Australian Government
Geoscience Australia

Northern Territory Government

Seismic and Magnetotelluric surveys in Georgina – Arunta

Seismic Acquisition and Processing team

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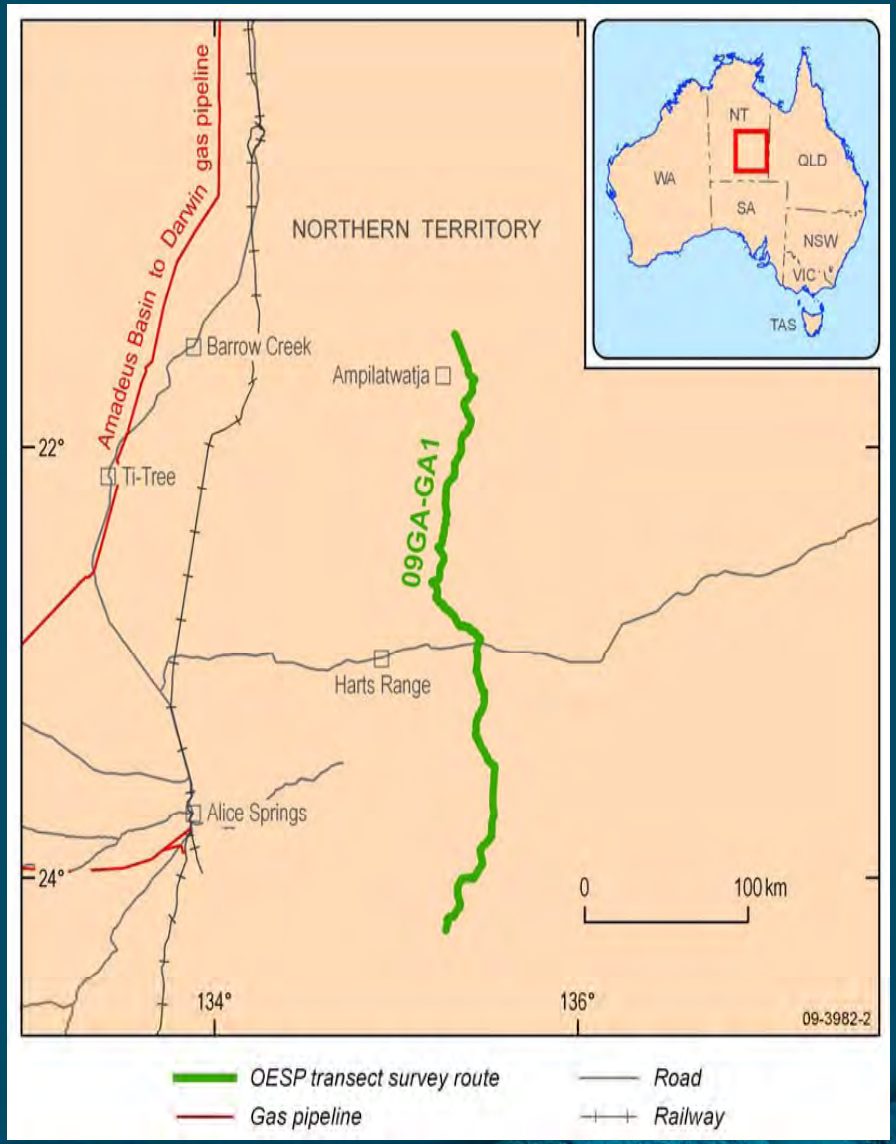
- Geodynamic Framework Project of Geoscience Australia
- ANSIR/AuScope for MT equipment

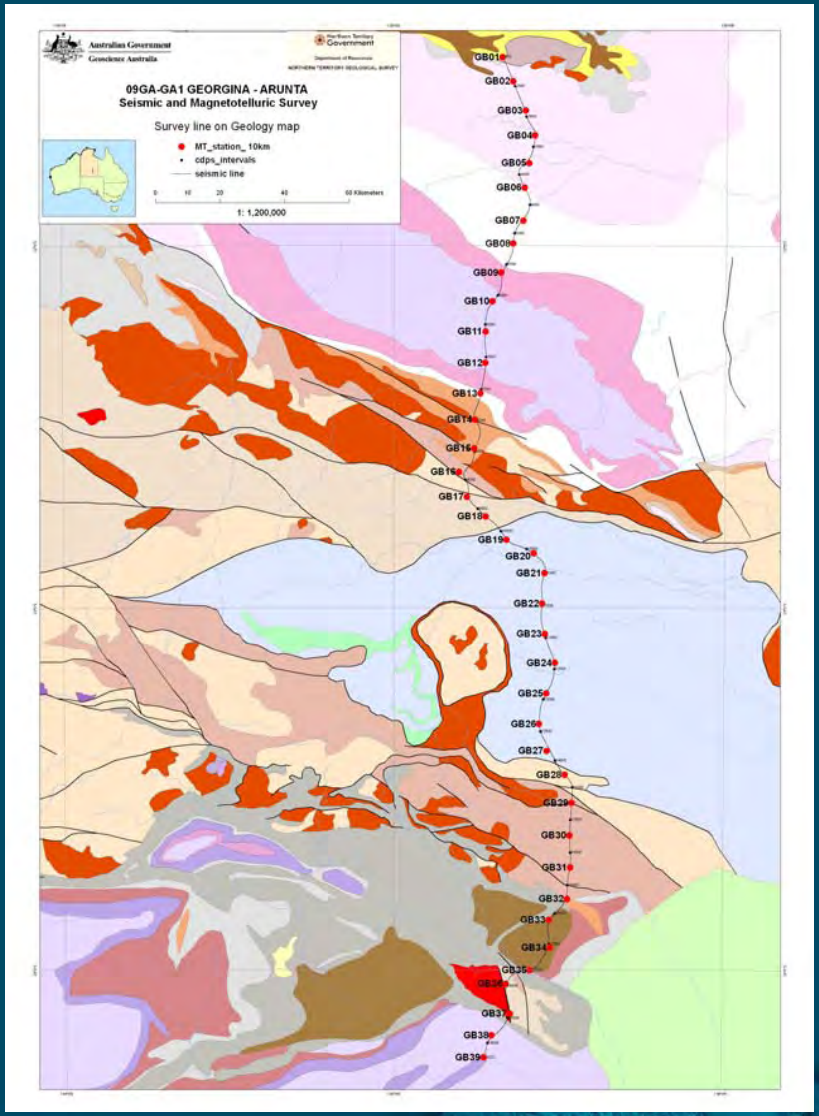
Georgina-Arunta Survey Line

- 373 km seismic reflection line (09GA-GA1)
- Seismic and gravity data were acquired in June - July 2009
- Magnetotelluric (MT) data were acquired in May - July 2009



