Bureau of Mineral Resources, Geology & Geophysics

R E C O R D

RECORD 1989/4

RESEARCH CRUISE PROPOSAL

LIGHT HYDROCARBON GEOCHEMISTRY OF THE BASS, OTWAY, STANSBURY AND GIPPSLAND BASINS, AND TORQUAY SUB-BASIN, SOUTHEASTERN AUSTRALIA

PROJECT 9131.20

Principal Investigators:- D.T.Heggie and G.W.O'Brien

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EXECUTIVE SUMMARY

The measurement of the concentrations and molecular compositions of light hydrocarbon gases within the water column overlying offshore sedimentary basins can provide, under suitable circumstances, significant information on hydrocarbon source rock maturity and/or type, and the most likely locations for petroleum accumulation within basins. These measurements are usually made using a hydrocarbon 'sniffer', which comprises a submersible fish which is towed near the seafloor, and from which water is pumped to the surface and continuously analysed via gas chromatography. Compared with overseas, relatively few 'sniffer' surveys have been carried out around Australia, and hence the applicability and usefullness of this technique to the Australian situation is as yet undetermined.

As a continuation of its geochemical research program, the Division of Marine Geosciences and Petroleum Geology (Australian Bureau of Mineral Resources) will conduct a co-operative geochemical research survey with Transglobal Exploration and Geoscience (TEG) of Leucadia, California, USA, in southeastern Australia between February 1 and March 2, 1989. The cruise will be of 30 days duration and will involve work in the Gippsland, Bass, Otway and Stansbury Basins and the Torquay Sub-basin. A detailed proprietary program will be carried out in the Bass and Stansbury Basins in co-operation with Amoco Production Company. Two regional lines will be run from the Torquay Sub-basin, across the Cape Otway-King Island High, to the Crayfish Platform in the west of the Otway Basin (see Fig. 2). Regional lines will also be run in the Gippsland Basin, with an additional detailed program over several known oil and/or gas accumulations. In addition to the water column geochemistry, a limited sampling program will investigate the light hydrocarbon geochemistry of sediments over known oil and gas fields in the Gippsland Basin.

INTRODUCTION

The majority of the world's hydrocarbons have been discovered via exploration around known oil and gas seeps (Link, 1952; Philp & Crisp, 1982). In spite of this, geochemical exploration techniques, which attempt to detect subsurface hydrocarbon accumulations by the analysis of light hydrocarbon (C_1-C_5) gas concentrations and compositions at or near the Earth's surface, have enjoyed a rather chequered history with respect to popularity, credibility and success within the oil exploration industry. These geochemical prospecting techniques can be very broadly subdivided into three types, which involve the analysis of gases in:- i.) soils (onshore); ii.) the water column (offshore); and iii.) sediments (offshore).

All geochemical prospecting methods rely upon relatively mobile light hydrocarbons migrating from petroleum accumulations to the surface by mechanisms such as diffusion and migration along microfractures and fault systems. The interpretation of light hydrocarbon gas data is complicated by the fact that light hydrocarbons (predominantly methane) can also be produced by microorganisms in near-surface anoxic zones. In addition, methane oxidizing bacteria are common in near-surface oxic zones, and can rapidly consume thermogenic hydrocarbons migrating to the surface.

In offshore areas, the principal geochemical prospecting technique employed involves the direct, underway measurement of dissolved hydrocarbon gases within seawater (e.g. Interocean's 'sniffer'). This device commonly consists of a towed "fish", which is attached to a ship via a special faired tubing containing hose, electrical and support cables (Sackett, 1977). The fish is towed near the sea bottom, and seawater is continuously pumped to the ship, where the light hydrocarbon gases are stripped and analysed by gas chromatography. It is essential that the fish be towed as close to the seafloor as possible because the concentration of seeping hydrocarbons is very rapidly diluted once the gas escapes from the seafloor. Moreover, ocean current activity disperses the gas and makes it difficult to accurately relate any anomaly detected by underway geochemical methods to its point source. For these reasons, the technique may be best suited to locating fairly major seeps and these are most common in tectonically and seismically active basins (Reed and Kaplan, 1977). Since most of the data obtained during underway geochemical surveys are proprietary, an evaluation of the usefulness of the method in actually delineating subsurface hydrocarbon occurrences is difficult.

The BMR Division of Marine Geosciences and Petroleum Geology has entered into a joint research program with Transglobal Exploration and Geoscience (TEG) to study the nature of seafloor gas seeps around the Australian continental margin. The geochemical analysis system that will be installed aboard 'Rig Seismic' is shown schematically in Figure 1. The laboratory system will analyse a variety of gases extracted from seawater, including C_1-C_8 hydrocarbons and CO_2 with facilities to collect gases for shore-based isotopic analyses. The system is designed to be deployed in conjunction with other remote sensing techniques, including high resolution seismic, 3.5 and 12 kHz sub-bottom profilers and side-scan sonar.

OBJECTIVES

As part of the Bureau of Mineral Resources Continental Margin Program, a 30-day geochemical reasearch program (Fig. 2) will be conducted in conjunction with Transglobal Exploration and Geoscience (TEG) of Leucadia, California, USA. The principal objectives of the program are to:-

1. to develop new information on source-rocks, maturation, and hydrocarbon migration within the Otway, Bass, Gippsland and Stansbury Basins, and the Torquay Sub-basin.
2. test the relationship between variations in source-rock maturation (as derived from well data and geohistory analyses) and the hydrocarbon gas composition and distribution within the overlying water and surface sediments from the basins.
3. to evaluate the usefulness and applicability of continuous underway detection of light hydrocarbons in seawater in the assessment of basin prospectivity. Specifically the method will be examined with respect to:-
    i. detecting subsurface hydrocarbon accummulations.
    ii. determining both regional and local variations in source rock type and/or maturity from the compositional characteristics of seeps.
    iii. comparing and contrasting the light hydrocarbon geochemistry of the sediments with that of the overlying water column.

4. to determine the relationship between gas macroseepage, seafloor

morphology and sub-seafloor geology. This will be done by integrating the underway geochemical data with side-scan sonar and high resolution seismic (15 cu. in. water gun) data.

GEOCHEMICAL RESEARCH PROGRAM

OTWAY BASIN - TORQUAY SUB-BASIN

A number of factors suggest that the Otway Basin is an attractive area for the application of geochemical prospecting techniques. For example, bitumen strandings are common along the coasts of Victoria and South Australia (Sprigg, 1986). These strandings are more common after earthquakes, suggesting that reservoired oil is migrating to the seafloor along fault planes reactivated by the tectonic activity. The strandings are most common in the western Otway Basin, where faulting can extend all the way through the Tertiary sequence to the sea-floor (Williamson et al., 1987).

