



# LKMT Conclave, February 2017

David Moore, CGG Multi-Pysics

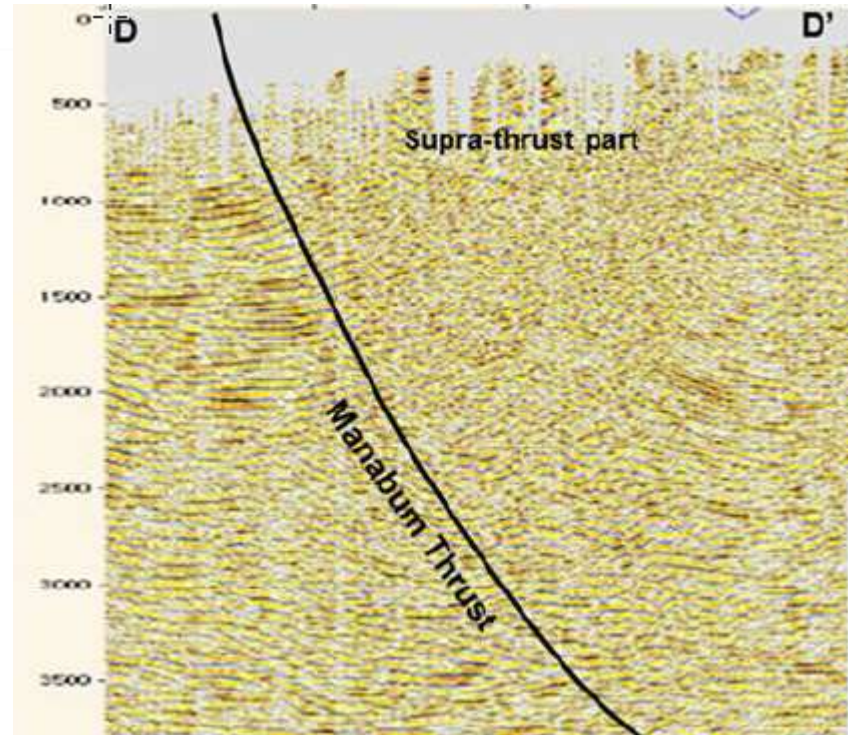
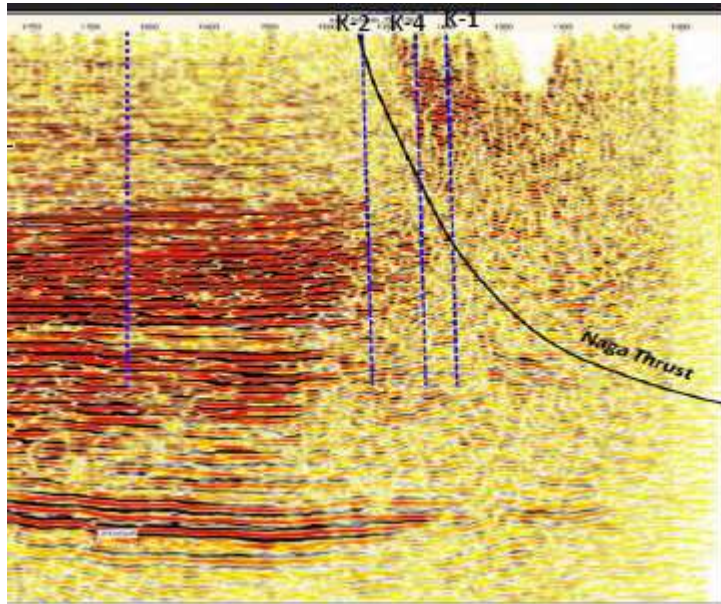


## Rugged Topography





## Poor Seismic Imaging





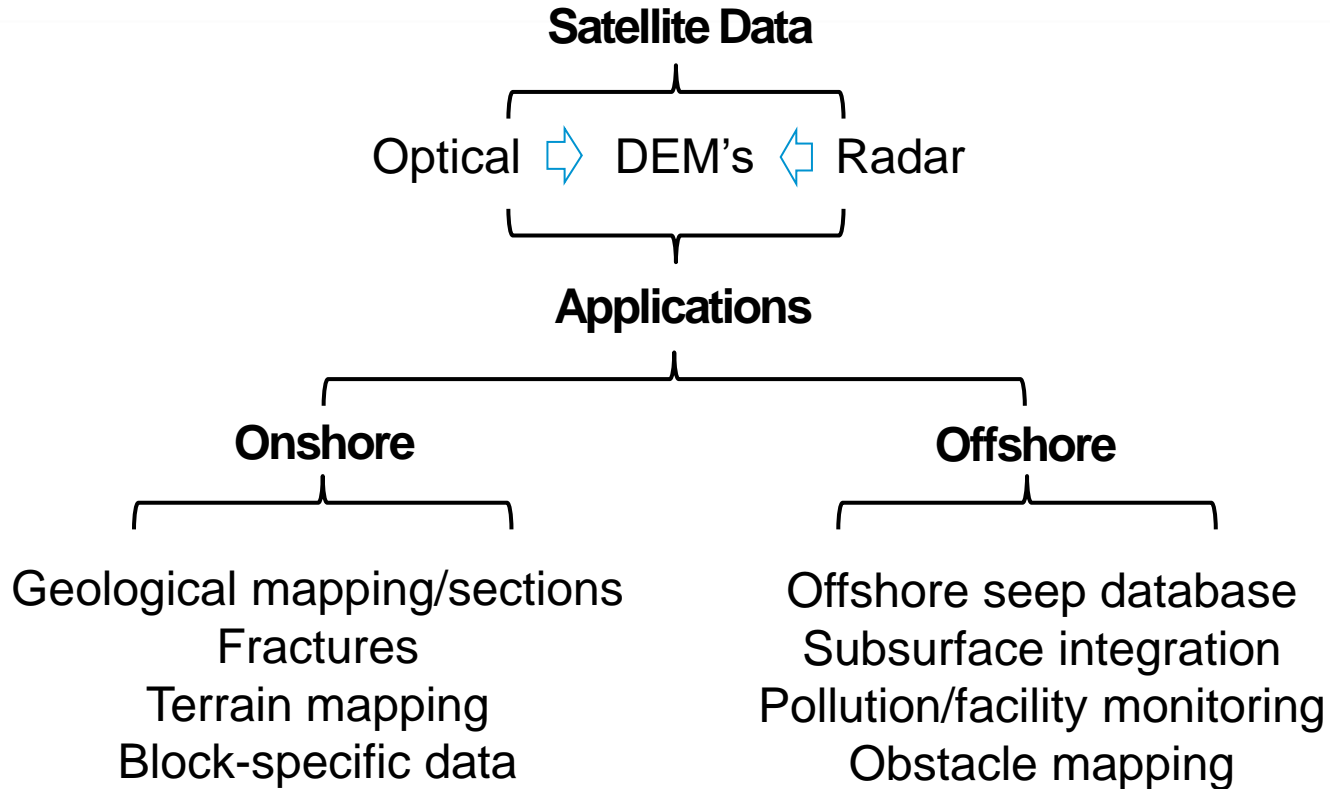
# Structural Mapping using Satellite Imagery and Airborne Gravity Gradiometry

# Satellite Mapping

Geological mapping and subsurface modelling



## NPA Satellite Mapping



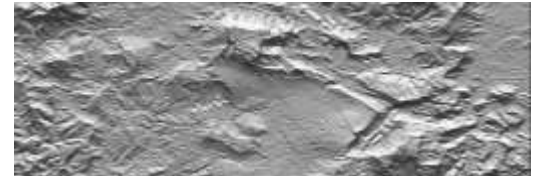
Satellite data



# Intelligence from imagery

## Choosing the right data

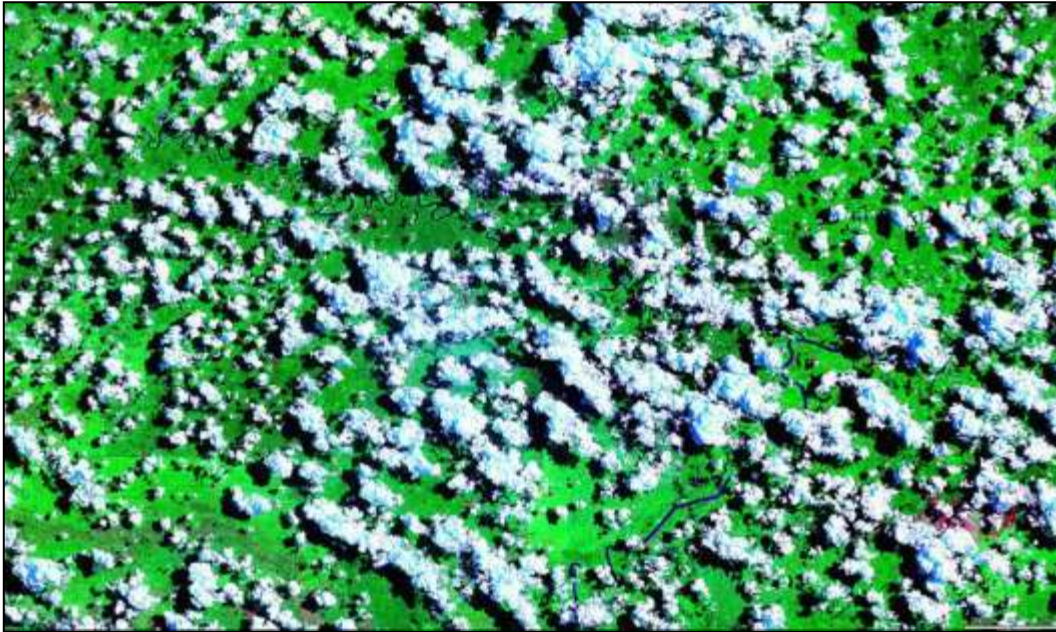
- Optical
- Radar
- Digital Elevation Model (DEM)







## Optical (passive sensing)

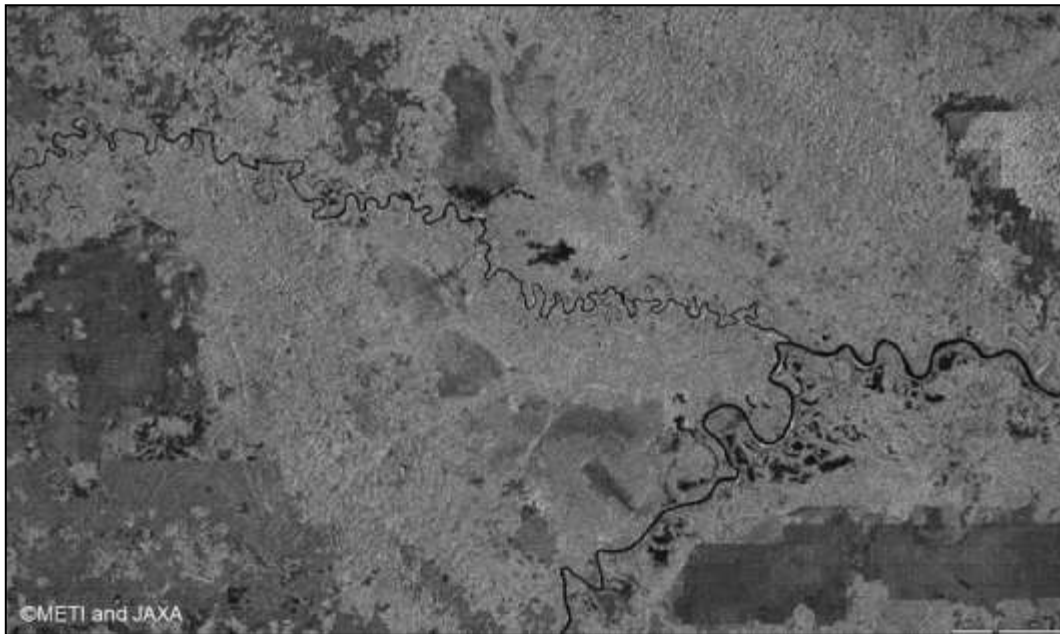


- Visual spectrum
- Used since the 1970's
- Cloud/atmospheric issues
- Used for mapping surface features
- Resolution 30cm - 30m





## Radar (active sensing)



Same area as previous image

- Images texture, not light
- Images both night and day
- Variety of wavelengths (e.g. X, C, L & P-bands)
  - 'Sees' through cloud
  - Longer wavelengths allow some canopy penetration
- Different polarizations highlight different features:
  - e.g. HV = good for lineament extraction and edge enhancement
- Resolution 1m downwards





## Visual v Spectral



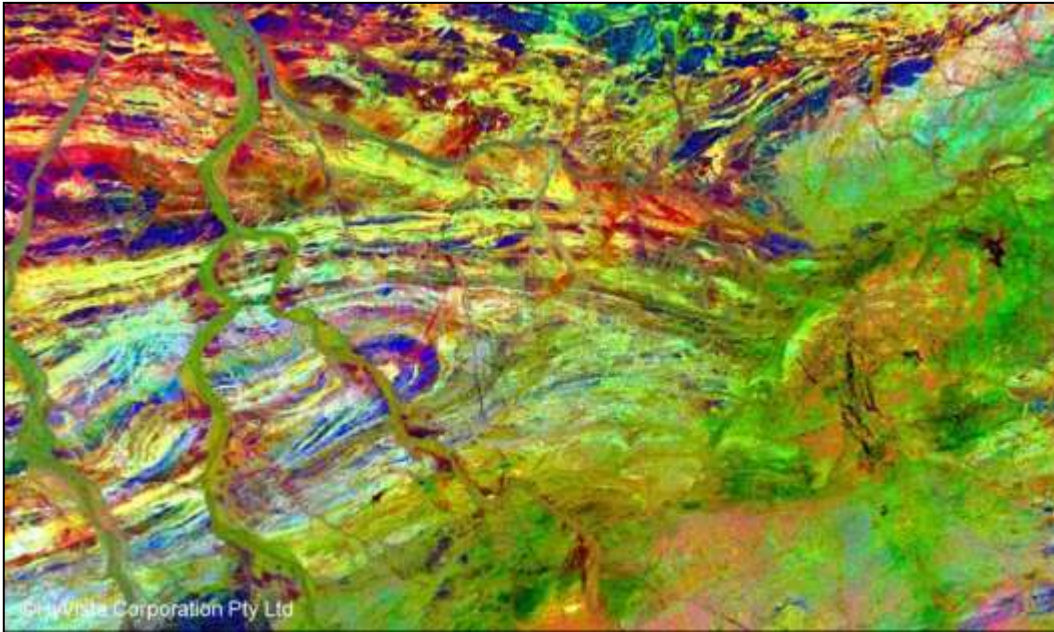
- Natural colour optical data
- High spatial resolution (pixel size), but low spectral resolution (only 3 or 4 spectral bands)
- Identifying roads, land cover, fractures, faults, drainage...
- Cloud can be an issue







## Visual v Spectral

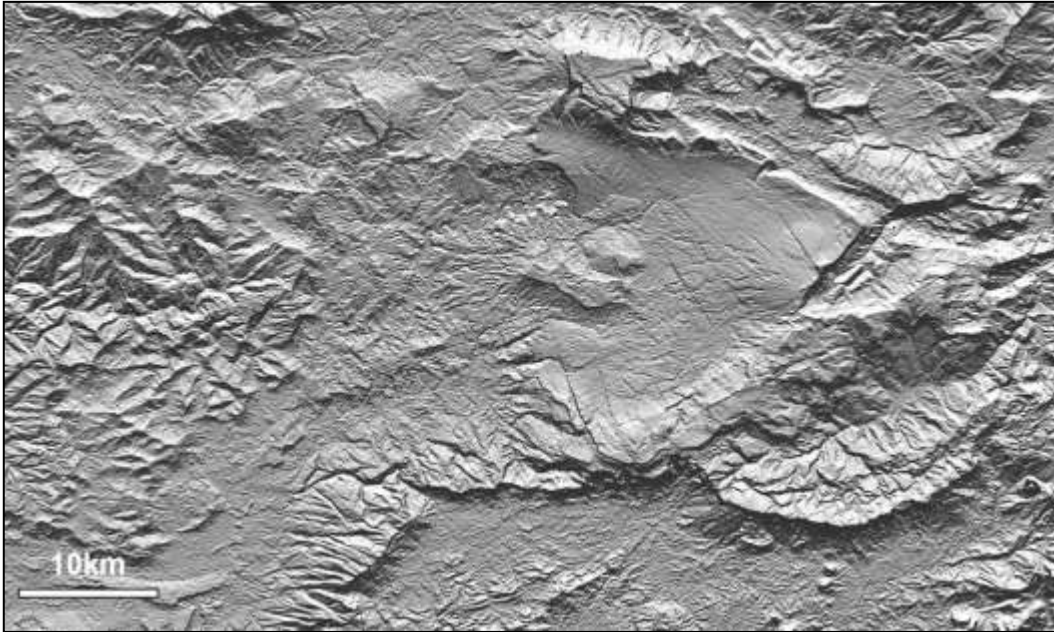


Same area as previous image

- Colour composite
- Lower spatial resolution (larger pixel size), but higher spectral resolution
- The more spectral bands, the more information can be extracted
- This example: bands selected to highlight lithologies/mineralogy
- Also possible to select bands to identify stressed vegetation (e.g. [linked to HC seepage](#))



# Digital Elevation Models (DEM's)



- Derived from optical, radar or LiDAR data
- Crucial for exploration projects
- Global DEM's typically 'off the shelf' products = rapidly available
- Resolution: 0.5m onwards



## Digital Elevation Models (DEM's)



SRTM (90m)



SRTM (30m)





## Digital Elevation Models (DEM's)



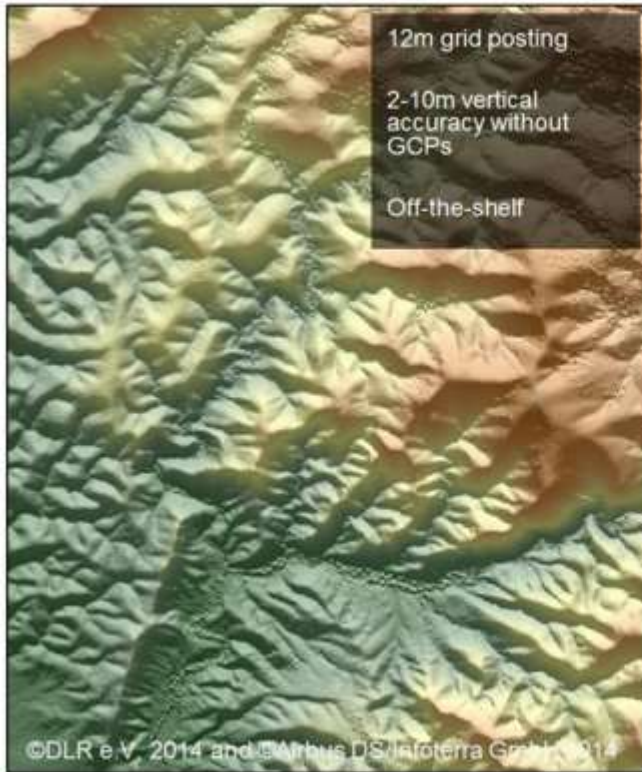
**ASTER GDEM (25m)**



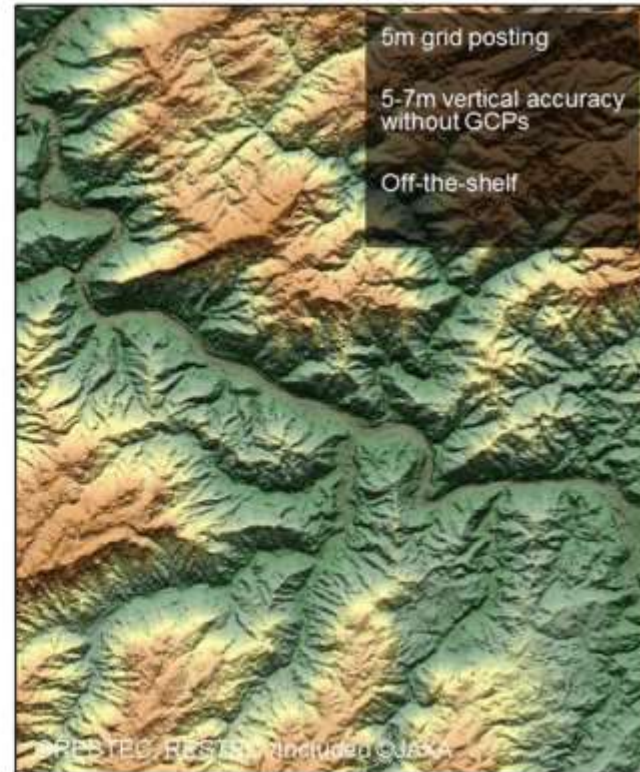
**ASTER GDEM (25m)**



# Digital Elevation Models (DEM's)



WorldDEM (12m)



