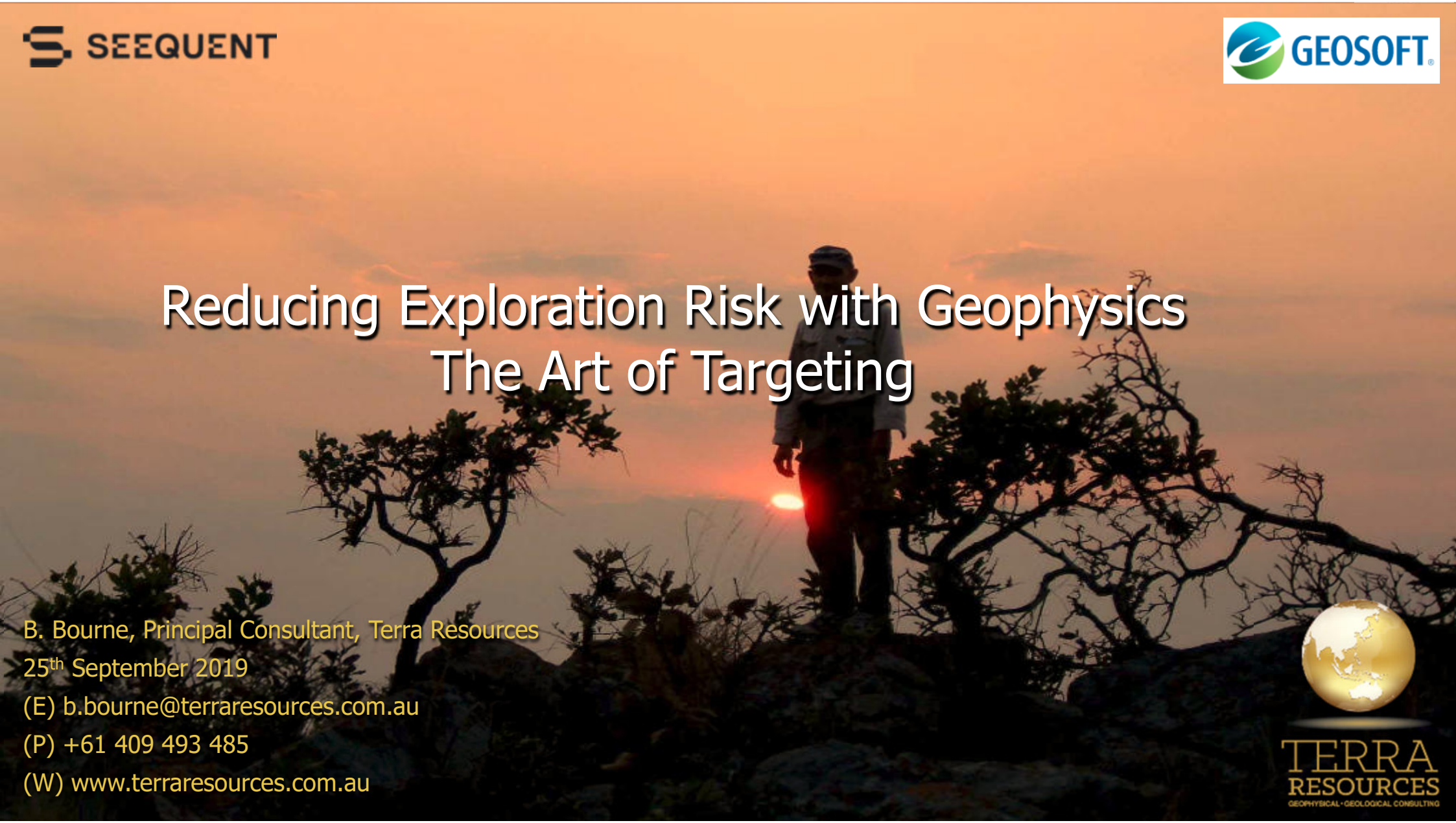


Reducing Exploration Risk with Geophysics
The Art of Targeting

B. Bourne, Principal Consultant, Terra Resources

25th September 2019

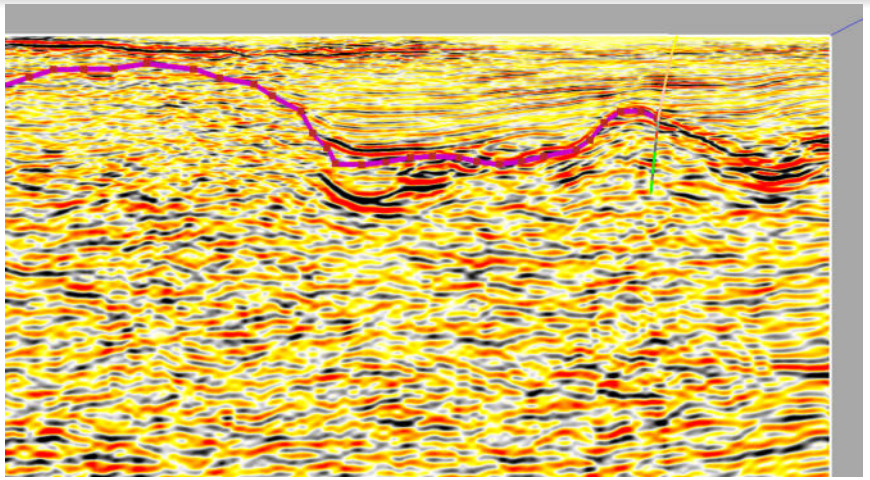
(E) b.bourne@terraresources.com.au

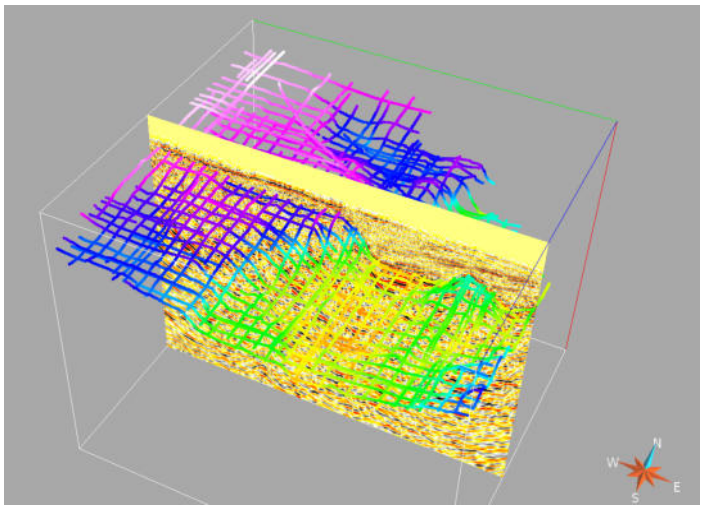
(P) +61 409 493 485

(W) www.terraresources.com.au

Outline

- Introduction
  - Interpretation versus Targeting
- Quality/Successful Interpretations
- Interpretation Impediments
- Speeding up the Interpretation Process
- Summary



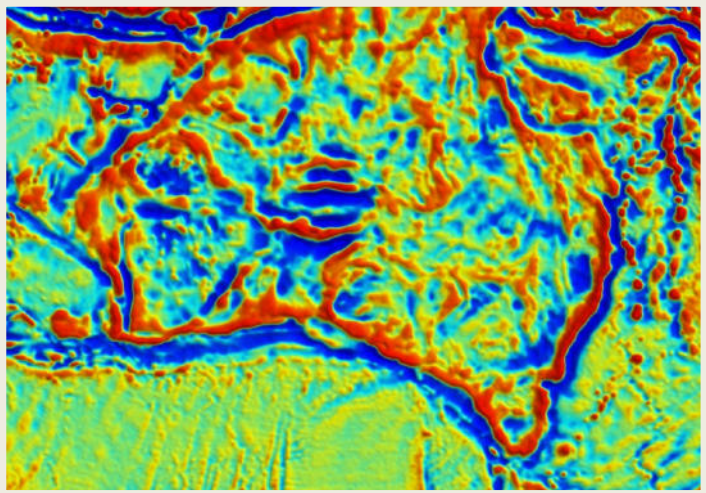


Introduction

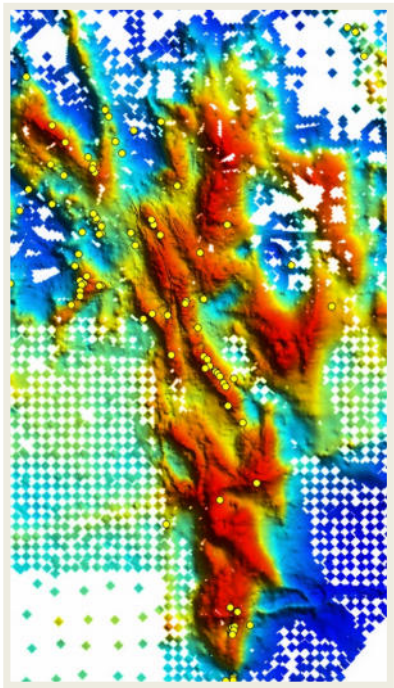
- Interpretation versus Targeting
- Interpretation: The most probable geological explanation of geophysical data based on prior information all available data
- Target: The most probable interpretation that can be easily be tested and could result in an ore grade intercept
- Important concept to grasp as it effects the way we go about interpreting data eg. do we need to interpret all the data now and at what scale?
- What processing products do we need to obtain the best possible target outcomes?

"The greatest victory is that which requires no battle." (The Art of War)

