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AGSO Marine Survey 176
Direct Hydrocarbon Detection North-West Australia: Yampi Shelf, Southern Vulcan Sub-Basin and Sahul Platform (July/September 1996)
-Operational Report & Data Compendium-

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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 continental margin, from 28 July to 02 September 1996. The survey acquired data on bottom water hydrocarbon concentration and composition on the Yampi Shelf, southern Vulcan Sub-basin and Sahul Platform. A primary goal was to detect natural hydrocarbon seepage. A total of 3535 line km (150 survey lines) of sniffer data were acquired during the program, using the *RV Rig Seismic*.

In addition to the sniffer program, the survey tested a new high-resolution seismic cable. Also, a total of eight gravity cores were taken.

The principal areas of seepage detected were on the Yampi Shelf where very high, dry, thermogenic gas concentrations (~1%wet) were detected where the regional seal thins onto the Kimberley Block basement (O'Brien et al., 1998a). Principal areas of seepage were located inboard from the Cornea trend.

In addition, siginificantly lower concentrations of relatively wet gas were detected around the Skua field, in the southern Vulcan Sub-basin. Dryer. low-level methane seepage was detected around the breached East Swan and Eclipse fields.

Introduction

Surface geochemistry and offshore exploration for hydrocarbons

Surface geochemical techniques can be used to:

(a) provide direct evidence for thermogenic generation of hydrocarbons in a sedimentary basin;

(b) to assist in locating sub-surface hydrocarbon accumulations; and

(c) to provide information on the likely composition of hydrocarbon accumulations within a given geologic province.

The most common technique used to detect hydrocarbon seepage offshore involves towing a submerged tow-fish close to the seafloor and continuously pumping seawater into a geochemical laboratory on board where the hydrocarbons are extracted and measured by gas chromatography. This equipment collectively is commonly referred to as the 'sniffer' or Direct Hydrocarbon Detection (DHD) system.

The Australian Geological Survey Organisation (AGSO), as part of it's offshore petroleum promotion activities, has been conducting bottom-water DHD surveys on parts of the Australian continental margin since 1989. Part of this work includes research into:

- The origins (biogenic or thermogenic) of bottom-water light hydrocarbons
- Light hydrocarbon 'sources' (liquids, condensate or gas)
- Bottom-water and seafloor expressions of seepage
- The relationships of seepage to the surface and sub-seafloor geology, including hydrocarbon accumulation and source rock types and distributions

Water Column Geochemistry

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. 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 *RV Rig Seismic* is as follows (O'Brien et al, 1992). Seawater is continuously delivered into the geochemical laboratory onboard the ship via a submersible fish (which is towed approximately 10 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. Total hydrocarbons (THC) are measured every thirty seconds, light hydrocarbons (C_1-C_4) are measured every two minutes and C_5 to C_8 are measured every 8 minutes. These data, as well as fish height 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 recognised in real time 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 4 knots, the measurement of THC is made every 70 m, C_1-C_4 every 250 m and C_5 to C_8 every 1400 m.

Survey Aims

AGSO Marine Survey 176 departed Darwin on the 28th of August 1996 with the aim of collecting approximately 5000 line kilometres of bottom-water DHD data to address some key scientific and exploration issues relating to trap integrity and fluid flow histories in the region. The acquired DHD data were to be subsequently correlated with high resolution seismic and aeromagnetic data.

The geochemical analysis system (DHD) aboard the *RV Rig Seismic* is shown schematically in Figure II-1 of Appendix II. The laboratory system analyses a variety of gases extracted from seawater, including C_1 to C_8 hydrocarbons with facilities to collect gases for shore-based isotopic analyses. Complete details of both the DHD system and the interpretative methodologies used are given in Appendices II and III.

This record presents the geochemical 'sniffer' data obtained during *RV Rig Seismic* Survey 176 in the Timor Sea (Figure 1) from July to September 1996. This report presents the DHD data and a preliminary interpretation of the results; other aspects such as the cable trials, gravity and magnetics are not dealt with. Data from the Yampi Shelf and the Vulcan Sub-basin parts of the survey have been presented previously in two AGSO Records: O'Brien et al. (1996a) and O'Brien et al. (1996b), respectively.

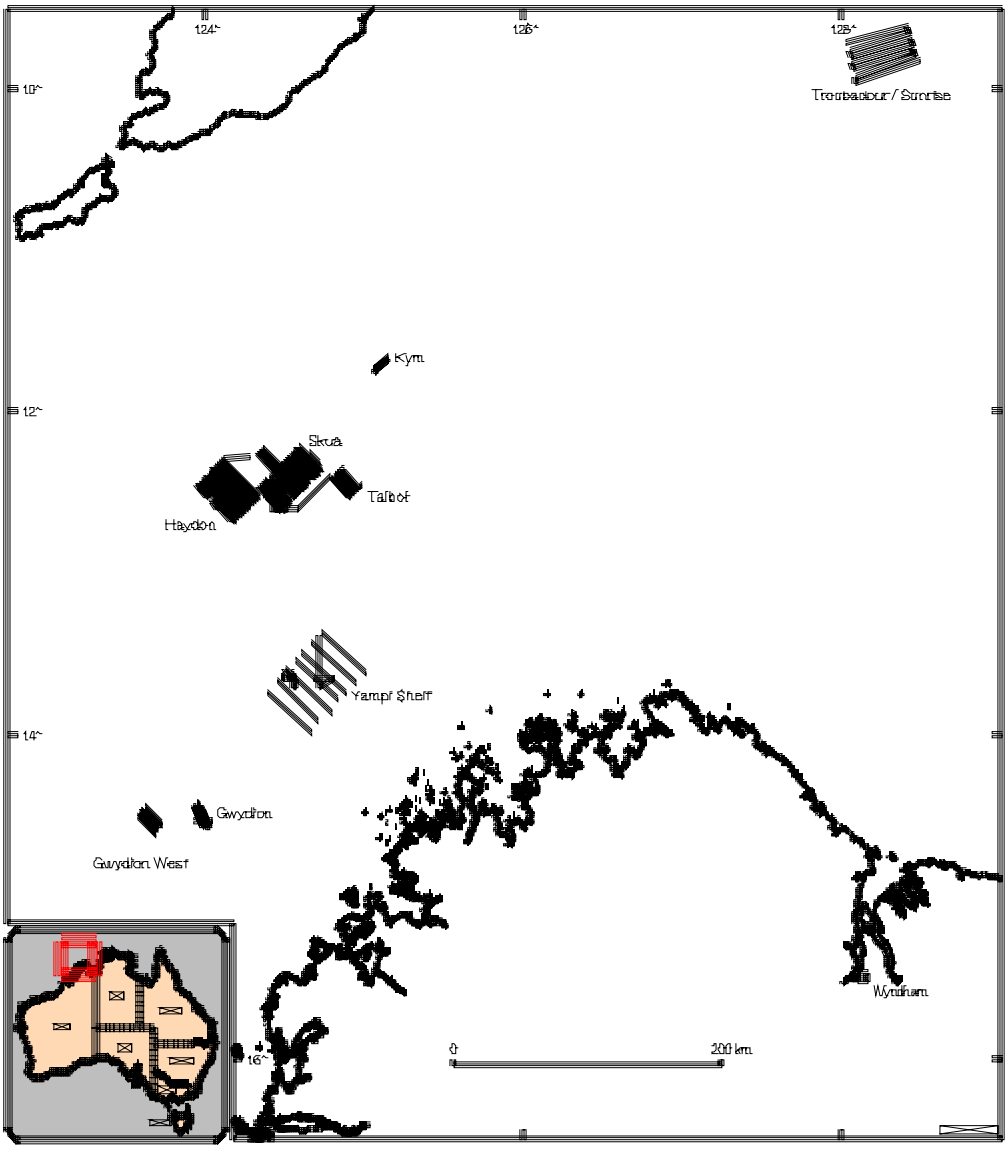

Figure 1. **Location and Ship's track – Survey 176.**

Results

General

Line summaries for the sniffer data acquired are presented in Appendix XI and all data are contained as spreadsheets at Appendix XII. In addition, each survey region has a gridded enclosure highlighting the results for 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.

Gwydion

No anomalies present (Enclosures 1 and 2).

Gwydion West

One moderate methane and ethane anomaly present on line 176016 (Enclosures 1 and 2).

Yampi Shelf

Moderate to strong methane and ethane concentrations were detected on parts of the Yampi Shelf (Enclosures 3 and 4). The levels measured, coincident with high-resolution seismic lines from AGSO Survey 165, indicate hydrocarbon leakage where the regional seal thins onto the Kimberley Block basement (O'Brien et al., 1998b).

Haydn

One very weak ethane anomaly was detected on line 176052 (Enclosure 5). Methane values were all background in concentration (Enclosure 6).

Skua

Elevated concentrations, several weak methane and ethane anomalies were detected (Enclosures 7,8 and 9). One moderate ethane anomaly was detected on line 176109 (Enclosure 7). These anomalies are in an area where the regional Early Cretaceous seal is thin and the displacement on the Neogene faults significant (O'Brien et al., 1998a).

Troubadour/Sunrise

Several moderate anomalies were detected as isolated points (Enclosures 10 and 11)

Kym

No anomalies present (Enclosures 12 and 13).

Talbot

No anomalies present (Enclosures 14 and 15).

Discussion

The highlight of the survey was the 100 times background anomaly detected over the Yampi Shelf. These results are discussed in detail in the Yampi Shelf Tie (YST) report, AGSO Record 1996/60 (O'Brien et al, 1996a). These discussions deal with the thinning of the regional Cretaceous seal as it ramps onto basement (Kimberley Block).

The data recorded over the Skua-Swan area are discussed in detail in the Vulcan Tertiary Tie (VTT) report, AGSO Record 1996/61 (O'Brien et al, 1996a). In particular, these data are considered together with high-resolution seismic data and Airborne Laser Fluorosensor (ALF) data.

References

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., Blackburn, G., Baird, J., Fellows, M. and Wilson, D., 1996a. Yampi Shelf Tie (YST) Basin Study and Interpretation Report: Yampi Shelf, Browse Basin, Northwestern Australia. *AGSO Record* 1996/60.

O'Brien, G.W., Barber, P., Sturrock, S., Woollard, K., Fellows, M. and Wilson, D., 1996b. Vulcan Tertiary Tie (VTT) Basin Study. Vulcan Sub-basin, Timor Sea, Northwestern Australia. *AGSO Record* 1996/61.

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.

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Survey Personnel

AGSO Crew

Ship Manager	Stephen Dutton
QC Scientist	Mark Alcock Robin Mu Luo
Scientific Technical Officers	Tiernan McNamara Paul Hyde Roger Albans Drue Edwards
Electronics Technicians	Joe Mangion Phil Doolan
Mechanical Technicians	Andrew Hislop David Sewter Ken Elphick Andy Hogan
Sniffer Group	Melissa Fellows (Client Representative) Donald Wilson Drewe Hampton Colin Tindall Jon Stratton Peter Davis

AMSA Crew

Master	Bob Hardinge
1st Mate	Bill Orgill
2nd Mate	Otto Weysenfeld
Chief Engineer	Roger Thomas
2nd Engineer	Russell Heaton
Electrician	Bob Dickman
Chief Integrated Rating	Bruce Noble
Integrated Rating	Dave Kane
Integrated Rating	Rob Campbell
Integrated Rating	Matt Stapleton
Chief Cook/Steward	Geoff Conley
Cook	Alex King
Catering Attendant	Sai Wo Wong
Catering Attendant	George Lilja

APPENDIX I

Cruise Narrative

The RV Rig Seismic departed the port of Darwin on the 28th of July 1996. The Survey objective was to conduct Direct Hydrocarbon Detection (Sniffer) investigations over 8 survey areas.

28 July 1996 Day 210

Sailed at 1800hrs and commenced transit to the 1st survey area.

28 July 1996 Day 210

Arrived at Gwydion Area and commenced the setting up and testing of equipment.

30 July – 02 August 1996 Days 212-215

Lines 176001 to 176022.

02 August 1996 Day 215

Completed Gwydion Area, fish recovered and transit commenced to the Yampi Area.

Line 176023.

03 August 1996 Days 215-216

Discovery of Methane high – 300ppm – 100 times background on Line 176026.

Lines 176024, 176025, 176026, 176027, 176028

04 August 1996 Day 217

Completed Yampi Area - transit to Haydn Area.

Lines 176029, 176030.

05 August 1996 Day 218

Retermination of the Sniffer cable in an attempt to alleviate Submersible Data Logger (SDL) faults.

