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A PRELIMINARY INTERPRETATION

of the

AMADEUS BASIN AEROMAGNETIC SURVEY

OP 236, N.T.

for

SYDNEY OIL COMPANY (ARUNTA) PTY LTD

27th March, 1985

GEOSPEX ASSOCIATES PTY LTD

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

An aeromagnetic survey of OP 236, N.T. was flown by Geometrics International Corp. in late 1984 using the transverse gradiometer system. The primary objective of the survey was to map structures associated with the volcanic member of the Bitter Springs Formation. A secondary objective was to locate shallow noise zones that might be associated with magnetite reduction over a buried petroleum reservoir.

Regional residual analysis of the magnetic data was successful in extracting information pertinent to three different levels of magnetic sources. Shallow sources are believed to be ironstone units that are conformable with the older sedimentary units. These have allowed mapping of anticline and syncline axes below the extensive sand dune cover. Intermediate depth anomalies are associated with a volcanic member of the Bitter Springs Formation while the deepest anomalies are believed to be caused by crustal deformations.

1.0 INTRODUCTION

A preliminary interpretation of the 1984 Amadeus Basin aeromagnetic survey of OP 236, N.T. for Sydney Oil Company (Arunta) Pty Ltd has been prepared at the request of Mr R. Schroder. The aeromagnetic survey was flown to assist with the mapping of structure and estimation of sediment thickness above the magnetic unit of the Bitter Springs formation.

Geospex Associates Pty Ltd has prepared a preliminary interpretation report on the data from this survey, and integrated the available regional gravity data. To assist the interpretation, the magnetic data has been processed to enhance the characteristics of shallow magnetic sources and the Bitter Springs Formation. Regional residual analysis of the Bouguer gravity data has also been performed to help improve the interpretation of this data.

Detailed interactive computer modelling has been performed on several aeromagnetic lines to assist with the mapping of the volcanic horizon within the Bitter Springs Formation. Werner deconvolution processing was also applied to all magnetic profiles to help with depth estimates to the Bitter Springs formation.

Information supplied for the purpose of this interpretation includes the following:

- Located data tape of raw magnetic data
- BMR gravity data base of Australia
- 1:100,000 magnetic contour map (Geometrics)
- 1:100,000 stacked profile map (Geometrics)
- 1:250,000 geology sheets for
  - Henbury (1965)
  - Lake Amadeus (1968)
- 1:250,000 Aeromagnetic map (BMR regional survey)

The interpretation was prepared at the scale of 1:250,000 because the geology and regional magnetic surveys were plotted at that scale. Due to the dominant regional magnetic gradient, the 1:100,000 scale magnetic contour maps and stacked profiles were of little assistance in this interpretation. These were also not supplied until late in the project. The majority of information has been derived from maps created from the located data tape.

2.0 AEROMAGNETIC SURVEY SPECIFICATIONS

A high resolution magnetic gradiometer survey of OP 236, N.T. was flown by Geometrics International Corporation in October, 1984 and processed in February, 1985. The specially equipped aircraft had magnetic sensors installed on the tail and each wing tip. This configuration allows the measurement of horizontal gradients in the direction of flight and transverse to the flight line.

Major benefits of this configuration are:

Detection and removal of diurnal magnetic field changes especially in the presence of magnetic storms.

Use of transverse gradient to allow wider flight line seprations over deep targets.

2.1 Geophysical Survey Equipment

Following is a list of the geophysical survey equipment used by Geometrics in the data acquisition phase of the survey.

Magnetometers	Geometrics G813
Sensitivity	0.2 nT
Flight Path Recorder	Hitachi colour video camera
Navigation	Singer Doppler Nav. system
Digital Acquisition System	Geometrics G-714

2.2 Sampling Specifications

The sampling specifications are standard for this type of survey except for the flying height which was set at 100 metres above mean terrain elevation. Normally petroleum surveys are flown at greater heights to remove surface noise influences. In this case an elevation of 100 metres was chosen to make it possible to detect high frequency magnetic changes that might be associated with hydrocarbon reduction zones (Henderson et. al, 1984).

Traverse spacing	1500 metres
Tie line spacing	15000 metres
Survey altitude	100 metres above mean terrain
Sample interval	40 metres
Flight path recovery	Visual onto 1:80,000 photo enlargements from video

2.3 Processing Specifications

Data from the survey was processed at the U.S. office of Geometrics to produce several computer generated products. These included:

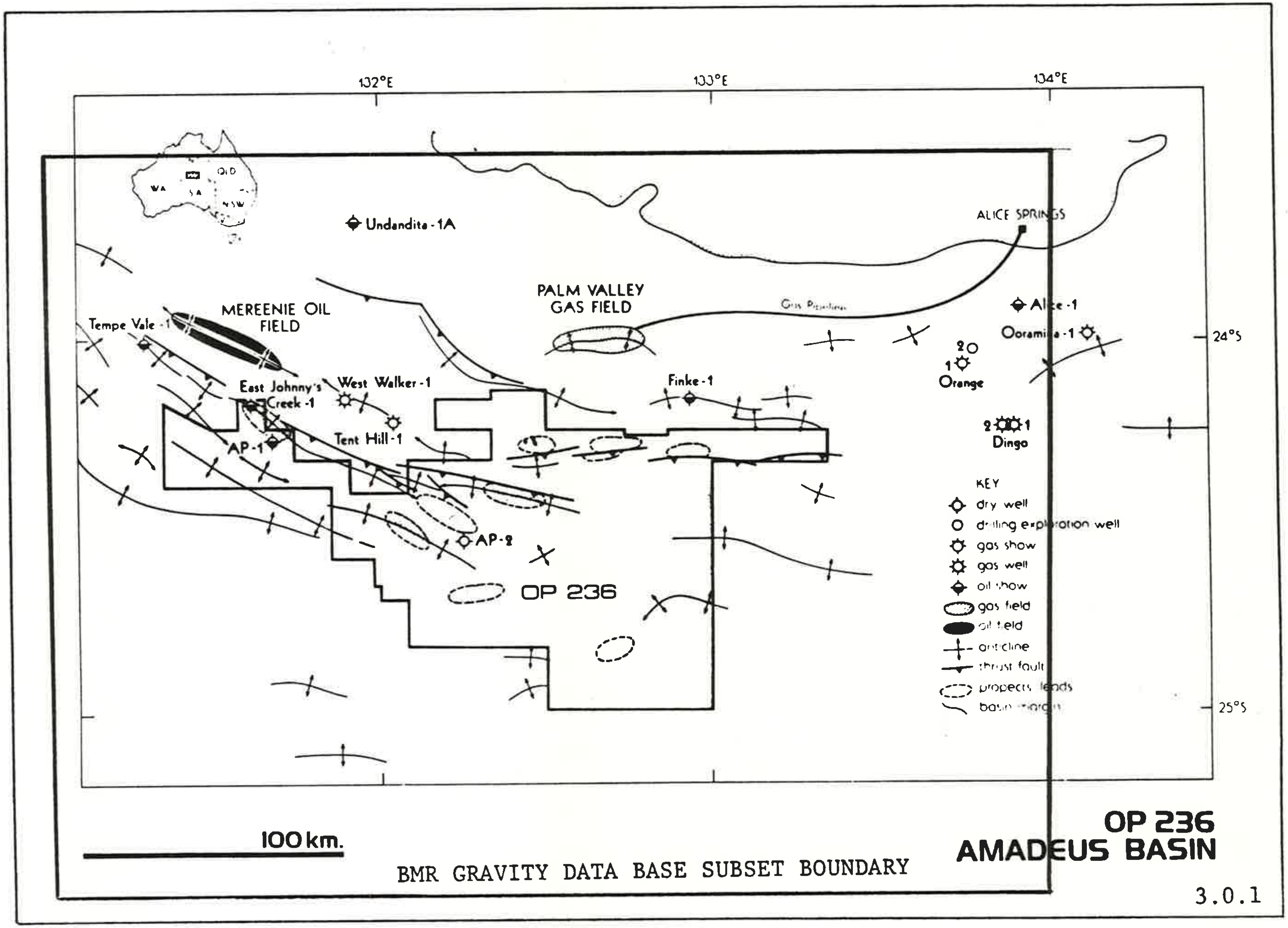
1:100,000 total magnetic intensity contour maps,
1:100,000 total magnetic intensity stacked profile maps,
1:100,000 flight path recovery maps.

The processing stages included:

Removal of the International Geomagnetic Reference Field (IGRF) from the raw tail stinger data,
Diurnal magnetic field removal,
Levelling of DC components in the magnetic field.

Only the tail stinger data was used in the production of the contour map since the cross track gradient was too low to be of any use in this process. This is attributed to the dominant east-west trend of the majority of magnetic features.

In the contouring of the data a primary mesh size of 190.5 metres was used which is reasonable for the line separation of 1500 metres. This has a filtering effect on the shallow magnetic sources and helps to join trends from line to line.



OP 236
AMADEUS BASIN

3.0.1

3.0 BMR GRAVITY DATA BASE

Gravity data for OP 236 was obtained from the Australian National Gravity Data Base as supplied on magnetic tape from the Bureau of Mineral Resources, Geology and Geophysics. The data is tied to the Australian National Gravity Base Station Network (Isogal Network) using the Potsdam 1930 gravity datum.

A subset of this data base was extracted from the magnetic tape to include the following area:

Latitude range	23.5 to 25.5 degrees
Longitude range	131.0 to 134.0 degrees

The boundaries of this area are shown in Fig. 3.0.1 and cover much of the areas adjacent to OP 236. A large area was chosen to allow examination of the regional gravity field.

This data is supplied as a magnetic tape of principal facts and must be reduced to Bouguer gravity. Bouguer corrections and latitude corrections were applied to the data. A density of 2.2 g/cc was chosen for the Bouguer correction to help compensate for the low densities of sand dune cover.

4.0 GEOLOGY

The geology of the OP 236 licence area consists predominantly of a Palaeozoic and Precambrian sedimentary sequence sitting on top of crystalline basement. The only magnetic unit within the sedimentary sequence is a volcanic horizon within the Bitter Springs Formation. This unit was first recognised by Blaydon and Davies (1982) in a drilling program designed to test a shallow source magnetic anomaly from a ground amgnetometer traverse.

From this work it is apparent that some of the older sedimentary formations contain ironstone bands that are magnetic and can be traced like marker horizons in drill holes. Wyatt (1983) found some evidence for these ironstones in an earlier survey by Weeks Petroleum to the south-west of OP 236.

The majority of geological information used in this interpretation has been extracted from the 1:250,000 preliminary geological sheet for Henbury (1965). The most useful information is dip, geological trends and the location of Bitter Springs Formation outcrop.

5.0 INTERPRETATION PROCEDURE

Interpretation of the geophysical data can be divided into three stages:

Map analysis
Quantitative interpretation
Qualitative interpretation.

These procedures do not occur as three separate stages as the decision making processes are all inter-related.

Map analysis normally occurs first where the major magnetic anomaly components are separated and associated with specific geological sources. This process involves regional residual analysis using band pass filters that are selected specifically for the local geology.

Quantitative interpretation is the process of computer modelling of the magnetic data to derive information on the nature of the geology associated with the magnetic anomalies. Both interactive geological modelling and Werner deconvolution have been used for this interpretation.

Qualitative interpretation can be defined as the process of synthesising all of the available geophysical and geological data to arrive at a plausible model for the subsurface geology.

The procedures used in the first two stages are discussed in this section. Section 6 discusses the synthesis of all the available information.

5.1 Magnetic Data Reduction

Magnetic data from the survey was provided by Geometrics prior to the completion of the contour maps. This data was recorded by the tail stinger magnetometer and was uncorrected for diurnal magnetic variation. Flight path recovery data was digitized by Engineering Computer Services (Bowral) and merged with the magnetic data. These locations were converted to latitudes and longitudes.

All latitude and longitude coordinates were converted to Australian Map Grid coordinates (metres) using the central meridian for zone 53. Part of the western section of the survey area is in zone 52, but only zone 53 coordinates are used.

The data was interpolated to an exact 40 metre sample interval, filtered with a cutoff wavelength of 360 metres and resampled at 120 metres. This was considered optimal for removal of non-geological noise and the reduction of processing time during Werner deconvolution. This data became the data base for all further processing and interpretation.

5.2 Magnetic Regional Residual Analysis

Regional residual analysis of the magnetic data consists of separating the anomalies associated with magnetic sources from different depth ranges. This can be performed on the contour map or individual profiles. In this case the analysis has been restricted to the profiles as it is believed that they contain all the required information.

Anomalies caused by magnetic sources at different depths have different wavelength components. The deeeper the source the longer the wavelength. In the OP 236 survey there are three distinctive source depth ranges.

1. Surface or near surface related anomalies from conformable ironstone horizons.

2. Volcanic horizon within the Bitter Springs Formation which varies from the surface to over 5,000 metres in depth. Magnetic crystalline basement in western part of survey at about 8,000 metres.

3. Deep intrabasement or crustal magnetic anomlies with depths ranging from 10,000 to 15,000 metres.

The magnetic contour map is dominated by the deep intrabasement anomalies (Type 3) which produce magnetic anomalies of the order of 200 nanotesla (nT). Anomalies of Types 1 and 2 have amplitudes in the range of 1 to 20 nT and are difficult to detect in the high gradient regions of the contour map.

Special processing techniques are required to separate the anomalies associated with the various sources. The techniques of regional residual analysis are akin to the techniques of band pass filtering used in seismic processing. In this case, they are applied in the spatial domain rather than the time domain. Type 1 anomalies are separated with a high pass filter, Type 2 a band pass and Type 3 a low pass filter.

Isolation of Types 1 and 3 is relatively simple to achieve. Unfortunately, the frequency spectrum of Type 2 magnetic anomalies overlaps both the Type 1 and Type 3 classes. This makes it difficult to isolate Type 2 without significantly distorting its shape or including components of Type 1 and 3. For this reason we have chosen to use only low and high pass filters in the regional residual process.

