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# Introducing AusAEM-1

and

# AEM 1.01 - *tips and tricks for understanding AEM*

Ian Roach and the AEM team

Queensland Government

APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

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# Introduction

AusAEM-1

AEM systems on the GA Deed

How does it work?

Data QA/QC (some things you'll never need to worry about)

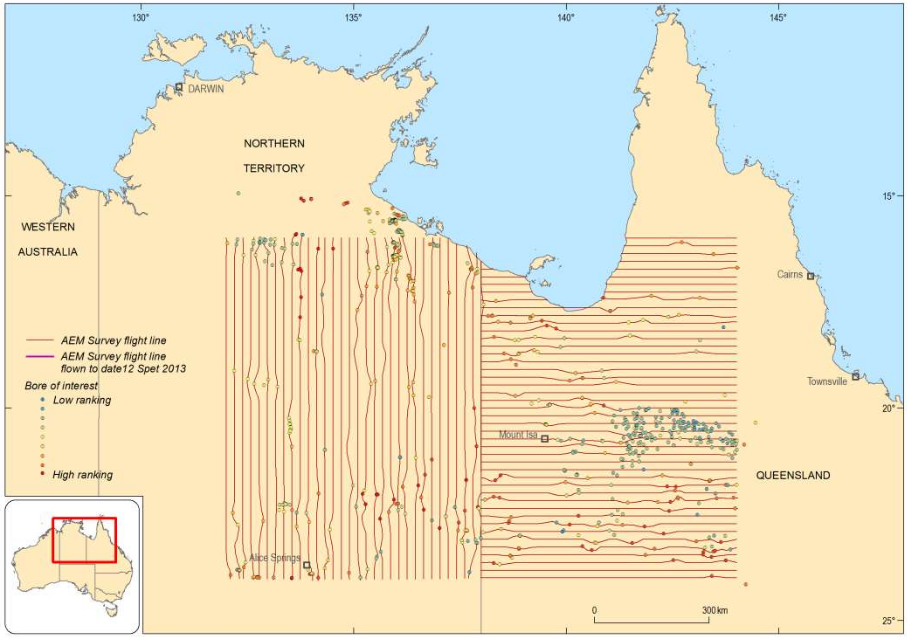
Validation (is what you see true?)

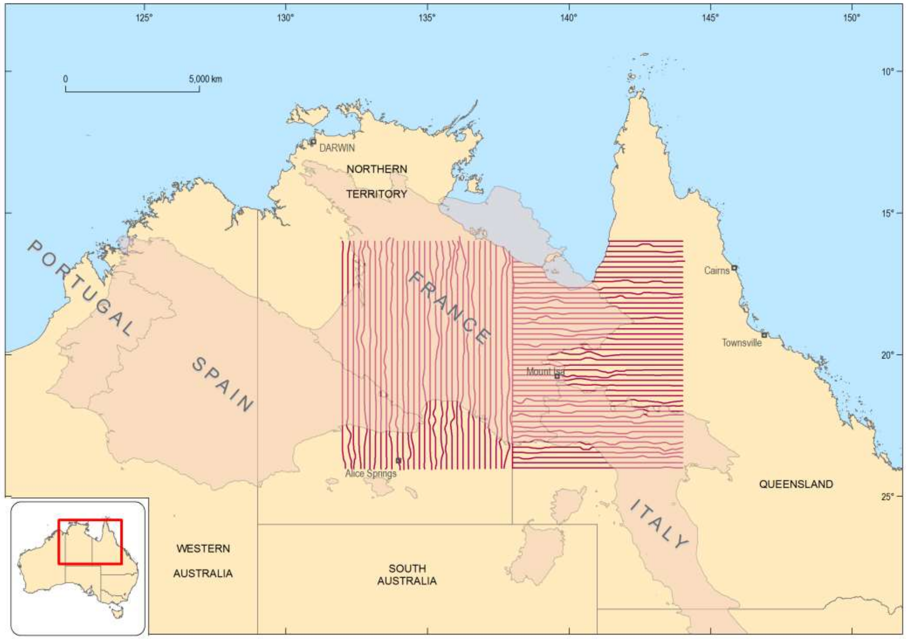
Traps

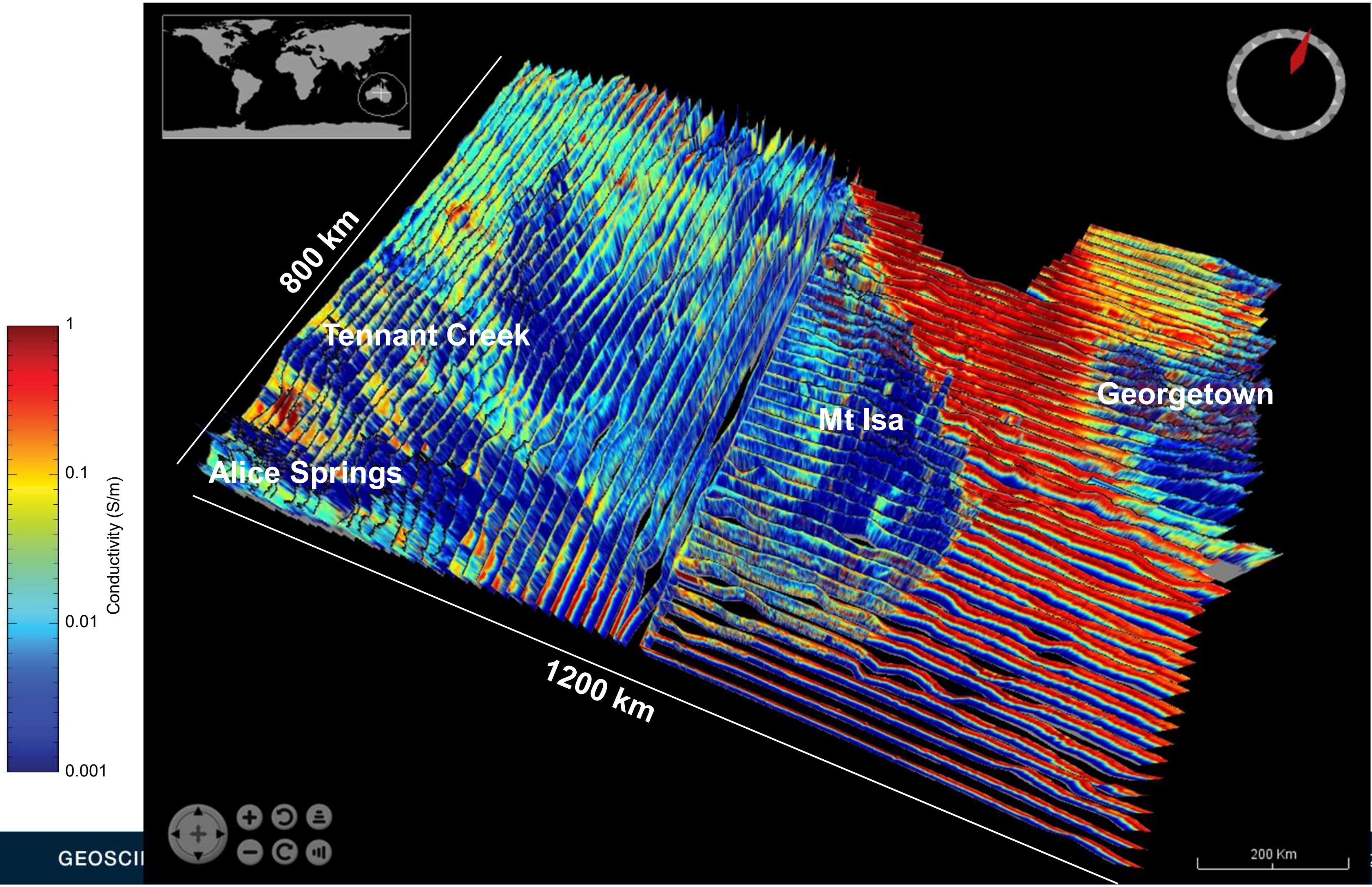
The good stuff

# AusAEM-1 survey

Largest (by area) AEM survey ever flown – 60,000 line km + 2,200 line km of company infill, ~ 1.1 million km$^2$



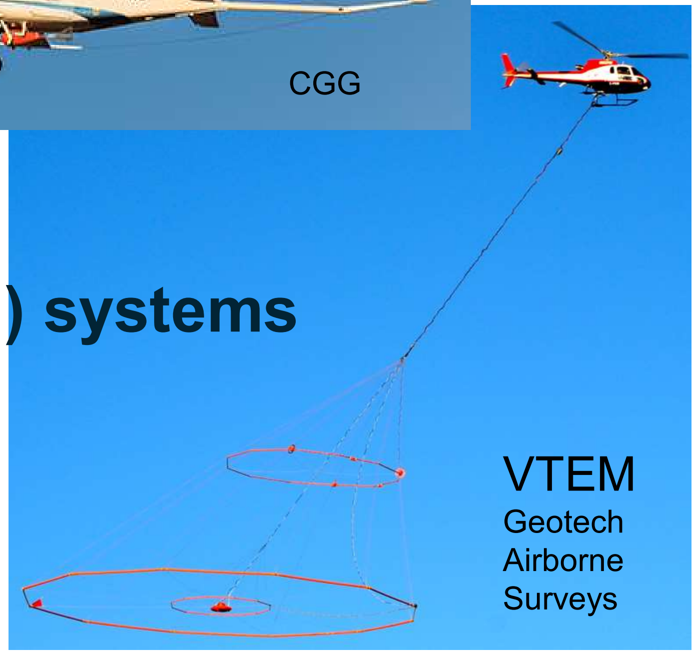





800 km
Tennant Creek
Alice Springs
Mt Isa
Georgetown
1200 km
200 Km
1
0.1
0.01
0.001
Conductivity (S/m)

# AEM systems on the Geoscience Australia Deed



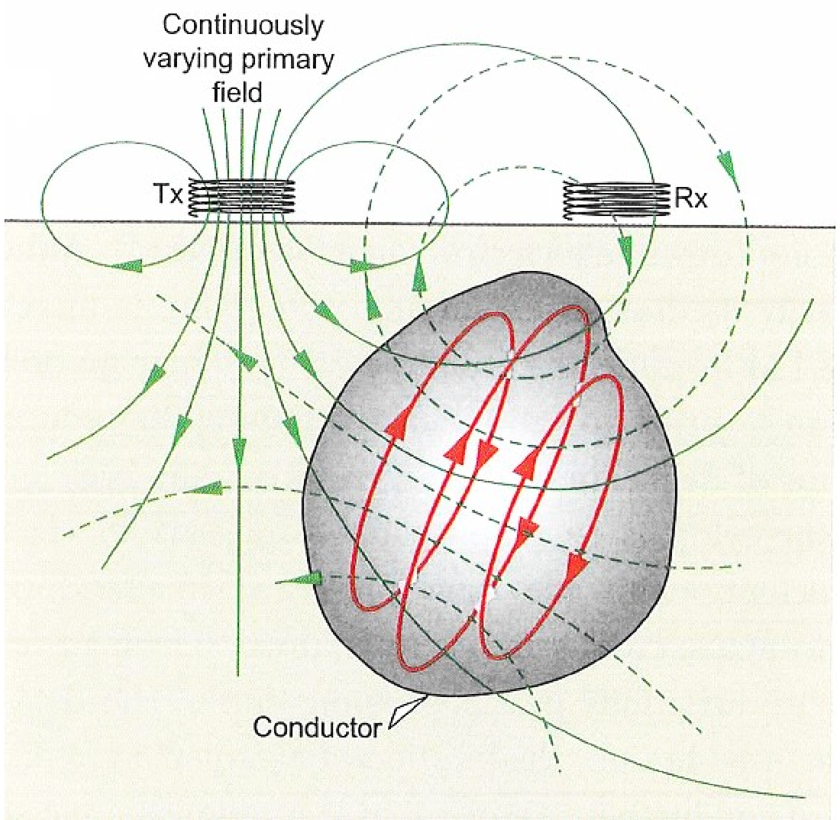

## All Time Domain EM (TDEM) systems

# AEM 1.01

How does AEM work?

By **electromagnetic induction**:

- A transmitted *varying* **primary** EM field will induce a *varying* **secondary** EM field in a conductor by **electromagnetic induction**
- The strength of the secondary EM field is dependent on a number of **rock properties** that **affect the bulk electrical conductivity of the Earth**




Dentith & Mudge (2014) after Grant and West (1965)

# AEM 1.01

# Factors controlling the AEM response

External information required for interpretation

**AEM response**

**Conductivity**

**Pore fluid conductivity ($\sigma_w$)**
**Pore fluid saturation (s)**
**Porosity (ø)**
**Conductivity of solid matter ($\sigma_s$)**
**Pore size and arrangement (a)**

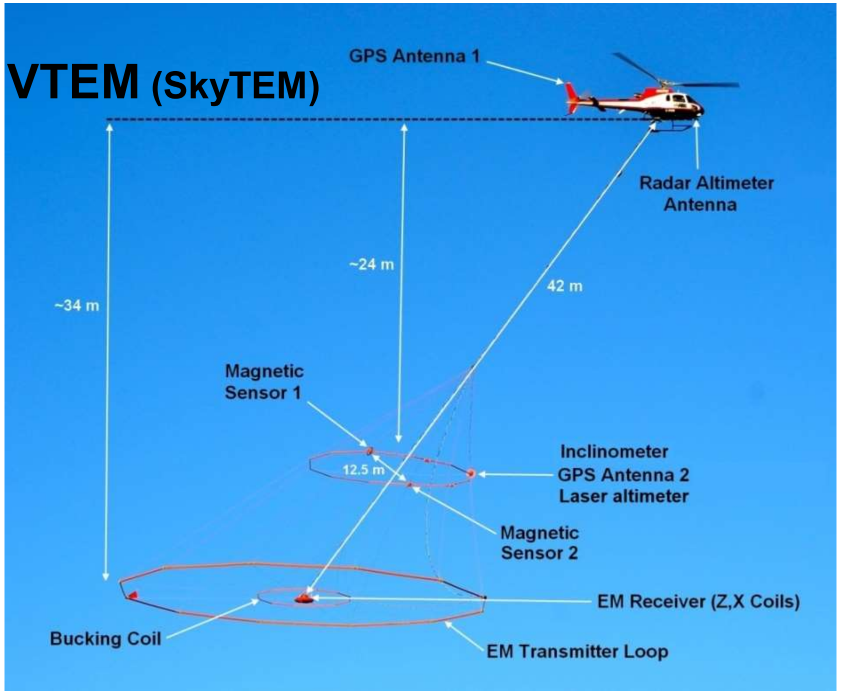
**Lithology**
**Structure**
**Alteration**
**Groundwater**

Richard Lane

# System geometry

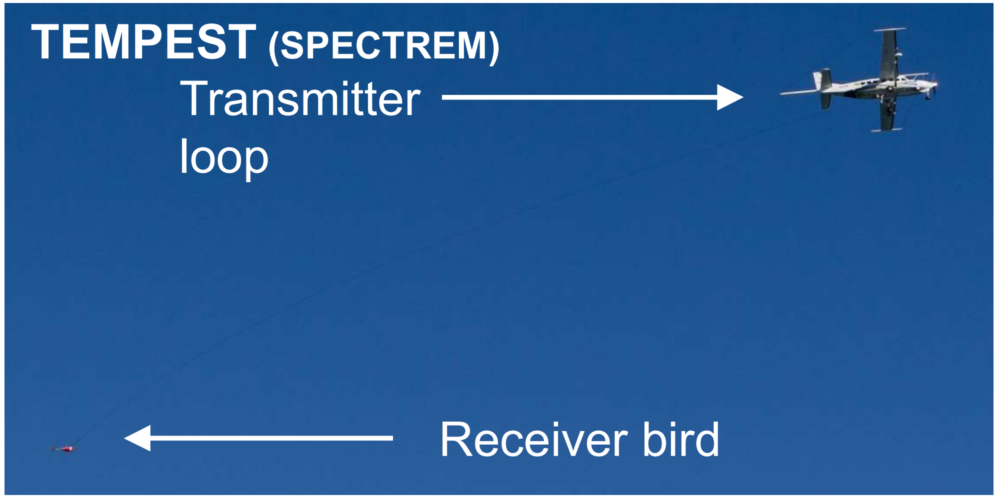
## Symmetrical system

### (Receiver Rx inside the transmitter Tx)




## Asymmetrical system

### (Receiver Rx outside the transmitter Tx)



# System geometry

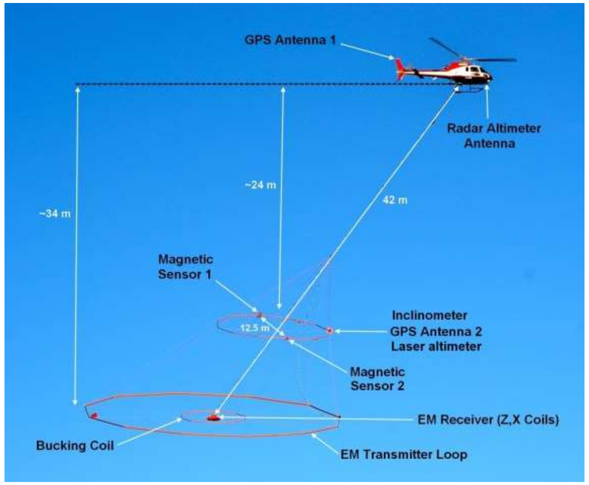
System geometry can affect the received signal.