The Importance of Scale



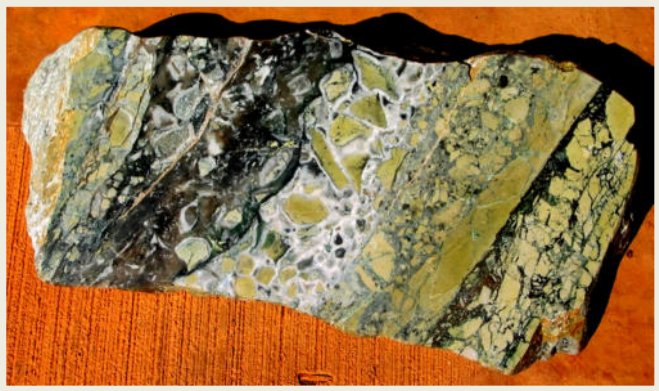
Continental



Regional

Camp

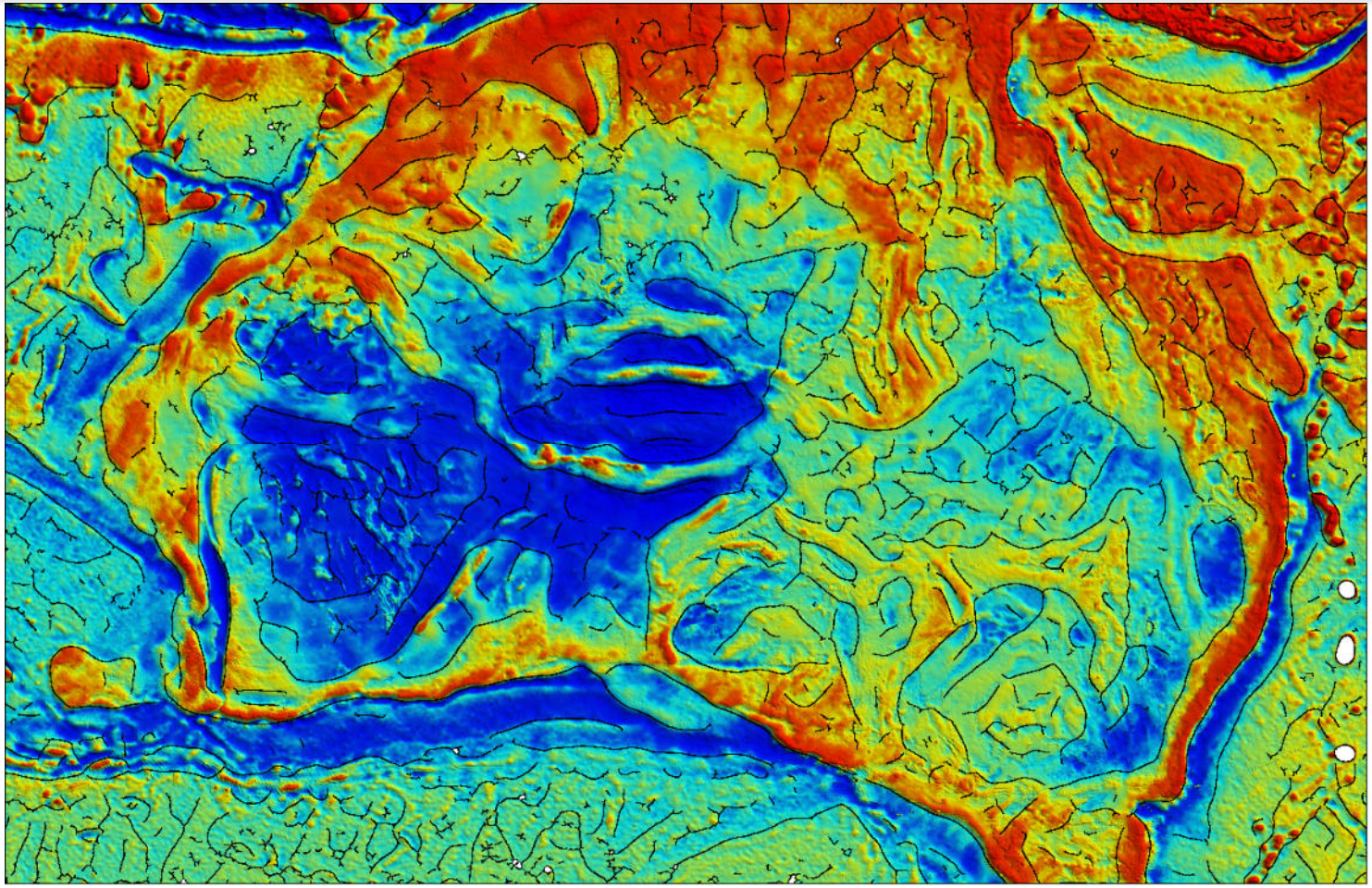
Local



Traditional focus on local to camp scale. More recent focus on continental to regional scale via "mineral systems" approach

The better explorers have been informally using this approach for decades

The Importance of Scale



Gravity Edges (Gradients)-50km

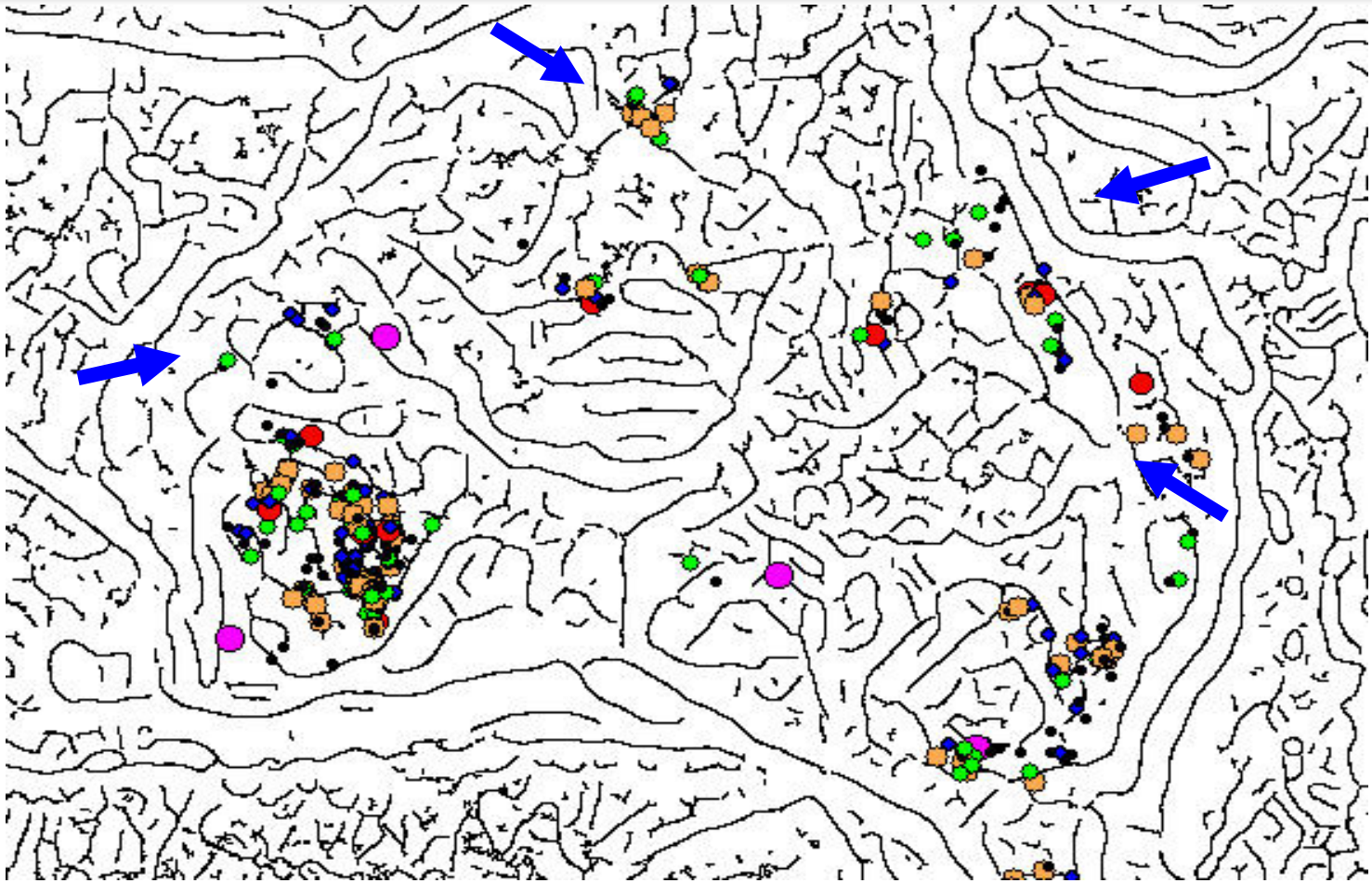
Crustal scale geophysics 25-50km resolution requires data sampled on at least 10km x 10km

At first glance it is just an off the shelf continental scale gravity image… or is it?

It contains bathymetry data, isostatically corrected land data, removes upper crust, gradient calculation, algorithm to vectors gradient etc

Geosoft – Gridding/Magmap/ CET Grid Analysis

The Importance of Scale



Gravity Edges (Gradients)- 50km with Major Gold Deposits

Important to use a consistent set of data that best represents the geology, not necessarily lots of data

