestra minutula	Rhabdosphaera claviger	Scapholithus fossilis	Small Gephyrocapsa spp.	Syracosphaera pulchra	Thoracosphaera	Umbilicosphaera sibogae
147-BC03,1	.	X	.	X	.	.	.	.	X	X	X	.	X	.	.	X	.	.	.	.	.	.	.	.	.	.	X	X	.	.
147-GC04,257	.	X	.	X	X	.	.	.	.	.	.	X	X	.	.	X	.	.	.	.	.	.	.	X	.	.	X	X	.	.
147-GC05,178	.	X	.	X	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	?	.	.	.	X	X	X	.	X
147-GC07,533	.	X	.	X	.	.	.	.	?	.	X	.	.	?	.	X	.	.	.	.	.	.	?	X	.	.	X	.	.	X
147-GC10,cc	.	X	.	X	.	.	.	.	?	.	X	.	X	.	X	X	.	.	.	.	.	.	.	.	X	.	X	X	.	.
147-GC11,cc	.	X	.	X	.	X	.	X	?	.	.	.	X	.	.	X	.	.	.	.	X	.	.	.	.	.	X	.	.	X
147-GC13,cc	.	X	.	X	X	X	.	.	.	.	X	.	X	.	.	.	.	.	.	?	X	X	.	.	.	.	X	.	.	.
147-GC14,ccB	.	X	.	X	.	.	.	.	.	X	X	.	X	.	.	X	.	.	.	.	.	.	.	.	.	.	.	X	.	.
147-GC15,400	.	X	.	X	.	.	.	.	.	X	X	X	X	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.
147-GC16,cc	.	X	.	X	.	.	.	.	.	.	.	.	X	.	X	X	.	.	.	.	.	.	.	.	.	.	X	X	.	.
147-GC17,cc	.	X	.	X	.	.	.	.	.	.	X	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.
147-GC20,cc	.	X	.	X	.	.	.	.	?	X	X	.	X	.	.	X	.	.	.	.	.	.	.	.	X	.	.	.	.	.
147-GC21,cc	.	X	X	.	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	X	.	.	.	X	.	.	X	.	.	.
147-GC22,cc	.	X	.	X	.	.	.	.	?	X	X	.	X	.	.	X	.	X	.	.	.	.	.	.	.	X	X	X	.	X
147-GC24,cc	.	X	.	.	.	.	.	.	.	.	X	.	X	.	.	X	.	.	.	.	.	.	.	.	X	X	X	X	.	X
147-GC25,cc	.	X	.	X	.	.	.	.	?	.	X	X	X	.	.	X	.	.	.	.	.	.	.	.	X	.	.	X	.	.
147-GC26,cc	.	X	.	X	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	X	.	.	.	.	.	X	X	.	X
147-GC27,cc	.	X	?	X	.	.	.	.	?	X	X	.	.	.	.	.	.	X	X	.	X	.	.	.	X	X	.	X	.	.
147-Gc28,cc	.	X	.	X	.	.	.	.	.	X	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.	X	.	.	.
147-GC30,cc	.	X	?	X	.	.	X	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	X	.	.
147-GC31,cc	.	X	.	X	.	.	X	.	.	X	.	X	X	.	.	X	.	.	.	?	.	.	.	X	.	.	.	.	.	.
147-GC32,cc	.	X	.	X	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.
147-GC33,cc	.	X	.	.	.	.	.	.	?	X	X	.	X	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	X
147-GC34,cc	.	X	.	X	.	.	.	.	.	X	X	.	X	.	.	X	.	.	.	.	.	.	.	.	.	.	.	X	.	.
147-GC35,cc	.	X	.	X	.	.	.	.	.	X	X	.	X	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	X	.
147-GS03,1	.	X	.	X	.	.	X	.	?	X	X	.	X	.	.	X	.	.	.	.	.	.	.	.	.	.	X	X	.	.
147-GS04,1	.	X	.	X	.	.	.	.	?	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
147-VC01,1	X	X	X	X	.	.	.	.	X	X	X	X	X	.	X	X	.	.	.	.	.	.	.	.	.	.	X	X	.	.

Pseudoemiliania lacunosa which has been estimated at 0.458 Ma (Thierstein et al., 1977). One exception is noted: an assemblage containing the key species *P. lacunosa* in the bottom of GC21. Nannofossils were found to be lacking in a few samples: a barren interval in the bottom of GC35 (age indeterminate) immediately beneath a younger Quaternary assemblage, as well as barren parts of GC01 and GC18.

VC01 sampled Holocene grey brown sandy ooze from 131 metres water depth, and thus should contain evidence for shallow-water deposition. Indeed, ascidian spicules are present and the nannofossil assemblage contains *Braarudosphaera bigelowii.* Other nannofossils in this core include the key species *Emiliania huxleyii*, whose first appearance datum (FAD) is about 0.268 Ma according to Thierstein et al. (1977). A similar assemblage minus *B. bigelowii* (the ascidian spicules are also lacking) was identified from the deeper core BC03, a cream brown ooze recovered from 3304 metres water depth. *Coccolithus pelagicus* is significantly more abundant in BC03. This species is a cold-water species, living today off western Tasmania (Hallegraeff, 1984).

The key species *Emiliania huxleyii* probably occurs in a number of the gravity cores (see Table 33), but identification of this species will always be uncertain with optical microscopy because of its small size. The other key species *Gephyrocapsa caribbeanica* and *G. oceanica*, indicating an older Quaternary age than the FAD of *E. huxleyii*, are found in most of the gravity core material examined (see Table 33).

The oldest assemblage found is that recovered from the foram mud at the bottom of GC21: abundant, poorly preserved fossils, with signs of dissolution abounding. *Calcidiscus leptoporus* and *C. macintyrei* are represented mostly by single shields, and nannofossils debris is abundant. The assemblage contains the key species *P. lacunosa.* This, in the absence of *Discoaster* spp. (including *Discoaster brouweri*) and the large *Gephyrocapsa* spp. (including *G. oceanica*), suggests an early Pleistocene age. However, the absence of *Discoaster* spp. could be an environmental exclusion rather than a true disappearance, and the assemblage could be as old as the Pliocene. The rare small *Gephyrocapsa* spp. found are not inconsistent with a Pliocene age. Several small *Gephyrocapsa* have been recorded from well below the LAD of *D. brouweri*, down to the Early Pliocene Zone NN 15 of Martini (1971) (Samtleben, 1980; Perch-Neilsen, 1985).

The sample examined from GC01 is green clay at 378 cm (near the core bottom), and being barren of calcareous nannofossils suggests that the Quaternary foraminiferids recorded from the very bottom of the core are contaminants (see Chaproniere, this report). Reflection seismic and lithological evidence suggests that this clay from 4238 metres water depth is part of a deltaic sequence of pre-Oligocene age, that has since subsided to its present depth. Samples examined from GC18 (bottom and top of kk: dark brown fine mudstone), and GC35-kk (a brown sandy clay) are also barren of nannofossils. The absence of nannofossils from both GC01 and GC18 samples probably has different explanations. In any case both these cores come from sediments which initially lacked nannofossils, deposition being in an environment unsuitable for nannoplankton. Because the mudstone of GC18 is underlain by a manganese crust formed in deepwater marine conditions, this core cannot be older than the Eocene, and is probably much younger. Its present water depth is 4368 metres, below the CCD, and it seems probable that the mudstone was below the CCD during deposition. The clay at the base of GC35 came from 2720 metres water depth, well above the present CCD, and supports the argument of an older environment unsuitable for nannoplankton (probably being shallow-water). Prolonged exposure to the cold currents is unlikely to entirely eliminate nannoplankton remains.

Remarks. The cold-water *Coccolithus pelagicus* is found in all coccolith-bearing Quaternary samples examined. Occasionally it is abundant, but in most other cases it is common to frequent. Where *C. pelagicus* is abundant, *Gephyrocapsa caribbeanica* becomes prominent. The warm-water *Florisphaera profunda* was not found. *Braarudosphaera bigelowii* may be regarded as an indicator for shallow-water deposition because of its association with ascidian spicules in shallow-water core (VC01) and its absence from deeper cores (e.g. BC03).

13. MAIN RESULTS OF THESE OFFSHORE TASMANIAN STUDIES AND FUTURE PLANS

The *Southern Rises* AGSO Cruise 147 has recovered a wealth of rocks, sediment cores and water column samples, that are being studied by specialists at present, but already our understanding of the Phanerozoic history of the submerged continental rocks of the Tasmanian region is greatly enhanced. This understanding is outlined in Section 1, "SUMMARY". Table 34 lists in summary all the seabed samples available from the region, and shows that samples taken on Cruise 147 make up a large proportion of those available: 15% of the cores, 67% of the dredges, and 47% of the grabs.

Table 34: Successful bottom sampling off Tasmania

Source	**Cores**	**Dredges**	**Grabs**
US institutions	39	1	2
Sonne 16	43	13	
BMR 67	18	3	
BMR 78	42	10	8
AGSO 147	25	54	9
Total	**167**	**81**	**19**

Excludes DSDP and vibrocores

Major results of the offshore Tasmanian studies to date include:

- The bathymetry and areas of outcrop have been accurately mapped by the swath-mapping technique
- Surface sediment types have been mapped and cored
- Swath-mapping results have been used by fishing regulatory and conservation bodies, and for UNCLOS
- Preliminary seismic mapping has been done, but final mapping needs new high-quality *Rig Seismic* seismic data
- Dredging has defined the nature of outcrops, including the limits of oceanic and continental crust
- On the South Tasman Rise the oldest basinal sediments sampled are Paleocene, but seismic evidence suggests a thick underlying Cretaceous sequence
- On the west Tasmanian margin the oldest rocks dredged and drilled are Late Cretaceous, but seismic evidence indicates the presence of a very thick older Cretaceous sequence
- Geochemical and seismic results indicate both regions have genuine hydrocarbon potential
- The East Tasman Plateau has been proven by dredging to be continental
- An area of thick Co-rich manganese crusts has been discovered on the South Tasman Rise
- Plate tectonic models have been refined

*Three periods of ancient tectonism have been identified: 450 Ma (Late Ordovician), 350 Ma (Early Carboniferous) and 305 Ma (latest Carboniferous)
*Australia-Antarctic breakup started along 320° in the Cretaceous (? 96 Ma, but had changed to 345° by the middle Eocene (43 Ma)
* There is a N-S suture apparent on the South Tasman Rise at 145°15'E

- A proposal for an Ocean Drilling Program leg has been submitted

Work in progress and planned includes:

- Production of a seafloor atlas
- Completion of the work on basinal sediments
- GECO-Prakla are processing three new *Rig Seismic* lines
- The *L'Atalante* six-channel seismic lines are to be processed in-house soon
- University of Tasmania petrologists are working on the basement rocks
- French scientists are working on the tectonic history of the basement rocks
- A University of Tasmania student (Michelle Elmes) is just completing a study of the volcanic rocks
- Dr J-Y Royer is working on the plate tectonic setting
- Various groups are working on the Neogene palaeo-oceanography
- *Rig Seismic* will soon gather key seismic lines across the South Tasman Rise
- *Rig Seismic* will soon gather UNCLOS seismic lines across the southern South Tasman Rise and the East Tasman Plateau
- AGSO scientists will interpret all seismic data, assess the regions petroleum potential, and document Australian UNCLOS claims
- All results are to be published in a special issue of the *AGSO Journal* in mid 1997

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APPENDIX I: CRUISE PARTICIPANTS

AGSO Representatives

Neville Exon	Cruise leader (sedimentology)
John Marshall	Deputy cruise leader (sedimentology)
Steven Dutton	Ship Manager
George Chaproniere	Micropalaeontologist
Mark Alcock	Quality control scientist
Jon Stratton	TO Science
Peter Davis	TO Science
Greg Sparksman	TO Science
Tony Hunter	TO Science
Jim Kossatz	TO Science
Joe Mangion	TO Electronics
Roger Curtis-Nuttall	TO Electronics
Mark James	TO Mechanical
Brian Dickinson	TO Mechanical
Alan Radley	TO Mechanical
Ken Elphick	TO Mechanical
John Keyte	TO Mechanical

Visiting scientists and technicians

Dr Dan McCorkle, Woods Hole Oceanographic Institution, USA (isotopes)
Ms Nadege Rollet, Laboratoire de Géodynamique Sous-Marine, Villefranche, France (pre-Mesozoic igneous & metamorphic rocks)
Mr Greg Whitmore, Geology Department, James Cook University (Cainozoic sedimentology & acoustic facies)
Ms Michele Elmes, Geology Department, University of Tasmania (Mesozoic & Cainozoic igneous rocks)
Ms Catherine Samson, Antarctic & Southern Ocean CRC, Hobart (planktic forams)
Ms Claire Findlay, Antarctic & Southern Ocean CRC (surface water nannofossils)
Mr Bob Connell, Antarctic & Southern Ocean CRC (technician)
Ms Lisette Robertson, Antarctic & Southern Ocean CRC (technician)

AMSA crew

Trevor Walters	Master
Mike Gusterson	1st Mate
John Weeks	2nd Mate
Peter Pittiglio	Chief Engineer
John Scott	1st Engineer
Laszlo Polgardi	Electrician
Rod Willis	Chief Integrated Rating

John Fraser	Integrated Rating
Tony Dale	Integrated Rating
Merv Hagner	Integrated Rating
Henk Dekker	Chief Cook
Kenny Beu	Cook
Ted Strange	Catering Attendant
Steve Staveley	Catering Attendant

APPENDIX 2: EQUIPMENT USED & ITS PERFORMANCE

For details refer to the AGSO Operational Report on Cruise 147, prepared by Steven Dutton. The cruise started in Melbourne and ended in Hobart, with geological stations from 42-49°S, and a track map is shown in Figure A.

