TERRA PETROPHYSICS PTY LTD

(ABN 7613484807)

PNX METALS LIMITED
PINE CREEK REGION
NORTHERN TERRITORY

HAYES CREEK PROJECT
MT BONNIE AND IRON BLOW

TECHNICAL REPORT NO. 17_008

PROJECTION/ LOCATION
GDA94 UTM Zone 53S

DISTRIBUTION

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TERRA PETROPHYSICS

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1.0 INTRODUCTION

Terra Petrophysics (Terra) were asked to perform petrophysical analysis on 7 samples from the Hayes Creek Project in the Northern Territory by PNX Minerals Limited. Petrophysical analysis included: induced polarization/resistivity; inductive conductivity; magnetic susceptibility; wet/dry bulk density/Porosity, sonic velocity and radiometrics (uranium ppm, % potassium, thorium ppm).

In each sample batch Terra have used a number of standards and reference samples during the measurement process to ensure precision and accuracy.

2.0 PETROPHYSICS

2.1 Sample Preparation

Samples for physical property measurements should be carefully selected for quality and representation of geology and/or alteration for meaningful results. Terra recommends samples between the sizes of 10cm to 15cm. In this study all samples were of adequate size and quality. The sample size and shape needs to be determined for most physical property measurements (eg. geometric and core size correction factors). All samples, cores and cut off remnants are returned to the client.

All samples submitted to the laboratory are photographed and marked with both client and Terra sample numbers. Samples for which magnetic remanence vector measurements are requested should be oriented in space. All samples should be accompanied by a project name, a brief description of each sample, requested physical property procedures and final disposal requirement for the samples.

Physical property determinations are nondestructive procedures. However, sample preparation requires the sample to have flat/ square ends and sometimes require them to be cut with a rock saw. In addition, samples are required to be submerged in water for 24 hours before being measured. Sometimes samples containing clays can absorb water and break.

2.2 Inductive Conductivity

The inductive conductivity measurement utilizes an inductive conductivity unit. The conductivity is measured in the frequency domain at 10 000 Hz by using the meter to apply an external magnetic field and inducing a small current in the sample. The measurement is most influenced by sample material at the receiver coil and within a 10cm radius from the center of the sample.

Inductive conductivity is calculated from the difference in amplitude between the sample and free air measurements. The limits of detectability are 0.1 S/m (maximum 100,000 S/m) and resulting data are presented in S/m. Several inductive conductivity measurements will be made and reported when the sample size permits.

2.3 Induced Polarization and Resistivity

The apparent resistivity and induced polarization (or chargeability) determinations are measured in time domain. The resistivity and chargeability is measured by passing a constant current through the sample and then switching it on and off at 2 second intervals. While the current is flowing through the sample, the resistivity (ohm-m) is calculated. When the current is switched off, the voltage across the sample drops and a decay curve is measured. The induced polarization (mV/V) is calculated from this decay between 450-1100 milliseconds after turn off (Newmont Standard). Resistivity and induced polarization is stacked and averaged a minimum of 10 times for one reading. Terra provide the average results for three readings (minimum).

2.4 Wet/Dry Bulk Density and Porosity

The density determinations are calculated using Archimedes Principle. Dry bulk densities are determined by dry weight divided by the buoyancy determined volume of each sample. Porosities are calculated from water saturated weights, dry weights, and the buoyancy-determined volume. All sample are soaked for 24 hours after dry weights are measured.

The accuracy of the buoyancy technique of density measurement is 0.01 grams per cubic centimeter. The results of the laboratory density determinations are reported in grams per cubic centimeter. Density measurements can be made on grab samples or drill core. Very large or heavy samples (>1kg) require coring or breaking prior to the density determination.

2.5 Magnetic Susceptibility and Remanence

The magnetic susceptibility is measured by a magnetic susceptibility meter. The susceptibility is measured by using the meter to apply an external magnetic field to the sample at an operating frequency of 8 kHz. Magnetic susceptibility is calculated from the frequency difference between the sample and free air measurements. The limits of detectability are approximately 1×10^{-7} SI units and resulting data is presented in 10^{-3} SI units. The measurement is most influenced by sample material at the receiver coil and within a 10cm radius from the center of the sample. Magnetic susceptibility measurements can be made on core, hand and surface samples.

For magnetic samples ($>5 \times 10^{-3}$ SI) the magnetic remanence can be measured. The measurement of remanence (Jr) in the field and the ratio of remanence to the induced magnetization (Jr/Ji = Q) has in the past been problematical. The induced magnetization can be estimated using the susceptibility (k, where Ji = kH and typically H = 40 – 50 Am^{-1}) which can be measured using a handheld meter, but magnetic remanence is more difficult.

A recent development in field instrumentation uses a miniature fluxgate magnetometer and a pendulum arrangement in which a magnetic rock may be swung generating a transient signal at the fluxgate which is converted to a magnetic moment and magnetization.

Remanent magnetism within a rock species represents the residual magnetism held within ferromagnetic minerals following the removal of the influencing external magnetic field. Measurements of the magnetic susceptibility, remanence and Koenigsberger ratio (Q) of a sample reflects the corrections required for the effects of the size and small scale magnetic behavior of mineral grains. A further explanation can be an isothermal remanent magnetism inflicted onto samples during drill extraction procedures (McWilliams, 1990). The influence this can have may vary the final remanent magnetism by a magnitude greater than the initial response depending on the proximity to the core barrel walls.

The Q ratio indicates the difference between the induced and remnant magnetism of a sample, for Q values greater than one the material is labelled as remanent, with those above ten indicating highly remanent. For those showing values less than one, we determine the sample have a greater induced magnetism. The calculations used to determine the induced and remanent magnetism, Q ratio and the overall magnetic susceptibility of a core sample was dependent on the total volume of the sample in terms of the allocated height, width and depth of each individual segment. Variation between the measurements half cores and quarter cores required the segments to be modelled as prisms with the total area allowing the calculation of each side of the core sample.

The meter operates at a frequency of 17 kHz, the transient signal generated over the fluxgate by the pendulum swinging sample is converted into a magnetism value. This method also allows for the induced magnetism and remanence to be calculated (Schmidt, 2014). The final calculated magnetic susceptibility is a product of the Earth's total magnetic field and the induced magnetization.

