Geophysics of Graphite
From Foe to Friend

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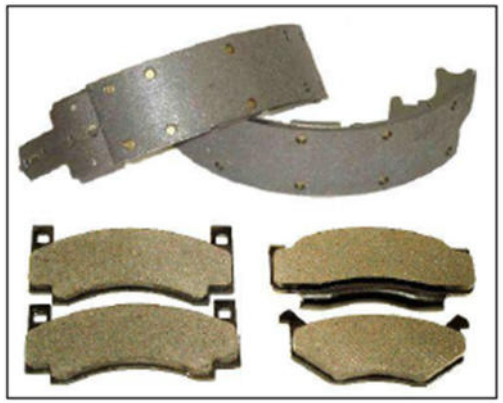
TERRA PETROPHYSICS
TERRA RESOURCES
GEOPHYSICAL • GEOLOGICAL CONSULTING

What is Graphite and Why is it Important

Graphite conducts electricity and heat, is self lubricating and has a melting point above 3,600 degrees Celsius.

- **Electrodes** – graphite electrodes are used primarily in the steel industry for recycling scrap steel via electric arc furnaces
- **Refractories** – Graphite crucibles that hold molten metal
- **Batteries** – Advanced rechargeable lithium–ion batteries require graphite electrodes from natural flake/ vein graphite. It requires an electrode with good porosity and a large surface area so Li atoms can flow to generate a charge.
  - ***This is a property that synthetic graphite lacks compared to natural graphite***. The batteries need 10 to 30 times more graphite than lithium. Demand estimated to increase between 30 – 40% annually (electric and hybrid cars, hand held electronics, etc.)
- **Brake linings** – Amorphous and fine flake graphite are used in heavy duty brakes as a substitute for asbestos
- **Lubricants** – Fine, high purity graphite is used in lubricants to withstand extreme temperatures. Some examples include lubricant for high temperature gearing, anti seizing agents and drill muds

Lithium Batteries

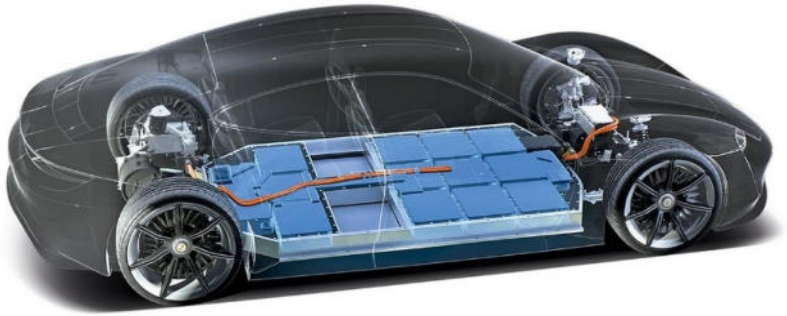


Brake Pads

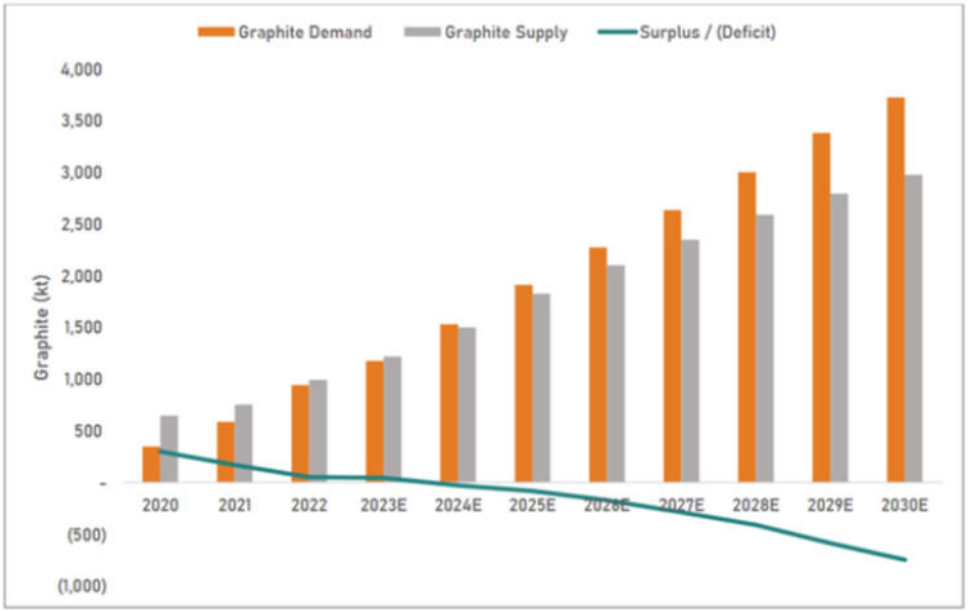
Graphite Uses

- **Fuel Cells** - Fuel cells contain flow field plates, also known as bipolar plates, which are generally composed of natural graphite and polymer composites. The plates are attached to the outside of the cathode and anode and therefore have to possess distinct properties: high electrical and thermal conductivity, impermeable to gases whilst being inert to cell chemistry.

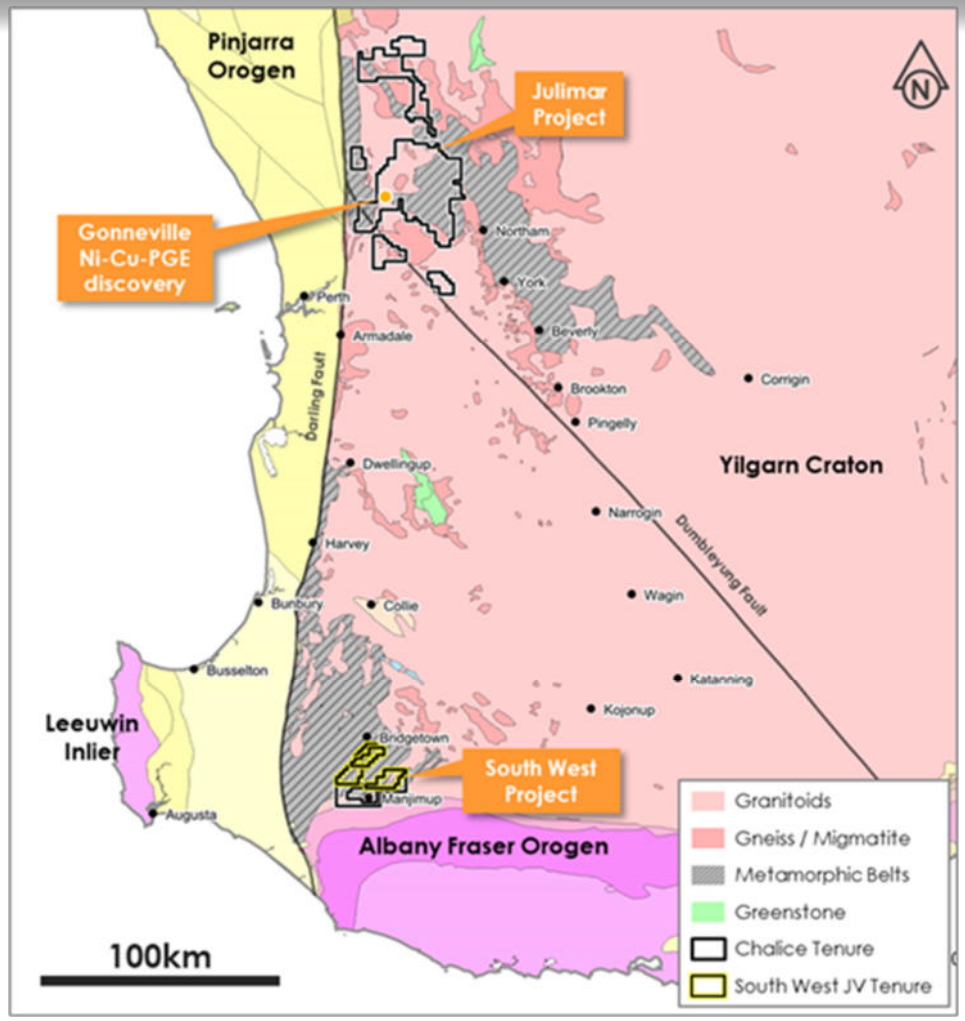
Fuel cells are becoming more popular for power generation backups in houses, or other facilities in remote locations and fuel cells have attracted interest in transport applications.



Graphite Product	Carbon Content (%)	Graphite Size (um)	Price (US$/t)
Large Flake	94-97%	>177um	$2,500-$3,000
Medium Flake	94-97%	149-177um	$2,200-$2,500
Fine Flake	94-97%	<149um	$2,200-$2,400
Amorphous	80-85%	=>37um	$850

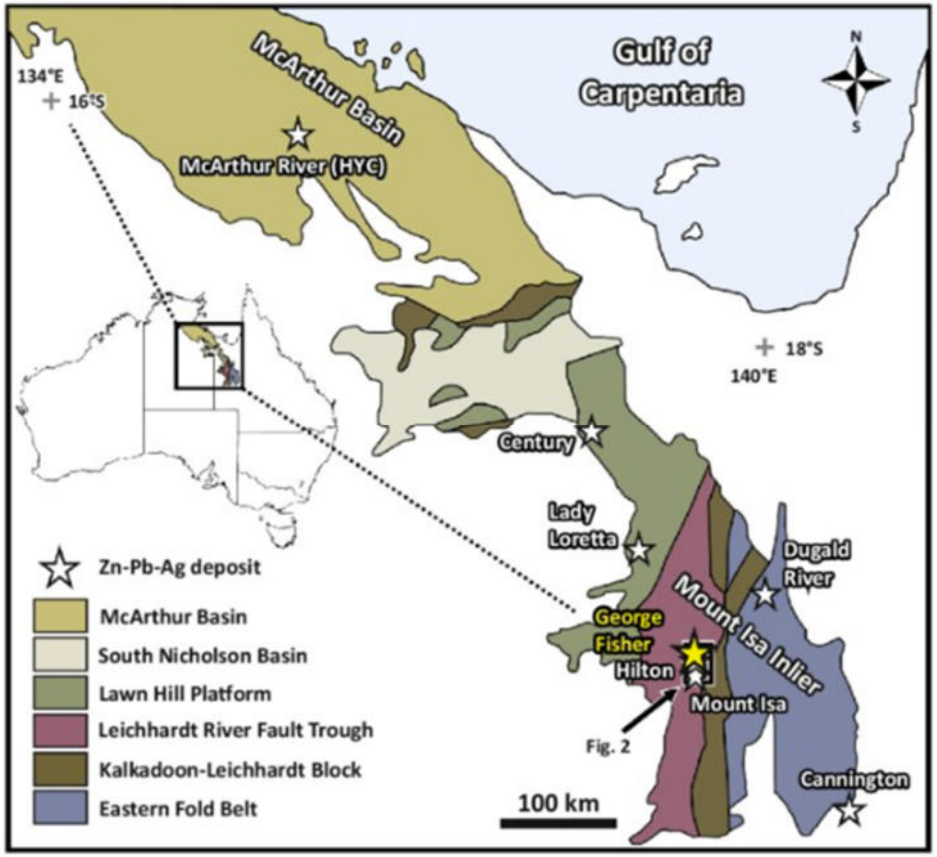


Southwest WA - Manjimup



- Ballingup complex consists mainly of metasedimentary rocks including interlayered quartzite, quartz-mica schist, quartz–feldspar–biotite (– garnet) gneiss, and banded iron-formation, together with minor layers of quartzofeldspathic gneiss, amphibolite, calcsilicate gneiss, and ultramafic rock (Wilde, 1980).
- These rocks have been isoclinally folded and metamorphosed predominantly to amphibolite facies but locally to granulite facies
- Archaean in age

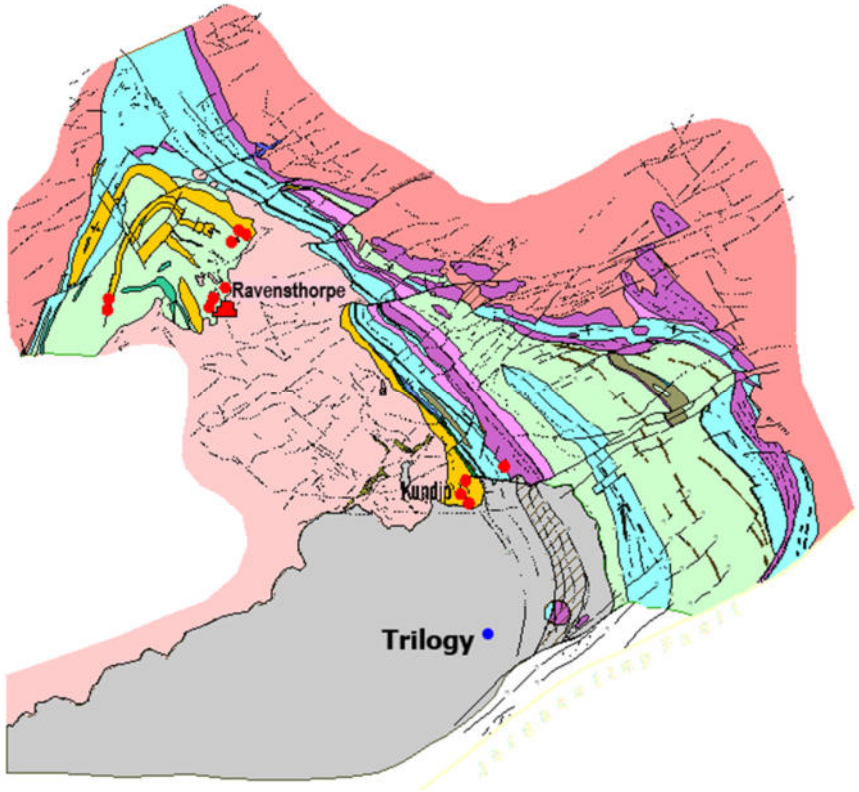
NW Qld – Mt Isa (Sediment Hosted Basemetals)



