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MEMORANDUM

TO	Richard Brescianini , Arafura Resources Ltd.
FROM	Pavel Jurza
DATE	31 May, 2013
REPORT NO.	SGC2625
RE	Nolans Bore Depth to Basement Processing

1 INTRODUCTION

Arafura are looking for water resources close to their Nolan's Bore Project. To assist with locating drill holes, they have requested SGC to use the available magnetic data to try and determine the depth to basement in selected areas. This is to be used to try and better define the Northern Burt Tertiary Basin.

The majority of the area of interest is covered by government airborne magnetic data flown at 400m line spacing and 60m clearance. For the middle-northern part of the area, more detailed surveys at 100m line spacing and 30m clearance are available. The area of interest and the coverage of airborne surveys are shown in Figure 1 below.

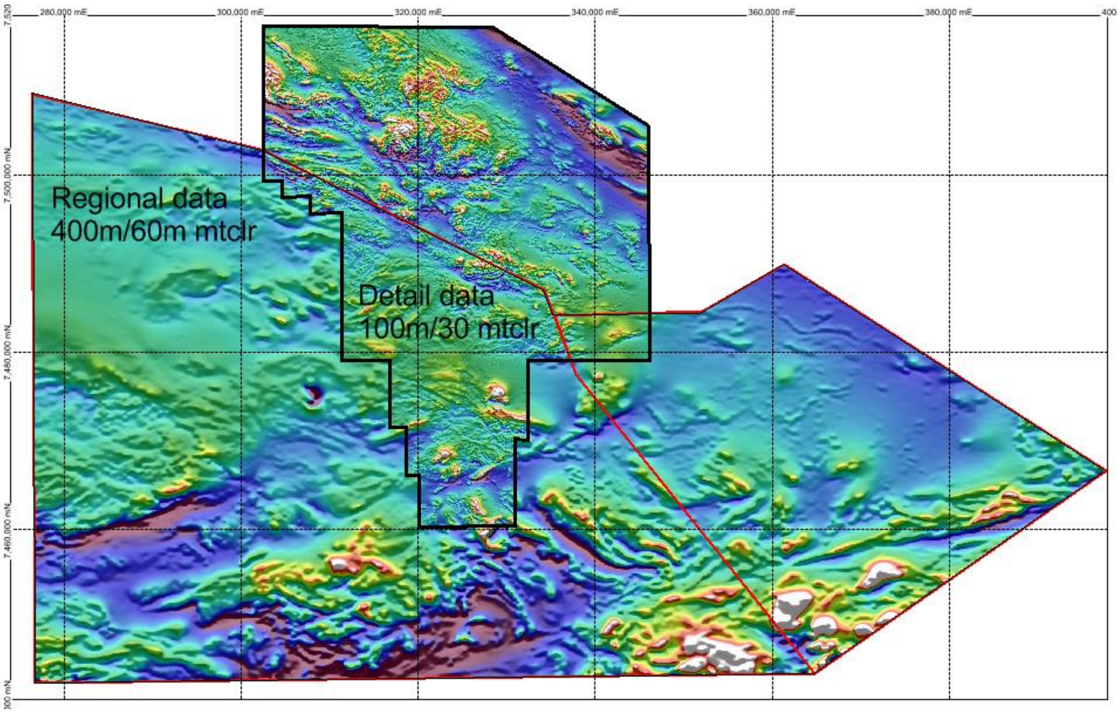


Figure 1: Nolans Bore project area with TMI shaded image in the background.

In order to carry out the depth-to-top of magnetic sources processing at a satisfactory level, we combined a range of methods with the aim of balancing the limitations of each particular approach. Our selection of methods included Naudy and Euler automatic magnetic depth estimation, magnetic spectral depth (Spector and Grant, 1970) and 2D modelling using Potent software. Also magnetic tilt contours were produced for the tilt-depth method.

The depth estimation exercise over the Nolans Bore project area returned a range of depths from shallow 'at surface' (about 25 m depth) to quite deep sources (over 300 m depth).