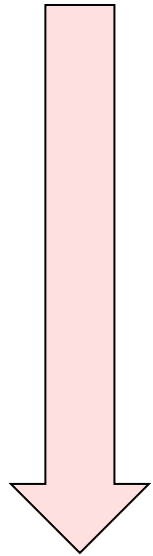
AlosWorld 3D (5m)



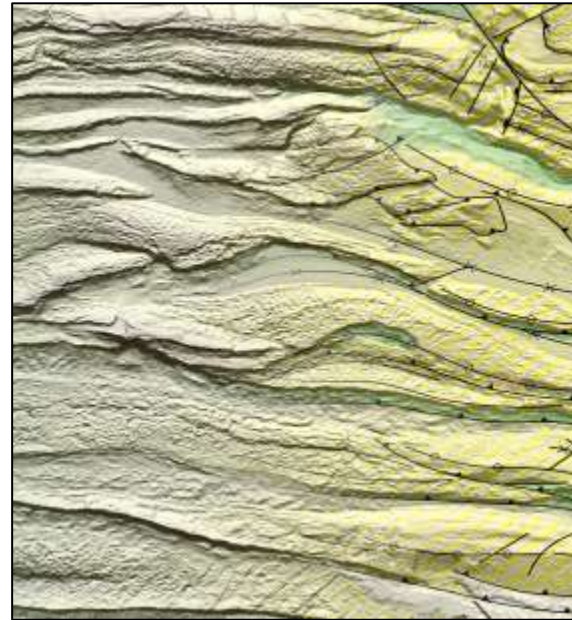
# Surface geological mapping



# Building the geological map



1. Satellite data
2. Review of public/client data
3. Structural mapping
4. Lithostratigraphic mapping
5. Element attribution
6. GIS delivery







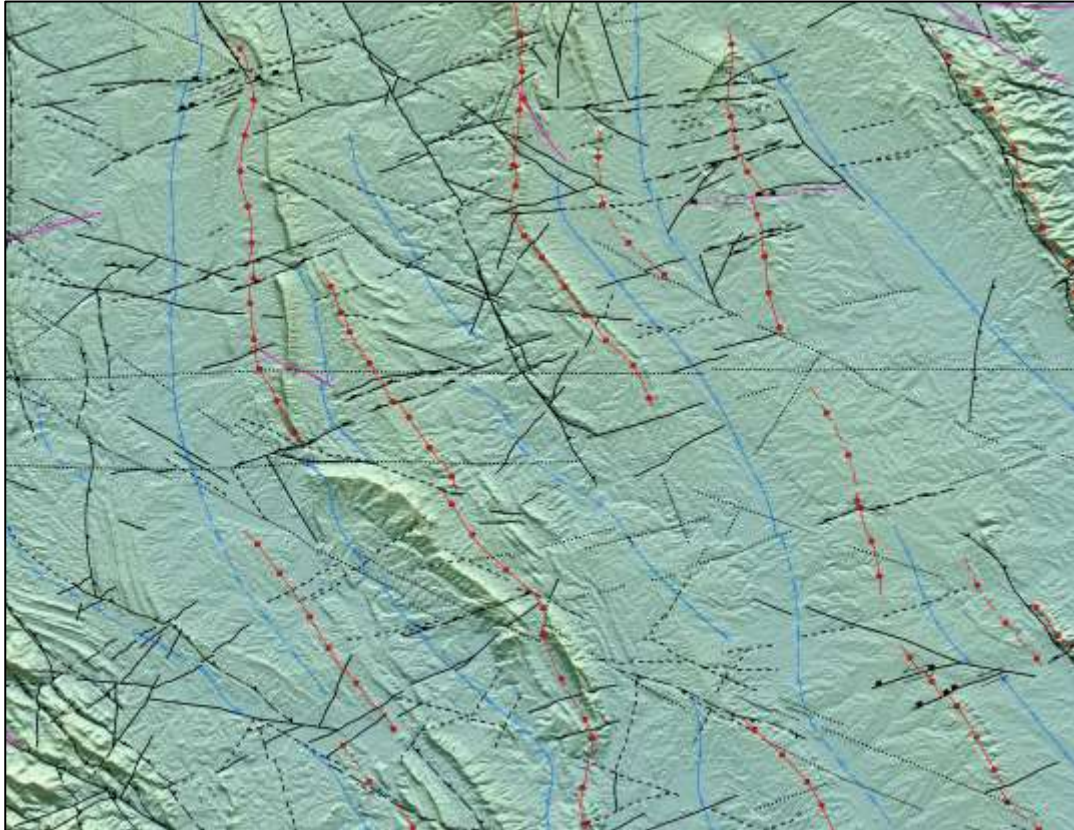
## From imagery...



- Satellite imagery



## From imagery...to information

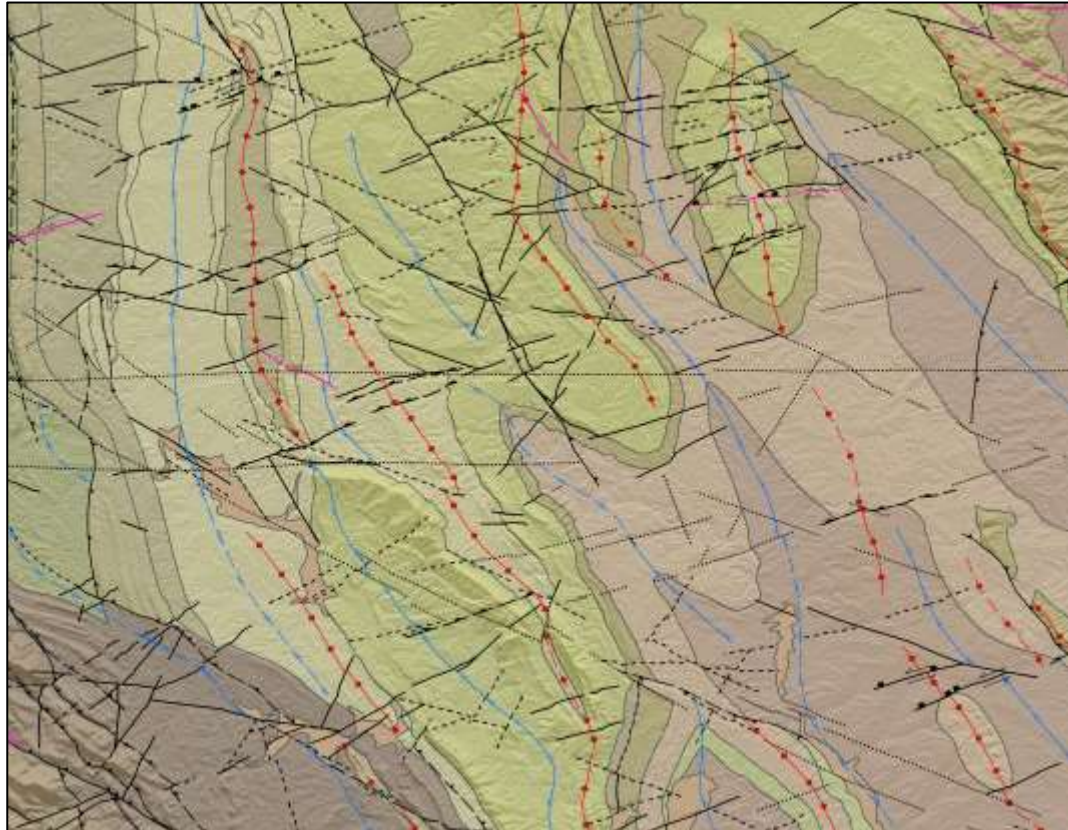


- Satellite imagery
- Structural interpretation





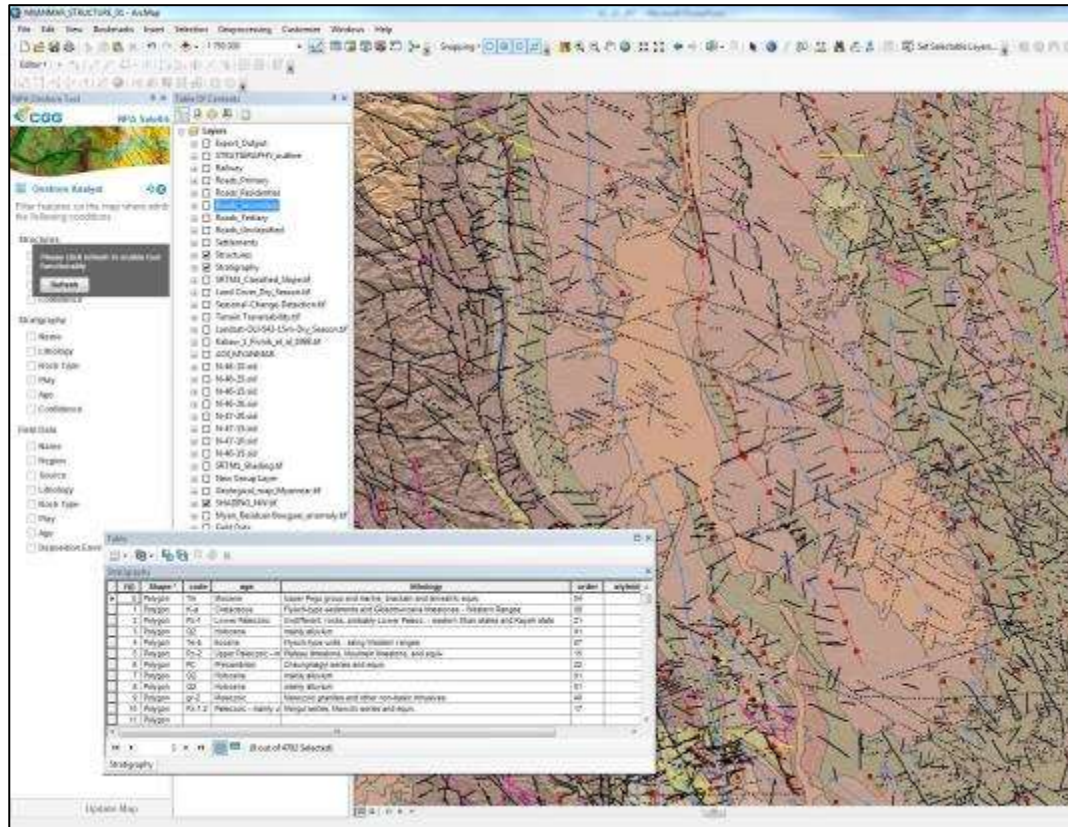
## From imagery...to information



- Satellite imagery
- Structural interpretation
- Lithostratigraphic interpretation



# From imagery...to information



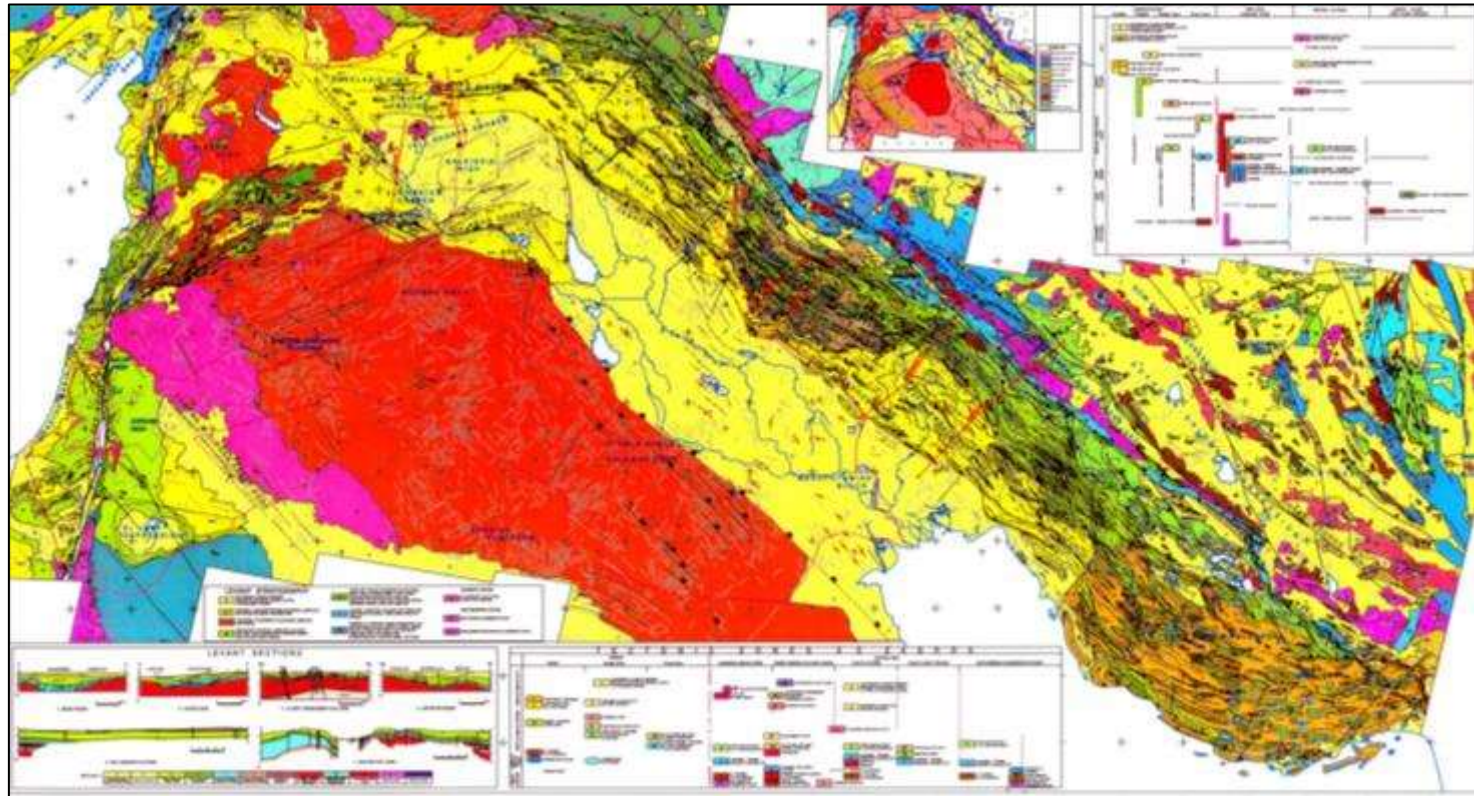
- Satellite imagery
- Structural interpretation
- Lithostratigraphic interpretation
- Fully attributed GIS dataset