06-10 August 1996 Days 219-223

Commenced Haydn lines.

Lines 176031 to 176061

10 August 1996 Day 223

Completed Haydn Area. Transit to Skua area.

11 August 1996 Day 224

Commenced Skua lines.

Lines 176063 to 176080.

13 August 1996 Day 226

Recovered fish and proceeded to the Skua Venture to pick up stores.

Resumed acquistion 1625hrs.
Lines 176081, 176082 and 176083.

At 2231hrs , the supporting pin for the sheave block either worked loose or failed resulting in the loss of the block, the fish and approximately 150m of cable.

2300 hrs, commenced transit to Darwin to arrange the manufacture of a new block. An alternate program was decided during transit, to allow for the construction and transport of the new equipment to Darwin.

14 August 1996 Day 227

Testing of the new high resolution seismic cable. This included seismic system training for the new QC and observers.

16 August 1996 Day 229

Testing completed and transit to alternate work area consisting of gravity coring commenced.

17 August 1996 Day 230

Coring commenced.
GC176001-GC176008

18 August 1996 Day 231

Gravity coring completed. Commenced transit to Darwin.
Arrived Darwin anchorage 1845hrs.

19 August 1996 Day 232

Berthed at Fort Hill Wharf, Darwin, 0800hrs.

19-21 August 1996 Day 232-234

Refit of new equipment.

22 August 1996 235

Equipment tested and transit commenced to the Troubadour Sunrise area.

23-24 August 1996 Days 236-237

Commenced Troubadour Sunrise lines.
Lines 176084 to 176090.

25 August 1996 Day 237

Completed Troubadour Sunrise area. Transit commenced to Skua area.
Diverted to Kym area.

26 August 1996 Day 238-239

Commenced Kym lines.

The following lines were collected:
176091 to 176095.

27-31 August 1996 Days 239-244

Transit to Skua area.
Recommenced Skua lines.
176096 to 176131

31 August 1996 Day 244

The survey was completed. The fish was recovered and transit commenced to Darwin.

02 September 1996 Day 246

Berthed at Stokes Hill Wharf, Darwin, at 0800hrs.

APPENDIX II

DHD Methodology (from O'Brien et al., 1992)

Many of the world's hydrocarbon accumulations 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 by AGSO is shown schematically in *Figure II-1*. 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.

Water Column Geochemistry

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.

D.J. Wilson: AGSO Marine Survey 176 Direct Hydrocarbon Detection, North-West Australia: Yampi Shelf; Southern Vulcan Sub-Basin: Sahul Platform.(July/September 1996)

The method used on the *RV Rig Seismic* is as follows. Seawater is continuously delivered into the geochemical laboratory onboard the ship via a submersible fish (which is towed approximately 10 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. Total hydrocarbons (THC) are measured every thirty seconds, light hydrocarbons (C_1-C_4) are measured every two minutes and C_5 to C_8 are measured every 8 minutes. 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 4 knots, the measurement of THC is made every 70 m, C_1-C_4 every 250 m and C_5 to C_8 every 1400 m.

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.

Sub-samples of extracted gas may be taken and stored for subsequent shore-based isotopic analyses.

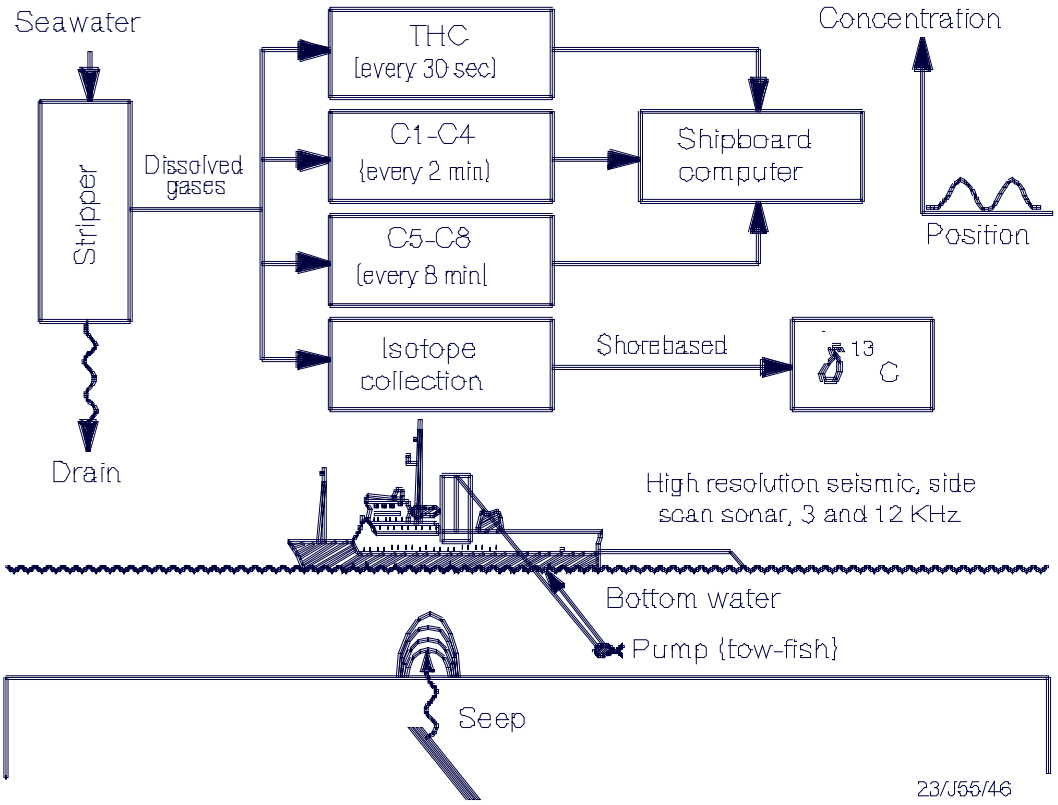


Figure II-1. Schematic of the geochemical equipment aboard Rig Seismic for the continuous profiling of hydrocarbons in seawater: the bottom water DHD technique.

APPENDIX III

Interpretative Methodology (from O'Brien et al., 1992)

The DHD equipment installed on *RV Rig Seismic* 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 (from O'Brien et al., 1992)

Direct hydrocarbon detection in bottom-water (DHD) is accomplished with the equipment schematically shown in Figure II-1. The equipment comprises four major components:

Deployed Equipment

Tow-fish

The Tow-fish is fitted with a submersible pump, which delivers seawater to the geochemical laboratory on the ship via a hollow cable. A submersible data logger (SDL) measures the depth of the tow-fish as well as the temperature and salinity of the seawater (to relate the depth of sampling to the depth of the thermocline, to detect hydrographic 'fronts' and to detect sub-seafloor freshwater acquifers that may drain through sedimentary layers from the continent).

Sonar

A sonar measures and continuously displays the altitude of the tow-fish above the seafloor allowing the operator to maintain the tow-fish at an altitude of about 10m.

Cable

A hollow cable (consisting of medical grade nylon tubing wrapped with insulated conductors which both transmit power to the tow-fish and relay the SDL and sonar data from the tow-fish) delivers bottom-water to the geochemical laboratory. The tubing and conductors are wrapped in a stainless steel braid. Plastic fairings, which are attached to the cable to reduce friction drag, allow the tow-fish to be towed almost directly beneath the ship.

Analytical Equipment

The analytical equipment includes a dynamic headspace gas extraction unit, or 'stripper', together with gas chromatographs connected in parallel to measure the concentrations of a variety of (C_1-C_8) hydrocarbons extracted from the seawater. 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.

Seawater samples can also be taken for later shore-based isotopic analysis.

Data Acquisition System

The data acquisition system is PC based: all data are displayed, edited and stored in a database for plotting at sea.

The tow-fish is deployed from the 'A-frame' on the port side of the RV Rig Seismic, which allows DHD data to be acquired concurrently with seismic data. Echo sounder data and dGPS navigation are displayed in the laboratory and these provide clues to the locations of surface expressions of gas seeps on the seafloor. All the data are recorded continuously so that any hydrocarbon anomalies in the water column can be quickly recognised and additional measurements (or samples) can be collected as appropriate.

Detector sensitivity is <10 parts per billion in the stripped headspace sample. Calibrations were conducted on a daily basis and were within 5% for the entire program and system blanks were less than 2ppm for methane and 5ppb for C_2 + compounds.

The following parameters are measured:

Parameter	**Unit of measure**	**Equipment Used**
Day	Julian Day	On-board dGPS
Time	hh:mm:ss	"
Line	176###	
Shot	Integer	
Total Hydrocarbons (THC)	ppm	Shimadzu Gas Chromatograph
Methane	ppm	"
Ethane	ppm	"
Ethylene	ppm	"
Propane	ppm	"
Propylene	ppm	"
i-Butane	ppm	"
n-Butane	ppm	"
Altitude	m	Altitude sonar
Water Depth	m	Pressure transducer
Tow-fish Depth	m	On-board 3.5Khz & 12 Khz echo sounders
Cond	µs/cm	
Temp	C^o	
Press	bar	
DO	%sat	
Turb	ntu	
pH	pH (acidity/alkalinity)	
Sali	ppt	
Dens	g/cm^3	
DO	mg/l	

Parameter	**Unit of measure**	**Equipment Used**
Lat	Latitude – North/South	On-board dGPS
LatD	Latitude - Degree	"
LatM	Latitude - Minute	"
LatDD	Latitude – decimal Degrees	"
Long	Longitude – East/West	"
LongD	Longitude – Degree	"
LongM	Longitude – Minutes	"
LongDD	Longitude – decimal Degrees	"

APPENDIX V

GENERAL DETAILS:- RV Rig Seismic

RV Rig Seismic was a seismic research vessel with dynamic positioning capability, chartered and equipped by AGSO to carry out the Continental Margins Program. The ship was built in Norway in 1982 and arrived in Australia to be fitted out for geoscientific research in October 1984. It was registered in Newcastle, New South Wales, and was operated for AGSO by the Australian Marine Safety Authority (AMSA). AGSO's charter of the vessel ended in 1998.

Gross Registered Tonnage:		1545 tonnes
Length, overall:		72.5 m
Breadth:		13.8 m
Draft:		6.0 m
Engines:	Main: Norma KVMB-12	2640 HP/825 rpm
	Aux: 3x Caterpillar	564 HP/482 KVA
	1x Mercedes	78 HP/56 KVA
	Shaft generator:	AVK 1000KVA; 440 V/60 Hz
Side Thrusters:		2 forward, 1 aft, each 600 HP
Helicopter Deck:		20 m diameter
Accommodation:		39 single cabins and hospital

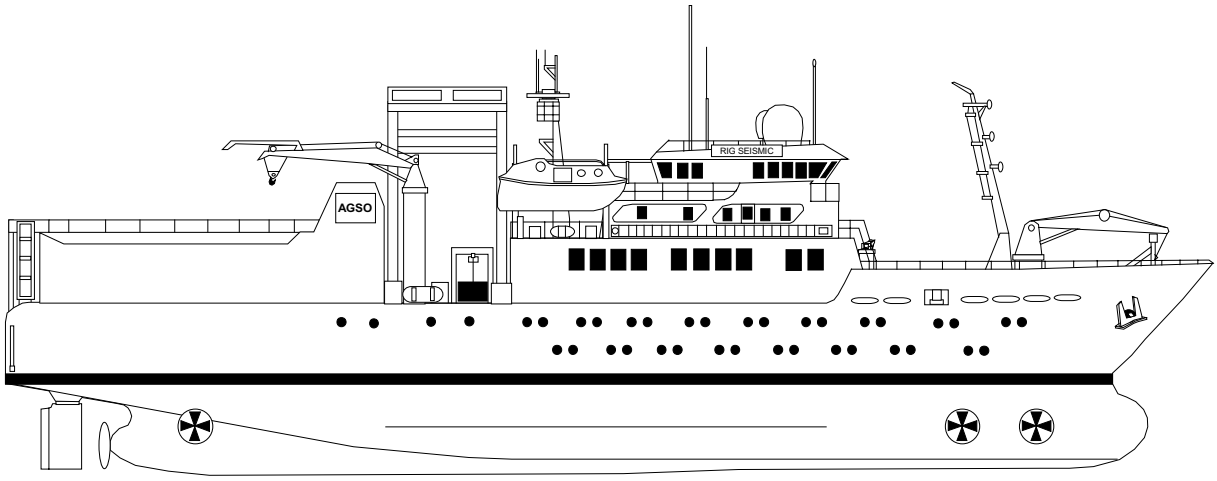


Figure V-1. AGSO Marine survey ship, *RV Rig Seismic*.