2 OVERVIEW OF METHODS AND THEIR LIMITATIONS

2.1 Potent 2D modelling

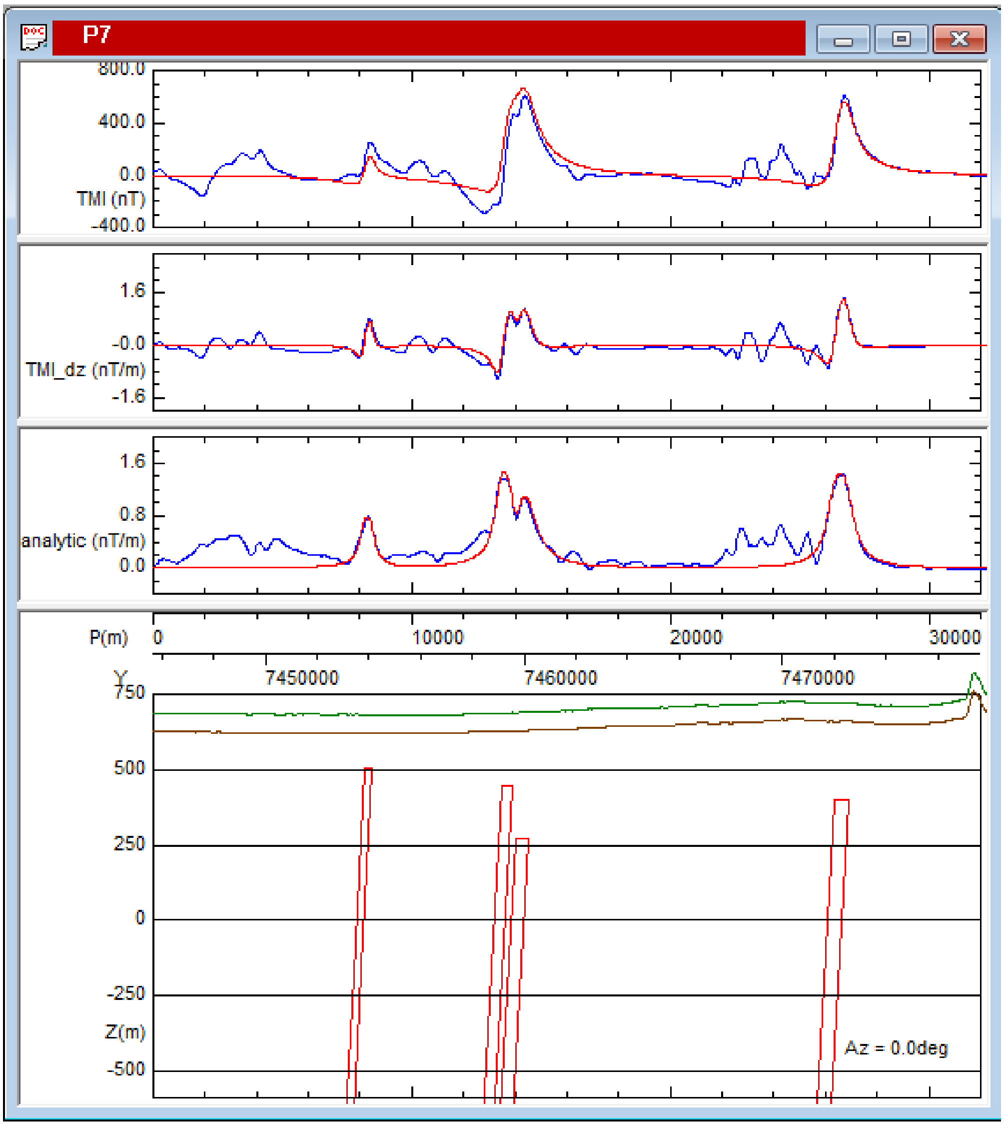


Figure 2: Example of Potent modelling - dykes at Nolans Bore project

Interactive 2D modelling/inversion packages such as Potent allow definition of idealised magnetic source geometries in 2D or 2.5D sense. Modelling is based on fitting of the calculated model response to the observed magnetic response curves on profiles (ideally) perpendicular to the strike of anomalous structures (see example in Figure 2 above). The limitation is the use of rather simple model body shapes and general ambiguity in estimated parameters such as depth, width and susceptibility; especially for deeper sources (this limitation holds for all magnetic/gravity modelling and inversion in general).

