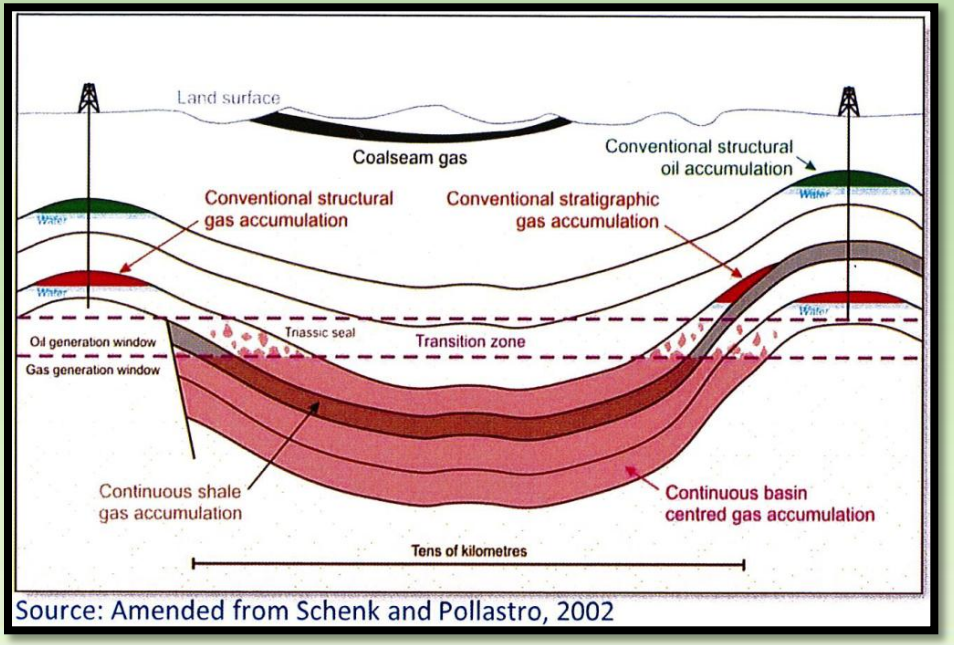
Archimedes

Introduction, Methodology and Examples

Introduction

Archimedes has a proven technology for processing & interpretation of potential field data: magnetics & gravity including gradiometry which is used successfully for oil & gas exploration worldwide.



Source: Amended from Schenk and Pollastro, 2002

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Archimedes Worldwide Experience

Archimedes has worked on every inhabited continent

For clients including: Shell, BP, ENI, BHPBilliton, PETRONAS, JX Nippon, ARAMCO, Statoil, Hess, Apache, PTTEP, Maurel et Prom, Woodside, Santos, Beach Energy, Murphy Oil, TGS, PetroVietnam, Oil Search, Ahava, Origin Energy, Government of Australia and over 40 others

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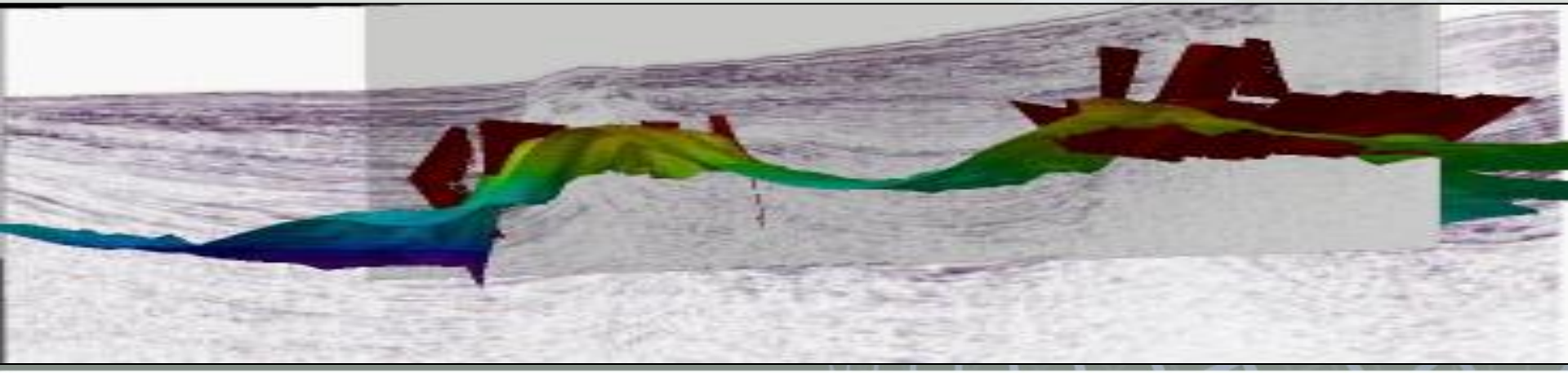
Archimedes' Unique Technology

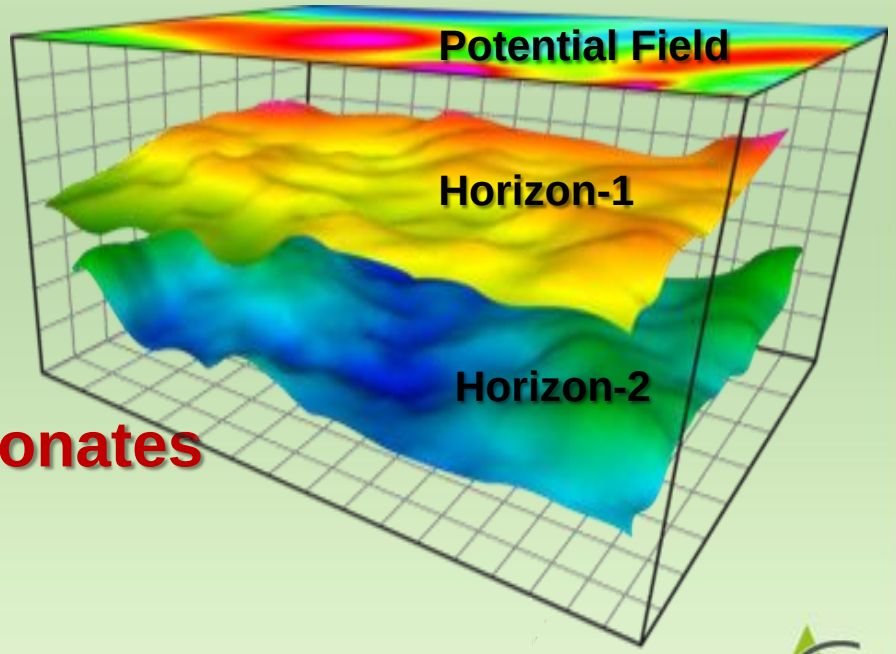
Horizon Mapping & ACM



Horizon Mapping Technique

Horizon Mapping detects:

- **Gravity**
  - Density contrasts
    - Top Carbonates
    - Basement
- **Magnetics**
  - Susceptibility contrasts
    - Volcanics
    - Top Shale/ Base Carbonates
    - Unconformities
    - Basement



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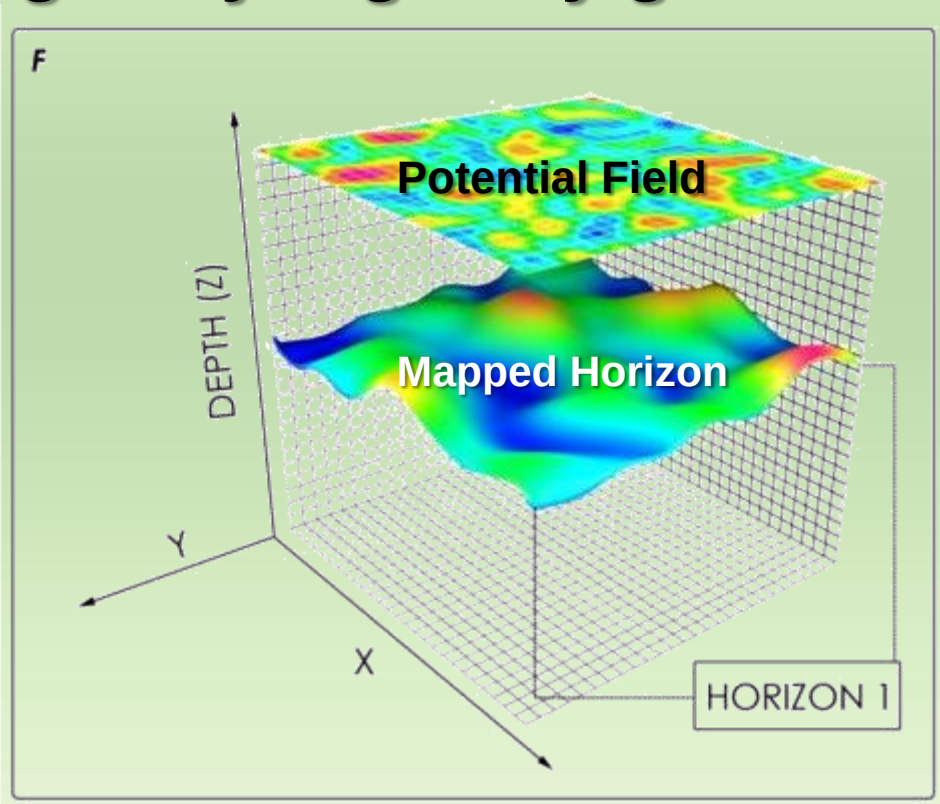
Horizon Mapping

Horizon Mapping from Magnetics or Gravity

We detect & map magnetic or density interfaces using Horizon Mapping Tool applied to magnetics, gravity & gravity gradiometry



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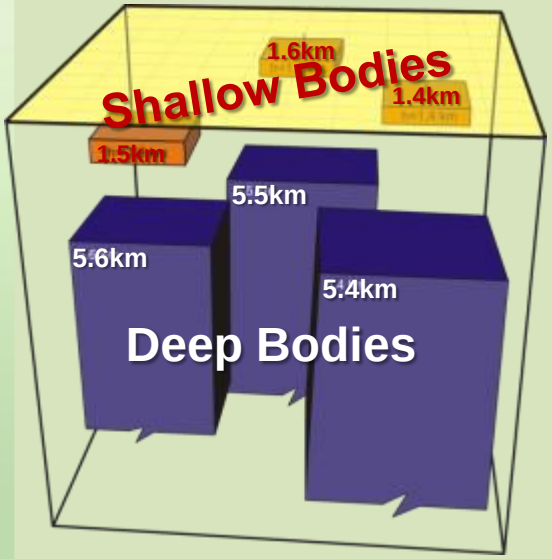
Horizon Mapping

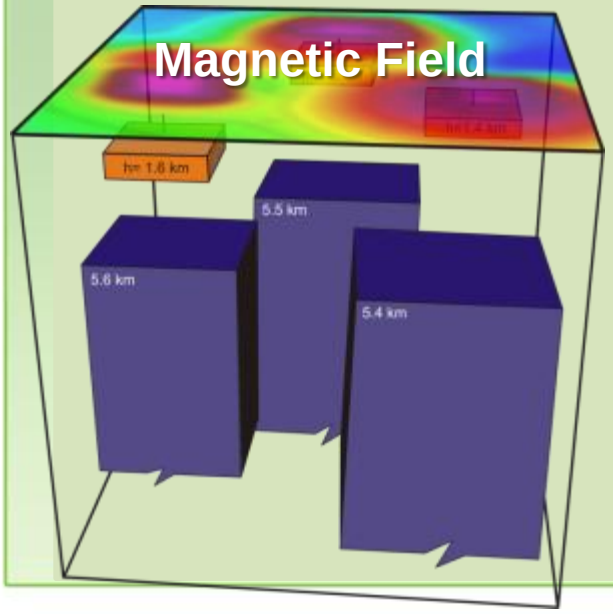
Energy Spectral Analysis Theory

Energy Spectral Analysis Theory

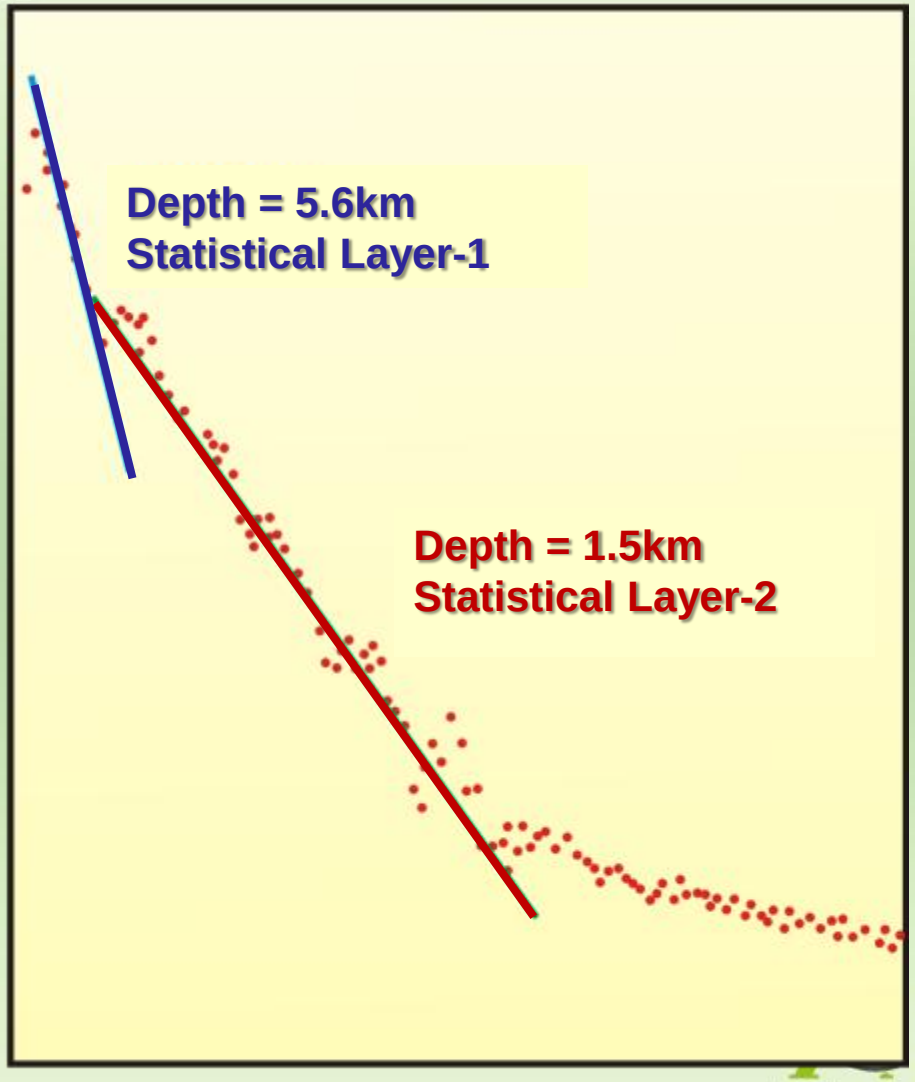


Layer-2

Layer-1



Energy Spectrum Graph



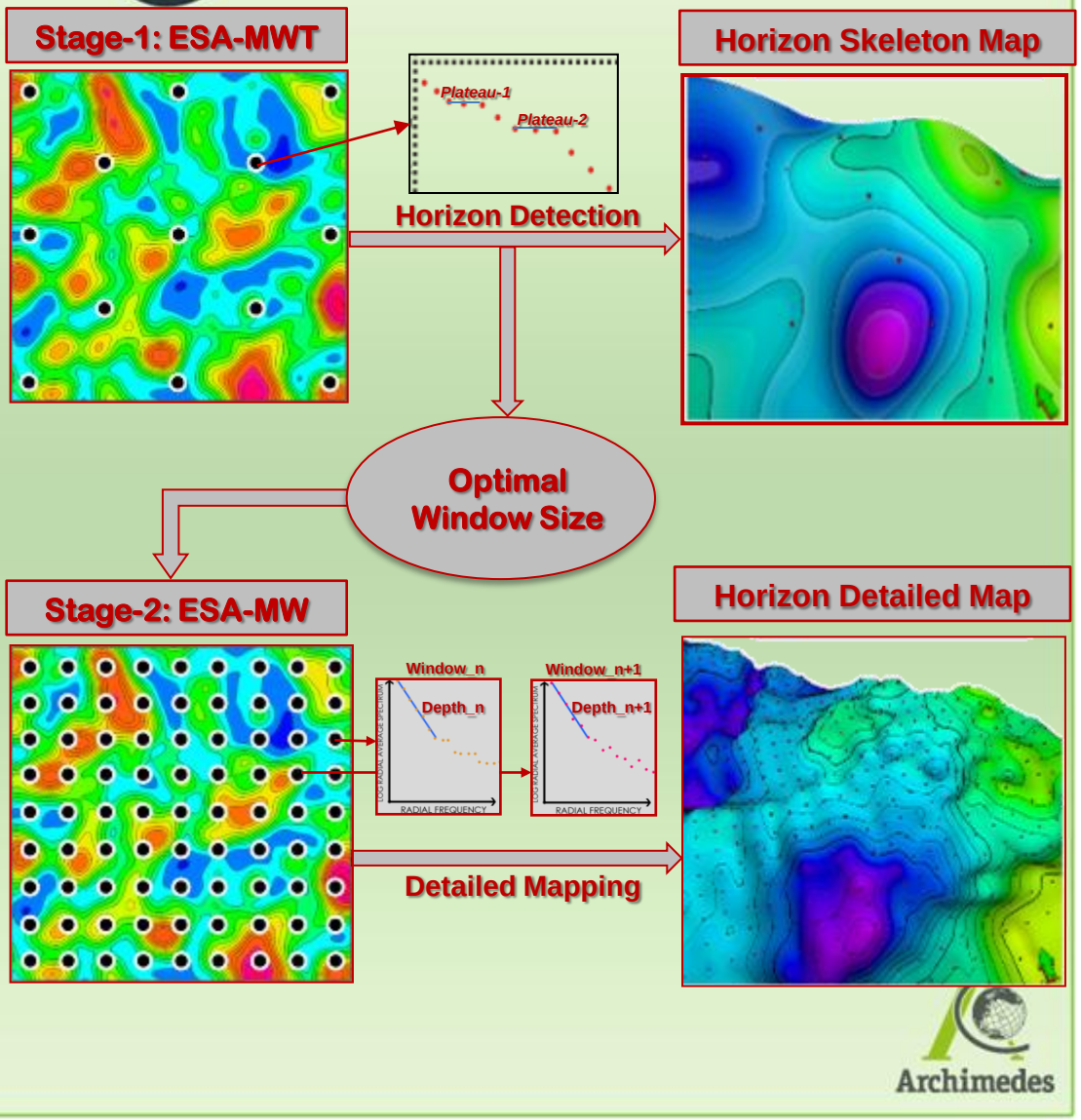
Horizon Mapping

Stage-1: Horizon Detection

- ESA-MWT on coarse mesh
- *Depth-Plateaus* laterally merged to construct Horizon Skeleton
- Optimal Windows selected
- QC of Horizon Skeleton

Stage-2: Detailed Mapping

- Depth mapping on dense mesh
- Spectra over Optimal Windows
- High-resolution Horizon Map is constructed



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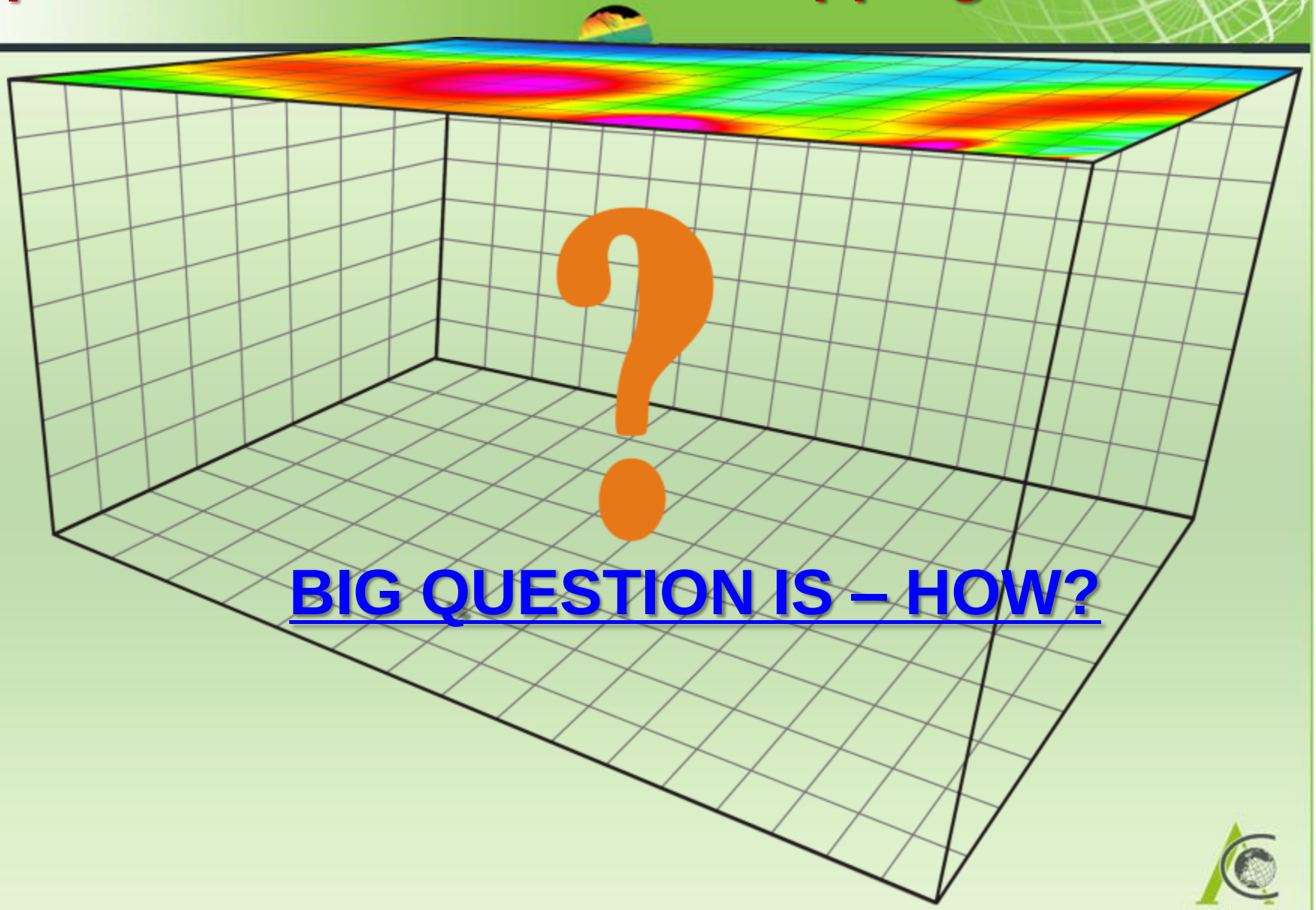
Horizon Mapping

Stage-1: Horizon Detection

Multi Window Test

Optimal Window Size for Mapping Horizons



BIG QUESTION IS – HOW?

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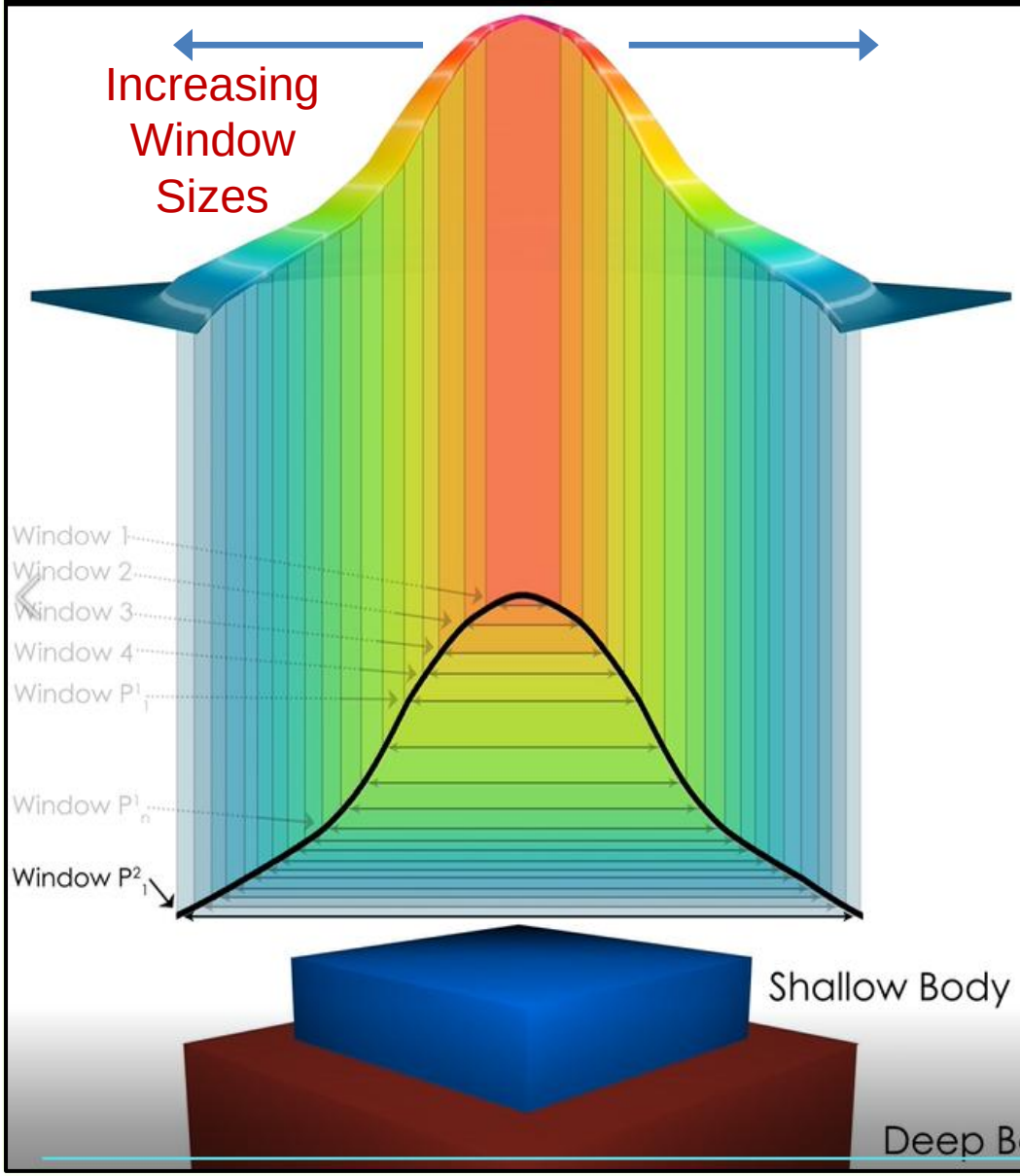
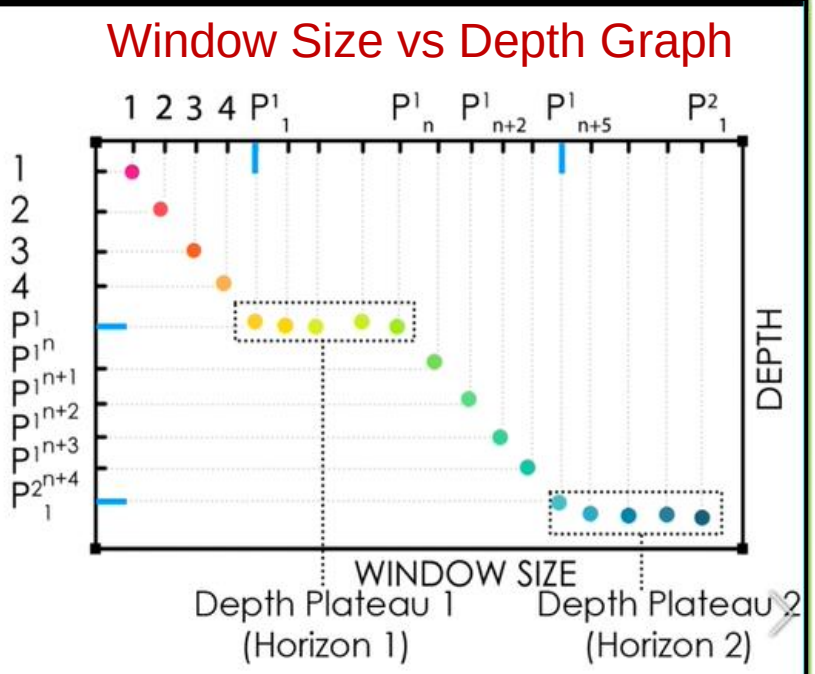
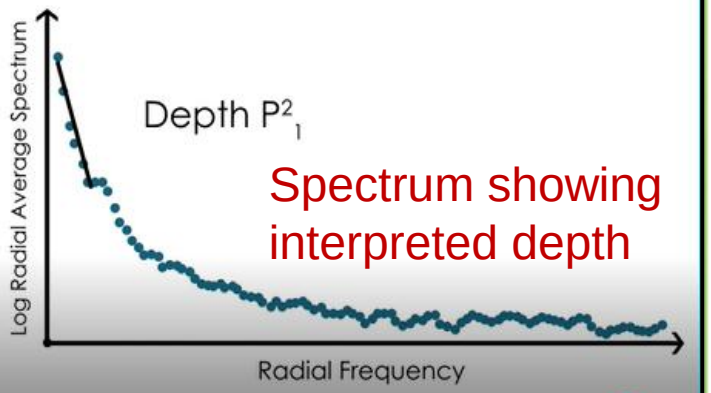
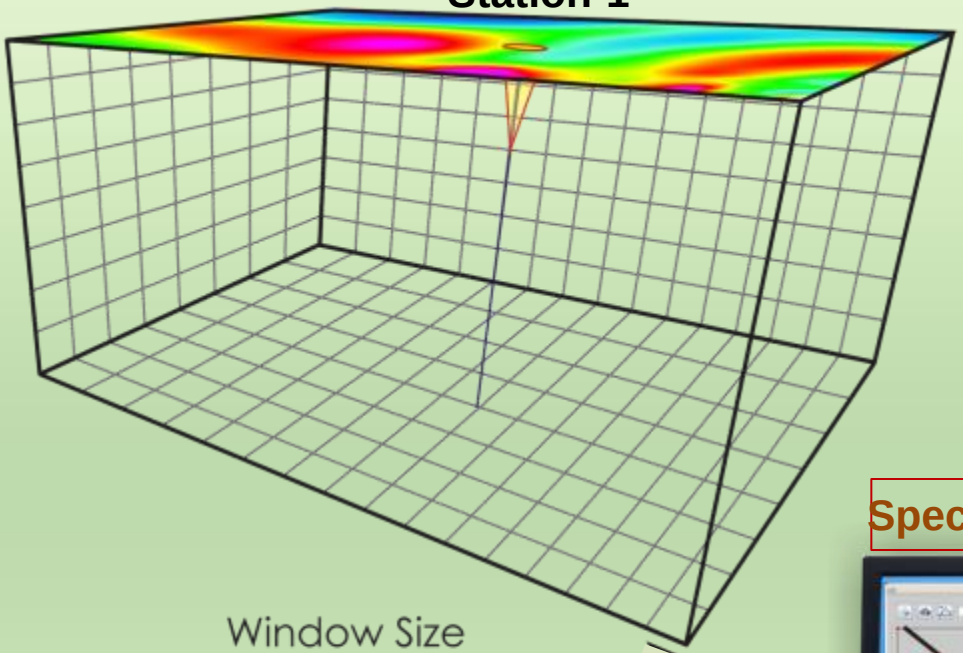
Multi-Window Test Method

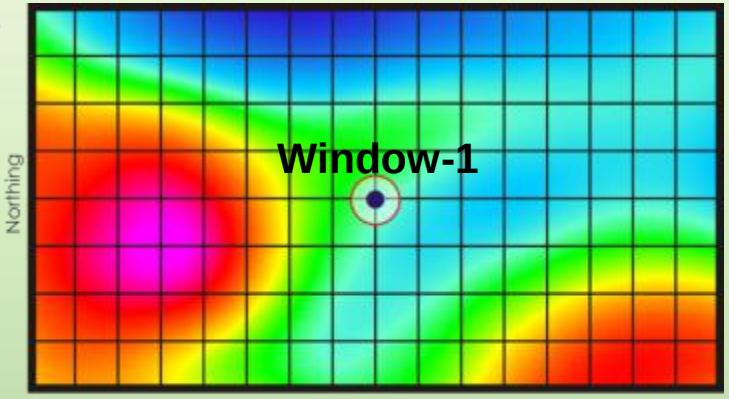






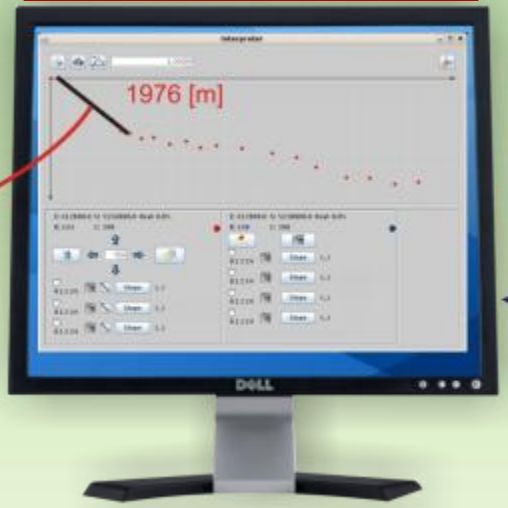
Horizon Mapping: ESA-MWT Procedure





Magnetic or Gravity Data Processing
&
Spectra Computation

Spectrum of Window-1



MWT-Graph at Station-1

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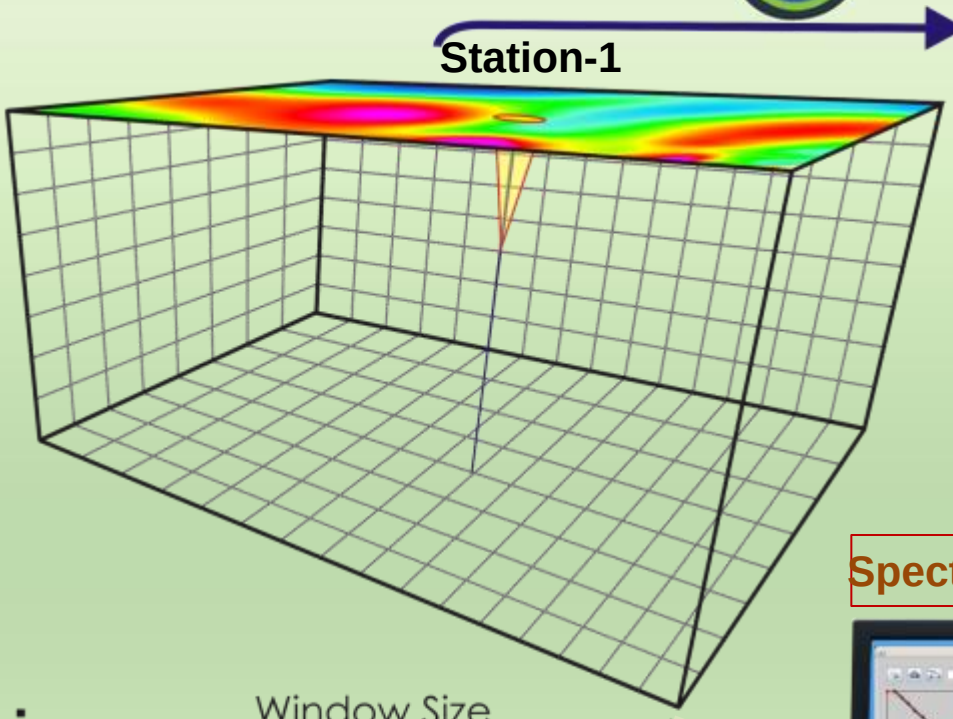
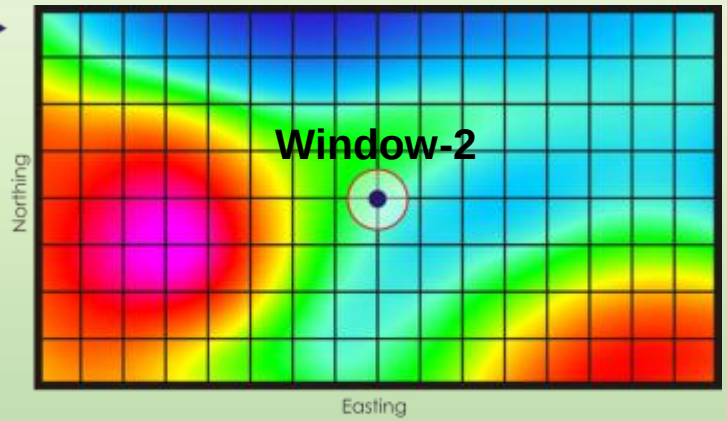
Horizon Mapping: ESA-MWT Procedure