Gas seeps have been discovered within the offshore Otway Basin (Sprigg, 1986). Two seeps were located during an Interocean Systems 'sniffer' survey conducted in 1981 for Shoreline Exploration Company and Ultramar Australia Ltd in EPP-18 (South Australia). One seep was located inshore from the Argonautl exploration well, near Lake Bonney and the other was located near Breaksea Reefl, off Cape Northumberland. The latter gas seep, which was clearly visible on side-scan sonar records (Sprigg, 1986), was apparently located over an infilled submarine canyon which had incised into and breached, the Miocene Mount Gambier Limestone.

Encouraging preliminary results were obtained during BMR sediment geochemical programs conducted in early 1987 (McKirdy & Heggie, 1987; Heggie et al., 1988) and mid-1988 (Heggie & O'Brien, 1988; O'Brien & Heggie, 1989). These studies indicated that thermogenic hydrocarbons generated within deeply buried source rocks were migrating into the near-surface sediments, with migration facilitated by deep-seated fault systems. A significant outcome of the studies by Heggie & O'Brien (1988) and O'Brien & Heggie (1989) was that thermogenic gases were significantly 'wetter' on the basin margins, namely the Crayfish and Mussel Platforms (Figs. 3 & 4). The wettness of the gases was correlated with the maturity of the basal Early Cretaceous; where the basal Early Cretaceous was overmature, the gases were dry, but where the Early Cretaceous was within the oil window, the gases were wetter . This was particularly noticable as the Otway Group shallowed towards the Cape Otway-King Island High.

The underway water column geochemical program, complimented by combinations of side-scan sonar and high resolution seismic data acquisition, will consist primarily of a transit across the Otway Basin along previously shot (BMR Survey 48) seismic lines (Fig. 5 and Table1) and other select areas including:-

i. the reported seeps in the vicinity of Cape Northumberland and Lake Bonney.

ii. undrilled geological structures on the Crayfish Platform, west of the Crayfish1 exploration well.

iii. a survey across the Cape Otway-King Island High to investigate the previously-defined wet thermogenic gas anomalies within the surface sediments (Heggie & O'Brien, 1988).

iv. undrilled geological structures within the Torquay Sub-basin (within Vic P28).

The above program will examine the relationship betwen the wet gas contents of seeps and the variations in source rock maturity across the basin.

BASS BASIN

A detailed proprietary underway geochemical water column program will be conducted within the Bass Basin (exploration permits T/14P, -15P, -18P, -22P) in collaboration with TEG and AMOCO Production Company (see Fig. 6 and Table 2). In addition, a side-scan sonar survey will be carried out to relate geochemically-defined macro-seeps to seafloor morphology.

STANSBURY BASIN

A regional proprietary underway geochemical water column program will be conducted within the Stansbury Basin in collaboration with TEG and AMOCO Production Company (see Fig. 2 and Table 3). A side-scan sonar survey will also be carried out in conjunction with this study.

GIPPSLAND BASIN

The geochemical program in the Gippsland Basin will be a combination of underway geochemical (water column) data acquisition, sediment geochemistry, side-scan sonar and high resolution seismic collection. The program will involve:-

i. underway geochemistry along a previously sampled (Heggie & O'Brien, 1988) seismic lines (BMR line 40/01) (Fig. 7).

ii. underway geochemistry along BMR seismic line 40/02.

iii. detailed underway geochemical surveys over several drilled and undrilled structures, which include known hydrocarbon accumulations (e.g. Baskerl, Basker Southl, Mantal, Chimaeral, Solel (Fig. 8, Table 4). Hydrocarbon gas analyses of sediments will be carried out in conjunction with the underway geochemistry at selected locations.

iv. reconnaisance underway geochemical surveying over known hydrocarbon accumulations including Barracouta, Snapper, Tuna and Flounder (Fig. 9, Table 5).

SURVEY TIMETABLE

Departure date from Melbourne:- February 1, 1989.

8 days Otway Basin.
14 days Bass Basin.
1 day Stansbury Basin.
6 days Gippsland.

Return to Melbourne:- March 2, 1989.

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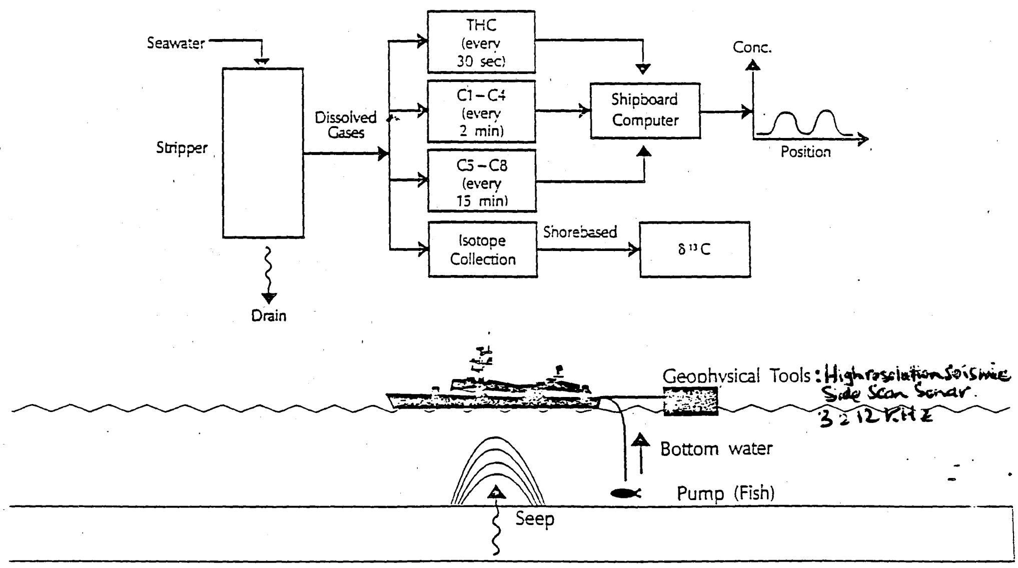

Figure 1. Schematic of shipboard operations conducted during acquisition of underway geochemical data.

