Bureau of Mineral Resources, Geology & Geophysics

R E C O R D

BMR Record 1991/85

SURFACE (LIGHT HYDROCARBON) GEOCHEMISTRY IN THE GIPPSLAND AND EASTERN OTWAY BASINS AND THE TORQUAY SUB-BASIN OF SOUTHEASTERN AUSTRALIA: Research Cruise 104 Proposal

Principal Investigators: D. Heggie, G. Bickford and J. Bishop.

Associate Investigator: G. O'Brien

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EXECUTIVE SUMMARY

The Bureau of Mineral Resources will conduct a limited surface geochemical survey (using R.V. Rig Seismic) in southeastern Australia during late September-October. The surface geochemical program will be carried out at the completion of a seismic reflection survey being conducted for Bridge Oil in the eastern Bass Strait. Hence, the geochemistry will be conducted on a time-available basis (estimated 12 days).

The objectives of the surface geochemistry program are to i. contribute new information on hydrocabon generation, migration and entrapment in the Gippsalnd and eastern Otway Basins and the Torquay Sub-basin, ii. test the application of bottom-water DHD (direct hydrocarbon detection) and sediment 'headspace' hydrocarbon geochemistry to both reconnaissance and prospect scale exploration, and iii. test the reproducibilty of seepage from the seafloor.

The proposed survey areas (shaded) are shown in figure 2 (the cruise tracks of an earlier DHD survey are shown), and include:- i. bottom-water DHD and sediment sampling surveys in the Torquay Sub-basin (including limited sampling in the vicinty of Port Phillip Heads and two ocean outfall sites), ii. bottom-water and DHD surveys in the northern sector of the Gippsland Basin and iii. a DHD survey in the eastern Otway basin. All surveys have been planned to complement the data obtained on previous geochemical surveys to these areas.

1. INTRODUCTION

The Bureau of Mineral Resources, as part of the Continental Margins Program is developing the capability to conduct surface geochemical surveys. The purpose of these types of surveys is to seek evidence for thermogenic hydrocarbons that have migrated from deeply buried source rocks or hydrocarbon accumulations into the near surface sediments or overlying bottom-waters. A demonstration of thermogenic seepage is unequivocal evidence of petroleum prospectivity in a frontier sedimentary basin.

While surface geochemistry has been used widely overseas, few surface geochemical surveys have been conducted around the Australian Continental Margin. InterOceans Systems Inc, who have pioneered the use of 'geochemical sniffer' technology (Schink et al., 1971; Sigalove & Pearlman, 1975) have collected about 1.5 million line kilometres of data from around the world. However, prior to 1988, only four 'geochemical sniffer' surveys had been conducted (all by InterOceans) in Australia. Those surveys were carried out in the Otway basin, the Duntroon Basin and two small surveys in the Gippsland basin. During 1989 Transglobal Environmental Geoscience (TEG) and the BMR conducted an extensive survey of several southeastern basins, including the Bass, and North Bass, Stansbury and Gippsland Basins and the Torquay Sub-basin (Heggie & O'Brien, 1989; O'Brien et al.,1991).

The BMR has conducted reconnaissance sediment 'headspace' hydrocarbon geochemical surveys to the Otway and Gippsland Basins (McKirdy & Heggie, 1987; Heggie & O'Brien, 1988; Heggie et al., 1988; O'Brien & Heggie, 1989; O'Brien et al., 1991).

This proposal will take advantage of an operational window of opportunity in Rig Seismic's movements (from Perth to Sydney) to conduct follow-up surface geochemical investigations in southeastern Australia. The work outlined herein will be conducted at the completion of a seismic reflection survey being carried out for Bridge Oil in the eastern Bass Strait. Specifically, the following program is designed to revisit areas from previous geochemical surveys to both contribute new information on hydrocarbon generation, migration and entrapment and to further evaluate the application of surface geochemical techniques to offshore exploration for hydrocarbons. This program is being conducted as part of the joint research Agreement with TEG into the nature of hydrocarbon seeapage from the seafloor.

2. OBJECTIVES.

The primary objectives of the petroleum hydrocarbon program conducted as part of the CMP include the following.

1. To develop new information on thermogenic hydrocarbon generation, migration and entrapment in the Gippsland, and eastern Otway Basins and the Torquay Sub-basin.

2. To test the application of bottom-water Direct Hydrocarbon Detection (DHD) and sediment 'headspace' hydrocarbon geochemistry techniques to both prospect and reconnaissance scale exploration in these southeastern Australian basins.

3. To test the reproducibility of seepage from the seafloor by resurveying some locations of previously detected seeps in the Gippsland and eastern Otway Basins and Torquay Sub-basins.

4. To test the application of cross-plots of molecular and isotopic compositions of anomalous gas concentrations in bottom-waters and sediments, as indicators of hydrocarbon 'source' (biogenic or thermogenic gas, gas-condensate or liquids-prone).

To achieve these objectives DHD in bottom-waters (schematically illustrated in Fig.1) will be conducted (in some cases with high resolution seismic reflection data acquisition) along predetermined cruise tracks. The areas that these surveys will be conducted are shown highlighted in figure 2. At select locations within these areas, sediment 'headspace' hydrocarbon geochemistry will be conducted using methods illustrated in figure 3. The different components of the program are summarised in Table 1. These components will be conducted on a time-available basis.

In addition a DHD survey will be conducted in the vicinities of ocean outfall sites off of Cape Barwon and Cape Schanks. This work will be conducted in support of the petroleum hydrocarbon program (see below), but also as a component of a marine environment program. The purposes of this work are:- i. to examine the light hydrocarbon characteristics of anthropogenic hydrocarbons associated with urban discharge (which in some cases interfer with the interpretation of bottom-water DHD hydrocarbon data) and, ii. to test the application of the continuous geochemical profiling equipment to tracing of discharge plumes from rivers or ocean outfall (urban and industrial sewage) sites.

3. GEOCHEMICAL RESEARCH PROGRAM.

3.1 SURFACE GEOCHEMISTRY IN THE TORQUAY SUB-BASIN.

Background.

