# Case study 2: Using seismic reflection to design a mine

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# Seismic Reflection technique - Geophysics

*Geophysics?*

*The study of the Earth by quantitative physical methods*

*What does geophysics measure?*

*Electrical conductivity, density, magnetisation, velocity or reflectivity of sound waves (seismic) …*

# Use of 3D seismic reflection technique

- Non-intrusive imaging of the sub-surface
- Highlight regions for further (expensive) in-situ study e.g. boreholes
- Characterise physical properties via geophysical parameters

# What geological information is required at a candidate site?

Characterisation of geological aspects includes:

- Long-term stability
- Faulting and extent of host rock fracturing
- Seismicity
- Volcanism
- Confirmation of volume of rock suitable for construction of disposal zones
- Geotechnical parameters relevant to design
- Groundwater flow regimes
- Geochemical conditions; and
- Mineralogy

*IAEA (2005)*

after Dr Bob Chaplow

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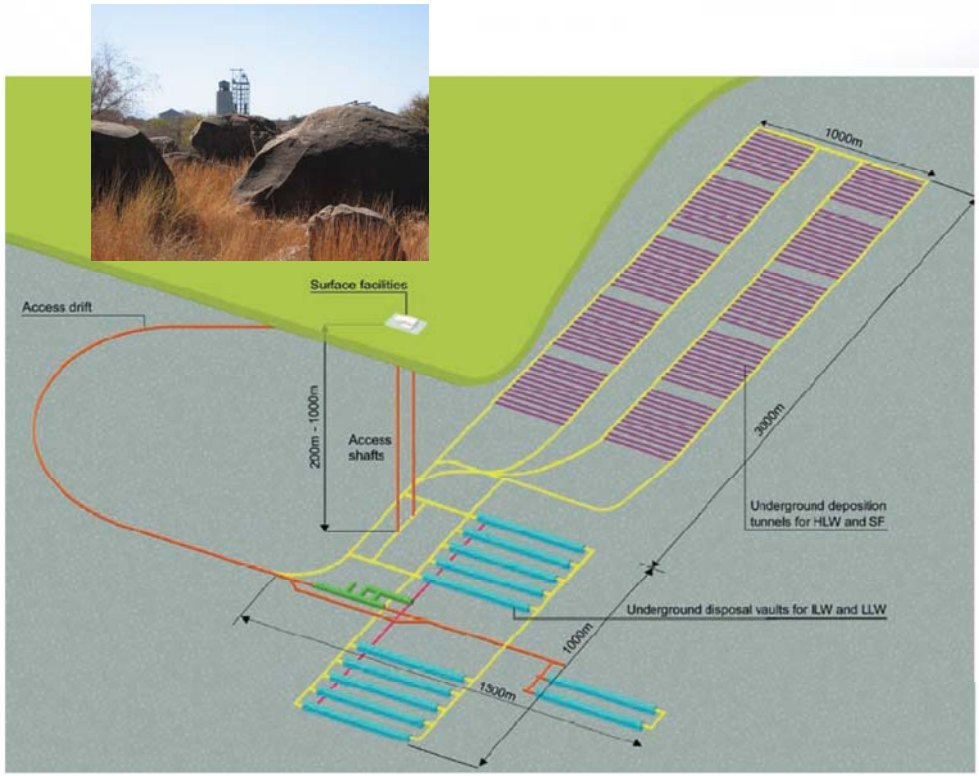
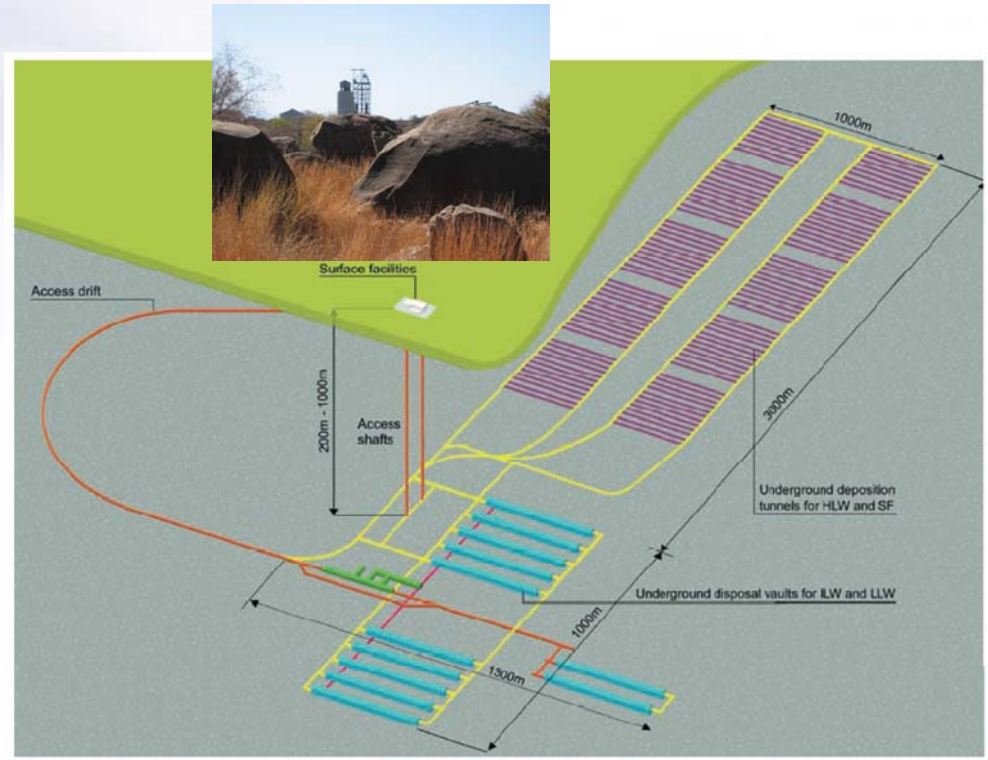
# Radioactive disposal site or Mine