**Symmetrical system**:

- Pitch-yaw-roll of Tx-Rx (system not ‘looking’ straight down)
- **Relatively simple errors to solve mathematically**

**Asymmetrical system**:

- Pitch-yaw-roll of Tx and Rx acting independently
- Rx not following straight behind, or above/below correct towing height behind Tx (system geometry)
- **Highly complex errors to solve mathematically**

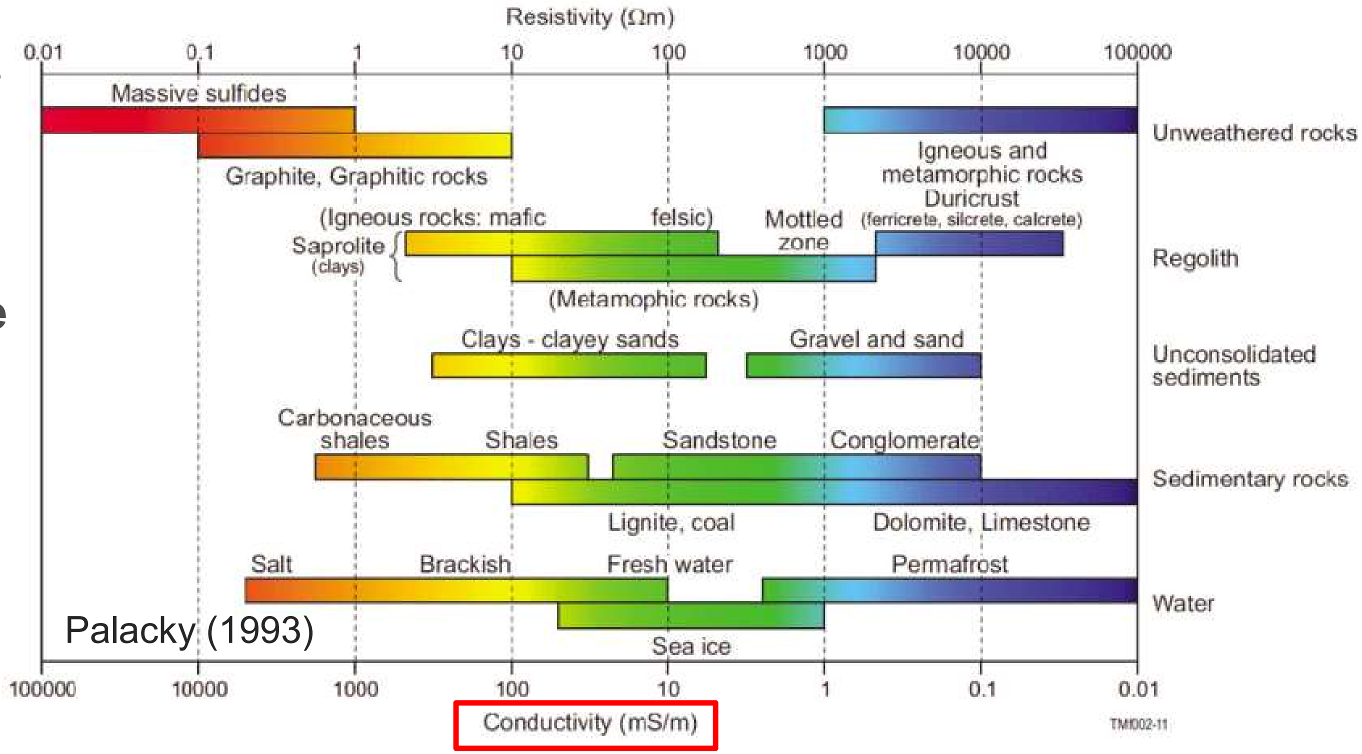



# Electrical conductivities of rocks, minerals and water

Typical ranges of electrical conductivities for common earth materials

**We tend to want to look for conductive objects**

Conductivity contrasts can help us map under-cover geology




**Where there is no contrast? We see nothing**

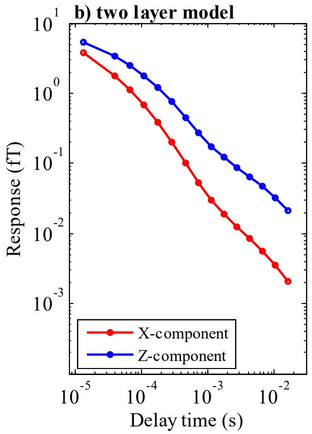
# Validation of AEM data

*“How do I know that what I’m looking at is real?”*

There is a long, complex, QA-QC process involved, that ultimately leads to..

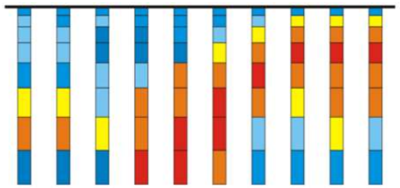
## INVERSION

Data for one AEM sample

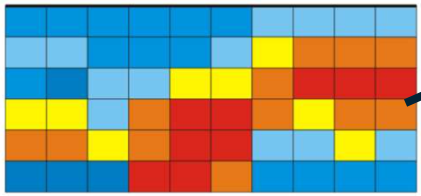



Brodie and Fisher (2008).

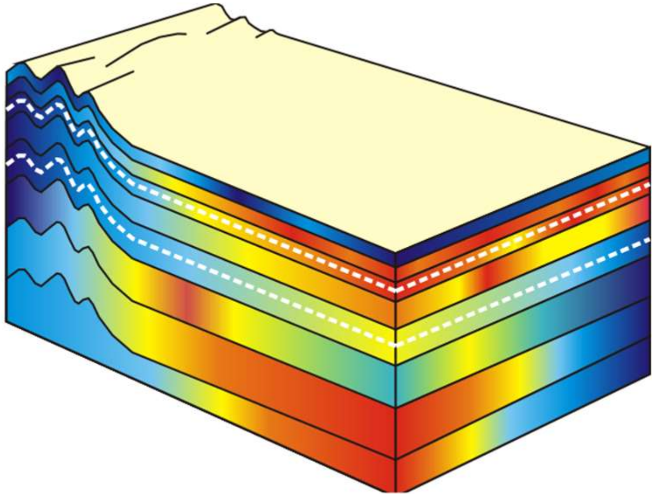
1D inversion model for each sample



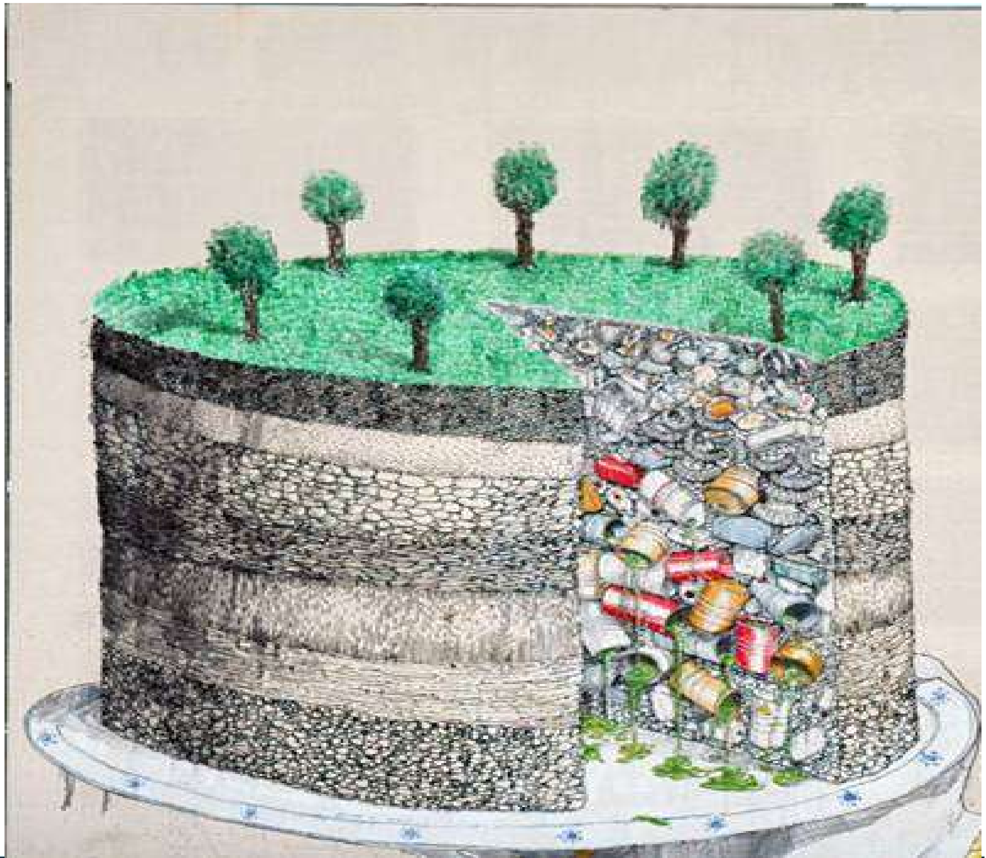
Stitch into a conductivity section for each flight line



Stitch all 1D models by gridding each layer conductivity



# The ideal EM modelling world is



A horizontally isotropic layered earth

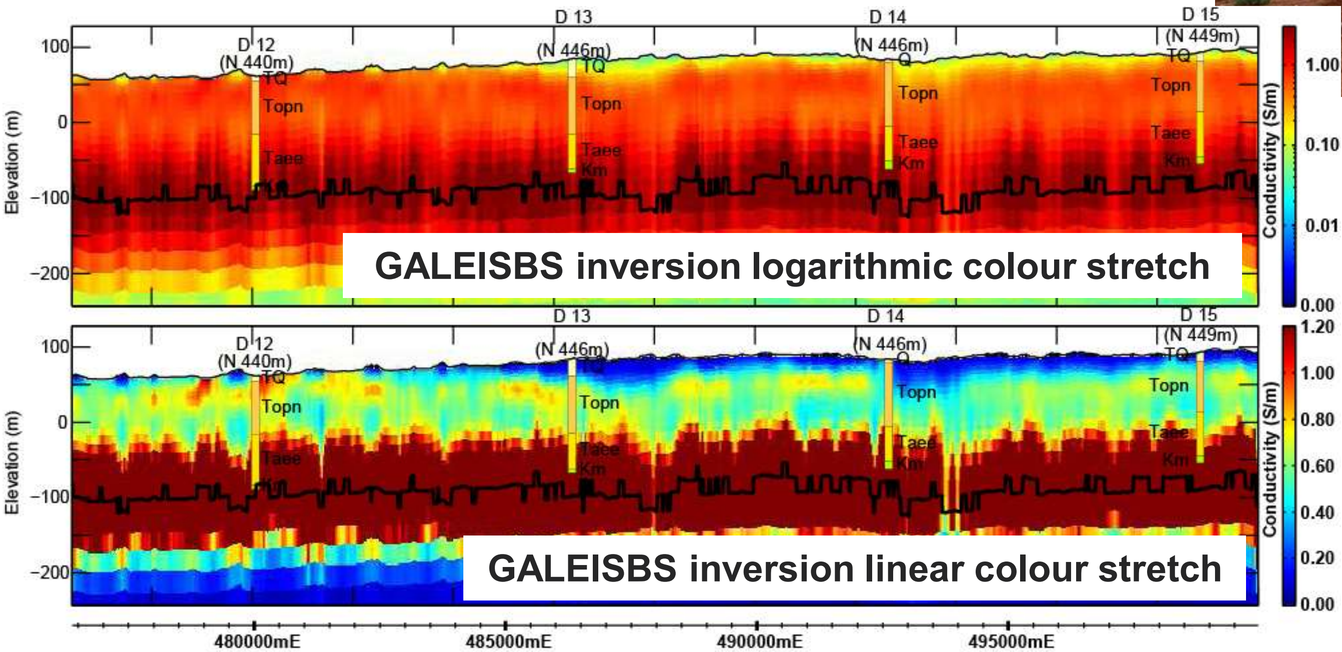
**There are risks when assuming layer-cake 1D geology, but we are often dealing with an anisotropic 2D/3D subsurface**