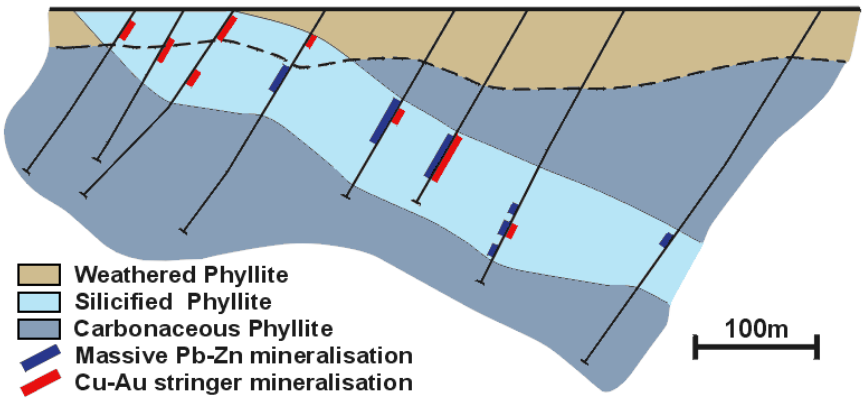
- The Mount Isa Cu and Zn-Pb-Ag deposits are hosted within the Mesoproterozoic Urquhart Shale of the 1670Ma Mount Isa Group
- The Urquhart Shale contains a series of thin tuff marker beds which form important stratigraphic markers for correlation of orebodies in the Mount Isa and George Fisher Mines
- These rocks have been folded and metamorphosed predominantly to greenschist facies (low temp) where bituminous
- Proterozoic in age, no economic graphite

	Cambrian limestone	Prot. sandstone (h/wall)	Prot. shale and siltstone (h/wall)	Ore zone	Prot. shale and siltstone (footwall)
Natural Gamma (API cps)	very low 25	high 160	moderate 125	low–mod 70–150	high 200
Magnetic Susceptibility (SI x 10^{-5})	very low <10	low 0–50	low-moderate 0 –100	v. low (ore)– mod (waste) 0–150	low–mod 50–150
Resistivity (ohm-m)	high >1000	low 60	low 75	variable 50–200	low 80
Density (g/cc)	moderate 2.7	low 2.6	moderate 2.7	mod–high 2.8–3.0	moderate 2.6–2.7
Neutron (API cps)	high 1500	high 1600	moderate 1200	low 700–variable	moderate 1200
Sonic Velocity (m/s)	very high 5000–6000	moderate 4500	moderate 4000	mod–high 4000–5000	moderate 4000

Southern WA – Ravensthorpe (Sediment Hosted Massive Sulphides)



- In 1997 Homestake discovered massive sulphide mineralisation in the Proterozoic metasedimentary Mount Barren Group, namely the Trilogy Deposit of the Albany-Fraser Orogen
- Discovered during drilling of gold soil geochemical anomalism thought to be derived from greenstones in the underlying Archaean basement
- These rocks have been folded and metamorphosed predominantly to mid amphibolite to granulite facies
- 4.30 Mt of ore containing 52.5 kt Cu, 149 000 oz Au 7.76 Moz Ag 76.4 kt Pb, 51.5 kt Zn



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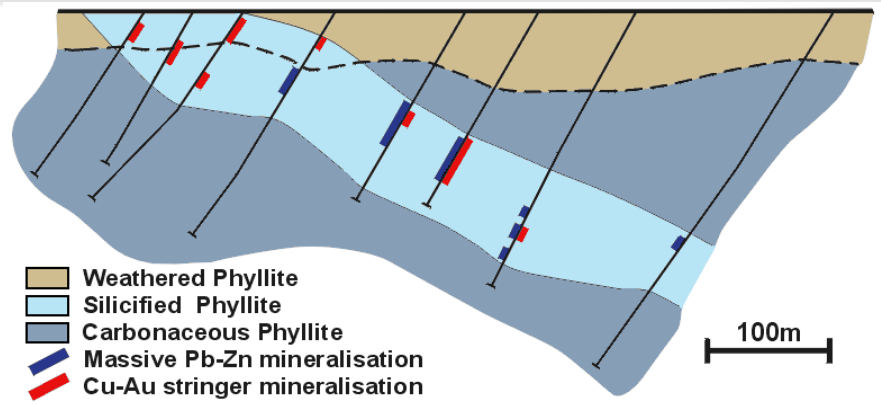
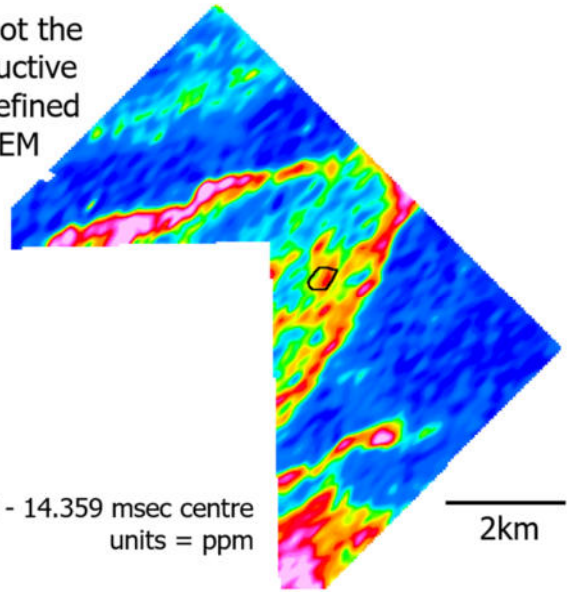
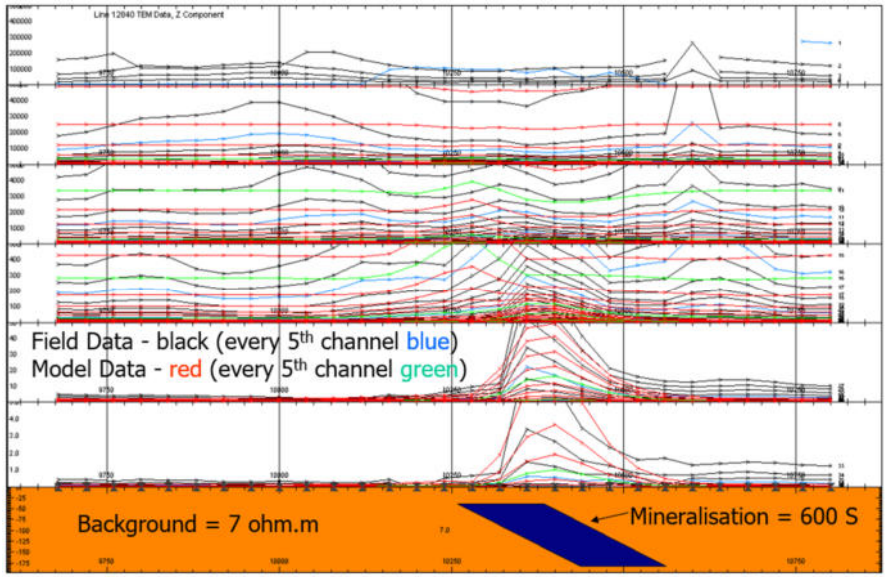


Rock Type	*Log Avg Resistivity (ohm.m)*
Kundip Quartzite	20000
Mount Barren Serecite Schist	n/a
Graphitic Phyllite/Siltstone	10-800
Silicified Graphitic Phyllite/Shale/Sandstone	35000-75000
Massive Cu-Pb-Zn mineralisation	0.01
Magnetite/Pyrrhotite/Pyrite Breccia	n/a

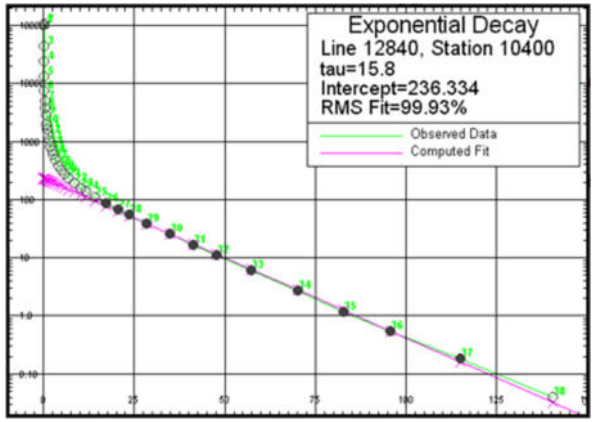
Trilogy is not the most conductive anomaly defined from the AEM survey.





Southern WA – Ravensthorpe (Sediment Hosted Massive Sulphides)

- The Trilogy deposit represents a challenging regional exploration target due to the relatively small size of the mineralised system and the conductive nature of the phyllite host material
- A combination of airborne EM with follow-up detailed gravity and ground EM have proven to be the most effective geophysical methods in locating Trilogy style mineralisation in the Mount Barren Basin



HOMESTAKE GOLD OF AUSTRALIA LIMITED

MEMORANDUM

TO: Simon Rigby FILE: 6136.701

CC: File DATE: 9th March 2000

FROM: Barry Bourne

SUBJECT: Mecury/Queen Sheba Downhole EM

In February 1999 GPX Services acquired 330m of 3 [illegible]ent downhole EM. The acquisition parameters were as follows

Array : Downhole
Transmitter (Tx) : Zonge (
Tx Current : 26A

Graphite

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In February 1999 GPX Services acquired 330m of 3 component downhole EM. The acquisition parameters were as follows

Array : Downhole
Transmitter (Tx) : Zonge GGT-10
Tx Current : 26A

Graphite

HOMESTAKE GOLD OF AUSTRALIA LIMITED

MEMORANDUM

: Simon Rigby FILE: 6136.701

: Doug Currie, Leigh Bettenay, Jeff [illegible] DATE: 17th February 1999

OM: Barry Bourne

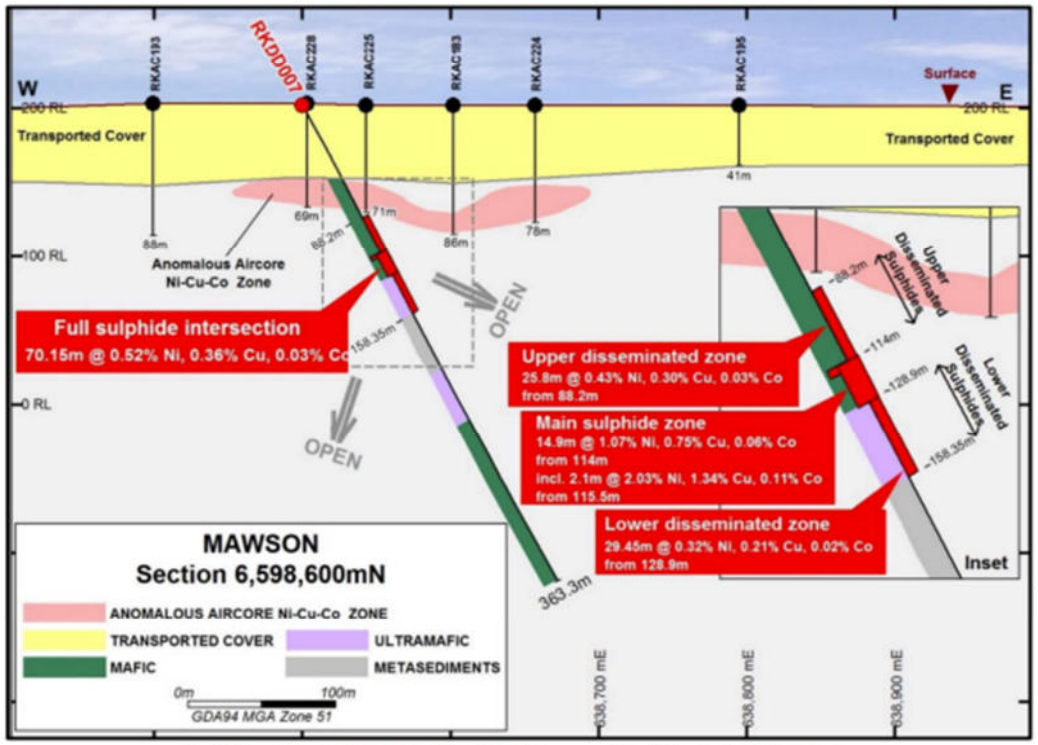
BJECT: Mercury [illegible]ing Loop EM

February 1999 GPX Services acquired 8 line km of moving loop EM. The isition parameters were as follows:

Array : In loop
Transmitter (Tx) : Zonge GGT-10
Tx Current : 30A
Tx Ramp Time : 100us
Tx Loop Size : 100m x 100m
Frequency : 0.5Hz
Receiver (Rx) : GDP32/8
Station Spacing : 50m

Graphite

Albany Fraser Orogen – Massive Ni Suphides



Drill Section 6,598,600N with Diamond Drillhole RKDD007

Mawson Prospect

RKDD007 Drill Hole Section

- Mineralisation starts 88m downhole – shallow
- Inhole metal content circa $150/t
- Best intercepts at mafic/ultramafic contact
- Fourth publicly announced massive Ni-Cu sulphide in Fraser Zone

Massive pyrrhotite-chalcopyrite-pentlandite sulphide in drillhole RKDD007, 119m (NQ2 core)

Discovery November 2019

Albany Fraser Orogen – Massive Ni Suphides

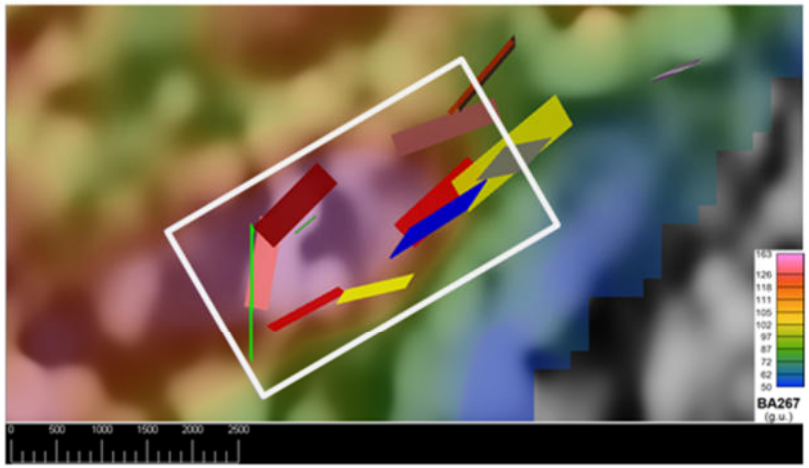


Figure: MLEM conductors with composite image of BA 2.67 + VD1 of TMI RTP.

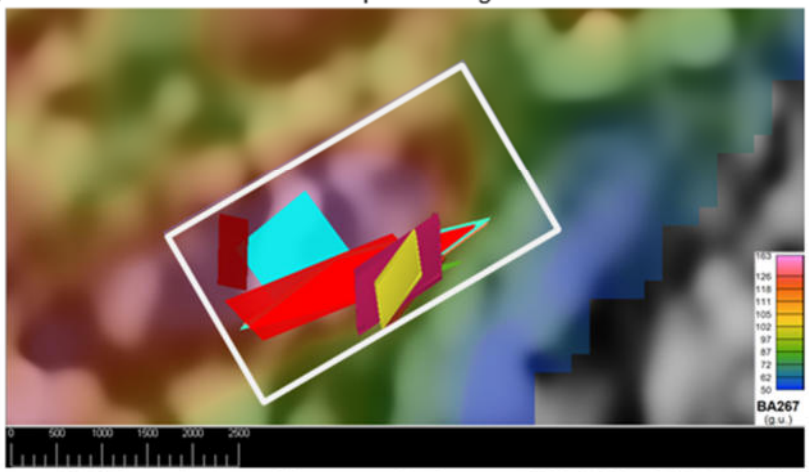


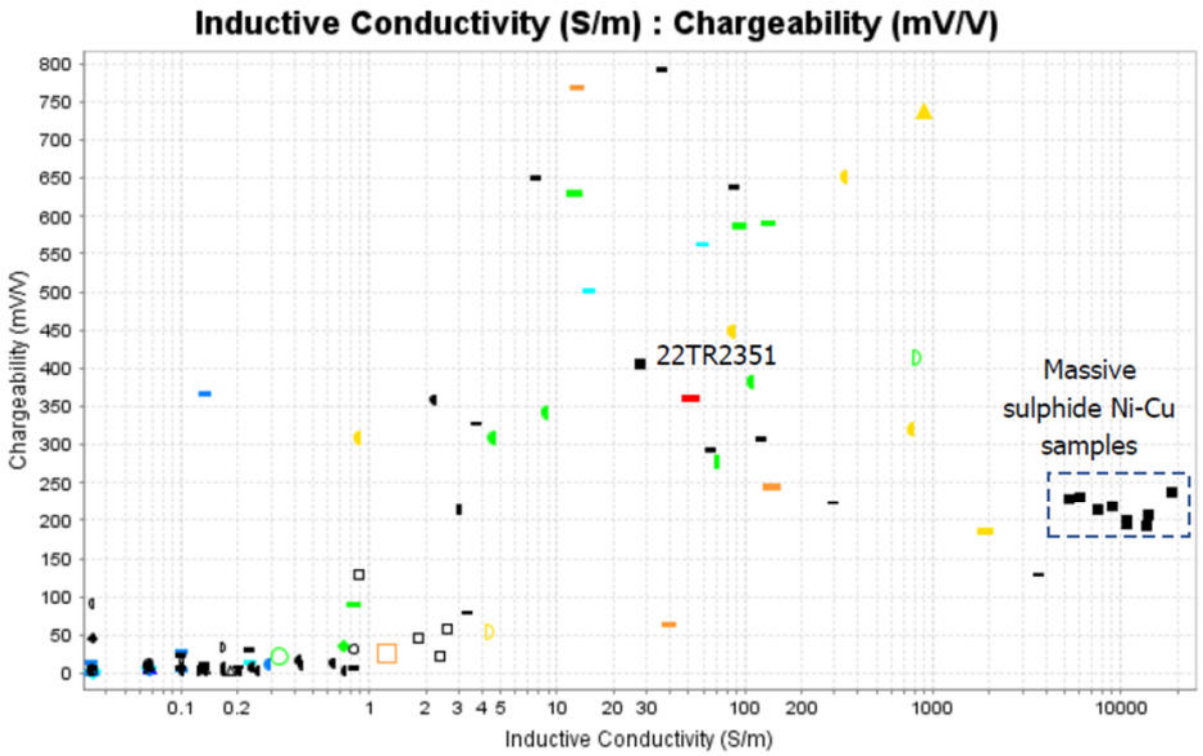
Figure: FLEM conductors with composite image of BA 2.67 + VD1 of TMI RTP.

- These rocks have been folded and metamorphosed predominantly to mid amphibolite to granulite facies
- Carbonaceous sediments deformed to graphite

Line	Freq	Strike Length	Depth Extent	CT	Peak Tau	Comments
6596950	0.25	2275	3340	5710	677	Off plate edge effects. Not used in drill targeting.
6597200	0.25	2930	2650	4450	685	Off plate edge effects. Not used in drill targeting.
6597450	0.5	1040	485	7600	235	Good double peak anomaly.
6597750	**0.5**	800	**500**	**5770**	**255**	**Good double peak anomaly. Main drill target. CT, tau values lower due to higher frequency.**
6598050	0.125	1435	1125	7540	690	Good double peak anomaly.
6598200	0.125	1600	200	29700	640	Double peak, thick plate might give better model.
6598350	0.125	2020	1000	7450	750	Off plate edge effects. Not used in drill targeting.
6598500	0.125	2000	1000	7500	785	Off plate edge effects. Not used in drill targeting.
6598650	0.5	4280	550	28425	450	Off plate edge effects. Not used in drill targeting.

Albany Fraser Orogen – Massive Ni Suphides

- These rocks have been folded and metamorphosed predominantly to mid amphibolite to granulite facies
- Carbonaceous sediments deformed to graphite
- GSWA Record 72201 – Petrophysics of the Albany-Fraser Orogen



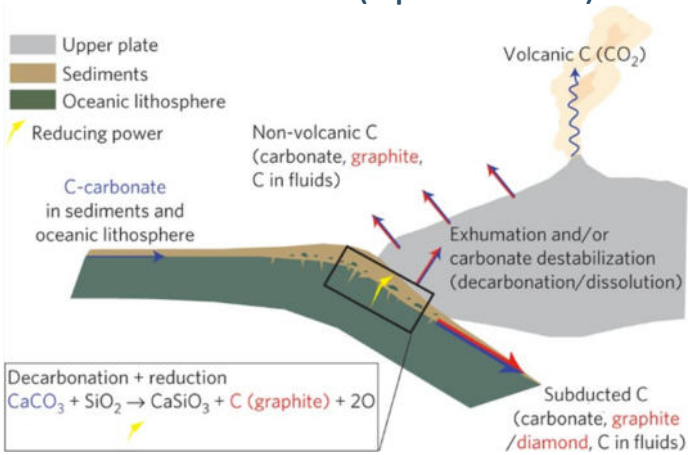
Colour
Cu (ppm): Progressive
- Unknown
- Cu ppm (below detection) [2.15%]
- Cu ppm to 47 [30.00%]
- Cu ppm to 172 [60.00%]
- Cu ppm to 431.7 [80.00%]
- Cu ppm to 526 [90.00%]
- Cu ppm to 684 [95.00%]
- Cu ppm to 1280.1 [98.00%]
- Cu ppm to 2683 [100.00%]

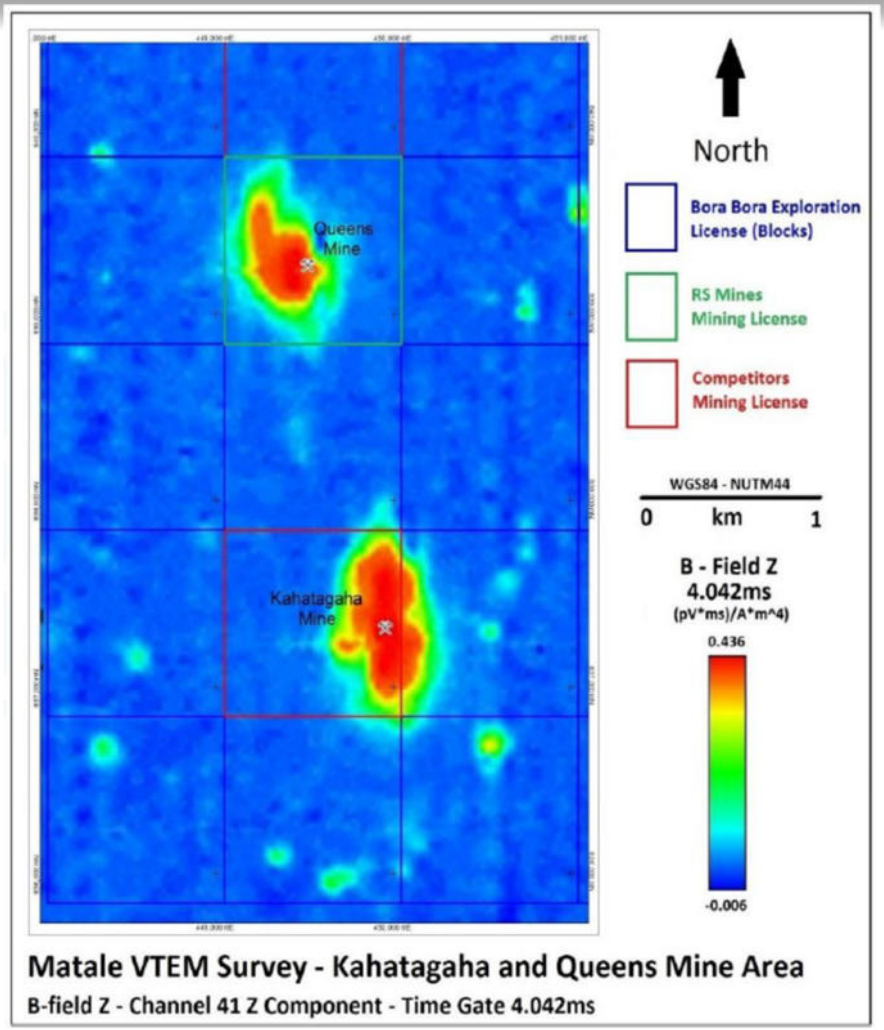
Size
Ni (ppm): Progressive
- Unknown
- Ni ppm to 73.4 [30.00%]
- Ni ppm to 129.7 [60.00%]
- Ni ppm to 201.1 [80.00%]
- Ni ppm to 814 [90.00%]
- Ni ppm to 927 [95.00%]
- Ni ppm to 1419 [98.00%]
- Ni ppm to 1977 [100.00%]