Because the 2D modelling is also very time demanding (as it needs a lot of interaction from the software user) we could not use 2D Potent modelling as a principal tool for depth estimation over such a large area as the Nolans Bore project. We used this method only to check against the results of other methods with the more global scope.

2.2 Naudy automatic depth estimation

We used the Naudy automatic depth estimation tool provided in the Intrepid software package. The technique is based on 2D profile modelling, however, the process of source identification, parameter estimation and refinement by inversion is automated. The technique does not allow for user adjustment of modelling parameters as in the interactive modelling packages and it produces a range of 'invalid' source solutions that need to be manually omitted from the final product. Also, the whole area is processed with one set of input parameters (such as body type, range of susceptibilities) which may not be optimal in the case of rapidly changing geology over the tested area. Time requirements to run automated depth estimation for a large area such as Nolans Bore are still quite considerable, and the following editing and clean-up is even more demanding. However, this process is still quicker than interactive modelling over a very large number of magnetic sources.

2.3 Euler automatic depth estimation

Conventional Euler deconvolution (Reid et al., 1990) of magnetic (or gravity) data estimates the spatial position and shape type of sources by assuming theoretical models of one singular source point. One-point sources have their position described by a single spatial location, e.g., the sphere centre, the thin rod top or sheet edge, the axis of an infinite circular cylinder, or the infinite contact top corner. The source coordinates and the degree of homogeneity N which is usually interpreted as shape or structural index (SI) (after Thompson, 1982), are coefficients in Euler's differential equation for homogeneous functions of degree $n = -N$. The N (or SI) can be seen also as a measure of the rate that the field falls off with the distance. In practice, the Euler equation is solved for every grid pixel inside of a moving rectangular window forming thus an over-determined system of equations solved usually by a standard least-squares inversion algorithm.

The benefit of the method is a quite simple algorithmic application which enables practical inversions of large data sets. One of the limitations of the method comes from the principle of the method itself as it searches for the optimum solution of the single source point based on the grid data within the specified window. The window must be wide enough to allow solutions at the desired depth range; however, the size must be on the other hand limited so that the window will not include multiple sources at once. Similar to the Naudy depth estimation, the Euler solutions are also dependent on the source geometry represented by the above mentioned structural index SI. The incorrect setting of the SI means large errors in the output of the method. Some implementations are using extended versions of the Euler equations and try to estimate the optimum SI for a given window location.

The traditional Euler deconvolution has a history of producing sprays of solutions, within which the correct answer for each discrete body needed to be found. A discrimination technique is needed to distinguish more reliable solutions from spurious ones, and to characterize geological features of interest. There are a number of various approaches suggested in the literature on how to deal with the discrimination problem. With the large amount of solutions the process can be quite demanding in finding the optimum approach which would work for a given dataset.

2.4 Spectral depth estimation

This method developed by Spector and Grant (1970) uses analysis of the radial power spectrum of magnetic field to identify groups of magnetic sources and their depths. This method has the advantage over the 2D modelling methods (as described above) of being largely independent of the geometry or susceptibility of the magnetic sources. However, it does have also its own limitations as noted by Gunn (1997). This method was designed to analyse broad areas with multiple magnetic sources at varying depths rather than for localised individual anomalies.