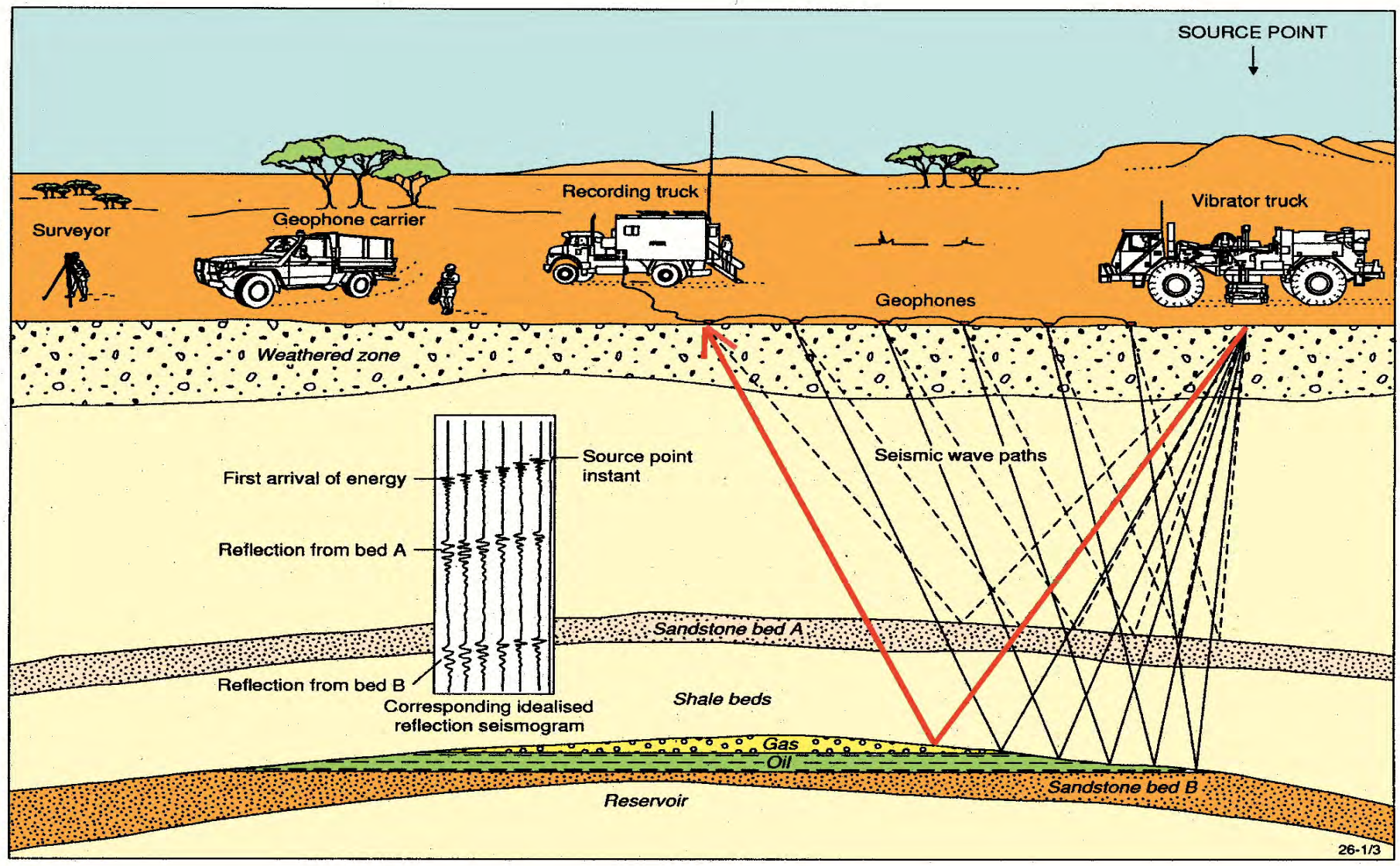
Georgina-Arunta Survey Line

- 57 MT sites were deployed at 39 locations along the deep seismic reflection transect
- 39 broadband MT sites and 18 long period MT sites



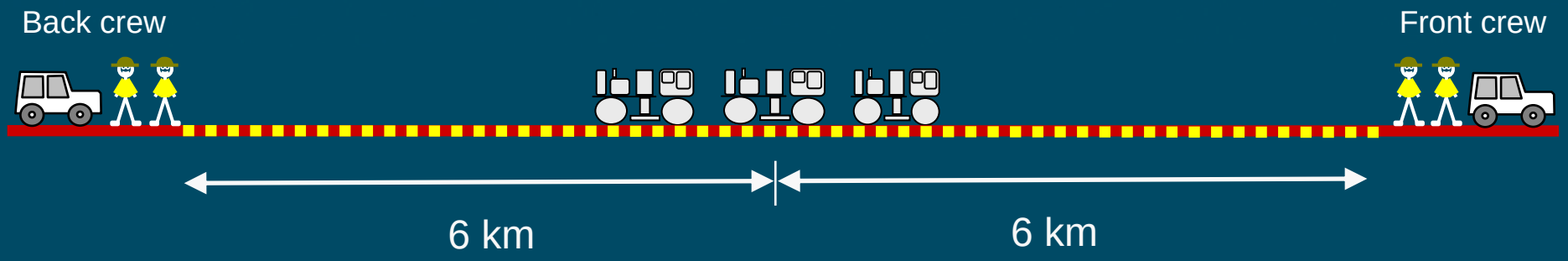
Seismic Acquisition and Processing

Seismic Reflection Method



Seismic Acquisition Parameters

Symmetrical split spread with maximum 6 km offset
300 channels, receiver groups at 40 m intervals



(not to scale!)