Shape
Lithology
- Ore
- Amphibolite
- Felsic granulite
- Gabbro
- Gneiss
- Granofels
- Graphitic schist
- Mafic granulite
- Metadiorite
- Metanorite
- Metanorite/ Metagabbro
- Pegmatite
- Saprock
- Ultramafic intrusive rock
- Vein

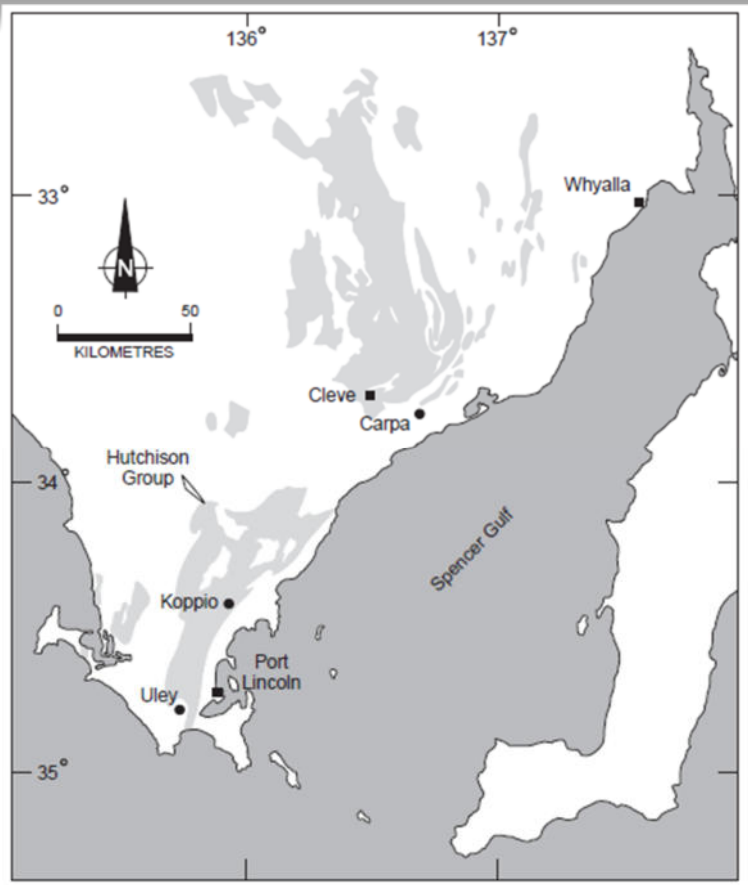
Sri Lanka Graphite Depoisits

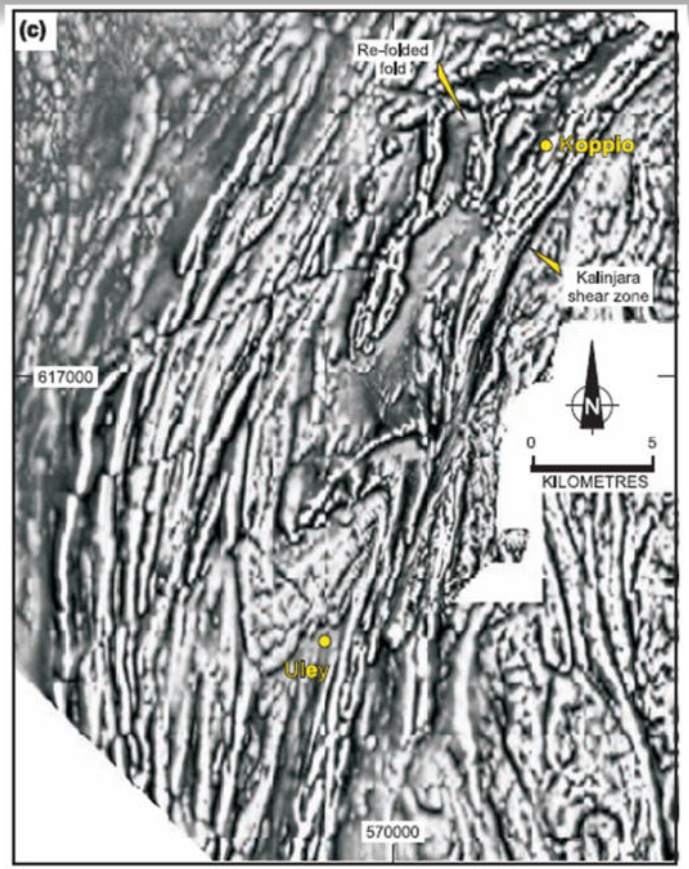
- Epigenetic Vein Style
- Characteristics of known graphite deposits
  - At surface
  - High grade metamorphic rocks, granulite facies 800-850 deg C
  - Structurally modified by large scale liner upright folds
  - First pass ground geophysics revealed 6 veins in one target area
  - Average thickness 60cms (up to 90cm)





South Australia – Uley and Koppio Graphite Deposits

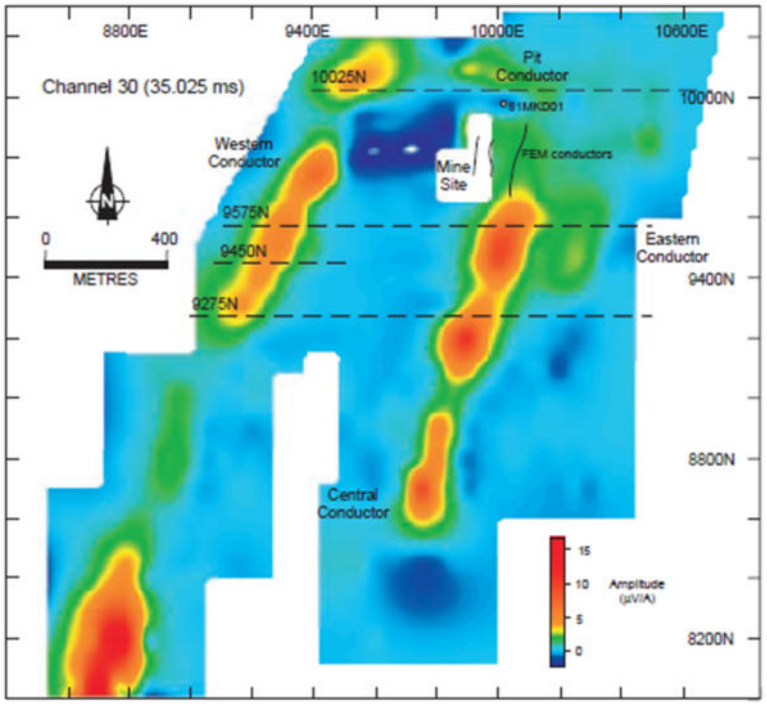




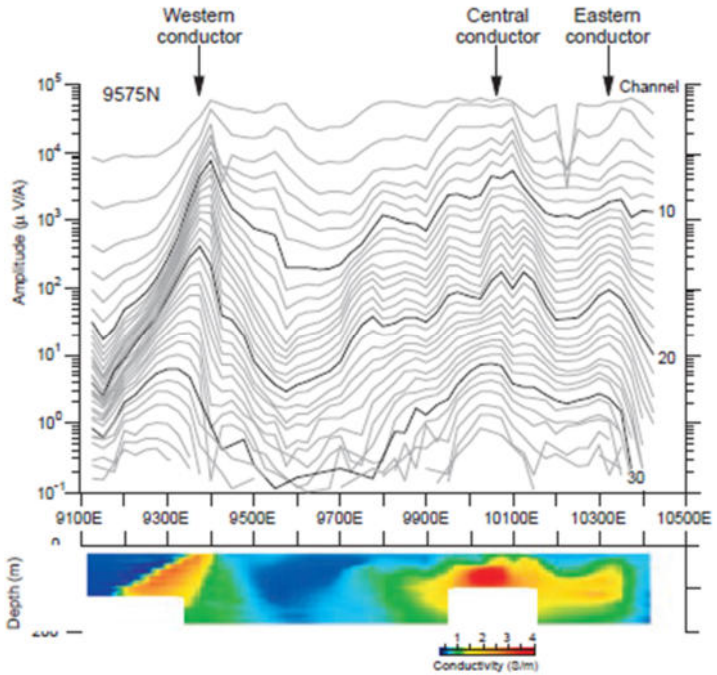
- The Hutchison Group forms an extensive basement sequence in the eastern Gawler Craton, comprising quartzite, dolomite, iron formation, schist and amphibolite
- Progressive deformation of the Palaeoproterozoic Hutchison Group metasediments, eastern Eyre Peninsula, South Australia, accompanied the development of a ~200 km-long suture, the Kalinjala Shear Zone and regional folding
- Mineralisation comprises disseminated flake graphite and occurs in Palaeoproterozoic schists and gneisses of the Hutchison Group.
- Upper amphibolite to granulite facies metamorphism

Summary geological map of the eastern Eyre Peninsula showing outcrop of Hutchison Group and the location of the Uley and Koppio graphite deposits and airborne magnetics image (after Dentith and Barret, 2003)

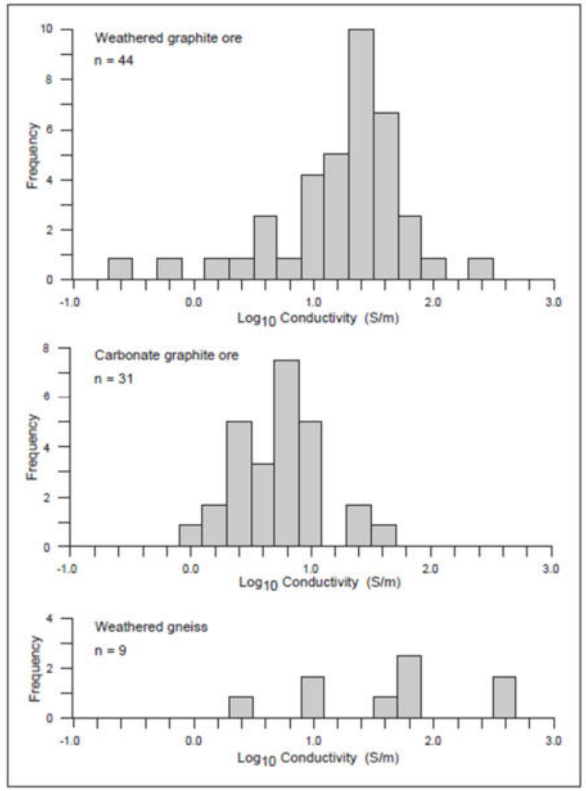
South Australia – Uley and Koppio Graphite Deposits



Late time amplitude SIROTEM decay channel 30 (35msec), Uley Mine area



SIROTEM decay profiles and inverted conductivity sections from the Uley Mine area



Histograms of conductivity measurements on samples from the Uley Mine

After Dentith and Barret (2003)

South Australia – Uley and Koppio Graphite Deposits

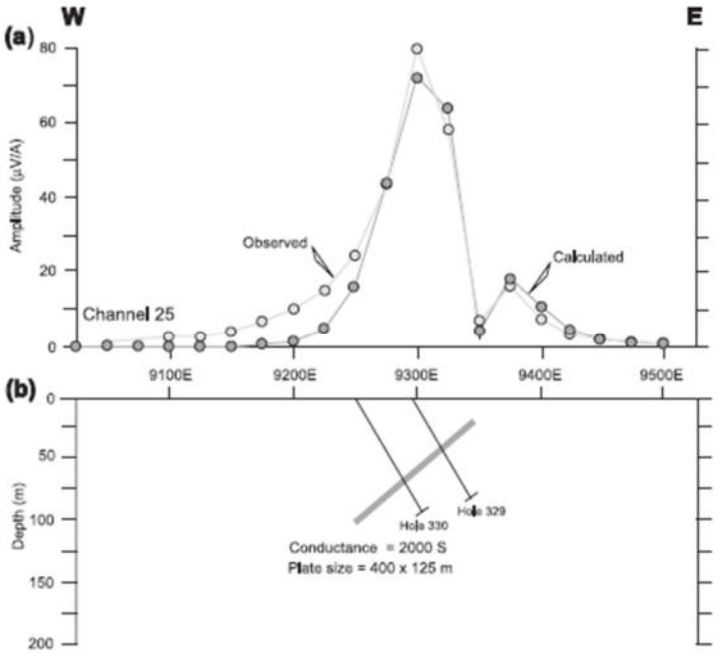
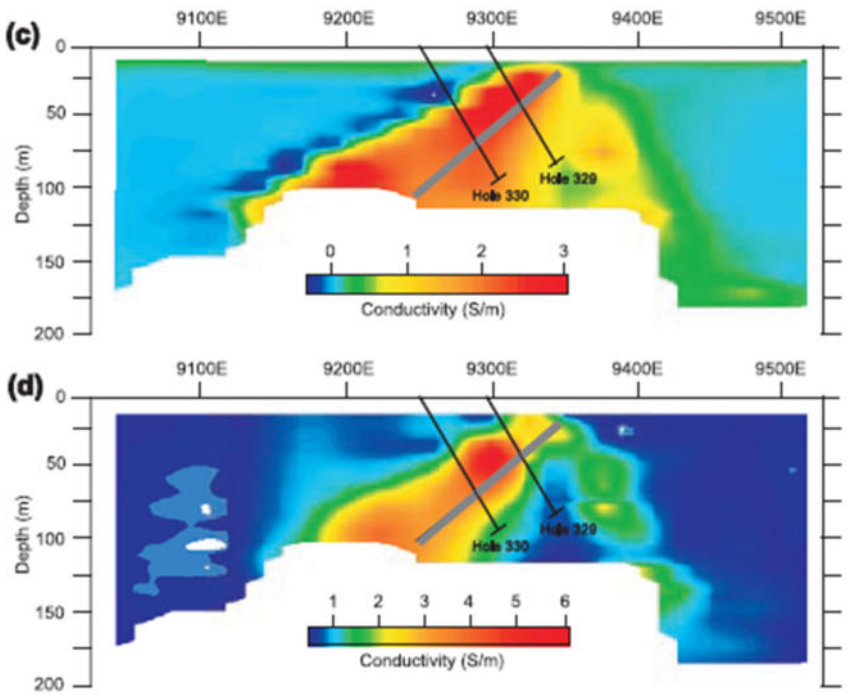


Plate modelling of Utley mineralisation



SIROTEM decay profiles and inverted conductivity sections from the Uley Mine area

After Dentith and Barret (2003)

South Australia – Koppio and Kookaburra Graphite Deposits

Geophysical Exploration for Graphite Mineralisation on the eastern Eyre Peninsula, South Australia.