Geological equipment

Australian Winch & Haulage deepsea dredging and coring winch (10 000 m of 18 mm wire): overall success, but electronic and mechanical problems, plus inaccurate wire-out readings
Australian Winch & Haulage hydrographic winch (4600 m of 6 mm wire): overall success, but electronic and mechanical problems, plus inaccurate wire-out readings
Large chain bag dredges for rock dredging, with small pipe dredges attached: functioned well
Gravity corer: functioned well in deep water, but could not penetrate winnowed sand in water depths of less than 2500 m. Some multiple penetrations in rough weather
Box corer: too light to use in rough weather
Vibrocorer: occasional unexplained failures to recover sediments at all
Van Veen grab: reliable in testing for deployment of corers in less than 2500 m
Freefall grabs: functioned well
Camera equipment: reasonable results but much film wasted by triggering in water column
Water bottles: functioned well
Water bottles and data logger ("SDL" for continuous temperature, pressure, salinity readings): functioned well
Pinger for camera and box corer deployments: generally functioned satisfactorily

Geophysical equipment

Differential global positioning system navigation: excellent results
3.5 and 12 kHz echosounders: very poor 3.5 kHz results, especially in bad weather, apart from short unexplained windows where excellent results were obtained with good sub-bottom penetration. Reasonable 12 kHz results. EPC recorders were generally unreliable
Magnetometer for longer traverses: worked well
Gravity meter: unserviceable

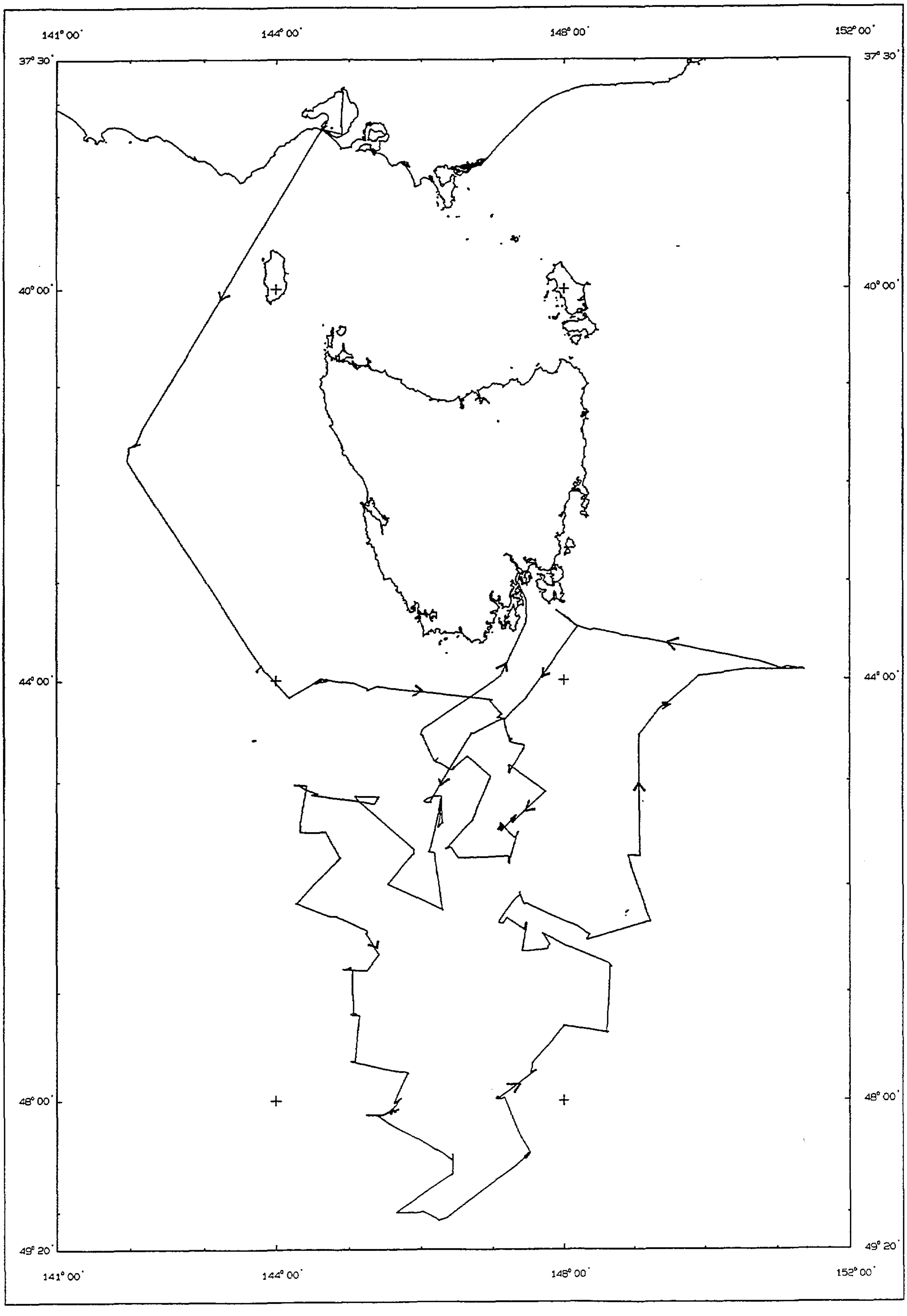


Figure A. Tracks of AGSO sampling Cruise 147.

APPENDIX 3: WEATHER CONDITIONS DURING AGSO CRUISE 147 OFF TASMANIA

C. Findlay, Antarctic & Southern Ocean Cooperative Research Centre, Hobart

The wind direction and speed, from 28th January to 27th February, were recorded every four hours in the ship's log and the latitude and longitude readings were recorded automatically every minute in the navigation log. From these records the attached graphs were produced.

The wind speeds throughout the cruise were rather greater than anticipated for these waters at this time of the year. The minimum wind speed recorded in the ship's log was 5 knots on 19th and 20th of February, and the maximum wind speed was 47 knots (Force 9 on the Beaufort Scale). However, gusts of 50 to 55 knots (Force 10 on the Beaufort Scale) were experienced on the 7th and 8th of February. The wind speed averaged around 20 knots for the cruise.

Modified Beaufort Wind Scale

Beaufort number	Description	Knots
0-6	calm and breezes	0-27
7	near gale	28-33
8-9	gale	34-47
10	storm	48-55
11	violent storm	56-63
12	hurricane	64 and over

The graphs plotting wind speed and latitude (Fig. A) indicate a drop of wind speed in the highest latitudes (above 45°S) from approximately 8th February to 14th February. Apart from this, there does not appear to be a correlation between wind speed and latitude. The morning readings (0400h, 0800h and 1200h) show greater variation in wind speed compared to the afternoon readings.

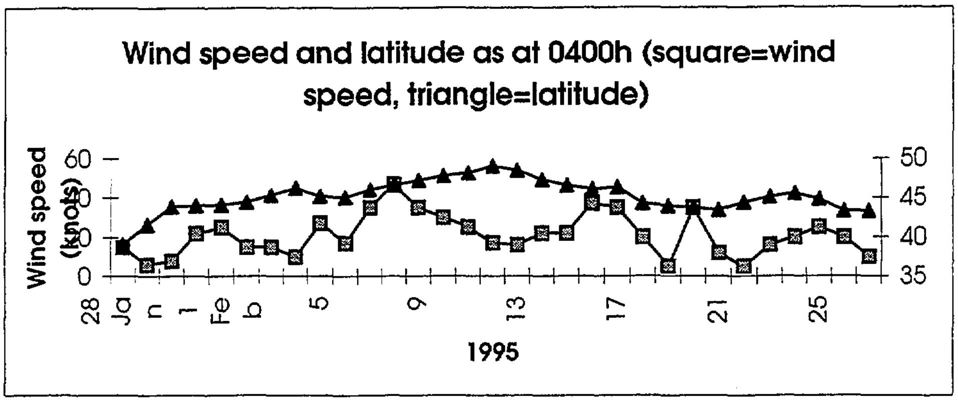
Comparison of wind direction and wind speed (Fig. B) indicates the dominant direction is from the southwest through to north (225 to 360 degrees). This includes the lowest wind speed of 5 knots from the west through to north (270 to 360 degrees) and the strongest wind speed of 45 knots from the west (270 degrees). On the few occasions when the wind direction was from the east through to south (90 to 180 degrees) the wind speed was below 25 knots, with the exception of 14th February which shows a slightly higher speed of approximately 27 knots.

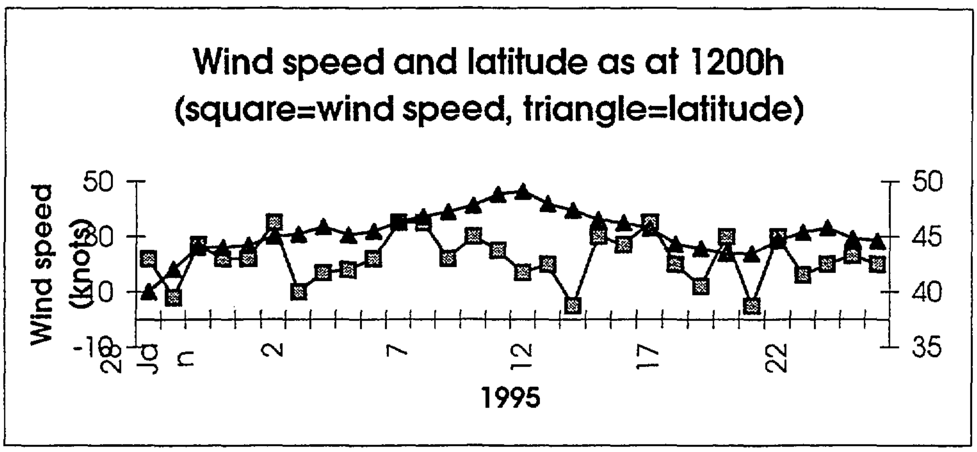
A copy of the weather map produced by the Bureau of Meteorology for 8th February (Fig. C) is indicative of the strong south-southwest winds experienced, and the map for the 20th February (Fig. D) illustrates the calmer conditions experienced during the cruise. The map for the 15th February (Fig. E) shows strong winds from the northeast.

No records were kept of wave height or swell height. The observable swell, as noted by officers on the bridge, varied from nil to approximately 6 metres.

A notable atmospheric phenomenon occurred on 9th February at 47°12'S, at approximately 9pm, with a spectacular display of the southern lights, the *southern aurora* or *aurora australis*.

In general the weather for Cruise 147 was cool with a maximum temperature before transit to Hobart of only 16.2°C. Cloud cover was dominant over clear skies throughout the cruise. Cloud cover for the most part was at least 50% on most days. Rain squalls were encountered relatively infrequently, but when present were normally fairly severe with heavy falls and associated strong local winds.