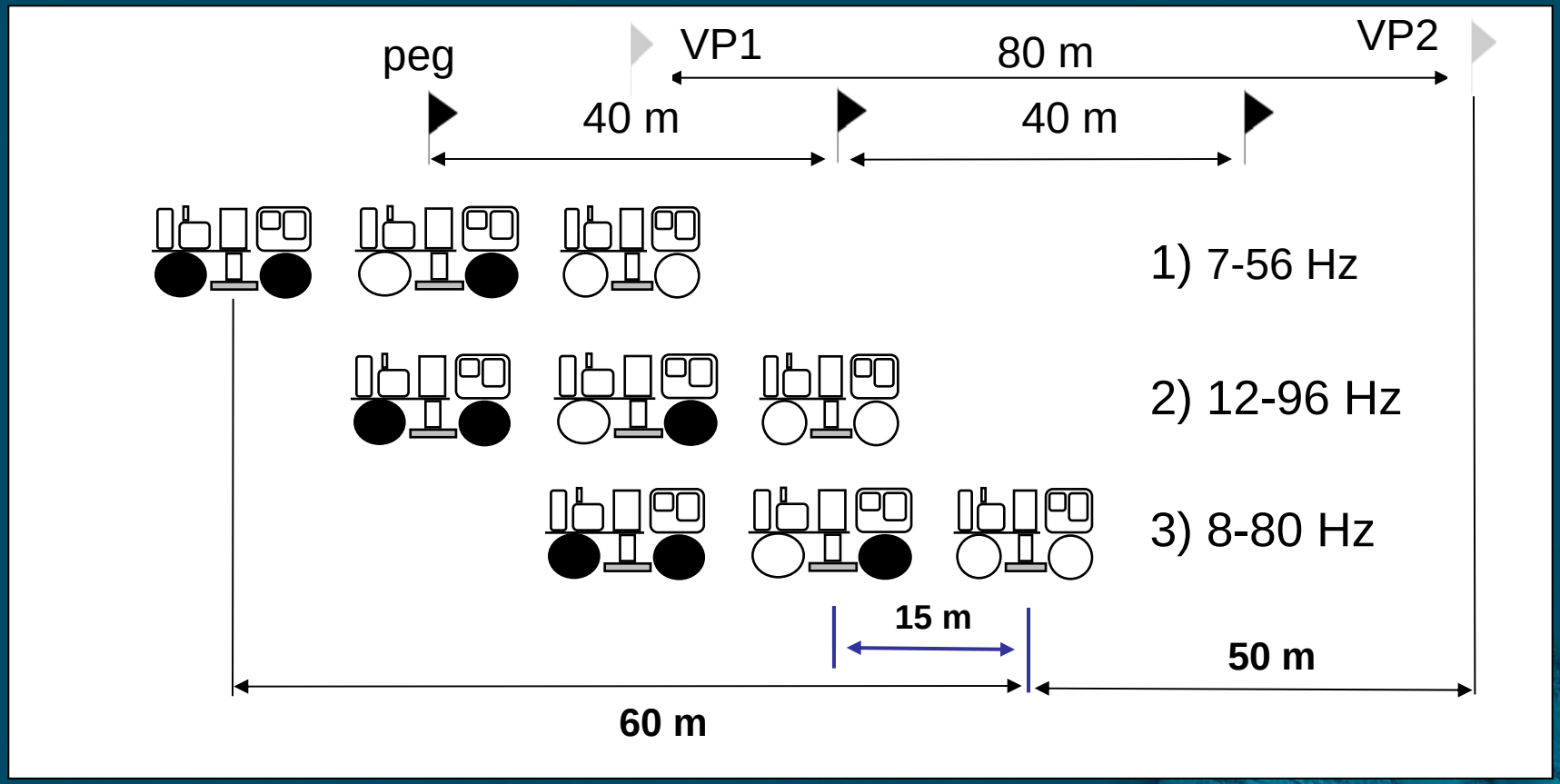
Seismic Acquisition Parameters

Source Array: 60 m centred between pegs

Vibe Point (VP) Interval: 80 m

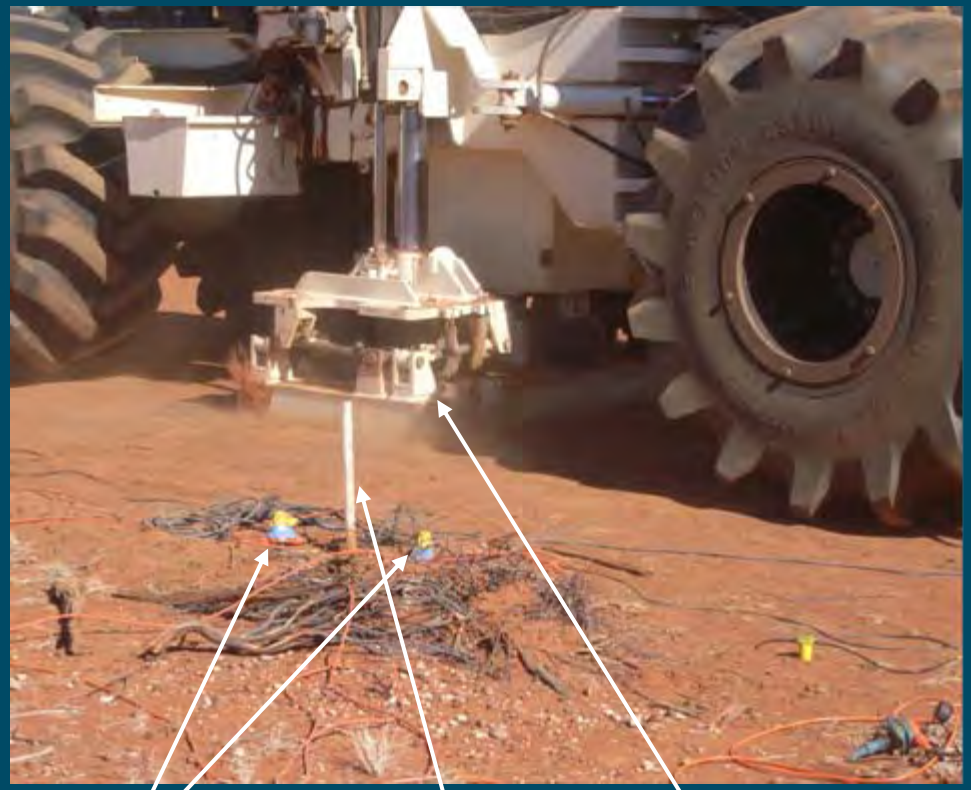
Vibe Config: 15 m pad/pad 15 m move up

Sweeps: 3 x 12 seconds vibes variable frequency sweeps



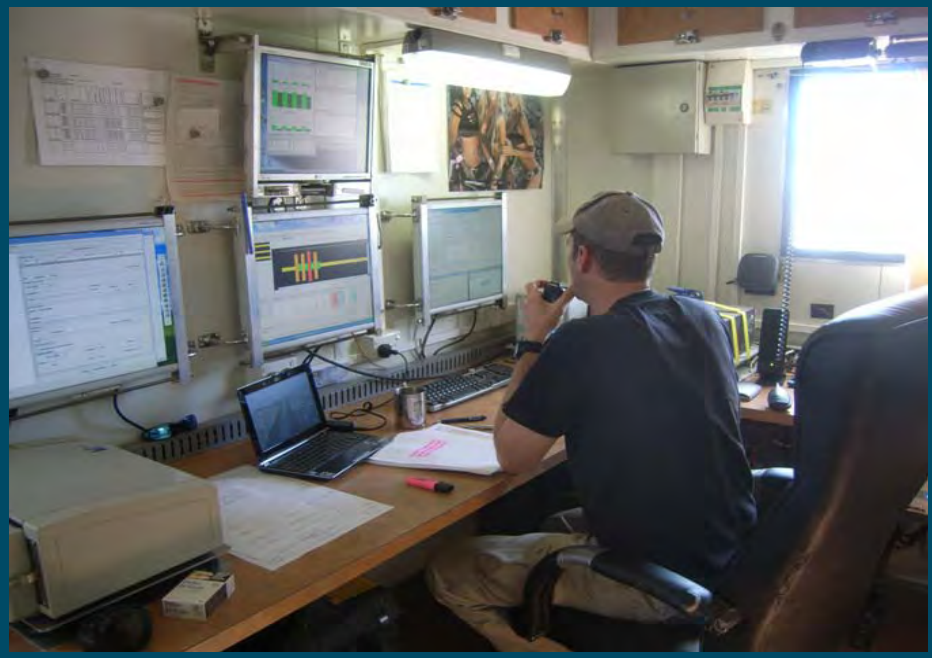
Front Crew

AHV-IV Vibes



Recording Data

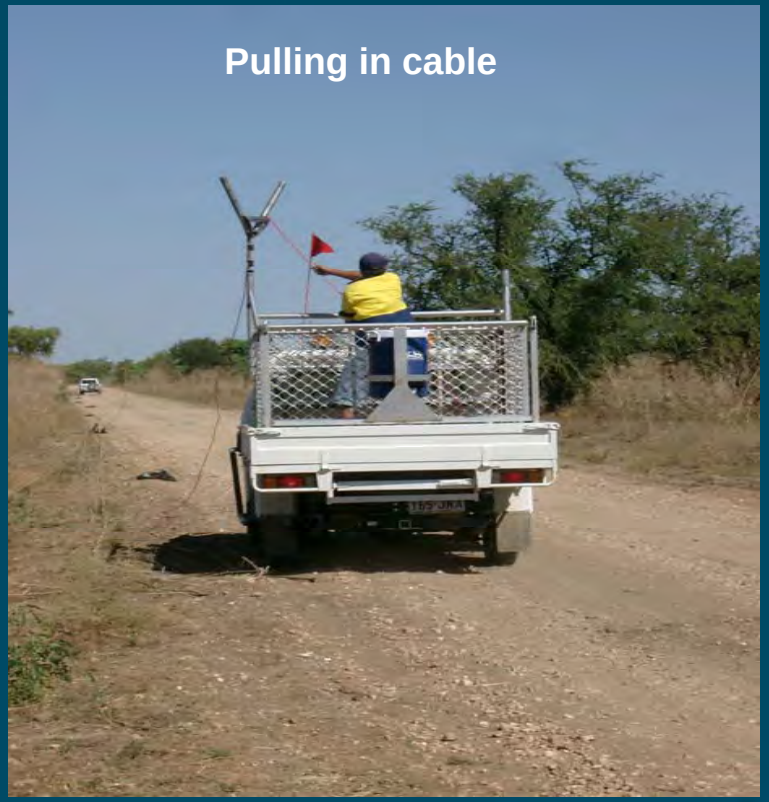
Recorded at 2 ms sampling interval and 20 s recording length



