AGSO Marine Survey 207

Direct Hydrocarbon Detection North-West Australia: Northern Carnarvon Basin; Yampi Shelf; Southern Bonaparte Basin (September/October 1998)

DONALD J. WILSON

RECORD 1999/51

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

AGSO RECORD 1999/51

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Abstract

The Australian Geological Survey Organisation (AGSO) carried out a regional water column geochemical 'sniffer' program on the North-West Australian Margin, from Dampier to west of Darwin, over the period 21 September to 23 October 1998. The overall objective of the survey was to acquire bottom water hydrocarbon data of the northern Carnarvon Basin, Yampi Shelf and the southern Bonaparte Basin, particularly in regard to detecting natural hydrocarbon seepage. A total of 4788 line km of sniffer data were acquired during the program, using the contract vessel *TSMV Pacific Conquest*. 160 survey lines were completed.

Weak to moderate concentrations of methane (C_1) and moderate to strong concentrations of ethane (C_2) were detected in the waters surrounding the Wandoo B Platform, northern Carnarvon Basin. Elsewhere in the northern Carnarvon, Skua, AC/P20, AC/P25-26, AC/P27 and AC/P23 survey areas, detected hydrocarbon seepage was close to background concentration indicating that seepage was either absent or of very low level.

Moderate to strong methane and ethane concentrations were detected on parts of the Yampi Shelf. It is significant to note that there is a measure of repeatability of methane and ethane sampled between AGSO Survey 176, recorded in 1996 and these data recorded in 1998. The levels measured, coincident with seismic lines from AGSO Survey 165, confirm hydrocarbon leakage where the regional seal thins onto the Kimberley Block basement (O'Brien et al., 1998a).

Introduction

Over the last few years, the Australian Geological Survey Organisation (AGSO) has been carrying out investigations into issues relating to trap integrity and hydrocarbon seepage on the North-West Australian Margin. In particular, these investigations have focussed upon the integration of seismic data with other remote sensing technologies, such as water column geochemical 'sniffer', Airborne Laser Fluorosensor (ALF) and Synthetic Aperture Radar (SAR) data to reduce exploration risk. Recently, AGSO has also embarked upon a program of systematically upgrading the national bathymetric and ship-board gravity and magnetic databases for north-west Australia (Petkovic et al, 1999).

The research program involves a number of studies, including:

1. Geochemical sniffer acquisition on inboard basin margin areas (2,000-4,000 line kilometres) over key basement features, as well as over pinchout of regional seal on inboard parts of the margin. This should define present day hydrocarbon charge as well as defining likely migration 'shadow' zones. High resolution ('multi-beam type') seismic acquisition synchronous with sniffer acquisition designed to better define areas of present day seepage.

2. SAR acquisition over the entire northern Carnarvon Basin, offshore Canning Basin and Timor Sea to define areas of active liquid hydrocarbon seepage. Presently RadarSat International, the Australian Centre for Remote Sensing (ACRES) and AGSO are undertaking a major integrated study of trap integrity and hydrocarbon seepage across the Yampi Shelf and Timor Sea (to the north of the Canning Basin) using a combination of SAR, ALF, sniffer and seismic data.

3. AGSO's Pilot study into the use of fluorescence signatures as a means of jointly detecting, mapping and correlating hydrocarbon seeps to their sources. The initial requirement was for databases that would enable explorationists to characterise and correlate fluorescence signatures obtained using ALF with knowledge of the aromatic hydrocarbon compositions that cause specific fluorescence responses. Aromatic composition can be related to the oil type, thereby making a link between fluorescence and specific oil families.

4. Develop new technology to measure water column fluorescence signatures as an adjunct to ALF and direct light hydrocarbon detection ('Sniffer') data. The expectation is that hydrocarbon anomalies encountered during ALF and 'sniffer' surveys may be reliably and directly related to local oil types and hence to their source rocks.

During the period 21 September to 23 October 1998, AGSO carried out a regional 'sniffer' program on the NW Australian margin between Dampier in the south and to the west of Darwin in the north (Appendix I). The overall objective of the survey was to acquire bottom water hydrocarbon data in parts of the northern Carnarvon Basin, offshore Canning Basin, Yampi Shelf and Bonaparte Basin, particularly in regard to detecting natural hydrocarbon seepage. A total of 4788 line km of sniffer data were acquired during the program (Figures 1a and 1b), using the contract vessel *TSMV Pacific Conquest*. 160 survey lines were completed.

This survey was the first full sea trial of AGSO's new modularised 'sniffer' system and this resulted in significant down time, particularly during the northern Carnarvon Basin component (S207 Leg 1) of the Survey (Figure 1a). Subsequently, the Offshore Canning component was cancelled. The second leg Ship's track is shown in Figure 1b. Hydrocarbons sampled included benzene, methane, ethane, propane, ethylene, propylene, toluene, *i*-butane and *n*-butane.

In addition to the water column geochemical data, some experimental water column fluorimeter data were also acquired as part of a separate AGSO testing and calibration program. These experimental ship-board fluorimeter data will be further discussed in a later separate report. Laboratory analyses of water samples are described in a separate record (Edwards et al, 1999, AGSO Record 1999/52).

Results

General

Full details of the acquisition methods used and the interpretative methodologies employed are given in Appendices II and III.

Line summaries for the sniffer data acquired are presented in Appendix VI and all data are contained as spreadsheets at Appendix VII. In addition, each survey region has a gridded enclosure for both methane and ethane.

AGSO defines 'weak hydrocarbon anomalies' (see Appendix III) as bottom waters which have concentrations which are above background, but have concentrations of C_1 – C_4 which are less than five times the background concentration. 'Moderate hydrocarbon anomalies' are defined as having concentrations five to ten times the background concentration, whereas 'strong hydrocarbon anomalies' have concentrations greater than ten times the background.

Wandoo B Platform

The Wandoo B Platform survey lines were designed to determine, if any, the spatial distribution of produced formation water (PFW). To determine this, the platform was surveyed in a circular pattern of varying radii, beginning at a distance of 500 m from the platform (Figure 2).

Line summaries for the sniffer data acquired are presented in Appendix VI, Table 1.

Weak to moderate concentrations of methane (C_1) with coincident moderate to strong concentrations of ethane (C_2) were detected (Figure 3) with a plume extending from the platform out in a northwest direction (Enclosures 1 and 2) owing largely to the prevailing currents/winds.

Northern Carnarvon
Lines 207007-207034

The survey design of S207 Leg 1 was based on a combination of Synthetic Aperture Radar (SAR) Satellite anomalies together with existing seismic tracks. Line summaries for the sniffer data acquired are presented in Appendix VI, Table 2.

Overall, the light hydrocarbon concentrations of the northern Carnarvon lines surveyed (Figure 4) are close to background concentrations (Figure 5), indicating that there was an either absent or very low level of, hydrocarbon seepage present.

Yampi Shelf

The objective of the Yampi Shelf survey area was two-fold: investigate the seepage of hydrocarbons in the region, particularly towards the zero edge of the sealing unit by surveying over existing seismic data (S165) and coincident with previous sniffer data (S176); and to conduct the main pilot study of the fluorimeter. The latter will be discussed in a subsequent record. Line summaries for the sniffer data acquired are presented as part of Appendix VI, Table 3.

The sniffer data acquired in the region (Figure 6) indicate that the background concentrations for methane (C_1) and ethane (C_2) in this region are 4.50 ppm and 0.04 ppm, respectively (Figure 7). Moderate to strong methane with coincident moderate to strong concentrations of ethane were detected. Enclosures 3 and 4 highlight the spatial locations of these main anomalies.

It is significant to note that there is a measure of repeatability of C_1 and C_2 sampled between S176, recorded in 1996 and these data recorded in 1998. The levels measured, coincident with AGSO seismic lines S165, indicate hydrocarbon leakage where the regional seal thins onto the Kimberley Block basement (O'Brien et al., 1998a)

Skua

Line summaries for the sniffer data acquired are presented as part of Appendix VI, Table 3. The data acquired in the Skua region indicate that the background concentrations for methane (C_1) and ethane (C_2) in this region are 5.00 ppm and 0.05 ppm, respectively (Figures 8 and 9). The light hydrocarbon concentrations throughout the Skua lines surveyed are close to these concentrations although the ethane results indicate a weak anomaly on line 207099 to the northwest of Skua 5 (Figure 10 and Enclosures 5 and 6).

AC/P20 (Coastal Oil & Gas)

Sniffer Data

Line summaries for the sniffer data acquired are presented in Appendix VI, Table 4. The sniffer data acquired in AC/P20 (Figures 11 and 12) indicate that the background concentrations for methane (C_1) and ethane (C_2) in this region are 6.00 ppm and 0.05 ppm, respectively (Figure 13 and Enclosures 7 and 8). The final northeast segment of the survey (Bronto-7A), recorded background concentrations of methane in the order of 3.50 ppm.

Overall, the light hydrocarbon concentrations throughout AC/P20 are close to these concentrations, indicating that hydrocarbon seepage was either absent, or of very low level, along the lines surveyed.

Several weak ethane anomalies (0.13-0.15 ppm) are present along survey lines *Bronto-1* (at SPs 9 and 51)*, Bronto-2* (at SPs 45 and 49), *Bronto-4* (at SP 32), *Bronto-6* (at SP 20) and *Bronto-7A* (at SPs 2, 12 and 18). A moderate ethane anomaly (0.24 ppm) is present on survey line *Bronto-7A* (at SP 16). There appears to be no coincident methane enrichment present.

Fluorimeter Data

The fluorimeter was set up in parallel with the sniffer and acquired simple 'total fluorescence intensity' measurements (Fconc.) from the bottom waters. Overall, AC/P20 was characterised by an almost complete absence of fluorimeter anomalies. One fluorimeter anomaly was detected (a peak of 0.07 fluorescence units) between geochemical shot points 16-18 (located on line *Bronto-6,* Figure 12). A weak ethane anomaly was coincident with this result.