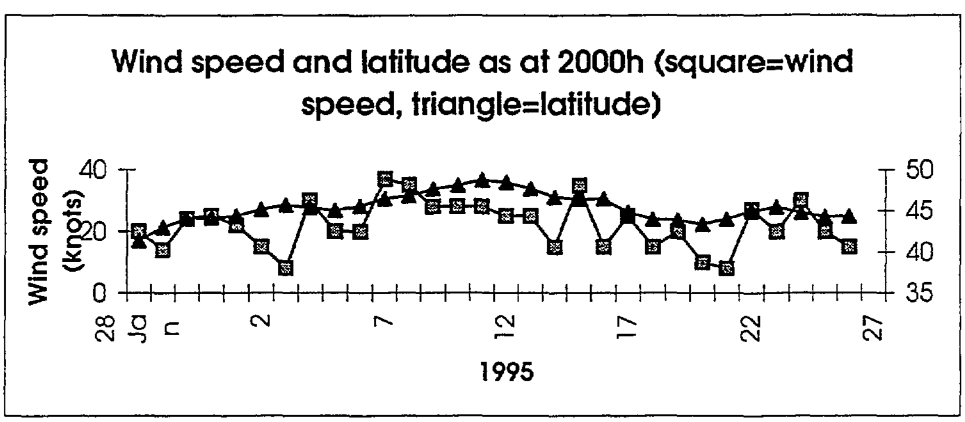
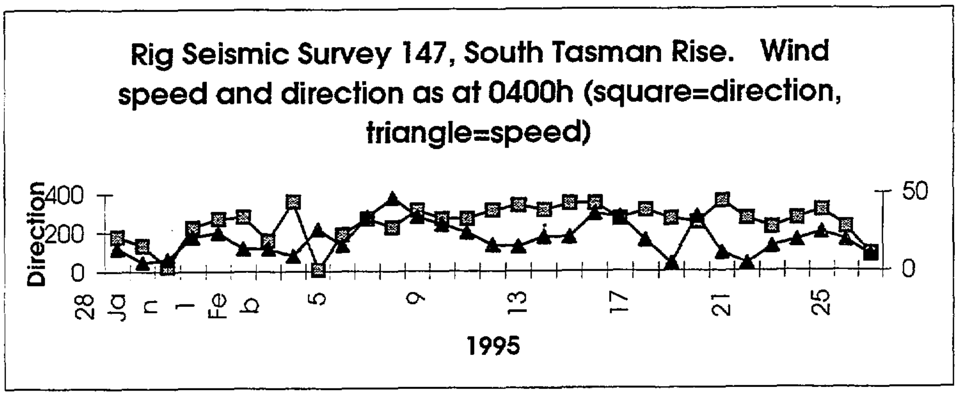
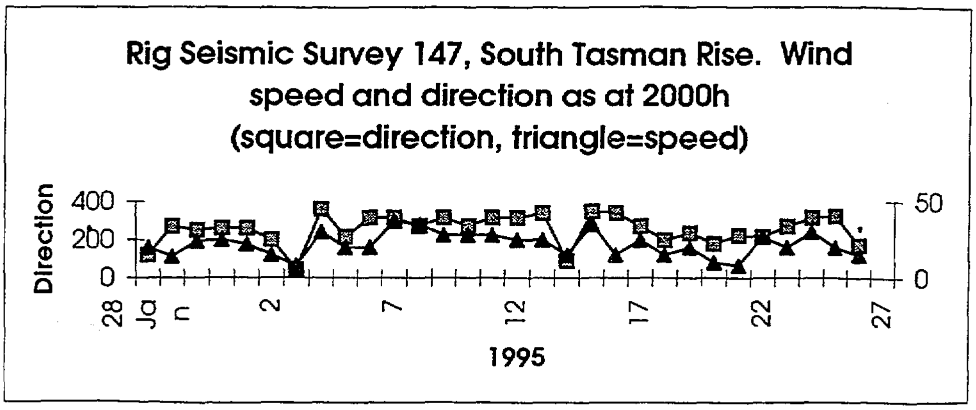


Figure A. Plots of wind speed and latitude against day of the month, for three times of day on Cruise 147.





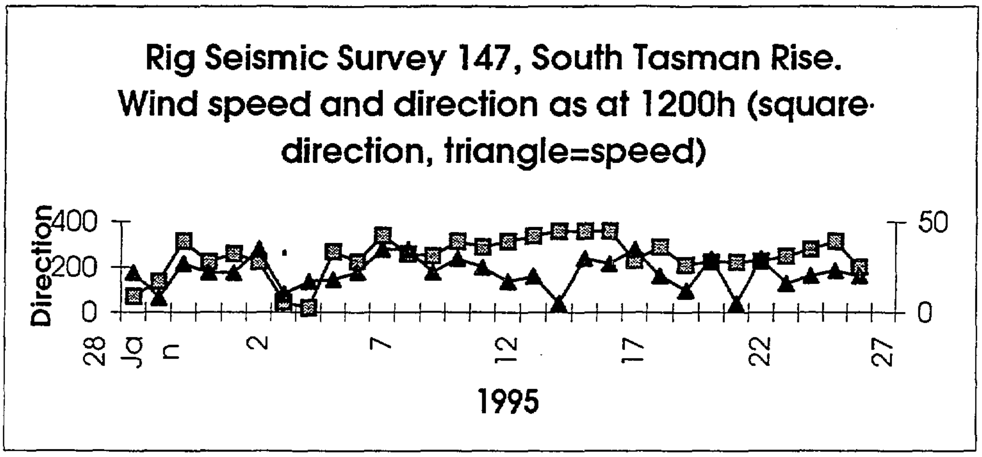


Figure B. Plots of wind speed and direction against day of the month, for three times of day on Cruise 147.

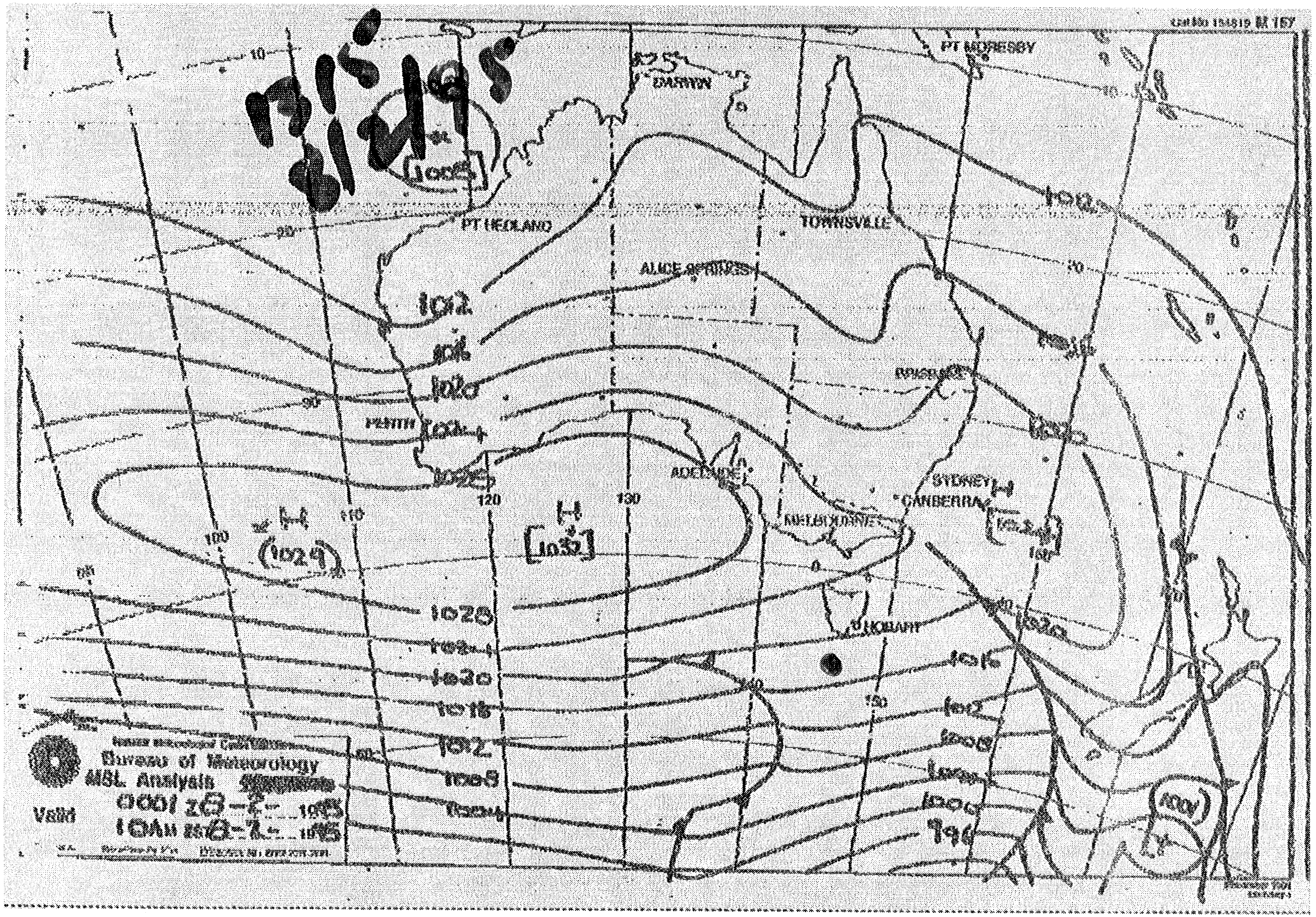


Figure C. Weather map for 8 February 1995, corresponding to strong south to southwest winds south of Tasmania.

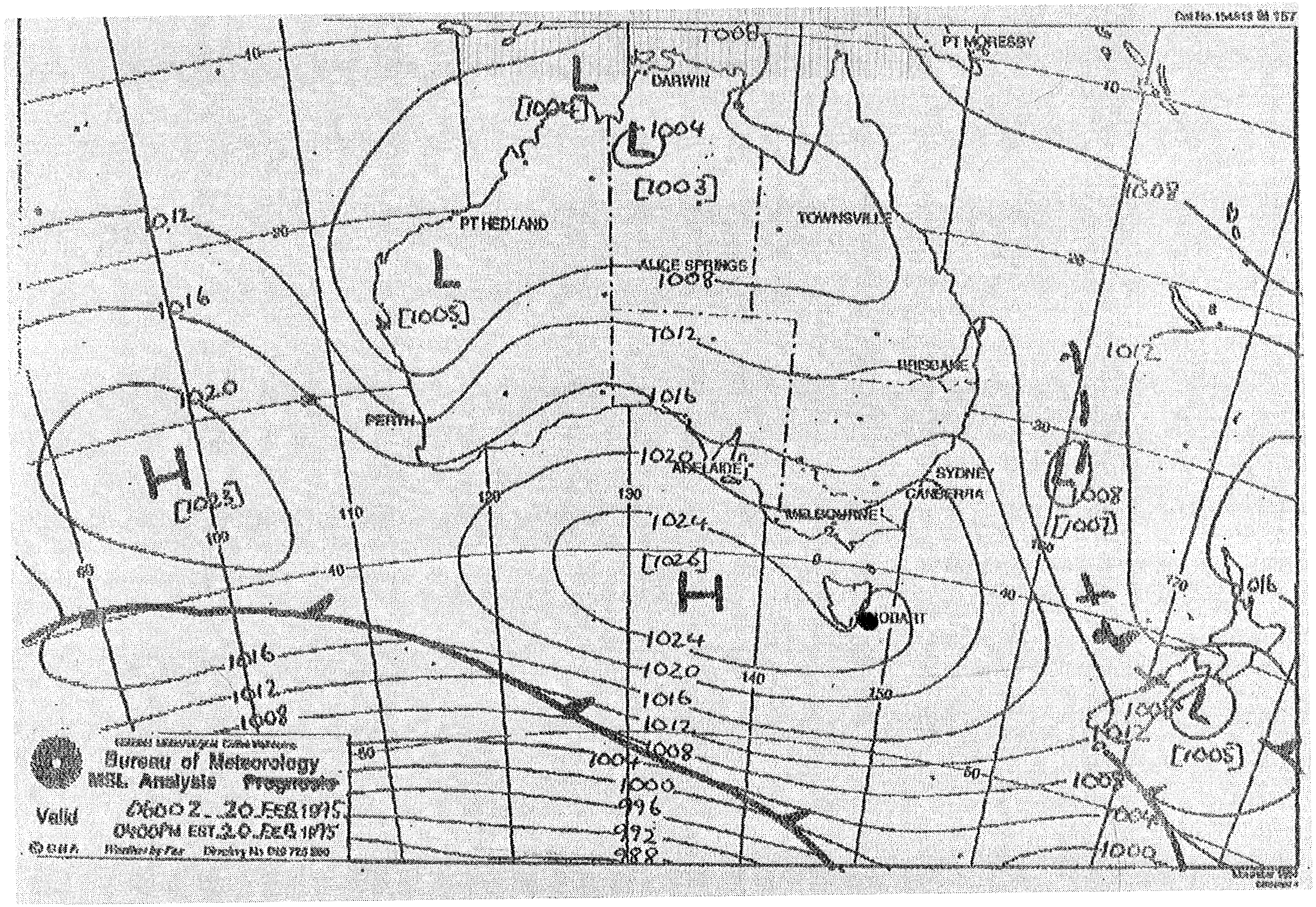


Figure D. Weather map for 20 February 1995, corresponding to a period of calm weather south of Tasmania.