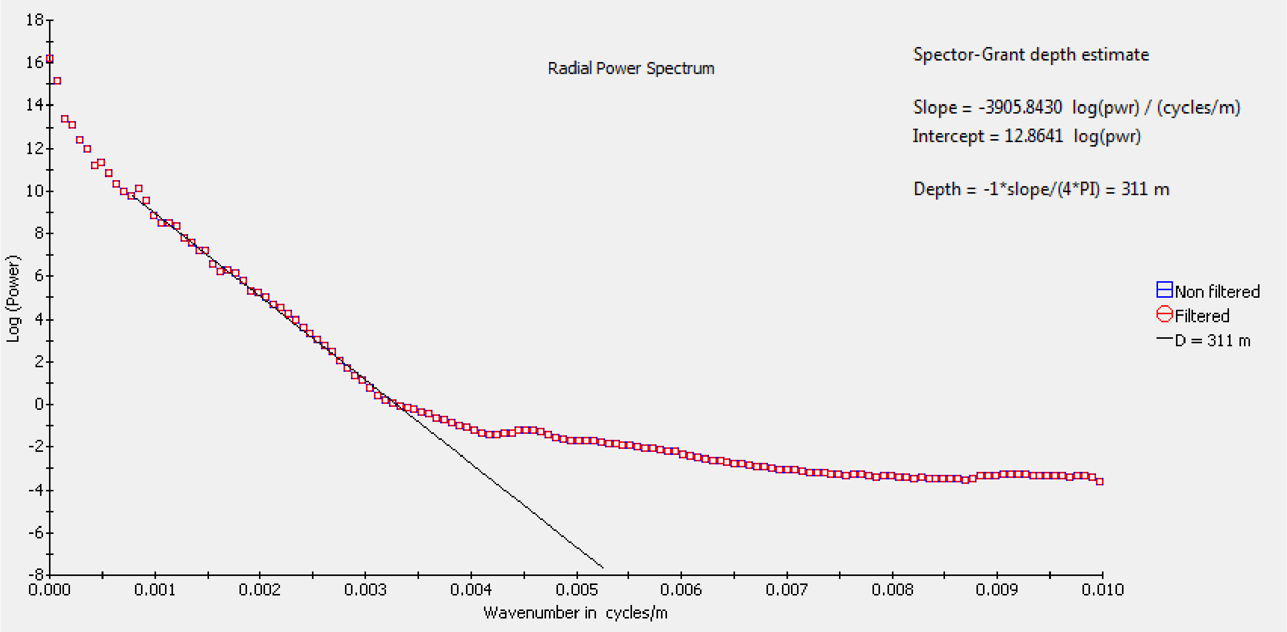


Figure 3: Example of the spectral depth estimation using slopes of the radial power spectrum

The process involves manually interpreting straight line segments on the power spectrum graph as shown in Figure 3 above.

3 NOTES ON THE DEPTH ESTIMATION AND MODELLING RESULTS

3.1 Potent 2D modelling

The 2D interactive modelling was done using Potent software over selected anomalies using the located data (regional 400m spaced survey). The selection was not easy as there were limited anomalies which would provide distinct responses suitable for modelling using simplified model bodies. We used the tabular (dyke) body model in all instances as it provides good flexibility for adjusting various parameters. To improve the reliability of solutions, modelling was based on total magnetic intensity (TMI), the first vertical derivative of TMI (1VD) and also on the analytical signal (AS) data. The results are presented in Table 1 below.

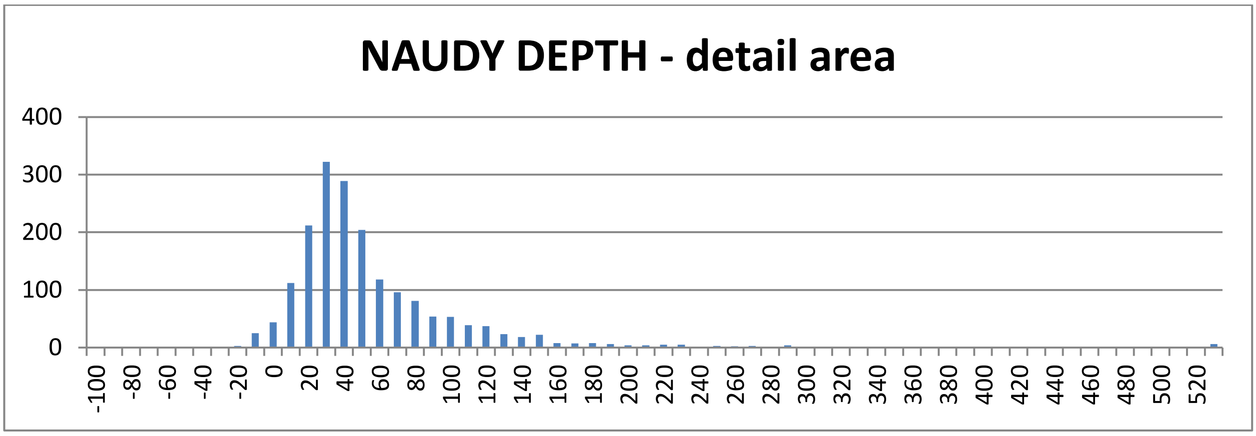
Table 1: Interactive 2D modelling results.