AC/P25-26 (Flare Petroleum)

Line summaries for the sniffer data acquired in AC/P25-26 (Figures 14 and 15) are presented in Appendix VI, Table 5. Several weak ethane anomalies (0.23-0.28 ppm) are present along survey lines *FM12* (at SP 1746), along transit lines *FM5-6* (at SP 531). There is no coincident methane enrichment present (Enclosures 9 and 10).

One weak methane anomaly of 5.90 ppm (Figure 16) was recorded along transit line *FM13-14* (at SP 1229) although, at less than twice the background, it is extremely weak.

Overall, the light hydrocarbon concentrations throughout AC/P25-26 are close to background concentrations, indicating that there was an either absent or very low level of, hydrocarbon seepage along the lines surveyed.

AC/P27 (ARC Energy)

Sniffer Data

Line summaries for the sniffer data acquired are presented in Appendix VI, Table 6. The sniffer data acquired in AC/P27 (Figures 17 and 18) indicate that the background concentrations for methane and ethane in this region are approximately 3.50 ppm and 0.05 ppm, respectively (Figure 19). Overall, the light hydrocarbon concentrations throughout AC/P27 are close to these concentrations, indicating that hydrocarbon seepage along the lines was either absent, or of very low levels (Enclosures 11 and 12).

A moderate/strong ethane anomaly (0.69 ppm) is present along survey line *ARC5* (at SP 313 total line SPs), approximately 5 km southeast of the Anderdon-1 well location. Here, attendant methane enrichment is present (*Figure 19*), albeit the anomaly is only weak (5.77 ppm), 1.5 times the background level.

During a regional sniffer survey through the Vulcan Sub-basin in 1990 (O'Brien et al., 1992), some data were acquired which are of relevance to the present study. A significant ethane anomaly was detected approximately 20 km southwest of Conway-1, in what is now AC/P23 (near the boundary between AC/P23 and 27). This anomaly, located on line 97/025, was in a similar structural position (inboard from the basin margin fault system) to the anomaly detected southeast of Anderdon-1.

Fluorimeter Data

The fluorimeter was set up in parallel with the sniffer and acquired simple 'total fluorescence intensity' measurements (Fconc.) from the bottom waters. Overall, AC/P27 was characterised by an almost complete absence of fluorescence anomalies. One fluorescence anomaly was detected (0.17 fluorescence units) at geochemical shot point 413 (total line SPs; located on line *ARC8,* Figure 18). This anomaly coincided with an ethane anomaly two times the background, thereby enhancing confidence in both anomalies.

AC/P23 (Nippon Oil Exploration)

Sniffer Data

Line summaries for the sniffer data acquired are presented in Appendix VI, Table 7. The sniffer data acquired in AC/P23 (Figures 20 and 22) indicated that the background concentrations for methane and ethane in this region are 4.00 ppm and 0.05 ppm respectively (Figure 21 and Figure 23). Overall, the light hydrocarbon concentrations throughout AC/P23 are close to these concentrations, indicating that there was either no, or very low levels of, hydrocarbon seepage along the lines surveyed (Enclosures 13 and 14).

A weak ethane anomaly (with no attendant methane enrichment) is present along survey line *Nippon14* (between SPs 762 and 817 total line SPs, Figure 22). Here, the maximum ethane concentrations range between 0.20 ppm - 0.30 ppm. One very localised ethane anomaly (0.28 ppm) is also present on line *Nippon8*, again with no attendant methane enrichment. Several of these relative ethane enrichments were also recorded on line *CHAMELEONA*.

The maximum concentration recorded for methane during the Nippon survey was only 5.52 ppm, which is still within background levels.

Discussion

AC/P20 and AC/P25-26

The sniffer data acquired throughout AC/P20 and AC/P25-26 indicate that natural hydrocarbon seepage is absent to weak along the lines surveyed. In contrast, strong hydrocarbon seepage (~15 times background values) was detected during Survey 207 south of AC/P20, immediately inboard from the Cornea-1 and Londonderry-1 wells, where the regional seal thins onto the Kimberley Block basement (O'Brien et al., 1998a). Similarly, strong anomalies have been previously detected around the Skua and Swift wells, in the southwest Bonaparte Basin (O'Brien et al., 1998b), in an area where the regional Early Cretaceous seal is thin and the displacement on the Neogene faults significant.

One noteable result is that the background level for methane (6.00 ppm) contrasts with areas to the southeast of AC/P20, which indicated background levels of 3.50 ppm.

The lack of seepage detected throughout the surveyed lines in AC/P20 and AC/P25-26 contrasts with data obtained on the northern Yampi Shelf, within the Vulcan Sub-basin and indeed along the boundary fault zone immediately north-east of the Anson-1 well location. Given that the Early Cretaceous sealing units within AC/P20 and AC/P25-26 are probably fairly thin and sandy (O'Brien et al., 1999), these data might suggest that the region has received relatively little hydrocarbon charge. Most of AC/P20 and AC/P25-26 would appear to rely upon charge from either the northern Browse Basin or from the Skua Trough; in either case, migration distances would be significant. Alternatively, the lack of detected seepage may reflect some combination of poor sampling (due to the wide line spacing of the survey or height of the 'fish' above the seafloor) and a relatively low GOR for the hydrocarbons in the permit.

As such, other indicators of the presence of hydrocarbons, such as seismic amplitude anomalies, Airborne Laser Fluorosensor (ALF) or Synthetic Aperture Radar (SAR) data should be examined for hydrocarbon indicators.

AC/P27 and AC/P23

Again, the sniffer data acquired throughout AC/P27 indicated that natural hydrocarbon seepage is generally absent to weak along the lines surveyed, though one moderate to strong anomaly was detected.

The lack of seepage detected throughout the surveyed lines in AC/P27 and AC/P23 could be due in part to the fact that the abundance and displacement of the Neogene faults are relatively small (O'Brien et al., 1999) through these permits, which effectively straddle the relay zone which defines the transition between the Bonaparte and Browse Basins. Counter-balancing this for AC/P27 is the fact that the permit is located in a marginward position, where the regional Early Cretaceous seal is probably thinner and more sandy (and therefore more 'leaky') than in more basinward locations.

References

Edwards, D.S. and Crawford, N., 1999. UV Fluorescence analysis of seawater from AGSO Survey 207 Western Australia. *Australian Geological Survey Organisation, Record 1999/52*.

O'Brien, G.W., Bickford, G., Bishop, J., Heggie, D.T. and Marshall, J.F., 1992. Light hydrocarbon geochemistry of the Vulcan Sub-Basin, Timor Sea: *Rig Seismic* Survey 97. *BMR Record* 1992/62.

O'Brien, G.W., Quaife, P., Cowley, R., Morse, M., Wilson, D., Fellows, M. and Lisk, M., 1998a. Evaluating trap integrity in the Vulcan Sub Basin, Timor Sea using integrated remote sensing geochemical technologies. *In Purcell, P.G. & R.R. (Eds), The Sedimentary Basins of Western Australia, 2*: *Proceedings of the Petroleum Exploration Society of Australia Symposium, Perth, WA*, 237-254.

O'Brien, G.W., Quaife, P., Burns, S., Morse, M. and Lee, J., 1998b. An evaluation of hydrocarbon seepage in Australia's Timor Sea (Yampi Shelf) using integrated remote sensing technologies. *Proceedings of The SEAPEX Exploration Conference*: 205-218.

O'Brien, G.W., Morse, M., Wilson, D., Quaife, P., Colwell, J., Higgins, R. and Foster, C.B., 1999. Margin-scale, basement involved compartmentalisation of Australia's North West Shelf: A primary control on basin-scale rift, depositional and reactivation histories. *APPEA Journal, 39, 40-63*.

Petkovic, P., Morse, M.P., Brett, J., Murray, A.S., Webster, M.A., Grabovszky, T.M., Mackey, T.E. and Roche, P., 1999. Gravity, magnetic and bathymetry grids from levelled data for northwest Australia. *Australian Geological Survey Organisation, Record 1999/41*.

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APPENDIX I

Cruise Narrative

The TSMV Pacific Conquest departed the port of Dampier on the 21st of September 1998. This was the first long-term trial of the newly developed modular sniffer system.

Due to failures in hydraulic equipment, the need to repair the sniffer cable and the trialing of an Acoustic Doppler Profiler (ADP), the beginning of the survey proper was delayed until the 26th of September 1998.

26 September 1998 Day 269

Lines 207001, 207002, 207003

27 September 1998 Day 270

Lines 207004, 207005 and 207006

The first area to be surveyed was an area immediately around the Wandoo B platform (Figure 2). This was achieved by acquiring data in ever increasing radii around the platform starting at a distance of 500m and doubling each circumference up to and including a distance of 16000m.

Water samples were also acquired for analysis back in Canberra. (Part 2)

Following the completion of the Wandoo B program, the survey continued in the northern Carnarvon Basin targeting locations which had indicated anomalies from the initial interpretation of Synthetic Aperture Radar (SAR) satellite scenes.

Lines 207007, 207008, 207009 and 207010

28 September 1998 Day 271

Lines 207011, 207012, 207013, 207014 and 207015

29 September 1998 Day 272

Lines 207016, 207017 and 207018

30 September 1998 Day 273

Lines 207019, 207020, 207021, 207022, 207023, 207024, 207025, 207026, 207027, 207028, 207029 and 207030

01 October 1998 Day 274

Lines 207031, 207032, 207033 and 207034

No significant concentrations were recorded in this second phase.

At 1000hrs GMT on the 2nd of October 1998, the cable jumped out of the sheath on the A Frame, causing significant damage to both the cable and the 'fish'. This damage resulted in the cancellation of the remainder of the 1st Leg (Offshore Canning) of Survey 207. The vessel proceeded to Broome to begin repair of the system prior to the higher profile, 2nd Leg of Survey 207.