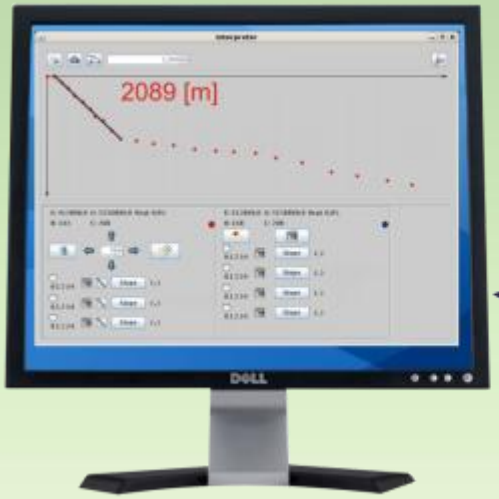


MWT-Graph at Station-1



Magnetic or Gravity Data Processing
&
Spectra Computation

Spectrum of Window-2



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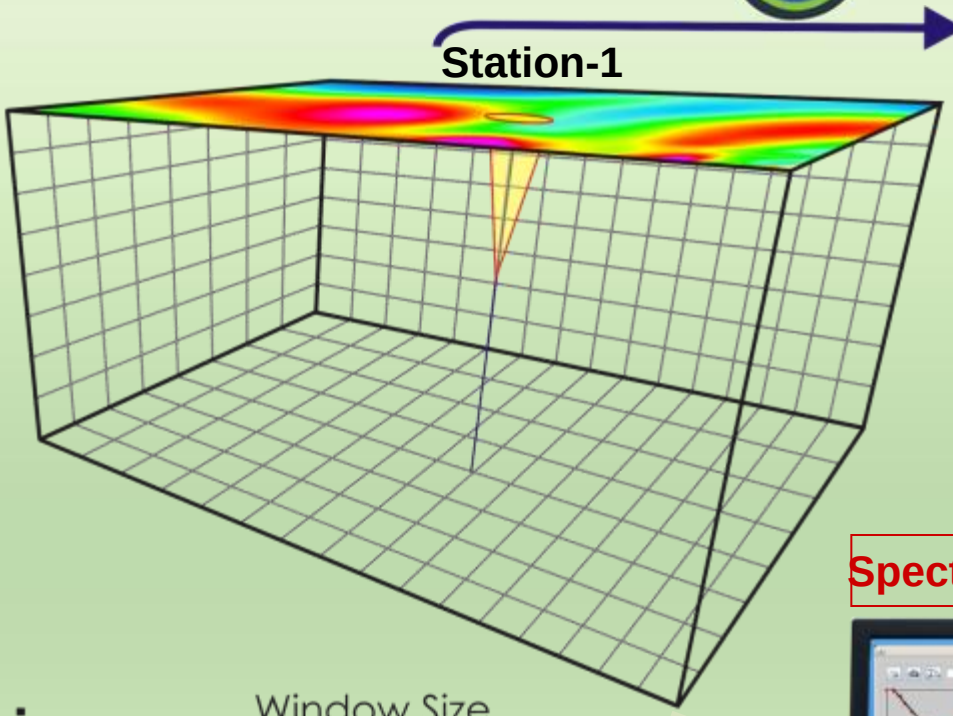
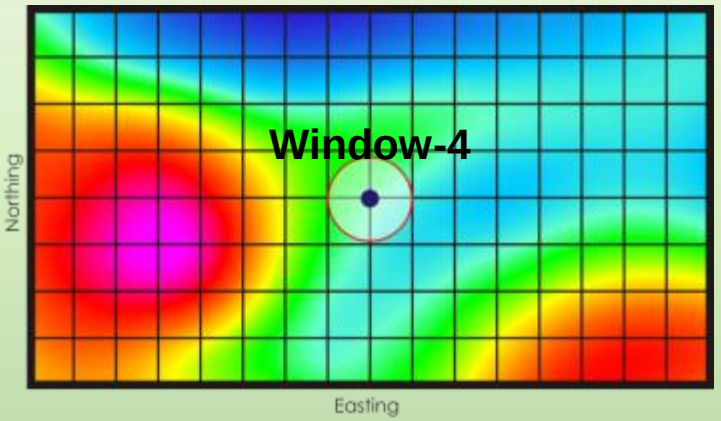
Horizon Mapping: ESA-MWT Procedure

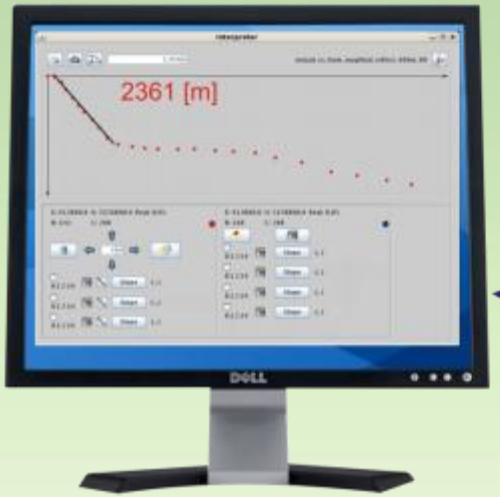


MWT-Graph at Station-1



Magnetic or Gravity Data Processing
&
Spectra Computation

Spectrum of Window-4



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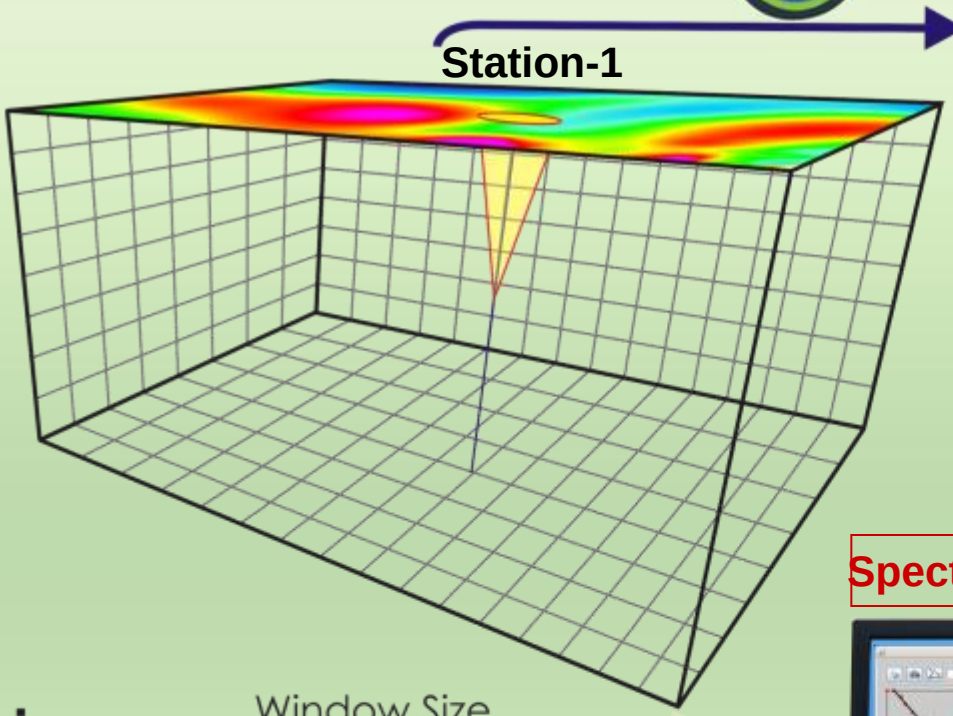
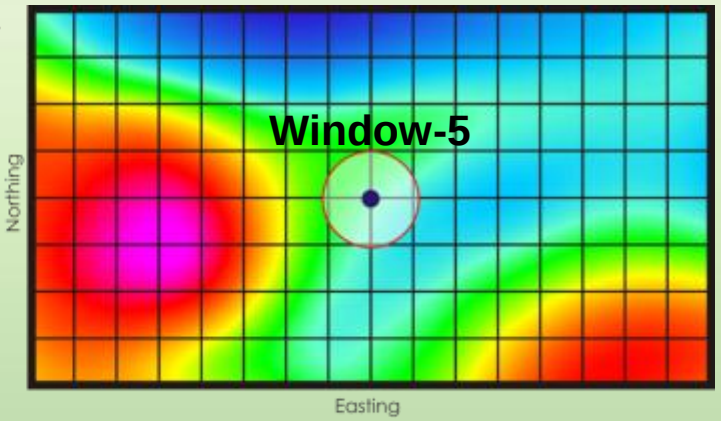
Horizon Mapping: ESA-MWT Procedure

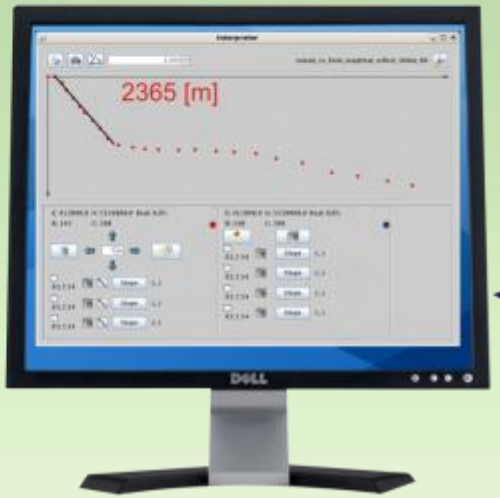


MWT-Graph at Station-1



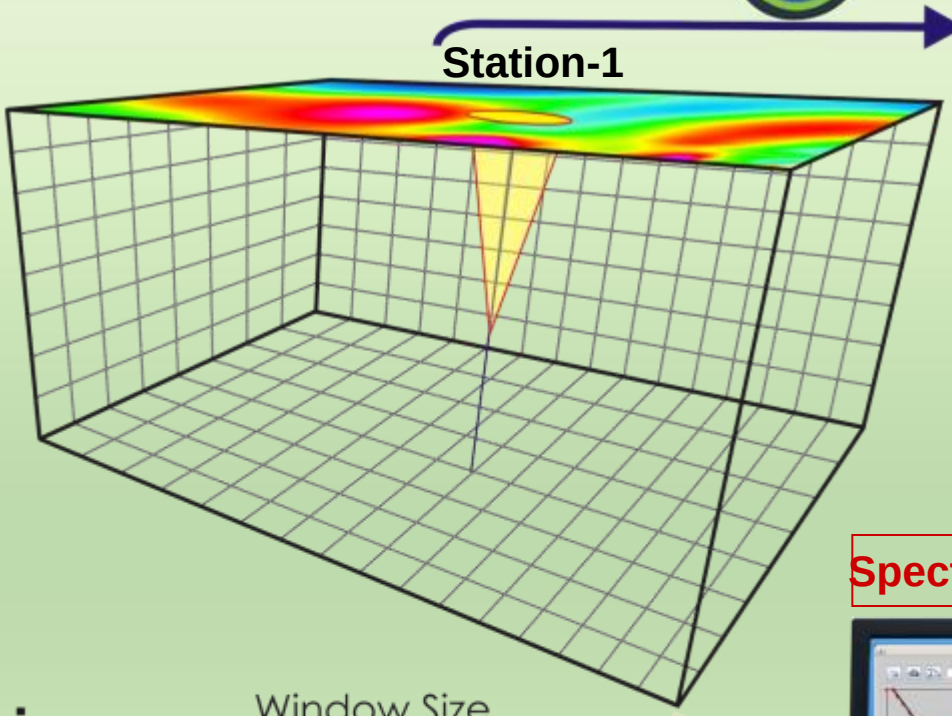
Magnetic or Gravity Data Processing
&
Spectra Computation

Spectrum of Window-5

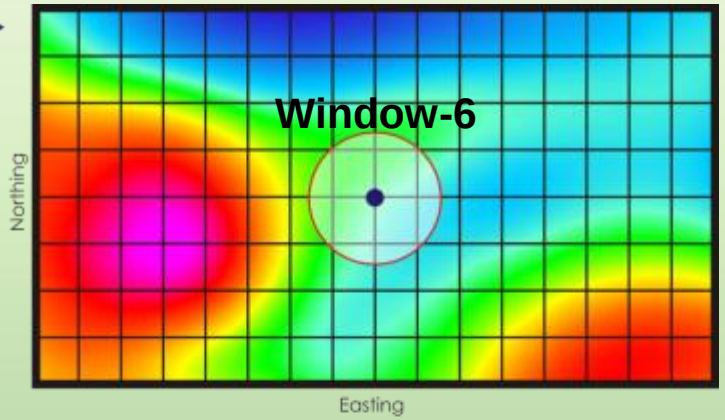


Archimedes

Horizon Mapping: ESA-MWT Procedure

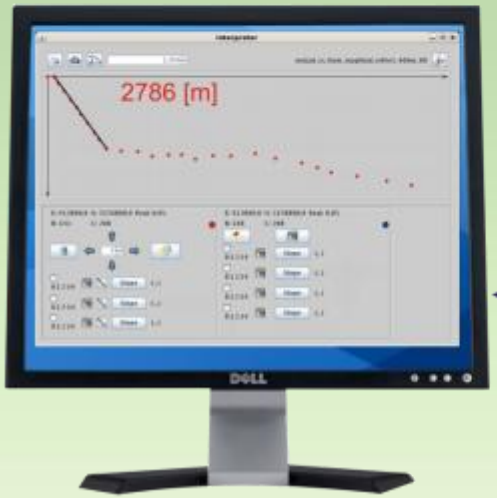


MWT-Graph at Station-1



Magnetic or Gravity Data Processing
&
Spectra Computation

Spectrum of Window-6



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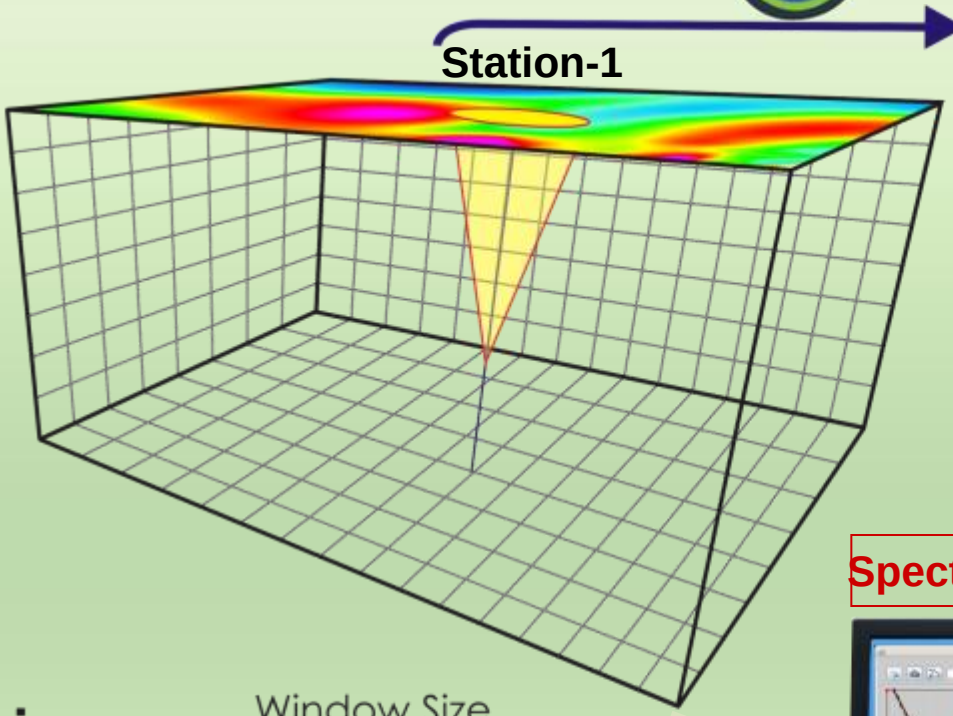
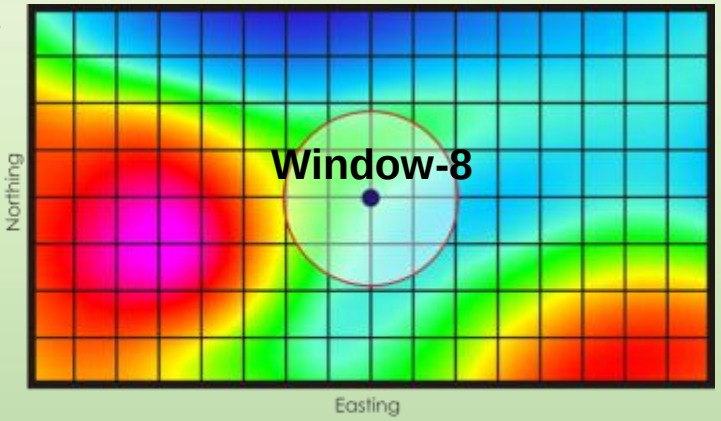
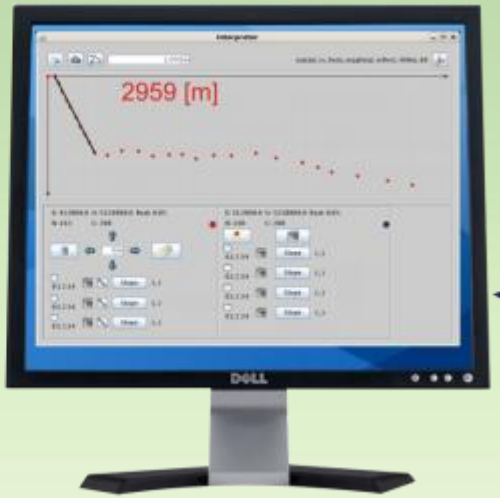
Horizon Mapping: ESA-MWT Procedure

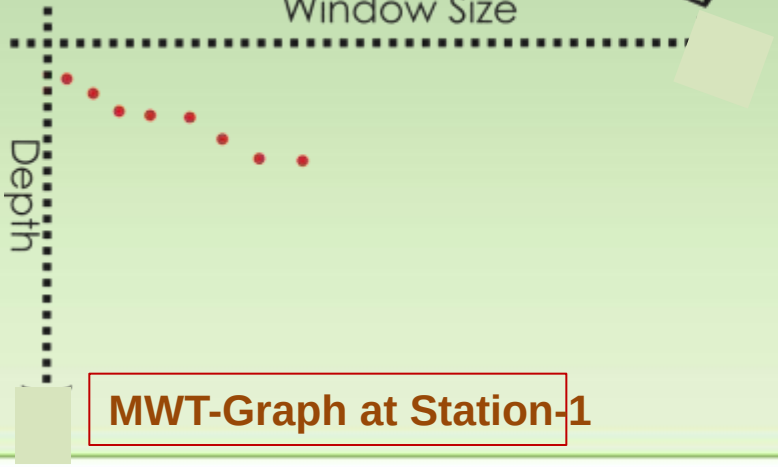




Magnetic or Gravity Data Processing
&
Spectra Computation

Spectrum of Window-8





MWT-Graph at Station-1

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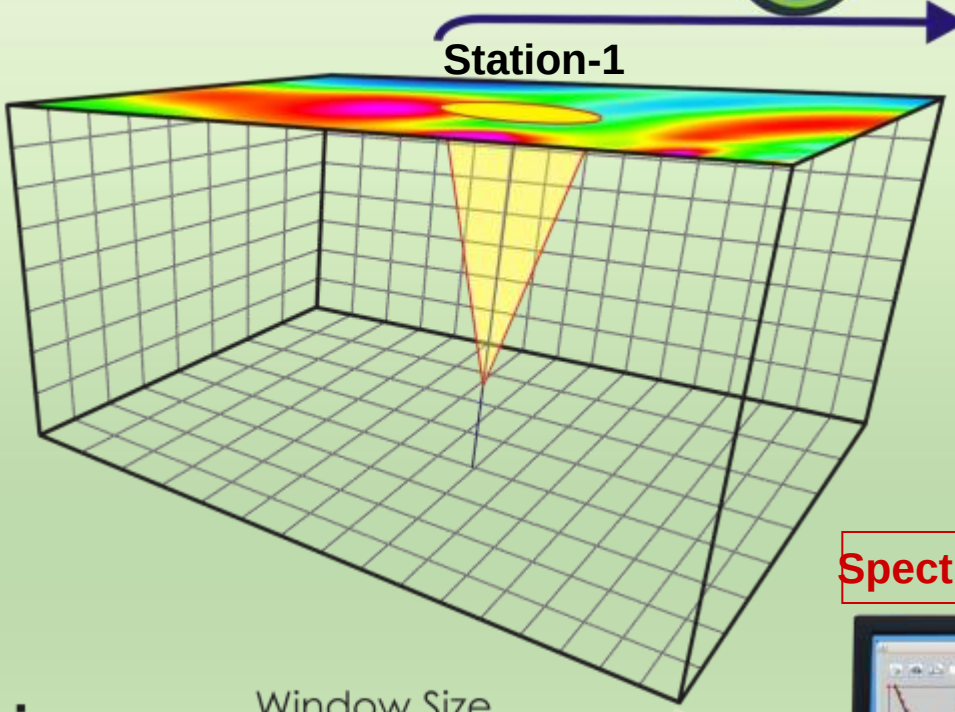
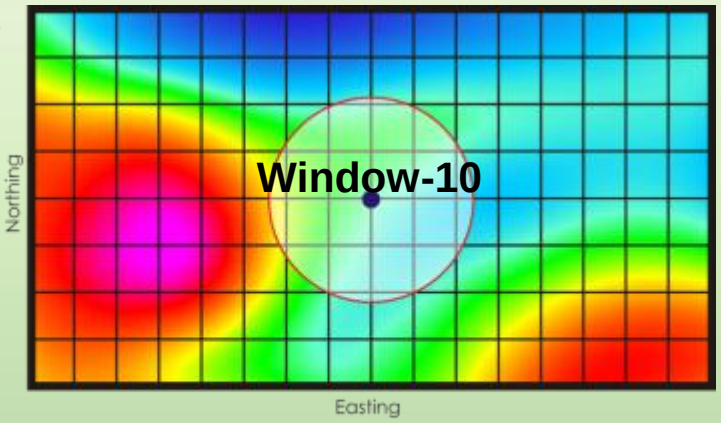
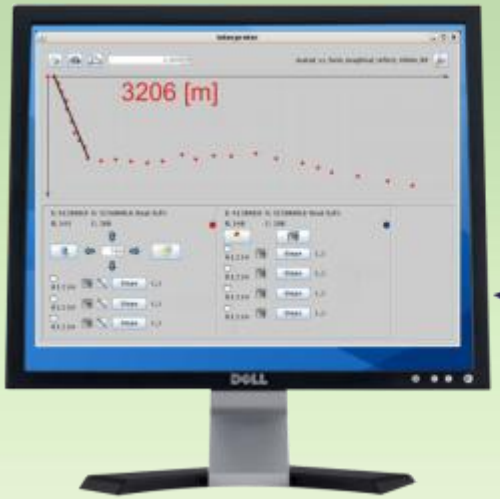
Horizon Mapping: ESA-MWT Procedure

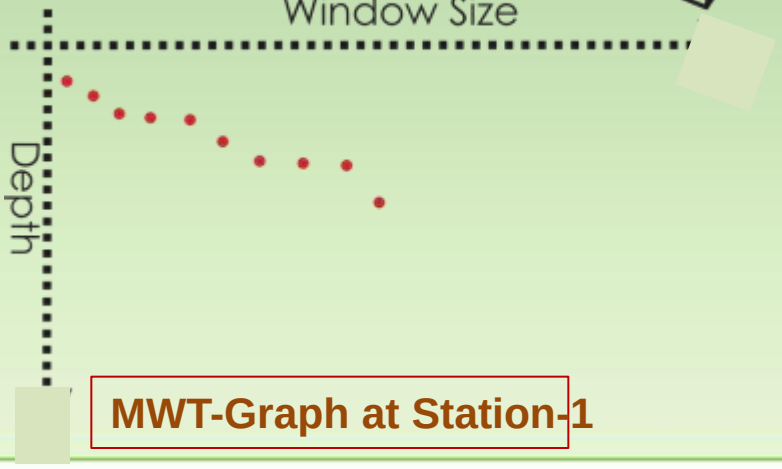




Magnetic or Gravity Data Processing
&
Spectra Computation

Spectrum of Window-10





MWT-Graph at Station-1

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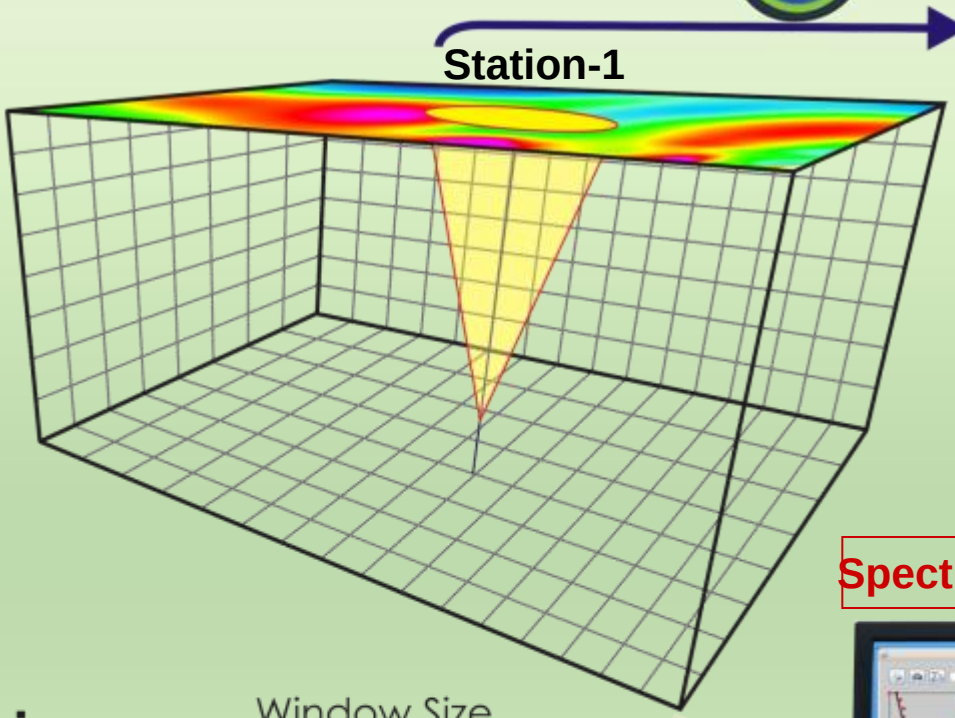
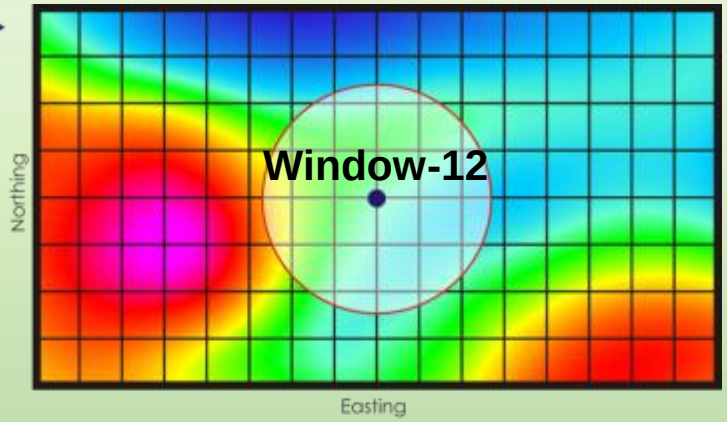
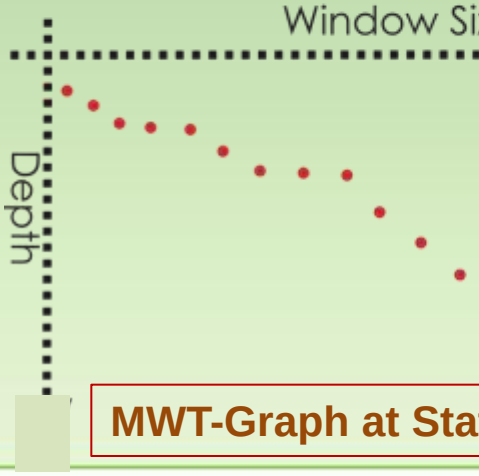
Horizon Mapping: ESA-MWT Procedure





Magnetic or Gravity Data Processing
&
Spectra Computation

Spectrum of Window-12



MWT-Graph at Station-1

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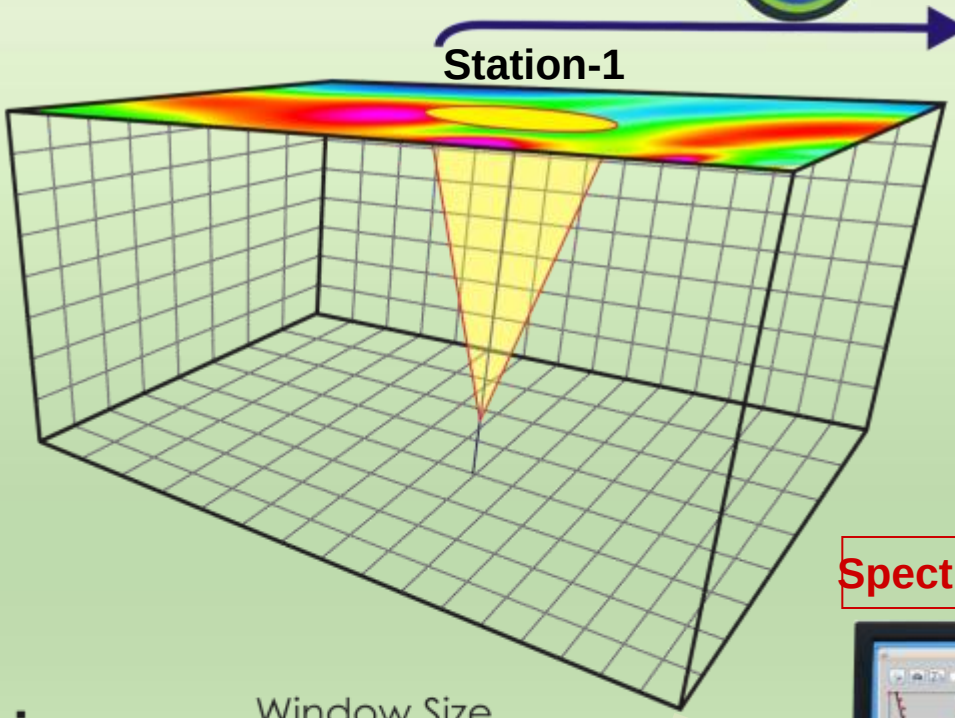
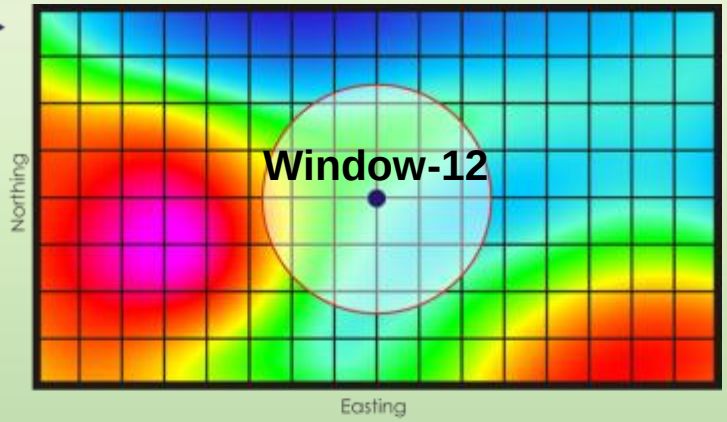
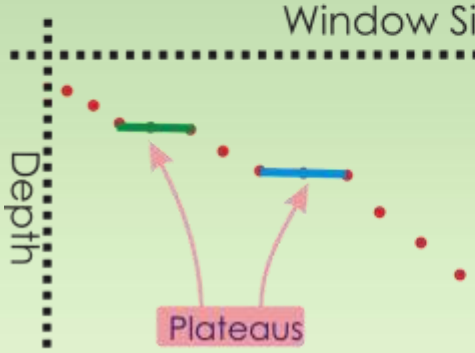
Horizon Mapping: ESA-MWT Procedure





Magnetic or Gravity Data Processing
&
Spectra Computation

Spectrum of Window-12



MWT-Graph at Station-1

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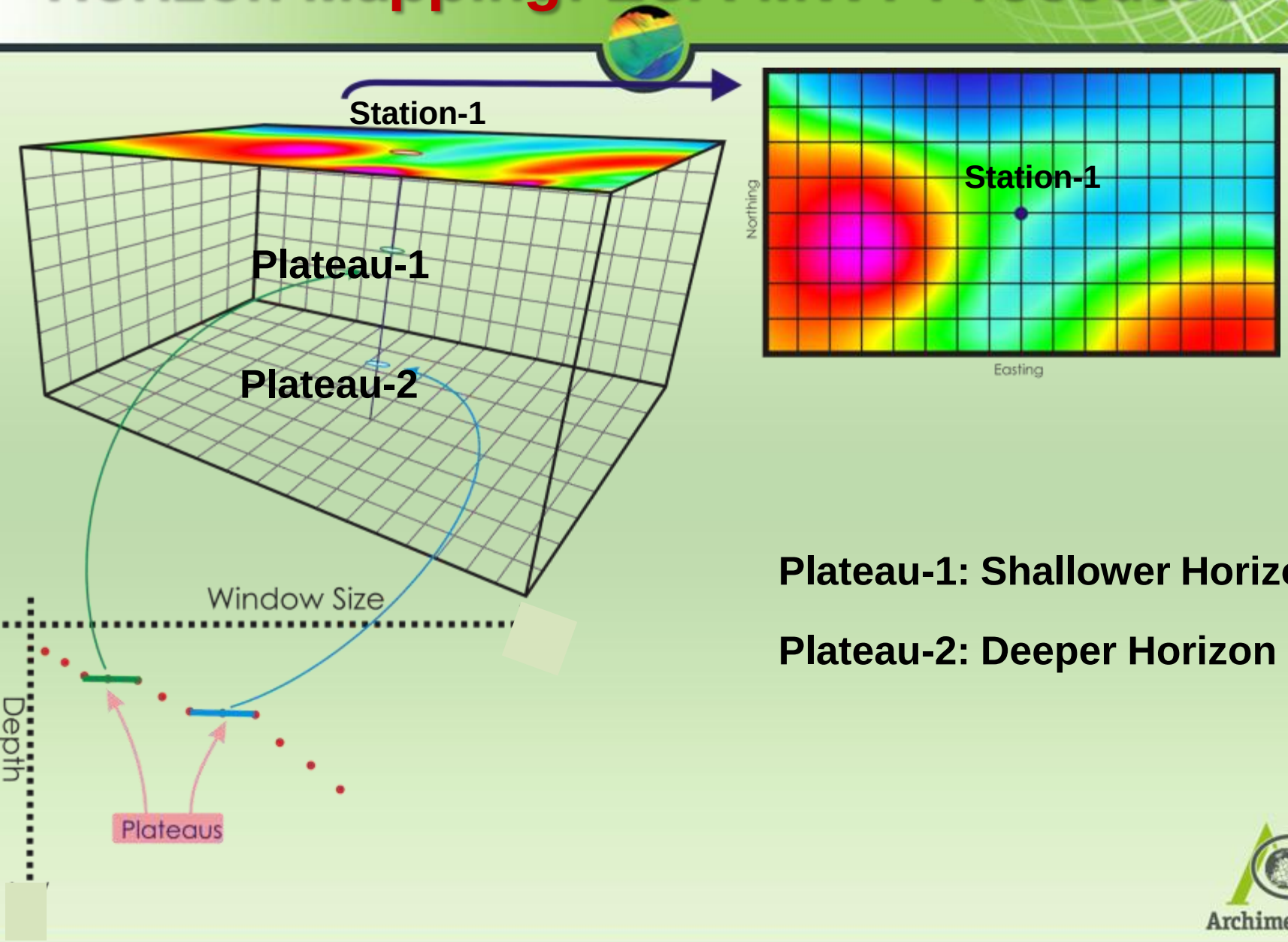
Horizon Mapping: ESA-MWT Procedure



Plateau-1: Shallower Horizon

Plateau-2: Deeper Horizon

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Mapping Shallower Horizon-1

Stage-1: Horizon Detection

MWT Plateau-1

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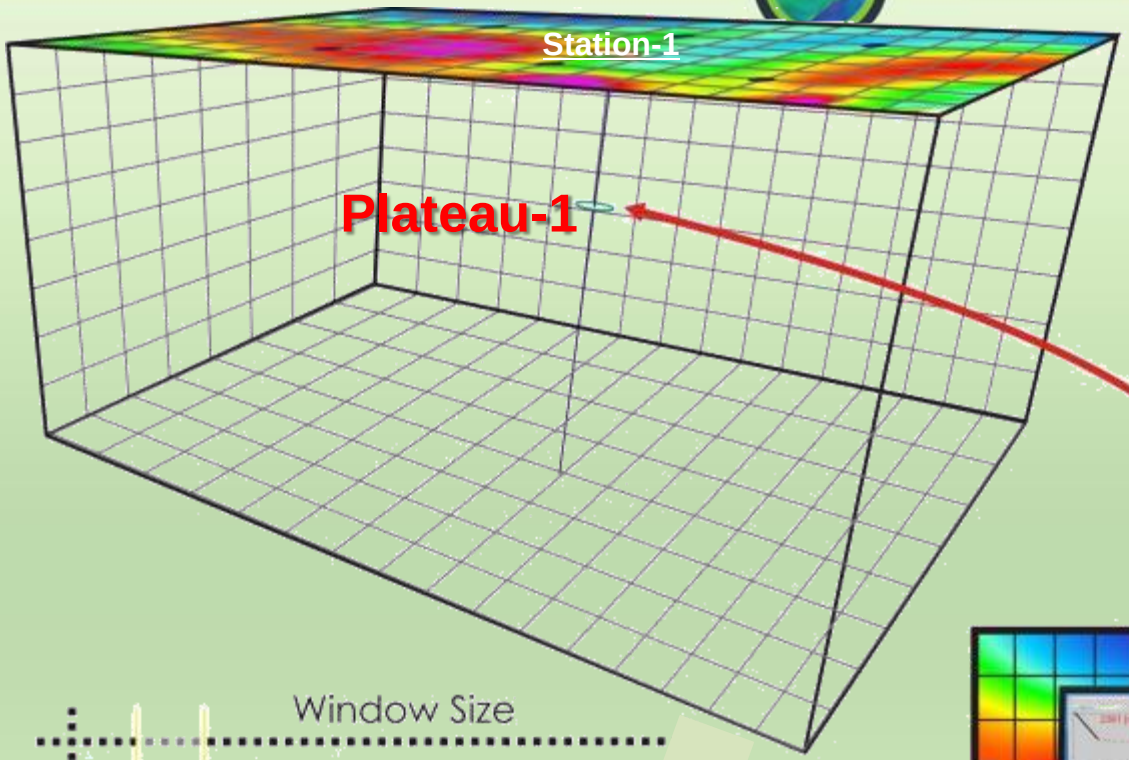
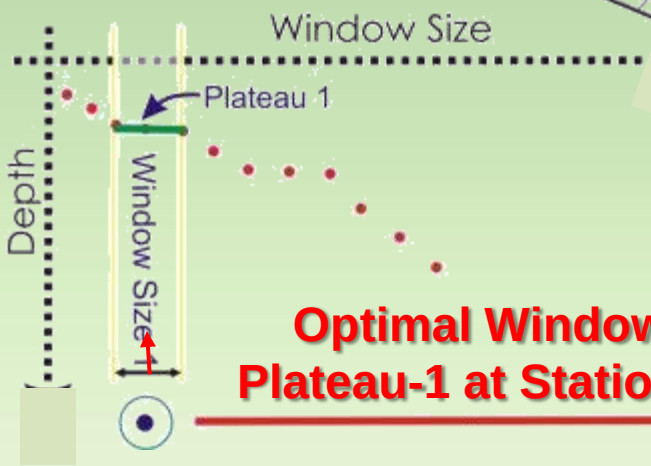
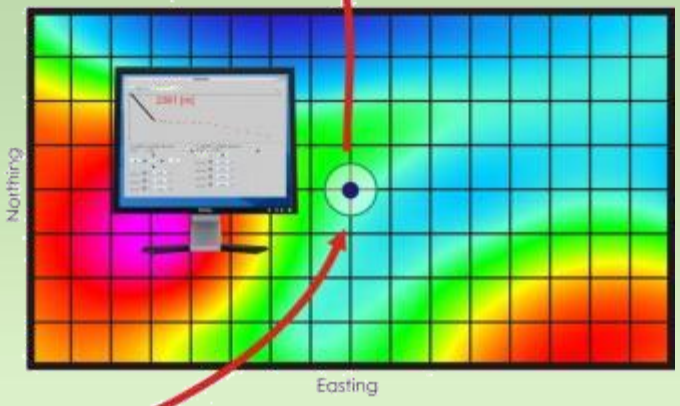
Mapping Shallower Horizon