Unfortunately the real world is not a homogeneous flat plate

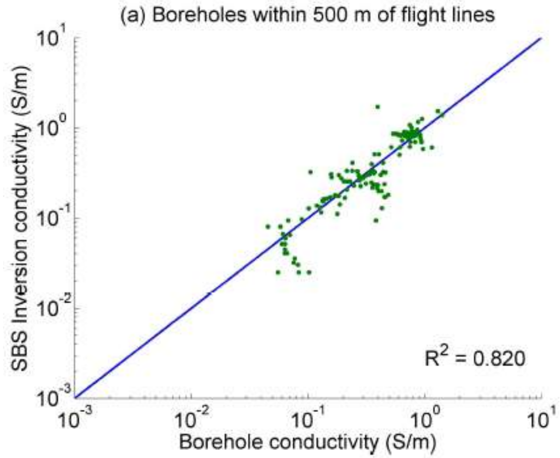
# Validation of AEM data

Inversion data should be consistent with

- Induction conductivity logging results
- Drill hole stratigraphy/lithology



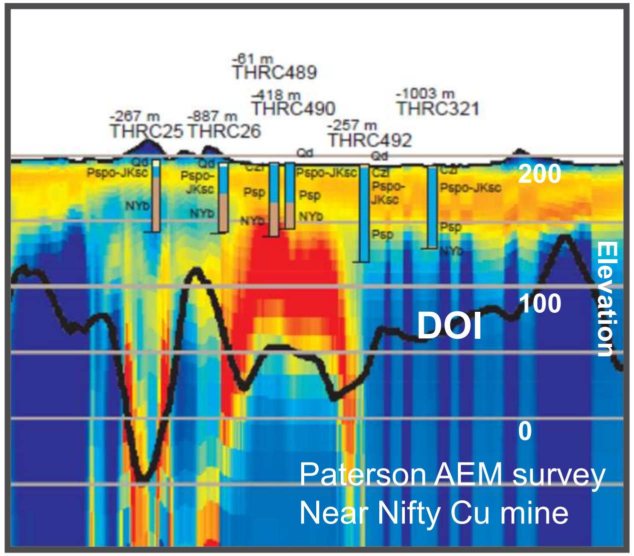

## Frome AEM Survey

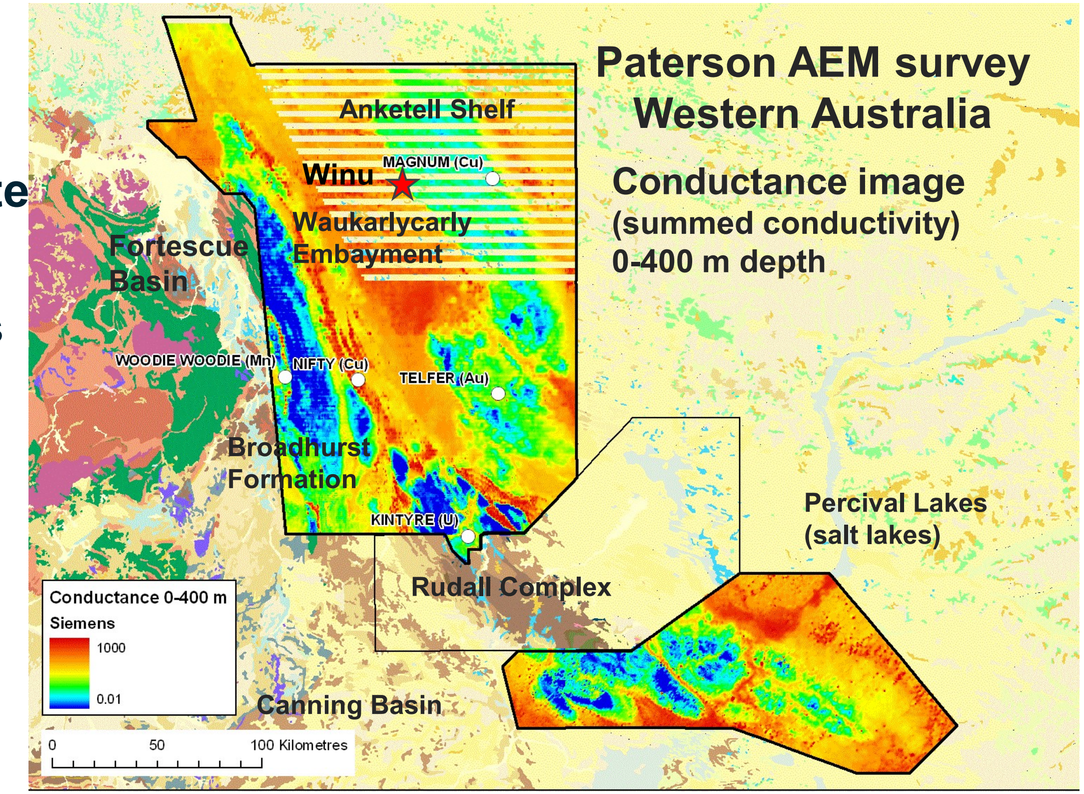


# Validation of AEM data

## Drill hole lithology is the ultimate arbiter of truth!

Often it is very difficult to get drill holes that lie exactly on flight lines




**Look for lateral continuity of conductivity patterns with mapped surface geology**

# Depth Of Investigation

## *“How deep are we seeing?”*

The answer entirely depends on bulk conductivity conditions

**Anywhere between 50 m and ~2000 m**

David Hutchinson

APRIL 2010 PREVIEW

David K. Hutchinson[1,2], Ian C. Roach[1] and Marina T. Costelloe[1]

Depth of investigation grid for regional AEM surveys

Feature Paper

Depth of investigation grid for regional airborne electromagnetic surveys

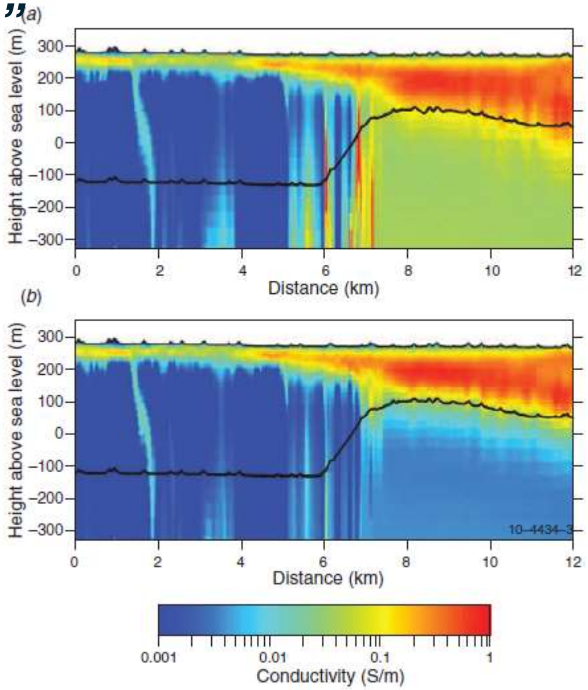



*Fig. 1. A sample conductivity depth section, comparing the results of inversions using reference models of (a) 0.04 S/m and (b) 0.004 S/m. The black line marks the depth of investigation (DOI) in each case. Above the DOI, the results are similar for both inversions, whereas below the DOI, the conductivity differs according to the reference model value.*

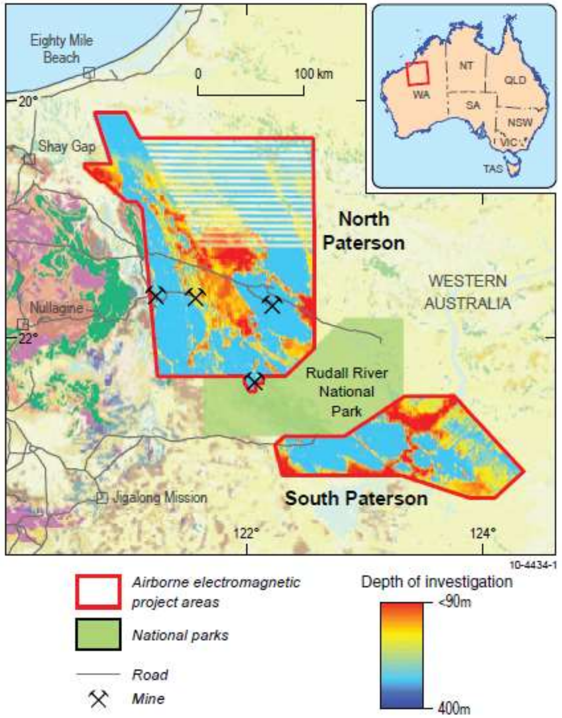



*Fig. 2. Depth of investigation (DOI) grid across the Paterson Survey. We have chosen not to interpolate between the lines of 6 km spacing in the north-west of the survey, since this may create misleading results.*

# Data QA/QC traps for new interpreters

- Poor system geometry/terrain clearance
- Anthropogenic effects:
  - Power lines
  - grounded metal objects (rail lines, gas/oil pipes)
  - pulsed cultural interferences (electric fences)
- Sferics (lightning)
- Inversion misfit due to excessive ground bulk conductivity
- Inversion artefacts due to sudden changes in geoelectrical stratigraphy
- Inversion artefacts due to 3D geology (folding and faulting)
- IP/SPM effects
- Direct detections (‘drill-heres’)

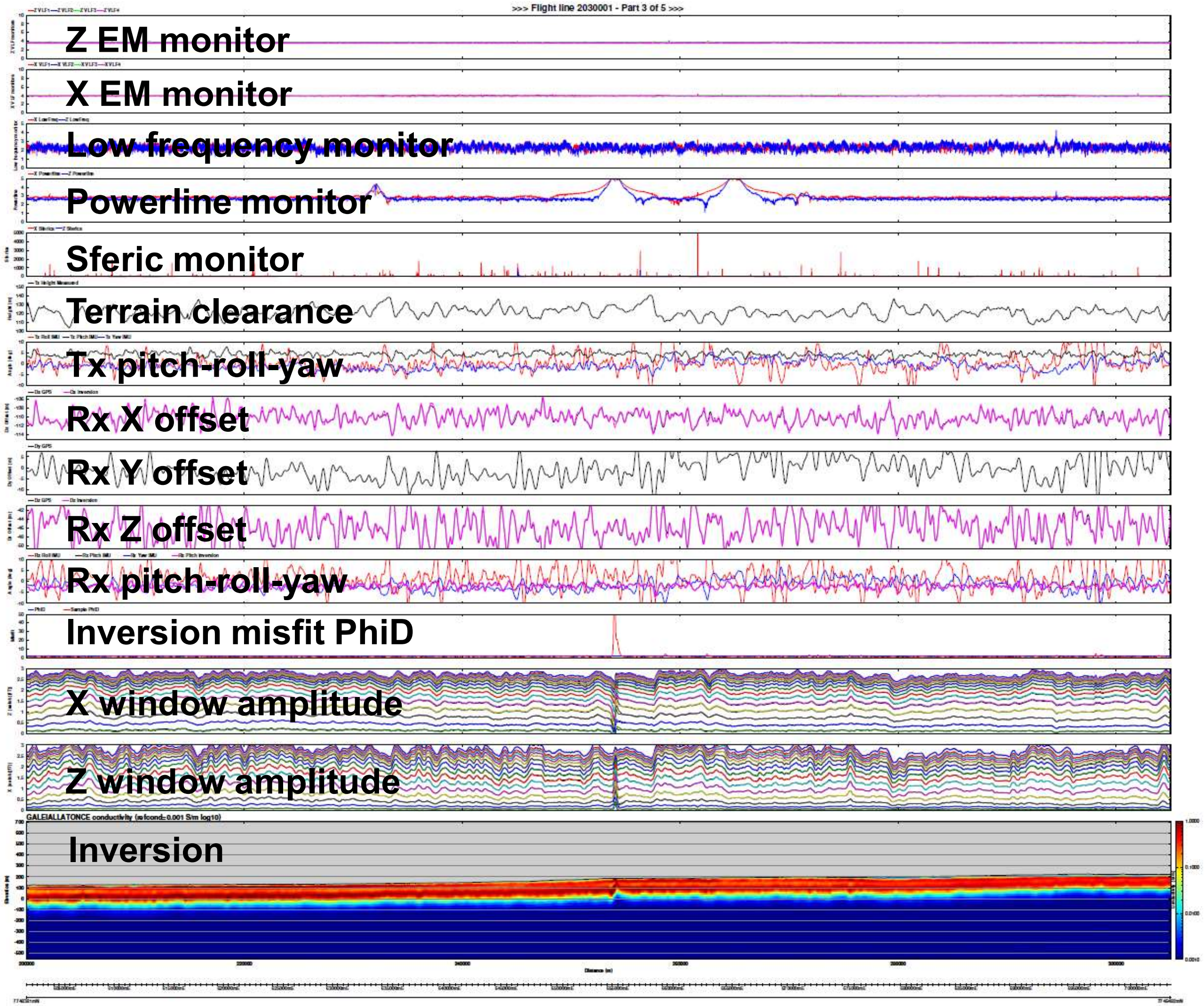
# Introducing the multiplot

Plot of multiple system parameters.

## Helps assess:

- **System geometry**
- **Noise sources**
- **Inversion misfit**
- **X and Z window channels**

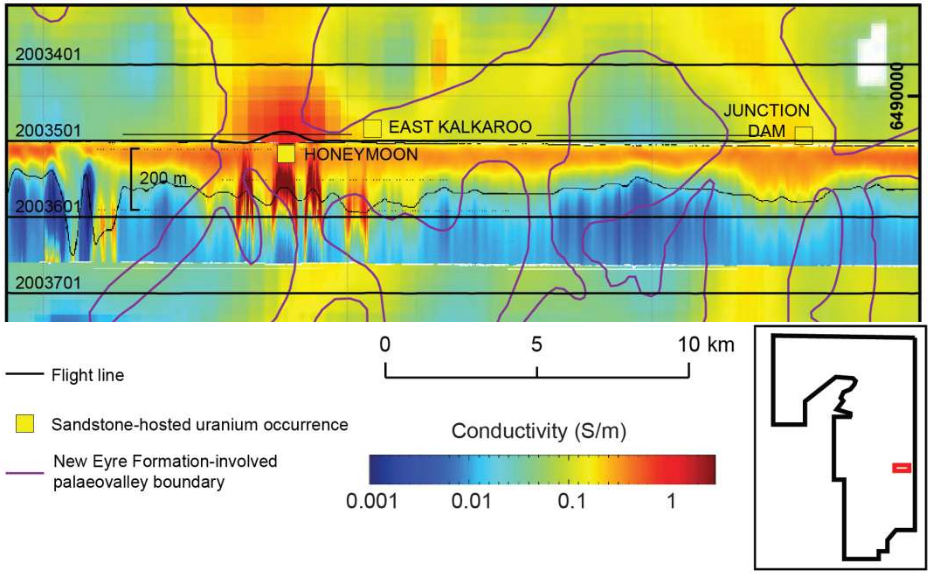
Contractor and GA multiplots will differ only slightly

