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A LOGISTICS REPORT
for a
GRAVITY SURVEY
conducted near
DALY WATERS, NT
ONSHORE
A LOGISTICS REPORT
for a
GRAVITY SURVEY
conducted near
DALY WATERS, N.T.
on behalf of
PACIFIC OIL & GAS PTY. LTD.

GEOTERRAX PTY. LTD.

Project No. 4-109

John Peacock
October 1989
# TABLE OF CONTENTS

1. INTRODUCTION ............................................................................. 1  
   1.1 LOCATION ............................................................................. 1  
   1.2 PURPOSE AND SCOPE OF THE PROGRAMME ......................... 1  
   1.3 PRODUCTION STATISTICS .................................................... 1  
   1.4 PERSONNEL AND EQUIPMENT ............................................... 1  

2. SURVEY PROCEDURES ................................................................. 3  
   2.1 THE GRAVITY SURVEY ......................................................... 3  
   2.2 POSITIONING ........................................................................ 3  

3. DATA PROCESSING AND PRESENTATION ..................................... 4  
   3.1 DATA REDUCTION .................................................................. 4  
   3.2 QUALITY CONTROL ............................................................. 4  
   3.3 FINAL PRODUCTS DELIVERED .............................................. 7  

5. CONCLUSIONS AND RECOMMENDATIONS ................................. 8
LIST OF FIGURES

FIGURE 1: Grid Map of Survey Area
FIGURE 2: Statistical Distribution - Gravity Repeats

APPENDICES

APPENDIX A: Computer Listing of Final Bouguer Data
APPENDIX B: Reduction to Final Gravity Values
APPENDIX C: Statistical Analysis and Error Calculations
APPENDIX D: Format of Located Data Tapes
1. INTRODUCTION

1.1 LOCATION

During the period 25-May-88 to 14-Jun-88, GEOTERREX PTY. LTD. of 13 Whiting Street, Artarmon, N.S.W. 2064, conducted a gravity survey on behalf of PACIFIC OIL & GAS Pty. Limited in two separate areas near Daly Waters in the Northern Territory on EP23 and EP24. (See Figure 1 for grid map.)

1.2 PURPOSE AND SCOPE OF THE PROGRAMME

The purpose of the gravity survey was to provide data in conjunction with the seismic survey taking place at the time. Station spacings of approximately 200 metres were used.

1.3 PRODUCTION STATISTICS

The field data acquisition phase of the survey lasted 19 days during which time a total of 1237 gravity stations were visited. This gives an average of 65 gravity stations per day.

1.4 PERSONNEL AND EQUIPMENT

The work performed by GEOTERREX provided gravity measurements made by Lacoste and Romberg Model G gravity meters and absolute survey co-ordinates provided by GEOSYSTEM surveyors.

GEOTERREX provided the following personnel for the data acquisition:
- Bradley George (Project Geophysicist)
- Larry Lawrence (Geophysical Technician)

GEOTERREX provided the following equipment for the data acquisition:
- one Lacoste and Romberg Model G gravity meter, Serial No. G473.
- Field and office supplies, as required.
- one field computer for data reduction.
Figure 1
Pacific Oil & Gas Pty. Ltd

Distribution of Gravity Repeatability, 4-109

Standard Deviation = 0.028 mgal

Figure 2
2. SURVEY PROCEDURES

2.1 THE GRAVITY SURVEY

To tie the gravity data into the Australian National gravity network, a base station was established in each area of the seismic survey. These bases were tied to the Gravity Network station listed below. The gravity values of the bases used during the survey were:

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<tr>
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<td>978355.86 mgal</td>
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<td>PoGB2</td>
<td>978359.02 mgal</td>
</tr>
</tbody>
</table>

All gravity readings taken during the course of the survey were tied to these base stations.