During 1989 the BMR, TEG and Shell Australia conducted a cooperative research DHD survey in an area of the Torquay Sub-basin where Shell had some seismic evidence of gases in the sediments. The DHD results in this area showed only a weak anomaly in methane (less than two-fold background) although there was other indirect evidence of seeping hydrocarbons. For example a 1-2 m depression on the seafloor and anomalous side-scan sonar signals suggested pock-marks on the seafloor. Pockmarks have previously been associated with seafloor seepage (Hovland & Judd, 1988). Furthermore, high resolution seismic reflection data showed a wash-out zone and rising reflectors, beneath the bottom-water gas anomaly, that is indicative of gases in the sediments. This gas anomaly was reproduced on resurveying. However, it was so weak that it's source could not be predicted from either molecular or isotopic compositional data.

The DHD results also showed strong ethane and propane anomalies to the north of the Nerita exploration well. However, these were not reproducible on a resurvey of the area. These anomalies may represent anthropogenic hydrocarbons from Port Phillip Bay or from either of two ocean outfall sites located nearby and which are transported via local tidal influences.

A limited coring program was subsequently conducted by TEG to that area where seismic data indicated gases in the sediments and where we found the weak methane bottom-water anomaly. Shallow cores (<3m) of unconsolidated sediment were collected, but the total gas concentrations were low and the data could not be adequately interpreted to determine the 'source' of gases in the sediments.

Proposed program.

The proposed program includes the following.

1. The DHD survey will include approximately 270 km of bottom-water DHD (Table 2). Approximately 140 km of DHD will be collected concurrently with high resolution seismic reflection

profiling (600m cable and 15 inch water gun). This survey will investigate hydrocarbon seepage from three prospects in the Torquay Sub-basin and revisit two locations of previously observed anomalies (to test the reproducibility of anomalies). Some detailed bottom-water sampling will be conducted in the vicinity of pockmarks on the seafloor. A DHD survey line will be run along the length of a major fault (reconnaissance exploration) to test if this fault serves as a common conduit for hydrocarbon migration.

2. Sediments in the vicinity of the seafloor pockmarks and previously defined anomaly will be sampled with a vibrocore and analysed for hydrocarbon gases (Table 3). All gas analyses will be conducted at sea. Gases will be collected for isotopic analyses which will be carried out in the shore-based laboratory. Detailed sampling will be conducted in some cores to examine for evidence of methane oxidation. Samples will be collected from these cores for basic sedimentology and geochemistry (e.g., water content, calcium carbonate, TOC, grain size). Sediment samples will be collected for petroleum biomarker geochemistry.

Adjunct program in environmental geochemistry.

One strong anomaly found in the Torquay Sub-basin during the earlier (1989) DHD survey was not reproducible. We suggested this anomaly originated from Port Phillip Bay.

It is proposed to conduct a limited surface-water DHD program near the entrance to Port Phillip Bay and also near two ocean outfall sites that discharge into the Bass Strait in the vicinity of the approaches to Port Phillip Bay (Table 4). The ocean outfall from the Geelong Water Board discharges into the sea near Cape Barwon, while approximately 45% of the urban waste from the City of Melbourne is discharged through an ocean outfall site near Cape Schanks, to the west of the entrance to Westernport Bay.

In addition to testing if Port Phillip Bay may act as a source of anomalous hydrocarbon signals in the Torquay Sub-basin, an objective of this work is to test the continuous profiling equipment aboard Rig Seismic in applications of environmental geochemistry. Specifically the program will trace the dispersion of anthropogenic hydrocarbons (and other components) derived from nearshore ocean outfalls and/or estuarine discharges.

3.2. SURFACE GEOCHEMICAL SURVEY IN THE GIPPSLAND BASIN.

Background

Esso (with InterOceans) conducted a 'geochemical sniffer' survey in the Gippsland Basin in 1983 (Burns & Emmet, 1984). Anomalous concentrations of hydrocarbons were found. However, these anomalies could not be reproduced and it was concluded that the initial observations were probably artefacts which resulted from contaminated water moving through the Gippsland. A more complete survey was cancelled on the basis of these results.

During 1989 BMR conducted a limited calibration (approximately 300 km) survey in the Gippsland Basin (Heggie et al., 1989; O'Brien et al., 1991). That survey found evidence of hydrocarbon seeps at five locations on the Northern Platform, near the trend of the Rosedale fault (Figs. 4 & 5). Two anomalies were identifed to the north and east of the Barracouta and Seahorse (oil-gas) accumulations while one anomaly was detected between Sunfish and Tuna and another to the north of Wahoo. Traces of thermogenic hydrocarbons were identified (albeit at low total hydrocarbon concentrations) in sediments from three vibrocores taken in the vicinty of this seep. These anomalies were in the vicinities of known exploration wells or hydrocarbon fields. Because of limited time these seep locations were not resurveyed and the reproducibilty criteria remains untested.

The purpose of the proposed program is to revisit the northern sector of the Gippsland Basin and to test some observations from the earlier Esso and BMR surveys (Fig. 5). Specifically the locations of earlier-documented anomalies will be revisited and samples collected for isotopic analyses (eg. Bernard et al., 1977; Fuex, 1977).

Proposed program.

1. Approximately 280 line km of DHD data will be collected in the vicinity of the Rosedale fault and known hydrocarbon accumulations, specifically in that area to the north and east of Barracouta and Seahorse, between Sunfish and Tuna and to the north of Wahoo (Table 5; Fig 5). Samples will be collected for isotopic analyses of the gases.

2. A vibroring program will be conducted in the vicinity of the Wahoo exploration well.

3.3 SURFACE GEOCHEMISTRY IN THE EASTERN OTWAY BASIN.

Background.

Bitumen strandings on the beaches of South Australia and Victoria and the finding of propane rich anomalies during an earlier InterOCeans 'geochemical sniffer' survey (Sprigg, 1986) suggested that surface geocehmistry could contribute to exploration of the offshore Otway basin.