Back Crew

Picking up geophones

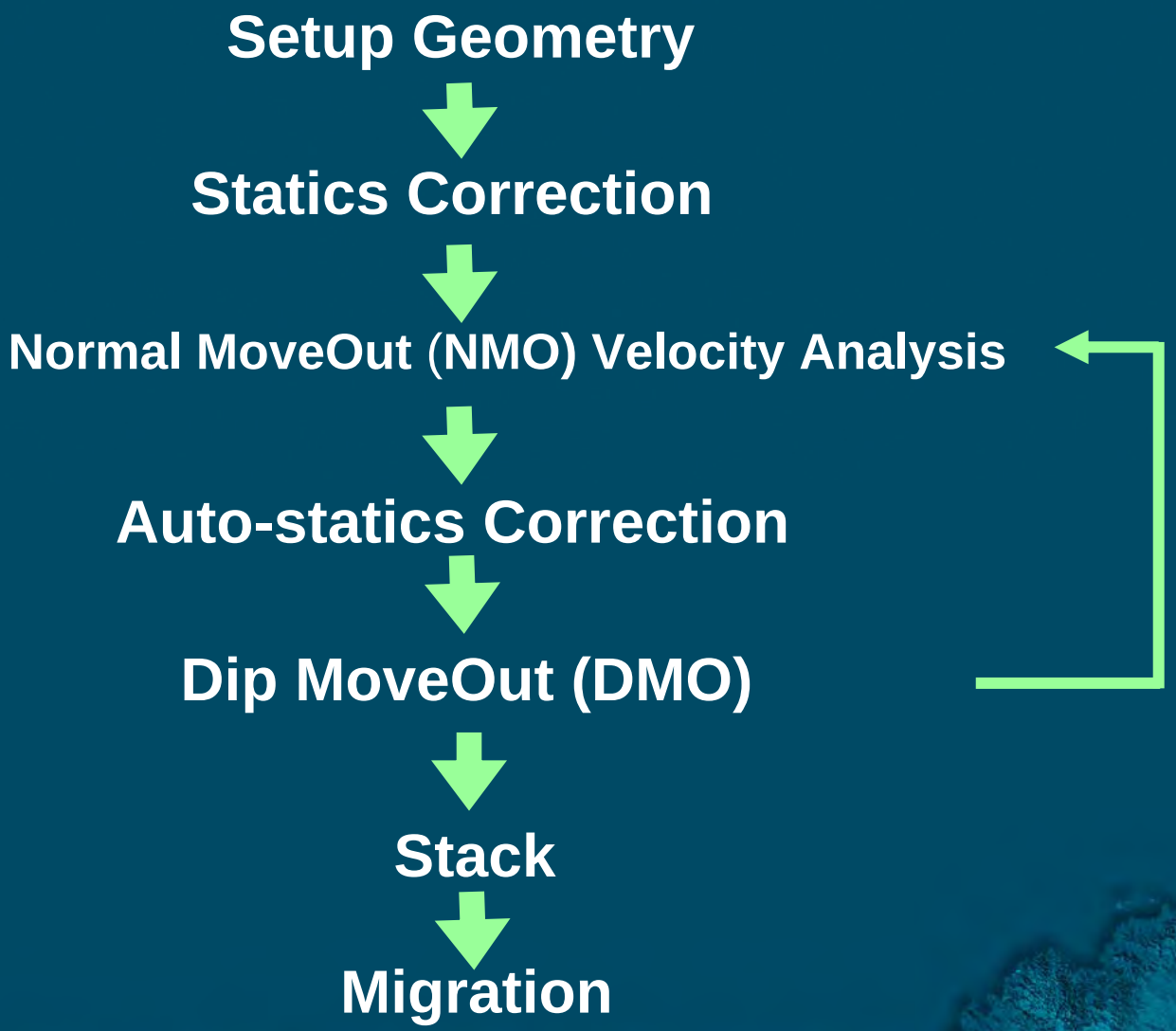
Pulling in cable



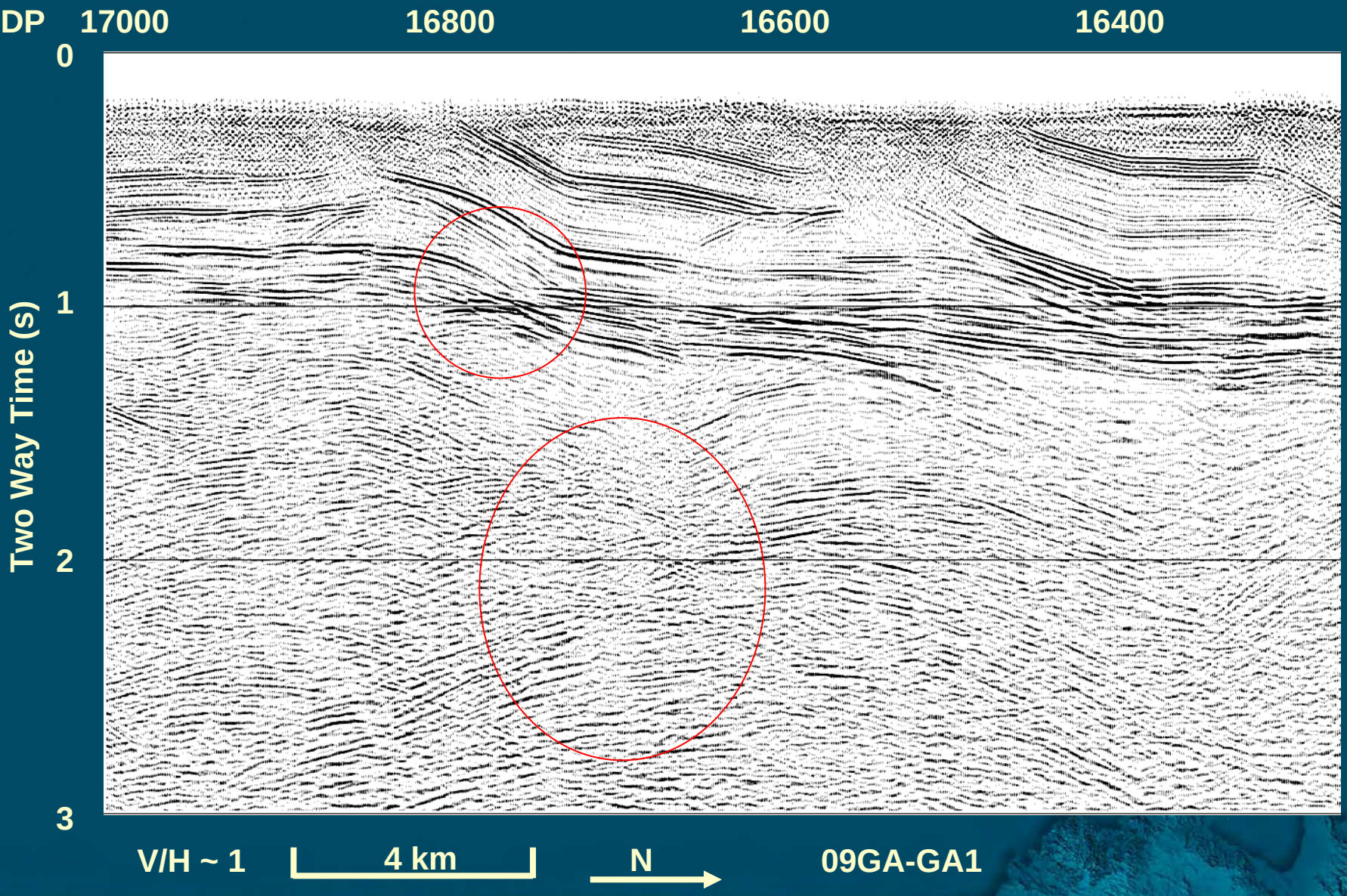
Seismic Processing

The overall goal is to produce an image of the sub-surface by enhancing and correctly positioning reflections and reducing undesired energy (noise)