No	X	Y	Z	DTM	Depth	Strike	Dip	Width	Length	D_Ext	Sus
1	284438	7460303	295.1	575	280	75	110	246	4000	8500	0.14
2	289266	7451790	210.94	581.1	370	80	149	330	3000	9659	0.06
3	289216	7461479	242.81	579	336	80	165	600	3000	800	0.20
4	292403	7497115	438.85	635.7	197	70	46	1000	2000	3126	0.03
5	292477	7488549	484.83	613.7	129	70	67	921	2000	957	0.00
6	319372	7471653	427.47	620.2	193	65	37	374	3000	811	0.05
7	319368	7450185	496.4	608.6	112	75	39	650	3000	811	0.04
8	308293	7454182	335.2	598.5	263	65	46	333	3000	689	0.06
9	332440	7472254	396.76	661.3	265	110	58	504	4000	8000	0.07
10	332440	7459914	270.04	630.3	360	110	58	464	4000	8000	0.08
11	332440	7459356	448.96	628	179	110	58	425	4000	8000	0.05
12	332436	7453967	503.6	623	119	110	60	300	4000	1281	0.02
13	340519	7477084	474.15	670.9	197	90	34	563	3000	1300	0.13
14	342371	7446725	197.37	639.4	442	90	60	700	3000	400	0.26
15	342373	7449475	228.55	638.2	410	90	25	690	3000	386	0.26
16	342368	7448250	213.63	639.7	426	90	36	300	3000	384	0.30
17	367247	7457652	289.07	671.5	382	75	25	389	3000	384	0.24
18	384962	7460853	292.27	689.7	397	80	136	463	4000	786	0.17
19	384967	7464450	555.44	679.5	124	115	49	315	4000	806	0.05
20	384968	7462442	524.47	684.9	160	115	74	403	1000	700	0.04
21	384963	7449838	483.8	732.2	248	100	93	518	6000	1318	0.14
22	384963	7450755	496.4	727.1	231	100	60	579	3000	1288	0.17
23	384963	7450338	496.2	730.3	234	100	60	179	3000	200	0.15
24	389340	7485244	438.6	626.9	188	80	36	418	5000	1162	0.02
25	355978	7458493	305.65	653	347	75	4	388	3500	150	0.80
26	292548	7464458	268.14	588	320	75	25	145	4000	965	0.58

By selecting the larger and more distinct anomalies to allow for reasonable 2D modelling, we may also have selected somewhat deeper magnetic sources. This may help explain the fact that all modelled bodies are at 100m depth or deeper, whereas the NAUDY or EULER solutions returned a majority of solutions around 50 to 60 m depth.

3.2 Naudy automatic depth estimation

The Intrepid software implementation of the Naudy method was carried out separately on regional and detail datasets because of the difference in the resolution of magnetic data flown at 30 and 60m respectively. The dyke model was selected with the option to automatically calculate trends using information from parallel flight lines. Histograms of the solutions are shown in Figure 4 below. The depth estimates are clustered around 30m for the detailed surveys and 50m for the regional surveys.