APPENDIX VI

Scientific Equipment

Geopysical Scientific Equipment

Non-seismic Systems

General

Raytheon echo sounders: 3.5 Khz (2 KW) and 12 Khz (2 KW)

Geometrics G801/803 magnetometer/gradiometer

Bodenseewerk Geosystem KSS-31 marine gravity meter

E.G. & G. model 990 side scan sonar

Nichiyu Giken Kogyo model NTS-11Au heatflow probe

Navigation

Trimble Differential GPS System (Dampier Sub-Basin)

Magnavox T-set Global Positioning System

Magnavox MX 1107RS and MX 1142 transit satellite receivers

Magnavox MX 610D and Raytheon DSN 450 dual axis sonar dopplers

Arma Brown and Robertson gyro-compasses; plus Ben paddle log

Decca HIFIX-6 radio-navigation system, modified for long range operations

APPENDIX VII

Mechanical Operations Report

Cruise Preparation

Three days were spent in Darwin preparing equipment for the cruise. The preparation of the sniffer equipment was completed during the prior survey. A signature test was done along side the wharf. The #1 tugger was used to deploy a section of cable coiled up on the test reel and a single GI gun was hung over the stern as the source. The coring cradle and bomb were lifted down and set up in the port alley.

Hydraulics and Winches

The DHD winch worked well for the sniffer cruise, until the end of the cruise. The main shaft bearing on the slip ring end collapsed. This will be looked at on the transit.

The 'A' frame hydraulic rams were bent after it was tried to be deployed with the locking pins in place. The foward locking pin was also bent and can not be put in. The crane was used to straighten out the rams. The rams will be looked at in Brisbane.

The sniffer block on the 'A' frame was lost. It parted at the pin between the swivel and the block which the main pin goes into that connects it to the 'A' frame. The reason for this, whether the pin fell out or sheared, is unknown. The new sniffer block made in Canberra was assembled and modified on arrival. This was done fairly quickly to get it up, there was not much time to play around with it and further adjustments will have to be done to the block and modifications documented back in Canberra.

The AWH hydraulic power pack was run for a few days prior and during coring. It ran well, only one pipe had a small leak but this was fixed.

The coring winch ran well with no problems. A total of 9 cores were taken, (eight 6 m cores and one 3 m core). The 6 m barrel was bent on the last core, this was cut to make a 3 m barrel. The chains that traverse the cradle trolley were adjusted and the clamping bolts for the adjuster were replaced.

The hydrographic winch ran ok after a few small maintenance jobs on the spooling gear and sheave on the A frame. The grab was sent down twice, but came back unsuccessful.

The Odim hydraulic power pack ran ok, but not much cooling water is coming out the discharge pipe over the side.

The vibracore winch was operated several times during the survey.

Compressors

High pressure air @ 2000 psi was supplied by running 1 of the 6 'Price Air Gun Master' compressors at 1600 rpm, while using a single GI gun.

Preventative maintenance was carried out during the survey on all the compressors, except #4 which was done on the last survey. The 3rd & 4th stages and cross-heads were re-ringed and honed on compressors # 1, 2, 3, 5 & 6. 2nd stage was re-ringed and honed on compressors # 1, 5 & 6. All gaskets removed were replaced.

All big end bearings on the high stages were removed, inspected and replaced where necessary.

The oil in some of the compressors that had maintenance done on them was replaced due to it being a milky colour or dirty looking after they were reassembled. The filters were changed as well. Samples of this oil have been kept.

150 ml of alfloc was added to the cooling water of all the compressors.

Diesel's

Only one diesel engine was run while the single GI gun was being used. There were no problems with it. All the diesels were started and run for a short while at regular intervals during the survey.

200 ml of alfloc was added to the cooling water of all the diesels.

All diesel heat exchanges will be cleaned and anodes replaced on the transit to Brisbane.

Compressor Set 1
Re-ringed and honed 2nd, 3rd & 4th stages and cross-heads.
Replaced 2nd, 3rd & 4th stage big end bearings.
Added alfloc

Compressor Set 2
Re-ringed and honed 3rd & 4th stages and cross-heads.
Replaced 2nd, 3rd & 4th stage big end bearings.
Added alfloc

Compressor Set 3
Re-ringed and honed 3rd & 4th stages and cross-heads.
Replaced 2nd, 3rd & 4th stage big end bearings.
Added alfloc

Compressor Set 4
Added alfloc

Compressor Set 5
Re-ringed and honed 2nd, 3rd & 4th stages and cross-heads.
Replaced 3rd & 4th stage big end bearings.
Changed oil & filter.
Added alfloc

Compressor Set 6
Re-ringed and honed 2nd, 3rd & 4th stages and cross-heads.
Replaced 2nd, 3rd & 4th stage big end bearings.
changed oil and filter
Added alfloc

Service Compressors

The two Ingersol service air compressors were serviced during the cruise. The receivers were inspected and were in fair condition.

GI Guns and Array

A single GI gun configured in 'true GI' mode (45/105) was used as an energy source for the small amount of seismic work completed. It was towed from the starboard mag boom approximately 50m from the stern. The gun was supported by a A6 Norwegian buoy with 4.5m braided rope, to give a depth of approx. 5m.

A single gun was also used for the signature test done in port. It was deployed on the port side approx. 2m below the surface. Only the generator was fired at 800 PSI.

Both guns used were cleaned and packed away after use.

Sleeve Guns

The solenoids on all the sleeve guns were removed, cleaned and reconditioned. The guns were moved to the correct rails ready for the next survey.

Bundles

One of the single gun bundles with ½" air line made in Fremantle was used for the single gun work. The air line had fittings swaged on and the electrical lines had pig tails potted on. A bundle clamp was also manufactured.

The starboard GI gun bundle had all faulty electrical lines reterminated and potted past the #6 gun. There are now 5 spare lines with connectors terminated on them and marked with yellow with shrink. Bundle was renetted.

Stock takes

Stock takes of Price, Detroit sleeve and GI gun parts were updated

Work on OH&S Matters

A ladder was erected between the port and starboard seismic reels for access to the mezzanine deck, to replace excising methods of access. The eye wash station was moved to the starboard side of the dancing deck because of this.

A pad was welded to the starboard side of the dancing deck for the magnetic base of the winch controller box.

The back deck roller has been pinned to prevent it rolling.

Safety catches have been placed on the 3 verlindes and the hooks on the 4 service winches were replaced. The wire ropes, chains and shackles used to lift the mag booms were replaced as well.

APPENDIX VIII

Seismic Electronics Group Survey Report

Introduction

Cruise 176 departed Darwin 28 August 1996 with the aim of surveying approximately 5000 line kilometres using the gas sniffer equipment to collect information to address some key scientific and exploration data and correlate this data from previously acquired high resolution seismic and aeromagnetic data in the Timor sea.

The gas sniffer program suffered with equipment problems from the onset of the survey. The gas sniffer program was extended by three days due to the loss of the sheave and the resultant breakage of the gas sniffer cable mid-way through the survey. While waiting for all relevant equipment to be sent from Canberra, the opportunity was taken to perform testing of the Hydroscience streamer and acquire gravity core samples.

Despite these problems, the gas sniffer survey successfully collected approximately 3400 km of relevant data.

Mechanical Potting on Sniffer Cable

The mechanical potting and consequently the electrical pottings were re-done on three separate occasions from the time we departed from Darwin. On the first occasion the Hilti potting compound used to terminate the fish coupling did not set properly and the sniffer cable slipped through the coupling. The coupling had to be cut off and all sniffer cable interconnection re-terminated and re-potted. This took approximately forty hours, and was done during transit to survey site. The second time was to investigate if the submersible data logger was not working due to an incorrect electrical potting, but this was not the case, and the third time was after the fish departed into the deep blue ocean.

Fish Simrad Echo Sounder

The Simrad echo sounder unit gave us some trying time. The unit would not give any sensible depth reading even after the new 12vdc to 24vdc converter was installed in the display unit to supply the Simrad echo sounder module.

To determine if the echo sounders were faulty, the sounders were configured in their simplest form, that is connected to a DC volt meter and powered from a linear 24vdc supply, which the reading was then interpreted directly as a depth reading. Testing the echo sounder using the above method proved that there was nothing wrong with the sounders.

When the sounder was placed back into its original configuration and tested by being powered from the DC-DC converter it failed and again it did not display any sensible depth reading. The problem was eventually traced to the DC-DC converters, as when the linear 24 vdc supply was used to power the Simrad the unit responded. The reason to why the Simrad echo sounder does not communicate when connected to a DC-DC converter is not known.

Half way through the survey echo sounder S/No. unknown was lost when the sniffer cable broke lose.

Echo sounder S/No. 9456 was installed in the fish but would give erratic readings, it was later discovered that this unit has 'suspect' written on its side.

The third spare echo sounder S/No 9832 was installed and it produced a reading instantly but then it began giving inconsistent readings without any apparent fault patterns. The fish was retrieved and water had ingress into the sea con connector. Although the connector was replaced the echo sounder still gave erratic readings going to default condition without logical reasons. To add to our confusion the echo sounder randomly comes good from periods of half an hour to days and then goes into a spurious default mode.

The unit is still useable because the good readings that are produced have been proven to be valid. It has been suggested to the client that further tests be performed in Canberra prior to sending them away for servicing

Submersible Data Logger

The SDL was installed in Darwin and tests before leaving port showed that although we were receiving data from the sensors it was not a full conclusion that all the data was correct from all sensors.

The SDL was deployed at the survey site and it was noticed that the data from the SDL was being corrupted when ever the gas extractor pump was switched on. A great number of hours were spent investigating the noise problem to no avail. This SDL leaked, it was replaced with another unit, this unit appeared to work for a few hours then gave bad data.

The new spare SDL and using the new 240V communications interface box that was supplied by Yeo-Kal failed to rectify the communication problem. At this stage sniffer block broke loose from the 'A' frame and fell into the sea. All contents in the fish, including the new SDL were lost.

Further investigations revealed that the 3 shielded twisted pairs used for communication to the SDL proved to be to lousy. Two heavier gauge unshielded wires had to be selected.

By using 'component substitution' it was shown to, and recognised by the client that one of the SDL inductive coupling heads was U/S - not allowing communication between the SDL and the computer, and that the recently arrived 240Vac Yeo-kal Interface wasn't performing to expectation, only being able to communicate to the SDL over a 30 meter cable and not over the remaining 350 meters of sniffer cable.

This left only one workable combination of inductive coupling head, 12VDC Interface that showed any sign of communication with the one remaining SDL.

However even using this best combination it was found that even over the short distance of a 30 meter cable, on deck, that there was still a communication problem, but now we were able to see that the one remaining SDL not only had difficulty in communicating on a continuing basis, but when it did, the data was out of tolerance and inconsistent.

At this stage the client decided not to use the SDL system.

The SDL systems has not been conclusively proven on the sniffer cable and has never worked successfully under operational conditions. Due to the fact that there has been no reliable SDL sys to work with we have been unable to confirm the working integrity of the sniffer cable and SDL sys.

All the Yeo-kal SDL equipment has been sent back to Yeo-kal for testing, repair and calibration.

HSI Streamer

Fourteen 6.25m section were deployed and tested prior arriving at Darwin. On arrival at Darwin three 6.25m and seven 12.5 m acoustic section were loaded onto the ship. These also have been tested and the results are with the systems QC.

Calibrated Hydrophone

The gun signature test was performed in Darwin port prior to departing to our survey site. The tests were ok and the results faxed to ships operations in Canberra.

Ship Video System

Last survey cruise report noted that we only had enough working cameras to do a seismic survey. During this survey another two cameras became unserviceable. A fax was received to inform us that spares are on there way, these spares will allow us to refurbish a few cameras over the next up coming surveys.

Magnetometer (nil data recorded)

Both of the G803 magnetometer were tested during this survey and both consoles are operating correctly. There is a constant difference in magnetic field readings as we head south -east, (2-4nt) & north-west, (2-10nt), this difference occurs on both mag consoles. We deployed the mag at various distances from the ship's stern to check the levels of field variation and try to correlate if the proximity of the ship/mag head relationship had any bearing on the inconsistent readings, ie ship influence.

The tests on the mag head towed at various distances, 90 & 150 meters, from the ship showed no appreciable differences in field values that could be attributed to ship influence, thus it still a mystery on why the difference on mag field values as the ship heads at different directions.