The results of the regional residual isolation process are illustrated in four figures with the specifications as listed in Table 5.1 below:

TABLE 5.1

FILTER SETTING FOR REGIONAL RESIDUAL ANALYSIS

Figure No.	Wavelength (km)	Frequency cylces/km	Filter Type	Anomaly Type
5.1.1	-	-	None	1 2 3
5.2.1	40	.0250	Low pass	- 2 3
5.2.2	40	.0250	High pass	1 - -
5.2.3	80	.0125	High pass	1 2 -

The filtering operations are implemented with a convolution filter which is at least as long as the cutoff wavelength and preferably twice the length. As the filter approaches the line end it shortens and automatically adjusts its characteristics so as to achieve the same band pass. The filter characterisitics gradually deteriorate as the it shortens and the results within one half wavelength of the end of the line are generally treated with some caution.

In the case of Fig. 5.2.3 a simple averaging filter was used to achieve the 80 km cutoff wavelength due to limitations in the available length of the convolution filter.

5.3 Werner Deconvolution Analysis of Magnetics

The Werner Deconvolution method is an automatic procedure for the interpretation of magnetic anomaly source locations. Werner (1953) first proposed the method for the interpretation of sheet like magnetic bodies such as dykes and volcanic horizons. Hsu and Tilbury (1977) of the Bureau of Mineral Resources extended the method to include the analysis of geological interfaces where changes in basement lithologies are associated with changes in magnetic susceptibility.

This method is complementary to direct modelling of magnetic surveys as it allows large quantities of magnetic data to be processed in a consistent manner. For an automatic interpretation procedure, it is reasonably robust in the presence of magnetic noise but not as accurate as direct modelling of the magnetic profile.

The basic principle of the method is that given any 11 points along the magnetic profile it is possible to obtain a theoretical solution for the position and depth to the top of a thin magnetic sheet or geological interface. Information is also obtained on the dip and magnetic characterisitics of the magnetic source. However, it is not possible to use the latter two measurement in a quantitative manner.

For well defined synthetic models, the Werner method generally gives results within 10 percent of the true depth. This accuracy is progressively degraded by the presence of noise and increasing geological complexity. In general it will only recognise the shallowest group of anomalies unless they are well separated spatially or in wavelength characteristics. However, with these limitations in mind the technique does provide useful results in a wide variety of geological environments. Our objective in this survey was to reduce the total amount of time required for interpretation of the airborne survey.

Figs 6.1.13 and 6.1.14 show the results of applying Werner decovolution to a synthetic model profile produced for line 310 by direct magnetic modelling of the original profile. The model depicts the undulating surface of the volcanic horizon within the Bitter Springs Formation. Fig. 6.1.13 shows the results for a thin sheet model and Fig. 6.1.14 is the result for a magnetic interface.

Magnetic profiles are shown in the top section and the geological cross section in the bottom half of the plot. The magnetic profiles are shown for each pass where the magnetic data is upward continued as a power of 2 times the data spacing. The horizontal lines show the width of the 11 point Werner operator at each continuation level.

In the geological section area of the plot, the results of each suitable Werner calculation are plotted as a rectangular box. The size of the box is related to the magnetization, its inclination relates to the direction of magnetization (inaccurate) and location gives the depth and horizontal position of the magnetic source.

Many of the solutions cluster together below a prominant magnetic anomaly, while others are scattered as small boxes through the section. The latter solutions are regarded as noise from minor oscillations in the profiles, or roundoff errors in calculations. Anomaly clusters are regarded as the most important results with the top of the cluster corresponding to the approximate location of the magnetic source.

The examples shown here are regarded as complex geological models which do not conform simply to a single magnetic sheet or interface. Yet, the results are surprisingly good. If a line were plotted through the shallowest of the two anomaly sets, then that line would be a very close approximation of the actual modelled surface.

Figs 6.1.16 and 6.1.17 show the results of applying the same process to the airborne profile from which the magnetic model was derived. The results are similar, but show a much wider scatter of solutions due to the presence of near surface geological noise. With the help of the direct modelling, it is possible to boost the confidence in the Werner results by extrapolating the control outwards from the modelled line.

In order to reduce calculation time and remove instrumental noise the data was filtered to remove wavelengths less than 360 metres and resampled at 120 metres intervals. The original sample interval was approximately 40 metres. This filter will not remove any magnetic anomalies from geological sources.

5.4 Interactive Magnetic Modelling

Interactive magnetic modelling refers to the process of matching field magnetic profiles with theoretical model profiles. The theoretical profiles are constructed by computing the magnetic response of a model geological cross section. Model are constructed interactively on a colour graphics computer screen and modified until there is a good match between the field magnetic profile and the theoretical profile. At this stage it is assumed that the model geological cross section is a good approximation of the actual geology of the magnetic rock units.

There are two underlying assumptions in the modelling process:

Non-uniqueness of model solution
Uniform geological cross section.

Non uniqueness of the solution refers to the fact that there are an infinite number of possible solutions that will produce practically the same magnetic profile. This is not as bad as it might first appear because:

A large number of the solutions are similar geologically,
Geological constraints reduce the number of possible solutions to a limited number of plausible solutions.

The geological constraints are derived from existing geological mapping, available drilling data and seismic mapping.

Uniform geological cross section means that the model cross section extends uniformly away from either side of the model profile for a distance of three to five times the modelling depth. This process makes the modelling much simpler as it is only necessary to define a two dimensional cross section rather than a three dimensional model.

Examples of the modelling results for four different magnetic profiles are shown in Figs 6.1.1 - 6.1.12.

5.5 Gravity Regional Residual analysis

Data from the BMR regional gravity data base was gridded and contoured at an interval of 1.0 mgal (Fig. 5.5.1). A regional gravity map (Fig. 5.5.2) was produced by applying a 40 x 40 km box filter to the Bouguer gravity grid. A residual gravity map (Fig. 5.5.3) was produced by subtracting the regional map from the original Bouguer map.

The data used in the preparation of these maps has an average spacing of 11 km and was collected as part of the BMR's helicopter gravity program. Barometric levelling was used in these surveys and the accuracy of individual stations is of the order of 1.0 - 2.5 mgals. Care must be taken not to over-interpret this data. Station locations are plotted on all the maps to assist with the analysis.

6.0 INTERPRETATION RESULTS

Discussion of the Interpretation is divided into quantitative and qualitative sections. The former includes a discussion of the interactive modelling results and Werner deconvolution plots. The qualitative stage discusses the magnetic regional residual analysis, Bouguer gravity and existing geology.

6.1 Quantitative Interpretation

Interactive modelling of selected lines from the survey proved to be most helpful for the interpretation of the Bitter Springs Formation. The Werner deconvolution profiles are of some assistance but are a little too noisy to rely on for depth or structural analysis.

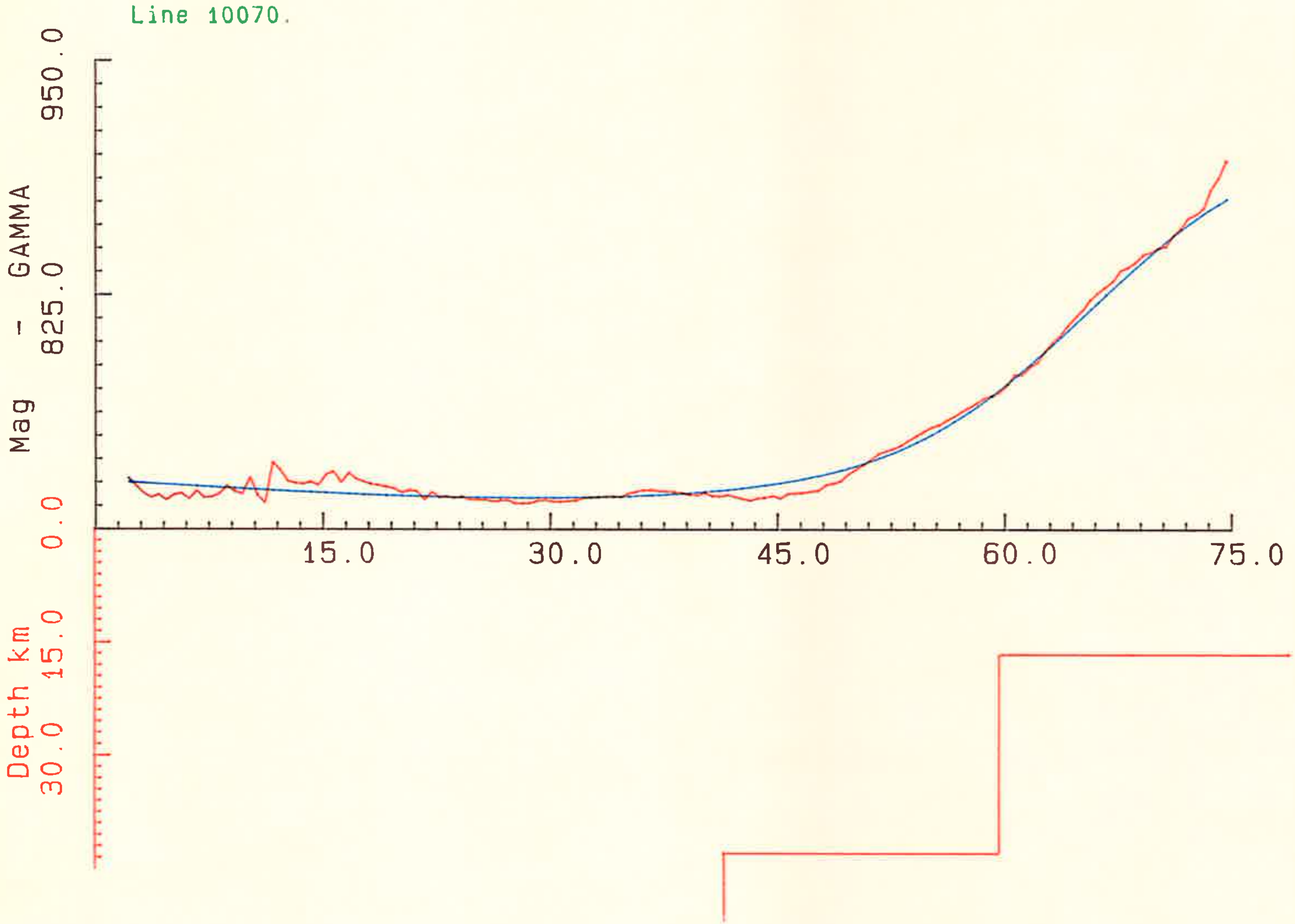
6.1.1 Interactive Modelling Interpretation

Lines 70, 180, 310 and 560 were selected for detailed magnetic modelling as they contain representative magnetic anomalies for the Bitter Springs Formation and crystalline basement. It was intended that these lines be used to control the interpretation of the Werner deconvolution plots. The theoretical model sections for the Bitter Springs volcanic horizon have been plotted on a base map (Fig. 6.2.2) to assist with geological correlation.

Each line was modelled in two stages. First the dominant regional was modelled by deep intrabasement magnetic sources. This regional model profile was then subtracted from the airborne magnetic profile to obtain a residual profile. The resulting profile contains magnetic anomalies from the Bitter Springs Formation and near surface occurrences of ironstone bands. Contributions from the shallow ironstone formations are short in wavelength and 10 to 50 percent of the anomaly amplitude from the Bitter Springs Formation. These have not been removed in the modelling process. Earlier attempts to use a least squares polynomial fitting procedure proved to be inadequate at the ends of lines. This is particulary true on the northern margin of the survey area where the gradient is very steep and there are several Bitter Springs Formation anomalies on the flank of the large regional anomaly.

Initial attemps to model the Bitter Springs Formation consisted of a series of discontinuous sheets where the ends of the sheets were responsible for the anomalies. Modelling was difficult and in the end was abondoned for a continuous undulating sheet as shown in Fig. 6.1.2. The latter appears more plausible geologically and suggests that the volcanic unit is present over a large part of the survey area. This approach does assume that the volcanic unit is relatively uniform in both magnetic and thickness characterisitics. Changes in either of these properties will influence the interpreted shape of the surface.

Note: All model line are plotted from south to north (looking west) and distances marked on the horizontal axis are distance from the start of the flight line.