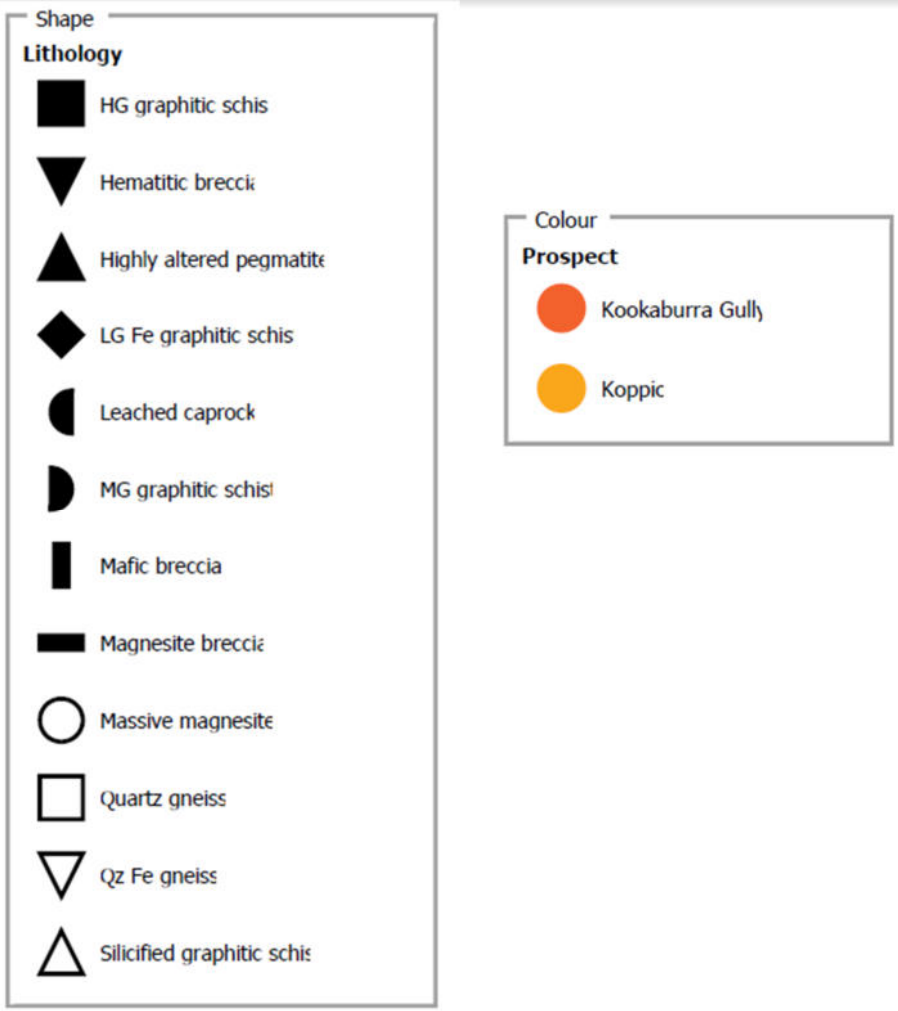
CLAIRE MORTIMORE (22482227)
SPONSORING COMPANIES: TERRA RESOURCES PTY. LTD., LINCOLN MINERALS LTD.

- The proposed research project concerns processing and interpretation of new geophysical data from the Koppio and adjacent Kookaburra Gully graphite prospects, seeking to understand geological controls on graphite mineralisation and to assess how best to use geophysical data when exploring for graphite resources in this geological environment.

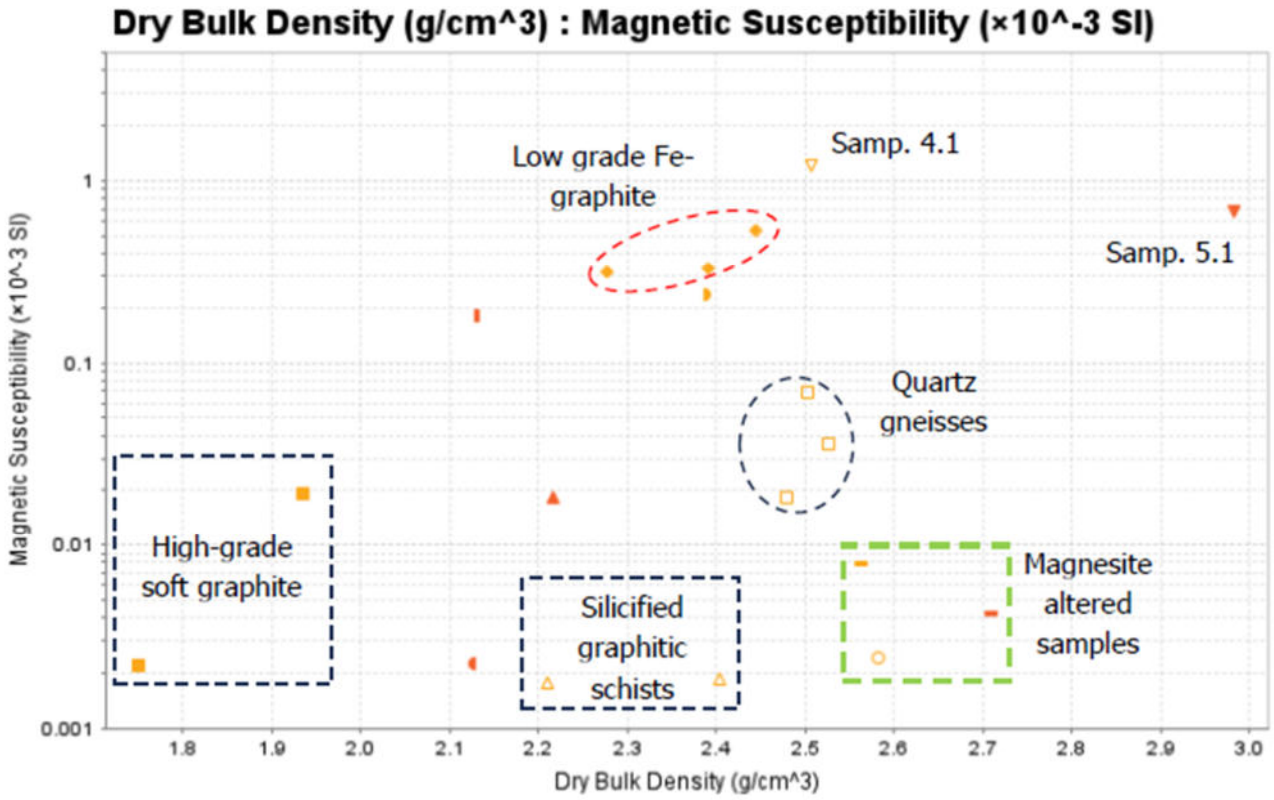
- Richard Lane Scholarship Award Recipient

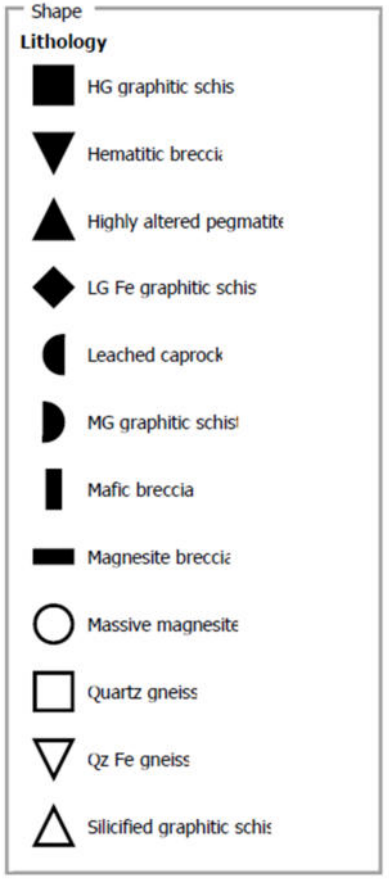
South Australia – Koppio and Kookaburra Graphite Deposits

- Petrophysics data has been acquisition on 19 samples
- Petrophysical data acquisition included: induced polarisation response (chargeability), galvanic resistivity, inductive conductivity, magnetic susceptibility, remanent magnetization, wet/dry bulk density/porosity, and sonic velocity measurements
- Data has been plotted and analysed in IOGas.



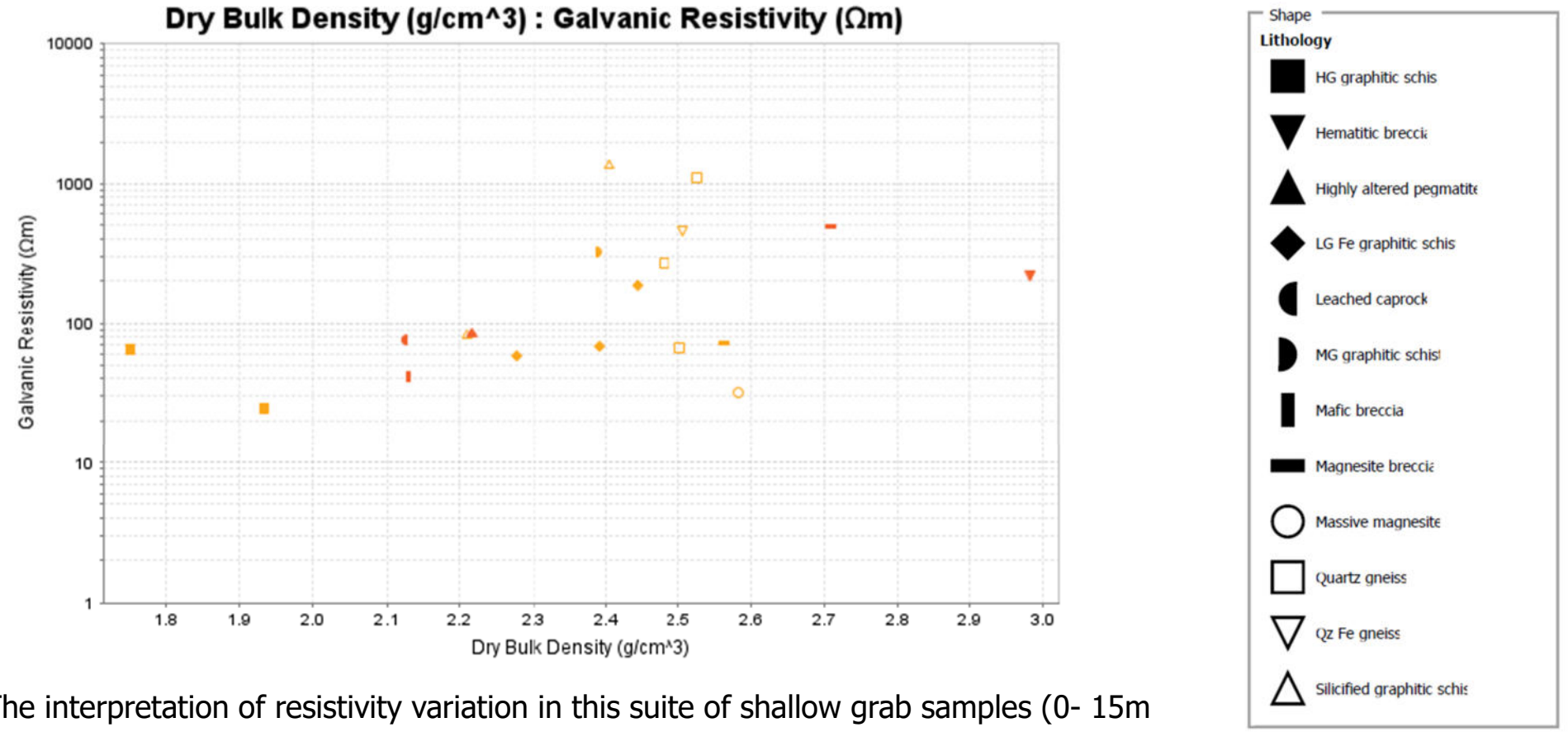
Dry Bulk Density vs. Magnetic Susceptibility