The BMR has conducted two sediment 'headspace' hydrocarbon geochemistry surveys to the Otway Basin (McKirdy & Heggie, 1987; Heggie & O'Brien, 1988). An integration of the surface geochemical data with geohistory analyses and maturation modelling showed that the wet gas contents of anomalies varied systematically and similarly to the predicted distribution of the basal Early Cretaceous Pretty Hill Sandstone, a potential source rock (Mc Kirdy et al, 1986; McKirdy,1987). These data showed that the Pretty Hill Sandstone is within the present day oil (Williamson et al., 1987) window on the Mussell Platform (eastern Otway) where the highest wet gas contents were found in the surface geochemical anomalies (Fig. 6). These data were further integrated into a detailed study of the Otway basin (Williamson et al, in press) to suggest an oil exploration play seaward of the Pecten exploration well.

The BMR and TEG ran a transit DHD survey line from Portland to Cape Otway during the DHD survey of several southeastern Australian basins (Heggie & O'Brien, 1989; O'Brien et al., 1991). A weak propane (with traces of butane) anomaly was found to the west of Cape Otway, offshore of earlier gas and condensate discoveries onshore (Miyazaki et al., 1990).

The proposed program (conducted in conjunction with BHP) will test the application of bottom-water DHD to prospect evaluation in this part of the eastern Otway.

Proposed program.

The program includes approximately 310 line km of bottom-water DHD data along the cruise track listed in Table 6 and illustrated in figure 7.

3.4 SURFACE GEOCHEMISTRY IN THE OFFSHORE SYDNEY BASIN.

If time permits a limited DHD survey line will be run from south of Sydney that links the ocean outfall sites at Cronulla, Malabar and North Bondi with runoff from Sydney Harbour. The purposes of this work are to :- i. investigate the implications of surface water runoff from urban and industrial discharges to DHD (petroleum) exploration surveys in the offshore Sydney Basin and, ii. test the continuous geochemical profiling equipment for application to monitoring plumes and discharges from the coastal zone into continental shelf waters.

4. ACKNOWLEDGMENTS

We thank Keith Spence and Bruce Thomas (Shell Australia), Garry Woodhouse, Tom Evans and Phil Abrams (BHP), John Emmett, and Brian Burns (Esso) and Peter Ashton (Geelong Water Board) and Peter Scott (Melbourne Water) for their discussions and contributions.