The fins that are on the ship are for a mag head with 6 inch diameter ours is a 7 inch diameter. The drogue we use to have on board for the mag head has also gone missing.

Ashtech GPS for Tailbuoy

The Tailbouy has had the Magnovox re-installed because the Ashtech GPS — Maxon modem setup was not successful.

The Ashtech and Maxons were set up on the bench using two aerials. The breakout box indicated that the cabling and connections seemed to be serviceable but all we received were garbage characters. It appears that there could be a protocol problem between the Ashtech and the Maxon modem, this will be investigated further in Canberra.

GI Gun Bundle

The STBD GI gun bundle has been repaired. All lines except for one, which is noted on the GI gun array list in the bird shack, have been recovered. All spare lines have had a red female connector potted to them and are identifiable by a yellow heat shrink close to the connector.

Computer

A new power supply has been installed in the electronics office PC.

Ships Echo Sounder

The ships Simrad echo sounder was not working, the problem was traced to a faulty 5 volt regulator, a burnt track and no trigger from the hall device trigger circuit. The echo sounder was operating displaying depth only on the LCD, there was no output to the chart recorder as we did not have any hall effect device to replace the faulty one.

The echo sounder operated for a week, after which it stopped operating. The unit was repaired in Darwin during our port call picking up the sniffer spares.

EPC

EPC number 4 stopped operating. The problem was traced to a faulty stepper motor. As there are no new stepper motor, three used motors were tried and only one worked. A decision needs to be made as to the future of the EPC as we have nil or are running out of spares.

APPENDIX IX

DHD Operations Report

There were several equipment problems experienced during the survey. Some with DHD equipment and some with AGSO ship board equipment. Details are given below.

A Frame Rams

At 0200 6 August whilst the sniffer fish was being deployed the operator forgot to remove the A frame pins and when moving the A frame out the rams bent. Most of the bending in the rams was removed when the hydraulic force was released but the rams were left with slight bends. The incident was reported in shipfax 176/23. The rams are to be landed in Brisbane on 11 September 96, assessed for damaged and if found to be OK, straightened and refitted. Otherwise new rams will have to be manufactured.

We need to fit a pressure relief valve, which will activate before the hydraulic pressure reaches the point where the rams will bend. There are no drawings of the AWH/A frame system aboard the ship but it was thought there was a pressure relief valve already in the system. If so why did it not work?

Sniffer Sheave Block

The sheave block for the sniffer cable parted from the A frame at 2231 on 13 August 1996. The sniffer fish, the sheave block and about 150 metres of faired sniffer cable were lost. The cause of the failure is not known but it is suspected the supporting pin either worked loose or shattered. A replacement block was manufactured in Canberra, flown to Darwin and fitted to the ship on 22 August 1996. The loss was reported in shipfax 176/41.

Sniffer Equipment

The sniffer equipment was flown from Perth to Darwin immediately prior to the start of the cruise. When it was set up there were several problems that caused many frustrating hours of work for AGSO's electronics technicians. Problems were encountered with the fish echosounders, the Submersible Data Logger (SDL), the gas chromatograph ovens, the gas stripper extractor pump and in the wiring. Sniffer cable terminations were done on three occasions for varying reasons. (See Electronics Report for details.)

Sniffer Winch

One of the main bearings on the sniffer winch failed late in the survey. Although damaged it was still able to be used during the last three days. The bearing will need to be replaced before the winch is used again. I believe a replacement bearing is being arranged and should reach the ship in Brisbane on 11/12 September 1996.

There was some discussion that the sniffer may only be used from smaller vessels in future in which case it may be desirable to land the sniffer winch which would take it out of the hostile marine environment which most likely was a major factor in the failed bearing. It could easily be fitted back onto the ship in future if needed.

The sniffer acquisition program was to collect approximately 5000 kilometres of data. 4000 kilometres in the Vulcan sub basin/Sahul Syncline/Sahul Platform with the remaining 1000 kilometres over the Yampi shelf. Unfortunately the original plans were altered when the loss of the sheave block halted sniffer operations for a total of 10 days. The ship eventually collected 3372.741 kilometres of sniffer data which included the Yampi shelf, the Troubadour/Sunrise block, the Kym prospect and mainly in the Skua platform area. The Kym prospect area was a last minute inclusion for the Cultus Petroleum Group.

Weather

Apart from two days where we experienced winds greater than 25 knots the weather was excellent. The wind was 10 knots or less for the remainder of the time with calm to slight seas. Beautiful one day and perfect the next.

DHD Geochemistry

Background values for hydrocarbons were very similar to those measured on previous DHD Surveys, with total hydrocarbons (THC) around 8-10 ppm, methane around 3-5 ppm and C_2 and C_3 hydrocarbons in the range 10-100 ppb.

A brief summary of the anomalies detected is given below:

Gwydion West

176/016 C_1 & C_2 high	– moderate	8 times background.

Yampi Shelf

176/025 C_1 & C_2 high	– moderate	5 times background.
176/026 C_1 & C_2 high	– strong	100 times background.
176/027 C_1 & C_2 high	– moderate	5 times background.
176/028 C_1 & C_2 elevated	– weak	2 times background.
176/029 C_1 & C_2 elevated	– weak	<2 times background.
176/030 C_1 & C_2 high	– strong	40 times background.

Haydn

176052 C_2 elevated	- weak	<5 times background

Skua

176109 C_1 & C_2 elevated	- weak	2-3 times background
176110 C_1 & C_2 elevated	- weak	2-3 times background
176115 C_1 & C_2 elevated	- weak	2-3 times background
176117 C_1 & C_2 elevated	- weak	2-3 times background
176118 C_1 & C_2 elevated	- weak	2-3 times background

Troubadour/Sunrise

176086 C_1 & C_2 high	- moderate	5-10 times background
176090 C_1 & C_2 high	- moderate	5-10 times background

APPENDIX X

Systems Report

Seismic System

This was a non seismic survey. No production seismic was recorded this survey.

Cable Calibration Test

At the start of survey, a calibration of two seismic sections was performed. this test was of limited value as there were problems with overdriving. The gun was operating at reduced pressure to try and avoid this but the proximity of the gun to the cable meant that overdriving still occurred. Even a single GI gun firing the 45CI chamber is too large a source for performing this test in port.

Cable Testing

Tests were performed on all the 6.25 metre sections that were on the ship as well as 10 new sections that arrived in Darwin.

DAS System

DAS Configuration

Navigation

Primary DGPS	Multifix V2.08, with altitude aiding
Secondary DGPS	Multifix V1.32, with altitude aiding
	DR 1 Magnavox SD + IR gyro
	DR 2 Raytheon SD + IR gyro
Echo sounders	frd 12 kHZ, frd 3 kHZ array
Magnetometer	None
Gravity Meter	Bodenseewerk

Racal 1 and Racal 2 used. Reference stations Broome, Dampier, Perth, Darwin and Ujang Padang for the network solution.

Micro Vax 3500

No problems.

Multiplexer (GyroLog box)

No problems.

Differential Global Positioning System

No GPS tie was performed at the start of survey. This is because no useable survey markers could be located on Stokes Hill wharf.

Racal # 1 (Multifix V2.08, AGSO dome)

No problems observed

Racal # 2 (Multifix V1.32, Racal minidome)

The attitude sensors for the dome malfunctioned for the first half of the cruise, slowly improving as the cruise progressed. I contacted Norman Mackay at Racal who will have someone sent to the ship in Darwin with replacement attitude sensors.

Dead Reckoning

No problems.

Gyro Compasses.

No problems.

Doppler Sonars

No problems.

Bathymetry

Hades operated for most of the survey until it was decided that it was more important to develop it than to use it for production, after this the 3.5KHz was recorded on an EPC. Both the 12KHz and the 3.5KHz echo sounders performed well, with good sub bottom on the 3.5khz.

Magnetics

Not recorded.

Gravity Meter

The gravity meter appeared to work reasonably well all survey. No unusual noise events were observed.

General

Guppie

No problems observed

Qual

Not used

Nav Processing

Nav processing was completed until the end of surveying by the time we got to port.

APPENDIX XI

Line Summary (Link to MS Excel spreadsheet)

APPENDIX XII

Digital Data

Excel Spreadsheets for each Survey region, which contain the following data fields:

Field	**Unit of measure**
CruiseID	176
Area Name	Eg. Yampi Shelf
LineID	eg. 176001
LineName	eg. 01
Shotpoint	Integer
LatD	Latitude - Degree
LatM	Latitude - Minute
Date	dd/mm/yy
Time	hh:mm:ss
FishDepth	m
WaterDepth	m
Temp	C^o
Methane	ppm
Ethane	ppm
Ethylene	ppm
Propane	ppm
Propylene	ppm
i-Butane	ppm
n-Butane	ppm
i-Pentane	ppm
n-Pentane	ppm
i-Hexane	ppm
n-Hexane	ppm
%Wetness	
Bernard	
Meth/Eth	ratio
Meth/Prop	ratio
Eth/Ethyl	ratio
Prop/Propyl	ratio
i-But/n-But	ratio

Survey data for cruise 176

Gwydion

Haydn

Kym

Londonderry

Skua

Skualnfill

Talbot

Troubadour

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

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.

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.

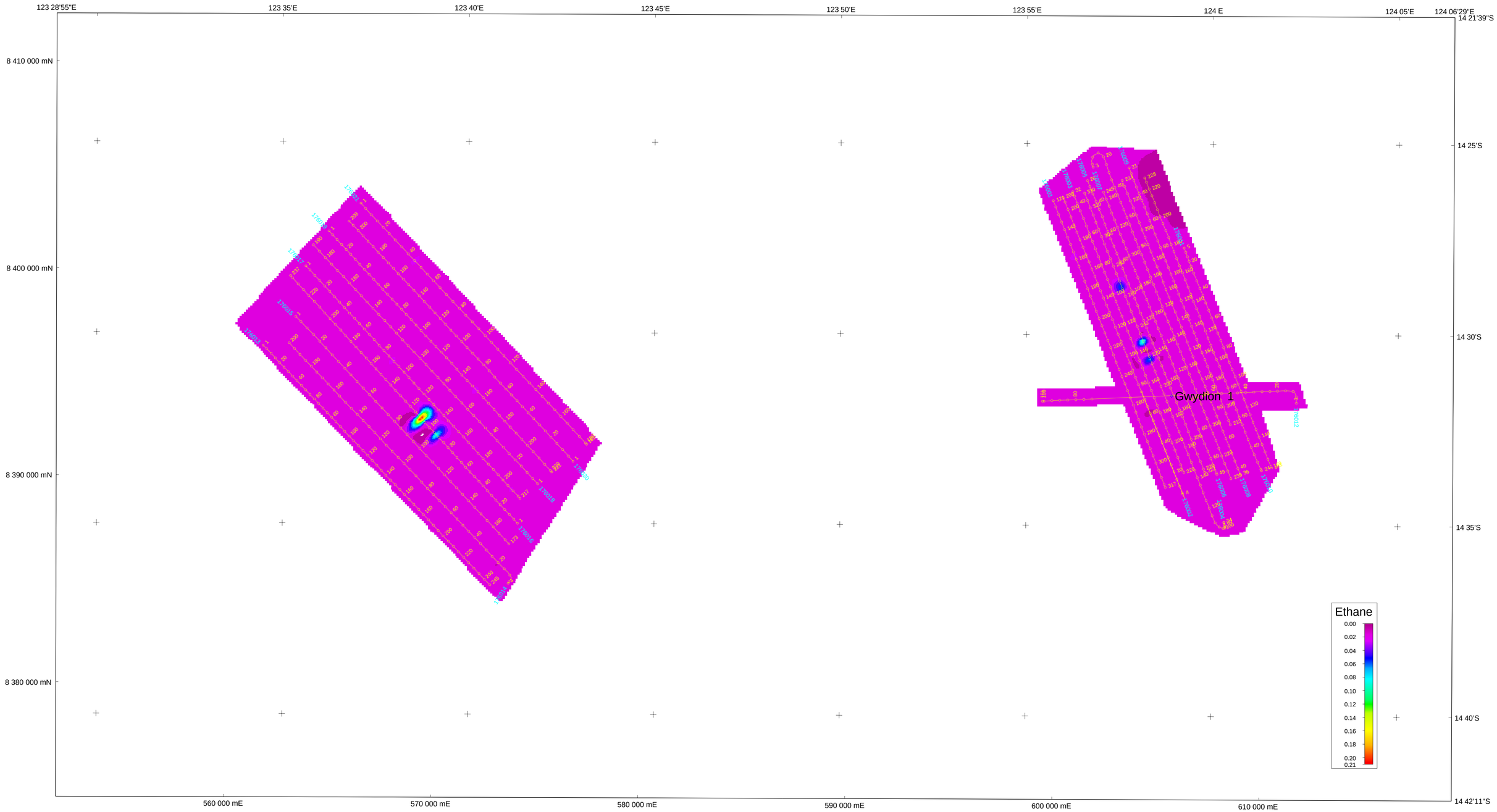
Sackett, W.M., 1977. Use of hydrocarbon sniffing in offshore exploration. *Journal of Geochemical Exploration*, 7:243-254.