PR85/036 A

SYDNEY OIL COMPANY (ARUNTA) PTY LTD

Line 70

Regional Magnetic Model

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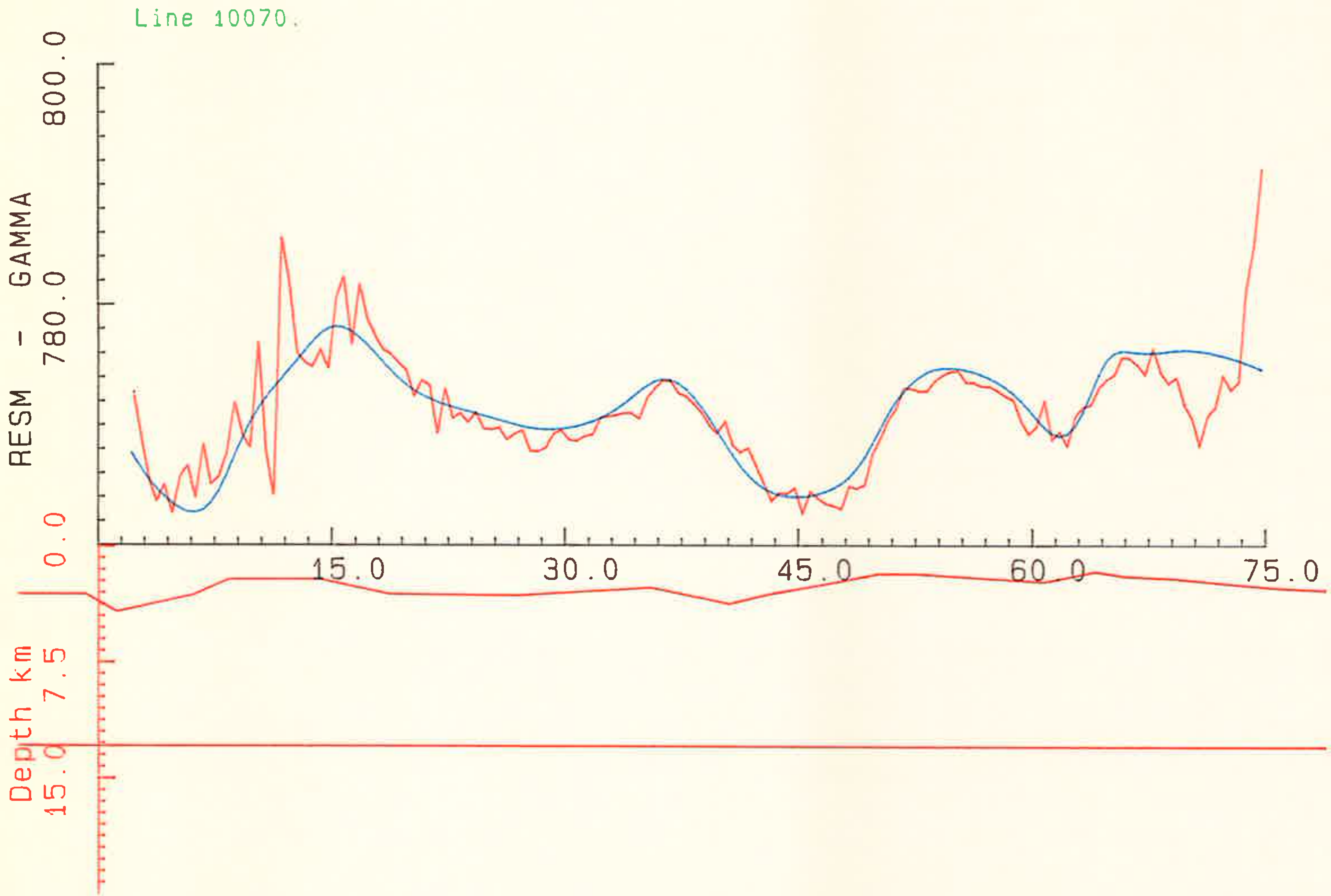
Drawn by: Geospex	Drawing No.:6.1.1



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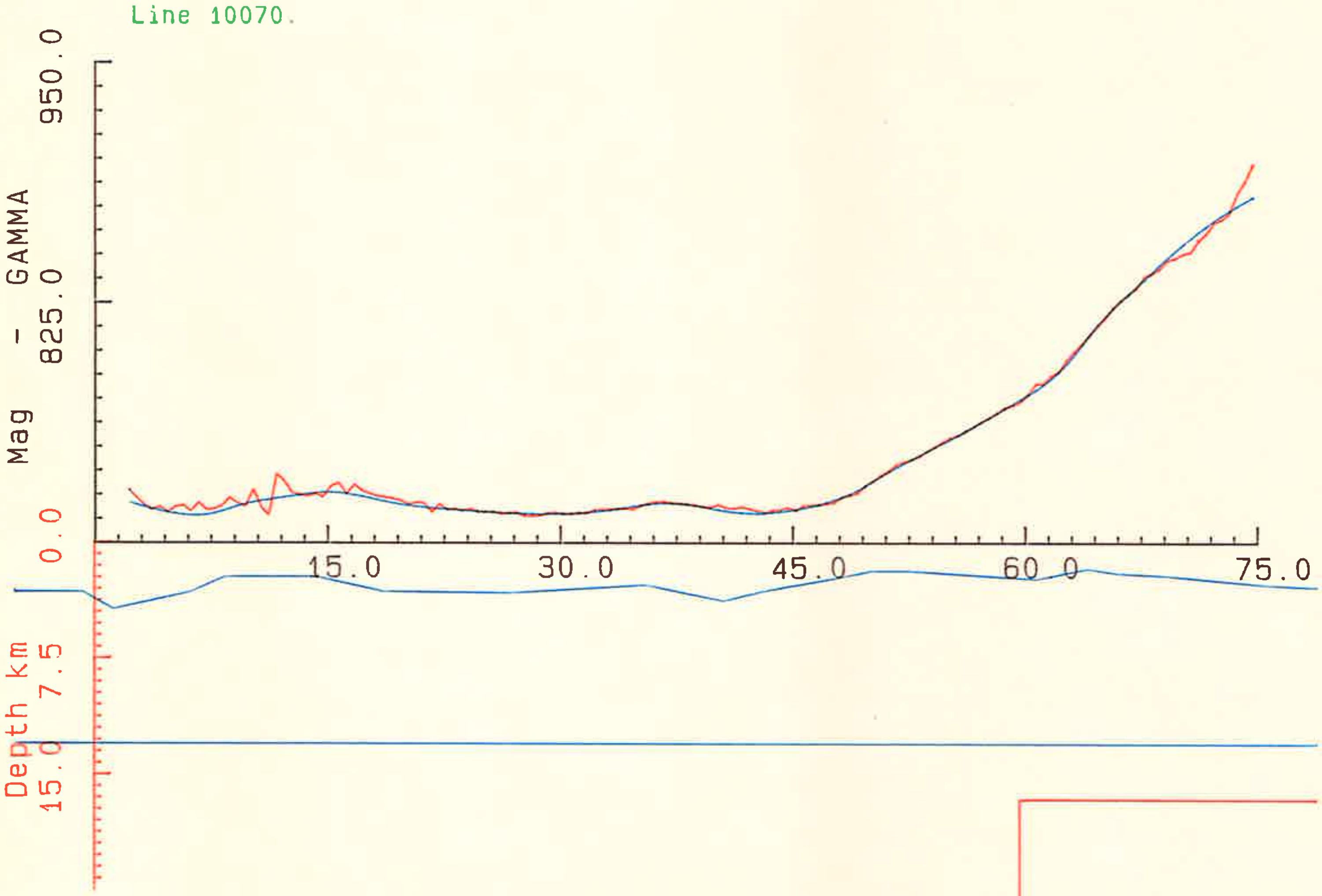
SYDNEY OIL COMPANY (ARUNTA) PTY LTD

Line 70

Bitter Springs

Residual Magnetic Model

Compiled by:	Date: 02-APR-85
Drawn by: Geospex	Drawing No.: 6.1.2



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Line 70

Regional + Residual

Magnetic Models

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Drawn by: Geospex	Drawing No.: 6.1.3

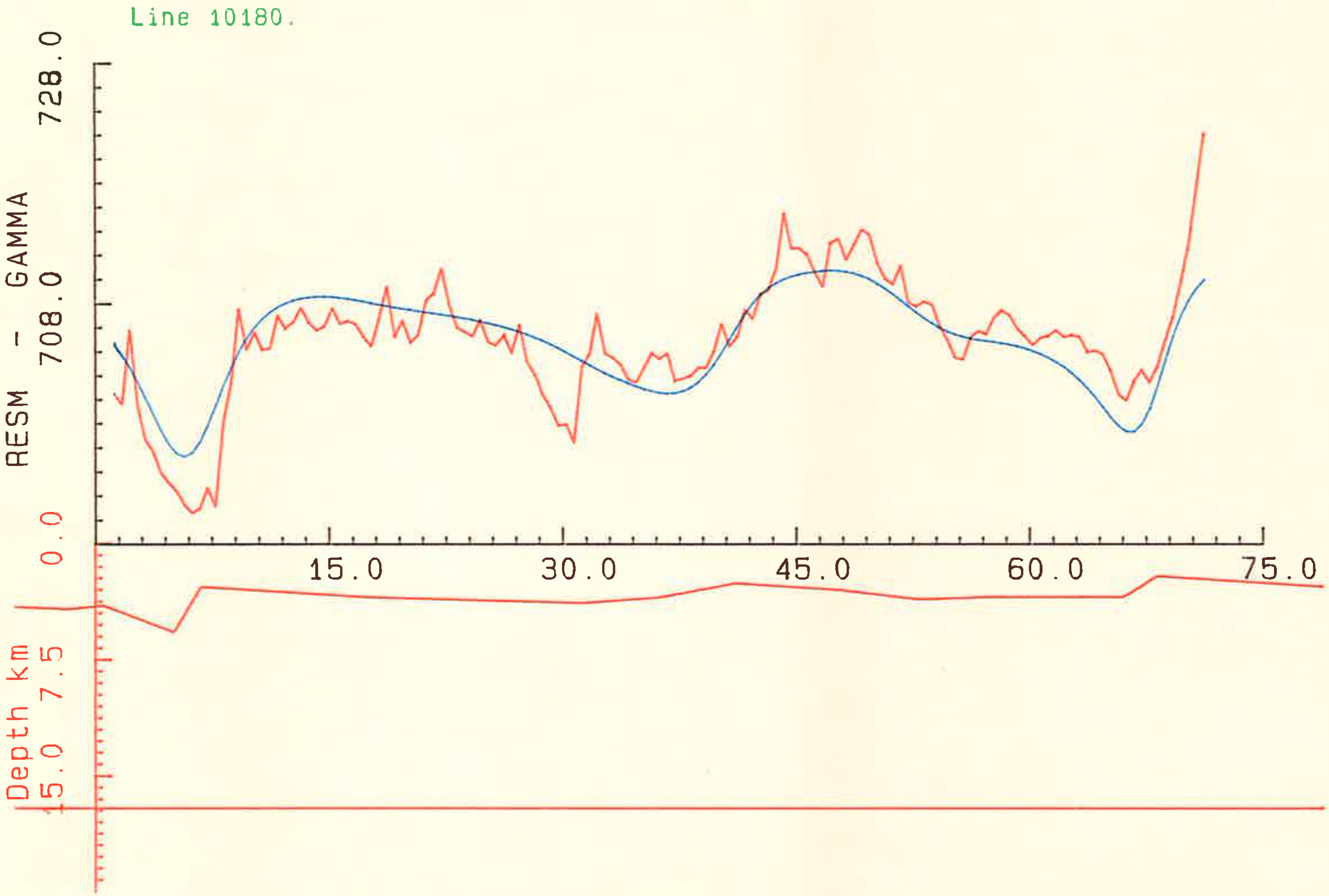
6.1.1.2 Line 70

Line 70 was chosen because it is the most easterly of the long flight lines and crosses four magnetic anomalies associated with the Bitter Springs Formation. The regional (Fig. 6.1.1) was removed by modelling a single stepped basement block with its shallowest section at approximately 15,000 metres. The modelled susceptibility of .0013 c.g.s. units is relatively high and probably relates to a major mafic unit. The depth of 15,000 metres is consistent with the other modelled lines and is well below the expected depth to crystalline basement. The source of the anomaly must be termed "intra-basement". The only other possibility is that the crystalline basement surface is dipping to the south. This appears to be inconsistent with the expected shape for the Southern Amadeus Basin. This deep magnetic source is responsible for the dominant east-west magnetic high along the northern margin of the aeromagnetic contour map.

Fig. 6.1.2 illustrates the final model for the volcanic unit within the Bitter Springs Formation. The magnetic profile was derived by subtracting the theoretical regional model from the airborne magnetic profile. The positions of the Bitter Springs model highs and low are important for locating anticline-syncline locations. Depths for the Bitter Springs volcanic horizon vary over the range 1,500 to 4000 metres. Depths can be in error as the amplitude of the model undulations is a function of the magnetic susceptibility contrast and average depth of burial. The depths should be used as a guide rather than absolute values. If additional information such as drilling, seismic or well data becomes available, then the model can be refined and tied to these known points.

The model cross section is sub-parallel to the cross-section C-D on the 1965 BMR 1:250,000 Henbury Preliminary Geological Map. In many respects, it is similar to the BMR section interpretation, but not all the synclines have been reproduced in the magnetic model. This is probably due to lateral changes in geology, and lack of magnetic sensitivity to small amplitude anticlines.

Fig. 6.1.3 shows the result of combining the Bitter Springs and regional models and comparing them with the original aeromagnetic profile. The "goodness of fit is" is high along the complete line except for the northern end of the profile where the profile rises rapidly. Without a longer magnetic profile, it is difficult to improve this interpretation. Similar problems are encountered on other lines. Errors in the interpretation can be larger at this location and the Bitter Springs volcanic horizon may be shallower than indicated here.