06 October 1998

TSMV Pacific Conquest departed the port of Broome, WA on 6th of October 1998 after a port call for repairs and personnel transfer. The ship transited northwest to the first survey area for near Adele Island. Problems were continuing with the sniffer equipment causing lines 207035, 207036, 207037 and 207038 to be completed using fluorimetry only.

07 October 1998 Day 280

A northeast transit line, 207039, was surveyed past the Gwydion area to the Londonderry/Cornea Survey Area.

8 - 10 October 1998 Days 281, 282 and 283

Initial grid lines were collected to maximise the time available to assess the fluorimeters in the area hydrocarbon anomalies were detected on AGSO Survey 176. The sniffer equipment was repaired and data started to be acquired on line 207040. Data was collected from the following lines:

207040 (281)
207041 (282)
207042
207043
207044
207045
207046 (283)
207047
207048
207049
207050

Hydrocarbon anomalies, with high methane values and ethylene approaching values higher than ethane were detected along lines, 207043, 207044, 207045, 207046, 207048 and 207050.

11 October 1998 Day 284

A zig-zag line was proposed for identifying peaks detected on the fluorimeter. The line was partially completed and under instruction from Andrzej Radlinski deviated to chase the fluorimeter peak. When this was not detected an area was infilled in concentric box shape to map an area of high methane, that had been detected as present in the area for several hours.

.
207051 to 207068
The lines did not pick up the anomaly at the same location as previously detected.

Continuation of 207050
207069

12 October 1998 Day 285

Grid lines were continued to be collected to the south;
207069 (285)
207070

Additionally a line extending shoreward to the south east of the grid area was collected.
207071

The ship transited overnight to Troughton Island to drop off two personnel and pick up another.

13-14 October 1998 Days 286 and 287

The ship then transited back to the Londonderry Sniffer survey area, collecting data along parallel inshore line.
207072 (286)
Data continued to be collected along the grid lines to the south.
207073
207074
207075 (287)
207076
207077
207078

An unknown peak was detected on line 207076. The hydrocarbon peak was outside the sampling window although identified by the system. Water samples were taken for identification at AGSO. The fish was taken out of the water and a transit line was taken south to the site of the well head Gwydion. Data was collected in a block to the east of the well's position working northwards in a loose array.

15 - 16 October 1998 Days 288 and 289

The following lines were collected;
207084
207085
207086
207087
207088
207089 (289)
207090
No anomalies were detected in the area.

Data was collected along a transit line to the Londonderry Survey area and a north east tie line was taken across the grid through positions the anomaly was detected on the first pass.
207091

Along this line a large peak was detected of an identified hydrocarbon that is normally not identified in the sniffer set up. The hydrocarbon shows a peak in the area of benzene, between n-Butane and benzene, it may be a light oil. It's likely to be a compound with a lower boiling point than benzene. The compound swamped the column with large late eluding peaks C_1-C_4 and peaks to match C_6-C_8. Water samples were taken for further analysis at AGSO. The unidentified hydrocarbon was present for most of the line.
207079

16-17 October 1998 Days 289 and 290

Lines to the north were collected to complete the array in Londonderry survey area.
207080
207081
207082 (290)
207083

After the completion of the Londonderry array the tow-fish was taken out of the water for servicing. A transit line was taken to an area to the south of where the anomaly was detected initially. This location is an area of basement high identified from seismic previously collected in the area. A grab sample was taken, from which a bucket of sediment bagged and kept. The sediment was a watery olive-grey fine to medium sized sand with a clay matrix. 13°43.467'S 124°45.479'E

17-18 October 1998   Days 290 and 291

A transit line was taken to the northeast to work in the Skua area and Brontosaurus Prospect.

Skua Area
207092
207093
207094
207095
207096
207097 (291)
207098
207099
207100
207101
207102

Brontosaurus Prospect
BRONTO1 (Benzene? Hydrocarbon between butane and benzene)
BRONTO2
BRONTO3
BRONTO4
BRONTO5
BRONTO5A
BRONTO6
BRONTO7
BRONTO7A
207103(transit line - data collected)

18-21 October 1998   Days 291, 292, 293 and 294

Data was collected along a series of east-west oriented lines to the south of 207104.

Note.   Lines listed as a transit from one point to another ie FM1-2, are listed for completeness. The data itself is not part of the main dataset.

207104
FM1
FM1-2
FM2
FM3-4
FM3 (292)
FM5-6
FM4
FM7-8
FM5
FM9-10
FM6
FM11-12
FM7
FM13-14
FM8
FM15-16
FM9
FM17-18

Computing problems were encountered on line FM18-19 with approximately 6 hours down time. During this time we were notified of extra lines to be completed in the Flare/Mosaic area. These were picked up after the down time.

FM13 (N-S line) (293)
FM14 (E-W line)
FM12EXT (existing NE line extended)
FM12
FM22-21
FM11
FM20-19
FM10

A transit line was taken south to the Arc survey area.
The following lines were collected:

ARC1
ARC2
ARC3
ARC4 (294)
ARC5
ARC6
ARC7

Transit to second Arc area to the west.

ARC8
ARC9
ARC10
ARC11
ARC14
ARC12
ARC13

No significant anomalies were detected in the Arc survey area. On line A17-18, the base line rose in a small mound on the chromatographs, however this was only for a few shots, it did not rise significantly and was not considered a major find.

21-22 October 1998 Days 294 and 295

Chameleon survey area.
The following lines were collected.
CHAMELEONA
CHAMELEONB (295)
CHAMELEONC

Water depths were deeper than previously sampled in 180 - 190 m and the effects of currents made the cable go out from the stern at an extreme angle. The resultant stress on the cable meant the ship's speed was reduced to 5-6 kts.
No anomalies found in the Chameleon Survey Area.
A transit line to the Nippon area was taken.

22 October 1998 Day 295

The Nippon Survey area was in deep water 190 - 200 m. Currents swept the cable out from the stern at a high angle and a significant amount of cable was sent out (up to 40 m more than water depth). This meant that great care had to be taken when reducing ships speed, which made the tow fish drop quickly. Tight turns at the ends of the survey lines also caused problems.

NIPPON1
NIPPON2
NIPPON3
NIPPON4
NIPPON5
NIPPON6
NIPPON7 (peak, suspected contamination of sample)
NIPPON8
NIPPON9
NIPPON10

NIPPON11
NIPPON12
NIPPON13
NIPPON14
NIPPON15

22-23 October 1998 Days 295 and 296

The survey was completed. A transit line was taken to Darwin.

The unknown peak was again detected in the Nippon area. This time it was positively correlated with an aerosol sprayed in the Portalab. Experiments were undertaken after the Nippon area was completed confirming this observation. The water samples taken will be analysed at AGSO to confirm the suspected contamination.

APPENDIX II

DHD Methodology

The majority of the world's hydrocarbons have been discovered via exploration around known oil and gas seeps (Link, 1952; Philp and 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. All geochemical prospecting methods rely upon relatively mobile light hydrocarbons migrating from petroleum accumulations to the surface along microfractures and fault systems etc.

Offshore, the most commonly used geochemical prospecting technique involves the direct, underway measurement of dissolved hydrocarbon gases within seawater (e.g. Interocean Systems Inc.'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.

The geochemical analysis system that has been used as part of the agreement is shown schematically in *Figure IV-1* of Appendix IV. The laboratory system analyses a variety of gases extracted from seawater, including C_1-C_8 hydrocarbons with facilities to collect gases for shore-based isotopic analyses. This system is referred to by AGSO as its Direct Hydrocarbon Detection or DHD system. Complete details of both the DHD system and the interpretative methodologies used during the survey, are given in Appendices III and IV. The DHD system is designed to be deployed routinely in conjunction with other remote sensing techniques, such as multi-channel seismic reflection systems, 3.5 and 12 kHz sub-bottom profilers, and side-scan sonar.

The Direct Hydrocarbon Detection (DHD) method continuously analyses C_1-C_8 hydrocarbons within seawater. Thermogenic hydrocarbons migrating up faults from source rocks and/or hydrocarbon reservoirs debouch into the seawater at the seafloor, producing higher concentrations of light hydrocarbons within the water column. These seep gases have molecular compositions that are distinctively different from that of the biogenically-produced hydrocarbons which are mainly produced by in-situ processes in seawater. If the hydrocarbons are present in sufficient amounts, the molecular composition of the thermogenic hydrocarbons may be used to infer whether the primary source of the seep was oil, condensate or dry gas.

The method used on the modularised sniffer system is as follows. Seawater is continuously delivered into the geochemical laboratory via a submersible fish (which is towed approximately 10 - 20 m above the seafloor). The seawater is degassed in a vacuum chamber and the resulting headspace gas is injected into three gas chromatographs, which sequentially sample the flowing gas stream and measure a variety of light hydrocarbons. Light hydrocarbons (C_1-C_8) are measured every minute. These data, as well as fish altitude (above the seafloor), the depth of the fish, hydrographic (temperature and salinity) and navigation data are recorded on computer. All these data are recorded and displayed continuously so that any hydrocarbon anomalies in the water column can be quickly recognised and additional measurements can be made when appropriate. Detection sensitivity is approximately 10 parts per billion in the stripped headspace sample. At a ship speed of 5 knots, the measurement of C_1-C_8 occurs every 150m. Calibration standards and zero (nitrogen) are passed through the gas chromatographs daily. Calibrations were within 10% for the entire program and system blanks were less than 2 ppm for Methane and 5 ppb for C_2+ compounds.

APPENDIX III

Interpretative Methodology

The DHD equipment installed in the AGSO modularised sniffer can be used for measuring hydrographic, environmental or petroliferous parameters. The light hydrocarbon data (C_1-C_8) contained in this report can be produced by a variety of sources. These sources include biological activity, degenerating organic matter and reservoired petroleum products (oil, gas and condensate). The aim of data interpretation is to determine the origin of the light hydrocarbon gases measured.

