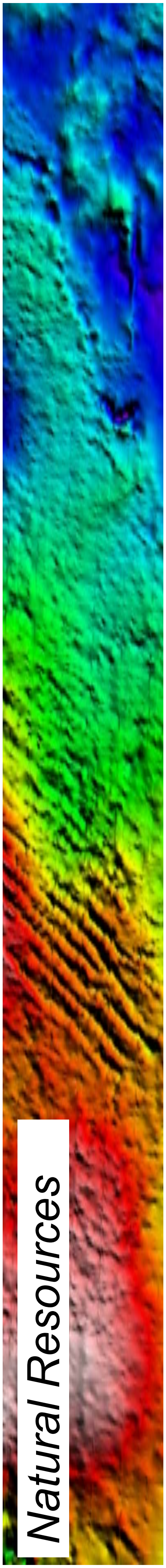

Report 32/2000D

Water Resource Assessment of the Sturt Plateau

Geophysical Investigations

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Northern Territory Government
Department of Infrastructure, Planning and Environment

Technical Report No. 32/2000D

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Anthony Knapton
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Natural Systems Division
Department of Infrastructure, Planning and Environment
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EXECUTIVE SUMMARY

OVERVIEW

A three year project jointly funded by the Northern Territory Government and Natural Heritage Trust, studied the water resources on the Sturt Plateau, located to the south of Katherine in the Northern Territory. Land in the region is primarily used for beef cattle production. However, the extended dry season, poor runoff potential and high evaporation rates, mean surface water options for stock watering are generally not proposed. Groundwater is considered to be the most reliable source and is being utilized in the vast majority of cases.

Test drilling has indicated that the most suitable resource for groundwater development is in a limestone aquifer overlying an undulating basalt basement. In some areas of the Sturt Plateau the success of individual bores has been dependent on the level of the basement in relation to the regional groundwater level.

GEOPHYSICAL TECHNIQUES

Geophysical methods including airborne magnetics, ground geophysics and borehole logging were employed to help understand the regional variations in the depth to the basalt.

Borehole geophysics has provided detailed lithological information such as the limestone/basalt contact and regional stratigraphic correlation between bores.

Joint VES and TEM soundings conducted provide limited information owing to the presence of clays and the limited electrical contrast between the dolostone and basalt. Most of the TEM data was considered suspect due to the presence of superparamagnetic effects.

Airborne magnetics has provided the most useful information concerning features in the basalt and indirectly information about the occurrence of saturated limestone. Regional structures have been shown to control basement highs and the magnetics data has proved to delineate such features. Lineaments evident in the magnetics data have been seen to correlate with confined regions of increased depth to basement.

OUTCOMES

Airborne magnetics and ground magnetics data in conjunction with basement elevation (and associated groundwater resource maps Yin Foo, 2001) derived from drilling results shows the most promise for regional assessment of groundwater availability. The data also provides a basis for a conceptual model of the groundwater flow regime to be developed. The magnetics data can be used to infer zones of increased dolostone submergence.

A strong recommendation for futher studies in this area is to gamma log holes when drilling to provide accurate lithological determination, especially when loss of circulation is expected.

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1.0 INTRODUCTION

1.1 Background

The Sturt Plateau is located to the south of Katherine and covers much of the Larrimah and Daly Waters 1:250,000 map sheets. Land is primarily used for pastoral fodder production for beef cattle. However, due to the monsoonal climate of the region, with an extended dry season occurring from May to October, poor runoff potential and high evaporation rates, surface water options for stock watering are generally not proposed. Groundwater is considered to be the most reliable source and is being utilized in the vast majority of cases.

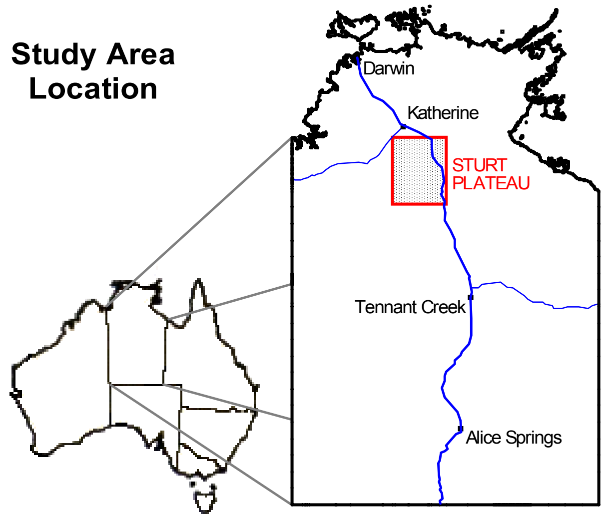


Figure 1.1 Sturt Plateau study area location.

A three year project jointly funded by the Northern Territory Government and Natural Heritage Trust - Landcare, studied the water resources on the Sturt Plateau. Data obtained from this project has enabled property scale mapping of water resources for development planning as well as regional scale information for resource evaluation studies

Test drilling has indicated that the most suitable resource for groundwater development is in a limestone aquifer overlying an undulating basalt basement. In some areas of the Sturt Plateau the success of individual bores has been dependent on the level of the basement in relation to the regional groundwater level. Localised variations in basement structure, evident from drilling results, are not reflected at the surface. Therefore, indirect methods for determining the basement topography were required.

Geophysical methods were employed to map local variations in the depth to the top of the basalt. The region has been studied in considerable detail using airborne magnetics, ground geophysics and borehole methods.

This report describes the techniques used; the results obtained and discusses their pertinence to defining groundwater potential in the Sturt Plateau and areas with similar characteristics.

1.2 Scope

The scope of this report is to:

- present the geophysical data available within the study area
- assess the merits of each method in relation to defining groundwater potential, primarily in the rocks above the Antrim Volcanics unit.
- determine the suitability of the methods in terms of costs, interpretation and data acquisition with respect to implementation by landholders.

1.3 Methodology

Studies in the Sturt Plateau have been conducted using a regional to local strategy. Regional data sets were assessed and compared with geological data. Following the cursory examination and correlation, ground based works were conducted for direct comparison with drilling results.

Drilling results indicate a sedimentary sequence (with aquifer submergence over much of the area) overlying a mafic volcanic sequence. The expected physical characteristics of the lithologies encountered in the study area determined the most prospective geophysical techniques.

Table 1.1: Geophysical technique determination from geological setting.

Geological Parameter	**Most Appropriate Geophysical Technique**
mafic basement	Use magnetics to define structural features in this sequence which may prove to show significant storage.
sediments (some saturated) overlying impervious igneous basement	Use electrical/electromagnetic (including conductivity logs) methods to determine depth to and thickness of saturated aquifer due to the anticipated contrast in electrical properties of the unsaturated sequence, saturated sequence and basement.
sedimentary strata with cavernous lithologies being encountered	Natural gamma logging was conducted to provide lithology of drilled strata, especially in situations where cavernous dolostone were encountered and loss of circulation resulted. The gamma logs also provided a basis for more objective correlation of the lithological logs across the study area.

2.0 STUDY AREA CHARACTERISATION

2.1 Geology

2.1.1 Stratigraphy

Sedimentary rocks of lower Middle Cambrian and Lower Cretaceous age crop out on the Daly Waters Sheet area. Tertiary laterite and other superficial deposits overlie these units. Lower Cambrian volcanic rocks are known in the subsurface but do not crop out. Figure 2.1 depicts a geological cross-section showing the stratigraphic relationship between the Mullaman Beds, Cambrian Limestone and Antrim Volcanics units.

Cambrian

Cambrian rocks are composed of the *Antrim Plateau Volcanics* consisting of a variable thickness basalt flows with some interbedded limestone, chert and quartz sandstone.

Disconformably overlying the volcanics are the lower Middle Cambrian described as:

Tindall Limestone - described as a yellow-brown to grey fossiliferous calcilutite with some dolomite.

Montejinni Limestone - Grey-brown fossiliferous calcilutite, minor dolomite; buff and red-brown mudstone.

Lower Cretaceous

Unconformably overlying these units are the Lower Cretaceous rocks:

Mullaman Beds - White, buff and pink siltstone and claystone; glauconitic sandstone; basal conglomerate and quartz sandstone with plant fossils.

Cainozoic

A deep Tertiary *laterite* profile has developed on the *Mullaman Beds* over much of the Sturt Plateau.

Alluvial deposits occur in broad valleys, watercourses and small sandy floodout fans of minor creeks on the plateau.

2.1.2 Structure

The Palaeozoic and younger rocks are almost flat lying; overlying moderately folded and faulted Precambrian sedimentary rocks. Deep seismic investigations of the Sturt Plateau, conducted by CRA in 1995 demonstrate the generally flat sequencing of the strata (Line MA91-600 is seen in Figure 4.5).

Some prominent stream lineaments are probably related to major fractures in the basement. The most prominent lineament extends about 400 kilometres NNW from near Wave Hill. It is expressed in the linear trends of the Victoria River, Coolibah Creek and part of the Armstrong, Dry and King Rivers. There are linear trends in the landform units correlating with the underlying structures in the volcanics as determined from aeromagnetics data.

Drilling results show varying basalt elevations (relative to the Australian Height Datum) which also suggest a history of minor deformation. This is in contrast to the horizontal nature of the overlying marine sediments of the Mullaman Beds.

Areas in the Sturt Plateau are coincident with a groundwater divide between three basins, the Wiso Basin to the south, the Daly River Basin to the north and the Georgina Basin to the Southeast. The divide is manifested as a basement high extending SSE from Bloodwood Downs to Sunday Creek and then west to Gilnockie. The elevation is seen to decrease abruptly to the south and east from this ridge, however, the decrease is gradual to the north and west into the Daly River Basin. The basement ridge is delineated to the south and east by sharp variations in basement elevation, which correspond to cross cutting linear features evident in the magnetics data.

The magnetics data also shows numerous linear features in the central portion of the study area. These features are thought to be due to jointing in the basalt, where decrease in magnetite content could occur. The nature of the magnetics anomalies is also consistent with dolerite dyke (exhibiting negative polarisation) emplacement along these zones of weakness (similar to the dyke features evident to the north of Katherine, Kruse *et al*, 1994).

Seismic information suggests that this was a region of topographic high prior to the episodic volcanic extrusion. Later down faulting has resulted in this region occurring deeper than the adjacent volcanics.

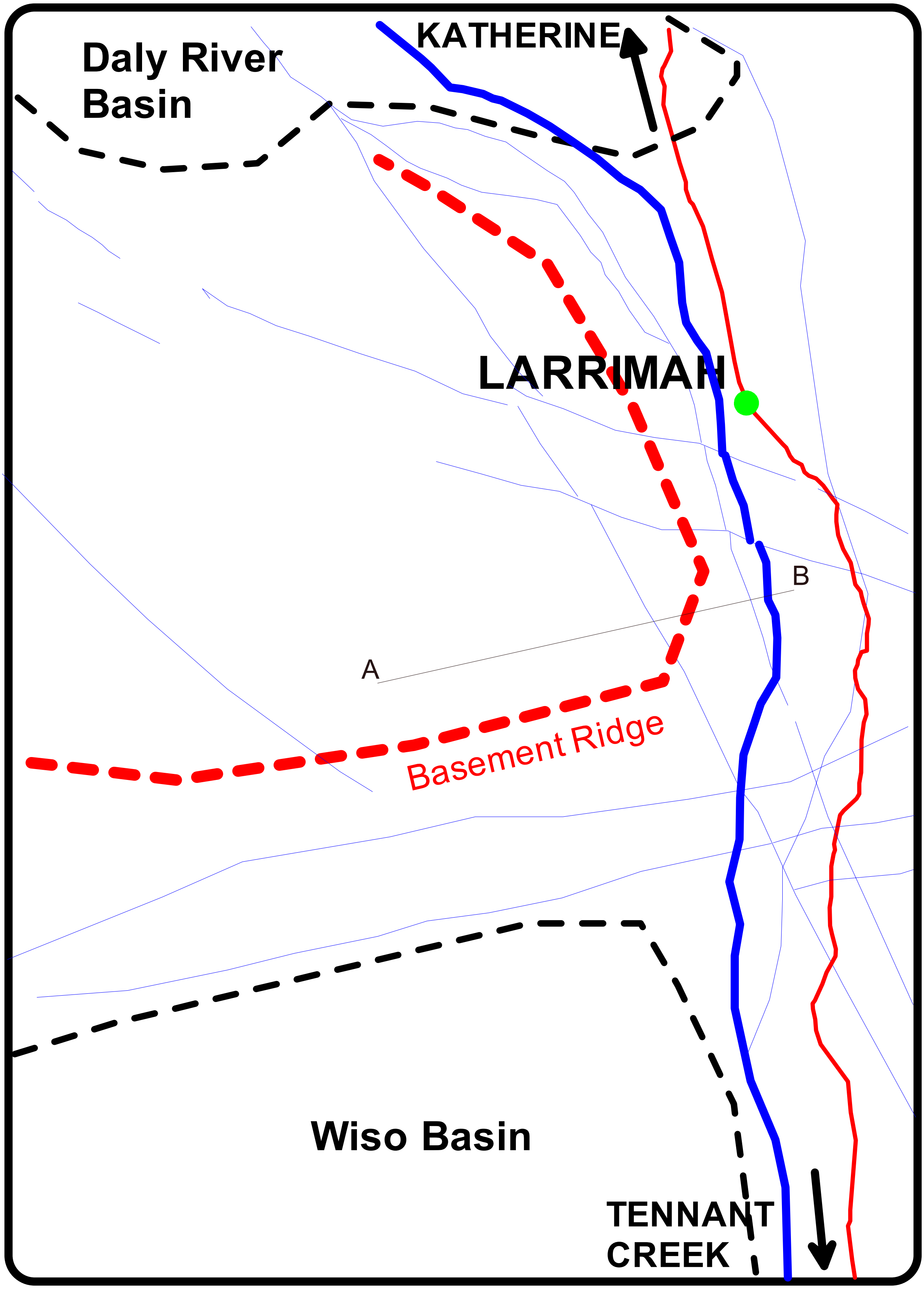


Figure 2.1 Major basement structures in the Sturt Plateau, derived from drilling and aeromagnetics data.

2.2 Hydrogeology

Previous works have indicated that groundwater is obtained from aquifers in the Lower Cambrian Antrim Plateau Volcanics, the Tindall Limestone and Montejinni Limestone.

Good water supplies occur in the limestone where the basement (Antrim Volcanics) is below the regional SWL and a thickness of submerged Tindall Limestone is encountered. Groundwater quality is highly variable, ranging from 300 to 1000 μS/cm (200 to 700 ppm TDS). This is equivalent to a resistivity of 3 to10 ohm.m. The level of the Antrim Volcanics is variable throughout the study area, with unpredictable localised variations common.

Groundwater of variable quality and quantity occurs in joints and faults in the Antrim Plateau Volcanics and porous strata within the Antrim unit.

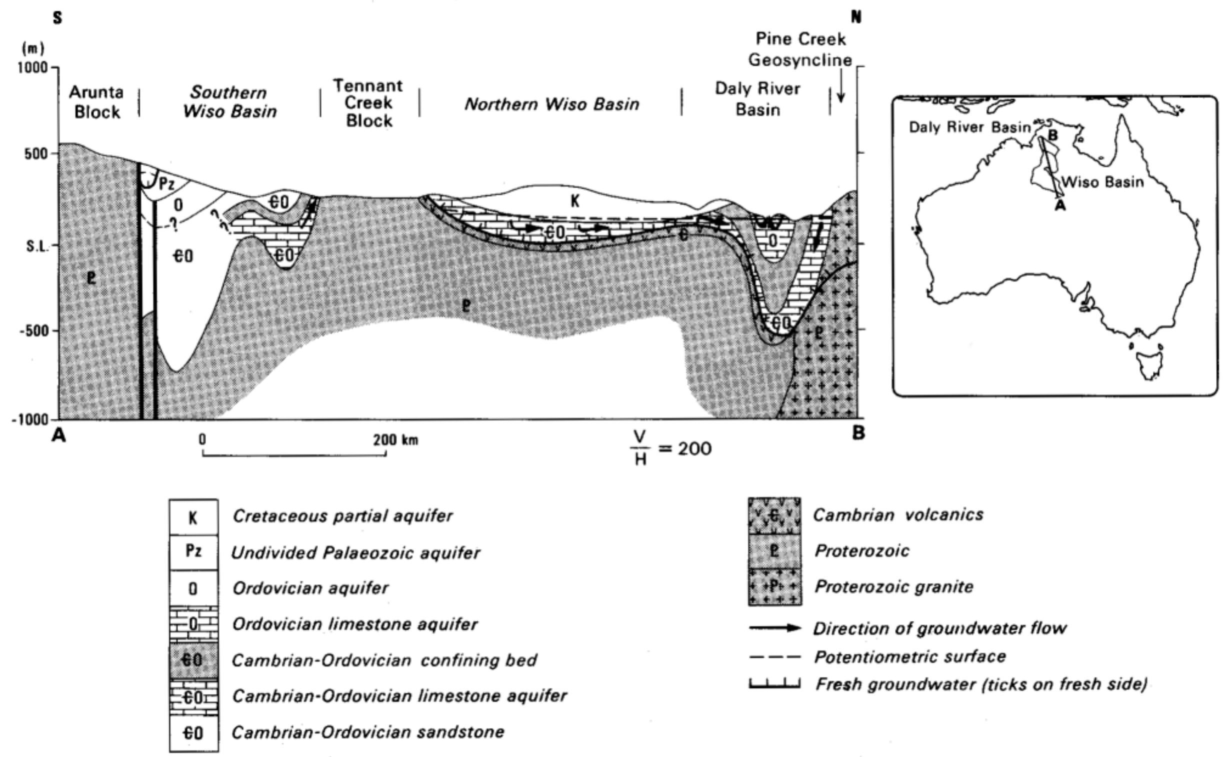


Figure 2.2 Hydrogeological cross-section of the Daly and Northern Wiso Basin from Commander *et al*.

3.0 GEOPHYSICAL TECHNIQUES USED IN GROUNDWATER EXPLORATION

3.1 Introduction

Generally the role of geophysics in this type of study is to define:

- the hydrogeological controls on the flow of ground water; that is features such as dolerite dykes, fractures, faults and shear zones
- the depth to water table
- the depth to hydrogeological basement (defined as a relatively impervious layer often coinciding with igneous rocks, in this case the Antrim Volcanics).

The following techniques are commonly used in ground water problems:

- magnetic method is often used to define lithological changes and structure in the basement it can also (under favourable conditions) be used to determine the depth to features often associated with the basement such as intrusive dykes (i.e. to infer the depth to basement),
- electrical methods including contact resistivity and electromagnetics are used to define aquifer thickness, depth to basement and groundwater quality,
- gravity is used to define structure and can be used to determine thickness of sediments,
- seismic refraction and reflection methods are used to define stratigraphy and structure. Refraction data can also determine water table depth,
- downhole geophysical logging

3.2 The Magnetic Method

The geomagnetic field is composed of three parts:

- The main field which varies relatively slowly and is of deep internal origin.
- A small field (compared to the main field), which varies rather rapidly with time and originates outside the Earth.
- Spatial variations of the main field, which are usually smaller than the main field, are nearly constant in time and place, and are caused by local magnetic anomalies in the near surface.

Local variations in the main field result from variations in the magnetic mineral content of the near surface rocks (primarily magnetite). In general igneous rocks show a greater concentration of magnetic minerals than weathered or sedimentary rocks (an exception being BIF). Generally weathering processes cause magnetic materials to hydrate into non-magnetic species (hence suppressing the induced magnetisation), however, weathering profiles with lateritic maghemite show highly variable concentrations of magnetic materials that can be close to the surface and sporadic in distribution (Dentith *et al*., 1994). The nature of these residual weathering products can also result in equally sporadic and variable measured magnetic signal and are generally considered geological noise.

Since magnetite is relatively highly concentrated in some rocks types and almost absent in others, a geophysical interpreter can make inferences about the types of rocks and geological structure from magnetic data. For instance, the strength and spatial frequency of an anomaly can be indicative of the depth of the source rocks while its shape may indicate that it is caused by a build up of magnetite in an ancient buried river system rather than a volcanic dyke. Fault and fracture zones often can also be identified because they appear as discontinuties in the data and can be places of preferential enrichment or depletion of magnetite (Anderson *et al*., 1993).

3.2.1 Airborne Magnetics

Airborne magnetic surveys measure the Earth's main magnetic field along with the subtly induced and remanent magnetic fields via a magnetometer mounted in a boom on the rear of the aircraft or in a bird towed behind. Airborne magnetic surveys have been used for fifty years in Australia and have met with considerable success when applied to mineral exploration and regional geological mapping. The magnetics methods is now considered to be the foundation stone of contemporary geological mapping programs in areas of limited outcrop.

Astier and Paterson, (1989), describes the use of magnetics to determine the position of shear zones in crystalline and metamorphic areas using aeromagnetics data. It was found that faults and shears manifest as:

- sharp gradients forming a linear boundary between areas of different magnetic level, relief, or texture. These may be fault contacts and are hard to distinguish from unfaulted, linear contacts. The magnetics of the Sturt Plateau shows this type of feature.
- disruptions and/or deflections of magnetic trends. These are commonly wrench faults or shears, often with distinguishable lateral movement.
- linear magnetic lows within country rocks of moderate or high magnetic relief. These are usually zones where surface weathering has oxidised magnetite to hematite or limonite. The magnetics of the Sturt Plateau shows this type of feature.
- narrow, linear features with direct magnetic expression. The magnetic response may be due to secondary magnetite resulting from metamorphism or narrow dykes intruding into the pre-existing faults.

Examples of faulting and jointing in the Sturt Plateau magnetics are discussed in sections 4.1 and 6.1.

3.2.2 Airborne Surveying and Estimated Costs

The airborne survey consists of an aircraft (fixed wing or helicopter) equipped with appropriate measurement, recording and GPS navigation equipment flown along regularly spaced (100 to 400 metre) 'flight lines' at a nominated height (60 to 120 metres) above the ground. 'Tie lines' are usually flown perpendicular to the flight lines with a much greater spacing (1 to 2 km) to help level final data.

Measurements are taken at regular intervals (3 to 70 metres depending on the type of equipment) along each line and the data are digitally recorded. The resulting dataset is of several hundred thousand regularly spaced raw data samples, known as the raw 'line data'. The raw line data is partially processed in the aircraft and then transferred to a ground based computing system for further data processing and presentation.

Processing involves calibration, validation, removal of unwanted information and noise as well as calculating other parameters that are more readily interpretable. The processed line data can then be presented for interpretation as profiles (graphs), or can be interpolated onto a regular grid (a process known as 'gridding') to enable production of contours maps or images similar to the now familiar satellite images. Presentations can be either in digital or hardcopy form.

Interpretation methods are then used (some qualitative and some quantitative) to relate the processed data to materials and processes occurring at and below the Earth's surface.