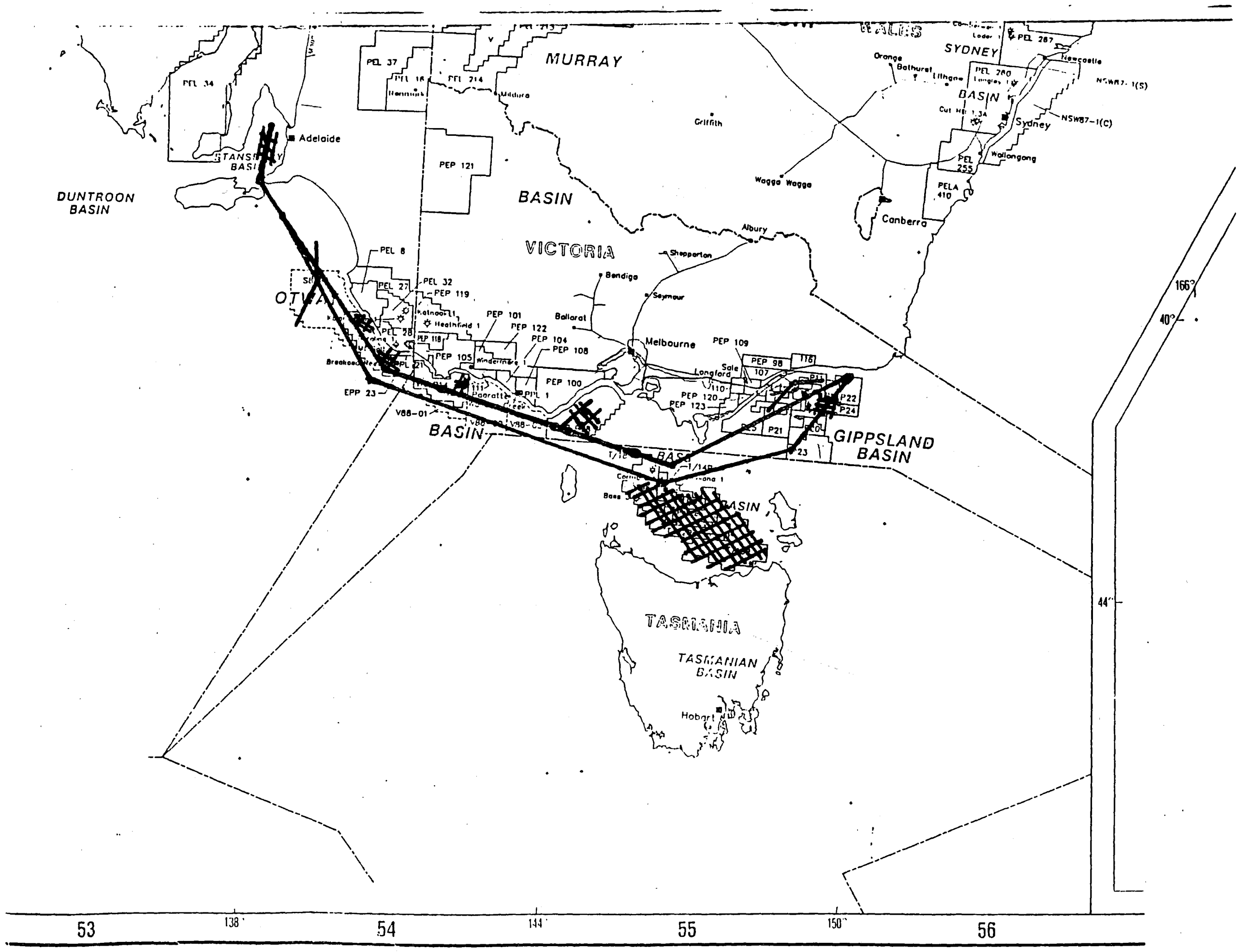

Figure 2. Map showing proposed underway geochemical sampling lines in the Otway, Bass, Gippsland and Stansbury Basins. Cross-hatching delineates areas of detailed work.

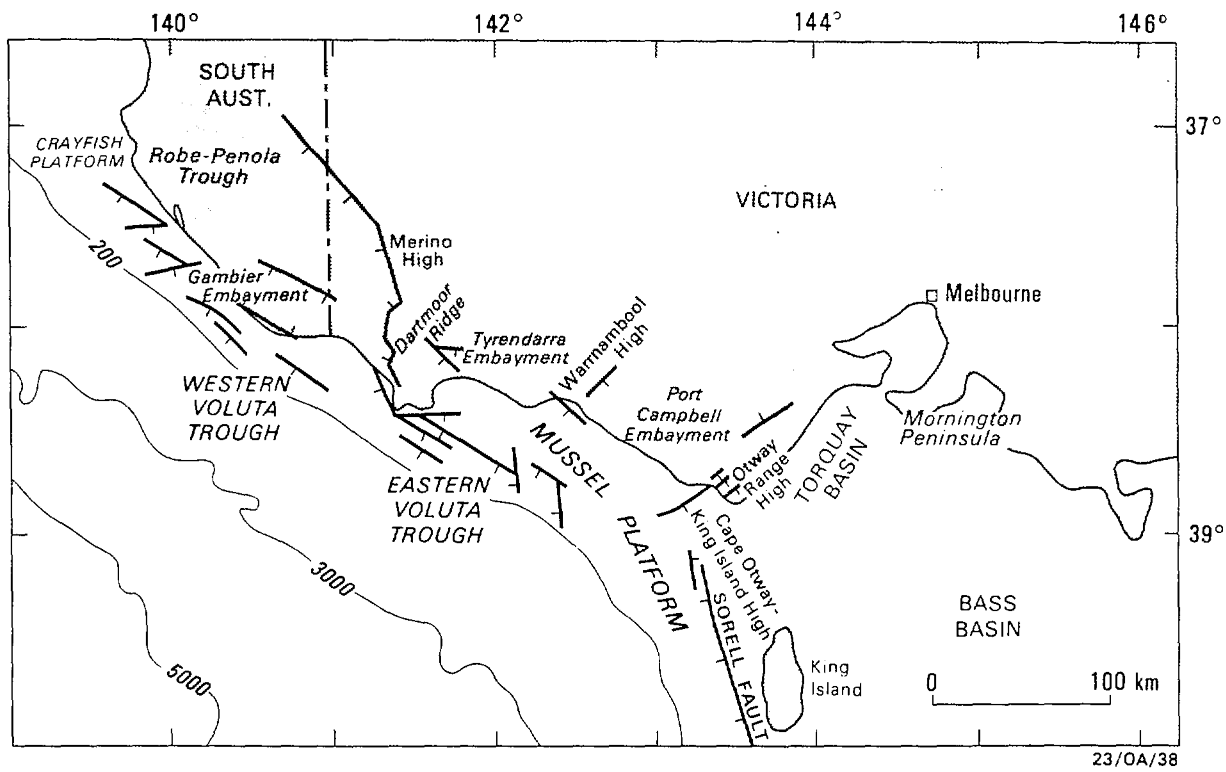

Figure 3. Structural elements of the offshore Otway Basin (after Williamson et al. (1987).