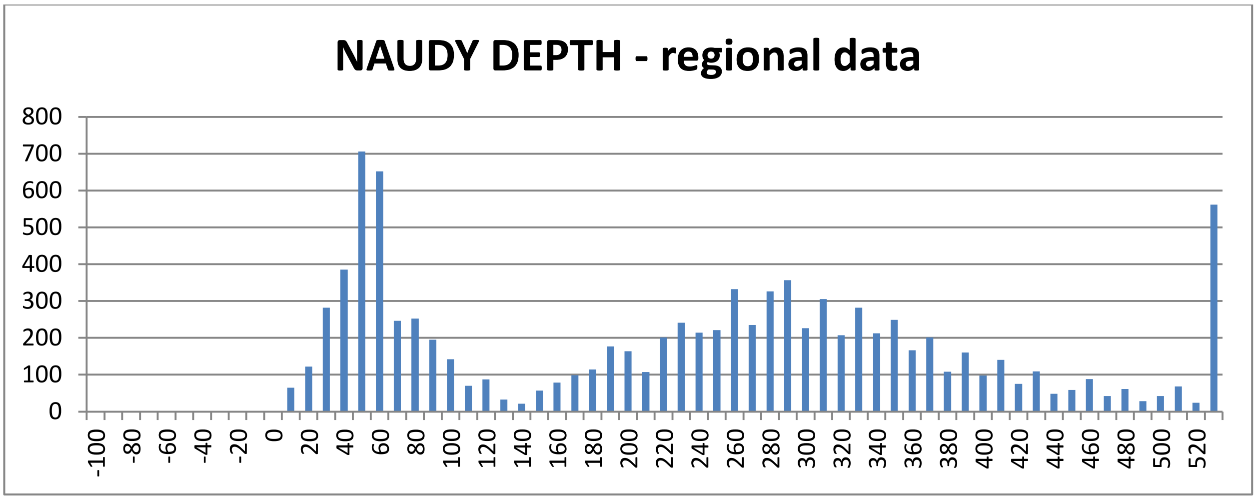


Figure 4: Distribution of NAUDY depths for detail and regional magnetic data.

The NAUDY depth solutions were imported into several MAPINFO tables with different depth ranges. The tables are attributed with the majority of parameters as output by the NAUDY automated process, including those necessary for further culling of spurious results. The large dispersion of NAUDY depth solutions may suggest that the geometry of magnetic sources at the Nolans Bore area is not well suited for the approximation by simple tabular (dyke-like) bodies as used by automated NAUDY process. The other model type options have a history of returning considerably worse results than the dyke model, so they were not tested at this stage.

3.3 Euler automatic depth estimation

The Intrepid software implementation of the Euler deconvolution process was also carried out separately on the detailed and regional magnetic data. Several options of the structural index (SI) were tested. The guide to the SI and its physical meaning is provided below in Table 2.

Table 2: Structural Index guide.

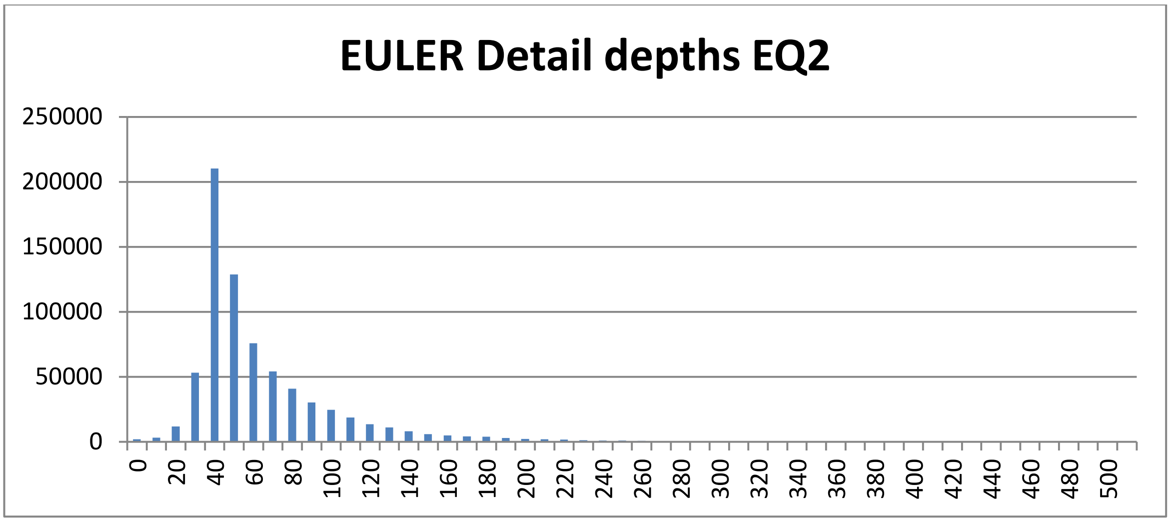
Model Geometry	Geological Setting	SI Magnetic
Point dipole		3
Line, cylinder	Thin bed, fault	2
Thin Sheet edge	Thin sill, dyke	1
Thick sheet edge	Contact	0