2.6 Spectral Radiometrics

Terra Petrophysics can offer radiometric analysis on any petrophysical sample submitted. The high sensitivity spectrometer contains two large Sodium Iodide (NaI) crystals (~100cm3) that auto stabilize on the naturally occurring (potassium-K, uranium-U and Thorium-Th) radioactivity. Terra Petrophysics provides results in %K and ppm of U and Th. Further work is currently being undertaken to eliminate background sources from measurements. Current measurement includes background radiation sources.

2.7 Velocity

Terra Petrophysics can offer P-wave velocity measurements on any petrophysical sample greater than 15cm submitted for analysis. Measurements are taken at 50,000 Hz. The velocity measurement range is between 1500-9999 m/s.

3.0 RESULTS

The petrophysical results have been included as Appendix 1. Photographs of the samples have been included as Appendix 2. A comparison of the dominant petrophysical responses are shown in Figures 6.1 to 6.10.

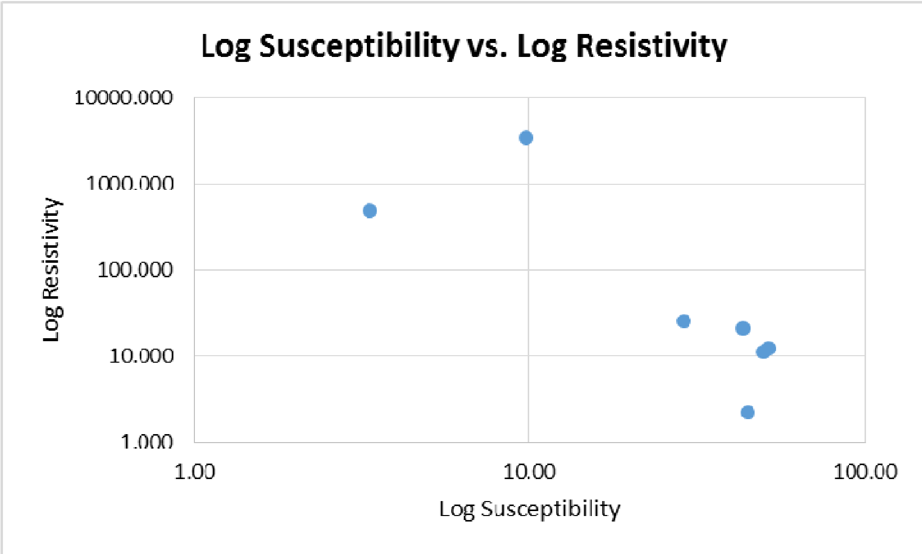


Figure 6.1 Log graph of magnetic susceptibility plotted against resistivity.

A trend of high magnetic susceptibility and an associated low resistivity is observed across a majority of the core samples (Figure 6.1). Unusually high resistivity combined with an average magnetic susceptibility reading is noted for sample BAD001, 52.61- 52.73m. The resistivity within samples BADD001, 75-75.07m and BADD001, 52.61-52.73m are likely influenced by bedding and foliation along the core.

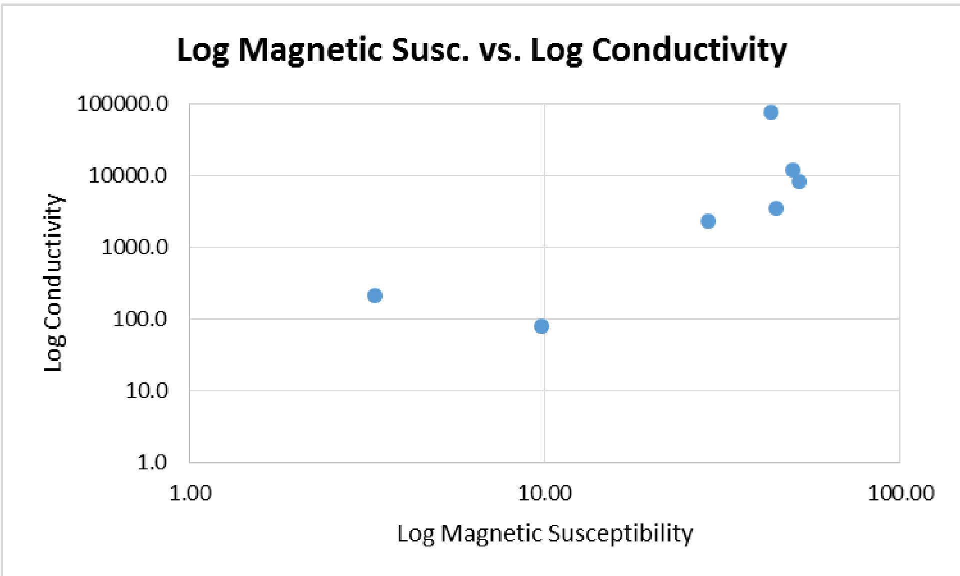


Figure 6.2 Cross plot of log magnetic susceptibility against log conductivity

The majority of the core samples show high magnetic susceptibility with an associated high conductivity response (Figure 6.2). The higher response observed within the conductivity and magnetic susceptibility is due to the increased percentage of sulphides (pyrrhotite).

