AGSO

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AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

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### Australian Geological Survey Organisation
### Petroleum and Marine Division



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# 1. Introduction

The Australian Geological Survey Organistaion (AGSO) has produced a set of digital bathymetry, gravity and magnetic grids for the northwest quadrant of Australia, using all available land, marine and satellite data. These grids are based on the WGS84 position datum, and are of resolution 0.01° (~1km). The grids can be purchased from the AGSO Sales Centre[1] (see Section 8). This document describes the methods and datasets used.

AGSO potential field databases hold data acquired since 1937, over marine and land areas of Australia. These data are from a variety of sources, vintages and levels of accuracy, and various attempts have been made in the past to synthesise these data to produce images for geological interpretaion. For example, Buchanan (1998) has produced an Australian bathymetry grid, Petkovic (1995) produced gravity and magnetic grids over the North West Shelf, and Petkovic et. al. (1996) produced gravity maps for northwest Australia. In addition, AGSO's Offshore Resource Map Series (1990-1997) is a set of interpreted bathymetric contour maps over the western and southern margins at 1:1,000,000 scale.

In this document we describe gridded datasets which can be reproduced from a source database of point and line data, according to a specified method, unlike earlier attempts which may have involved arbitrary adjustments to observed values, and did not return adjusted values to a database. The compilation described here covers the north-west quadrant of the Australian continent (8°-24°S, 106°-143°E), and work is currently under way to extend this coverage into the south-west (24°-46°S, 106°-140°E).

There are serious problems associated with integrating data from disparate sources, due to variations in levels of accuracy of observations, processing methodologies, and availability of supporting documentation. It becomes a daunting task if one attempts to produce, from all available data, an absolute representation of the measured parameters. Thus, projects which attempt this restrict themselves to consistent datasets whose specifications are uniformly and completely defined. For example, the Hydrographer produces maritime charts for navigation purposes in which soundings from known sources give minimum absolute water depth to a specified level of accuracy. These compilations can be usefully extended, however, if we restrict ourselves to modelling the variations in a parameter. In doing this we gain enormously in breadth of coverage, while paying a small sacrifice in accuracy.

The current document describes work undertaken during 1998/99, in which AGSO and Desmond Fitzgerald & Associates (DFA), with significant bathymetric data input from the Australian Hydrographic Office (AHO), performed a network adjustment on marine ship-track gravity, magnetic and bathymetry data, and combined the result with onshore and satellite-derived data over the North West Shelf.

The following describes the datasets and the process used to prepare the grids.

[1] Email: Sales@agso.gov.au, Web: www.agso.gov.au

## 2. Databases

The following section describes the data sources used in the production of the grids and images. Table 1 summarises the sources.

**Table 1 – Data sources for potential field and bathymetry grids**

| Source | Database |
|---|---|
| AGSO | 'Mardat' marine shiptrack database |
| AGSO | Australian National Gravity Database |
| AGSO | National Airbourne Geophysical Database |
| AUSLIG, AGSO, CRES | 'Geodata' 9" digital elevation model |
| Australian Hydrographic Office | Natmap and other chart data |
| BHPP | Timor bathymetry database |
| GEBCO | GEBCO 97 |
| NGDC | 'Geodas' shiptrack database |
| Smith & Sandwell (1995) | 'Geosat 7.2' world gravity grid |
| USGS | 'Gtopo30' world topography grid |

### *2.1 AGSO Marine Shiptrack Database - Mardat*

The Australian Geological Survey Organisation (AGSO) has been collecting gravity, magnetic and water depth data routinely on its seismic and geological sampling surveys of the Australian margin since 1963. These data are stored in the database 'Mardat', which consists of approximately 1 Gb of shiptrack positions and associated geophysical parameters at resolutions of 25-200m along line, organised as flat files, one file per survey. The database has a 'foreign' component of surveys from other institutions, such as exploration companies and the National Geophysical Data Centre[2] to which various institutions have contributed.

Mardat contains 911 surveys currently registered, whose extent is 34°N-79°S, 90°E-180°E. Approximately 15% of these surveys were acquired by AGSO.

Mardat contains data indexed by time, by shot, and have a small component of non-indexed surveys.

- The time-indexed data are stored as binary 4-byte floating point words.
- The shot-indexed dataset is an 80 character ASCII format, similar to the UKOOA[3] standards, but modified to include gravity data. Formats are described by Barton et al., (1993), Tracey (1995) and Parums (1998).

[2] U.S. Department of Commerce, http://www.ngdc.noaa.gov

[3] United Kingdom Offshore Operators Association

- Shot-indexed data are derived from seismic surveys.

- Time-indexed data are generally produced from research surveys, and coverage is usually port-to-port.

- Non-indexed data, commonly referred to as 'XYZ' data (position and parameter value), are also held from digitisation of National Mapping Bathymetric Series (Natmap), and swath-mapping surveys.

- For many AGSO surveys surveys, both time- and shot-indexed survey files are available.

The database is extended as new data become available. For example, AGSO has recently undertaken to digitise Natmap bathymetric maps not previously digitised by the AHO, and AHO 'fair-sheets'. Table 2 gives some statistics for Mardat, but excludes XYZ data from AHO and swath surveys. See Figure 1 for the distribution of ship tracks in the northwest of Australia.

**Table 2 - Mardat along-line vital statistics (at end 1998). Depth$_1$ are depths from time-indexed files; depth$_2$ are depths from shot-indexed files.**

| Parameter | Points | Line km |
|---|---:|---:|
| Depth$_1$ | 5,681,000 | 1,310,500 |
| Depth$_2$ | 6,201,900 | 1,168,300 |
| Gravity | 4,486,100 | 899,200 |
| Magnetic | 4,176,000 | 910,800 |

The data densities for bathymetry, gravity and magnetic data are given in Figures 2,3 and 4 respectively. Figure 2 also includes the Australian Hydrographic Office data (see below).