Table 3.1: Estimate Costs of Airborne Magnetics and Radiometrics Survey

Item	Cost
Acquisition of Mag/Rad/DEM	$8.00/line-km
Processing & Maps	$8.50/line-km
Interpretation	$15.25/line-km
Mobilisation Fee	Variable depending on location

3.2.3 Ground Magnetics

Data is collected on the ground using a portable magnetometer. The sensor height can be between 0 to 4 metres above the ground surface and sampled along line at sub-metre to tens of metres. The ground survey has the advantage of lower equipment and mobilisation costs.

3.2.4 Survey Requirements and Estimated Costs

The survey requires the use of two magnetometers, one for field data collection and a second to measure diurnal variations in the magnetic field. Magnetics data were collected along access tracks and fence lines. It should be remembered that a considerable distance should be maintained from magnetic objects (fences, sheds, etc) to prevent interference.

Table 3.2: Estimate Costs of Ground Magnetics Surveying

Item	Cost
Operator/Geophysicist	$440/day
Field technicians	$150/day/person (up to 3 persons)
Equipment	$1000/day
Vehicle Hire	$240/day
Mobilisation Fee	Variable depending on location of departure.

3.3 Electrical Methods

3.3.1 Electrical Properties of Groundwater

McNeill, (1990), describes the properties of the soil which control the conductivity of the sub-surface. In most groundwater studies it can be assumed that the soil and rock matrix does not contain conductive metallic materials, and electrical current flow therefore takes place through the soil and water. Under these conditions it can be assumed that the major factors affecting the electrical conductivity (reciprocal of resistivity) of the bulk soil or rock are:

- porosity
- conductivity of included soil moisture
- shape of soil/rock pore spaces
- degree of saturation (fraction of pore space actually filled with moisture)
- temperature
- presence of clays with moderate cation exchange capacity

While clay rich areas will always be rather conductive due to cation exchange capacity the resistivity of the porous rock is primarily dependent upon the conductivity of the contained water and degree of saturation (Keller, 1988; Palacky, 1988). The electrical properties of a saturated or moist soil profile allows for the use of methods, which measure the geo-electrical characteristics of the soil profile. Most literature states the use of either electromagnetic or contact electrical (resistivity) methods.

3.3.2 Contact Electrical Methods

The electrical resistivity techniques (Wenner and Schlumberger) are popular methods (Humphreys *et al*., 1990; Dodds and Ivic, 1990), which involves the injection of current into the ground through grounded electrodes and measuring the resulting potential difference, the arrangement of current and potential electrodes is known as an array. Figure 3.1 depicts the common electrical arrays with their respective geometric factors for determining apparent resistivity.

These methods primarily reflect variations in ground resistivity and can be used to map depth to groundwater, resistivity (and therefore quality) of groundwater and depth to basement. However, the use of grounded electrodes can encounter problems in areas of high surface resistivity, where obtaining sufficient current flow can be difficult. Considerable effort is also required to layout the array so that the resistivity survey can be expensive.

3.3.3 Resistivity Survey Requirements and Costs

Vertical electrical soundings generally require three personnel, an operator and two field assistants to increase electrode spacings. Approximately 4 Schlumberger soundings per day can be expected with AB/2 spacings of less than 1000 metres (depth of investigation approaching 300 metres).

Table 3.3: Estimate Costs of Resistivity Survey

Item	Cost
Operator/Geophysicist	$440/day
Field technicians	$150/day/person (up to 3 persons)
Equipment	$1000/day
Vehicle Hire	$240/day
Mobilisation Fee	Variable depending on location.

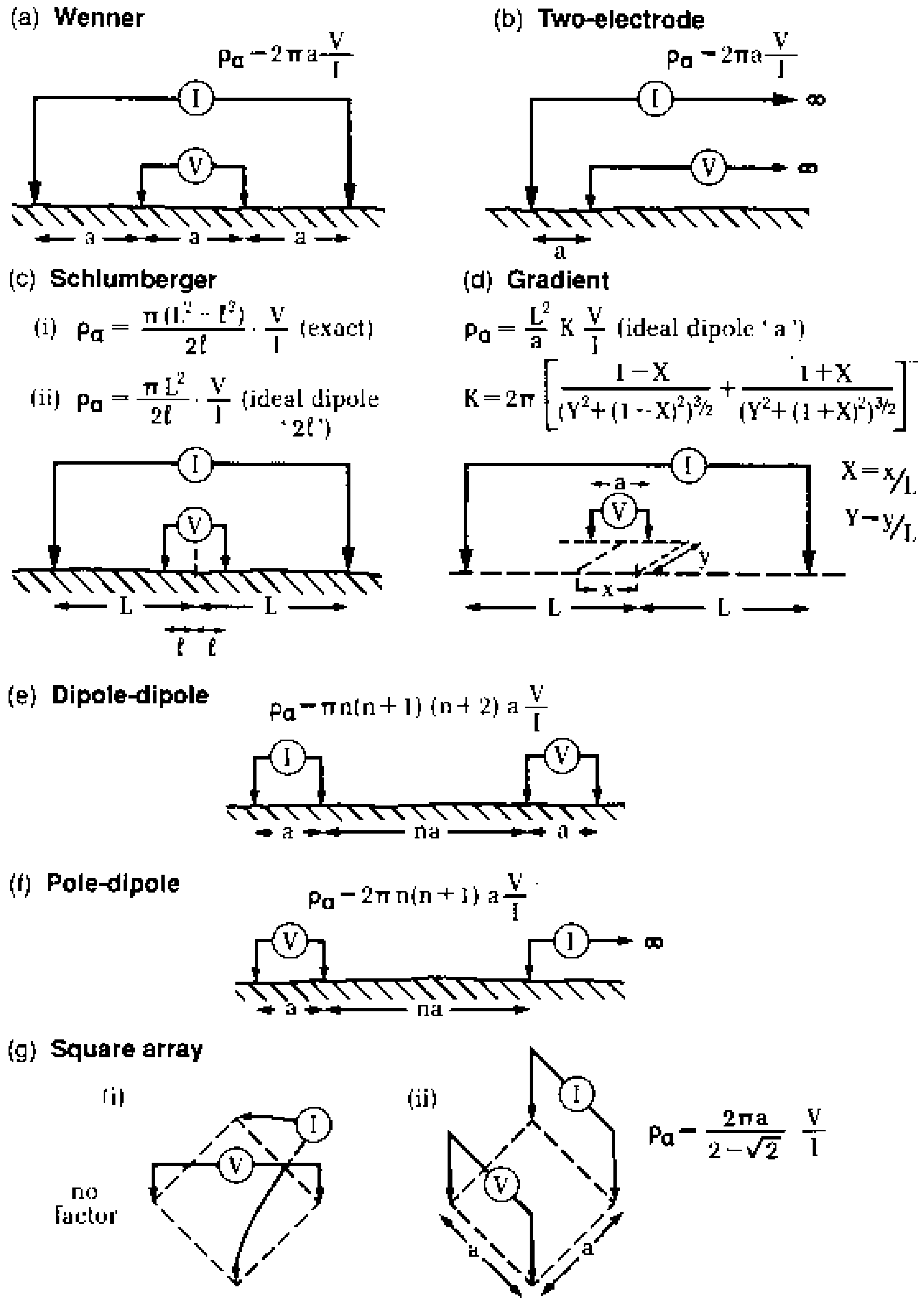


Figure 3.1: Common DC resistivity arrays and their geometric factors. (a) Wenner; (b) Two electrode; (c) Schlumberger; (d) Gradient; (e) Dipole-dipole ; (f) Pole-dipole; (g) Square array [(i) diagonal (ii) broad side].

3.3.4 TDEM Soundings

The time domain electromagnetic method employs a square current waveform to energize a square transmitter loop. The fall in the transmitter current in the loop during turn-off creates a time varying magnetic field around the transmitter loop. This magnetic field induces eddy currents in the ground. Shortly after turn-off, the currents are closely confined to the ground under the transmitter. With increasing time, the currents diffuse down and away from the transmitter loop. The relative current strength is directly related to the conductivity of the ground. The diffusing currents create a decaying, secondary magnetic field. Thus by measuring the decaying magnetic field from these currents at progressively later times, we are exploring the Earth to progressively greater depths.

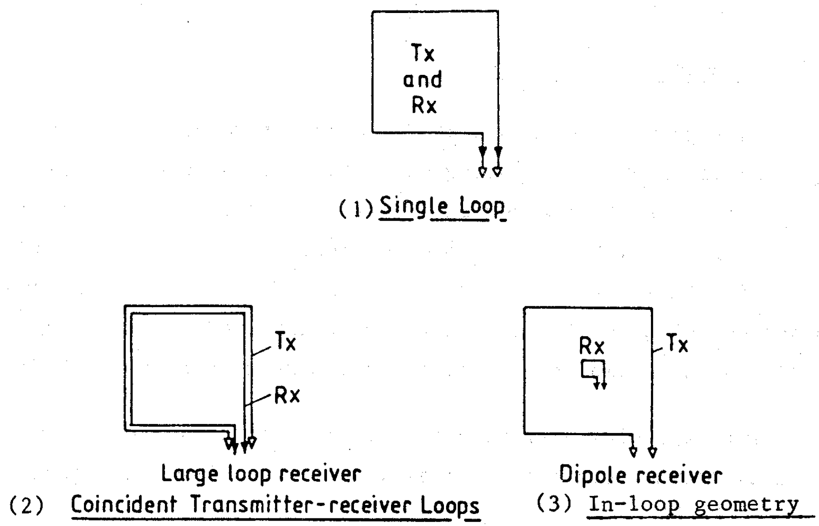


Figure 3.2 Diagram of the loop layouts of time domain electromagnetic method.

Non-contacting electromagnetic techniques show very good lateral resolution and relatively good rejection of localised resistivity inhomogeneities. Soundings are also faster to carry out than conventional resistivity (10 minutes c.f. >2 hours for a sounding AB/2 =1000 metres), for these reasons the electromagnetic method is becoming more common in their application to ground water problems.

The TDEM method is widely used in shallow <100 metre environmental and groundwater problems (Fitterman and Stewart, 1986; Dodds and Ivic, 1990; Hoekstra and Blohm, 1990; McNeill, 1990; Anderson *et al.,* 1993). In general the depth and resistivity of groundwater, extent of salt-water lenses/groundwater contaminants and depth to resistive basement are determined.

The resolution of certain electrical equivalencies is better in the EM method compared to the resistivity technique, however the EM method 'prefers' conductive layers and is poor at resolving resistive layers (McNeill, 1990). In some cases both electromagnetic and conventional resistivity techniques are used together in a 'joint' sounding to overcome the problems of equivalence. In many cases however, the electromagnetic technique is the main electrical 'tool' used to resolve groundwater problems (McNeill, 1990).

3.3.5 The Effects of Near-Surface Superparamagnetic Materials

SPM or superparamagnetiic effect is due to the presence of SPM materials close to the transmitter/receiver loop. Superparamagnetism is exhibited by fine-grained particles of maghemite and magnetite (common minerals in laterite deposits) with radii of the order of 250Å or less. Particles of this size exhibit magnetisation relaxation times of the order of milliseconds. Buselli, (1985), demonstrated that this relaxation or decay is proportional to the inverse of time (ie t^{-1}).

Basically these particles are magnetised by the presence of the magnetic field induced by the transmitter. Cessation of this field allows the domains of the particles to return to their natural state over a time period of a few milliseconds. The result is a magnetic field decaying with time, taking several milliseconds to return to the background value.

Figure 3.3 demonstrates the SPM effect on the TDEM data. The diagram shows the measured decay response, the modeled SPM effect and the resultant response with SPM removed. It can be seen that the SPM has little effect on early time data, but as the response decays at later times the response is due primarily to SPM effects. This late time data is needed to discern information about the deep sub-surface.

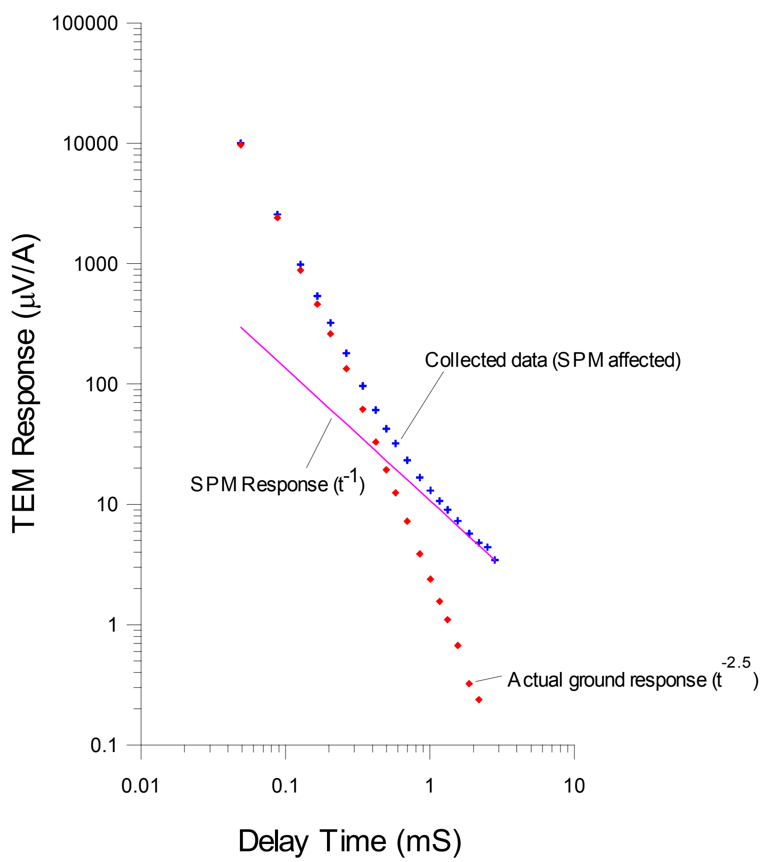


Figure 3.3 SPM effect on TDEM data.

The anomalous transient response is localised to approximately 3 metres of the transmitter loop; it is consequently detected only by loop configurations where the receiver loop is in proximity to the transmitter loop (Figure 3.2 (1) - single loop and 3.2 (2) - coincident loop). The effects caused by the presence of a superparamagnetic response within 3m of the transmitter loop apply to all electromagnetic methods (Buselli, 1985).

3.3.6 Survey Requirements and Costs

Time-domain electromagnetic surveying usually involves three people, a geophysicist or skilled operator and two field assistants. Approximately 15 soundings per day can be expected with 100x100 metre loops and an RVR (depth of investigation approaching 120 metres).

Table 3.4: Estimate Costs of TEM Sounding Survey

Item	Cost
Operator/Geophysicist	$440/day
Field technicians	$150/day/person (up to 2 persons)
Equipment	$1000/day
Vehicle Hire	$120/day
Mobilisation Fee	Variable depending on location of departure.

3.4 Gravity

The gravity technique measures the minute variations in the gravity field of the earth due to the varying distribution of density in the Earth's crust. The objective of gravity surveying is to determine the distribution of densities and hence rock types in the sub-surface. The gravity technique can be used to delineate faults and structure. In groundwater studies the gravity technique is also used to determine depth to basement where there is a sufficient density contrast between the overlying strata (usually sediments) and the basement rocks (usually igneous). The limestone and basalt units of the Sturt Plateau are interpreted to have similar densities and therefore a depth to basement is not expected to be derived.

The gravity method is expected to define major structural features such as the fault bounding the western edge of the Georgina Basin. Direct delineation of the depth to basalt is not expected and is therefore detailed gravity is not recommended in this area.

3.4.1 Survey Requirements and Costs

The corrections applied to the raw gravity data need to have accurate position and height data, this is usually the most expensive stage in the survey.

Table 3.5: Estimate Costs of Gravity Survey

Item	Cost
Operator/Geophysicist	$440/day
Surveyors	$150/day/person (2 persons)
Gravity meter	$1000/day
Vehicle Hire	$120/day
Mobilisation Fee	Variable depending on location of departure.

3.5 Seismic Refraction and Reflection

Seismic methods rely on variations in the acoustic-impedance of rocks. Seismic reflection can provide detailed information on the strata. Both reflection and refraction surveying employ an energy source and receivers. The energy source is generally an explosive charge and the receivers (geophones) record the signal of either the refracted or reflected waves created by the interaction of the geology with the waves from the source.

3.5.1 Survey Requirements and Costs (Seismic Reflection)

Seismic reflection is a resource intensive and expensive technique. Data acquisition and processing are both time consuming and expensive, generally requiring specialist contractors to complete, process and interpret.

3.5.2 Survey Requirements and Costs (Seismic Reflection)

Seismic refraction data is less expensive to obtain than reflection data it is still labour and resource intensive.

3.6 Down-hole Geophysical Logging

3.6.1 Natural Gamma Logging

Natural radioactivity results from the presence of small amounts of uranium, thorium and potassium 40. It is usually lowest in basic igneous rocks (ie basalt) and highest in sedimentary units, especially clays and shale, although clean mature sands and clay free limestone can produce very low counts (The Tindal limestone being an example). The γ-ray log, therefore, reflects mainly the clay content because radioactive elements tend to concentrate in clays and shale. Figure 3.4a is an example of a natural gamma log from borehole RN 30711, Avago Station with lithological log.

It should be noted that the gamma logs need to be correlated with a range of strata logs to provide interpretation. The gamma logs are useful in this environment since the sedimentary sequences are highly correlatable providing a highly degree of prediction from the logs.

3.6.2 Downhole Induction Conductivity Logging

These devices operate on the same principles as ground conductivity meters. Permitting the measurement of the electrical conductivity of the ground outside of a plastic-cased bore hole or monitoring well, while at the same time being insensitive to the presence of the usually much more conductive bore hole fluid within the casing. A co-axial coil geometry with an inter-coil spacing of 50 cm gives reasonable vertical resolution for layered earth measurements while maintaining an adequate radial range of investigation (Salama *et al*., 1993). Figure 3.4b is the conductivity log of bore RN 30711 in relation to the gamma reponse. The response is dominated by the presence of clays and basalt.

3.6.3 Caliper Log

The caliper log measures the variation in uncased borehole diameter. Caliper measurements provide information about cavity location. This is particularly useful when drilling in cavernous environments such as in limestone.

NOTE: Caliper logs are only useful in the open uncased section of a hole.

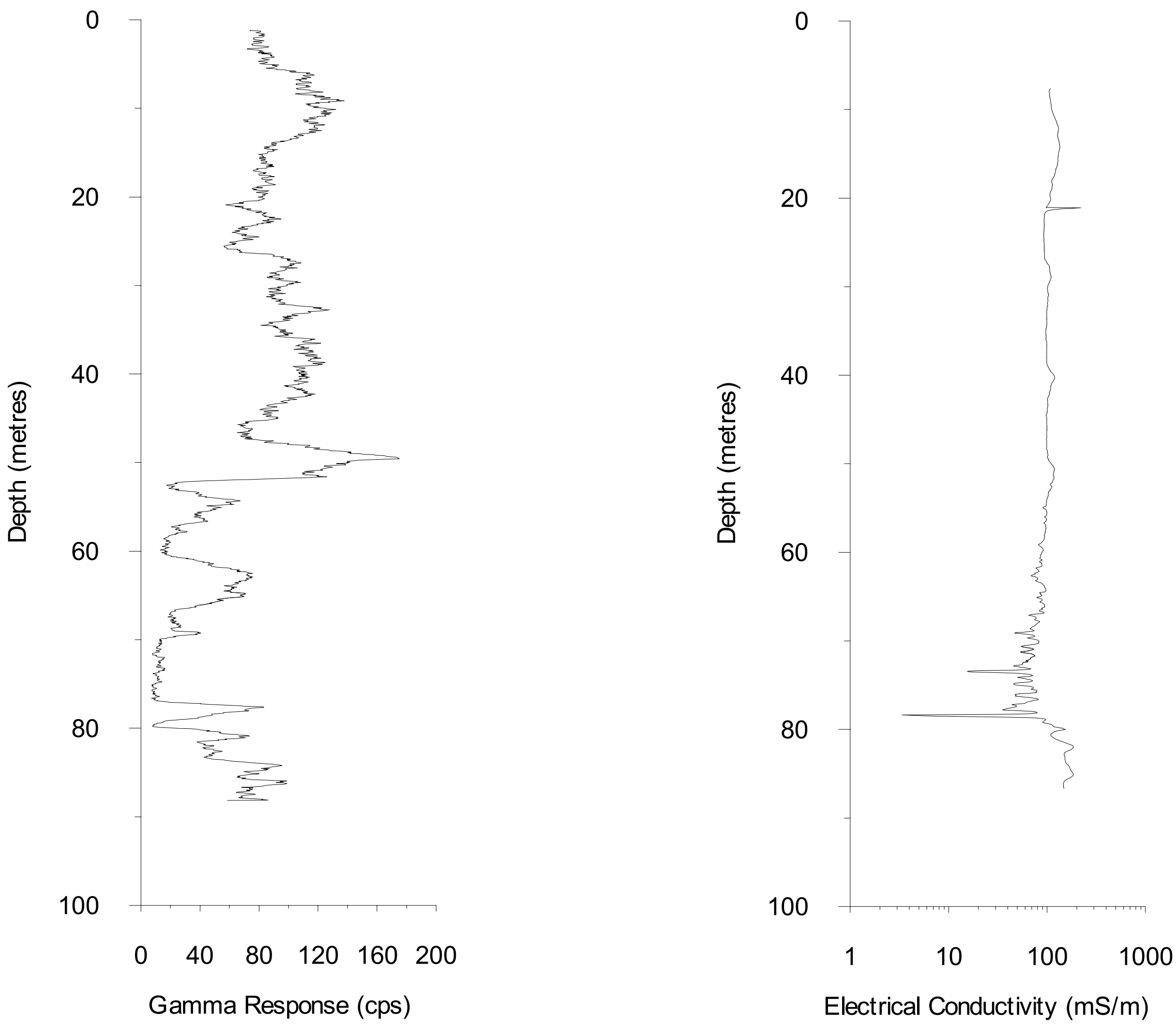


Figure 3.4 Downhole gamma and conductivity response of RN30711.

4.0 GEOPHYSICAL DATA OF THE STURT PLATEAU

4.1 Airborne Geophysical Datasets

4.1.1 1971 AGSO Regional Aeromagnetics

Total magnetic intensity for Larrimah (SD 5313) and Daly Waters (SE 5301) sheets were purchased from AGSO. Lines were orientated north – south with line separation of 1600 metres. The flying height was approximately 150 metres and average along line sample spacing was 70 metres.

Data is presented as unprocessed TMI (cell size 200x200 metres). Figure 4.1a is a colour-draped image using a histogram equalised stretch with sun-illumination 45° azimuth and 45° inclination.

The magnetic response shows the following characteristics:

- Regional response with high magnetic values to the south and lower values to the north. The regional magnetics high is coincident with a gravity high, suggesting that the source of this feature may be due to a deep seated body.
- Superimposed onto the regional response are high frequency features (response that when seen in profile extend for a relatively short distance see Figure 4.1a) due to structures in the basement.
- The magnetic "texture" is seen to vary with highly textured response in the centre of the image
- Areas of minimal magnetic "texture" suggest a lack of volcanics i.e. only sedimentary units occur below the sensor (since the sediments are non-magnetic). These regions occur along the eastern margin of the study area.