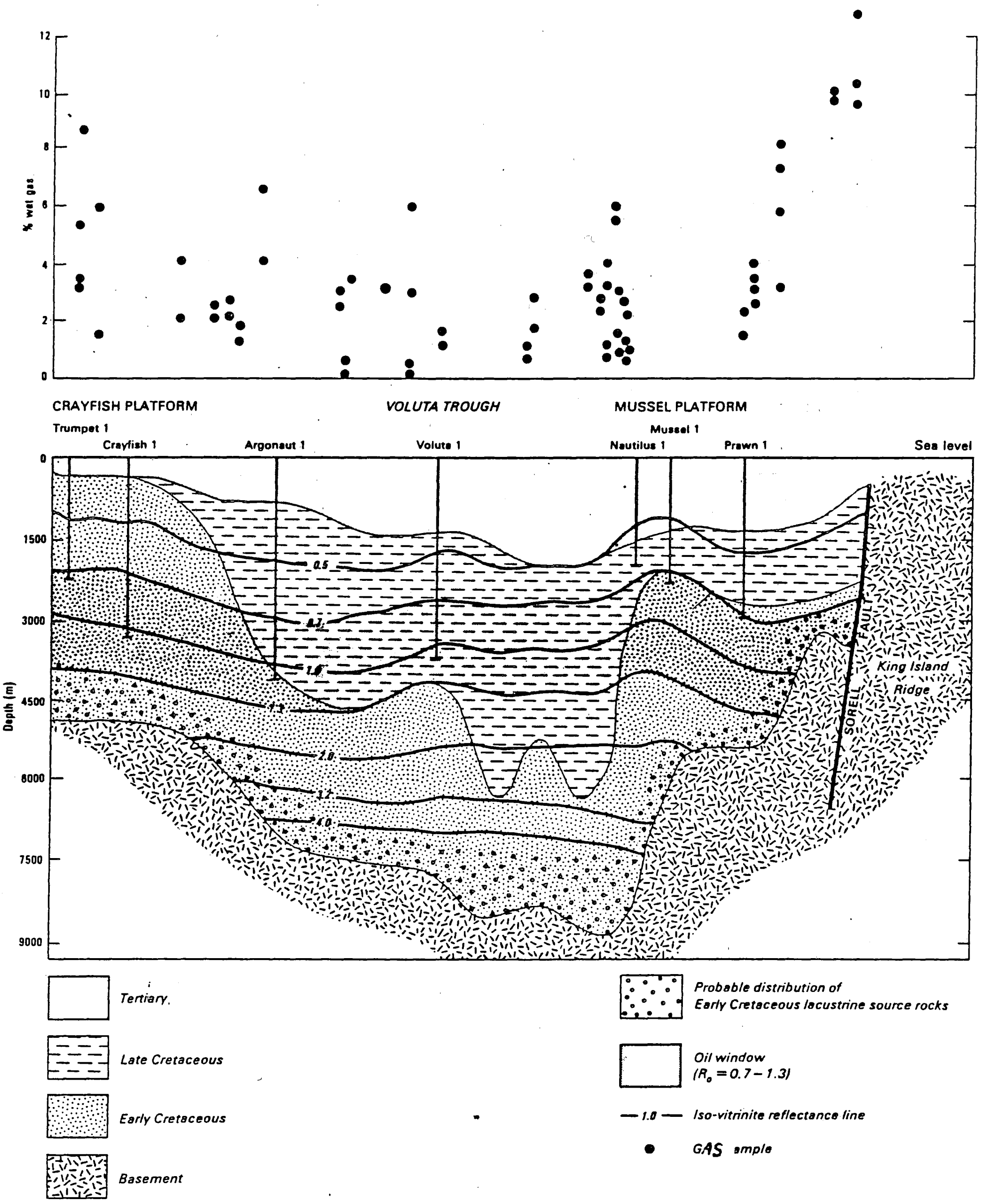

Figure 4. Schematic Otway Basin cross-section, showing interpreted vitrinite reflectance and wet gas content of thermogenic anomalies across the basin. (after Heggie & O'Brien, 1988; O'Brien & Heggie, 1989).