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.

TIMOR SEA - Gwydion Area



1:100000

0 2 4 6 8 10

KILOMETRES

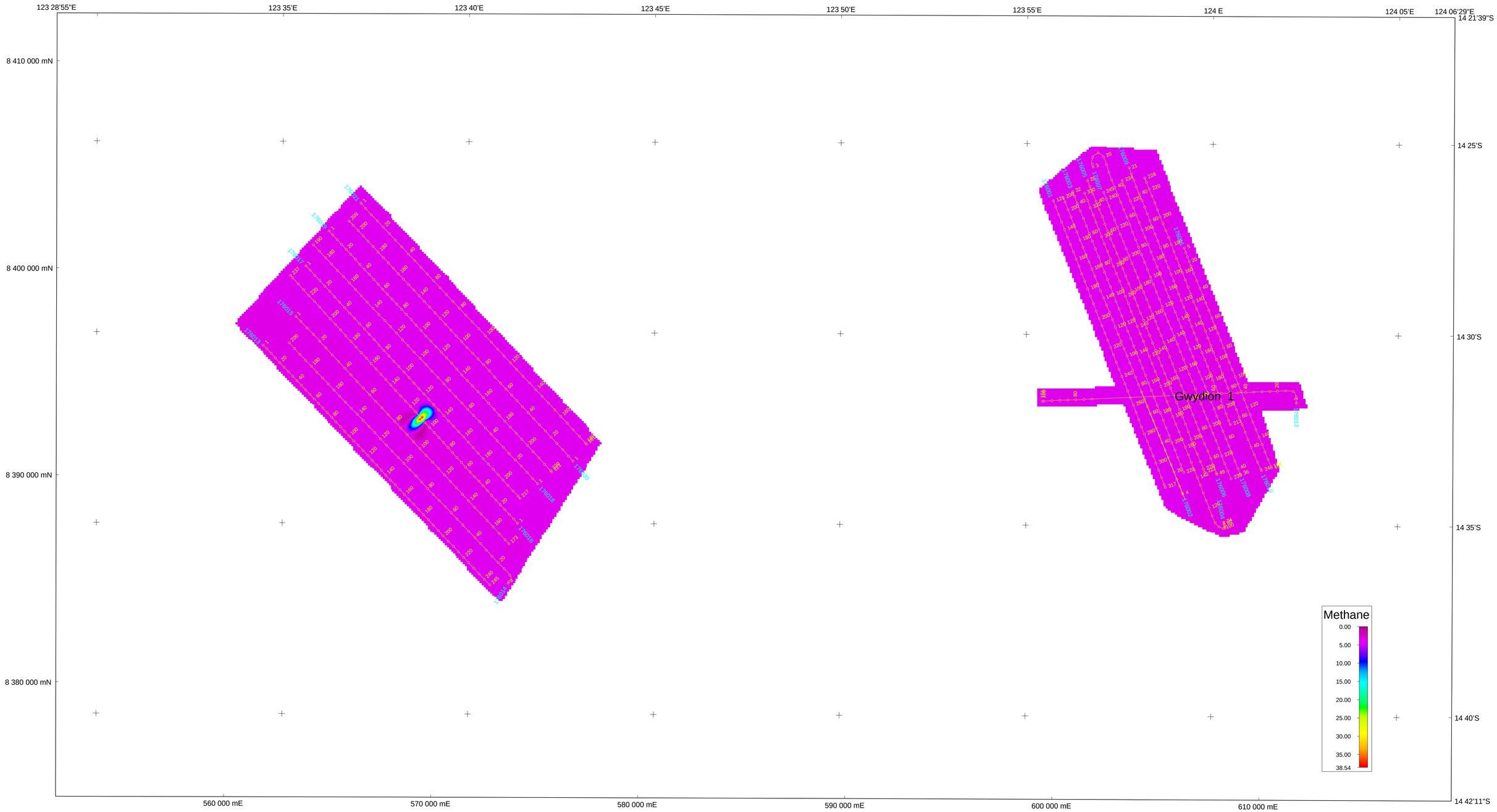
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 123 E

AGSO

Timor Sea - Sniffer Program
Gwydion Area
Measured Ethane

Enclosure 1

TIMOR SEA - Gwydion Area



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KILOMETRES

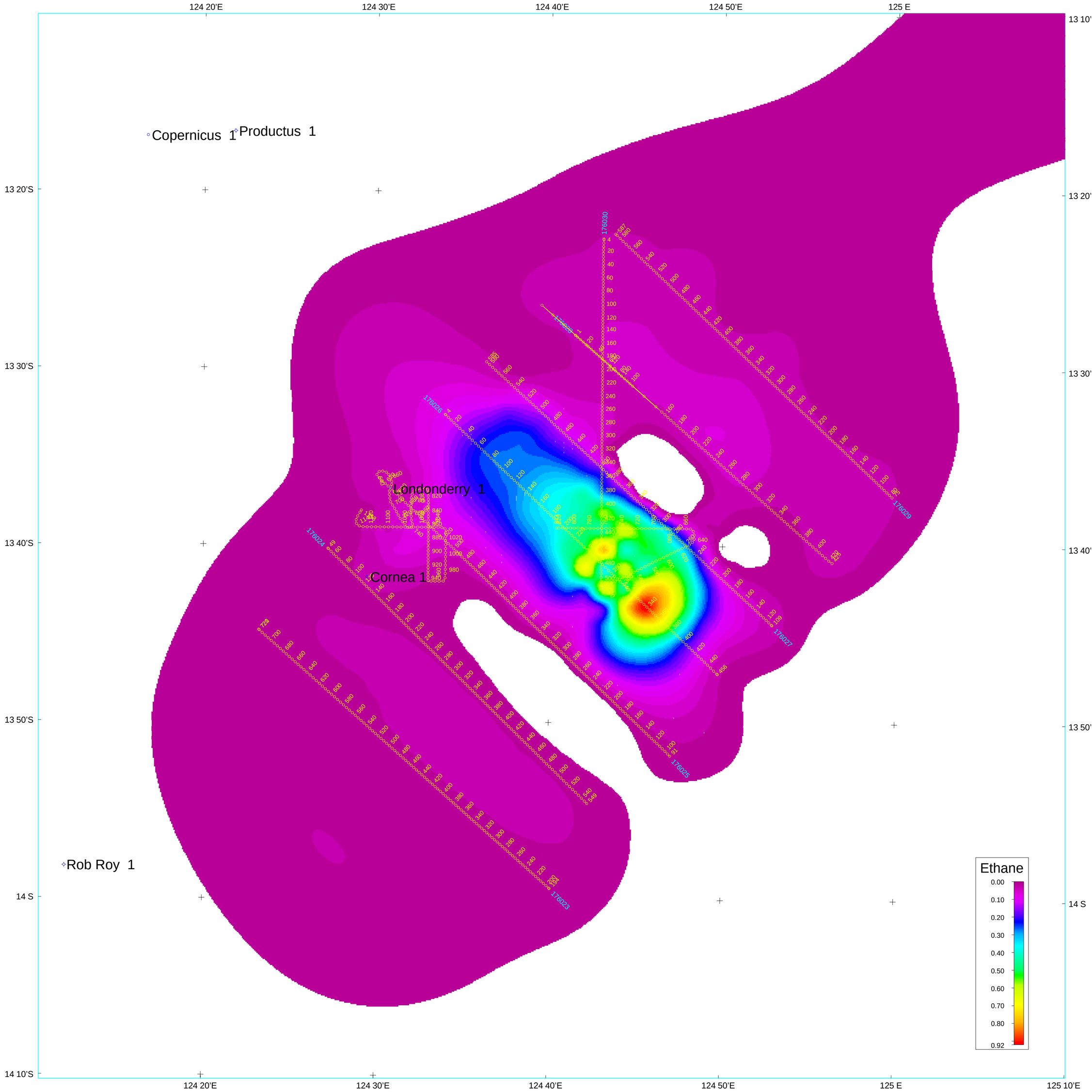
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 123 E

AGSO

Timor Sea - Sniffer Program
Gwydion Area
Measured Methane

Enclosure 2

YAMPI AREA



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KILOMETRES

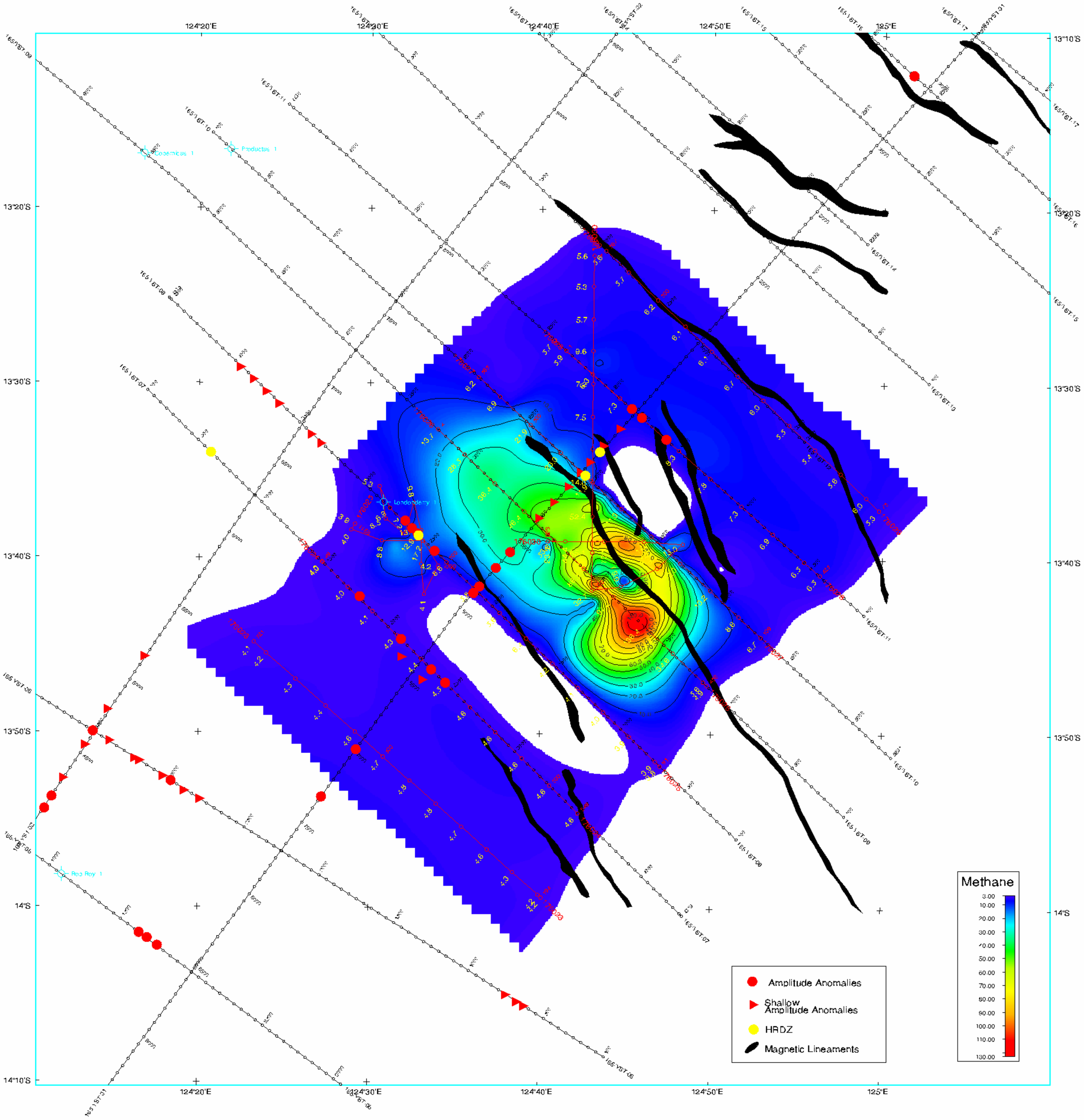
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 123 E