**Figure 1 - AGSO gravity, magnetic and bathymetry database Mardat**

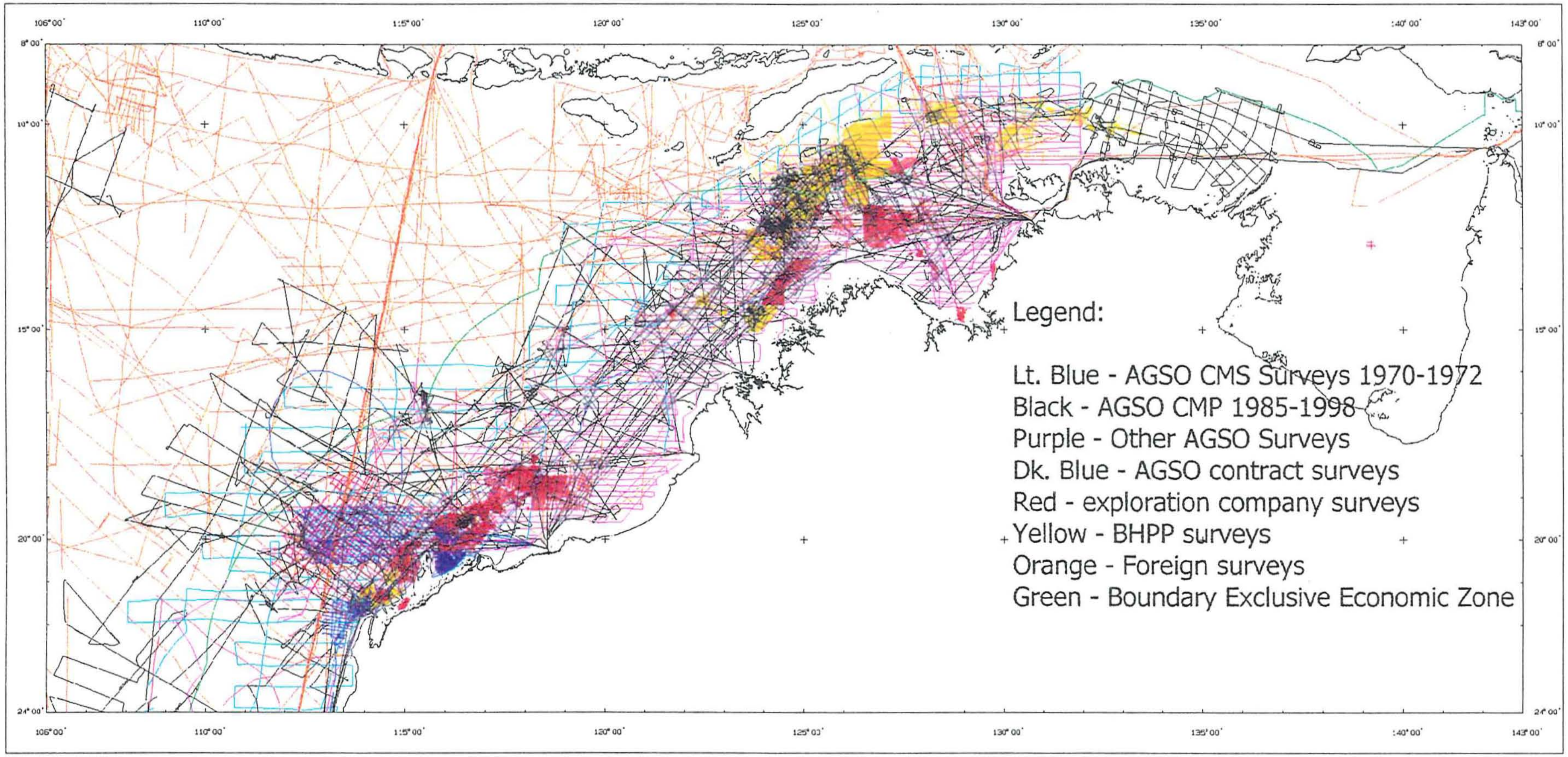


**Figure 2 - Bathymetry data density, incorporating Mardat and AHO databases**

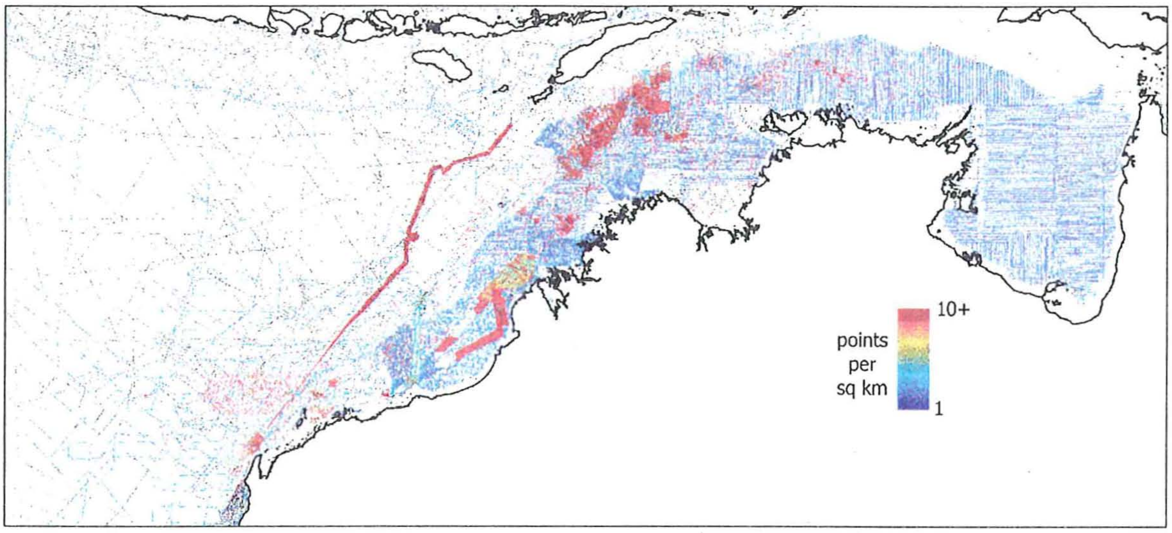



**Figure 3 - Gravity data density**

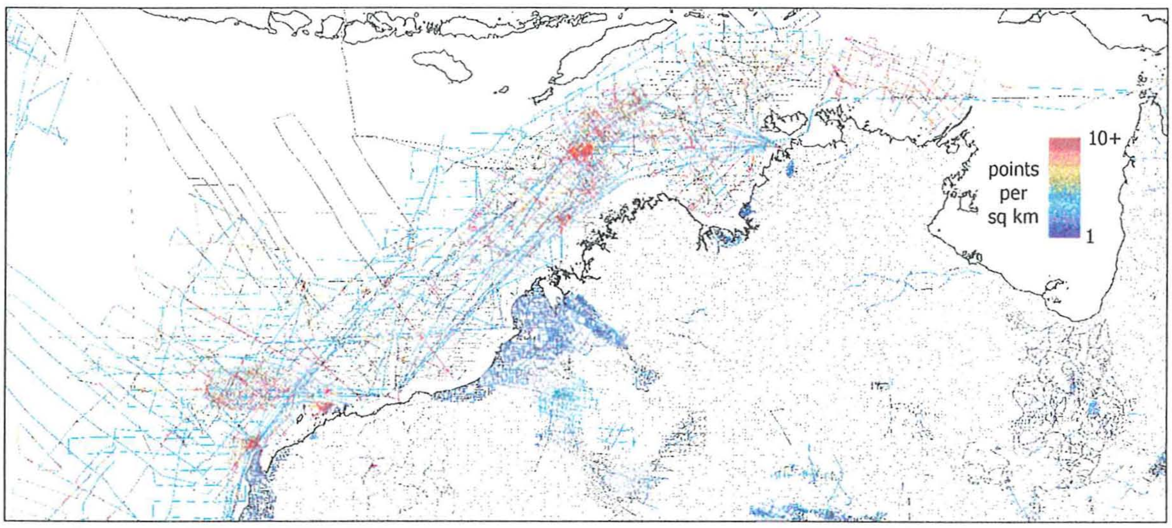
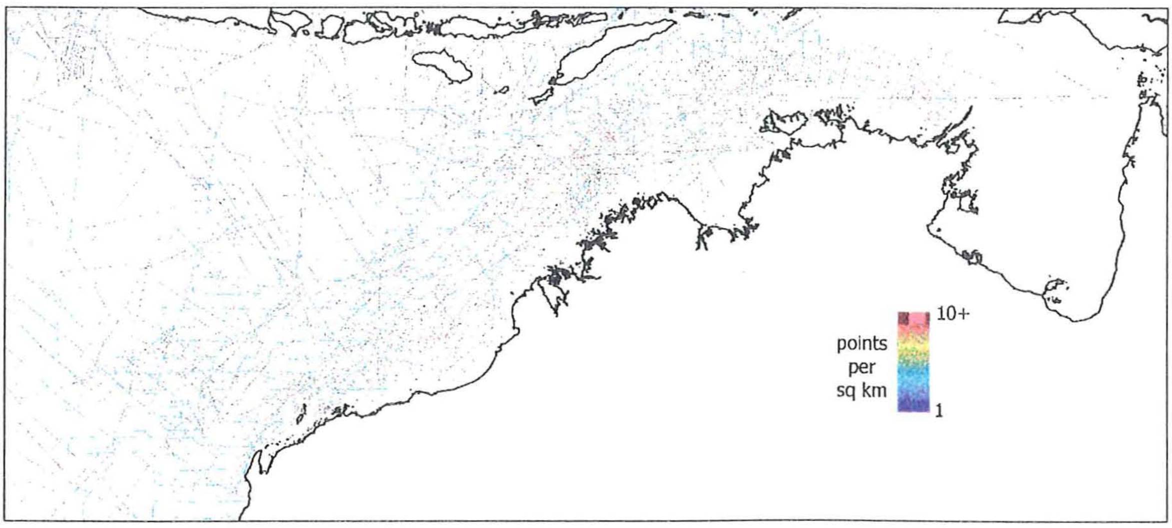



**Figure 4 - Magnetic anomaly data density (from Mardat)**



## *2.2 Australian Hydrographic Office*

The Royal Australian Navy Hydrographic Service (RANHS) is Australia's national charting authority and is composed of the Hydrographic Survey Force and the Australian Hydrographic Office (AHO). The RANHS has been responsible for providing Australia's official navigational charts for over 55 years.

In 1971 the former Division of National Mapping (NatMap) commenced a survey programme to produce bathymetric maps of the 2.3 million sq km of Australia's continental shelf. The seabed involved is equivalent to 30% of the land area of Australia. In July, 1988 the programme became the responsibility of the RANHS.

The NatMap contour maps (1x1.5 deg, 1;250,000) were designed to provide generalised detail of the seabed of the Continental Shelf from 20-300m below Mean Sea Level as a base for offshore research, exploration, development and management. The NatMap bathymetric maps are not designed for navigation and for that purpose the appropriate nautical chart should be used. The digital Natmap data available prior to 1998, in the Great Australian Bight, east coast, Gulf of Carpentaria and Arafura Sea, originated during the acquisition and subsequent processing by NatMap.

In 1998 AGSO undertook to complete the digitisation of the soundings printed on Natmap maps, and in this process covered a significant area of the North West Shelf. At the time of writing, digitisation of charts supplied by the AHO is continuing, the aim being to fill remaining holes in shiptrack coverage on the shelf to within 20 nautical miles of the coast. These data form the basis of the bathymetric grid over the continental shelf and the present digital coverage is depicted in Figure 5.

## *2.3 Australian National Gravity Database*

AGSO maintains a database of gravity measurements from over 1000 surveys dating back to 1937. The database consists of over 900,000 point observations tied to the International Gravity Standardization Net 1971. This represents a point spacing of 11 km or better across the entire continent (Murray, 1997). Data from the gravity database were used to compute Bouguer anomaly values over the continent, and these were gridded with the levelled ship-track free-air anomaly data. Figure 3 shows the data density for the land and ship-track gravity data.

## *2.4 Gtopo30*

The Global Topographic 30-arc second model (Gtopo30), computed by the U.S. Geological Survey (http://edcwww.cr.usgs.gov/landdaac/gtopo30/gtopo30.html), was used to define the heights of the islands of the Indonesian archipelago and Irian Jaya.

### 2.5 National Airborne Geophysical Database

The airborne magnetic data were used for the onshore coverage of the magnetic field and are based on the magnetic anomaly map of Australia (Tarlowski, Milligan & Mackey, 1996). These data are archived in the National Airborne Geophysical Database maintained by AGSO. Most of the surveys were flown by AGSO using its own aircraft as part of the airborne geophysical reconnaissance of Australia. Some surveys were flown under contract to AGSO, Northern Territory Geological Survey and Geological Survey of Western Australia, either separately or in joint projects (Figure 6).

The data were acquired mostly on lines spaced 1500-3200 m apart, with some surveys flown at closer line spacing. Pre-1990 surveys were flown at an altitude of 150 m above ground. Since 1990, most of the surveys have been acquired with line spacing of 400 m or less at altitudes of 100 m or less. The processed data for individual surveys were gridded with a cell size of 15 seconds of arc. The surveys were joined together by minimising differences along the boundaries of the surveys. The IGRF for an appropriate epoch was removed from each survey, and the data micro-levelled.