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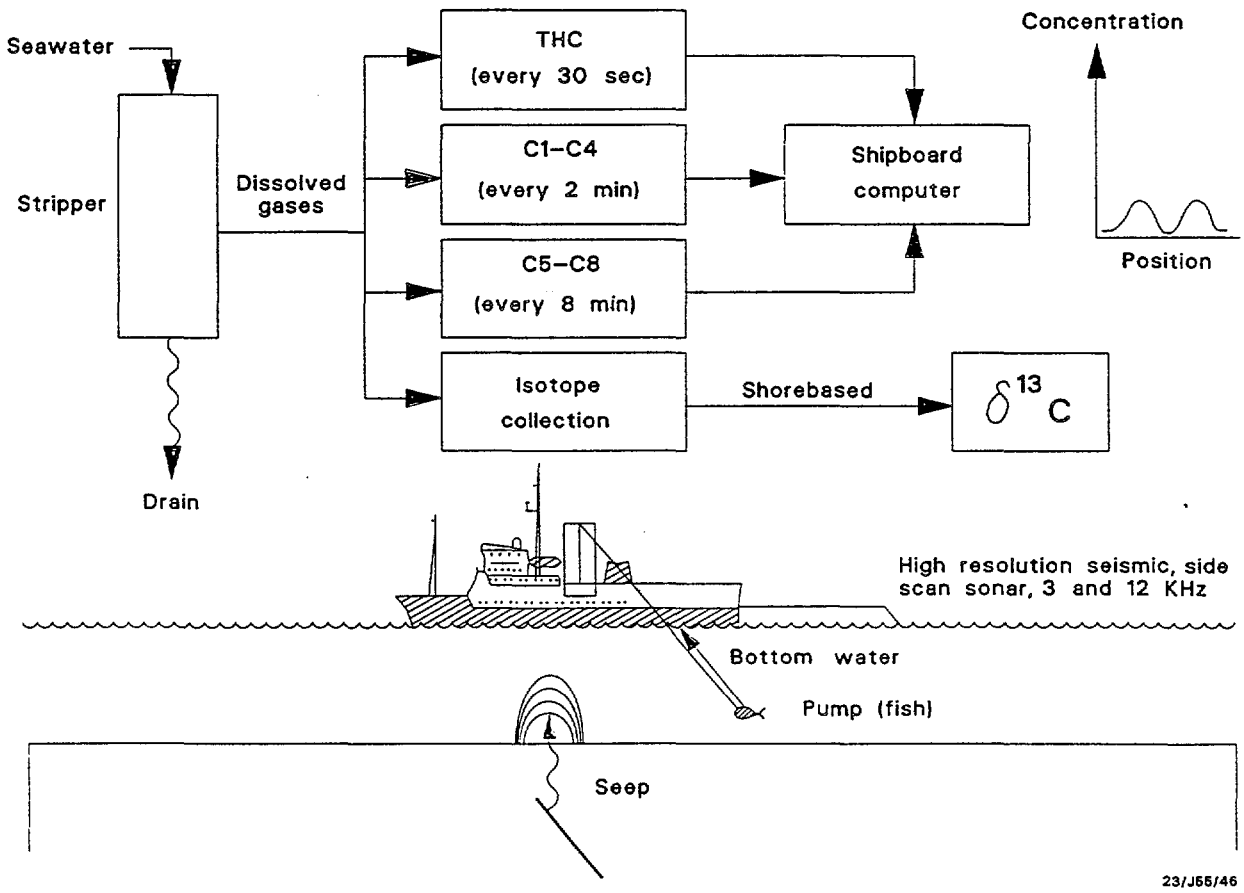
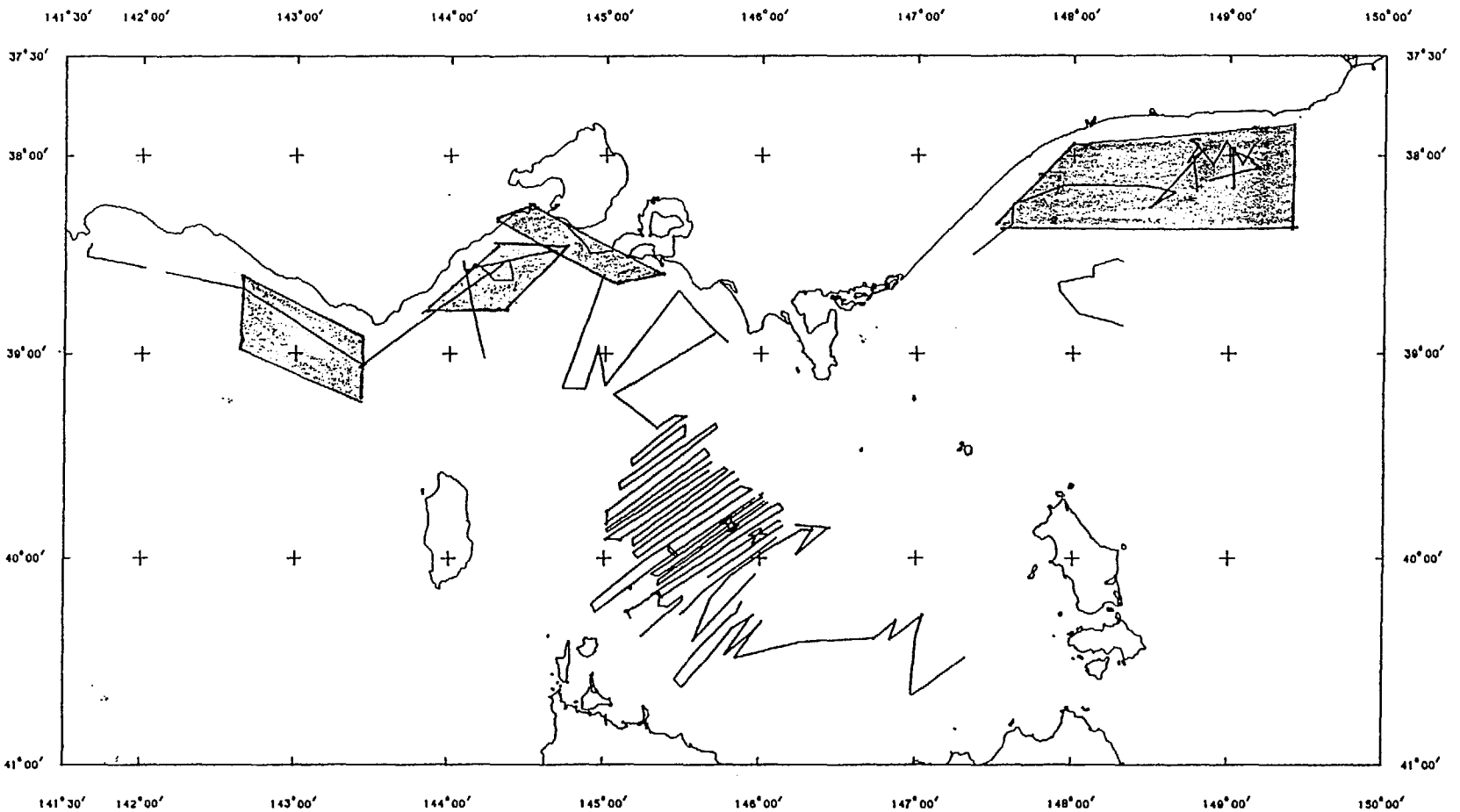
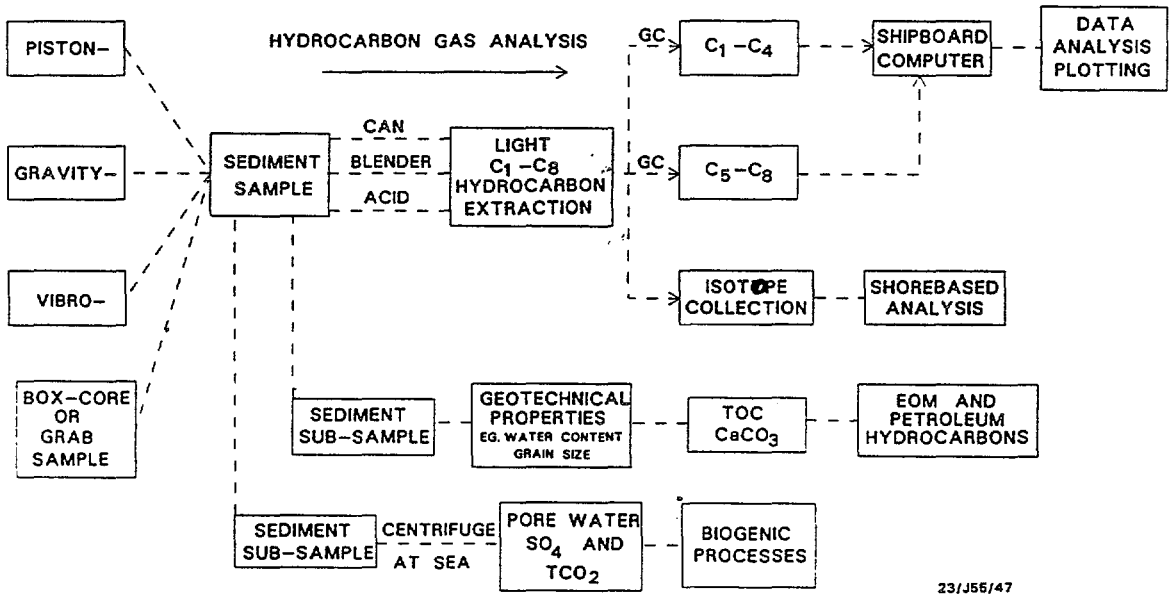