4.1.2 2001 NT Geological Survey "Semi-detailed" Magnetics, 256 Ch Radiometrics and Digital Terrain Model Data

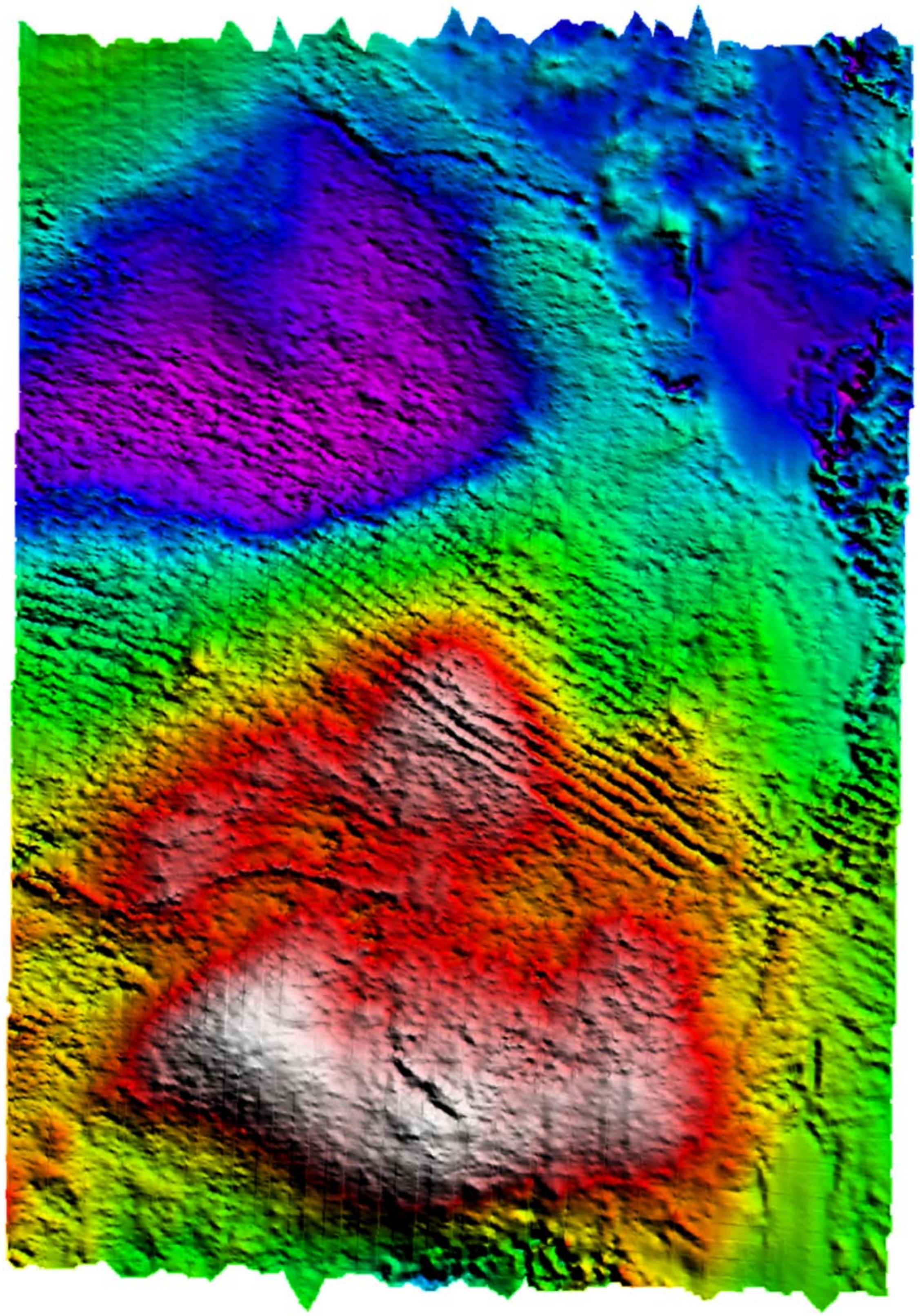
During 2001 semi-detailed (flight line spacing 400 metres and flying height of 80 metres) total magnetic intensity, 256 channel radiometrics and terrain elevation data were collected and processed by Kevron Geophysics Pty Ltd. The survey covered the following 1:100000 sheets: Birrimba 5366, Birrimba 5367, Elsey 5467, Middle Creek 5465 and Western Creek 5466. The data is available free from the Northern Territory Geological Survey. Figure 4.1b is of colour draped TMI image.

Figures 4.2 a) and b) are images of the radiometrics and digital terrain model derived from the NTGS data. The radiometrics image is a RGB composite of the potassium, thorium and uranium channels respectively. The information derived from the radiometrics data relates to the spatial distribution of potassium, thorium and uranium in the top 0.7 metres of the surface. Airborne radiometrics and terrain data is becoming a powerful tool in soil mapping and land resource assessment.

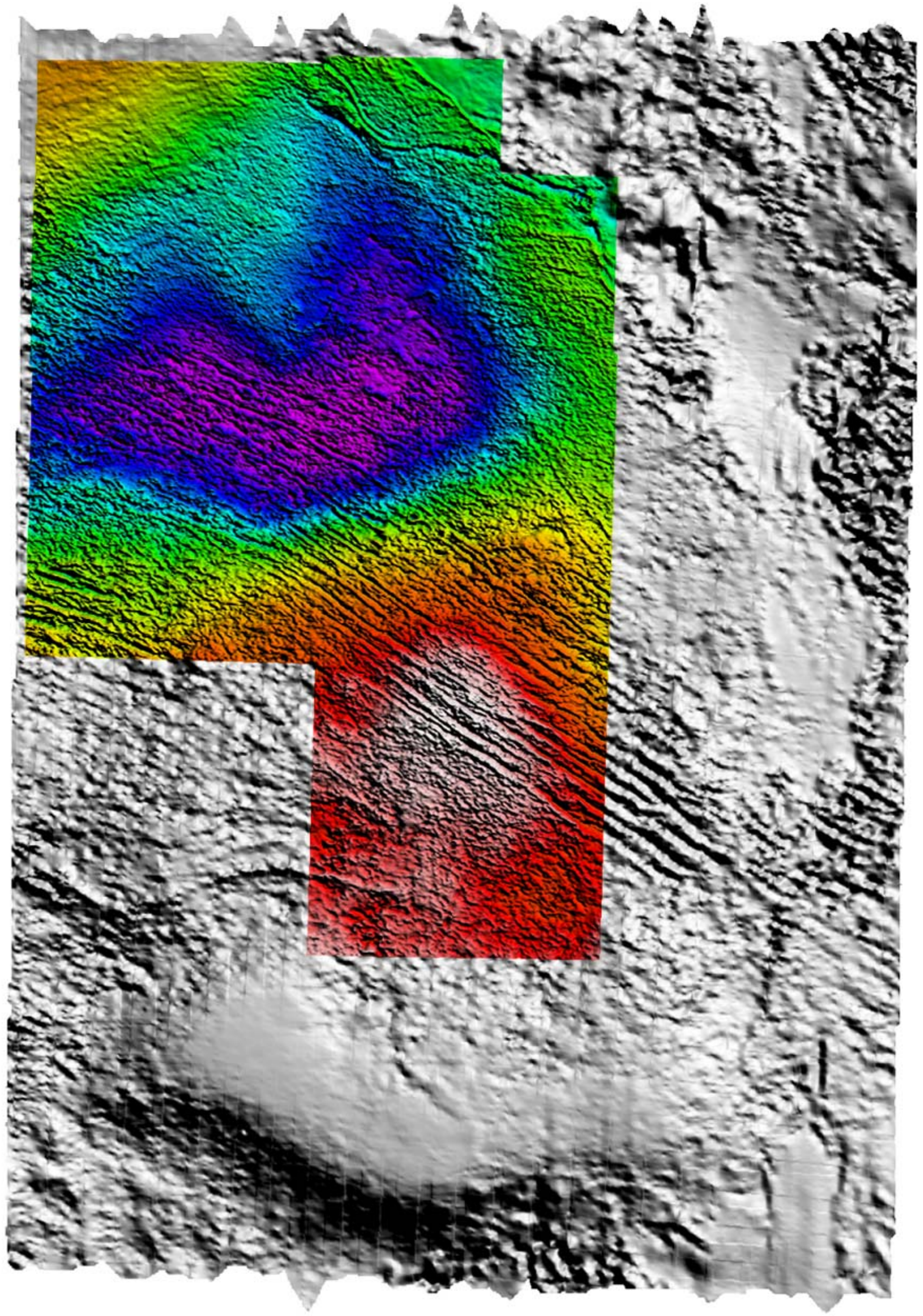
The presence of groundwater appears to be unrelated to the surface expression and soil properties (a major contribution to the radiometrics signal) and therefore the radiometrics and DTM will not be referred to again in this report.

4.1.3 Combined NTGS and AGSO magnetics Data

The detailed NTGS aeromagnetics data has been merged with the AGSO data. The AGSO data was re-leveled and scaled from a correlation between data covering the same region. Figure 4.3 is the result of this combination. Cadastre and bore locations have been included for reference.

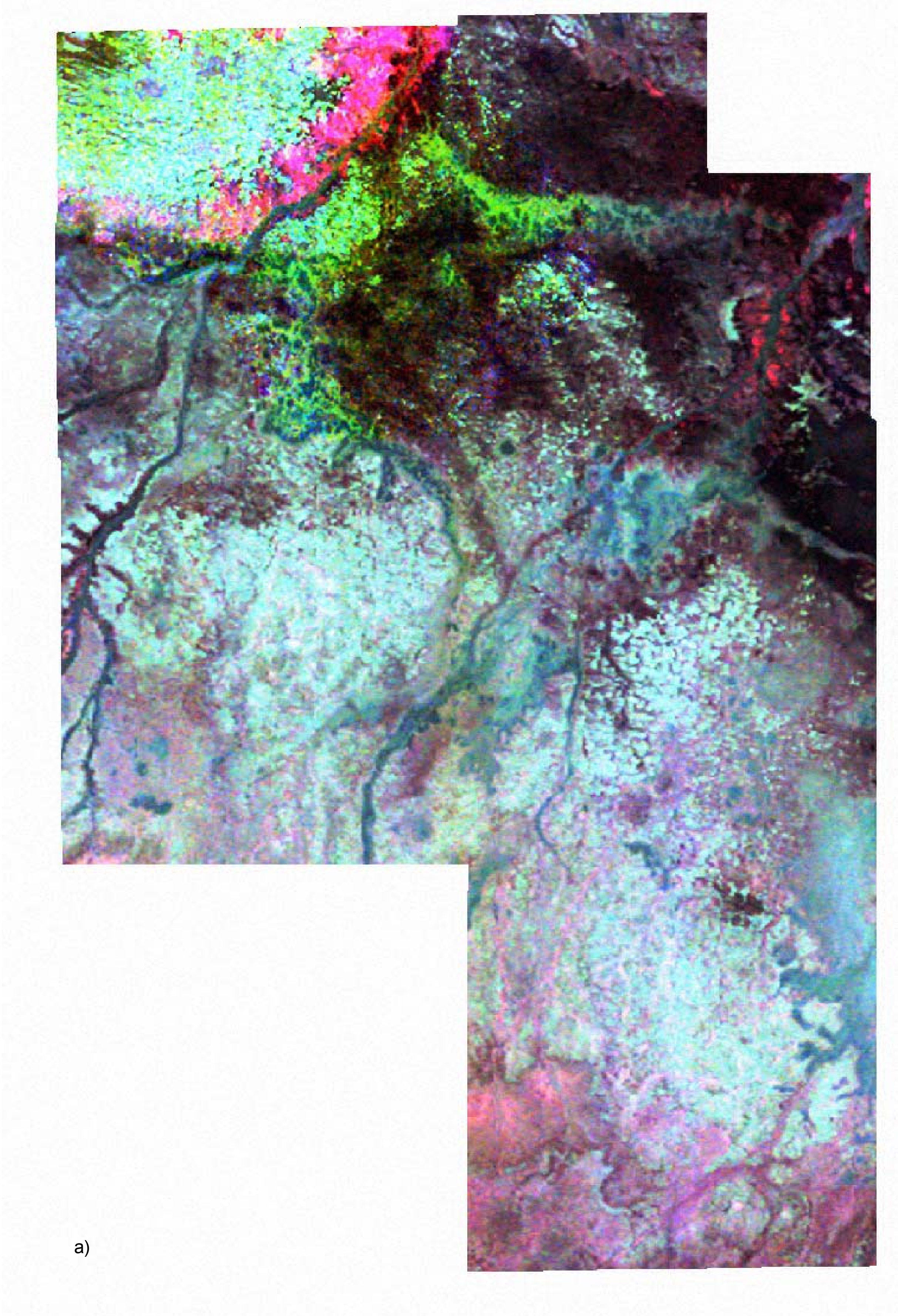


a)



b)

Figure 4.1 data comparison of a) Colour draped TMI image of the AGSO magnetics data. b) Colour draped TMI imae of the 1965 NTGS magnetics data. Greyscale AGSO data is for location.



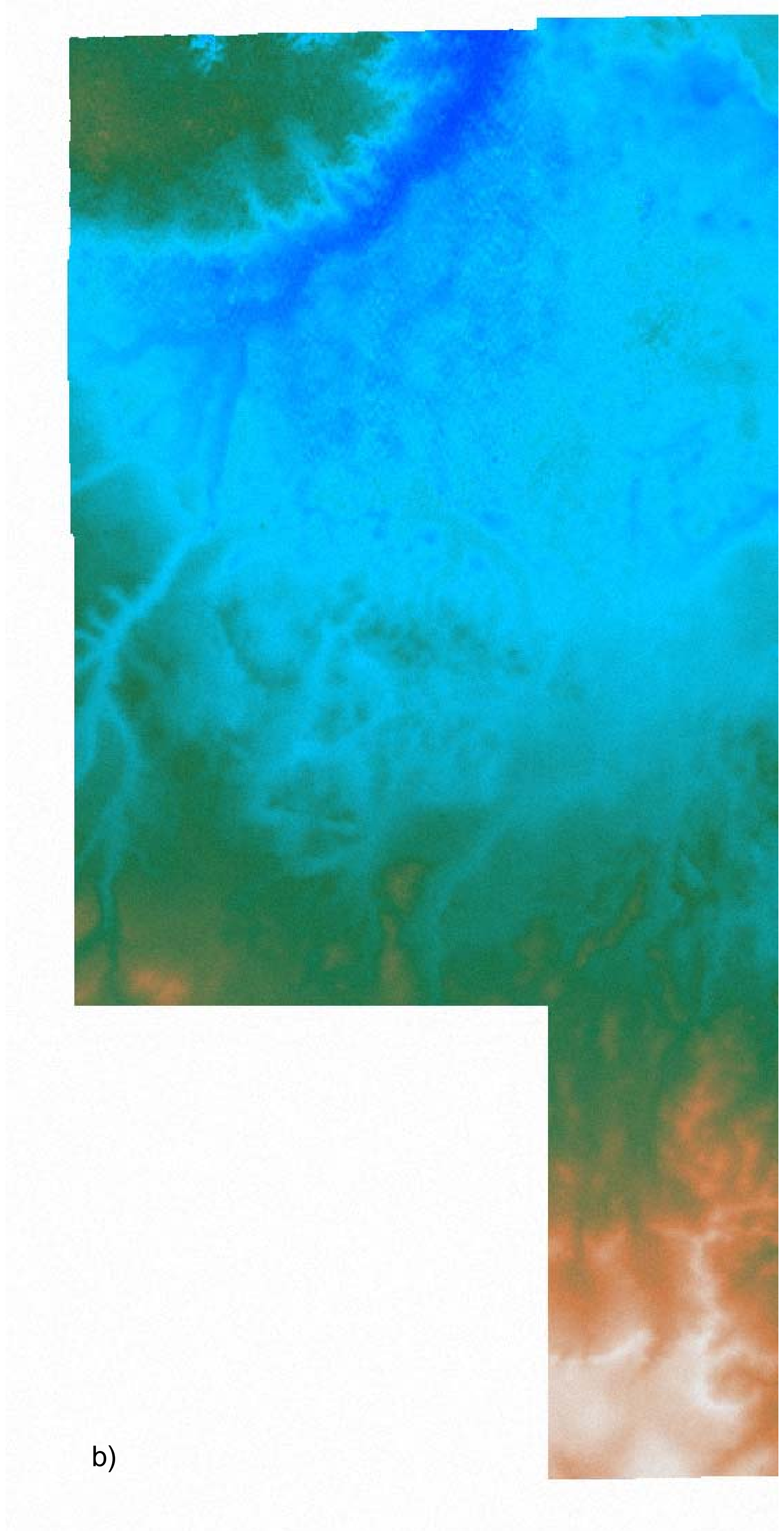


Figure 4.2 data comparison of a) RGB image of the 2002 NTGS radiometrics and b) 2002 NTGS digital terrain model

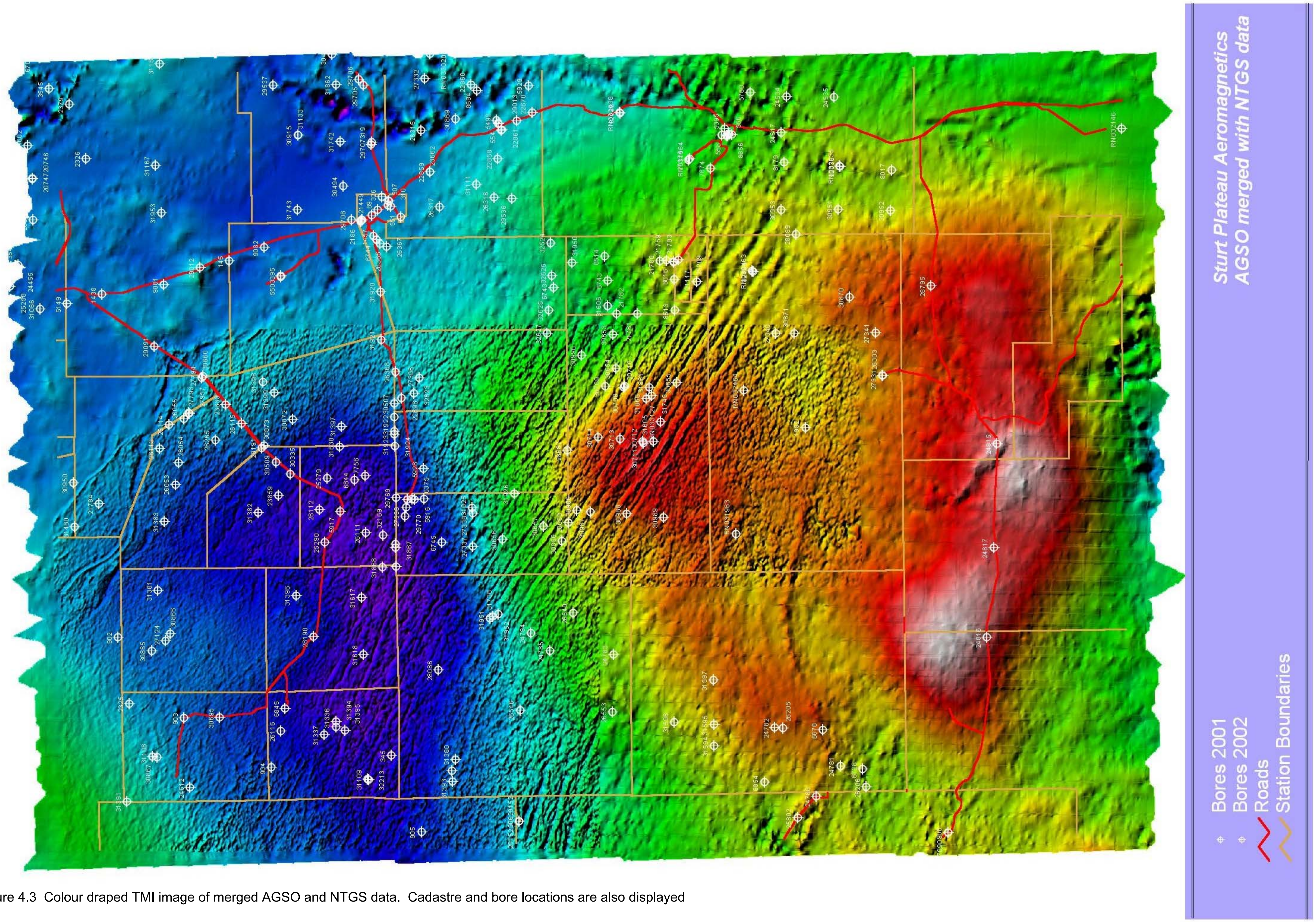


Figure 4.3 Colour draped TMI image of merged AGSO and NTGS data. Cadastre and bore locations are also displayed

4.2 BMR Regional Gravity Data

Data were digitized from the BMR regional bouguer maps of the Daly Waters, Larrimah and Katherine Sheets. Stations are located on a regional grid with nominal 11 km spacing. Figure 4.4 is of the digital image with station locations and cattle station boundaries. The bouguer response over the sheet is dominated by a low response extending SSE from the centre of the Larrimah sheet and into the eastern half of the Daly Waters sheet. The patterns in the data are attributed to the relative depth to the sediments underlying the Antrim Volcanics. The major north – south trending structure is evident in the data, with a zone of low extending south, which terminates abruptly along its eastern margin at this feature. A high (-4 to –10 mGals) occurs in the south and southeast of the study area this is coincident with the regional magnetics high.