### 2.6 Australian 9-Second Digital Elevation Model

The Australian 9-second digital elevation model (Geodata 9-S DEM) was produced by the Australian Surveying & Land Information Group (AUSLIG), AGSO, and the Centre for Resource and Environmental Studies (CRES) Australian National University (Carroll, 1996).

Data used in the compilation of the model were derived from the AUSLIG Geodata database of spot heights, stream lines and water bodies, and heights from AGSO gravity and airborne magnetic surveys. The data from these sources were checked and corrected for height errors and drainage integrity, and gridded using the CRES program ANUDEM (Hutchinson, 1989, 1996).

The Geodata 9-s DEM was used at 1km resolution to continue the offshore grid to the coastline and complement the bathymetry grid by filling the continent.

### 2.7 BHP Petroleum Bathymetry Database

Sixty two surveys acquired by BHP Petroleum Pty Ltd containing bathymetry data comprise the largest contribution from an exploration company source. Appendix 3 lists these surveys, and see Figure 7 for data distribution.

**Figure 5 - Density of data sourced from Australian Hydrographic Office**

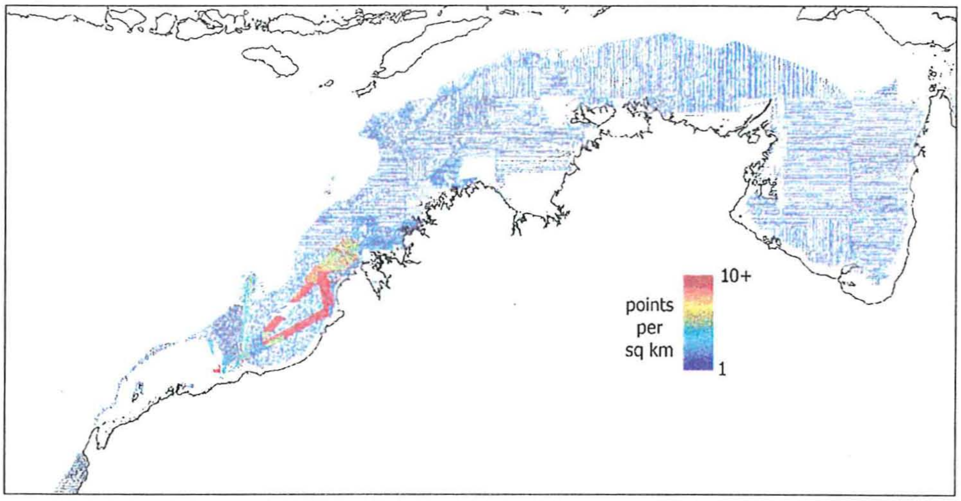



**Figure 6 - Aeromagnetic surveys distribution**

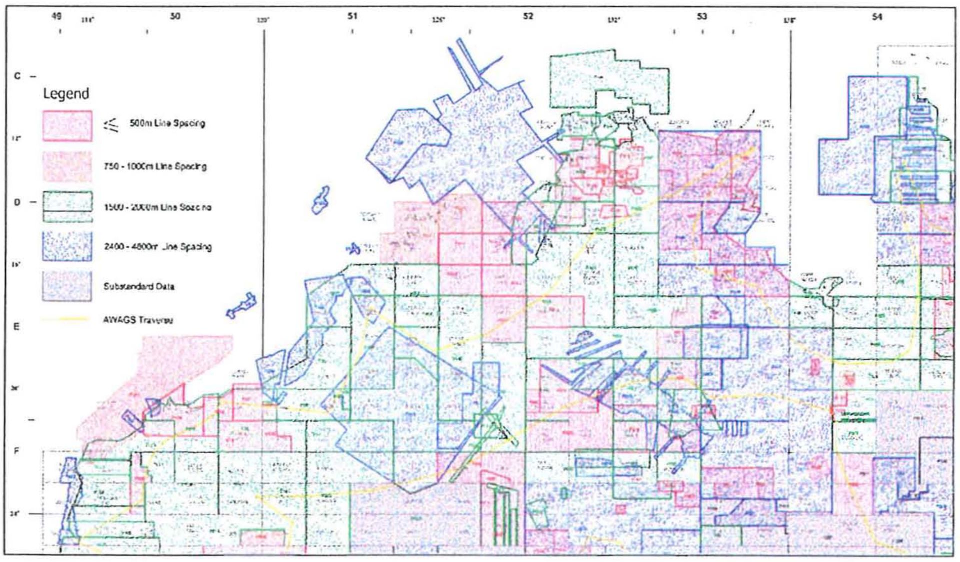
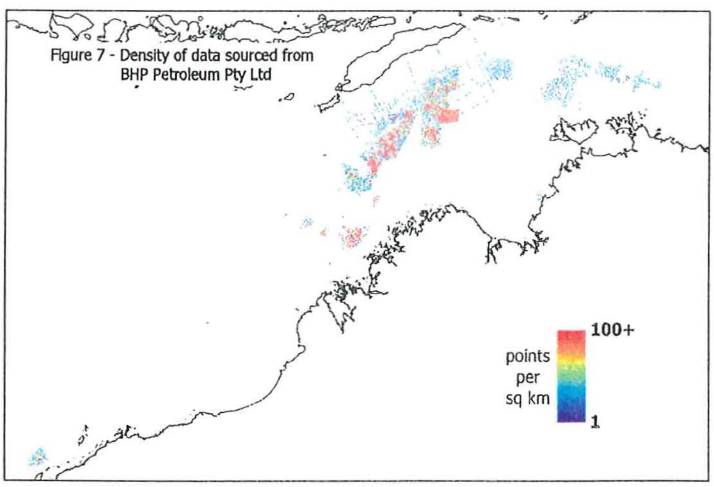



**Figure 7 - Density of data sourced from BHP Petroleum Pty Ltd**



### *2.8 Geosat 7.2*

Satellite radar measurements of the height of the ocean surface, which approximates the geoid, have been used to compute the gravity anomaly. The Geosat v7.2 gravity anomaly grid (Smith and Sandwell, 1995 and see http://topex.ucsd.edu/mar_grav.html) has been used in the deep ocean areas where ship-track data density is too low to give a reasonably continuous surface. The areas where the Geosat data predominate, for example in the Argo Abyssal Plain, are identified by the 'wormy' noise effect which has a wavelength of ~20 km (Figure 8).

### *2.9 General Bathymetric Chart of the Oceans*

The General Bathymetric Chart of the Oceans (GEBCO 97) is available as a digital product (Jones et. al. 1997), and was used as supporting data north of the Timor Trough. The points defining the bathymetry contours were entered unaltered prior to the gridding process, and provide improved form to the bathymetry in this region of sparse ship-track data.

### *2.10 NGDC 'Geodas' Database*

Ship-track data obtained from the National Geophysical Data Centre (NGDC) have been incorporated into Mardat. They include most of the surveys whose AGSO identifying number is greater than 1000 and are from a foreign source (see Appendix 1). For further information on the NGDC database and access to its data, see http://www.ngdc.noaa.gov/mgg/geodas/geodas.html

The data sourced from foreign institutions via the NGDC were used in the deep water areas off the continental shelf to give expression to areas such as the Argo Abyssal Plain. Figure 1 shows the distribution of these data under the category 'foreign'.

## 3. Levelling of Ship-track Data

Observed data from disparate marine surveys of a range of vintages will not necessarily be single valued at a crossover between any two survey lines. Gridding such data at small cell sizes produces spurious anomalies near crossovers, and results in a seriously distorted image. Crossover errors are due to errors in positioning, instrumentation and recording precision, and quality of processing.

Errors in position are most serious in older surveys where navigation was by dead-reckoning tied to Transit satellite fixes. Position accuracy ranges from 50m at the fix and on the shelf to perhaps 2 km in deep water between fixes. On the other hand, on recent surveys using differential GPS, positions are probably within 10 m. Surveys which used stand-alone GPS before the advent of differential GPS may have been accurate to 30 m. Improperly corrected offsets between the measured position and sensor location also contribute to position errors. Position errors make a significant contribution to misties and are most serious in areas of steep gradient, such as on the continental slope.

Accuracy of water depth measurements depends on several factors, such as the speed of sound used to convert echo sounder times to depth, and whether tidal and datum corrections were applied. The speed of sound varies depending on temperature and salinity of the sea water. For AGSO surveys in Mardat, the depths were calculated using a constant speed of sound of 1500 m/s, while some of the U.S. ships used 1463 m/s. The speed of sound used to calculate the water depth and other processing parameters is not always documented.

Accuracy of gravity measurements at sea is typically quoted as within 5 mgal, but misties between surveys tied to the same onshore gravity stations can be much higher. Errors in measurement arise from phase lags in the gravity meter, non-linearity of meter drift and levels of acceleration due to changes in ship's heading and sea state.

Magnetic data are affected by diurnal variations, which are rarely corrected in processing, and instrument noise arising from water leakage. If the sensor is towed too close to the ship (< 2 ship lengths), the observed data will include a component due to the magnetic field of the ship. The position error due to uncorrected sensor offset can be of the order of 200 m.

Thus, misties arise due to an accumulation of errors. In the project described in this document, misties were reduced by a process of network adjustment. The levelling software is based on existing methods used for levelling aeromagnetic data developed by Desmond Fitzgerald & Associates (DFA) within their 'INTREPID' system. Different approaches were used for the three parameters, as described below. They all aimed at reducing crossover errors, either by minimising misties within surveys, or between one survey and another.