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Line 180

Bitter Springs

Residual Magnetic Model

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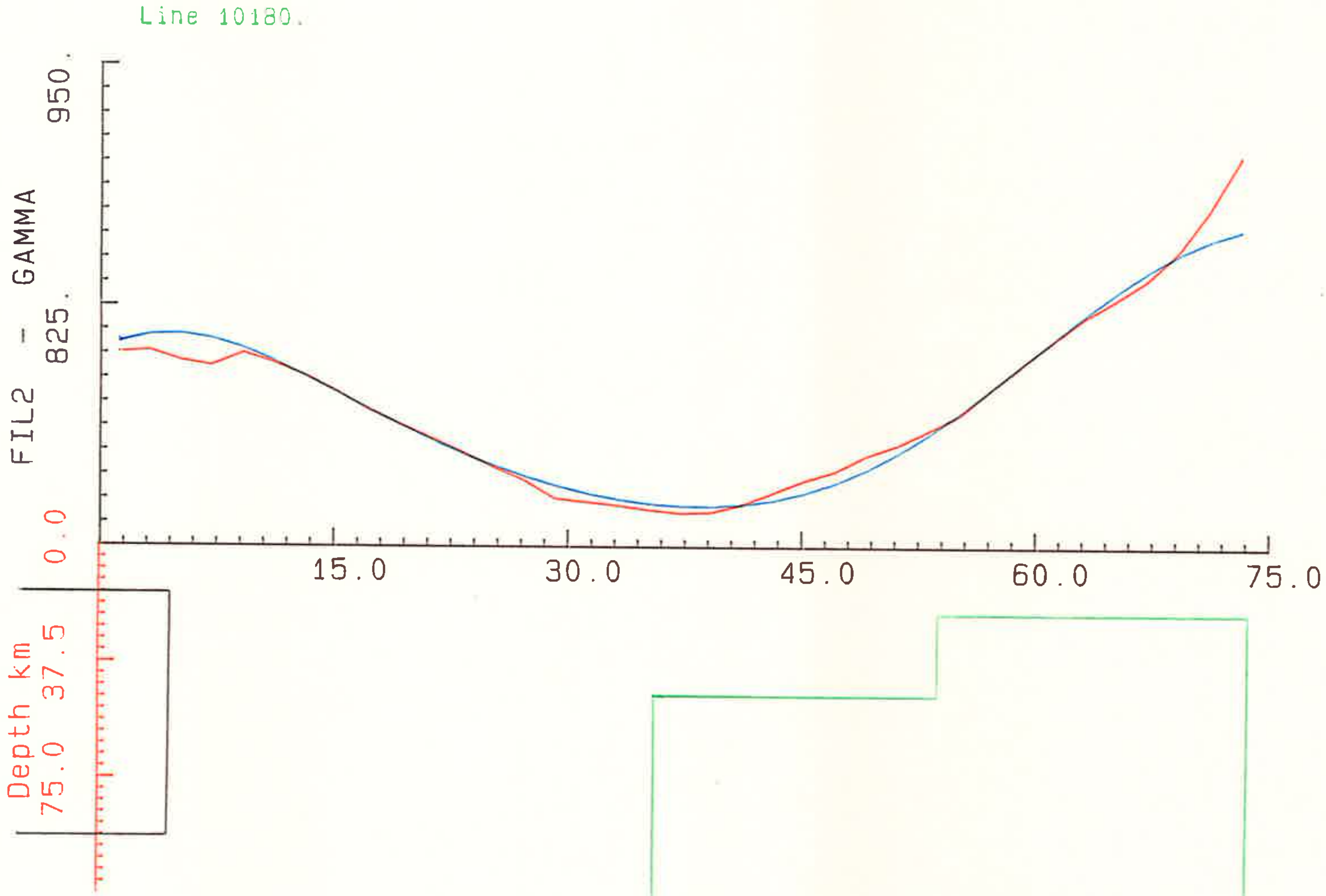
Drawn by: Geospex	Drawing No.:6.1.5



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Line 180

Regional Magnetic Model

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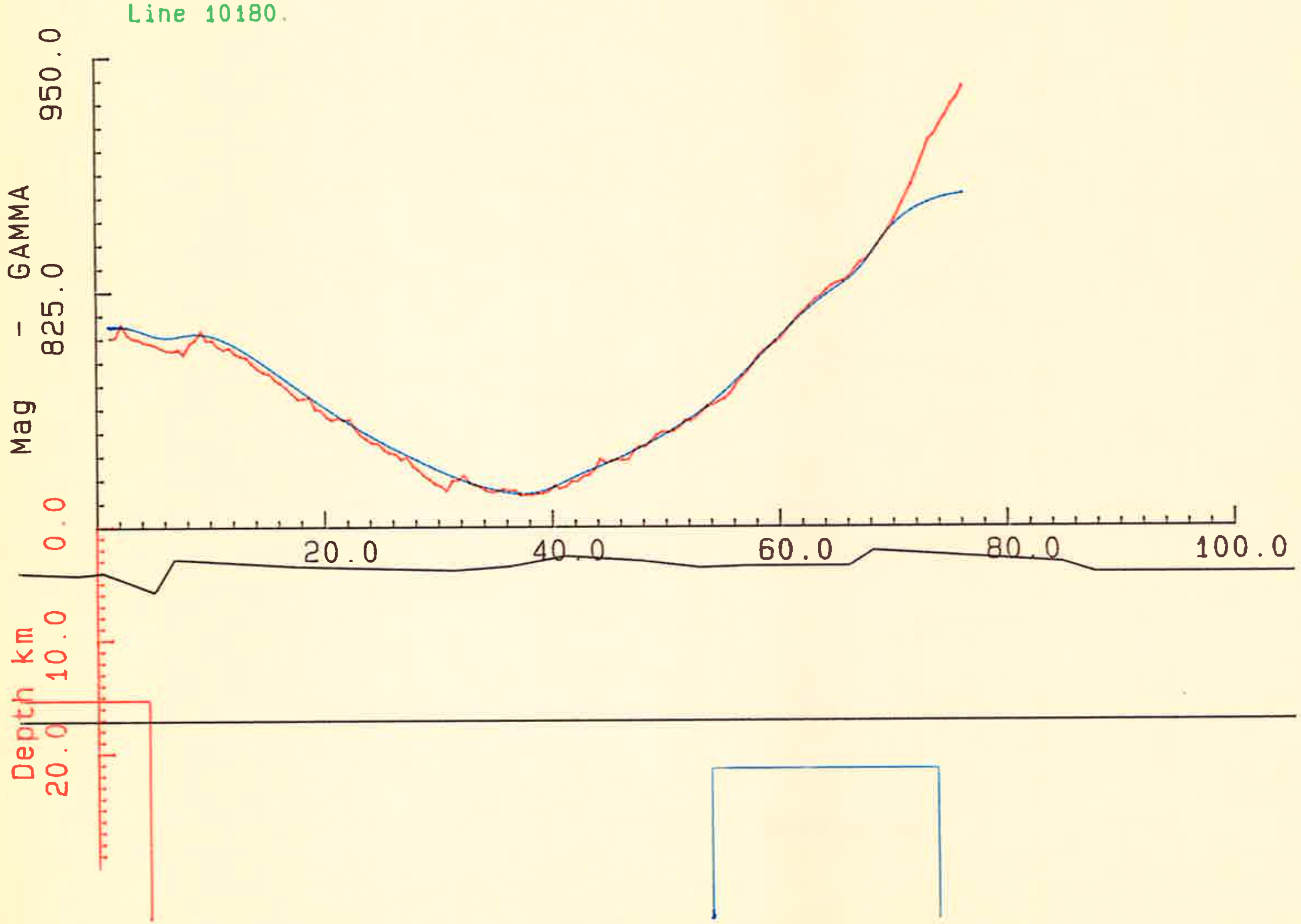

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Line 180
Regional + Residual
Magnetic Models

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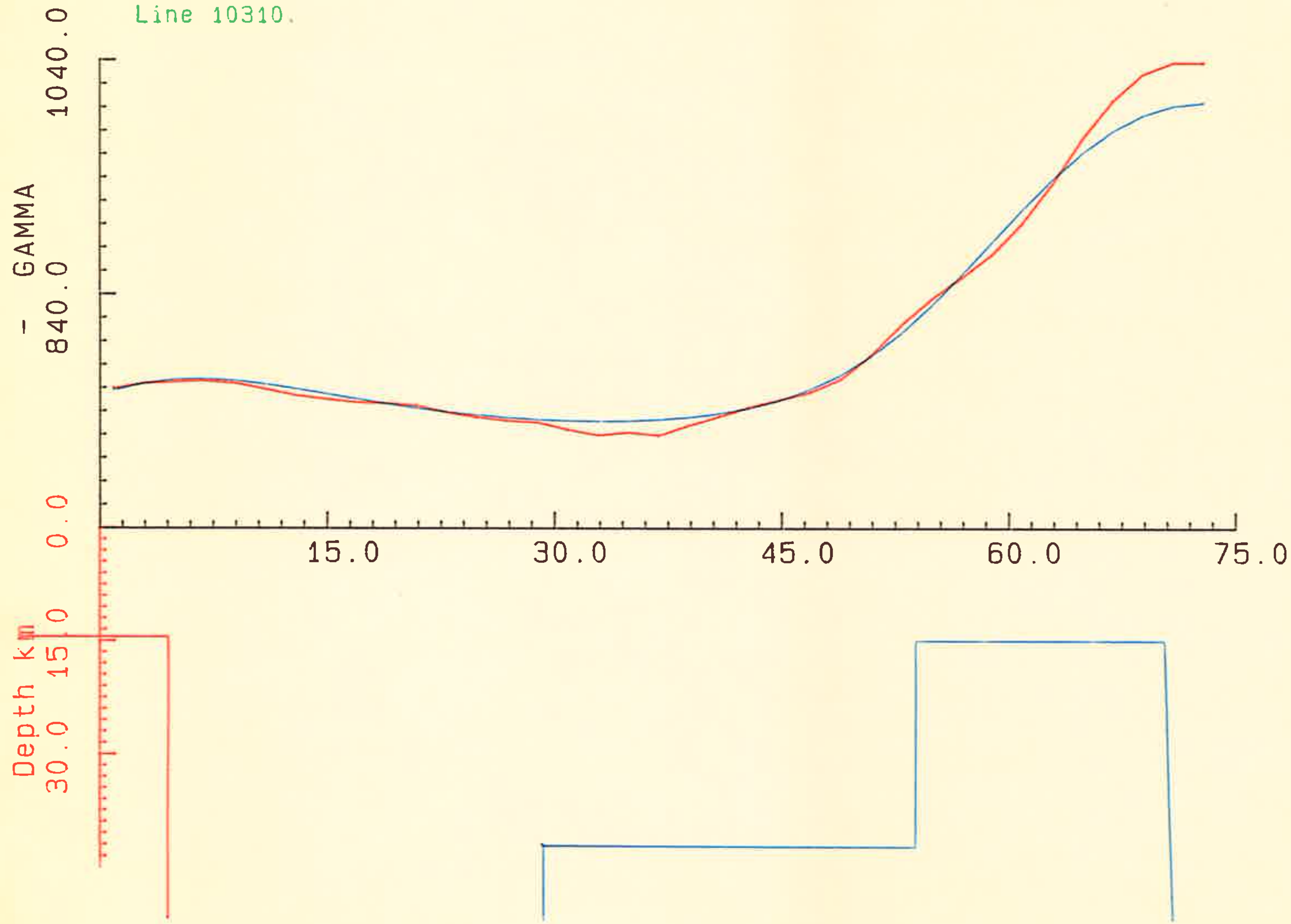

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Line 310

Regional Magnetic Model

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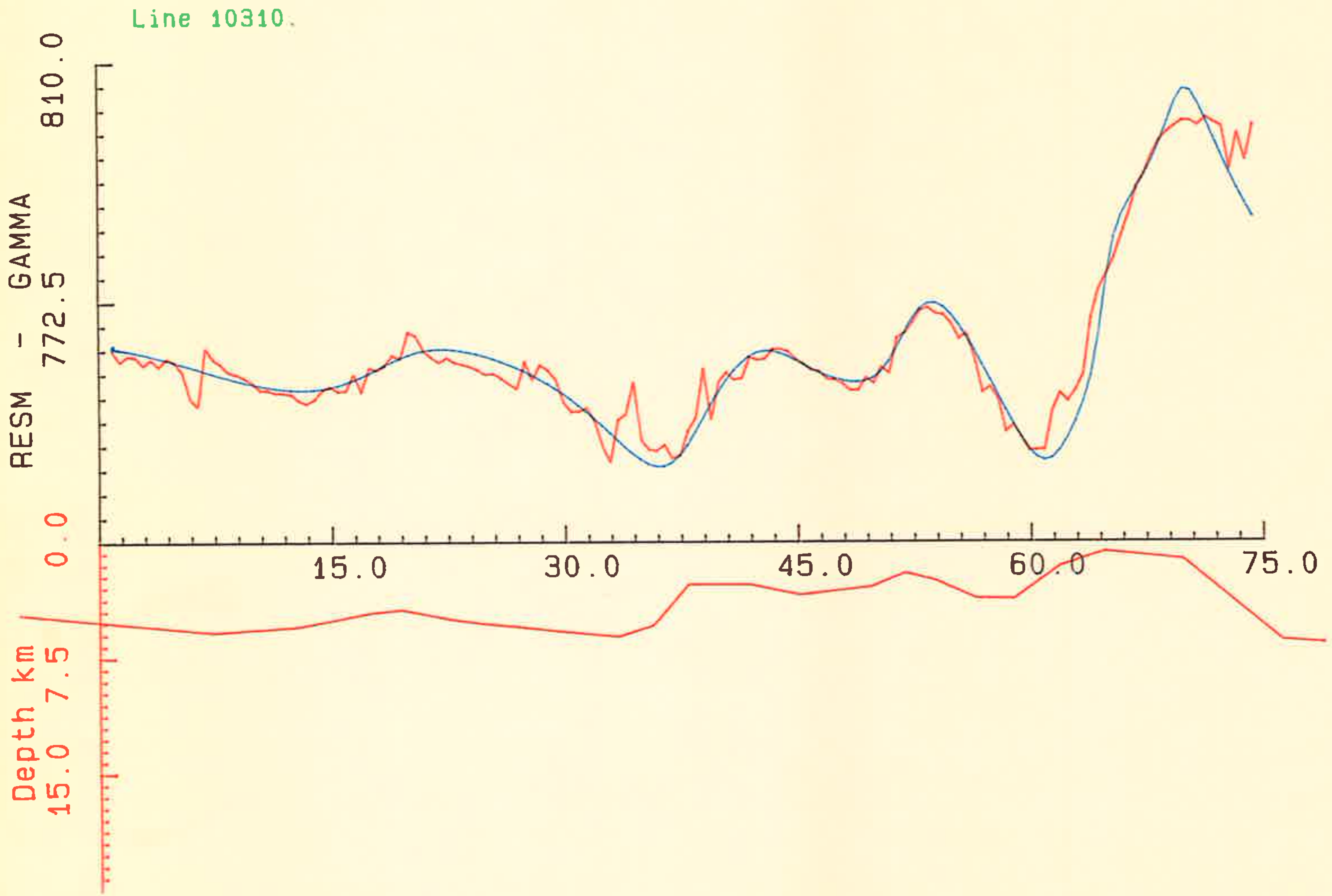
Drawn by: Geospex	Drawing No.: 6.1.7