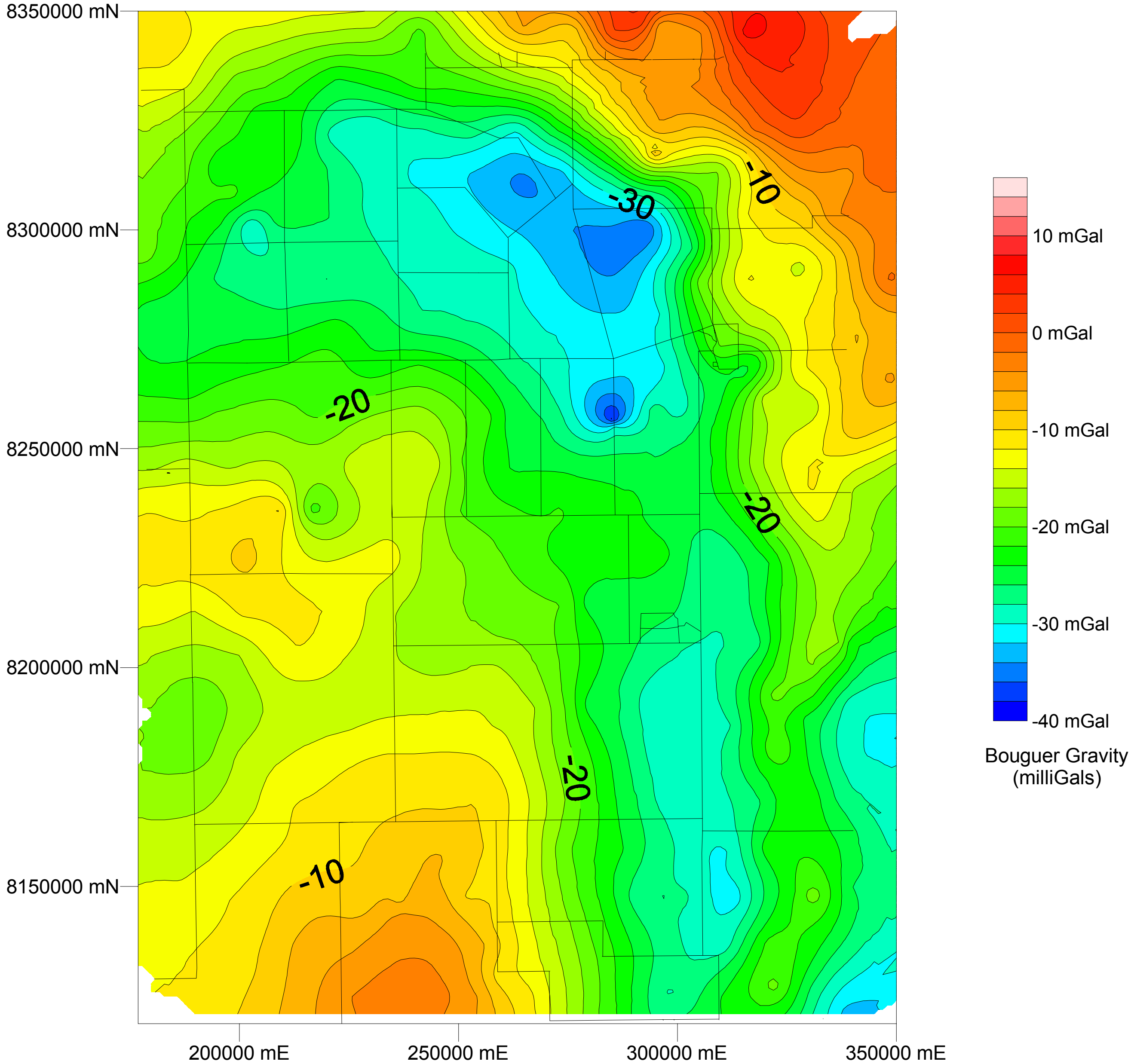


Figure 4.4 AGSO Regional Bouguer Gravity

4.3 Seismic Reflection Data

During 1991, Digital Exploration Ltd completed two deep seismic reflection (4 second record length) lines, EL90-200 and MA91-600, for CRA. Only pre-processed hard copy format was available.

The locations of the lines are depicted in Figure 4.5. The survey parameters suggest that the data would be unsuitable for defining shallow reflectors (< 400 metres; TWT < 250 milliseconds). However, the seismic results indicate that the top and bottom of the Antrim Volcanic unit is relatively well defined. This is expected due to the good density and velocity contrasts (change in acoustic impedance) at these horizons.

The data provides information on the deep (up to 7000 metres) Archaean sedimentary sequences of sandstone and siltstone with some maker horizons, which can be delineated on both sections.

Figure 4.5 is a scanned image of the section from line MA91-600. The surface datum, top of basalt, bottom of basalt and marker horizons in the Archaean sediments – showing folding and faulting. The section shows where the basalt ‘pinches out’. The major fault zone near the Stuart Hwy is evident.

4.4 Electrical Resistivity Data

Electrical resistivity surveys have been completed on and Sunday Creek (Doherty, 1982 and Doherty, 1983a) and Western Creek (Doherty. 1983b). These surveys were used in an attempt to define the depth to the basalt unit and to discern the presence of water.

4.4.1 Western Creek Survey

In July 1983, a total of 12 Schlumberger soundings were completed on the Western Creek Station to delineate suitable bore sites on the property.

4.4.2 Sunday Creek Surveys

A resistivity survey, incorporated both VES and profiling techniques, was conducted on the Sunday Creek property in June of 1982. The purpose of the survey was to locate bore sites capable of producing viable yields.

Another survey employing the VES technique was undertaken in July 1983. The survey was conducted to correlate drilling information with electrical resistivity data and to “test” proposed bore sites. A total of thirteen soundings were completed, eight in the vicinity of drilled bores and five at proposed bores sites.

4.4.3 Survey Conclusions

It was concluded that the method was unsuccessful at defining either the top of the basalt layer or the presence of water. No consistent results were obtained from modeling, that is, no resistivity parameter were determined as being typical for the basalt layer, thus depth estimates were considered unreliable. Similarly there was a high variability in the resistivities in the rest of the geoelectrical section suggesting that the presence of water can not be discriminated by sounding data.

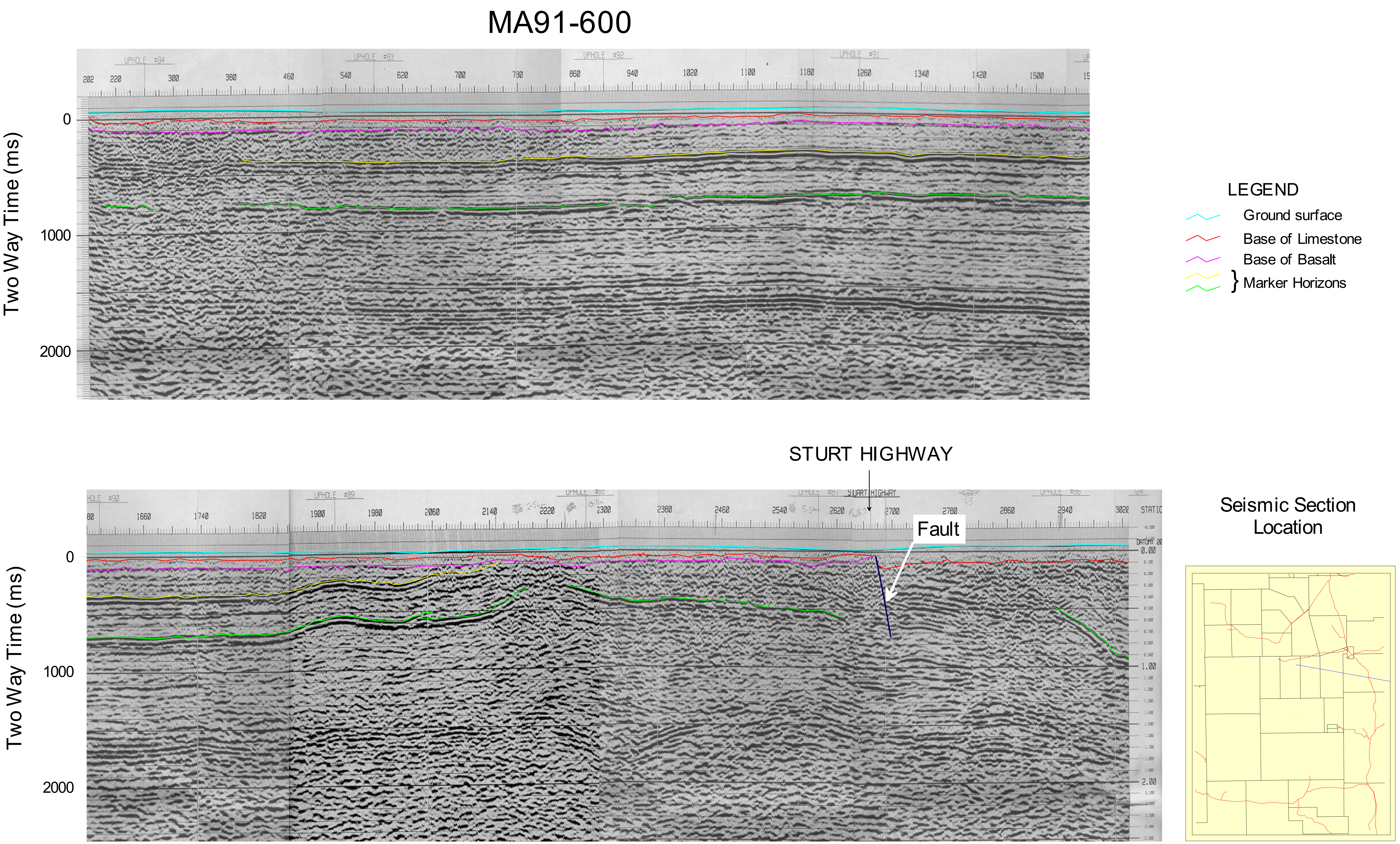


Figure 4.5 Deep seismic section across the Sturt Plateau.

5.0 GEOPHYSICAL PROCEDURES

5.1 Introduction

Ground methods were employed on the basis of anticipated vertical and lateral physical contrasts of strata in the study area.

Four ground techniques were employed in the study of the Sturt Plateau:

5.1.1 Ground magnetics

Airborne magnetics shows prominent structural features associated with deformation of the Antrim volcanics sequence. The coarse nature of the AGSO data (70 metre along line spacing) and the anticipated error in positioning relative to the ground required ground magnetics to be collected to locate features accurately for targeting of features.

5.1.2 Vertical Electrical Soundings

VES's were conducted in an attempt to determine the depth to the basalt. It was anticipated that the sediments would be less resistive than the volcanics, thus, providing an electrical contrast that could be used to determine the depth to the basalt.

5.1.3 Time Domain Electromagnetic Soundings

Time domain EM soundings were collected for the same reason as the VES data and to provide further controls on joint inversion modelling of the data.

5.1.4 Downhole geophysics

One third of the bores completed during the study were gamma logged. This was to differentiate lithological character and provide objective correlation of bore stratigraphy throughout the study area. Caliper, induction and susceptability logs were also conducted in several bores. The induction and susceptability information was then used to determine the electrical and magnetic properties of the statigraphic units. This information was later used in the interpretation of the surface geophysical techniques.

5.2 Ground Magnetics

A total of 19 ground magnetics lines have been completed in the study area to date, 6 completed during 1997 (Lines 1 to 6) and 10 during 1998 (Lines 7 to 19). The locations of these lines relative to the regional magnetics data are seen in Figure 5.1 and the profiles are in Appendix A.

Data were collected using two Scintrex Envimag systems. One was used to collect field data, the other to monitor diurnal variations during the time of data acquisition. The sensor was 3 metres above the ground and samples were taken at 10 metre intervals along each traverse.

The ground magnetics was used to ground truth the features evident in the airborne data. The response is a combination of a high frequency signal, associated with the Antrim Volcanics superimposed on a regional trend, thought to be associated with the presence of a deep seated feature (sections 4.1, 6.1 and 6.4). Susceptibility logs show that the laterite and volcanics are the only shallow units with appreciable magnetic mineral content.

The ground magnetics data is of variable quality relating primarily to the presence of Fe_2O_3 rich laterite on or near the surface. An example is seen in Figure 6.4.

A low-pass convolution filter (a simple 5 sample running average) has been applied to the ground magnetics data to smoothes the spurious data caused by the presence of near surface laterite.

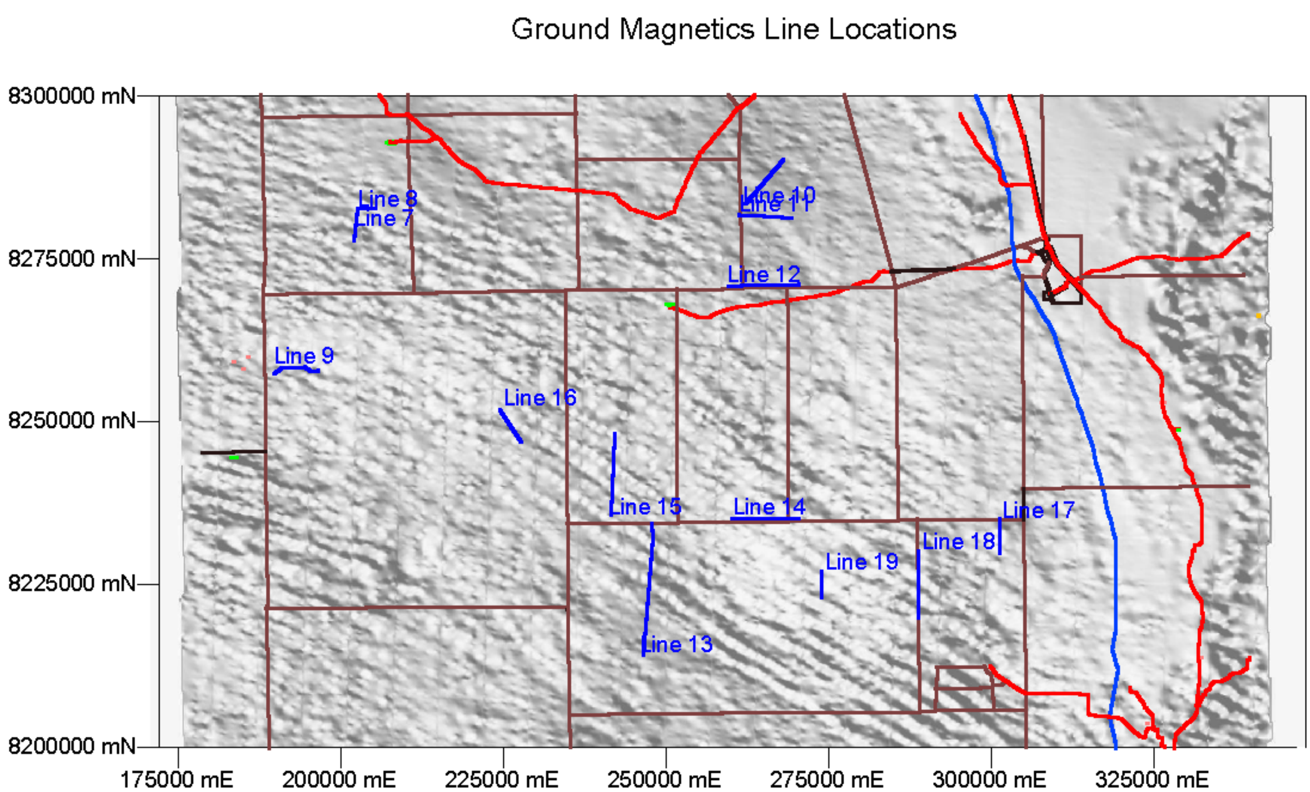


Figure 5.1: Ground magnetics traverse locations with respect to airborne magnetics and station boundaries.

Locations of each line are as follows:

Line 7: is located along a north-south line on Margaret Downs. The total length of the line is 4000 metres, extending south from an east west fence line.

Line 8: is located along an east-west fence line on Margaret Downs. The total length of the line is 3000 metres, with chainages increasing to the east.

Line 9: is located along an east-west cleared line extending from the western boundary of Gilnockie Station.

Line 10: located on a northeast – southwest fence line. Chainages increase to the north

Line 11: is located along an east-west fence line on Gorrie Block E. The total length of the line is 8000 metres

Line 12: is located along an east-west fence line on Gorrie Block E. The total length of the line is 12,600 metres and chainages increase to the east.

Line 13: is located on a north-south graded line on the western portion of Avago Station. The total length of the line is 22,200 metres, with chainages increasing to the north.

Line 14: is located on an east-west fence line between Avago Station and Western Creek Station. The total length of the line is 8500 metres, with chainages increasing to the east.

Line 15: is located along a north-south track extending north from Crab Hole Bore on Western Creek Station. The total length of the line is 12,500 metres with chainages increasing to the north.

Line 16: is located along a southeast-northwest fence line on Gilnockie Station. The total length of the line is 6300 metres with chainages increasing to the northwest.

Line 17: is located along a north-south track on Sunday Creek Station. The total length of the line is

Line 18: is located along the boundary between Avago and Sunday Creek. The total length of the line is 10,000 metres with chainage increasing to the north.

Line 19: is located along the railway corridor on Avago Station. The total length of the line is 4600 metres, with chainages increasing to the north.

5.3 Schlumberger and SIROTEM Soundings

In May 1992 and June 1994 joint Schlumberger/SIROTEM soundings were completed in the Sturt Plateau region. Sounding locations are seen in Figure 5.2. TEM data were collected using the SIROTEM MkII SE system using the early time series. Three loop configurations have been employed in the TEM soundings

- Soundings prior to 1997 were completed using a coincident loop configuration with 85x85 metre transmitter and 77x77 metre receiver.
- An in-loop geometry, comprising either a 100x100 or 50x50 Tx and RVR (roving vector reciever) with 10,000 m^2 effective area, was used after this date.
- 100x100 metre and 50x50 metre single loop arrays were used in areas where SPM effects were absent. A transmitter turn-off accelerator was used to reduced the nominal turn-off time from 50μsec to 16μsec.

The VES data is quite variable throughout the study area. The results tend to have a three layer Type H curve (Telford *et al*, 1990). The curve is typified by a low resistivity layer confined by two relatively resistive layers.

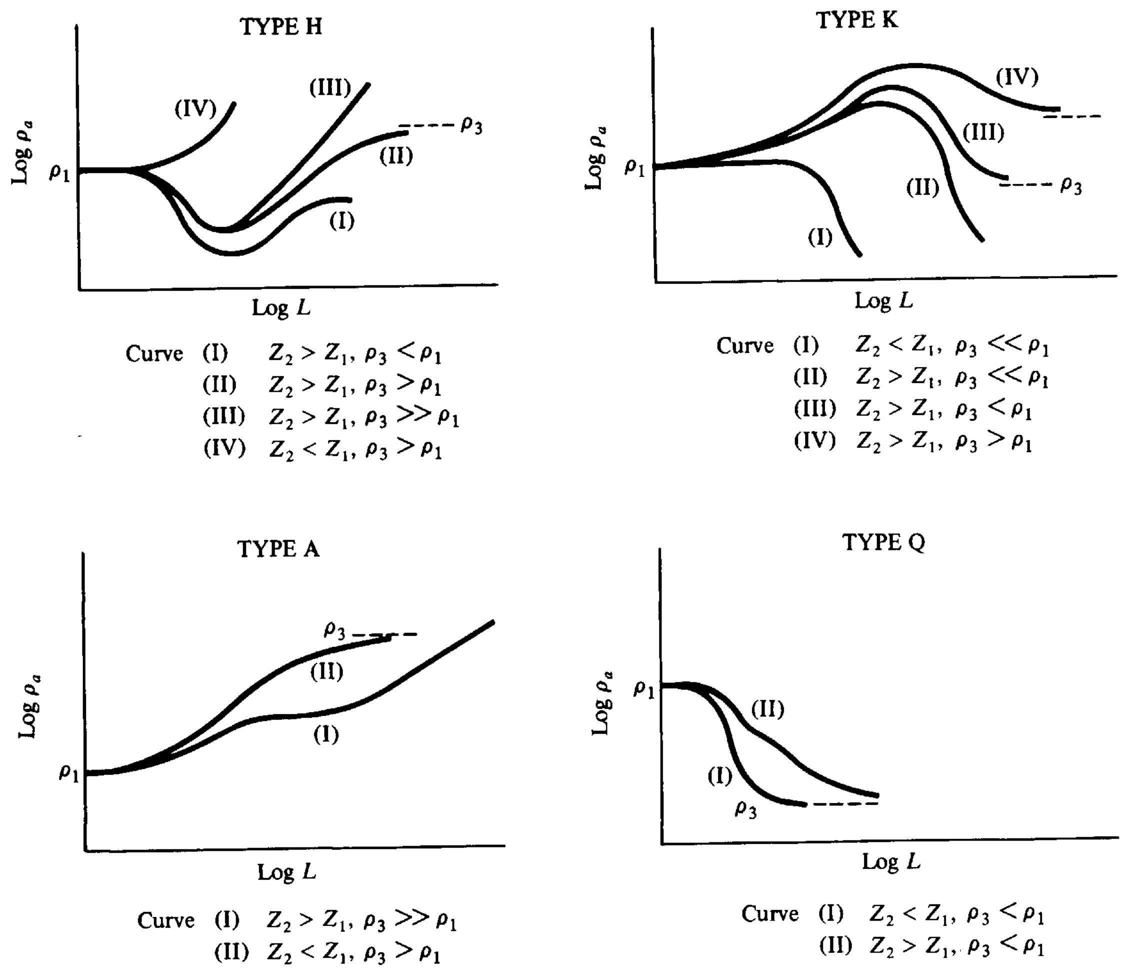


Figure 5.2: 3 layer A-Type, Q-Type, H-Type and K-Type sounding curves.
(Telford *et al*, 1990)

The TEM data shows very similar curve shape throughout the study area ie 4 layer Type H-K curve. However much of the data collected prior to the use of a RVR is suspect due to the interpreted presence of SPM effects.

5.3.1 SPM Removal from TDEM Data

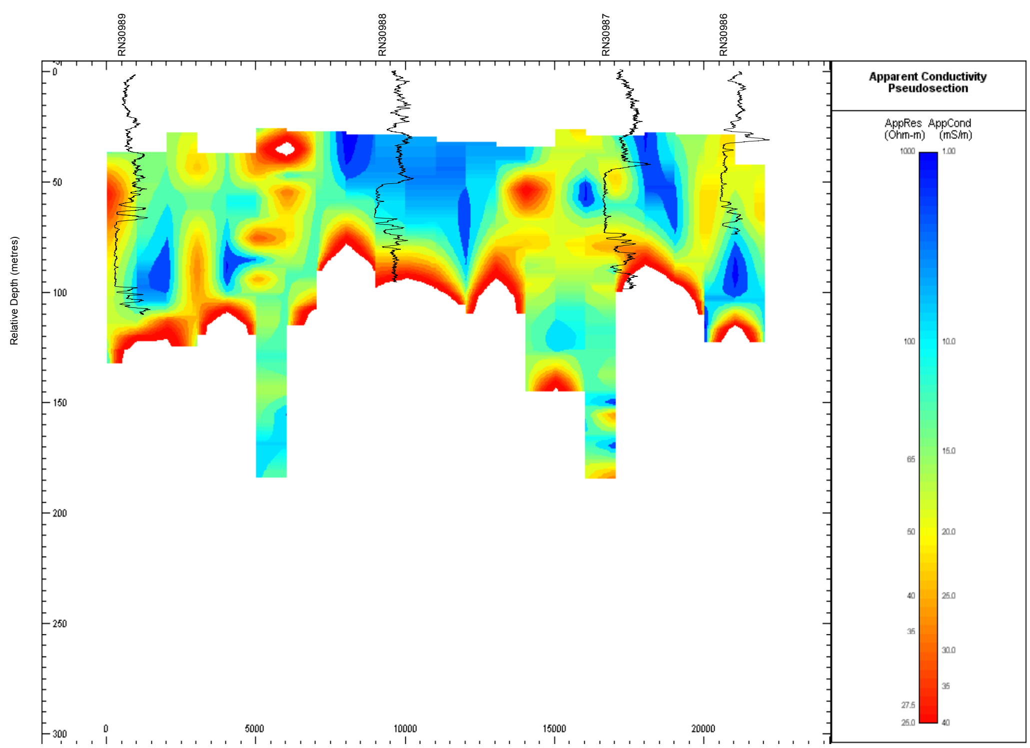
Comparison of VES data to TEM data indicates the presence of SPM effects. Generally the VES data indicates a thick resistive basement, however, TEM data suggest a conductive basal feature which is not apparent in the electrical soundings. It is estimated that the depth of penetration of the VES data would be comparable, if not deeper than the TEM data and therefore suggest SPM artifacts in the TEM data.