Optimal Window
Plateau-1 at Station-1



LOCATION OF MWT STATIONS

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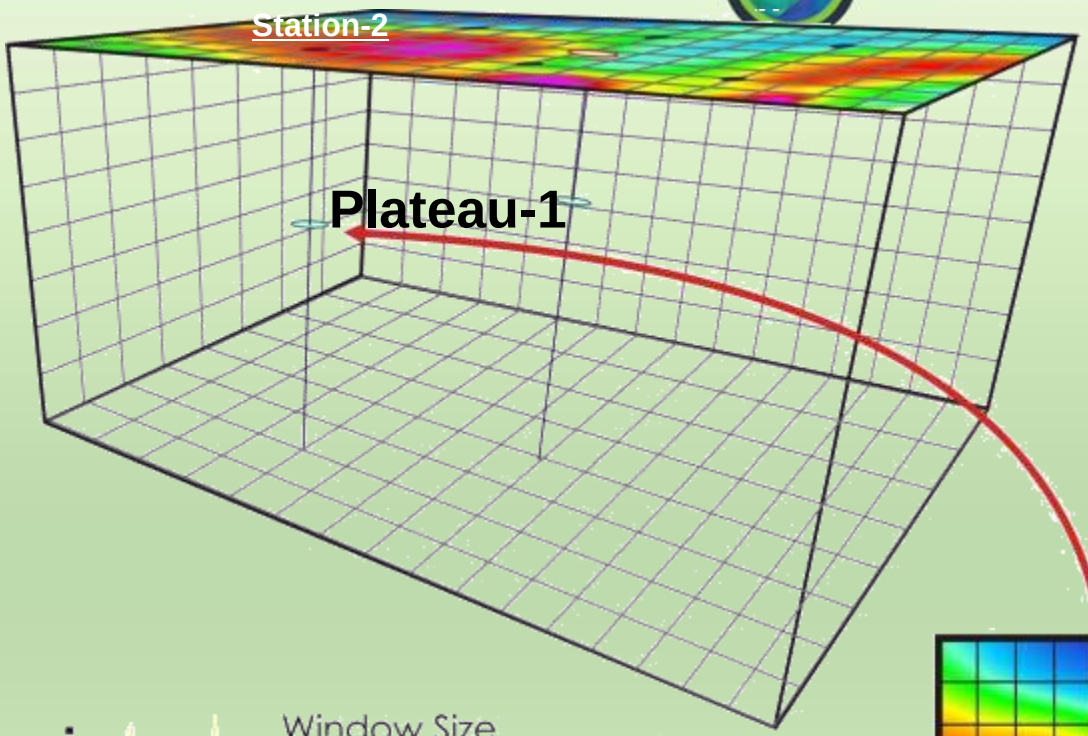
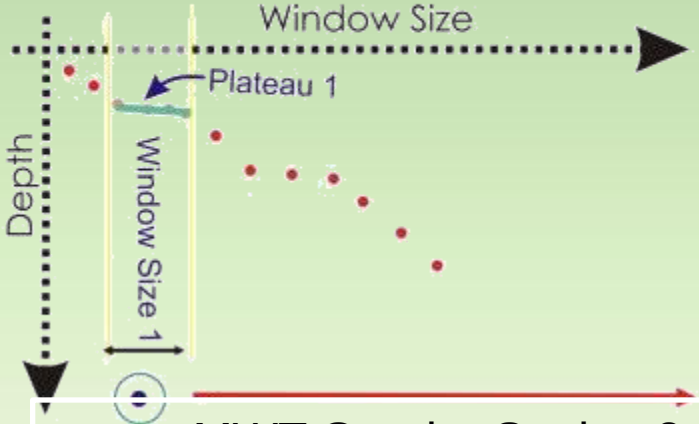
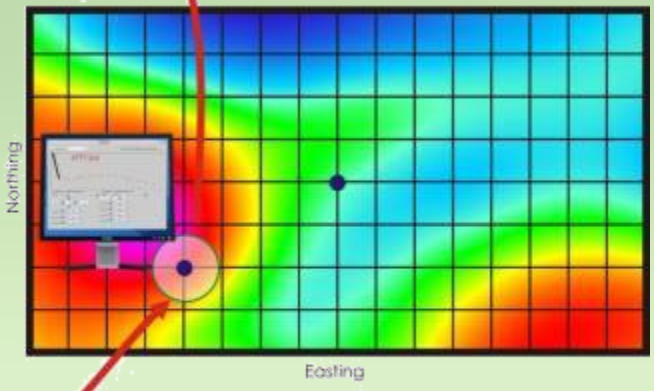
Mapping Shallower Horizon