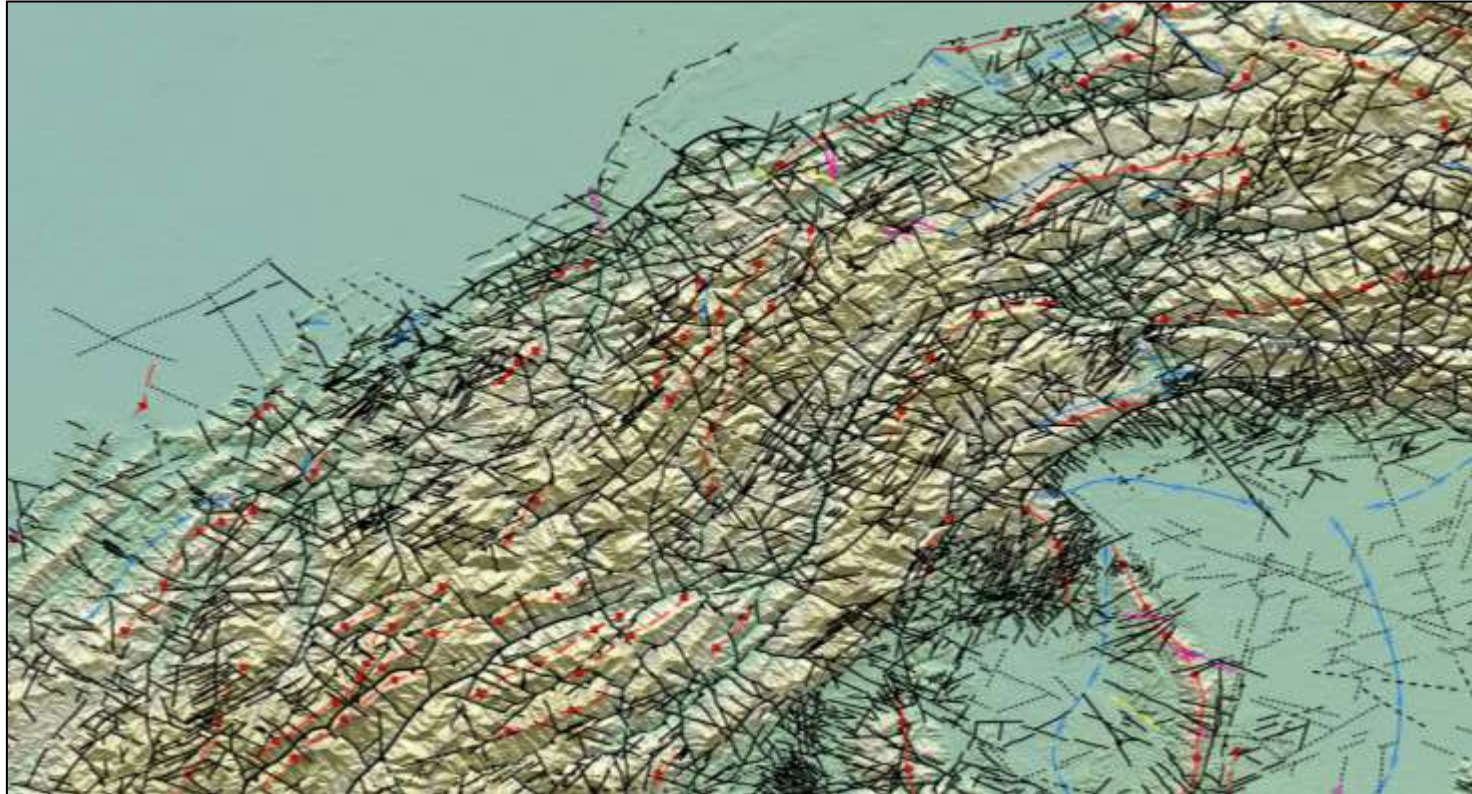




## Mega regional scale: Arabia (1:500,000+)



## Regional scale: Northeast Assam/North Myanmar structure (1:200,000)



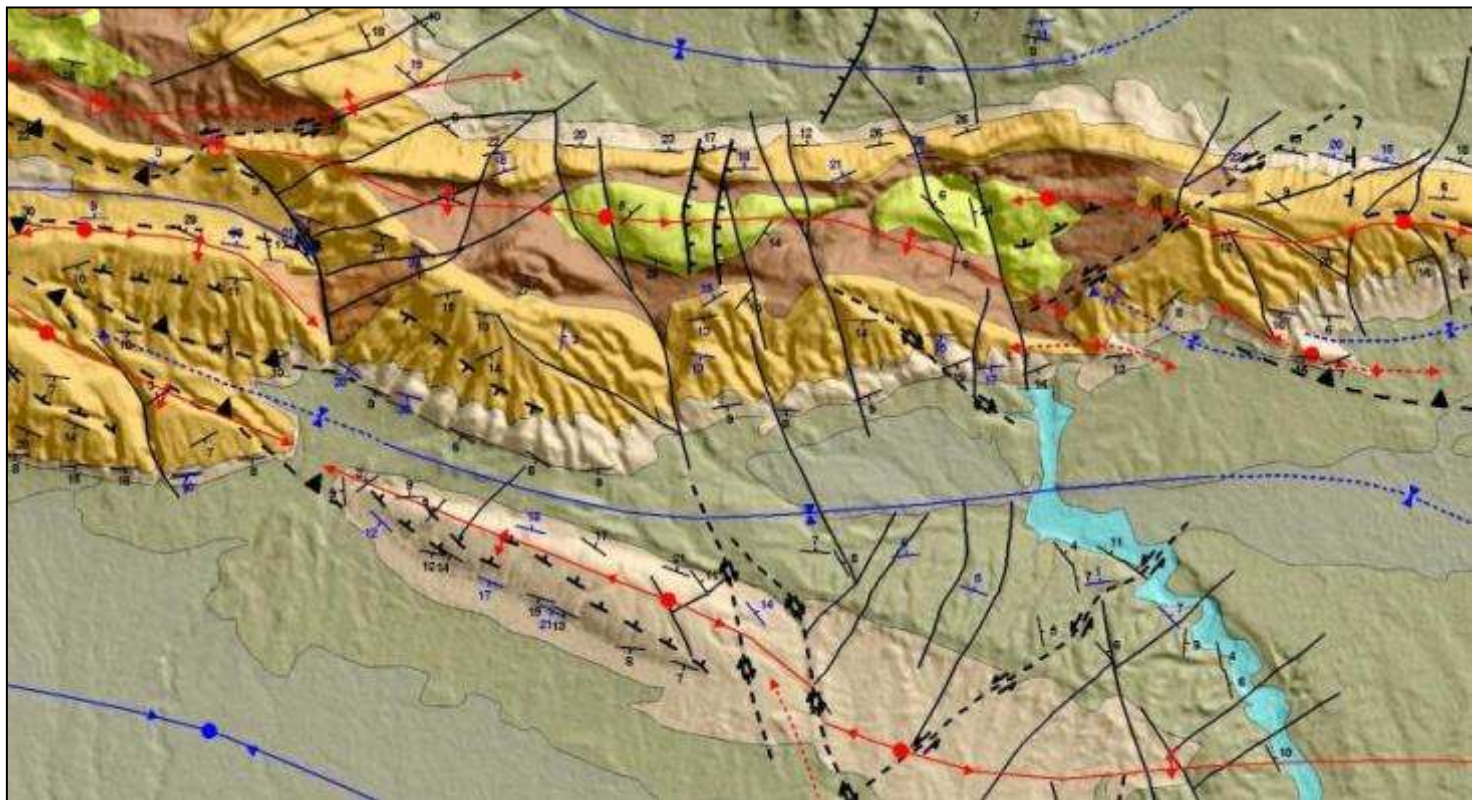




## License block scale: Salin Basin, Myanmar (1:100,000)



## License block scale: Zagros (1:10,000)







Surface to subsurface





# Structural cross-sections

- Better understand structural and stratigraphic histories
- Provide valuable insight prior to seismic acquisition
- Aid seismic interpretation
- Provide additional input for subsurface models
- Integrate with potential field data (AGG, Mag)
- Reduce risk and uncertainty





# Structural cross-sections

**Building the structural model starts with best DEM that can be afforded:**

- SRTM (Shuttle Radar Topography Mission) DEM (90m & 30m resolution)
- ASTER (25m resolution)
- SPOT (20m resolution) / SPOT 6/7 (8m resolution)
- AW3D (5m resolution)
- VHR (0.5m resolution)

**DEM's used to perform dip extraction, Midland Valley's Move for model building:**

- 3-point method used with detailed DEMs or slope/azimuth method
- Topographic profiles, dips and formation picks transferred to Midland Valley's Move package for dip domain and section construction



## Structural cross-sections: dip extraction from DEM's



- Satellite imagery  
(DEM and optical data)



## Structural cross-sections: dip extraction from DEM's



- Satellite imagery (DEM and optical data)
- Manually pick three points on a single bedding plane



## Structural cross-sections: dip extraction from DEM's

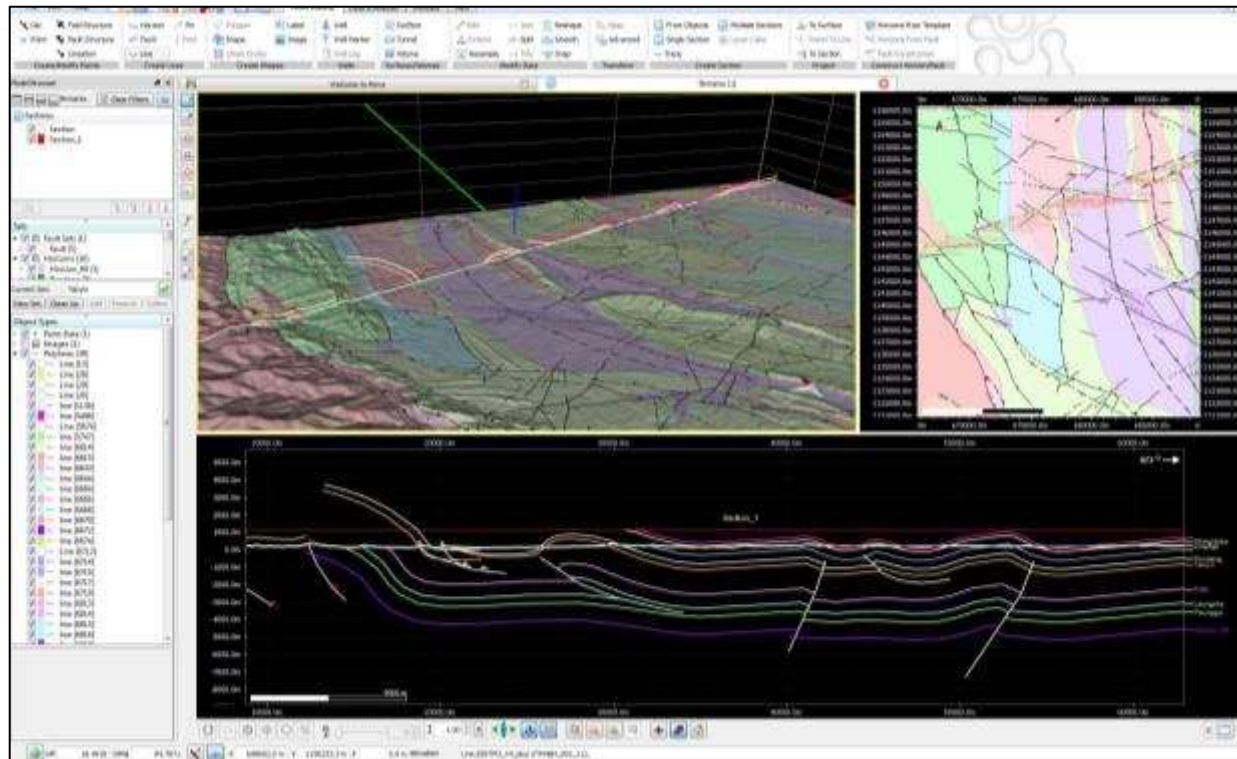


- Satellite imagery (DEM and optical data)
- Manually pick three points on a single bedding plane
- Three-point algorithm automatically generates strike/dip





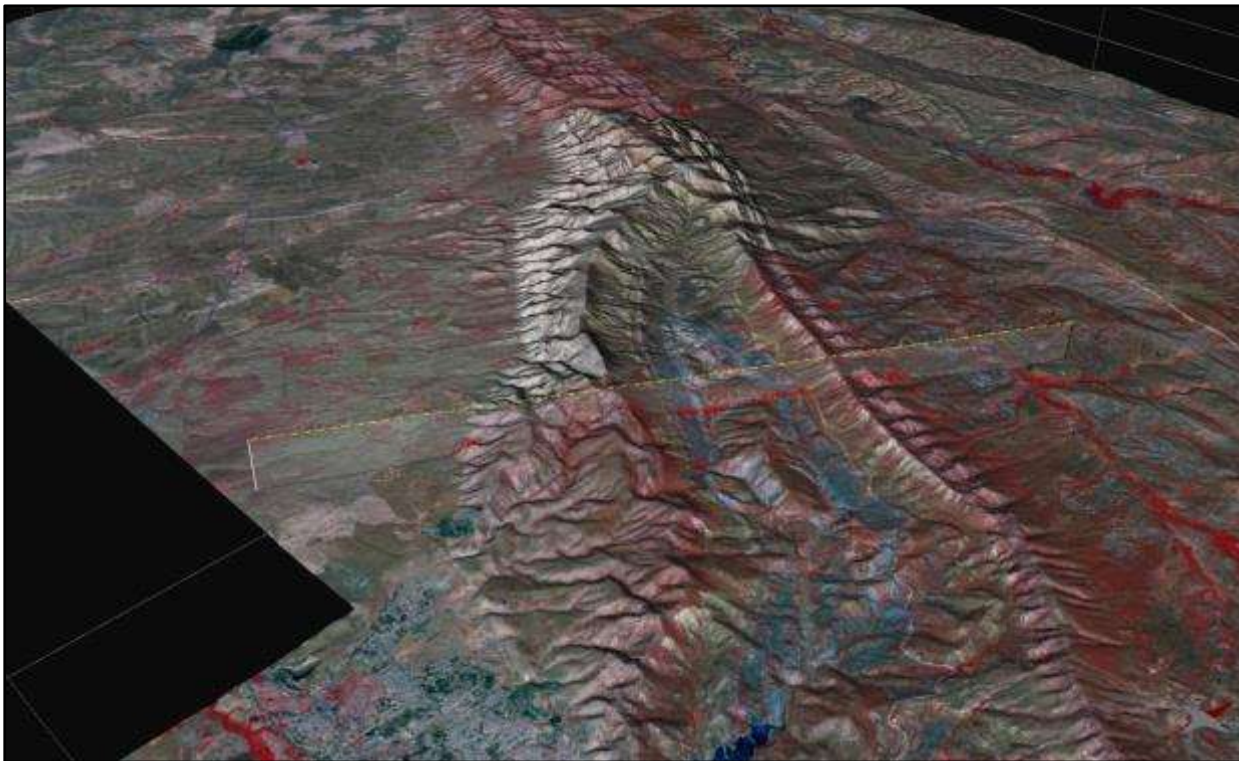
# Structural cross-sections: modelling into the subsurface



- Dips
- Topographic profile
- Formation picks



## Structural cross-sections: modelling into the subsurface

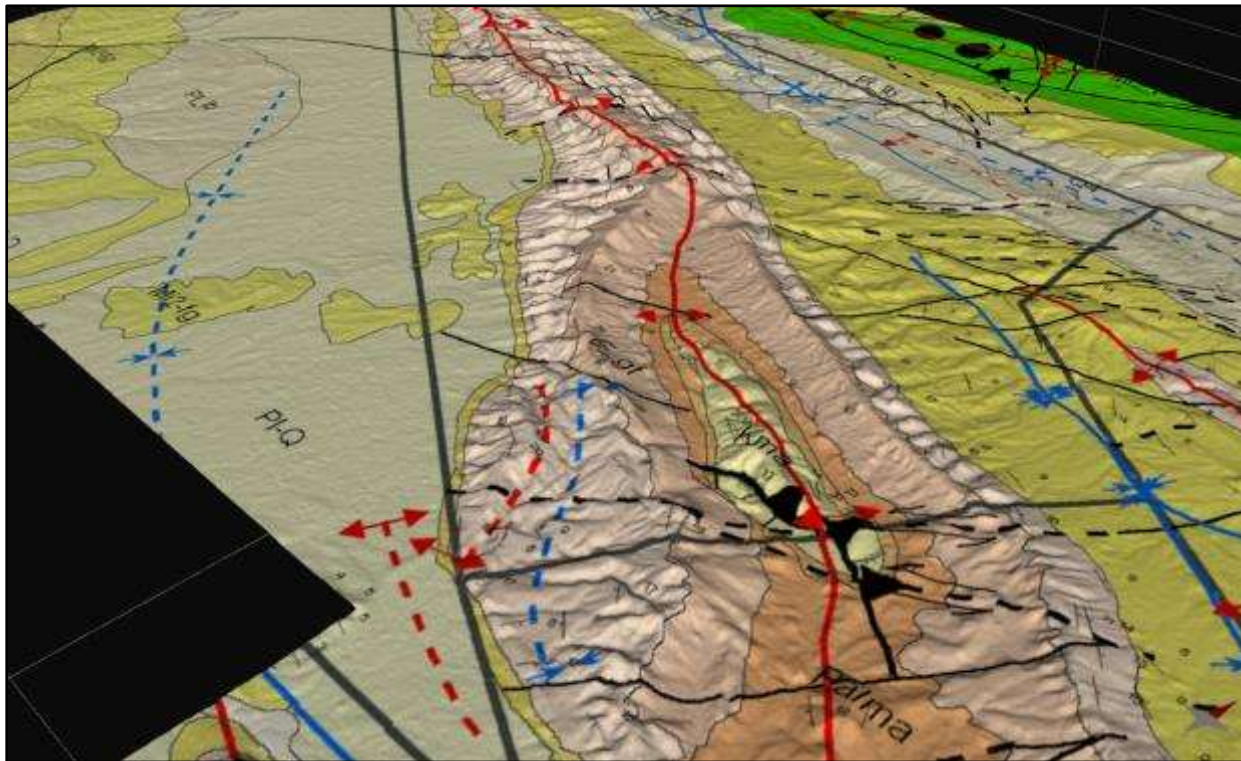


Integrate:

- Seismic/Well data
- Field data
- Grav. / Mag.



## Structural cross-sections: modelling into the subsurface



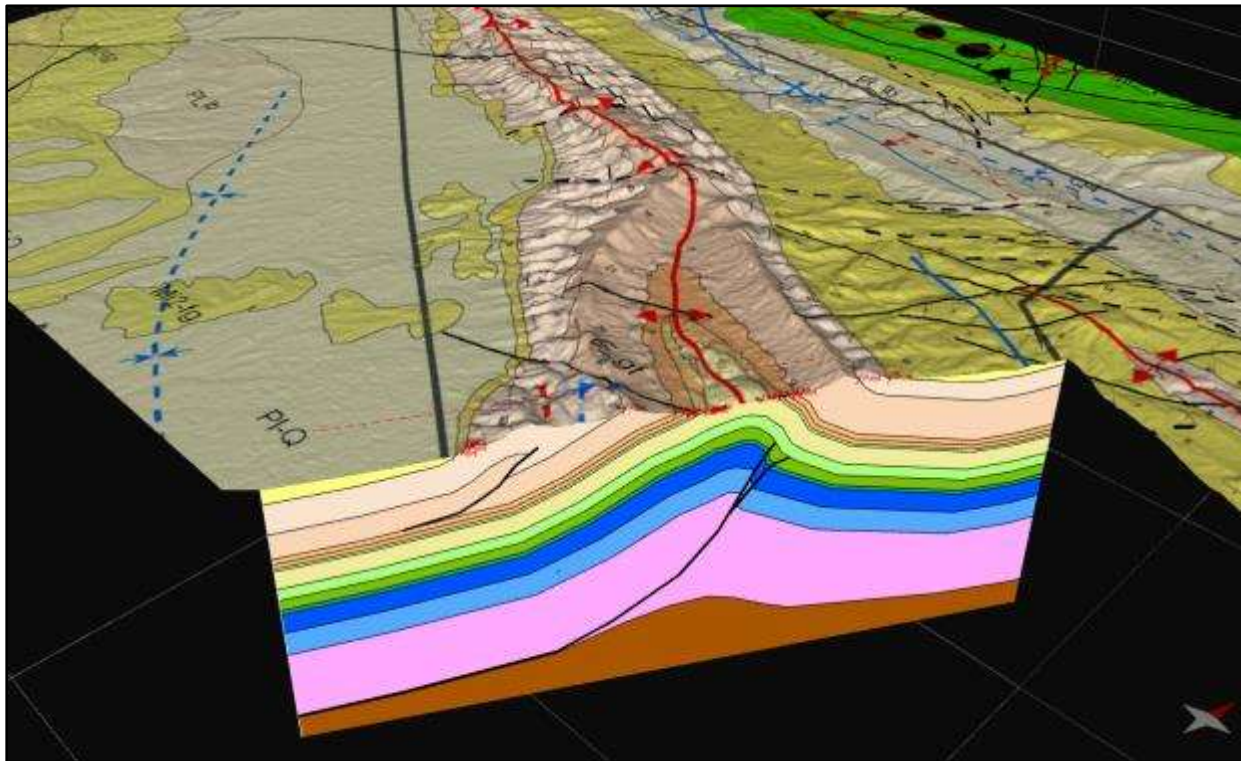
Integrate:

- Seismic/Well data
- Field data
- Grav. / Mag.





## Structural cross-sections: modelling into the subsurface



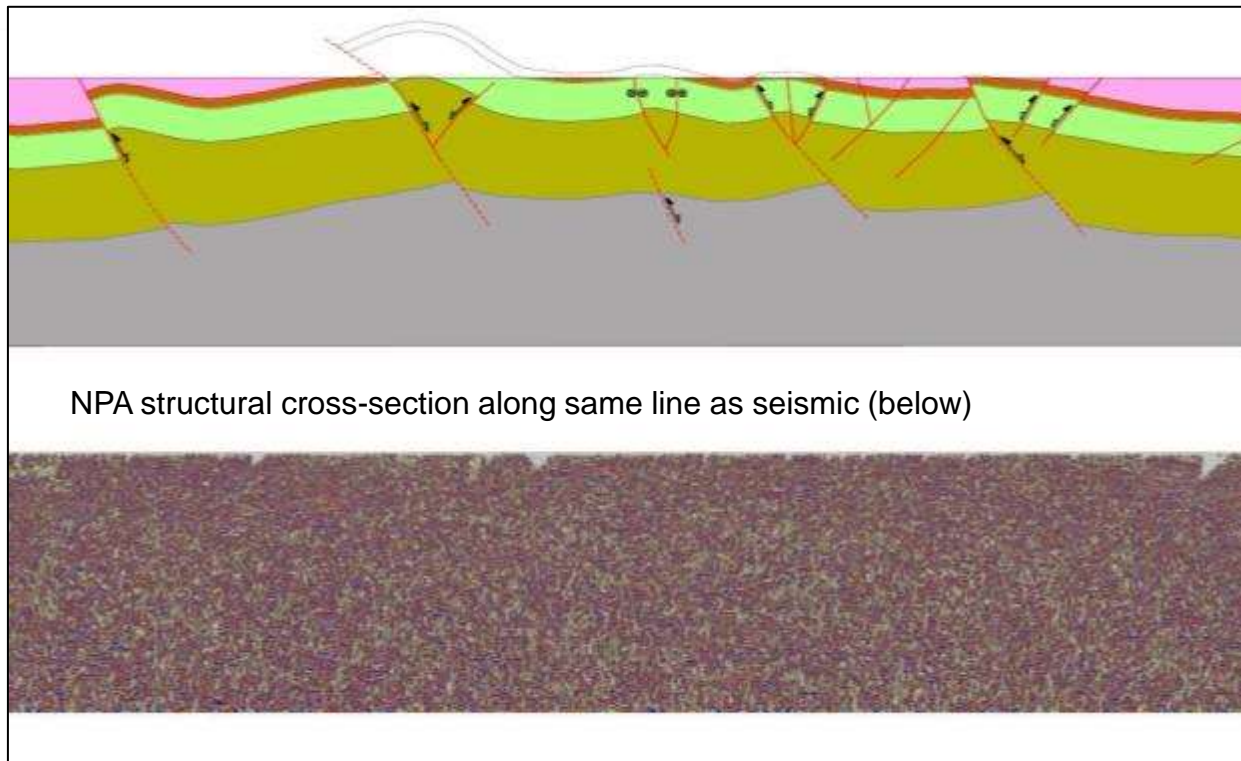
Integrate:

- Seismic/Well data
- Field data
- Grav. / Mag.