Estimates of SPM effects were used in locations where both in-loop and coincident data were collected. Although the results appear satisfactory, the removal of SPM using a numerical model is not applicable across different geological environments. It has been found that the SPM phenomenon is not consistent in terms of initial amplitude and decay constant with parameters varying over small distances. A predictive model is therefore difficult to derive especially where subtle changes in decay are important. This is particularly evident in a resistive terrane where the correction procedure may produce its own artifacts in the data. This is in contrast to the results obtained by Buselli, (1985).

Figure 5.3 shows an apparent conductivity pseudosection with SPM effects. The data has been correlated with gamma logs of the bores drilled along the lines.

Figure 5.4 shows an apparent conductivity pseudosection with SPM effects removed. Stations where in-loop information was not available, the SPM contribution was estimated using models derived from adjacent in-loop data.

Figure 5.3 Apparent conductivity pseudosection prior to SPM removal compared to gamma logs of bores along Line 13



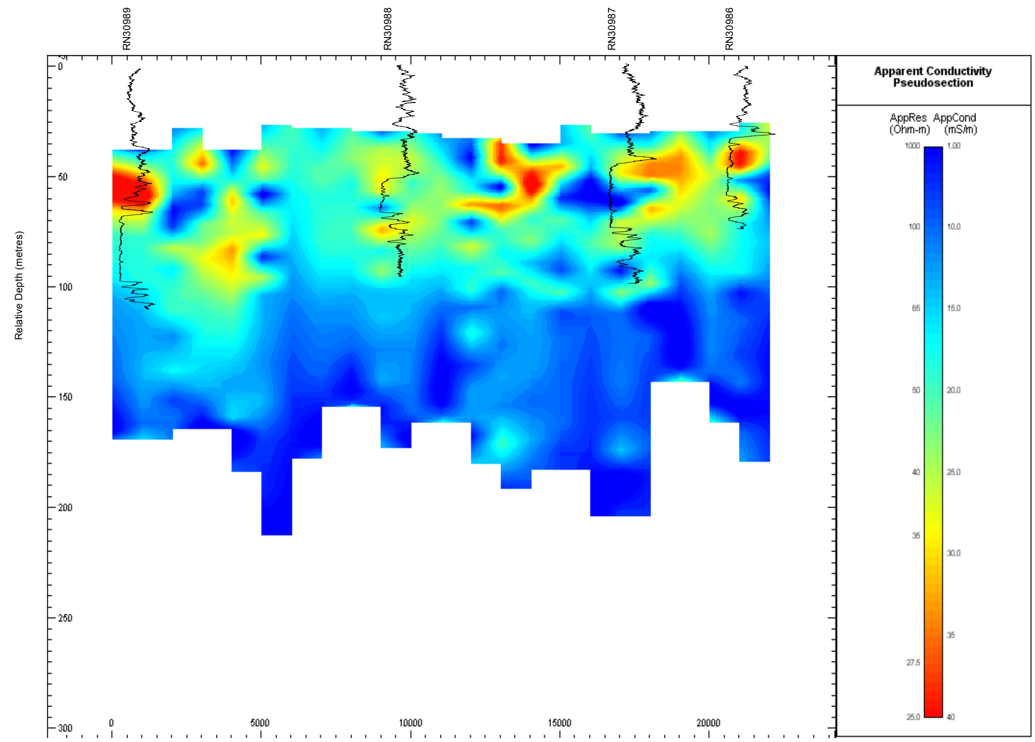


Figure 5.4 Apparent conductivity pseudosection after SPM removal compared to gamma logs of bores along Line 13.

The pseudo sections have been derived from application of the EMVision Spiker Algorithm (ENCOM, 2000). This process calculates conductivity and depth values directly from the field response. This is in contrast to the modelling process which uses layer properties (thickness and conductivity) to derive the a response for comparison with the field response.

5.4 Borehole Geophysics

Gamma logs have been completed for 103 of the 315 bores drilled in the Sturt Plateau (Figure 5.5). The gamma logs are of particular interest when RAB drilling in cavernous limestone/dolostone terrane where poor or no sample return due to loss of circulation is common. The information provides lithological determination and can be used to show the depth of the limestone aquifer and the limestone/basalt contact in the sediment column. The clean or clay free limestone is characterised by low gamma counts per second (the measure of natural radiation). Marker beds are evident in the sediments overlying the basalt allowing for correlation between bores across the whole study area. Marker correlation indicates that the deformation of the basalt may have occurred contemporaneously with the deposition of the basal units of the Tindal limestone.

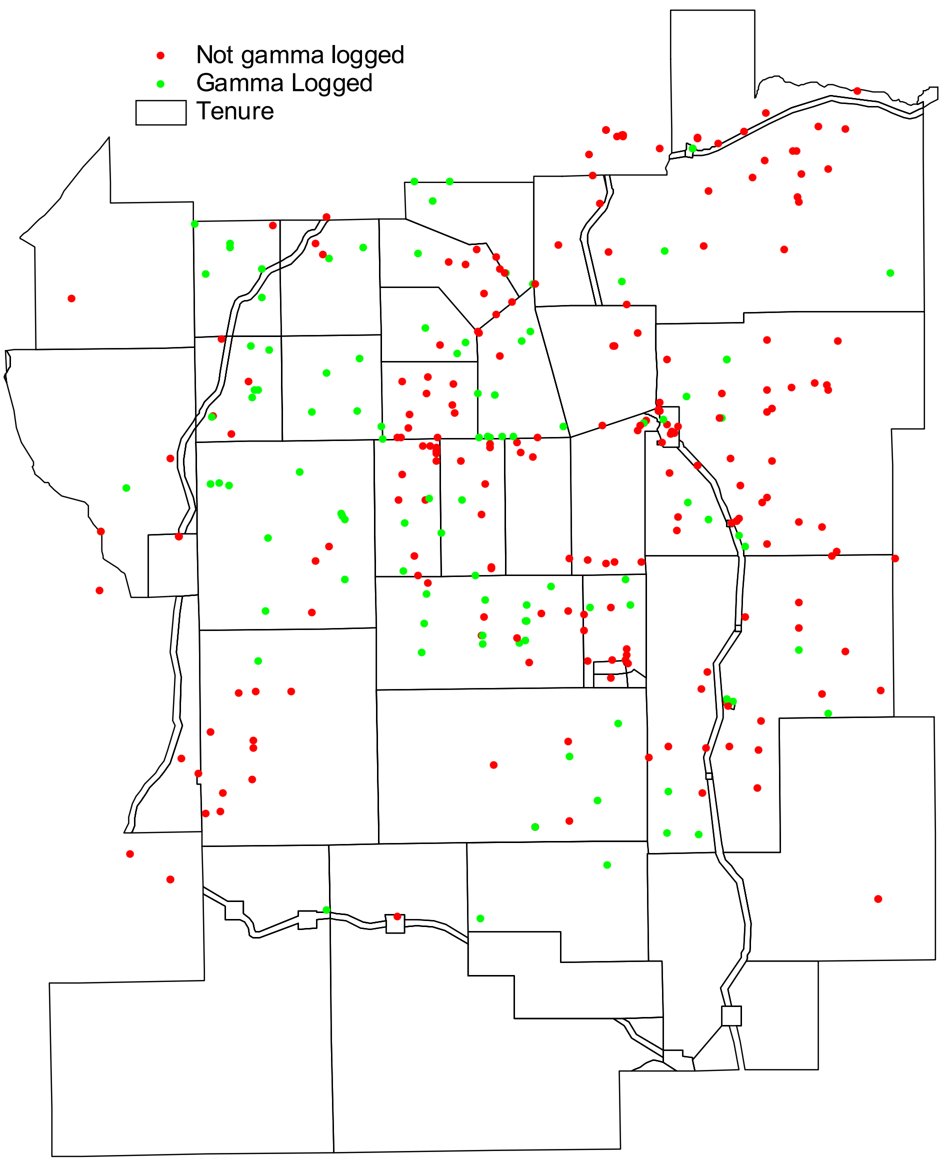


Figure 5.5 Distribution of gamma logged bores in the Sturt Plateau.

Figure 5.6 demonstrates the correlation of the gamma logs along the magnetics Line 13 on Avago Station. The logs have been corrected for topography, it can be seen how the layers display either warping or faulting (probably the former). The variation in the available submergence in the limestone is also evident from the amount of limestone below the ground water table.

Conductivity logs were completed in six bores the information was used to determine the suitability of surface electrical methods in defining the limestone basalt interface.

Susceptability logs were completed in three holes to provide information concerning the magnetic character of the sediments. It was found that apart from surficial laterite deposits the Antrim Volcanics was the only appreciably magnetic unit.

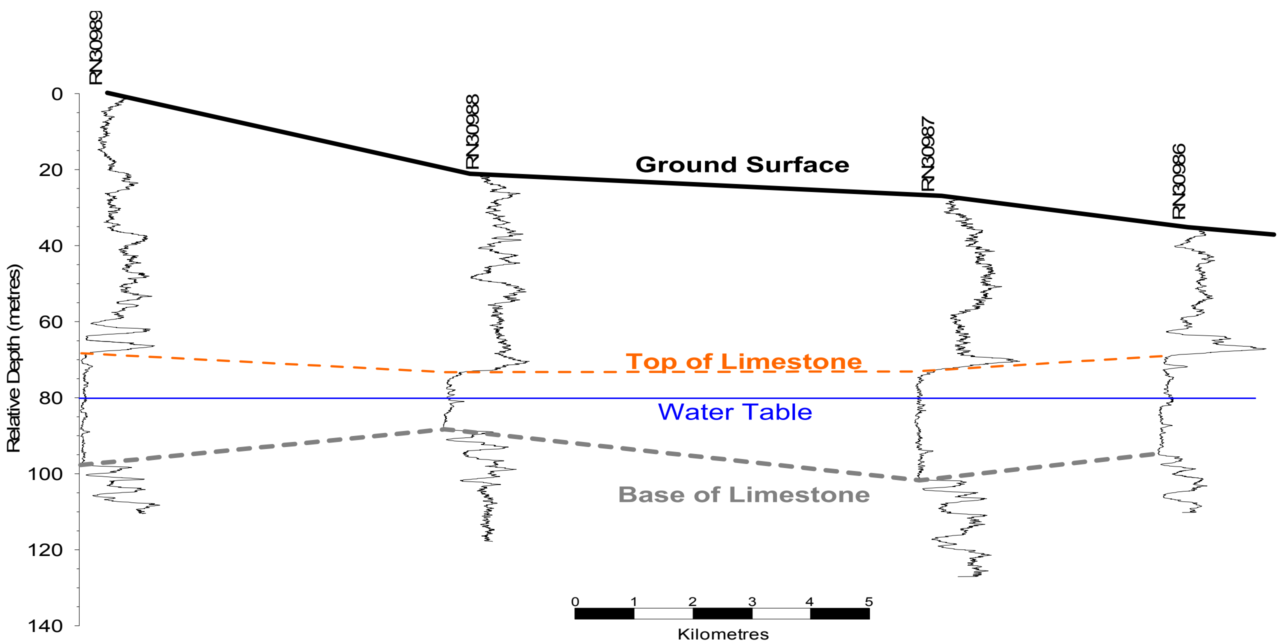


Figure 5.6: Correlation of gamma logs along Line 13, Avago Station.

6.0 INTERPRETATION

In the following discussion the geological interpretation of the various geophysical methods both airborne and ground are covered. The area defined by the aeromagnetics will be used as the extents of the study.

6.1 Airborne Magnetics - Structural Interpretation

The regional effects appear to be topographically controlled, however, they are thought to be due to the presence of deep magnetic body, which are evident in the gravity data (section 6.4). In areas of high magnetic response the sequence is present, and low where the sequence is absent. The response corresponds with a gravity high and structures evident in the magnetics data (see Figure 6.4).

Normally the variation in “texture“ of the magnetic image would suggest variations in rock lithology, however, in this case the “texture” is a function of the depth, thickness and deformation of the magnetic unit (in this case the ‘unit’ being Antrim Plateau Volcanics). The high frequency component (defined by the sun angle) of the magnetics response shows the greatest amount of information since there are few lateral variations in lithology, therefore, only structural features in the basalt are evident.

Areas of very little texture are interpreted to represent regions devoid of the volcanic sequence. This is reaffirmed by the seismic data, which indicates that the volcanics do not cover certain portions of the Proterozoic sediments Figure 4.5.

Information suggested from the seismic data indicates that, generally, the volcanics sequence is of a consistent thickness averaging 150 metres, but it has been shown to vary between 0 and 350 metres.

6.1.1 Linear Features

Structural features are dominated by regional faults with complementary NNW-SSE and NNE-SSW sets evident. The relationship to the present day drainage suggests that these faults occurred after the deposition of the Cretaceous units. The joint swarm is interpreted to have occurred prior to or during the deposition of the Cretaceous limestone since there is no surface expression of these features. The gamma response along Line 13 (Section 5.4) indicates the variation in the depth to the basalt, however, the depth to the top of the limestone is flat lying suggesting no deformation of these younger sediments.

The zone of linear features is interpreted to be due to the presence of joints, fractures and faults. Preferential weathering or syn-deformational alteration along these features has resulted in the reduction of magnetic mineral content and therefore lower magnetic response. It is expected that preferential weathering along these features, prior to deposition of more recent sediments, may have resulted in the increased depth to basalt. The presence of a palaeosol at the basalt/limestone interface, evident in drilling results, indicates the basalt was subject to weathering prior to limestone deposition.

6.1.2 A Conceptual Model of the Linear Magnetic Features

A conceptual model of a joint/fault is provided in Figure 6.1 with the calculated magnetic response. A section of the NTGS data was modelled with two tabular bodies. An estimate of the regional response was inferred from the trend in the line data. Depths to the tabular bodies is relative to the sensor height (in the case of the NTGS a flying height of 80 metres was used) with the following physical parameters:

- a negative magnetic susceptability (-0.004 SI units)
- a strike of 135 degrees (derived from the aeromagnetics images)
- an strike length of 100 km (centred on the modelled line data)
- a depth extent of 250 metres (estimated thickness of basalt from drilling and seismic data)
- a variable width of up to 1 km

The AGSO data has been modelled (Figure 6.2) using tabular bodies with depths relative to the sensor (in the case of the AGSO data a flying height of 150 metres was used) using the afore mentioned physical parameters.

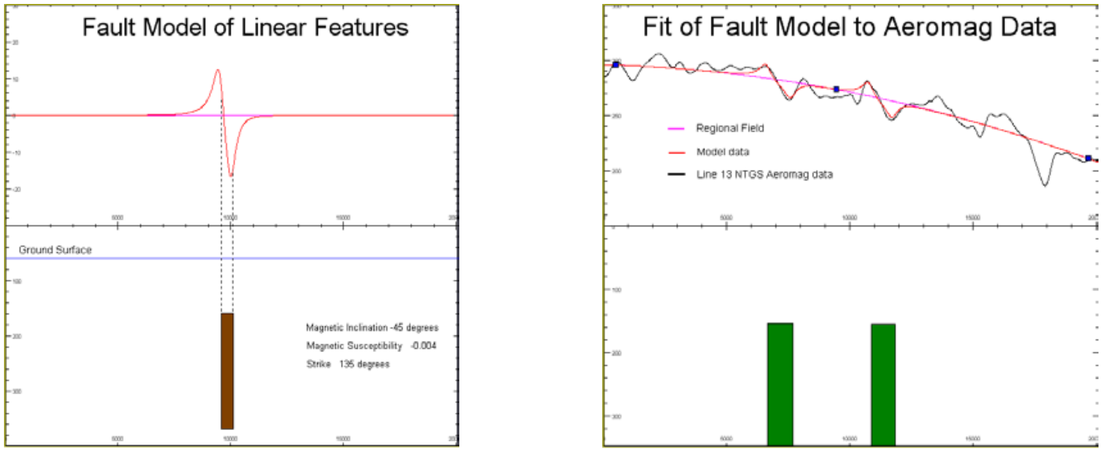


Figure 6.1: Fault model used to calculate the magnetic response seen in the NTGS aeromagnetics data of the Sturt Plateau magnetics data. The profile chainages increasing from south to north.

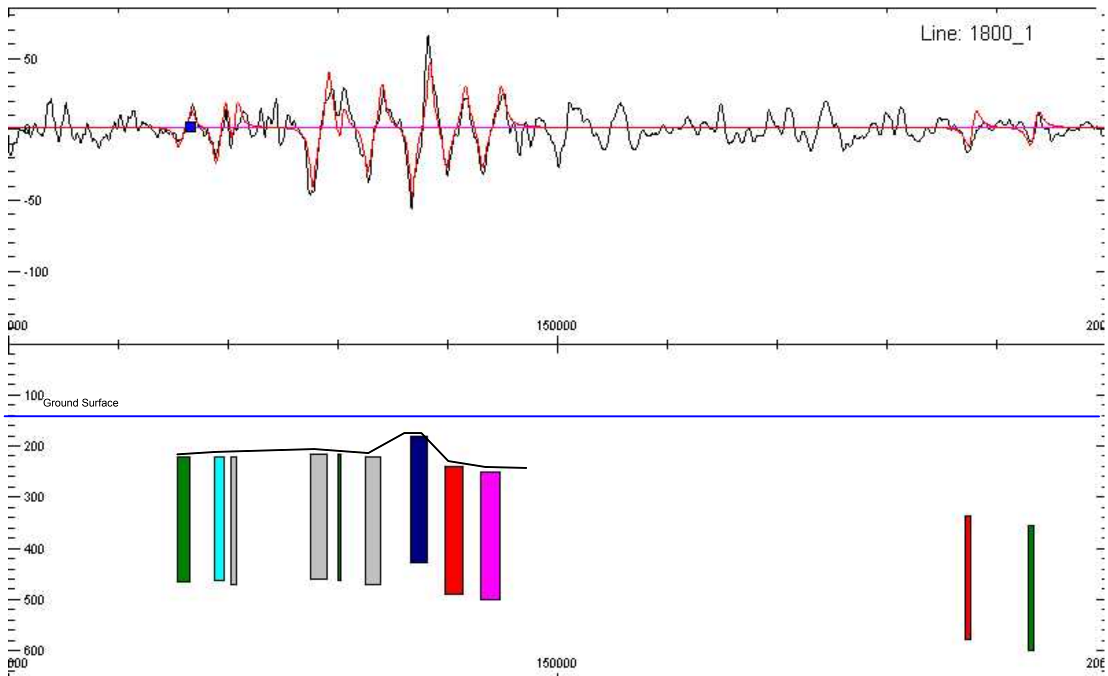


Figure 6.2: Interpreted model of linear features from AGSO aeromagnetics data of the Sturt Plateau magnetics data. The profile chainages increasing from south to north.

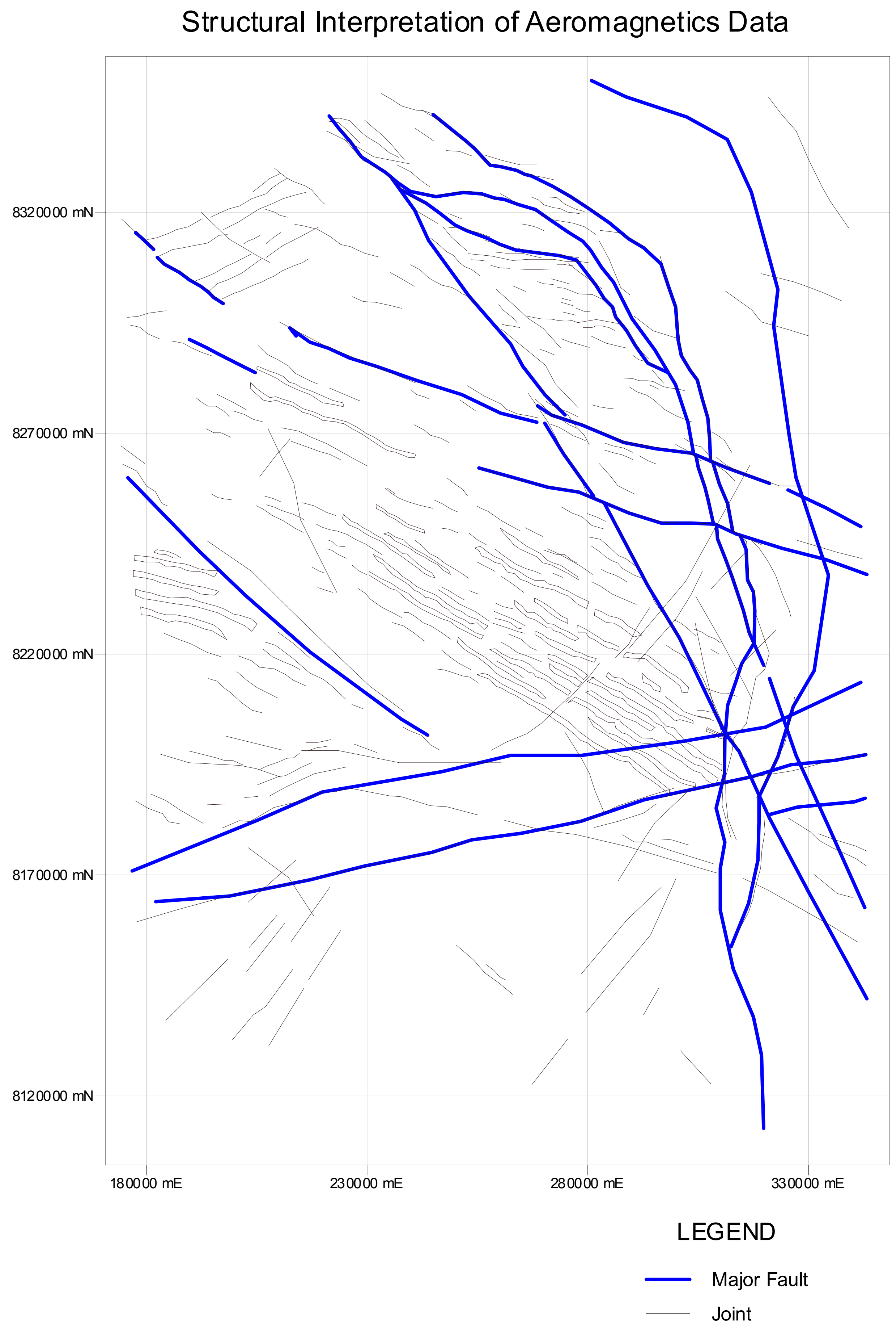


Figure 6.3 Structural interpretation of aeromagnetics data.

6.2 Airborne Magnetics and Ground magnetics

Correlation between ground and airborne magnetics data is quite close. Effects from near surface laterite are not evident in the magnetics data. However, gross features correlate well see Figure 6.4.

