GRANITES – TANAMI BLOCK
GRAVITY SURVEY

In the Northern Territory under the National Geoscience Mapping Accord

Contract No. 98/NG2

OCTOBER 1999

Report Number 99008-2
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1. INTRODUCTION

The Granites Tanami Gravity Survey was carried out between 2nd June 1999 and 30th July 1999 as part of National Geoscience Mapping Accord for the Australian Geological Survey Organisation (AGSO). The job comprised 3488 new 4km by 4km stations, 269 1km by 1km stations and 100 4km by 4km existing stations merged into the new data set.

Gravity was acquired concurrently with GPS using Scintrex CG3 digital gravity meters. Position and level information was obtained using three Ashtech Z12 dual frequency GPS receivers to produce precise kinematic differential GPS locations. Positional control were tied to existing first order horizontal control points. Observations were made using a Bell 47 G5 Helicopter and Toyota Landcruisers.

Gravity data was reduced using standard reductions on the ISOGAL84 gravity network. GPS data were reduced to GDA and AGD coordinates with levels expressed as metres above the Australian Height Datum. Two gravity metres were used for the set up of gravity bases both being Scintrex CG-3s, serial numbers 8810110 (Daishsat) and 9408271 (Scintrex). Data acquisition was carried out with both meters. These were tied to AGSO gravity bases, 9992·9064 at the Tanami Mine airstrip, and 9992·1802 at the Granites Goldmine airstrip.

Helicopter and crew at Wilsons Range Exploration Camp

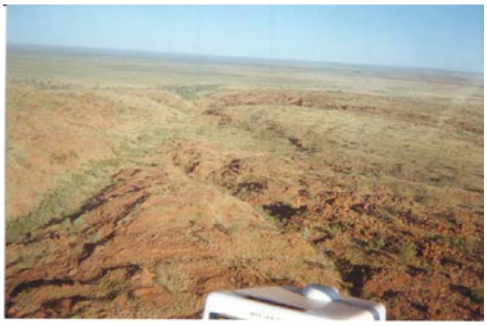
2. SURVEY OVERVIEW

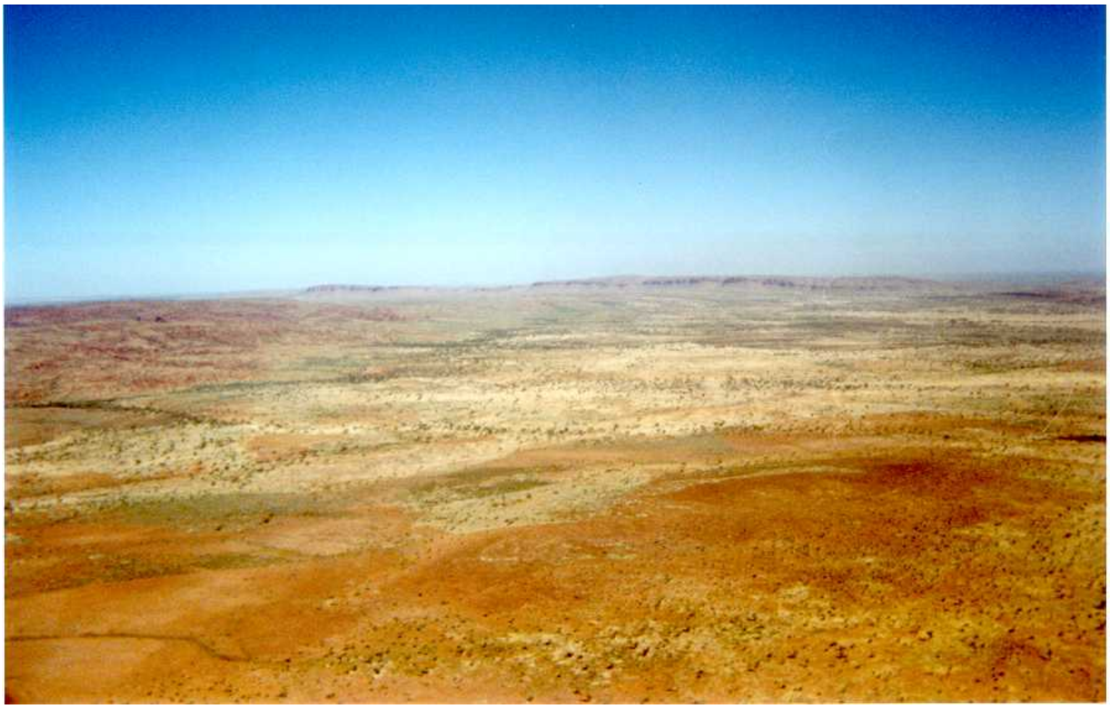
The area to be surveyed was bounded by 19° 30’ to 21° 30’ and 129° to 131°, covering parts of the Tanami, the Granites, Highland Rocks, Mount Solitaire and Mount Theo 1:250 000 sheet areas in the Northern Territory.