The general approach to levelling the marine data was as follows:

- Import of observed data from ASCII format files into an Intrepid database. Checking and correction of spikes and bad values. Correction of time order errors in time-indexed files.

- Location of changes in ship's heading to identify straight line segments within each survey.

- Calculation of misties at intersections of line segments, or against a reference dataset if there was one.

- if reference dataset exists, level datasets to minimise misties using:

  - constant shift of the entire survey
  - constant shift of individual line segment
  - polynomial correction for each line segment

- if no reference dataset exists, level using a loop closure method as commonly used for surveying.

Other levelling techniques used where special circumstances warranted included grid decorrugation and microlevelling, and manual levelling of individual line segments.

The effectiveness of the method was assessed by inspection, as well as more objectively by calculation of three measures of dispersion. Table 3 lists these for the levelled and unlevelled data.

Mean absolute deviation:

$$\text{madev} = \Sigma[|x - \text{xmean}|]/N$$

The standard deviation:

$$\text{stdev} = \sqrt{[\,\Sigma[x - \text{xmean}]^2 / N\,]}$$

where N = number of samples, xmean = mean of x values

**Table 3 - Misties for levelled and unlevelled data**

| Parameter | madev | stdev | N | Units |
|---|---|---|---|---|
| observed magnetic anomal | 28.1 | 52.3 | 853,552 | nT |
| levelled magnetic anomaly | 21.5 | 40.8 | | nT |
| observed free-air anomaly | 2.9 | 6.3 | 1,418,144 | mGal |
| levelled free-air anomaly | 2.0 | 3.3 | | mGal |
| observed depth | 56.9 | 153.6 | 14,153,157 | m |
| levelled depth | 13.5 | 52.6 | | m |

### *3.1 Magnetic Data*

The magnetic data were imported after subtraction of the International Geomagnetic Reference Field (IGRF), and line segments identified as given in the general procedures above. Polynomial levelling was attempted, using the IGRF as a reference field, but this procedure was not successful, as the IGRF does not have sufficient high frequency content. Loop levelling was then performed, resulting in an improved image, and this was followed by decorrugation and microlevelling of the generated grid to remove remaining line levelling errors.

Decorrugation is a directional filtering process which is normally applied to parallel survey lines. The technique was modified to apply to the haphazard marine data by progressively rotating the gridded dataset and applying the filter at each rotation step. The length and width of the filter were determined empirically, and were necessarily a compromise due to the great variation in line segment length and spacing. The filter parameters used for the loop-levelled data were a minimum streak length of 30km and streak width of 20 km. This produced an acceptable final product with a minimum loss of signal.

### *3.2 Gravity Data*

After line segments were identified, a free-air correction was applied to the gravity data. A convenient reference surface exists in the Geosat gravity grid v 7.2 (Smith and Sandwell, 1995). After applying a low-pass filter to remove wavelengths shorter than 25 km, and some of the noise which permeates this dataset, the Geosat grid contained sufficient resolution to act as a reference surface to polynomial levelling. Best results were obtained by fitting a zero-order polynomial to the data using the misties between the free-air anomaly and Geosat grid. Finally, to remove 'pock-marks' coinciding with short line segments near heading changes, and line segments of less than 50 data samples (~7 km), were removed.

### *3.3 Bathymetry Data*

The processing of the bathymetry was more involved than that of the gravity and magnetic data, due to the greater volume of data and the widely varying quality of the datasets. In addition, many oil exploration company surveys did not contain datum information. As it was common practice for these surveys to use an AGD, a conversion to the common datum WGS84 was performed in all cases.

Attempts to level the data against a global topographic reference surface were only partially successful. The method finally adopted consisted of generating a reference surface using the data itself, a 'bootstrap' method, as follows:

- Establish a grouping of surveys according to the navigation systems used, and sort the list on the basis of this criterion. Table 4 shows this grouping.

- Level each survey grouping internally using loop levelling and create a series of grids. Stitch these grids using the more reliable datasets as the primary grids, and build up a reference surface. In building the reference surface, the values from surveys in category 1 in table 3 were not altered.

- Using this reference surface, perform a polynomial levelling correction on the entire dataset except the AHO and swath data, adjusting the depth value for each point in the dataset.

**Table 4 - Hierarchy of surveys containing bathymetry data, from most to least reliable**

| Rank | Criterion | Surveys |
|---|---|---|
| 1 | Consistent dataset | AHO data |
| 1 | GPS but with accurate soundings | l'Atalante swath survey 157 |
| 2 | Differential GPS | 100-122,124,126-130,135-151, 159-196,1070 |
| 3 | GPS and DR/Transit | 48-81, 89, 98-99 |
| 3 | Radio navigation | 3,4,82,90,91,1069 |
| 4 | Dead reckoning/Transit satellite | 5-46 |
| 5 | GPS | 123,125,134,157,501,502,1150 |
| 6 | unknown navigation system | 1, 34-45, 49, 54, 58-60, 83-86, 131, 149, 186, 1001-1068, 1071-1149, 1151-1807 |

The polynomial levelling correction included an additional constraint on the magnitude of adjustment to the depth values. An inverse weighting scheme was used, which meant that the greater the depth value the less weight was given to that reading for the polynomial correction. This was used to prevent the deeper values causing inappropriately large adjustments to the shallow data.

The final stage of processing was to reduce sub-meter corrugations in the AHO data which aligned with the major line directions for each survey (Figure 2).

## 4. Gridding

The following section describes the process used to generate each of the grids from the source data.

### *4.1 Gravity Data*

Gravity data from the levelled ship-track database were combined with the onshore gravity database to create a mask, which was then applied to the Geosat satellite gravity field. The masked satellite data filled in the holes in the ship-track coverage. The combined dataset was then gridded using a new technique using multiple passes developed by one of the authors, Murray. The technique uses the minimum curvature method, which will allow high precision gridding to be performed practically on any gravity station distribution. Gravity data integration usually involves, as it does in this case, the compilation of several separate datasets of widely differing observation (point value) spacing (Figure 3). Traditional one-pass gridding techniques often demand a compromise between achieving a high frequency response in areas of dense observations while avoiding high frequency noise or ringing in areas of sparse coverage. This compromise may be avoided by piecewise gridding of the area and feathering the grid pieces together, or by using a triangulation technique. However, both these methods will introduce spurious artefacts into the frequency response, which will hamper a unified interpretation of the area.

The gridding method which best suits the well defined behavior of a gravity field is the minimum curvature technique; unfortunately, this method is particularly sensitive to the cell size chosen for the gridding in relation to the observation spacing. If the cell size is less than one sixth of the station spacing obvious boxing and ringing effects become evident in images or contours based on the derived grid. The best results are obtained when the cell size lies between one third and one fifth of the observation spacing. The ideal gridding technique will effectively approximate this spacing everywhere within the area being gridded notwithstanding even extreme variance in the observation spacing.

This new technique of multiple pass gridding combines the original observed data with cell values from the previous pass filling any gaps in the original dataset. This additional 'pseudo-data' holds the grid constant in areas of sparse data while the cell size is progressively refined to make full use of the dense data. The method has been tested in areas where the observation spacing varies from 25 metres to 7 kilometres, and appears to have worked successfully in the present context where the data density variation is much greater and a minimum cell size of 0.01 degree was used (Figure 8).

### *4.2 Magnetic Data*

The levelled ship-track magnetic data were gridded using a minimum curvature technique and stitched to the magnetic anomaly map of Australia derived from aeromagnetic data and sub-sampled to 0.01 degree cell size to match the offshore data. The offshore aeromagnetic surveys were not used in this version of the stitched magnetic anomaly grid. This method of combining the offshore and onshore grids was adopted for pragmatic reasons, as the regeneration of the Magnetic Anomaly Map of Australia was not a manageable task at the time.

A first order polynomial was removed from both the ship-track data and the airborne data to remove regional gradients from the data. The ship-track data grid was interpolated to 15 seconds of arc to match the airborne data. The two datasets were merged by minimising differences along the boundary between the grids.

The relatively sparse coverage of the ship-track data is apparent where holes remain in the grid. Large parts of the Gulf of Carpentaria and Agro Abyssal Plain remain unsurveyed.

A mis-match between the onshore and offshore grids (Figure 9) is most apparent in the vicinity of Broome and is due to a warp in the Magnetic Anomaly Map in that region.

### *4.3 Bathymetry Data*

The levelled ship-track data, the decorrugated but otherwise unaltered AHO data, the unaltered l'Atalante swath data, the Geodata 9-s DEM onshore grid and the Gtopo30 grid were gridded in combination using ANUDEM (Hutchinson, 1989, 1997). This program was chosen for its particular suitability to topographic data as it models escarpments and streams faithfully. It was used successfully in a terrain modeling pilot study of the Tasmanian region. (Bernardel, 1997). Figure 6 shows the distribution for the offshore component of the data used in creating the grid (Figure 10).

The gridding parameters used in Hutchinson's program ANUDEM are given in Table 5. Drainage enforcement was switched off as the great variability in data coverage gave rise to spurious valleys and channels in areas of sparse coverage, and did not properly characterise the seafloor topography. As with the other grids, a cell size of 0.01 degree was chosen. However it was possible to produce a satisfactory grid using a cell size of 0.0045 degree (~500m) in the Timor and Browse compartments where the dense BHP Petroleum data are central, and the AGSO-digitised Natmap coverage is most complete. This detailed grid is included in the North West CD (Figure 11).