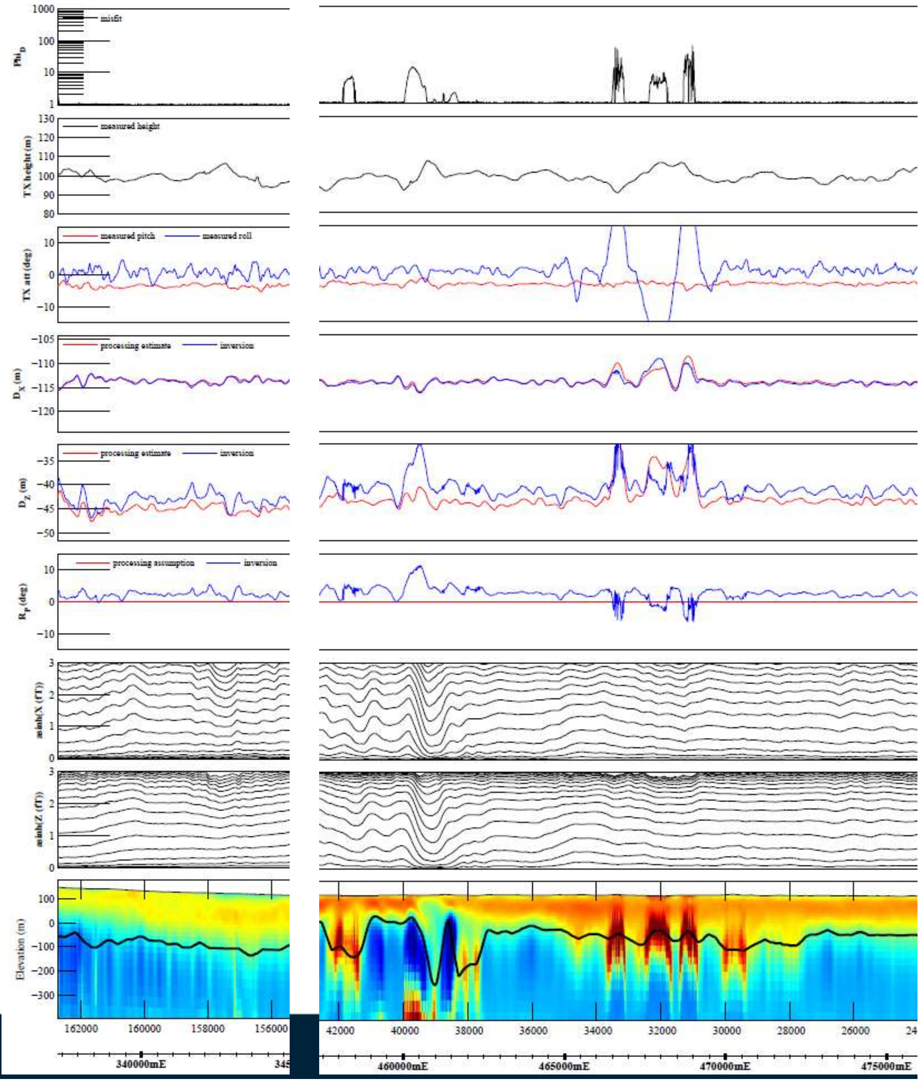


# Poor system geometry

**Aircraft turns lead to poor inversion fit and false anomalies** (TEMPEST)

Example from Frome AEM survey over the Honeymoon uranium mine



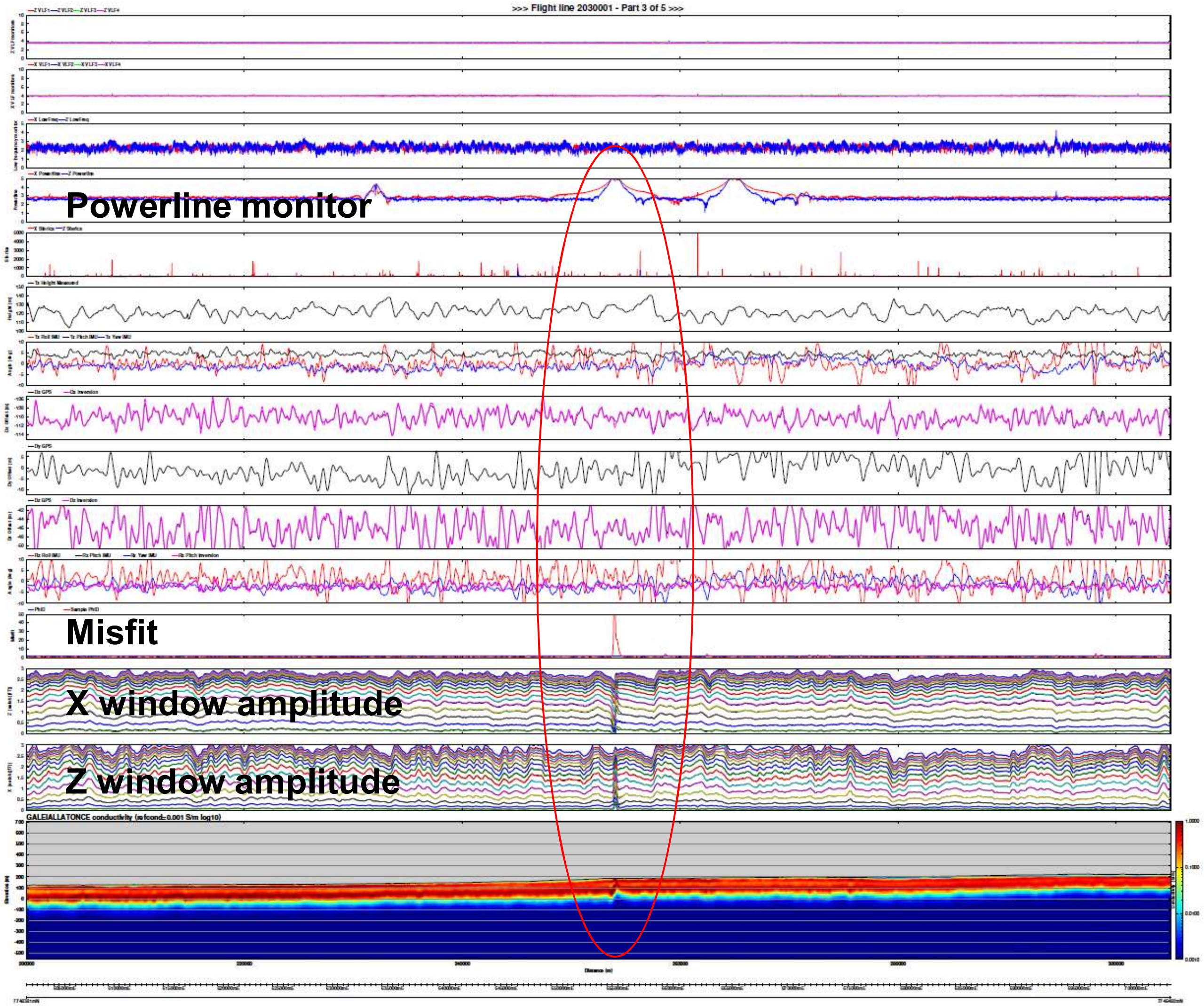
# Powerlines

AusAEM-1

Line 203001 shows spikes in X and Z component powerline monitors

## Affects:

- **X and Z window data**
- **Inversion misfit**
- **Inversion**



# Gas pipelines

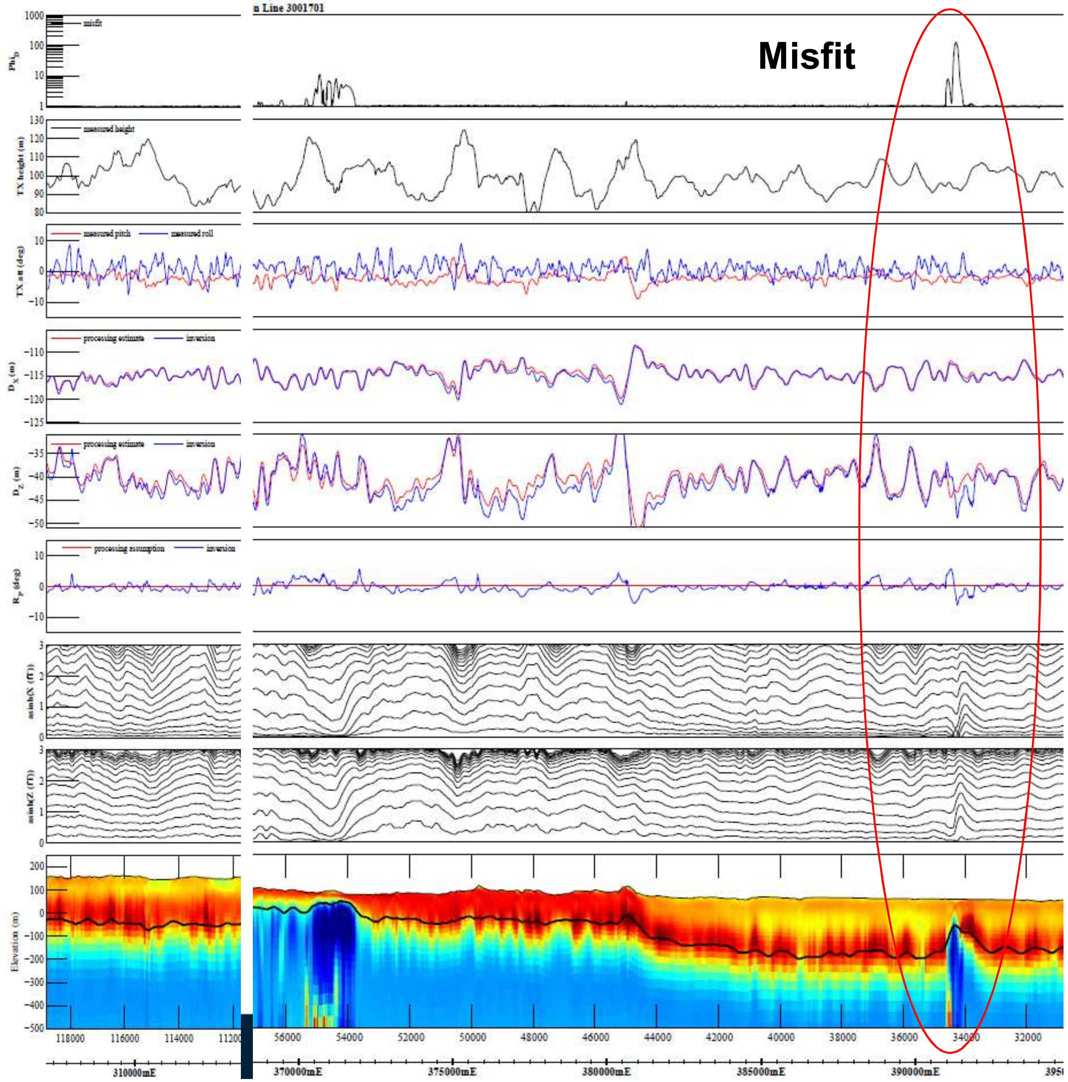
Buried gas infrastructure

Frome L3001701

**Moomba-to-Adelaide gas pipe line appears as:**

- **an inversion misfit**
- **a perturbation in X and Z windowed amplitude data**
- **resistive basement in the inversion**
- **TMI-1VD blip**
- **Powerline anomaly**

Cause: earthed metal object, 50 Hz power and sacrificial anodes on pipe

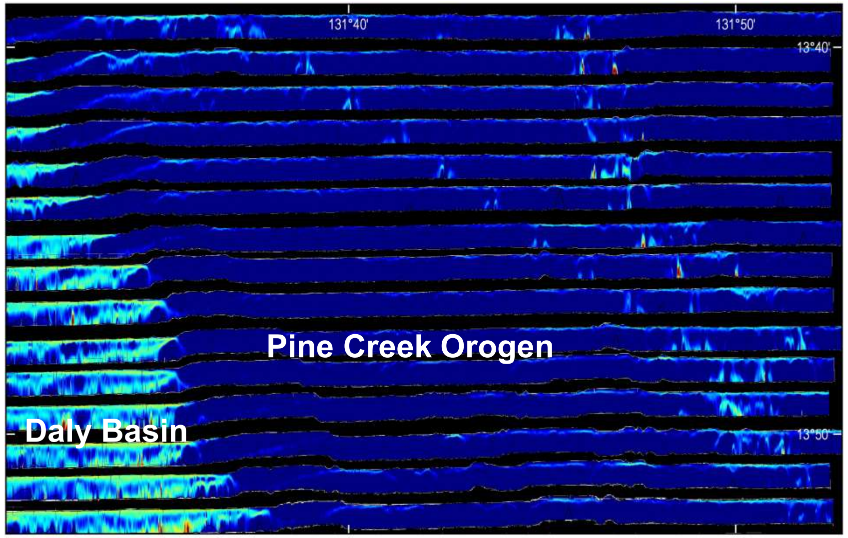


# The double-whammy

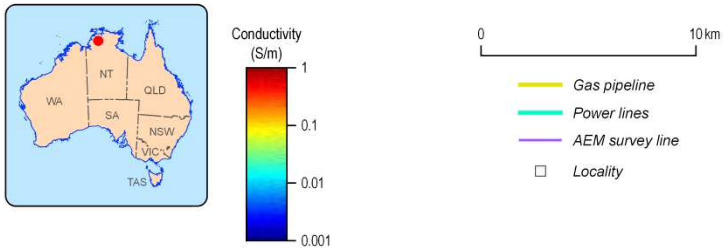
Pine Creek Shear Zone:

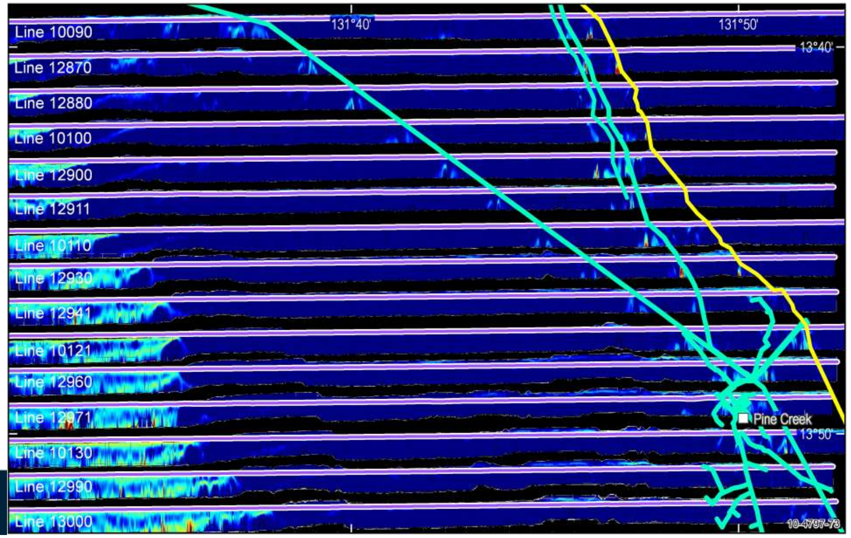
**Almost all of the ‘geological’ information in the AEM data from the PCO are actually related to pipe lines and power lines.**

The Pine Creek Orogen is very resistive!