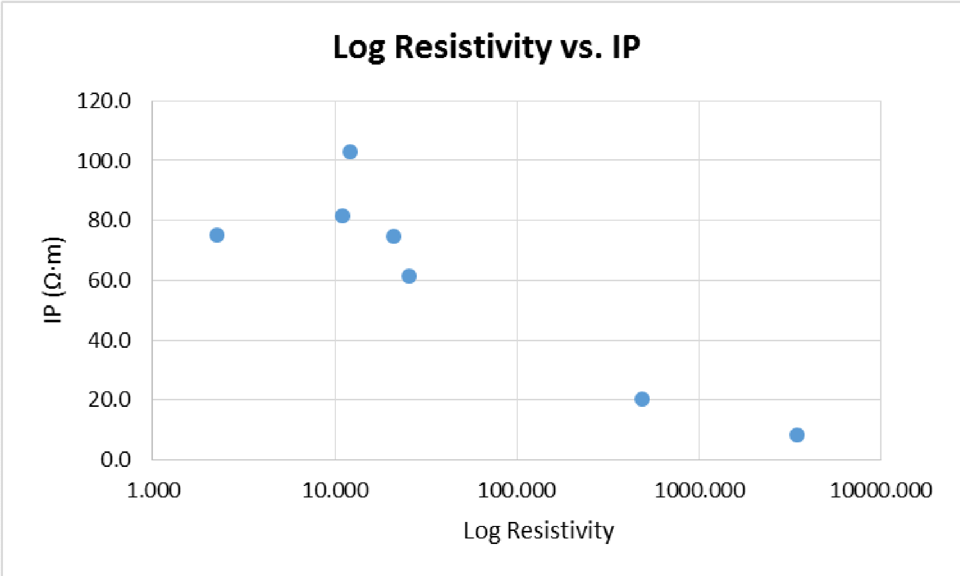


Figure 6.3 Cross plot of of log resistivity against chargeability (IP) readings

The resistivity against IP (Figure 6.3) shows as resistivity increases, the overall chargeability is observed to decrease, with exception to sample BDH023.

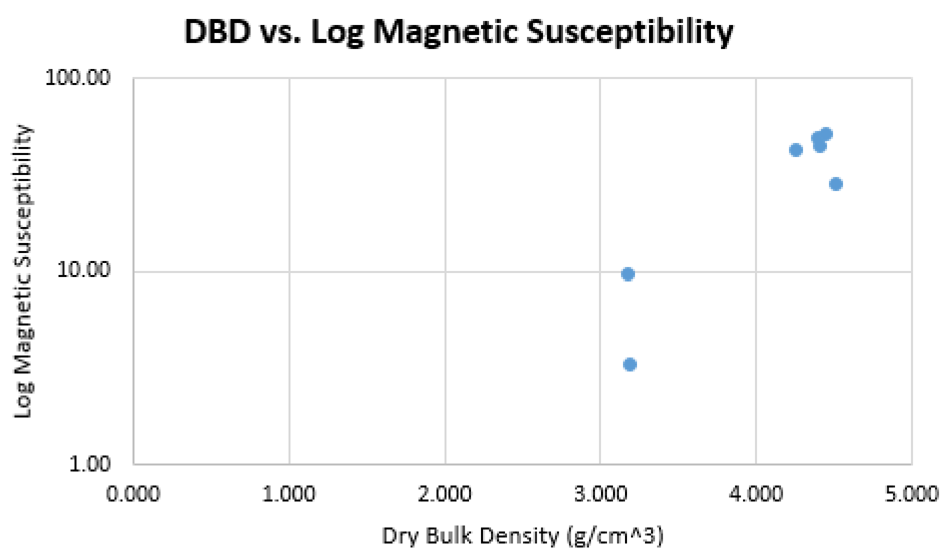


Figure 6.4 Cross plot of dry bulk density vs. magnetic susceptibility readings

Highly magnetic minerals within the overall composition are observed to contibute towards dry bulk densities of the samples (Figure 6.4). A majority of the samples display higher dry bulk densities with moderate to high overall magnetic susceptibilities. The trend of increasing density with increasing susceptibility is consistant with pyrrhotite bearing rocks (Figure 6.5).

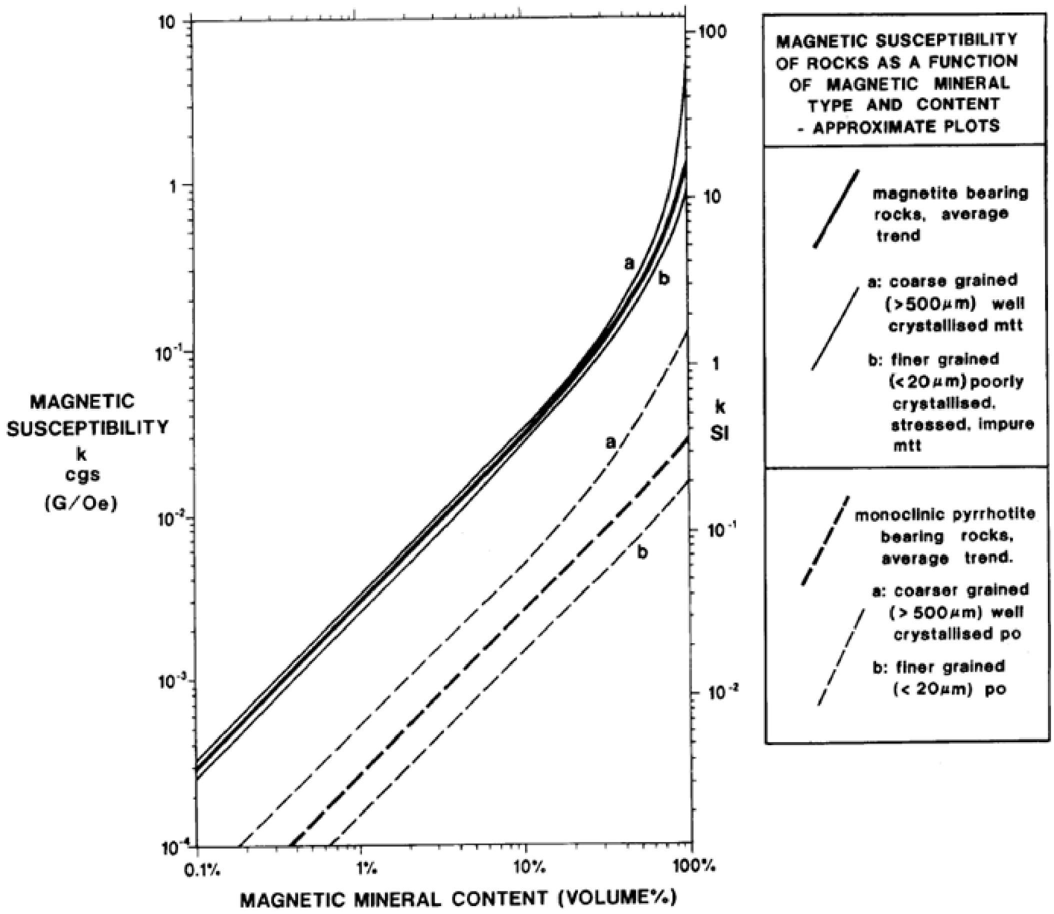


Figure 6.5. Graph displaying magnetic susceptibility of rocks with respect to overall magnetic mineral content (Emerson, 1997)