The original planned survey consisted of a total of 3483 stations on a 4km by 4km grid. However, due to restrictions set by the Central Land Council some stations were omitted due to areas of cultural significance.

Late in the survey an area of about 100 4km by 4km stations was added to the north east of the project area. Along with this, some infill was completed in the Tanami sheet area.

Some typical landscapes of the Tanami desert viewed from the air





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3. PERSONNEL AND EQUIPMENT

3.1 Personnel

The supervisor in charge of the project was David Daish B.Surv MIEMS who was responsible for the daily running of the job and processing of the data. Gravity measurements and set up of the control was carried out by Harley Jones, Paul Jacobs and Iain Robertson. Pilots were Peter Muddle and Greg McGuinness. Additional quality control during the survey and final data reduction and inspection were performed by the company geophysicist, Mr. Leon Mathews B.Sc (Hons).

3.2 Survey equipment

- One Scintrex CG-3 gravity meter (Daishsat),
- One Scintrex CG-3 gravity meter (Scintrex),
- Three Ashtech Z12 dual frequency GPS receivers (Daishsat),
- Two 4wd Landcruiser vehicles, one field, one standby (Daishsat),
- One Bell 47G5 helicopter (Helicopters Pty Ltd),
- Two Compaq notebooks for data processing (Daishsat),

Some of the personnel and equipment on the survey

3.3 Vehicles and access

In order to maintain a reasonable station occupation rate the entire 4km by 4km survey was carried out by helicopter. All the control and infill survey was completed by vehicle. To maintain the high Daishsat safety record the helicopter was fitted with a range of safety equipment including:

- One 10l can of water,
- Up to four 20l jerry cans of avgas,
- UHF and HF radio's,
- Satellite phone,
- Survival and first aid kits,
- Each crew member carried a EPIRB emergency locator beacon.

Chief pilot, Peter Muddle using a satellite phone

3.4 Camp

The camp included a caravan, generators and associated camping equipment. Accommodation at exploration camps was used when available.

4. GPS SURVEYING AND PROCESSING

4.1 Set out of the grid

The 4km by 4km grid was set out using the Garmin GPS II$^+$ in autonomous mode. Typical setout accuracy for this system is about ±15m. Positional data was collected by the on board Ashtech Z12 dual frequency GPS receivers. This was done concurrently with the gravity data acquisition. Where possible, the readings were taken as close to the ideal coordinates as possible. Vegetation and steep terrain were the main factors in determining what the offset from the nominated station coordinates was (maximum ±400m offset).

Repeat gravity stations were marked with a pin flag. A length of flagging was also tied to available features to enable easy location from the air of the repeat station.

4.2 Set up of GPS control

Positional control stations were set up using three Ashtech Z12s. Locations for the bases to be used were chosen for their coverage of the area to be surveyed, and their proximity to tracks, or other landmarks. Stations were marked with a 500mm star picket driven into the ground, with a witness plate attached to a 1.5m star picket giving the station number. The gravity base consisted of a hexagonal concrete plate set next to the 1.5m star picket.

Gravity and GPS base showing Short Star Picket, Witness post and plate and hexagonal gravity base plate

4.3 Surveying of the position and level data

Position and level data were surveyed using the Ashtech Z12 dual frequency GPS receivers. The satellite antenna was securely fixed to the tail boom of the helicopter allowing reliable and repeatable levels to be obtained.

Ashtech Z12 GPS receiver set up on station 0009 and logging base GPS data

4.4 Post processing of the position and level data

The kinematic GPS data was downloaded onto the Compaq computers daily. Processing of the data was carried out using Ashtech PNAV software on a daily basis. Small portions of data were processed with Waypoint GrafNav V6.02 when problems were encountered with PNAV.