Figure 8 - Bouguer anomaly onshore, free-air anomaly offshore

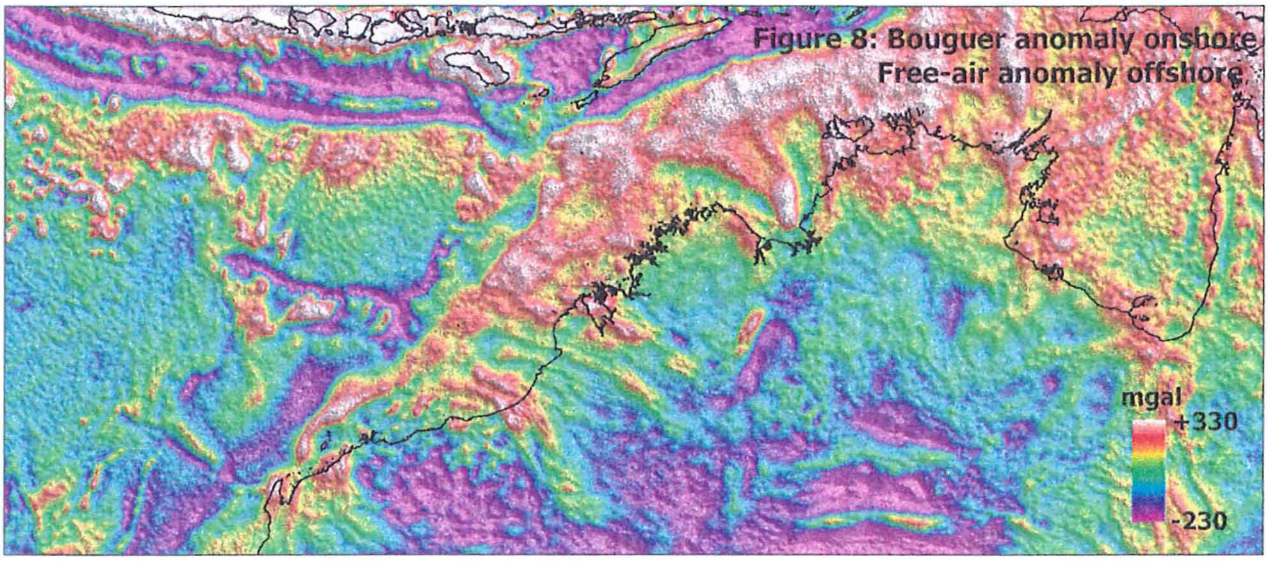



Figure 9 - Magnetic anomaly

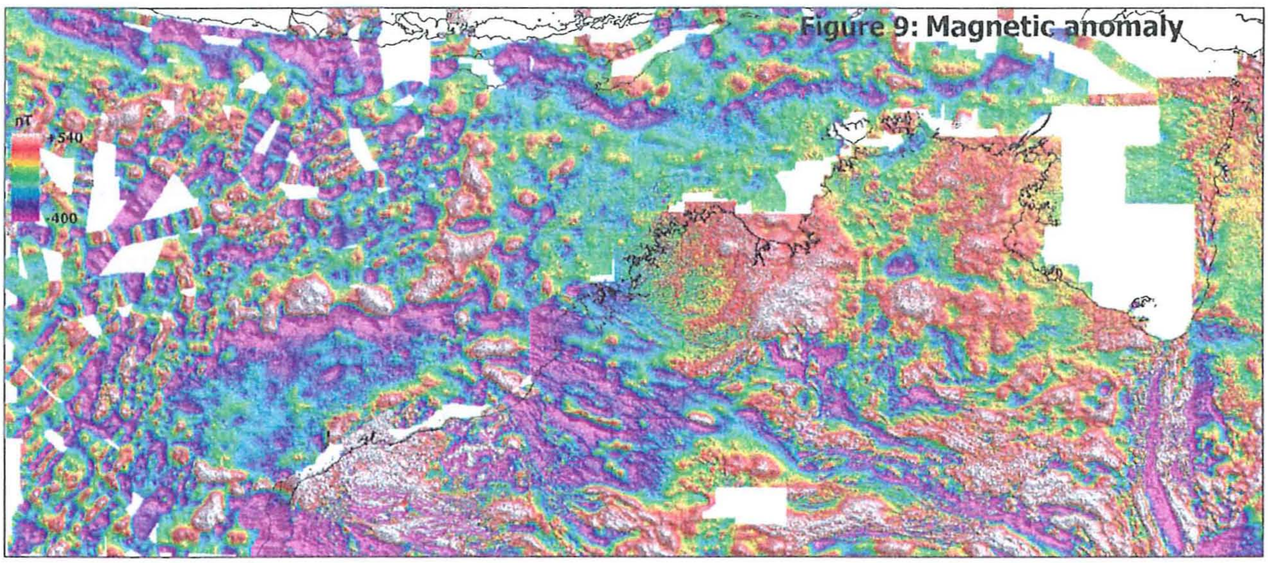


Figure 10 - Bathymetry and topography using 1km cell size

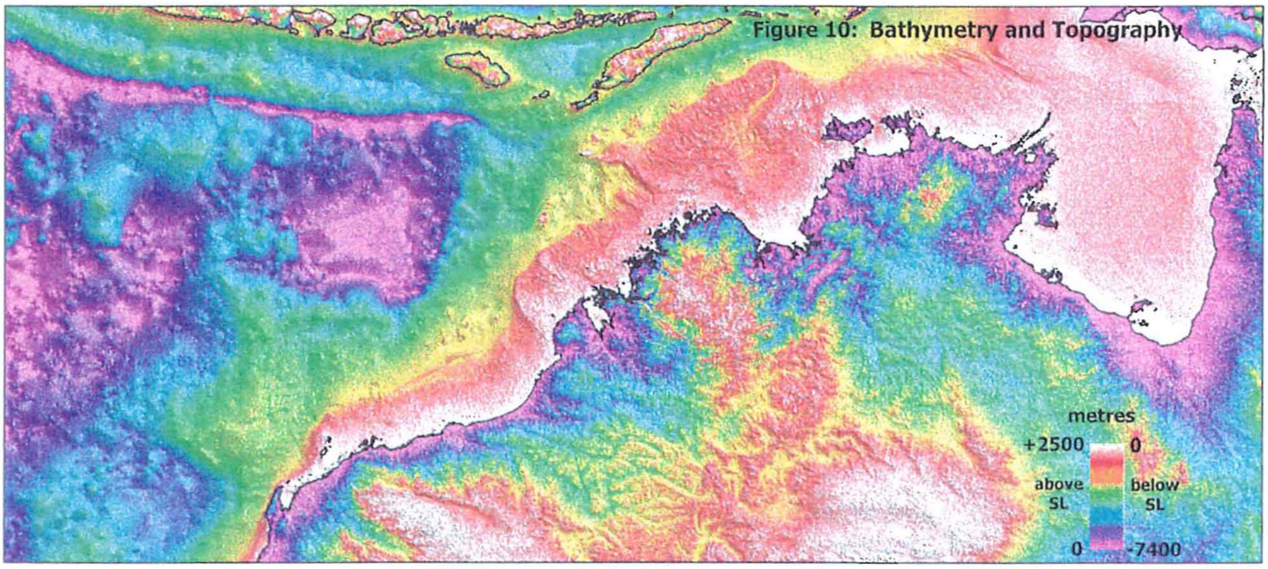



Figure 11 - Bathymetry and topography using 500 m cell size

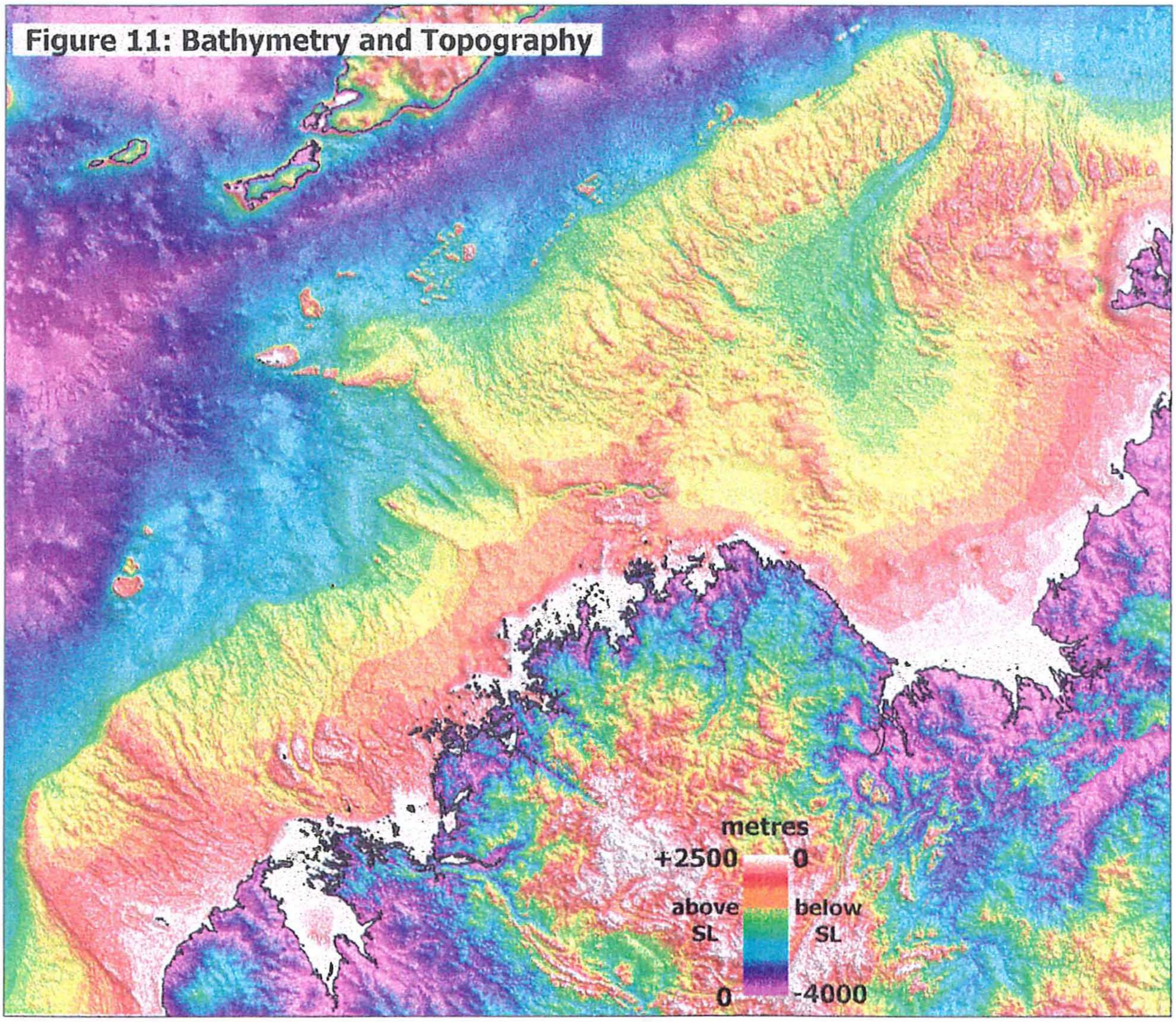


**Table 5 - Gridding parameters for ANUDEM**

| Value | Description |
|---:|---|
| 0 | drainage enforcement: 0 => off, 1 => on |
| 0 | spotheight/contour option: 0 => spot heights |
| 1.0, 0.0 | discretasation error, vertical standard error |
| 0.5 | roughness penalty |
| 50.0 200.0 | elevation tolerances |
| 40 | max. no of iterations |
| 1 | 1=elevations in metres, 2=elevations in feet |
| -9000.0, 3000.0 | height limits |
| 1 | corner/centre option: 1 => centre, 0 => corner |
| 5 | position units, 5 = Degrees |
| 106.0, 143.0 | longitude limits (West and East) |
| -24.0, -8.0 | latitude limits (South and North) |
| 0.01 | grid spacing in degrees (eg .009= 1km, .0083=30") |
| 0.2 | margin width - region beyond extents gridded |
| 6 | no. of input files |

Note that there are several areas in the bathymetry grid which are known artefacts and will be the subject of further work (see below). These are itemised below:

- In the waters south of Irian Jaya AGSO data are sparse or non-existent,
- coastal waters out to 20-30 nautical miles are not well represented by data in the AGSO database,
- corrugations in the grid where AHO Natmap data predominate (mainly in the Gulf of Carpentaria, Bonaparte Gulf) ,
- irregularities in the grid in a broad region near 19.7S, 116.7E where there is much exploration company data but insufficient control on the levelling process,
- irregularities in the grid along a strip between 16.8S, 119.3E to 18.5S,119E

To estimate the accuracy of the bathymetry values, the grid depths are compared with the water depths measured at Deep-Sea Drilling Project[4] and Ocean-Drilling Project[5] sites in table 6 below:

[4] ftp://ftp.ngdc.noaa.gov/MGG/geology/dsdp
[5] http://www-odp.tamu.edu and http://janusaxp.tamu.edu/predef-queries/curation/holesumm.htm

**Table 6 - Comparison of water depths at deep sea drilling sites and grid depths**

| Prog | Leg | Site | Latitude | Longitude | Depth | Grid | G-D | \|%\| |
|---|---|---|---|---|---|---|---|---|
| ODP | 122 | 759A | -16.95420 | 115.56020 | 2103 | 1973 | 130 | 6.2 |
| ODP | 122 | 760A | -16.92200 | 115.54130 | 1981 | 1865 | 116 | 5.9 |
| ODP | 122 | 761A | -16.73760 | 115.53500 | 2179 | 2203 | -24 | 1.1 |
| ODP | 122 | 762A | -19.88720 | 112.25430 | 1371 | 1377 | -6 | 0.4 |
| ODP | 122 | 763A | -20.58670 | 112.20830 | 1379 | 1381 | -2 | 0.2 |
| ODP | 122 | 764A | -16.56600 | 115.45720 | 2710 | 2854 | -144 | 5.3 |
| ODP | 123 | 765A | -15.97586 | 117.57516 | 5732 | 5740 | -8 | 0.1 |
| ODP | 123 | 766A | -19.93209 | 110.45405 | 4008 | 4025 | -17 | 0.4 |
| DSDP | 27 | 260 | -16.14450 | 110.29870 | 5702 | 5705 | -3 | 0.1 |
| DSDP | 27 | 261 | -12.94720 | 117.89270 | 5667 | 5672 | -5 | 0.1 |
| DSDP | 27 | 262 | -10.86980 | 123.84630 | 2298 | 2330 | -32 | 1.4 |
| DSDP | 27 | 263 | -23.32380 | 110.96350 | 5048 | 4896 | 152 | 3.0 |

The deep-sea drilling data were not used as reference data in the levelling process, and so allow an independent check. The comparison suggests that the depths are generally within 5% of true measured depths.