# Structural cross-sections: modelling the subsurface

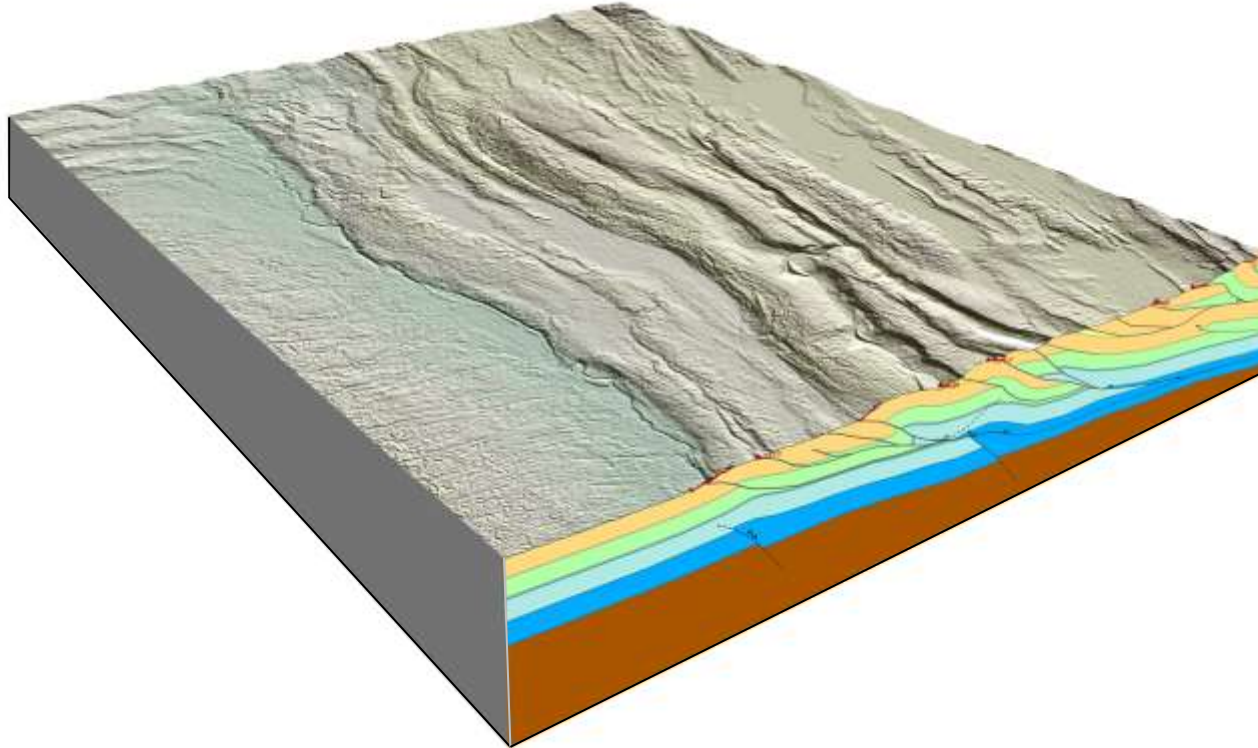


Integrate:

- Seismic/Well data
- Field data
- Grav. / Mag
- Aids seismic interpretation
- Provides geological insight to inversion models



## Transects in fold and thrust belts



Experience in:

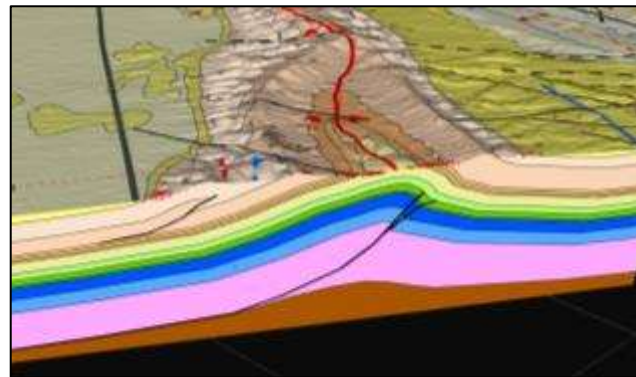
- Papua New Guinea
- Himalaya
- Zagros
- Carpathians
- Alps
- Pyrenees
- Anti Atlas



# Summary – from surface to subsurface

Using appropriate satellite data enables us to:

- Map lithology
- Map structures
- Distinguish lithologies, minerals and alteration
- Extract structural data
- Model the subsurface in 2D and 3D



The subsequent results:

- Improve understanding of the geology and structural evolution of an area  
...this is particularly valuable in areas of limited or no surface/subsurface data
- Reduce exploration risk/cost (focus more costly geophysical surveys)



# Airborne Gravity Gradiometry

**FALCON AGG**

**CASE STUDY from the Fitzroy Trough, onshore Canning Basin**

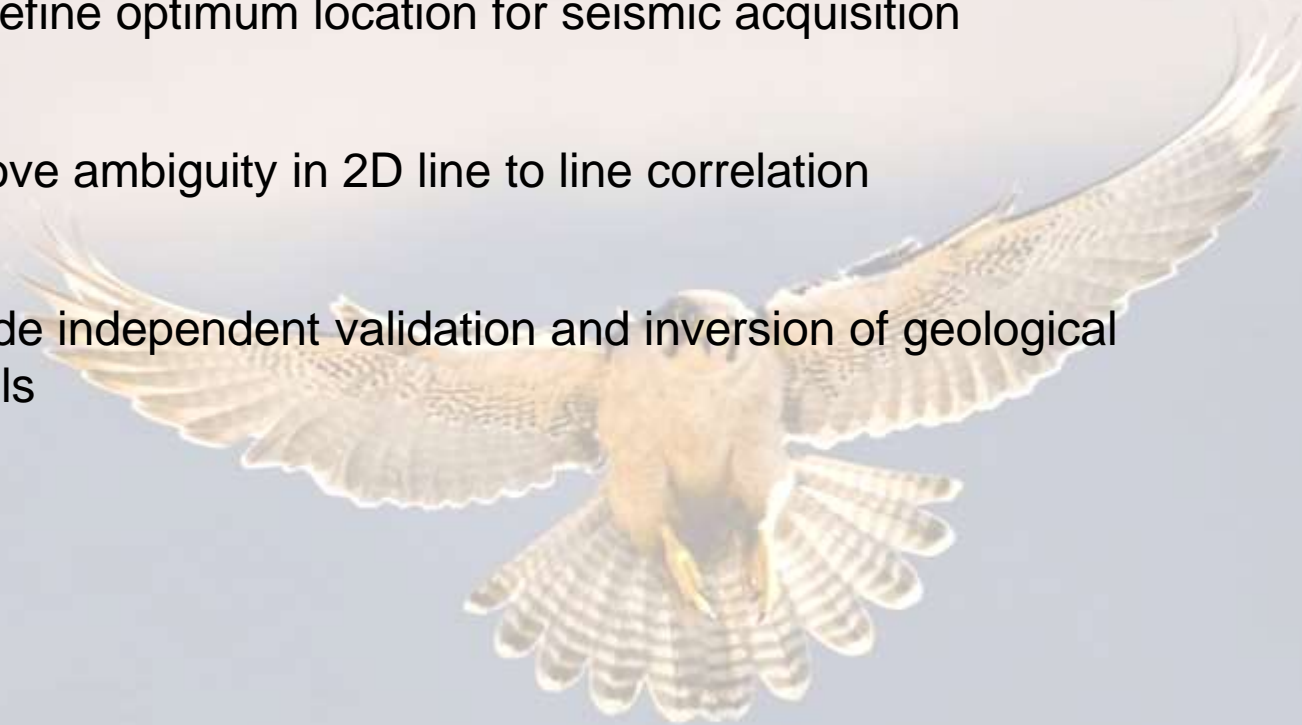




# Introduction

## FALCON® AGG

- Will define optimum location for seismic acquisition
- Remove ambiguity in 2D line to line correlation
- Provide independent validation and inversion of geological models





# FALCON® AGG – Canning Basin Case Study





## Survey Location



Survey Area:  
1,500km<sup>2</sup>

No outcrop



## Regional Setting – Tectonic Elements

Survey area sits north of the Broome Platform.

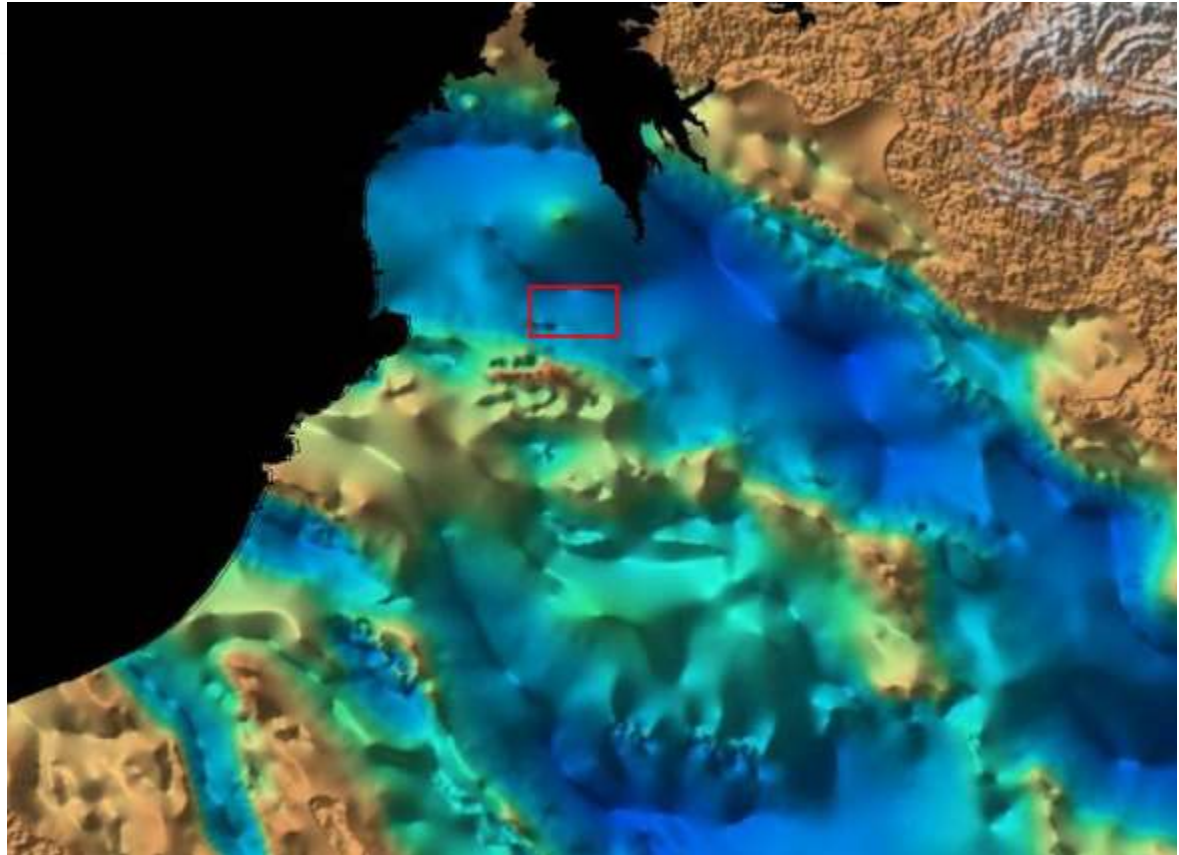
Expect to see WNW faults and terraces.





## Regional Setting – Depth to Basement

SEEBASE image showing interpreted depth to basement.

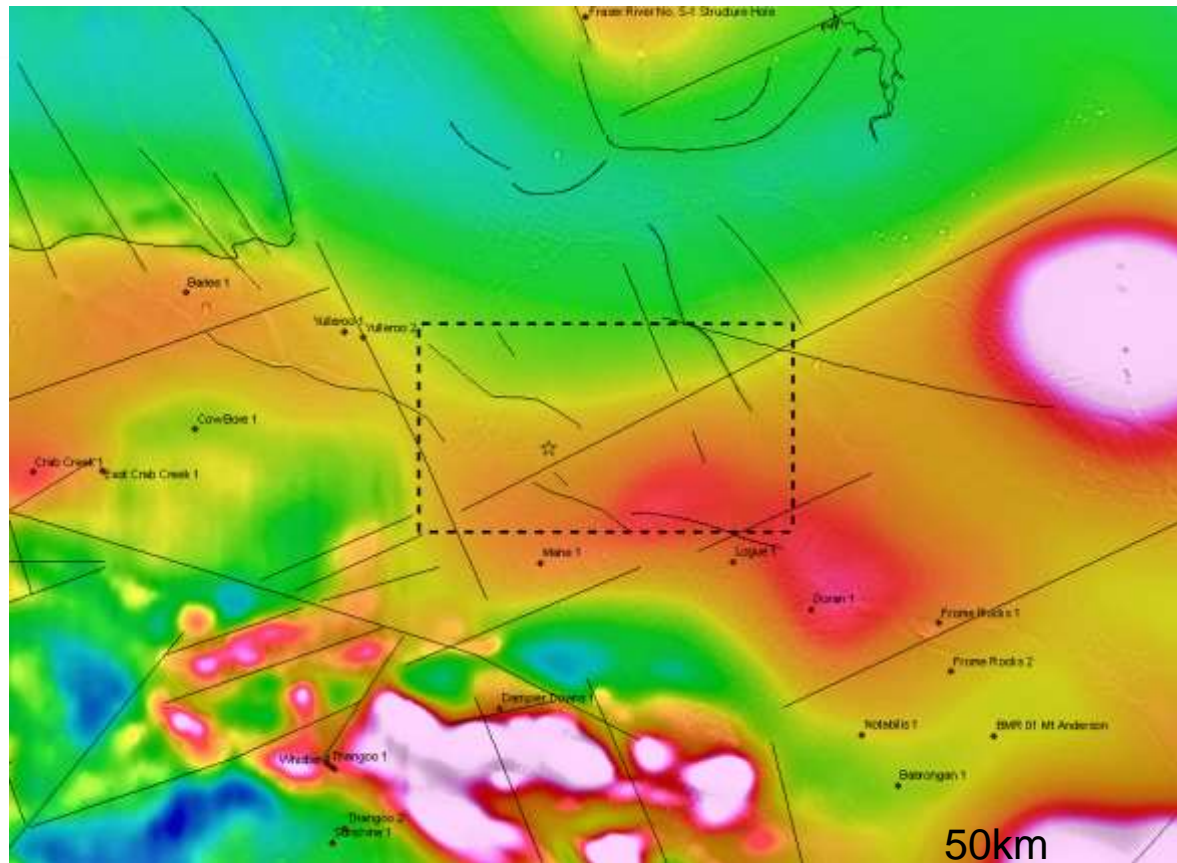


## Regional Magnetics & Lineaments

Magnetic RTP  
image with survey  
area marked.

Basic lineament  
interpretation  
shown.

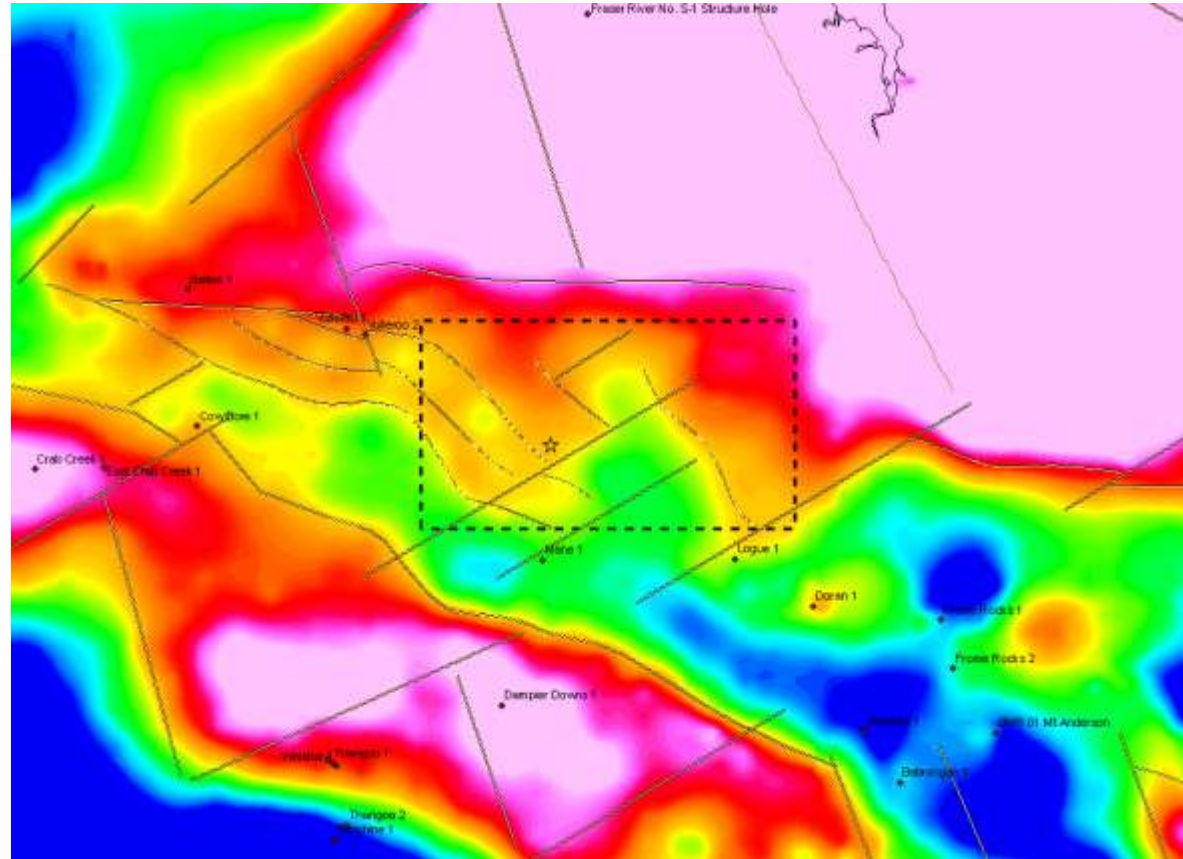
Smooth response  
indicative of deep  
basement.



## Regional Gravity & Lineaments

Regional gravity image with basic trend and lineament interpretation.

Again, the relative high in the south west interpreted to be the one of the terraces approaching the Broome Platform to the south.