## Pine Creek AEM survey

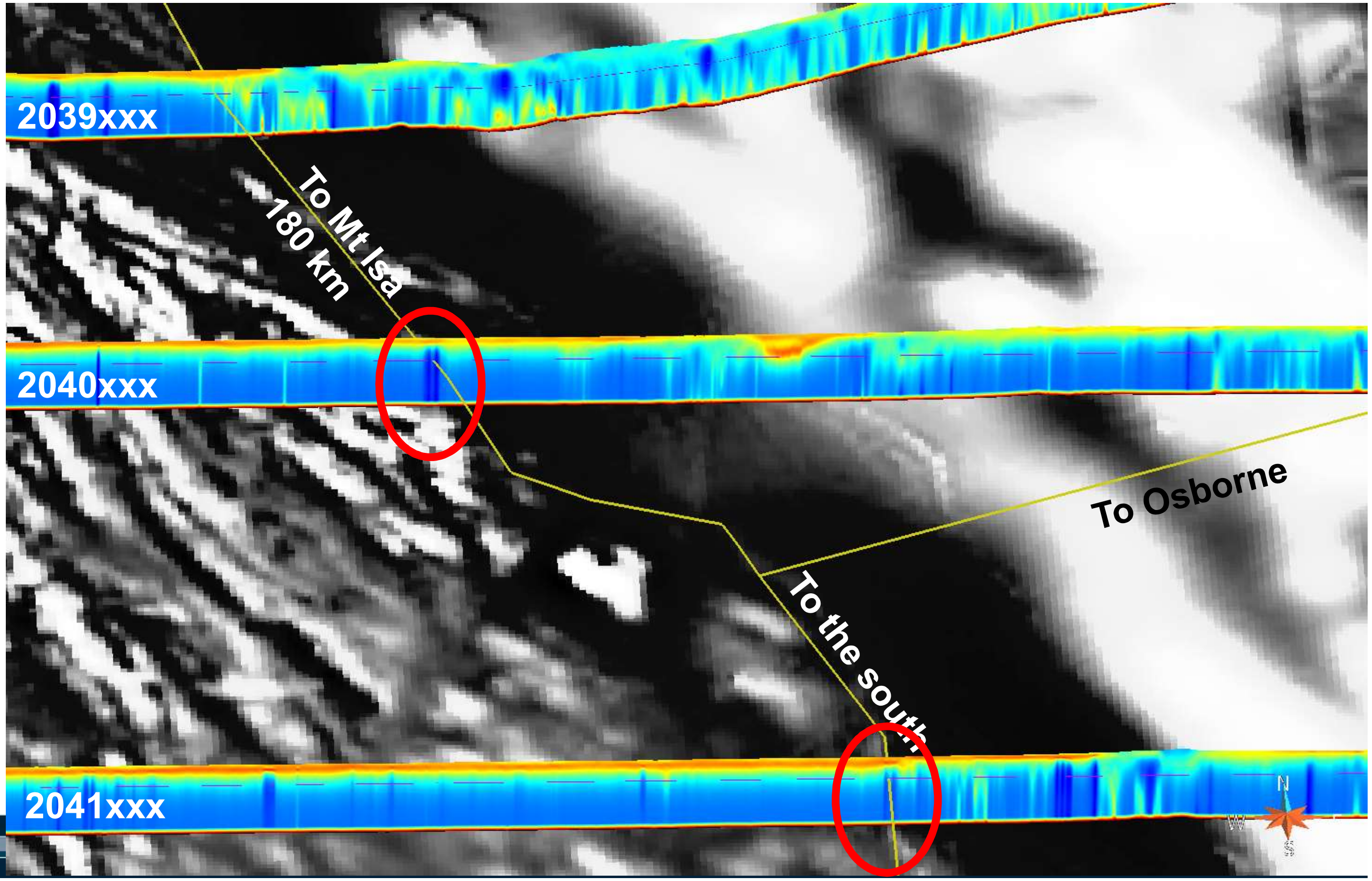


# AusAEM-1 gas pipe lines

AusAEM-1 SBS
totalxy inversion:

**Conductivity anomalies associated with buried gas infrastructure**



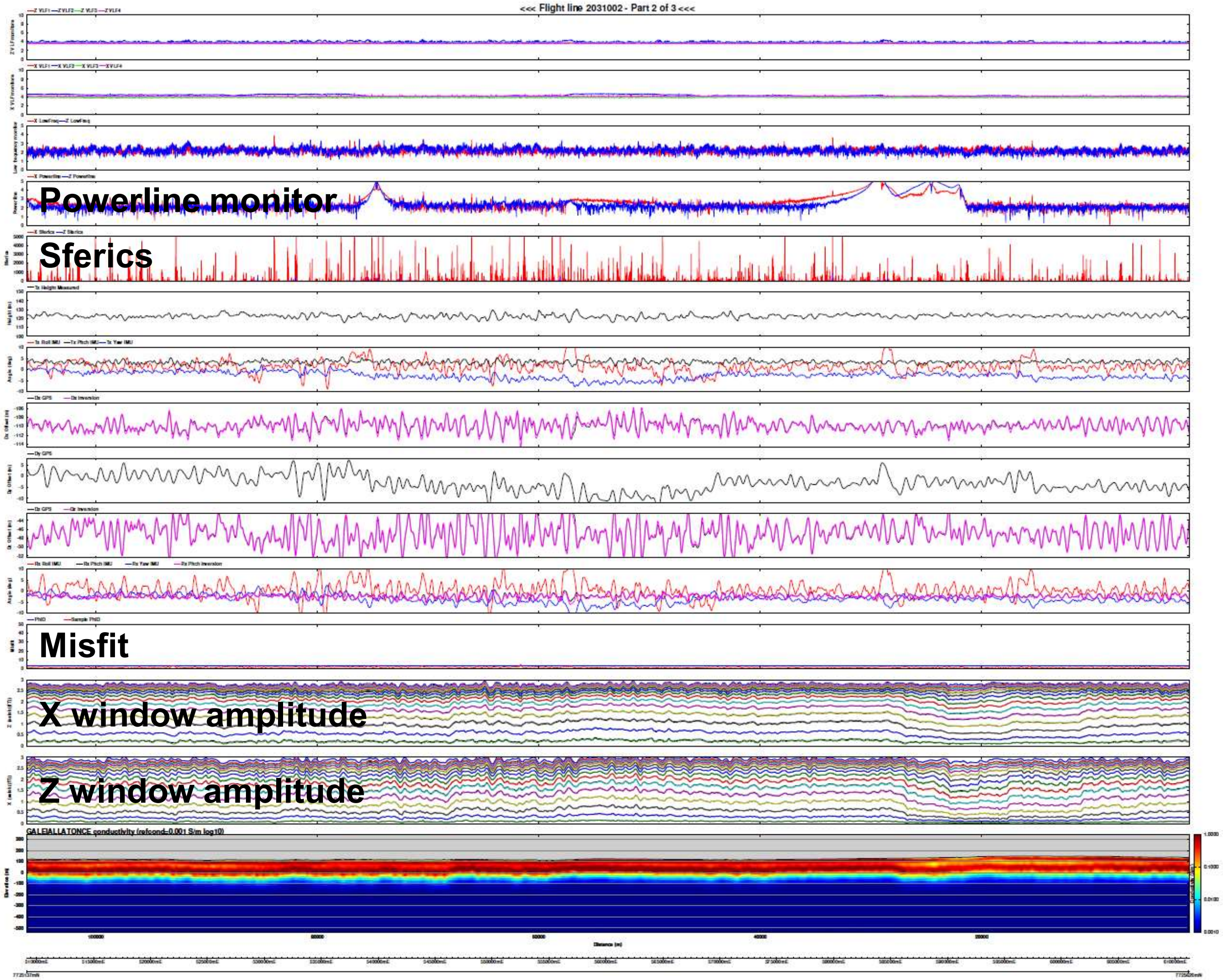

GOCAD oblique image of AusAEM-1 conductivity sections over TMI 1VD
And national pipe line data

# Sferics

Sferics (atmospheric noise) are related to world-wide lightning activity.

**Sferics contribute to overall system noise and degraded data quality**

AusAEM-1 line 2031002; a bad day for sferics



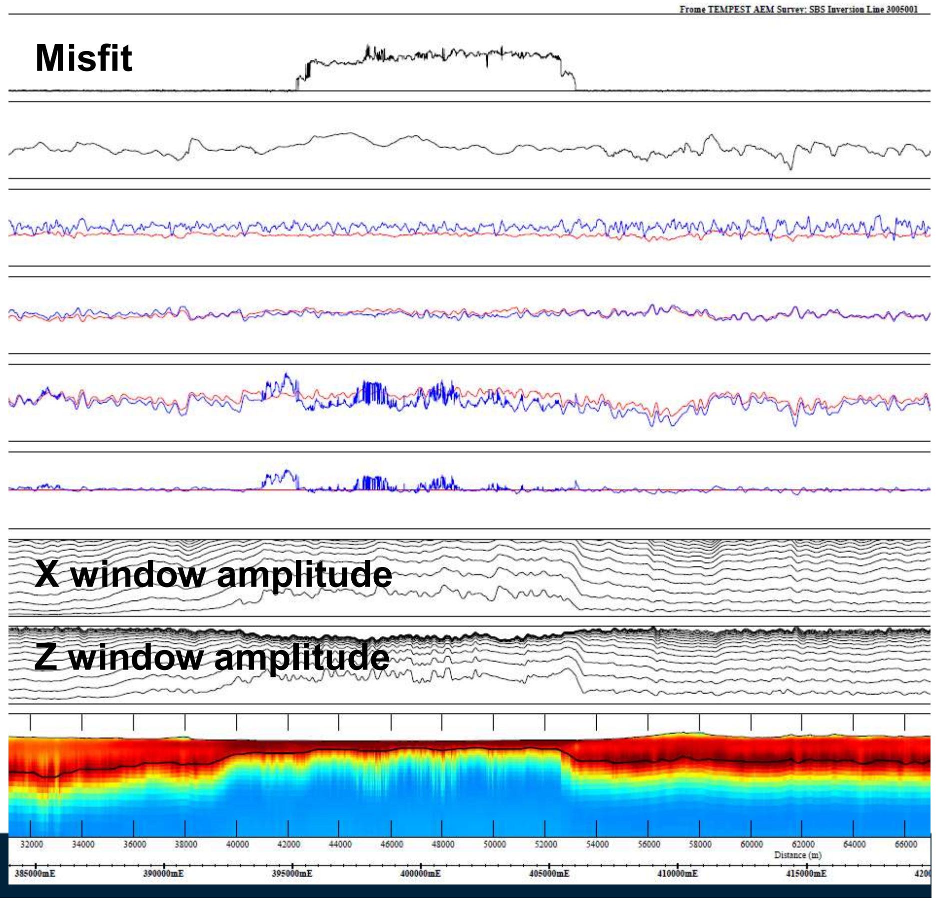
# Excessive ground conductivity

Excessive ground conductivity will cause inversion misfit

AEM signal is trapped in upper portion of the Earth and will not penetrate

Normally associated with salt lakes/playas and carbonaceous shales (e.g. Eromanga Basin Wallumbilla Fm/Bulldog Shale), also airborne IP - AIP (see later)

Plenty of this in AusAEM-1 over the Eromanga Basin



# Excessive ground conductivity

Excessive ground conductivity may cause inversion misfit

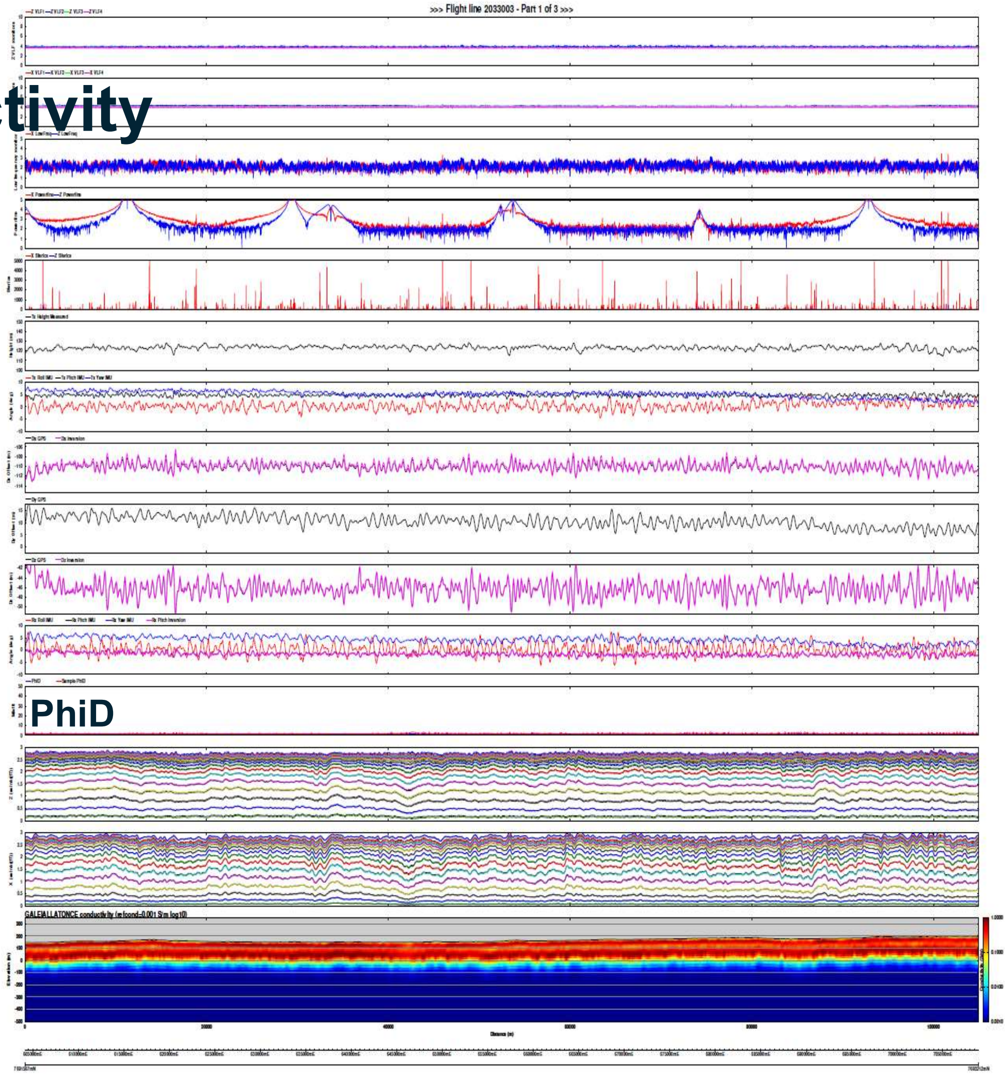
AEM signal is trapped in upper portion of the Earth and will not penetrate

**Normally associated with salt lakes/playas and carbonaceous shales (e.g. Eromanga Basin Wallumbilla Formation/Bulldog Shale)**, also airborne IP - AIP (see later)