Light Hydrocarbons In Seawater

Light (C_1-C_4) and intermediate (C_5-C_8) hydrocarbons are present in seawater and sediments principally as a result of the following processes:

(1) Thermogenic Processes.

The effect of heat on organic matter (catagenesis and metagenisis) buried to depths of several kilometres in sedimentary basins, produces thermogenic hydrocarbons (Hunt, 1979; Tissot and Welte, 1984). The products of these reactions include methane and the saturated (C_2-C_8) hydrocarbons, which are the hydrocarbons most analysed in surface geochemical techniques. Some of the thermogenic hydrocarbons migrate to the surface, either directly from source rocks (primary migration) or indirectly, from gas, gas-condensate or liquid reservoirs (secondary migration). Hydrocarbons may migrate kilometres to permeate the near-surface sediments and seep into the overlying bottom-water resulting in thermogenic anomalies.

(2) Biological Processes.

Hydrocarbons are produced microbially and photochemically in seawater. In addition, during early diagenesis, a variety of hydrocarbons are produced by the activities of microbial organisms during aerobic and anaerobic destruction of organic mater which occurs primarily in the top few tens of metres of sediments. The products of these reactions include methane and minor quantities of both saturated and unsaturated hydrocarbons (Hunt, 1979; Claypool and Kvenvolden, 1983 and references cited therein). The presence of unsaturated hydrocarbons, which are only produced biochemically (Primrose and Dilworth, 1976; Claypool and Kvenvolden, 1983), provides one criteria to distinguish between biogenic and thermogenic hydrocarbons.

These compounds produced *in-situ* generally occur in low concentrations as background hydrocarbons in seawater (Claypool and Kvenvolden, 1983). However, high concentrations of biogenically-produced hydrocarbons may accumulate in relatively shallow-buried sediments and seep into the overlying water, resulting in biogenic anomalies (Brooks et al., 1974; Bernard et al., 1976).

(3) Anthropogenic Processes.

Man's activities can introduce anthropogenically-sourced hydrocarbons into the marine environment. Anthropogenic hydrocarbons may be of a thermogenic origin (e.g., ship spills, refined petroleum products used in industrial processes) or a biogenic origin (such as those produced from urban sewage when excessive loads of organic matter are dumped into the sea and degraded microbially).

The concentrations of in-situ biogenic (ie., background) light hydrocarbons in seawater are generally an order of magnitude lower than those in the underlying seafloor sediments (Claypool and Kvenvolden, 1983). Consequently, it is relatively easier to detect migrated thermogenic hydrocarbons in seawater (low background concentration) than in seafloor sediments (high and variable concentrations). Herein, lies one perceived advantage in the use of bottom-water DHD compared with sediment geochemistry in offshore petroleum exploration.

The bottom-water DHD technique is dependant upon hydrocarbons migrating from hydrocarbon reservoirs or petroleum source rocks to the seafloor. Although the exact mechanism(s) of migration may be variable or even unknown, some form of vertical migration, as evidenced by the many observations of seepage (e.g., Brooks et al., 1974; Bernard et al., 1976; Reed and Kaplan, 1977; Cline and Holmes, 1977; Nelson et al., 1978; Reitsma et al., 1978; Brooks et al., 1979; Kvenvolden et al., 1979; Kvenvolden and Field, 1981; Hovland and Judd, 1988) does occur (via porous sediments, fault planes and microfissures etc). It is generally accepted that migration by diffusion is not important (Leythaeuser et al., 1982; Reitsma et al., 1981; Whelan et al., 1984) although bubble ebullition from saturated solution, oil and gas transport in solution in carbon dioxide and advective processes involving basinal fluids are all likely mechanisms (e.g., (Claypool and Kvenvolden, 1980; Hunt 1984; Sweeney 1988; Hovland and Judd, 1988).

Data Interpretation: the mixing model

The detection of seepage requires that anomalous concentrations of hydrocarbons be distinguished from the background inventory of hydrocarbons. Thermogenic hydrocarbons that seep into the bottom-waters, mix with the background concentration of hydrocarbons. One approach to defining anomalies and distinguishing seep hydrocarbons from background hydrocarbons requires that a mean background concentration be defined (either statistically or graphically) and this mean concentration is then subtracted from the measured concentrations. Because of variability in the background concentrations, this approach may be problematic, particularly where seepage is weak and the anomalies very subtle.

Our initial approach is to review the data on a line-by-line basis and compare measured concentrations with the regional background.

Classification of anomalies

'Strong' (arbitrarily defined here as when some of the measured C_1-C_4 concentrations increase more than an order of magnitude above the background concentration) and 'moderate' anomalies (some C_1-C_4 increase 5-10 fold above background) are obvious and are accompanied by large increases in individual C_1-C_4 hydrocarbons with no increase in the biogenic components (ethylene and propylene). 'Weak' anomalies (individual C_1-C_4 is less than five-fold the background concentration) are more difficult to discern. In some cases, what appear to be weak anomalies may result from variations in the depth of the fish above the seafloor, a shoaling of the water depth, penetration of the fish above the local thermocline or combinations of these factors. In these cases, plotting the saturated hydrocarbon (methane, ethane, propane) concentrations against the 'fish' depth, seawater temperature and salinity, or against the biogenic hydrocarbons (ethylene, propylene), generally resolves any apparent anomalies from those anomalies related to seepage.

APPENDIX IV

Sniffer System Description

The system is designed to be modular when configured for petroleum applications as follows:

Towfish and Cable

A 'towfish' containing a submersible pump, echo sounder and data logger is suspended on an armoured cable. The cable consists of a nylon tubing core surrounded by 22 conductor lines for data and power transfer and has a stainless steel braided shield and an outer plastic coating for protection. Fairings are used to reduce the drag on the cable through the water. A typical tow speed for the fish during acquisition is 5 to 7 knots. The echo sounder is used in order to control the height at which the towfish is 'flown' above the sea floor. The effective working depth is around 240 metres with the current winch and cable.

Data Logger

The data logger is fitted with various probes and samplers: temperature, dissolved oxygen, salinity, conductivity, depth, turbidity, Ph and oxidation / reduction potential.

Winch and'A' Frame

The cable is deployed from a winch with a 2 metre diameter drum which incorporates a hub with a universal pipe coupling /slip ring assembly which allows seawater to be pumped and data and power to be transferred from the cable. The winch can be controlled remotely by joystick. The cable is fed onto the winch drum in a single wrap via a sheave and screw assembly fitted to an 'A' frame. The 'A' frame is placed at the stern of the vessel and is positioned such that it allows the towfish to be launched and recovered whilst keeping clear of the ship's hull.

Fairing Platforms

Two fairing platforms are placed between the winch and 'A' frame (where possible) to allow replacement fairings to be fitted to the cable as necessary.

Dynamic Headspace Gas Extractor ('Stripper')

Seawater pumped from the fish is sprayed into a glass chamber that has an automatic level control. A vacuum pump applies a negative pressure to the headspace thereby extracting volatile hydrocarbons, which are piped to gas chromatographs for analysis.

The extracted hydrocarbons from the stripper flow to a set of 8 parallel sample loops, each of which is attached to a 10 port electronically, actuated flow-switching valve, housed within the oven of a Gas Chromatograph.

Gas Chromatographs (GCs)

The set-up for petroleum work is as follows:

2 x Shimadzu GC17a Gas Chromatographs each fitted with four FID detectors such that there are four asynchronous acquisition channels per GC. One GC is set to do C_1-C_4 hydrocarbon analyses on each channel whereas the other GC is set-up for benzene/toluene analysis. At one minute intervals (shot points), a set of 2 channels, one from each GC, is 'fired' simultaneously with an analysis time of just under 4 minutes. Each set of two channels is the fired every four minutes continually. The output is then one complete set of result C_1-C_4 +benzene/toluene every minute. At 5 knots this is one set of results ~ every 150 metres of travel.

Computer Control and Software

The analogue signal from each detector is passed through an 'intelligent' interface (an A/D converter) which in turn dumps the data to a PC installed with GC integration software (Perkin Elmer, Turbochrom). The control of firing, and real-time display of analysis results is performed by AGSO designed software. All raw and processed data is electronically stored (against a shot point number) in a database on hard disk and on 120 mb floppy disks. Independently acquired navigational position (dGPS) from an in-built receiver in the lab and oceanographic data from the logger in the fish are also stored on the database. This allows for an accurate geographic location of all data to be established. Third party software such as Surfer for Windows can then be used to prepare graphic presentations of the data in the search area.

Navigation Software

The Portalab is fitted with a dGPS system and Windows NT based Endeavour navigational software with a Raster Chart Display System which displays real time position, historical track with cross-course error, bearing and distance to waypoint etc. superimposed on Australian Hydrographic Office Seafarer or the British ARCS charts. The set-up should allow a split signal to be directed to the Bridge to display the same video display of route and position as seen in the PortaLab.

Gas Supply System

Occupational Health & Safety considerations and the logistics of handling large numbers of high pressure gas cylinders at sea have led us to construct a gas generator/purification system which delivers the instrument grade hydrogen and air used for the FID detectors. However it has not been possible (at this stage) to do away with the need for some bottled gas, namely UHP helium, cylinders of which needs to be fixed in a collar arrangement on the outside of the 'PortaLab'

Demountable Laboratory (PortaLab)

A 20' ISO sea container fitted with insulation, air conditioning, marine grade windows and doors, laboratory benches, sink, lighting and power fittings, has been built. The winch, A-frame, fairing platform and the portalab have been designed to minimise the logistical problems of deployment. The lab is designed to be transported as any sea container to the ship by truck, lifted by crane to the deck and welded or otherwise secured in place. Similarly the winch power pack and A- frame need to be welded or secured to the deck.