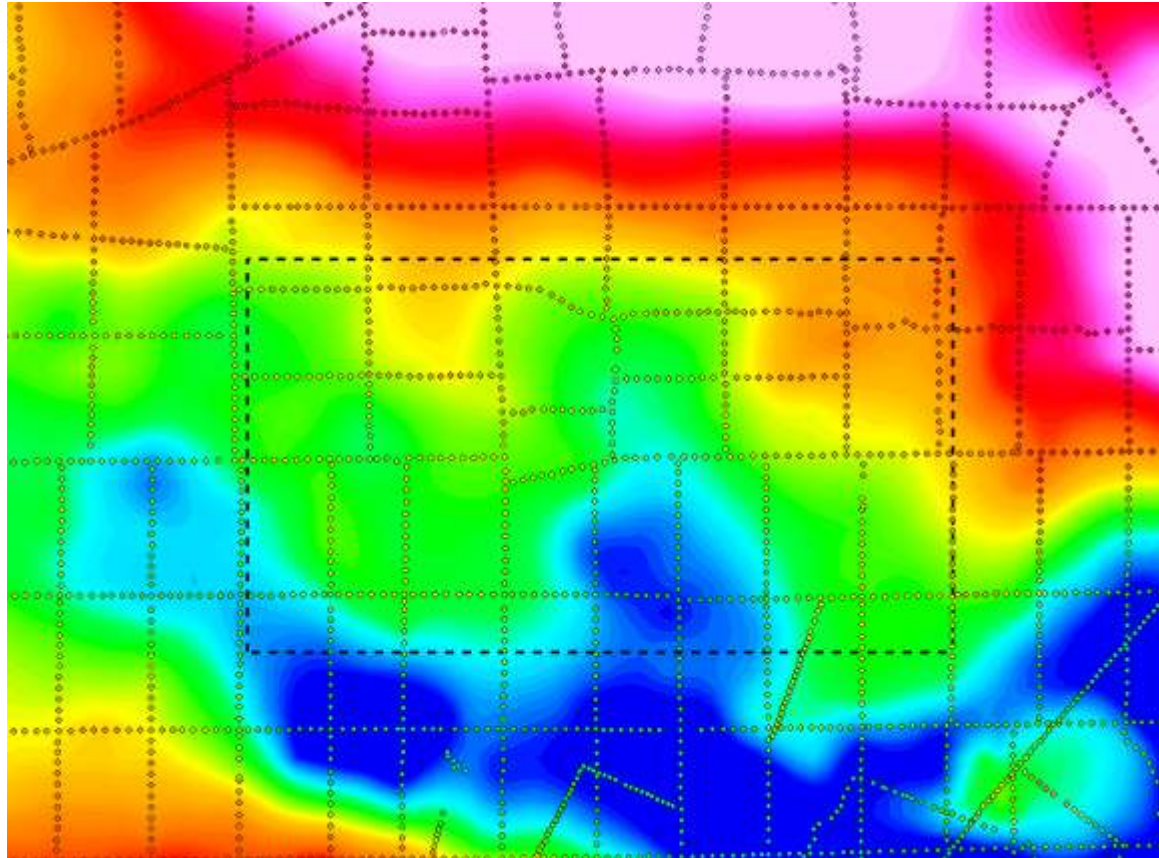


## Regional Gravity – Station locations

Gravity station location map, to give an idea of the quality of gravity data in the area.

Grid is essentially 10 x 6km with 1km stations.

Excellent regional dataset.



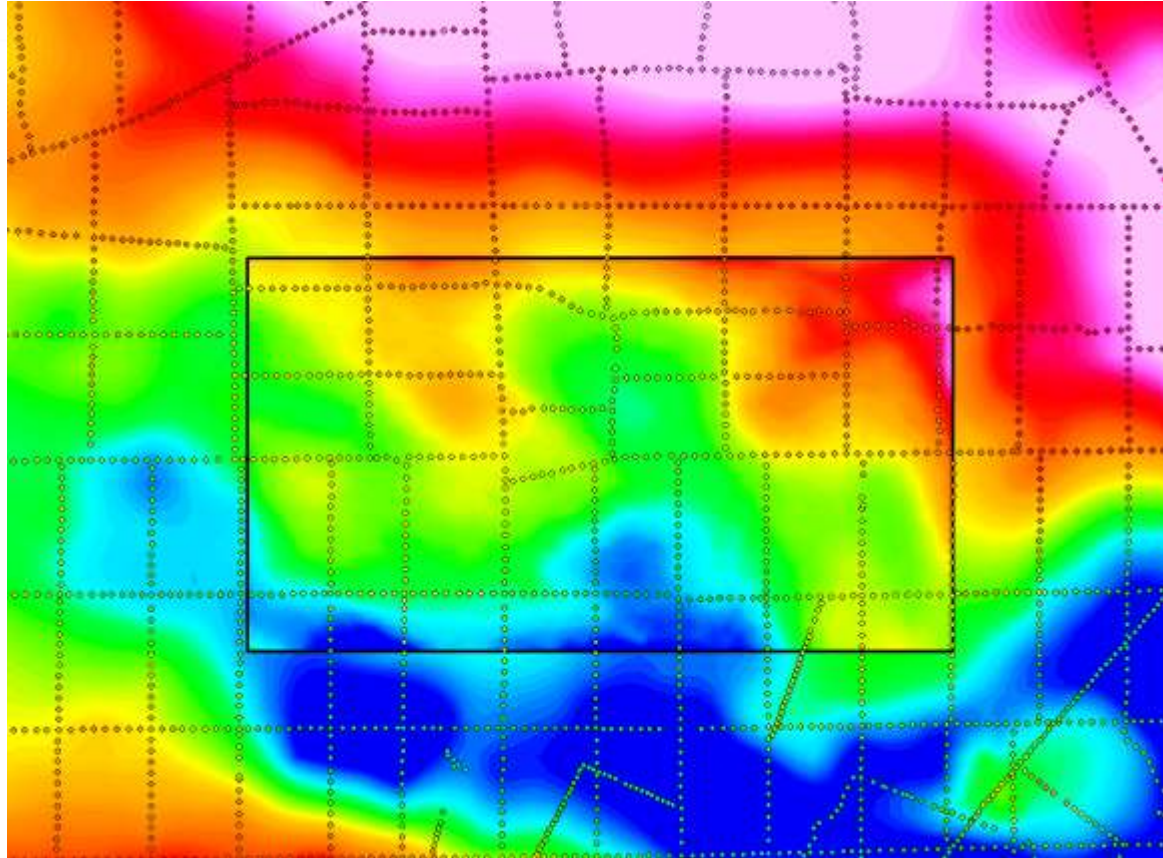


## Conformed $g_D$ with Regional Gravity

FALCON survey  
flown at 500m line  
spacing.

$g_D$  – (Vertical  
Gravity) from  
FALCON mimics  
regional data, with  
resolution  
improvements.

Conformed to  
regional trends for  
complete signal





## $G_{DD}$ with Regional Gravity

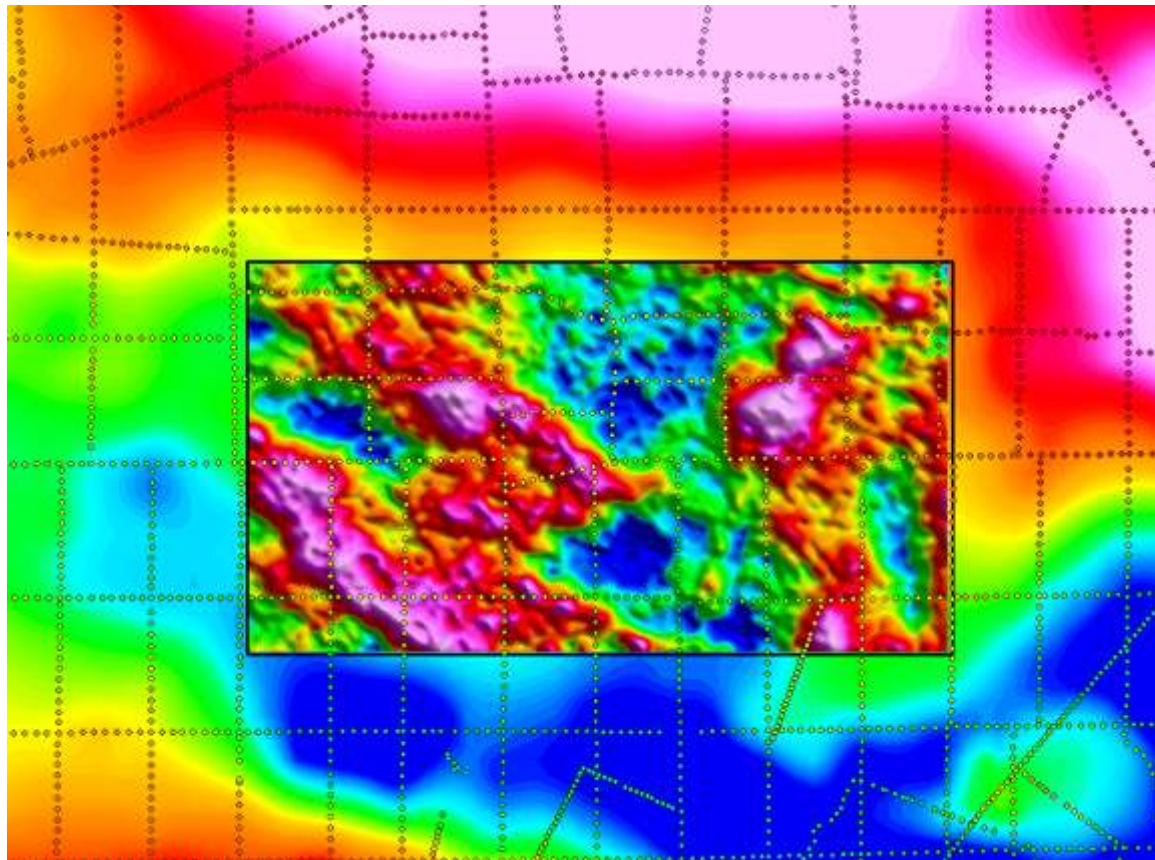
Gravity Gradients are what the Falcon system is actually measuring.

$G_{DD}$  – (Vertical Gravity Gradient) from FALCON Shows the uplift in resolution and detail.

~3000 line-km

500m line spacing

< 1 week to acquire

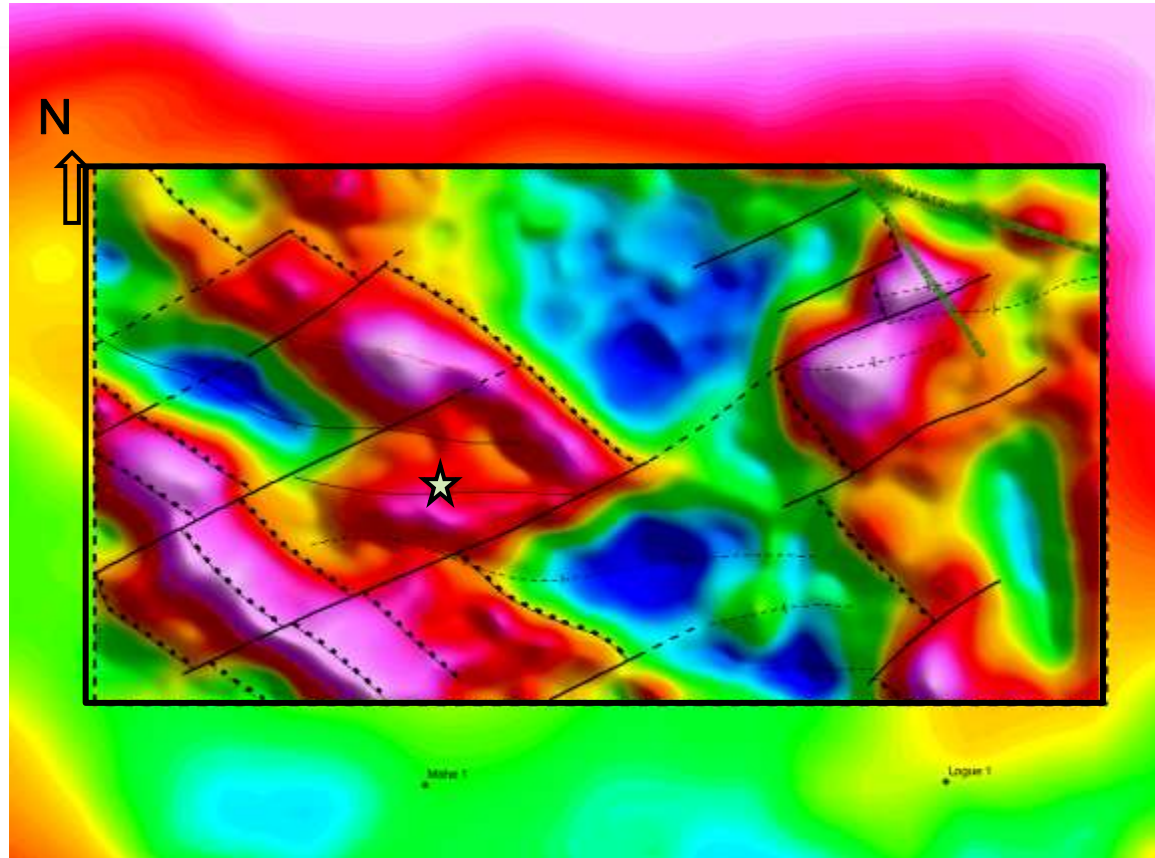


## Pseudo depth-sliced $G_{DD}$ & interpretation

Integrating the seismic information as well as the gravity gradiometry data allows a more detailed interpretation.

Deepest slice, responding primarily to dense dolomitised limestone at the reservoir level