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Line 310

Bitter Springs

Residual Magnetic Model

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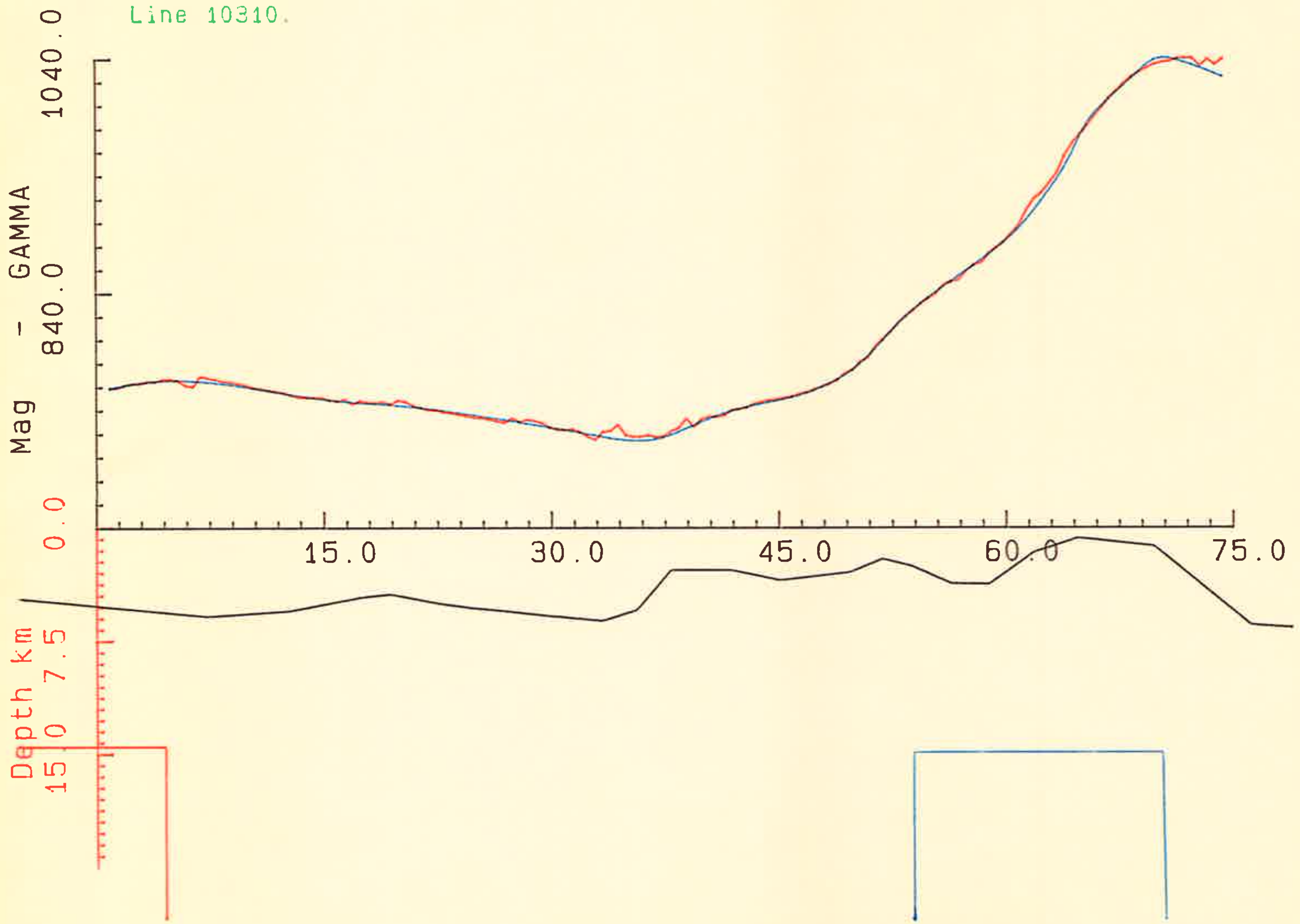

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Line 310
Regional + Residual
Magnetic Models

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Drawn by: Geospex	Drawing No.:6.1.9

6.1.1.3 Line 180

Line 180 contains a more complex regional magnetic field (Fig. 6.1.4) than Line 70 and it is necessary to use two intrabasement magnetic sources to match the field. On the northern end of the profile is the same deep source as used in Line 70. This is associated with the major east-west magnetic anomaly along the northern margin of the aeromagnetic contour map. In this case it has been deepened to 20,000 metres. The second source at 15,000 metres on the southern end of the line is responsible for the broad magnetic high in the south-eastern corner of the aeromagnetic contour map. Magnetic susceptibilities for these two sources are 0.0019 and 0.0016 c.g.s. units respectively, slightly higher than modelled for Line 70. These values suggest that the source of the magnetic anomalies are similar geologically.

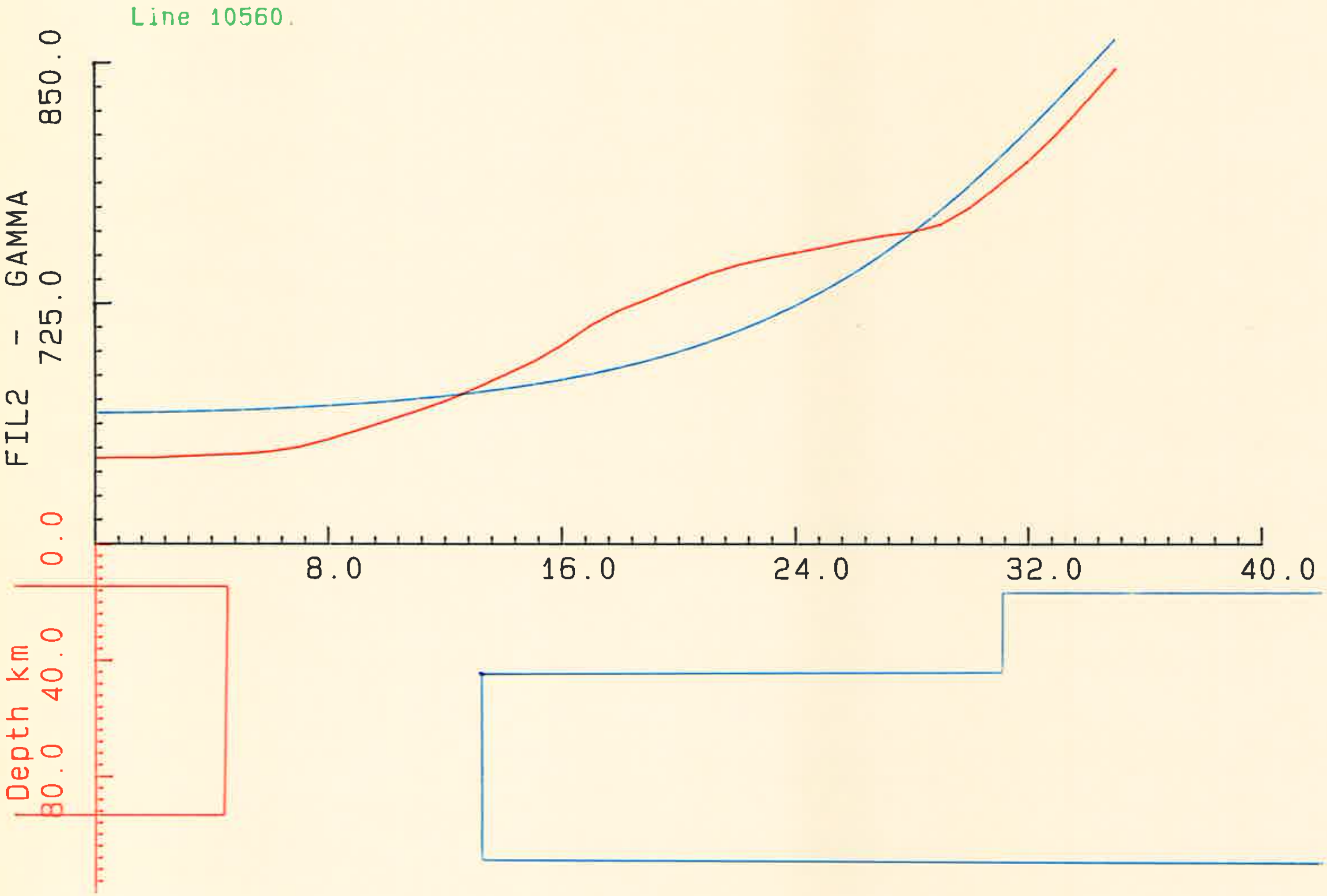
Fig. 6.1.5 illustrates the Bitter Springs model for the residual magnetic field obtained by subtracting the results for the regional model from the aeromagnetic profile. Anomaly amplitudes are slightly lower than for the previous line and the influence of the shallow ironstone related anomalies tend to dominate those from the Bitter Springs volcanic horizon. Depths vary from around 2,000 metres to approximately 4,000 metres. The depression at the southern end is influenced by surface magnetic features, but does suggest the presence of a major fault. The northern end of the line is unreliable due to inadequate compensation for the regional magnetic field.

Fig. 6.1.6 illustrates the result of adding both the Bitter Springs and regional models. Apart from the northern edge, the "goodness of fit" is excellent.

6.1.1.4 Line 310

Line 310 is the western most long flight line in the survey area. It exhibits the same two regional magnetic anomalies as Line 180. Fig. 6.1.7 shows the results of modelling both the deep intra basement magnetic sources. The amplitude of the anomaly for the southern most source is reduced in comaprison with Line 180 as it is near the western edge of this deep source. As a result, the modelled susceptibility of 0.0012 c.g.s. units is lower. If the source was modelled as a true three dimensional shape, then this amplitude reduction would be accounted for automatically.

Fig. 6.1.8 shows the residual model results for the Bitter Springs volcanic horizon. The anomaly wavelengths are shorter than for Lines 70 and 180 and indicate shallowing of the Bitter Springs Formation. Near the northern end of the line, the horizon approaches within 700 metres of the surface at a point where Bitter Springs is mapped in outcrop. This result is significant, as it suggests that the volcanic member of the Bitter Springs Formation is of the order of 700 metres below the formation top. Due to inaccuracies in the removal of the regional, the estimate could be 400 metres for a different regional model.



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SYDNEY OIL COMPANY (ARUNTA) PTY LTD

Line 560

Regional Magnetic Model

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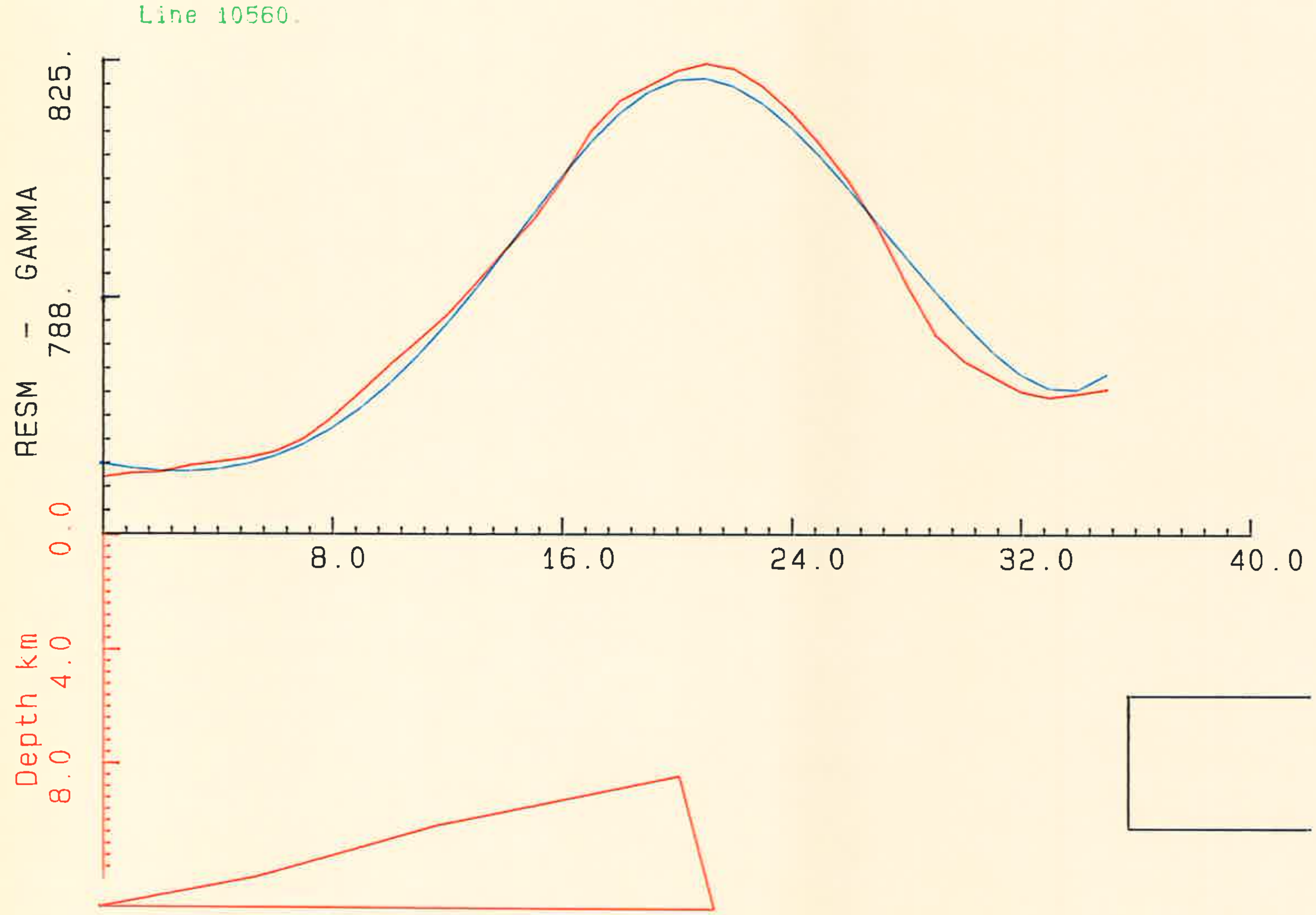
Drawn by: Geospex	Drawing No.:6.1.10