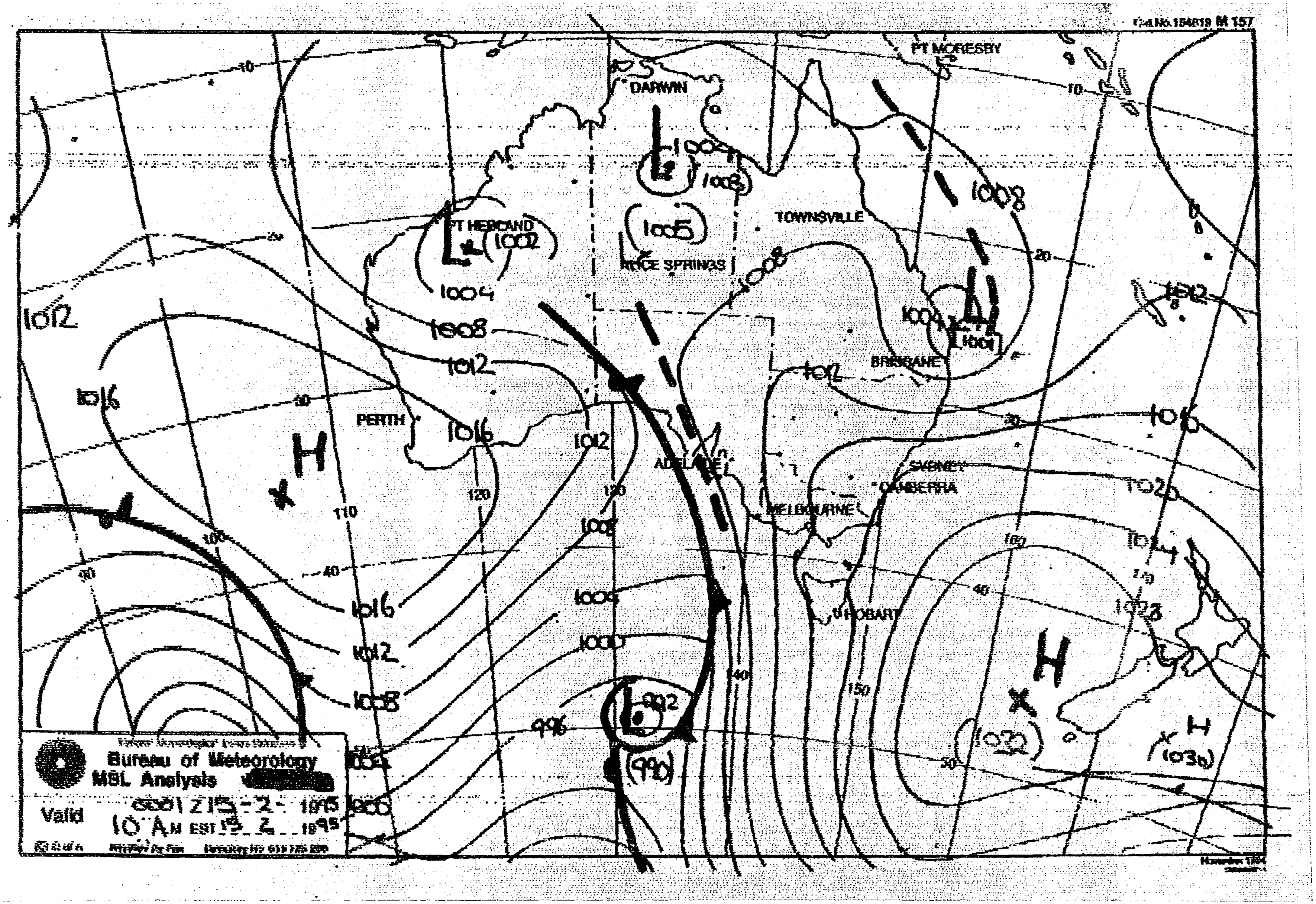


Figure E. Weather map for 15 February 1995, corresponding to strong northeast winds south of Tasmania.

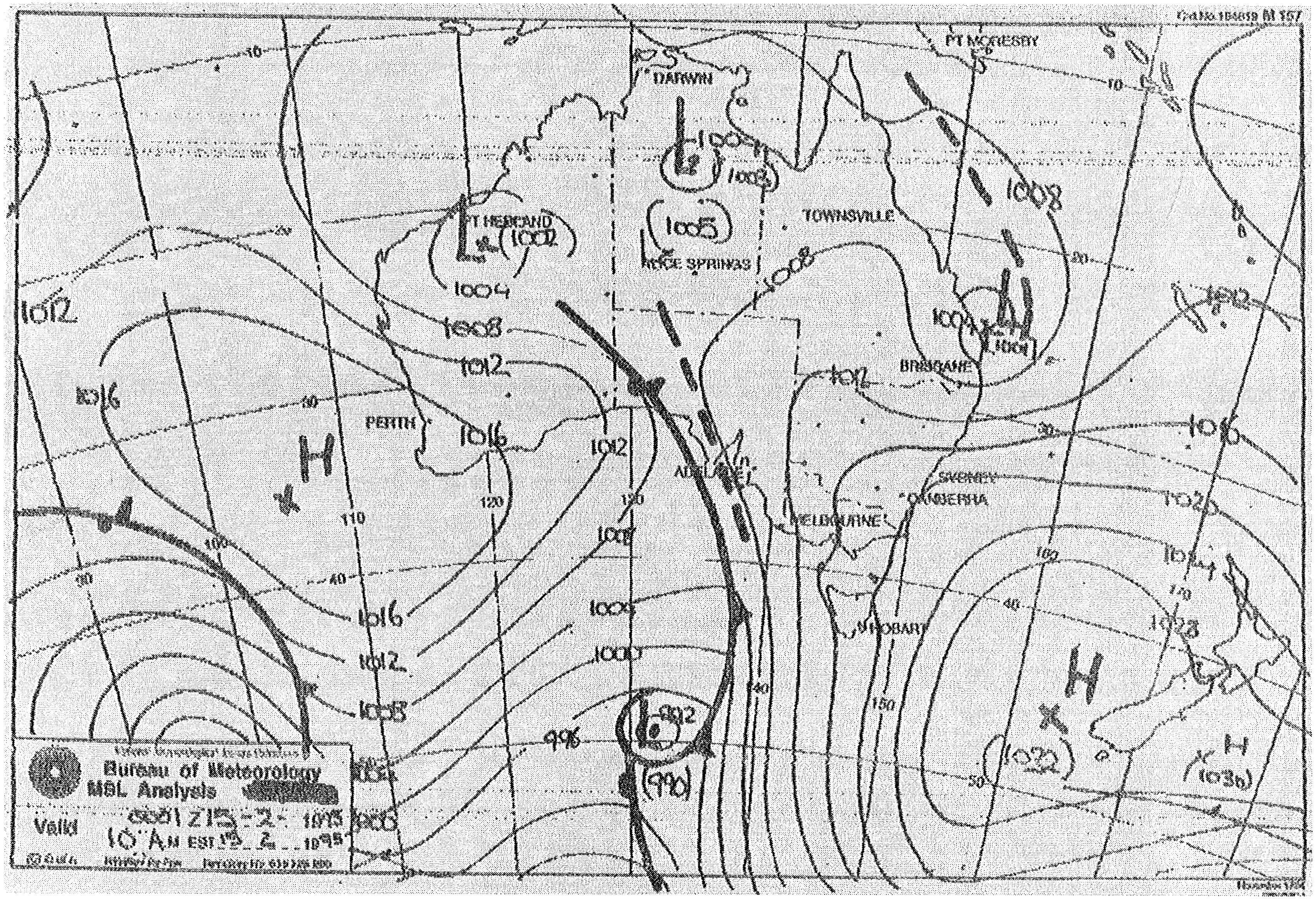


Figure E. Weather map for 15 February 1995, corresponding to strong northeast winds south of Tasmania.

APPENDIX 4: BRIEF DESCRIPTIONS OF THIN SECTIONS FROM AGSO CRUISE 147

N.F. Exon, AGSO

Igneous basement rocks

DR15/A1: Coarse grained, highly weathered, porphyritic leucodiorite consisting dominantly of clay-altered plagioclase laths 2-3 mm across, and a few grains altered to zeolites, set in a highly altered feldspathic groundmass. A ferromanganese oxide crust is visible and the rock is heavily impregnated with opaque oxides.

DR15/B1: Porphyritic leucodiorite consisting dominantly of plagioclase and orthoclase phenocrysts 2-3 mm across, and lesser pyroxene, set in a feldspathic groundmass. Extensive chlorite alteration.

DR17/A1: Altered microgabbro with abundant crystals of 1-2 mm of plagioclase, pyroxene, and chlorite-replaced minerals including feldspar, biotite, and groundmass, with lesser ilmenite laths.

DR17/B4: Microgabbro with abundant crystals of 1-2 mm of plagioclase, pyroxene and chlorite-replaced minerals including feldspar, biotite and groundmass, with ilmenite going to leucoxene. Unaltered groundmass is dominantly wispy feldspar. Fresher than DR17/A4.

DR20/D1: Microgranite with abundant orthoclase, quartz and biotite, and some plagioclase (and some perthite). Minor accessories are zircon and opaques. Generally fresh, but some chorite alteration.

DR22/D1: Microdiorite (grainsize ca. 0.2-0.5 mm) with abundant somewhat clay-altered orthoclase and plagioclase, green hornblende and chlorite (probably after biotite). Minor opaque mineral and rare zircon.

DR22/D2: Microdiorite as above.

DR22/D3: Microdiorite (grainsize ca. 0.5-1 mm) with abundant orthoclase and plagioclase, green biotite and green hornblende. Very minor opaque mineral and zircon. Very little alteration.

DR22/D4: Microdiorite as for DR22/D3.

Metamorphic and sedimentary basement rocks

DR5/A1: Coarse gneiss containing abundant intergrown quartz and feldspar (altering to kaolinite), and lesser altered muscovite and biotite (some perhaps going to chloritoid). No obvious fabric although hand specimen description was gneiss.

DR25/C1: Metasandstone (grainsize 0.1-0.2 mm) consisting of strongly oriented quartz and brown biotite laths, and occasional clots of light gray, high-relief ?garnet. Minor grey altered ?feldspar and very minor fine-grained opaque minerals.

DR25/C2: Cleaved metasandstone, (grainsize 0.1-0.2 mm), consisting of abundant quartz and grey altered ? feldspar, and common muscovite straps. Minor opaque mineral of similar grainsize.

DR25/D1: Coarse metasandstone (0.1-0.5 mm) containing abundant quartz, metamorphic polyquartz grains, and other rock fragments including slatey fragments rich in brown biotite. Some grey altered ?feldspar, and highly birefringent colourless groups of equant crystals that could be epidote.

DR30/B: Polymictic conglomerate with rounded pebbles of quartzite and amphibolite (dominantly quartz + hornblende) in a quartz and a siliceous/clay matrix.

DR38/G: Garnet-biotite-gneiss (average grainsize 0.2-0.5 mm, but with mineral aggregates to 2 cm). Little altered. 80% quartz/orthoclase/plagioclase with some opaque mineral and some highly birefringent altered ?pyroxene. Remainder consists of clots of brown biotite and light grey garnet.

DR44/A1: Granitic gneiss with grainsize 0.2-2 mm. Intergrown quartz and dusty alkali feldspar, with some large brown biotite and muscovite straps (10%) giving a rough foliation direction. Some brown chlorite alteration of mica, but generally fairly unaltered.

DR44/A2: Granitic gneiss as above, but with cross-cutting fine grained fracture zones, and minor plagioclase.

Volcanic rocks

DR10/C1: Fine grained feldspathic tuff consisting largely of fairly fresh fine plagioclase laths up to 0.5 mm long; with lesser more equant feldspar phenocrysts of similar maximum size, pyroxene, and intergrown and corroded quartz inclusions; all set in palagonitised perlitic glass (20%). No lamination apparent.

DR14/D: Green altered glass with abundant fragments 2-3 mm across in a similar fine grained matrix. Glassy fragments are picked out by zeolite rims and zeolites are also common diffuse alteration products. Glass has altered into palagonite with perthitic whirls picking out original structures.

DR25/G1: Trachyte consisting of plagioclase laths to 0.5 mm long set in a fine groundmass of fine feldspar laths and microlites, with a common opaque mineral, and palagonite-altered glass grains, some with perlitic texture. The groundmass is grey and heavily clay-altered.

DR38/A1: Weathered vesicular basalt consisting of plagioclase crystallites to 0.3 mm and equant oxidised ferromagnesian crystals, with some completely chlorite-altered pyroxene or olivine phenocrysts (0.2-0.4 mm).

DR38/B1: Hyaloclastite consisting of ferruginous vesicular glass clasts to 1 cm across (20%), set in light coloured vesicular glass that shows a fine network of cooling fractures.

DR38/B2: Coarse hyaloclastite consisting of highly vesicular ferruginous glass to 2 cm across (50%), set in a light coloured cherty groundmass that could be silicified carbonate ooze.

DR38/B3: Hyaloclastite consisting of ferruginous basalt clasts (10%) and light coloured vesicular glass fragments (70%) averaging 2-4mm across, and some altered ferromagnesian crystals (?hornblende & pyroxene, 5%), set in a light coloured cherty groundmass (15%) that could be silicified carbonate ooze.

DR40/B1: Hyaloclastite consisting entirely of altered glass, some vesicular and some not, impregnated in part with ferromanganese. Reddish clasts to 0.5 cm (10%) appear to be enclosed in buff coloured glass that has cracked to form a 1-2 mm mosaic. The glass is variably altered to palagonite or grey dusty ?silica.

DR42/A4: Hyaloclastite consisting of small (0.1 mm) to large, buff to reddish vesicular glass fragments (60%), set in a buff cherty matrix representing altered calcareous ooze. Glass is altering to brown palagonite. There are also some opaques and rounded cherty (ex-limestone) clasts.

DR57/B1: Microcrystalline basalt with about 50% plagioclase laths 0.2-0.3 mm long, and rare plagioclase phenocrysts up to 1mm in size. Heavily clay-altered equant phenocrysts (10%) that include plagioclase laths may have been orthoclase, and there are some fine grained opaques and rare pyroxene. The brownish groundmass is altered and may have been a mixture of ferromagnesian minerals and glass.