The most striking feature of the bathymetry image (figure 10) is the channelling of the shelf and in particular the reverse channel in the Timor Sea, which has a depth of approximately 120m relative to its surroundings. The deepest part of this channel is between 200-225m below sea level at its northern end from 10.38S, 128.58E to 10.07S, 128.67E, where it is approximately 10km wide and 120-140 m below its surroundings. Its central part becomes shallower as it broadens southwest. The myriad of channels that braid to the northwest are typically 10-30 m in depth. They appear to terminate at the edge of the shelf, but this may be an artefact of the loss in data density at that depth. It is possible that this channelling continues down the slope. Evidence for it is found at the base of the slope where there is a section of densely spaced points from the l'Atalante swath survey which define channels at the same scale as on the shelf.

## 5. Image Processing

The grids were imaged with ER-Mapper 5.5a[6], using a colour drape and hill-shade algorithm as described by Pelton (1987). The palette is a spectrum with white added at the red end to give additional colour spread, to which a non-linear histogram equalisation was applied (Figures 8, 9, 10, 11).

The colour spread in the bathymetry/topography image (Figures 10, 11) was enhanced further by using two identical palettes above and below the zero contour at the coastline.

## 6. Future Work

The bathymetry grid has several known deficiencies, and these should be addressed in a future version of the grid:

- Grim and Edgar (1998) have produced a bathymetric chart of the Gulf of Carpentaria and Arafura Sea. The contour strings are available in digital form and these data will be incorporated in future versions, and will permit filling of the data hole in the waters south of Irian Jaya.

- Several deep-water areas on the shelf are covered by AHO charts ('fairsheets') on which spot depths have been hand written, and these are currently being digitised. The process involves scanning the charts to produce digital image files which are used to manually digitise each point along a survey line. The aim is to digitise lines which are not more than 2 km apart, to allow production of grids at the 500m cell size resolution.

- Coastal waters have been charted by the AHO, but these data do not exist in digital form. Digitisation of charts is a labour intensive and expensive process, and will be done in priority areas to complete the coverage of the shelf.

- The bathymetry grid represents variations in depth rather than true depth, because the source line data were levelled. The grid is tied to the AHO Natmap database on the shelf and the l'Atalante swath survey in deep water (see NW trending line end at approximately 12.1S, 121.7E). Comparison with deep-sea drilling sites (Table 6) suggest grid depths are generally within 5% of absolute depths, however the accuracy of depths needs to be more closely determined.

For gravity data, the Bouguer anomaly will be calculated for the offshore regions and combined with the Bouguer anomaly data onshore.

For magnetic data:

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[6] Earth Resource Mapping Pty. Ltd., http://www.informationgraphics.com/ermapper/index.html

- There are offshore areomagnetic datasets that can be incorporated into the grid (see Figure 6).

- When AGSO releases a new edition of the Magnetic Anomaly Map of Australia, the warp in the onshore grid along the western margin will be removed and a more continuous onshore/offshore coverage will be produced.

- The decorrugation process (described in section 4.2 above) is a crude method of removing the artifacts resulting from crossover errors, and has produced spurious anomalies in the underlying line data. A future version will attempt to retain the true shape of anomalies in the line data.