5. GRAVITY ACQUISITION AND PROCESSING

5.1 Set up of Gravity control

Two gravity meters were used to set up gravity bases within the survey area, both being Scintrex CG-3s, serial numbers 8810110 (Daishsat) and 9408271 (Scintrex). Gravity control was usually coincident with the GPS control. The gravity base was a hexagonal concrete slab adjacent to the star picket. Full details of established gravity bases are contained in Appendix A.

All established gravity control was tied to AGSO gravity bases, 9992.9064 at the Tanami Mine airstrip, and 9992.1802 at the Granites Goldmine airstrip.

Gravity control being completed by vehicle

5.2 Gravity data acquisition

The entire 4km by 4km survey was carried out by helicopter, using the standard loop procedure, with each loop starting and ending at a particular base station. Loops were generally less than 6 hours duration. Daily drift was monitored by comparing earth tide corrected readings at the base at the start and end of each loop. The infill survey and control was undertaken by vehicle.

Gravity operations utilised a two-man crew, pilot (or driver) and gravity meter operator. Gravity readings were taken as close to the aircraft as was safe and practical. Generally the gravity reading was taken a couple of meters away from the skids.

David Daish and Scintrex CG-3 a couple of metres from the chopper with the Ashtech GPS antenna just visible on the tail boom behind the red collision light.

Iain Robertson taking a gravity observation next to the Landcruiser during vehicle Gravity/GPS acquisition.

5.3 Gravity data processing

Raw gravity data was processed on a daily basis to check for quality and integrity. This interim process produced a set of Bouguer Gravity values which were contoured to provide a check for any anomalous readings that would need repeating. A couple of large anomalies were detected and the field readings were repeated. These anomalies turned out to be real features.

At the conclusion of the job, the data were reprocessed to Bouguer Gravity using GPS data reduced to AHD and an adopted density of 2.67 gm/cc. Gravity reduction was performed using Geosoft software with the following corrections (a list of formulae and constants used has been included in Appendix B):

1. Instrument scale factor : This correction was used to correct a gravity reading (in dial units) to a relative milligal value based on the meter calibration.

2. Tidal correction: This correction was used to correct for background variations due to changes in the relative position of the moon and sun. The Scintrex calculated ETC was removed and a new ETC calculated using Geosoft Formulae.

3. Instrument Drift: Since gravity meters are mechanical, they are prone to drift (extension of the spring with heat, obeying Hooke's law). If two base readings are taken one can assume that the drift between the two readings is linear and can therefore be calculated. The drift and tidal corrected value is referred to as the observed gravity.

4. Theoretical Gravity: The theoretical value of gravity was calculated using the 1967 variant of the International Gravity Formula and used to latitude correct the observed gravity

5. Free-Air Correction: Since gravity varies inversely with the square of distance, it is necessary to correct for changes in elevation between stations to reduce field readings to a datum surface (in this case, AHD).

6. Bouguer Correction: This correction accounts for the attraction of material between the station and datum plane that is ignored in the free-air calculation. An adopted density of 2.67 gm/cc was used in the correction.

7. Bouguer Gravity: This is obtained when all the preceding reductions or corrections have been applied to the observed gravity reading.

5.4 Gravity meter calibration

5.4.1 Kensington Gardens - Norton Summit Calibration

The gravity meters used on this project were calibrated on the Kensington Gardens – Norton Summit calibration range in Adelaide, both before and after the survey. Hardcopies of the raw dump files obtained from the calibration are contained in Appendix F. Table 5.1 contains the results of the calibration run after processing for drift and earth tide. The table contains observed gravity values calculated for Norton Summit using Kensington Gardens as the base.

Table 5.1 *Results of Kensington Gardens Norton Summit Calibration*

Location	BMR station #	Gravity Value mgal
Kensington Gardens	6091.0108	979692.76
Nortons Summit	6091.0208	979630.10

Meter	Date	Calculated G_{obs} (mGal)
9408271	30/5/99	**979630.08**
8810110	30/5/99	**979630.09**

Meter	Date	Calculated G_{obs} (mGal)
9408271	18/9/99	**969630.09**
8810110	18/9/99	**979630.11**

5.4.2 Gravity meter drift calibration

While the survey was in progress, the meter was cycled overnight as a check on instrument drift. This was adjusted as necessary to keep the drift as low as possible. Even after the meter has been cycled and adjusted some drift in the field observations will still be present due to the movement and shaking of the instrument. This is to be expected and is normal for a CG-3.