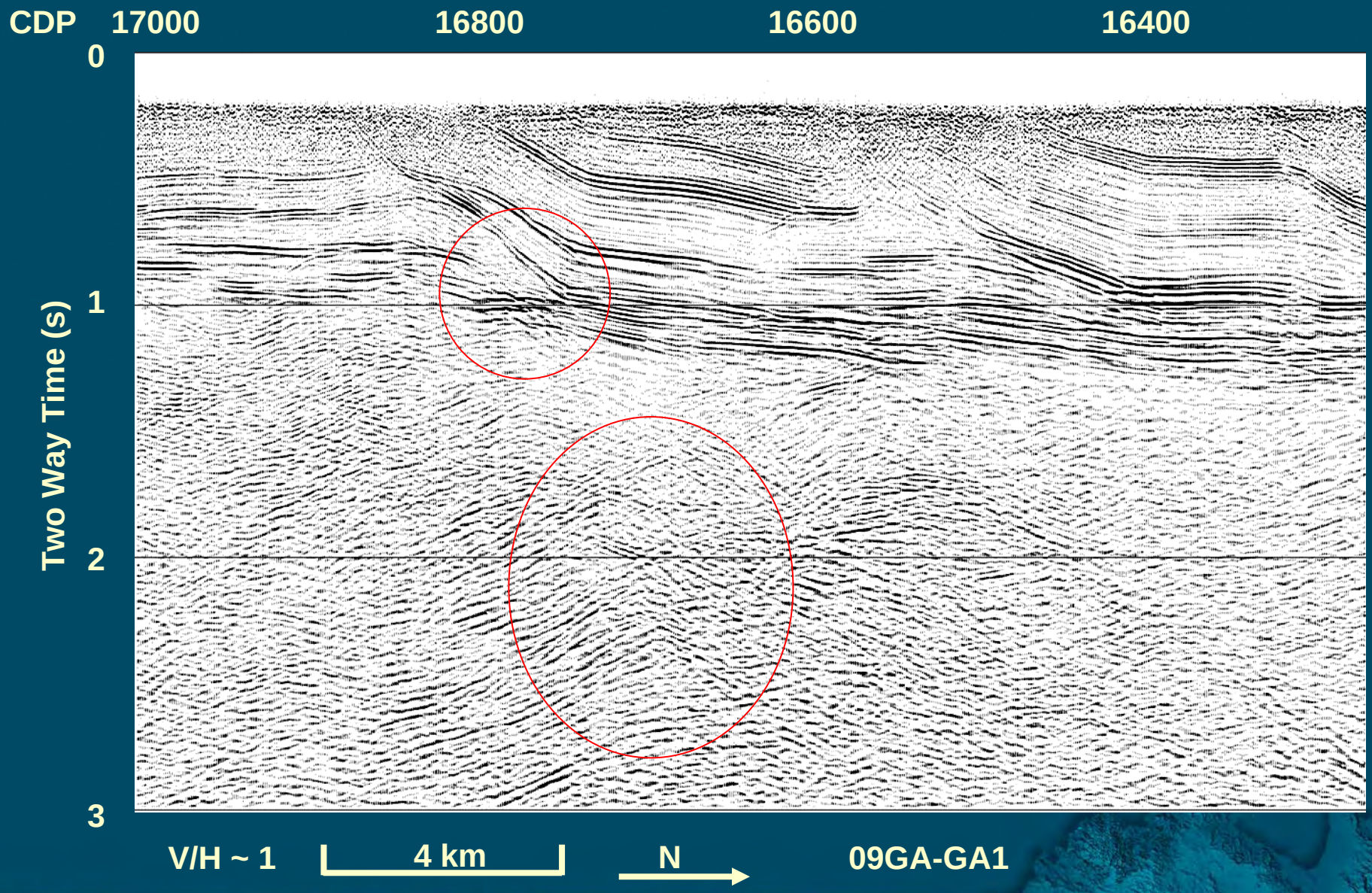
Seismic Processing Sequence



Stack


CDP
17000
16800
16600
16400
0
1
2
3
Two Way Time (s)
V/H ~ 1
4 km
N
09GA-GA1

Migration


CDP
17000
16800
16600
16400
0
1
2
3
Two Way Time (s)
V/H ~ 1
4 km
N
09GA-GA1

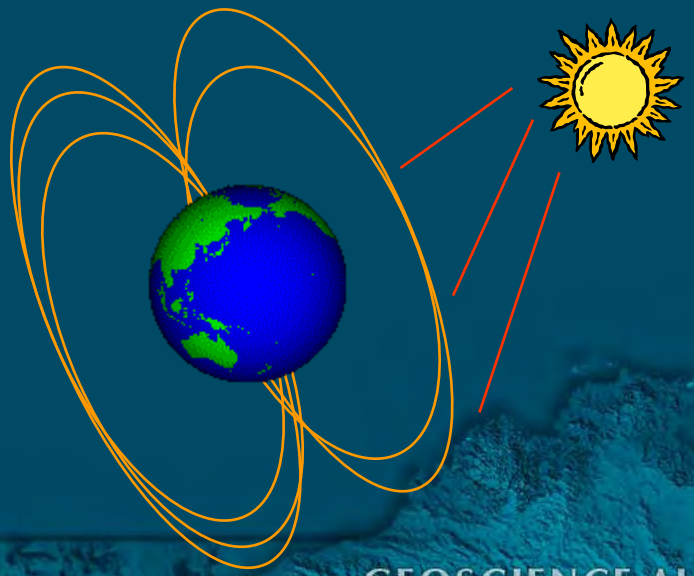
MT Acquisition and Processing

MT Method

- Magnetotelluric (MT) is a passive electromagnetic (EM) sounding technique
- Measures variations in the Earth's natural electric (E) and magnetic (B) fields in time series
- Ratio of E / B is used to derive resistivity distribution of Earth's crust and upper mantle
- Frequency range 10^{4} Hz to 10^{-4} Hz (10^{-4} s to 10^{4} s)
- Investigation depths of tens of metres to hundreds of kilometres

MT Source Field

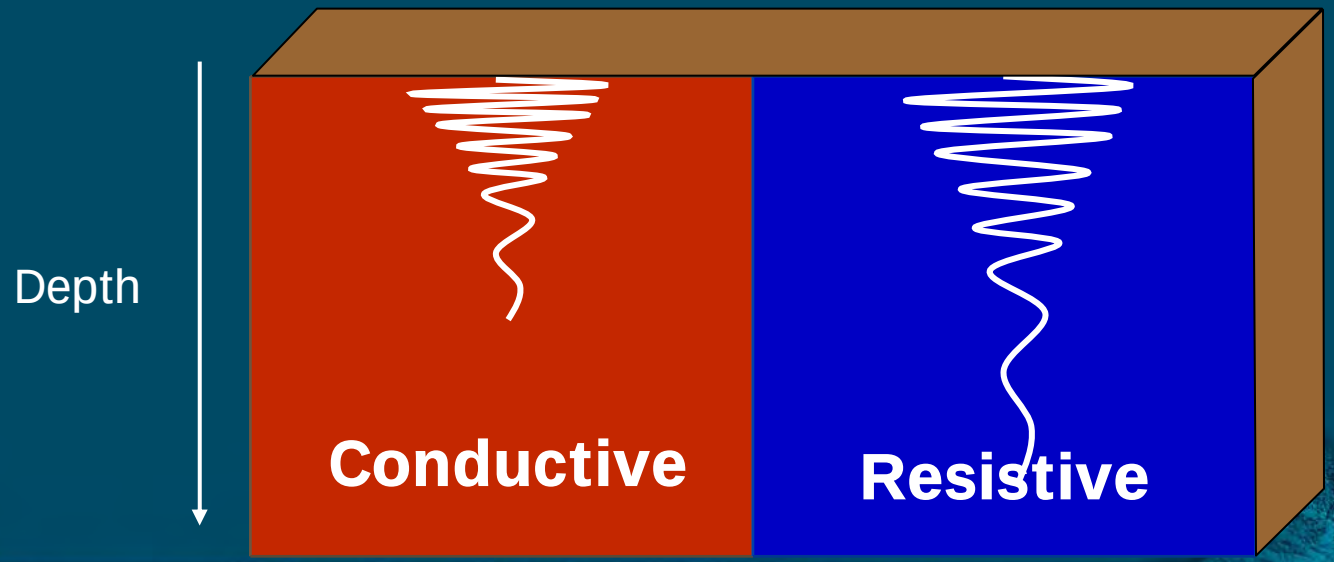
- High frequencies >1 Hz from Spherics
  - Lightning (thunderstorm) activity world-wide
- Low frequencies <1 Hz from
  - Interaction between solar wind and magnetosphere
- Vary with periods of seconds, minutes, hourly, daily, yearly cycles



Depth of Investigation

- **Depend upon frequency and resistivity**
  - High frequencies image the near-surface
  - Low frequencies penetrate to greater depths
  - Higher resistivity means deeper penetration

- **Skin depth** is an approximate estimate depth of EM energy penetration at particular frequency and resistivity



MT Acquisition System

- 9 MT systems from ANSIR/AuScope
- Portable data recorder with 24 bits resolution
- GPS clock synchronization
- Magnetic sensors

  - induction coils and fluxgate magnetometer

- Electric sensors

  - copper/copper sulfate electrodes with dipole length 50 m)

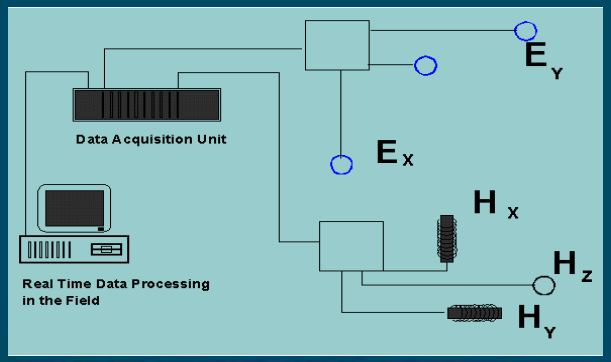
Magnetic Sensors

Broadband Induction coils

3 component Fluxgate magnetometer

Electric Sensors

System layout



MT Acquisition Parameters

Type of MT	Broadband	Long period
Recording channels	4	5
Sampling rate	1000 Hz	10 Hz
Recording time	30 - 60 hours	5 - 7 days
Site spacing	8 - 10 km	15 - 20 km
Deployment	3 or 4 sites at a time	5 or 6 sites at a time
Data format	MiniSeed	MiniSeed