2.2 POSITIONING

All coordinates were provided by GEOSYSTEMS surveying crews. Absolute positions were then assigned to stations during the data processing stage.
3. DATA PROCESSING AND PRESENTATION

3.1 DATA REDUCTION

The sequence of calculations to convert raw gravity and positional data to final Bouguer gravity is shown in Appendix B.

The final processing in Sydney consisted of dumping the data into the GEOTERRA computer facility. Data was immediately in a form which could be plotted, printed or put on to a floppy disc or 9-track tape. After a paper copy of each map sheet was examined for possible errors, final ink on plastic profiled plots and posting maps were produced at 1:50,000 scale.

3.2 QUALITY CONTROL

1. The Gravity Data

A total of 66 revisits of stations yielding 127 deviations (10.3%) were collected to monitor the accuracy of the gravity data. The deviations were calculated by taking the difference of each reading at a station from the average reading of the station. A histogram of these deviations is shown in Figure 2. This histogram conforms roughly to a normal distribution with a standard deviation of 0.028 mgal. Thus the accuracy (from Appendix C) of the observed gravity is:

\[ \pm \frac{0.028}{1.414} = 0.020 \text{ mgal}. \]

2. Horizontal and Vertical Co-ordinates

It was estimated by GEOSYSTEMS surveyors that the horizontal co-ordinates were accurate to approximately 0.20 metres within the grid and to within 20 metres absolutely. Quoted accuracy for the vertical co-ordinate was 0.02 metres.

3. Accuracy of the Final Bouguer Gravity Data

The total probable error in the final Bouguer data, \( e_{bg} \), is a result of the expression:

\[
\begin{align*}
\text{\( e_{bg} \) = } & \text{\( e \) + \( e \) + (c \times e) \}} \\
\text{\( e \) = } & \text{\( g - gT - h \})}
\end{align*}
\]
where:

- $e$ is the error in the observed gravity $g$
- $e$ is the error in the theoretical gravity value used $g_T$
- $e$ is the error in the elevation value $h$

$$c = (0.3086 - 2 \times \pi \times \rho \times G)^{-2}$$

$$G = 6.67 \times 10^{-8} \frac{\text{dyne cm}}{\text{g}}$$

$$\rho = 2.67 \text{ g/cc}$$

$$c = 0.1967 \text{ mgal/metre}$$

From the preceding sections:

- $e = 0.020 \text{ mgals}$
- $g$
- $e = 0.71 \text{ metres}$
- $h$

$$e = 0.00081 \sin(2A) \text{ mgals/metre} \times \text{ northing error}$$

where $A = 14$ latitude

$$= 0.0001 \text{ mgal}$$

It follows:

$$e = 0.020 + 0.0001 + (0.71 \times 0.1967)$$

$$= 0.0199$$

and

$$e = 0.14 \text{ mgal}$$

This is the probable error in the final Bouguer gravity values.
3.3 FINAL PRODUCTS DELIVERED

One copy of this report and the products listed below have been delivered to PACIFIC OIL & GAS PTY. LTD. to this date:

1) Multichannel reproducible plots of the Bouguer gravity at 2.67 g/cc, the Free Air gravity, and Elevation at 1:50,000 scale.

2) Reproducible final Bouguer posting maps at 1:50,000 scale.

3) Reproducible elevation posting maps at 1:50,000 scale.

4) One computer listing of the relevant survey information (see Appendix A).

5) Two Located Data Tapes.
5. CONCLUSIONS AND RECOMMENDATIONS

This survey has shown that the gravity data collected was of excellent repeatability but was subsequently effected by elevation control of dubious quality. When used in conjunction with seismic, it is a very cost-effective survey method. Although the field phase of the programme proceeded without incident, delivery of the coordinates for some of the survey lines did slow down processing.

At the final data processing stage, it is recommended that a horizontal scale no coarser than 1:50,000 be chosen to facilitate plotting at this station interval.