after Dr Bob Chaplow

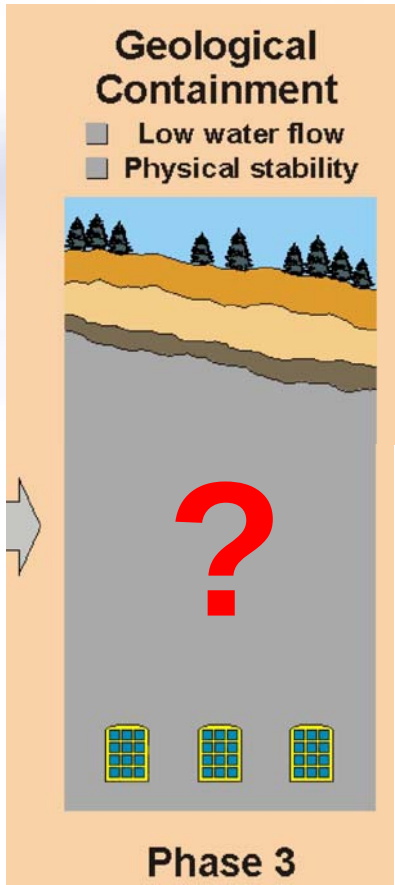
Radioactive waste disposal

# Radioactive disposal site or Mine



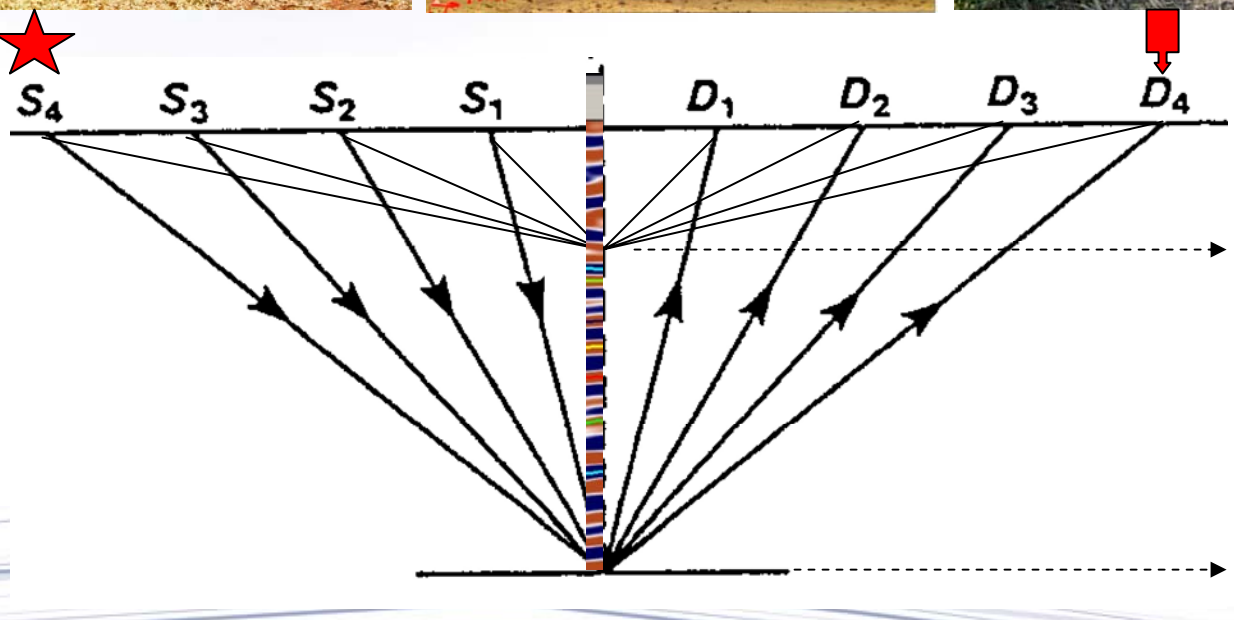

Radioactive waste disposal