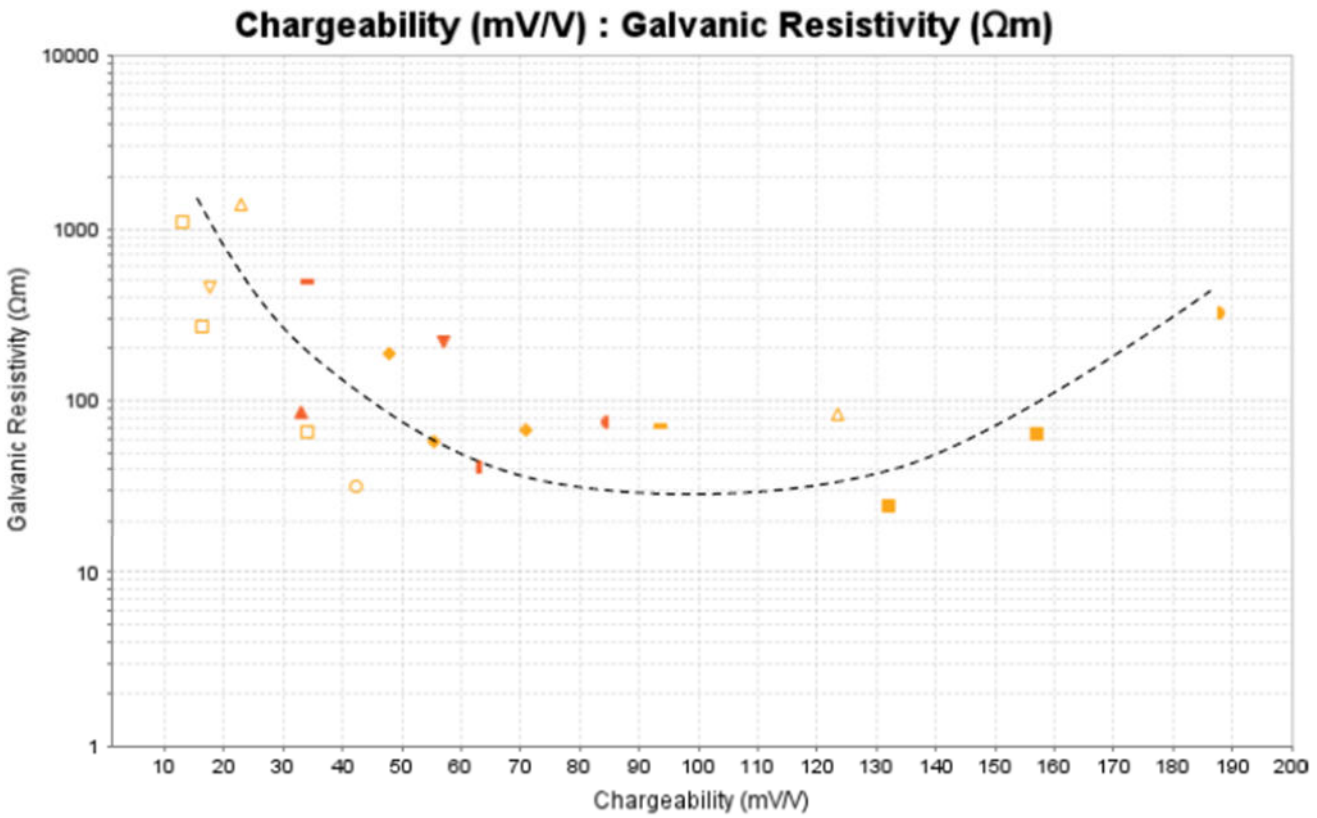
- High grade soft graphitic schists show very low DBD and magnetic susceptibility while silicified graphitic schists show slightly higher DBD values (~2.3 g/cm$_3$).

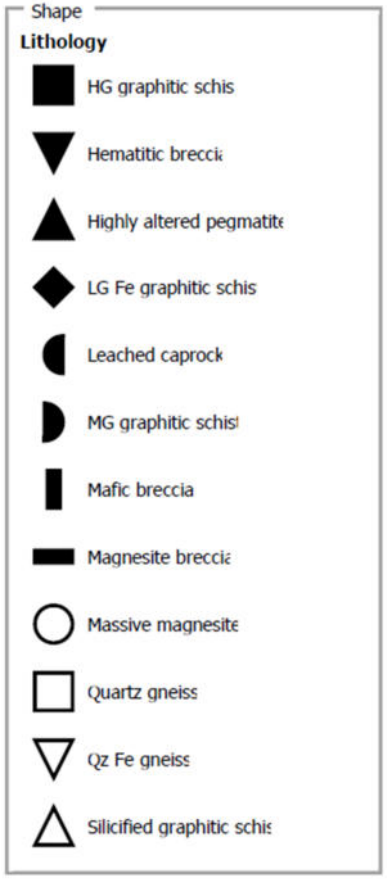
Dry Bulk Density vs. Galvanic Resistivity



The interpretation of resistivity variation in this suite of shallow grab samples (0- 15m below surface) is complicated by a number of factors: alteration- abundant silicification and carbonate alteration (magnesitic) and clayey alteration.

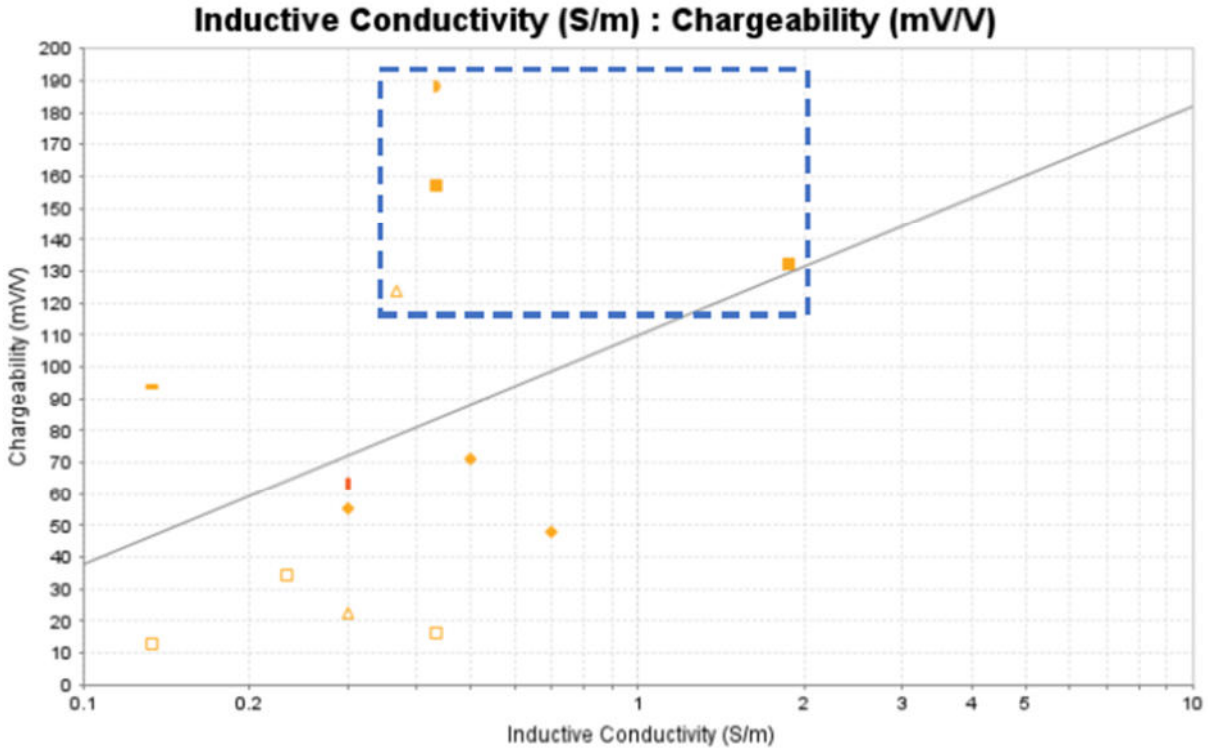
Chargeability vs. Galvanic Resistivity

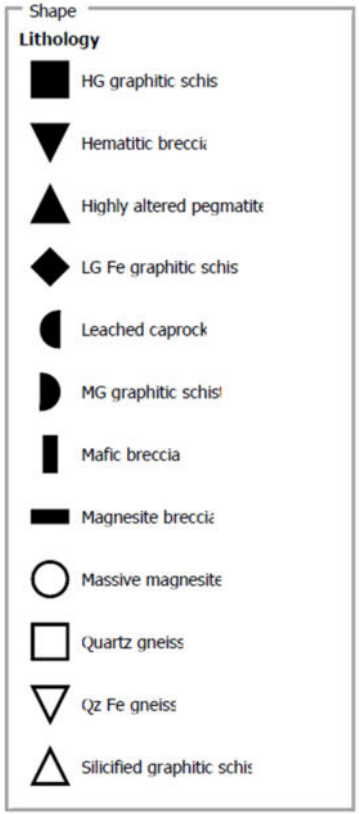




All medium-high grade graphite samples show values >100mV/V. Sample 7.1 shows the highest chargeability but this might be a reflection of clay alteration as well as graphitic content as pervasive yellow clay seems characterise the sample.

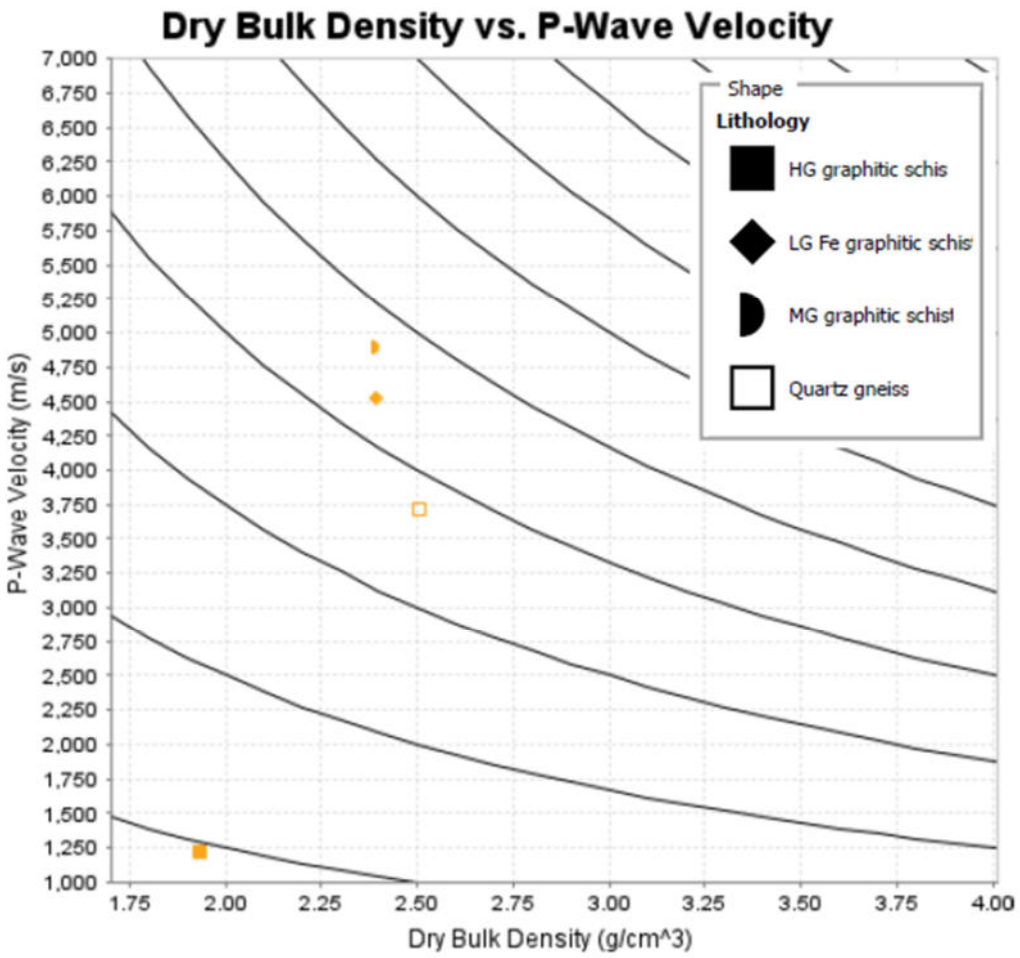
Inductive Conductivity vs. Chargeability





Inductive conductivity values are lower than anticipated which likely reflects mineralisation style - disseminated graphite in mineralised samples. Quartz gneisses (hollow squares) show inductive conductivity values >0.1 S/m which might be a function of graphite at the graphite/ quartz gneiss contact.