AGSO

Timor Sea - Sniffer Program
Yampi Area
Measured Ethane

Enclosure 3

METHANE SEEPAGE CONTOUR, AMPLITUDE ANOMALIES AND LINEAMENTS



AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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KILOMETRES

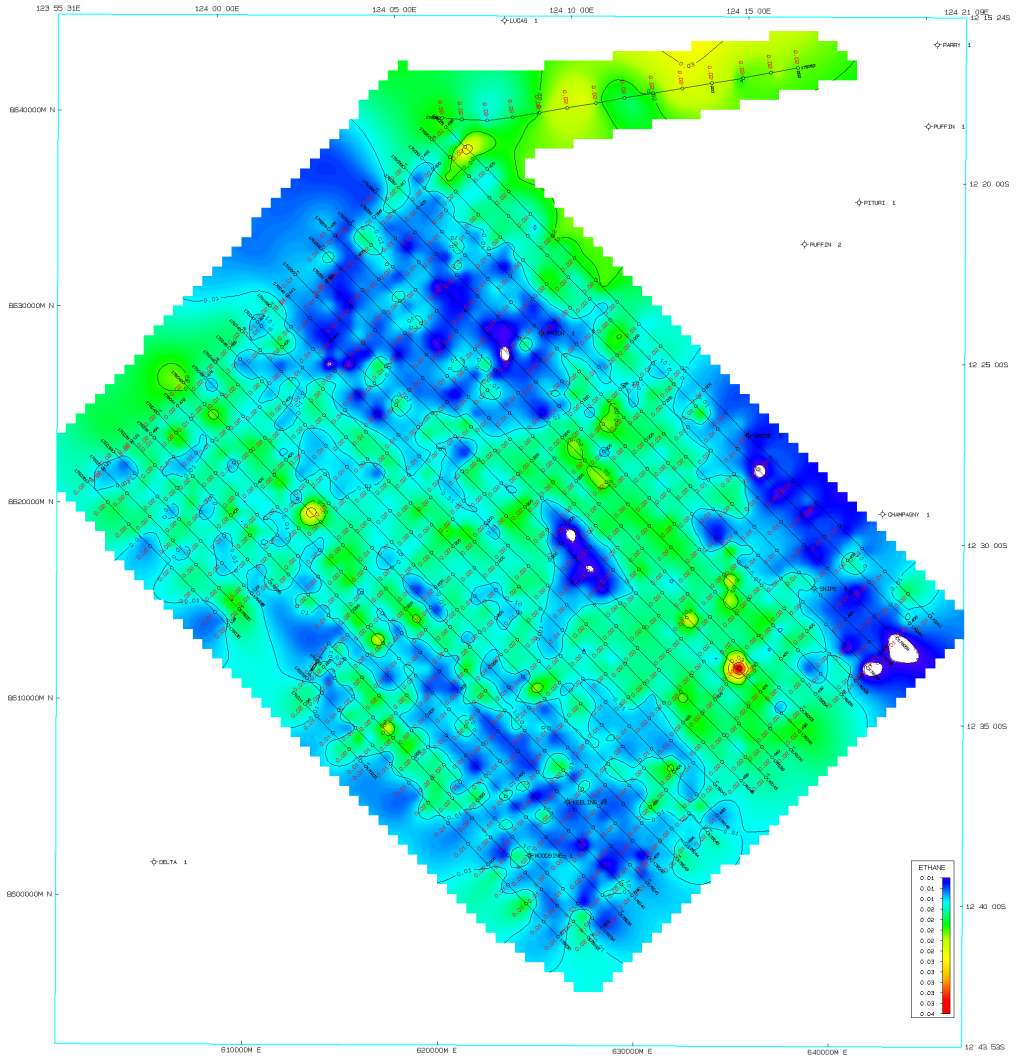
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 122 E

METHANE SEEPAGE CONTOUR

YST STUDY GROUP

M.E. Fellows Nov 96

HAYDN AREA



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KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 125 00 00E

AGSO

TIMOR SEA - SNIFFER PROGRAM
HAYDN AREA
MEASURED ETHANE

SCALE 1: 100000		12-DEC-96
CELL SIZE = 500M	M FELLOWS	

Haydn Area

123 55'31"E | 124 E | 124 05'E | 124 10'E | 124 15'E | 124 20'E | 124 21'09"E

12 15'24"S | 12 20'S | 12 25'S | 12 30'S | 12 35'S | 12 40'S | 12 43'53"S

8 640 000 mN | 8 630 000 mN | 8 620 000 mN | 8 610 000 mN | 8 600 000 mN

610 000 mE | 620 000 mE | 630 000 mE | 640 000 mE

Methane
2.92
3.00
3.20
3.40
3.60
3.80
4.00
4.20
4.40
4.60
4.66

1:100000

0 2 4 6 8 10

KILOMETRES

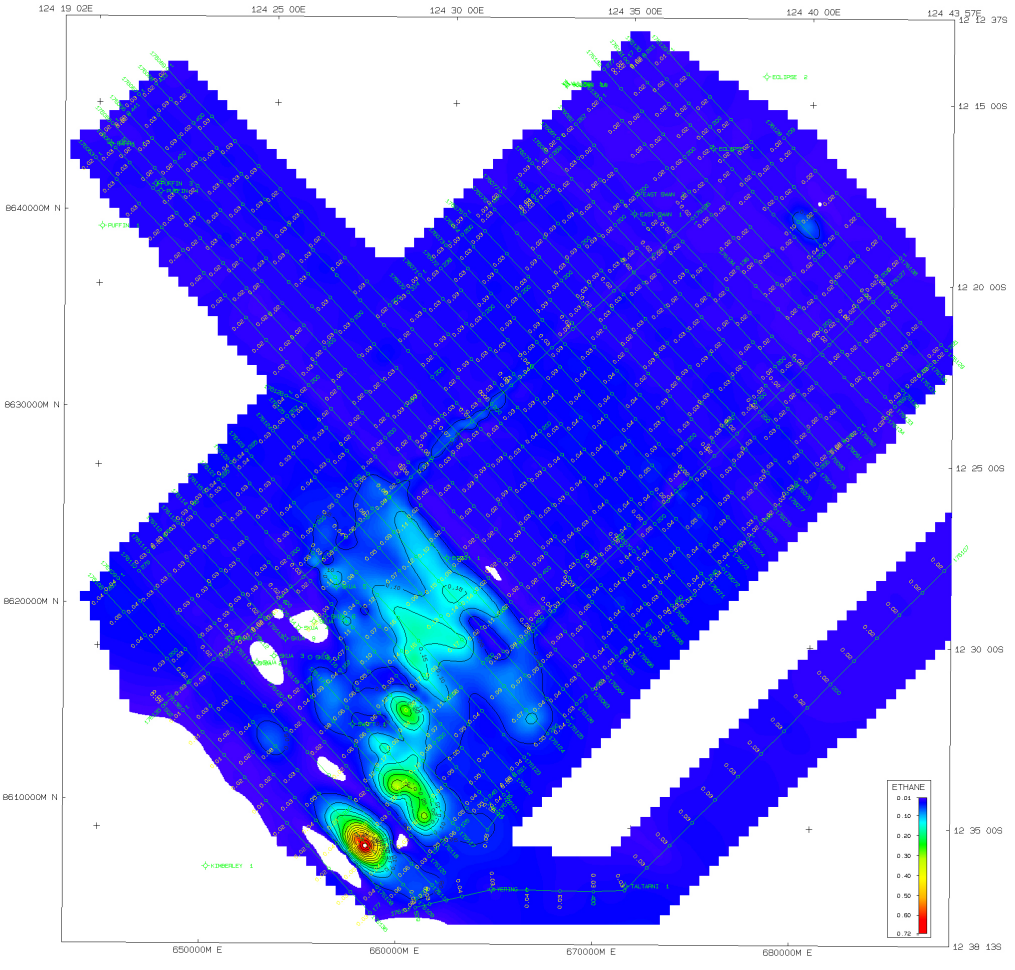
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 123 E

AGSO

Timor Sea - Sniffer Program
Haydn Area
Measured Methane

Enclosure 6

Skua-Swan Sniffer Area



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0 2 4 6 8 10

KILOMETRES

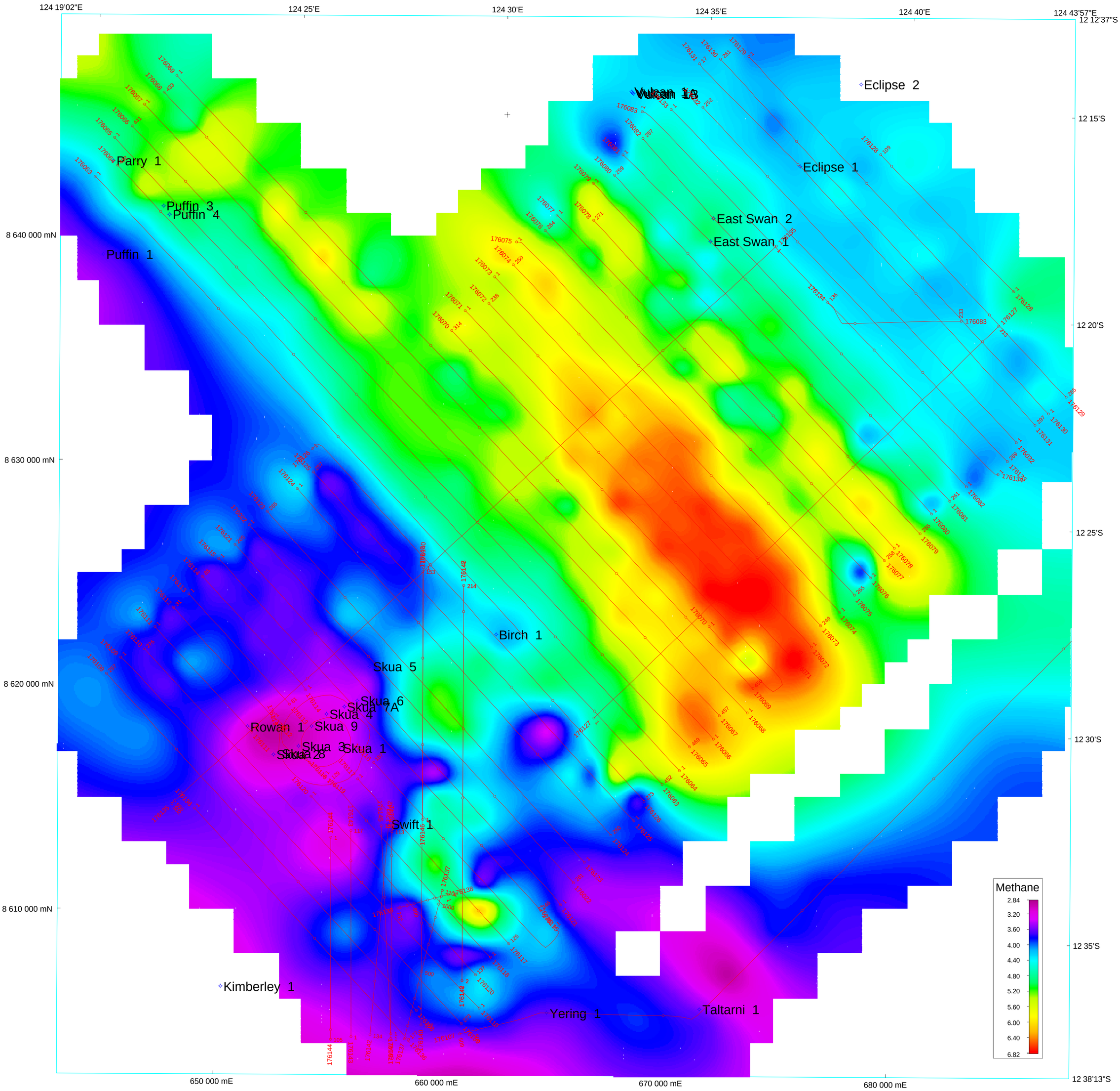
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 123 00 00E

AGSO

Timor Sea - Sniffer Program
Skua-Swan Area
Measured Ethane

SCALE: 1:100000		DATE: 12-DEC-98
CELL SIZE = 500M	N. FELLOWS	

Skua-Swan Area



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KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 123 E