Respectfully submitted,

John Peacock
GEOPHYSICIST
APPENDIX A

Computer Listing of Final Bouguer Data
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**Note:** The table contains numerical data that seems to be formatted in a way that is not clearly readable or interpretable. It appears to be a list of numbers with various values, but the context or purpose of this data is not clear from the image provided.
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**Additional Notes:**
- Power and Voltage values are measured in Watts and Volts, respectively.
- The Current is measured in Amperes.
- Frequency is measured in Hertz.
- Temperature is measured in Celsius.
- Hours, RPM, and other parameters are provided for reference purposes.
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89-203 6100 8206734 449120 -16.201260 134.5239754 245.79 978350.49 0.46 -22.19 -24.25 -27.03
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89-203 6180 8209658 449380 -16.192395 134.5264278 242.39 978359.35 0.70 -21.64 -23.67 -26.41
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APPENDIX B

Reduction to Final Gravity Values
THE REDUCTION TO FINAL BOUGUER GRAVITY VALUES

The final Bouguer gravity, \( B \), is the result of the expression:

\[
B = g - g_v + \frac{dg}{dh} \cdot h - (2 \cdot \pi \cdot G \cdot q) \cdot h = g - g_v + c \cdot h
\]

Where:

(1) \( g \) is the observed gravity value (milligals)
(2) \( g_v \) is the theoretical gravity (milligals)
(3) \( h \) is the station elevation (metres);
(4) \( \frac{dg}{dh} \) is the Free Air effect (-0.30861 mgal/metre above the datum)
(5) \( q \) is the Bouguer density (gm/cm³)
(6) \( G \) is the Universal Gravity Constant \((6.67 \times 10^{-8} \text{ dyne-cm/g})\)
(7) \( c \) is the combined Free Air and Bouguer effect:

\[
(c = \frac{(dg}{dh} - 2 \cdot \pi \cdot G \cdot q)
\]

Observed Gravity

All readings of the gravimeter are reduced to observed gravity values according to the equation:

\[
g = g_v + c - \frac{(g - g_v)}{(t - t_b)} \cdot t_p - g + g_{amb} + g_{amb}
\]

Where:

(1) \( g \) is the observed gravity (milligals)
(2) \( g_v \) is the gravity reading at each station (milligals)
(3) \( c \) is the tidal correction calculated from Longman's tide formulae (published in the "Journal of Geophysical Research", Vol. 64, No.12) in milligals
APPENDIX C

Statistical Analysis and Error Calculations
ASSUMING all of the factors contributing to the final Bouguer gravity are mutually independent, then the expected error in the final Bouguer gravity is the square root of the sum of the squares of the error in each factor:

\[ E = \sqrt{E^2 + E^2 + (C \times E)^2 + E^2} \]

\[ E_{BG} \quad E_{OBSE.G} \quad g_{V} \quad h \quad g_{T} \]

This assumption is not absolutely valid, since a small amount of cross-correlation does exist (for instance, an error in the vertical will affect the the terrain correction if measured elevations rather than grid elevations are used to calculate the terrain correction). These cross-correlations will however, be generally small, so the above error calculation will yield results that are very close to the true values.

In order to quantitatively measure the so-called expected error, it is necessary to define the confidence limit. This gives some meaning to the term expected error (or put more positively, expected accuracy) by making the following statement possible:

X percent of the measured values will be accurate to within +/-Y.

For our purposes, we have defined the confidence limit to be 1 sigma, or roughly 67%, hence we are after the error range (i.e. +/-0.3mgal.) that will allow us to confidently state that 67% of the data satisfies this criterion. We could have chosen a 2 sigma limit, in which our expected error would have been larger, since our confidence limit would be about 95%. Similarly, we could have gone for a 50% confidence limit, which would have resulted in a smaller expected error. By choosing the 1 sigma limit, we are conforming to a fairly widely accepted industry standard.

The solution of the error equation for the final Bouguer gravity reduces to collecting enough data to determine the 1 sigma confidence limit of each of the factors in the equation. This is done by repeating enough samples to derive a statistically significant error limit. For simplicity, we will look at the probable error in observed gravity. The calculation of the probable errors in the other factors is analogous.