Palaeogene detrital sediments

DR10/A1: Coarse immature sandstone consisting of dominant angular quartz, with abundant altered potash feldspar, and iron-altered muscovite and biotite. Some pore space and some clay infilling.

DR10/B1: Muddy siltstone consisting of quartz, clayey fragments and lesser woody debris, set in clay matrix. Weakly laminated.

DR13/A1: Muddy fine grained sandstone consisting largely of angular to subrounded quartz and mica straps (muscovite and biotite), with lesser fine grained rock fragments, opaque minerals and woody fragments. Poorly developed bedding

DR14/A6: Laminated mudstone (varve) consisting of light layers 1 mm thick, and dark layers 2-4 mm thick. The light layers consist of light coloured clay, and the dark layers of dark clay and carbonaceous material. Silt-sized quartz and lithic fragments are present in both types. The dark layers probably represent the spring thaw. Palynology on associated sediments gives a late Eocene age and a glacial shallow marine environment.

DR18/A2: Very fine grained carbonaceous sandstone and siltstone, laminated to thin-bedded. Dominantly angular quartz, with common wispy plant material and claystone grains, and some muscovite and opaque minerals.

DR43/D2: Labile, fine to coarse grained sandstone consisting of subangular clasts (80%) of quartz, with lesser fine lithic clasts, plagioclase and orthoclase, set in a fine chlorite-altered clay matrix (20%). Poorly size sorted, only moderately lithified.

DR48/D: Soft, fine grained muddy sandstone consisting of about 70% grains and 30% clayey matrix. Clasts are dominantly angular quartz, with abundant muscovite and green chloritic lithic grains (some probably altered glass), and some chlorite-altered mica and clay clasts. Burrows up to 0.5 mm across are either open, or filled with pinkish micritic foram wackestone. Diffuse ferromanganese has made its way into the sandstone.

Neogene altered carbonate rocks

DR11/C1: Pale yellowish orange micritic carbonate wackestone containing occasional rounded to subrounded clasts of wackestone and carbonate mudstone to 1 cm in size. Borings filled with lime mud. Clasts are largely forams, algae and echinoderms; with lesser pyroxene, biotite, feldspar and quartz. Micritic matrix. XRD shows major calcite, minor fluorapatite and a trace of quartz.

DR 11/C2: Greyish orange phosphatic micritic limestone (not birefringent) containing angular moderate brown powdery clay clasts to 1 cm in size; occasional fresh quartz, altered ?glassy clasts, glauconite, biotite, possible rare ghosts of forams and echinoderms. Occasional veins appear to be phosphatic. XRD shows a trace of to minor calcite, major fluorapatite and a trace of quartz.

DR11/C3: Pale yellowish brown ?phosphatic/silicified micritic limestone (not birefringent) containing abundant subangular clasts of quartz to 2-3 mm in size. Other clasts about 0.5-2 mm in size include common phosphatic fine grained ?volcanic clasts with plagioclase laths, green biotite; some plagioclase, glauconite, rare radiolarians, forams and altered limestone (packstone) clasts. Brown rims around many clasts are alteration features.

DR11/C4: Very pale orange ?phosphatic/silicified micritic limestone (not birefringent) containing abundant large grey mottles, some bioclasts, and brown clay clasts; some fresh quartz, plagioclase, altered volcanic fragments with mica straps.

DR12/E1: Pale yellowish brown ?phosphatic/silicified micritic limestone, containing distorted beds that consist of angular sand-sized quartz, other lithic clasts, and lesser feldspar, glauconite and altered mica, set in an amorphous, poorly to non-birefringent greenish groundmass. Bulk of slide is altered micrite with minor silt to sand sized angular quartz and rounded very fine grained lithic fragments (including greenish altered ?glass). Some vague planktic and benthic forams.

DR15/E: Pale yellowish orange mottled ?silicified (not birefringent) micritic limestone. Interbedded mudstone containing common foram ghosts but little else, and packstone with grains around 1 mm of subrounded quartz and lithic fragments (including some green, palagonitised glass?) in a micritic matrix.

DR38/C1: Very pale orange micritic (weakly birefringent) chalk pebble, encrusted with moderate yellowish brown to white clasts in a manganese cement. Chalk contains some planktonic forams and rare greenish altered ?glass, and shows some evidence of bioturbation. Crust contains clasts of altered vesicular glassy volcanic material with feldspar crystallites, and foram-rich micritic chalk. The crust may in fact be altered basalt with sedimentary inclusions.

DR38/C2: Very pale orange mottled phosphatic micritic (not birefringent) chalk, containing some palagonitised ?glass and forams picked out with pyritic rims. XRD shows a trace of to minor calcite, major carbonate-hydroxylapatite and a trace of quartz.

DR38/C3: Very pale orange micritic (weakly birefringent) chalk, containing 5% forams (including benthic forms), and some sandy horizons with clasts up to 10 mm in length, consisting of dark lithic grains (altered ?glass fragments, palagonitised and zeolite altered), carbonate pellets (some sparry), bioclasts, brown clay clasts, and minor pyrite. Large mottles and wisps represent bioturbation. XRD shows major calcite and minor fluorapatite.

DR44/B2: Grayish orange micritic packstone, containing bioclasts (50%) up to 3 cm in size, set in a wackestone groundmass (50%). The coarse bioclasts consist of colonial and solitary corals, bryozoans and barnacles. The groundmass is wackestone with similar but smaller bioclasts, abundant angular fine quartz sand grains, some muscovite and biotite, and rare lithic fragments, set in weakly birefringent micrite. XRD shows major calcite, traces of apatite and minor quartz.

DR44/B3: Very pale orange carbonate packstone to wackestone, consisting of about 60% grains (0.2-10 mm) and 40% birefringent micrite. Common grains are echinoderm plates, micritic clasts (including some curved ?desiccation rip-up clasts), angular quartz, and forams. Less common are peloids, pyrite (especially infilling forams), muscovite, feldspar, woody wisps and highly birefringent ferromagnesian crystals. XRD shows major calcite, traces of apatite, and minor quartz.

DR47/F1: White to very pale orange packstone, containing bioclasts and intraclasts up to 2 cm in size. Bioclasts include corals, barnacles, bryozoans, and benthic forams, and the intraclasts include pellets and lumps of sparry calcite. Moderately birefringent micrite makes up 20% of the rock.

DR47/F2: Very pale orange, heavily bored, hard, very coarse packstone, containing bioclasts up to 3 cm in size. Bioclasts include large barnacles, corals and bryozoans, and there are some basaltic clasts. Micrite cement (15-20%) is moderately birefringent.

DR54/D2: Very pale orange micritic (non-birefringent) gritty calcilutite. Clasts are detrital and non-calcareous and include occasional dark lithic grains to 5 mm across; most are fine sand sized and include abundant angular quartz, and some muscovite, biotite, green ?glass, and red claystone. The micrite is somewhat mottled. There are younger reddish-brown burrow fillings, several mm across, of ferruginous silty clay with clasts of angular quartz, and a little muscovite and ?glauconite.

DR55/B2: Very pale orange, micritic (birefringent), mottled hard calcilutite (90%), with discontinuous thin quartz laminae (generally less than 1 mm) and lenses picking out the bedding. One thicker vein (1-3 mm) contains secondary quartz, dusty ?feldspar and calcite crystals (1 mm), but also what appear to be original quartz, quartzite and lithic grains with reaction rims. A tapered pinkish mudcrack or pehaps burrow (1-3 mm) cuts across the bedding, breaking the quartz laminae; it consists of slightly ironstained micrite with quartz grains, lithic clasts and some forams and other shell fragments. Very fine (<1 mm) quartz veins also cut across the laminae in places. XRD shows a trace of to minor calcite, major quartz, and major potash feldspar.

DR55/B3: White and grey micritic (weakly birefringent) hard calcilutite, with secondary quartz laminae more abundant (40%) and more diffuse than in DR55/B2, but still oriented in the bedding. Some calcite occurs with the quartz (1 mm across) and there is one purely calcite vein in the bedding, 1 mm across. Cross-cutting micritic cracks, containing quartz and rare lithic grains, are less than 1 mm across. Pyrite cubes and altered plagioclase laths are a minor constituent. The micrite is either slightly birefringent or dusty grey, in mottles. XRD shows minor calcite, major quartz, and minor plagioclase feldspar.

DR55/B4: White micritic (weakly to moderately birefringent) hard calcilutite consisting largely of mottled micrite, containing angular quartz grains (0.1-0.2 mm, 10%). Common fine grained pyrite cubes are partly oxidised. Cross-cutting, partly polygonal, greyish orange cracks (1-10 mm) contain abundant fine grained quartz, and some lithic fragments, chloritic ?glass grains and pyrite, set in a fine grained, variably birefringent, ?phosphatic cement.

APPENDIX 5: LIST OF DREDGE SAMPLES HELD BY UNIVERSITY OF TASMANIA AND N. ROLLET (VILLEFRANCHE GEODYNAMIC INSTITUTE)

Thin sections (University of Tasmania)

147DR04 A1, A2, B1, B2, B3, B4, B5
147DR05 B1, C1, D1, E1, E2, F1, G1
147DR09 A1, A2, A3, A4, C1
147DR11 A1, A3, B3
147DR12 A1, G1
147DR16 A2
147DR17 B1, B3, C1, C2, C3, D4
147DR18 C1
147DR20 A1, C1
147DR22 D1, D2, D3, D4
147DR24 D1
147DR25 L1
147DR28 C1, D1, G1
147DR36 D1, F1
147DR40 D1, E1
147DR43 A1, B1, B2, C1, G1
147DR45 B1, C1, C2, G1
147DR46 A1
147DR47 A1, A7, A8, B1, C1, D1, E1, G1
147DR48 A1, B1
147DR50 A1, A2, B1, C1

Rocks (held by N. Rollet)

The above plus

147DR05 A2, D1
147DR09 B, D
147DR11 A2, B1, B2
147DR12 A2, B1, C1, E1
147DR15 A1, B1, C1
147DR16 A1
147DR17 A1, B2, B4
147DR20 B, D
147DR22 A, B
147DR24 A, C
147DR25 A1
147DR27 A1, A2
147DR31 A1, C
147DR38 G
147DR44 A
147DR45 A1, A2, B1, B2, C2, G1
147DR48 C

147DR52 A1, B1, C1
147DR54 A1, A3, B1, H1

APPENDIX 6: LIST OF DREDGE SAMPLES HELD BY MICHELE ELMES

Thin sections

DR01 A1-8, G1-3
DR02 A1-6
DR07 A1-7, B1, C
DR08 A1-3
DR09 A1-4, B
DR32 A1-3, C, D
DR34 A1, B1
DR35 B1-6, C1
DR37 A1-7
DR38 A1-8
DR40 C1,C2
DR42 B1-9
DR43 C
DR51 (3 samples)

Rocks

The above plus

DR07 B2-5
DR08 A4, C1-5
DR09 A5-7, C, D
DR32 A4-9
DR34 B2-5
DR35 B7-9, C2-6
DR37 A8, A9
DR38 B
DR40 B1
DR42 A1-4
DR45 C1-4
DR51 (6 blocks)
DR52 B1, A2
DR54 B1-4

Italicised samples sent down to Tasmania late, may finish up as thin sections

APPENDIX 7: MANGANESE SAMPLES ANALYSED FROM AGSO CRUISE 147

Analabs of Welshpool, Western Australia, analysed 43 crust and nodule samples from 36 dredge stations for 30 components, using induction coupled plasma spectrometry or x-ray refraction on samples dried at 105° C and pulverised using chrome-free steel. The results are discussed in the body of the Record under "Manganese crusts and nodules". Key nodule and crust geochemical data are summarised in the Record in Table 24, nodule data in Table 25, and crust data in Table 27. The following is *Analabs'* report.

Analabs

Analabs Pty. Ltd.
ACN 004 591 664
52 Murray Road, Welshpool
Western Australia 6106
P.O. Box 210, Bentley, W.A. 6102
Telephone : (61 9) 4587999
Facsimilie: (61 9) 4582922

Job No: **PE004832**
Project Code:
Order No: AGSO951119
Date Received: 12/04/95
Date Reported: 01/05/95

ANALYTICAL REPORT

Greg Sparksman

Australian Geological Survey Org.
GPO Box 378
Canberra City

ACT 2601

Number of pages of report : 12 (excl cover sheet) First Sample: 147DR1B1
Number of Samples : 43 Last Sample: 147DR55A1

Invoice to:

Australian Geological Survey Org.
GPO Box 378
Canberra City

ACT 2601

Electronic Data Transmission :
Modem / /
Facsimile / /
Disk Report / /

Preliminary Reports :
28/04/95 Report
01/05/95 Report

Results to:

Results to:

Remarks : Note - Nb,Zr,Ta data is Acid Soluble only and as such data may bias low.
If total results are required, method GX401 is recommended.