Power Requirements

The Portalab requires a 32 Amp 415V 3-phase supply. The laboratory apparatus has a 7Kva UPS system with minimum 7 minutes of backup power to run essential instruments. The deck gear consisting of two compressors which require, 2 x 250 Volt, 10A AC supplies and an hydraulic power pack, a winch and an A-frame which requires 1 x 32 amp 415V 3 phase supply.

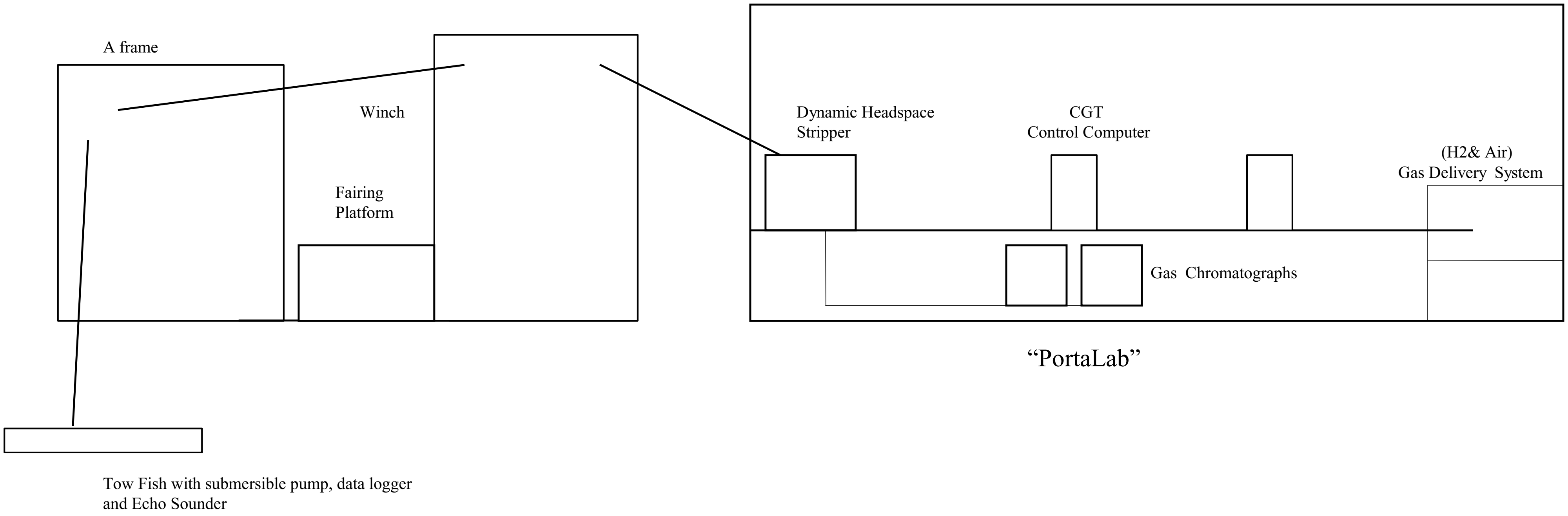

Figure IV-1. **Schematic view of 'Sniffer' System**

Operational problems

Winch System

There were a few problems with the main sheave on the A-frame. Due to the cable fleet angle of up to 30’, when the fish was retrieved at speed, the cable could ride up on the edge off the sheave until it dropped off onto the leadscrew. This occurred several times, and fortunately there was no damage to the cable. Modifications were made to the sheave by fitting extended cheek plates. This alleviated the problem, but a certain amount of care is still required during retrieval.

The majority of the cruise was accomplished at a speed of 8 to 8 1/2 knots. At this speed, the forces caused a side to side vibration in the A-frame. If left unchecked, this could induce fatigue cracks in the mounting.

Fairings

The old system of fairings developed to cope with the characteristics of side deployment and a swivelling, narrow sheave, leaves a lot to be desired. Although the concept of a consumable, break-a-way fairing allowed the cable to be retrieved, ripping the fairings off rather than jamming the works, it is not suitable for use with the stern deployed, fixed pivot, open sheave system now being used.

The sniffer system would be better served with a more durable fairing design, preferably one offering the advantages of reliability and longer life. This would be best accomplished with a solid, firm compound type, similar to that used on the CSIRO vessel.

The new fairings could be a firm fit on the cable and be secured with stainless fasteners rather than stables. The design could include a urethane strip rather than elastic cord, and may even have the split sections bonded with adhesive for added durability.

Hydraulics

The majority of the equipment operated correctly, but there was a problem with the operation of the winch brake, which was tending to slip under load. After discussions with contractor that modified the hydraulics in Canberra, several attempts were made to correct the fault, but these were unsuccessful. The vessel then returned to Hampton harbour where a local contractor, “Karratha Hydraulic Services”, found that there was a fault in the circuit, with the brake signal was being taken from the wrong side of the counterbalance valve. After the contractor re-routed the line and the counterbalance valve was adjusted, the valve operated correctly easily holding the full weight of the fish.

The hatch fitted to the top of the hydraulic reservoir tended to leak when the ship rolled, spilling oil onto the bolster and down the side of the container. Although adjustments were made to the catches, the leak continued to be a problem during the cruise.

There were also minor problems with leakage of oil from the main system, pressure relief valve. A contractor had installed the incorrect style of fittings, using tapered rather than a face seal type. The correct type of fitting were purchased and fitted in Dampier.

Stripper System

A few problems were apparent with the stripper system, mainly with the Jabsco pump and plumbing. With the higher temperatures in the north, the suction hose softened and collapsed. There were difficulties maintaining a steady water level in the stripper chamber, which was eventually traced down to a damaged impellor in the Jabsco pump. The suspected cause of the exhaust pump failure was due to the high vacuum on the suction line.

During one line, the glass cylinder on the stripper fractured. The spare cylinder was fitted and operations continued. The cause of the damage was believed to be a combination of factors, including stress induced by the rigid pipework, and a lack of clearance between the glass and the end plates.

Towed Fish

Two terminations were made to the fish after the cable was damaged. The cable problems are concentrated on the termination, within a few inches of the bottle. Consideration needs to be given to a possible modification to alleviate this problem, possibly a short tapered rubber sheath fitted to the top of the bottle, similar to that fitted to the old mag heads. This would tend to reinforce the neck and spread the stress over a greater area.

Ancillaries

During the installation two transducer stems were fitted to the side of the vessel. These 2" stems later proved to be flimsy, and vibrated at speeds higher than 4 knots. The larger sonar head more so than the small fish finder / fluorimeter stem which stayed stable up to 8 knots.

APPENDIX V

GENERAL DETAILS:- TSMV Pacific Conquest

TSMV Pacific Conquest is a hydrographic/seismic/research/salvage/towing/surveillance/dive support vessel operated by Samson Marine & Engineering.

The ship was built in Fremantle in 1985.

Gross Registered Tonnage:	221 tonnes		
Length, overall:	30.0 m		
Breadth:	9.2 m		
Draft:	2.2 m		
Engines:	Main:	2 x Caterpillar D343	365 BHP/1800 rpm (each)
	Shaft generator:2 x 85 KVA 415v,240v,24v		
Accommodation:	9 x 2 berth, 1 x 4 berth		
Navigation:	Differential GPS System		

APPENDIX REFERENCES

Bernard, B.B., Brooks, J.M. and Sackett, W.M., 1976. Natural gas seepage in the Gulf of Mexico. *Earth and Planetary Science Letters,* 31, 48-54.

Brooks, J.M., Gormly, J.R. and Sackett, W.M., 1974. Molecular and isotopic composition of two seep gases from the Gulf of Mexico. *Geophysical Research Letters*, 1, 213-216.

Brooks, J.M., Bernard, B.B., Sackett, W.M. and Schwarz, J.R., 1979. Natural gas seepage on the south Texas shelf. *In: 11th Offshore Technology Conference Houston Texas*, OTC 3411, 471-474.

Claypool, G.E. and Kvenvolden, K.A., 1983. Methane and other hydrocarbon gases in marine sediment. *Annual Review of Earth and Planetary Science*, 11, 299-327

Cline, J.D. and Holmes, M.L., 1977. Submarine seepage of natural gas in Norton Sound, Alaska. *Science*, 198, 1149-1153.

Hovland, M. and Judd, A.G., 1988. *Seabed Pockmarks and Seepages Impact on Geology, Biology and the Marine Environment*. Graham and Trotman, Ltd. London., 293pp.

Hunt, J.M., 1979. *Petroleum Geochemistry and Geology*. Freeman and Co., San Francisco, 617pp.

Hunt, J.M., 1984. Generation and migration of light hydrocarbons. *Science*, 226, 1256-1270.

Kvenvolden, K.A., Vogel, T.M. and Gardner, J.V., 1979. Geochemical prospecting for hydrocarbons in the outer continental shelf, southern Bering Sea. *Journal of Geochemical Exploration*, 14, 209-219.

Kvenvolden, K.A. and Claypool, G.E., 1980. Origin of gasoline-range hydrocarbons and their migration by solution in carbon dioxide in Norton Sound, Alaska. *American Association of Petroleum Geologists Bulletin*, 64, 1078-1086.

Kvenvolden, K.A. and Field, M.A., 1981. Thermogenic hydrocarbons in unconsolidated sediment of Eel River Basin, offshore northern California. *American Association of Petroleum Geologists Bulletin*, 65, 1642-1646.

Leythaeuser, D., Schaefer, R.G. and Yukler, A., 1982. Role of diffusion in primary migration of hydrocarbons. *American Association of Petroleum Geologists Bulletin*, 66, 408-429.

Nelson, H., Kvenvolden, K.A. and Clukey, C., 1978. Thermogenic gases in near-surface sediments of Norton Sound, Alaska. 10th *Offshore Technology Conference Houston Texas*, OTC 3354, 2623-2633

Philp, R.P. and Crisp, P.T., 1982. Surface geochemical methods for oil and gas prospecting- a review. *Journal of Geochemical Exploration*, 17:1-34.