after Dr Bob Chaplow

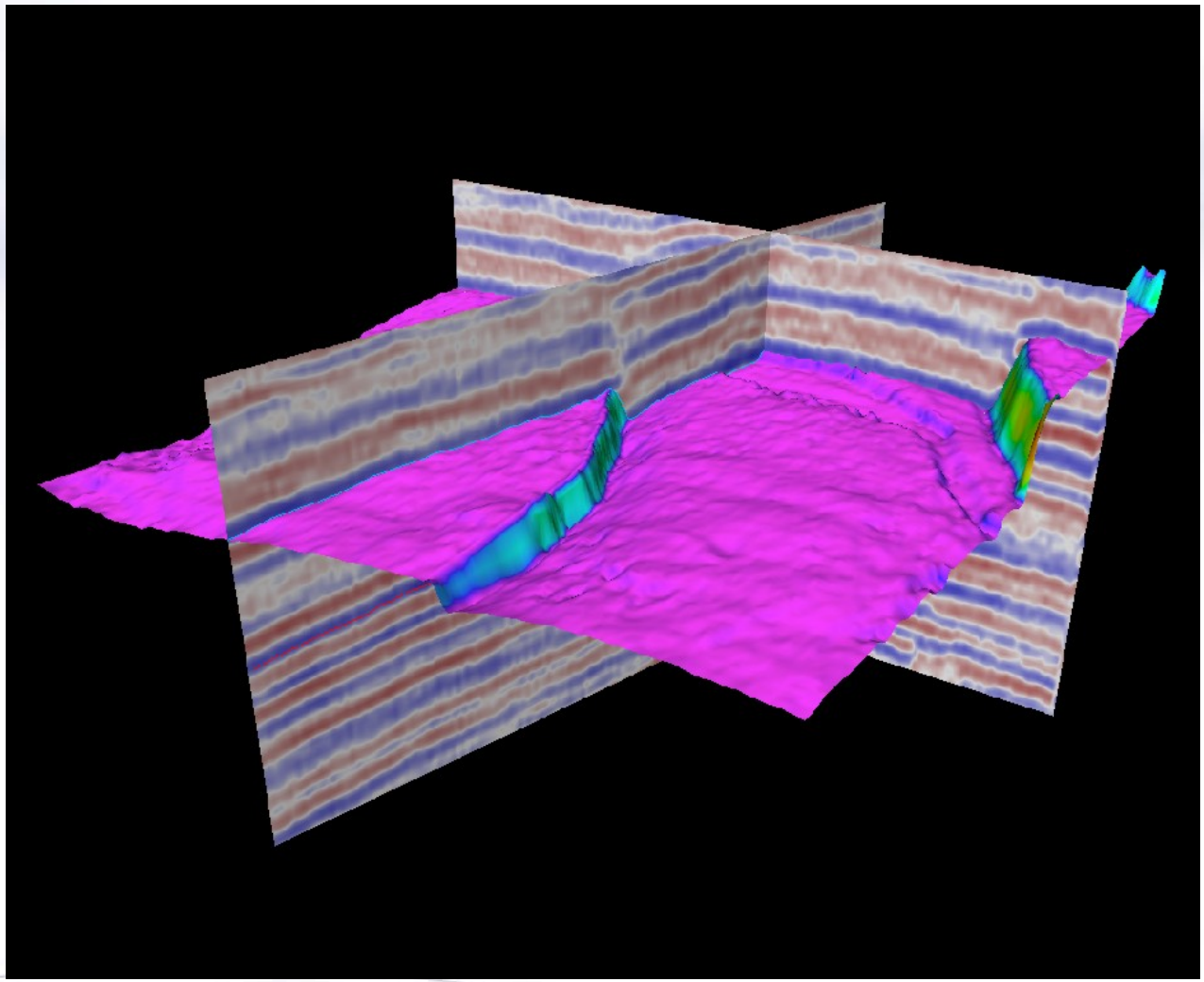



after Dr Bob Chaplow

# Seismic Reflection Technique



# Development of the interpretation



# Seismic reflection signal - vertical