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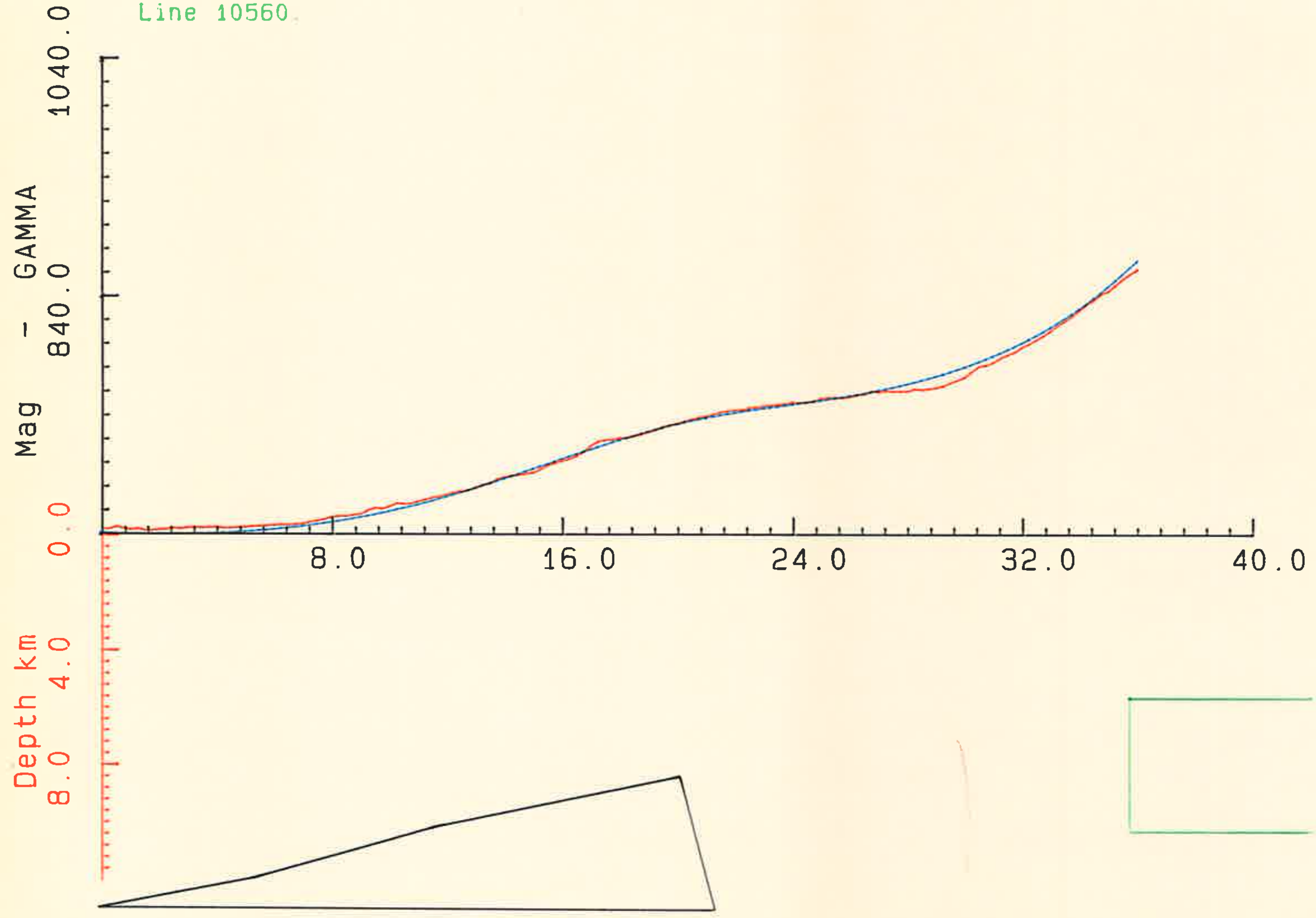
SYDNEY OIL COMPANY (ARUNTA) PTY LTD

Line 560

Crystalline Basement

Uplift Model

Compiled by:	Date: 02-APR-85
Drawn by: Geospex	Drawing No. 6.1.11



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SYDNEY OIL COMPANY (ARUNTA) PTY LTD	
Line 560 Regional + Residual Magnetic Models	
Compiled by:	Date: 02-APR-85
Drawn by: Geospex	Drawing No. 6.1.12

A combined Bitter Springs and regional model is shown in Fig. 6.1.9 with an excellent "goodness of fit" between the aeromagnetic profile and theoretical model.

6.1.1.5 Line 560

Line 560 is short flight line that was chosen because it contains a relatively high amplitude Type 2 anomaly. The regional magnetic field was modelled in a similar manner to the previous lines as shown in Fig. 6.1.10. Removal of the regional magnetic field is only approximate as the flight line is very short compared with the wavelength of the regional. Note that this profile has been filtered and resampled at a coarse sample interval. The influence of the shallow ironstone units has been removed from the profile.

Fig. 6.1.11 shows the results of modelling the residual magnetic field. The main anomaly has an amplitude of approximately 70 nT and is modelled as a truncated wedge with a susceptibilty of 0.0017 c.g.s. units. The rectangular model on the northern end has been included to help explain the rapid fall-off of the main anomaly, but should not be used for geological interpretation. This susceptibilty is of the same order as that of the deeper intra basement anomalies and is much higher than the estimated susceptibility for the volcanic member of the Bitter Springs Formation. The steep northern edge of the wedge is unlikely to be a fault. It is probably the boundary with another basement unit that is non-magnetic. The gravity also indicates a high which would be inconsistent with a downthrown northern margin. The validity of the southerly dipping surface could be suspect, as the regional gravity map (Fig. 5.5.2) suggest that basin deepens to the north at this location. The gravity hinge line between the north and south gravity lows is 20 kilometres to the south of this magnetic source.

It is also significant from these results, that there is no anomaly detectable for the Bitter Springs. This could indicate that there is a facies change from east to west with loss of the magnetic member of the volcanics at approximately longitude 132 degrees 20 minutes.

Fig. 6.1.12 shows the result of combining the regional and intermediate magnetic models. The "goodness of fit is satisfactory" appart from incomplete compensation for the magnetic low at 32 km as discussed above.

6.1.2 Werner Deconvolution Interpretation

Werner deconvolution was applied to all the north-south profiles in the early stages of the project to assist with depth estimates for the Bitter Springs Formation. The initial results were disappointing as it was difficult to distinguish between noise and valid results. Most of the depth estimates were in the range of 2,000 to 4,000 metres which was as expected. However, the confidence in any individual interpretation was very low. The results of the automatic depth interpretations are presented in a separate binder for future reference.

Following the detailed interactive modelling, the Werner plots were re-examined to determine if any more information could be extracted. Prior to this exercise, Line 310 was chosen for detailed analysis. The Werner program was upgraded to improve its noise rejection capabilities in an attempt to enhance the interpretation possibilities. The new version of the program was applied to Line 310 for the following cases:

1. model magnetic profile of Bitter Springs Formation
2. aeromagnetic profile with model regional removed
3. aeromagnetic profile with regional present.

Both the thin sheet and interface models were applied to cases 1 and 2 (Figs 6.1.13 - 6.1.16). Only the thin sheet model was applied to case 3 (Fig. 6.1.17). In each of the cases, the theoretical model has been plotted on the Werner depth section for comparison with the automatic depth plots.

In the case of the theoretical model profile for the Bitter Springs volcanic horizon (Figs 6.1.13-14), the results are excellent for all anticline crests. If both the thin sheet and interface models are superimposed, the theoretical surface is very close to the upper limit of the Werner solutions. The syncline axes are less precise but in general correspond to the lower limit of the grouped Werner solutions.

Figs 6.1.16-17 show the equivalent results for the aeromagnetic profile with the theoretical regional magnetic field removed. The results are similar, but noisier. The deepest anticline at 17 km is the most difficult to detect. Most of the degradation can be attributed to the short wavelength anomalies associated with shallow ironstone formations.

Fig. 6.1.18 shows the result of Werner deconvolution without the removal of the regional mangetic field. The results are further degraded in the presence of the regional magnetic field. The deeper anticline has been completely missed.

These results indicate that better performance can be achieved from the Werner deconvolution method if band-pass filtering is applied to remove the surface related anomalies and regional anomalies.

With the aid of the direct modelling for Lines 70, 180 and 310 it was hoped that the control could be extended by use of the Werner interpretation plots. This exercise was only partly successful because of the above mentioned problems. The preliminary interpretations are included on each of the Werner plots. However, the confidence in these results is too low to plot the depths on an interpretation plan. These plots should only be used in a supportive role in conjunction with further interpretation work.

If further interpretation is to be performed in conjunction with the seismic data it is recommended that the data is reprocessed using a band pass filter and the new version of the Werner program.

6.2 Qualitative Interpretation

Synthesis of the map analysis and computer modelling results is divided into a discussion of the three major magnetic anomaly types:

Shallow ironstone formations,
Bitter Springs volcanic horizon,
Crystalline basement

and

Structure.

This analysis includes discussion of both the aeromagnetic and regional gravity data.

6.2.1 Shallow Ironstone Formations

As discussed in the section on interpretation procedure, there are numerous low amplitude, short wavelength magnetic anomalies superimposed on the regional magnetic field profiles. These are attributed to magnetic horizons within the sedimentary formations of the Palaeozoic sequence. Wyatt (1983) reports the presence of oolitic ironstones to the west of OP 236 in an area formerly held by Weeks Petroleum but suggests that the anomaly amplitudes will be no greater than 1 nT. This is inconsistent with the results from this survey where ironstone related anomalies may be as high as 20 nT. It is possible that the shallower Bitter Springs in the Weeks area was dominating the ironstone anomalies.

The interesting feature of these anomalies is the fact that they are not restricted to a single formation but are present in a number of formations. Evidence for this statement is obtained from magnetic lineament interpretation map (Fig. 6.2.1) where it is possible to correlate small anomaly trends from line to line for distance upto 20 to 30 kilometres. In areas of outcrop, these trends show excellent correlation with the mapped geology.

The lineament interpretation map was produced from the residual magnetic profile map in Fig. 5.2.3 which used an 8 km high pass filter to resolve type 1 and 2 magnetic anomalies. The trends were produced initially in an unbiased manner by pencilling in lines by visible correlation from one line to the next. In several cases, it was possible to produce orthogonal correlations where trends are at 45 degrees to the flight path. In these cases, available geological data was used to resolve the most likely trend direction.

One of the most spectacular results of the residual analysis is the zoning of magnetic anomalies. The middle of synclines are in most cases magnetically quiet, while the anticlines are magnetically active. This is consistent with the magnetic units emerging at the ground surface, or Cainozoic unconformity surface. Furthermore it is consistent with the structural style of the Amadeus Basin where the synclines are relatively shallow dipping while the anticlines change dip rapidly.

By using the trend line map and the quiet magnetic zones it is possible to draw in the axes of the synclines. By further examination of the dip information from the 1965 BMR geological map it is also possible to draw in some, but not all the anticline axes. All the interpreted syncline and anticline axes are shown on the interpretation map (Fig. 6.2.1). The result is most significant as it has allowed the fold axes to be mapped for many kilometres below extensive sand dune cover and provides considerable additional information about the structural style of the basin. This data should greatly assist correlation between seismic lines.

Note: the interpretation of syncline and anticline axes is based on the recognition of interpreted dip slopes on the 1965 BMR geological map. In some cases, it is possible that the relationship of anticline or syncline could be reversed depending upon the reliability of the dip estimates, proximity and steepness. No attempt has been made to interpret the dip direction from the shape of individual magnetic anomalies. If the magnetization of the ironstone formation is non-remanent, then approximate dip estimation may be possible.

Since the BMR gravity data is sampled at approximately 11 kilometre intervals, it is of no use in detecting narrow near surface formations. However, detailed gravity along the seismic lines will help to analyse individual units as well as structure (Schroder & Gorter, 1984).

6.2.2 Bitter Springs Volcanic Horizon

Bladon and Davies (1982) from the BMR drilled two holes in the Southern Amadeus Basin aimed at intersecting the shallow source of a magnetic anomaly. A magnetic unit was detected and interpreted to be within the Bitter Springs Formation. This information provided the basis for an airborne survey by Weeks Petroleum carried out in the north-east corner of the Ayers Rock 1:250,000 sheet. This area is immediately to the south-west of OP 236. A summary of the survey results by Wyatt, (1983) reports that anomalies from the Bitter Springs Formation have amplitudes ranging from 30 to 300 nT. These are related to Bitter Springs occurrences within 100 metres of the surface. This would be consistent with the modelling results discussed here, but no anomalies in OP 236 are larger than 20 to 30 nT. Wyatt also predicted that the anomalies from the Bitter Springs volcanic unit would be of the order of 1 to 5 nT at 2,000 metres depth. In fact, the anomaly amplitudes are slightly higher than this with values ranging from 5 to 20 nT in the depth range 2,000 to 4,000 metres. This could be attributed to lithological or thickness changes within the volcanics. If the amplitudes were any lower, they could become lost in the anomalies from the shallow ironstone formations.