Primrose, S.B., and Dilworth, M.J., 1976. Ethylene production by bacteria. *Journal of General Microbiology*, 93, 177-181.

Reed, W.E. and Kaplan, I.R., 1977. The chemistry of marine petroleum seeps. *Journal of Geochemical Exploration*, 7, 253-293.

Reitsma, R.H., Lindberg, F.A. and Kaltenback, A.J., 1978. Light hydrocarbons in Gulf of Mexico water: sources and relation to structural highs. *Journal of Geochemical Exploration*, 10, 139-151.

Reitsma, R.H., Kaltenback, A.J. and Lindberg, F.A., 1981. Source and migration of light hydrocarbons indicated by carbon isotopic ratios. *American Association of Petroleum Geologists Bulletin*, 65, 1536-1542.

Sackett, W.M., 1977. Use of hydrocarbon sniffing in offshore exploration. *Journal of Geochemical Exploration*, 7:243-254.

Sweeney, R.E., 1988. Petroleum-related hydrocarbon seepage in a recent North Sea sediment. *Chemical Geology*, 71, 53-64.

Tissot, B.P. and Welte, D.H., 1984. *Petroleum Formation and Occurrence*. Springer-Verlag, New York., 697pp.

Whelan, J.K., Hunt, J.M., Jasper, J. and Huc, A., 1984. Migration of C_1-C_8 hydrocarbons in marine sediments. *Organic Geochemistry*, 6, 683-694.

APPENDIX VI

Tables stating the locations of the start and ends of each line.

Table 1

Direct Hydrocarbon Detection (Sniffer) line summary   Wandoo B Platform

Line Number	Latitude Start	Longitude Start	Julian Day Start	UTC Start	Line Length
	Latitude Finish	**Longitude Finish**	**Julian Day Finish**	**UTC Finish**	**NM/km**
207001	-20.1245	116.4402	269	17:52:02	2.4/4.5
	-20.1197	116.4429	269	19:31:46	
207002	-20.1181	116.4422	269	19:32:46	17.2/31.8
	-20.1309	116.4735	269	22:19:46	
207003	-20.1167	116.4719	269	22:27:17	19.9/36.8
	-20.1649	116.5004	270	02:02:18	
207004	-20.1475	116.5078	270	02:13:54	19.5/36.1
	-20.1887	116.3172	270	05:41:55	
207005	-20.1994	116.3179	270	05:48:16	22.1/41.0
	-20.0762	116.5703	270	10:02:16	
207006	-20.0742	116.5942	270	11:55:36	30.1/55.7
	-20.2097	116.3332	270	17:33:36	
TOTAL					**111.2/205.9**

Table 2

Direct Hydrocarbon Detection (Sniffer) line summary   Offshore Canning

Line Number	Latitude Start	Longitude Start	Julian Day Start	UTC Start	Line Length
	Latitude Finish	**Longitude Finish**	**Julian Day Finish**	**UTC Finish**	**NM/km**
207007	-20.2045	116.3551	270	18:58:02	8.6/15.9
	-20.0824	116.2880	270	20:19:02	
207008	-20.0815	116.2864	270	20:20:02	2.5/4.7
	-20.0553	116.2545	270	20:51:02	
207009	-20.0524	116.2529	270	20:53:02	5.5/10.2
	-19.9854	116.3141	270	21:46:03	
207010	-19.9439	116.3521	270	22:19:14	22.4/41.5
	-19.7202	116.6507	271	01:50:14	
207011	-19.7187	116.6524	271	01:51:14	21.5/39.9
	-19.5295	116.8891	271	09:23:20	
207012	-19.4918	116.9396	271	10:00:17	23.6/43.7
	-19.2402	116.9197	271	13:37:17	
207013	-19.2368	116.9172	271	13:38:27	1.1/2.0
	-19.2232	116.9056	271	13:46:27	
207014	-19.1364	116.8428	271	15:05:26	22.8/42.2
	-18.8308	116.6270	271	17:55:21	
207015	-18.8285	116.6259	271	17:56:21	32.8/60.7
	-18.4224	116.8857	271	22:08:41	
207016	-18.8465	117.1317	272	10:35:48	43.3/80.1
	-19.4242	117.5414	272	17:23:23	
207017	-19.4336	117.5418	272	20:06:38	11.3/21.0
	-19.3243	117.6788	272	21:59:25	
207018	-19.3228	117.6798	272	22:00:25	4.2/7.8
	-19.2722	117.6391	272	22:36:24	
207019	-19.1992	117.6525	273	00:27:31	27.9/51.6
	-19.3732	117.6254	273	04:34:31	
207020	-19.3630	117.6175	273	04:41:41	0.3/0.6
	-19.3590	117.6144	273	04:44:41	
207021	-19.3574	117.6132	273	04:45:41	6.9/12.8
	-19.2682	117.5419	273	05:54:30	
207022	-19.2678	117.5400	273	05:55:30	8.4/15.5
	-19.3699	117.5804	273	07:12:30	

Table 2 cont'd

Line Number	Latitude Start	Longitude Start	Julian Day Start	UTC Start	Line Length
	Latitude Finish	**Longitude Finish**	**Julian Day Finish**	**UTC Finish**	**NM/km**
207023	-19.3767	117.5869	273	07:21:02	7.4/13.7
	-19.4688	117.6443	273	08:28:03	
207024	-19.4733	117.6399	273	08:32:44	17.3/32.1
	-19.3205	117.4459	273	11:16:44	
207025	-19.3209	117.4453	273	11:17:44	17.7/32.7
	-19.5375	117.6336	273	14:04:45	
207026	-19.5455	117.6408	273	14:12:26	3.1/5.8
	-19.5857	117.6738	273	14:40:26	
207027	-19.6091	117.6929	273	15:07:28	4.3/8.0
	-19.6580	117.7349	273	15:41:28	
207028	-19.6583	117.7370	273	15:42:28	29.7/55.0
	-19.1817	117.7840	273	20:06:28	
207029	-19.1798	117.7841	273	20:07:28	16.7/31.0
	-18.9107	117.8170	273	22:34:28	
207030	-18.8868	117.8205	273	22:47:58	20.6/38.1
	-18.5594	117.8550	274	01:44:12	
207031	-18.5576	117.8542	274	01:45:12	8.6/15.9
	-18.7466	117.5596	274	05:27:12	
207032	-18.7476	117.5587	274	05:28:12	6.2/11.4
	-18.6874	117.6653	274	07:06:11	
207033	-18.6839	117.6749	274	07:50:51	9.1/16.9
	-18.6835	117.7784	274	08:53:51	
207034	-18.6833	117.7799	274	08:54:51	6.1/11.3
	-18.7174	117.7434	274	09:49:51	
TOTAL					**389.9/722.1**

Table 3

Direct Hydrocarbon Detection (Sniffer) line summary Leg 2

Line Number	Latitude Start	Longitude Start	Julian Day Start	UTC Start	Line Length
	Latitude Finish	**Longitude Finish**	**Julian Day Finish**	**UTC Finish**	**NM/km**
207035	-15.7403	121.7199	280	11:09:57	16.3/30.2
	-15.7397	122.0012	280	12:50:09	
207036	-15.7375	122.0021	280	12:51:09	13.8/25.6
	-15.5266	122.0751	280	14:44:09	
207037	-15.5249	122.0771	280	14:45:09	46.7/86.4
	-15.1256	122.7467	280	20:04:10	
207038	-15.1247	122.7484	280	20:05:09	69.3/128.3
	-14.7029	123.8418	281	04:17:09	
207039	-14.7020	123.8443	281	04:18:09	35.0/64.9
	-14.1550	124.0104	281	10:04:09	
207040	-14.0588	124.0814	281	10:54:32	29.0/53.7
	-13.6065	124.3873	281	19:14:51	
207041	-13.6056	124.3880	281	19:15:51	31.0/57.4
	-14.0578	124.8620	282	00:52:50	
207042	-14.0587	124.8637	282	00:53:49	20.4/37.7
	-13.8213	125.1063	282	03:38:51	
207043	-13.8194	125.1060	282	03:39:51	42.7/79.1
	-13.3536	125.5614	282	09:05:47	
207044	-13.3436	124.5415	282	09:39:41	44.5/82.5
	-13.8637	125.0735	282	15:12:40	
207045	-13.8803	125.0914	282	15:34:59	42.9/79.4
	-13.4062	124.5085	282	21:47:24	
207046	-13.3936	124.4949	282	22:04:49	38.9/72.0
	-13.9025	125.0330	283	04:14:15	
207047	-13.9127	125.0401	283	04:31:21	44.9/83.2
	-13.4227	124.4786	283	10:53:21	
207048	-13.4532	124.4698	283	11:26:38	40.7/75.3
	-13.9413	124.9968	283	16:42:39	
207049	-13.9577	124.9837	283	17:17:02	42.4/78.6
	-13.4692	124.4458	283	23:03:13	
207050	-13.4703	124.4350	283	23:19:24	40.1/74.2
	-13.9387	124.9108	284	18:55:46	