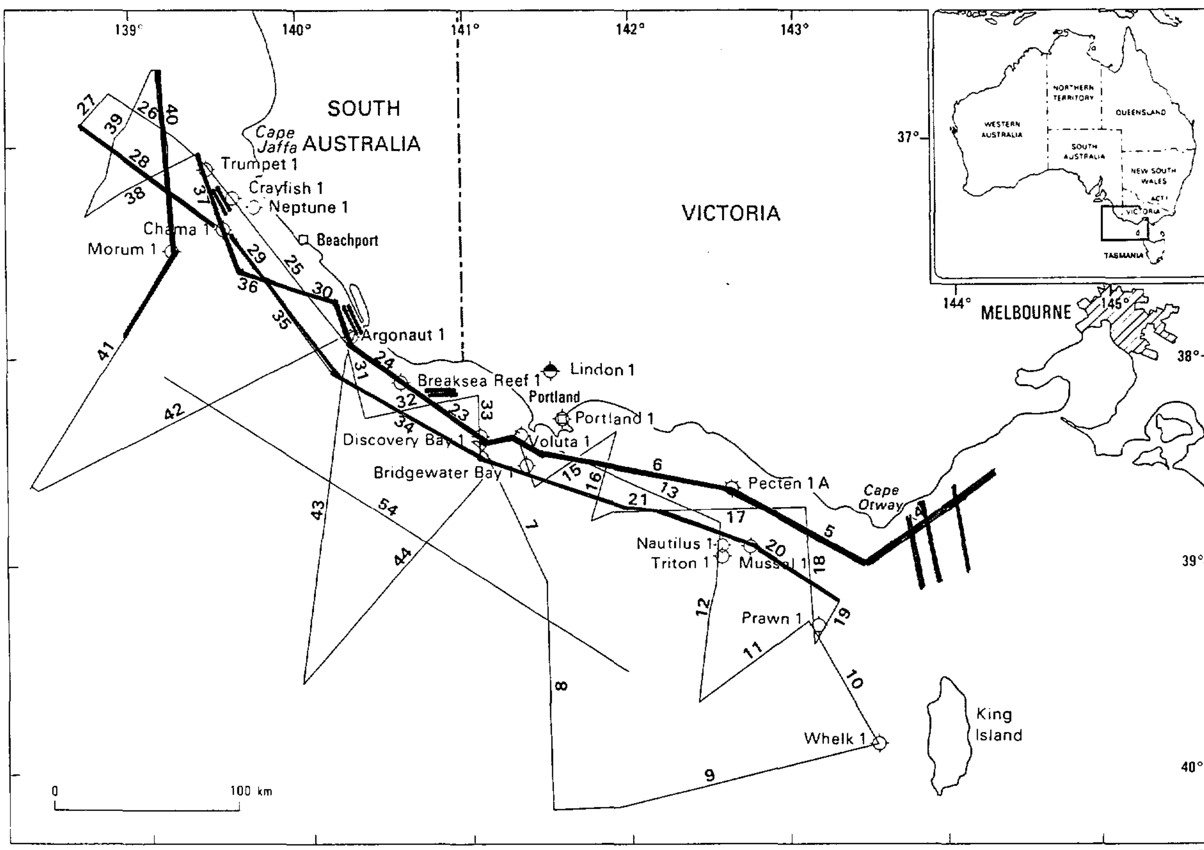

Figure 5. Map showing location of BMR seismic lines collected during Survey 48 (1985). Underway geochemical surveying will be carried out in the Otway Basin and Torquay Sub-basin in highlighted areas. Torquay Sub-basin program developed in collaboration with Shell Australia.

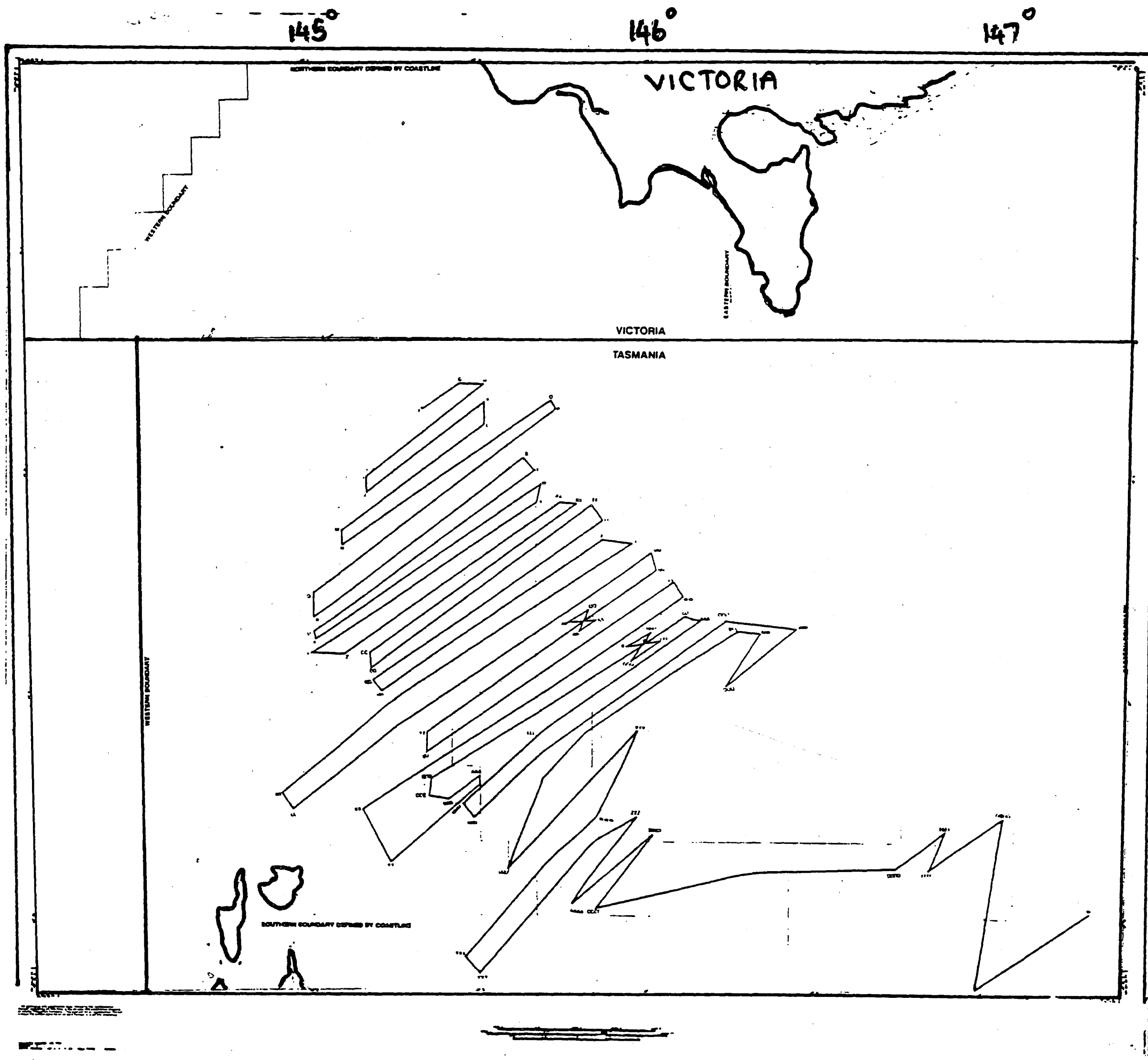

Figure 6. Map showing locations of underway geochemical program in the Bass Basin. Geochemical program developed in collaboration with AMOCO Production Company (Houston, Texas, USA).

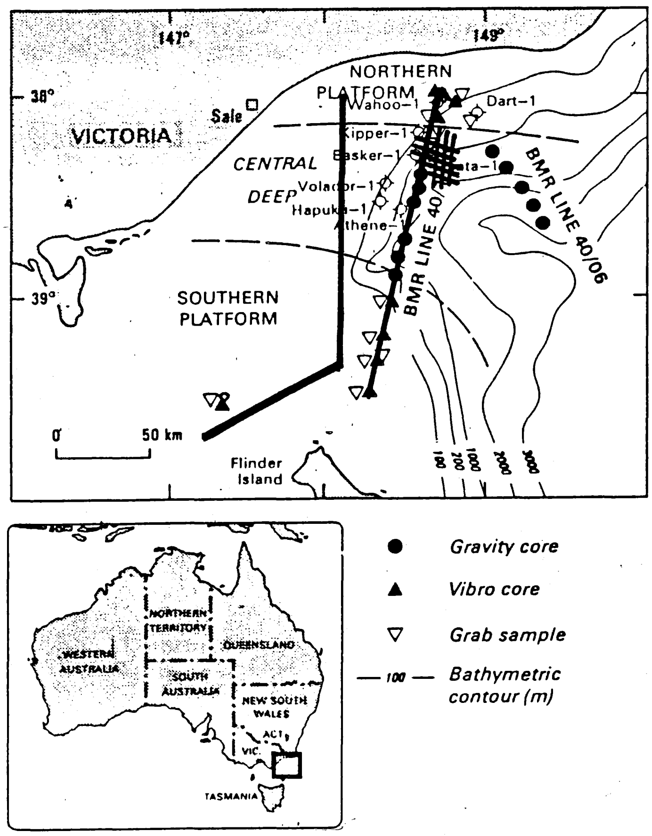

Figure 7. Map showing locations of regional underway geochemical lines in the Gippsland Basin. The locations of sediment samples taken during the 1988 Gippsland Basin geochemical program, bathymetry, and selected exploration well locations are also shown.