MT System Set up

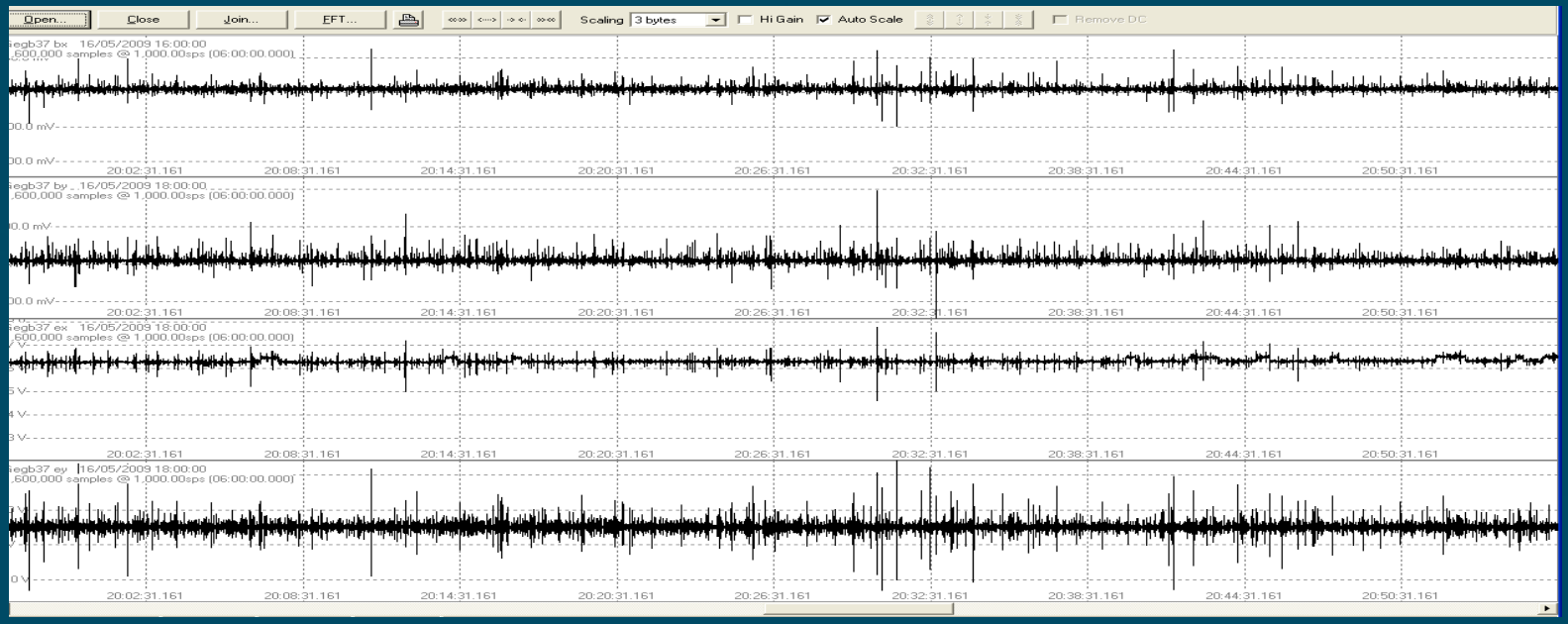
Example of Time Series Data

Magnetic N

Magnetic E

Electric N

Electric E



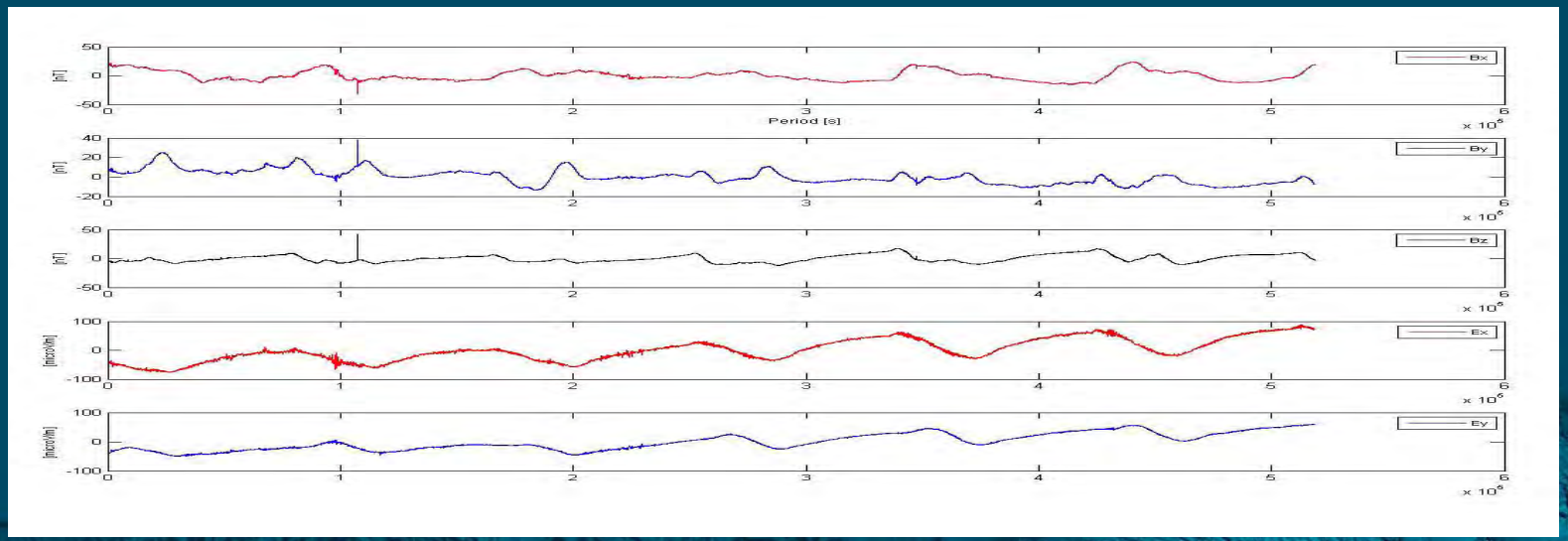
Magnetic N

Magnetic E

Magnetic Z

Electric N

Electric E



MT Processing Sequence

Time series data pre-processing

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Transform data into frequency domain

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Derive spectra and impedance tensors

↓

Calculate apparent resistivity and phase
Calculate tipper function for long period data