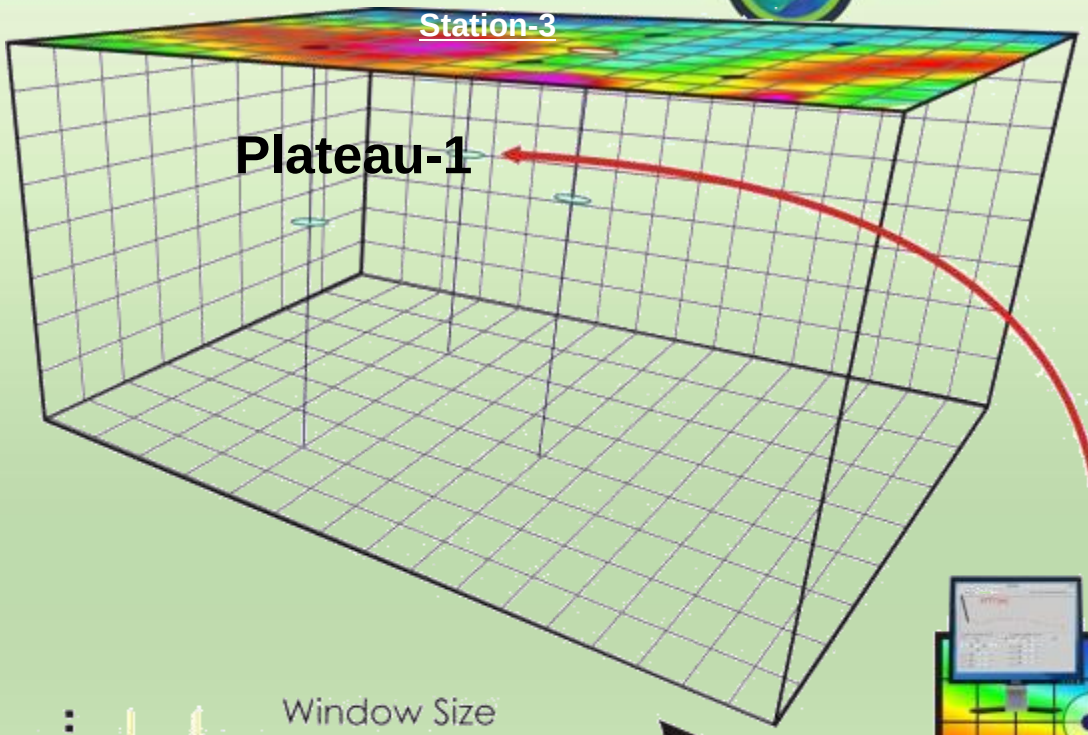
MWT Graph– Station 2

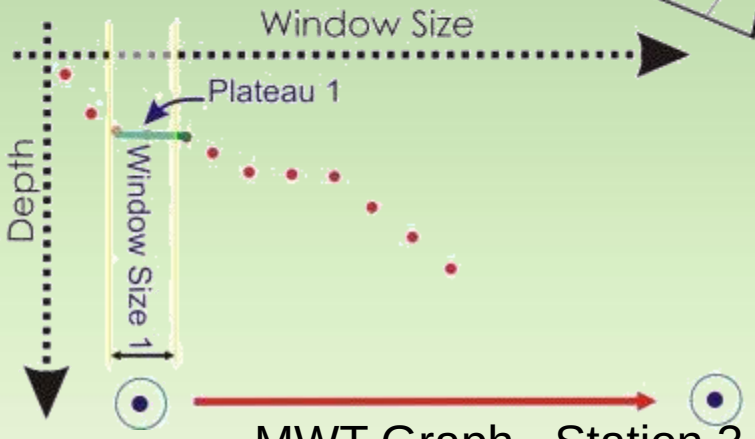


LOCATION OF MWT STATIONS

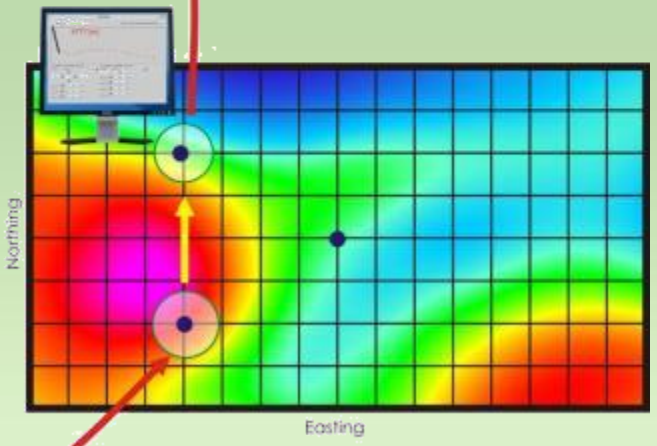
Archimedes

Mapping Shallower Horizon





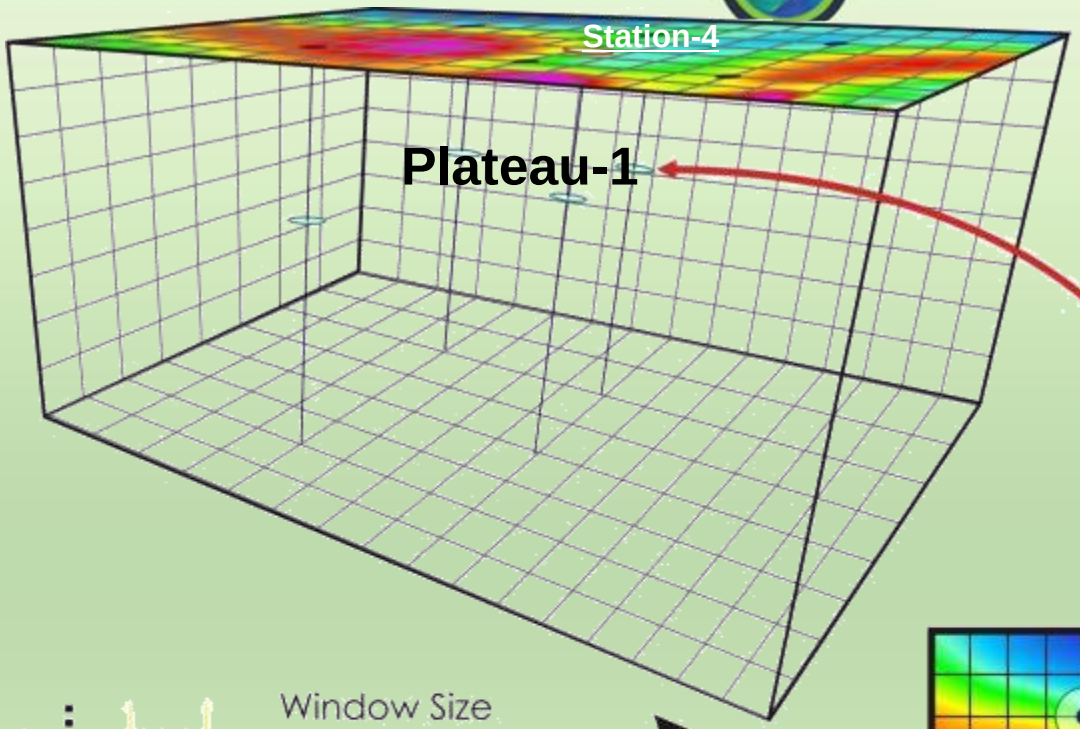
MWT Graph– Station 3

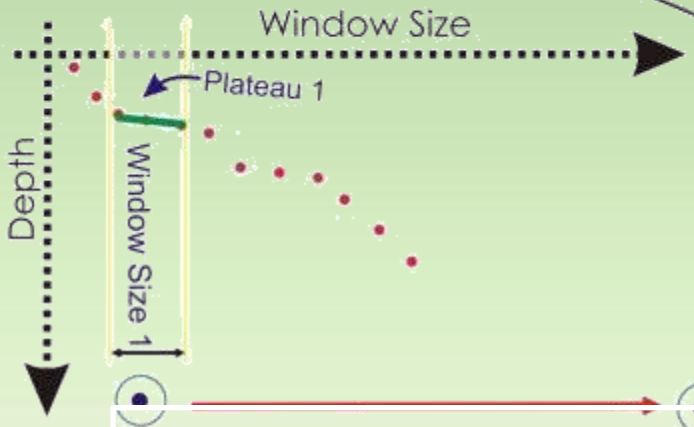


LOCATION OF MWT STATIONS

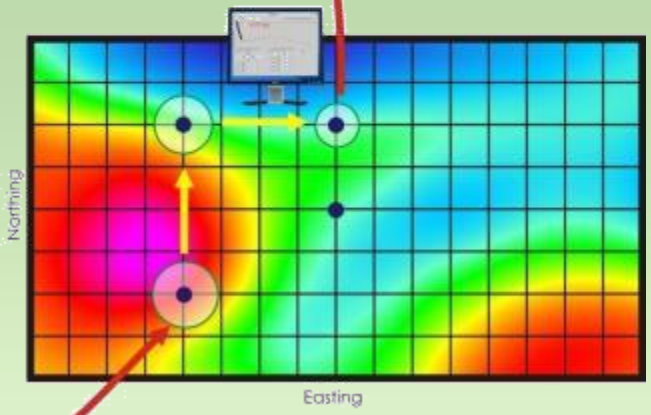
Archimedes

Mapping Shallower Horizon





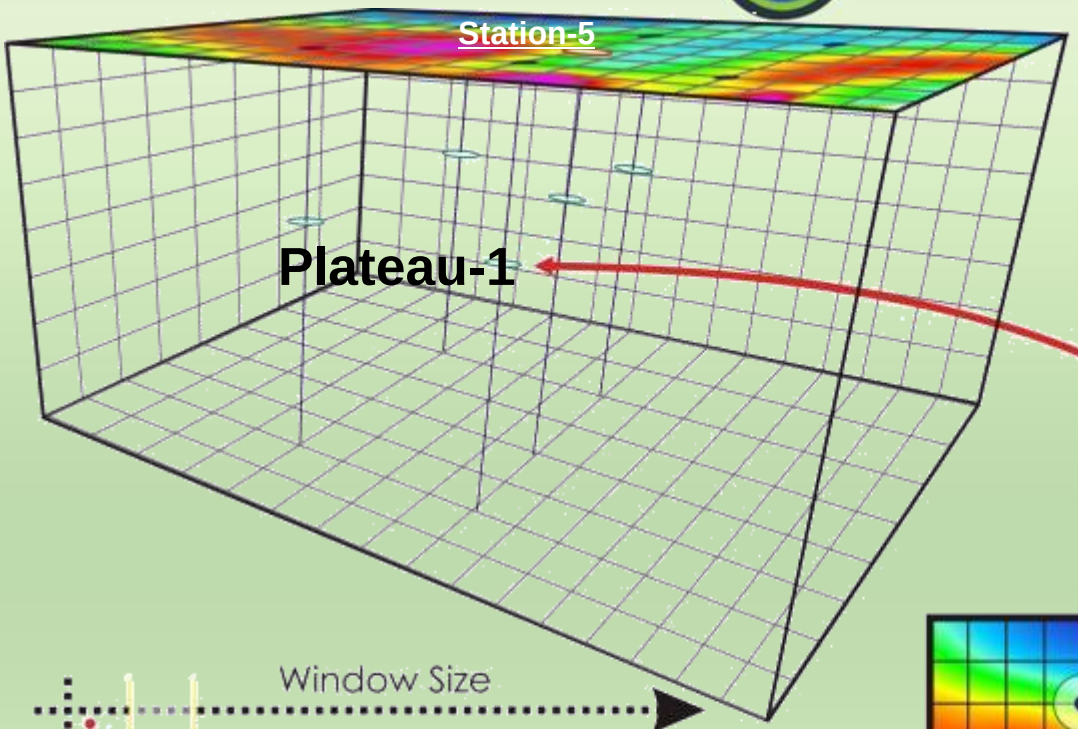
MWT Graph– Station 4

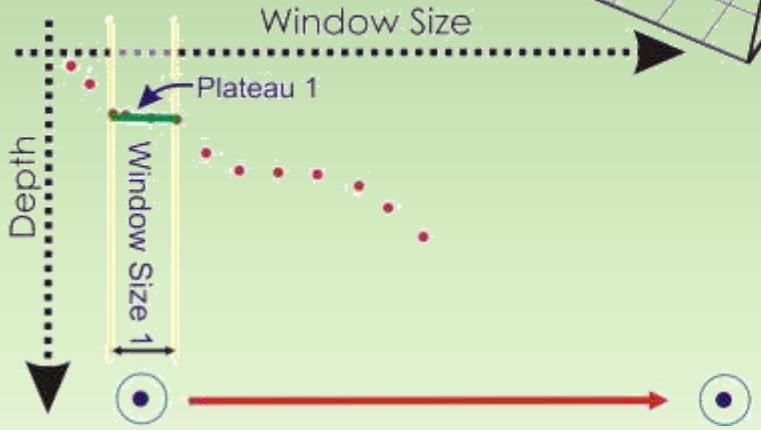


LOCATION OF MWT STATIONS

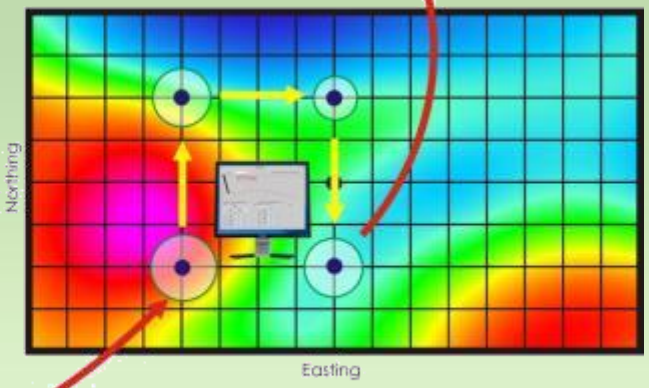
Archimedes

Mapping Shallower Horizon





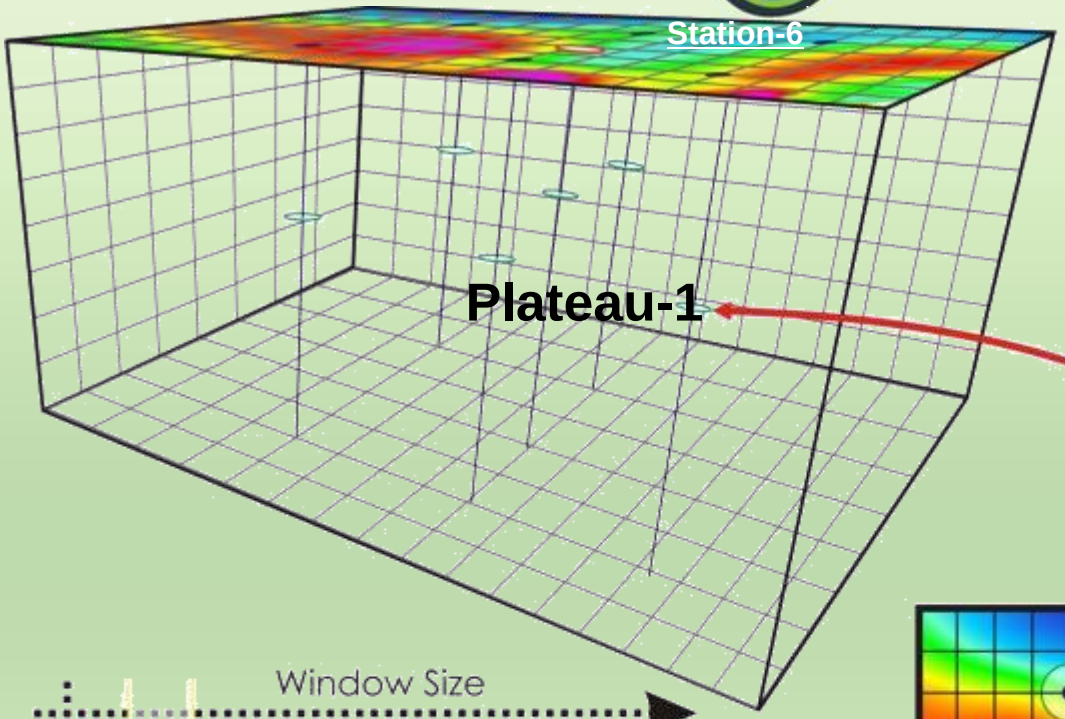
MWT Graph– Station 5

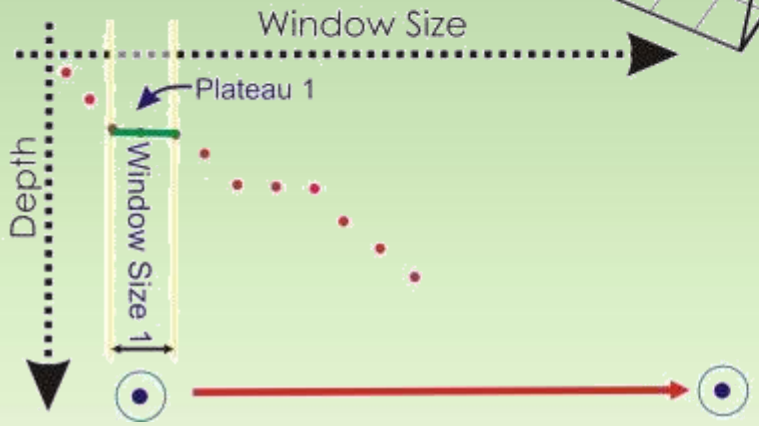


LOCATION OF MWT STATIONS

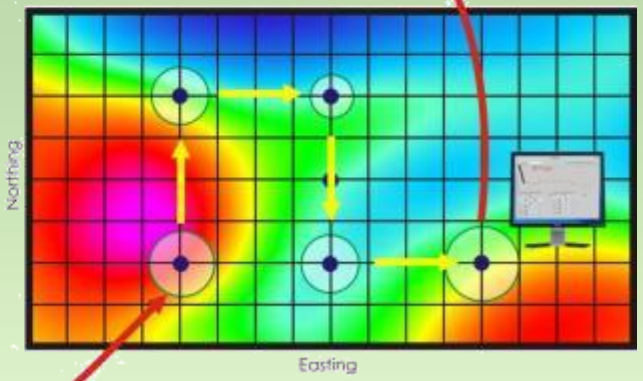
Archimedes

Mapping Shallower Horizon





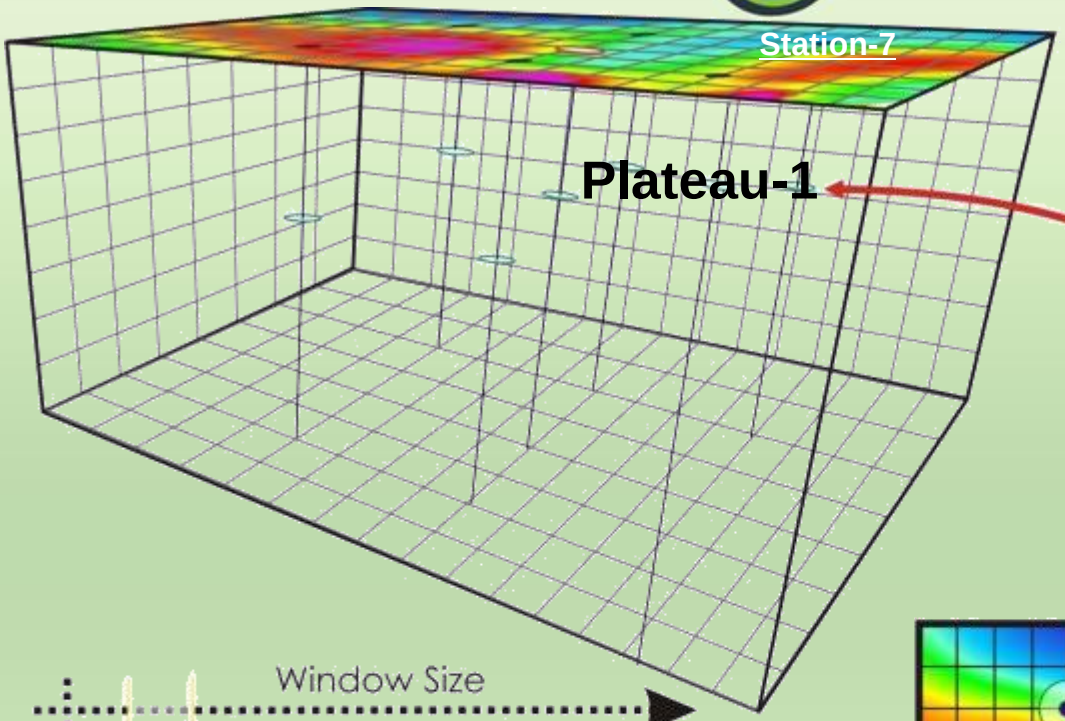
MWT Graph – Station 6

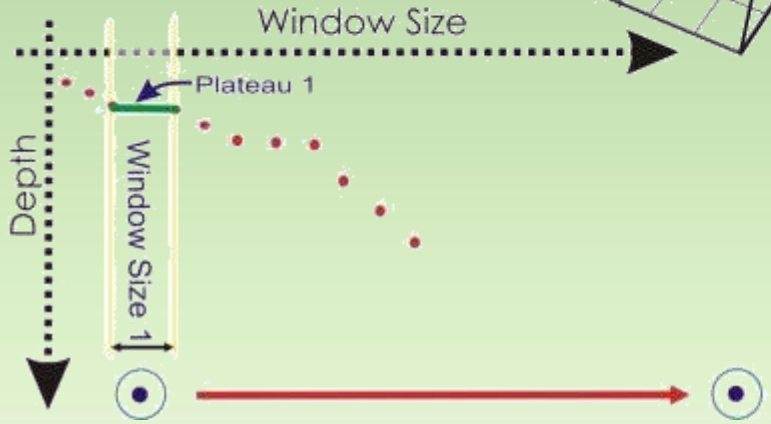


LOCATION OF MWT STATIONS

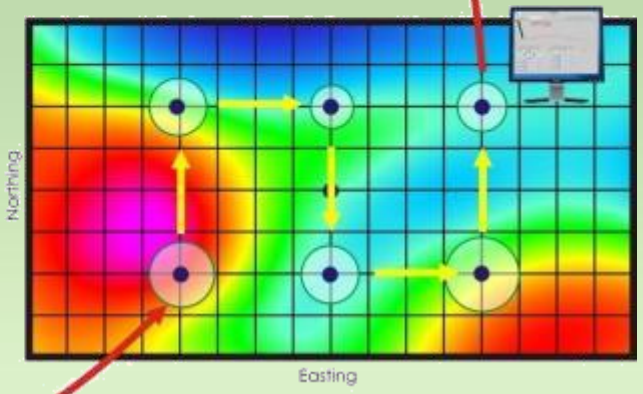
Archimedes

Mapping Shallower Horizon





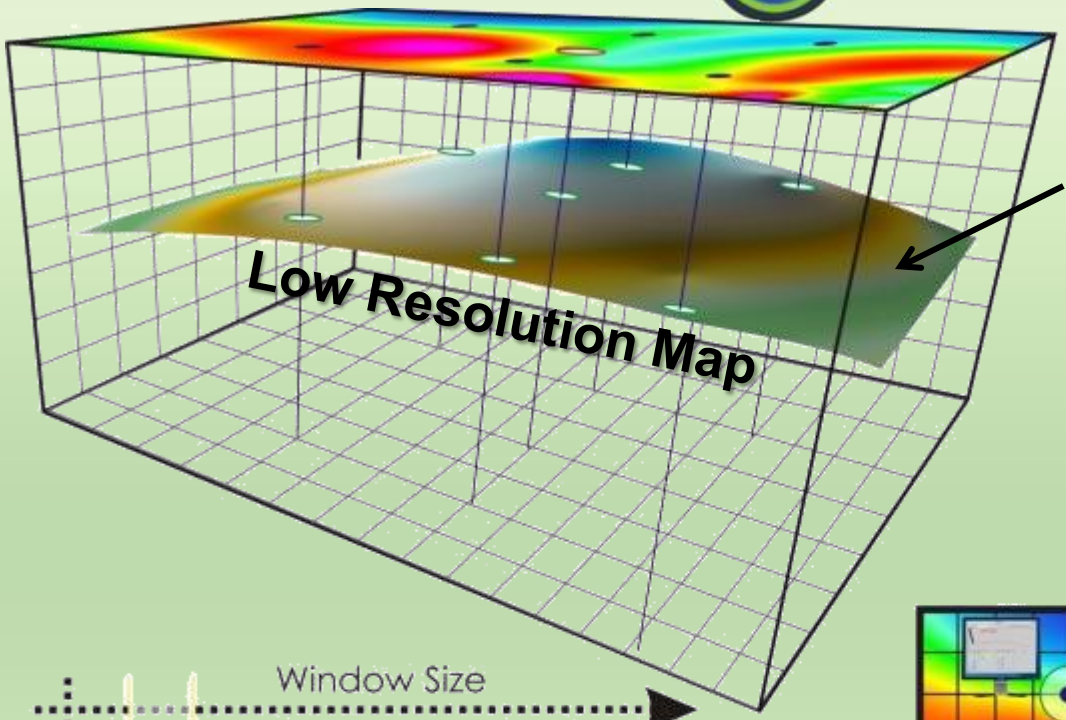
MWT Graph – Station 7

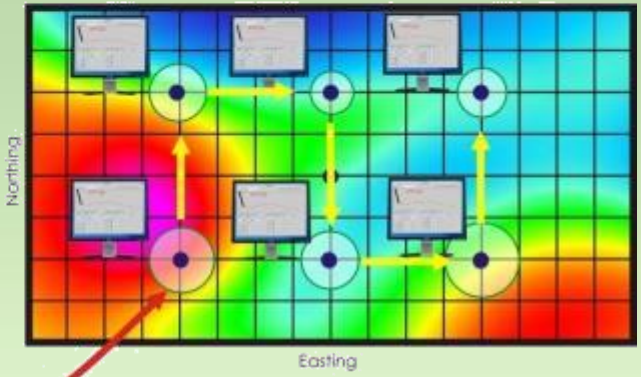


LOCATION OF MWT STATIONS

Archimedes

Skeleton Map of Shallower Horizon





LOCATION OF MWT STATIONS

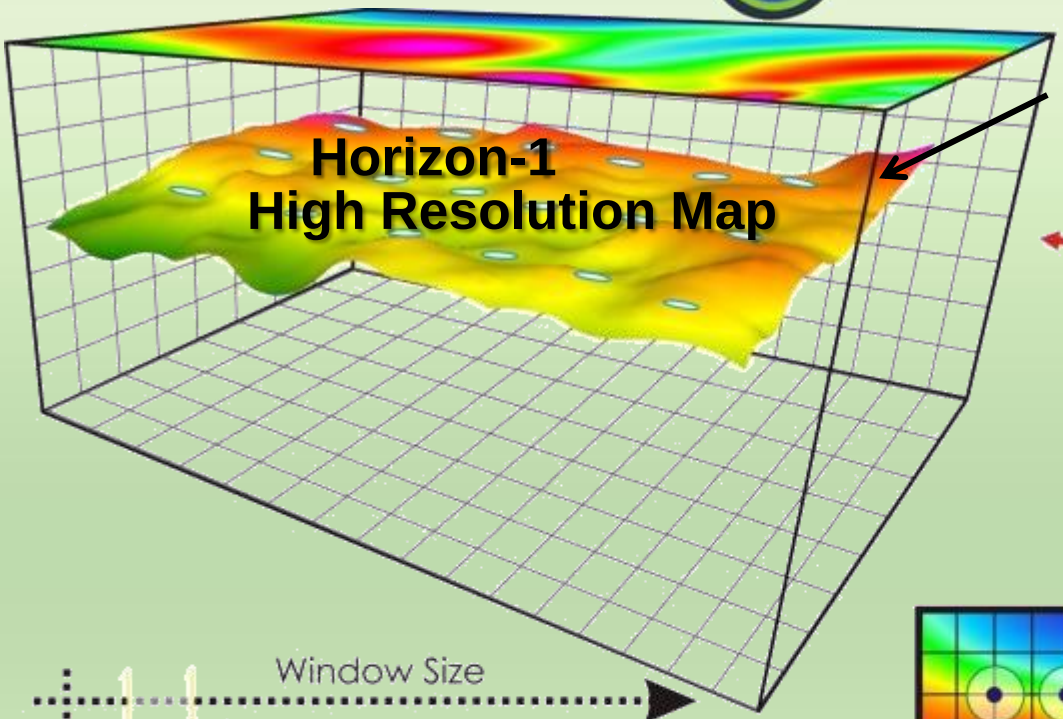
Archimedes

Horizon Mapping

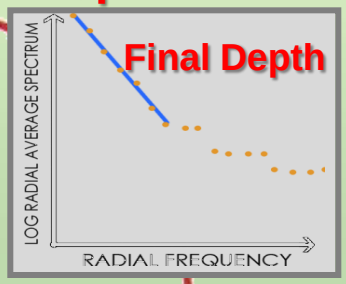
Stage-2: Detailed Maping

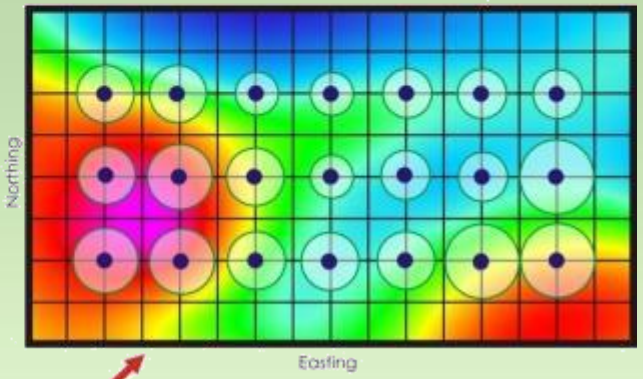
Moving Optimal Window

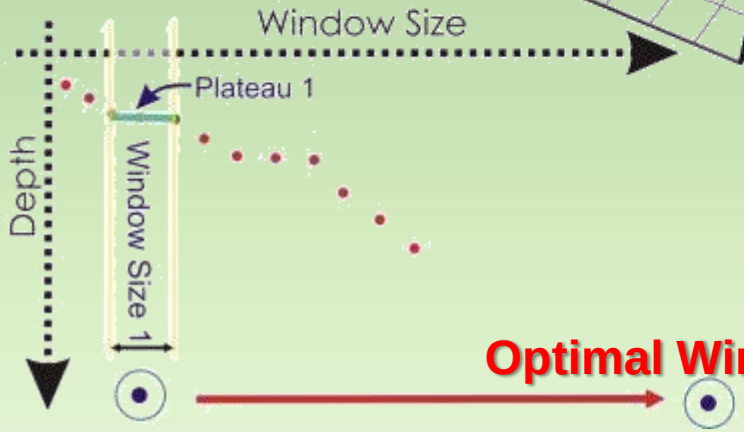
Detailed Mapping of Shallower Horizon-1



Spectrum



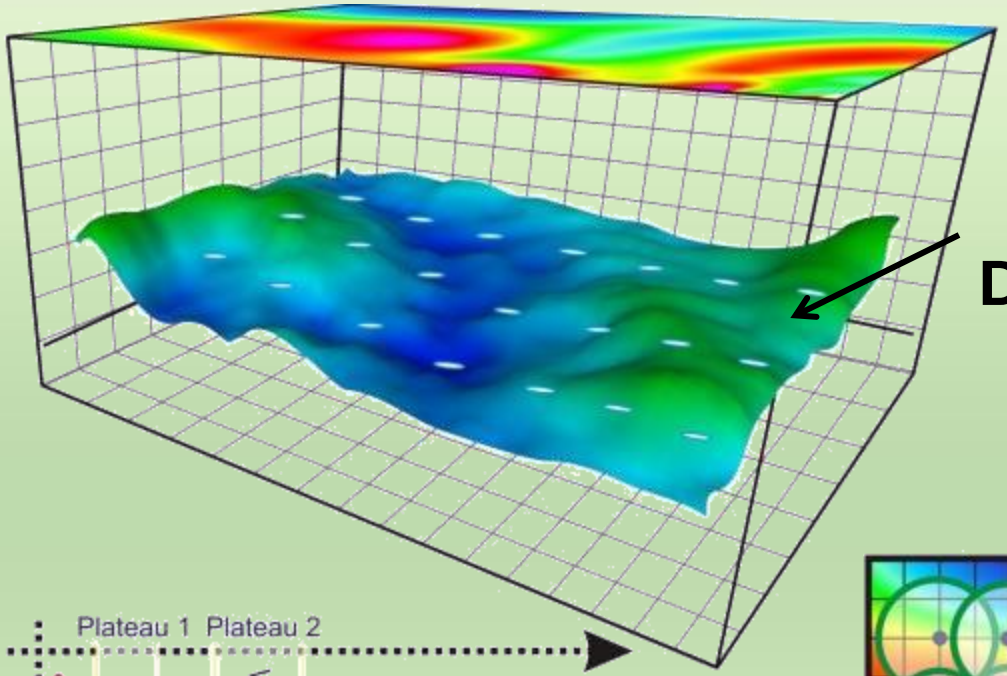




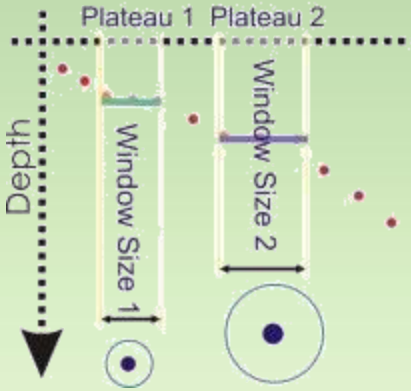
Optimal Windows

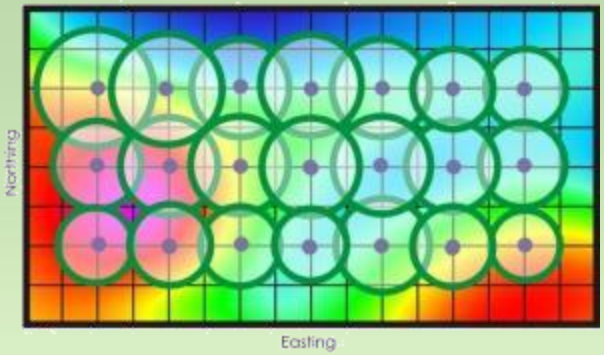
Archimedes

Detailed Mapping of Deeper Horizon



Horizon-2 Detailed Map

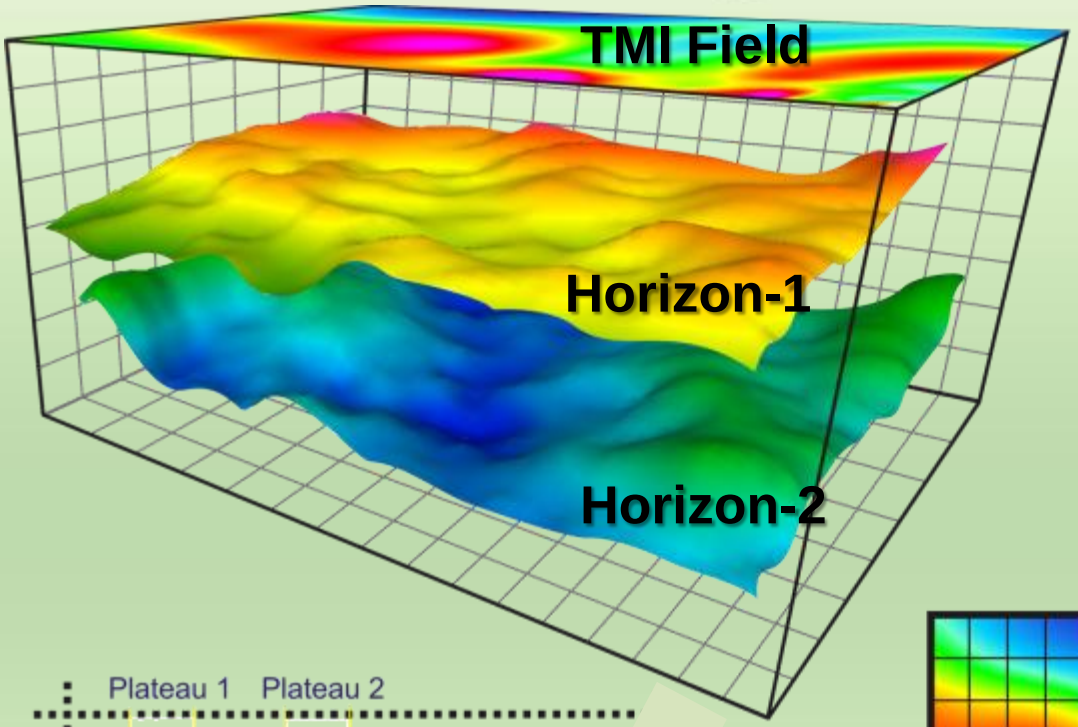


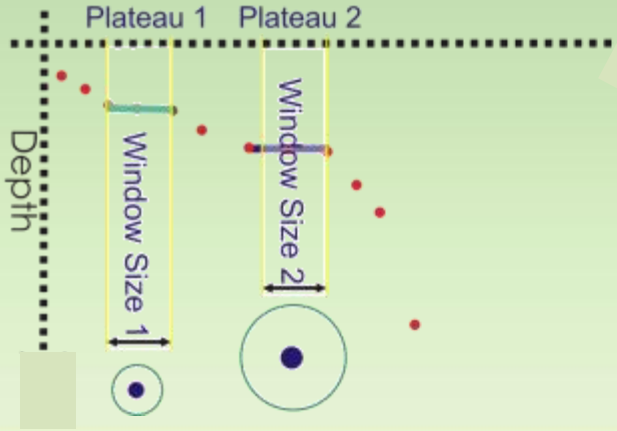


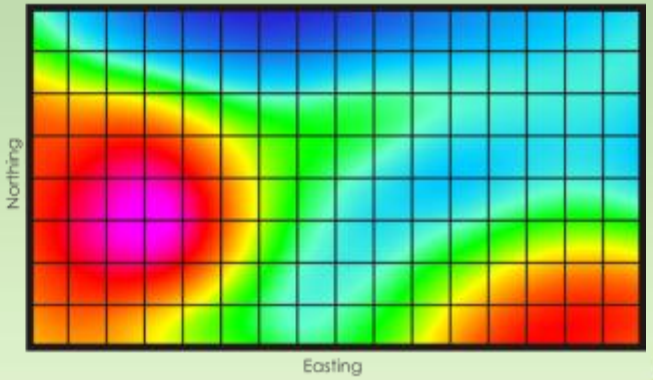
LOCATION OF SPECTRA OF ESA-MW COMPUTED OVER VARIABLE WINDOW

Archimedes

Mapping Two Horizons

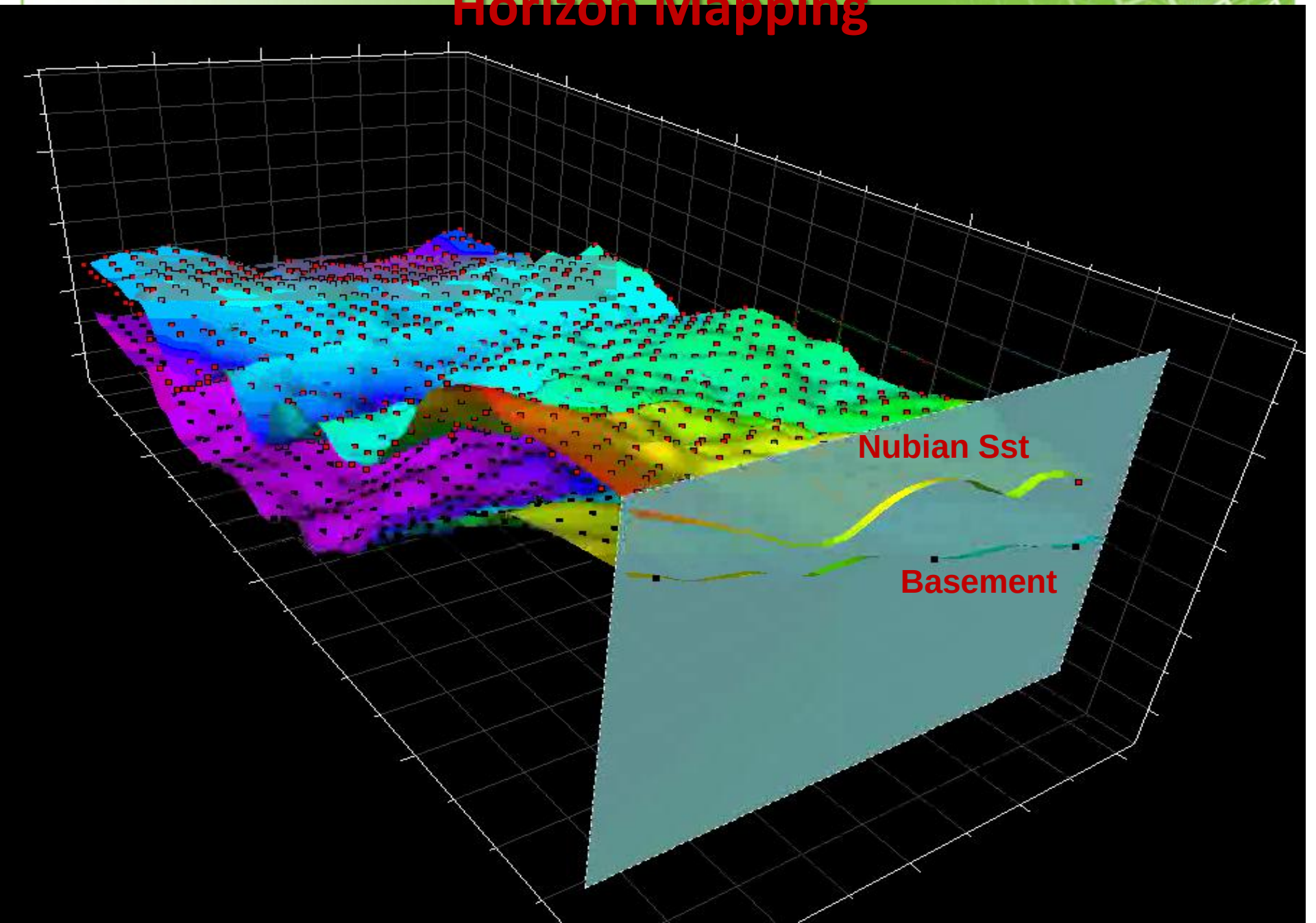






Archimedes

Horizon Mapping



Horizon Mapping

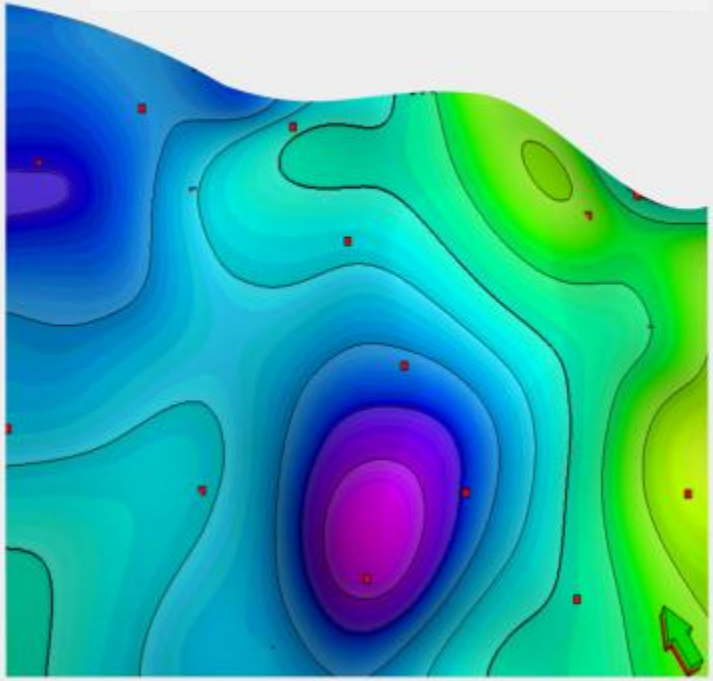
Different Resolutions

Horizon Mapping

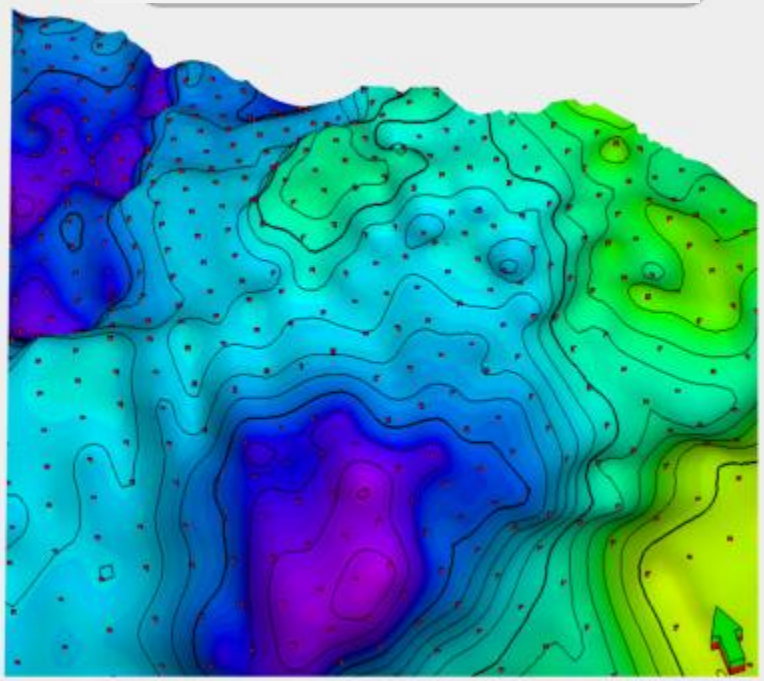
Horizon Skeleton from ESA-MWT

Horizon Detailed Map - ESA-MW

STAGE-1: Horizon Detection



STAGE-2: Detailed Mapping



Archimedes

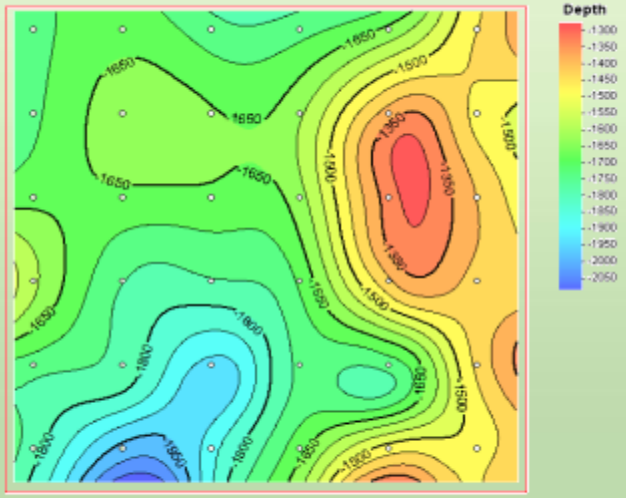
Detailed Mapping

Different Resolution

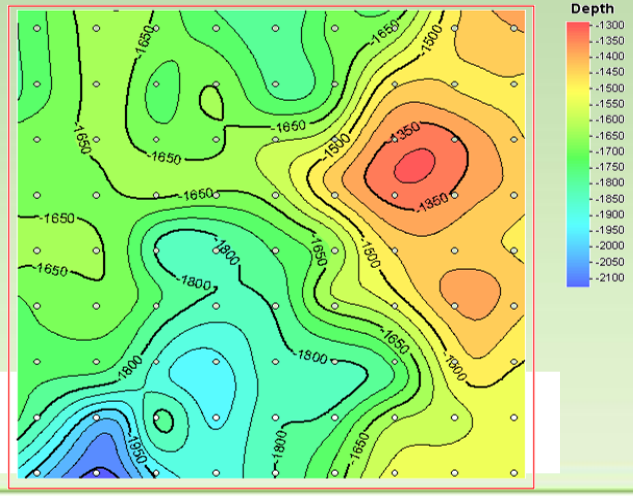
Examples

Detailed Horizon Mapping at Different Resolutions

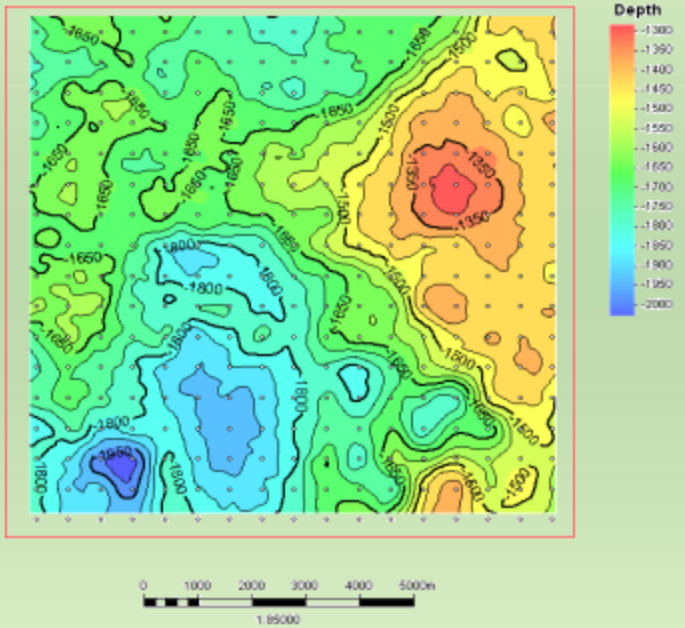
Low-Resolution: Depth Estimates
1.8km x 1.8km spacing