resolution issue

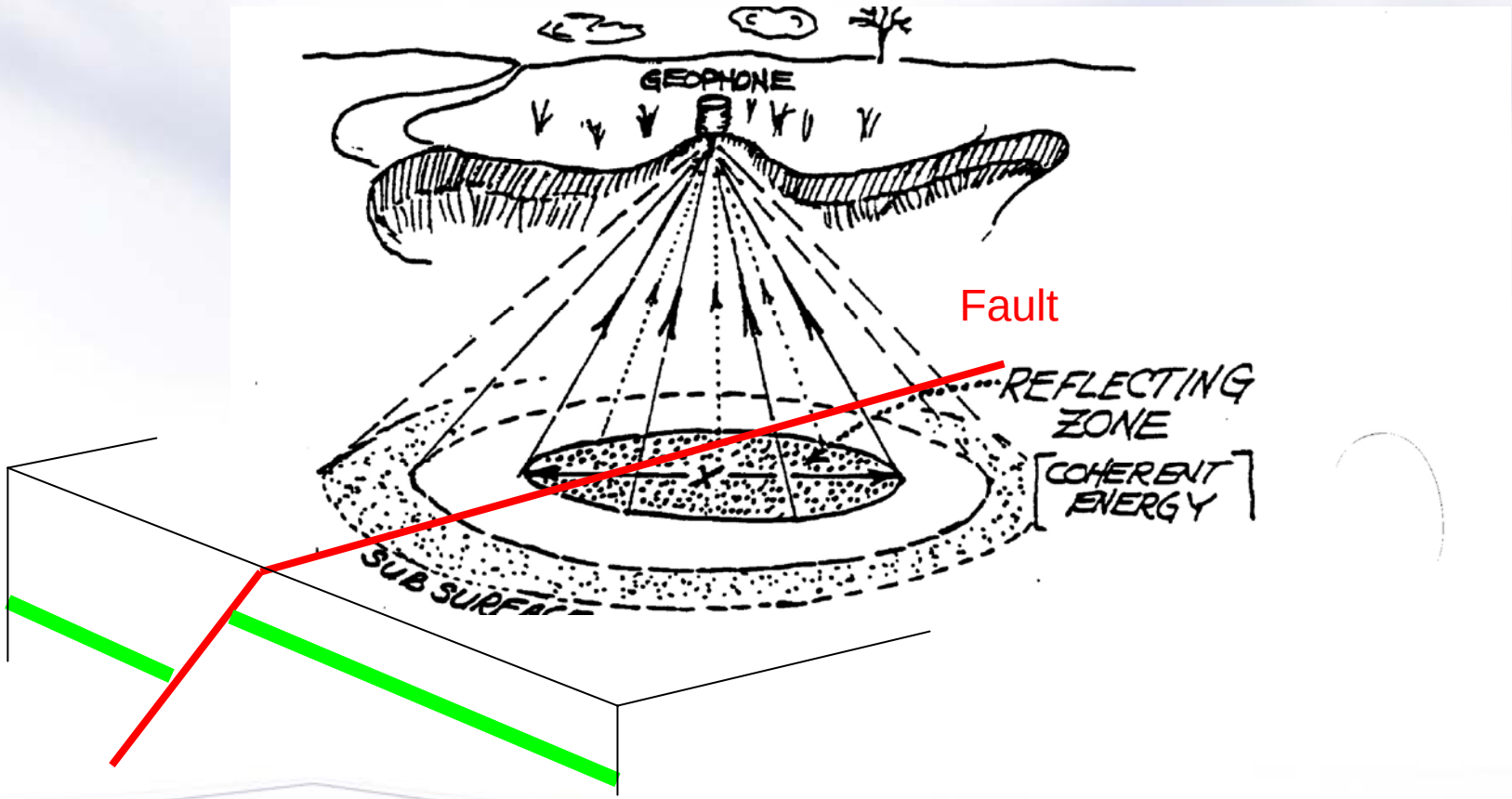
Physical properties of the rock

Centimeters

Signal wavelength

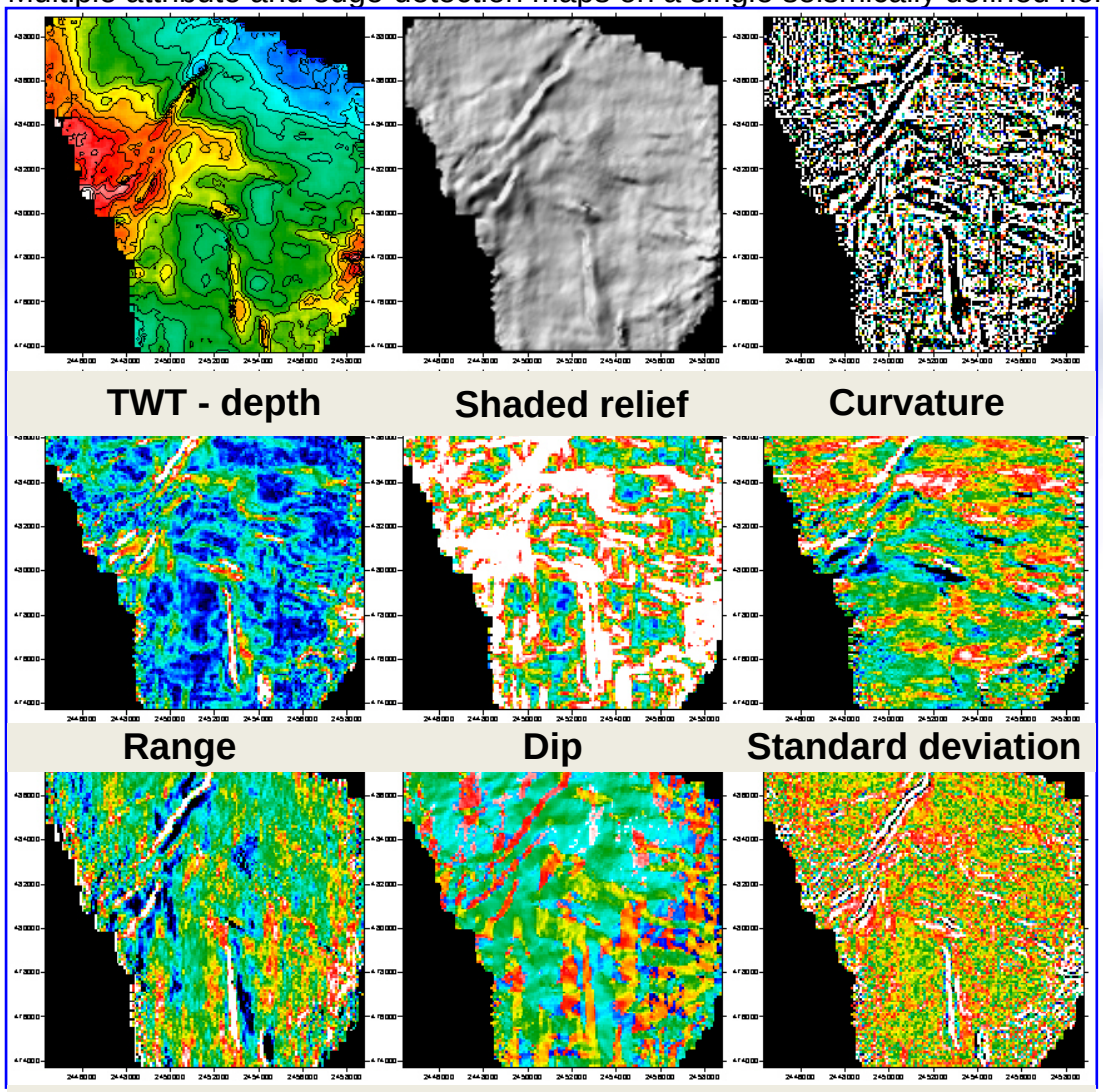
10’s meters