6. RESULTS

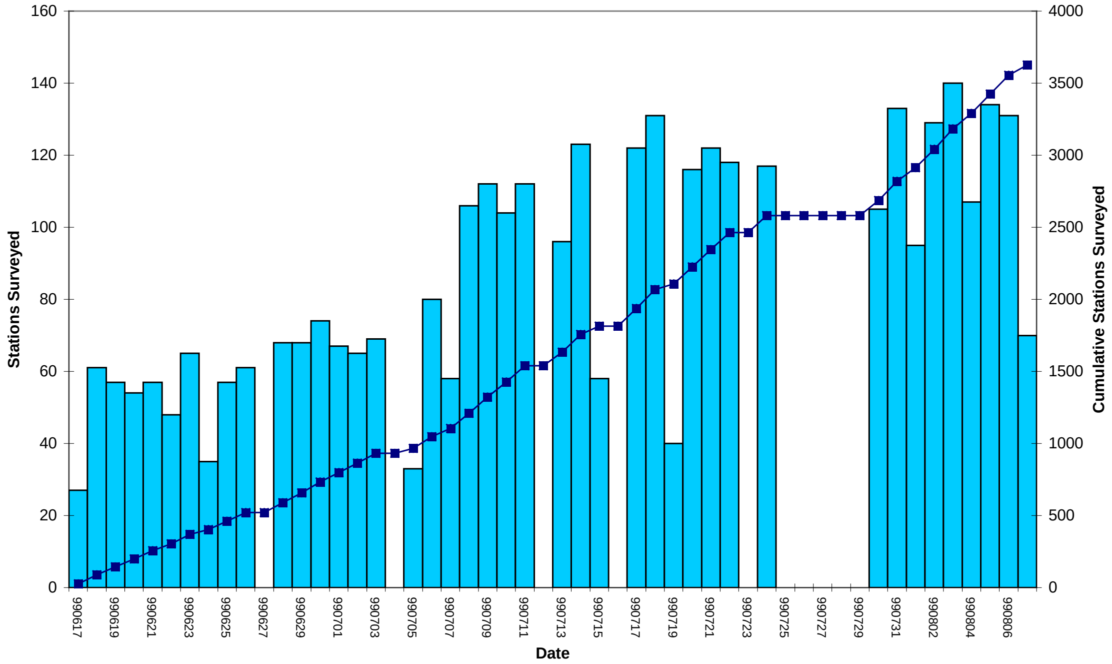
Raw and processed GPS and gravity data are contained in the Appendices at the back of this report. Data are presented digitally.

6.1 Stations Surveyed and Survey Progress

Stations set out and levelled (including repeats)	**3620**	**stations**
Gravity stations acquired (including repeats)	**3620**	**stations**
Gravity/GPS station repeats	**131**	**3.61%**
GPS and gravity production days	**42**	**days**
Total accidents	**0**	**accidents**
Total hours lost this period from accidents	**0**	**hours**
Average Daily Production Rate	**82**	**Stns/day**

Production was lost for about 5 days due to the crew needing to move camp and about another 6 days were lost due to servicing difficulties with the helicopter.

Production and running total summary



6.2 Data Repeatability

Analysis of the repeat data shows that measurement repeatability is excellent for both GPS and Gravity observations. An analysis for the repeats is included in Appendix C. Based on the repeat data, one can assume the following typical accuracies for the observables:

Z position observation : 0.10 m
Gravity observation : 0.02 milligals

Generally the repeats were very good although using a helicopter has its limitations in being able to land exactly on the same position. All repeat stations were marked with a pin flag and the gravity reading was taken in the exact same spot for each occupation. The pilot made all attempts to land on the same skid marks. If the prevailing wind is in a different direction to that on the first occupation, then landing in the same direction would be extremely dangerous for both the aircraft and crew. The aircraft must always land into the wind. In some instances the helicopter did not land in the exact same position and this was a major factor in some of the bigger repeat differences. Even so the repeat statistics show standard deviations of around 0.1m for height.