The success of the Weeks survey also provided the rationale for the OP 236 aeromagnetic survey by Geometrics. The detailed modelling of the Bitter Springs volcanic horizon has shown that it is possible to predict the location of major anticlinal axes at depth. However, the accuracy of the method needs to be verified by comparison with seismic reflection data. The interpreted depth sections have been plotted on

Fig. 6.2.2 for Lines 70, 180 and 310. The section for Line 560 relates to a crystalline basement magnetic source.

These interpretations have been made with little control other than occassional outcrop information on the Bitter Springs Formation. Line 310 shows the most relief, while the others are relatively flat and may have missed a number of anticlinal structures. These results could be improved by application of additional constraints from inferred subsurface geology or seismic reflection data.

On Line 310 at 24 degrees 45 minutes there is a major change in level for the Bitter Springs which could suggest a major cross cutting fault. There does not appear to be any major surface evidence for such a fault.

Interpretation of the gravity data is difficult with an 11 km spacing, especially since the wavelength of many of the anticline-syncline pairs is less than the 11 km spacing. This will introduce a severe aliasing effect in the gravity data. It is expected, that much more useful data will be obtained from the gravity survey along the seismic lines. There is no obvious relationship between gravity lows and sediment thickness as suggested by the magnetic interpretation. In fact in some cases the contrasts are reversed. Such a reversal can be explained by a density inversion in the geological sequence. That is, density decreases with depth over a significant length of section. Such a reversal has been reported by Schroder and Gorter (1984) for part of the Amadeus sequence.

An attempt to explain the gravity low trends in a manner consistent with the magnetic interpretation is shown in Fig. 6.2.3. The shaded horizon represents a qualitative estimate of the location of a low density unit above the Bitter Springs Formation. Where this unit outcrops, there is a gravity low in the residual gravity map (Fig. 5.5.3). In the gravity map they correlate with two truncated east-west linear gravity lows. Further to the west, the gravity low turns north in a manner consistent with the magnetic and geological trends.

6.2.3 Crystalline Basement

The true nature and depth of the crystalline basement is not obvious from the magnetic data alone. The simplistic models used for regional analysis suggest depths of the order 15 km which appear much deeper than the expected depths to the top of crystalline basement. These anomalies may be reflecting crustal deformation as suggested by Lambeck (1983). By changing the shape of the upper surface of the magnetic models, it should be possible to decrease the interpreted depth by up to 3000 metres.

The only magnetic anomaly that appears to be related to the top of crystalline basement is modelled on line 560 and plotted on Fig. 6.2.2. The shallowest depth of this feature is 8,000 metres. Its susceptibility is approximately 0.0017 c.g.s. units which suggest a basic or mafic rock unit, perhaps similar to those occuring in the

Arunta Complex on the northern margin of the Amadeus Basin. The trend of this zone is north-west and correlates with a change in direction of the surface structures.

The regional gravity field as depicted in Fig. 5.5.2 shows the hinge line between the Amadeus North and Amadeus South basins lies along the southern edge of OP 236. This is a dominant regional feature which can be seen clearly on the gravity map of Australia. An interesting feature of this regional map is the gravity embayment along the eastern edge of OP 236. This embayment corresponds generally with shallower basement which would be expected to produce a local gravity high.

There are two possible explanations for this low:

Older sediments are lower in density than the overlying sediments,

or

Granite intrusion within the basement.

The latter conclusions would be consistent with the magnetic data which shows no positive response in this region. The north-eastern edge of the gravity embayment lies along a major north-west trending gravity lineament that extends beyond the Amadeus Basin (Fig.6.2.3). It is possible that the parallel lineament intepreted from the magnetics on the western side of the embayment is a sympathetic regional structure.

6.2.4 Structure

The major structural elements that have been interpreted from the magnetic and gravity data are:

Anticline axes,
Syncline axes,
Faults.

These elements have been plotted on Figs 6.2.1 and 6.2.3. The more easterly north-west trend in Fig. 6.2.1 correlates with a discontinuity in the mapped geology.

The anticline and syncline axes have been deduced from the shallow source magnetic anomaly trends and are displayed in Fig. 6.2.1. The basis for these interpretations has been discussed above. Discontinuities in these trends has suggested the presence of two major north-west trending faults which parallel the major gravity discontinuity.

A further interesting structural feature is a warping of the magnetic trendline in the western portion of the magnetic survey. The trend of this warp changes from north-west to north as it traverses a series of anticlines. There are two possible explanations for this warp:

Orthogonal anticline,

or

Overthrust.

The latter was suggested by Schroder (1985) on the basis of brute stack seismic section from the 1985 seismic survey. This option appears more plausible since there is no evidence for other north-south anticlinal structures in this area.

6.3 Direct Indication of Hydrocarbons

It was originally proposed by Geometrics that the airborne magnetic survey data could also be used for the direct indication of hydrocarbons. This assertion is based on empirical results from surveys over several oil fields in the U.S.A. (Henderson et al, 1984). The theory is based on the presence of a reducing environment above oil reservoirs which in turns provides the necessary conditions for the alteration of non magnetic iron oxides to the magnetic form of magnetite. This conversion takes place above the water table and has the effect of creating short wavelength noise-like anomalies on aeromagnetic profiles that are flown at low survey altitudes.

There is no certainty that this phenomenon will be recorded over all oil fields, but can be used as additional information when assigning exploration priorities. In the case of the Amadeus Basin, the magnetic results are dominated by anomalies of this nature which are attributed to ironstone bands in the sedimentary units. As these are very shallow it would be almost impossible to recognise any direct hydrocarbon signature from a reduction zone.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The aeromagnetic survey has been most successful in defining details of the geological structures below much of the sand dune cover in OP 236. This information should be useful in assisting correlations between the widely spaced seismic lines from the 1985 seismic survey. The detailed structural trends were obtained from short wavelength magnetic anomalies associated with what is believed to be conformable ironstone bands within the sedimentary formations. These were detected by the survey because it was flown at an altitude of 100 metres above mean terrain height. This clearance is much lower than would be used in most airborne surveys for petroleum and this valuable information would otherwise have been lost or not recognised.

In addition, detailed modelling of some of the magnetic lines has shown that the Bitter Springs volcanic horizon can be mapped as a continuous undulating unit. The approximate depths and anticline locations can be interpreted from these models.

Two major north-west trending lineaments or faults that parallel major gravity lineaments have been detected. The major gravity lineament appear on the national gravity map of Australia and extend well beyond the margins of the Amadeus Basin.

The magnetic field response is dominated by large amplitude regional anomalies which were removed to allow interpretation of the Bitter Springs Formation and shallow magnetic ironstone units. The source of these anomalies is at an estimated depth of 15,000 metres, well below the expected depth for crystalline basement. The source of the anomalies probably relates to major crustal deformations.

Regional gravity data from the BMR provides some additional information at a regional scale. It is apparent that there may be some density inversions that complicate the interpretation. This relationship will become more clear when the detailed gravity data from the seismic lines is available.

It is recommended that some section of the magnetic survey be interpreted in detail in conjuction with the seismic data, when this data becomes available. The object of this detailed study will be to map the Bitter Springs more accurately between seismic lines.

It is also recommended that all the flight line are reprocessed by the new Werner deconvolution program after removal of the crustal magnetic anomalies (regional). This will further assist the mapping of the Bitter Springs volcanic horizon.

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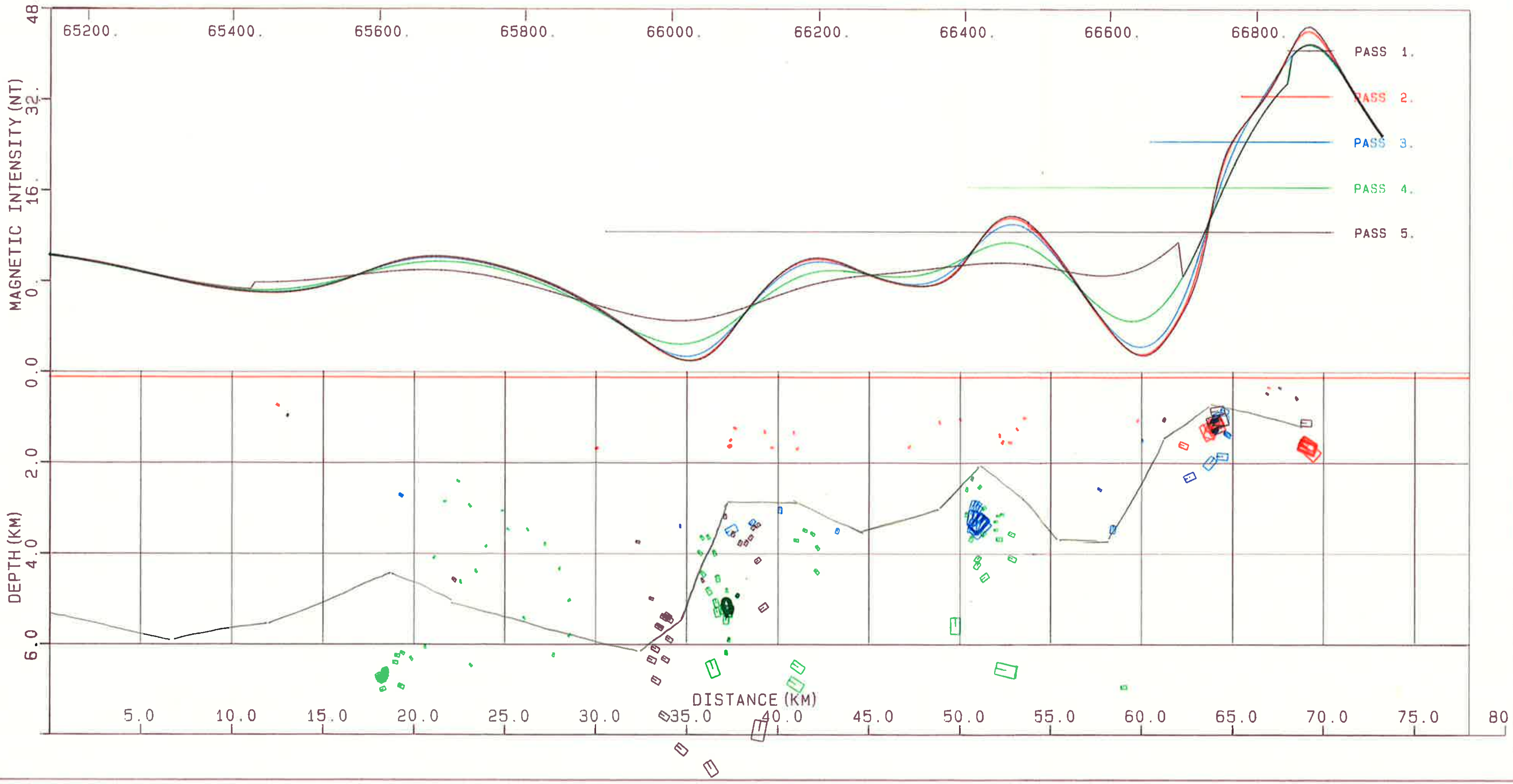

Bitter Springs Horizon Magnetic Model

SYDNEY OIL COMPANY

LINE L 10310

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Data spacing = 250 m

Scanning step = 1.

PROJECT: 6.1.13

DATE: 27-MAR-86

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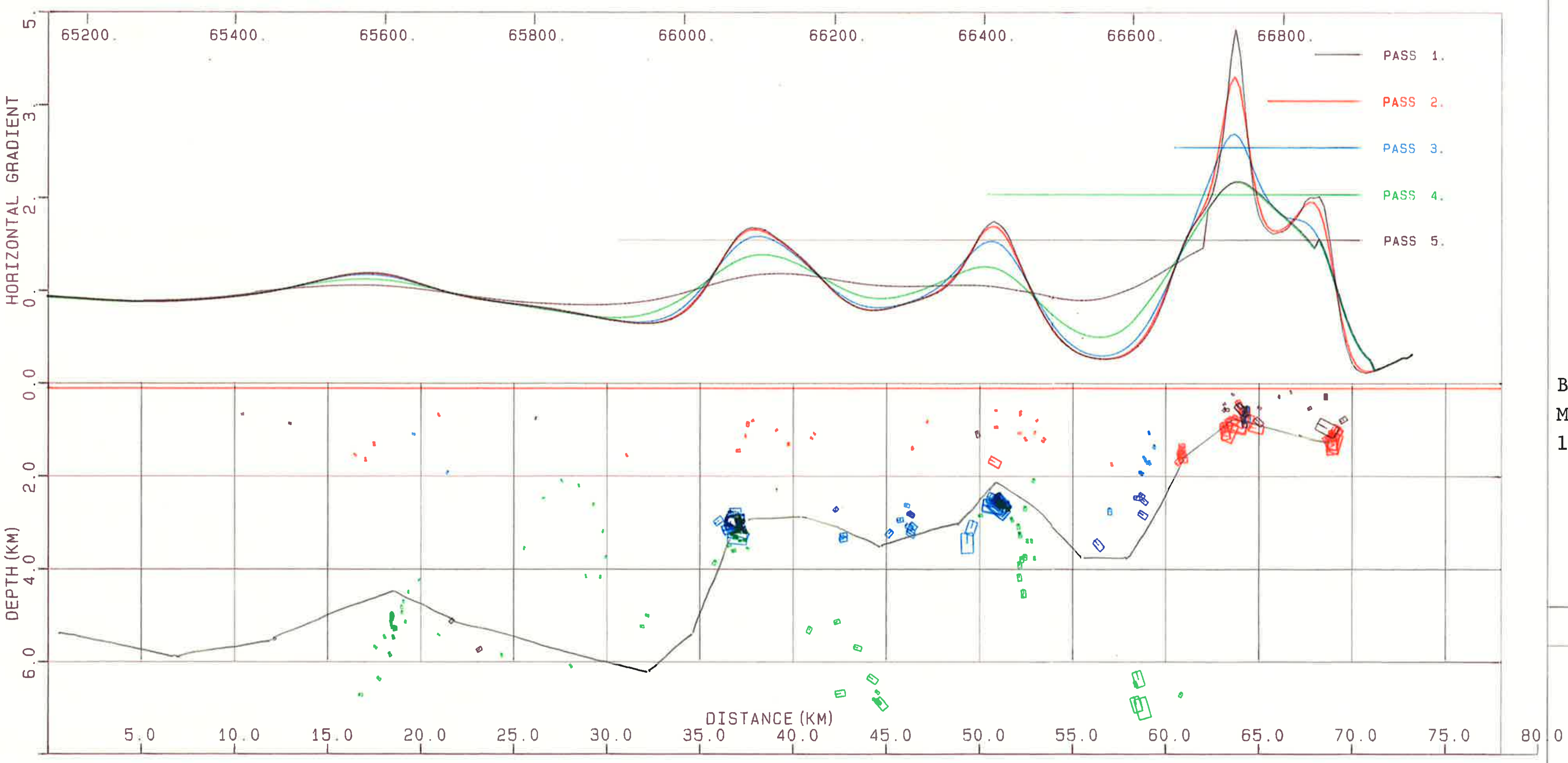