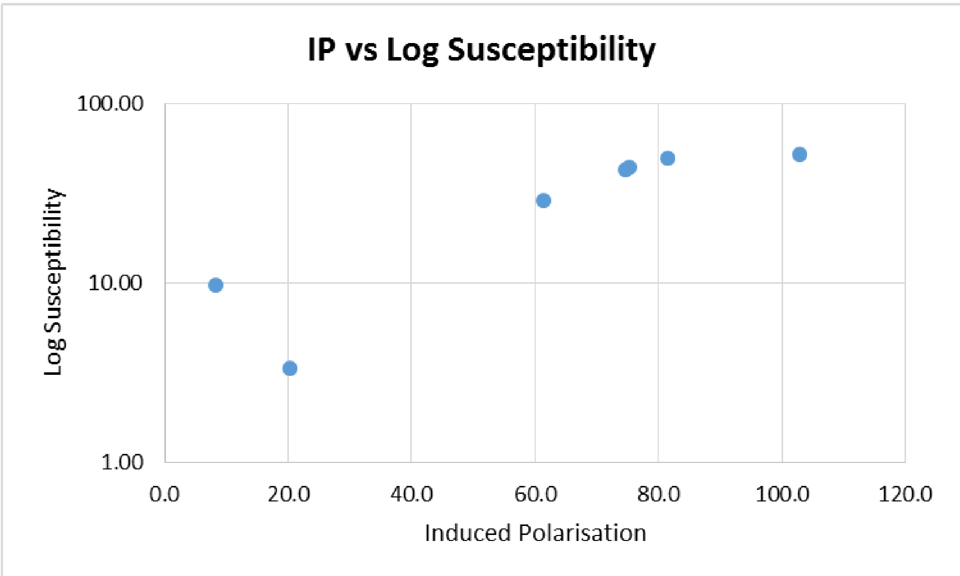


Figure 6.6 Graphed results of chargeability (IP) against susceptibility of samples.

The IP and susceptibility is shown to follow a linear trend. A slight deviation, observed in sample BADD001, 52.61-52.73m, is likely due to bedding and foliation along the core. (Figure 6.6).

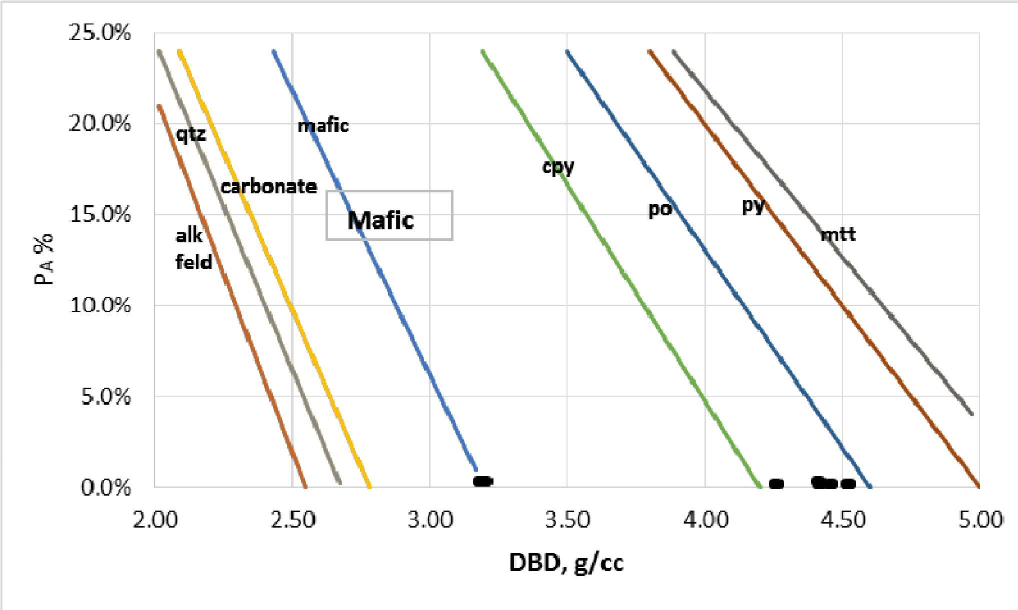


Figure 6.7. Plot of apparent porosity against dry bulk density of core samples. Graph displaying estimated linear trends of common minerals with respect to Dry Bulk Density (g/cc) vs. Apparent Porosity, PA (%) (Emerson, 1997).

The trendlines observed of dry bulk density against apparent porosity associated with common minerals provides insight into the expected minerals within the measured core samples. A composition (assuming 100% of a particular mineral) approaching cpy to po is shown from a dry bulk density ranging between 4.2 and 4.6 g/cc. The total porosity of the samples are very low.

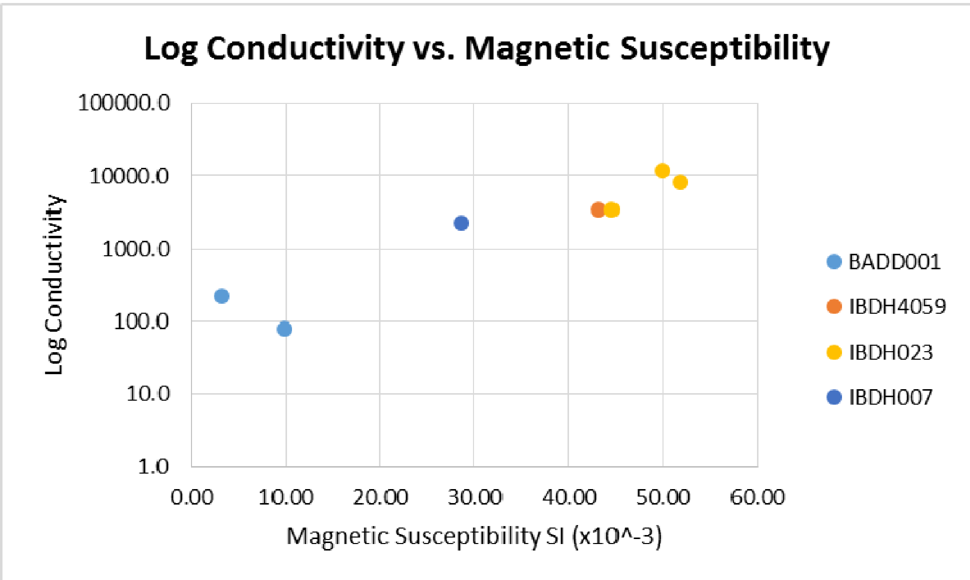


Figure 6.8. Cross plot of Log Conductivity against Magnetic Susceptibility for respective drill holes.