1. Schematic of the bottom-water DHD equipment installed on Rig Seismic.

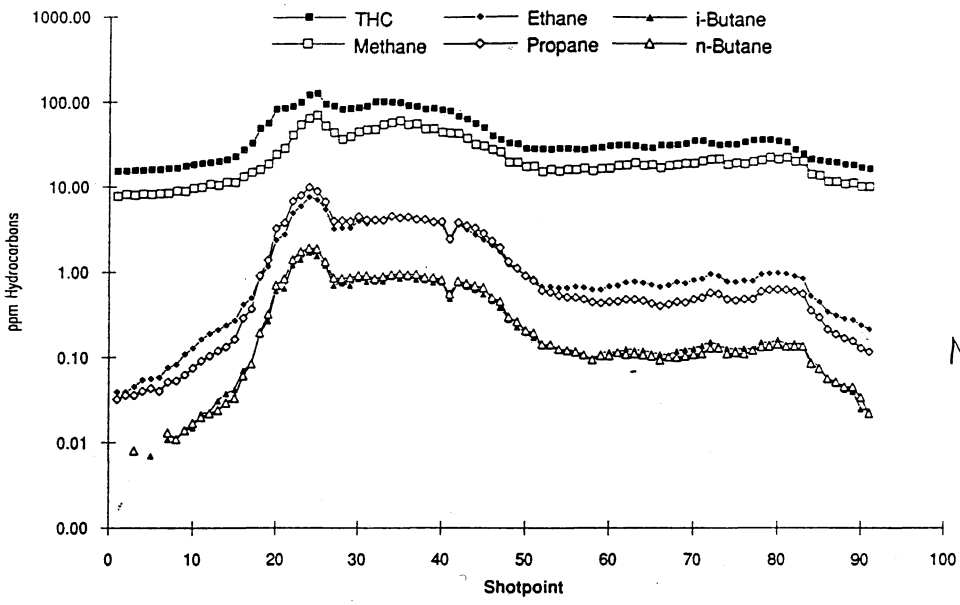


2. Map of southeastern Australia showing areas of proposed surface geochemical surveys (shading). Also shown are the bottom-water DHD survey lines conducted as part of the BMR/TEG survey to southeastern Australia conducted in 1989.

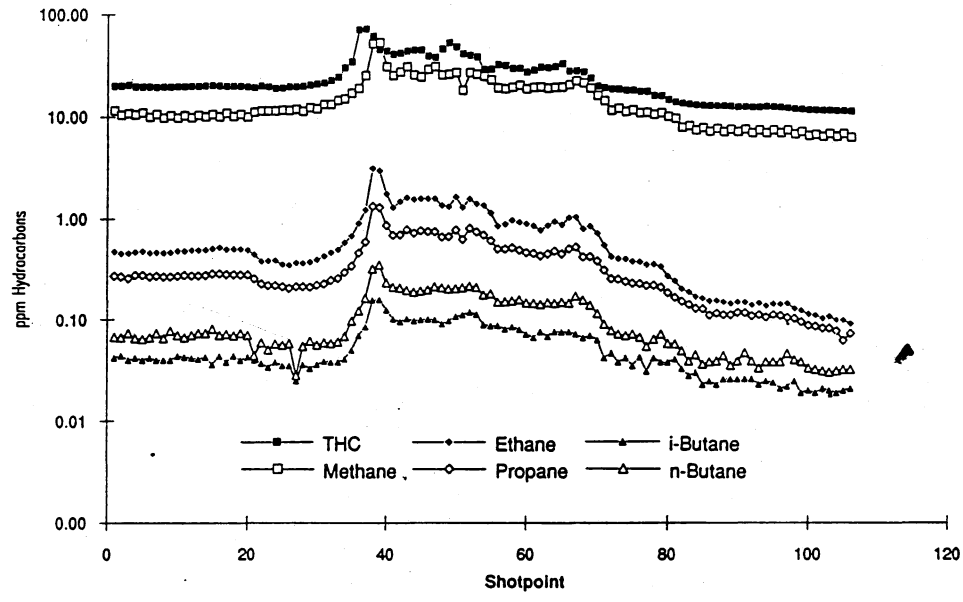
Geochemical Exploration DHD Sediment



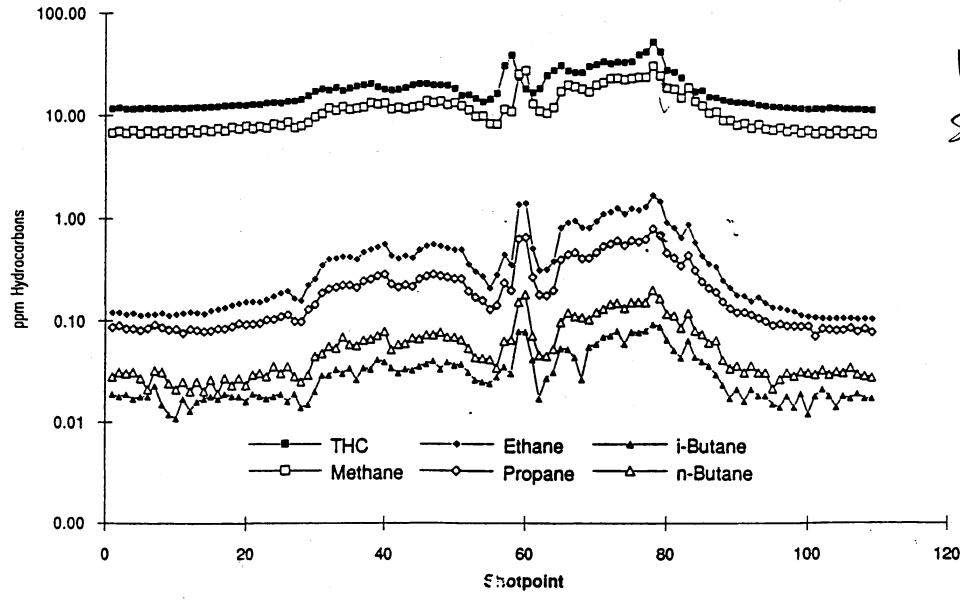
3. Schematic of the protocol for sampling and analyses (hydrocarbons) of sediment cores.