It is considered that much of the aeromagnetic data are in response to structures and the variation in depth to the relatively shallow basalt.

The localised signature observed from the ground data does not suggest that the features are due to variations in the thickness of the basalt, ie due to the basalt being extruded onto features such as dunes etc. Similarly the features can not be attributed to the difference in depth to the magnetic horizon since both these scenarios would result in relatively small fluctuations in the magnetic field compared to the variations in the observed response.

6.3 Joint VES/TEM and TEM Soundings

Contact electrical and electromagnetic sounding data was inconclusive for determining:

- the presence of water and
- reliable depth to basalt.

Data derived from the bore-hole conductivity method indicate that the presence of clay is the major contributor to the response measured by the electrical techniques.

6.3.1 Contact Electrical VES Interpretation

The electrical methods appear to define layering within the Cretaceous sediments. This would be expected, as this would has been shown to have the greatest resistivity variations in the profile.

6.3.2 SIROTEM Interpretation

The results from the Spiker Algorithm are compared to the gamma log data collected along Line 13 (Figure 5.4). It can be seen that the estimated depth of the basalt (defined by the occurrence of the pale to dark blue features at around 80-100 metres below the surface) is of the order of 5-20% greater than depth to the basalt defined by the gamma log data. This suggests that the EM data may provide regional variations in the depth to the basalt, however, reliable estimates of local variations in depth to basalt were not obtained. The variation in the difference between successful and non-prospective areas is of this order magnitude.

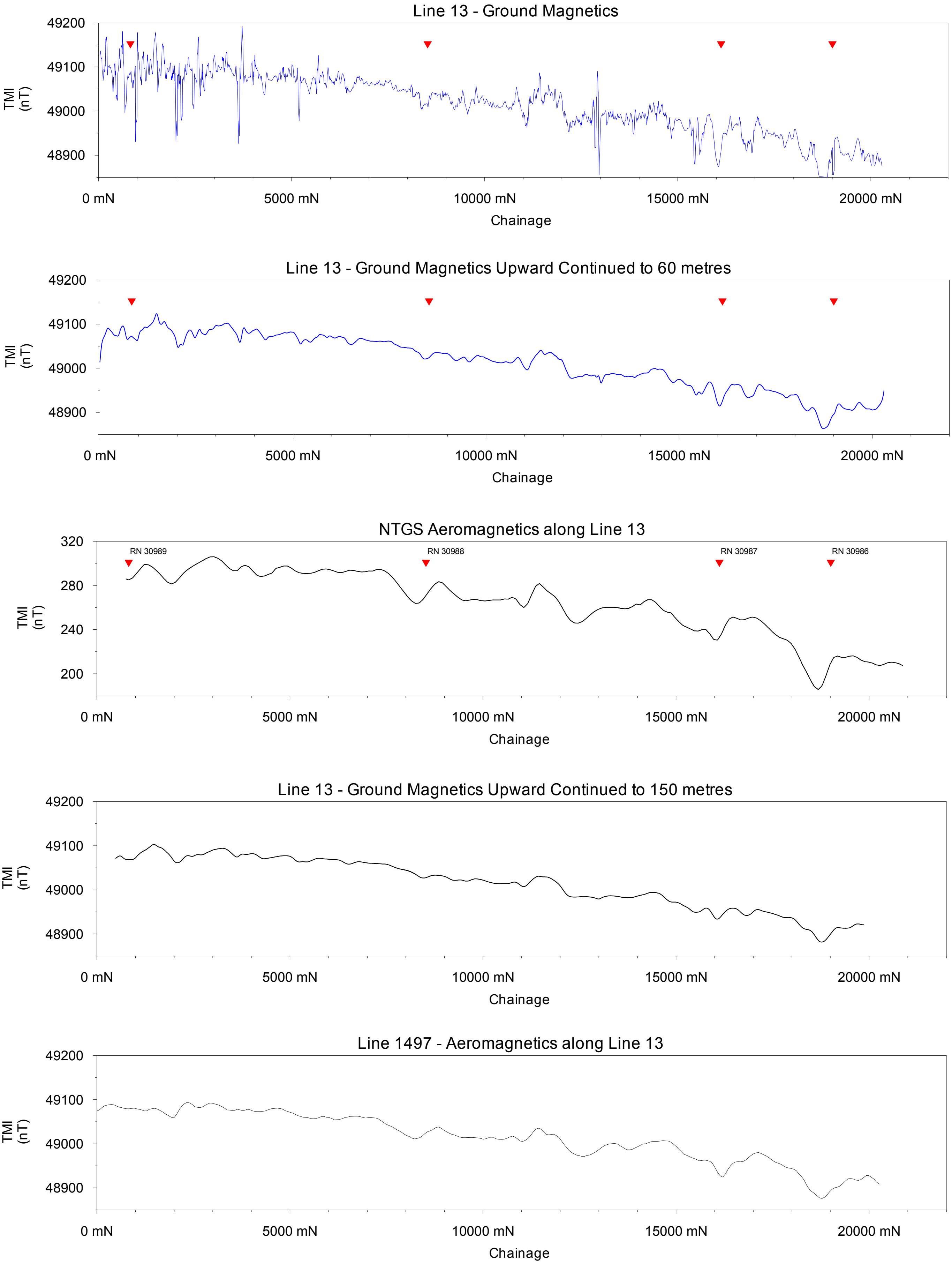


Figure 6.4 Airborne magnetics vs ground magnetics

6.4 BMR Gravity

The gravity data was expected to mirror the variation in depth to the basalt (lavas/basalt generally having a higher density than sedimentary rocks). The response, however, is interpreted to be due to the depth to the sediments underlying the Antrim Volcanics and Limestone units.

The limestone and volcanic sequences are thought to be of similar densities relative to the Archaean sediments (2.7 c.f. 2.3). The negative density contrast expected would produce the responses observed.

The shallow sandstone associated with the horst or antiform fold like structure would produce a bouguer low in this region in response to a thinner section of limestone and volcanics overlying it and the proximity of the sandstone to the surface.

Seismic data correlates with the gravity data, that is the two way travel time to the Archaean markers is much shorter at the gravity low.

A comparison of the gravity data with the structural interpretation of the aeromagnetics data show the structures “wrapping” around the gravity high in the southern portion of the Sturt Plateau Figure 6.5.

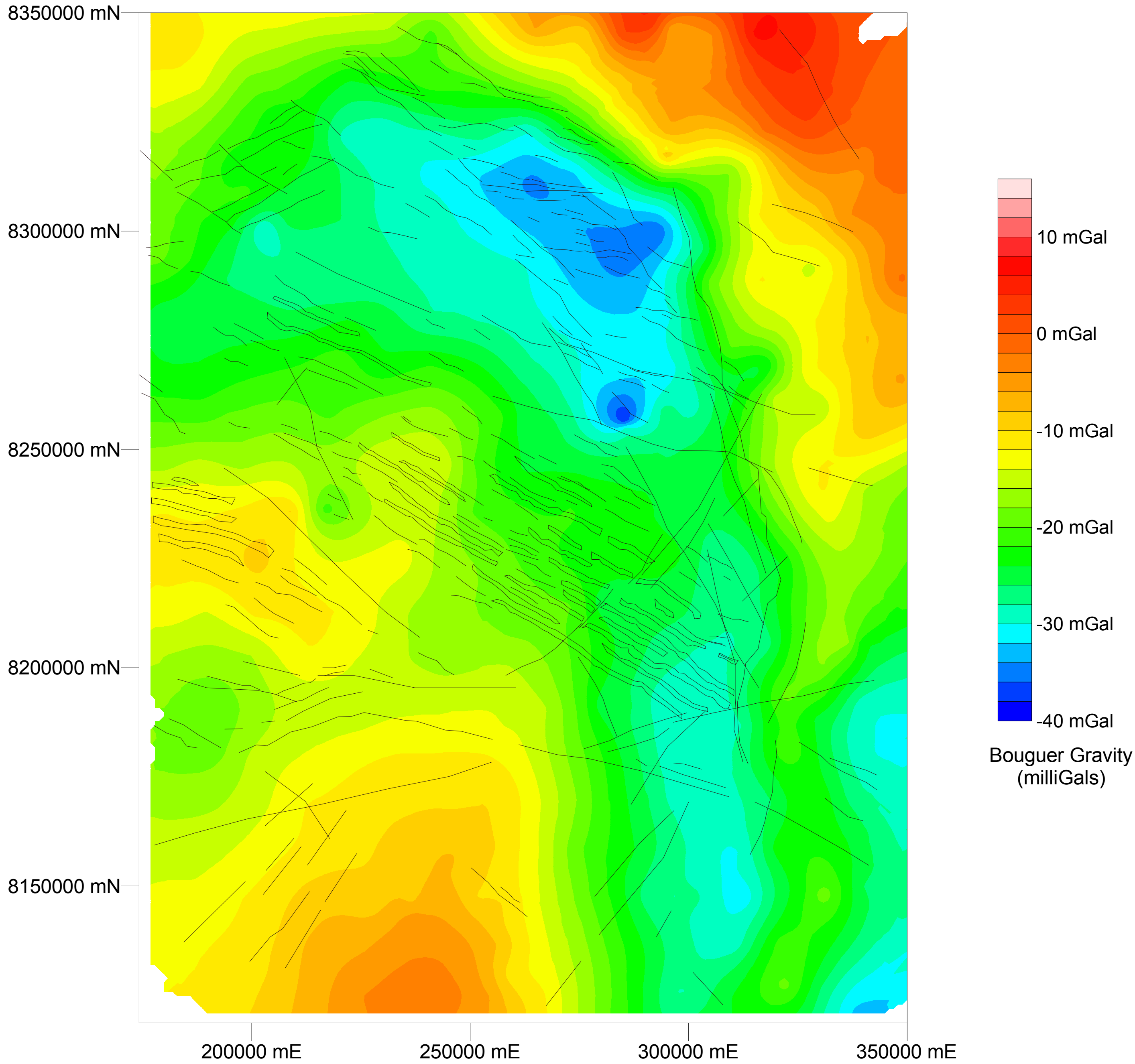


Figure 6.5 Bouguer Gravity compared with aeromagnetics structural interpretation

7.0 Assessment of Geophysical Techniques

7.1 Airborne Magnetics and Ground Magnetics

7.1.1 AGSO Data Coverage

In terms of delineating prospective targets for ground water, the magnetics method has been found to be the most useful. The majority of the Sturt Plateau has been covered with regional AGSO magnetics, and although the data is very coarse (1600 metre line spacing), is a useful tool for locating areas for follow up work with ground magnetics.

7.1.2 NTGS Detailed Data Coverage

Areas covered by the 2001 NTGS data is of greater detail and have a higher degree of reliability in position. This data could be used directly for determining drill sites, however, locating the corresponding site on the ground will require GPS positioning. Accurate location of features on the ground may still require ground magnetics to be completed.

7.2 Electrical Methods (Resistivity and Electromagnetics)

7.2.1 Contact Electrical Methods

It was found that the electrical methods were poor at delineating the depth to basalt or the presence of groundwater.

No consistent results were obtained from modeling, that is, no resistivity parameter were determined as being typical for the basalt layer, thus depth estimates were considered unreliable. Similarly there was a high variability in the resistivities in the rest of the geoelectrical section suggesting that the presence of water can not be discriminated by sounding data.

7.2.2 Electromagnetic Methods

Results of Sirotem profiling along Line 13 (section 5.3.1 and Figure 5.4) demonstrate that the EM profiling with appropriate processing and analysis can provide some information concerning the depth to basalt. The information gained from the technique is, however, not worth the effort required to obtain the data. This in conjunction with the processing required makes the EM method unsuitable and non-cost effective.

7.3 Seismic Reflection and Refraction

The seismic methods appear to have been successful in delineating the various sequences of interest in the Sturt Plateau, however, the prohibitive cost of these surveying methods makes them unlikely to be a regularly utilised.

7.4 Gravity

The regional gravity data provides insight into the regional structures and lithology of the basement. The gravity high to the south is interpreted to be due to a deep seated feature in the basement and is also evident in the magnetics data. The poor density contrast between the basalt and the overlying sediments means that the technique is unsuitable for defining localised variations in the depth to the basalt.

8.0 CONCLUSIONS

The correlation of geophysical methods with geological information has resulted in the the following conclusions:

- Although largely a tool of qualitative nature the Total Magnetic Intensity data can provide valuable information as to where "drilling dollars" would most effectively be spent.
- The magnetics data (both airborne and ground) can be used to define regions where there is greater depth to the basalt, which, can be related to increased limestone submergence. This, however, does not define areas with increased secondary porosity, which, is also needed to produce adequate water supplies.
- Bore hole methods provided detailed stratigraphic information, particularly useful when drill cutting returns are poor or nil due to loss of circulation. Stratigraphic correlation across the study area has also been possible using marker horizons.
- TEM and resistivity data has limited use, owing to the poor resistivity contrast between the aquifer material and the underlying basalt. It does, however, provide information about the thickness of the Cretaceous material overlying the limestone.
- The seismic method (reflection and refraction), although costly to implement may provide the most detailed information concerning the stratigraphy (and thus the depth to the basalt) of the Sturt Plateau.

9.0 RECOMMENDATIONS

Recommendations from the outcomes of the study undertaken are as follows:

- Targeting of prospective features using the airborne magnetics data and locating the feature on the ground using ground magnetics.
- The flight line profile data from the high resolution airborne magnetics survey can be used directly to define prospective sites as it has been located more reliably and has been collected at a relatively high density and low flying height (80 metres above ground level). Data may be obtained from the NTGS.
- Gamma logging of all drilled bores, especially when loss of circulation is to be expected. This is to determine if basalt has been encountered and to determine the interval of the limestone.
- Further work using the seismic refraction technique is suggested, especially since this is likely to provide direct information about the depth to the basalt. The amount of submergence may also be inferred if the depth of the local water table is known.

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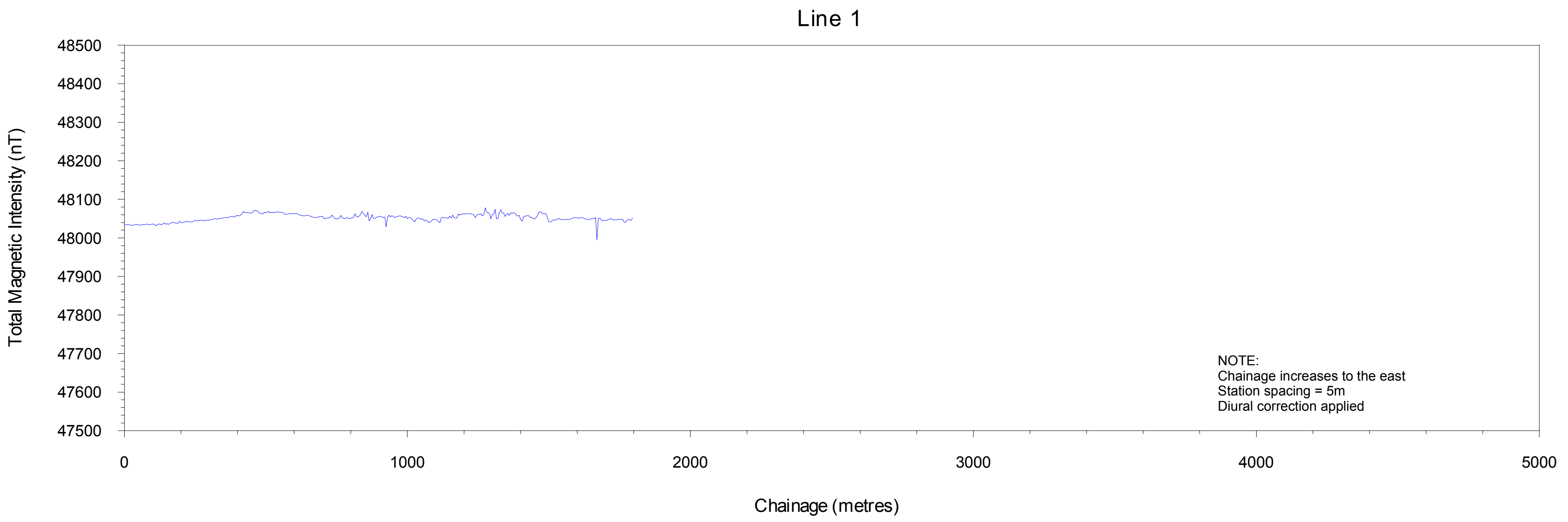
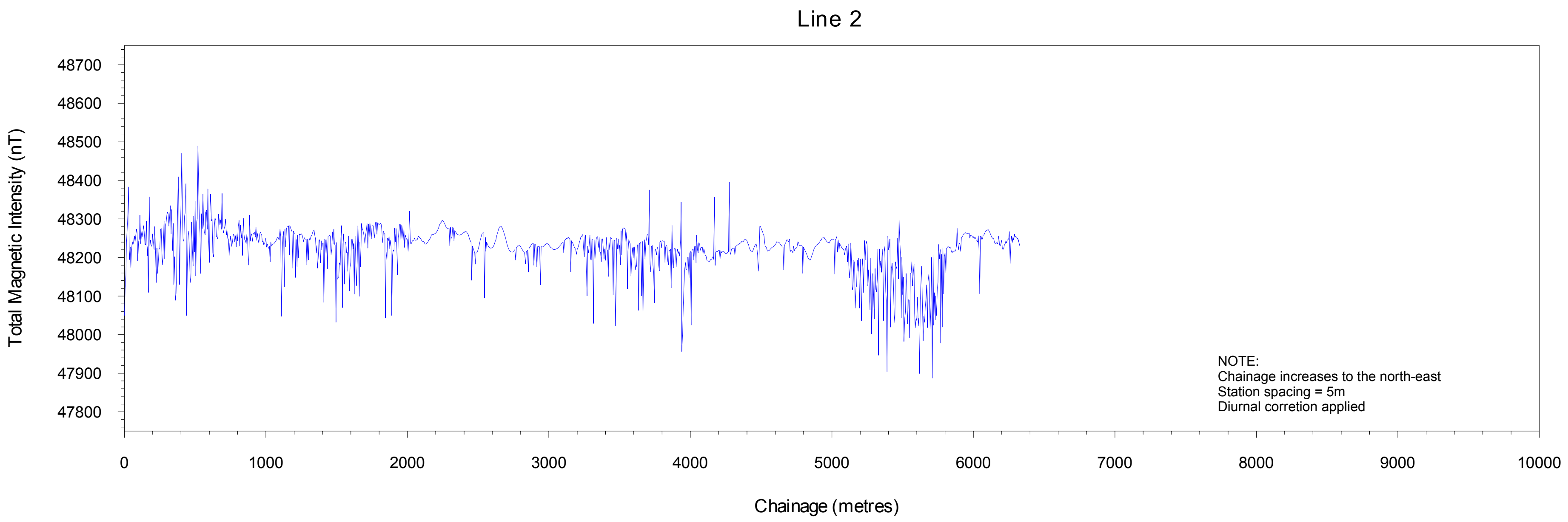
Appendix A