# Seismic reflection signal - horizontal resolution issue

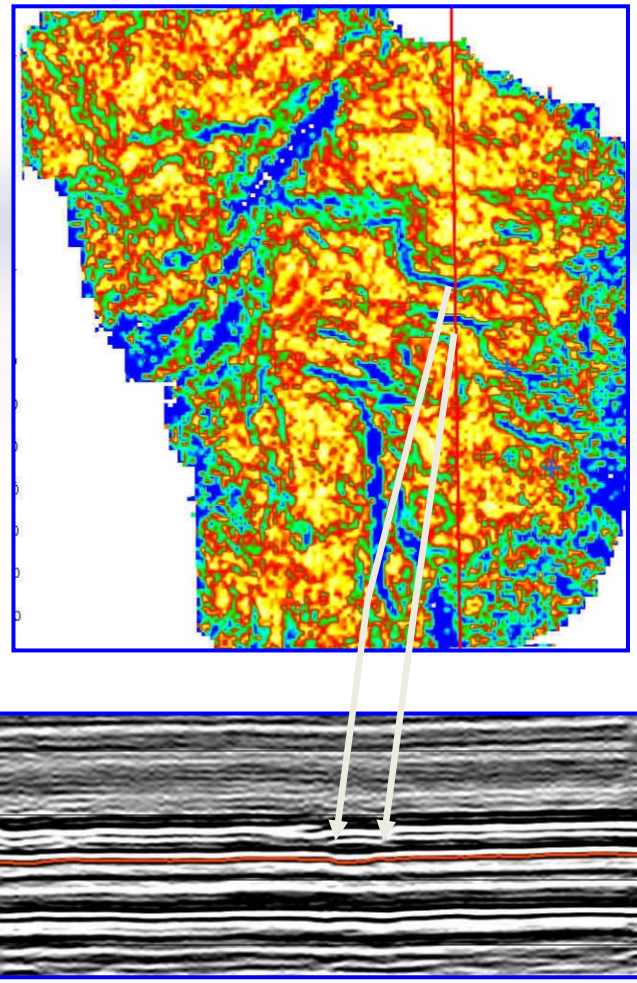


# Seismic Reflection Attribute Analysis

Multiple attribute and edge-detection maps on a single seismically defined horizon