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## 8. Contacts

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Digital data sourced from National Bathymetric Mapping Programme and Royal Australian Navy Hydrographic Service source data are available from Australian Hydrogrpahic Office. For more information contact:

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Fax: +61 (0)2 4221 8597
Email: lcd.hydro@navy.gov.au
Web: www.hydro.navy.gov.au

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Manager, Sales
G.P.O. Box 378, Canberra, ACT, 2601
Phone: +61 (0)2 6249 9519
Fax: +61 (0)2 6249 9982
Email: sales@agso.gov.au
Web: http://www.agso.gov.au

# Appendix 1 - Mardat surveys used in compilation

| AGSO Id. | Survey Name | Institution | Platform | Year |
|---|---|---|---|---|
| 1 | BONAPARTE GULF | AGSO | | 1963 |
| 3 | TIMOR SEA | AGSO | WYRALLAH | 1967 |
| 4 | NW SHELF | AGSO | ROB ROY | 1968 |
| 17 | W COAST | AGSO | LADY CHRISTINE | 1972 |
| 18 | INDIAN OCEAN | AGSO | LADY CHRISTINE | 1972 |
| 53 | NE AUSTRALIA HF | AGSO | RIG SEISMIC | 1986 |
| 55 | EXMOUTH 1 | AGSO | RIG SEISMIC | 1986 |
| 56 | EXMOUTH 2 | AGSO | RIG SEISMIC | 1986 |
| 83 | EXMOUTH ODP | ODP | RESOLUTION | 1988 |
| 94 | ARAFURA SEA 1 | AGSO | RIG SEISMIC | 1990 |
| 95 | CANNING-EXMOUTH | AGSO | RIG SEISMIC | 1990 |
| 96 | NW SHELF | AGSO | RIG SEISMIC | 1990 |
| 97 | VULCAN GRABEN 1 | AGSO | RIG SEISMIC | 1990 |
| 98 | VULCAN GRABEN 2 | AGSO | RIG SEISMIC | 1990 |
| 99 | BONAPARTE 1 | AGSO | RIG SEISMIC | 1991 |
| 100 | BONAPARTE 2 | AGSO | RIG SEISMIC | 1991 |
| 101 | S NW SHELF 1 | AGSO | RIG SEISMIC | 1991 |
| 106 | ARAFURA SEA 2 | AGSO | RIG SEISMIC | 1991 |
| 107 | CHRISTMAS IS. | AGSO | RIG SEISMIC | 1992 |
| 110 | S NW SHELF 2 | AGSO | RIG SEISMIC | 1992 |
| 116 | ZOCA | AGSO | RIG SEISMIC | 1993 |
| 118 | MALITA GRABEN | AGSO | RIG SEISMIC | 1993 |
| 119 | BROWSE BASIN | AGSO | RIG SEISMIC | 1993 |
| 120 | S NW SHELF 3 | AGSO | RIG SEISMIC | 1993 |
| 122 | SAHUL SHOALS | AGSO | RIG SEISMIC | 1993 |
| 127 | S ENDERBY TERRACE | AGSO | RIG SEISMIC | 1994 |
| 128 | NW MARGIN TRANSECT | AGSO | RIG SEISMIC | 1994 |
| 130 | BROWSE BASIN | AGSO | RIG SEISMIC | 1994 |
| 135 | WALLABY PLATEAU | AGSO | RIG SEISMIC | 1994 |
| 136 | CARNARVON T. TIE | AGSO | RIG SEISMIC | 1994 |
| 157 | ADEDAV | IFREMER | L'ATALANTE | 1994 |
| 160 | KUNUNGA | MIMPEX | RIG SEISMIC | 1995 |
| 161 | COGNAC | MIMPEX | RIG SEISMIC | 1995 |
| 162 | WEST EXMOUTH PLAT | AGSO | RIG SEISMIC | 1995 |
| 163 | VULCAN TERTIARY | AGSO | RIG SEISMIC | 1995 |
| 165 | YAMPI SHELF TIE | AGSO | RIG SEISMIC | 1995 |
| 166 | CHIVE 2D SEISMIC | CARNARVON | RIG SEISMIC | 1995 |
| 167 | INNER EXMOUTH | JNOC | RIG SEISMIC | 1995 |
| 168 | OBS NW SHELF PART1 | AGSO | RIG SEISMIC | 1995 |
| 168 | OBS NW SHELF PART2 | AGSO | RIG SEISMIC | 1996 |
| 174 | EXMOUTH SOUTH | PGS/NOPEC | RIG SEISMIC | 1996 |
| 175 | BROWSE BASIN R.TIE | AGSO | RIG SEISMIC | 1996 |
| 176 | TIMOR SEA SNIFFER | AGSO | RIG SEISMIC | 1996 |
| 198 | TIMOR SEA GEOLOGY | WOODSIDE | RIG SEISMIC | 1997 |
| 1028 | GULF NE-NW AUST. | GULF | GULFREX | 1971 |
| 1038 | V3305 | LDGO | VEMA | 1976 |
| 1039 | VEMA 3308 | LDGO | VEMA | 1976 |
| 1055 | BOBBIE II | WESMINCO | | 1990 |
| 1056 | KENDREW/COOTA. | WOODSIDE | | 1994 |
| 1057 | HCB90A | BHP | | 1990 |
| 1058 | HCB91A | BHP | | 1991 |
| 1059 | KUHUMA | KUFPEC | | 1990 |
| 1060 | MARIE | WESMINCO | | 1985 |
| 1061 | POMPANO | MINORA | | 1985 |

| | | | | |
|---|---|---|---|---|
| 1062 | TAMAR SPEC | HGSI | | 1987 |
| 1063 | TAMAR SPEC | HGSI | | 1989 |
| 1064 | TAMAR SPEC | HGSI | | 1989 |
| 1065 | TAMAR SPEC | HGSI | | 1989 |
| 1066 | YORK SOUND | ARCO | | 1976 |
| 1067 | LASMO LEC91 | LASMO | | 1991 |
| 1068 | ROXANNE | WESTERN | | 1989 |
| 1069 | CAPE FORD/DOOLEY | CNW | | 1990 |
| 1070 | 92-SA-14-ZA | ENTERPRISE | | 1992 |
| 1071 | LASMO LM92 | LASMO | | 1992 |
| 1072 | ADRIENNE | MESA | | 1983 |
| 1073 | MAURA | WESMINCO | | 1985 |
| 1075 | GORGON 2 | WAPET | | 1988 |
| 1076 | GORGON 3 | WAPET | | 1989 |
| 1077 | VLAMING 467 | WAPET | | 1989 |
| 1078 | CE94AU11 | | | 1900 |
| 1079 | KIRSTEN | WMC | | 1991 |
| 1080 | NATALIE | AMPOLEX | | 1994 |
| 1081 | CASUARRINA | AQUITAINE | | 1981 |
| 1082 | ANGEL-2D | WOODSIDE | | 1990 |
| 1083 | ECHO/DIXON | WOODSIDE | | 1990 |
| 1084 | GOODWYN 3D | WOODSIDE | | 1990 |
| 1085 | LEWIS-BRECKNOCK | | | 1900 |
| 1086 | N92A | ESSO | | 1992 |
| 1087 | H93B | HADSON | | 1993 |
| 1088 | HH92A | BHP | | 1992 |
| 1089 | ERICA | LASMO | | 1985 |
| 1090 | GUMNUT | MARATHON | | 1990 |
| 1098 | 85DB | GSI | | 1986 |
| 1102 | RACHEL/JENNY | AMPOL | | 1991 |
| 1103 | RAMBLER | LASMO | | 1993 |
| 1104 | SC94A | ESSO | | 1994 |
| 1105 | ROSEMARY 3D | WOODSIDE | | 1992 |
| 1106 | YVETTE 2D | WMC | | 1993 |
| 1107 | MADELEINE | | | 1900 |
| 1108 | MYRMIDON | LASMO | | 1992 |
| 1109 | GOODWYN-DOCKRELL | WOODSIDE | | 1900 |
| 1111 | DAMPIER | | | 1900 |
| 1112 | CORELLA | | | 1900 |
| 1113 | HILDA E3D | BHP | | 1988 |
| 1115 | PD91 | PHILLIPS | | 1991 |
| 1116 | N91A | NORCEN | | 1992 |
| 1117 | N90A | NORCEN | | 1990 |
| 1118 | WA-249-P | MOBIL | | 1994 |
| 1119 | OUTER BEAGLE | MOBIL | WESTERN HORIZON | 1993 |
| 1121 | MAHAKAM | KUFPEC | | 1992 |
| 1122 | WA-58-P | HUDBAY | | 1981 |
| 1123 | BORONIA | MARATHON | | 1983 |
| 1124 | H93B-2 | HADSON | | 1993 |
| 1125 | H93B-3 | HADSON | | 1993 |
| 1126 | WA-202-P | ARCO | | 1988 |
| 1127 | EAGLEHAWK | WOODSIDE | | 1986 |
| 1128 | CC82 | CNW | | 1982 |
| 1129 | KOOLINDA | WAPET | | 1985 |
| 1130 | A89K | AMPOL | | 1989 |
| 1131 | 88MPF | MARATHON | | 1988 |
| 1132 | ECHIDNA | MARATHON | | 1986 |
| 1133 | EAGLEHAWK 86B | WOODSIDE | | 1986 |
| 1134 | EAGLEHAWK 86A | WOODSIDE | | 1986 |
| 1135 | WA-28-P | WOODSIDE | | 1985 |
| 1136 | WA-191-P | MARATHON | | 1982 |