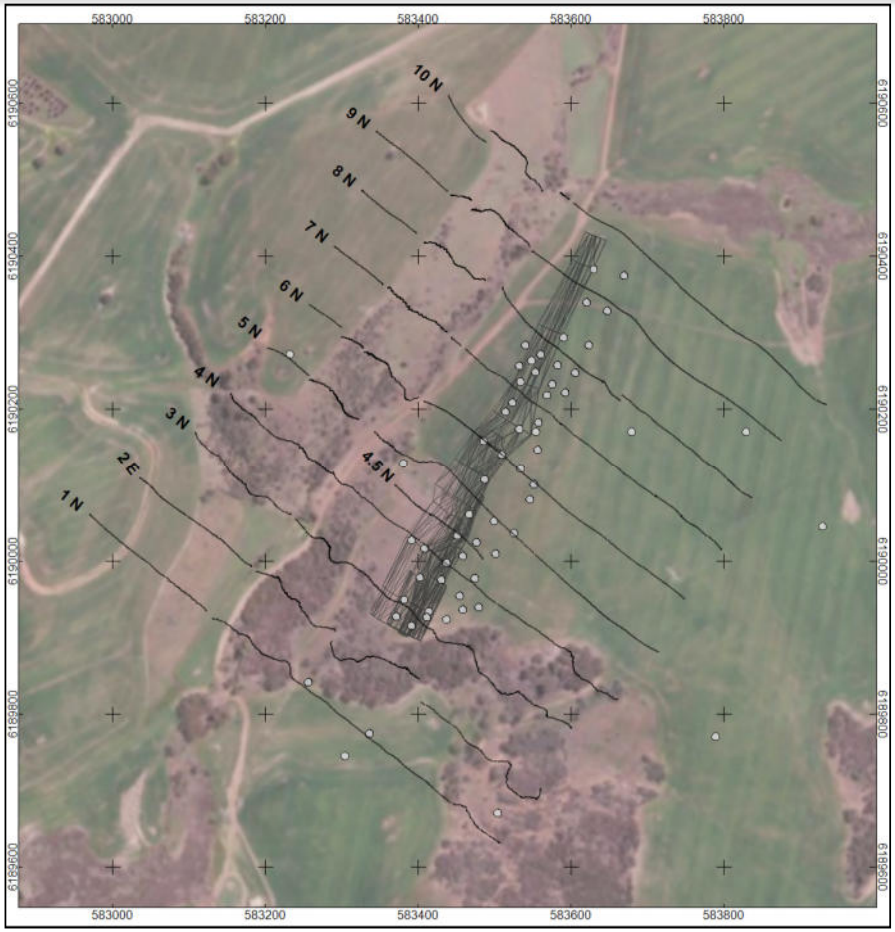
Density vs. P-Wave Velocity



There is a good distribution of data for this project given the very small sample size and soft HG graphite appears to have quite different acoustic properties from the other samples measured in this dataset.

South Australia – Koppio Loupe Survey

- Time domain EM
- February 2023
- Frequency – 75Hz
- Line length - ~650m
- Line spacing - 80m
- Line orientation – 040-310°

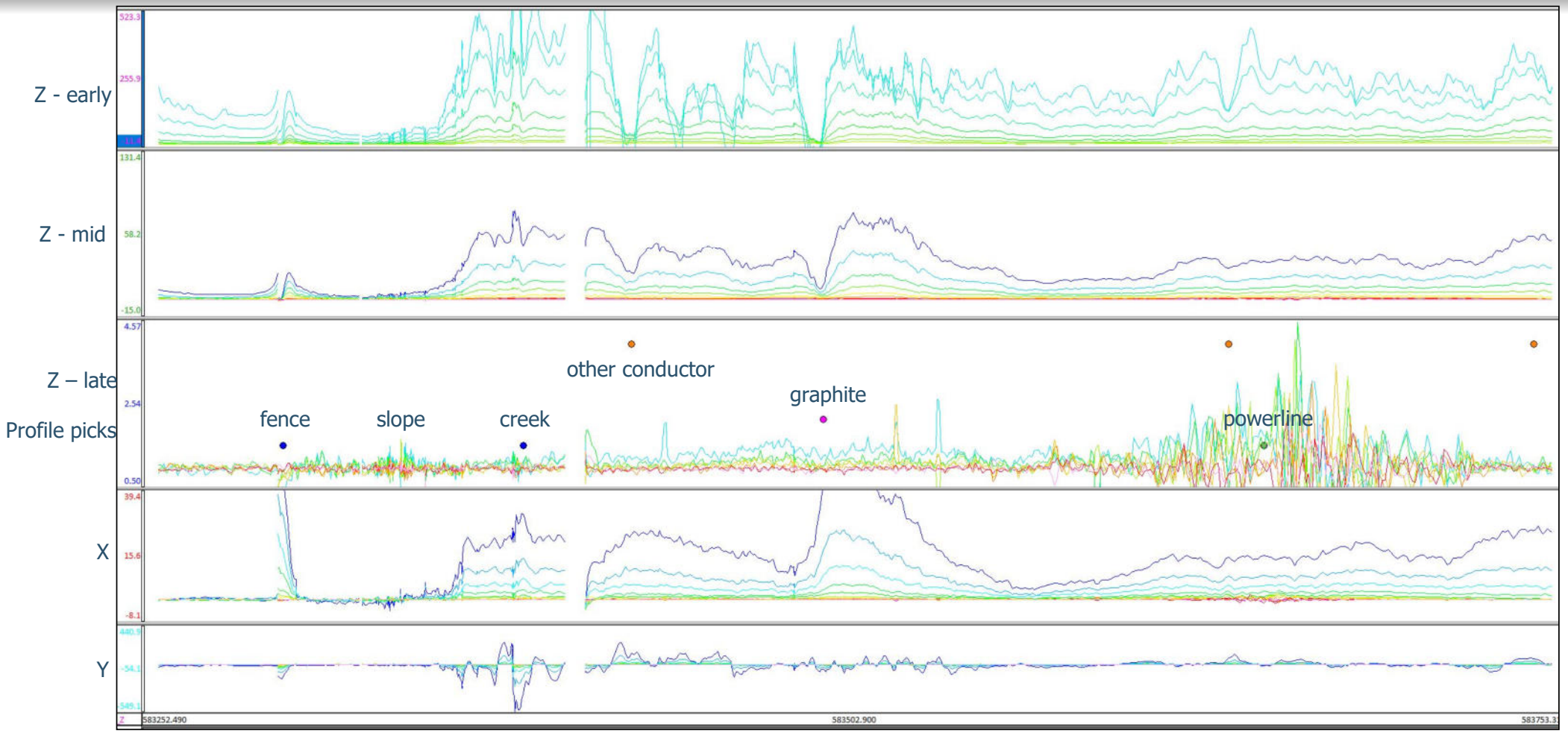


Loupe lines with collars and 5% graphite shell.

South Australia – Koppio Loupe Survey

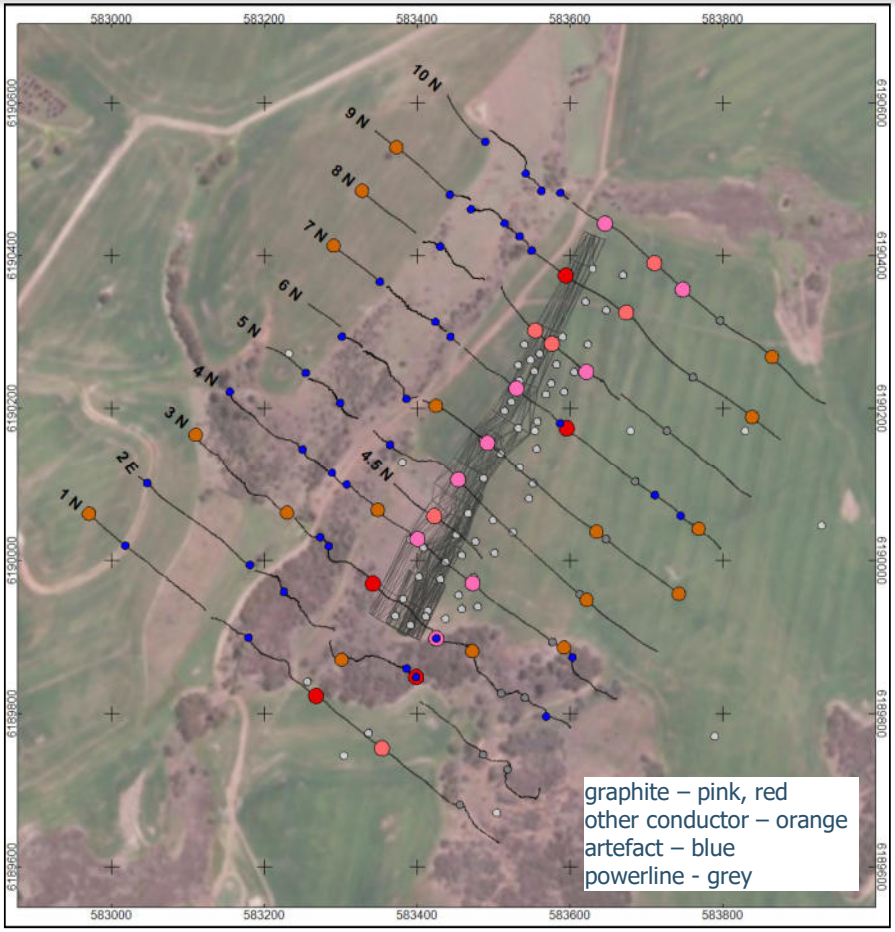
- Loupe format data was converted to Ascii files and then imported into Maxwell for preliminary QAQC. TEM files were exported and then imported into software where the profiles could be reviewed
- Line segments were merged and duplicate stations deleted. Data was reformatted to allow for coincident profile viewing of Z, X and Y components for each line
- Profile interpretation was undertaken, primarily using Z component data. Interpretation consisted of picking anomalies caused by conductors, as well as distinguishing conductors caused by cultural artefacts including power lines, fences and creeks. Steep slopes also resulted in acquisition noise, likely due to the amount of movement of both the transmitter and receiver loops
- Z component time channel data was gridded and imaged
- Inversion of Z component data was undertaken using Emax Air inversion software, with results displayed as conductivity isosurfaces

South Australia – Koppio Loupe Survey Interpretation



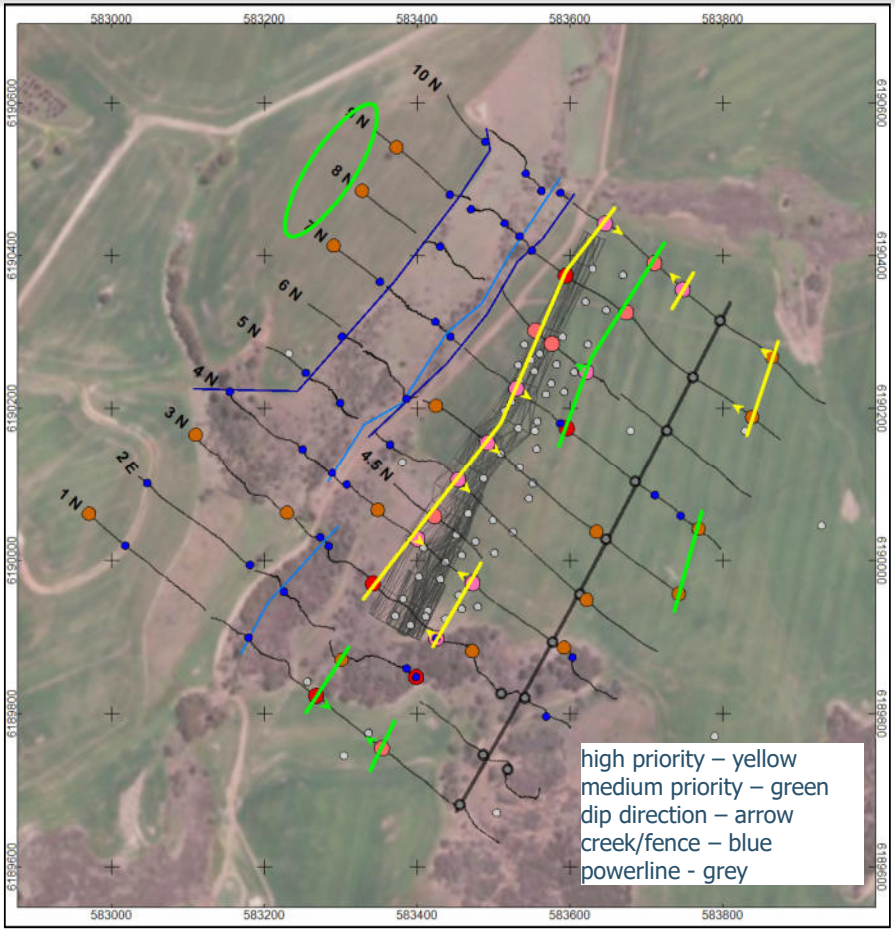
Interpretation example - Line 6 EM profiles with interpretation.