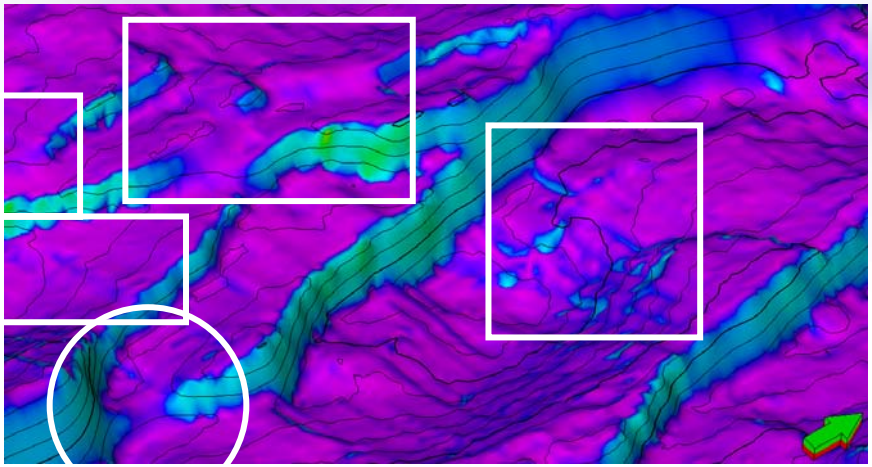

Composite multiple attribute map



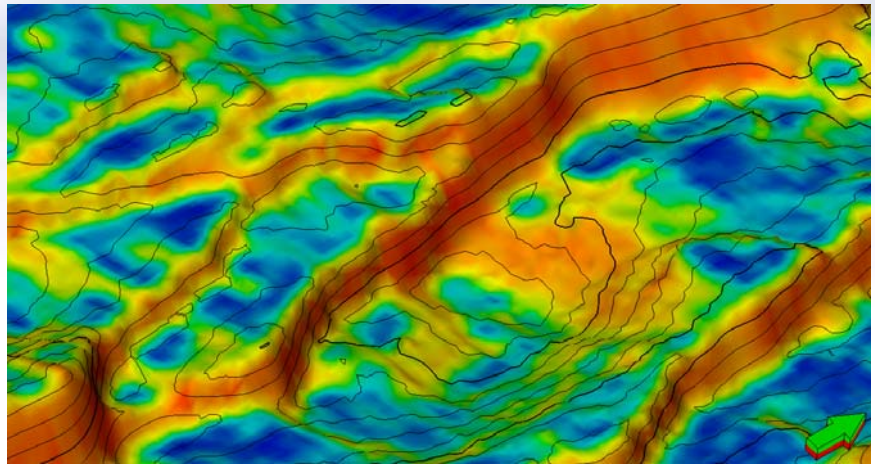
# Enhanced structure imaging

We have ... significantly ... greater number ...