Authorised by ....
On behalf of:

Mr Alastair Inglis
Manager-Minerals

Analabs

ANALYSIS DESCRIPTION

Job number : PE004832 Order number : AGSO951119

Scheme code : GP006 - Drying @ $0.70/kg

Drying; other samples

Scheme code : GP009 - Boyd crushing @ $0.70 per kg

Boyd crushing of samples to nominal - 12mm

Scheme code : GP017 - <300g Ring mill pulverising to 75μM

Ring mill pulverising to nominal 75μM (200 mesh)
samples up to 300g

Scheme code : OX406 - Glass fusion XRF

Glass fusion XRF - high level concentrations

Mn	: Manganese
Fe	: Iron
SiO2	: Silica
Al2O3	: Alumina
P	: Phosphorous
BaO	: Barium Oxide
TiO2	: Titanium Dioxide
CaO	: Calcium Oxide
K2O	: Potassium Oxide
MgO	: Magnesium Oxide
Na2O	: Sodium Oxide
Wt1	:
Wt2	:
Wt3	:
LOI	:

Scheme code : D201 - Aqua regia/perc/hydroflu acid digest (.2g sample)

Aqua regia/perchloric/hydrofluoric acids digest
(0.2g sample)

Scheme code : GI201 - ICPOES determination

ICPOES determination

Cr	: Chromium

Analabs

ANALYSIS DESCRIPTION

Job number : PE004832 Order number : AGSO951119

Ni	: Nickel
V	: Vanadium
Cu	: Copper
Zn	: Zinc
Pb	: Lead
Sr	: Strontium
Ce	: Cerium
Co	: Cobalt
Zr	: Zirconium
La	: Lanthanium

Scheme code : GS201 - ICPMS determination

ICPMS determination

As	: Arsenic
Be	: Beryllium
Cd	: Cadmium
Mo	: Molybdenum
Nb	: Niobium
Sn	: Tin
Ta	: Tantalum
W	: Tungsten
Y	: Yttrium

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Order No: AGSO951119
Project Code:
Report Date: 01/05/95
Report Status: Final

Job No: **PE004832**

ANALYTICAL DATA

Sample	Mn	Fe	SiO2	Al2O3	P	BaO
147DR1B1	16.78	13.71	19.4	2.76	0.208	0.25
147DR1C1	5.59	17.78	34.5	6.10	0.222	0.15
147DR2B1	10.23	17.35	33.1	3.66	0.217	0.19
147DR2B2	2.32	8.34	45.4	15.1	0.131	0.03
147DR5H2A	11.98	15.60	28.4	2.28	0.279	0.24
147DR5H2B	11.49	19.41	21.7	2.37	0.326	0.26
147DR7DI	22.34	15.91	4.47	1.12	0.487	0.31
147DR10E1	14.73	17.36	13.0	2.09	0.517	0.23
147DR11E1A	15.49	18.94	10.4	1.94	0.371	0.27
147DR11E1B	14.27	19.99	13.4	2.14	0.375	0.29
147DR12G1	13.62	14.29	25.1	3.25	0.395	0.25
147DR13G1	15.10	17.01	9.92	1.69	0.340	0.22
147DR13H1	13.80	14.63	17.4	2.92	0.935	0.19
147DR14B1	10.87	15.65	32.2	4.47	0.214	0.17
147DR14B2	10.08	16.18	28.1	3.91	0.245	0.14
147DR15F1	9.37	14.00	36.6	4.54	0.208	0.30
147DR16C1	12.46	17.36	19.5	3.05	0.314	0.21
147DR18E1	13.56	12.23	21.8	4.33	0.188	1.86
147DR20F1	12.43	16.82	22.2	5.13	0.290	0.20
147DR22H1	12.77	18.61	13.4	2.84	0.313	0.19
147DR23A1	11.17	19.05	20.7	4.60	0.413	0.18
147DR24F1	18.16	17.17	5.55	0.88	0.353	0.28
147DR25H1	10.15	12.98	33.4	6.86	0.212	0.15
147DR27D1	18.04	15.98	15.5	2.35	0.239	0.26
147DR28A1	24.10	14.81	2.87	0.54	0.408	0.27

Method	OX406	OX406	OX406	OX406	OX406	OX406
Units	%	%	%	%	%	%
Detection Limit	0.01	0.01	0.05	0.05	0.001	0.01

Notes:
N.A. = not analysed
-- = element not determined
I.S. = insufficient sample
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Project Code:
Report Date: 01/05/95
Report Status: Final

Job No: **PE004832**

ANALYTICAL DATA

Sample	Mn	Fe	SiO2	Al2O3	P	BaO
147DR31G1	20.23	16.86	4.15	0.66	0.453	0.28
147DR32E1	23.95	16.46	3.50	0.89	0.457	0.28
147DR33B1	18.51	17.35	6.12	1.07	0.377	0.30
147DR36J1	20.49	17.77	6.52	0.99	0.407	0.25
147DR36I1	20.00	16.08	9.11	2.11	0.374	0.26
147DR37B1	19.80	18.92	5.97	0.95	0.418	0.29
147DR38D1	20.10	18.24	7.15	1.09	0.499	0.30
147DR39A1	15.43	20.51	15.0	1.90	0.409	0.26
147DR40A1	14.01	19.53	19.8	2.28	0.387	0.24
147DR42C1	20.25	15.67	13.0	2.43	0.378	0.31
147DR45H1	14.69	17.41	19.6	4.51	0.302	0.27
147DR46D1	10.37	18.90	28.6	3.28	0.294	0.35
147DR47H1	14.42	19.86	14.3	2.70	0.352	0.25
147DR48E1	12.15	21.91	20.9	2.52	0.391	0.28
147DR50E1	19.97	16.15	10.4	1.77	0.328	0.25
147DR51B1	15.32	15.27	17.9	3.12	0.815	0.35
147DR53A1	17.06	18.92	8.30	1.34	0.383	0.22
147DR55A1	19.41	18.32	8.78	1.55	0.378	0.25

Method Units Detection Limit	OX406 % 0.01	OX406 % 0.01	OX406 % 0.05	OX406 % 0.05	OX406 % 0.001	OX406 % 0.01

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Job No: **PE004832**

ANALYTICAL DATA

Sample	Cr	Ni	V	Cu	Zn	Pb
147DR1B1	40	6040	515	1670	839	513
147DR1C1	43	1640	502	810	536	353
147DR2B1	52	2390	484	1530	553	622
147DR2B2	196	888	282	512	228	131
147DR5H2A	55	1890	637	562	588	1020
147DR5H2B	74	1780	852	768	779	977
147DR7DI	73	3170	844	405	686	2470
147DR10E1	65	2350	698	670	680	1120
147DR11E1A	64	2290	683	595	652	1450
147DR11E1B	61	2280	876	919	863	1290
147DR12G1	63	3890	561	1430	750	977
147DR13G1	58	2330	678	833	575	1150
147DR13H1	59	3810	496	1600	702	801
147DR14B1	49	2120	430	1660	547	596
147DR14B2	44	2070	409	1440	494	634
147DR15F1	45	2580	377	1730	618	495
147DR16C1	55	1540	529	763	474	961
147DR18E1	73	6570	348	3740	775	422
147DR20F1	49	2400	508	945	534	996
147DR22H1	51	2860	541	1320	616	903
147DR23A1	57	1310	489	1070	438	860
147DR24F1	66	3060	766	907	714	1660
147DR25H1	44	2150	378	981	436	742
147DR27D1	67	4640	626	1840	947	1090
147DR28A1	75	3830	818	517	673	2470

Method	GI201	GI201	GI201	GI201	GI201	GI201
Units	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	10	10	2	5	5	50

Notes:
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Job No: **PE004832**

ANALYTICAL DATA

Sample	Cr	Ni	V	Cu	Zn	Pb
147DR31G1	68	2980	830	467	651	2130
147DR32E1	83	3750	849	448	667	2630
147DR33B1	91	2680	807	734	659	1650
147DR36J1	71	3690	785	747	700	2050
147DR36I1	81	5050	623	1340	800	1490
147DR37B1	72	2950	870	701	689	1840
147DR38D1	74	2880	899	421	710	1820
147DR39A1	64	2420	847	792	727	1130
147DR40A1	61	2390	673	612	650	1210
147DR42C1	108	7450	664	843	1040	895
147DR45H1	72	4820	637	1050	1050	792
147DR46D1	52	1730	734	963	868	607
147DR47H1	59	2590	669	1230	647	1160
147DR48E1	61	2080	859	995	868	995
147DR50E1	54	6650	649	1590	866	1190
147DR51B1	60	4790	626	1030	1010	870
147DR53A1	61	2470	714	754	585	1490
147DR55A1	69	3430	816	660	713	1180

Method / Units / Detection Limit						
Method	GI201	GI201	GI201	GI201	GI201	GI201
Units	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	10	10	2	5	5	50

Notes:
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Report Status: Final

Job No: **PE004832**

ANALYTICAL DATA

Sample	As	Be	Cd	Mo	Nb	Sn
147DR1B1	149	3.8	10.7	412	23.4	1.7
147DR1C1	198	6.2	1.6	164	17.4	3.6
147DR2B1	170	4.8	3.5	243	49.0	3.3
147DR2B2	30	1.3	1.0	29.6	20.6	1.9
147DR5H2A	187	6.5	3.4	339	37.6	3.9
147DR5H2B	227	6.9	3.0	406	29.0	3.3
147DR7DI	315	6.3	6.9	746	51.4	6.1
147DR10E1	267	8.5	3.8	575	62.0	5.6
147DR11E1A	275	8.9	4.1	457	84.6	8.1
147DR11E1B	318	9.5	4.4	659	62.5	4.7
147DR12G1	198	6.7	4.9	425	40.2	4.1
147DR13G1	241	6.8	3.7	482	63.1	5.7
147DR13H1	147	6.4	4.4	340	52.2	4.5
147DR14B1	136	5.6	3.0	243	43.3	3.3
147DR14B2	134	5.6	2.7	239	50.4	4.3
147DR15F1	97	5.2	2.8	186	21.8	2.5
147DR16C1	215	6.7	3.1	361	63.9	4.4
147DR18E1	93	4.2	5.2	234	13.7	3.3
147DR20F1	168	6.3	3.1	262	54.0	5.0
147DR22H1	178	6.0	3.4	261	69.8	5.2
147DR23A1	170	5.6	2.6	254	54.7	3.6
147DR24F1	254	7.3	4.7	587	59.9	6.2
147DR25H1	124	4.1	2.7	187	62.9	3.8
147DR27D1	174	6.7	4.7	479	63.7	4.9
147DR28A1	306	5.2	6.4	733	45.5	6.6

Method	GS201	GS201	GS201	GS201	GS201	GS201
Units	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	1	0.1	0.1	0.1	0.2	0.5

Notes:
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Job No: **PE004832**

ANALYTICAL DATA

Sample	As	Be	Cd	Mo	Nb	Sn
147DR31G1	274	6.5	6.1	589	63.4	6.7
147DR32E1	308	5.6	6.1	679	40.8	6.2
147DR33B1	250	6.8	4.6	628	67.7	6.4
147DR36J1	309	7.3	5.4	639	69.1	6.8
147DR36I1	230	6.6	6.5	490	79.8	6.8
147DR37B1	311	8.1	5.6	649	74.9	7.7
147DR38D1	328	8.7	6.5	738	48.1	7.0
147DR39A1	326	8.9	5.4	881	96.7	6.0
147DR40A1	216	7.0	3.6	401	39.3	4.3
147DR42C1	233	4.5	13.1	508	22.9	2.4
147DR45H1	242	6.7	5.4	415	56.8	4.3
147DR46D1	181	7.9	3.1	361	19.6	2.1
147DR47H1	219	7.0	3.6	324	94.4	7.1
147DR48E1	314	8.9	3.2	564	64.7	3.6
147DR50E1	192	5.4	9.2	467	51.8	3.9
147DR51B1	190	6.7	5.7	458	57.6	3.0
147DR53A1	262	6.7	3.5	483	63.5	5.3
147DR55A1	290	7.3	4.3	669	64.3	6.3

Method Units Detection Limit	GS201 ppm 1	GS201 ppm 0.1	GS201 ppm 0.1	GS201 ppm 0.1	GS201 ppm 0.2	GS201 ppm 0.5

Notes:
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Order No: AGSO951119
Project Code:
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Report Status: Final

Job No: **PE004832**

ANALYTICAL DATA

Sample	TiO2	CaO	K2O	MgO	Na2O
147DR1B1	0.35	1.60	0.97	2.27	1.67
147DR1C1	0.46	0.75	0.80	1.83	1.57
147DR2B1	0.68	1.23	0.75	1.68	1.58
147DR2B2	1.64	9.19	0.63	3.96	3.47
147DR5H2A	0.83	1.83	0.41	1.20	1.34
147DR5H2B	0.75	1.80	0.38	1.32	1.39
147DR7DI	1.16	3.41	0.54	1.66	1.98
147DR10E1	1.12	2.92	0.71	1.44	1.64
147DR11E1A	1.44	2.37	0.51	1.42	1.72
147DR11E1B	0.85	2.19	0.54	1.43	1.54
147DR12G1	0.89	2.62	0.78	1.65	1.54
147DR13G1	1.11	2.35	0.48	1.37	1.61
147DR13H1	0.83	4.29	0.82	1.51	1.67
147DR14B1	0.76	1.57	1.32	1.26	1.83
147DR14B2	0.70	1.48	0.90	1.47	1.67
147DR15F1	0.58	1.73	1.03	1.33	1.71
147DR16C1	0.97	2.02	0.74	1.38	1.66
147DR18E1	0.61	1.57	1.18	2.02	2.09
147DR20F1	1.00	1.89	1.70	1.28	2.15
147DR22H1	1.01	1.93	0.68	1.58	1.67
147DR23A1	1.17	2.30	0.87	1.70	1.96
147DR24F1	1.34	2.67	0.41	1.48	1.69
147DR25H1	0.91	1.86	0.92	1.33	2.85
147DR27D1	1.19	2.53	0.82	1.75	2.01
147DR28A1	1.60	3.54	0.43	1.71	2.02