Medium-Resolution: Depth Estimates
1.2km x 1.2km spacing



High-Resolution: Depth Estimates
600m x 600m spacing



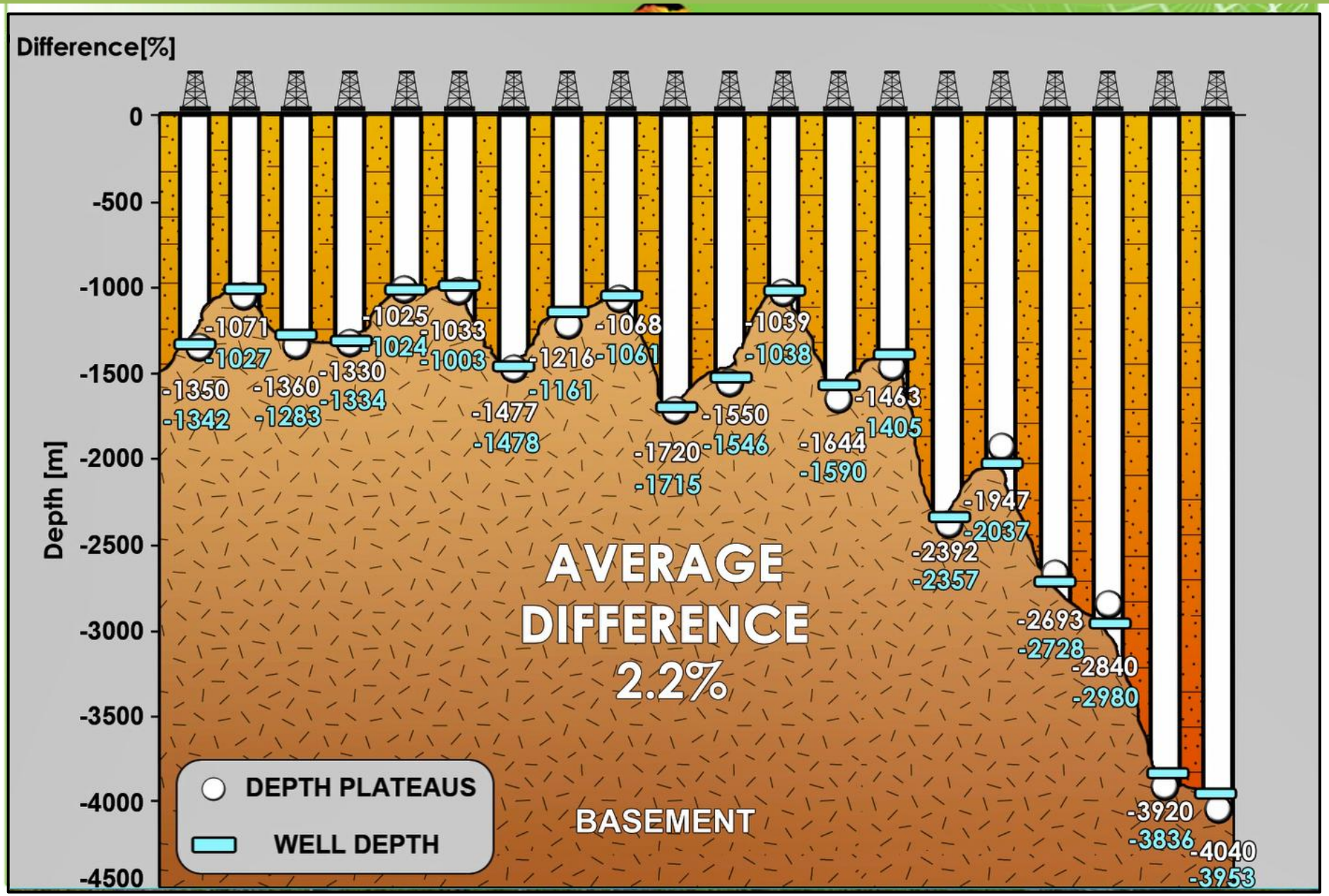
Archimedes

Horizon Mapping

vs

Well Data

Depth-Plateaus vs Well Depths



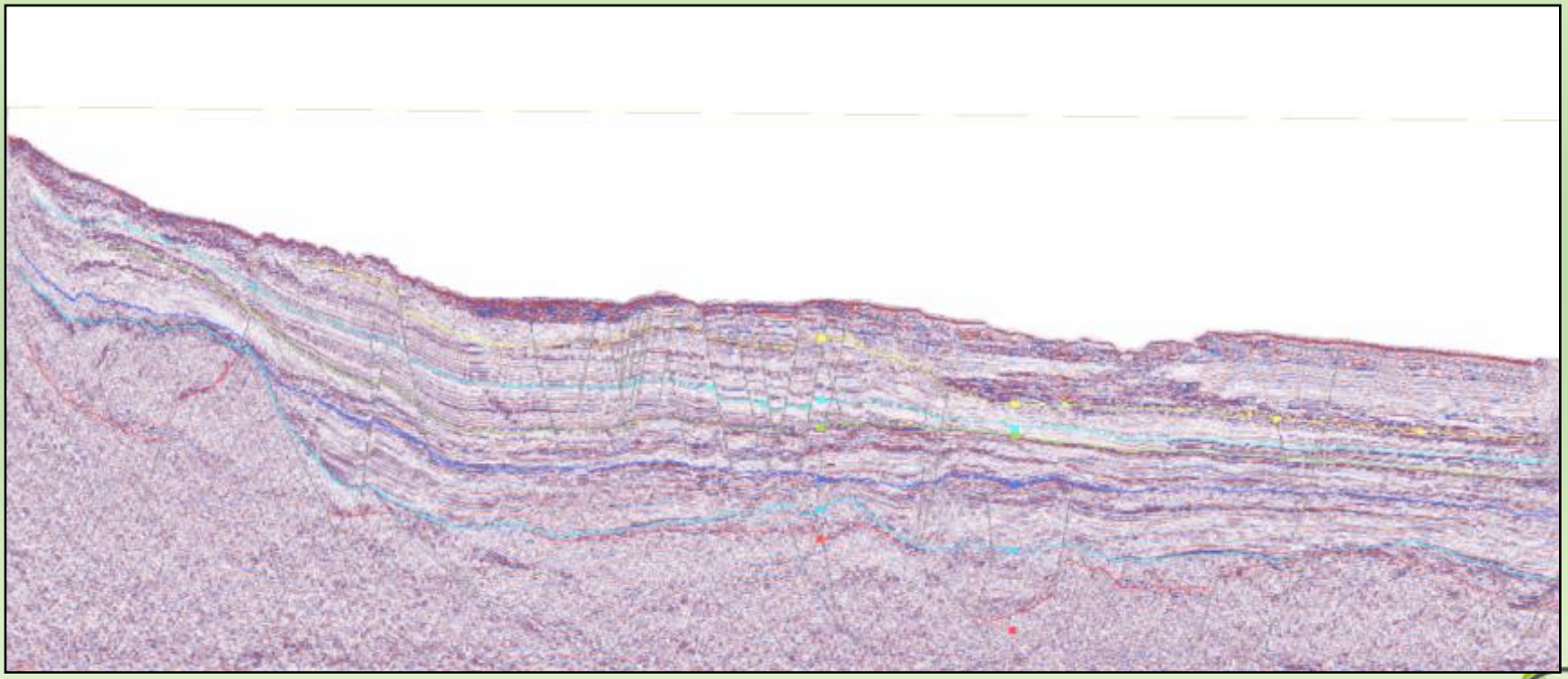
Horizon Mapping

vs

Seismic

Seismic Line: Location 1

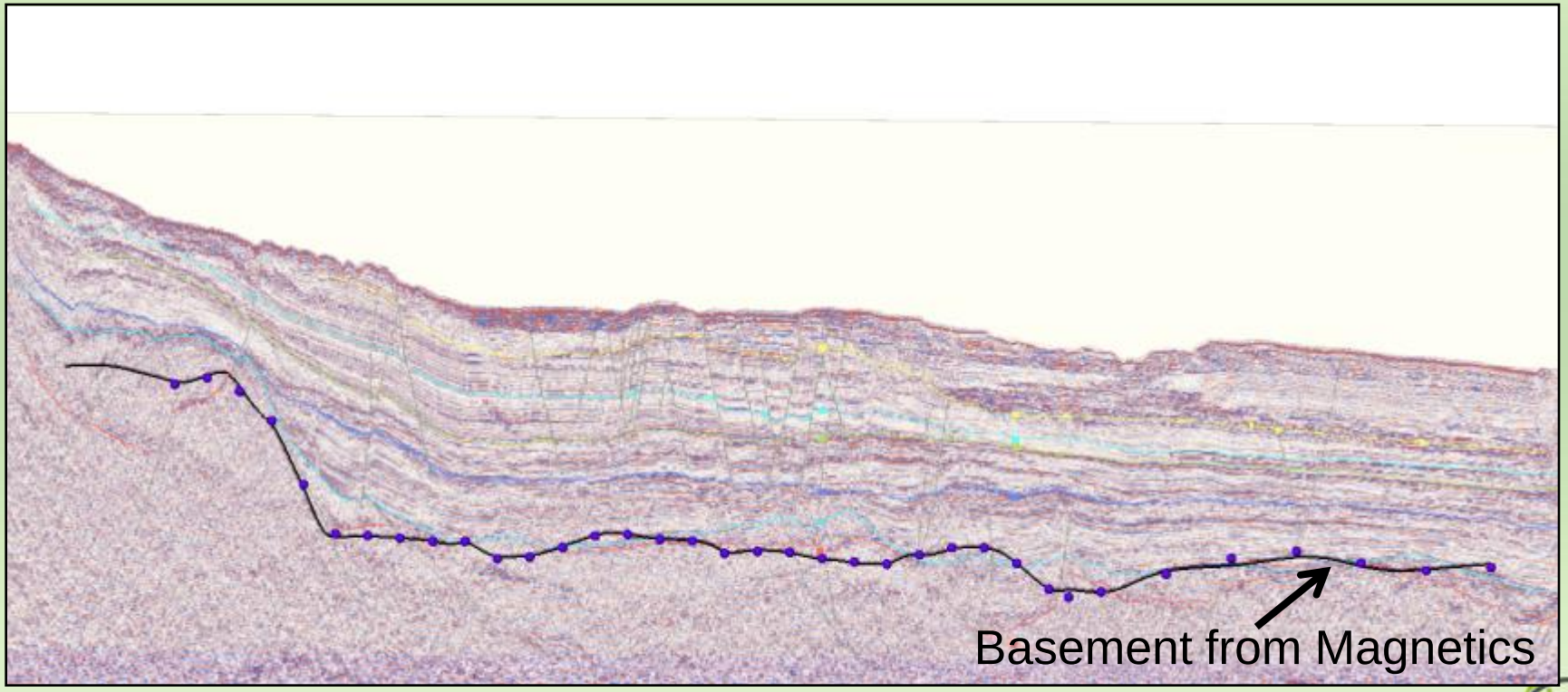
Mapping Basement from Magnetics



Archimedes

Seismic Line: Location 1

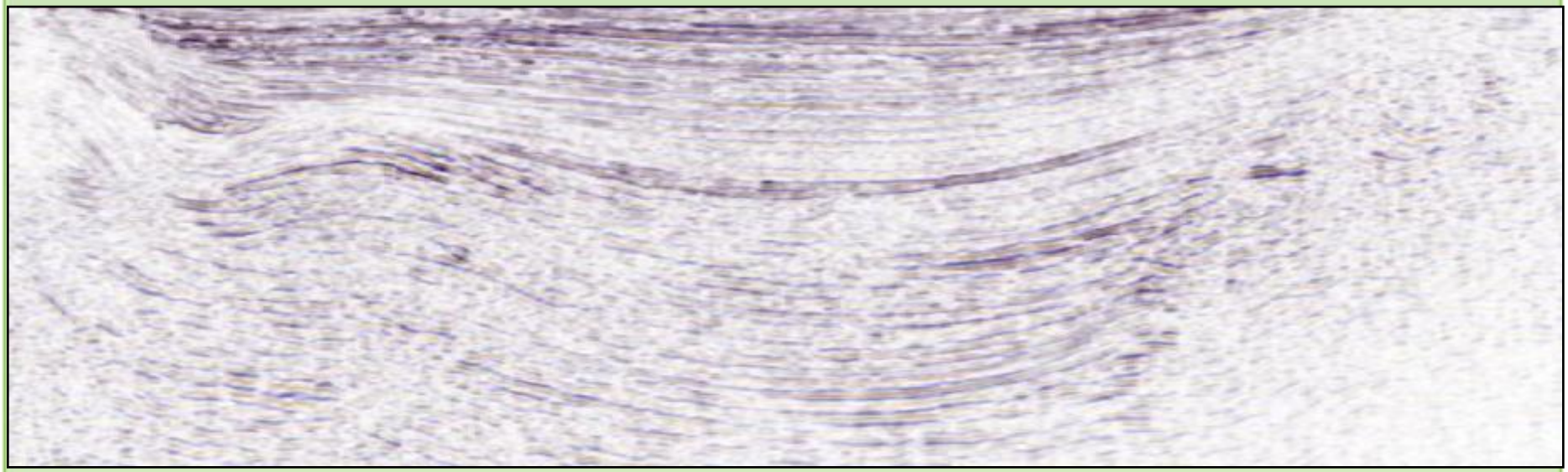
Basement from Magnetics



Archimedes

Seismic Line: Location 2

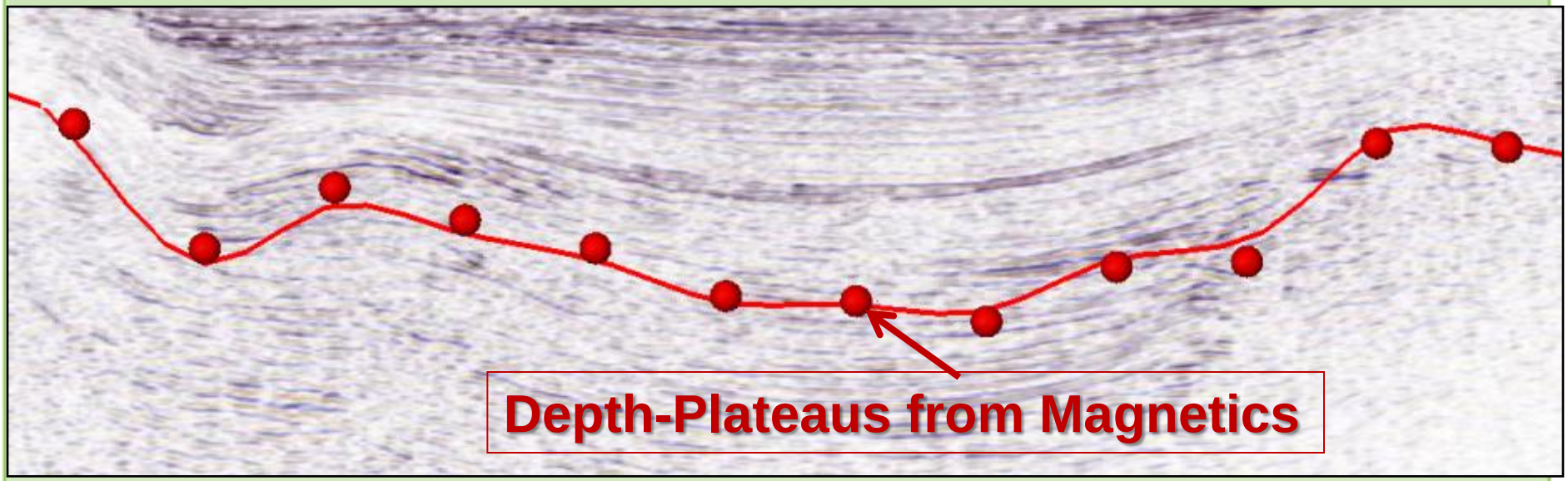
Horizon Mapping from Magnetics



Archimedes

Seismic Line: Location 2

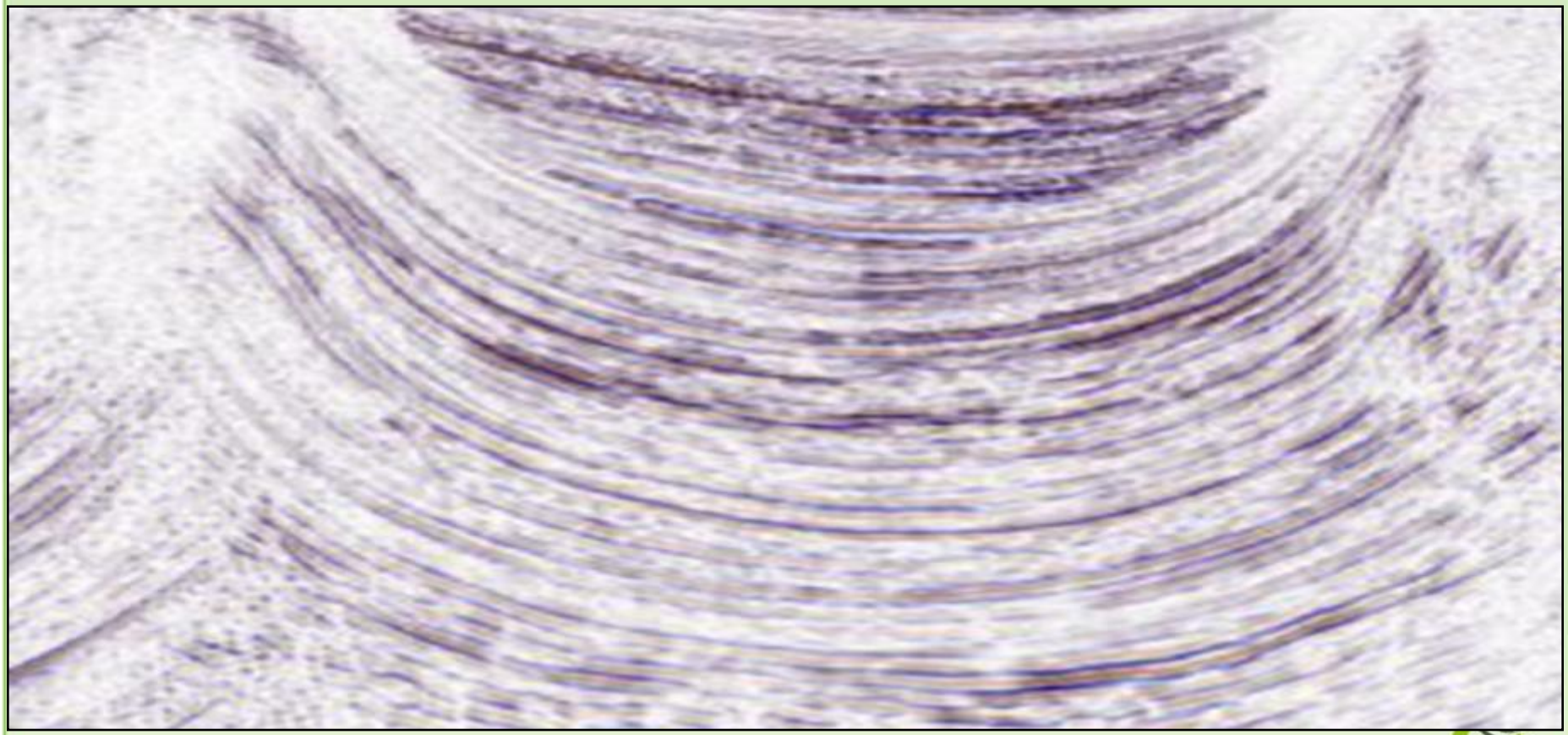
Horizon Mapping from Magnetics



Archimedes

Seismic Line: Location 3

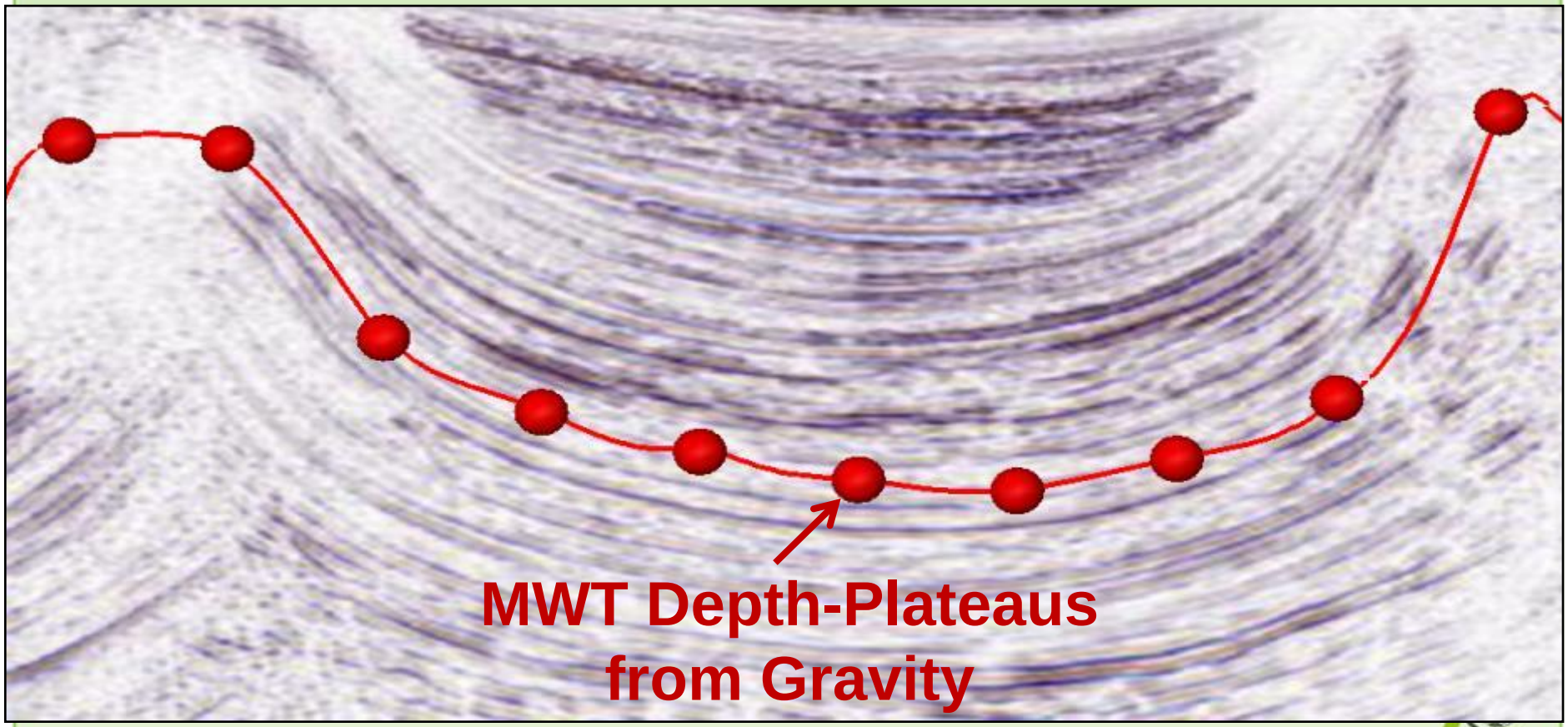
Horizon Mapping from Gravity



Archimedes

Seismic Line: Location 3

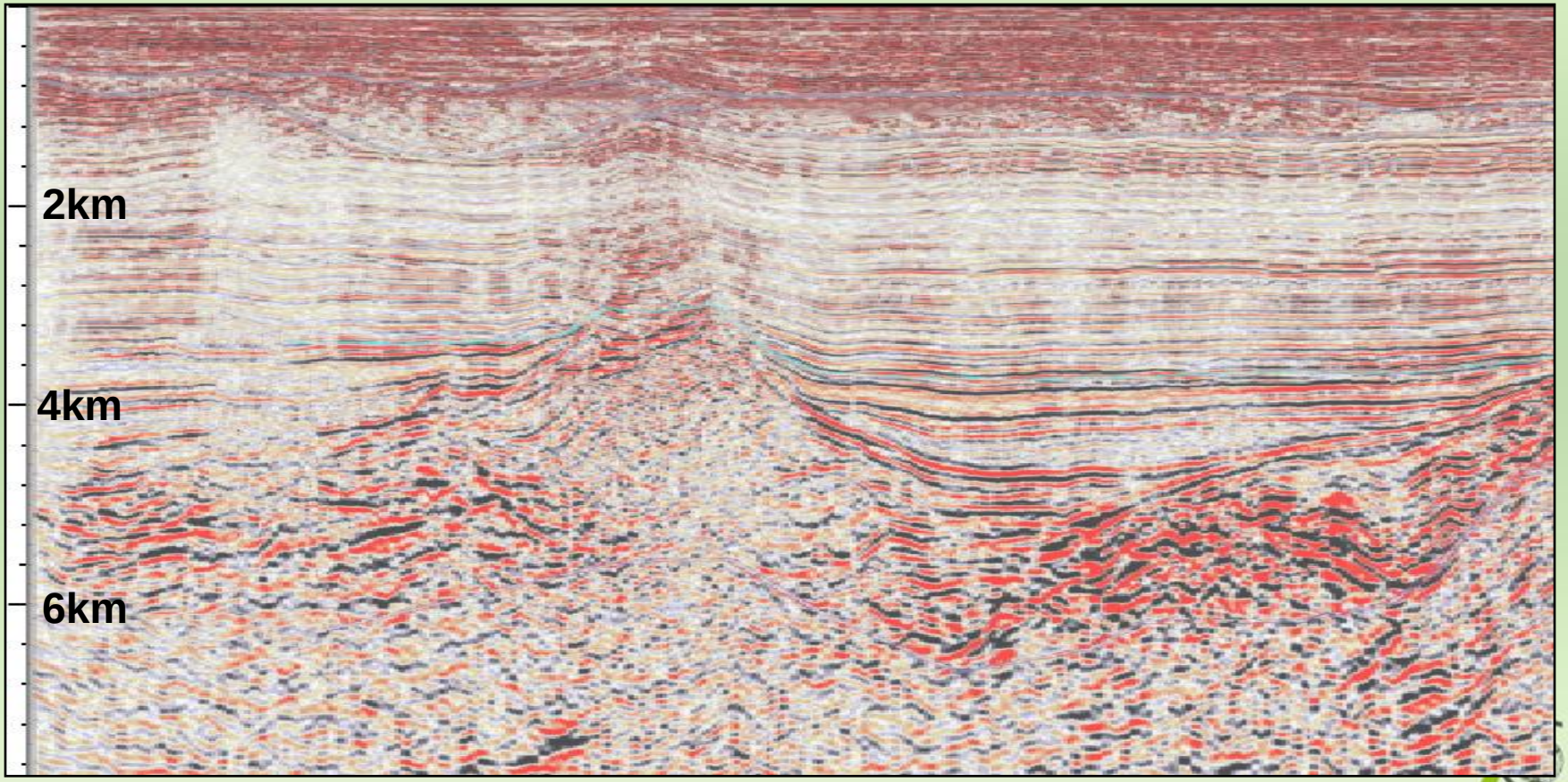
Horizon Mapping from Gravity



Archimedes

Seismic Line: Location 4

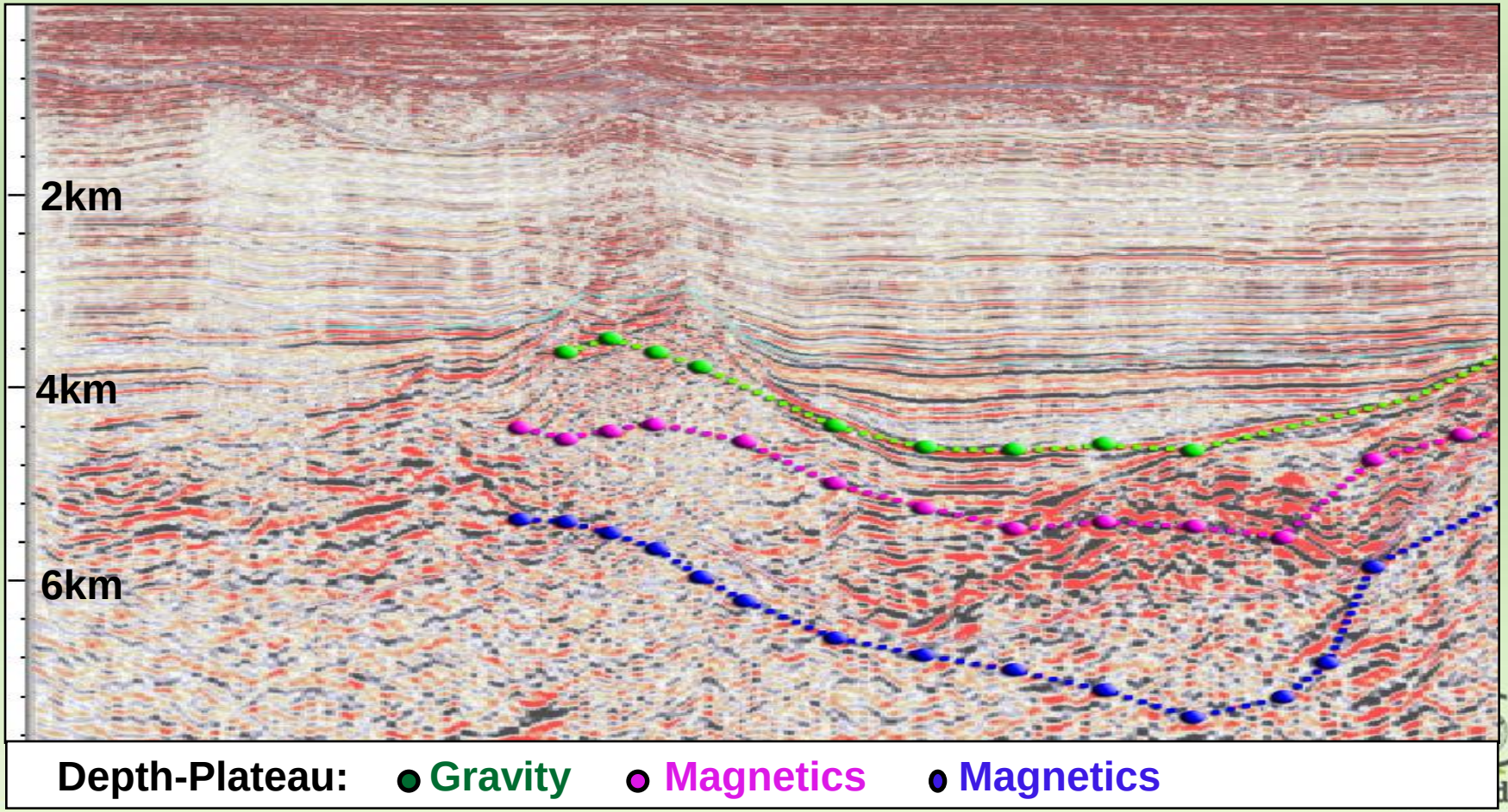
Basement & Sedimentary Horizons from Magnetics & Gravity



Archimedes

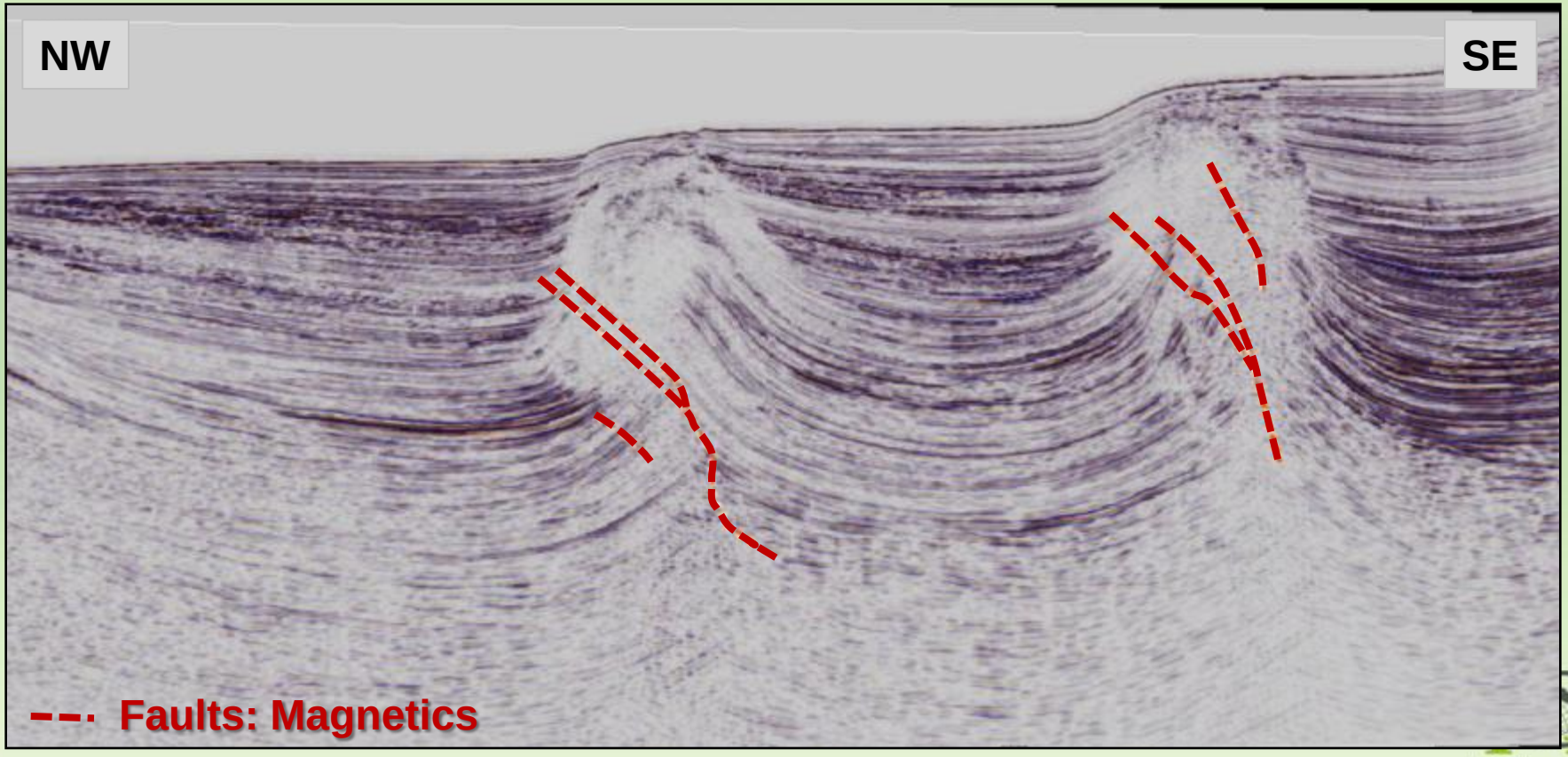
Seismic Line: Location 4

Basement & Sedimentary Horizons from Magnetics & Gravity



Seismic Line: Location 5

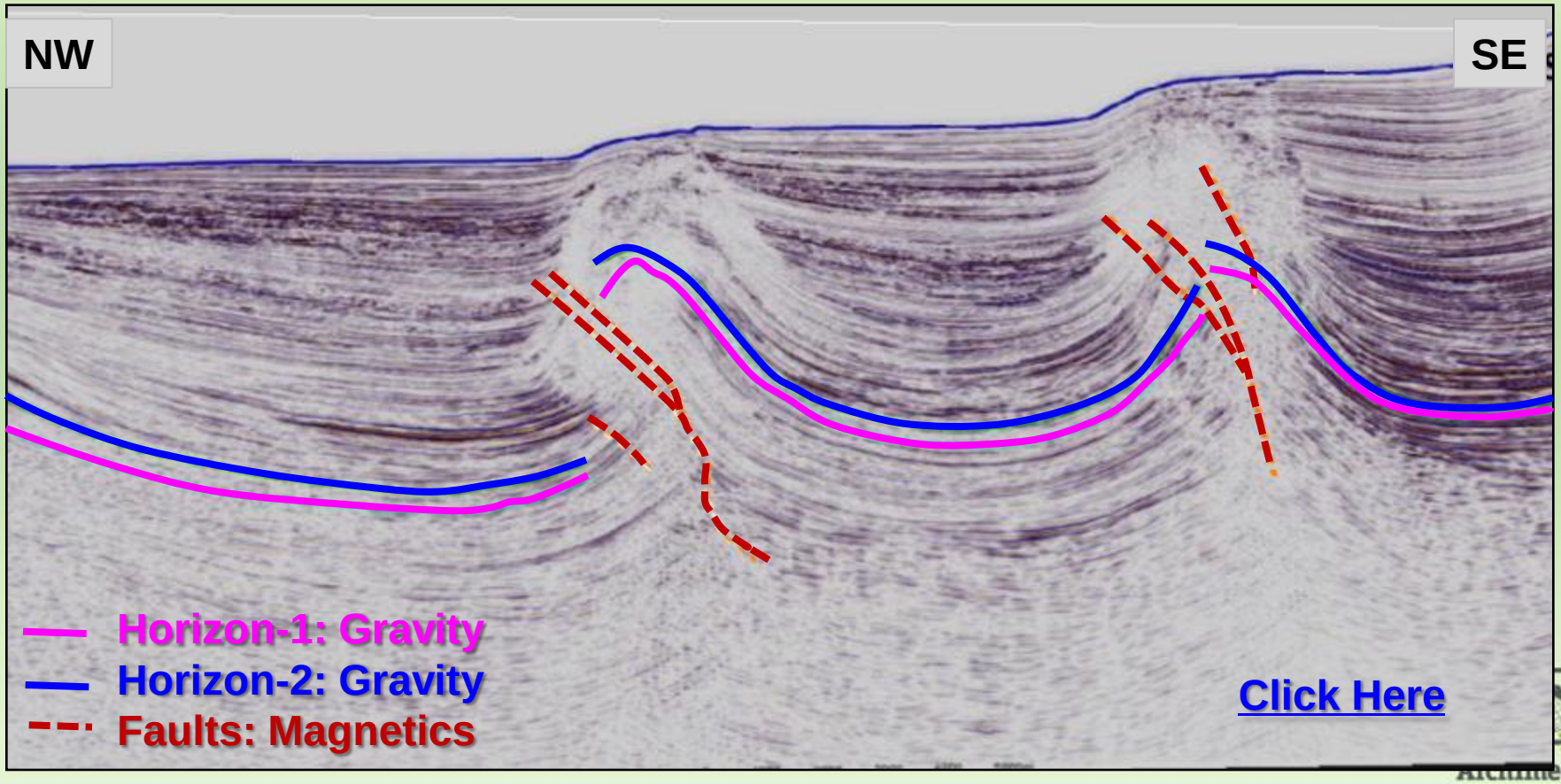
Faults Mapped from Magnetics



Archimedes

Seismic Line: Location 1

Horizons Mapping from Gravity
Faults from Magnetics

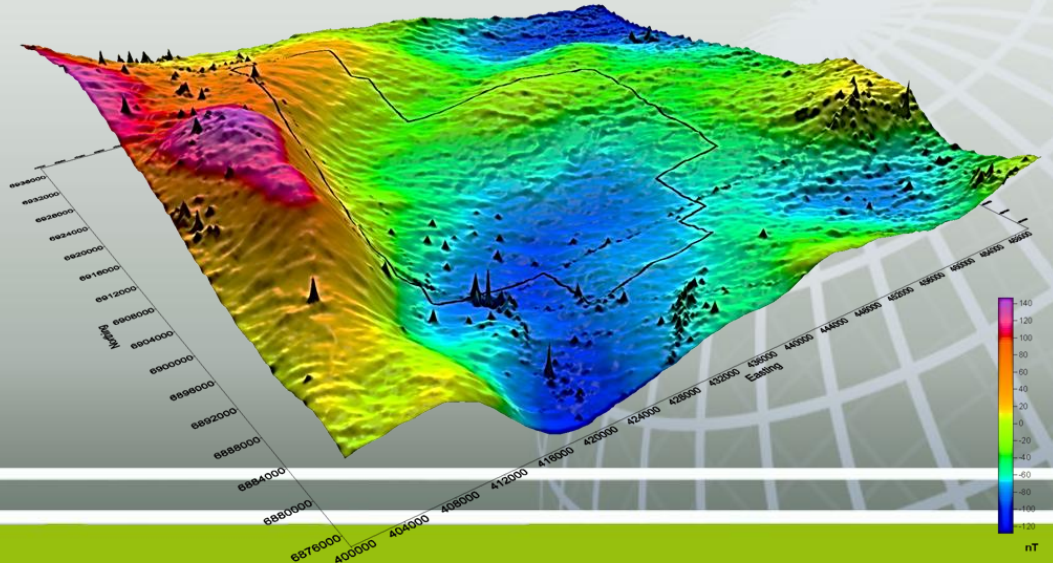


Horizon Mapping Examples

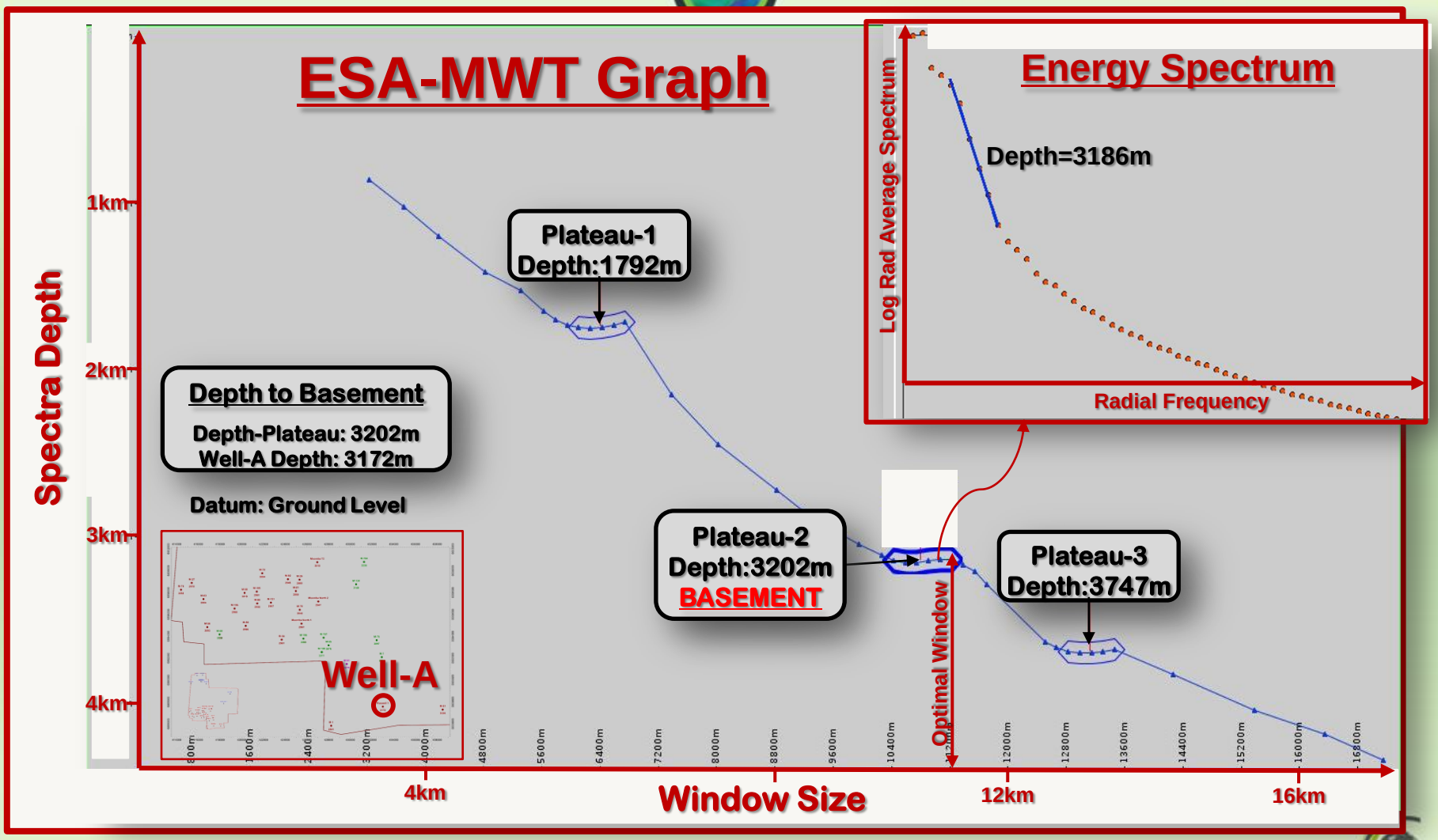
- Magnetics
- Gravity Gradiometry

Basement

Magnetic Data
Cooper Basin, Australia



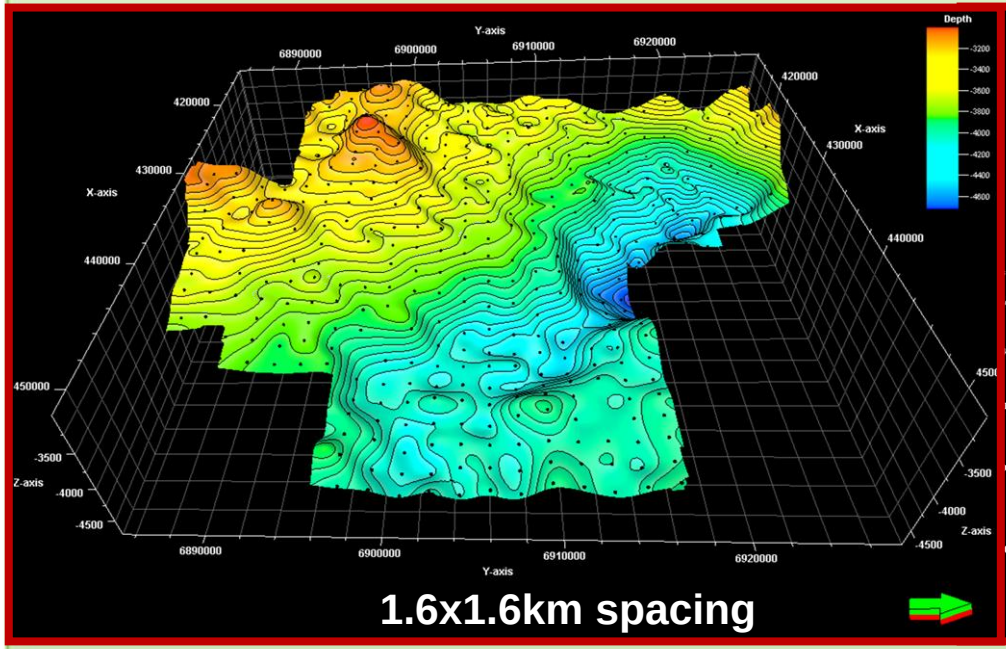
Well-A: MWT-Graph



Archimedes

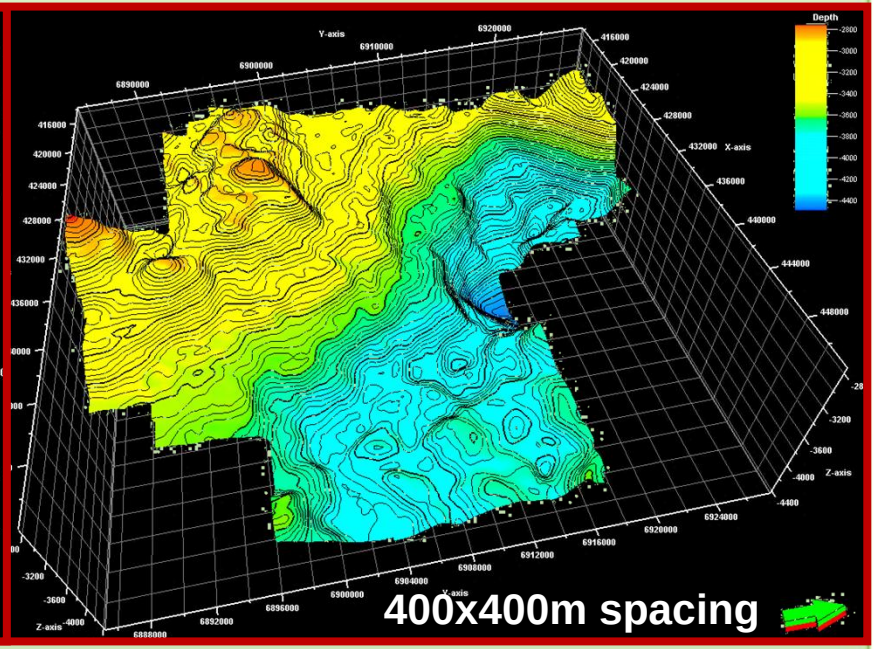
Magnetic Basement

Low-Resolution Basement



1.6x1.6km spacing

High-Resolution Skeleton



400x400m spacing

ESA-MWT at 27 wells

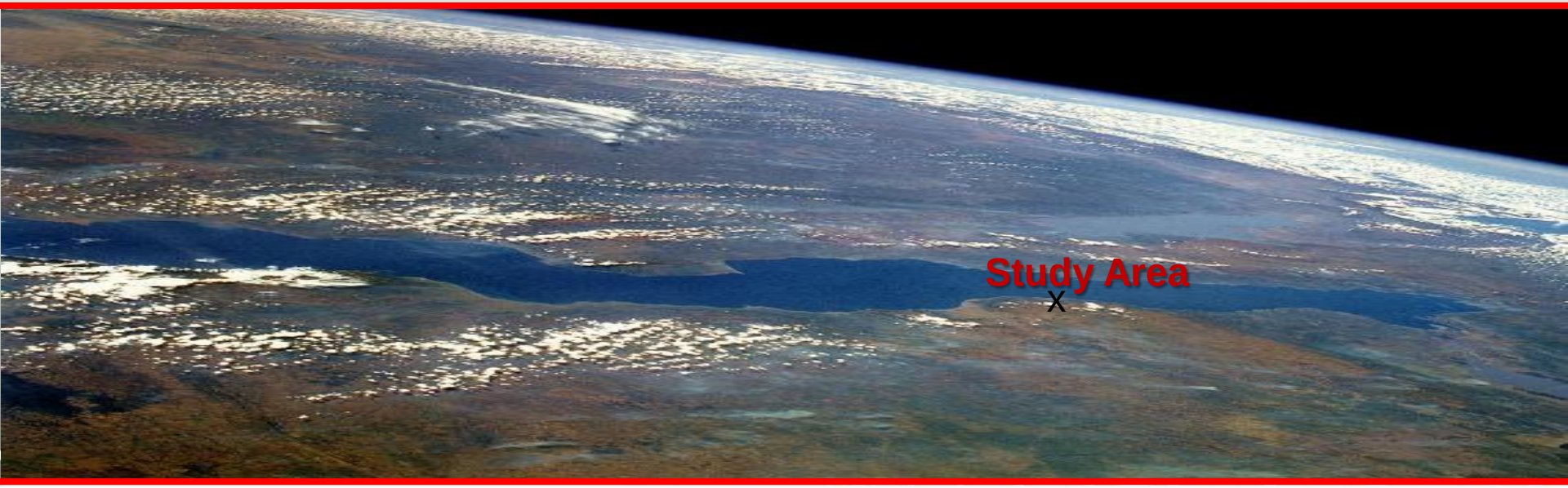
Well Depth vs *Depth-Plateaus*

Error < 1%

Archimedes

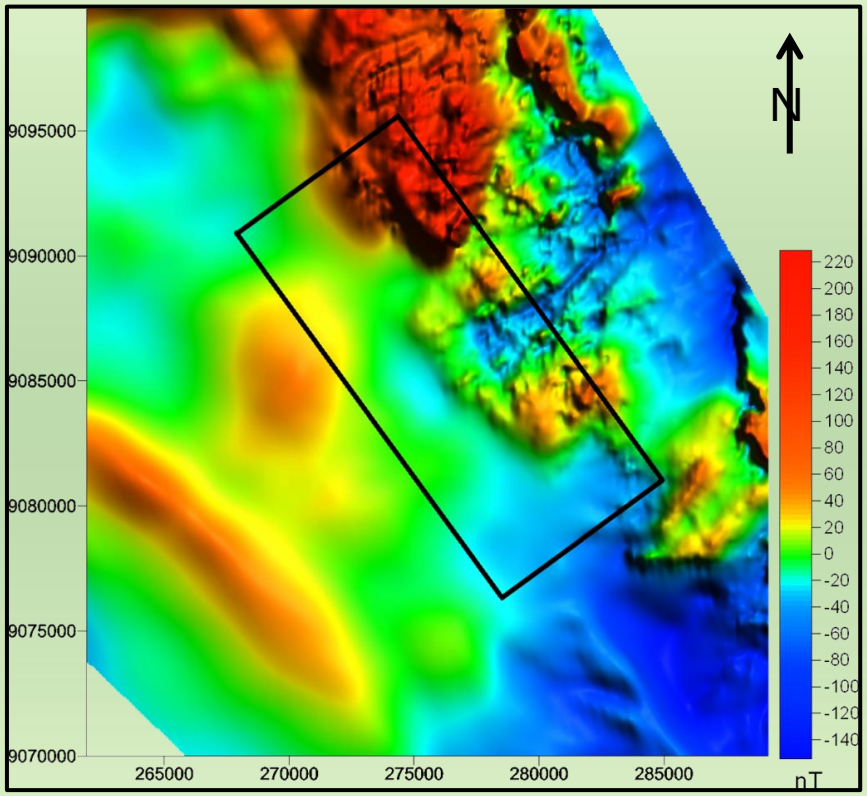
Basement

Gravity Gradiometry Data
Lake Tanganyika Tanzania

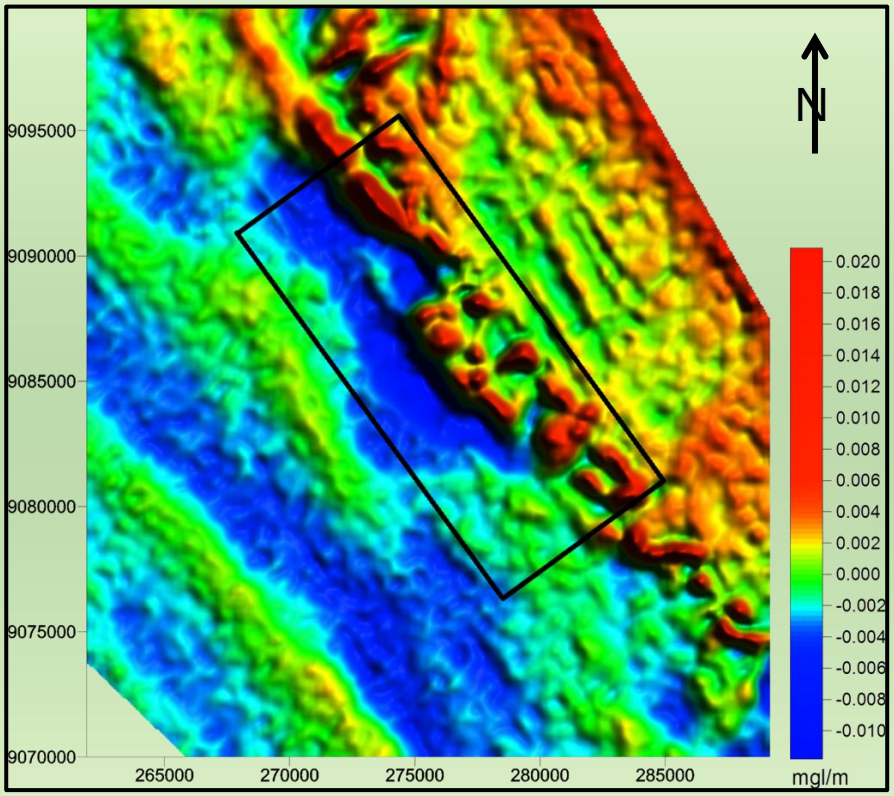


Lake Tanganyika: AGG & Magnetics

RTP Field



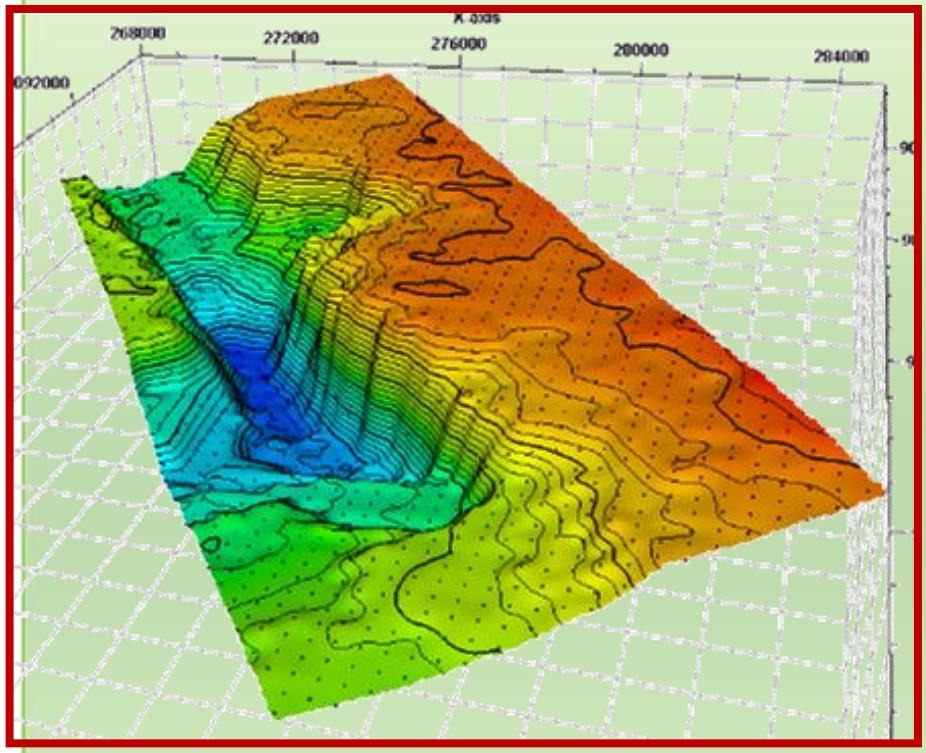
VG of Bouguer Gravity

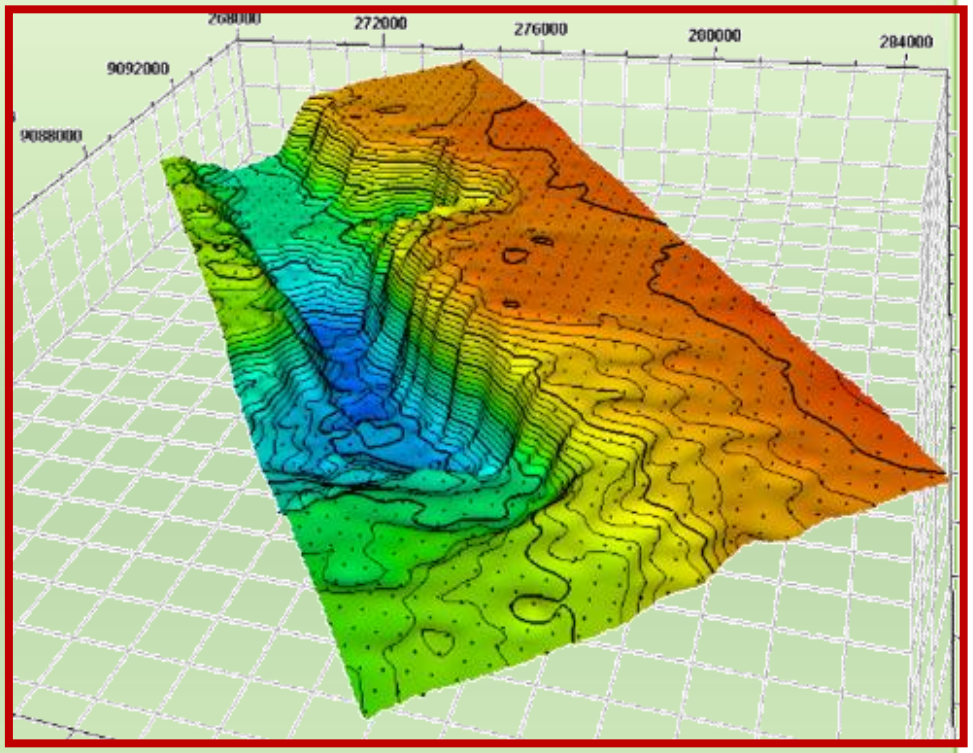


Archimedes

Mapping Basement from AGG & RTP: Rift Basin

Datum: Mean Lake Level





Basement from AGG

Basement from Magnetics

Archimedes

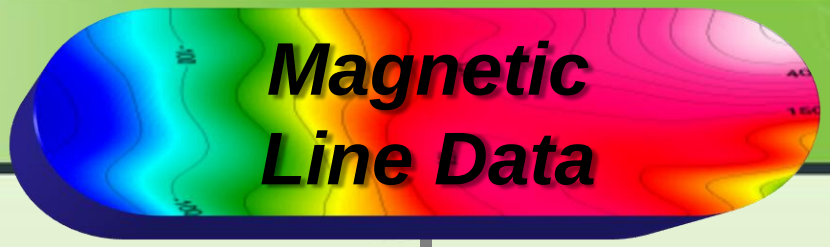
Archimedes' ACM Method

Automatic Curve Matching Method

- **ACM** is a very powerful tool, when applied to **Magnetic data extracted from grids or from flight lines**