↓

Store MT response into EDI file

↓

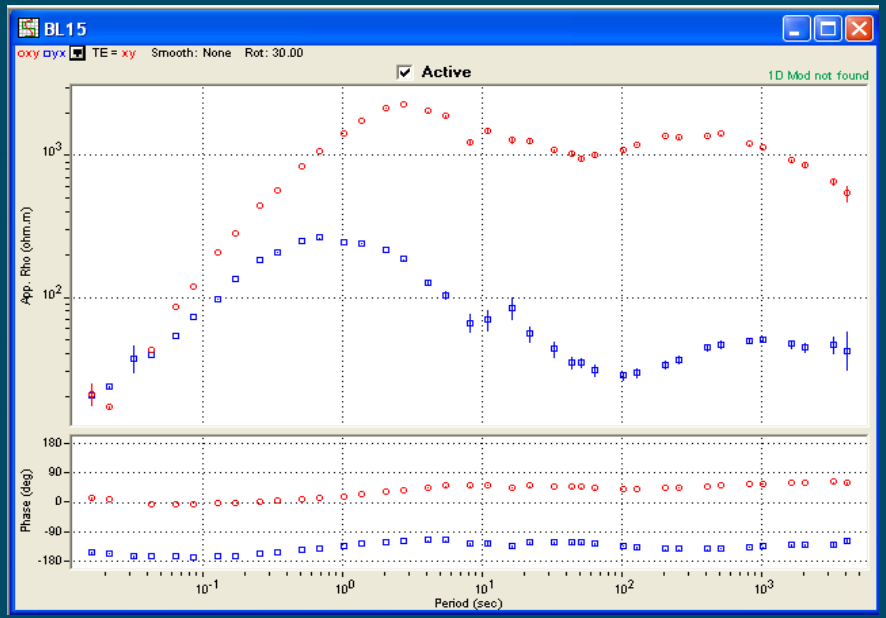
Data analysis

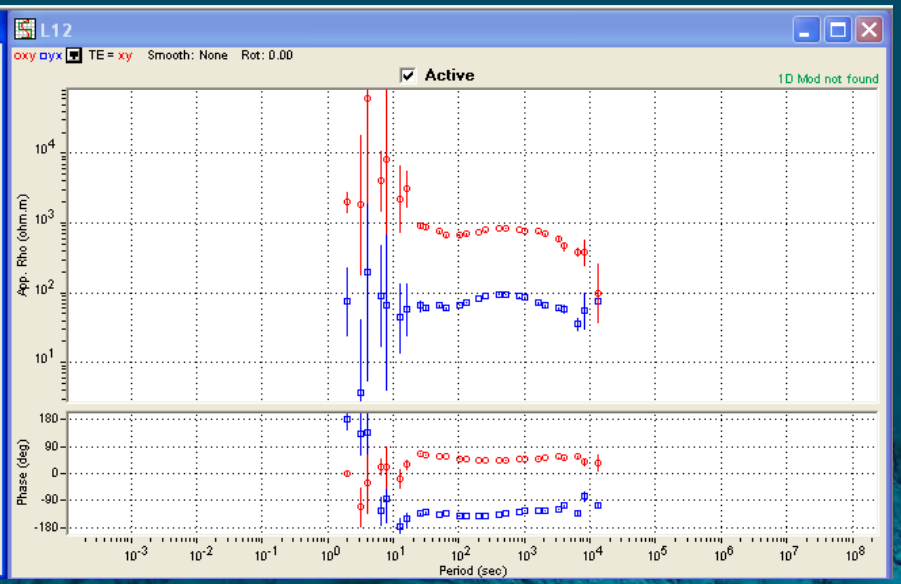
↓

Modelling

MT Data Response

- **Apparent resistivity** is a volume average of a heterogeneous half-space.
- **Transverse magnetic (TM) mode**: the electric field is perpendicular to geoelectrical strike.
- **Transverse electric (TE) mode**: the electric field is parallel to geoelectrical strike.





Data Analysis

- Analyse MT response for the data set
- Define the dimensionality and electric strike angle of the data set
- Several techniques have been used, such as, phase tensor decomposition, Mohr circle technique, WALDIM method, vertical induction vector (arrow), etc
- PseudoSection of data set gives a qualitative impression of resistivity variations with depth and distance

Data Analysis

Type of MT response	Broadband data	Long period data	Merged data
No of period	30 periods	26 periods	45 periods
Range of period	0.003 s to 100 s	10 s up to 14000 s	0.003 s up to 10000 s

PseudoSection of Apparent Resistivity and Phase

South — Distance 370 km — North

TM mode:

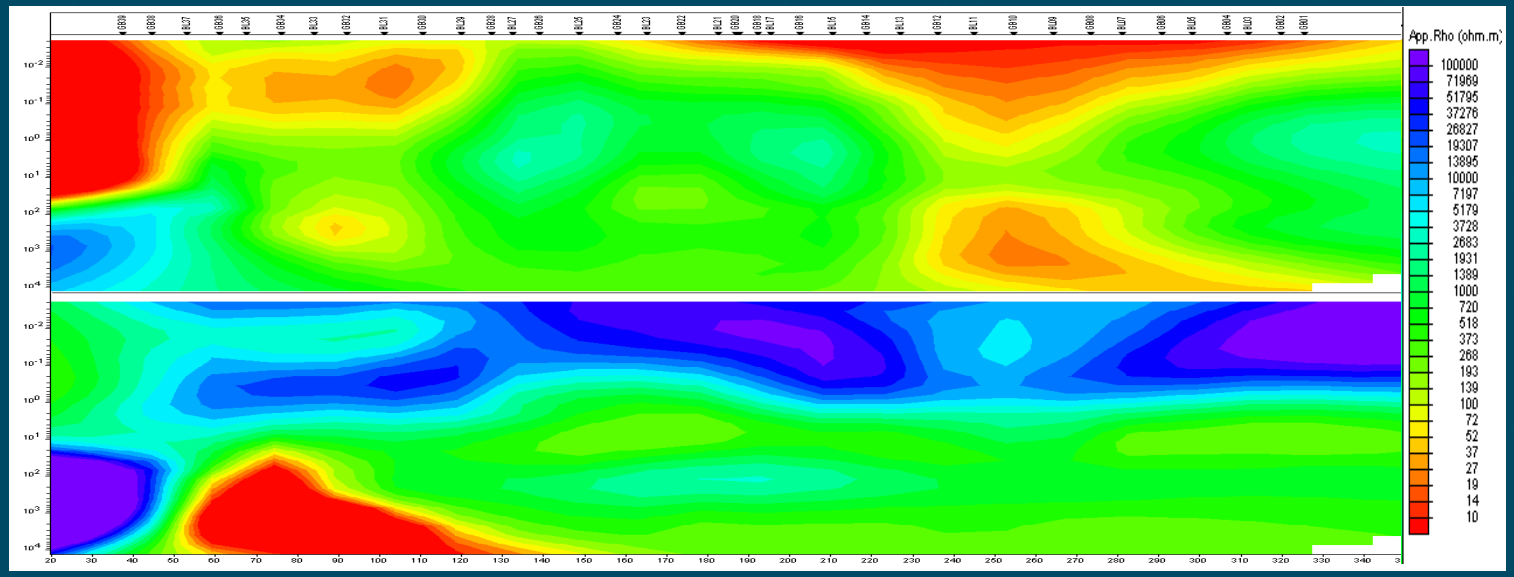
high

Apparent resistivity XY

Frequency

Phase XY

low



TE mode:

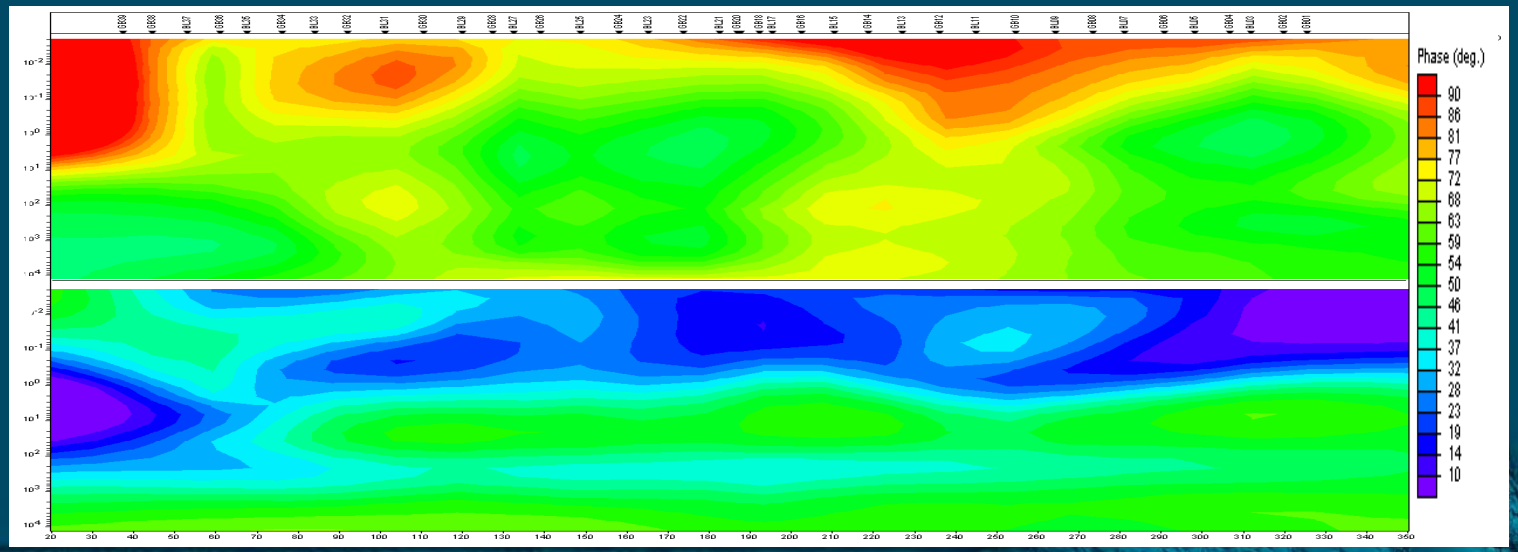
high

Apparent resistivity XY

Frequency

Phase XY

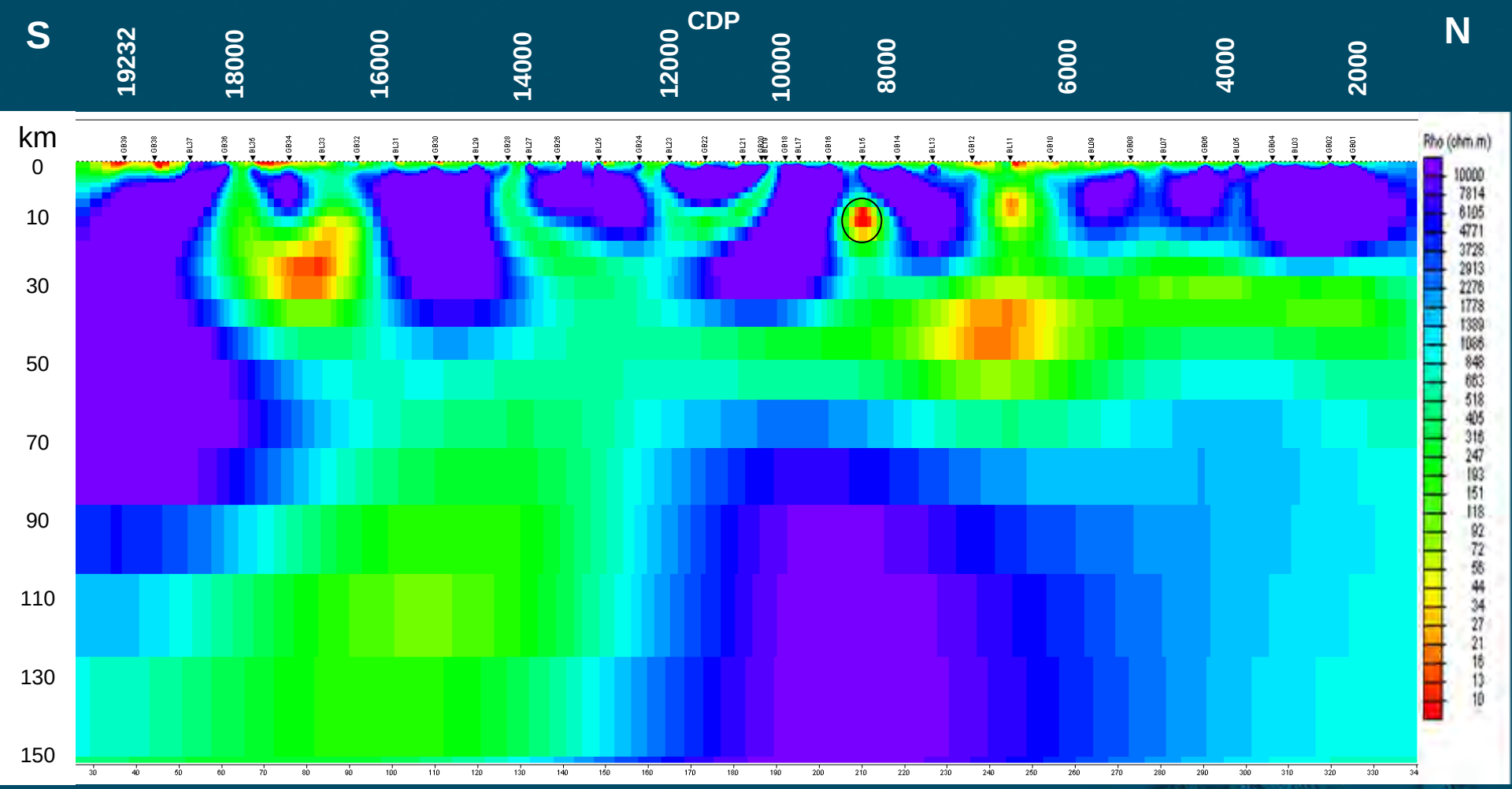
low



Inversion and Modelling

- 1D model used different 1D codes
- A preliminary 2D model implemented by using the Non-Linear Conjugate Gradient (NLCG) algorithm of Rodie and Mackie (2001)
- Wide range of regularization parameters were tested for different 2D models
- Test robustness of the model (forward model, compare with other geophysical results)

Preliminary 2D MT model

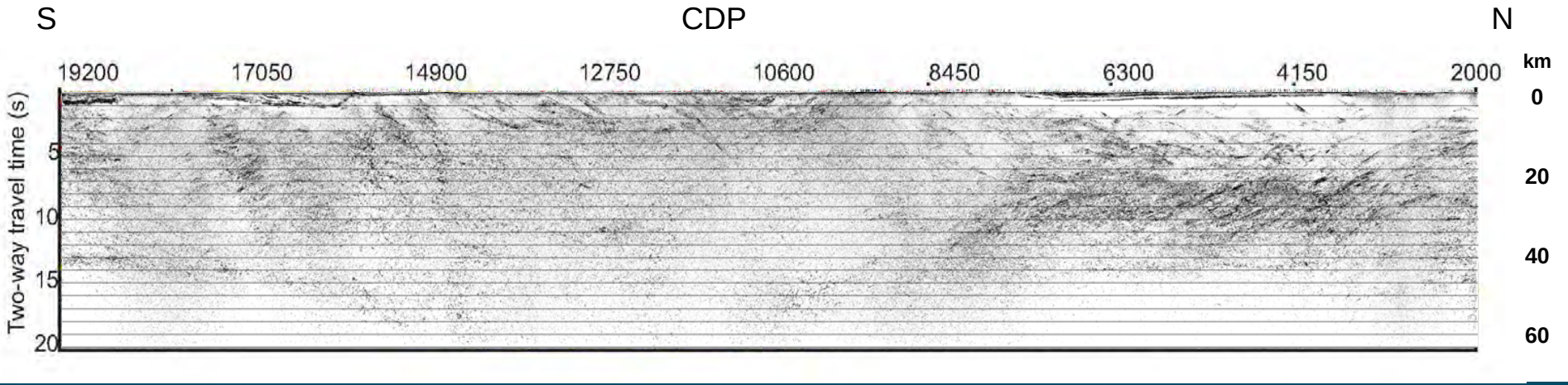


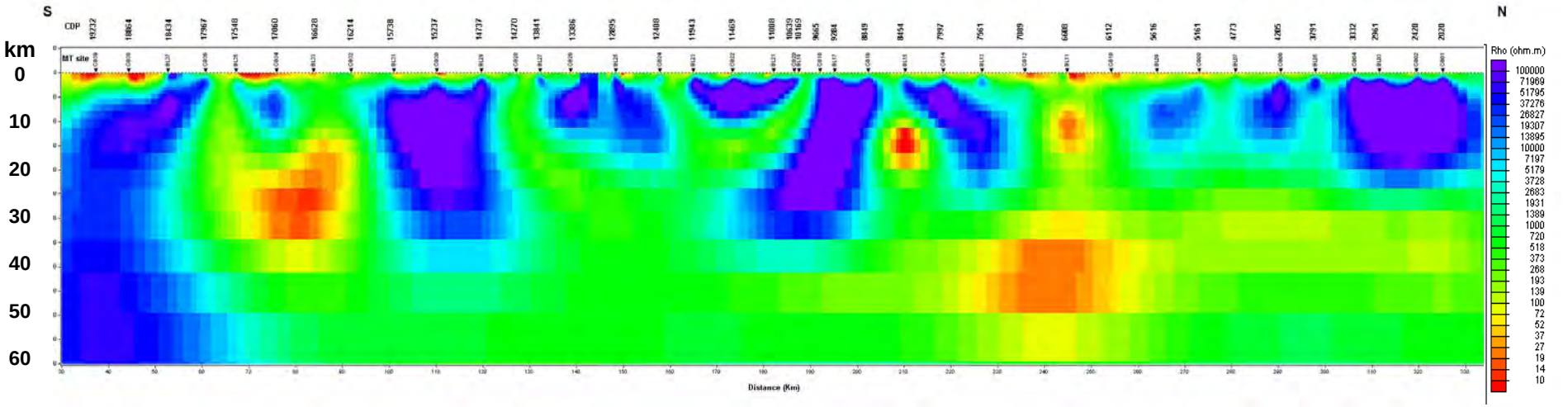
Distance 370 km

Limitations of the Model

- MT inversion is non-linear, non-unique and an unstable problem. There are an infinite set of models
- Impossible to accurately estimate physical properties from a finite set of uncertain data
- The model may not exactly represent some features due to large station spacing
- Complicating factors need to be considered, static shift, distortion, 3D effects
- Prior geological and geophysical information should be applied to constrain the 2D model

Seismic Image and MT Preliminary 2D Model





Distance 370 km

Conclusions

- Seismic and MT data were acquired along a 373 km transect
- The Seismic and MT data have been processed and analysed
- Seismic image and MT preliminary 2D model show that near-surface sediments are well-resolved. They also provide evidence of geological structures in this region

Thank you !