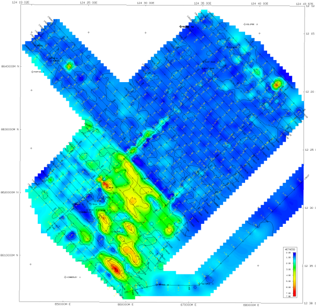
AGSO

Timor Sea - Sniffer Program

Skua-Swan Area
Measured Methane

Enclosure 8

Skua-Swan Sniffer Area



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KILOMETRES

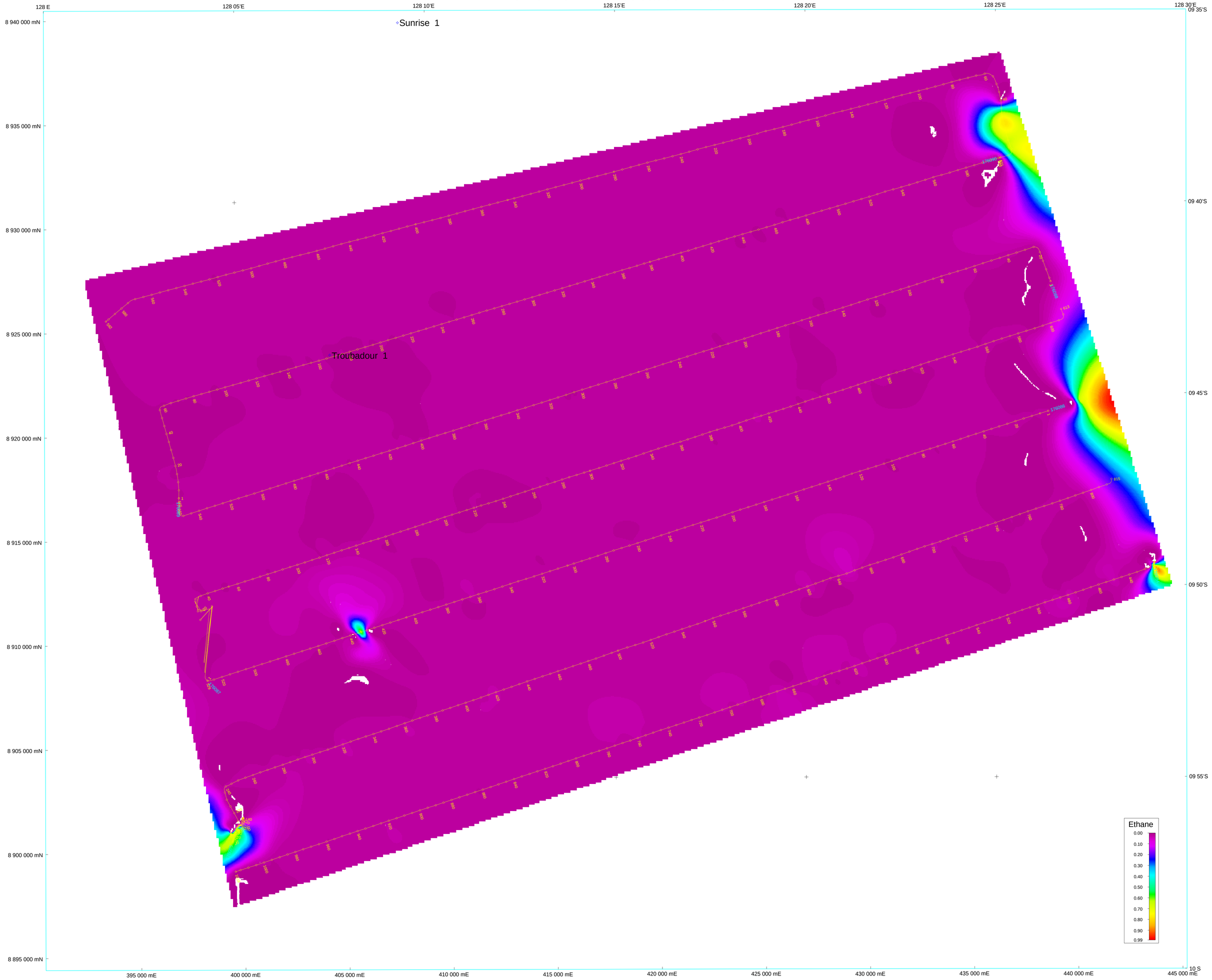
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 123 00 00E

AGSO

Timor Sea - Sniffer Program
Skua-Swan Area
Wetness Data

SCALE: 1:100000		12-DEC-96
CELL SIZE = 500M	R. FELLOWS	

TIMOR SEA - Troubadour Area



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KILOMETRES

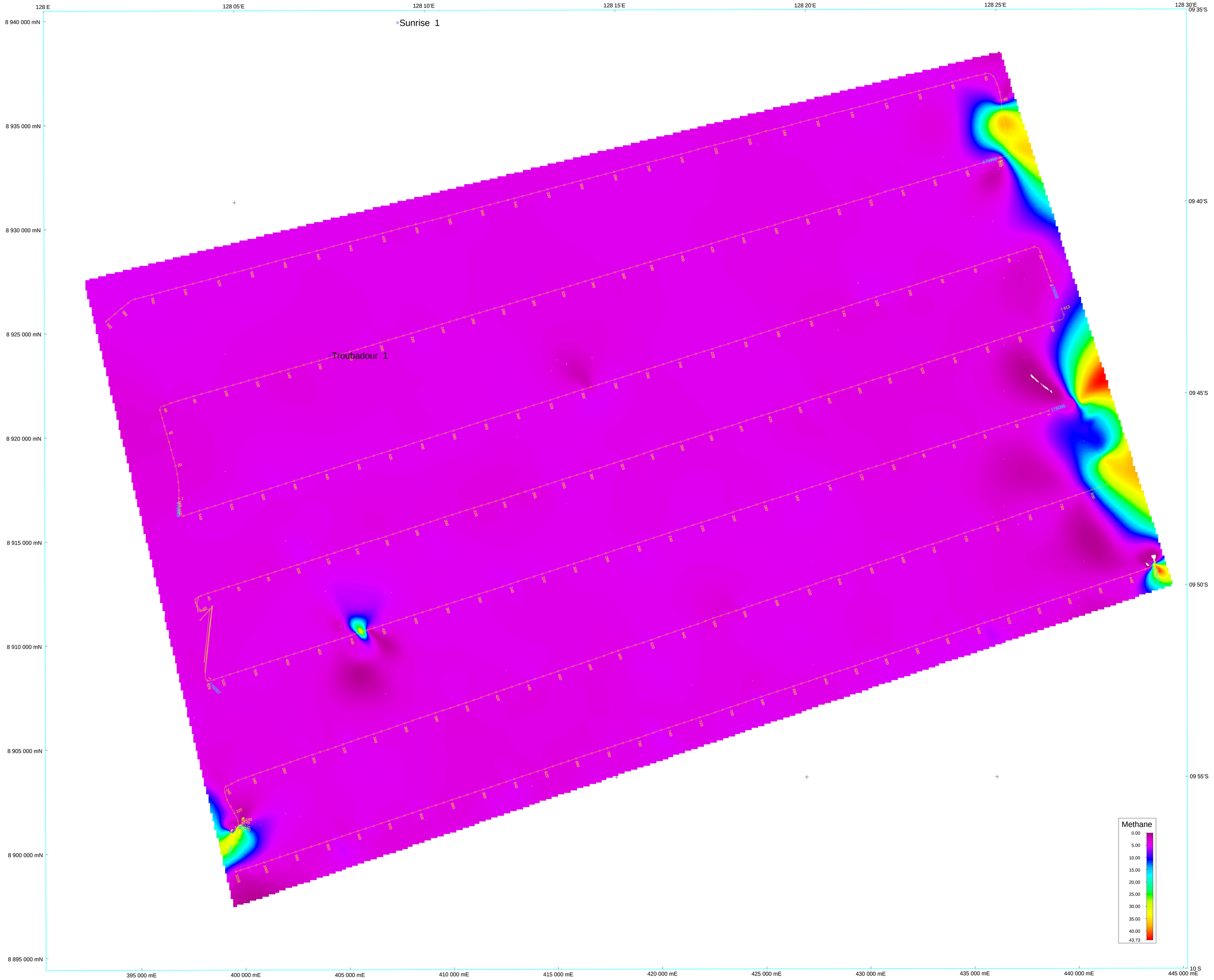
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 129 E

AGSO

Timor Sea - Sniffer Program
Troubadour Area
Measured Ethane

Enclosure 10

TIMOR SEA - Troubadour Area



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KILOMETRES

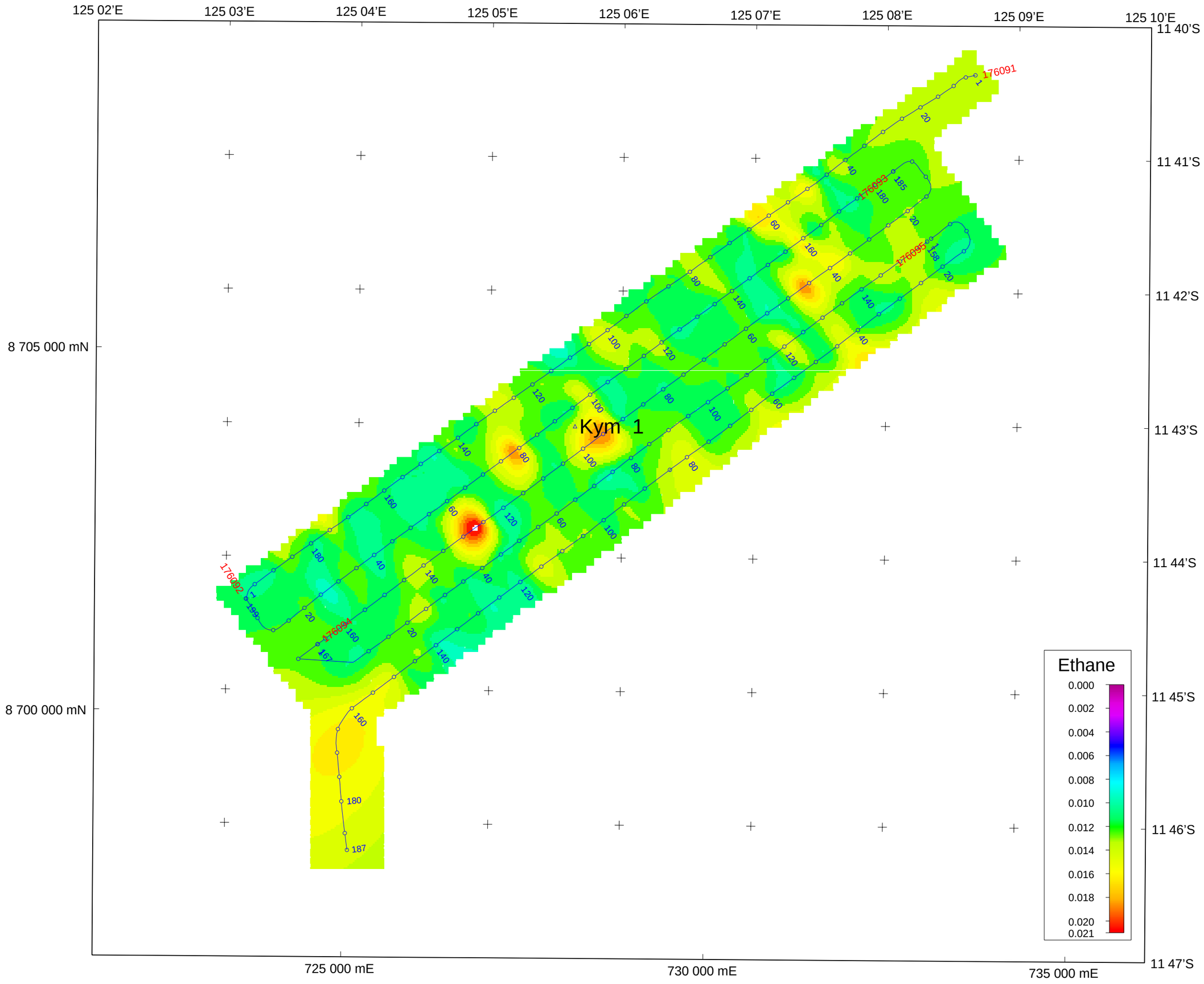
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 129 E

AGSO

Timor Sea - Sniffer Program
Troubadour Area
Measured Methane

Enclosure 11

Timor Sea - Kym Area



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KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 123 E