APPENDIX A

Base station information

APPENDIX B

Formulae / constants used in gravity reduction

Meter	**Meter Serial Number**
Daishsat - Scintrex CG3	8810110
Scintrex – Scintrex CG3	9408271

Formulae Used

Astronomic Tide Correction

Longman formula – see over for code.

International Gravity Formula 1967

g_n = 9780318(1+0.0053024sin^{2}f-0.0000059sin^{2}2f)

where f is latitude

g_n is Theoretical Gravity in gu

International Gravity Formula 1930

g_n = 978049.0(1+0.0052884sin^{2}f-0.0000059sin^{2}2f)

where f is latitude

g_n is Theoretical Gravity in milligals

Free Air Correction

FA = 3.086h

where h is in m AHD

FA is correction in milligals

Bouguer Anomaly

BA = 0.419rh

where r is rock density (2.67 gm/cc)

h is in m AHD

BA is correction in milligals

Bouguer Gravity

$BG_{2.67}$ = ObsG- g_n + (FA-BA)

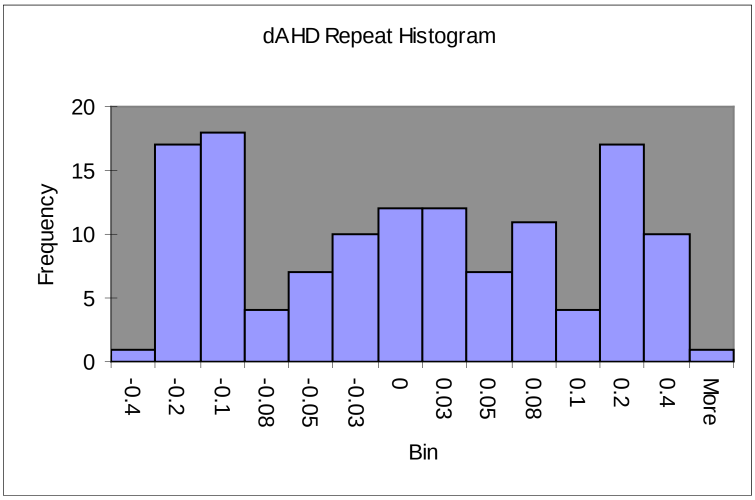
where $BG_{2.67}$ is in milligals

APPENDIX C

Repeat Tabulation/Repeat Analysis

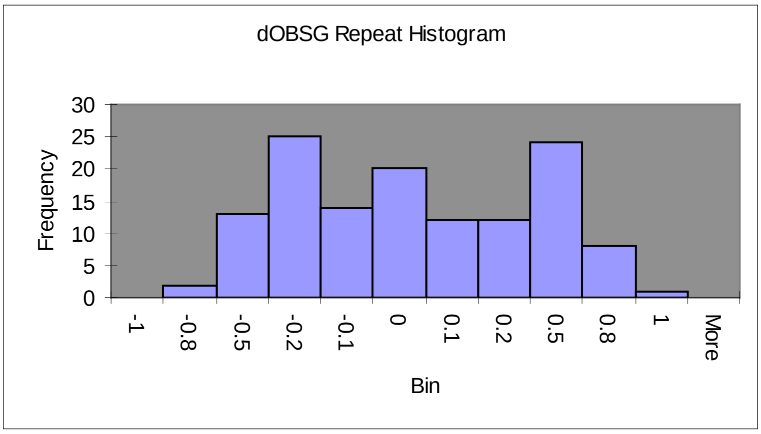
REPEATABILITY OF AHD

dAHD	
Mean	0.123
Standard Error	0.009
Median	0.100
Mode	0.000
Standard Deviation	0.105
Sample Variance	0.011
Kurtosis	0.614
Skewness	1.043
Range	0.480
Minimum	0.000
Maximum	0.480
Sum	16.177
Count	131



REPEATABILITY OF OBSG

dOBSG	
Mean	0.284
Standard Error	0.018
Median	0.200
Mode	0.100
Standard Deviation	0.211
Sample Variance	0.045
Kurtosis	0.485
Skewness	0.871
Range	1.000
Minimum	0.000
Maximum	1.000
Sum	37.200
Count	131



APPENDIX D

Station location plot

APPENDIX E

Contour plot

APPENDIX F

Calibration data

APPENDIX G

CD of results