  It will detect Magnetic Sources:
  - **Depth to the individual causative Source**
  - **Magnetic susceptibility**
  - **Geometry of the Magnetic Source**

Archimedes



Magnetic
Line Data

Grid Data

Filtered
Grid Data

Geo-Data

Profile Data

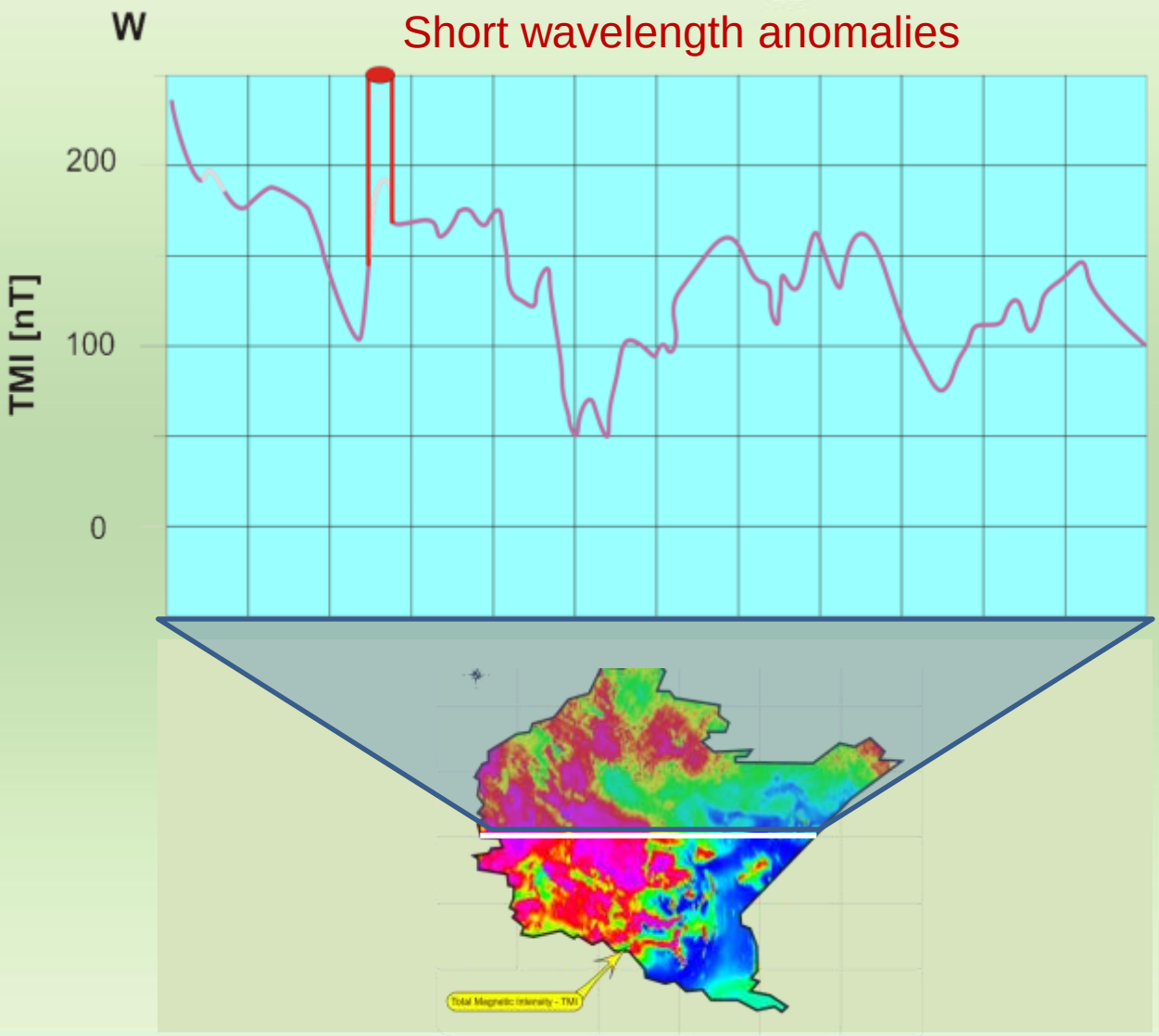
ACM

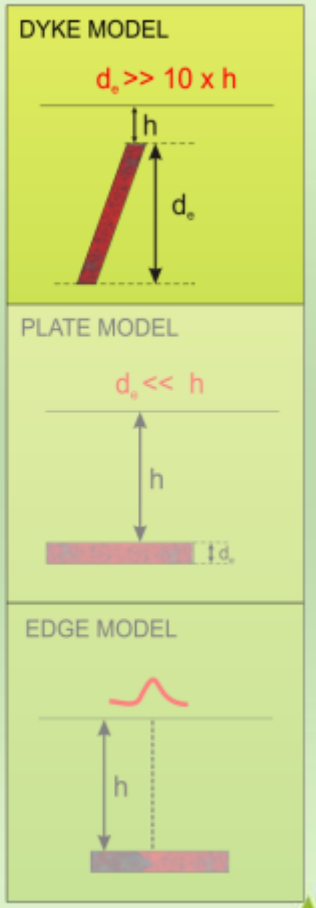
Magnetic Sources

Interpretation:
Faults, Fractures, Dykes, Volcanics

Archimedes

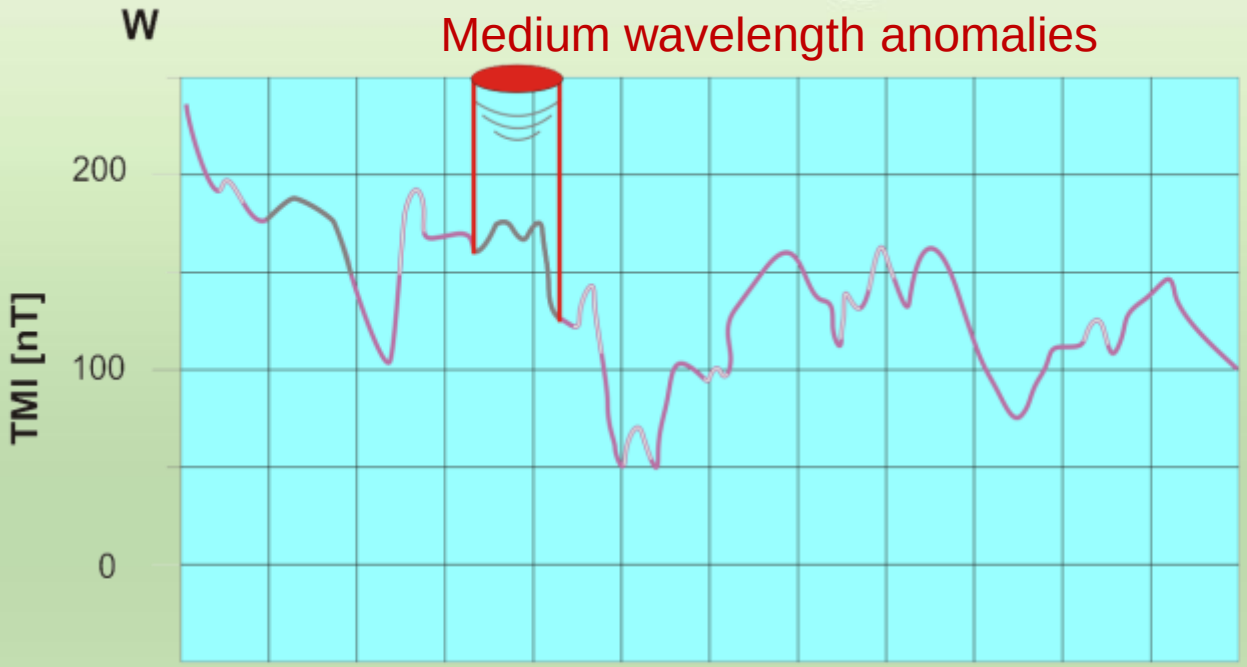
ACM: Theory

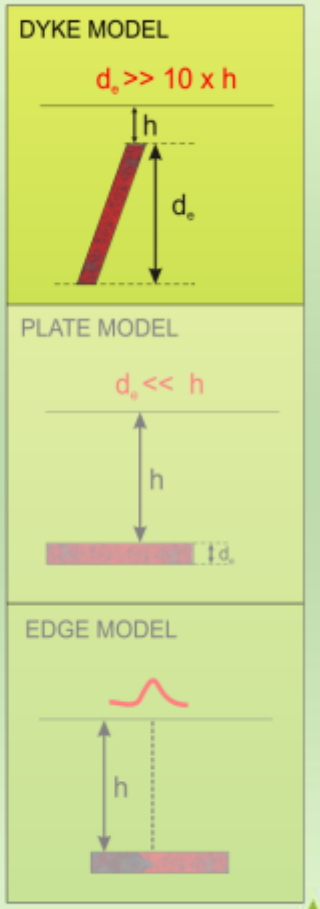




Archimedes

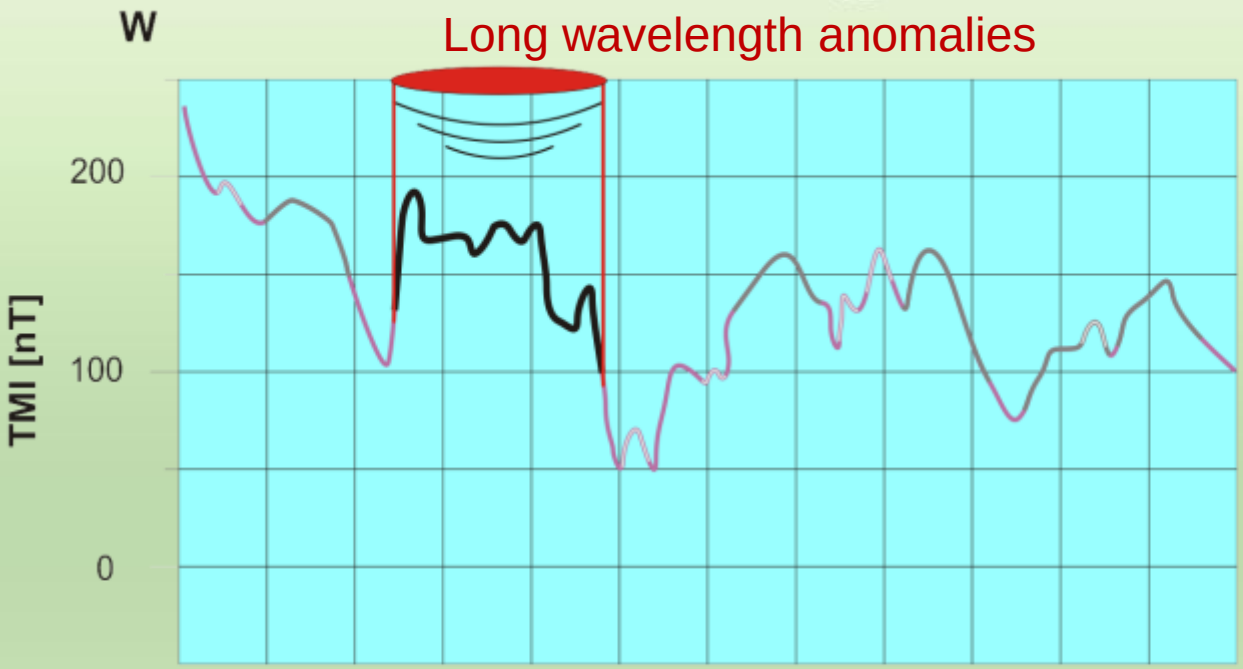
ACM: Theory

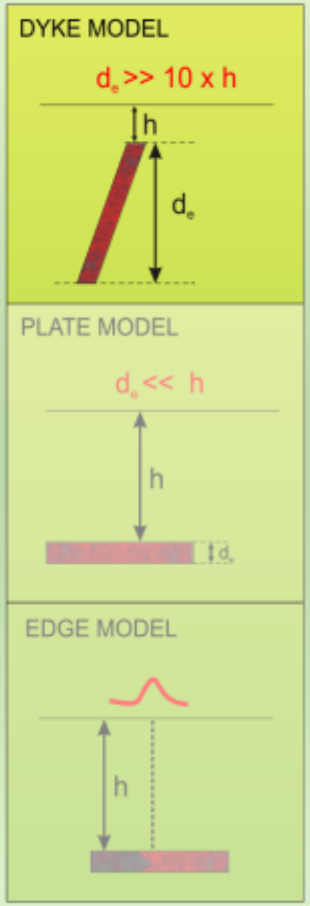




Archimedes

ACM: Theory



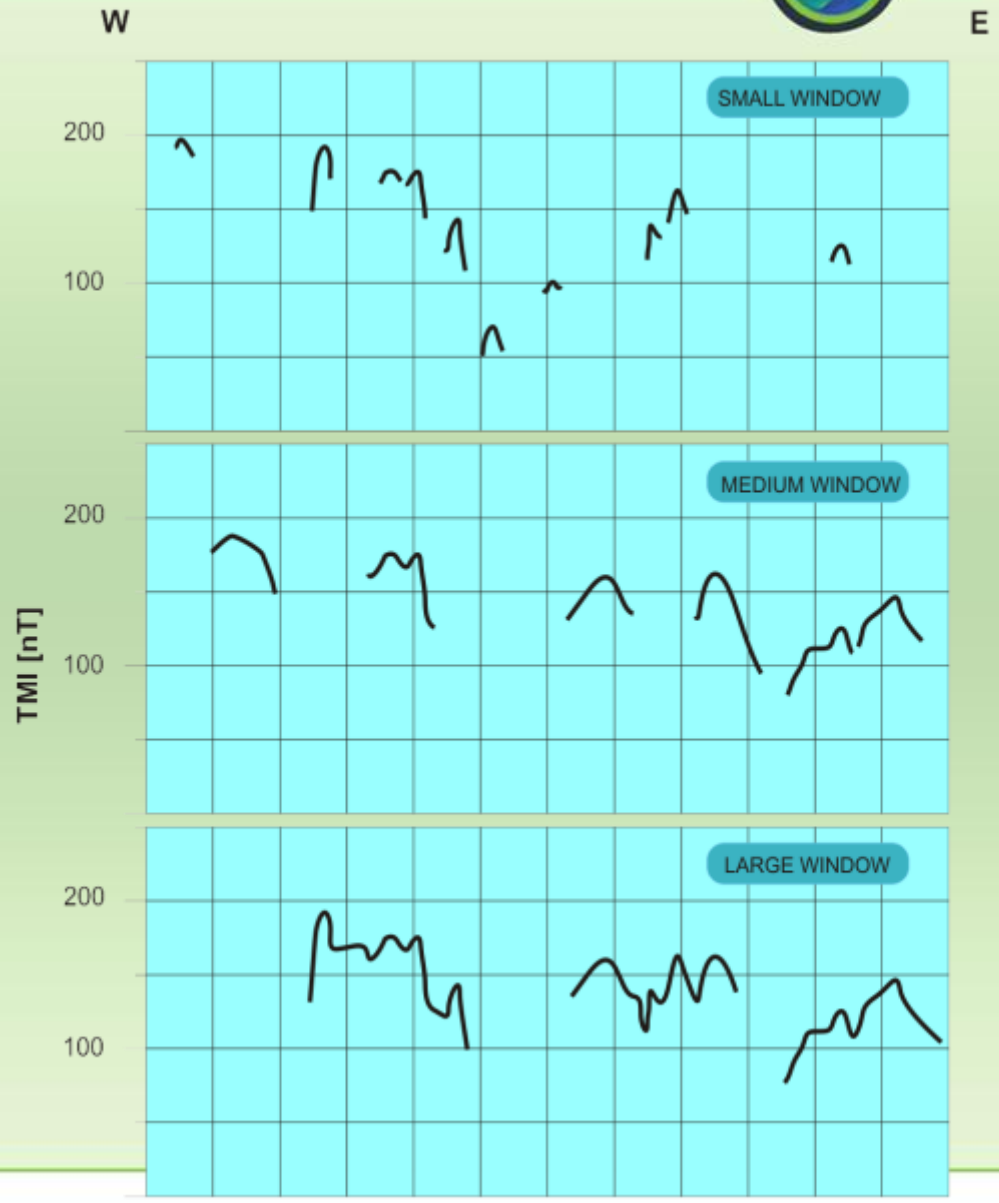


SCANNING PROFILE

LARGE WINDOW

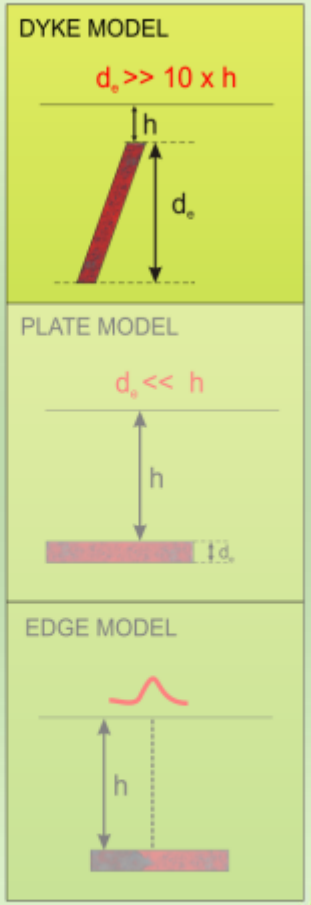
Archimedes

ACM: Theory



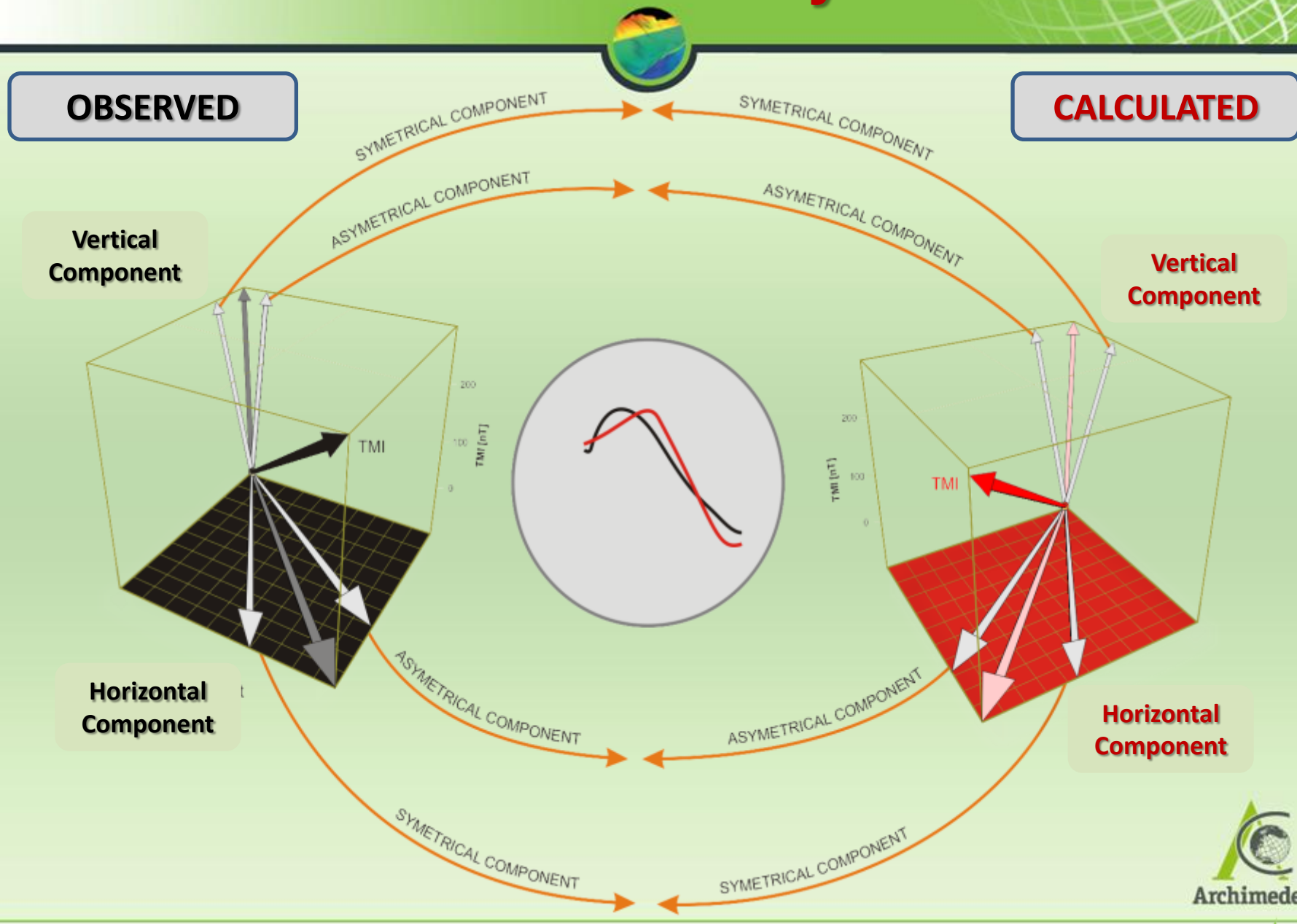
Geophysical Models

SCANNING RESULTS FOR DYKE MODEL



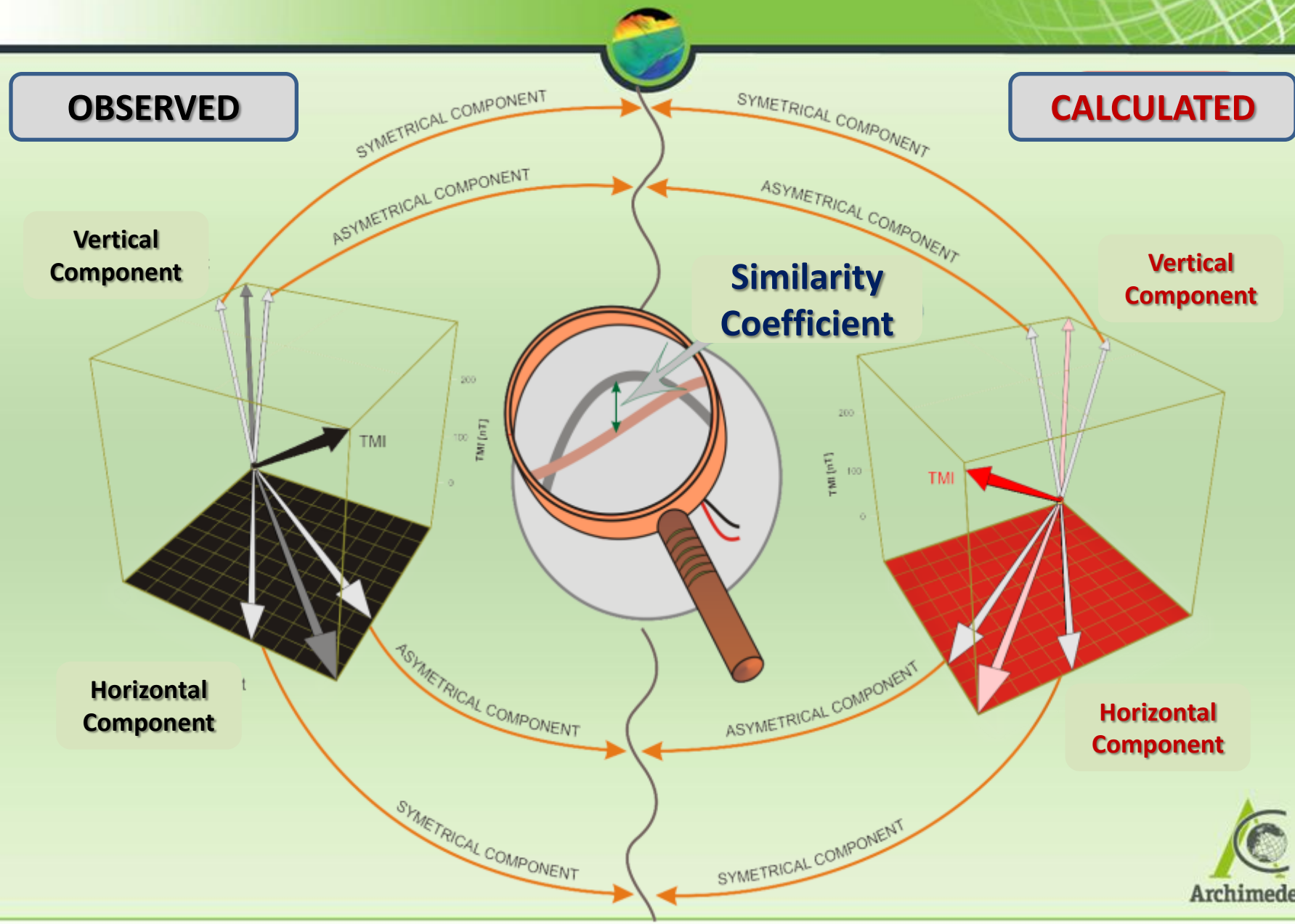
Archimedes

ACM: Theory

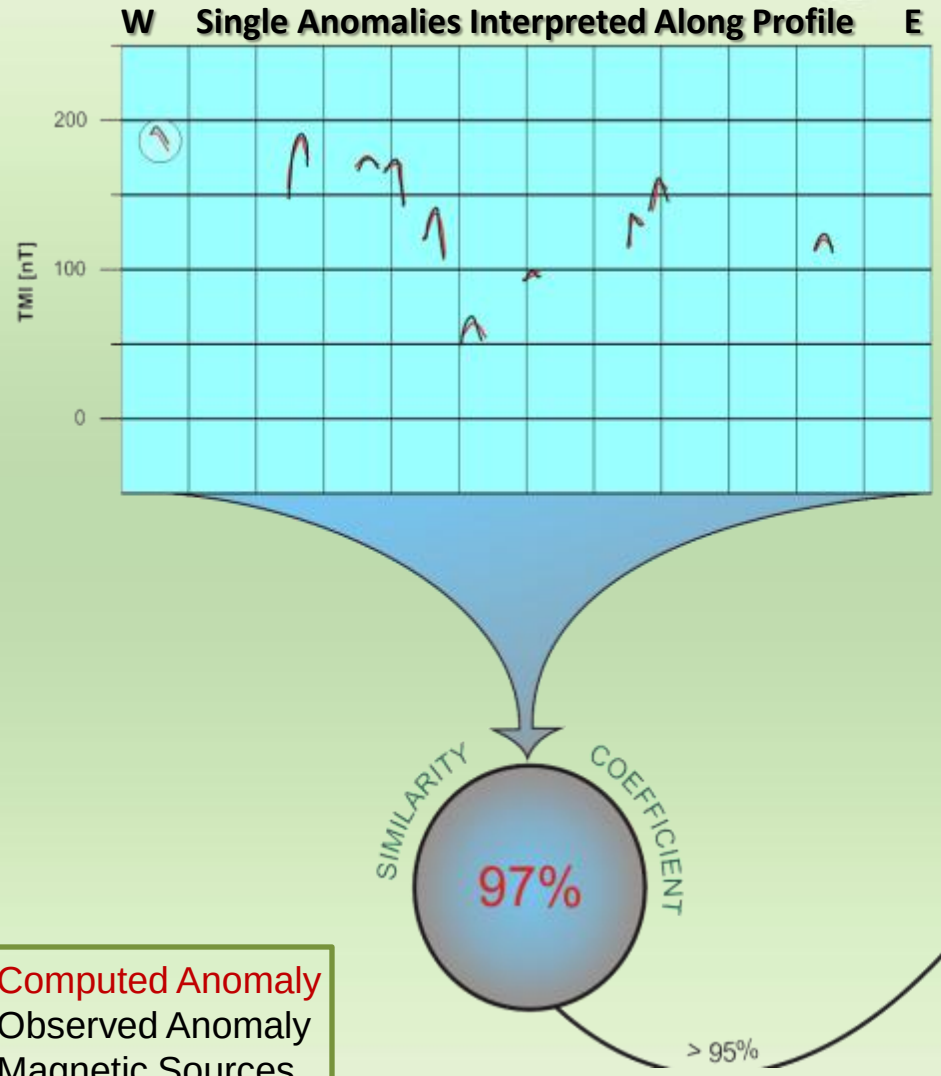


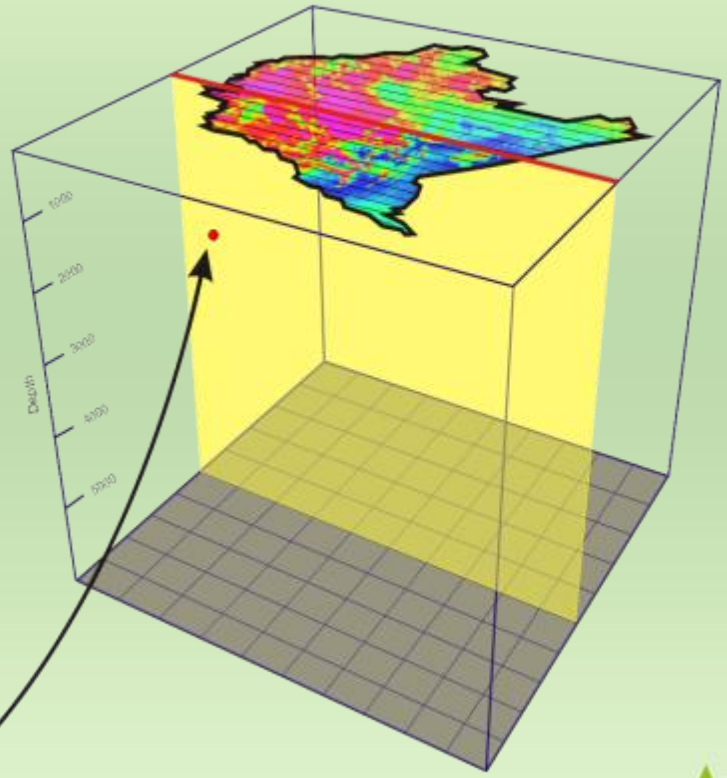
Archimedes

ACM: Goodness of Fit



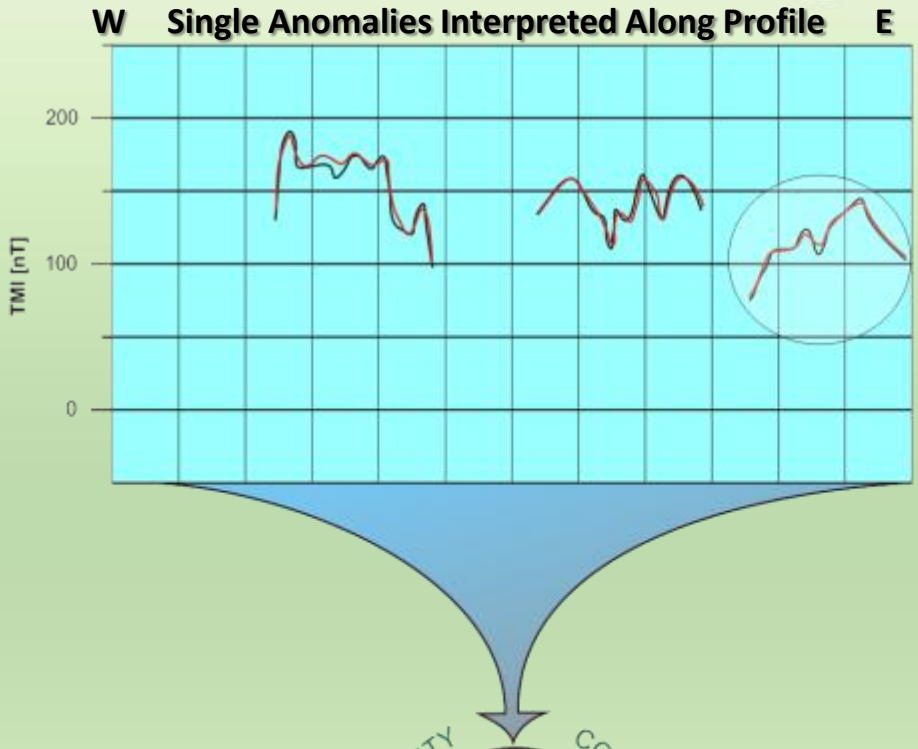
ACM Magnetic Sources: Goodness of Fit

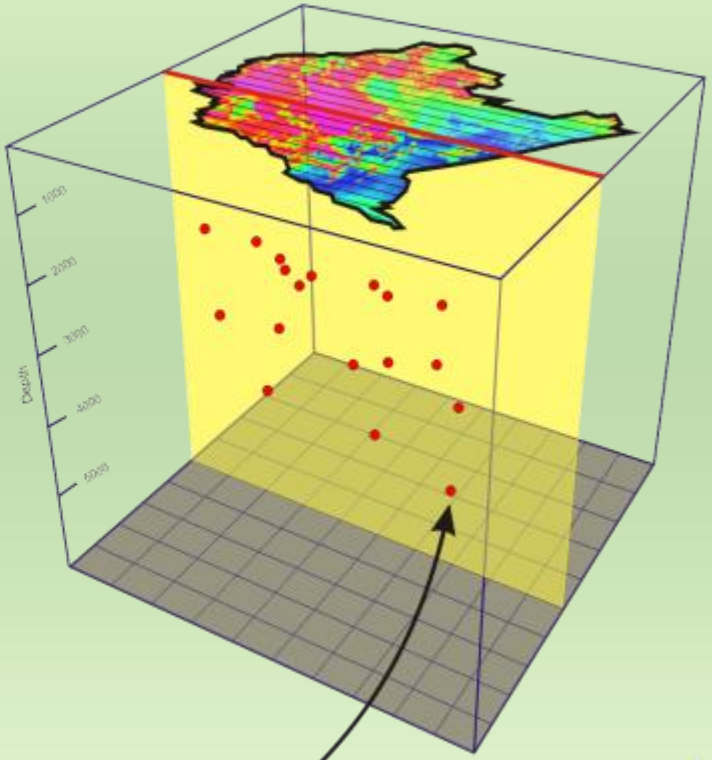




Archimedes

ACM Magnetic Sources: Goodness of Fit



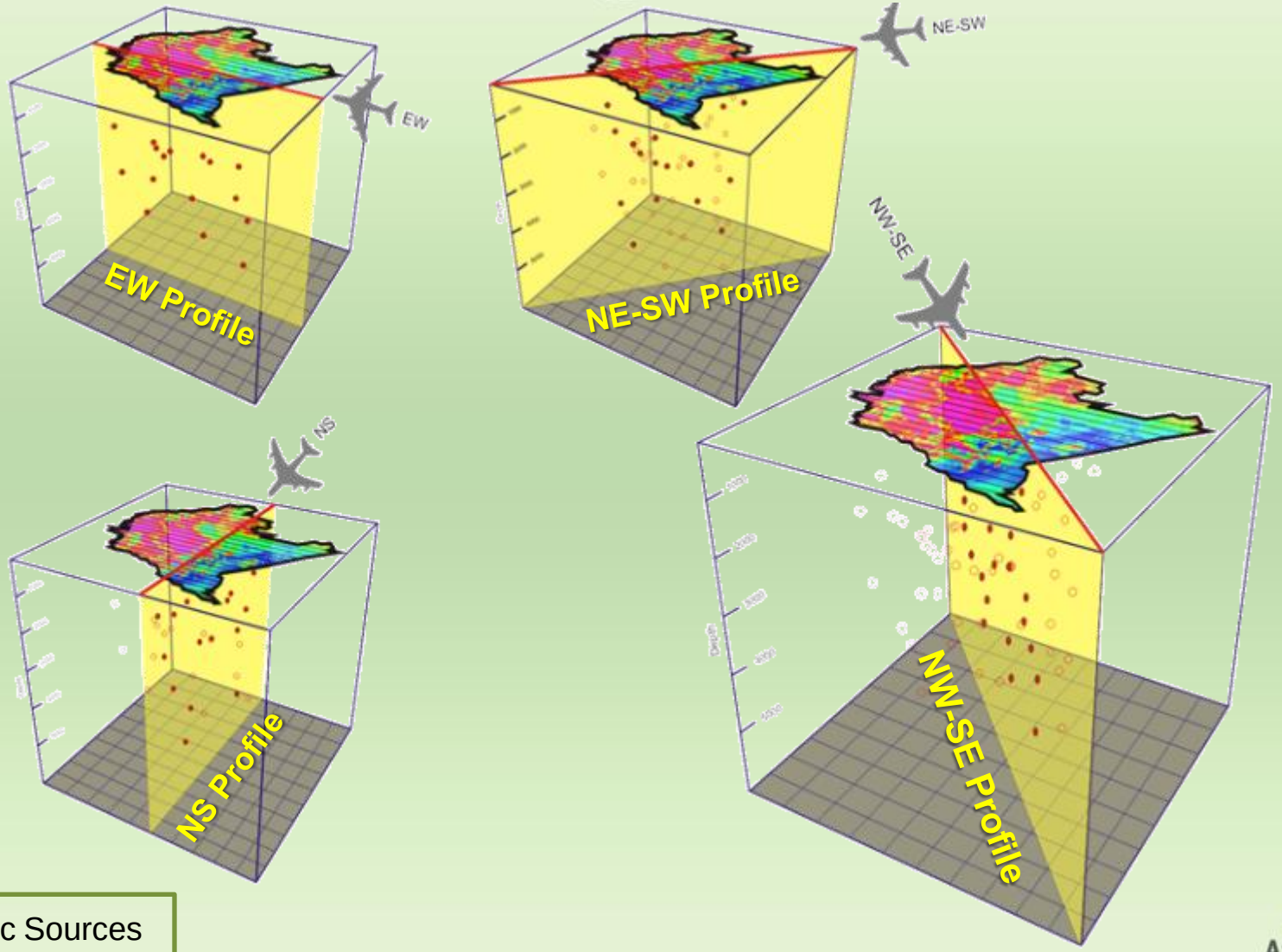


> 95%

Computed Anomaly
Observed Anomaly
Magnetic Sources

Archimedes

ACM Magnetic Sources: EW, NS, NE, NW Profiles



- Magnetic Sources

Archimedes

Fault & Fracture Interpretation

Horizontal Crustal Depth Slices (HCDS)