Hole IBDH007 shows high conductivity and similar to those observed from drill hole IBDH023, however IBDH007 shows a moderate magnetic susceptibility. Further inspection of the sample derived from IBDH4059 reveals a highly variable magnetic susceptibility across the core with values ranging from very low to extremely high. Negative readings also were observed in IBDH4059, an issue commonly observed where the rocks are remanently magnetized.

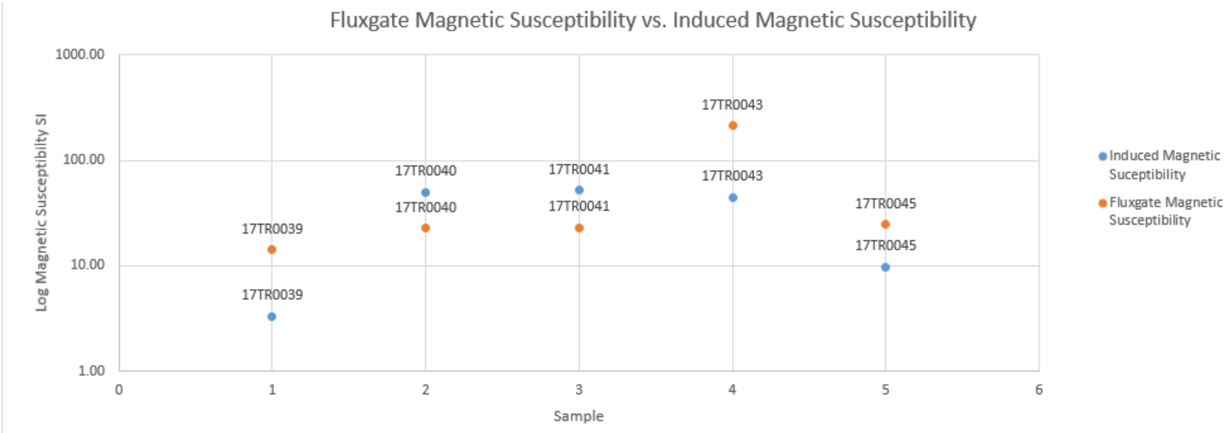


Figure 6.9 Plot of induced magnetic susceptibility readings against fluxgate magnetic susceptibility readings.

There are variations in the induced susceptibility measurements compared to those calculated determine the fluxgate magnetometer (Figure 6.9). Samples 17TR0040, 17TR0041 and 17TR0043 are observed to show a lower final susceptibility compared to the averaged value found from the magnetic susceptibility meter. These samples are shown to have remanent magnetisation which is reflected in the higher J/Rem value (shown in Figure 6.10).

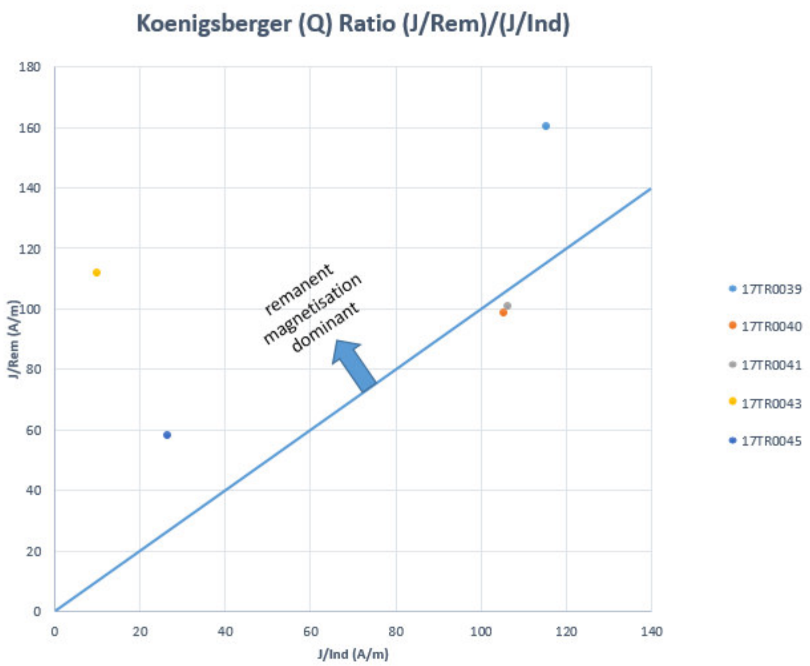


Figure 6.10. Cross plot of the core samples remanent magnetism against their induced magnetism, this represents the Koenigsberger (Q) ratio.

Figure 6.10 Shows variability in the Q ratio across the majority of samples. Core derived from drill hole IBDH023 (i.e. 17TR0040, 17TR0041 and 17TR0043) all display similar induced magnetism, however the induced magnetism decreases significantly in sample 17TR0043, this is reflected in the extremely high Q ratio of 11.34. Samples 17TR0039 and 17TR0045 are both from drill hole BAD001 and show substantial changes in the overall induced and remanent magnetism. As the samples in holes IBDH4059 and IBDH007 (not on graph) are magnetic, contained massive sulphides (pyrrhotite) and exceeded the known limits of the fluxgate magnetometer, they are thought to be remanently magnetized.

As the overall remanence is characterized by the small scale properties of pyrrhotite (magnetic) grains contained within the rock, this may be an indication of variability in grainsize and/or mineral composition. Remanent magnetism, when present in a rock, can be effected by induced isothermal remanence from the drilling processes.

Graphite is known to have a conductivity response (Figure 6.11) is often associated with alteration of marine sediments. Graphite hasn't been observed in the samples.