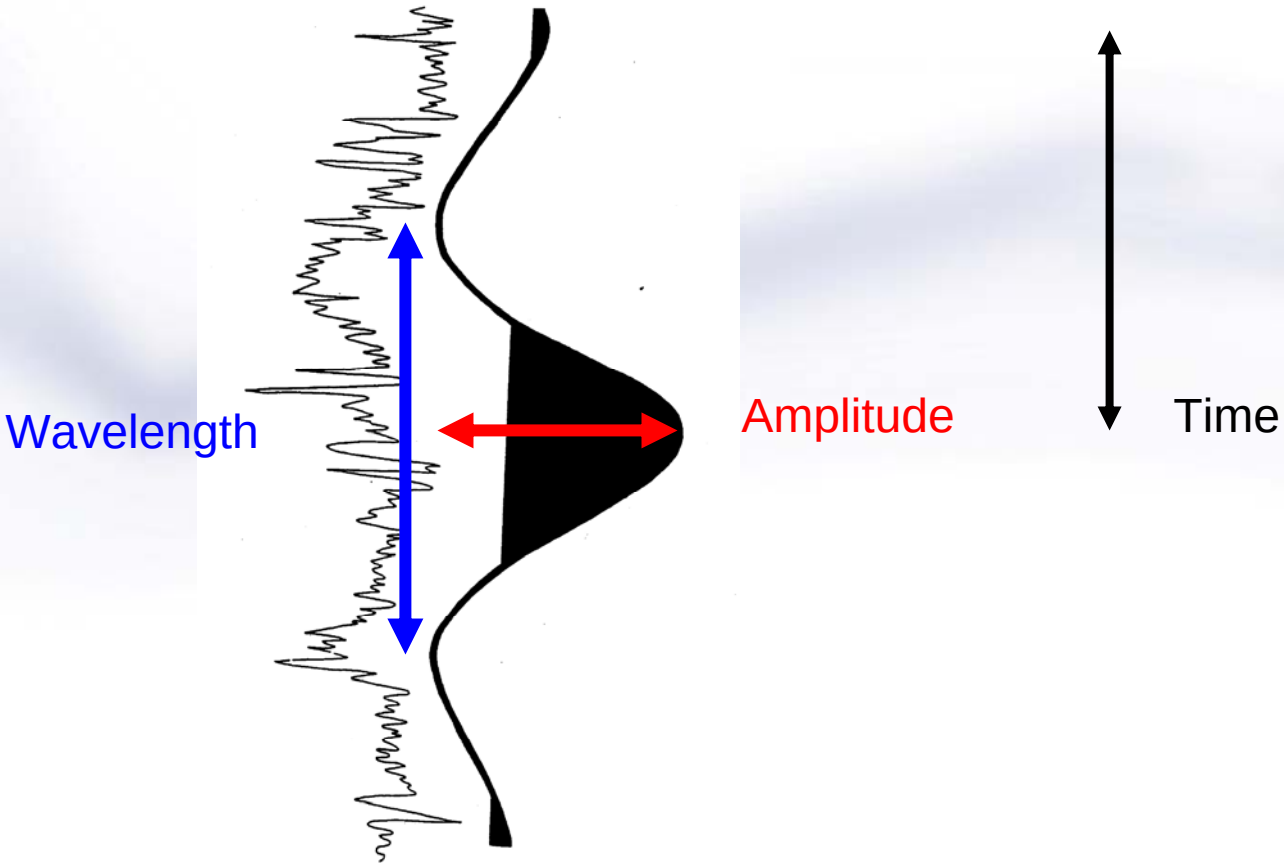
**Dip of horizon**



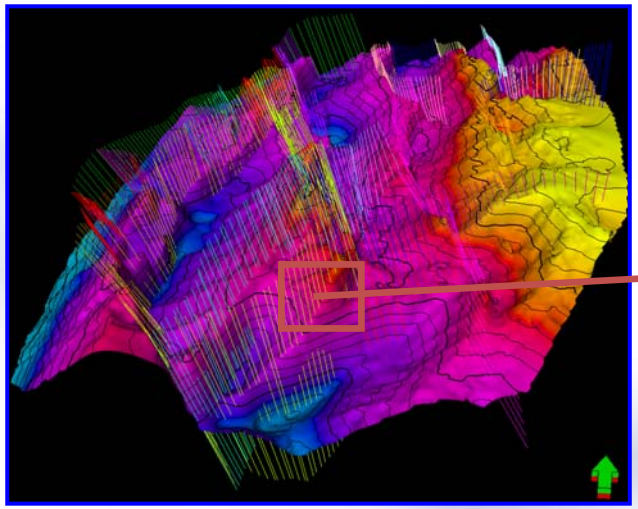
**Edge detection attribute**

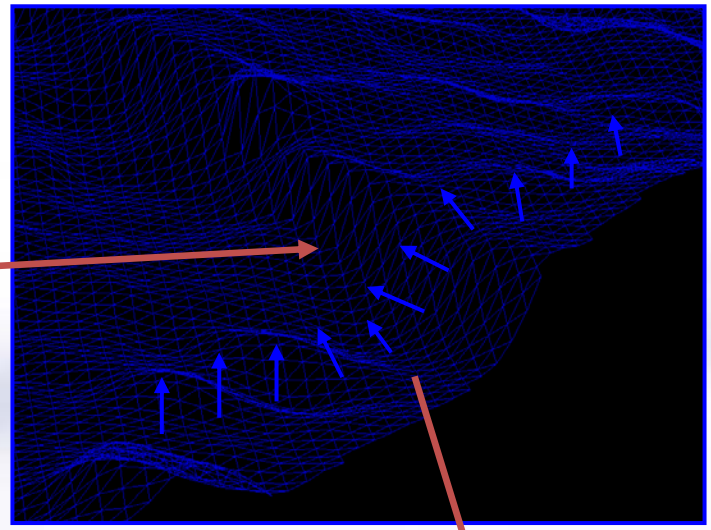


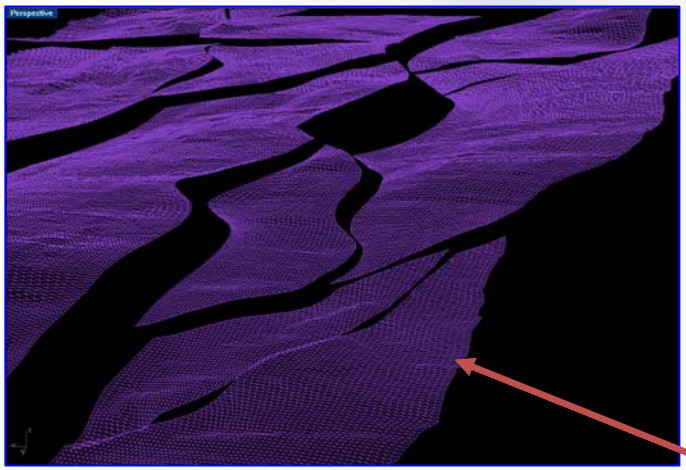
# Seismic reflection attributes

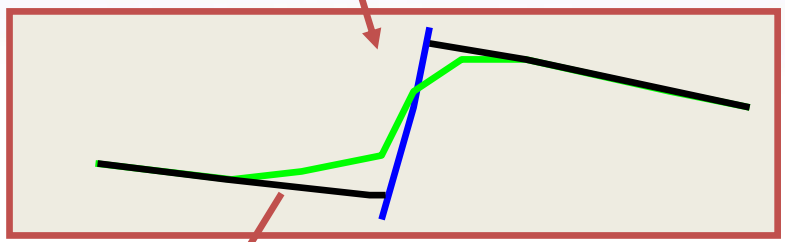