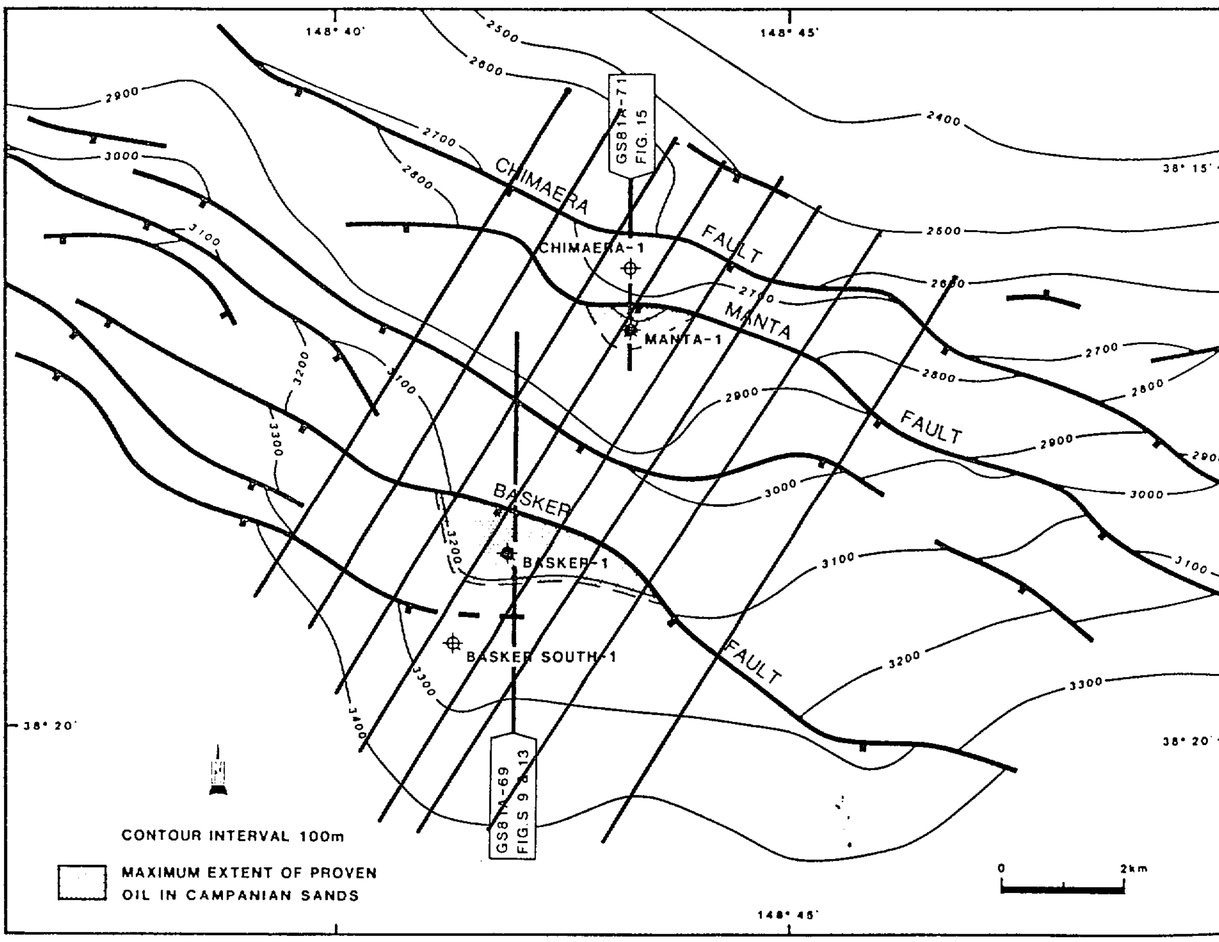

Figure 8. Depth structure map of the Basker/Manta area in the Gippsland Basin, with proposed underway geochemistry tracks. Program developed in conjunction with Shell Australia.