NE Barracouta

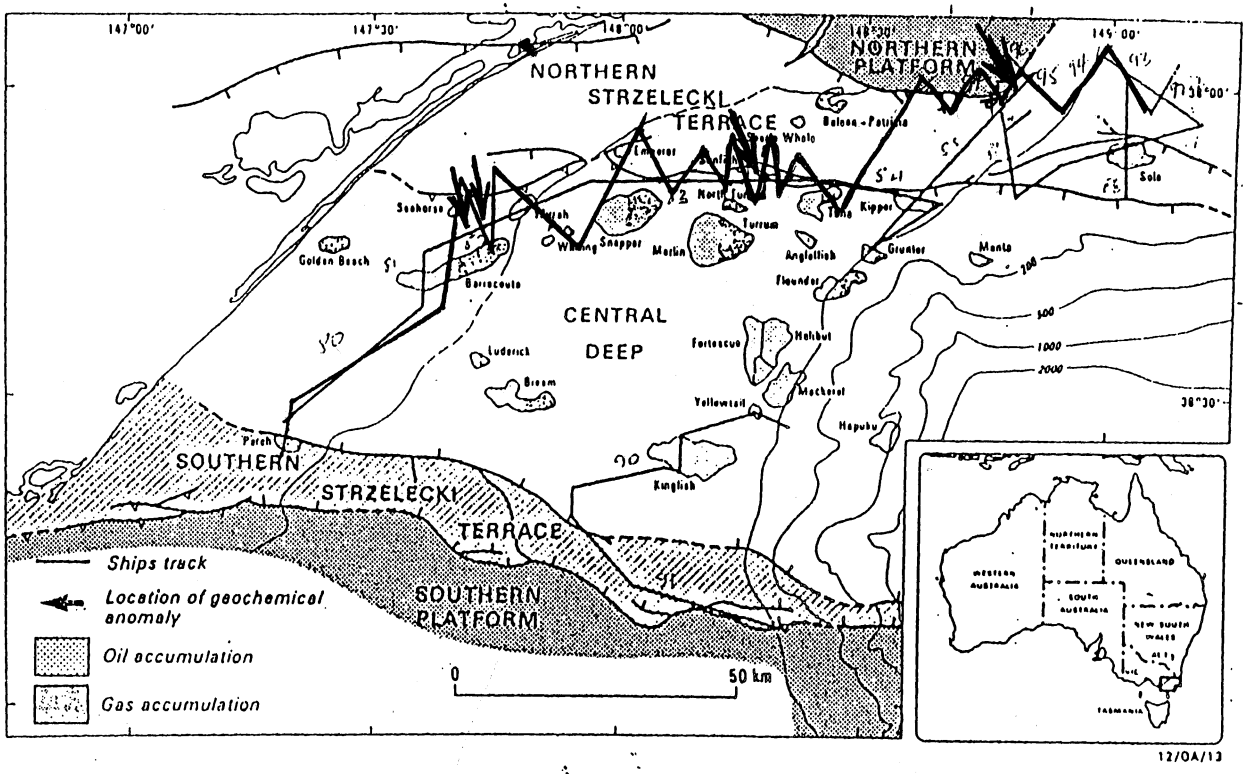


NE Seahorse

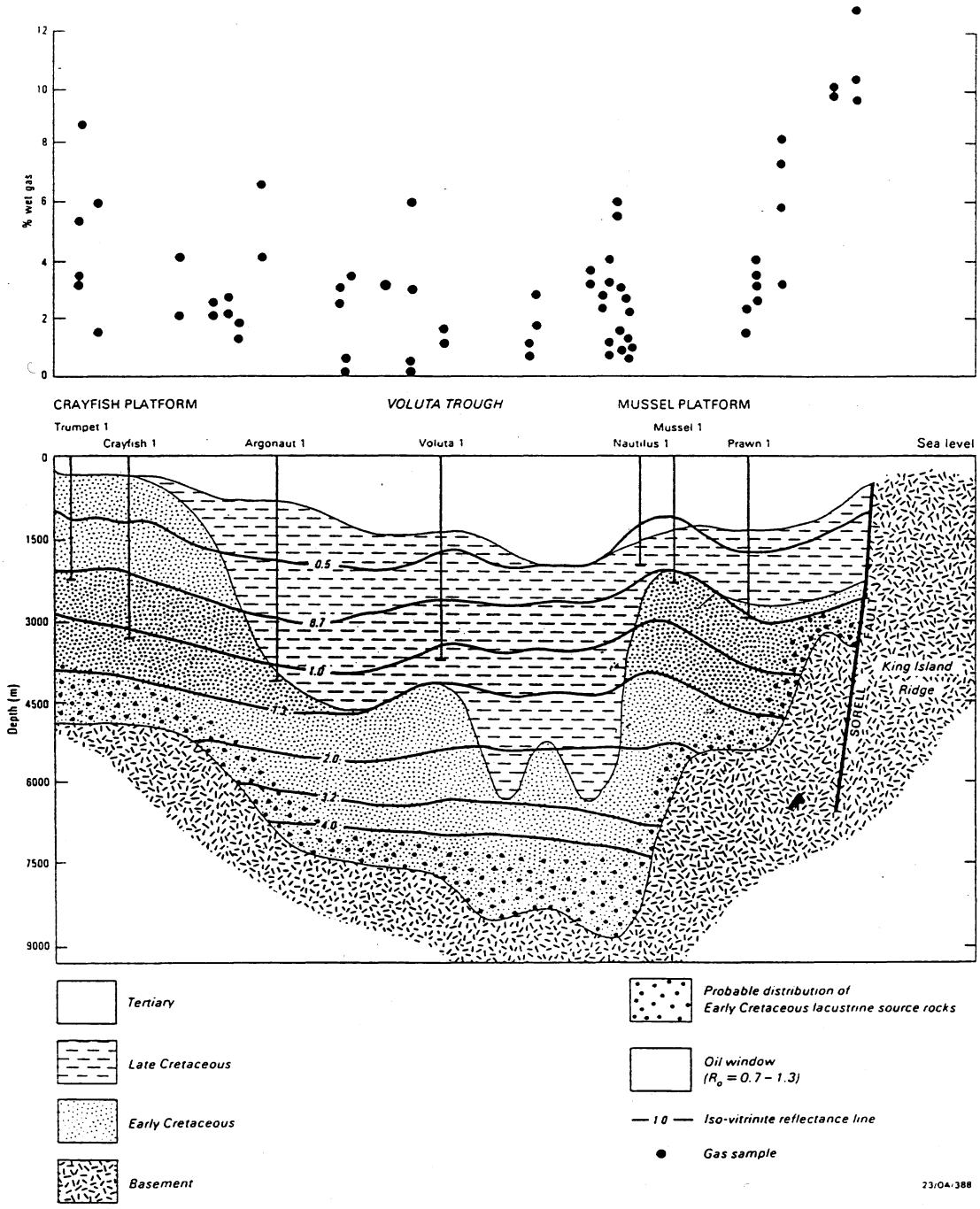


Between Sunfish & Tuna

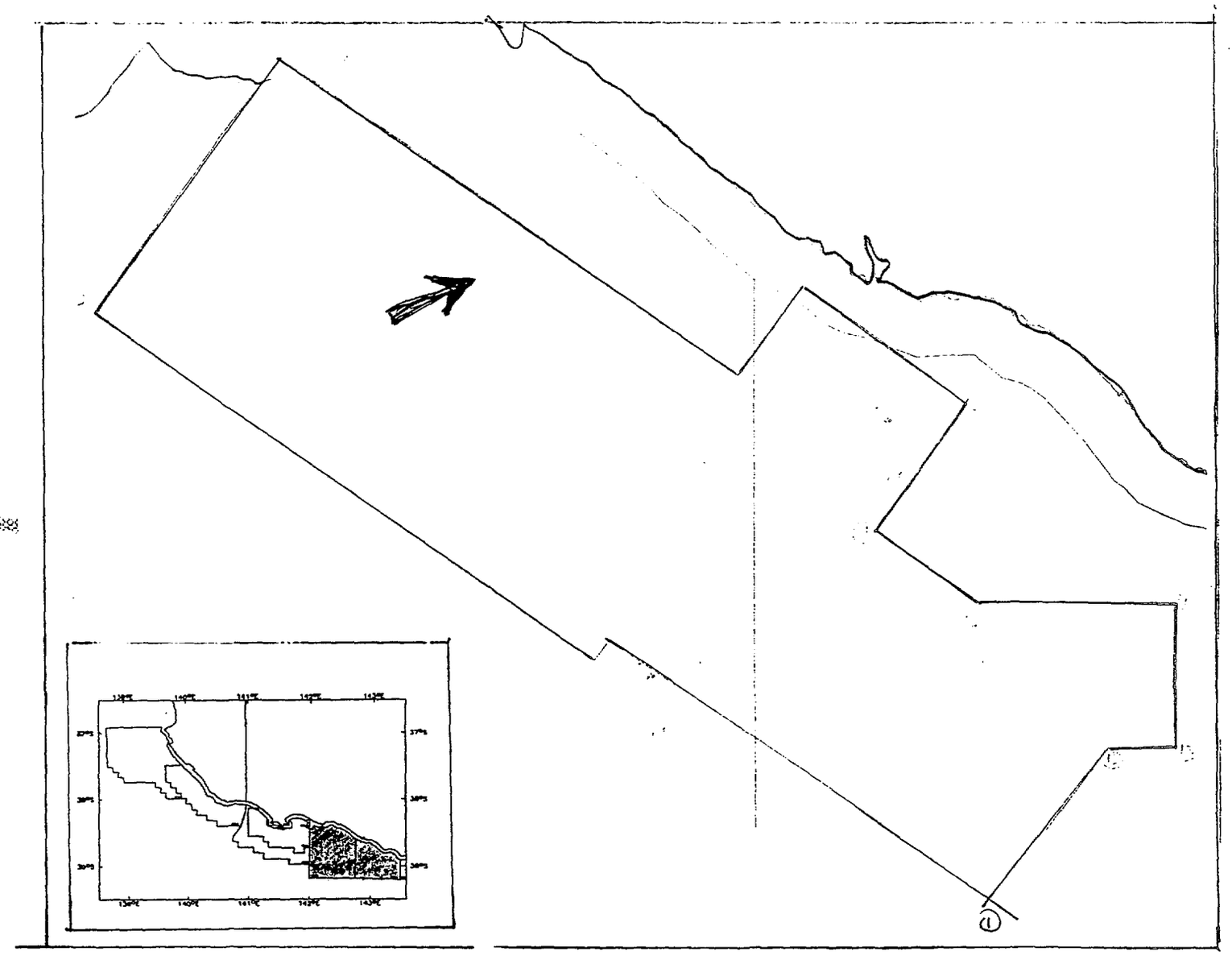
4. Bottom-water DHD anomalies found in the Gippsland Basin during the BMR/TEG survey conducted in 1989. The figure plots C1-C4 concentrations and shot point. Approximately three data points are obtained per kilometre of seafloor. THe seeps could be detected over distances of about 15-30 km.



5. Map of the proposed sampling survey lines in the northern Gippsland basin (heavy lines). Also shown are the locations of anomalies (arrows) and the 1989 survey lines.



6. Plot of the wet gas content of hydrocarbon anomalies and the distributions of potentail source rocks and the distribution of the present day oil window across the Otway Basin between the Mussell Platform (east) and the Crayfish Platform (west).



7. Cruise track in the eastern Otway Basin (shown is the location of a weak propane anomaly detected during the BMR/TEG transit line during 1989).