Plenty of this in AusAEM over the Eromanga Basin

AusAEM-1 line 2033003

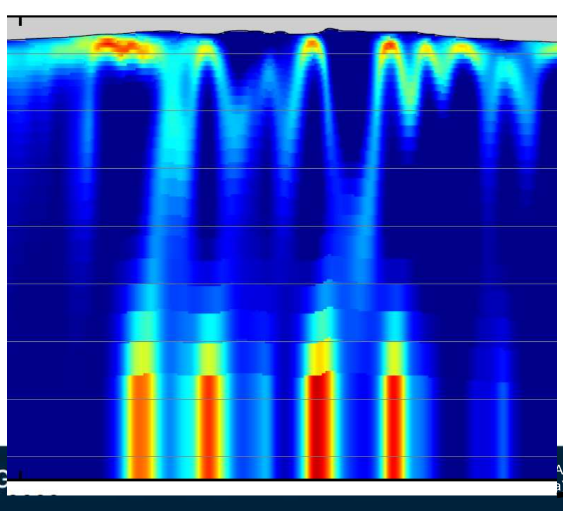
**DOI lucky to be > 100 m**

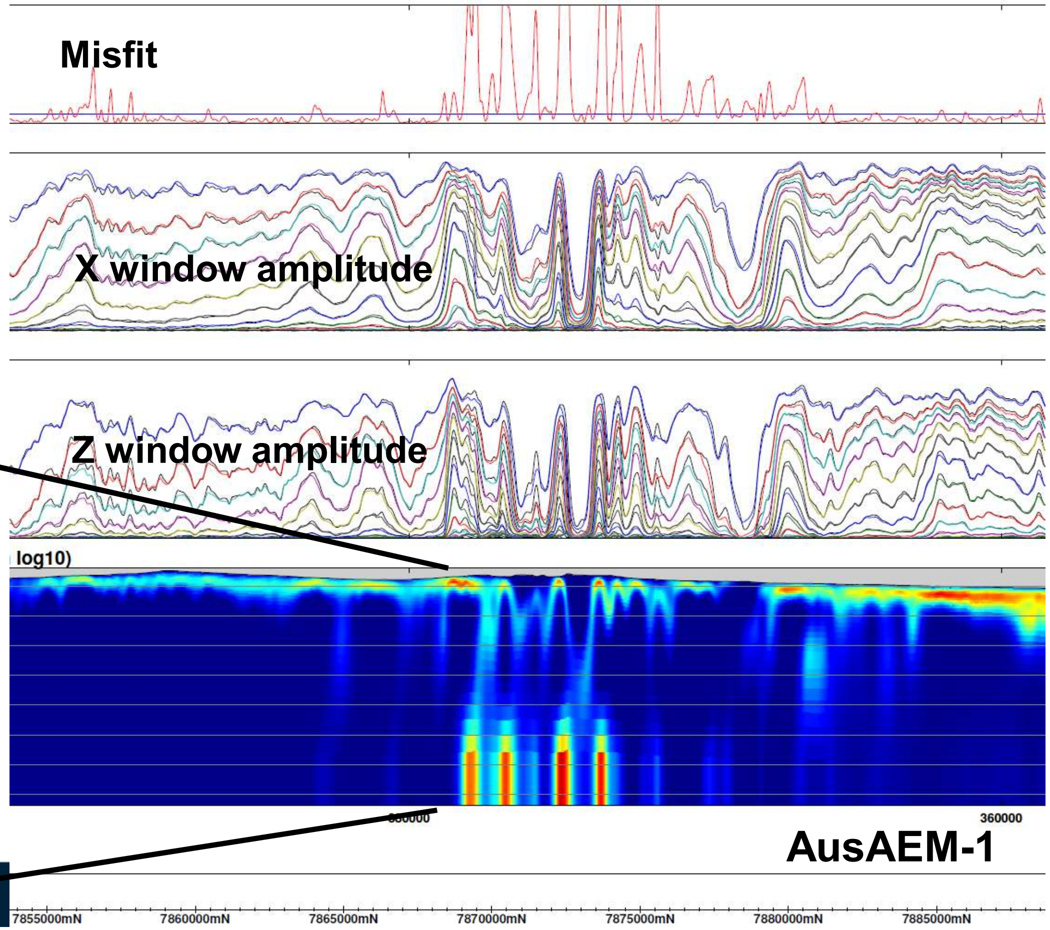


# Inversion artefacts due to sudden changes in geology

Inversion artefacts may be caused by sudden changes in geology; **‘disrupted layer lithology’**

Also known as ‘pantlegs’

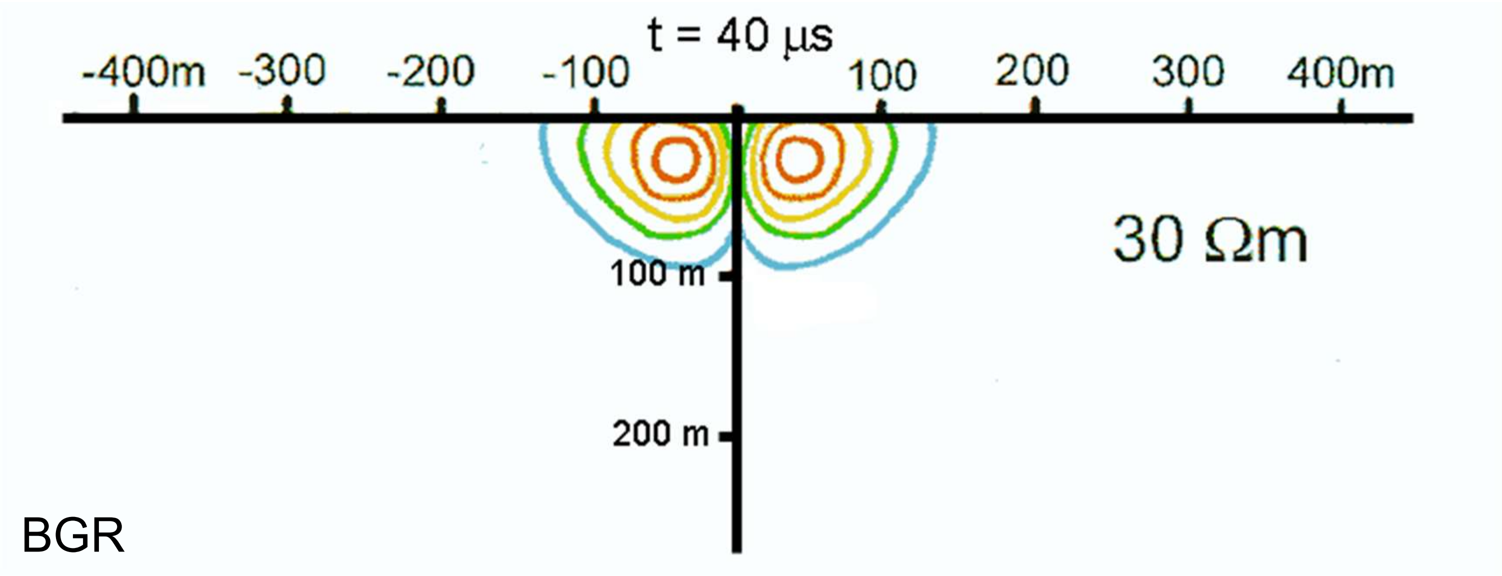




# EM signal diffusion

The EM signal diffuses as a **'smoke ring'**

Wave-front becomes wider, deeper and more attenuated with time

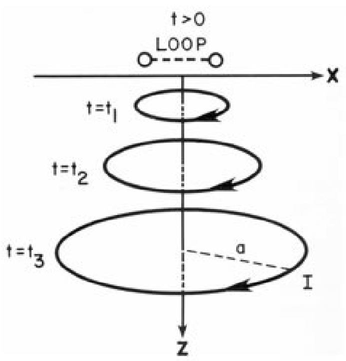


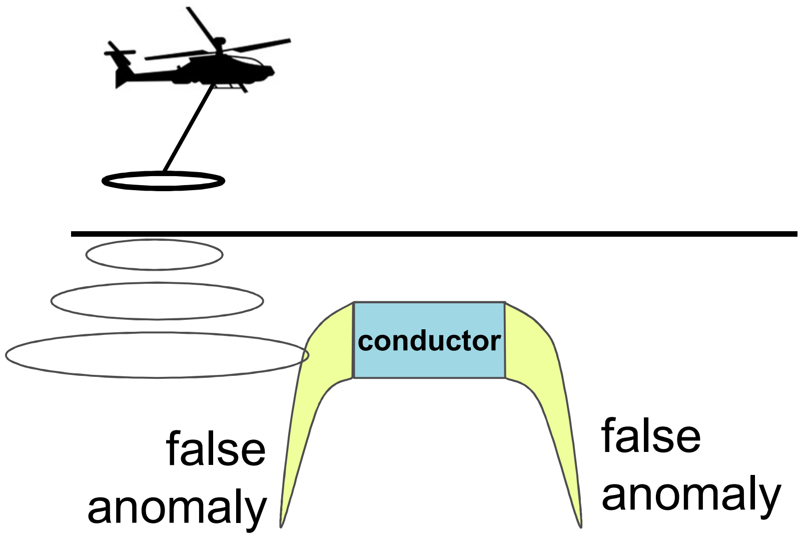
# EM signal diffusion artifacts

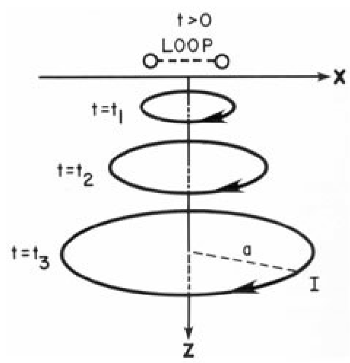
A conductive body will be sensed first in late-time windows by the expanded **‘smoke ring’** and appear ‘deeper’, creating to a leading-edge false anomaly

The body will be seen in earlier time windows as the aircraft flies overhead

Same but in reverse as the aircraft flies away, leading to a trailing-edge false anomaly



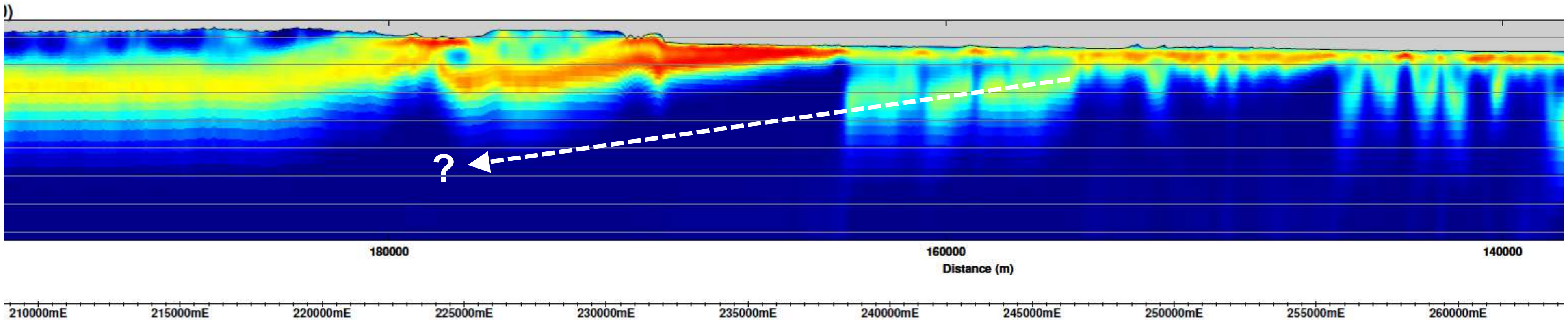



# Signal ‘theft’

Over-riding highly conductive unit ‘steals’ signal from a more weakly conductive underlying unit

**The loss of signal does not necessarily mean that the more weakly conductive unit is not there; just loss of signal at depth**

AusAEM-1 line 2045002



# Terrain clearance

Fixed wing aircraft are not as responsive as helicopters; cannot change altitude as quickly

**Terrain clearance effects** become noticeable where **sudden elevation changes occur**

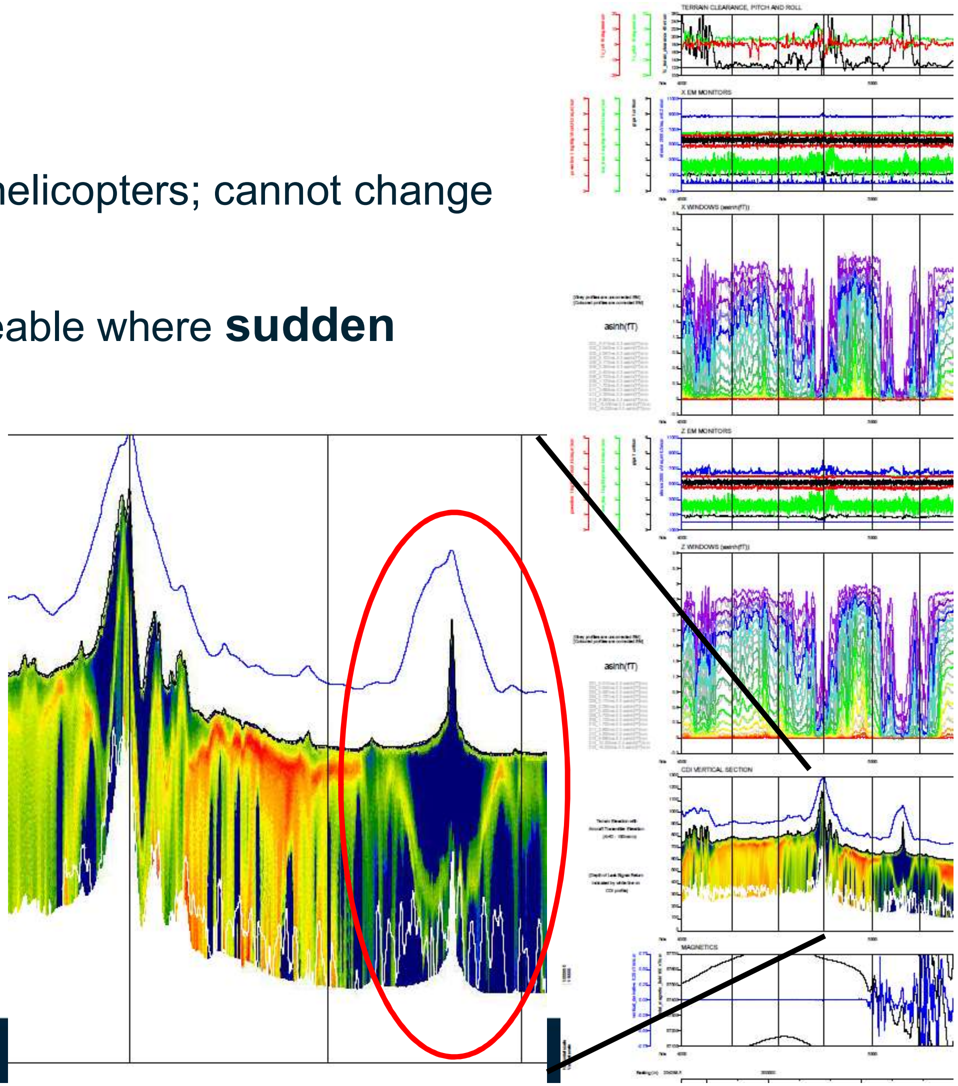
**Aircraft often can not maintain the correct terrain clearance over hills**

Inversion artefacts can occur:

- False resistive ground
- Pants legs

Caveat: sometimes ridges ARE resistive!