| | | | | |
|---|---|---|---|---|
| 1137 | MUIRON/OUTTRIM | BHP | | 1993 |
| 1140 | DIXON | | | 1990 |
| 1141 | GORGON3 | | | 1989 |
| 1142 | HC90A | | | 1990 |
| 1147 | KUHUMA | | | 1990 |
| 1224 | CD3088 | UKIOS | CHARLES DARWIN | 1988 |
| 1243 | JARE27L1 | IPR | SHIRASE | 1985 |
| 1245 | JARE28L1 | IPR | SHIRASE | 1986 |
| 1247 | JARE29L1 | IPR | SHIRASE | 1987 |
| 1250 | JARE30G1 | IPR | SHIRASE | 1988 |
| 1253 | JARE32L1 | IPR | SHIRASE | 1990 |
| 1257 | JARE33L1 | IPR | SHIRASE | 1991 |
| 1271 | JARE34A | JODC | SHIRASE | 1992 |
| 1301 | V2410 | LDGO | VEMA | 1967 |
| 1305 | WI343815 | USN | USNS WILKES | 1978 |
| 1306 | INDP14WT | SIO | THOMAS WASHINGTON | 1977 |
| 1307 | LUSI6DAR | SIO | ARGO | 1963 |
| 1309 | A2093L14 | WHOI | ATLANTIS II | 1976 |
| 1310 | RAMA05WT | SIO | THOMAS WASHINGTON | 1980 |
| 1311 | ERDC05WT | SIO | THOMAS WASHINGTON | 1975 |
| 1312 | DME07 | RSRIG | DMITRIJ MENDELEEV | 1972 |
| 1313 | DME10 | RSRIG | DMITRIJ MENDELEEV | 1973 |
| 1314 | DSDP22GC | SIO | GLOMAR CHALLENGER | 1972 |
| 1316 | MONSO2AR | SIO | ARGO | 1960 |
| 1317 | WI343811 | USN | USNS WILKES | 1978 |
| 1322 | KH7201 | UTOKYO | HAKUHO MARU | 1972 |
| 1323 | KH7605 | UTOKYO | HAKUHO MARU | 1977 |
| 1324 | ODP122JR | TAMU | JOIDES RESOLUTION | 1988 |
| 1327 | C1403 | LDGO | R.D. CONRAD | 1971 |
| 1328 | V2819 | LDGO | VEMA | 1971 |
| 1331 | 85000511 | IFREMER | JEAN CHARCOT | 1985 |
| 1332 | ODP123JR | TAMU | JOIDES RESOLUTION | 1988 |
| 1334 | DSDP27GC | SIO | GLOMAR CHALLENGER | 1972 |
| 1336 | COR700 | ORSTOM | CORIOLIS | 1982 |
| 1337 | C2701 | LDGO | R.D. CONRAD | 1986 |
| 1338 | C2703 | LDGO | R.D. CONRAD | 1986 |
| 1339 | A2093L11 | WHOI | ATLANTIS II | 1976 |
| 1340 | C1107 | LDGO | R.D. CONRAD | 1967 |
| 1341 | C1404 | LDGO | R.D. CONRAD | 1971 |
| 1342 | V2009 | LDGO | VEMA | 1964 |
| 1344 | V3405 | LDGO | VEMA | 1977 |
| 1345 | DODO05AR | SIO | ARGO | 1964 |
| 1348 | CH100L07 | WHOI | CHAIN | 1971 |
| 1349 | A2015L04 | WHOI | ATLANTIS II | 1965 |
| 1350 | LUSI6CAR | SIO | ARGO | 1962 |
| 1352 | RAMA12WT | SIO | THOMAS WASHINGTON | 1981 |
| 1353 | 83011602 | SOEST | KANA KEOKI | 1983 |
| 1354 | 83011603 | SOEST | KANA KEOKI | 1983 |
| 1355 | MW8802 | SOEST | MOANA WAVE | 1988 |
| 1359 | C2702 | LDGO | R.D. CONRAD | 1986 |
| 1360 | BARTLETT | USNAVY | BARTLETT | 1971 |
| 1361 | LUSI03HO | SIO | HORIZON | 1962 |
| 1362 | UM69-1 | UTOKYO | UMITAKA MARU | 1969 |
| 1421 | V2008 | LDGO | VEMA | 1964 |
| 1424 | V2409 | LDGO | VEMA | 1967 |
| 1428 | V2818 | LDGO | VEMA | 1971 |
| 1434 | V3309 | LDGO | VEMA | 1976 |
| 1438 | V3404 | LDGO | VEMA | 1977 |
| 1445 | CH100L08 | WHOI | CHAIN | 1971 |
| 1447 | A2093L12 | WHOI | ATLANTIS II | 1976 |
| 1448 | A2093L13 | WHOI | ATLANTIS II | 1976 |

| | | | | |
|---|---|---|---|---|
| 1450 | IIOECGS | NOAA | PIONEER | 1964 |
| 1574 | ERDC04WT | SIO | THOMAS WASHINGTON | 1974 |
| 1576 | INDP07WT | SIO | THOMAS WASHINGTON | 1976 |
| 1577 | INDP08WT | SIO | THOMAS WASHINGTON | 1976 |
| 1579 | MARA09WT | SIO | THOMAS WASHINGTON | 1979 |
| 1650 | COR300 | ORSTOM | CORIOLIS | 1981 |

Number of values, their range and line km:

| Param. | Total | Min | Max | Line km |
|---|---|---|---|---|
| Depth | 1605010 | -7754 | 0 | 289103 |
| Gravity | 1427685 | 9779611 | 9789097 | 266532 |
| Magnetic | 820672 | 43516 | 55125 | 161284 |

Navigation Codes:

A - differential GPS
B - as E plus differential GPS
C - as E plus stand-alone GPS (no SA)
D - radio navigation
E - dead reckoning tied to Transit satellite fixes
F - stand-alone GPS (subject to SA)

## Appendix 2 - Contributing Organisations

The following codes are used in Appendix 1.

| Institution Code | Name |
| --- | --- |
| AA | Australian Archives |
| AGSO | Australian Geological Survey Organisation |
| AHO | Australian Hydrographic Office |
| AMPOL | Ampol Pty Ltd |
| AMPOLEX | Ampolex Ltd |
| AQUITAINE | Elf-Aquitaine |
| ARCO | Atlantic Richfield Company |
| BHP | BHP Petroleum Pty Ltd |
| BODC | British Oceanographic Data Centre |
| CARNARVON | Carnarvon Petroleum Pty Ltd |
| CNW | Canada Northwest Oil (Australia) Pty. Ltd. |
| ENTERPRISE | Enterprise Oil Exploration Pty. Ltd. |
| ESSO | Esso Australia Ltd |
| GSI | Geophysical Services International |
| GULF | Gulf Oil |
| HADSON | Hadson Oil |
| HGSI | Haliburton Geophysical Services International |
| HUDBAY | Hudbay Oil & Gas |
| IFREMER | Institut Francais de Recherche pour l'Exploitation de la Mer |
| IPR | Institute of Polar Research |
| JNOC | Japan National Oil Corporation |
| JODC | Japan Oceanographic Data Centre |
| KUFPEC | Kuwait Foreign Petroleum Exploration Company |
| LASMO | LASMO plc |
| LDGO | Lamont Doherty Geophysical Observatory |
| MARATHON | Marathon Oil |
| MESA | Minerals & Energy South Australia |
| MIMPEX | Mimpex Ltd |
| MINORA | Minora Resources NL |
| MOBIL | Mobil Corporation |
| NGDC | National Geophysical Data Centre |
| NORCEN | Norcen Energy Resources Ltd. |
| ODP | Ocean Drilling Program |
| OOVM | l'Observatoire Oceanologique de Villefranche-sur-Mer |
| ORSTOM | Institut de Recherche pour le Developpement |
| PGS/NOPEC | Nopec International |
| PHILLIPS | Phillips Oil Company Australia |
| RSRIG | All-Russian Scientific and Research Institute for Geophysics |
| SIO | Scripps Institute of Oceanography |
| SOEST | School of Ocean and Earth Science & Technology |
| TAMU | Texas A & M University |
| UKIOS | Institute of Oceanographic Sciences, UK |
| USNAVY | US Navy |
| UTOKYO | University of Tokyo |
| WAPET | West Australian Petroleum Pty. Ltd. |
| WHOI | Woods Hole Oceanographic Institute |
| WESMINCO | Western Mining Corporation |
| WESTERN | Western Geophysical |
| WMC | Western Mining Corporation |
| WOODSIDE | Woodside Offshore Petroleum Pty. Ltd. |

## Appendix 3 - BHP Petroleum Surveys

| BHPP Survey id | number of lines |
|---|---|
| 93A | 28 |
| A91E | 19 |
| A91M | 31 |
| ACB90 | 17 |
| ASB | 7 |
| C92 | 27 |
| EV89 | 45 |
| H92 | 38 |
| HA1 | 39 |
| HA2 | 4 |
| HA3 | 43 |
| HA5 | 65 |
| HA6 | 48 |
| HA7 | 47 |
| HA88B | 32 |
| HA89A | 44 |
| HA89B | 26 |
| HA91A | 39 |
| HA91B | 41 |
| HB1 | 31 |
| HB2 | 64 |
| HB5 | 61 |
| HB96B | 1901 |
| HC96X | 1 |
| HE96 | 47 |
| HH1 | 102 |
| HH2 | 1 |
| HH4 | 29 |
| HH6 | 20 |
| HJ10 | 36 |
| HJ11 | 35 |
| HJ13 | 201 |
| HJ14 | 10 |
| HJ4 | 113 |
| HJ5 | 98 |
| HJ5_6 | 8 |
| HJ6 | 30 |
| HJ9 | 227 |
| HJ94 | 30 |
| HP92HR | 26 |
| HV12 | 29 |
| HV13 | 60 |
| HV2 | 29 |
| HV3 | 78 |
| HV6 | 10 |
| HV6R | 41 |
| HV7 | 62 |
| HV8 | 22 |
| HV9 | 20 |
| HY95 | 26 |
| HY95B | 56 |
| HZI92 | 80 |
| JA95 | 55 |

| | |
|---|---|
| LM92 | 115 |
| NC92 | 129 |
| PW91 | 88 |
| S92 | 70 |
| WAIT96 | 34 |
| WG96I | 15 |
| WP92 | 120 |
| XB4 | 5 |
| ZPW92 | 136 |