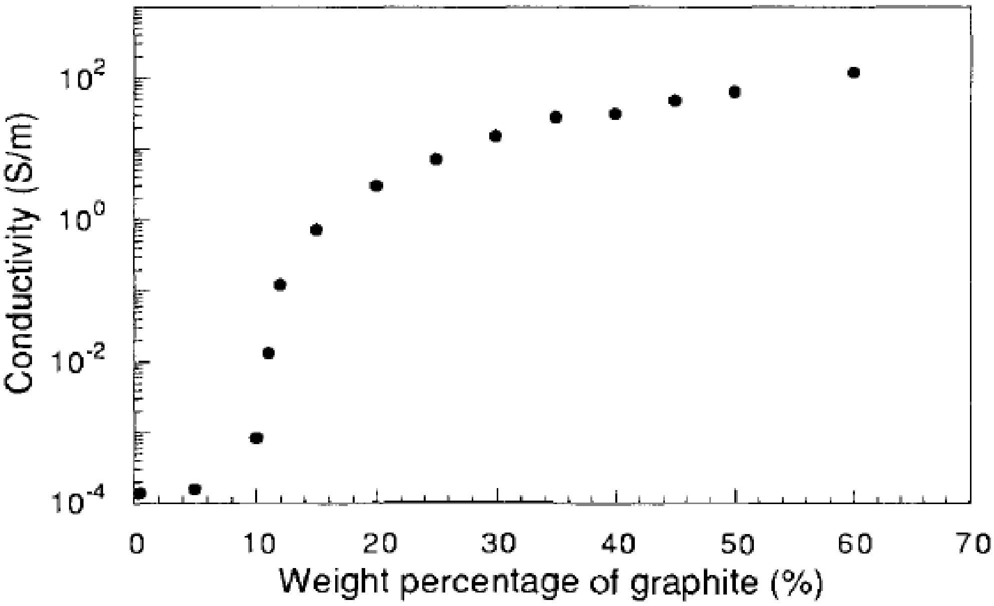


Figure 6.11. Graph displaying trend of increasing of overall conductivity of a sample with respect to overall graphite content (Emerson, 1997)

Magnetic susceptibility and density of common sulfide minerals is shown in Figure 6.12.

Mineral	Density[1]	Susceptibility[2]
Barite	4.5	-
Chalcopyrite	4.2	0.4
Pyrite	5.02	5
Pyrrhotite	4.62	3,200
Sphalerite	4	0.8
Galena	7.5	-0.03
Magnetite	5.18	5,700
Hematite	5.26	40

Figure 6.12. Magnetic susceptibility and density of common sulfide minerals. Densities (g/cm3) from Klein and Hurlbut (1985) and susceptibilities (x 10-3) from Hunt et. al (1995).

7.0 REFERENCES

Emerson, D.W., and Yang, Y.P. 1997. Insights from laboratory mass property cross plots. ASEG Preview 70:10-14.

Hunt, C.P., Moskowitz, B.M. and Banerjee, S.K. 1995. Magnetic properties of rocks and minerals, in Ahrens, T.J., ed., Rock physics and phase relations—A handbook of physical constants: American Geophysical Union. p. 189–204.

Klein, C., and Hurlbut, C.S. 1985. Manual of mineralogy (after J.D. Dana): New York. John Wiley and Sons. p. 596 .

McWilliams, M. and Pinto, M.J. 1990. Drilling-Induced Isothermal Remanent Magnetization. Geophysics. 55: 111-115.

Schmidt, P.W., and Lackie, M.A. 2014. Practical Considerations: Making Measurements of Susceptibility, Remanence and Q in the Field. Exploration Geophysics. 45: 305-313

APPENDIX 1

Sample Information					
Drill	Footage		Sample	Terra	Comments
Hole ID	From	To	ID	ID	
BADD001	75	75.07	BADD001, 75-75.07	17TR0039	Quartz with disseminated sulphides. Foliated, alternating pyrite and feld/qtz bands, amphiboles and chlorite
IBDH023	175		175	17TR0040	Disseminated cpy, py and po, high magnetism
IBDH023			3	17TR0041	Disseminated cpy, py and po, high magnetism
IBDH4059	211.5	211.67	1BD4059, 211.5-211.67	17TR0042	High sulphide comp, irregular dissemination, high pyrrhotite, high mag. Elongated amphibole grains, show slight foliation. Patches chalcopyrite, blue mineral (Glaucophine?)
IBDH023	173.8		BDH023, 173.8m	17TR0043	Dominated by disseminated sulphides, irregular chalcopyrite (cpy) distribution
IBDH007			Red Arrow	17TR0044	Sulphide dominated, accumulations of cpy, py and po grain. High mag, increased po
BADD001	52.61	52.73	BAD001, 52.61-52.73	17TR0045	Irregular foliations, banding of alternating host rock, chloritized biotite/chl, patches increased felsic sandstone and sulphides (increased pyrite)

Sample Information					Electrical Properties											
Drill	**Footage**		**Sample**	**Terra**	**Resistivity Readings**			**Chargeability Readings**			**Av. Resistivity**	**Av. Charge-ability**	**Inductive Conductivity**			**Av. Cond.**
Hole ID	**From**	**To**	**ID**	**ID**	**(mV/V)**			**(Ω·m)**			**(Ω·m)**	**(mV/V)**	**(S/m)**			**(S/m)**
BADD001	75	75.07	BADD001, 75-75.07	17TR0039	498.3	518.6	431.61	23.9	20.011	17.177	482.850	20.4	159	126	366	217.0
IBDH023	175		175	17TR0040	10.85	11.23	11.15	83.41	83.62	77.39	11.077	81.5	12116	11945	11612	11891
IBDH023			3	17TR0041	13.21	11.70	11.45	108.09	100.219	100.673	12.120	103.0	7149	8955	8475	8193.0
IBDH4059	211.5	211.67	1BD4059, 211.5-211.67	17TR0042	18.8	21.94	22	84.2	70.744	69.209	20.917	74.7	95450	109581	18076	74369
IBDH023	173.8		BDH023, 173.8m	17TR0043	2.21	2.14	2 .44	75.7	73.5	76.4	2.263	75.2	3491	4105	2637	3411.0
IBDH007			Red Arrow	17TR0044	24.55	26.45	26.03	57.0	58.073	69.043	25.677	61.4	2129	2110	2585	2274.7
BADD001	52.61	52.73	BAD001, 52.61-52.73	17TR0045	6875.6	1498.92	1915.4	7.9	8.557	8.627	3429.98	8.4	65.6	81.6	89	78.7