Bitter Springs Horizon
Magnetic Model
1st Derivative Plot

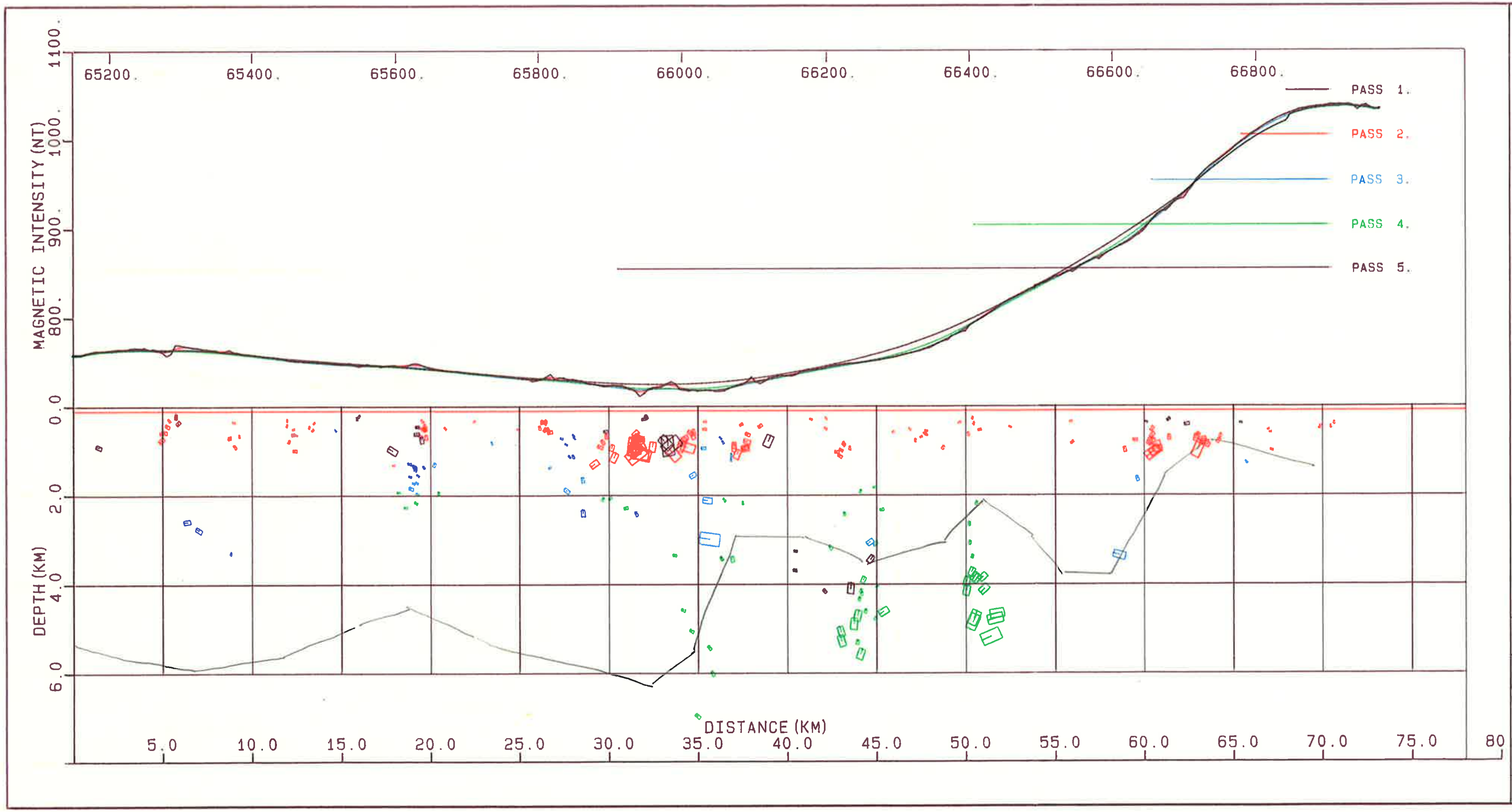
SYDNEY OIL COMPANY

LINE L 10310
MODEL TYPE = INTERFACES
Data spacing = 250 m
Scanning step = 1 .

PROJECT: 6.1.14

DATE: 28-MAR-85

PR85/036A



Aeromagnetic Profile

SYDNEY OIL COMPANY

LINE L 10310

MODEL TYPE - THIN SHEET

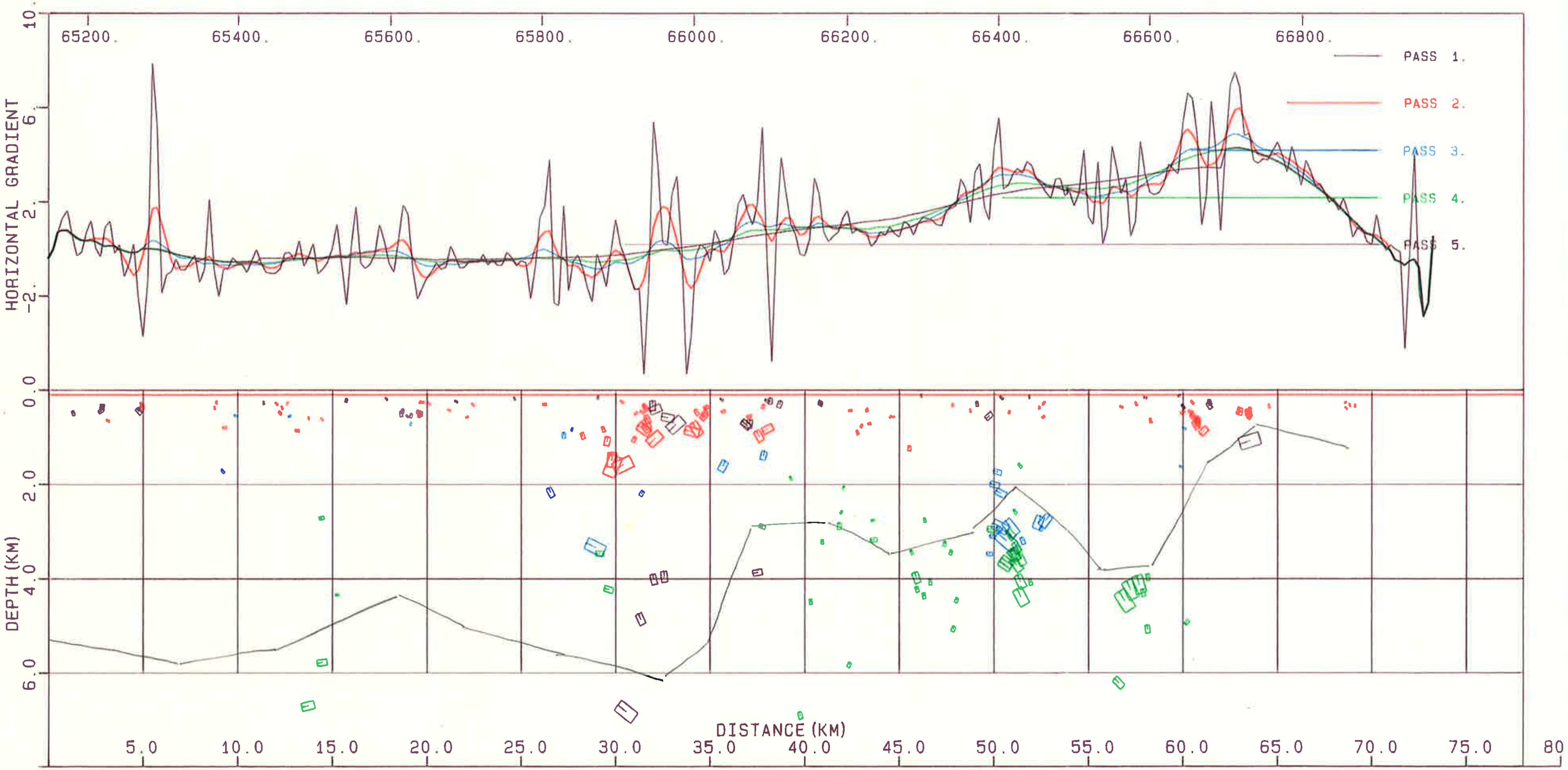
Data spacing = 250 m

Scanning step = 1.

PROJECT: 6.1.15

DATE: 27-MAR-86

PR85/036 A



Aeromagnetic Profile
1st Derivative Plot

SYDNEY OIL COMPANY

LINE L 10310
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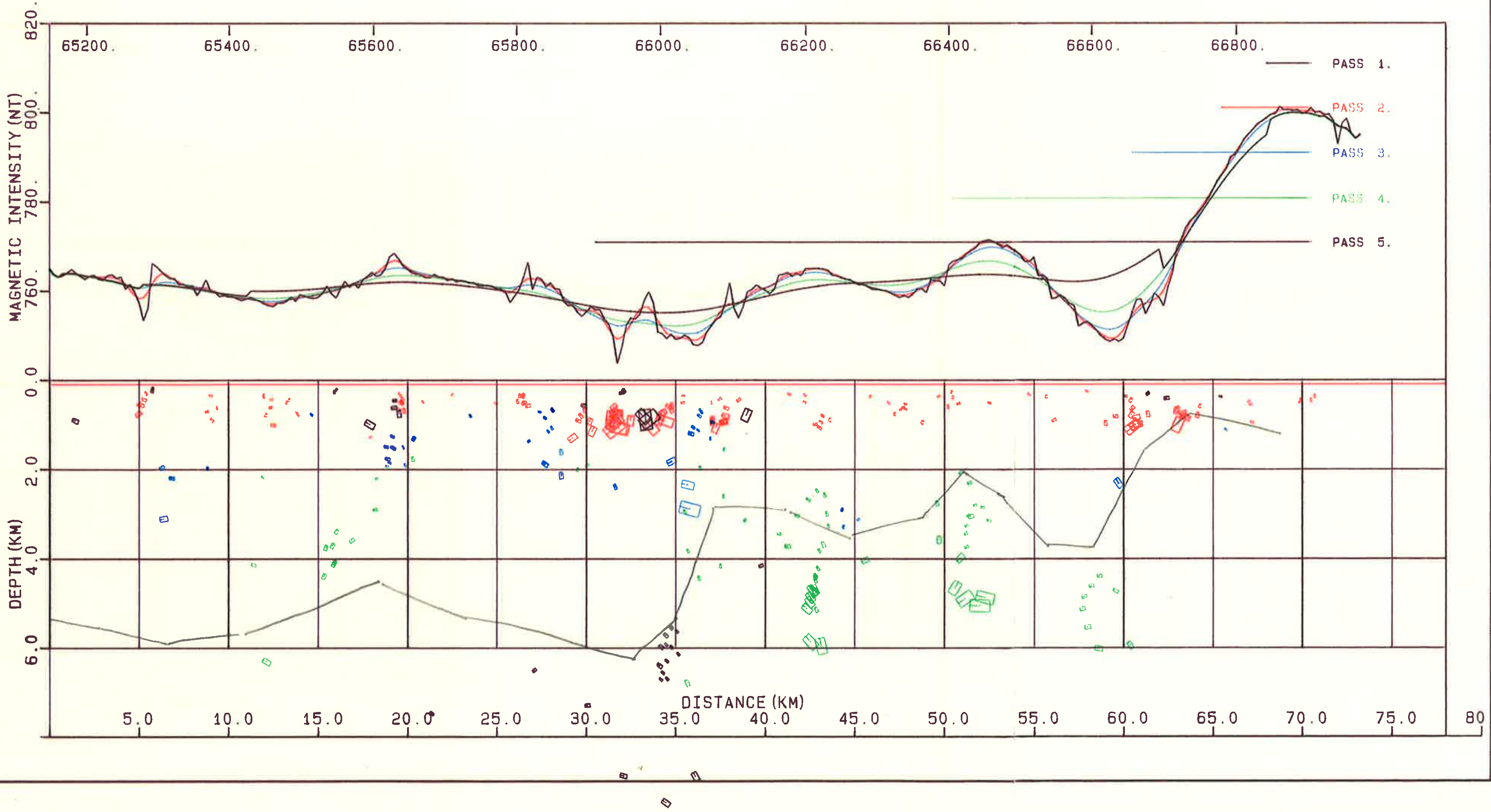
PROJECT: 6.1.16
DATE: 28-MAR-85

PR85/036 A



Aeromagnetic Profile
with Regional Removed

SYDNEY OIL COMPANY

LINE L 10310

MODEL TYPE = THIN SHEET

Data spacing = 250 m

Scanning step = 1 .

PROJECT: 6.1.17

DATE: 27-MAR-85