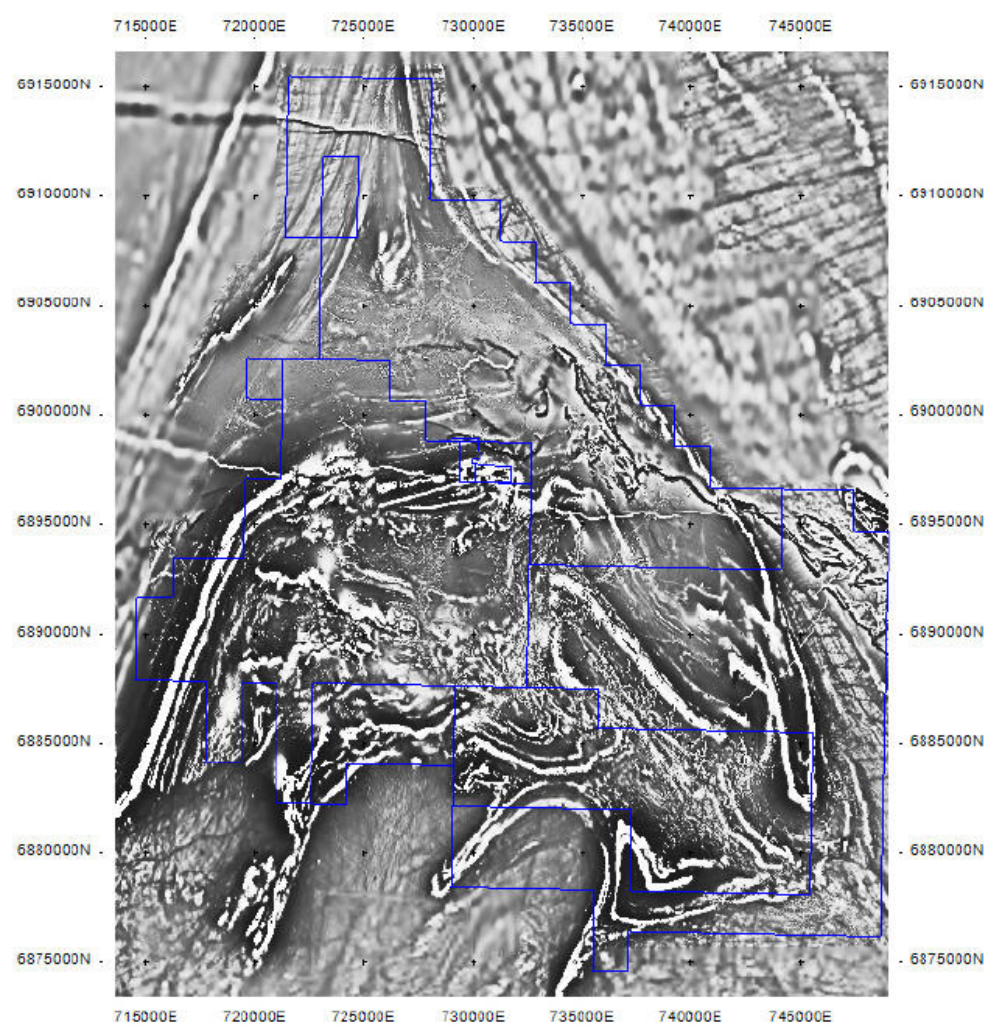
Geosoft - CET Grid Analysis

Quality/ Successful Interpretations

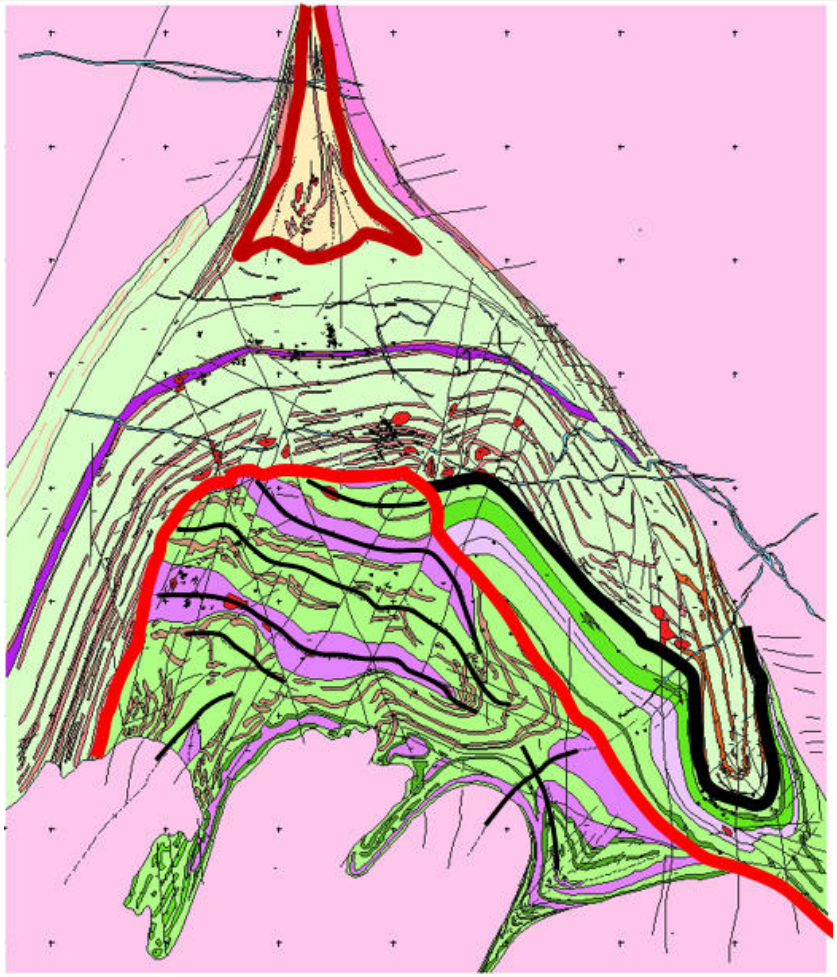
- Based on Quality Acquisition – the highest priority projects in a geophysics portfolio are those where you are either acquiring data or you are in the processing of drilling an idea
- Petrophysical Data – Fundamental to not only interpretation but survey planning
- Geological/Geochemical Input- Can set broad constraints and assist with targeting. Better interpretation/ understanding
- Consider Alteration versus Lithology – Most world class mineral systems have a geophysical response associated with the alteration
- Separate Fact from Inference – Quality/acceptance of an interpretation can be improved significantly if all the factual information is captured
- Presentation – Key concepts and ideas are presented in a way that is easily understood. May vary from 2D (section and plan) to 3D
- Iterative – Good interpretations are reviewed and reassessed as new data becomes available

"In the midst of chaos, there is also opportunity" (The Art of War)

Interpretation – Structure / Host Sequence

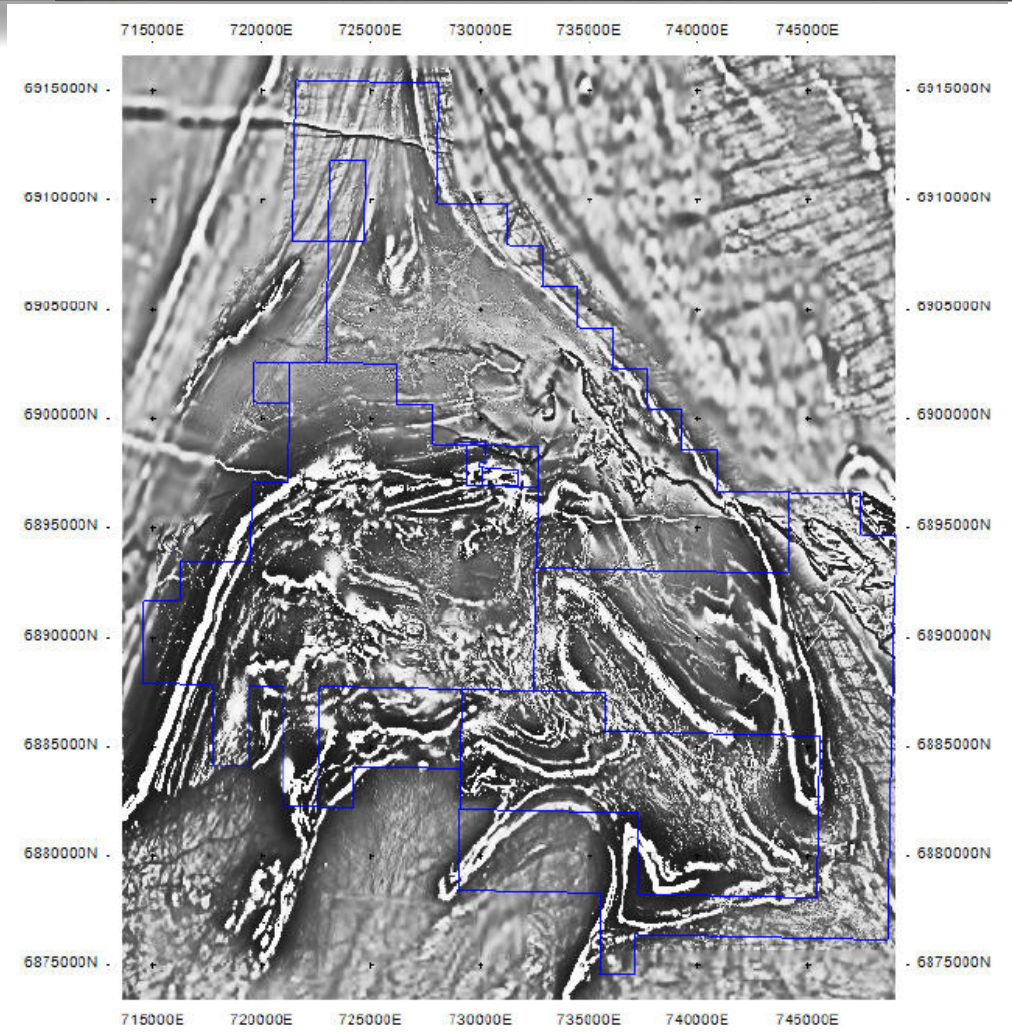


1VD Greyscale of RTP magnetics

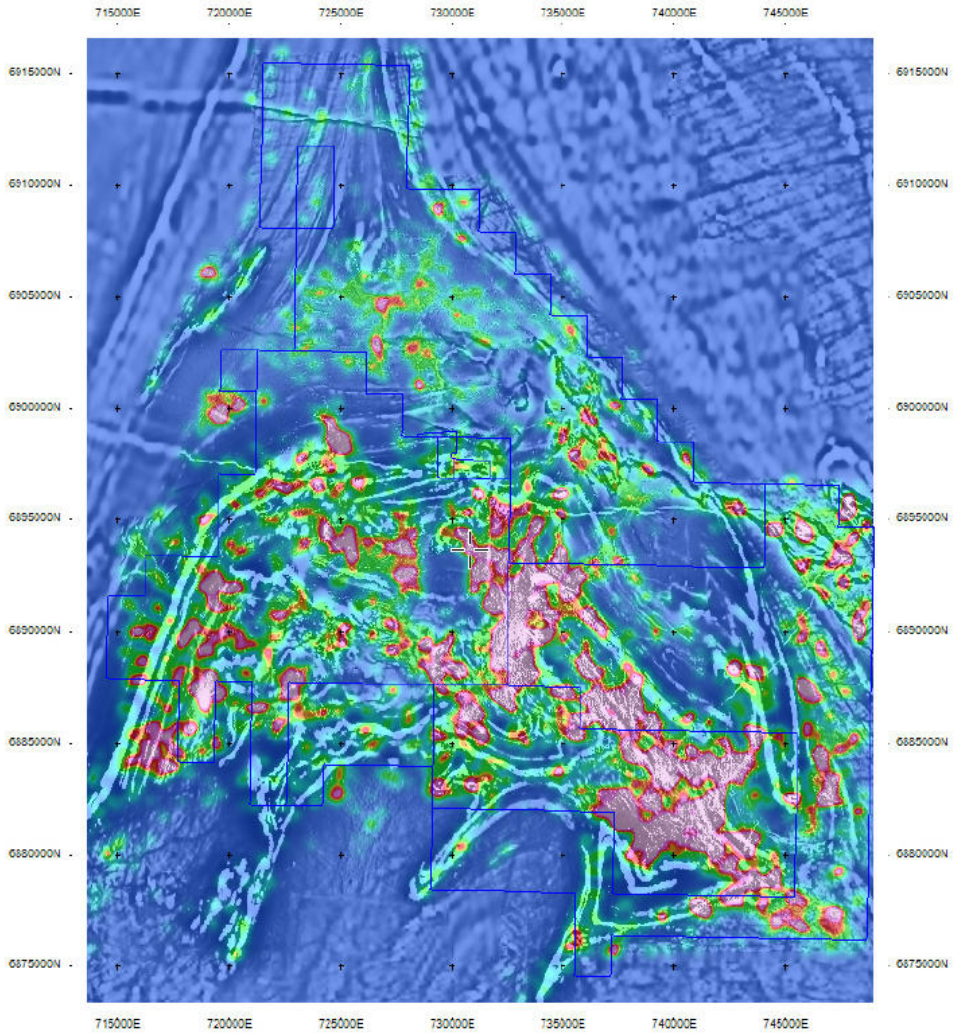


Interpretation of Airborne Magnetic data

Interpretation – Structure / Host Sequence



1VD Greyscale of RTP magnetics



CET texture based analysis. Heat map that highlights high density of structure/contacts