Table 3 cont'd

Line Number	Latitude Start	Longitude Start	Julian Day Start	UTC Start	Line Length
	Latitude Finish	**Longitude Finish**	**Julian Day Finish**	**UTC Finish**	**NM/km**
207051	-13.7248	124.6735	284	02:15:26	3.2/5.9
	-13.7076	124.7252	284	02:41:33	
207052	-13.7065	124.7269	284	02:42:33	7.4/13.7
	-13.6400	124.8330	284	03:42:33	
207053	-13.6385	124.8348	284	03:43:33	2.2/4.0
	-13.6154	124.8626	284	04:01:33	
207054	-13.6142	124.8619	284	04:02:33	2.9/5.4
	-13.5765	124.8346	284	04:27:33	
207055	-13.5756	124.8334	284	04:28:33	3.0/5.5
	-13.6142	124.8034	284	04:54:33	
207056	-13.6151	124.8021	284	04:55:33	6.6/12.3
	-13.6792	124.7121	284	05:55:32	
207057	-13.6800	124.7109	284	05:56:33	3.5/6.4
	-13.7129	124.6644	284	06:38:33	
207058	-13.7134	124.6636	284	06:39:33	3.7/6.8
	-13.6917	124.6057	284	07:36:33	
207059	-13.6909	124.6000	284	07:53:52	9.4/17.5
	-13.6928	124.7312	284	10:21:08	
207060	-13.6936	124.7320	284	10:22:08	3.4/6.3
	-13.6799	124.6739	284	11:09:33	
207061	-13.6802	124.6079	284	11:45:12	2.0/3.7
	-13.7135	124.6079	284	12:02:11	
207062	-13.7271	124.6092	284	12:08:55	6.1/11.3
	-13.7243	124.7143	284	12:57:54	
207063	-13.7232	124.7143	284	12:58:55	2.1/3.9
	-13.6880	124.7128	284	13:16:55	
207064	-13.6875	124.7116	284	13:17:55	5.1/9.4
	-13.6856	124.6270	284	14:06:54	
207065	-13.6874	124.6284	284	14:07:55	1.9/3.5
	-13.7150	124.6302	284	14:25:55	
207066	-13.7152	124.6325	284	14:26:55	2.3/4.2
	-13.7156	124.6712	284	14:43:55	
207067	-13.7155	124.6925	284	14:53:24	1.0/1.8
	-13.6983	124.6950	284	15:05:24	
207068	-13.6982	124.6932	284	15:06:25	3.2/6.0
	-13.6984	124.6381	284	15:38:24	

Table 3 cont'd

Line Number	Latitude Start	Longitude Start	Julian Day Start	UTC Start	Line Length
	Latitude Finish	**Longitude Finish**	**Julian Day Finish**	**UTC Finish**	**NM/km**
207069	-13.9755	124.9497	284	19:24:47	29.8/55.1
	-13.5070	124.3995	285	01:41:56	
207070	-13.5079	124.3831	285	02:00:48	44.2/81.8
	-14.0178	124.9140	285	07:57:53	
207071	-14.0349	124.9329	285	08:18:21	27.2/50.4
	-14.1915	124.1431	285	11:19:53	
207072	-14.2125	125.2999	286	08:50:37	25.0/46.3
	-13.9364	124.9882	286	12:22:37	
207073	-13.9380	124.9870	286	12:23:37	8.3/15.3
	-14.0348	124.8883	286	13:40:37	
207074	-14.0470	124.8801	286	13:56:15	43.8/81.1
	-13.5427	124.3659	286	20:22:15	
207075	-13.5414	124.3430	286	20:40:19	46.1/85.3
	-14.0839	124.8471	287	03:12:44	
207076	-14.1066	124.8509	287	03:41:44	44.8/83.0
	-13.6015	124.3003	287	09:09:08	
207077	-13.5939	124.2769	287	09:25:43	44.4/82.2
	-14.1203	124.8082	287	14:59:16	
207078	-14.1322	124.8135	287	15:13:48	45.1/83.6
	-13.6371	124.2564	287	20:52:38	
207079	-13.8670	124.5002	289	05:41:13	34.0/62.9
	-13.5027	124.9397	289	10:22:32	
207080	-13.5114	124.9461	289	10:36:51	23.4/43.3
	-13.2577	124.6547	289	13:29:47	
207081	-13.2692	124.6317	289	13:49:24	44.0/81.5
	-13.7659	125.1692	289	19:17:24	
207082	-13.7871	125.1674	289	19:36:41	43.7/80.9
	-13.3004	124.6218	290	01:03:51	
207083	-13.3068	124.6019	290	01:17:22	43.3/80.2
	-13.8043	125.1244	290	06:38:22	
207084	-14.5074	123.9894	288	03:10:42	28.2/52.2
	-14.7731	124.4501	288	07:14:02	
207085	-14.7887	124.4648	288	07:34:48	21.4/39.7
	-14.4895	124.6088	288	10:12:42	
207086	-14.4946	124.6120	288	10:26:05	41.4/76.6
	-14.1512	124.0072	288	15:28:51	

Table 3 cont'd

Line Number	Latitude Start	Longitude Start	Julian Day Start	UTC Start	Line Length
	Latitude Finish	**Longitude Finish**	**Julian Day Finish**	**UTC Finish**	**NM/km**
207087	-14.1485	123.9946	288	15:43:39	17.3/32.1
	-13.9353	124.1624	288	17:52:38	
207088	-13.9290	124.1544	288	18:13:24	43.4/80.4
	-14.3710	124.7471	288	23:46:02	
207089	-14.3854	124.7452	289	00:00:55	12.1/22.5
	-14.2001	124.8261	289	01:30:20	
207090	-14.2001	124.8261	289	01:43:31	16.6/30.7
	-14.2001	124.8261	289	03:41:31	
207091	-14.2001	124.8261	289	03:56:42	13.3/24.7
	-14.2001	124.8261	289	05:29:43	
207092	-12.5378	124.3611	290	18:18:37	7.7/14.2
	-12.4382	124.4399	290	19:17:37	
207093	-12.4368	124.4403	290	19:18:37	2.6/4.9
	-12.4118	124.4040	290	19:38:37	
207094	-12.4109	124.4021	290	19:39:37	1.5/2.7
	-12.4286	124.3850	290	19:52:37	
207095	-12.4308	124.3831	290	19:54:37	11.8/21.8
	-12.5823	124.5276	290	21:27:47	
207096	-12.5801	124.5295	290	21:43:27	1.0/1.9
	-12.5669	124.5241	290	21:52:26	
207097	-12.5653	124.5240	290	21:53:26	11.7/21.7
	-12.4222	124.3891	290	23:26:26	
207098	-12.4213	124.3887	290	23:27:26	0.5/1.0
	-12.4165	124.3952	290	23:33:27	
207099	-12.4160	124.3965	290	23:34:27	11.8/21.9
	-12.5625	124.5315	291	00:58:26	
207100	-12.5625	124.5324	291	00:59:27	0.6/1.1
	-12.5576	124.5409	291	01:07:27	
207101	-12.5566	124.5411	291	01:08:26	9.7/18.0
	-12.4380	124.4361	291	02:25:27	
207102	-12.1959	124.6739	291	05:04:43	3.5/6.5
	-12.1357	124.6839	291	05:30:43	
207103	-11.9726	124.7852	291	12:39:41	15.6/28.8
	-12.1944	124.9165	291	14:37:30	
207104	-12.1961	124.9172	291	14:38:30	17.8/32.9
	-12.3797	125.1606	291	17:09:02	
TOTAL					**1503.9/2785.3**

Table 4

Direct Hydrocarbon Detection (Sniffer) line summary AC/P20

Line Number	Latitude Start	Longitude Start	Julian Day Start	UTC Start	Line Length
	Latitude Finish	**Longitude Finish**	**Julian Day Finish**	**UTC Finish**	**NM/km**
BRONTO-1	-12.1959	124.6739	291	05:04:43	8.4/15.5
	-11.9969	124.6500	291	06:31:42	
BRONTO-2	-11.9887	124.6412	291	06:48:00	7.0/13.0
	-12.0563	124.7380	291	07:42:00	
BRONTO-3	-12.0559	124.7399	291	07:43:00	7.9/14.7
	-11.9779	124.6564	291	08:42:00	
BRONTO-4	-11.9764	124.6545	291	08:43:00	7.9/14.6
	-12.0138	124.7540	291	09:38:00	
BRONTO-5	-12.0145	124.7564	291	09:39:00	5.2/9.7
	-11.9599	124.7254	291	10:20:01	
BRONTO-5A	-11.9554	124.7193	291	10:23:31	1.8/3.3
	-11.9369	124.6947	291	10:38:31	
BRONTO-6	-11.9352	124.6929	291	10:39:32	3.1/5.7
	-11.9169	124.7144	291	11:01:31	
BRONTO-7	-11.9184	124.7162	291	11:02:31	6.5/12.1
	-11.9211	124.7455	291	12:07:03	
BRONTO-7A	-11.9376	124.7443	291	12:16:41	3.0/5.6
	-11.9711	124.7832	291	12:38:41	
TOTAL					**50.8/94.2**

Table 5

Direct Hydrocarbon Detection (Sniffer) line summary AC/P25-26

Line Number	Latitude Start	Longitude Start	Julian Day Start	UTC Start	Line Length
	Latitude Finish	**Longitude Finish**	**Julian Day Finish**	**UTC Finish**	**NM/km**
FM1	-12.3861	125.1792	291	17:27:23	22.6/41.9
	-12.3746	124.8108	291	20:14:23	
FM2	-12.3973	124.7740	291	20:53:01	22.8/42.2
	-12.3987	125.1582	291	23:41:04	
FM3	-12.4205	125.1511	291	23:59:03	22.9/42.5
	-12.4157	124.7580	292	02:52:03	
FM4	-12.4373	124.7475	292	03:24:36	23.7/43.8
	-12.4443	125.1486	292	06:17:36	
FM5	-12.4658	125.1374	292	06:42:38	23.4/43.4
	-12.4582	124.7351	292	09:29:36	
FM6	-12.4822	124.7220	292	09:41:36	18.0/33.3
	-12.4848	125.1295	292	12:38:48	
FM7	-12.5043	125.1225	292	12:49:48	24.0/44.4
	-12.5011	124.7029	292	15:51:49	
FM8	-12.5209	124.7055	292	16:40:43	24.5/45.3
	-12.5242	125.1170	292	19:38:44	
FM9	-12.5449	125.1097	292	19:53:43	24.8/46.0
	-12.5406	124.6891	292	23:39:41	
FM13	-12.5518	125.0104	293	09:30:07	3.7/6.8
	-12.5130	125.0002	293	09:59:26	
FM14	-12.4698	124.9767	293	10:28:25	8.4/15.6
	-12.4698	124.8340	293	11:26:18	
FM12EX	-12.4705	124.8320	293	11:27:18	1.4/2.6
	-12.4878	124.8202	293	11:37:18	
FM12	-12.4896	124.8182	293	11:38:18	7.5/13.9
	-12.5783	124.7270	293	12:29:19	
FM11	-12.5792	124.6634	293	12:57:18	24.2/44.8
	-12.5822	125.0880	293	16:13:09	
FM10	-12.5624	125.1015	293	16:47:44	22.4/41.5
	-12.5635	124.6775	293	19:49:18	
TOTAL					**274.3/508.0**