Sample Information					Magnetic Properties				
Drill	**Footage**		**Sample**	**Terra**	**J/Ind (A/m)**	**J/Rem (A/m)**	**Koenigsberger Q**	**Fluxgate Mag Sucs**	**Mag Susc.**
Hole ID	**From**	**To**	**ID**	**ID**			**Ratio**	**SI Units (x10^-3)**	**SI Units (x10^-3)**
BADD001	75	75.07	BADD001, 75-75.07	17TR0039	115.2	160.1	1.39	14.25	3.33
IBDH023	175		175	17TR0040	105.5	98.78	0.94	22.70	49.83
IBDH023			3	17TR0041	106.4	100.9	0.95	22.89	51.80
IBDH4059	211.5	211.67	1BD4059, 211.5-211.67	17TR0042				n/a	43.13
IBDH023	173.8		BDH023, 173.8m	17TR0043	9.867	111.9	11.34	212.34	44.60
IBDH007			Red Arrow	17TR0044				n/a	28.70
BADD001	52.61	52.73	BAD001, 52.61-52.73	17TR0045	26.65	58.34	2.19	24.79	9.81

*Note: Readings of the magnetic properties were limited due to a combination of conductivity and high remanence in two samples. Whilst measurements were able to be derived from the positive Z direction of the sample, +XZ and +YZ, negative orientations of the core, -XZ and –YZ, resulted in the Q meter being unable to plot and process the oscillating measurements of the field against alpha. Sensitivity of the equipment is restrictive when measuring highly responsive samples. Associated error for final magnetic susceptibility calculated at ± 10%

Sample Information				Density Calculations							
Drill	Footage		Terra	Dry Mass	Saturated	Submerged	Bulk Volume	Dry Bulk	Imbibed Water	Apparent	Grain Density
Hole ID	From	To	ID	(g)	Mass (g)	Mass (g)	(cm^3)	Density (g/cm^3)	Volume (cm^3)	Porosity (%)	(g/cm^3)
BADD001	75	75.07	17TR0039	171.15	171.32	117.76	53.67	3.189	0.17034	0.32%	3.20
IBDH023	175		17TR0040	130.96	131.05	101.34	29.77	4.399	0.09018	0.30%	4.41
IBDH023			17TR0041	146.17	146.24	113.43	32.88	4.446	0.07014	0.21%	4.46
IBDH4059	211.5	211.67	17TR0042	802.6	802.98	614.45	188.91	4.249	0.38076	0.20%	4.26
IBDH023	173.8		17TR0043	703.79	704.10	544.64	159.78	4.405	0.31062	0.19%	4.41
IBDH007			17TR0044	739.12	739.41	575.73	164.01	4.507	0.29058	0.18%	4.51
BADD001	52.61	52.73	17TR0045	183.9	184.10	126.18	58.04	3.169	0.20040	0.35%	3.18

Sample Information				Spectral Properties			Spectral Properties (Background)			Velocity	Dimensions
Drill	Footage		Terra	K	Th	U	K	Th	U	Sonic Velocity	HC= Half Core , QC=Quarter
Hole ID	From	To	ID	(%)	(ppm)	(ppm)	(%)	(ppm)	(ppm)	(m/s)	Lx W (mm)
BADD001	75	75.07	17TR0039	0.6	8	1.4				n/a	70 x 30 QC
IBDH023	175		17TR0040	0.3	4.3	2.1				n/a	51 x 28 QC
IBDH023			17TR0041	0.3	7.6	4.9				n/a	55 x 28 QC
IBDH4059	211.5	211.67	17TR0042	0.4	5.3	1.8	0.2	6.3	2.8	n/a	127 x 63 HC
IBDH023	173.8		17TR0043	0	10.5	3.4	0.4	13.4	0.4	5070	245 x 29 QC
IBDH007			17TR0044	0.3	9	2.1				n/a	106 x 63 HC
BADD001	52.61	52.73	17TR0045	0.3	7.4	2.4	0.3	8.4	2.7	n/a	78 x 29 QC

*Spectral Properties-final measurements are close to or equivalent to background readings. Further work is required to eliminate background sources from measurements

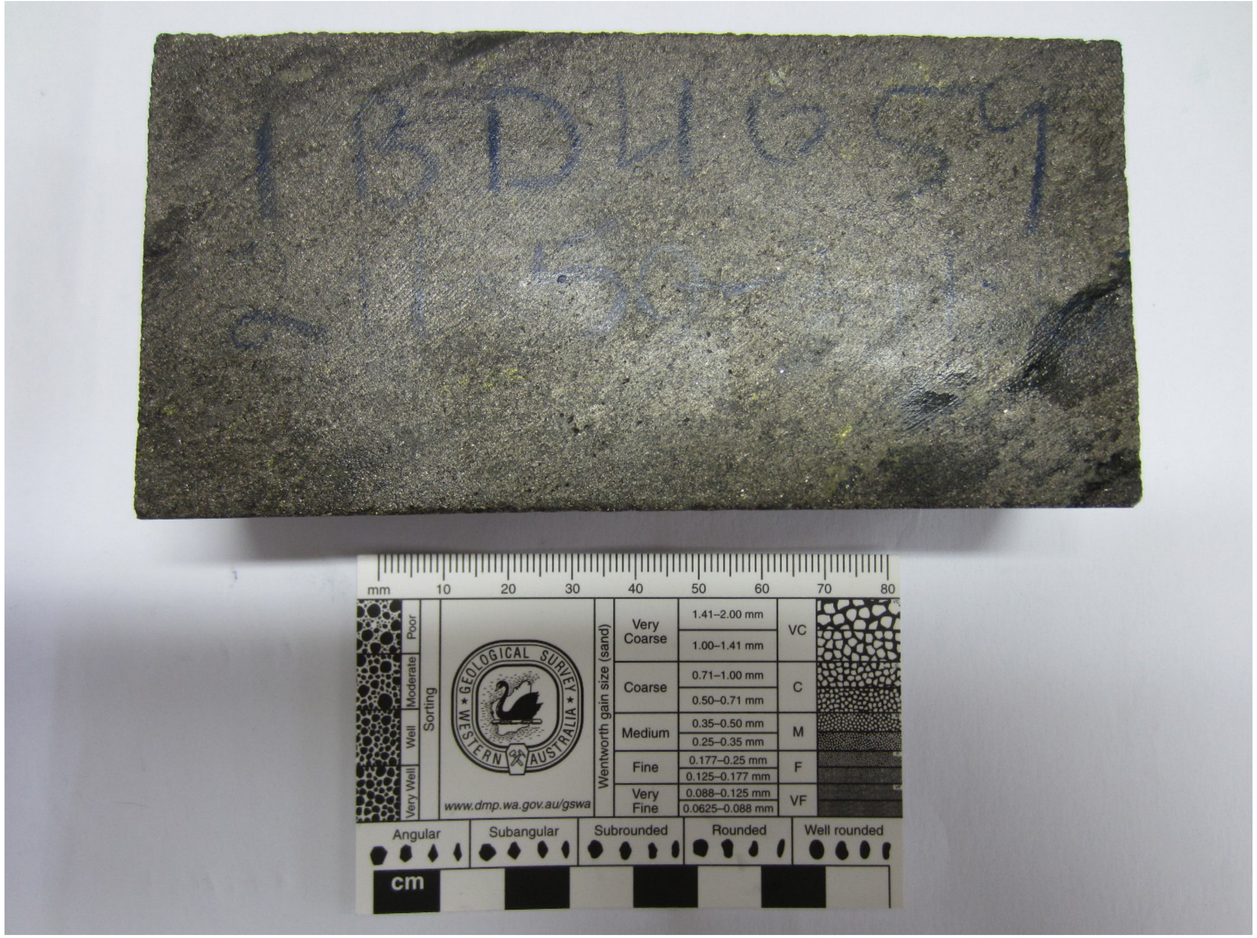
*Sonic Velocity- N/A measurements due to core samples not within the minimum 15cm range required for velocity testing