Interpretation - Regional Structures Bends/Jogs

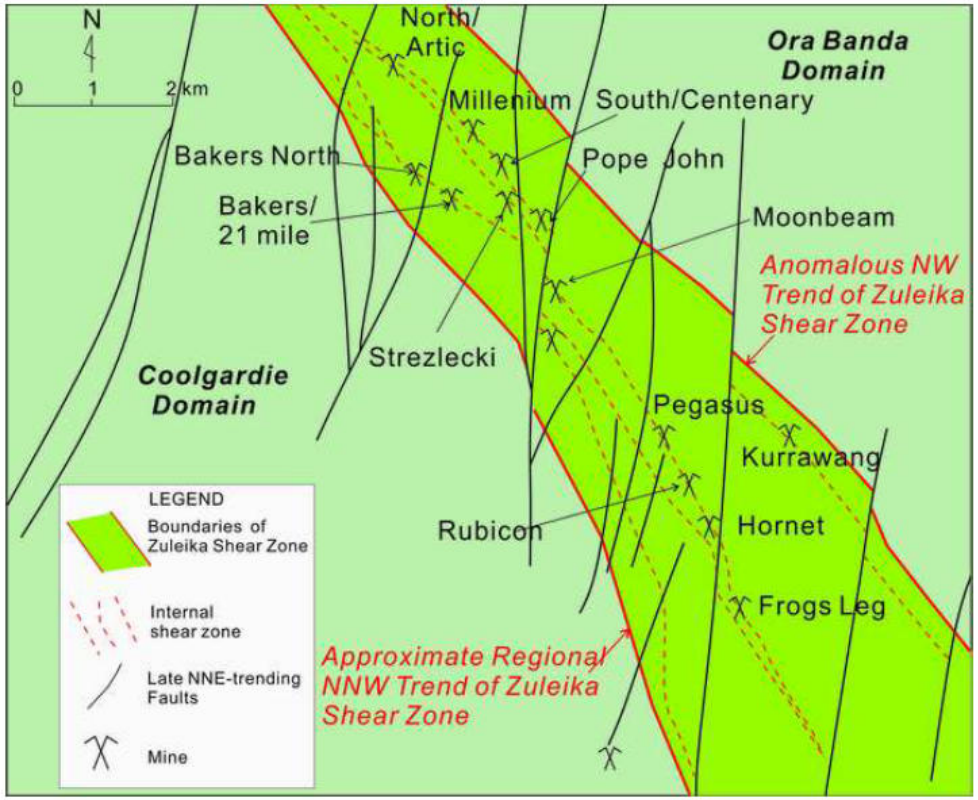
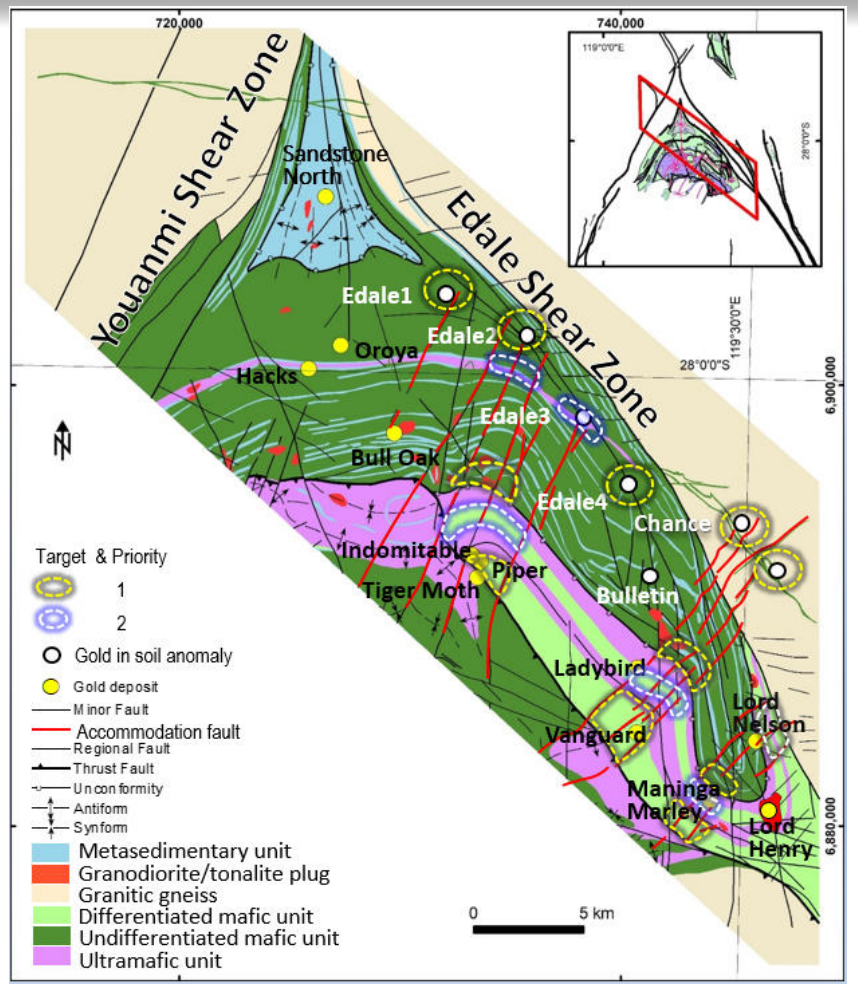


Image from Structural geometry of orogenic gold deposits: implications for exploration for world-class and giant deposits. 2017. D. Groves *et al.*

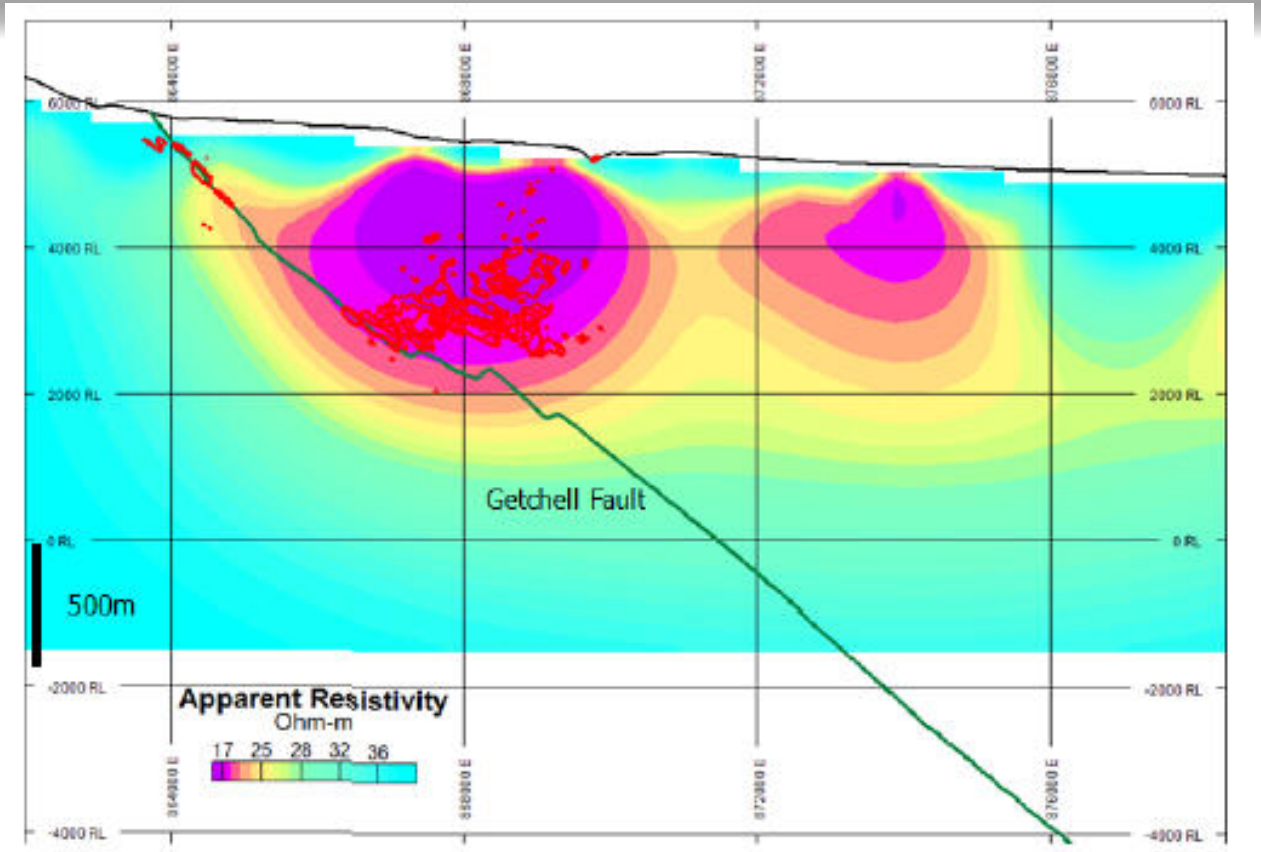


Interpretation Impediments

- Poor Acquisition /Legacy Data eg. survey design that doesn't address scale and/or petrophysics
- Lack of Geological Experience/ Support eg. no interpretation overlap with geologist (the same can be said for geologist with lack of geophysical understanding)
  - Lack of Geology in Undergraduate Courses and a Focus on Processing and Inversion eg. 40% of graduates when asked what the magnetic minerals are can't give the correct response
- Lack of Petrophysical Data
- Increased Complexity of Acquisition and Processing eg. time series acquisition and inversion of large 3D electromagnetic surveys/ seismic. Appropriate meshes that replicate geology and geophysical inversion parameters
- Lack of Time – Other demands on individual time. Processing time
- Interpretation Platform and Presentation of Results– How interpretations are delivered eg VOXEL, shape surface, 3D v 2D, GIS?
- Example from Nevada – alteration/ porosity alone explains the geophysical response

"Ponder and deliberate before you make a move." (The Art of War)

Getchell/ Turquoise Ridge (26 Moz)

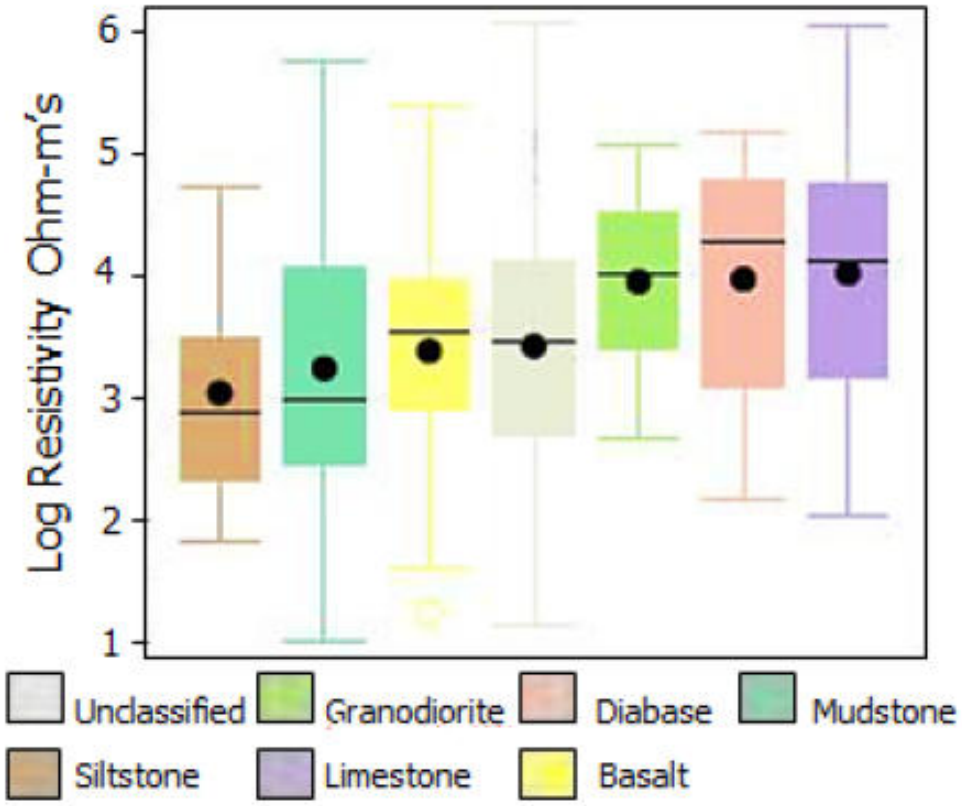


MT cross west to east cross section with deposit location (red) and the Getchell Fault (green) overlain

Geosoft – Target/Drillhole

(After Howe et al., 2014)