Method	OX406	OX406	OX406	OX406	OX406
Units	%	%	%	%	%
Detection Limit	0.01	0.01	0.01	0.01	0.05

Notes:
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Report Status: Final

Job No: **PE004832**

ANALYTICAL DATA

Sample	TiO2	CaO	K2O	MgO	Na2O
147DR31G1	1.52	3.07	0.38	1.57	1.84
147DR32E1	1.57	3.56	0.44	1.89	1.97
147DR33B1	1.49	2.79	0.43	1.56	1.80
147DR36J1	1.36	3.00	0.42	1.74	1.89
147DR36I1	1.33	2.68	0.62	1.84	1.98
147DR37B1	1.40	2.92	0.41	1.61	1.94
147DR38D1	1.37	3.29	0.44	1.55	1.90
147DR39A1	1.12	2.37	0.44	1.51	1.84
147DR40A1	0.97	2.10	0.48	1.48	1.60
147DR42C1	0.52	2.43	0.78	2.69	1.85
147DR45H1	0.63	1.76	0.72	2.19	1.65
147DR46D1	0.43	1.34	0.71	1.24	1.53
147DR47H1	1.32	2.13	0.59	1.58	1.84
147DR48E1	0.68	1.97	0.48	1.50	1.60
147DR50E1	0.88	2.29	0.60	2.09	2.01
147DR51B1	0.63	3.77	0.80	1.92	1.60
147DR53A1	1.19	2.58	0.40	1.49	1.76
147DR55A1	1.31	2.98	0.44	1.71	2.02

Method	OX406	OX406	OX406	OX406	OX406
Units	%	%	%	%	%
Detection Limit	0.01	0.01	0.01	0.01	0.05

Notes:
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I.S. = insufficient sample
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ANALYTICAL DATA

Sample	Sr	Ce	Co	Zr	La
147DR1B1	709	384	1760	30	105
147DR1C1	420	760	509	37	98
147DR2B1	691	662	1410	254	124
147DR2B2	257	130	310	179	31
147DR5H2A	975	1350	2070	49	175
147DR5H2B	974	1570	1990	45	193
147DR7DI	1660	1500	7590	176	217
147DR10E1	1270	857	2270	318	246
147DR11E1A	1340	1030	3320	363	232
147DR11E1B	1230	1470	2330	277	233
147DR12G1	997	862	2050	269	132
147DR13G1	1280	837	3080	293	261
147DR13H1	1190	653	2000	270	154
147DR14B1	854	502	1330	70	97
147DR14B2	780	586	1230	43	148
147DR15F1	824	459	938	53	110
147DR16C1	1100	1080	1440	339	247
147DR18E1	1580	380	1550	37	94
147DR20F1	1070	852	2460	108	208
147DR22H1	1060	744	2110	433	199
147DR23A1	1010	819	1640	61	236
147DR24F1	1530	1160	4100	347	284
147DR25H1	851	597	1900	468	139
147DR27D1	1340	765	2700	72	217
147DR28A1	1690	1530	10000	122	283

Method	GI201	GI201	GI201	GI201	GI201
Units	ppm	ppm	ppm	ppm	ppm
Detection Limit	1	15	5	5	5

Notes:
N.A. = not analysed
-- = element not determined
I.S. = insufficient sample
L.N.R. = listed not received

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Facsimilie: (61 9) 4582922

Job No: **PE004832**

ANALYTICAL DATA

Sample	Sr	Ce	Co	Zr	La
147DR31G1	1620	1340	5970	249	280
147DR32E1	1780	1500	8740	121	256
147DR33B1	1630	1120	4690	361	281
147DR36J1	1640	1190	5340	338	264
147DR36I1	1440	966	4540	430	192
147DR37B1	1690	1250	4870	349	317
147DR38D1	1700	1270	4330	179	295
147DR39A1	1380	1000	2660	394	311
147DR40A1	1160	926	2020	54	212
147DR42C1	1120	376	3530	43	72
147DR45H1	925	1180	1650	182	115
147DR46D1	859	1320	685	65	158
147DR47H1	1190	1010	3070	419	234
147DR48E1	1090	1540	1490	68	241
147DR50E1	1150	728	3350	259	195
147DR51B1	1100	1230	1260	264	106
147DR53A1	1440	990	3490	292	300
147DR55A1	1530	997	4350	87	283

Method Units Detection Limit	GI201 ppm 1	GI201 ppm 15	GI201 ppm 5	GI201 ppm 5	GI201 ppm 5

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Order No: AGSO951119
Project Code:
Report Date: 01/05/95
Report Status: Final

Job No: PE004832

ANALYTICAL DATA

Sample	Ta	W	Y
147DR1B1	0.5	51.9	106
147DR1C1	0.6	22.1	63.4
147DR2B1	0.8	32.0	70.2
147DR2B2	4.2	8.7	45.4
147DR5H2A	0.8	86.6	107
147DR5H2B	0.5	103	93.1
147DR7DI	1.2	171	156
147DR10E1	1.3	120	180
147DR11E1A	1.9	101	161
147DR11E1B	2.7	147	121
147DR12G1	0.9	90.3	93.4
147DR13G1	1.8	111	156
147DR13H1	0.9	64.2	126
147DR14B1	0.9	34.7	63.5
147DR14B2	0.8	46.3	97.2
147DR15F1	0.4	32.4	68.3
147DR16C1	1.5	78.7	172
147DR18E1	0.2	24.9	64.0
147DR20F1	1.3	62.0	151
147DR22H1	1.3	57.3	125
147DR23A1	1.4	62.7	189
147DR24F1	1.4	134	163
147DR25H1	1.2	33.7	81.3
147DR27D1	1.1	93.8	83.1
147DR28A1	1.0	176	203

Method	GS201	GS201	GS201
Units	ppm	ppm	ppm
Detection Limit	0.1	0.1	0.05

Notes:
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Project Code:
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Report Status: Final

Job No: PE004832

ANALYTICAL DATA

Sample	Ta	W	Y
147DR31G1	1.4	140	187
147DR32E1	0.9	157	182
147DR33B1	1.5	126	129
147DR36J1	1.6	140	193
147DR36I1	1.6	105	127
147DR37B1	1.6	166	199
147DR38D1	1.1	156	188
147DR39A1	6.6	139	179
147DR40A1	0.6	77.1	135
147DR42C1	0.3	93.2	70.5
147DR45H1	1.0	72.0	73.8
147DR46D1	0.7	76.6	74.1
147DR47H1	1.7	78.8	139
147DR48E1	1.3	145	134
147DR50E1	0.8	92.7	127
147DR51B1	2.2	82.7	79.2
147DR53A1	1.2	102	180
147DR55A1	1.0	138	124

Method Units Detection Limit	GS201 ppm 0.1	GS201 ppm 0.1	GS201 ppm 0.05

Notes:
N.A. = not analysed
-- = element not determined
I.S. = insufficient sample
L.N.R. = listed not received

APPENDIX 8: PALYNOLOGICAL ANALYSES

Because of the importance of dating the sediment fill in the basinal areas of the South Tasman Rise, tweny-five samples of muddy sedimentary rocks from AGSO Cruise 147 were submitted to Laola Pty. Ltd., of 10 Lefroy Avenue, Bellevue, Western Australia 6056. Many of these rocks were not as fresh as one would have liked. In the event only four of the samples yielded dateable assemblages. The samples are listed below (all have prefix 147DR):

Sample 147DR/	**sample weight (gms)**	**yield (cc)**	**yield/weight**	**comments**
10A2	20.4	0.00		
10B2	20.6	0.01		
13A1	20.2	0.2	0.009	sporomorphs
13A2	20.1	0.01		
13A3	21.0	0.01		
14A7	20.3	0.2	0.009	
14A8	20.7	0.2	0.009	sporomorphs
14A9	21.3	2.9	0.136	
18A1	21.5	1.0	0.046	sporomorphs
18A2	19.9	1.9	0.095	sporomorphs
20E1	22.5	0.05	0.002	
20E2	21.3	0.01		
21A1	20.8	0.01		
21B1	21.0	0.2	0.009	
23C1	2.7	0.0		
23D1	2.1	0.0		
25F2	22.2	0.05	0.002	
25F3	20.5	0.0		
27C2	21.5	0.01		
27C3	22.4	0.01		
31F1	21.7	0.0		
43D1	22.6	0.0		
43E1	20.6	0.0		
48D1	21.5	0.0		
54C1	21.9	0.0		

APPENDIX 9: AGSO CRUISE 147 SMEAR SLIDE DATA

Greg Whitmore, James Cook University

During AGSO cruise 147, a great number of smear slides were prepared and examined to aid in core description. The results are tabulated on the following three pages.

AGSO cruise 147 sediment smear slide data - March 1995

SAMPLE		SEDIMENT NAME	TEXTURE				MINERALOGY (%)															
Type No.	Depth (cm)		Clay %	Silt %	Sand %	Sand Grain size	Spng Spic.	Rad	Diat.	Calc. nann	For- ams	Carb.	Zeol.	Mn	Pyr.	Volc. Glass	Recy Seds	Clay	Hvy Mins	Mica	Feld.	Qtz.
GC01	0	clayey foram ooze	35	25	40	fs	+	+		5	53							40				2
	38	quartz bearing foram clay	60	20	20	vfs	+			7	30				1	+		60				2
	50	quartz bearing silty clay	70	20	10	vfs-z ^ms					+	5	+		+	+		90				5
	70	quartz bearing silty clay	70	20	10	vfs-z ^ms					+	5	+		+	+		90				5
	93	quartz bearing silty clay	70	20	10	vfs-z ^ms					+	5	+		+	+		88				7
	122	quartz bearing silty clay	70	20	10	fs ^ms					+	5	+		+	+		90				5
	160	quartz bearing silty clay	70	20	10	vfs-z ^ms					+	5	+		+	+		88				7
	208	quartz bearing silty clay	70	20	10	vfs-z ^ms					+	5	+		+	+		88				7
	262	quartz bearing silty clay	70	20	10	vfs-z ^ms					+	5	+		+	+		90				5
	304	quartz bearing silty clay	70	20	10	vfs-z ^ms					+	5	+		+	+		90				5
	358	quartz bearing silty clay	70	20	10	vfs-z ^ms					+	5	+		+	+		90				5
GC04	0	clayey nanno foram ooze	60	20	20	vfs	+			20	40				+			40		+	+	+
	35	nanno foram clay	60	15	25	vfs	+			10	40				+			46			1	3
	57	foram sand	10	10	80	ms	1	1		+	79						10	5	+	2	+	2
	77	silty foram clay	80	15	5	vfs-z	+			10	28							60				2
	102	foram sand	5	15	80	fs	+	+		+	83						5	5	+	3		4
	128	silty foram clay	70	20	10	vfs-z				10	28				1	+		60		+		1
	152	silty foram clay	70	20	10	vfs-z				10	28				1	+		60		+		1
	207	silty foram clay	70	20	10	vfs-z				10	28				1	+		60		+		1
	237	micaceous foram sand	20	20	60	vfs	1				60							20		15	1	3
	247	silty foram clay	70	20	10	vfs-z				10	28				1	+		60		+		1
GC05	0	clayey nanno foram ooze	40	10	50	fs	+	+		10	50				1			38		+		1
	16	clayey nanno foram ooze	40	10	50	fs	+	+		10	50				1			38		+		1
	120	clayey nanno foram ooze	40	10	50	fs	+	+		10	50				1			38		+		1
	128	clayey nanno foram ooze	40	10	50	fs	+	+		10	50				1			38		+		1
	170	clayey nanno foram ooze	40	10	50	fs	+	+		10	50				1			38		+		1
GC06	4	clayey nanno foram ooze	30	20	50	fs	+			5	60				1			32		1		1
	18	clayey nanno foram ooze	30	20	50	fs	+			5	60				1			32		1		1
	35	clayey nanno foram sand	30	20	50	vfs	+			20	60				2			15				3
	78	clayey nanno foram ooze	30	20	50	fs	+			5	60				1			32		1		1
GC07	10	clayey foram ooze			10	fs																
	100	clayey foram ooze				ms																
	170	foram rich clay																				
	220	clayey foram ooze										GC07 samples examined for texture										
	250	clayey foram ooze										and sediment name only.										
	285	foram sand				ms																
	370	foram rich clay																				
	470	clayey foram ooze																				
	520	clayey foram ooze																				
GC11	5	clayey foram ooze	40	20	40	fs	+			4	50				+			45				1
	21	clayey foram ooze	40	20	40	fs	+			8	46				+			45				1
	40	foram sand	15	15	70	fs ^ms	+			2	86							10				2
	100	clayey foram ooze	40	20	40	fs	+			4	50				+			45				1
	116	clayey foram ooze	40	20	40	fs	+			4	50				+			45				1
	130	clayey foram ooze	40	20	40	fs	+			4	50				+			45				1
	150	clayey foram ooze	40	20	40	fs	+			4	50				+			45				1
	190	clayey foram ooze	40	20	40	fs	+			4	55				+			40				1
	210	foram silty sand	15	20	65	fs ^ms	+			2	86							10				2
	230	foram silty sand	15	20	65	fs ^ms	+			2	86							10				2
	255	clayey foram ooze	40	20	40	fs	+			4	50				+			45				1
GC14	60	nanno bearing foram clay	50	20	30	fs	+			10	40				+			50		+		
	150	clayey nanno foram ooze	40	10	50	ms	+			10	50							40		+	+	+
	192	nanno foram clay	70	10	20	fs				20	20							60		+	+	+
GC15	130	clayey nanno foram ooze	40	10	50	fs	+			10	50							40		+	+	+
	142	clayey nanno foram ooze	40	10	50	fs	+			10	55				1			34	+		+	+
	165	clayey nanno foram ooze	40	10	50	fs	+			10	55				1			34	+		+	+
	190	foram silty clay	75	20	5	vfs	+			5	25				+			70				
	200	foram silty clay	65	25	10	vfs	+			5	35				+			60				
	230	clayey nanno foram ooze	40	10	50	vfs	+			5	50				+	+		45		+		
	270	foram silty clay	60	25	15	vfs	+			5	35				+			60				
GC16	40	clayey nanno foram ooze	30	10	60	vfs	+	+		5	60				+			35	+			
	60	clayey foram ooze	40	10	50	fs	+	+		1	54				+	+		45		+		+ +
	80	nanno foram clay	60	10	30	fs	+	+		10	30							60			+	+
	130	nanno foram silty clay	55	10	35	fs	+	+		5	35							60			+	+
	226	nanno foram silty clay	75	15	10	vfs	+	+		10	30					+		60		+		+
GC17	5	foram clay	60	20	20	vfs	+	+		2	40				+			58		+		+
	30	foram clay	60	10	30	vfs	+	+		2	40				+			58		+		+
	100	foram clay	60	20	20	vfs	+	+		2	40				+			58		+		+
	120	foram clay	65	20	15	vfs-z	+	+		2	35				+			63		+		+