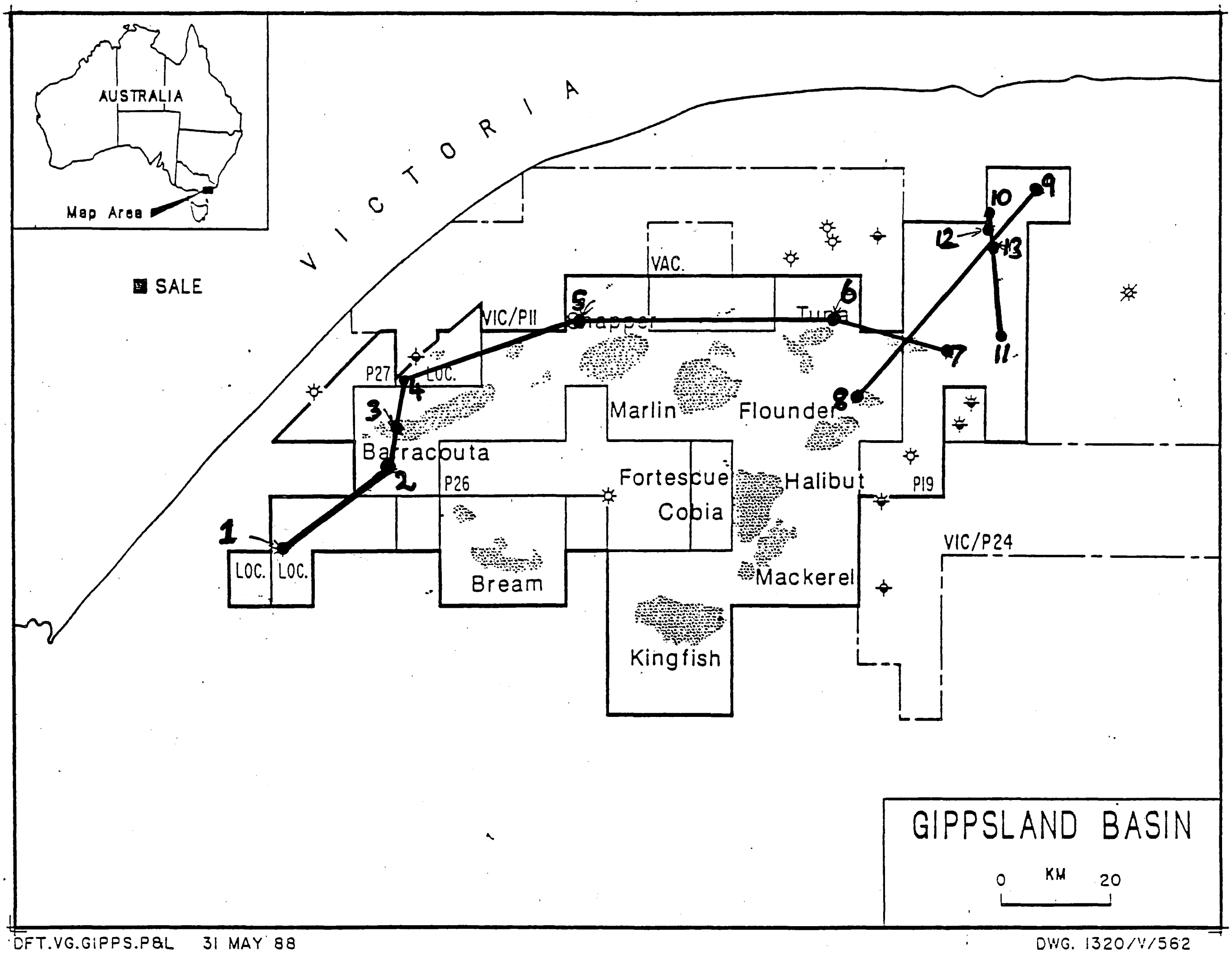

Figure 9. Locations of proposed underway geochemical program around major oil/gas fields in the Gippsland Basin. Program developed in collaboration with ESSO Australia.

TABLE 1: WAY POINTS FOR THE OTWAY BASIN AND TORQUAY SUB-BASIN GEOCHEMICAL PROGRAM.

OTWAY BASIN

BMR Line	Latitude (°S)	Longitude (°E)	Length of line (km)
48/05	39 03.500	143 25.999	120
48/06	38 40.700	142 39.901	86
48/23	38 26.000	141 06.599	52
48/24	38 09.660	140 36.480	33
48/25	37 54.700	140 13.099	106
48/26	37 07.750	139 27.700	66

TABLE 1 (CONTINUED).

TORQUAY SUB-BASIN

Line nos.		Latitude (^{o}E)	Longitude (^{o}S)
48/04		38 37.200	144 14.400
48/05		39 03.500	143 25.999
OS88A-12		38 41 14.7	143 52 44.9
		38 30 29.8	144 54 57.6
	-15	39 00 8.4	144 12 54.3
		38 32 1.0	144 04 59.9
	-17	38 59 1.9	144 16 8.4
		38 29 14.6	144 07 51.8

TABLE 2: WAY POINTS FOR BASS BASIN GEOCHEMICAL SURVEY - TURNING POINT CO-ORDINATES.

Latitude (°E)	Longitude (°S)
38°37'10.10	144°58'49.35
39°10'09.96	144°43'25.03
39°10'31.05	144°52'07.41
38°58'03.80	144°57'13.50
39°09'21.81	144°59'52.40
38°41'26.06	145°28'06.33
38°54'14.23	145°42'20.63
39°12'08.43	145°03'12.10
39°21'51.49	145°20'09.10
39°18'29.29	145°26'32.26
39°18'32.29	145°30'49.57
39°31'06.47	145°09'54.86
39°33'04.17	145°10'04.59
39°20'54.85	145°31'00.21
39°24'01.57	145°30'57.87
39°38'14.92	145°09'27.29
39°40'12.79	145°05'38.92
39°20'38.68	145°42'47.44
39°21'47.09	145°43'40.57
39°46'31.76	145°00'36.07
39°49'51.43	145°00'36,40
39°28'29.40	145°37'50.21
39°30'08.06	145°39'51.03
39°51'44.31	145°00'35.31
39°52'43.70	145°00'55.23
39°32'01.77	145°40'57.55
39°34'28.67	145°40'10.73

39°54'31.75	145°00'17.97
39°54'47.24	145°05'53.02
39°34'23.56	145°44'25.88
39°34'33.78	145°47'19.56
39°54'40.26	145°10'30.80
39°56'45.95	145°10'38.09
39°34'45.56	145°50;01.85
39°36'47.86	145°51'51.68
39°58'19.66	145°10'58.84
39°59'52.46	145°12'37.00
39°39'25.17	145°51'50.85
39°39'53.39	145°57'03.09
40°00'41.52	145°15'31.52
40°13'29.06	144°54'37.71
40°15'43.62	144°56'38.24
40°04'39.74	145°15'16.92
39°41.03.13	145°00'34.48
39°42'03.36	146°00'45.53
39°48'14.21	145°49'31.54
39°50'27.37	145°45'10.26
39°52'10.71	145°47'44.60
39°50'01.11	145°51'30.30
40°04'54.04	145°17.53.31
40°05'25.69	145°20'38.39
39°43'28.93	146°01'20.48
39°43'42.87	146°03'02.44

TABLE 2 CONTINUED.

Latitude (°E)	Longitude (°S)
40°06'42.92	145°20'30.12
40°08'05.21	145°20'31.25
39°44'59.74	141°04'24.77
39°47'00.17	146°06'06.78
40°15'48.66	145°08'55.09
40°22'55.93	145°13'49.47
40°12'27.56	145°30'02.58

40°11'17.44	145°30'01.22
40°14'26.86	145°24'23.21
40°13'58.39	145°20'54.34
40°11'39.95	145°21'20.29
39°53'17.25	145°59'01.07
39°53'01.41	146°02'00.36
39°55'46.50	145°56'53.34
39°51'46.37	146°00'31.11
39°53'42.07	145°56'06.54
39°49'35.81	146°06'30.17
39°50'14.91	146°09'06.51
40°05'53.14	145°39'57.70
40°14'59.16	145°26'56.20
40°16'50.80	145°28'51.01
40°08'49.17	145°40'00.58
39°50'16.33	146°13'33.53
39°51'14.81	146°26'16.63
39°59'00.47	146°13'41.12
39°51'52.91	146°19'44.31
39°51'40.14	146°15'53.35
40°05'14.40	145°49'14.14
40°10'18.96	145°42'45.67
40°11'43.33	145°41'10.88
40°23'44.48	145°34'53.80
40°05'02.48	145°58'00.14
40°16'32.86	145°50'49.93
40°23'31.70	145°41'07.60
40°35'39.90	145°27'05.43
40°37'47.12	145°29'41.62
40°20'09.07	145°50'05.48
40°16'39.98	145°57'49.62
40°28'21.20	145°46'22.94
40°18'59.87	146°00'43.20
40°29'05.16	145°50'34.53
40°24'31.33	146°15'37.69
40°23'27.56	146°43'56.48
40°18'21.91	146°52'52.55
40°23'41.97	146°49'55.88
40°16'28.74	147°03'07.33

40°39'40.08	146°58'34.96
40°29'11.09	147°18'51.44

TABLE 3: WAY POINTS FOR STANSBURY BASIN GEOCHEMICAL LINES.