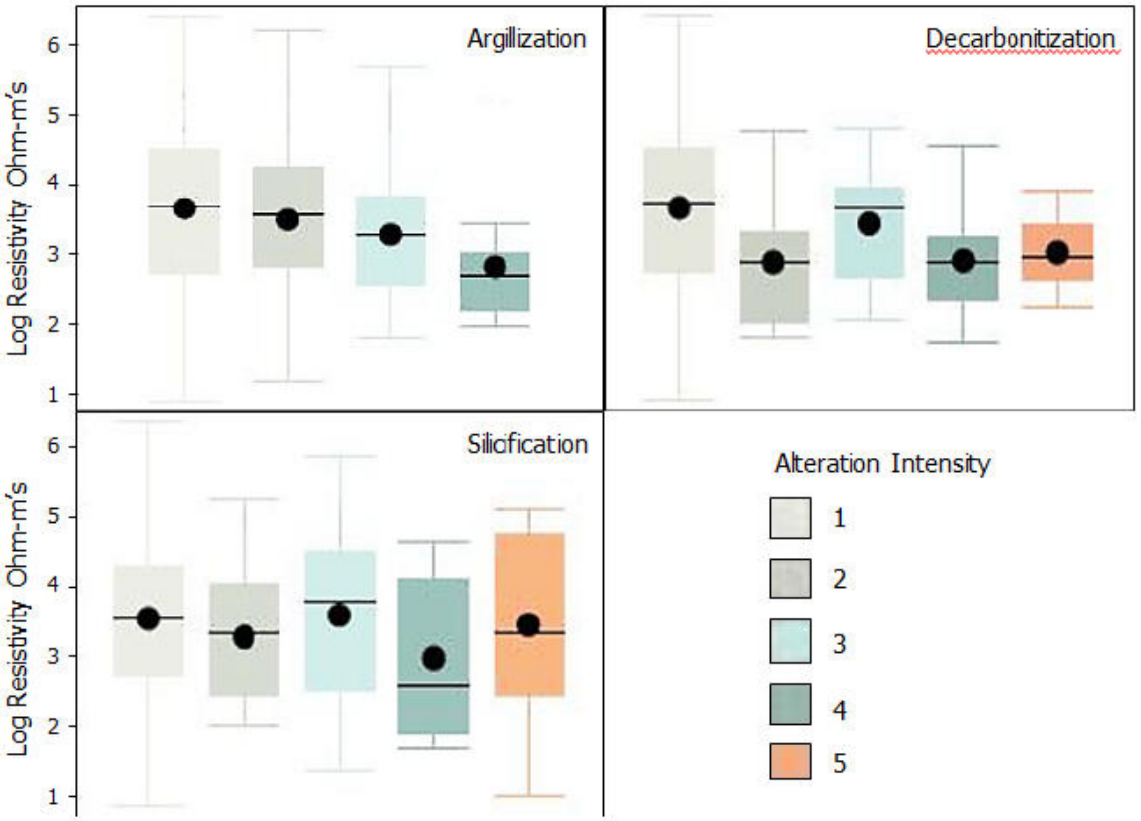
Getchell/ Turquoise Ridge (26 Moz)



Box and whisker plot of resistivity variation compared to logged lithology. The black dot represents the mean, the solid line the median, and the coloured lines the data range

(After Howe et al., 2014)

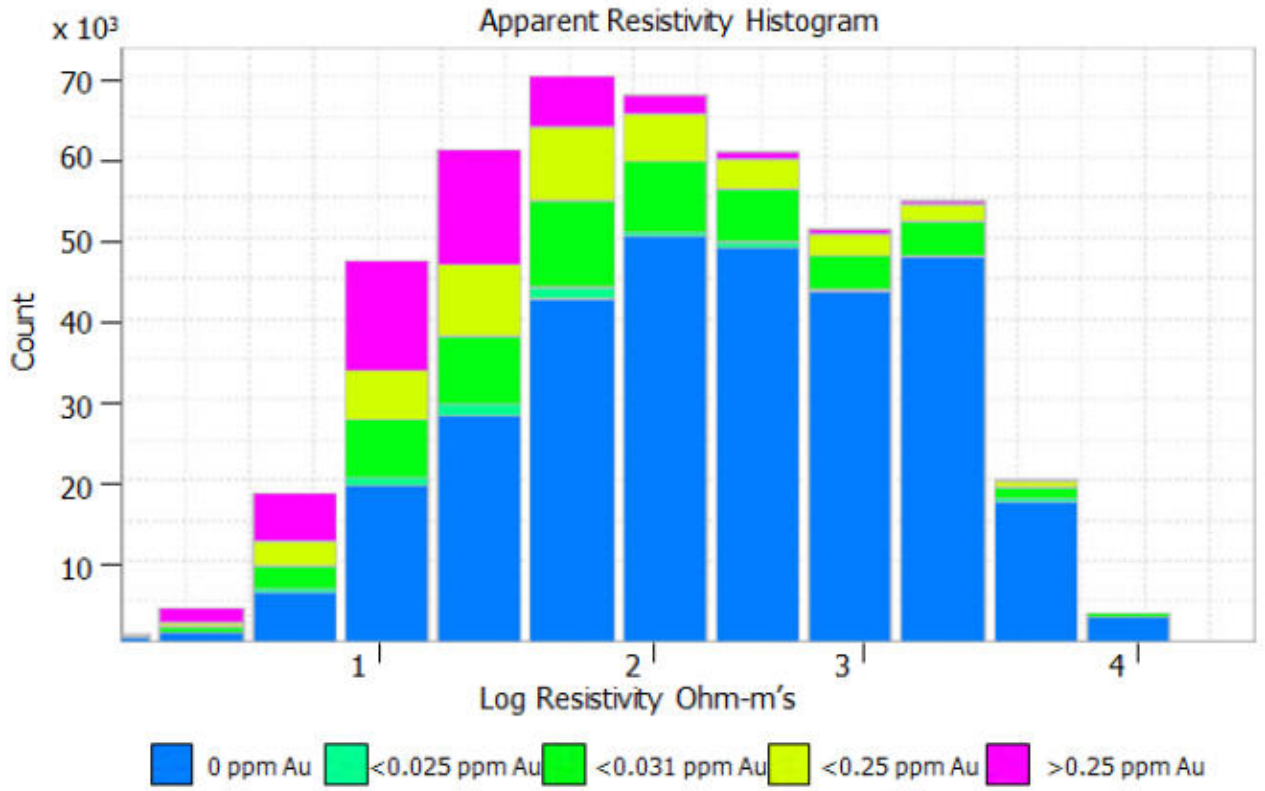
Getchell/ Turquoise Ridge (26 Moz)



Box and whisker plots comparing typical Carlin type alteration with resistivity

(After Howe et al., 2014)

Getchell/ Turquoise Ridge (26 Moz)



Downhole resistivity histogram coloured by Au grade

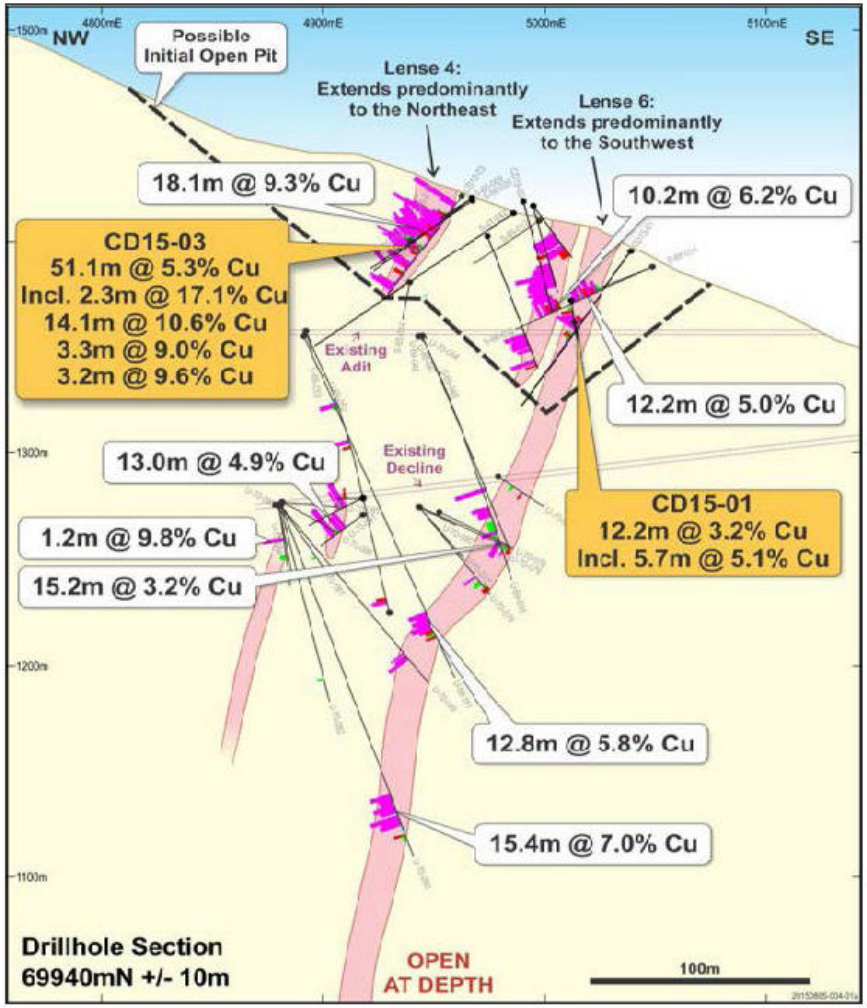
(After Howe et al., 2014)

Speeding Up Interpretations

- Best interpreters aren't acquiring data
- Well documented processing/interpretation workflows for common techniques
- Embedded specialists/ champions – Internal or external to company. Portions of workflow outsourced to keep focus on interpretation
- Introducing good geological constraints at an early stage of the interpretation
- Increase processing time with more efficient codes/ access to clusters (Azure)
- Interpretation Presentation/ Processing – use of commercial software and allows integration of all data
- An example from Alaska – QA/QC, cluster processing and targeting

"Thus the expert in battle moves the enemy, and is not moved by him." (The Art of War)