AGSO cruise 147 sediment smear slide data - March 1995

SAMPLE		SEDIMENT NAME	TEXTURE				MINERALOGY (%)															
Type No.	Depth (cm)		Clay %	Silt %	Sand %	Sand Grain size	Spng Spic.	Rad	Diat.	Calc. nann	For- ams	Carb.	Zeol.	Mn	Pyr.	Volc. Glass	Recy Seds	Clay	Hvy Mins	Mica	Feld.	Qtz.
	145	clayey nanno foram ooze	45	15	40	fs	+			5	50				+			45		+		
	195b	clayey foram ooze	40	20	40	fs	+			1	60				+			39			+	+
	195s	silty foram clay	60	30	10	vfs	+			+	40				+			60		+		+
	220	foram clay	60	15	25	vfs	+	+		2	40				+			58		+		+
GC18	2	foram mang. clayey sand	30	10	60	ms	+			1	20			40	?	+		39			+	+
	25b	mang. bearing foram clay	50	15	35	ms				1	40			4	?			55		+		+
	25s	quartz bearing mang. clay	75	15	10	ms	+	?			1			20	?			74				5
	225	clay	95	5	0	-					1		2					95				2
	229	foram mang. bearing clay	85	5	10	ms	+				5			10	?	+		84				1
GC20	10	foram sand	5	5	90	ms	+	+		1	95				+			4				
	25	clayey foram sand	40	15	45	fs ^ms	+	+		1	60				1	+		38				+
	100	nanno foram clay	55	10	35	fs	+			5	40							55				+
	200	foram sand	5	5	90	vfs	+	+		1	95				+			4				
	250	clayey foram sand	40	15	45	fs ^ms	+	+		1	60				1	+		38				+
	320	foram sand	10	10	80	ms	+	+		5	80				+			15				
GC21	2	clayey foram ooze	35	20	45	fs	1	1		1	55				+			42				+
	104	foram clay	35	20	45	fs	1	1		1	45				+			52				+
	125	clayey foram sand	20	15	65	vfs	1	1		3	75							20				
	145	clayey foram sand	30	10	60	fs	1	1		3	65							30				
	215	clayey foram sand	20	15	65	vfs	3	2		3	67							25				
GC26	cc	foram sand	10	10	80	ms	+	+		3	85							10				2
GC28	10	clayey nanno foram ooze	50	10	40	vfs	+	+		10	40				1			47				2
	50	clayey foram sand	25	15	60	fs	+			5	65				+	+		29				1
	65	sandy foram nanno clay	65	15	20	vfs	+			38	30				1			30				1
	95	sandy nanno foram clay	65	15	20	vfs	+			33	35				1			30				1
	143b	clayey nanno foram ooze	40	15	45	fs	+			20	45		+			+		35				+
	143s	sandy foram nanno clay	60	15	25	vfs	+	+		30	25							45				+
	160	clayey nanno foram ooze	50	10	40	vfs	+	+		15	40				1			42				2
	218	clayey nanno foram ooze	40	10	50	fs	+			10	50				+			40				+
	266	sandy foram nanno clay	65	15	20	vfs	+			38	30				1			30				1
GC30	10	clayey foram ooze	45	15	40	vfs ^ms	+			1	45					+		53				1
	27	silty foram ooze	35	25	40	fs-ms	+			3	55							41				1
	67	clayey nanno foram sand	35	5	60	fs-ms	+	+		8	61							30				1
	100	clayey nanno foram ooze	50	10	40	fs	+			5	44					+		50				1
	190	clayey nanno foram sand	35	5	60	fs-ms	+	+		8	61							30				1
	230	silty foram ooze	35	25	40	fs-ms	+			3	55							41				1
	280	clayey nanno foram sand	35	5	60	fs-ms	+	+		8	61							30				1
	350	silty foram clay	75	20	5	vfs-z	+			2	10							87				1
	365	silty nanno foram ooze	30	40	30	vfs	+			30	50					+		20				+
GC31	5	clayey nanno foram ooze	55	10	35	vfs-z	1	+		10	40				1	+		47		+		1
	69	clayey nanno foram ooze	53	10	37	vfs-z	1	+		10	40				1	+		45		+		3
	81	clayey nanno foram ooze	50	10	40	fs-vfs	1	+		8	45				1	+		42		1		2
	129	clayey nanno foram ooze	50	10	40	fs-vfs	1	+		8	45				1	+		42		1		2
	169	clayey nanno foram ooze	55	10	35	vfs-z	1	+		12	40				1	+		45		+		1
	215b	clayey nanno foram sand	25	15	60	fs	1			10	70				2			15				2
	215s	clayey nanno foram ooze	45	15	40	fs-z	1			15	51				2			30				1
	326	silty nanno foram sand	15	20	65	ms	1			5	75							15		1		3
	369	clayey nanno foram ooze	55	10	35	vfs-z	1	+		12	40				1	+		45		+		1
	436	clayey nanno foram ooze	55	10	35	vfs-z	1	+		12	40				1	+		45		+		1
	523	clayey nanno foram ooze	55	10	35	vfs-z	1	+		10	40				1	+		47		+		1
GC32	5	clayey nanno foram ooze	45	15	40	fs ^ms	+	+		20	45				1	+		33		+		1
	32	clayey nanno foram ooze	45	15	40	fs ^ms	+	+		20	45				1	+		33		+		1
	60	clayey nanno foram ooze	50	10	40	fs ^ms		+		25	43				1	+		30		+		1
	81b	clayey nanno foram sand	30	10	60	fs ^ms	rare			20	58				1			20				1
	81s	clayey nano foram ooze	50	10	40	fs		+		20	40							39		+		1
	172	clayey nanno foram ooze	45	15	40	fs ^ms		+		20	45				1	+		33		+		1
	218	clayey nanno foram ooze	45	15	40	fs ^ms		+		18	50				1	+		30		+		1
	222	clayey nanno foram ooze	45	15	40	fs ^ms		+		20	45				1	+		33		+		1
	260	clayey nanno foram ooze	45	15	40	fs ^ms	+	+		20	45				1	+		33		+		1
GC34	5	foram bearing silty clay	65	30	5	vfs-z	1			5	10				1	+		82		+		1
	30	foram bearing silty clay	65	30	5	vfs-z	1			5	10				1	+		82		+		1
	42	foram bearing silty clay	60	30	10	vfs	1			5	15				1	+		75		+		3
	90	foram bearing silty clay	65	30	5	vfs-z	1			5	10				1	+		82		+		1
	183	clayey foram ooze	40	20	40	fs ^ms	1	+		2	45							45		5		2
	185	quartose foram sand	10	20	70	fs ^cs	+	+		+ +	80							11		3		6
	197	quartose foram sand	10	20	70	ms	+	+		+ +	80							11		3		6
	242	*? pyritic clay	43	? 50	7	vfs-z				5	5				*? 50			38				2
	270	clayey foram ooze	40	20	40	fs ^ms	1	+		2	45							45		5		2
	370	foram bearing silty clay	65	30	5	vfs-z	1			5	10				1	+		82		+		1

AGSO cruise 147 sediment smear slide data - March 1995

SAMPLE		SEDIMENT NAME	TEXTURE								MINERALOGY (%)										
Type No.	Depth (cm)		Clay %	Silt %	Sand %	Sand Grain size	Spng Spic.	Rad	Diat.	Calc. nann	For-ams	Carb.	Zeol.	Mn	Pyr.	Volc. Glass	Recy Seds	Clay	Hvy Mins	Mica	Feld.	Qtz.
	438	quartose foram sand	15	20	65	fs ^cs	+	+		+ +	75							16		3		6
	510	foram bearing silty clay	65	30	5	vfs-z	1			5	10				1	+		82		+		1
GC35	1	foram sand	10	20	70	vfs		+		2	85							11				2
	5	foram sand	15	20	65	ms	+	+		5	78							15				2
	30	clayey foram ooze	40	20	40	fs ^ms	+			5	50					+		43				2
	70	clayey nanno foram ooze	50	20	30	vfs	+	+		20	42				1	+		35				2
	100	clayey foram ooze	40	20	40	fs ^ms	+			5	50					+		43				2
	140	foram nanno clay	65	15	20	vfs		+		30	25							44				1
	185	clayey nanno foram ooze	50	20	30	vfs	+	+		20	42				1	+		35				2
	200	clayey nanno foram ooze	50	20	30	vfs	+	+		15	45				1	+		37				2
	209	clayey nanno foram ooze	50	20	30	fs	+	+		20	42				1	+		35				2
	kk	glassy zeol. qtz. silty clay	50	40	10	fs ^ms				2			15		* 5	10		50		3		15
GR01	-	foram sand	10	15	75	ms-fs	+	+		5	90		? +					2				3
GR02	-	clayey nanno foram sand	20	10	70	fs ^ms	+	+		5	70				2			20		+		3
GR03	-	clayey nanno foram sand	15	10	75	fs ^ms	+	+		5	79							15				1

GC = gravity core, GR = bottom grab, cc = core catcher, kk = core cutter, Mn = manganese micmodules and flakes, z = silt, vfs = very fine sand, ^ms = up to medium sand, cs = coarse sand, + = trace amounts, ? = mineral tentatively identified in trace amounts,

*? = silt sized opaque clumps (possibly framboidal pyrite)

APPENDIX 10: X-RAY DIFFRACTION PRELIMINARY REPORT ON NEOGENE CARBONATES FROM AGSO CRUISE 147

Julienne Kamprad, AGSO

These analyses concentrated on the carbonate and apatite minerals. The feldspar in samples NE 7 and NE 8 is noteworthy. HCl was applied to the powdered samples and all fizzed. Blank spaces indicate mineral not detected.

Lab no.	Sample no.	HCL react	Calcite	Apatite	Quartz	K-felds	Plagioclase
NE 2	147DR11C1	+ve	major	(Fluorapatite) minor	trace		
NE 3	147DR11C2	+ve	trace to minor	(Fluorapatite) major	trace		
NE 4	147DR38C2	+ve	trace to minor	(Carbonate-hydroxylapatite) major	trace		
NE 1	147DR38C3	+ve	major	(Fluorapatite) minor			
NE 5	147DR44B2	+ve	major	trace	minor		
NE 6	147DR44B3	+ve	major	trace	minor		
NE 7	147DR55B2	+ve	trace to minor		major	major	
NE 8	147DR55B3	+ve	minor		major		minor