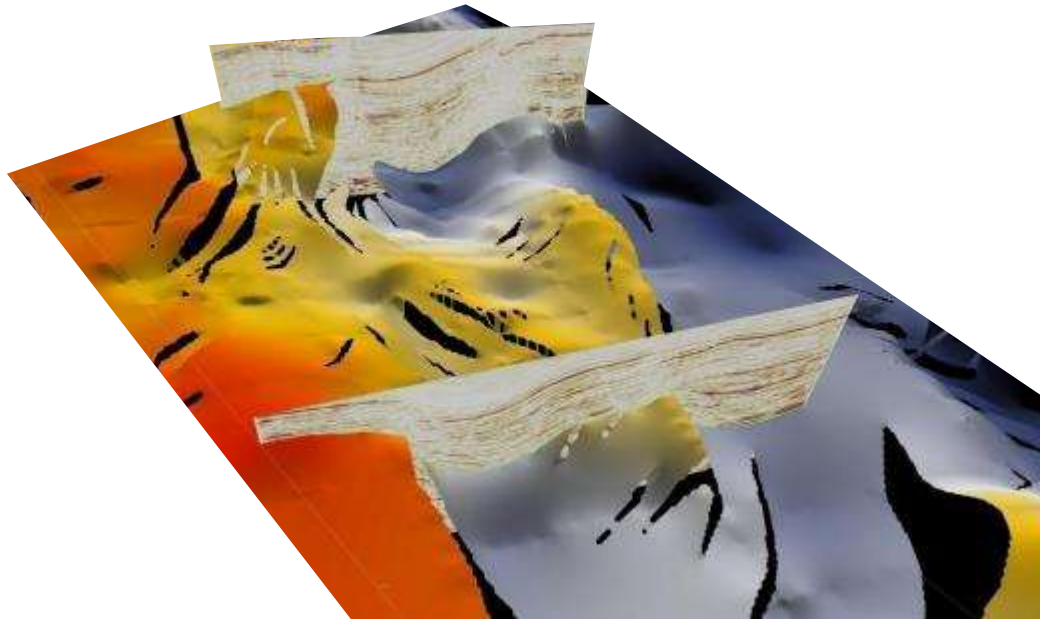
Ungani-1 location





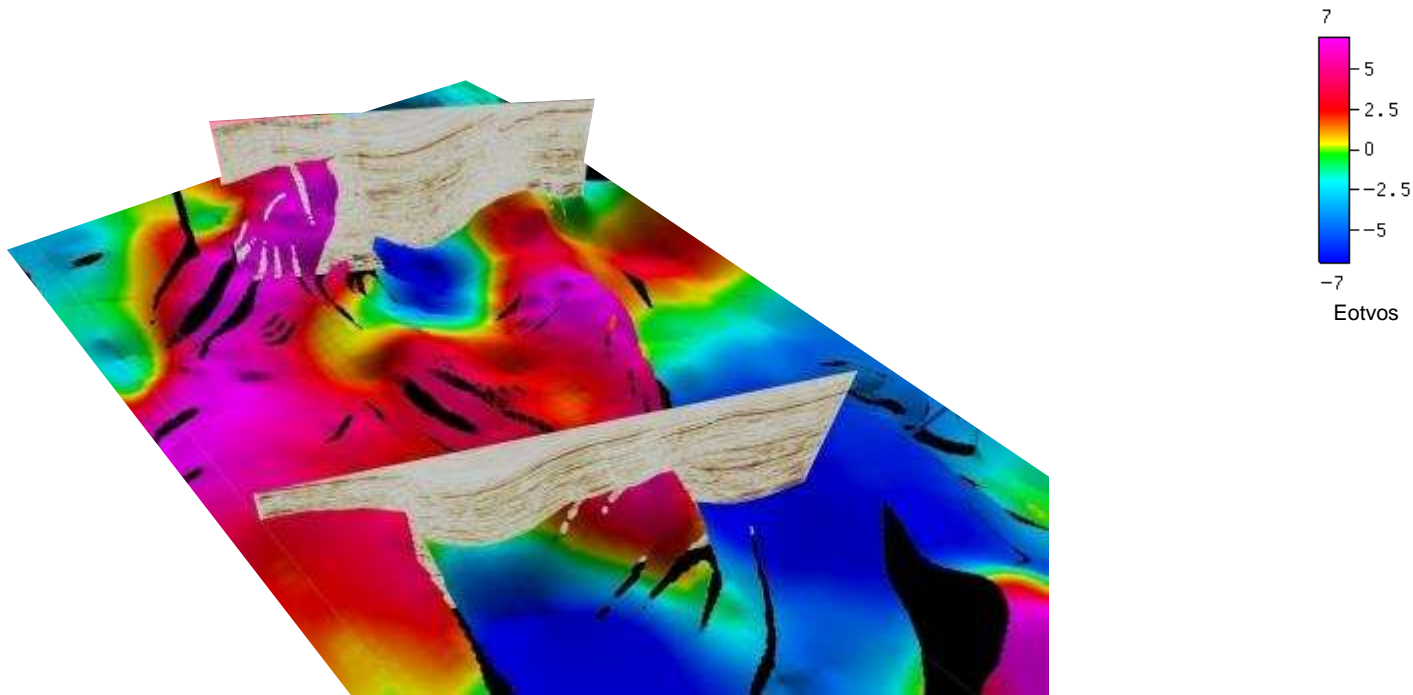


## Interpreted dolomitised limestone Surface





# FALCON $G_{DD}$ image (draped on surface)



# The Extra Dimension

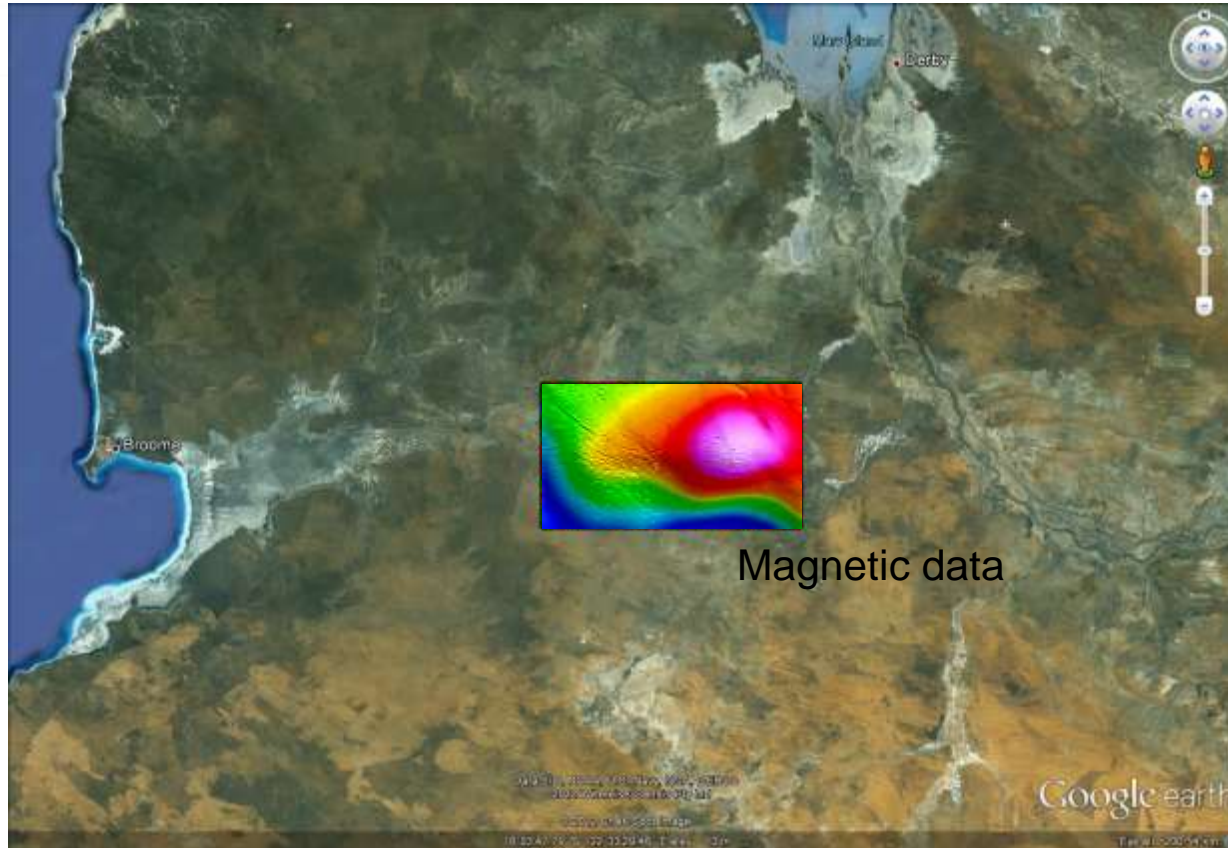
Seismic survey planning



## How do I effectively position seismic?



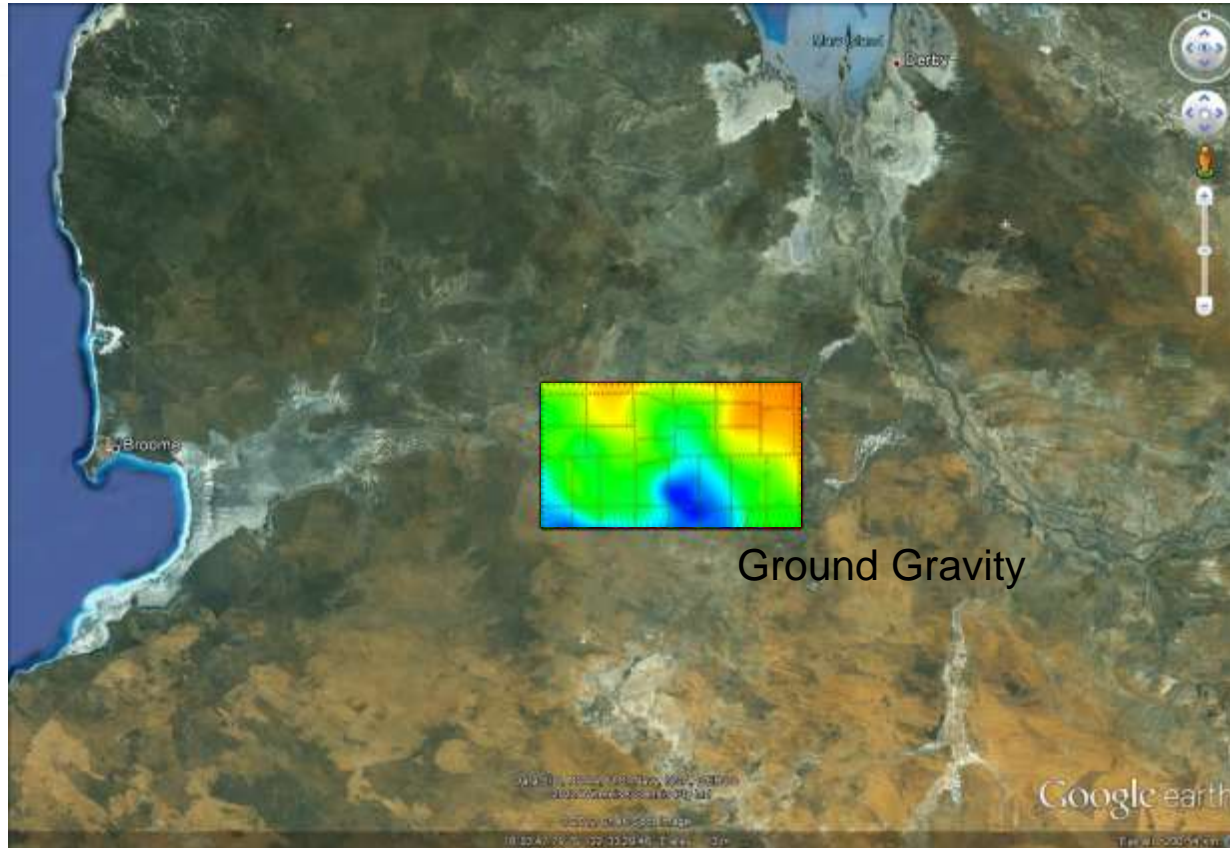
# How do I effectively position seismic?