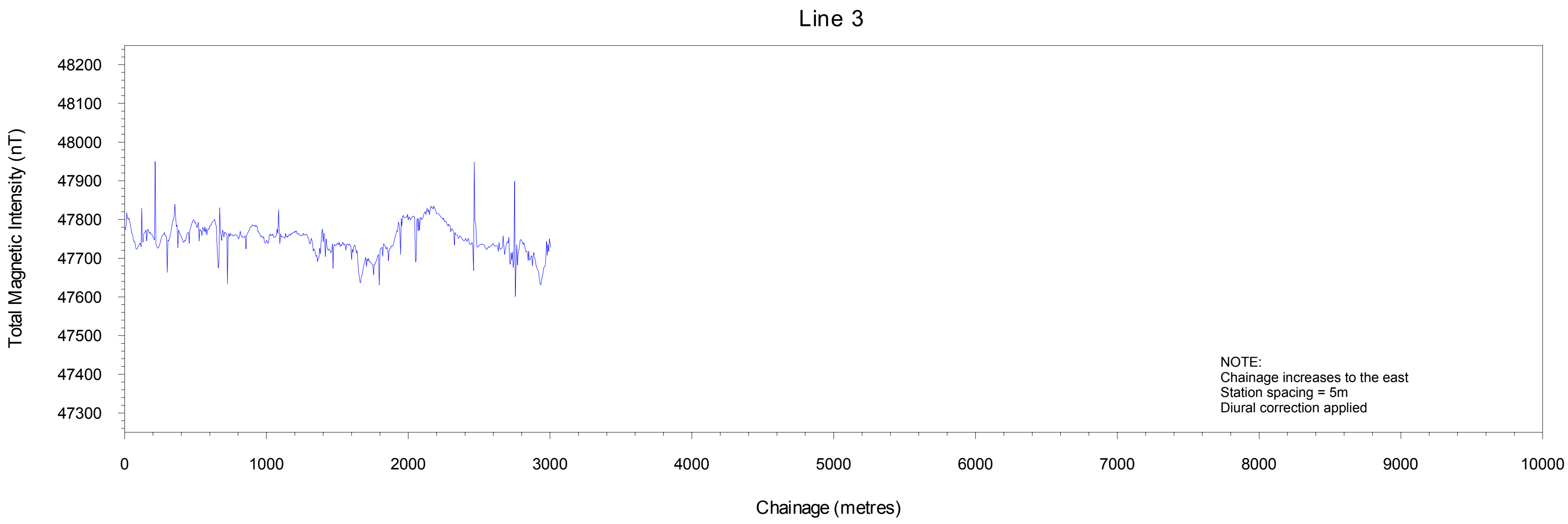
Ground Magnetics Profiles

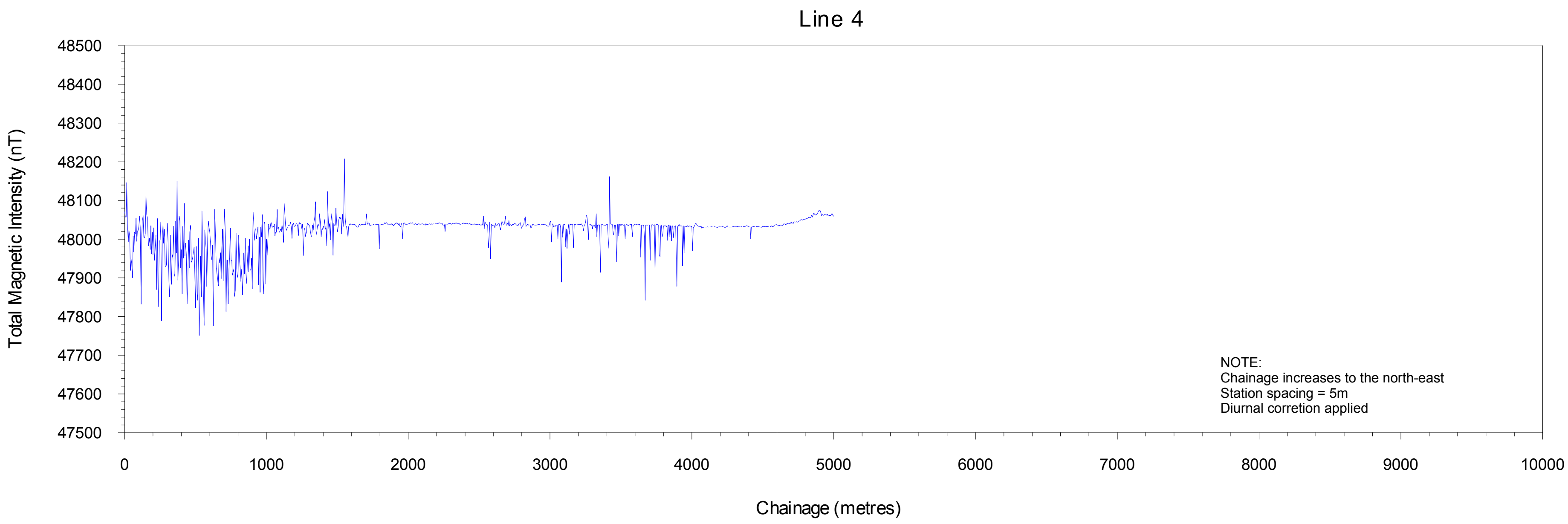


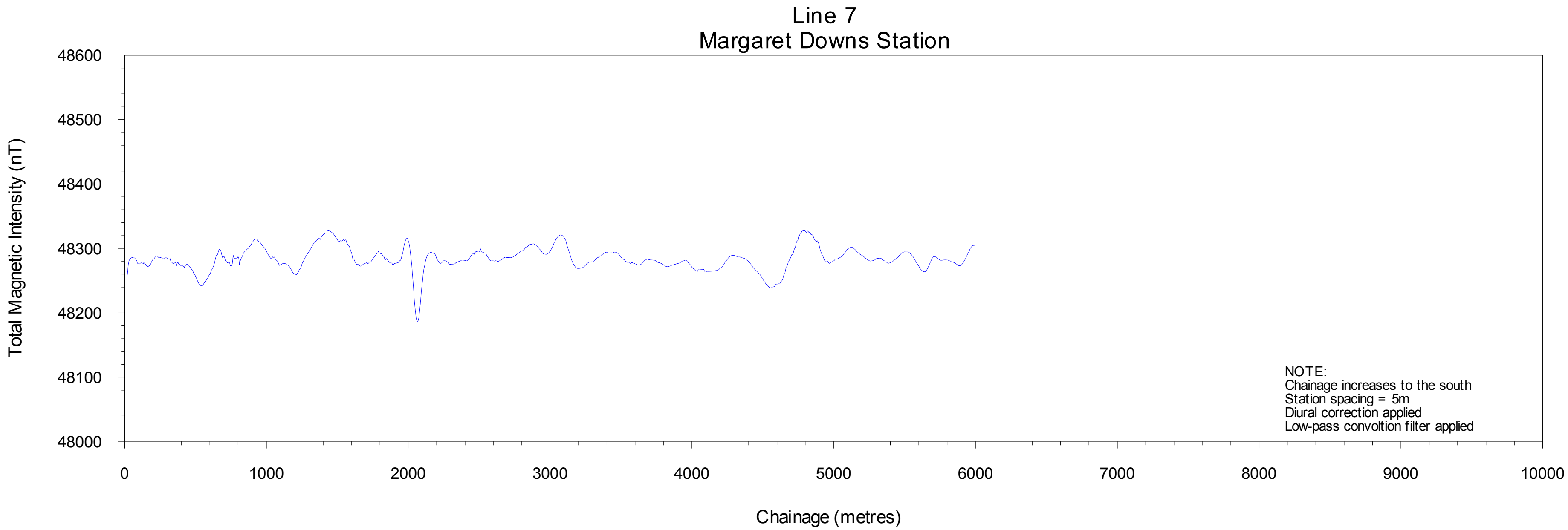
Line 1
Total Magnetic Intensity (nT)
48500
48400
48300
48200
48100
48000
47900
47800
47700
47600
47500
0
1000
2000
3000
4000
5000
Chainage (metres)
NOTE:
Chainage increases to the east
Station spacing = 5m
Diural correction applied

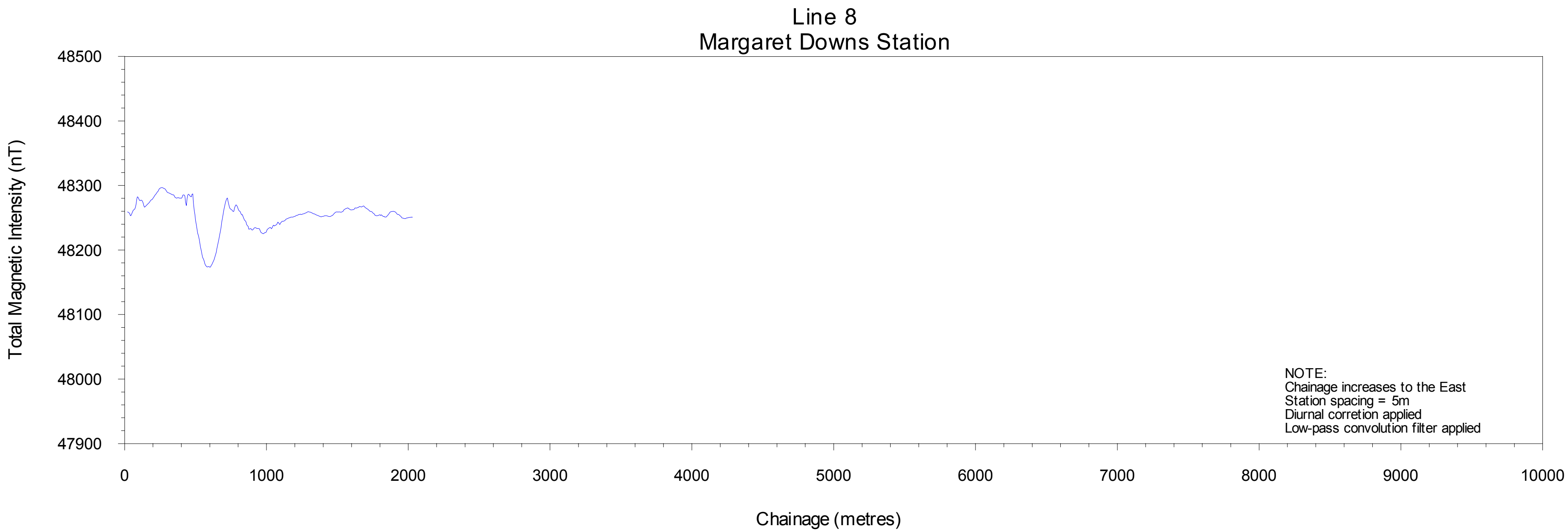


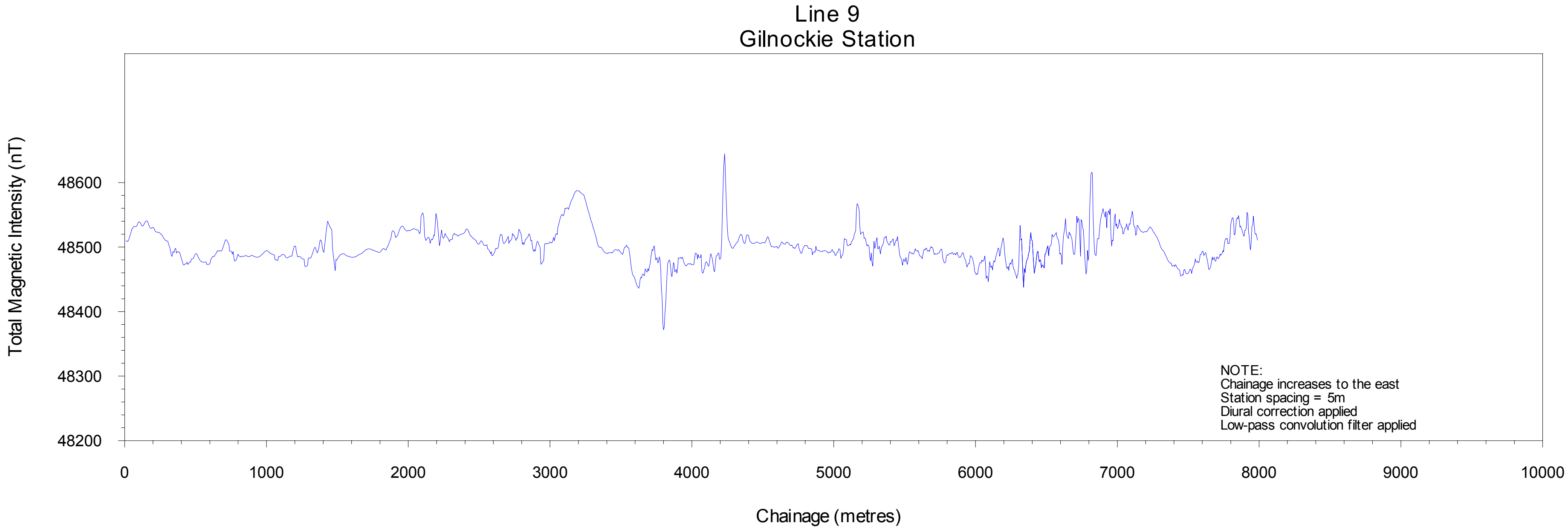
Line 2
Total Magnetic Intensity (nT)
48700
48600
48500
48400
48300
48200
48100
48000
47900
47800
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Chainage (metres)
NOTE:
Chainage increases to the north-east
Station spacing = 5m
Diurnal corretion applied

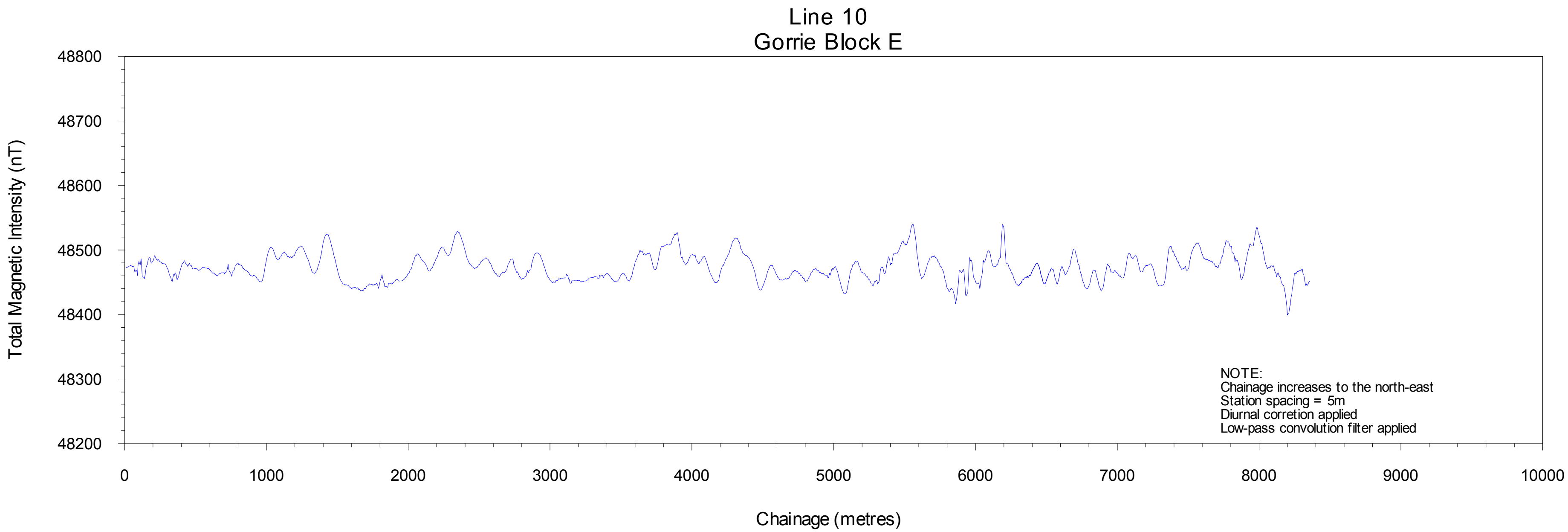

Line 3
Total Magnetic Intensity (nT)
48200
48100
48000
47900
47800
47700
47600
47500
47400
47300
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Chainage (metres)
NOTE:
Chainage increases to the east
Station spacing = 5m
Diural correction applied

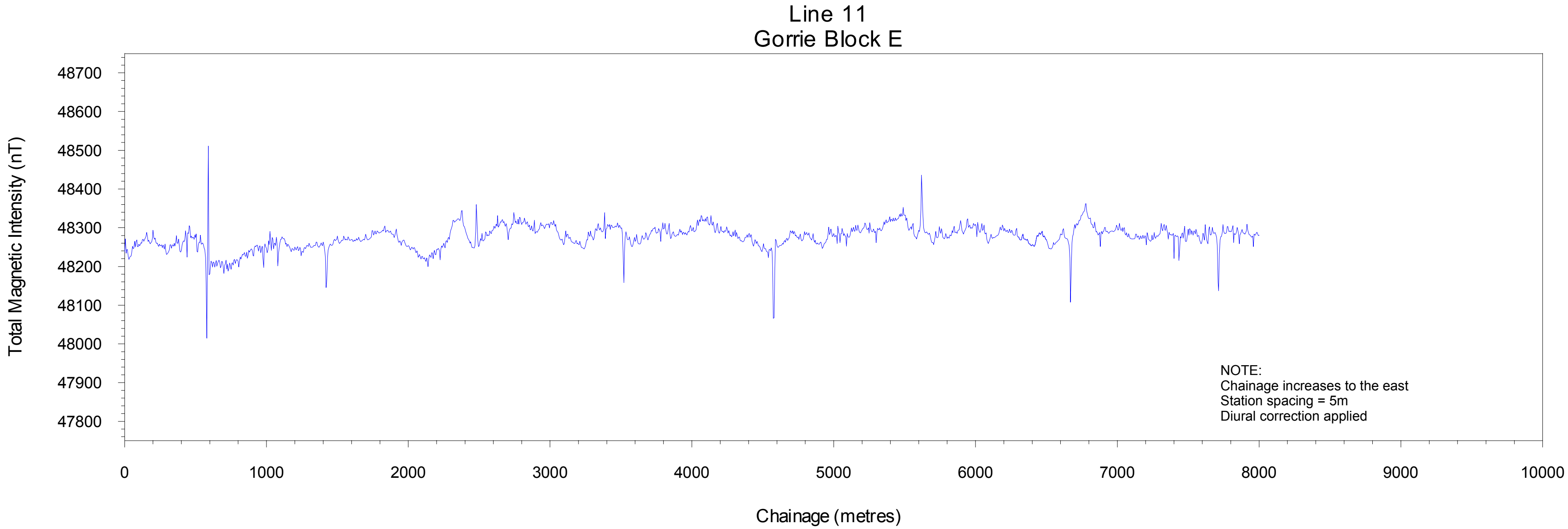

Line 4
Total Magnetic Intensity (nT)
48500
48400
48300
48200
48100
48000
47900
47800
47700
47600
47500
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Chainage (metres)
NOTE:
Chainage increases to the north-east
Station spacing = 5m
Diurnal corretion applied


Line 7
Margaret Downs Station
Total Magnetic Intensity (nT)
48600
48500
48400
48300
48200
48100
48000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Chainage (metres)
NOTE:
Chainage increases to the south
Station spacing = 5m
Diural correction applied
Low-pass convoltion filter applied

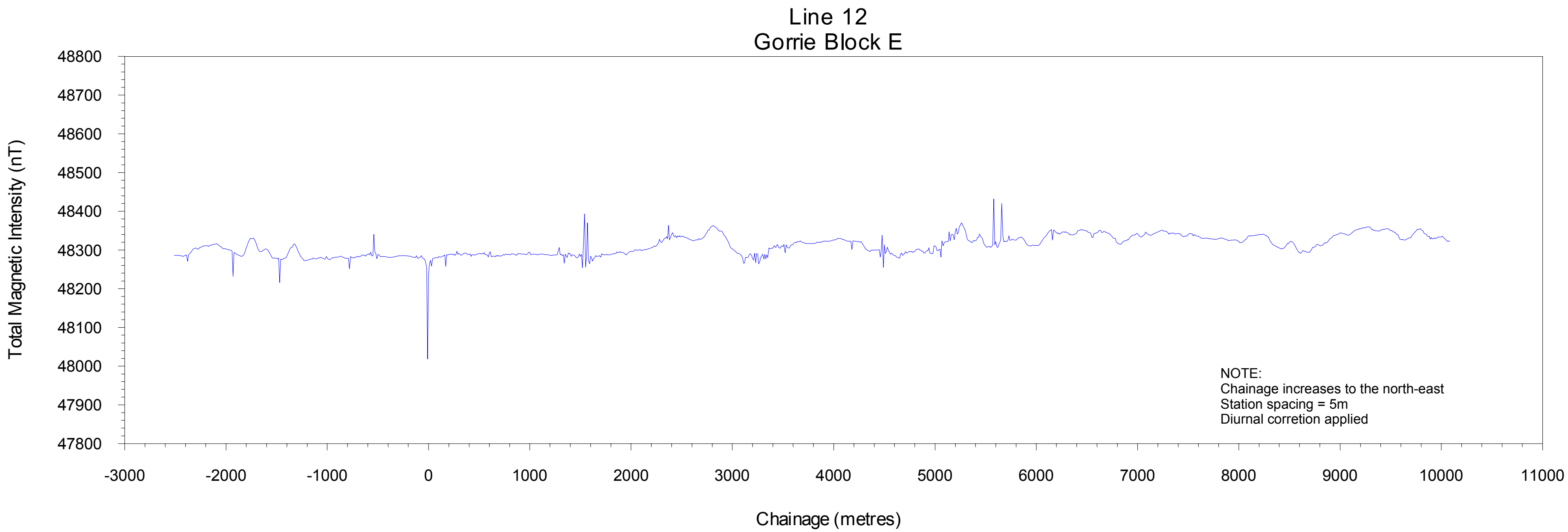

Line 8
Margaret Downs Station
Total Magnetic Intensity (nT)
48500
48400
48300
48200
48100
48000
47900
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Chainage (metres)
NOTE:
Chainage increases to the East
Station spacing = 5m
Diurnal corretion applied
Low-pass convolution filter applied


Line 9
Gilnockie Station
Total Magnetic Intensity (nT)
48600
48500
48400
48300
48200
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Chainage (metres)
NOTE:
Chainage increases to the east
Station spacing = 5m
Diural correction applied
Low-pass convolution filter applied

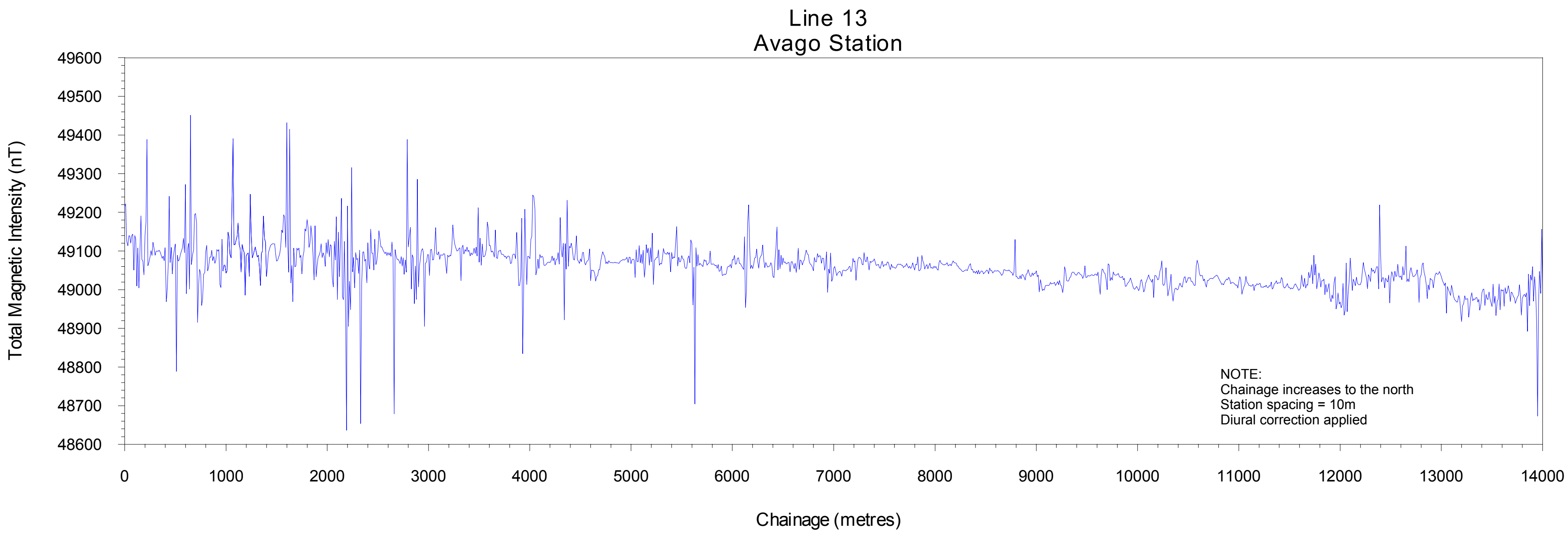

Line 10
Gorrie Block E
Total Magnetic Intensity (nT)
48800
48700
48600
48500
48400
48300
48200
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Chainage (metres)
NOTE:
Chainage increases to the north-east
Station spacing = 5m
Diurnal corretion applied
Low-pass convolution filter applied