South Australia – Koppio Loupe Survey Interpretation



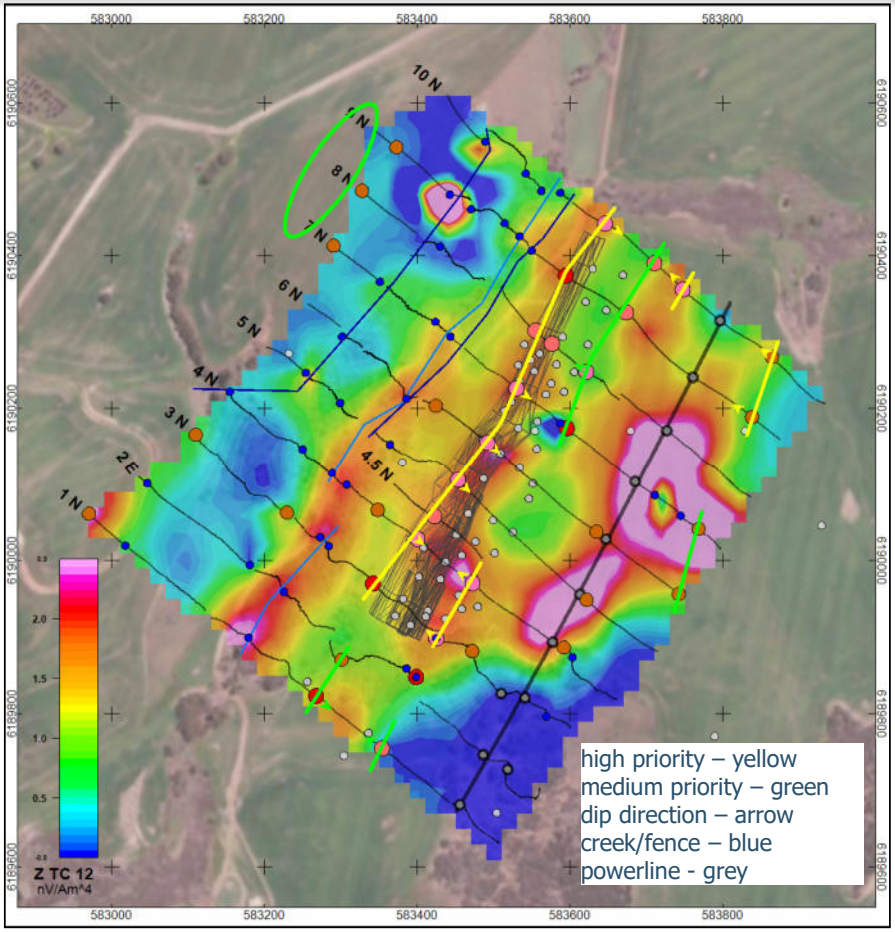
Profile picks.

South Australia – Koppio Loupe Survey Interpretation



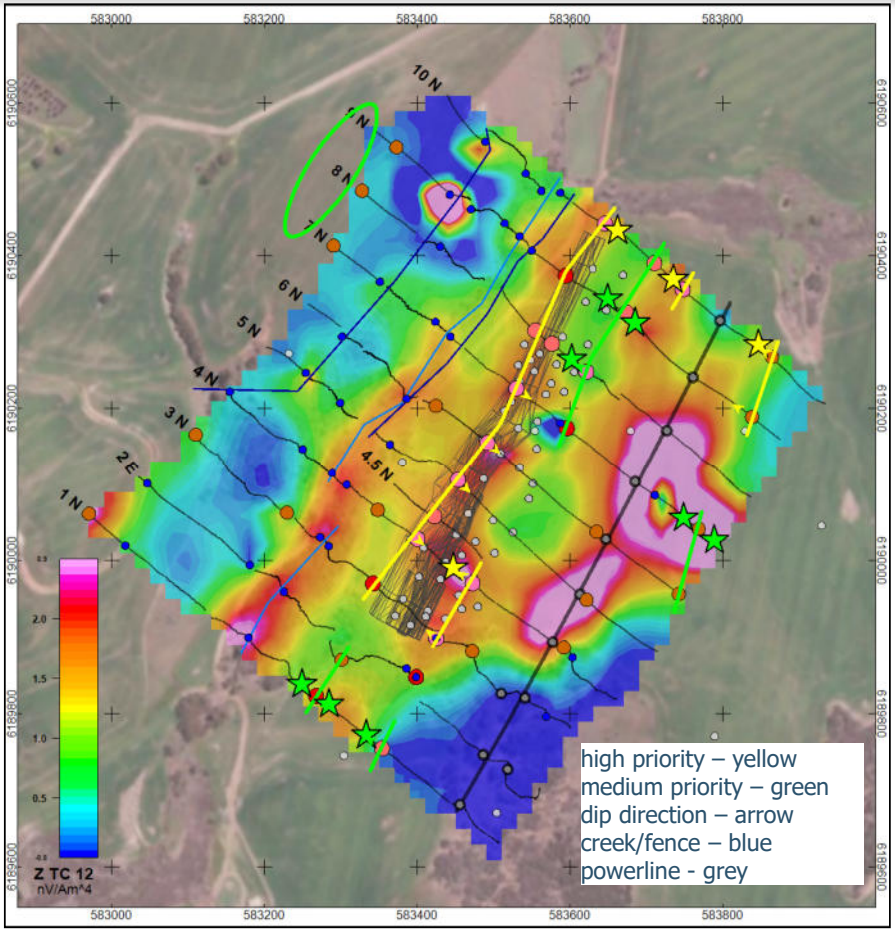
Interpretation and targets.

South Australia – Koppio Loupe Survey Interpretation



Interpretation and targets.

South Australia – Koppio Loupe Survey Interpretation



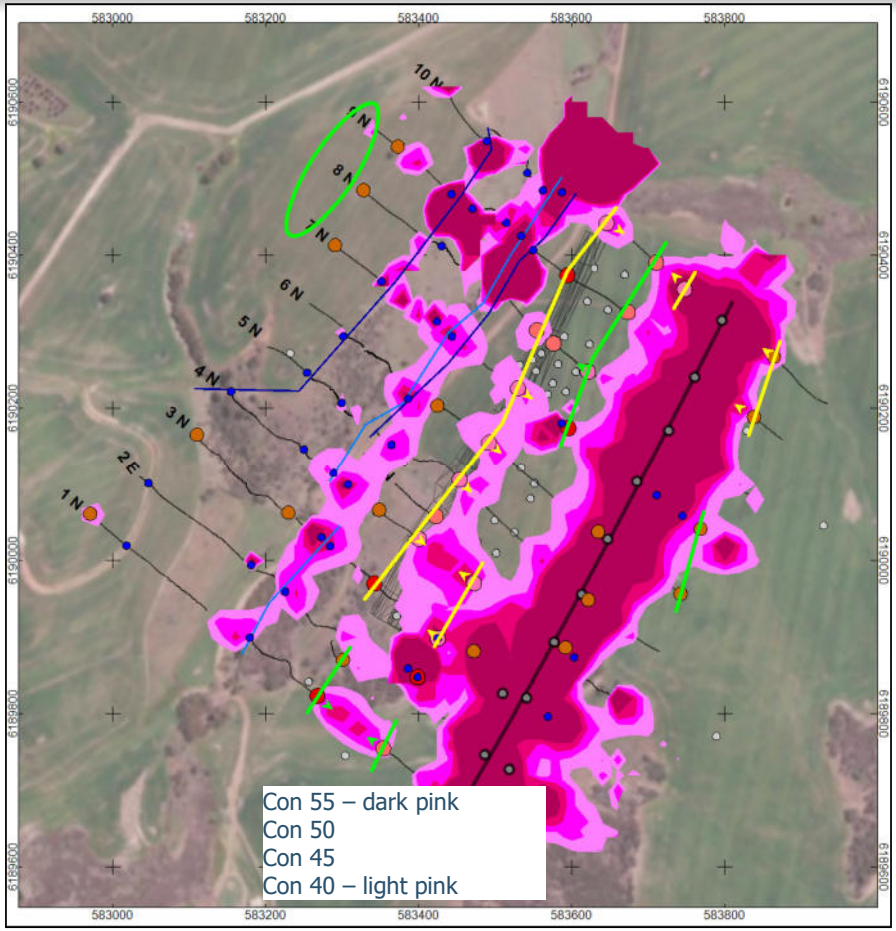
Interpretation and targets with possible drillholes to test targets.

South Australia – Koppio Loupe Survey Interpretation

Inversion was undertaken using Emax Air inversion software

The results are dominated by cultural features (powerline, creek and fences)

Inversion results could likely be improved by manual editing of data to remove noise (very time consuming)



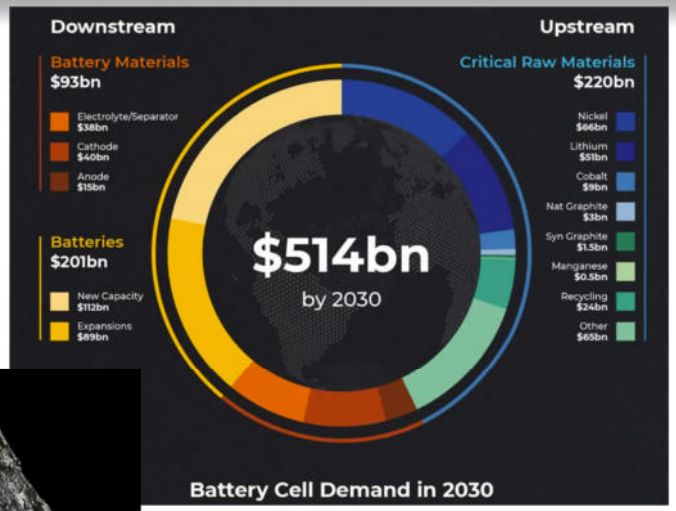
Conductivity isosurfaces with interpretation overlain.

South Australia – Koppio Loupe Survey Interpretation

- EM data from a Loupe survey over the Koppio Project has been processed and interpreted. Interpretation was hampered by cultural noise from to fences, creeks and powerlines throughout the survey area. In addition, a steep slope caused acquisition noise in one area of the survey
- Known (drilled) graphite mineralisation within the survey area had a conductive response that could be interpreted from the profile data. Other targets with a similar response were identified and classified based on their response, with four high priority and four medium priority targets in total
- Drillholes to test the targets over the greatest response have been planned (locations and orientations need fine tuning based on geological dips in the survey area)
- Inversion was undertaken using Emax Air, and used to assist ranking and prioritising targets

Summary

- Graphite seemingly “everywhere” ?
- Characteristics of known graphite deposits
  - At surface
  - High grade metamorphic rocks
  - Structurally modified
- Future Graphite Deposits
  - At surface
  - Near shipping, infrastructure
- Graphite Threats
  - Synthetic graphite (graphitization)
  - Change in battery technology



Spherical natural graphite prices plunge to 11-year lows on more competition from synthetic graphite

The price for spherical natural graphite in China has fallen to its lowest level in June 2023 since Fastmarkets began tracking it in 2012. The question remains, what is behind this historically low price?

Summary

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ASX ANNOUNCEMENT

ASX: KNG

kingslandminerals.com.au

6 June 2023

EM survey confirms immense potential of Leliyn Graphite Project in NT

Dimensions of the graphitic schist outlined in the survey are entirely consistent with the large Leliyn Exploration Target

Highlights

- Ground electro-magnetic (EM) survey completed over Leliyn Exploration Target
- Leliyn has a large Exploration Target of 200-250Mt at 8-11% Total Graphitic Carbon for 16-27Mt of contained graphite[1]
- EM survey generates strong response over interpreted graphitic schist unit

ANNOUNCEMENT
ASX:CDT

1 August 2023

CASTLE

Additional Graphite Targets At Kambale

Summary

- 13 priority-one targets defined by a 275-line km Loupe EM geophysical survey at the Kambale Graphite Project, Ghana.
- EM has previously been successful in identifying graphite mineralisation.
- New targets are distal from the main Kambale deposit and Mineral Resource Estimate ("MRE") of 15.6Mt at 9.0% TGC containing 1.41Mt of graphite.
- Results and updated MRE from recently completed 43-hole infill and extensional RC drilling programme expected late-August.
- Any additional mineralisation delineated on the 149m^2 Kambale licence will improve options for optimising any future development.
- EM surveys still cover only 50% of the prospective area of the licence.
- New EM targets will be tested asap.

Acknowledgements

Geological Survey of Western Australia

TERRA PETROPHYSICS

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Legend mining limited

THE UNIVERSITY OF WESTERN AUSTRALIA

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CASTLE

Geophysics of Graphite
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