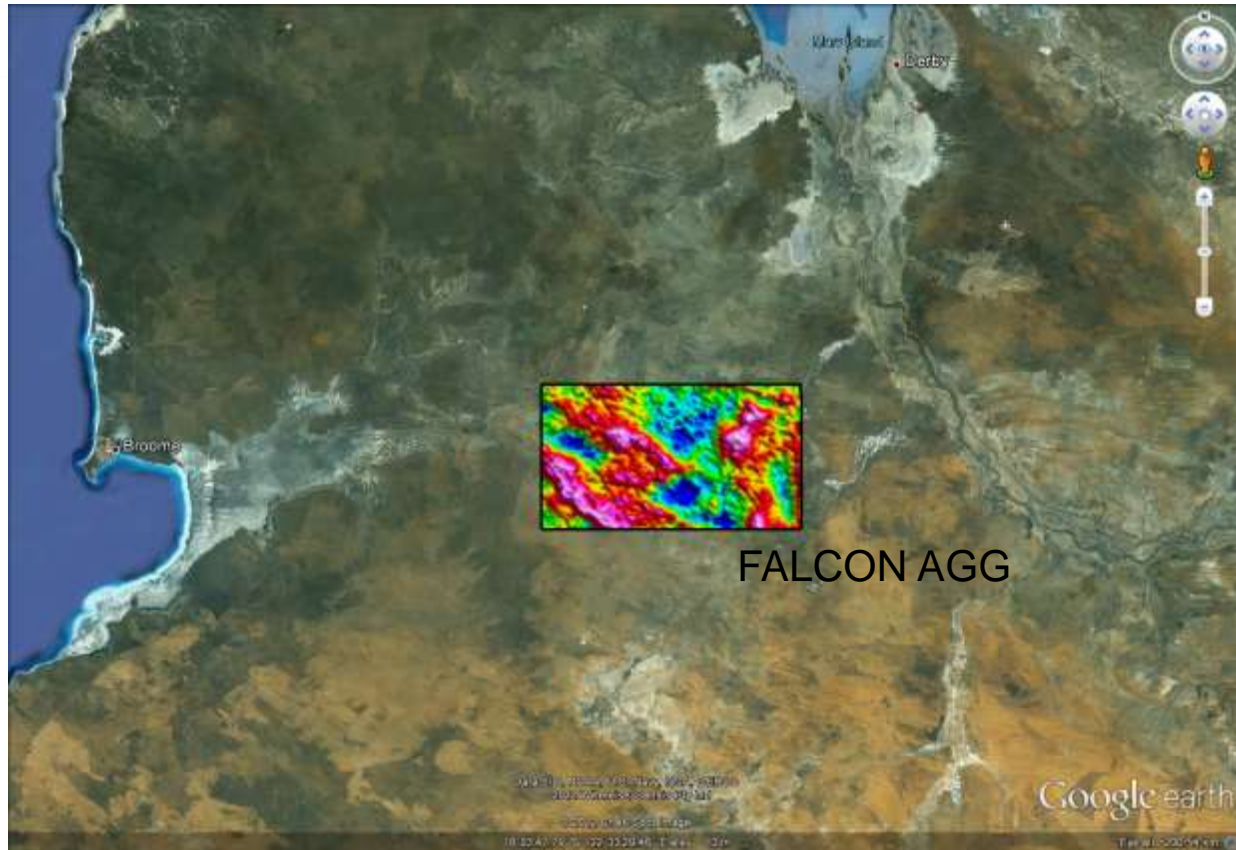




## How do I effectively position seismic?



# How do I effectively position seismic?

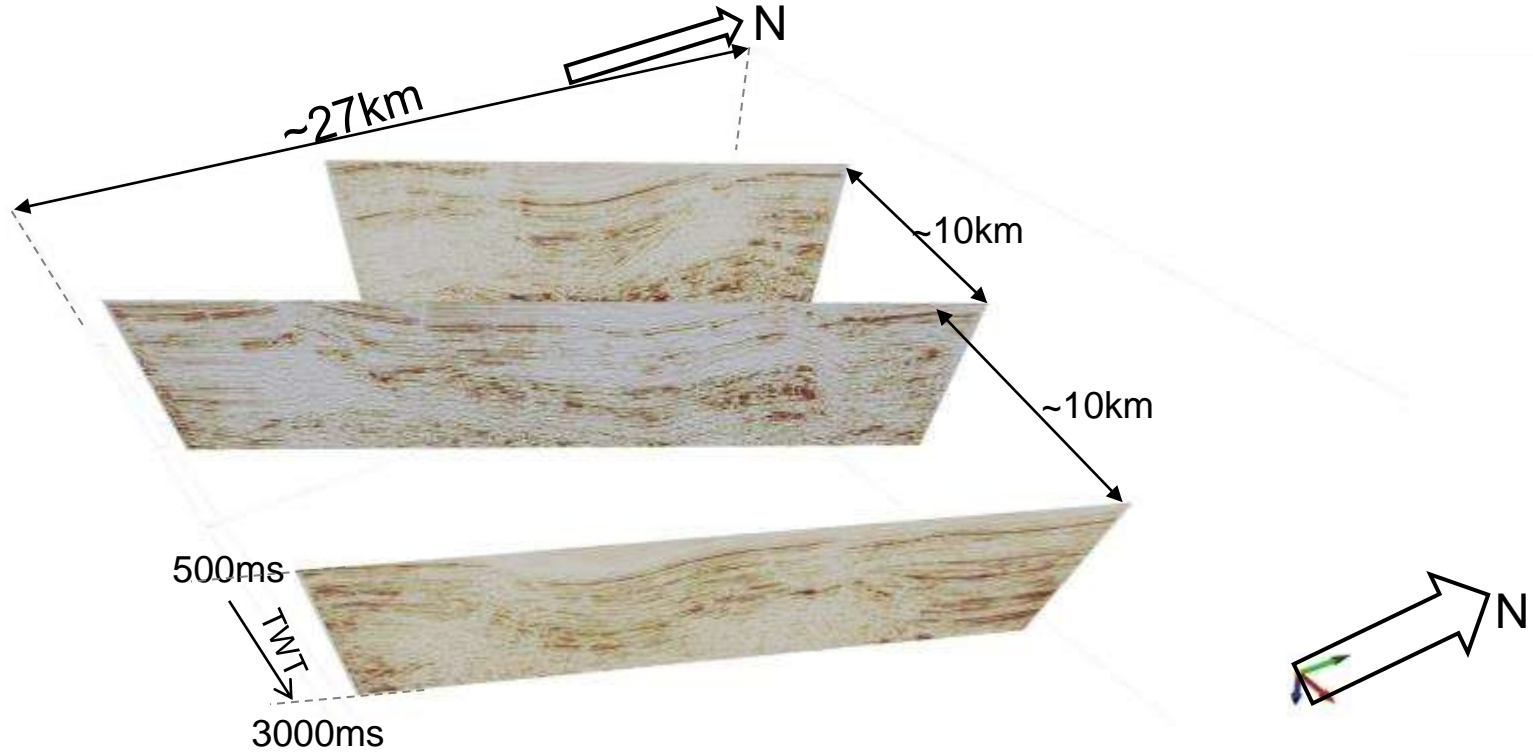


# The Extra Dimension

## 2D Seismic Interpretation



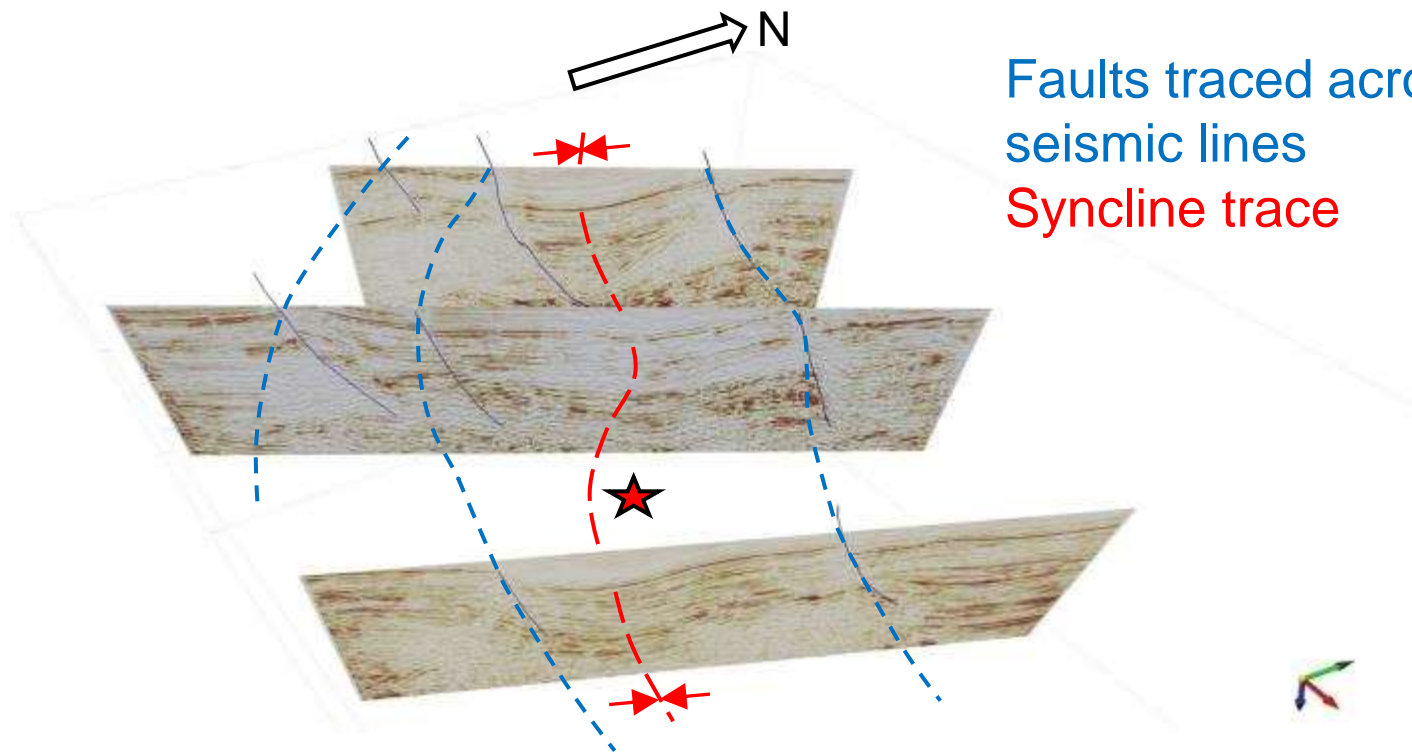
# Reconnaissance Seismic







## Basic interpretation



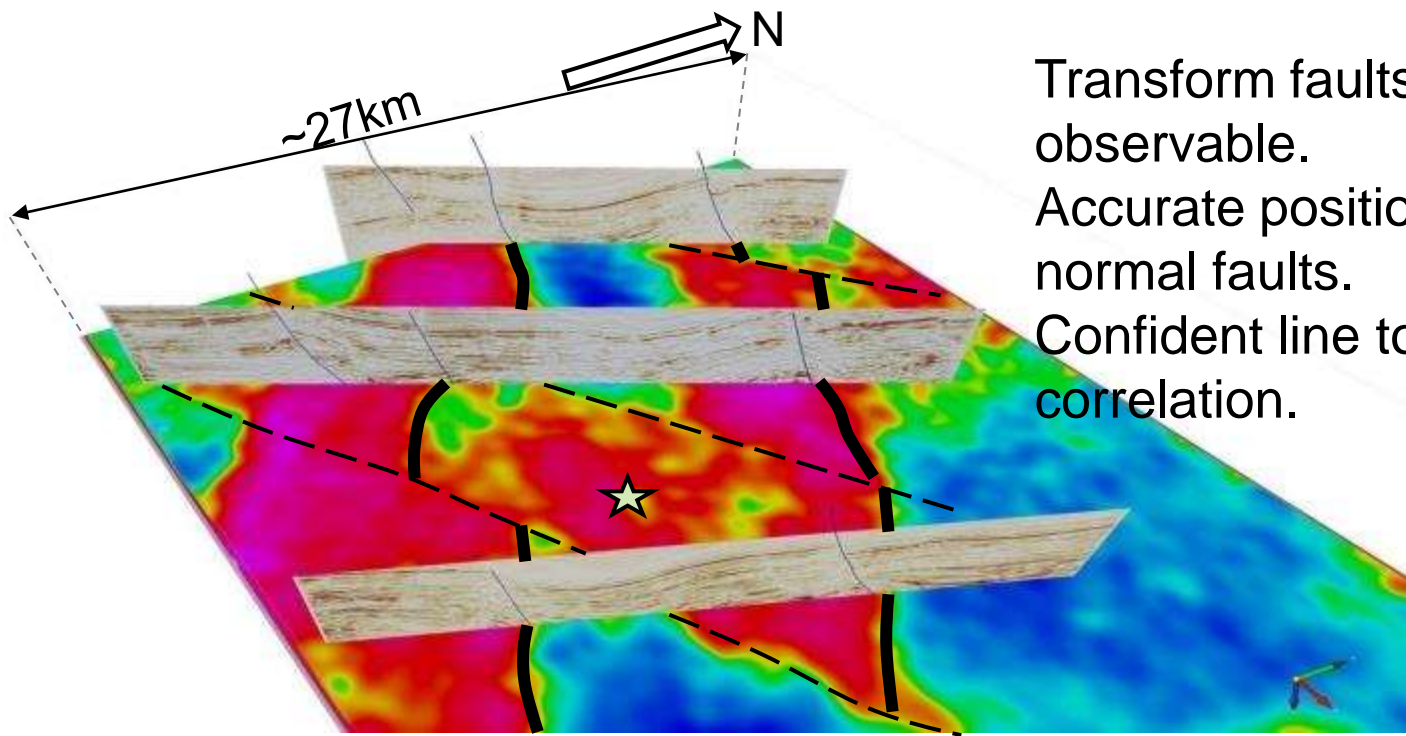
Faults traced across  
seismic lines

Syncline trace





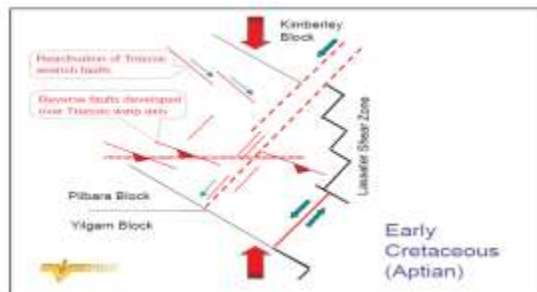
## Falcon AGG data



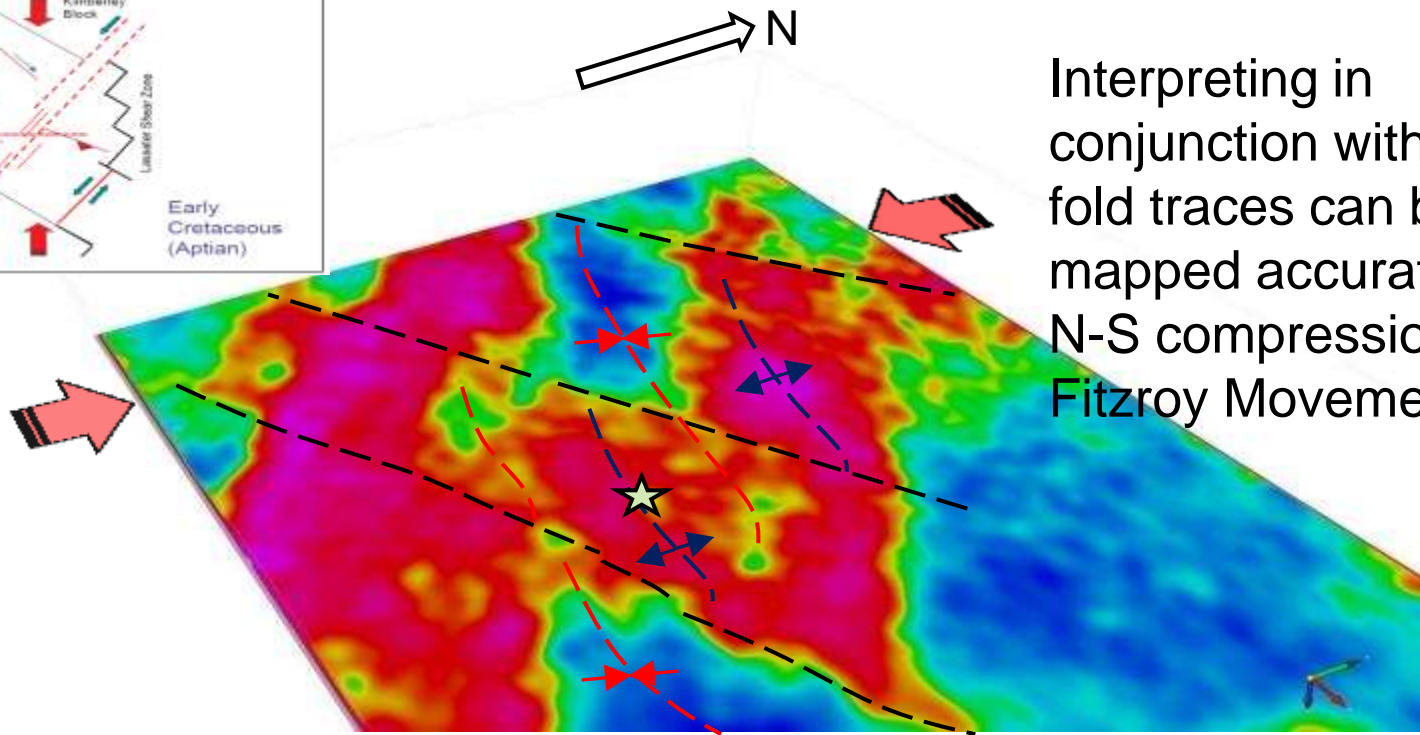
Transform faults  
observable.  
Accurate positioning of  
normal faults.  
Confident line to line  
correlation.



## More detailed interpretation



(SRK report)

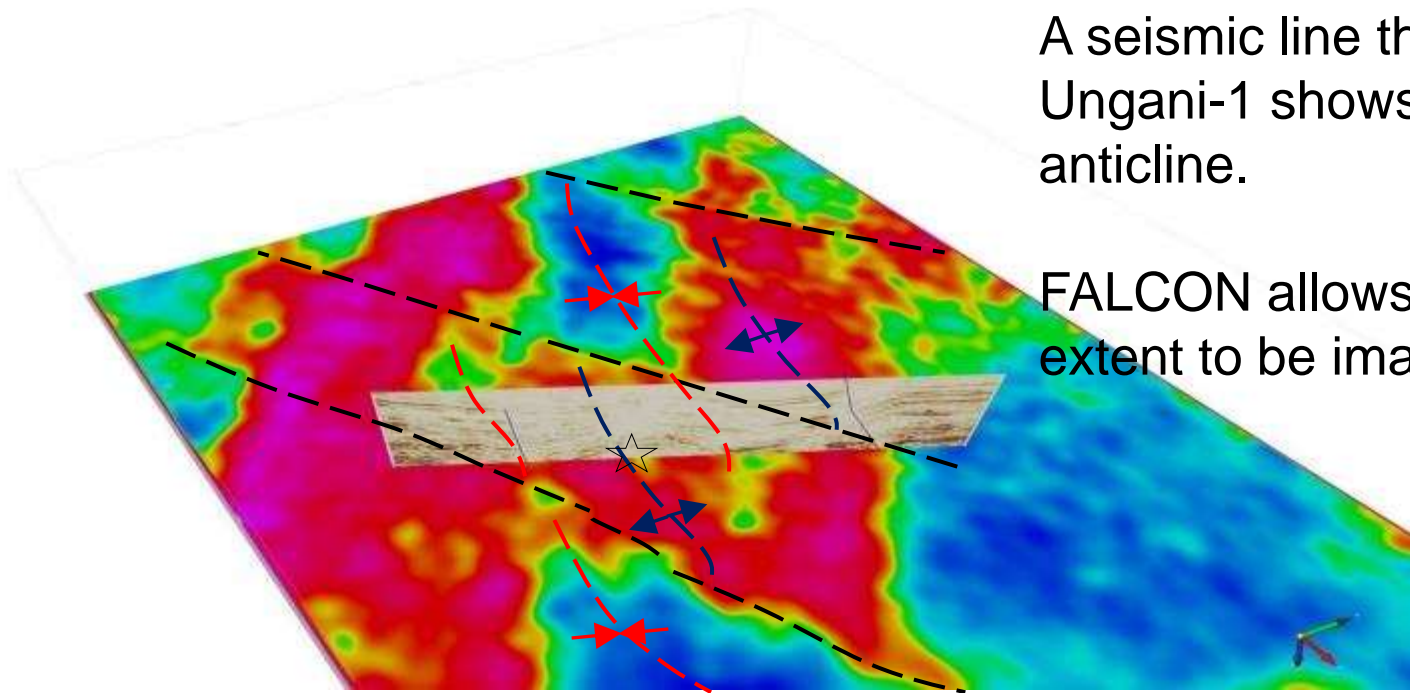


Interpreting in conjunction with seismic, fold traces can be mapped accurately. N-S compression of the Fitzroy Movement.





## Ungani structure



A seismic line through Ungani-1 shows anticline.

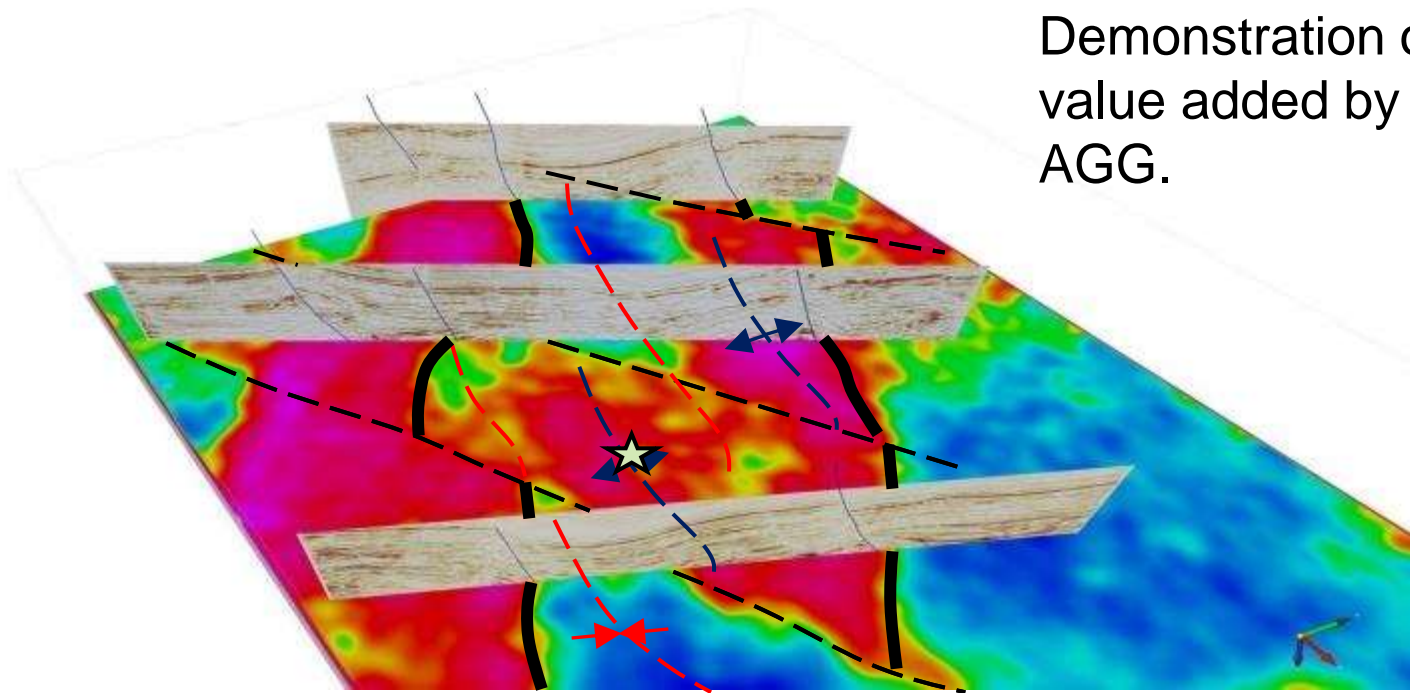
FALCON allows lateral extent to be imaged.







## Integrated interpretation

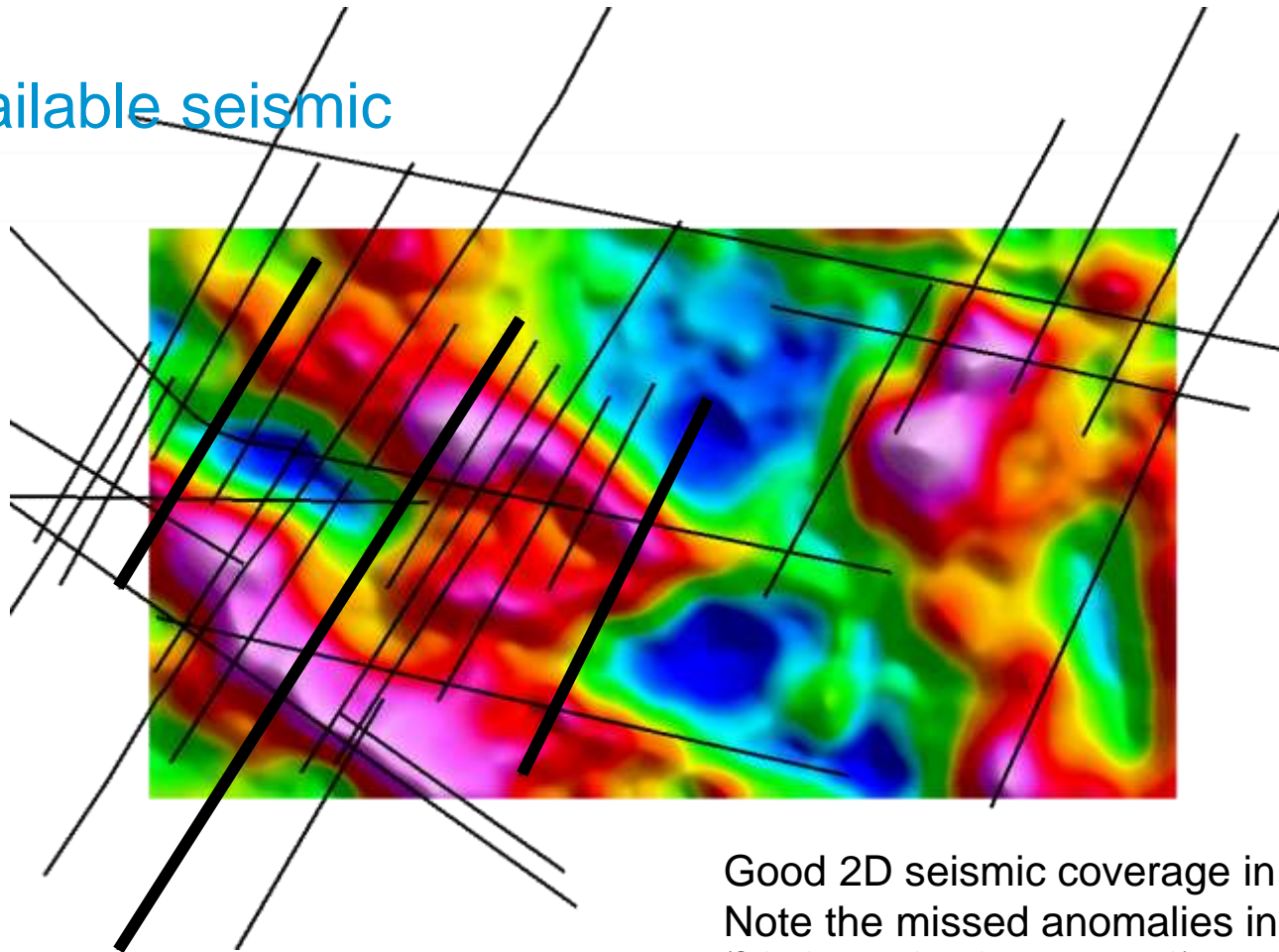


Demonstration of the  
value added by FALCON  
AGG.





## Available seismic



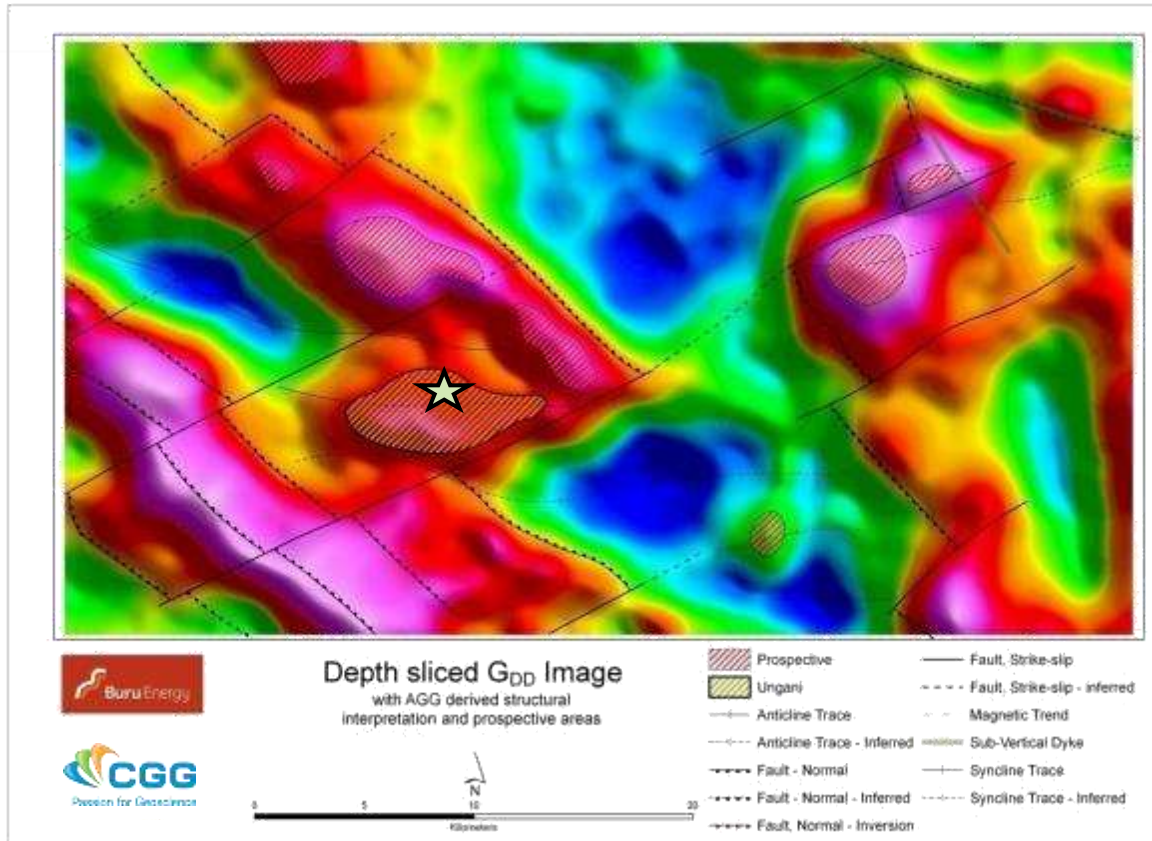
Good 2D seismic coverage in west.  
Note the missed anomalies in the northeast.  
(Seismic currently underway as a result)

Thick lines show lines used in previous 'cartoon interpretation, sequence





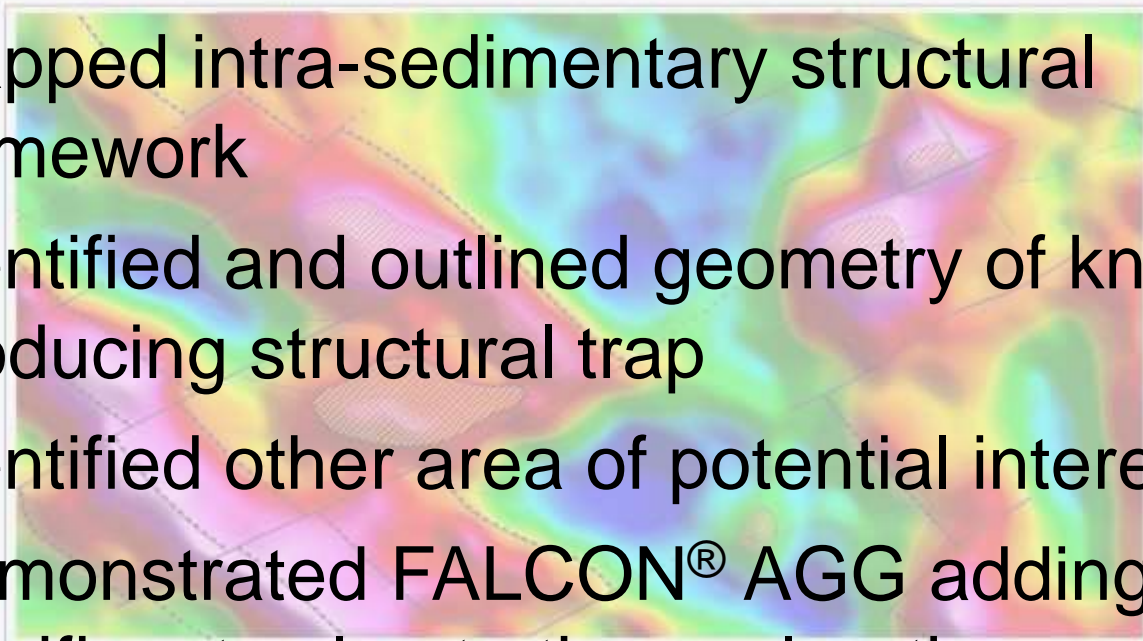
# Structural interpretation and potential targets