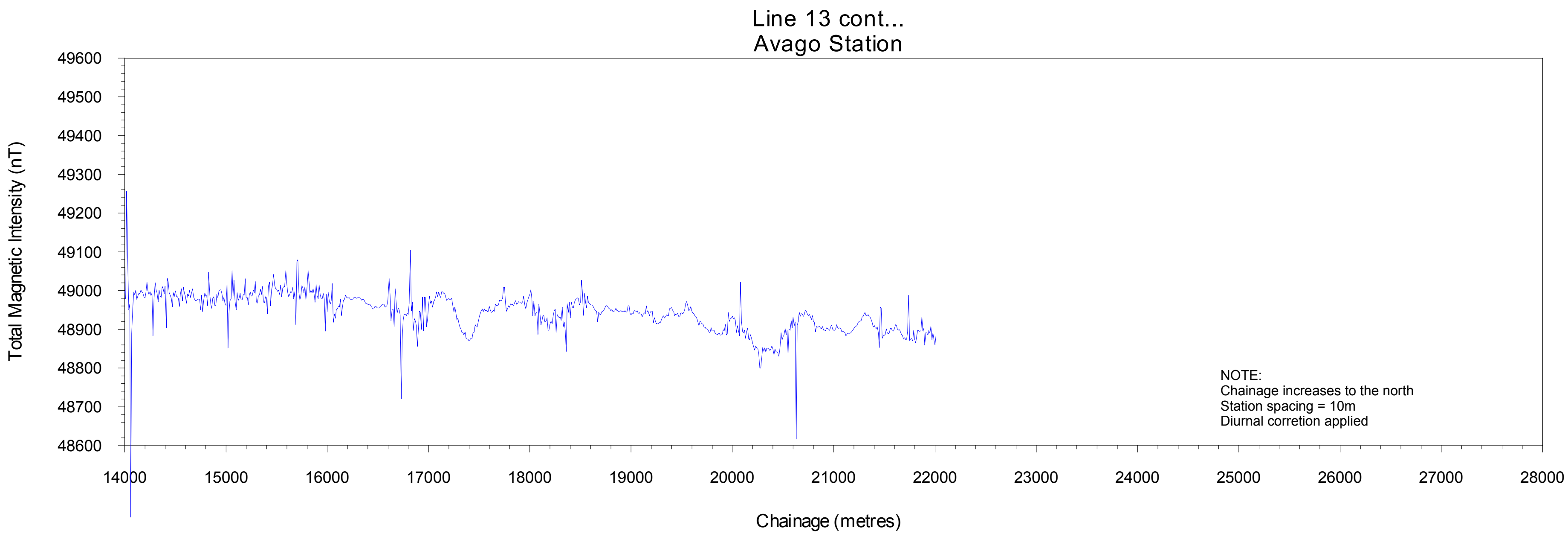


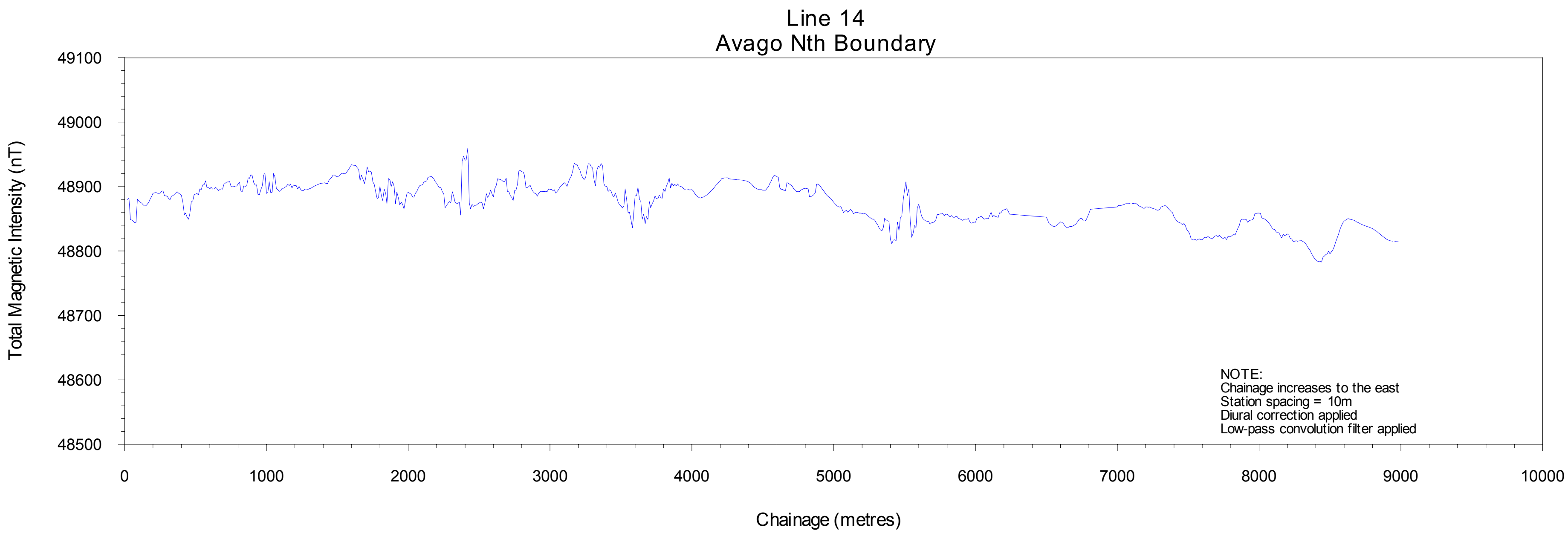
Line 11
Gorrie Block E
Total Magnetic Intensity (nT)
48700
48600
48500
48400
48300
48200
48100
48000
47900
47800
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Chainage (metres)
NOTE:
Chainage increases to the east
Station spacing = 5m
Diural correction applied

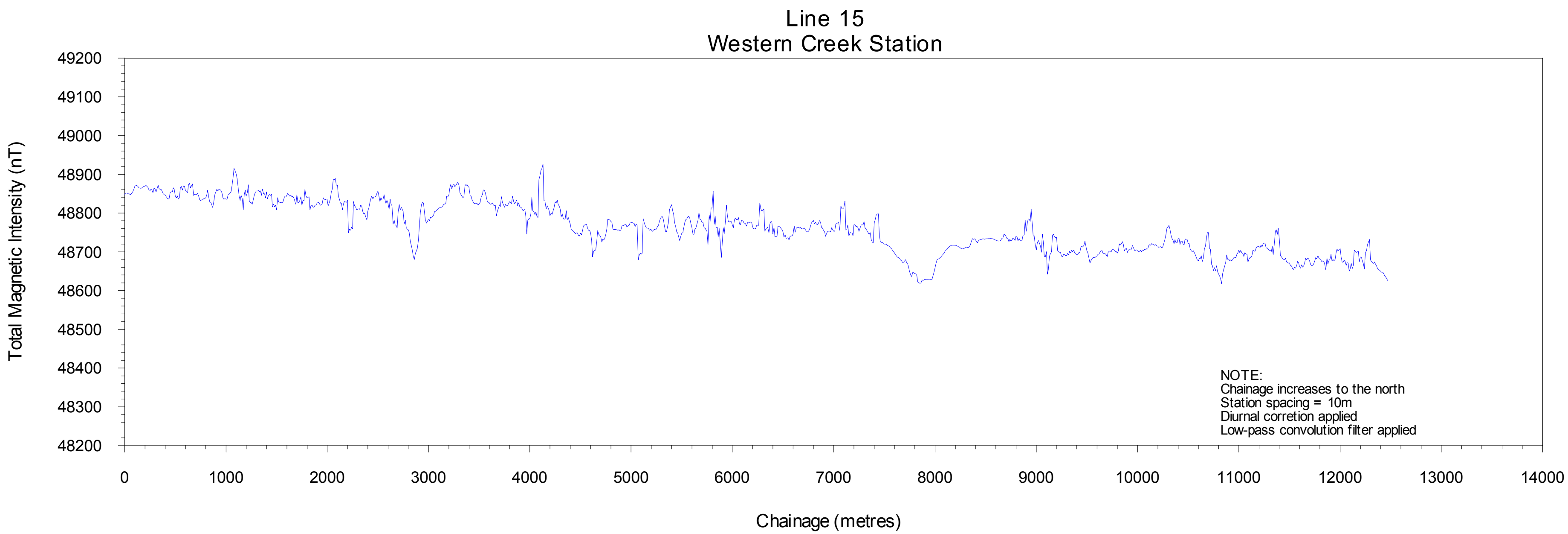


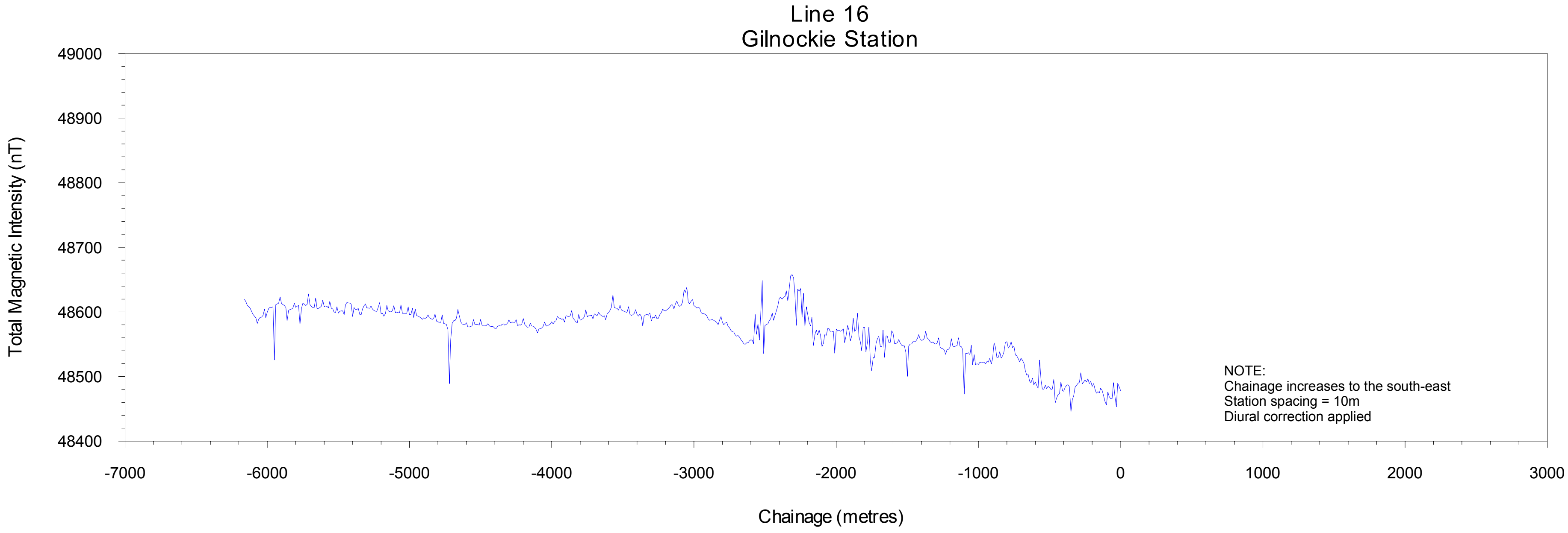
Line 12
Gorrie Block E
Total Magnetic Intensity (nT)
48800
48700
48600
48500
48400
48300
48200
48100
48000
47900
47800
-3000
-2000
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
Chainage (metres)
NOTE:
Chainage increases to the north-east
Station spacing = 5m
Diurnal corretion applied

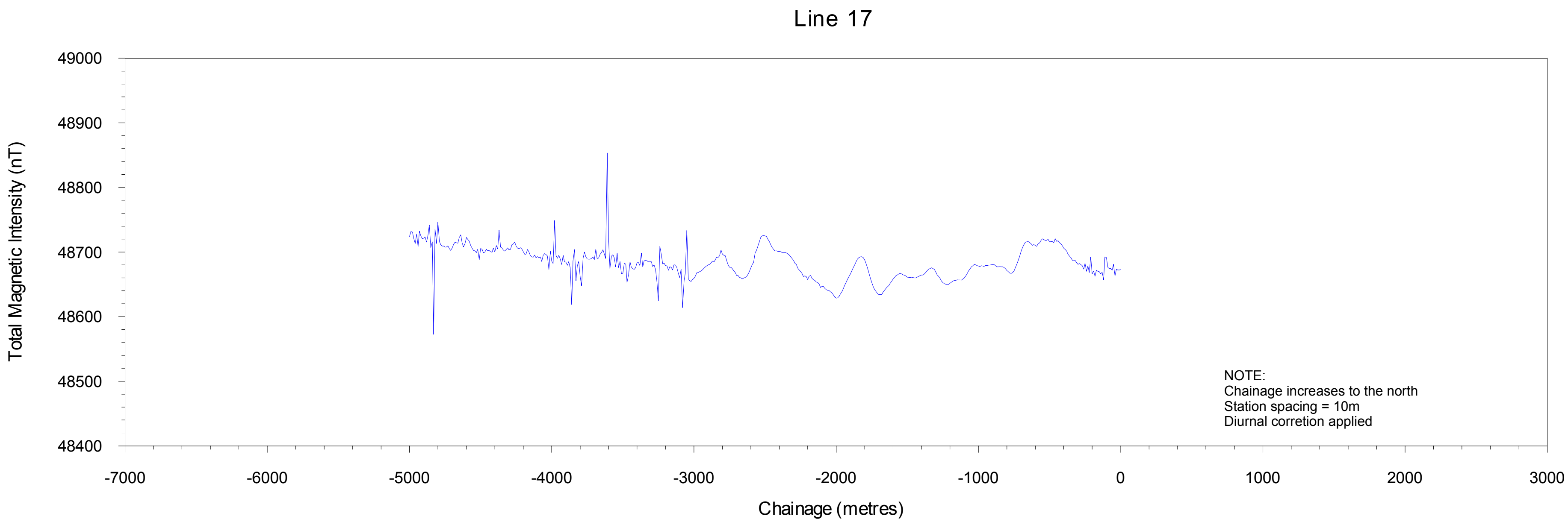

Line 13
Avago Station
Total Magnetic Intensity (nT)
49600
49500
49400
49300
49200
49100
49000
48900
48800
48700
48600
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
Chainage (metres)
NOTE:
Chainage increases to the north
Station spacing = 10m
Diural correction applied


Line 13 cont...
Avago Station
Total Magnetic Intensity (nT)
49600
49500
49400
49300
49200
49100
49000
48900
48800
48700
48600
14000
15000
16000
17000
18000
19000
20000
21000
22000
23000
24000
25000
26000
27000
28000
Chainage (metres)
NOTE:
Chainage increases to the north
Station spacing = 10m
Diurnal coretion applied

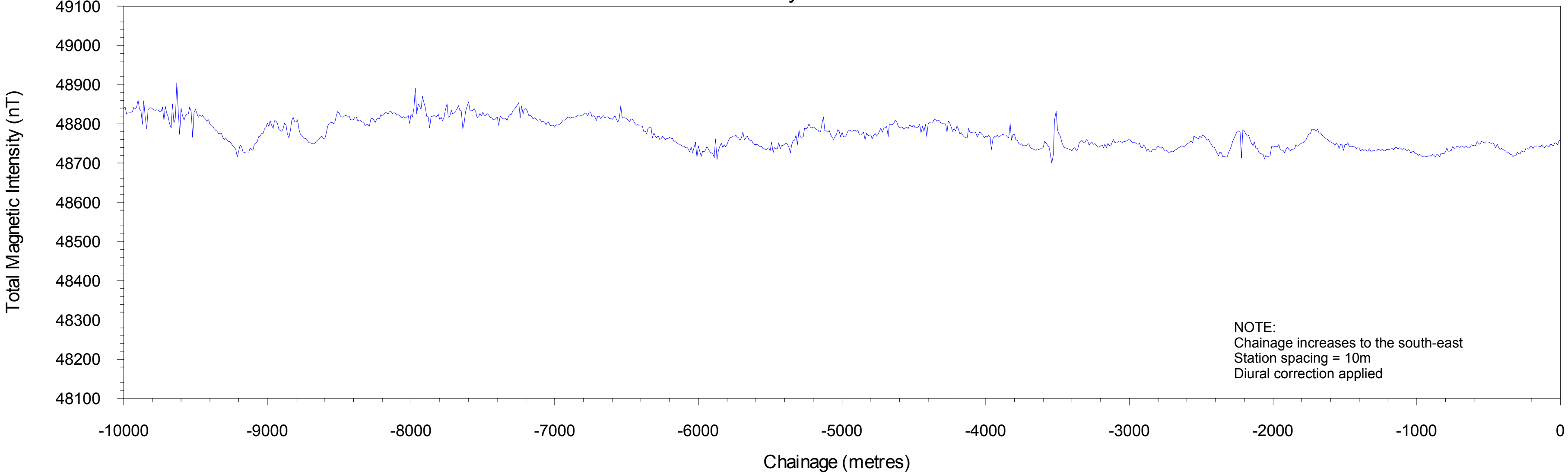

Line 14
Avago Nth Boundary
Total Magnetic Intensity (nT)
49100
49000
48900
48800
48700
48600
48500
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Chainage (metres)
NOTE:
Chainage increases to the east
Station spacing = 10m
Diural correction applied
Low-pass convolution filter applied


Line 15
Western Creek Station
Total Magnetic Intensity (nT)
49200
49100
49000
48900
48800
48700
48600
48500
48400
48300
48200
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
Chainage (metres)
NOTE:
Chainage increases to the north
Station spacing = 10m
Diurnal corretion applied
Low-pass convolution filter applied

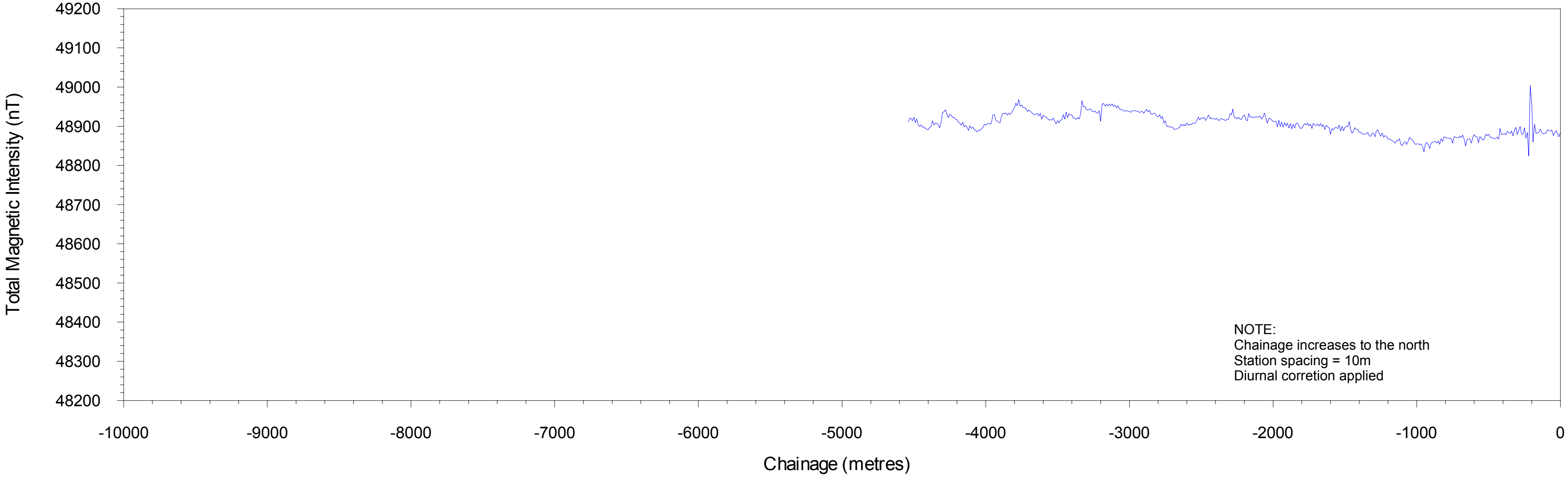

Line 16
Gilnockie Station
Total Magnetic Intensity (nT)
49000
48900
48800
48700
48600
48500
48400
-7000
-6000
-5000
-4000
-3000
-2000
-1000
0
1000
2000
3000
Chainage (metres)
NOTE:
Chainage increases to the south-east
Station spacing = 10m
Diural correction applied


Line 17
Total Magnetic Intensity (nT)
49000
48900
48800
48700
48600
48500
48400
-7000
-6000
-5000
-4000
-3000
-2000
-1000
0
1000
2000
3000
Chainage (metres)
NOTE:
Chainage increases to the north
Station spacing = 10m
Diurnal coretion applied

Line 18
Sunday Creek Station



Line 19



Appendix B

Electrical Sounding Locations

Sounding No.	Easting (metres)	Northing (metres)	Sounding Type	Location	
Sounding 1	284977	8170468	TEM	Hidden Valley Station	RN 27341
Sounding 2	284860	8187200	TEM	Hidden Valley Station	4km's S. of RN27340
Sounding 3	292707	8173077	TEM	Hidden Valley Station	
Sounding 4	265140	8184970	Joint	Hidden Valley Station	150m W RN1982
Sounding 5	239966	8144350	TEM	Murranji Stock Route	150m N RN588
Sounding 6	305350	8187026	TEM	Kalala Boundary	
Sounding 7	305340	8192801	TEM	Kalala Boundary	
Sounding 8	300240	8211350	Joint	Sunday Creek Station	RN 21783
Sounding 9	288656	8212243	Joint	Sunday Creek Station	RN 8513
Sounding 10	300030	8213523	Joint	Sunday Creek Station	RN 21759
Sounding 11	300064	8214882	Joint	Sunday Creek Station	RN 21780
Sounding 12	301020	8226673	Joint	Sunday Creek Station	RN 8514
Sounding 13	215063	8251359	Joint	Gilnockie Station	
Sounding 14	296171	8212429	Joint	Sunday Creek Station	RN 21117
Sounding 15	305239	8205541	TEM	Sunday Creek Station	
Sounding 16	206547	8244102	Joint	Gilnockie Station	RN 26546
Sounding 17	215095	8260654	Joint	Gilnockie Station	1300m LINE 2 MAG
Sounding 18	226755	8233289	Joint	Gilnockie Station	RN 26549
Sounding 19	215262	8253911	Joint	Gilnockie Station	1200m LINE 1 MAG
Sounding 20	219952	8257468	Joint	Gilnockie Station	750mE LINE 4 MAG
Sounding 21	309550	8275150	TEM	Larrimah Stuart H'way	RN 28082
Sounding 22	304933	8274621	TEM	Larrimah Western Ck.	RN 24616 600m NE
Sounding 23					
Sounding 24					
Sounding 25					
Sounding 26	260000	8337250	Joint		
Sounding 27	265000	8337275	Joint		
Sounding 28	269375	8338500	Joint		
Sounding 29	268000	8312875	Joint		
Sounding 30	275875	8319375	Joint		
Sounding 31	275875	8310750	Joint		
Sounding 32	317250	8253500	Joint	Maryfield	
Sounding 33	324250	8251875	Joint	Maryfield	
Sounding 34	328500	8251125	Joint	Maryfield	
Sounding 35	332500	8250438	Joint	Maryfield	
Sounding 36	336500	8249750	Joint	Maryfield	
Sounding 46	261398	8328086	TEM	Lakefield	
Sounding 47	261245	8329100	TEM	Lakefield	
Sounding 48	260994	8330242	TEM	Lakefield	
Sounding 49	260830	8331240	TEM	Lakefield	
Sounding 50	260628	8332318	TEM	Lakefield	
Sounding 51	260433	8333378	TEM	Lakefield	

Sounding 52	260237	8334439	TEM	Lakefield
Sounding 53	260042	8335499	TEM	Lakefield
Sounding 54	259846	8336560	TEM	Lakefield
Sounding 55	259651	8337620	TEM	Lakefield
Sounding 56	192100	8275840	TEM	Margaret Downs
Sounding 57	194490	8295706	TEM	Margaret Downs
Sounding 58	199250	8294620	TEM	Margaret Downs
Sounding 59	203750	8293680	TEM	Margaret Downs
Sounding 60	208350	8292870	TEM	Larrizona
Sounding 61	212870	8292900	TEM	Larrizona
Sounding 62	215865	8292360	TEM	Larrizona
Sounding 63	219380	8289117	TEM	Larrizona
Sounding 64	222570	8287270	TEM	Larrizona

NOTE: Coordinates in AGD66 Zone 53