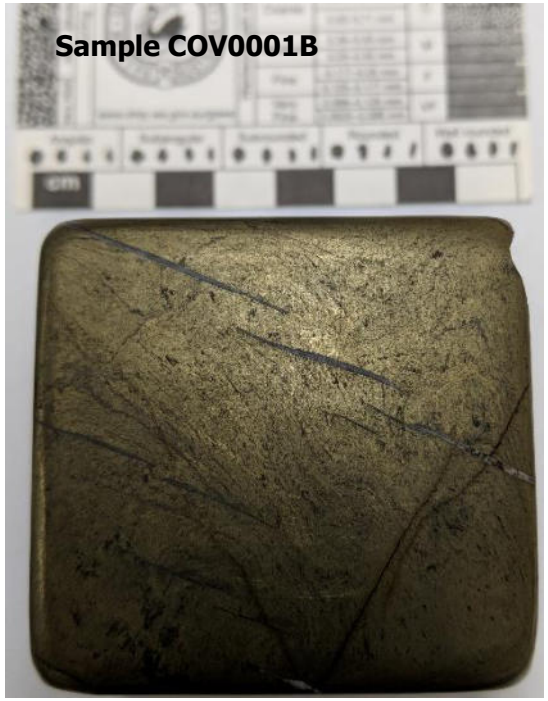
Caribou Dome – Mineralisation



Drill core from CD15-14 (Lense 7/8 Target) – containing >16% Cu

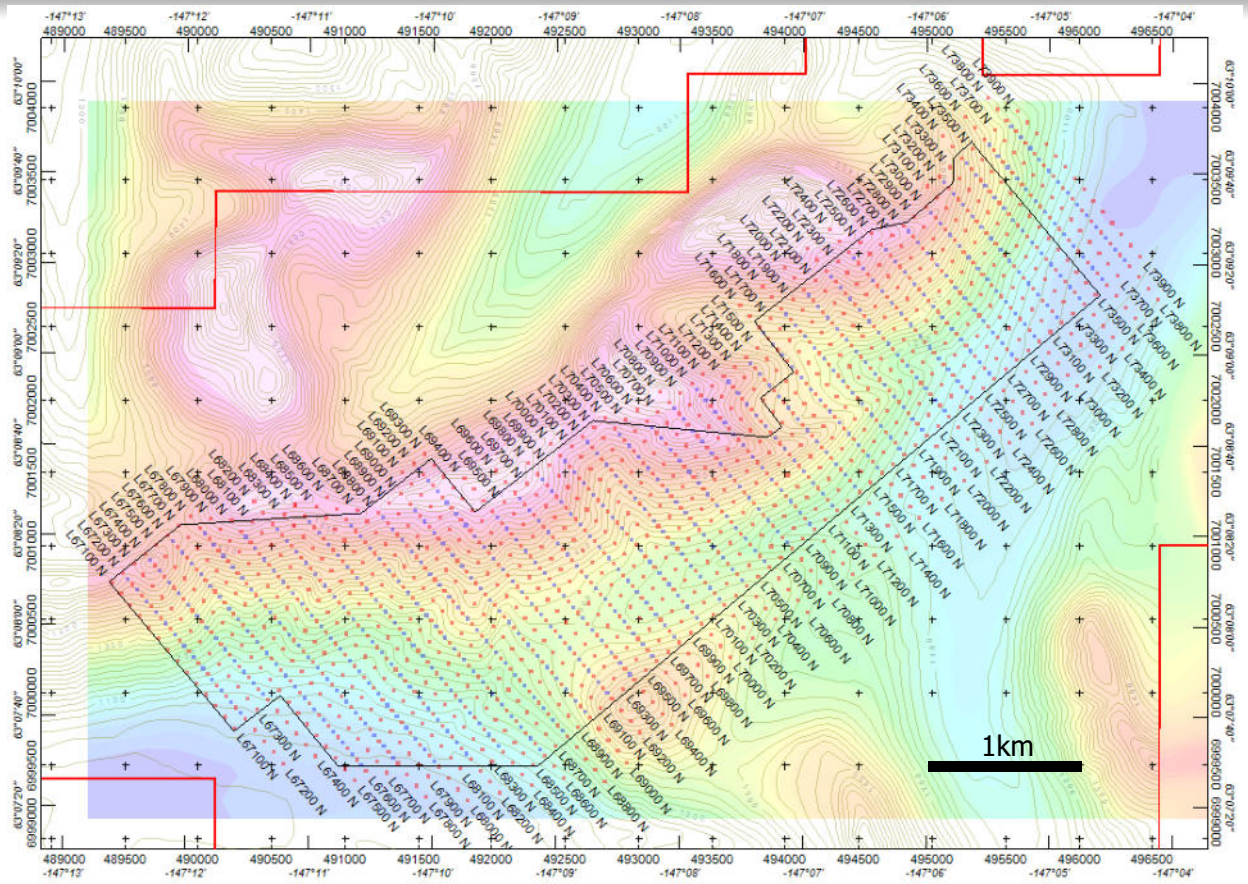
Caribou Dome – Petrophysics

Sample Information		IP/Resitivity		Inductive Conductivity
Sample ID	Comments	Resistivity (Ω·m)	Chargeability (mV/V)	Conductivity S/m
COV0001B	Block- coil parallel to fabric	57.89	86.75	3.90
COV0001A	Block – coil perpendicular to fabric	24.16	67.21	2.20
COV0002	Quarter Core	n/a	n/a	0.00



Drill core from CD15-14 (Lense 7/8 Target) – containing >16% Cu

Caribou Dome IP – Survey Details



Map of survey area showing location of IP lines and station locations on elevation image. Final modelling area depicted in black polygon

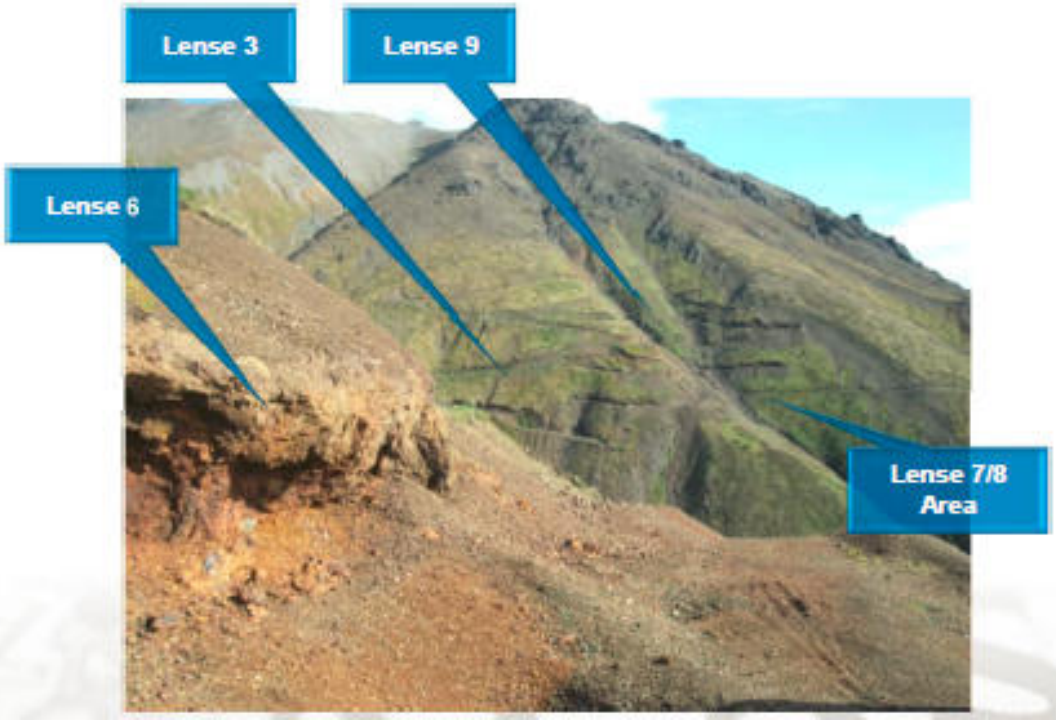
Planning

- Forward modelling using petrophysics
- Broad coverage with enough detail to resolve geological problem
- Achieve greater depth penetration (off-end Tx injection)
- Good lateral and across-line resolution
- High data redundancy so noisy data points can be ignored

Survey Specifications:

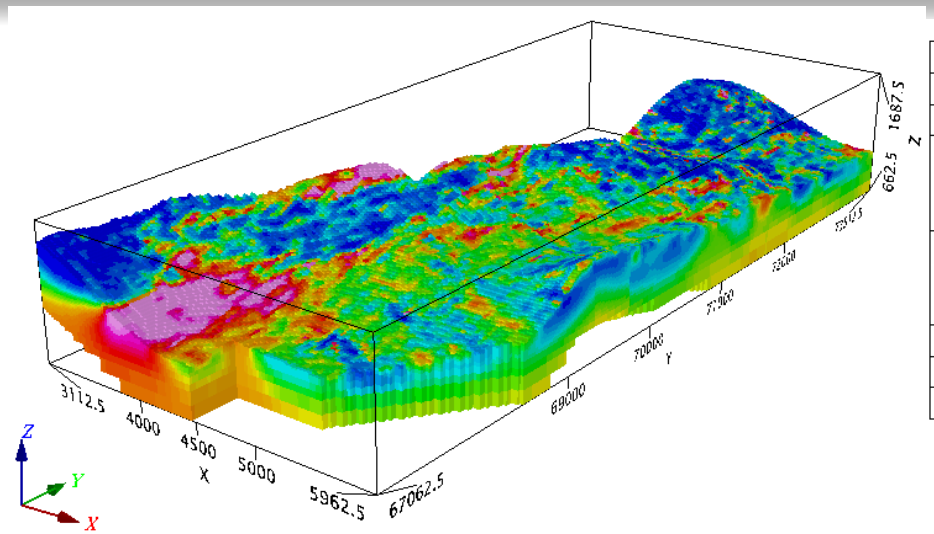
- Array type: Double-Offset Pole-Dipole 3DIP Array in swaths
- Time Domain: 50% duty cycle
- Frequency: 0.125Hz
- Dipole spacing: 100m
- Rx line spacing: 200m
- Tx line spacing: 100m
- Current locations: Offset from potential electrode locations by 50m (along line) on both the same and adjacent lines. The adjacent lines were offset from the receiver lines by 100m in both directions

Caribou Dome IP – Terrain



The 2016 exploration camp at the Caribou Dome Project located directly down-slop of Lenses 4, 5 and 6

Caribou Dome IP - Processing & Modelling

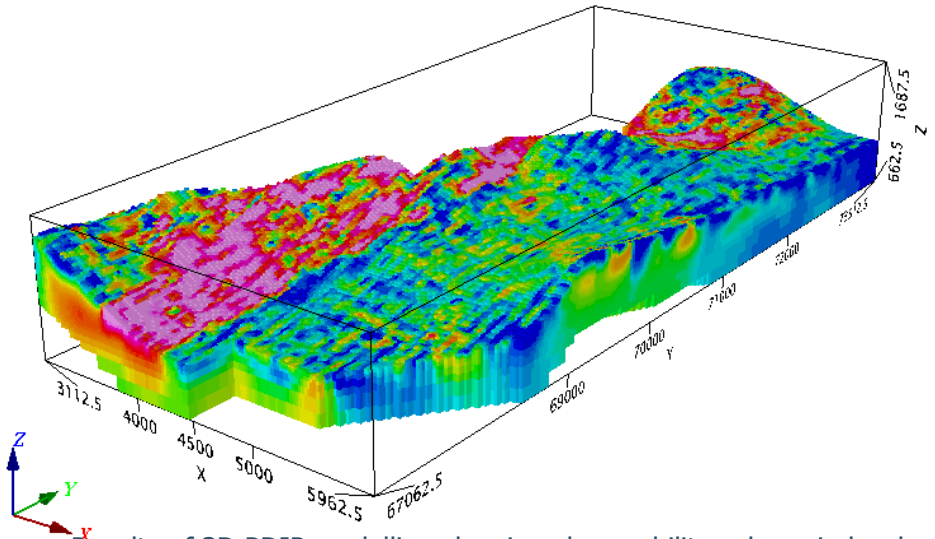


Results of 3D PDIP modelling showing resistivity volume in local coordinates.

Table 1: Inversion parameters used in final modelling.