Table 6

Direct Hydrocarbon Detection (Sniffer) line summary AC/P27

Line Number	Latitude Start	Longitude Start	Julian Day Start	UTC Start	Line Length
	Latitude Finish	**Longitude Finish**	**Julian Day Finish**	**UTC Finish**	**NM/km**
ARC1	-12.5813	124.8296	293	14:17:18	10.0/18.5
	-12.5821	124.9987	293	15:33:09	
ARC2	-12.6064	124.8275	293	21:00:12	9.8/18.1
	-12.6067	124.9965	293	22:17:13	
ARC3	-12.6292	124.9978	293	22:29:13	9.5/17.6
	-12.6295	124.8359	293	23:32:13	
ARC4	-12.6543	124.8334	293	23:43:16	7.8/14.5
	-12.6522	124.9686	294	00:45:13	
ARC5	-12.6740	124.9816	294	01:31:18	7.6/14.1
	-12.6747	124.8335	294	02:33:16	
ARC6	-12.6982	124.8339	294	02:43:16	4.8/8.9
	-12.6968	124.9150	294	03:19:16	
ARC7	-12.7042	124.9503	294	04:02:16	8.7/16.1
	-12.5893	124.9146	294	05:02:29	
ARC8	-12.7628	124.7867	294	06:49:43	12.1/22.4
	-12.7673	124.5833	294	08:07:43	
ARC9	-12.7857	124.5858	294	08:18:43	12.9/23.8
	-12.8035	124.7822	294	09:56:44	
ARC10	-12.8034	124.7796	294	09:57:44	10.7/19.9
	-12.8033	124.5969	294	11:08:44	
ARC11	-12.8226	124.5841	294	11:38:50	11.3/20.9
	-12.8204	124.7842	294	13:09:48	
ARC14	-12.9325	124.8309	294	14:02:03	17.2/31.8
	-12.7379	124.5921	294	16:20:58	
ARC12	-12.7533	124.6005	294	17:03:36	4.8/8.9
	-12.8334	124.6006	294	17:38:36	
ARC13	-12.8335	124.6967	294	18:24:35	4.0/7.5
	-12.7667	124.6947	294	18:55:35	
TOTAL					**131.2/243.0**

Table 7

Direct Hydrocarbon Detection (Sniffer) line summary AC/P23

Line Number	Latitude Start	Longitude Start	Julian Day Start	UTC Start	Line Length
	Latitude Finish	**Longitude Finish**	**Julian Day Finish**	**UTC Finish**	**NM/km**
ChameleonA	-12.8948	124.3906	294	21:28:34	3.0/5.6
	-12.9013	124.3712	294	23:19:28	
ChameleonB	-12.9120	124.3601	294	23:41:28	2.8/5.1
	-12.9311	124.3873	295	0:04:06	
ChameleonC	-12.9020	124.3796	295	1:10:05	2.5/4.6
	-12.9346	124.3550	295	1:32:05	
NIPPON1	-12.9078	124.2966	295	2:25:52	7.7/14.3
	-12.9068	124.1755	295	3:39:52	
NIPPON2	-12.9139	124.1809	295	4:02:32	7.2/13.3
	-12.9148	124.2891	295	5:17:38	
NIPPON3	-12.9229	124.3040	295	5:44:19	8.3/15.3
	-12.9271	124.1604	295	6:45:19	
NIPPON4	-12.9301	124.1622	295	6:47:20	6.6/12.2
	-12.9293	124.2917	295	7:50:51	
NIPPON5	-12.9370	124.3155	295	8:08:49	8.7/16.2
	-12.9364	124.1681	295	9:07:49	
NIPPON6	-12.9364	124.1656	295	9:08:50	7.6/14.0
	-12.9508	124.2967	295	10:20:43	
NIPPON7	-12.9507	124.2925	295	10:22:42	7.8/14.5
	-12.9504	124.1677	295	11:17:09	
NIPPON8	-12.9499	124.1634	295	11:19:09	7.9/14.6
	-12.9563	124.3042	295	12:33:59	
NIPPON9	-12.9578	124.3063	295	12:34:59	7.9/14.7
	-12.9648	124.1658	295	13:43:13	
NIPPON10	-12.9646	124.1636	295	13:44:13	8.4/15.5
	-12.9724	124.2965	295	14:56:52	
NIPPON11	-12.9721	124.2982	295	14:57:52	8.7/16.1
	-12.9798	124.1663	295	16:03:52	
NIPPON12	-12.9867	124.1664	295	16:15:52	8.5/15.7
	-12.9868	124.2863	295	17:13:52	
NIPPON13	-13.0015	124.3031	295	17:39:30	7.5/13.8
	-13.0003	124.1673	295	18:33:35	

Table 7 cont'd

Line Number	**Latitude Start**	**Longitude Start**	**Julian Day Start**	**UTC Start**	**Line Length**
	Latitude Finish	**Longitude Finish**	**Julian Day Finish**	**UTC Finish**	**NM/km**
NIPPON14	-13.0130	124.1755	295	18:45:35	7.1/13.2
	-12.8980	124.1745	295	19:39:02	
NIPPON15	-12.9080	124.2692	295	20:27:01	5.7/10.5
	-12.9902	124.2673	295	21:03:01	
TOTAL					**123.9/229.5**

APPENDIX VII

Digital Data

Excel Spreadsheets: Survey Data Leg 1; and Survey Data Leg 2, which contain the following data fields:

Field	**Unit of measure**
Line	eg. 207001
Shot	Integer
Day_Time	dd/mm/yy hh:mm
Day	Julian Day
Time	hh:mm:ss
LatD	Latitude - Degree
LatM	Latitude - Minute
NS	Latitude – North/South
LatDD	Latitude – decimal Degrees
LongD	Longitude – Degree
LongM	Longitude – Minutes
EW	Longitude – East/West
LongDD	Longitude – decimal Degrees
Cnd10	ms/cm
Cond	µs/cm
Temp	C^o
Turb	ntu
Depth	m
pH	pH (acidity/alkalinity)
DO	%sat
Press	bar
Sali	ppt
Dens	g/cm^3
DO	mg/l
Conc.	Arbitrary Fluorosensor unit
Benzene	ppm
Ethane	ppm
Ethylene	ppm
Methane	ppm
Propane	ppm
Propylene	ppm
Toluene	ppm
i-Butane	ppm
n-Butane	ppm

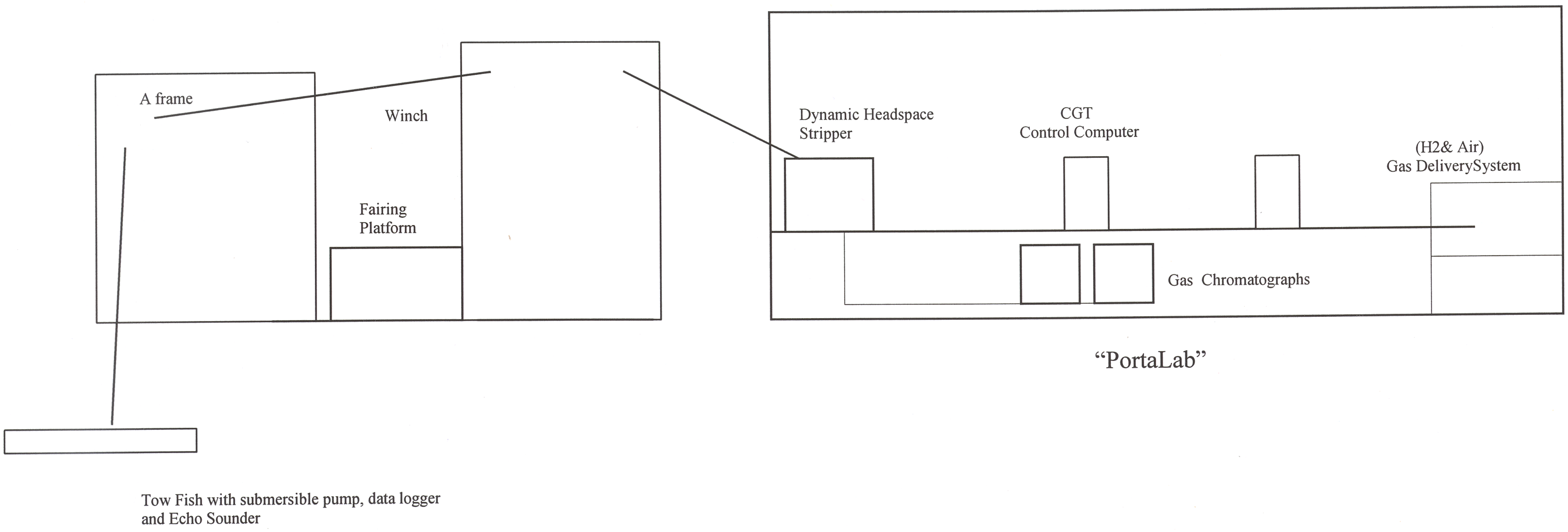

Figure IV-1. Schematic view of 'Sniffer' System