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Table 1. Proposed components of the surface geochemical survey to southeastern Australia.

Component	Program
Torquay Sub-basin DHD	260 line km (2 days)
Torquay Sub-basin	Seafloor sampling (2 days)
Torquay Sub-basin	Environmental sampling (<1 day)
Gippsland Basin DHD	280 line km (2 days))
Gippsland Basin	Seafloor sampling (1 day)
Otway Basin DHD	310 line km (2 days)

2. Way points for the bottom-water DHD survey in the Torquay Sub-basin.

Torquay Sub-Basin waypoints

All coordinates are relative to the Australian National Spheroid, except where noted.

WP	Latitude S	Longitude E	Notes
1	38 56.92	144 09.37	
2	38 41.72	144 05.17	
3	38 29.03	144 27.14	
4	38 44.76	144 27.27	
5	38 37.76	144 12.03	
6	38 35.52	144 13.69	
7	38 36.64	144 14.44	WGS-72
8	38 37.73	144 13.76	Nerita-1
9	38 40.328	144 07.333	Pockmark / WGS-72
10	38 45.75	143 59.92	
11	38 49.63	144 04.70	
12	38 45.48	144 06.19	
13	38 48.98	144 09.75	
14	38 43.06	144 15.17	
15	38 45.11	144 23.71	
16	38 44.14	144 29.52	
17	38 32.18	144 29.69	
18	38 28.01	144 25.03	

Torquay Sub-Basin lines

Line	From	To	Length	Notes
1	1	2	30.0	
2	2	3	43.5	
3	3	4	35.0	
4	4	5	30.0	Retrieve seismic at EOL 138.5 km seismic acquisition
5	6	7	4.0	
6	8	9	13.0	Break off for vibrocore sampling
7	9	10	16.0	
8	10	11	11.0	
9	11	12	8.0	
10	12	13	8.5	
11	13	14	13.5	
12	14	15	13.0	
13	15	16	9.0	
14	16	17	22.0	
15	17	18	10.5	

		Total	267.0 km	(approx 36 hours)

3. Sampling locations in the Torquay Sub-basin.

Torquay Sub-Basin sample locations

All coordinates are relative to the WGS-72 Spheroid.

Site	Latitude S	Longitude E	Notes
1	38 40.328	144 07.333	Pockmark
2	38 40.288	144 07.375	100m NE
3	38 40.369	144 07.368	100m SE
4	38 40.356	144 07.281	100m SW
5	38 40.281	144 07.294	100m NW
6	38 39.887	144 07.006	1000m NW
7	38 40.006	144 07.768	1000m NE
8	38 40.762	144 07.650	1000m SE
9	38 40.644	144 06.893	1000m SW

4. Environmental sampling in the Torquay Sub-basin and Bass Strait.

Environmental Sampling

a) Approximately 50 km sampling around Geelong Water Board outfall west of Barwon Heads.

b) Approximately 50km sampling around Melbourne Water Board outfall west of Cape Schanks.

c) Transit line across Port Phillip Heads linking a) and b).

Due to the proximity of the coastline, the positions of the waypoints and lines will be determined after consultation with the Master of 'Rig Seismic'.

5 Way points for the bottom water DHD survey in the Gippsland basin.

Gippsland Basin waypoints

All coordinates are relative to the Australian National Spheroid.

WP	Latitude S	Longitude E	Notes
1	38 35.61	147 18.63	
2	38 27.70	147 23.42	
3	38 20.81	147 38.63	
4	38 09.19	147 40.77	
5	38 15.81	147 45.00	
6	38 07.70	147 45.00	
7	38 14.86	147 55.30	
8	38 04.29	148 01.00	
9	38 10.00	148 06.32	
10	38 06.00	148 08.80	
11	38 10.00	148 10.60	
12	38 05.00	148 10.60	
13	38 05.00	148 13.67	
14	38 10.00	148 13.67	
15	38 10.00	148 14.79	
16	38 05.00	148 14.79	
17	38 05.00	148 16.75	
18	38 10.00	148 16.75	
19	38 10.00	148 17.69	
20	38 05.81	148 20.85	
21	38 11.08	148 26.15	
22	37 58.92	148 33.33	
23	38 02.30	148 36.92	
24	37 58.78	148 40.42	
25	38 02.43	148 43.93	
26	37 58.11	148 48.03	

Gippsland Basin lines

Line	From	To	Length	Notes
1	1	2	16.0	
2	2	3	25.0	
3	3	4	22.0	
4	4	5	14.0	
5	5	6	15.0	
6	6	7	20.0	
7	7	8	21.0	
8	8	9	13.0	
9	9	10	8.0	
10	10	11	8.0	
11	11	12	9.0	
12	13	14	9.0	
13	15	16	9.0	
14	17	18	9.0	
15	19	20	9.0	
16	20	21	13.0	
17	21	22	25.0	
18	22	23	8.0	
19	23	24	8.0	
20	24	25	8.0	
21	25	26	10.0	

		Total	279.0 km	(approx 36 hours)

6. Way points for the DHD survey in the eastern Otway Basin.

Otway Basin waypoints

See BHP-supplied list of waypoints (Australian National Spheroid coordinates).

Otway Basin lines

Line	From	To	Length	Notes
1	1	2	50.0	
2	2	3	2.5	
3	3	4	58.0	
4	4	5	30.0	
5	5	6	53.0	
6	6	7	11.0	
7	7	8	19.0	
8	8	9	15.0	
9	9	10	12.0	
10	10	11	19.0	
11	11	12	14.0	
12	12	13	6.5	
13	13	14	22.0	

		Total	312.0 km	(approx 36 hours)

Possible shortened program in Otway Basin:

1	1	2	50.0	
2	2	3	2.5	
3	3	6	28.0	
6	6	7	11.0	
7	7	8	19.0	
8	8	9	15.0	
9	9	10	12.0	
10	10	11	19.0	
11	11	12	14.0	
12	12	13	6.5	
13	13	14	22.0	

		Total	199.0 km	(approx 24 hours)