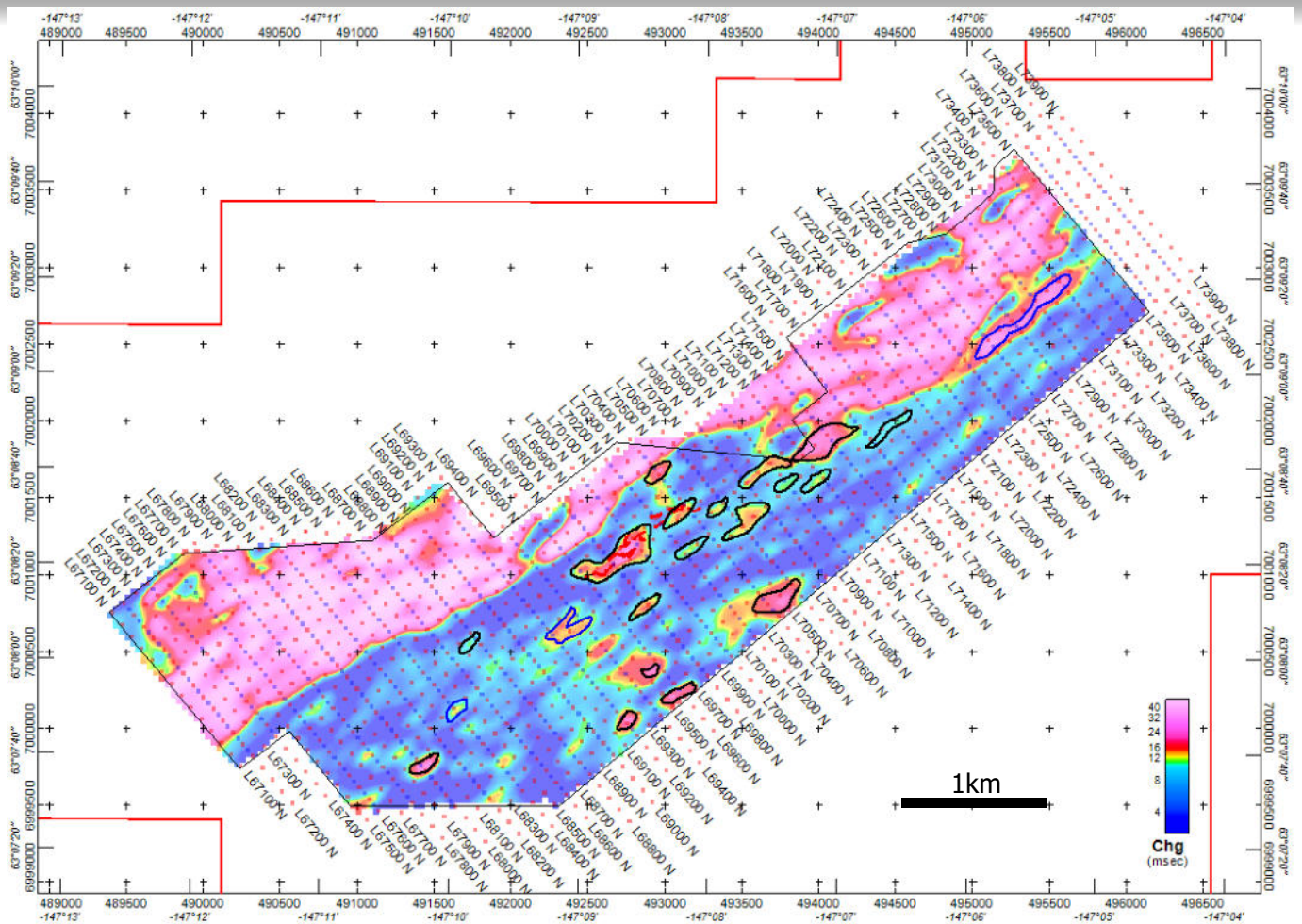
Resistivity			IP		
Resistivity % error		5	IP % error		5
Resistivity error floor		8	IP error floor		2
Mesh	X	25	Mesh	X	25
	Y	50		Y	50
	Z	12.5		Z	12.5
Length Scales	X	50	Length Scales	X	25
	Y	100		Y	100
	Z	75		Z	75
Regularisation		Line Search	Regularisation		Line Search
Chi-factor		1	Chi-factor		1
Number of Iterations		15	Number of Iterations		4

- 96 x lines (32 blocks) total to n=6
- Corrected for Tx/Rx station locations
- QA/QC input currents (I) and voltage potentials (Vp's), remove noisy and/or poorly recorded data, within TQIPdb
- Averaged in Newmont Standard time windows (450-1100ms) and output to perform modelling within UBC3D / VOXI
- Optimal inversion parameters chosen from numerous preliminary 2D and 3D modelling



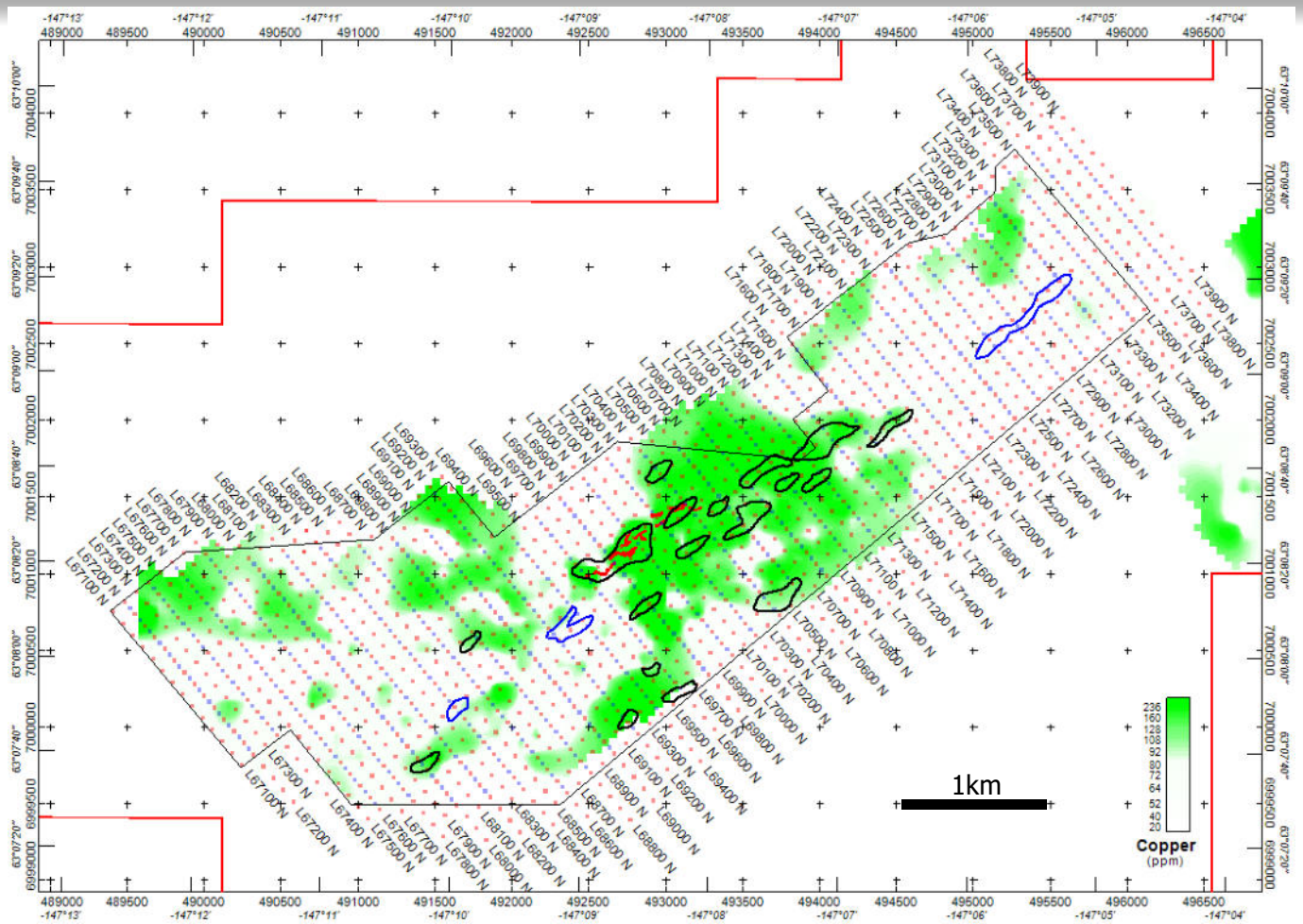
Results of 3D PDIP modelling showing chargeability volume in local coordinates.

Caribou Dome IP – Results



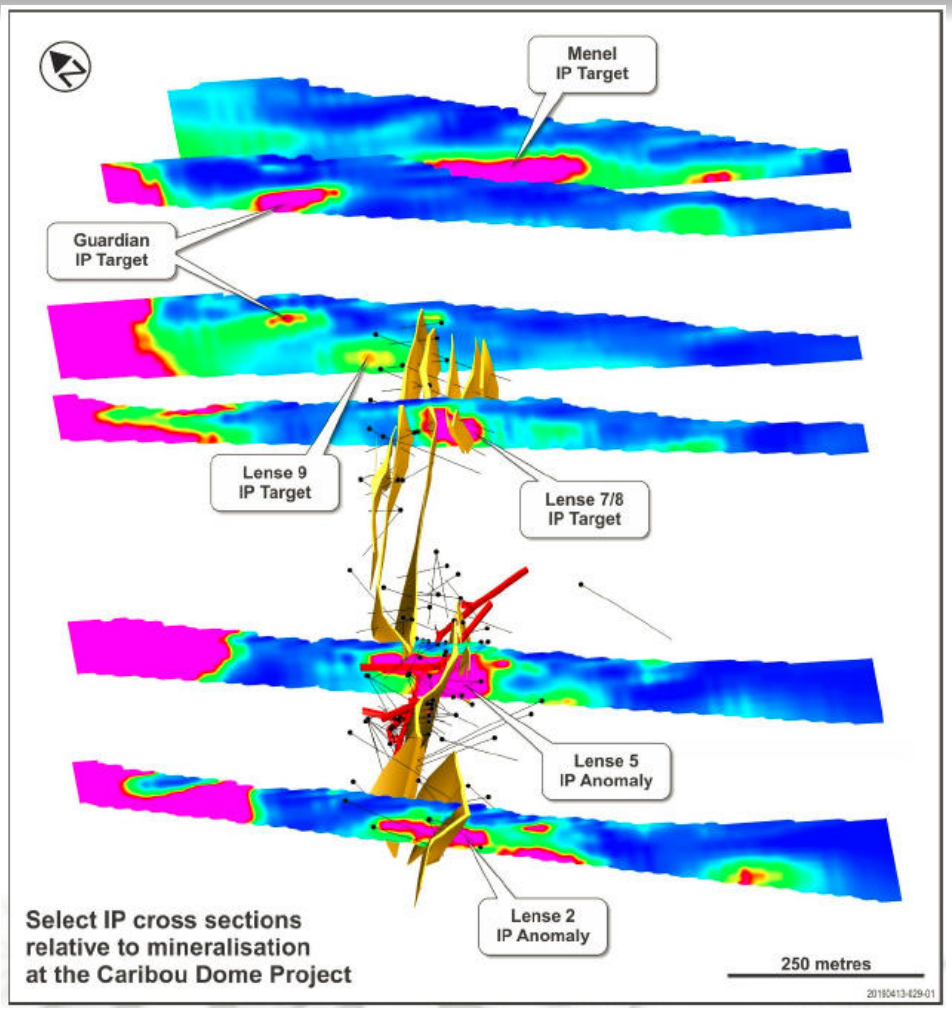
Map of survey area showing location of high priority (black outlines) and lower priority (blue outline) IP targets with respect to chargeability at -100m below surface. Red areas show known zones of mineralisation.

Caribou Dome IP – Results



Map of survey area showing location of high priority (black outlines) and lower priority (blue outline) IP targets with respect to surface sampling for copper concentrations. Red areas show known zones of mineralisation.