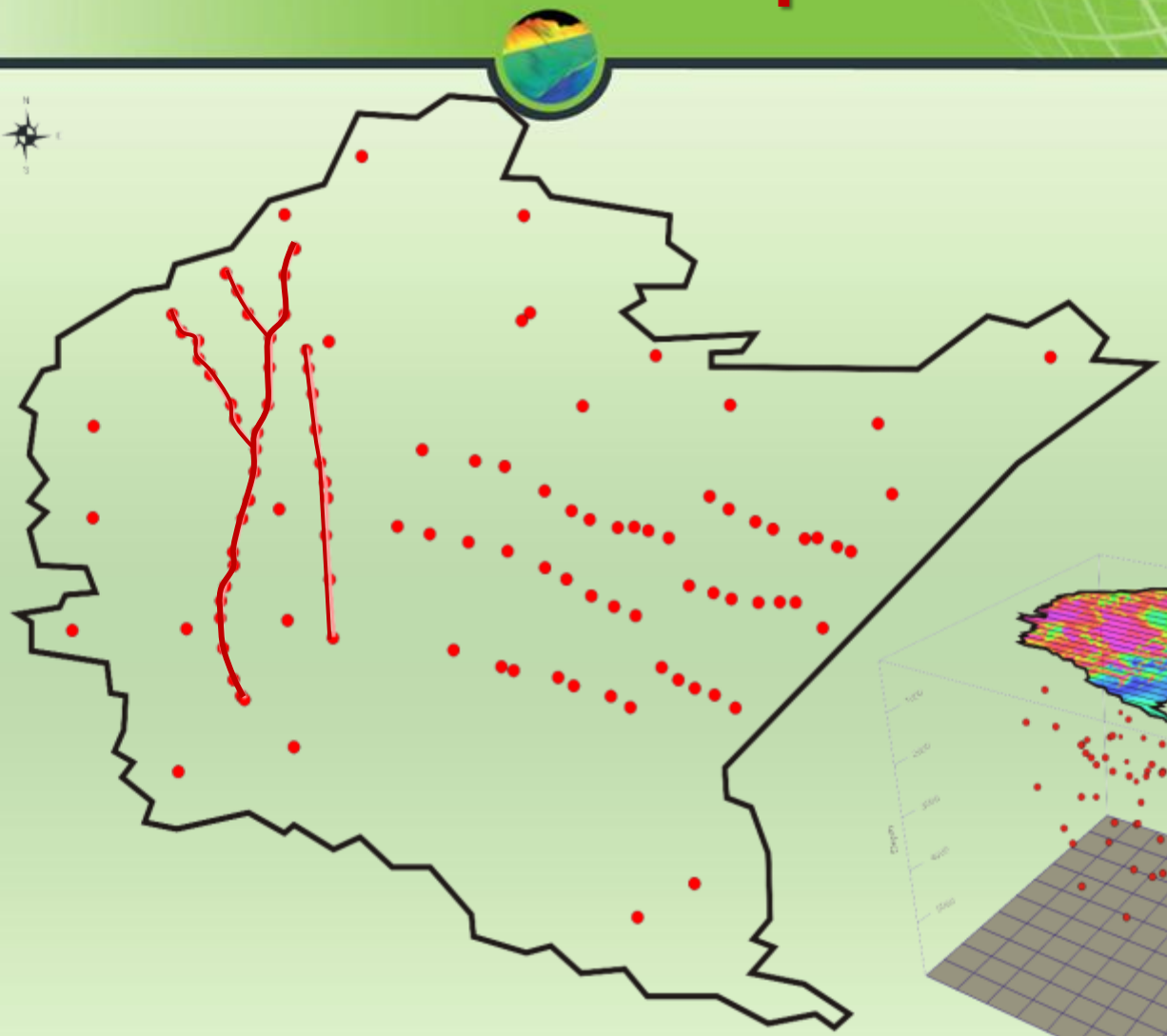
ACM Structural Interpretation

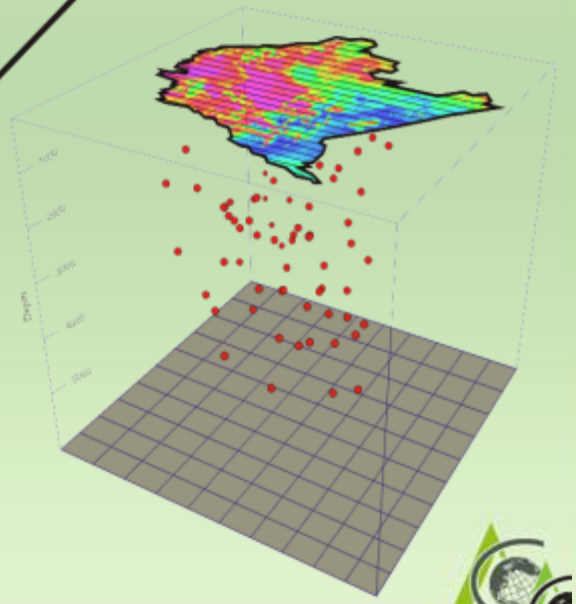
Top-Centre Point
of Magnetic Source

- Magnetic Sources

Archimedes

ACM Structural Interpretation

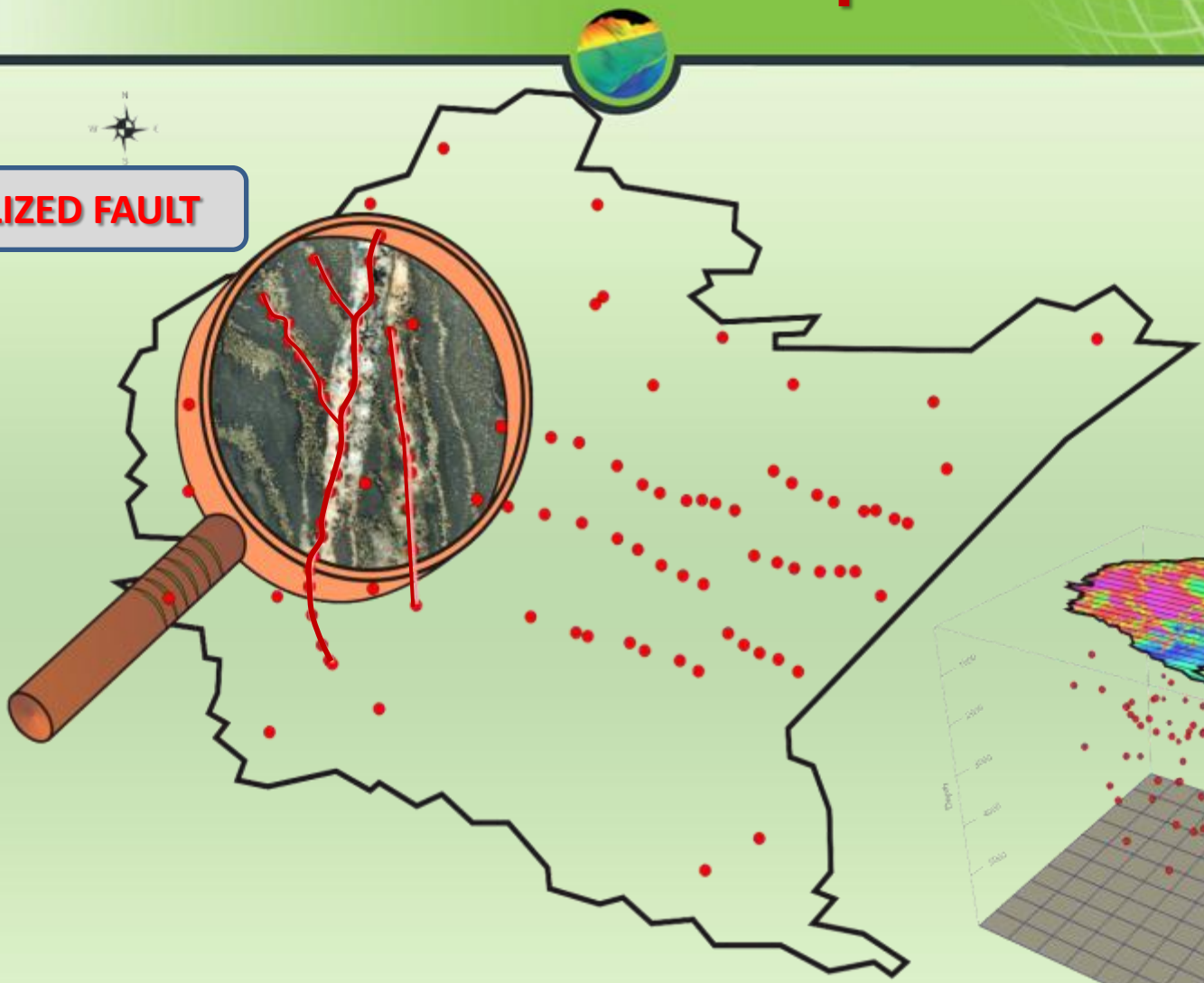




- Magnetic Sources
- **Mineralized Fault**

Archimedes

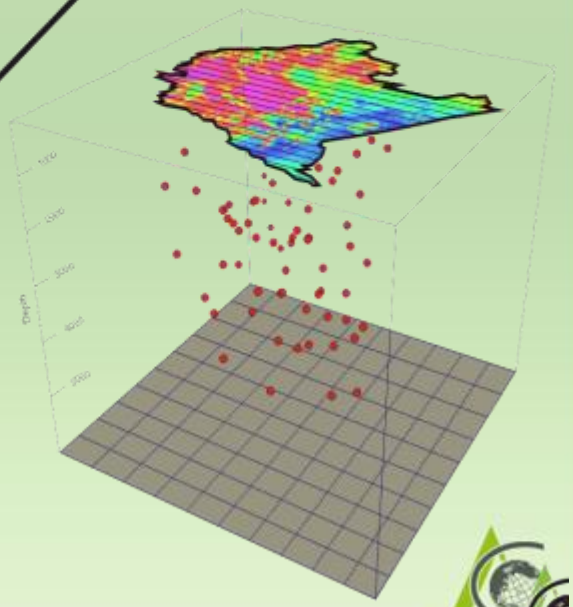
ACM Structural Interpretation



Archimedes

ACM Structural Interpretation

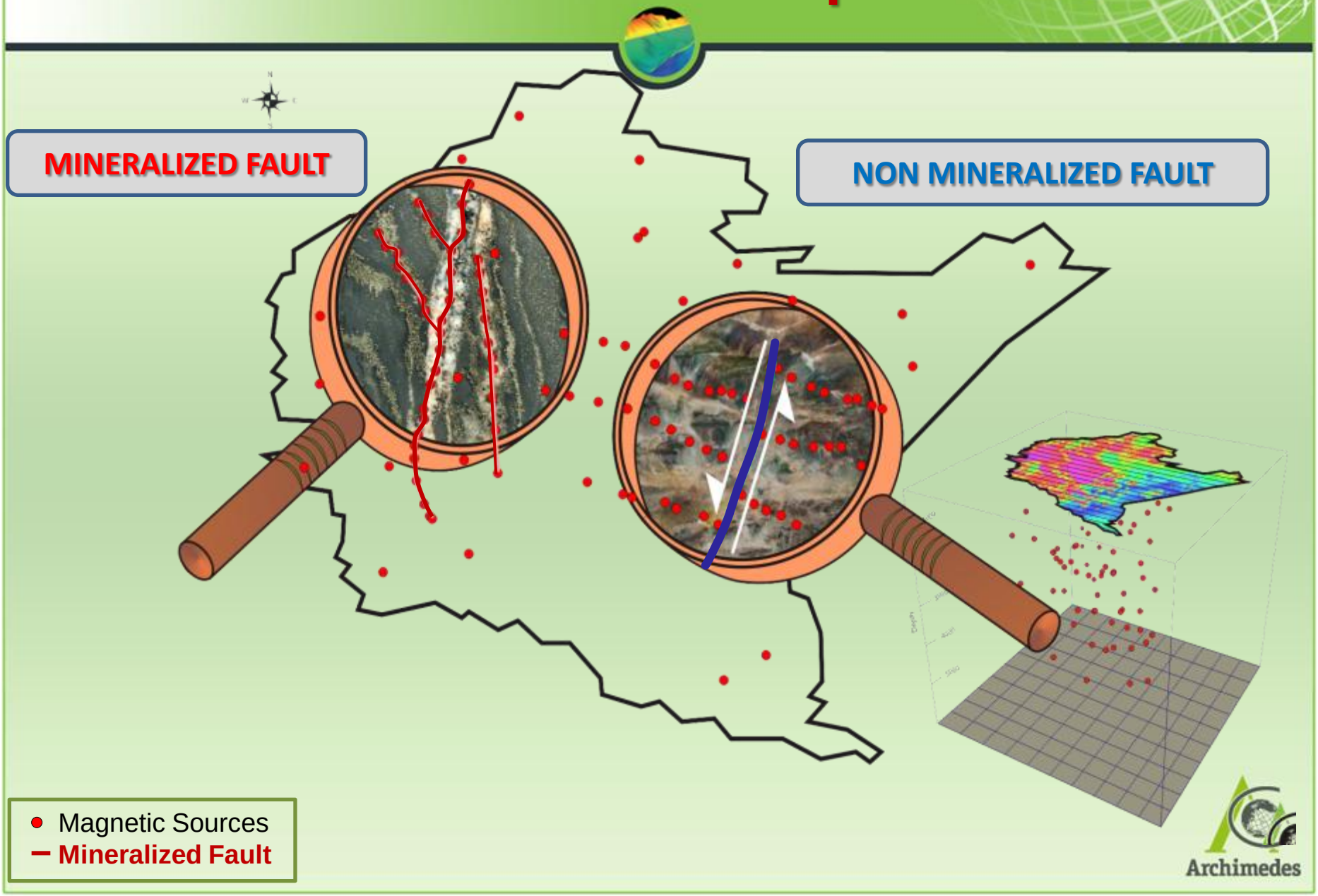
MINERALIZED FAULT



- Magnetic Sources
- **Mineralized Fault**
- **Non Mineralized Fault**

Archimedes

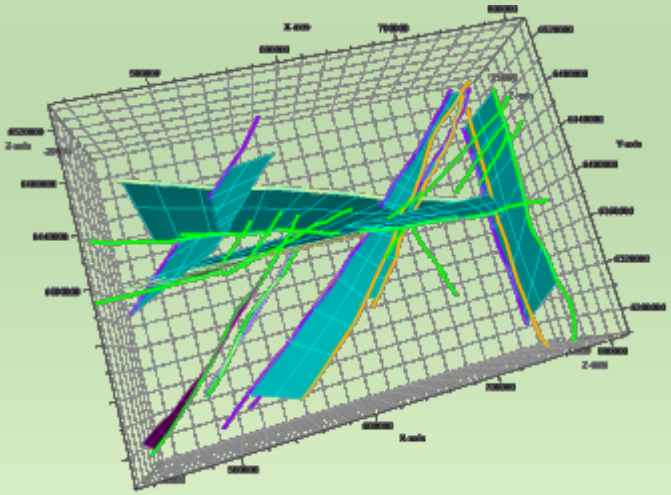
ACM Structural Interpretation

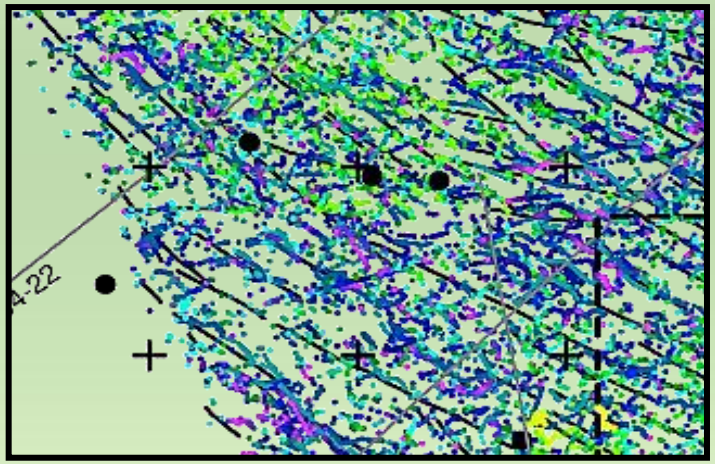


ACM
Mapping Faults

Faults & Fractures

- **Many faults & fractures have a magnetic signature & may not be apparent on seismic – these may be critical for drilling and completion planning**
- **ACM is applied to map Magnetic Lineaments (ML) & Small Extent Magnetic Features (SEMF) in 3D**





Magnetic sources in a depth window can delineate orientation of faults directly or by inference

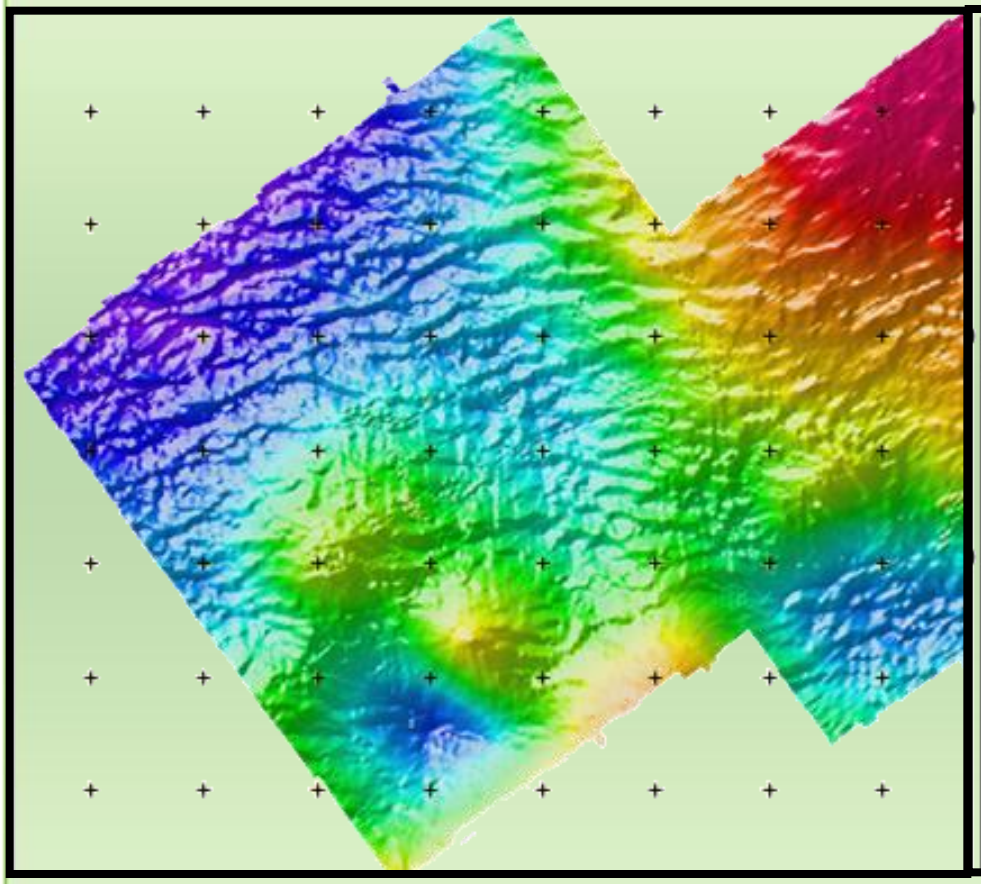
Archimedes

Mapping Faults

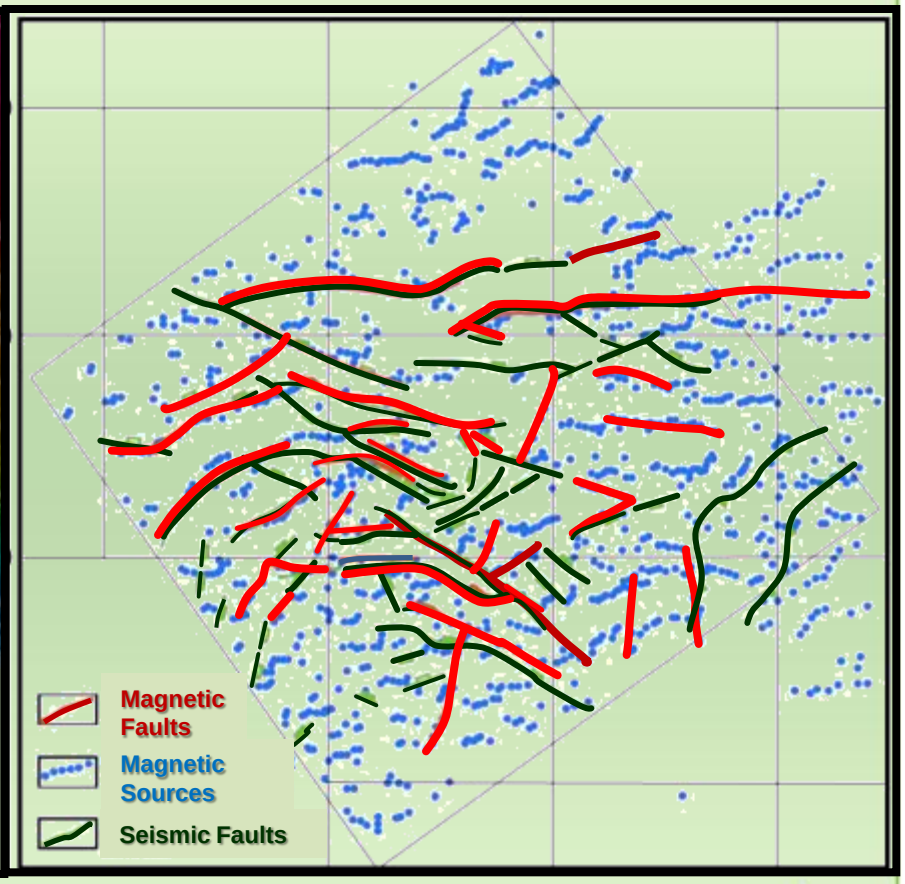
Example: Cooper Basin

Faults & Fractures

Faults in Sediments Detected by ACM: HCDS 100-1200m



Magnetic Field

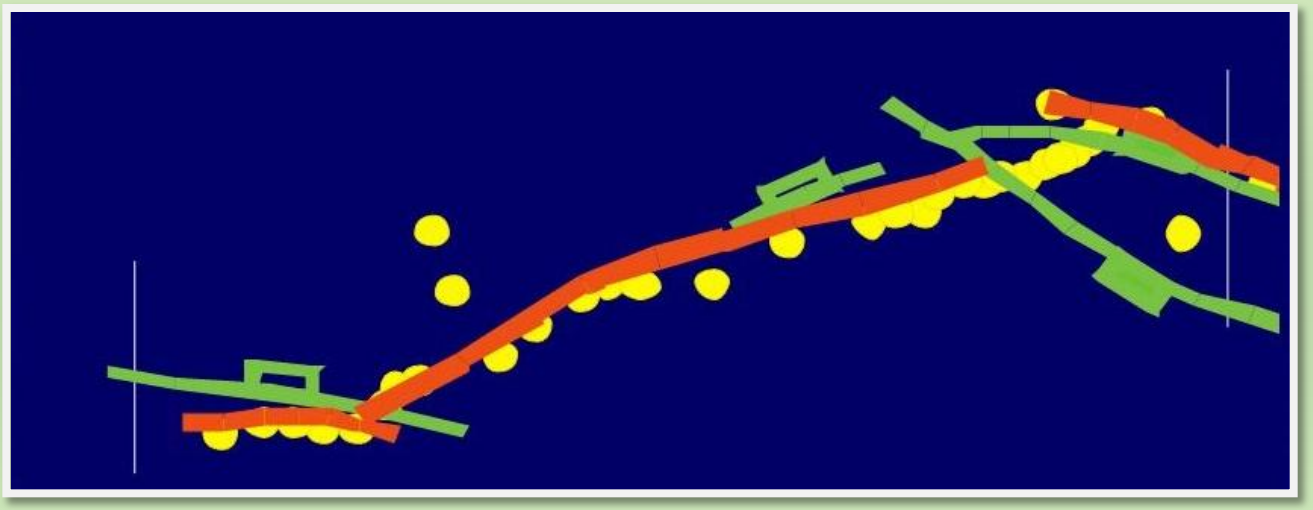


Fault Interpretation

Archimedes

Faults & Fractures

Faults in Sediments
Mineralized Fault Zone



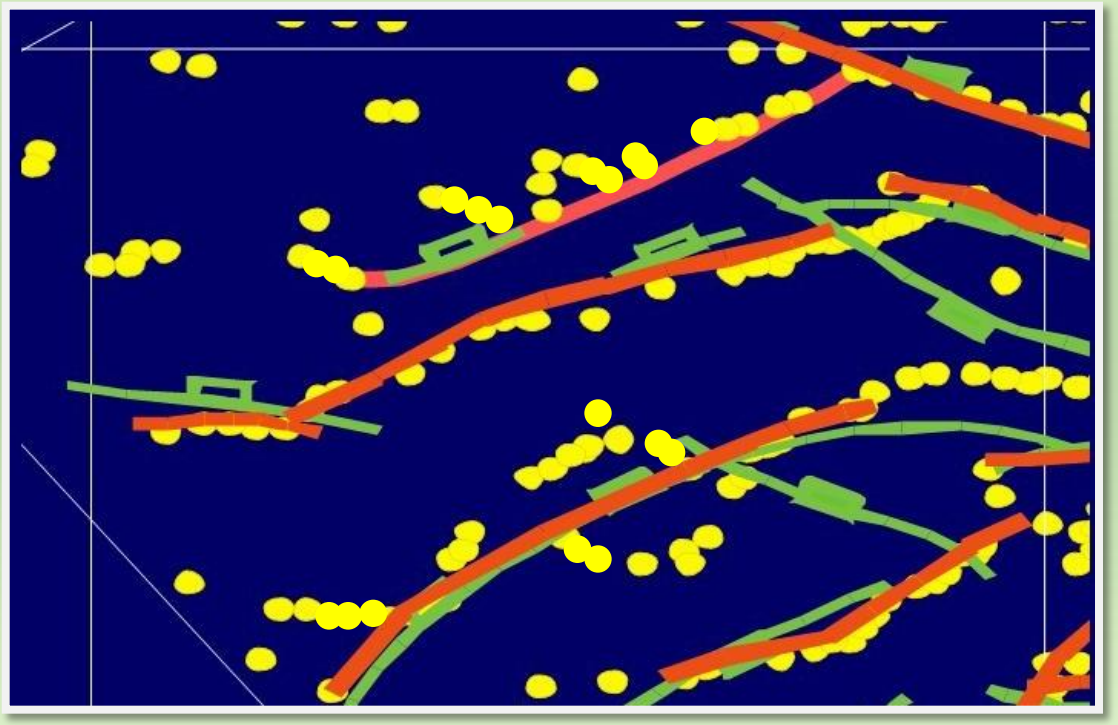
ACM: Cooper-Eromanga Basin

- ○ Magnetic Sources
- – Faults from magnetics
- – Faults from seismic

Archimedes

ACM Structural Interpretation

Mineralized & Non-Mineralized Faults in Sediments



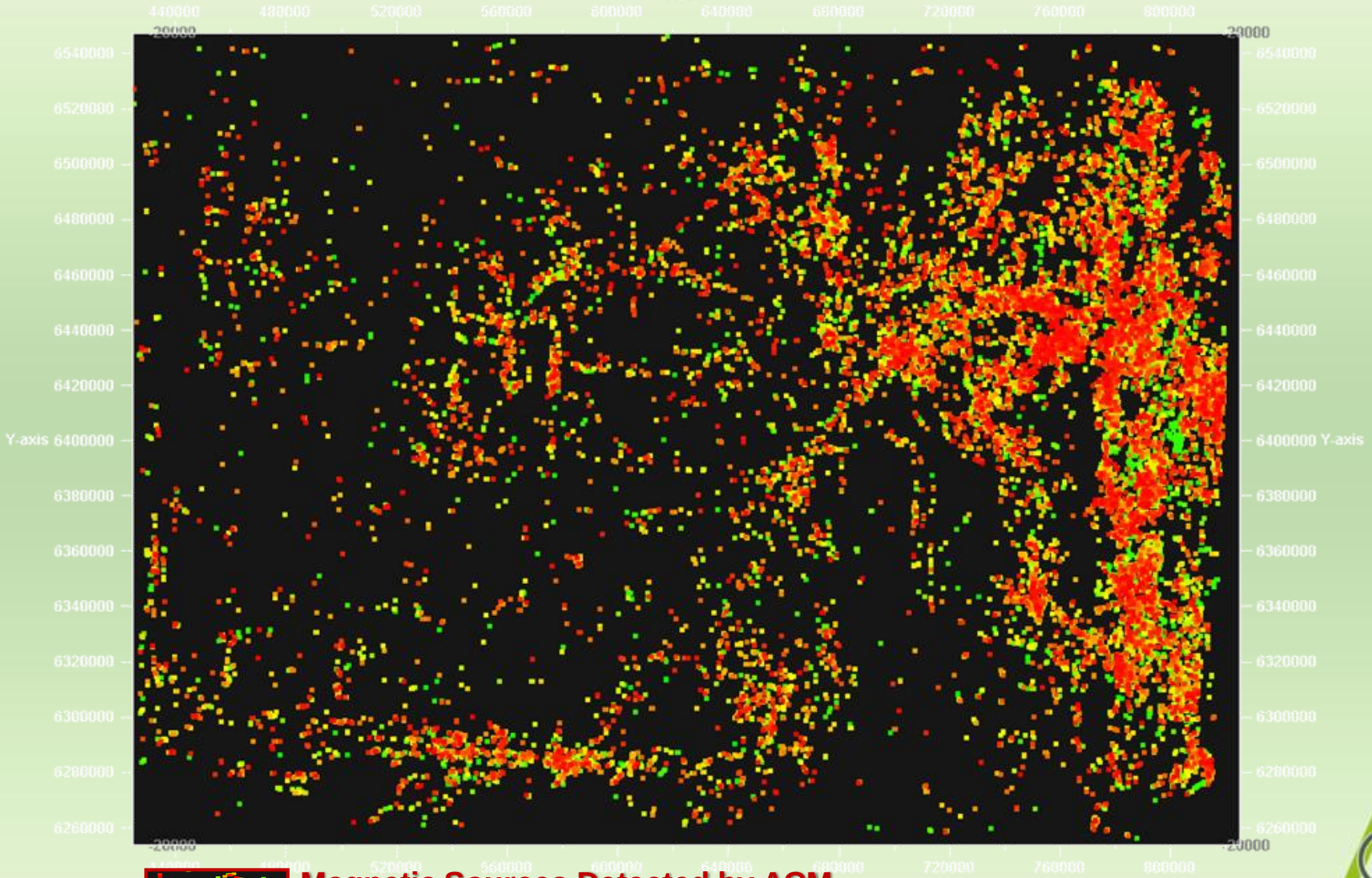
- Magnetic Sources
- Faults from magnetics
- Faults from seismic