Line 1

Lat.	34 degrees 57 minutes 36 seconds South
Long.	138 degrees 00 minutes 33 seconds East
Lat.	35 degrees 23 minutes 18 seconds South
Long.	138 degrees 18 minutes 05 seconds East

Line 2

Lat.	35 degrees 08 minutes 00 seconds South
Long.	137 degrees 54 minutes 40 seconds East
Lat.	35 degrees 29 minutes 40 seconds South
Long.	138 degrees 09 minutes 50 seconds East

Line 3

Lat.	35 degrees 13 minutes 12 seconds South
Long.	137 degrees 45 minutes 33 seconds East
Lat.	35 degrees 37 minutes 15 seconds South
Long.	138 degrees 02 minutes 20 seconds East

TABLE 4: GIPPSLAND BASIN PROGRAM 1.

Coring Program

26 core locations will be sampled, on an opportunity basis, along 3 dip lines at approximately 1 km intervals (Fig. 8).

Sediment Geochemistry

Collection	Longitude (^{o}E)	Latitude (^{o}S)
Core-1	148 39 57.439	-38 18 21.410
Core-10	148 41 11.483	-38 19 24.424
Core-11	148 41 31.097	-38 18 56.598
Core-12	148 41 50.983	-38 18 28.249
Core-13	148 42 11.217	-38 17 59.116
Core 14	148 42 31.428	-38 17 30.955
Core 15	148 42 50.901	-38 17 3.095
Core 16	148 43 10.694	-38 16 35.003
Core 17	148 43 30.357	-38 16 6.815
Core 18	148 43 50.545	-38 15 38.391
Core 19	148 44 10.325	-38 15 10.296
Core 2	148 40 17.466	-38 17 53.485
Core 20	148 42 56.428	-38 19 42.593
Core 21	148 43 15.938	-38 19 14.245
Core 22	148 43 36.744	-38 18 45.197
Core 23	148 43 55.315	-38 18 17.575
Core 24	148 44 15.706	-38 17 48.725
Core 25	148 44 34.963	-38 17 20.864
Core 26	148 44 54.350	-38 16 53.422
Core-3	148 40 37.260	-38 17 26.341
Core-4	148 40 57.781	-38 16 57.045
Core 5	148 41 17.704	-38 16 28.729
Core 6	148 41 37.785	-38 16 0.313
Core 7	148 41 57.763	-38 15 32.935
Core 8	148 42 15.031	-38 15 7.737
Core 9	148 40 51.152	-38 19 53.491

TABLE 4 (CONTINUED).

100 km underway water column geochemistry (see Fig. 8).

9 dip lines covering Basker South-1, the Basker and Manta accumulations and Chimaera-1 will be acquired. These lines would be spaced 800 m apart and are approximately 12 km long. The cores are located along three of these lines (see map).

Gippsland Seawater Geochemistry

Line number	Longitude (°E)	Latitude (°S)
Profile-1	148 39 16.347	-38 19 19.251
Profile 2	148 39 30.494	-38 19 50.909
Profile 3	148 40 00.764	-38 20 05.273
Profile 4	148 40 31.446	-38 20 21.251
Profile 5	148 41 02.685	-38 20 34.428
Profile 6	148 41 41.613	-38 20 36.268
Profile 7	148 42 26.739	-38 20 24.875
Profile 8	148 43 04.130	-38 20 26.211
Profile 9	148 43 37.715	-38 20 33.795

Sole Area

A geochemical survey will be conducted along existing seismic profiles. The co-ordinates of the lines are :

Line GS88B-97	149°01' 2.9"E	38°16' 15.2"S
	149°01' 7.7"E	37°58' 42.2"S

Line G69B-248	148°52' 25.1"E	38°07' 52.4"S
	149°09' 57.5"E	38°04' 29.9"S

TABLE 5: WAY POINTS FOR GIPPSLAND PROGRAM 2.

Point 1	Line End			
Latitude	-38 deg	-30 min	-21.81 sec	
Longitude	147 deg	21 min	45.01 sec	
Point 2 (Barracouta)	Turn/Sediment Sample			
Latitude	-38 deg	-21 min	-22.29 sec	
Longitude	147 deg	36 min	16.14 sec	
Point 3 (Barracota)	Sediment Sample			
Latitude	-38 deg	-18 min	-51.76 sec	
Longitude	147 deg	36 min	32.67 sec	
Point 4 (Barracouta)	Turn			
Latitude	-38 deg	-14 min	-53.39 sec	
Longitude	147 deg	36 min	56.77 sec	
Point 5 (Snapper)	Turn			
Latitude	-38 deg	-8 min	-54.10 sec	
Longitude	147 deg	57 min	33.16 sec	
Point 6 (Tuna)	Turn			
Latitude	-38 deg	-9 min	-21.94 sec	
Longitude	148 deg	27 min	1.87 sec	
Point 7 (Tuna)	Line End			
Latitude	-38 deg	-11 min	-17.08 sec	
Longitude	148 deg	39 min	1.72 sec	

Point 8 (Flounder)	Line End		
Latitude	-38 deg	-15 min	-46.48 sec
Longitude	148 deg	29 min	36.81
Point 9 (VIC P19)	Line End		
Latitude	-37 deg	-58 min	-10.85 sec
Longitude	148 deg	50 min	35.27 sec
Point 10 (VIC P19)	Line End		
Latitude	-37 deg	-59 min	-45.43 sec
Longitude	148 deg	45 min	53.04 sec
Point 11 (VIC P19)	Line End		
Latitude	-38 deg	-10 min	-59.20 sec
Longitude	148 deg	47 min	3.07 sec
Point 12 (VIC P19)	Sediment Sample		
Latitude	-38 deg	-1 min	-3.57 sec
Longitude	148 deg	46 min	.49 sec
Point 13 (VIC P19)	Sediment Sample		
Latitude	-38 deg	-2 min	-4.44 sec
Longitude	148 deg	46 min	6.22 sec