APPENDIX 2

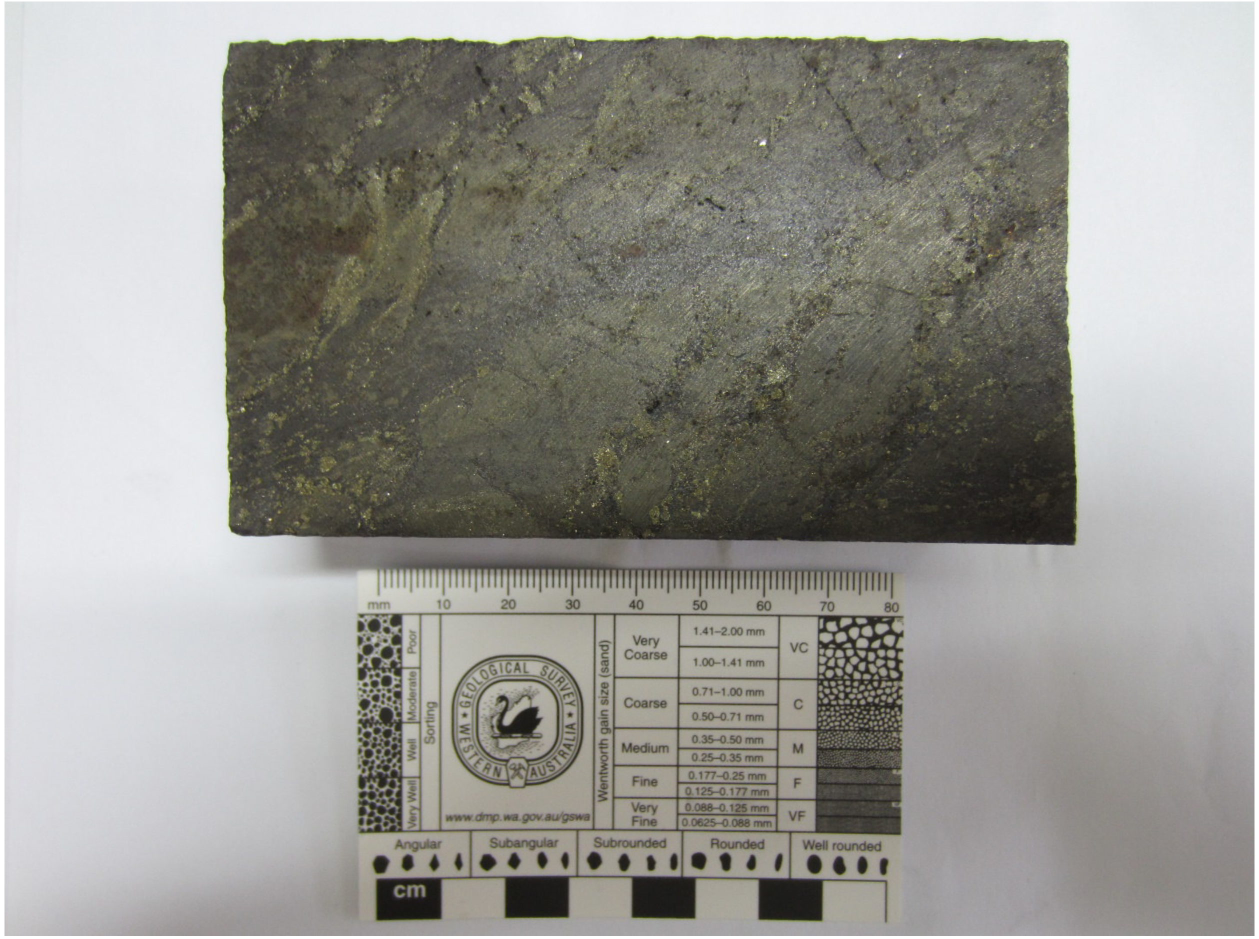
Sample ID. BADD001, 52.61-52.73 Terra ID. 17TR0045

Sample ID. (3)   Terra ID. 17TR0041

Sample ID. 175m Terra ID. 17TR0040



Sample ID. 1BD4059, 211.50-211.67   Terra ID. 17TR0042



Sample ID. Red Arrow Terra ID. 17TR0044

Sample ID. BDH023, 173.8m   Terra ID. 17TR0043

Sample ID. BADD001, 75.0-75.07m Terra ID. 17TR0039