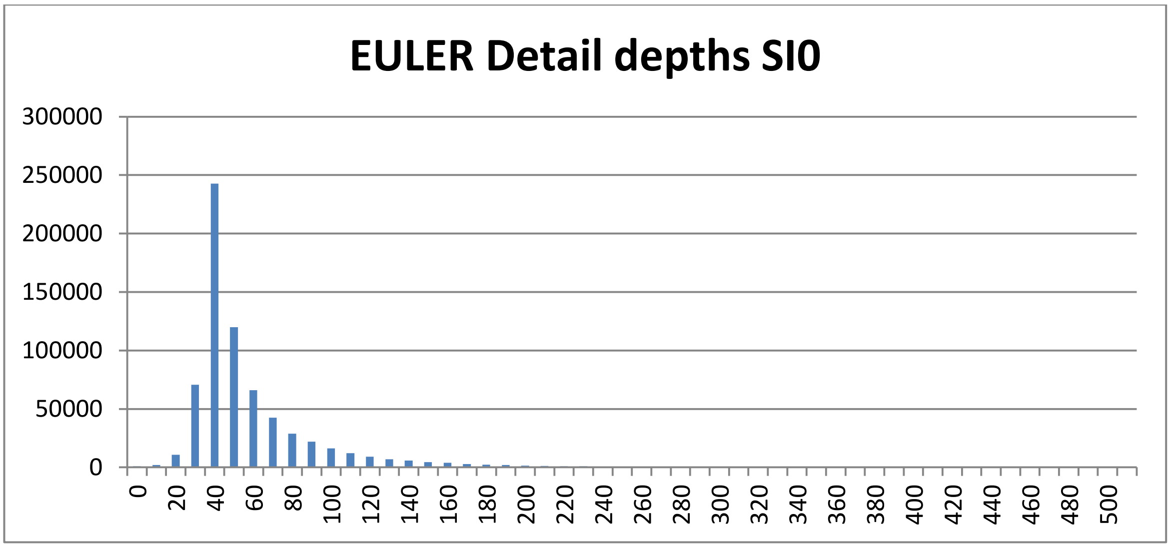
The Intrepid software now also includes an option with extended Euler equation inversion which enables it to look for the optimum SI for a given solution. In the output data as imported into MAPINFO tables we provide solutions for structural index SI=0 and SI=1 (referred in the outputs as SI0 and SI1 respectively) and also for the automated SI solver referred to in the outputs as EQ2. The SI0 (contact) and EQ2 produced solutions at similar depth range while the SI1 (thin dyke) produced significantly larger depths. The automatic SI solver (EQ2) actually returned an average SI=0.16 which is consistent with the result where SI=0 depth distributions are closer to the automatic SI solver (EQ2) depth distributions than to the SI=1 depth distributions.

Histograms showing the range of solutions are shown in Figure 5. The depths are centred around 50m for the EQ2 and SI0 solutions and 70m for the SI1 solutions.

Due to the vast volume of the Euler solution “sprays”, the discrimination process of the Euler depth solutions on the basis of individual points has not been done in this stage. Instead the resulting depth data for all solutions were gridded allowing thus for natural “binning” by the grid averaging process. These elevation grids may be further processed by suitable spatial filtering such as median or minimum filtering over a specified kernel window.

Discrimination of the solutions can be done using a variety of attributes such as goodness of fit, reliability, offset of the solution from the calculation point, etc.