## Summary

- Mapped intra-sedimentary structural framework
- Identified and outlined geometry of known producing structural trap
- Identified other area of potential interest
- Demonstrated FALCON<sup>®</sup> AGG adding significant value to the exploration workflow





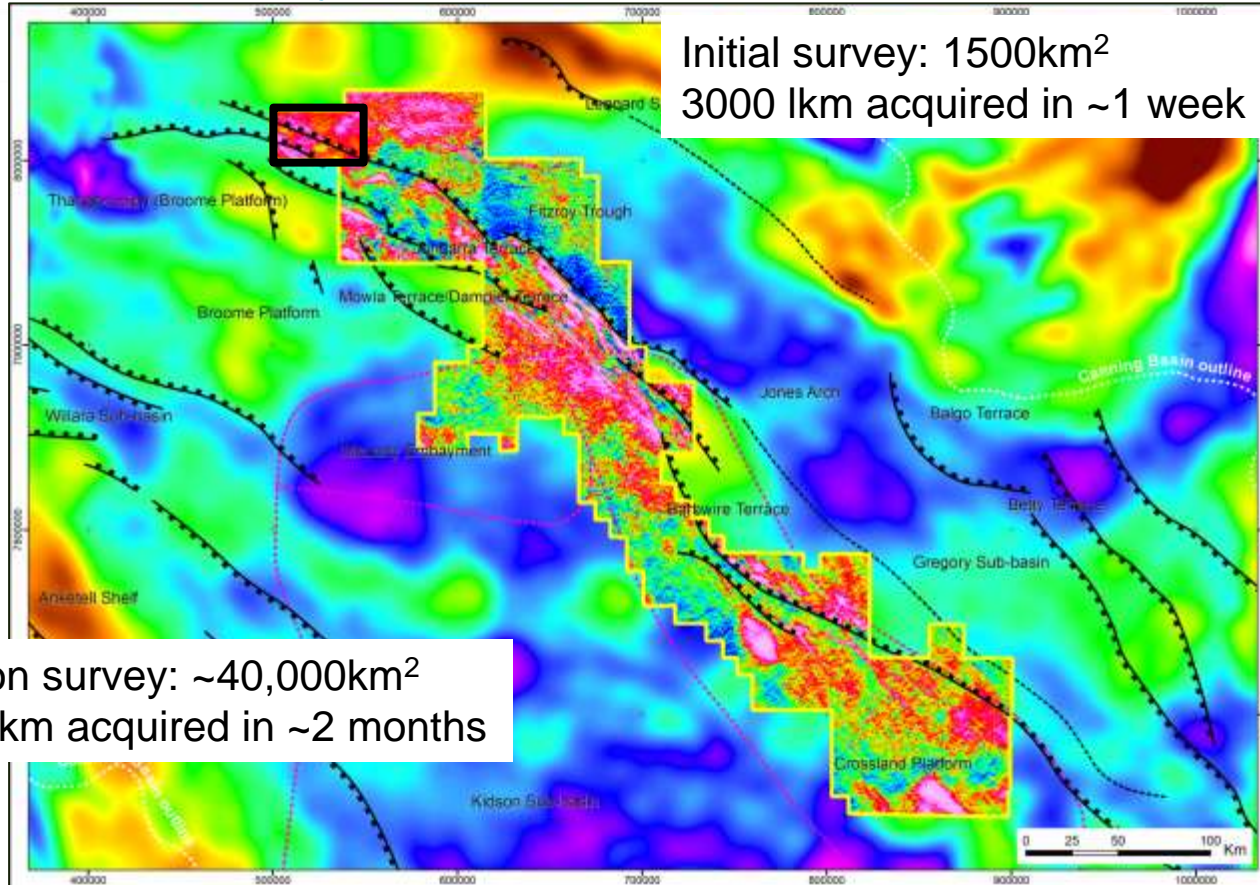
# The Extra Dimension

The Next Step



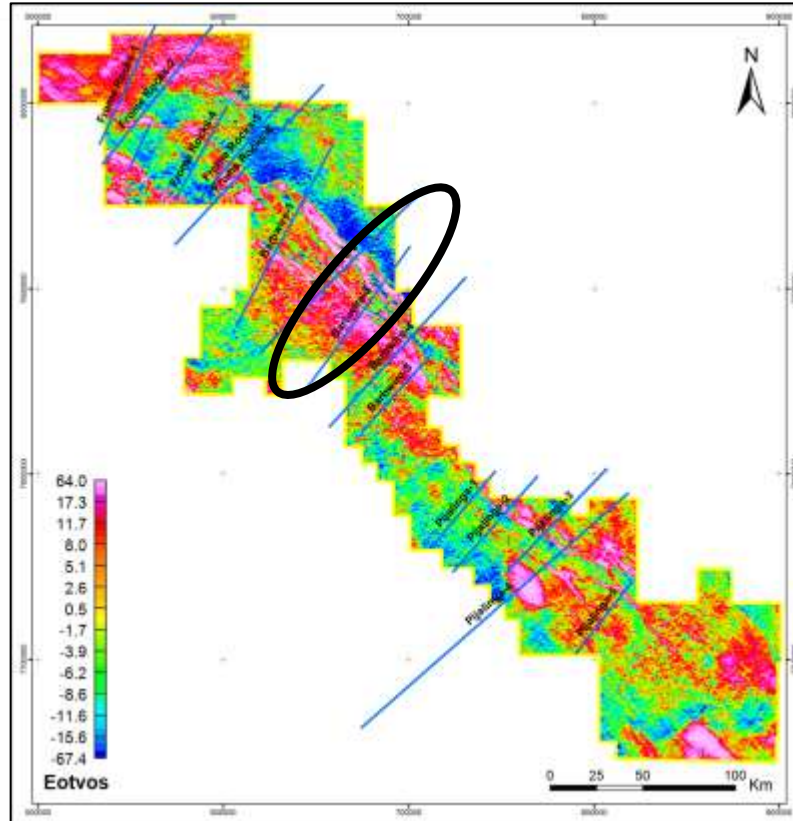


## Follow-on Survey





## Evaluation of existing seismic traverses

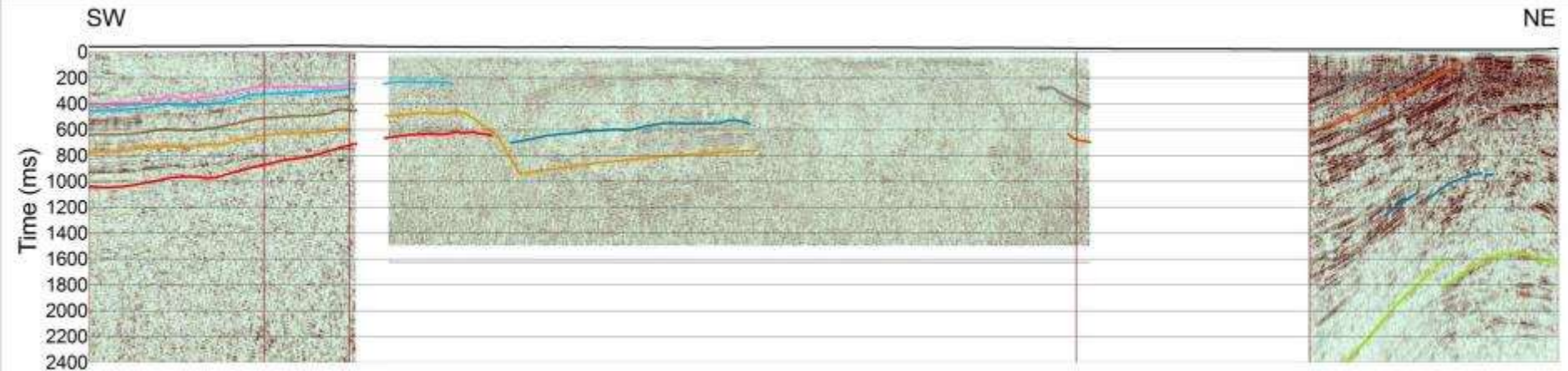




# Evaluation of existing seismic traverses

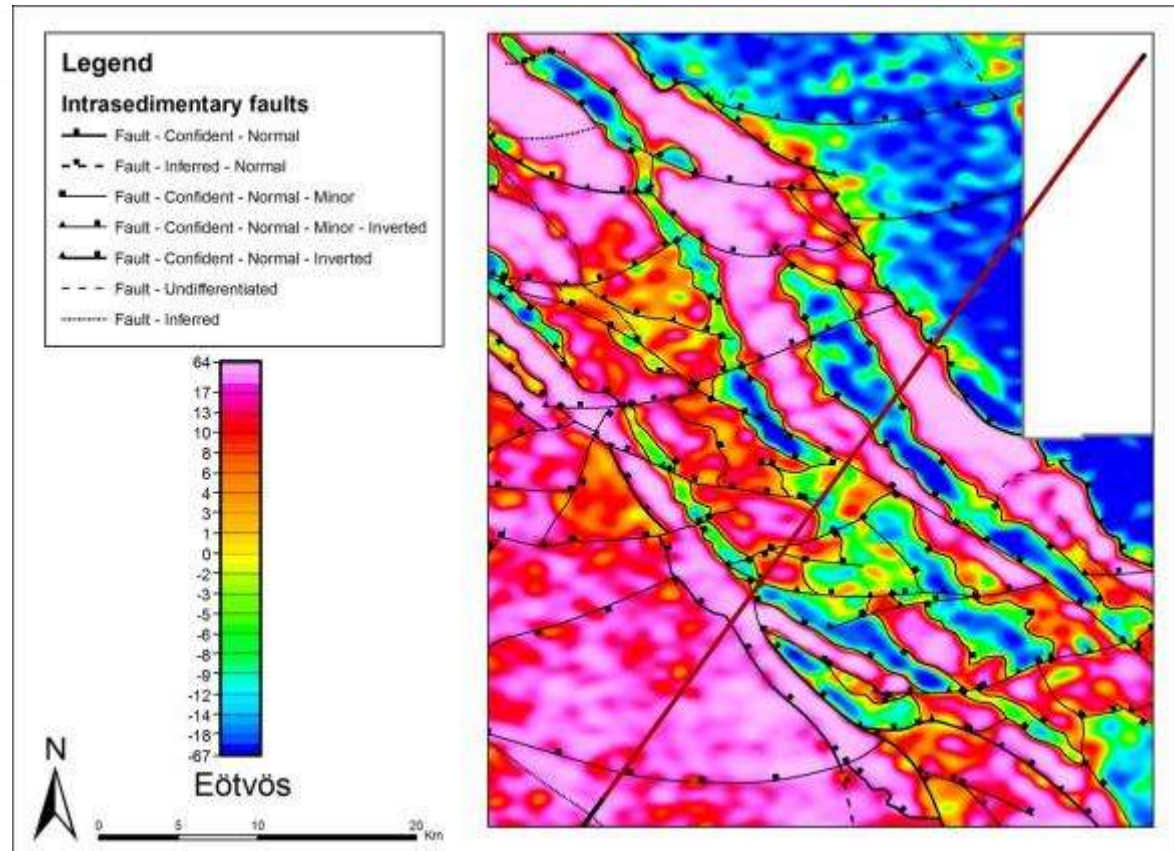
Seismic data along a modelled traverse

The original seismic interpretation of this 'vintage' seismic data (coloured lines)





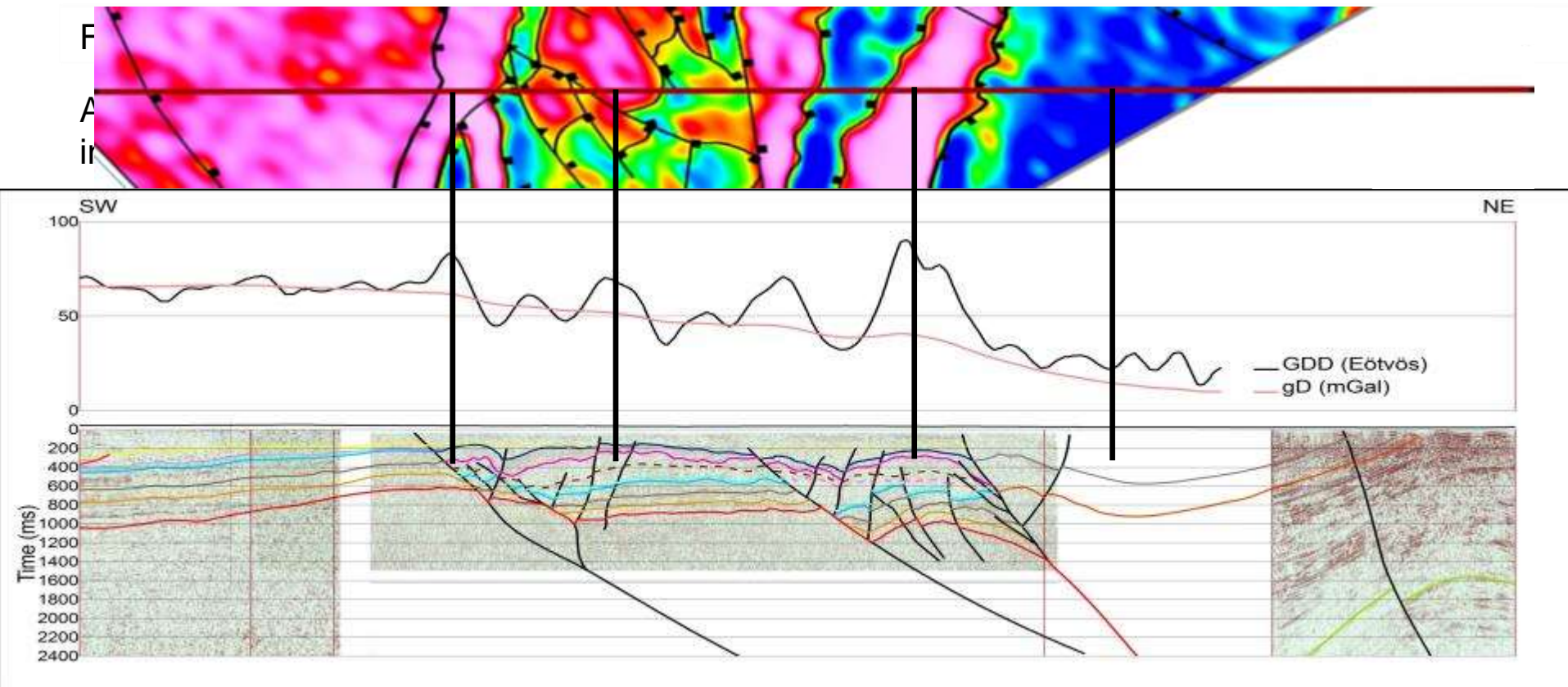
# Reinterpretation of seismic profiles



Background image: Vertical gravity gradient ( $G_{DD}$ )



## 4. Reinterpretation of seismic profiles





- Will define optimum location for seismic acquisition
- Remove ambiguity in 2D line to line correlation
- Provide independent validation and inversion of geological models

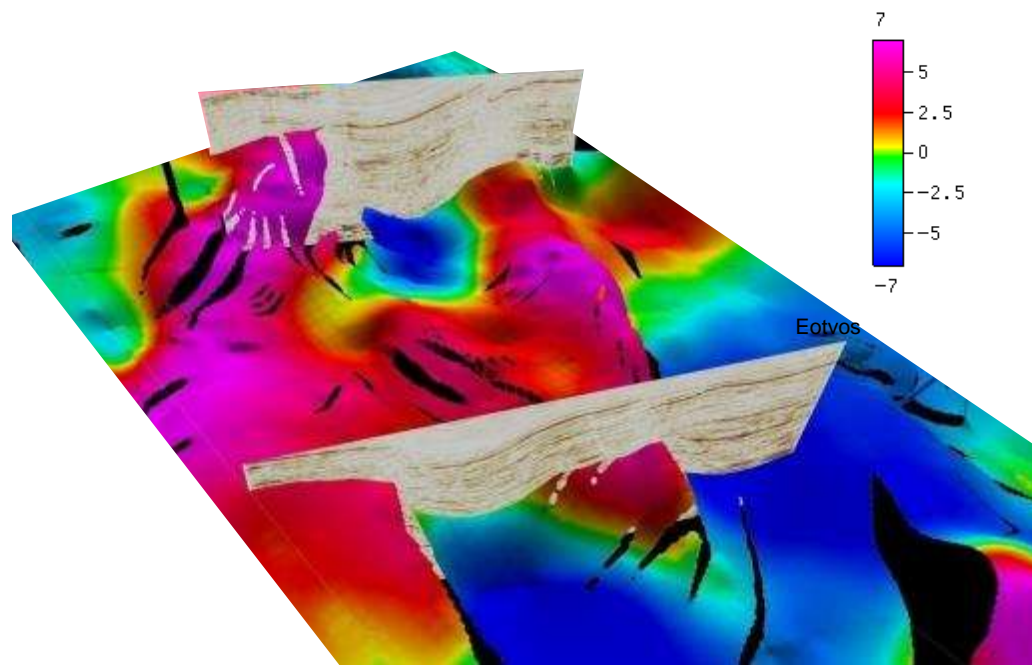
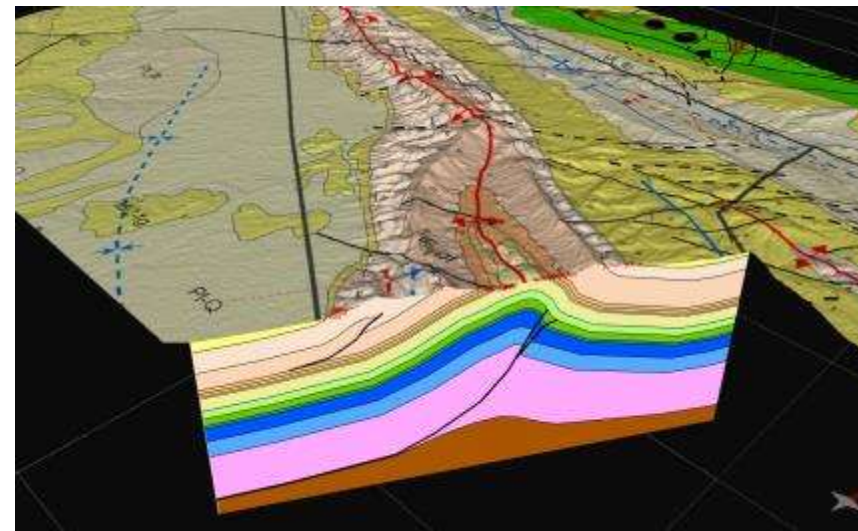


Depth sliced G<sub>pp</sub> Image  
with AGG derived structural  
interpretation and prospective areas





# FALCON® AGG – and Satellite Imagery







[cgg.com/multiphysics](http://cgg.com/multiphysics)

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