Archimedes

Mapping Faults in 3D

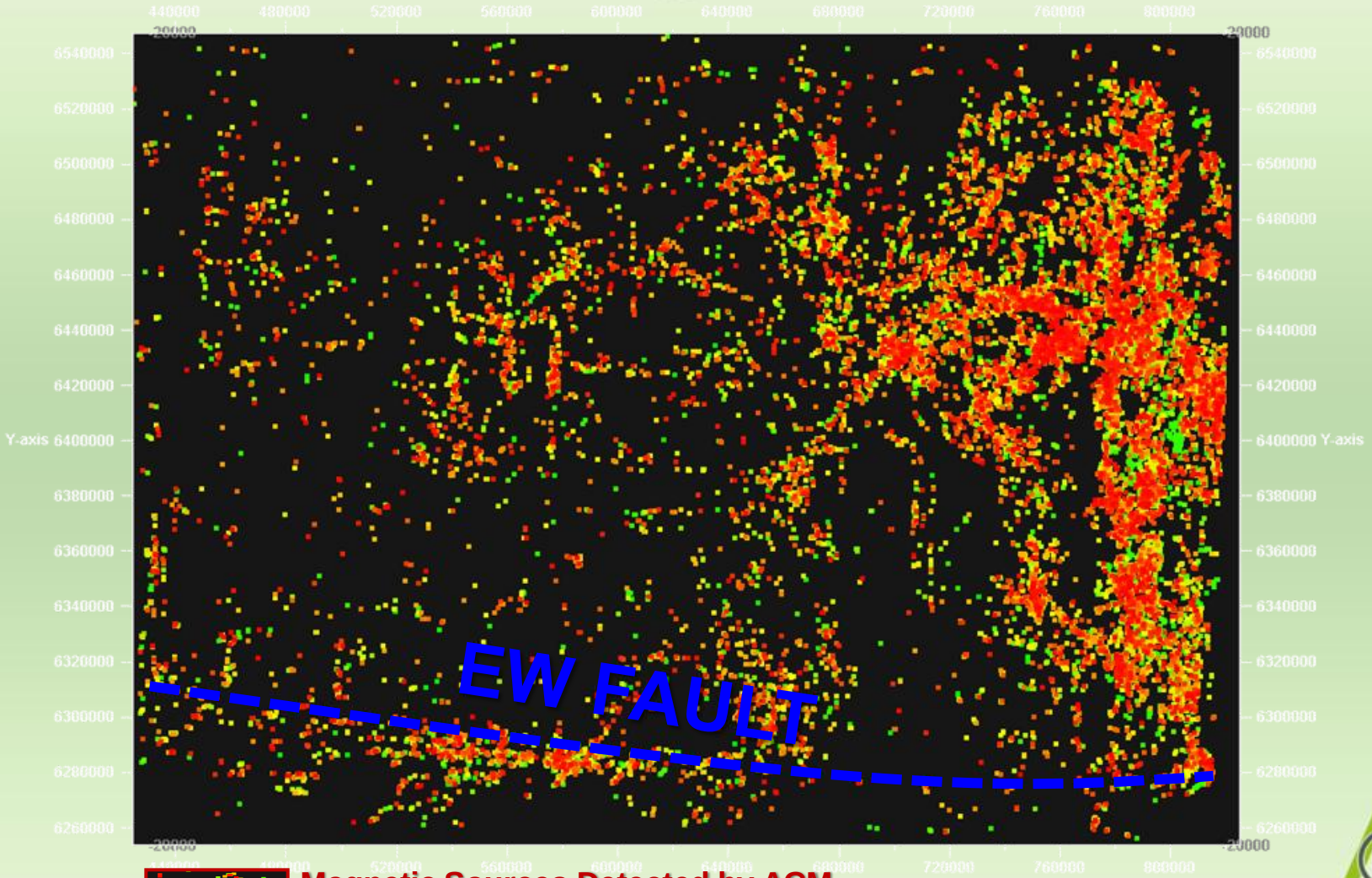
Example: Officer Basin

Mapping Faults: HCDS Depth 5-6km



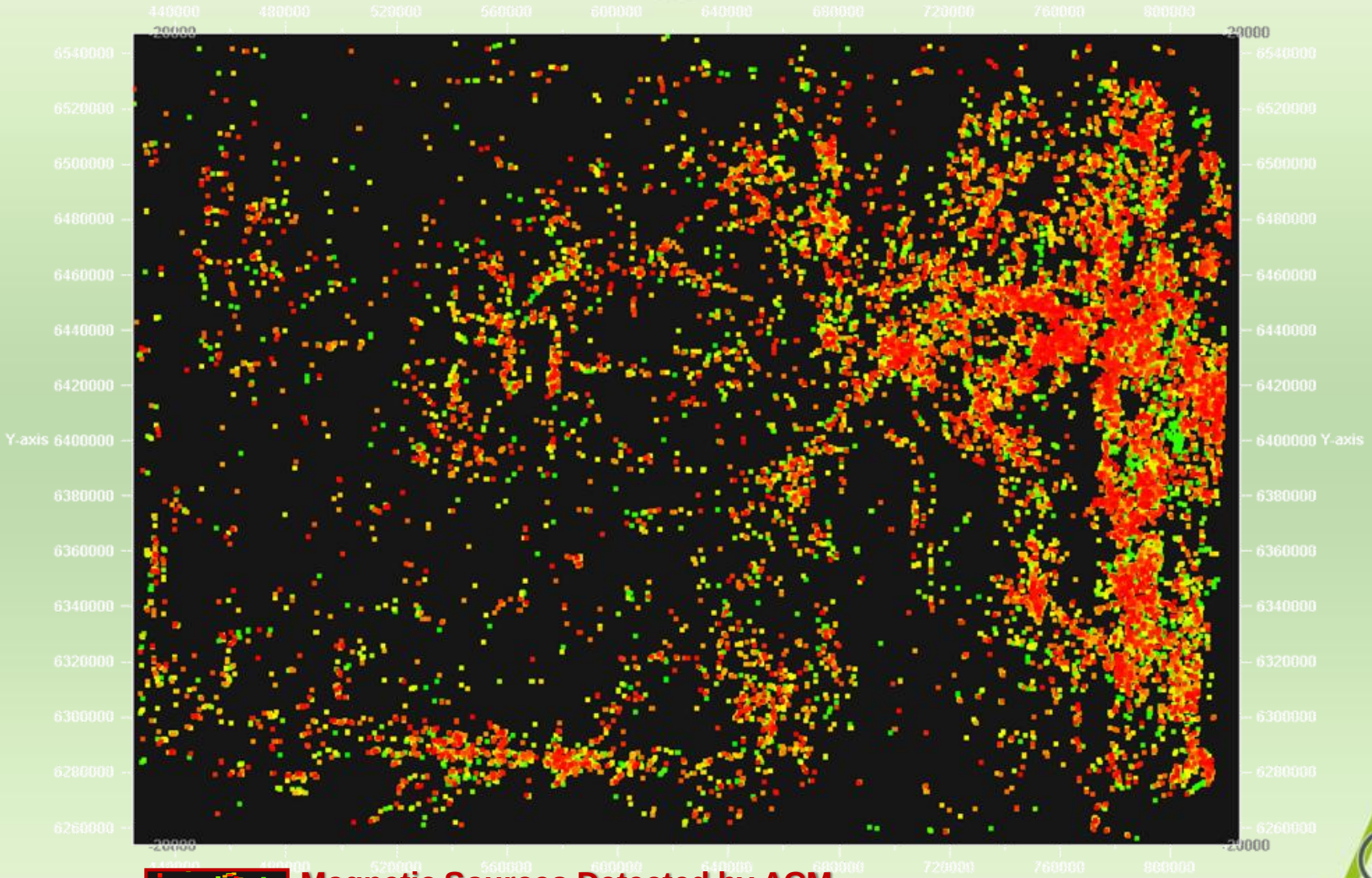
Archimedes

Mapping Faults: HCDS Depth 5-6km



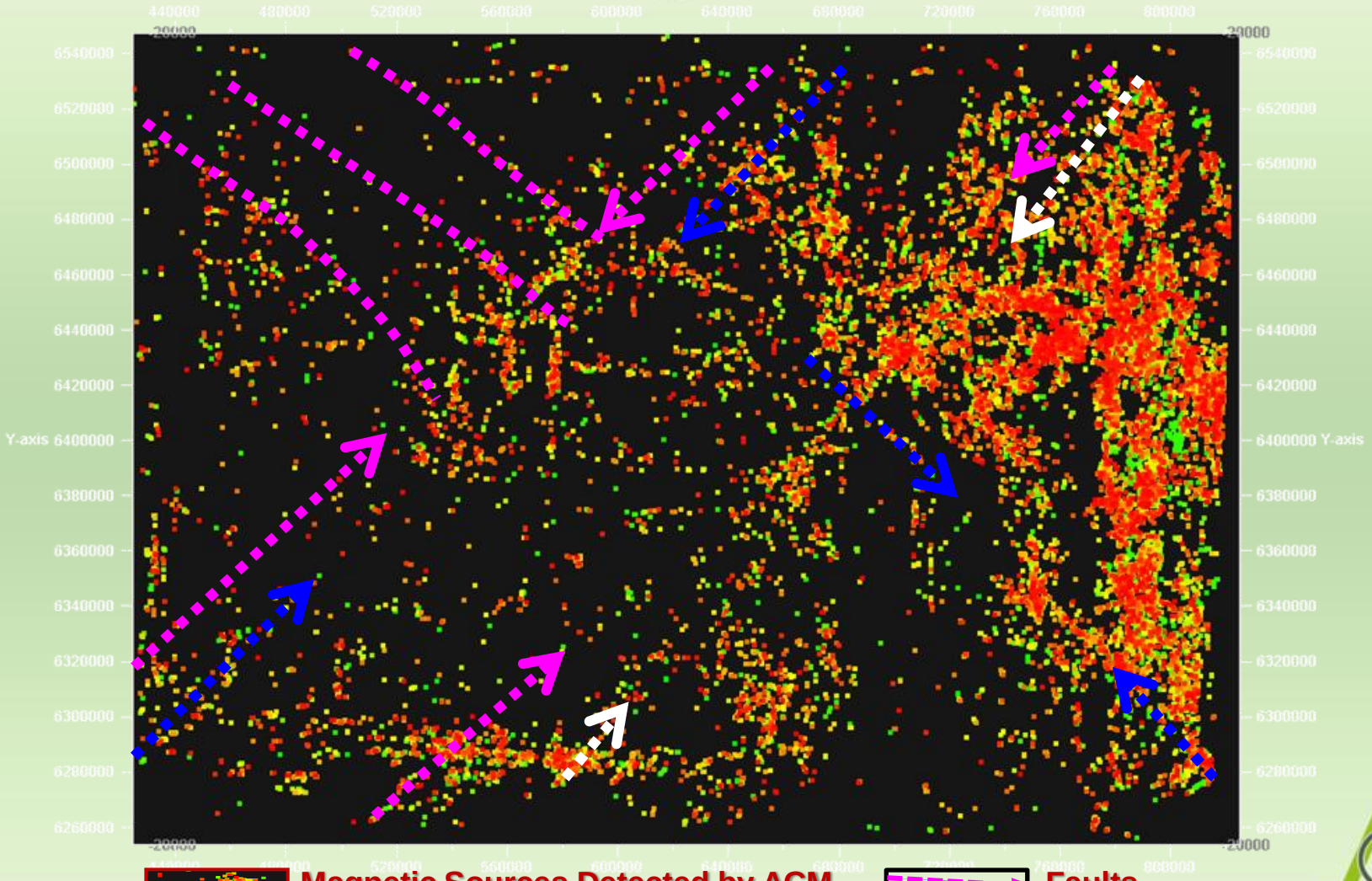
Archimedes

Mapping Faults: HCDS Depth 5-6km



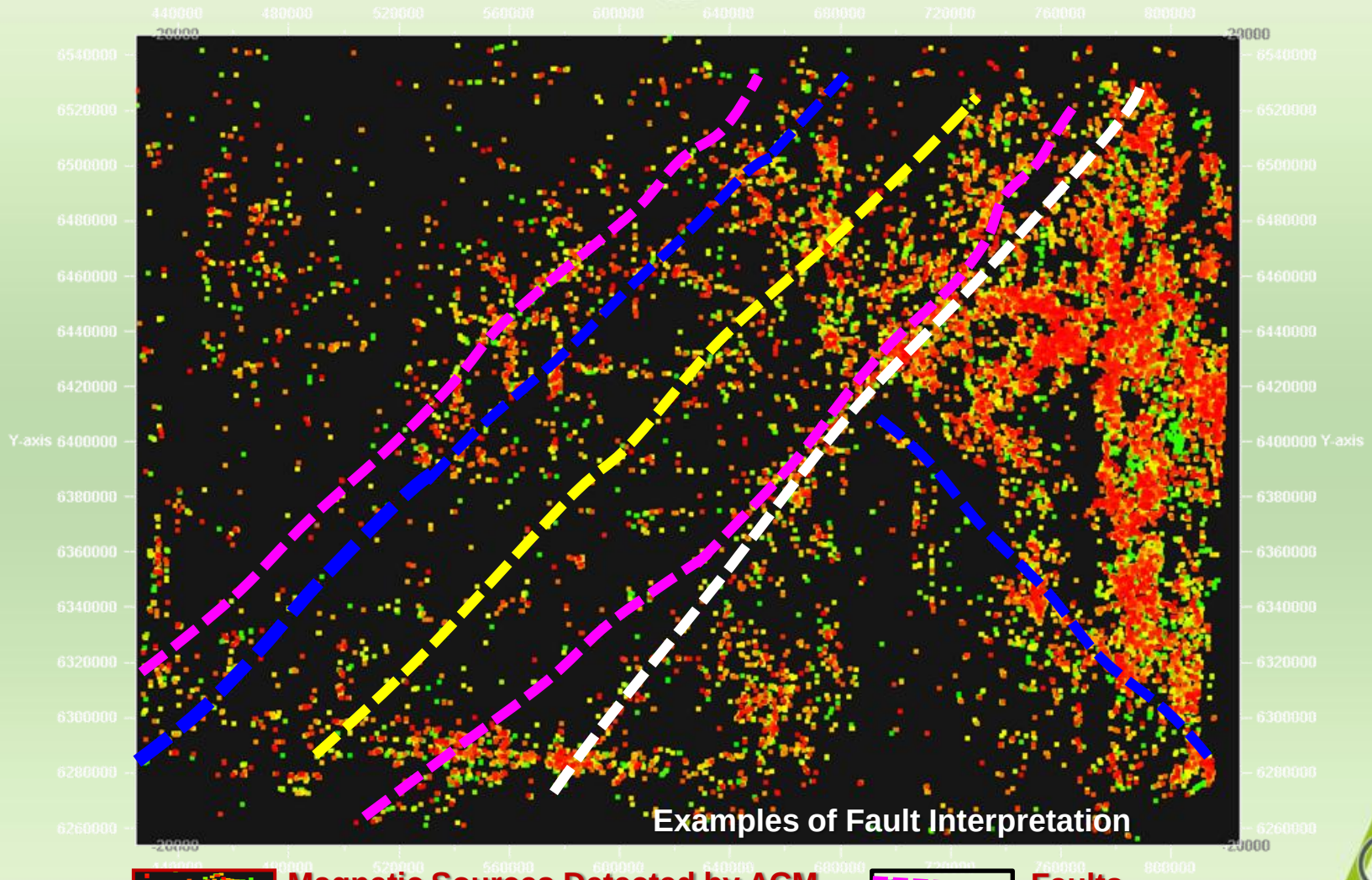
Archimedes

Mapping Faults: HCDS Depth 5-6km



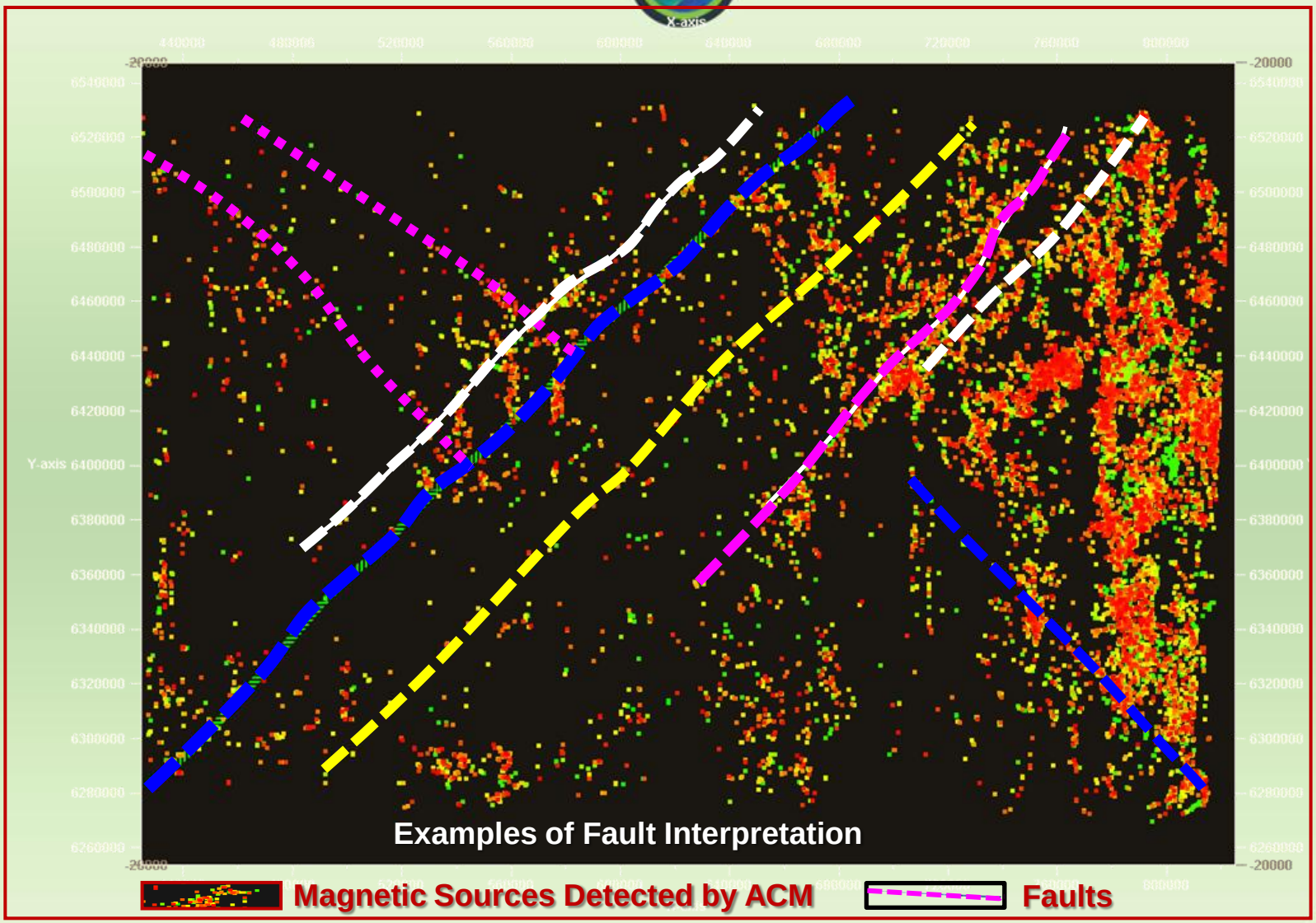
Archimedes

Mapping Faults: HCDS Depth 5-6km



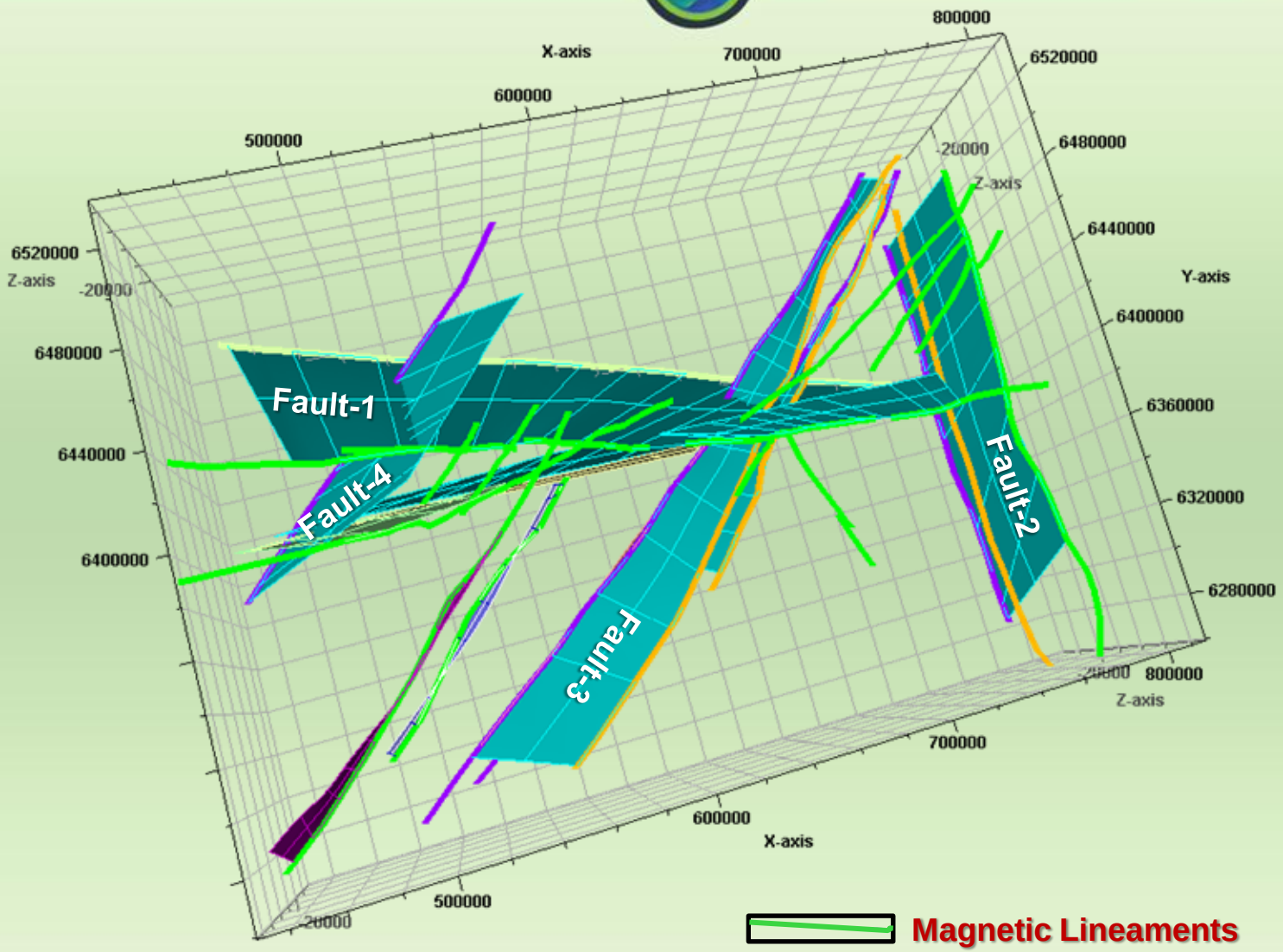
Archimedes

Mapping Faults: HCDS Depth 6-7km



Archimedes

Mapping Faults in 3D

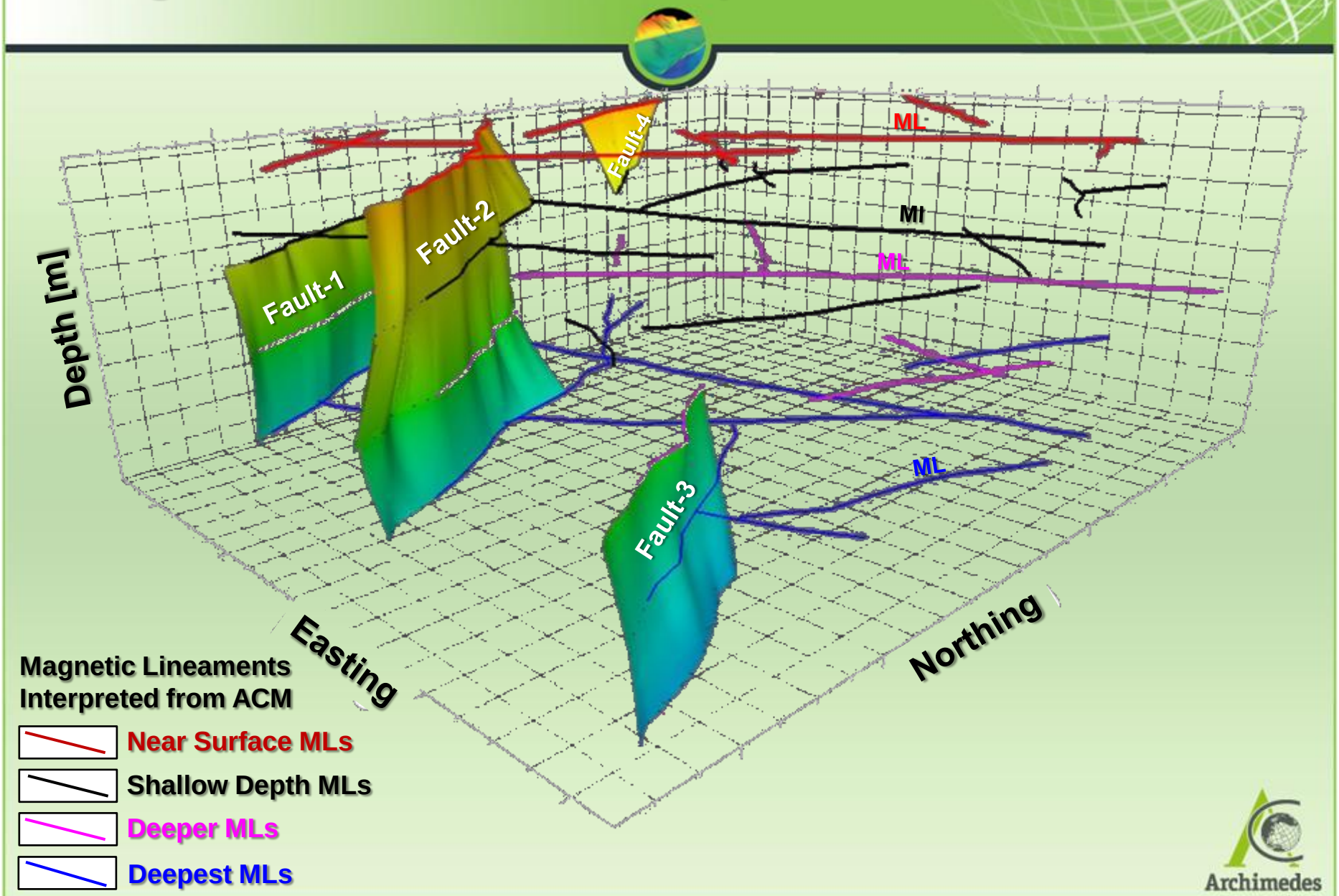


Magnetic Lineaments

Fault Plane

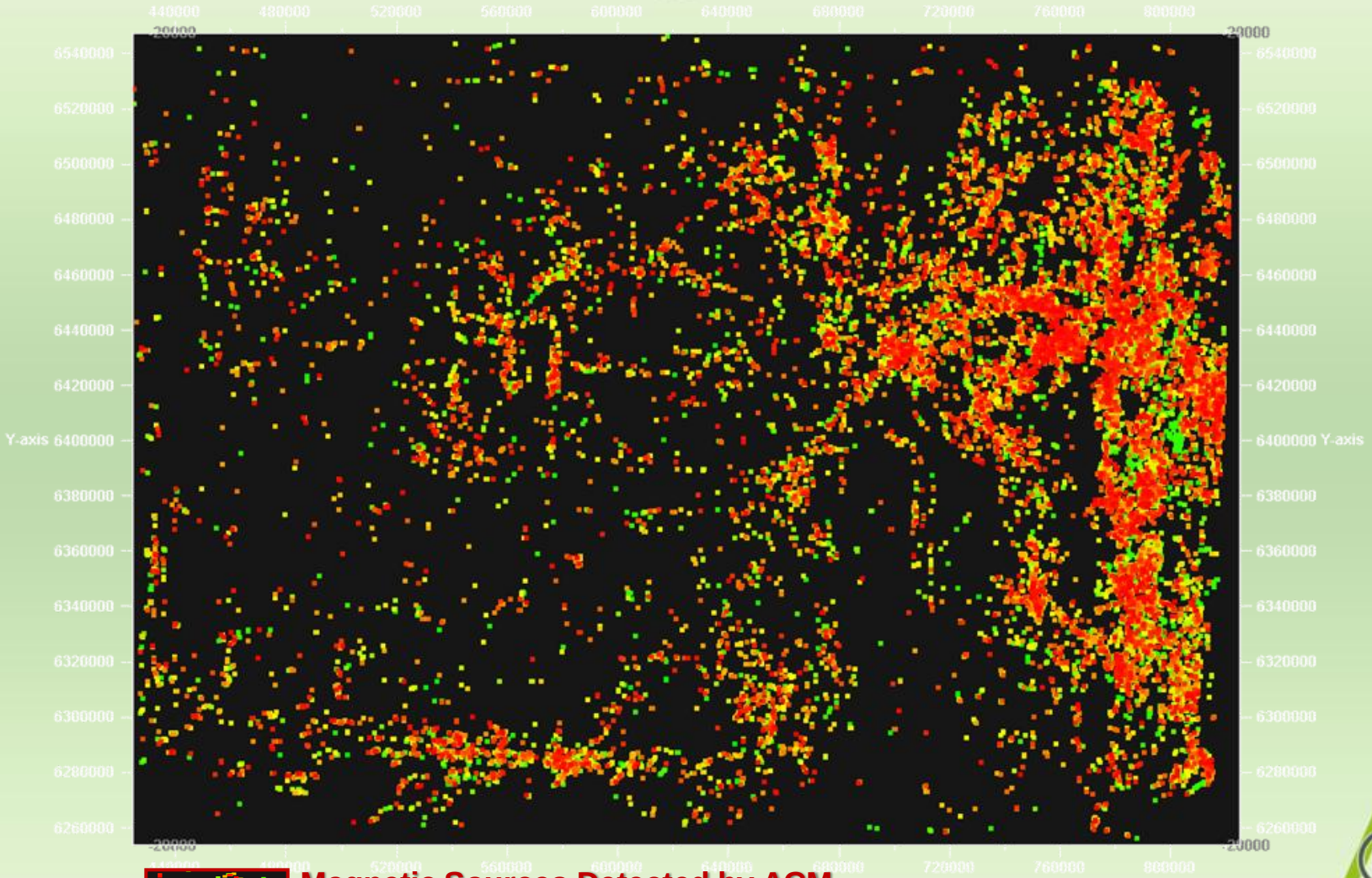
Archimedes

Magnetic Lineament Interpreted as Faults in 3D



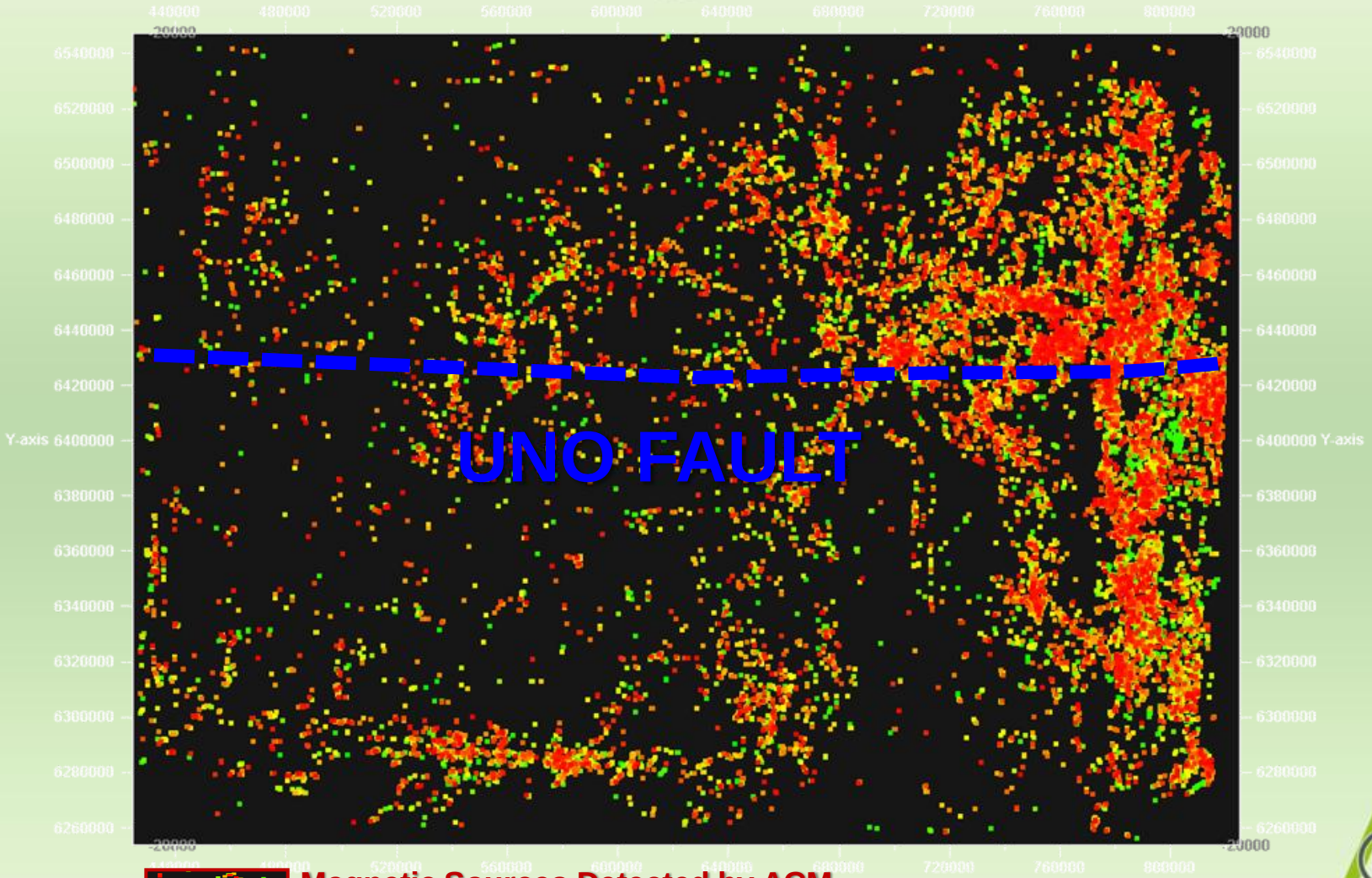
Archimedes

Mapping Faults: HCDS Depth 5-6km



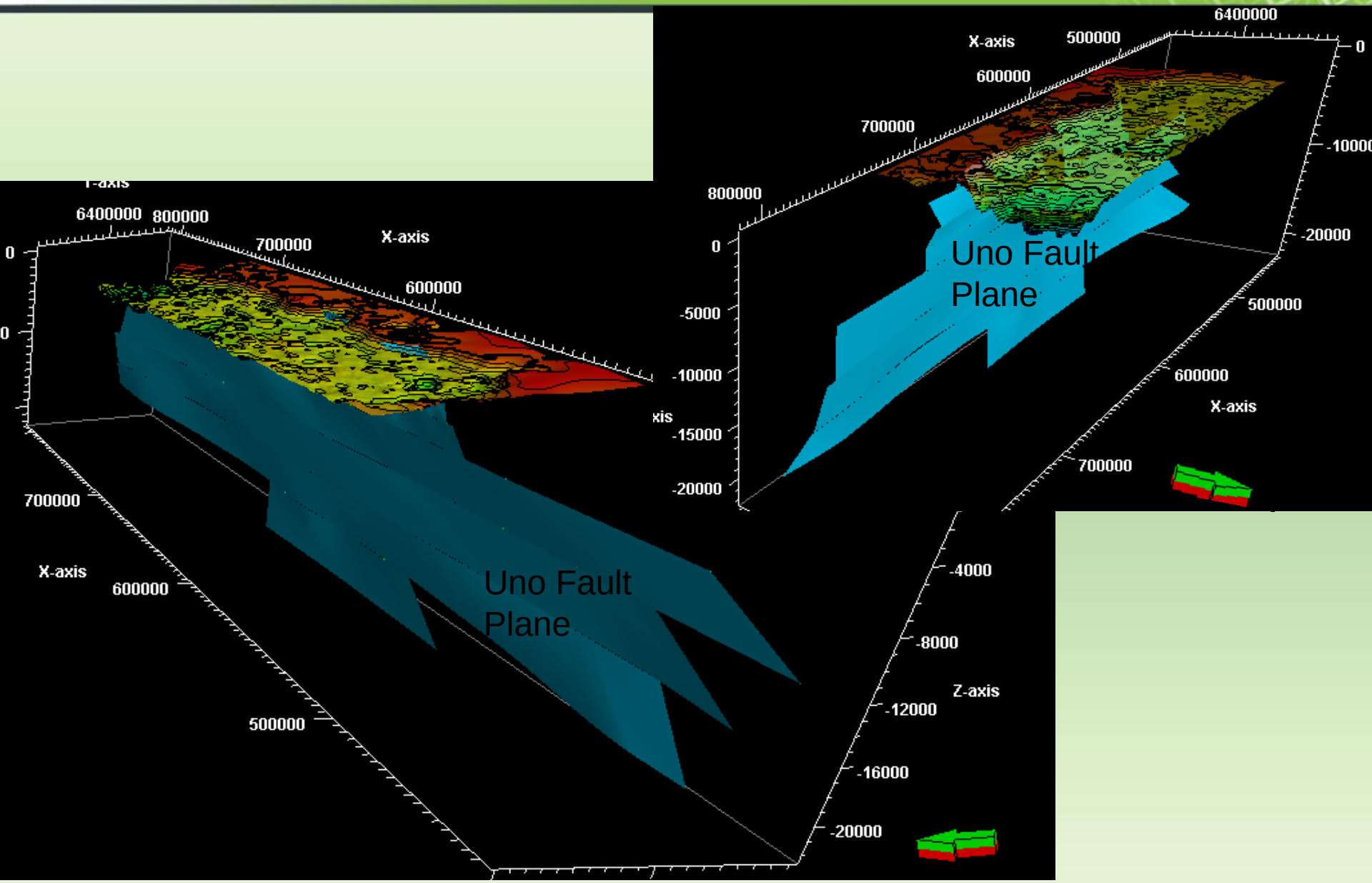
Archimedes

Mapping Faults: HCDS Depth 5-6km

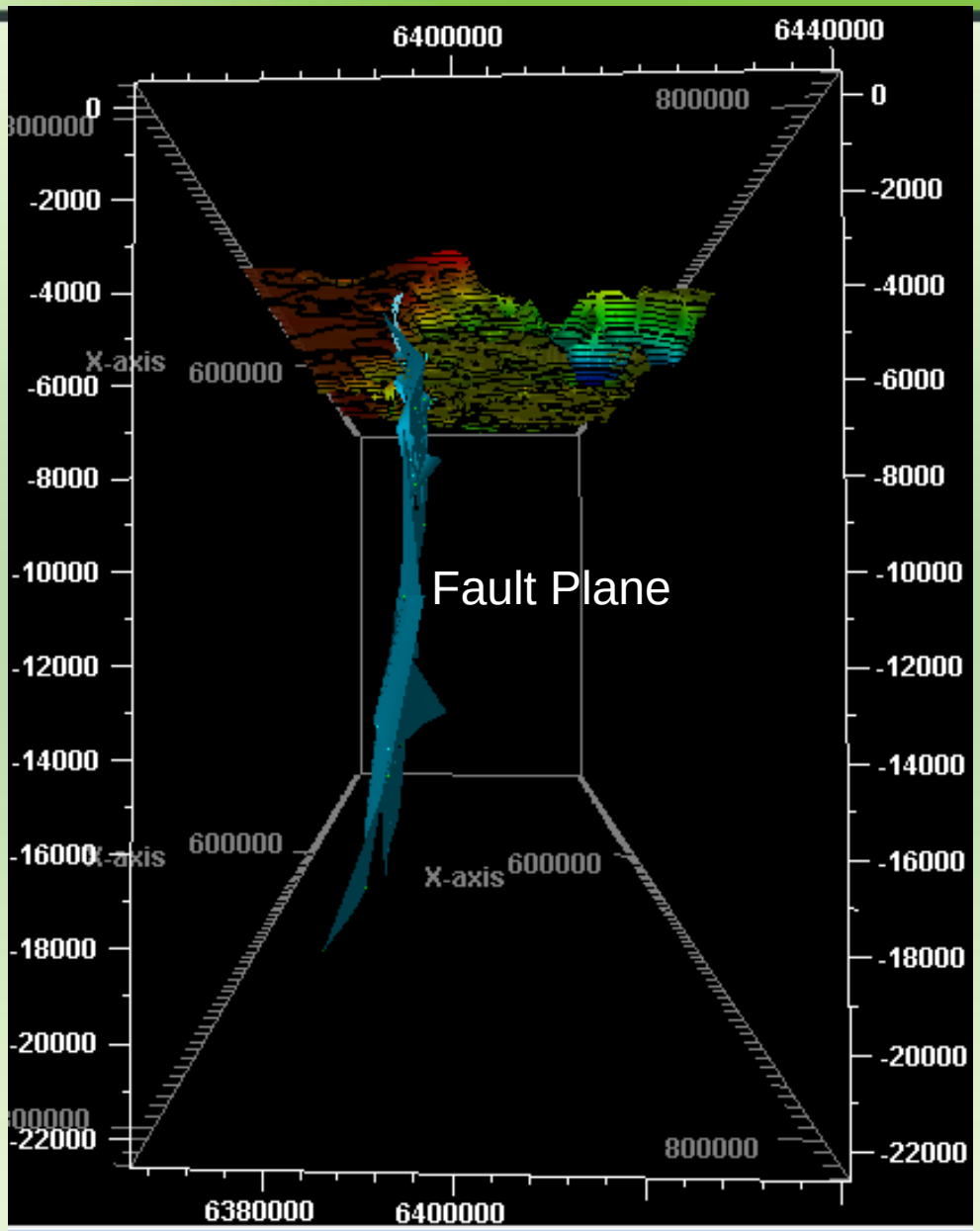


Archimedes

South Australia: 3D Model of Uno Fault



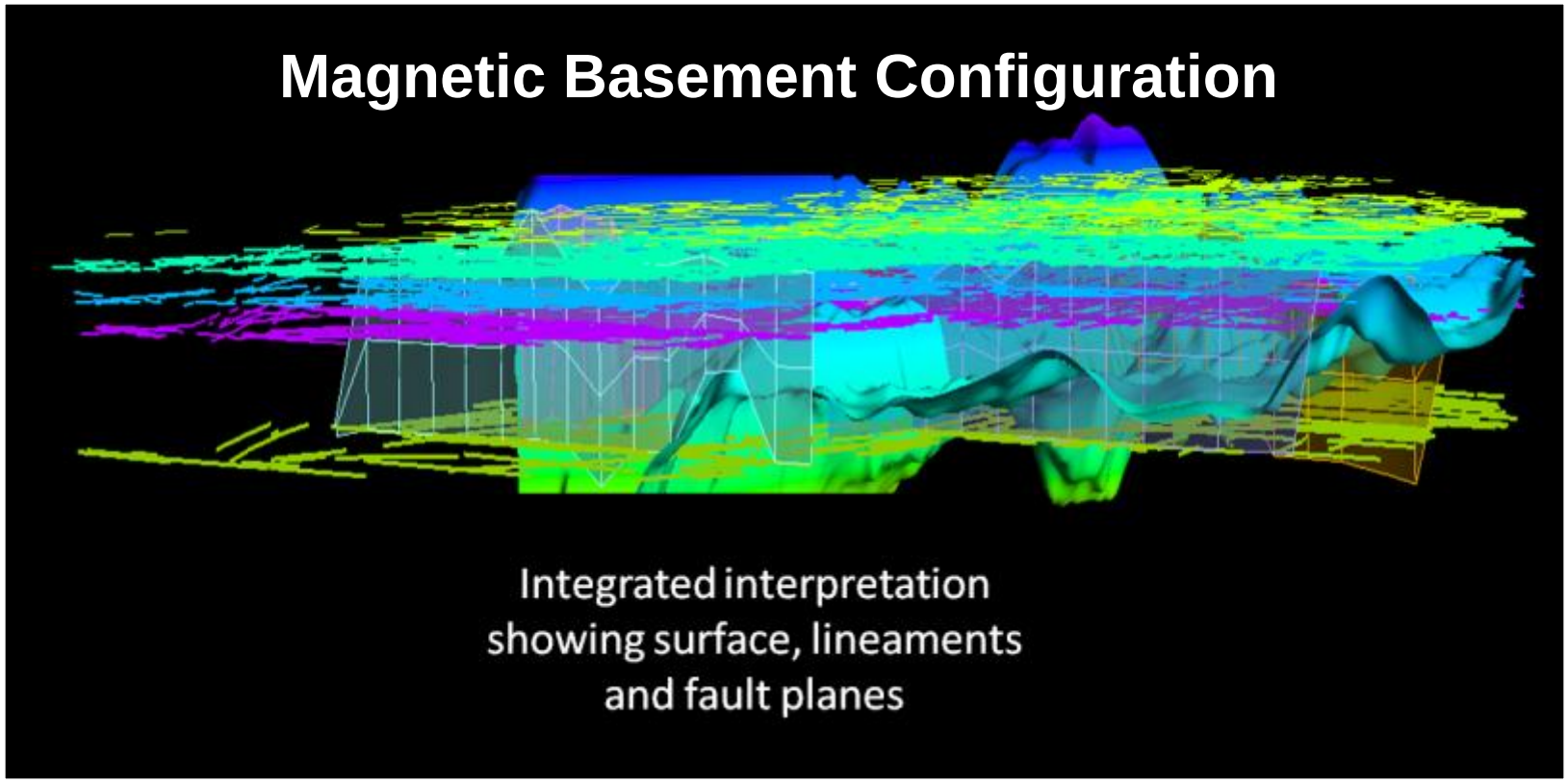
3D Model of Uno Fault



N

View from East

Basement Map and Faults 3D



Archimedes