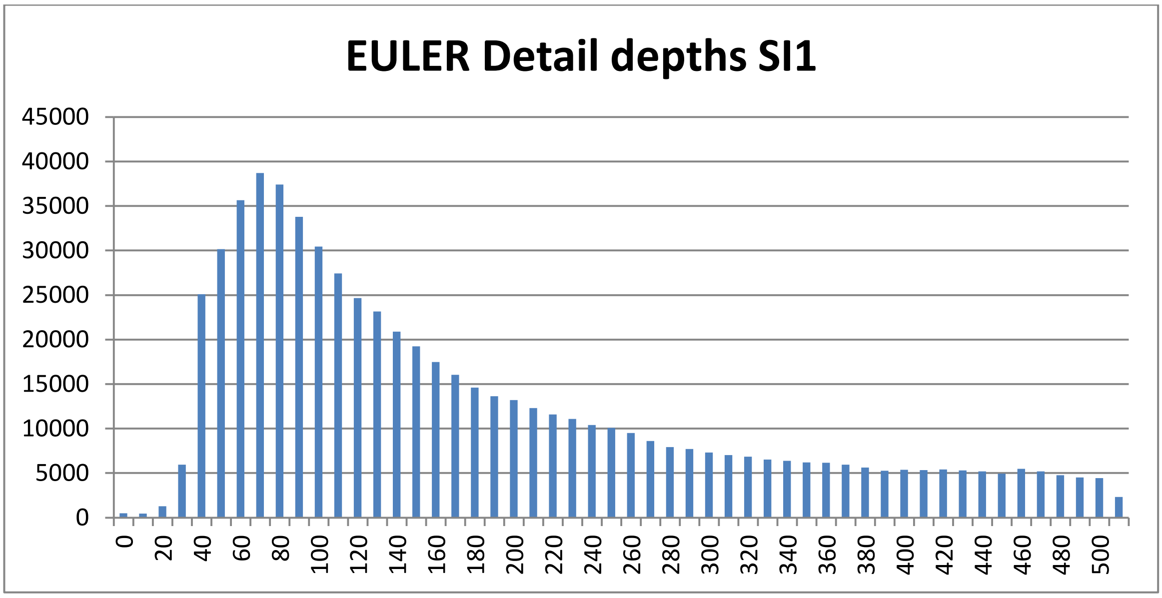


Figure 5: Depth distributions from Euler deconvolution.

3.4 Spectral depth estimation

For the purpose of the spectral depth estimation, the regional data and detail data grids were separated into a number of blocks. Unlike the Naudy or Euler methods which can produce depth estimates for localised sources, the spectral depth estimation method needs larger areas to populate the radial power spectrum with the required confidence. The regional survey data were broken into nine blocks and the detail survey data were separated into four blocks. Power spectrums were produced for each block of data and four to five magnetic layers were identified for each individual block. The block outlines and respective layers are provided in the form of MAPINFO tables and the results are also provided in Table 3 and Table 4 below.

Table 3: Spectral depths - regional data blocks

Clearance 60m removed

BLOCK	Layer4	Layer3	Layer2	Layer1	near surface
1	1402	430	250	75	0
2	1560	360	175	80	25
3	990	332	210	55	5
4	1140	340	200	50	10
5	590	290		55	10
6	940	365	155		5
7	1745		125		-5
8	955	345		70	5
9	555	370		65	5
Average	*1097*	*354*	*186*	*64*	*7*

Table 4: Spectral depths - detail data blocks

Clearance 33m removed

BLOCK	Layer4	Layer3	Layer2	Layer1
1		187	63	25
2	567	157	47	22
3	297		62	30
4	332	107	47	17
Average	*399*	*150*	*55*	*24*

4 RECOMMENDATIONS

The results from the various methods are very varied with numerous solutions of varying validity and confidence. The next step would be to devise procedures to filter the data based on various attributes to remove solutions that have low confidence and/or look unrealistic.

At this stage Arafura have requested that no further work be done until they have assessed the usefulness of some AEM data over the area for depth determinations. Depending on this assessment they have delineated an area that may be used as a trial for filtering.

5 REFERENCES

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