AusAEM-1 line 1010001:8 CDI section



# Airborne IP (AIP) and superparamagnetism (SPM)

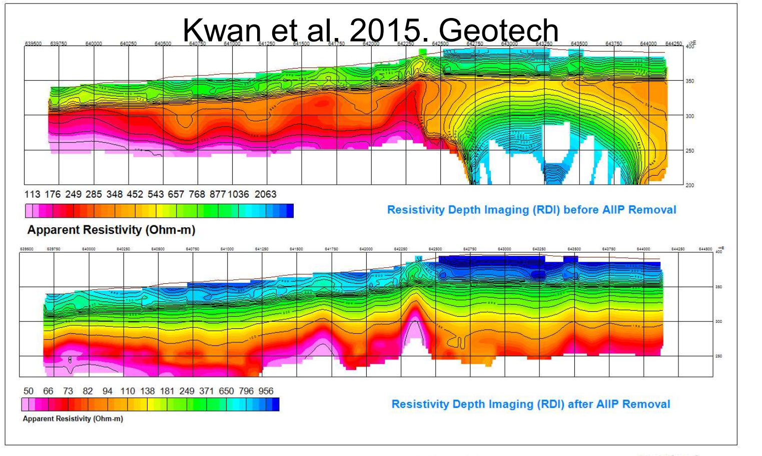
AIP:

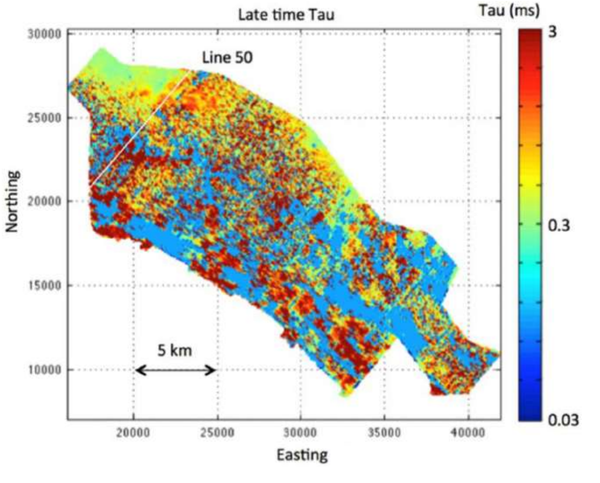
- Chargeable fine-grained sulphides and clays can cause IP anomalies in AEM data, trapping signal

SPM:

- Fine-grained magnetic particles (e.g. maghemite) cause slow decay of the AEM signal due to high magnetic susceptibility, giving false anomalies
- Can be recognised by flying the same line at two different heights
- Mitigate by accurate assessment of regolith materials under flight path

**Both are largely removed during TEMPEST data processing, but beware in other systems, e.g. VTEM, SkyTEM, SPECTREM**



# Geological mapping and direct detection

Once you have satisfied yourself:

- that the AEM data are **fit for purpose**
- that that **you can identify** the various **artefacts** that can occur

you can get on and interpret geology and look for the good stuff

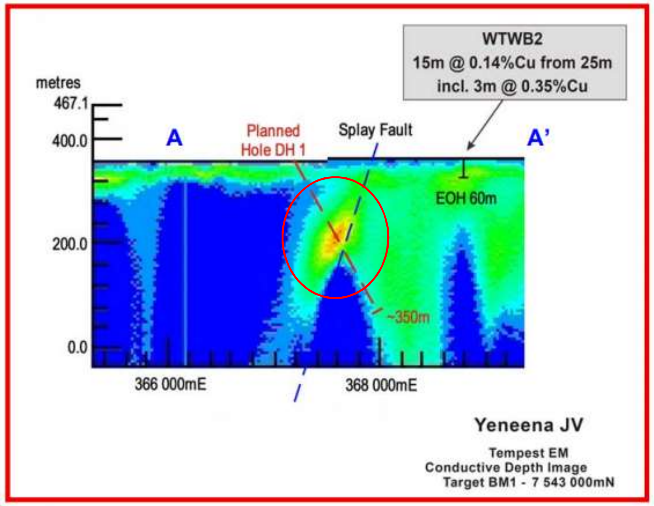
The following are some examples from AusAEM-1 and Geoscience Australia's AEM program.

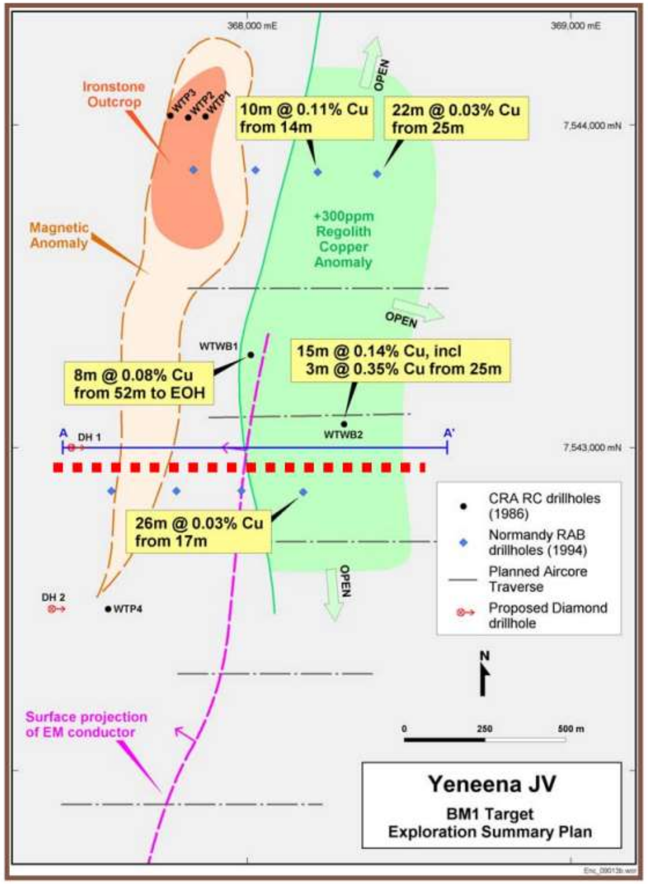
# Discrete conductors

## Sometimes you are lucky enough to see a discrete conductor

Example: Encounter Resources Yeneena Project, Paterson Province

## Paterson Province – BM1



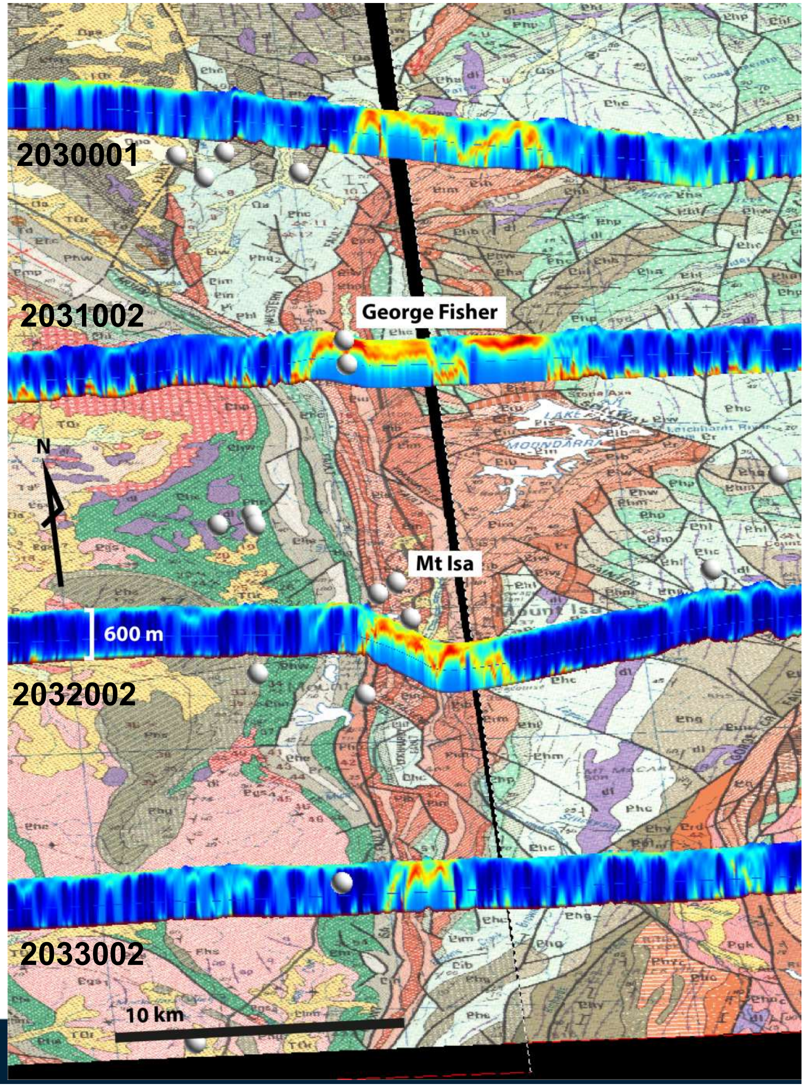




encounter RESOURCES LIMITED

# Conductive host rocks

AusAEM-1 data in the Mount Isa-George Fisher area:

- **Conductivity anomalies highlight the electrically conductive sedimentary rocks of the Mt Isa Group (Urquhart Shale) filling the basin**
- Carbonaceous, pyritic shales and siltstones generally are good conductors




GOCAD oblique image: AEM conductivity sections and Mt Isa-Cloncurry 1:250k geology maps

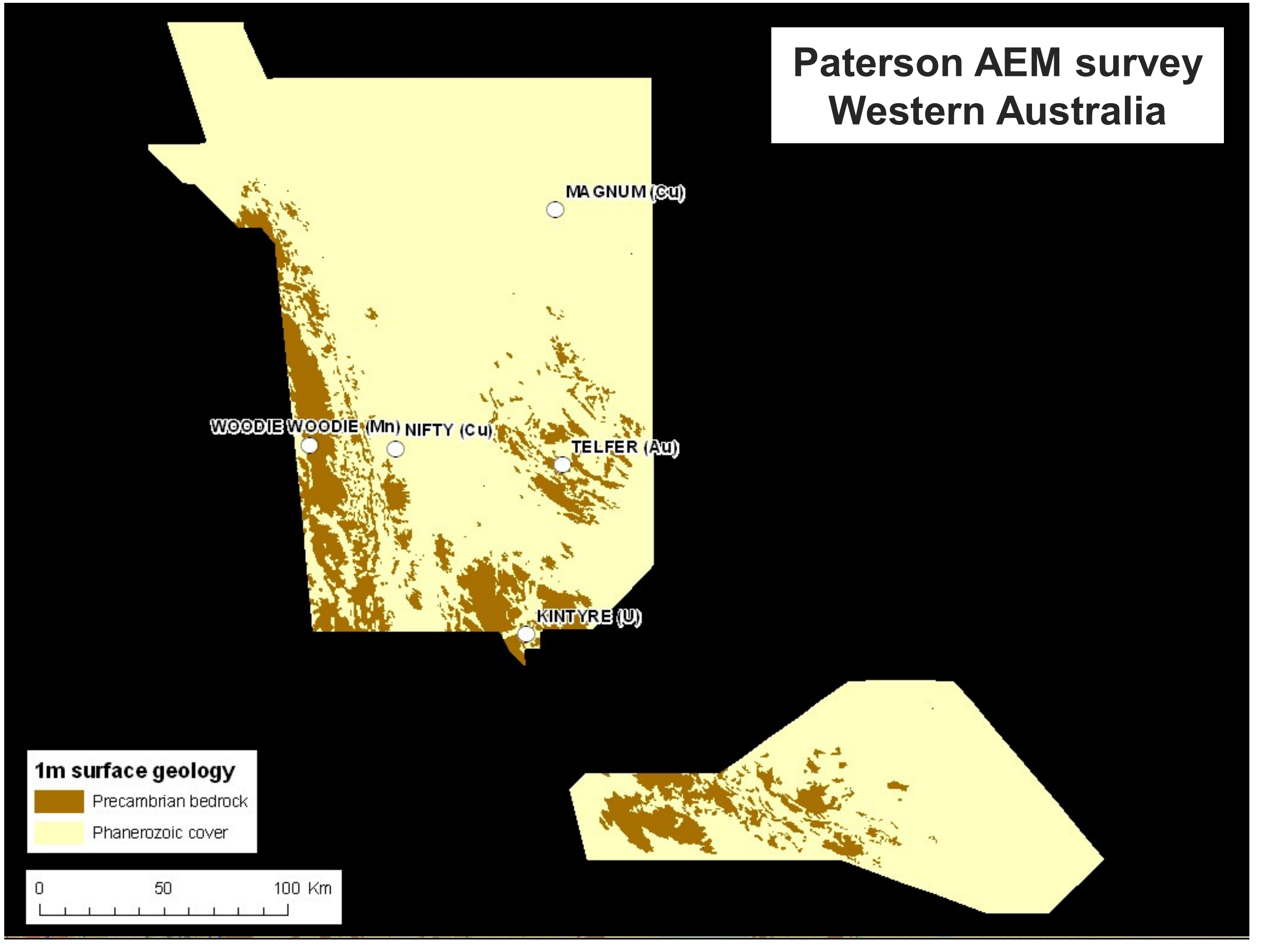
# Mapping under cover

84% cover in the AEM survey area

**Lateral continuity of conductivity patterns with mapped surface geology**

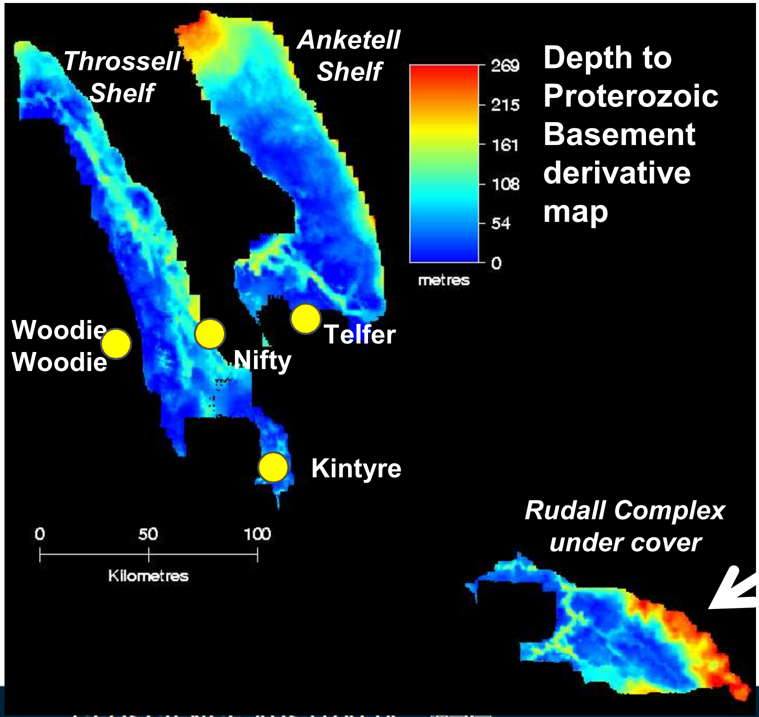
Informs on:

- Extensions of geology under cover
- Potential rock types under cover

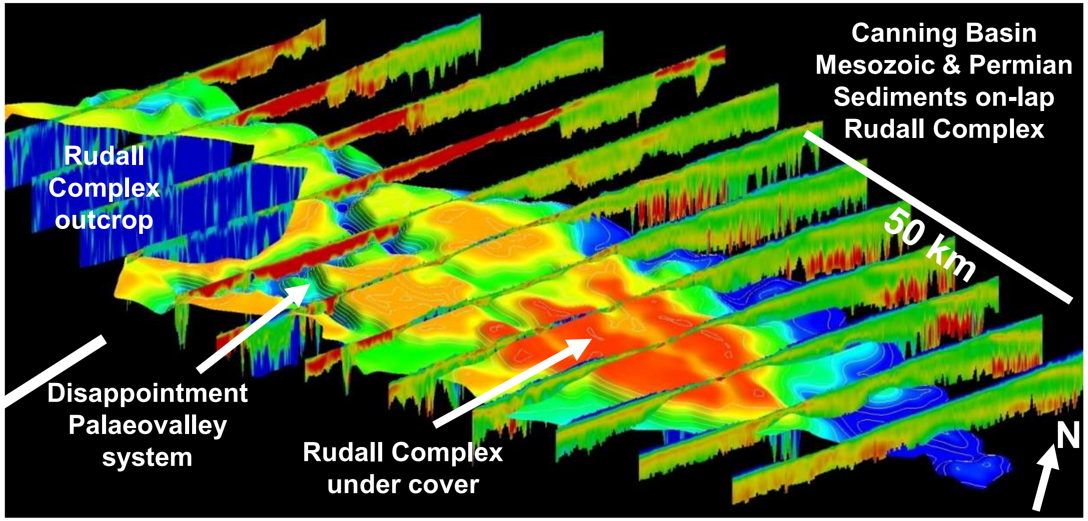


# *"Just tell us how thick the cover is!"*

Paterson WA: excellent results in mapping regional cover thickness and extent of under-cover high-prospectivity terrains