AGSO

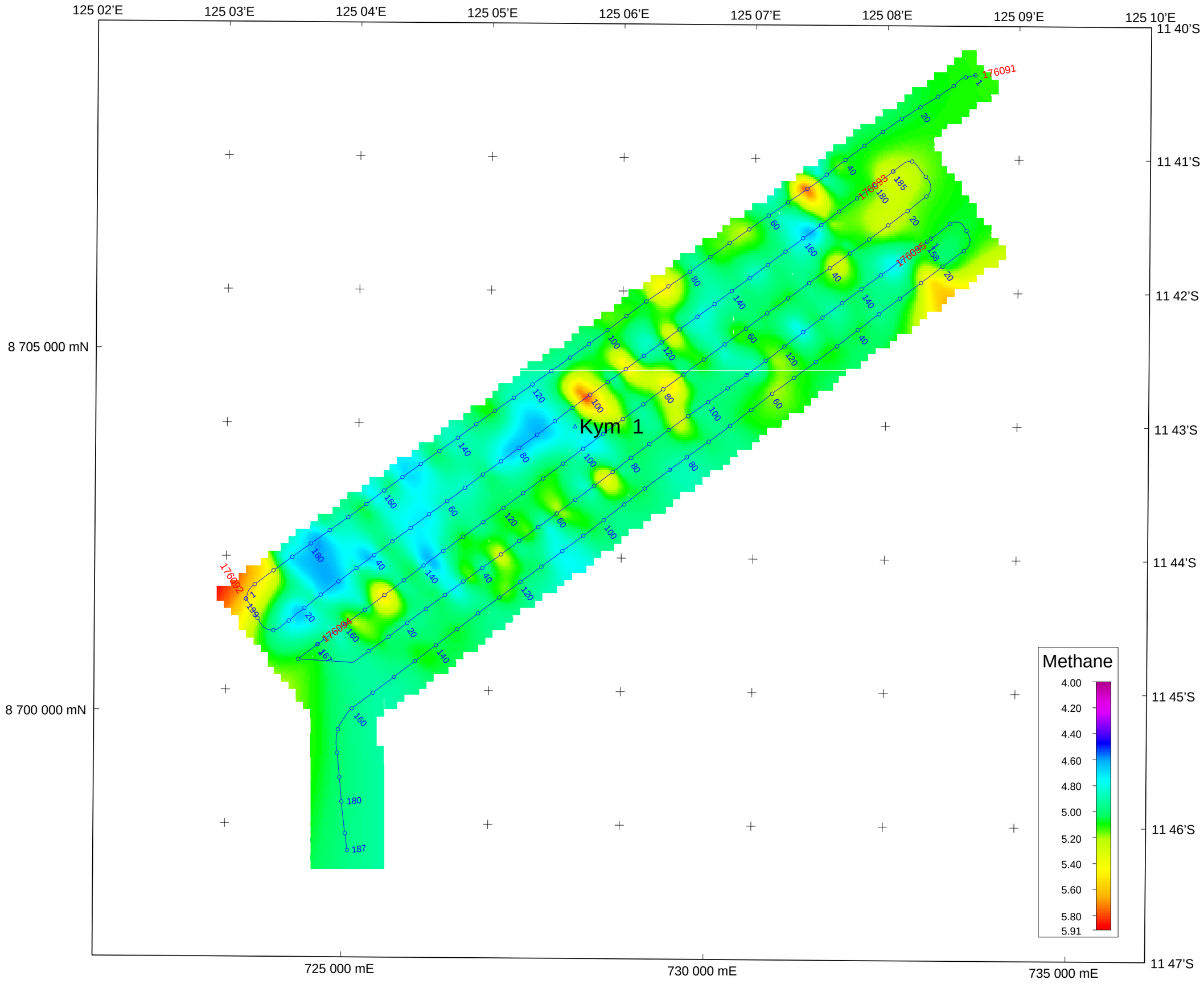
Timor Sea - Sniffer Program

Kym Area

Measured Ethane

Enclosure 12

Timor Sea - Kym Area



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KILOMETRES

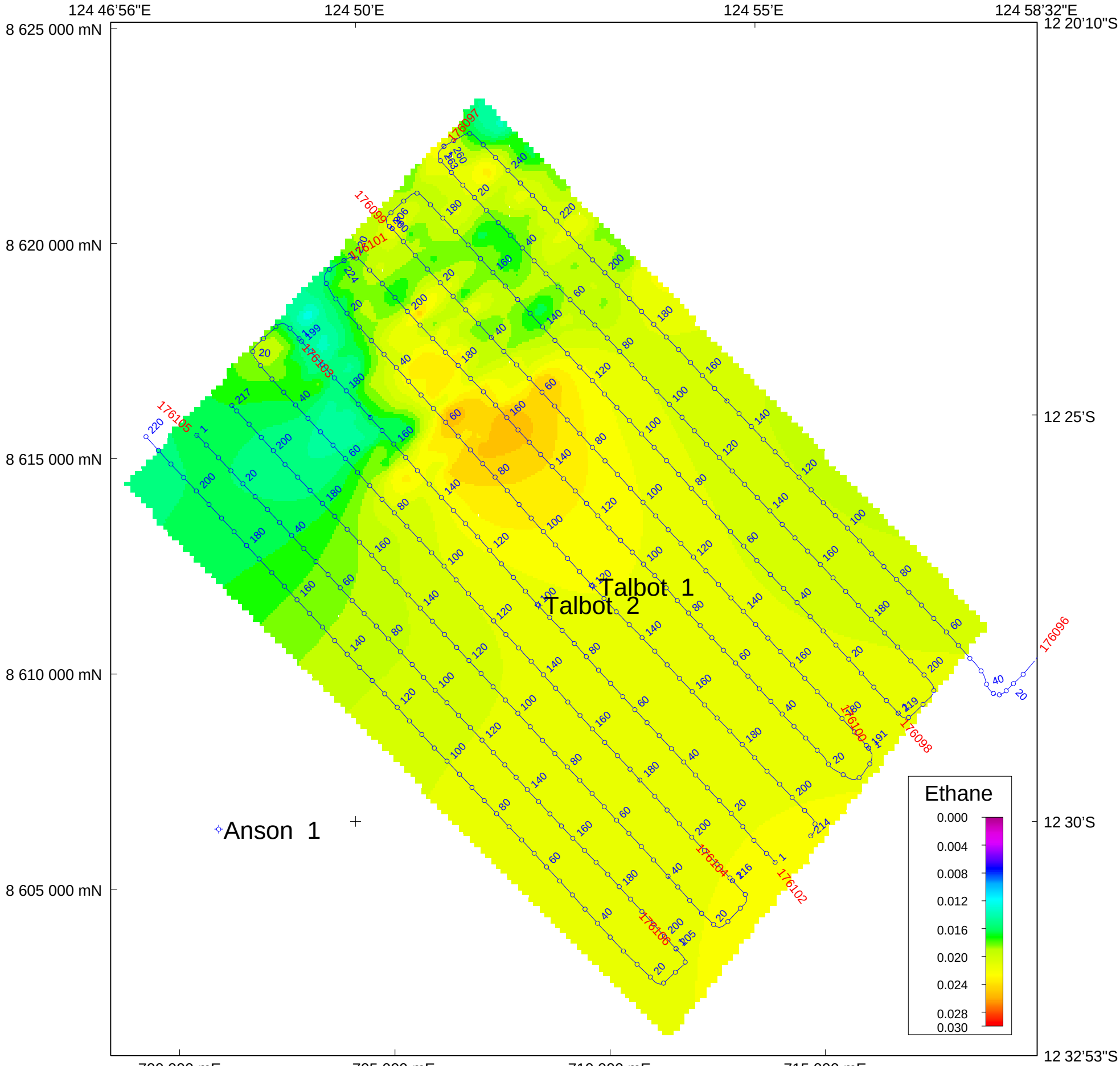
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
WGS 1984 SPHEROID
CENTRAL MERIDIAN 123 E

AGSO

Timor Sea - Sniffer Program
Kym Area
Measured Methane

Enclosure 13

TIMOR SEA - Talbot Area



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KILOMETRES

MERCATOR PROJECTION
WGS 1984 SPHEROID
EQUATORIAL ORIGIN OF TRUE SCALE. CENTRAL MERIDIAN 123 E

AGSO

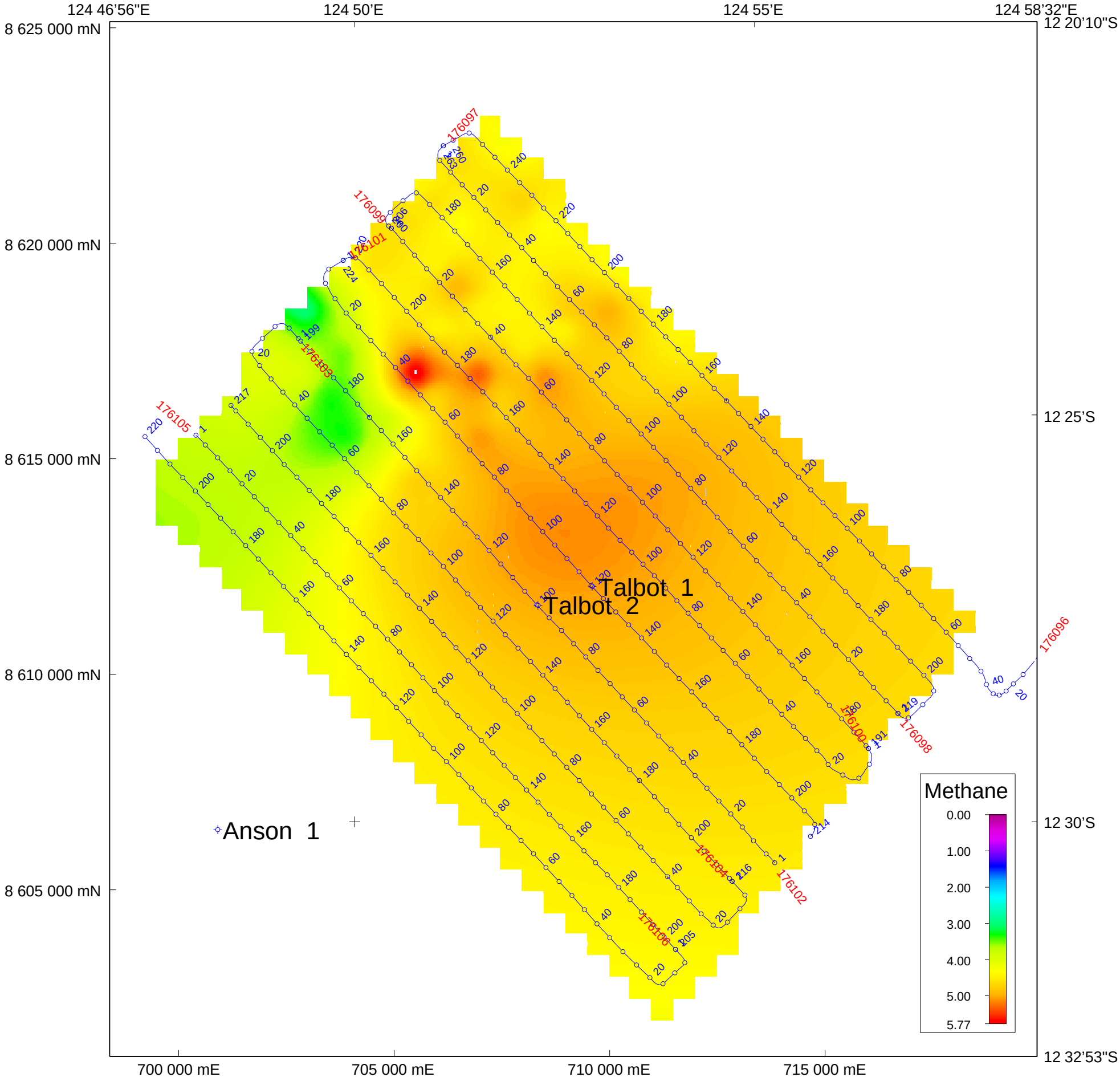
Timor Sea - Sniffer Program

Talbot Area

Measured Ethane

Enclosure 14

TIMOR SEA - Talbot Area



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KILOMETRES

MERCATOR PROJECTION
WGS 1984 SPHEROID
EQUATORIAL ORIGIN OF TRUE SCALE. CENTRAL MERIDIAN 123 E

AGSO

Timor Sea - Sniffer Program

Talbot Area

Measured Methane

Enclosure 15