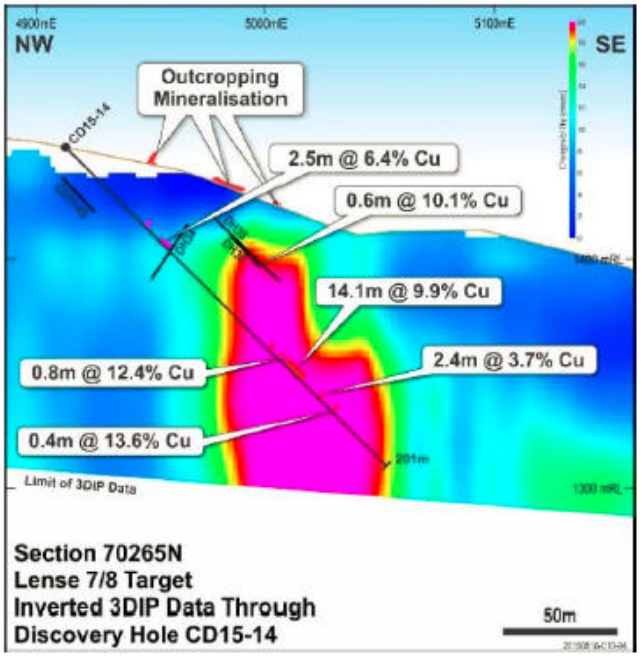
Caribou Dome – Induced Polarisation



Select IP cross sections relative to mineralisation at the Caribou Dome Project

Lense 7/8 IP Target

- First hole ever drilled to test this target, in 2015, intersected 14.1m @ 9.9% Cu



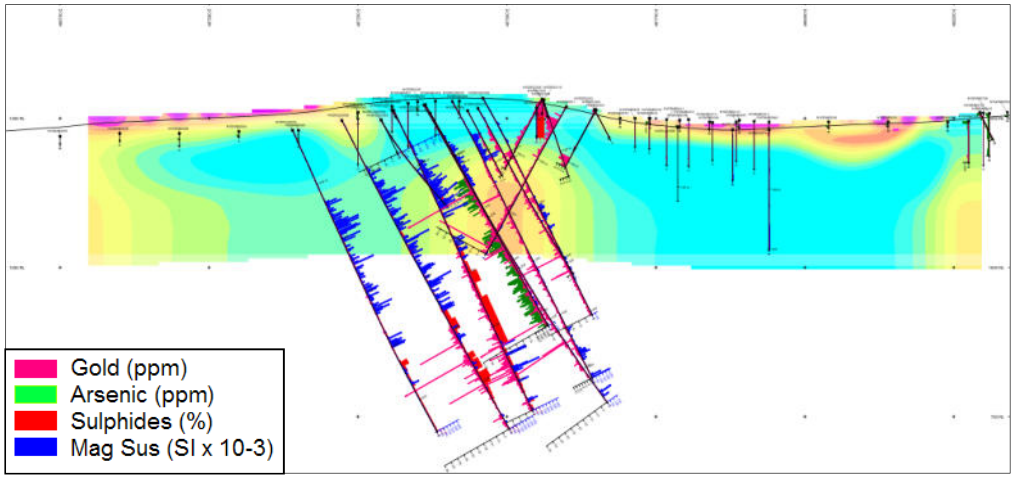
Summary

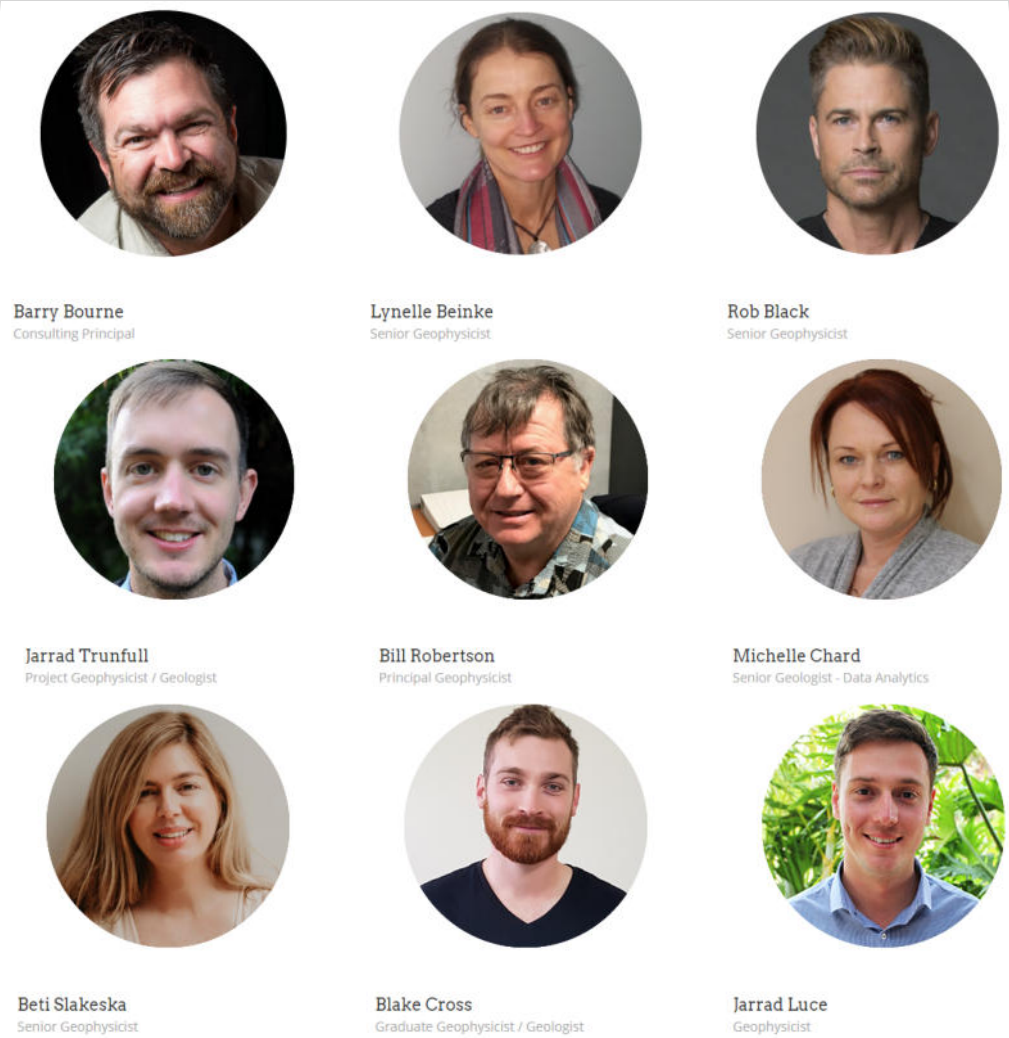
- Objectives – Be clear on results of survey, what it was trying to achieve and what your target concept should look like
- Acquisition – Extremely important to get it right but not let good interpreters get too involved with execution. Planning yes
- Workflows – Have more routine/ regular processes documented with examples. Use specialists/ consultants to make them more efficient
- Petrophysics – Fundamental to survey planning and interpretation of geology
- Geology – For better understanding and communication of target concept/interpretation deliver in a geological context/framework
- Presentation/ Delivery of Results – It can be the difference between a good and bad interpretation

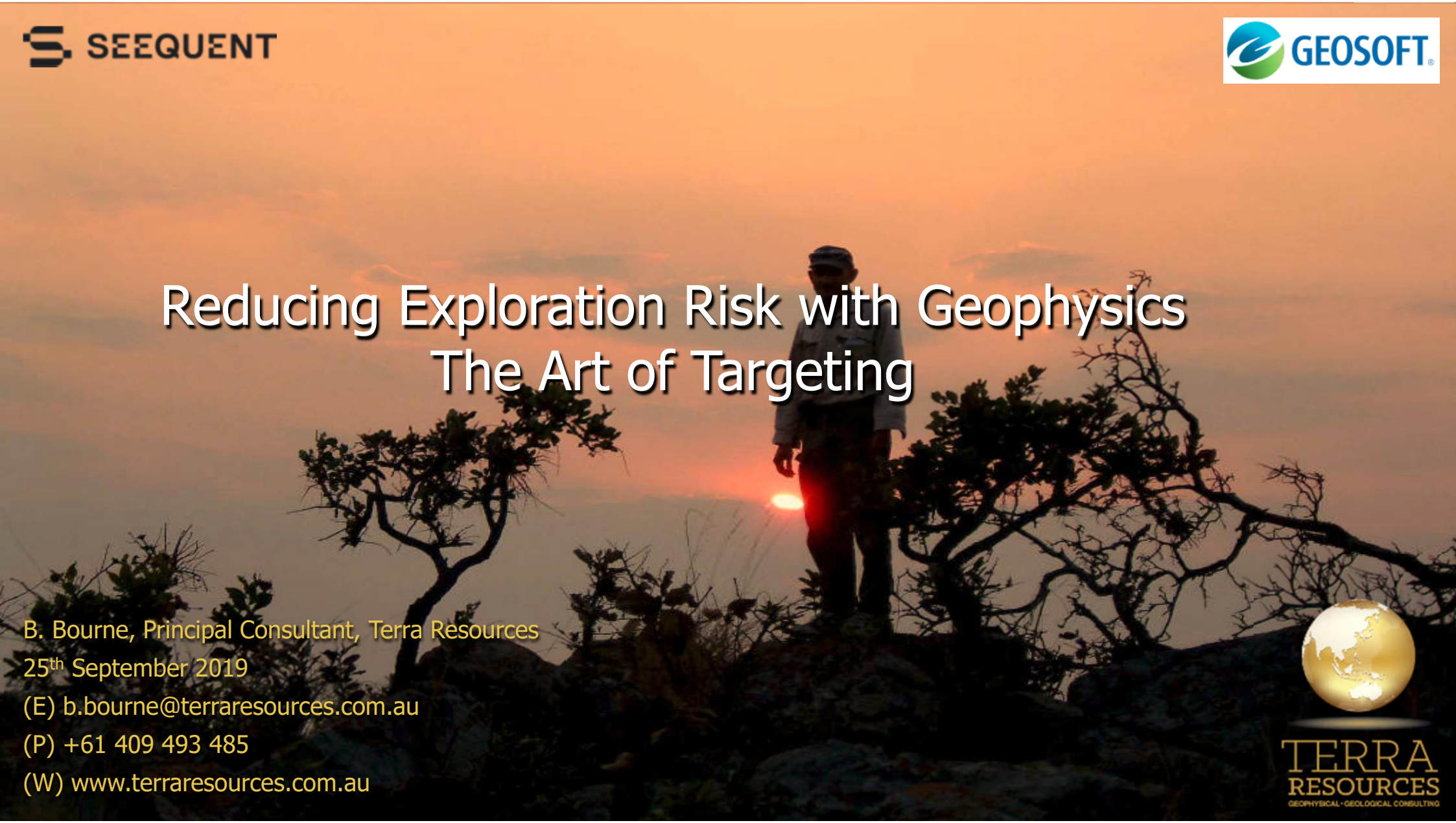
"One may know how to conquer without being able to do it. " (The Art of War)

Acknowledgements

- Terra Resources Team
- Terra Petrophysics
- Alto Metals/ Polar X
- Geosoft/ Seequent







Reducing Exploration Risk with Geophysics
The Art of Targeting

B. Bourne, Principal Consultant, Terra Resources

25th September 2019

(E) b.bourne@terraresources.com.au

(P) +61 409 493 485

(W) www.terraresources.com.au