To derive the probable error in the observed gravity, stations are revisited and the gravity reading is taken again. Each reading at a station is compared with the mean of all readings taken at that station. For example, a station with three readings would yield three deviations from the mean value. It is believed that this method yields a much better statistical analysis of the data. Once all the deviations for a survey have been calculated, they are plotted on a histogram. The repeat differences will fit a normal distribution curve with a mean (zero in theory, very close to zero in practice) and a standard deviation (sigma). Statistically, 67% of the repeat differences will fall within +/-1 sigma of the mean.
According to our definition:

\[ E = \pm \sigma \]

\[ \text{RPT DIFF} \]

In other words, the expected repeatability of an observed gravity reading is \( \pm \sigma \).

It is very important to realize that expected repeatability is not the expected accuracy of an individual reading. The expected repeatability and expected accuracy of the individual reading are only the same if the repeat reading has an expected error of zero. This follows logically from our definition of expected error as the square root of the sum of the squares of the expected error of each independent factor (see the formula for expected error of final Bouguer gravity). There may be other small cross-correlations (i.e. the observer may look up the previous reading to speed up the repeat reading), but for our purposes, we assume they are totally independent.

Thus:

\[ E = E + E \]

\[ \text{RPT.DIFF} \quad \text{RPT RDG} \quad \text{FIRST RDG} \]

But we assume:

\[ E = E \]

\[ \text{RPT RDG} \quad \text{FIRST RDG} \]

(This assumption is a good one: you expect to be able to read a gravimeter on the same spot with the same precision at different times).

Therefore:

\[ E = 2 \times E \]

\[ \text{RPT DIFF} \quad \text{FIRST RDG} \]

Or:

\[ E = 0.71 \times \sigma \]

\[ \text{FIRST RDG} \]

The expected error of an individual observed gravity value is equal to 0.71 times the expected repeatability.

The above calculation for observed gravity is carried through for each factor in the final Bouguer value and the end result is a 67% confidence limit of final Bouguer gravity which we have defined as expected accuracy.
APPENDIX D

Format of Located Data Tapes
PACIFIC OIL AND GAS PTY LTD
MCARTHUR BASIN
GRAVITY SURVEY
LOCATED DATA TAPE FORMAT

<table>
<thead>
<tr>
<th>COLUMN</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 6</td>
<td>DATE IN ddmmyy</td>
</tr>
<tr>
<td>7 - 10</td>
<td>FLIGHT number</td>
</tr>
<tr>
<td>11 - 16</td>
<td>TIME in seconds</td>
</tr>
<tr>
<td>17 - 23</td>
<td>LINE number</td>
</tr>
<tr>
<td>24 - 29</td>
<td>FIDUCIAL</td>
</tr>
<tr>
<td>30</td>
<td>ASTERISK (*)</td>
</tr>
<tr>
<td>31 - 42</td>
<td>AMG EASTING coordinate</td>
</tr>
<tr>
<td>43 - 56</td>
<td>AMG NORTHING coordinate</td>
</tr>
<tr>
<td>57 - 62</td>
<td>SHOT POINT</td>
</tr>
<tr>
<td>63 - 68</td>
<td>ELEVATION</td>
</tr>
<tr>
<td>69 - 74</td>
<td>Free Air Gravity Value</td>
</tr>
<tr>
<td>75 - 80</td>
<td>Bouguer Gravity Value - 2.2 g/cc</td>
</tr>
<tr>
<td>81 - 86</td>
<td>Bouguer Gravity Value - 2.4 g/cc</td>
</tr>
<tr>
<td>87 - 92</td>
<td>Bouguer Gravity Value - 2.67 g/cc</td>
</tr>
</tbody>
</table>

RECORD LENGTH = 92 Bytes
BLOCK SIZE = 5060 Bytes
9-TRACK ASCII = 1600 bpi