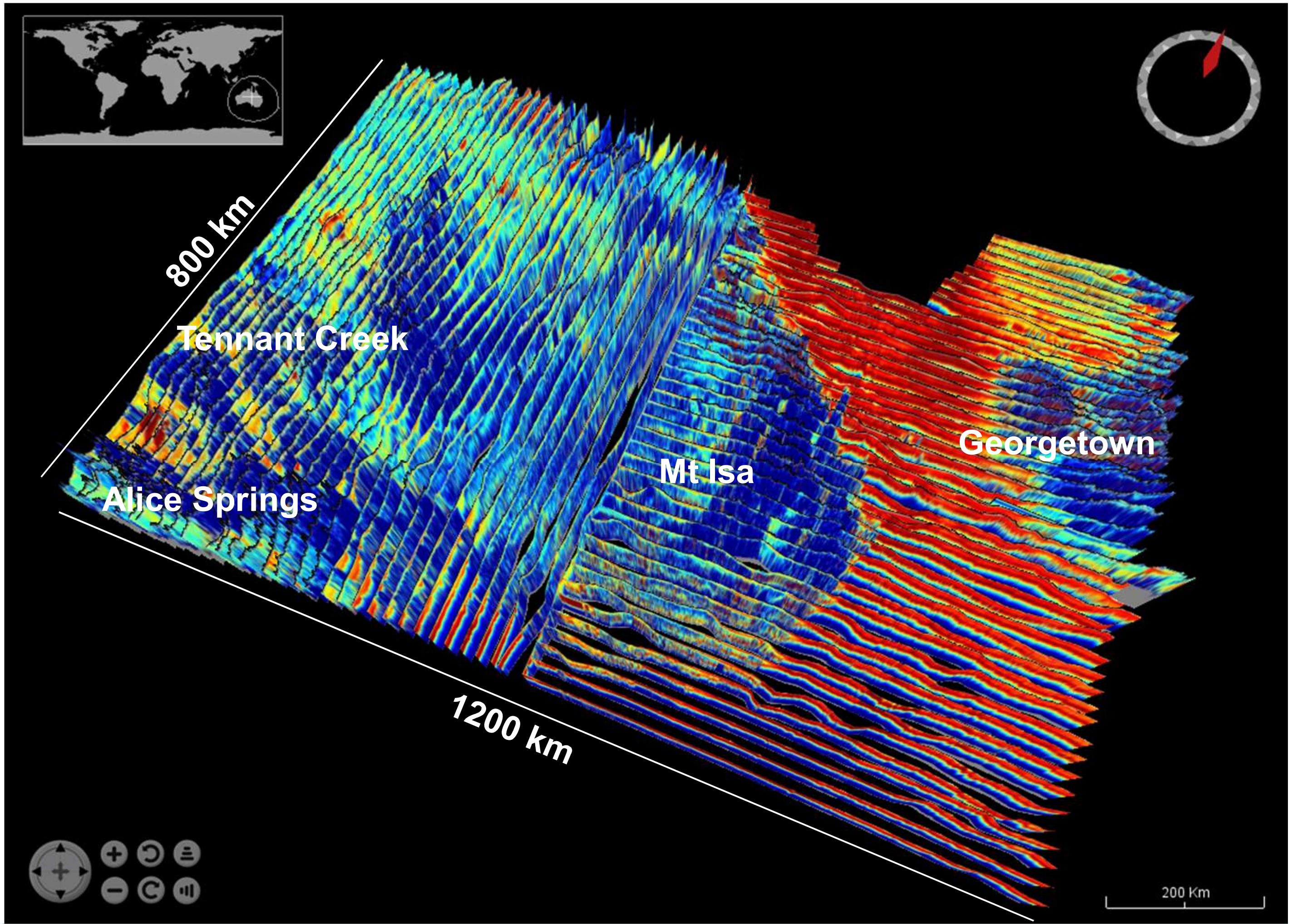

Excellent results in mapping large palaeovalley systems



# AusAEM-1

Work commencing on:

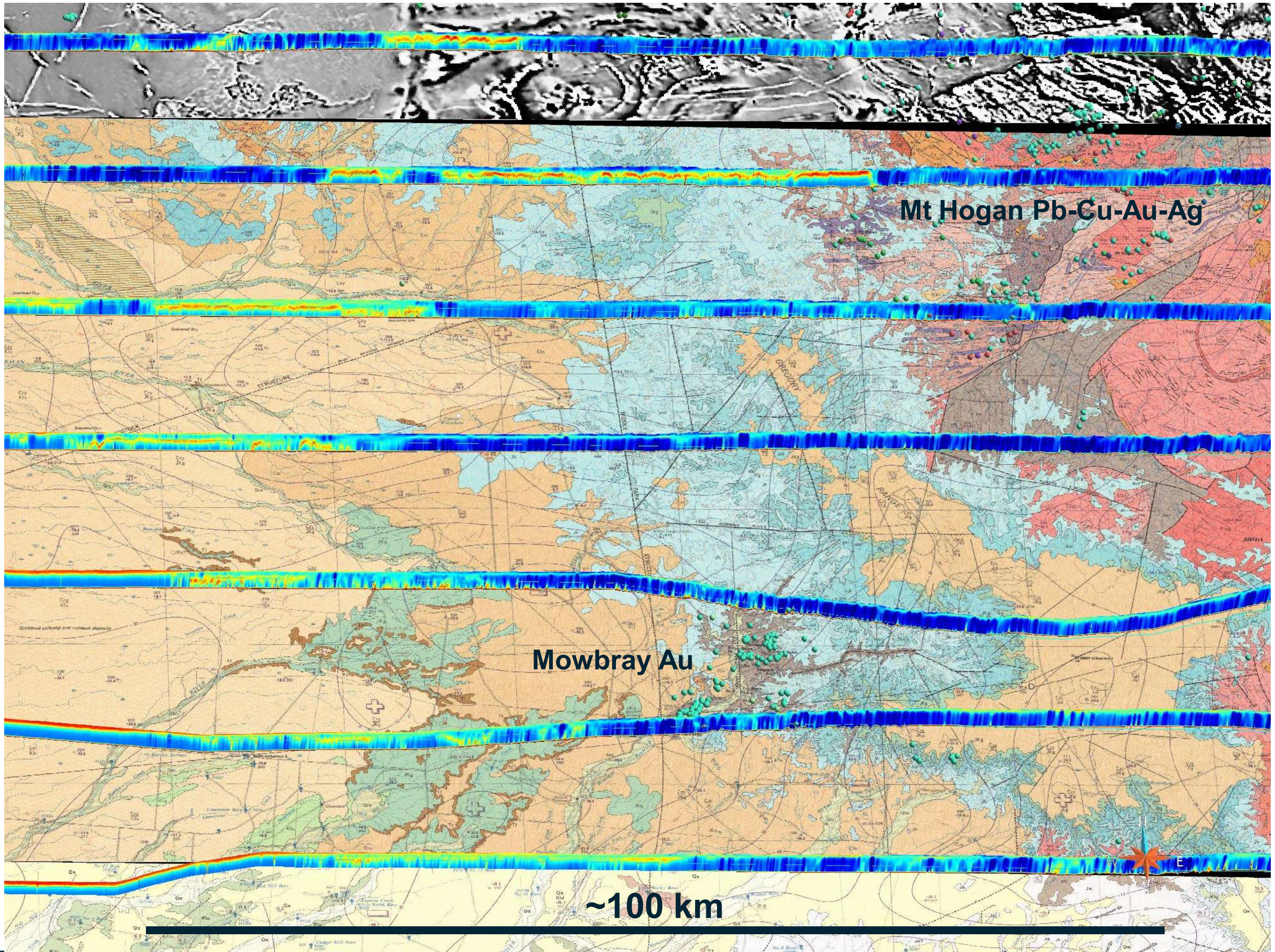
- Depth to basement mapping
- Mapping under-cover geology
- Interpreting groundwater resources



# AusAEM-1

Gilberton 1:250k

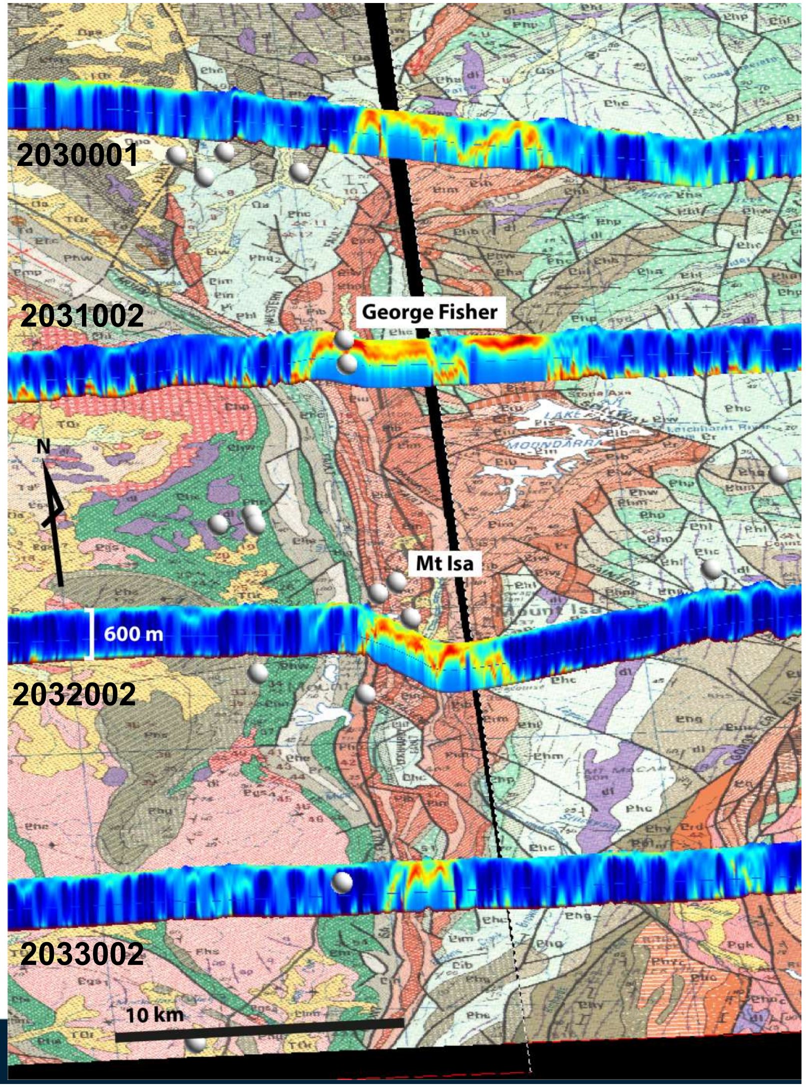
## Extensions of prospective rocks under cover of the Eromanga Basin at Mt Hogan and Mowbray



# Conductive host rocks

AusAEM-1 data in the Mount Isa-George Fisher area:

- Conductivity anomalies highlight the electrically conductive sedimentary rocks of the Mt Isa Group (Urquhart Shale) filling the basin.
- Carbonaceous, pyritic shales and siltstones generally are good conductors

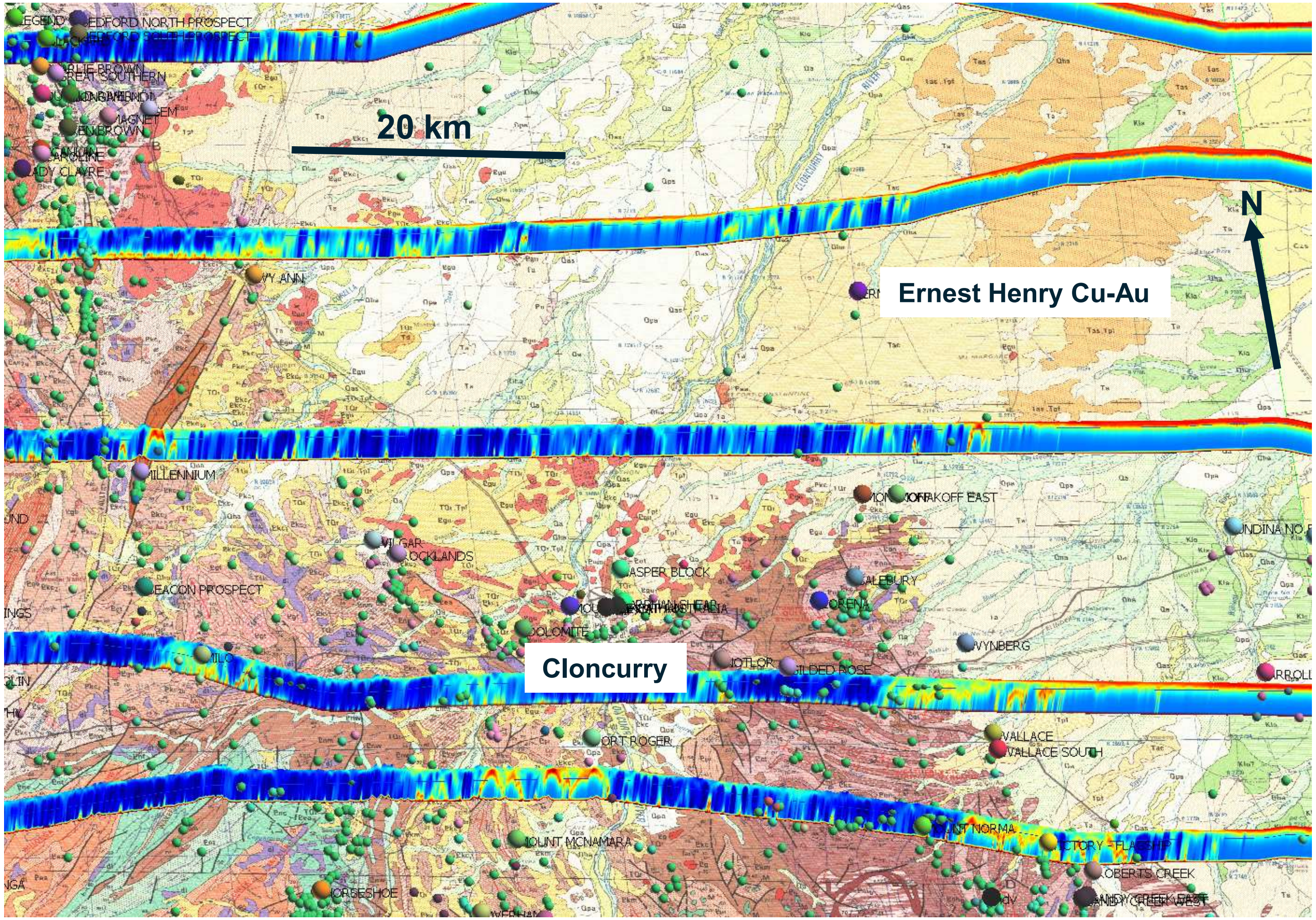



GOCAD oblique image: AEM conductivity sections and Mt Isa-Cloncurry 1:250k geology maps

# AusAEM-1

Mapping in the Cloncurry area:

- **Cover thickness** (EGGS database)
- **Basement conductors**
- **Structures**




GOCAD oblique view: QLD producing mines, major and minor occurrences, Cloncurry 250k geology, AusAEM GASBStotalxy inversion

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# AusAEM-1 contractor-delivered data are now available:

# www.ga.gov.au/eftf

## Geoscience Australia inversion and interpretation product package to be released imminently


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