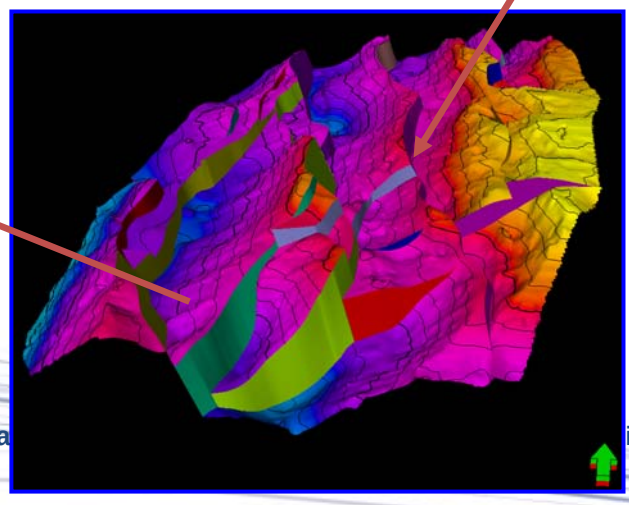
# Modelling the faults







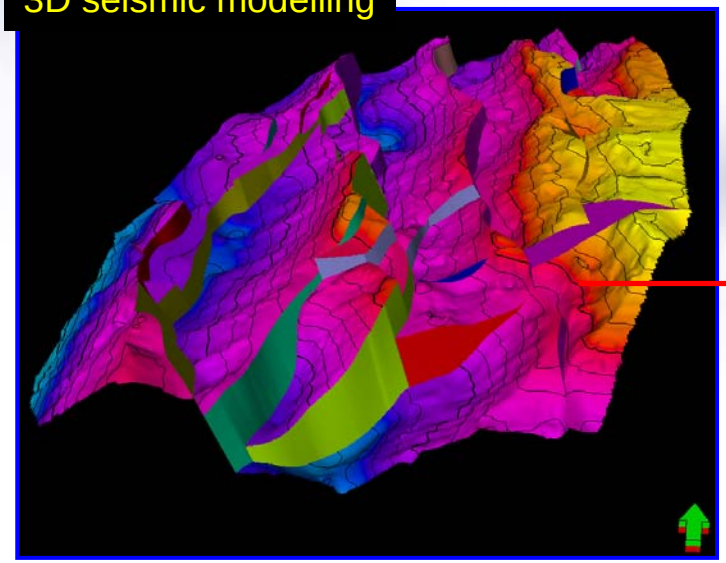




**Create continuously defined geological volume which can be incorporated directly into CAD packages for ore evaluation**

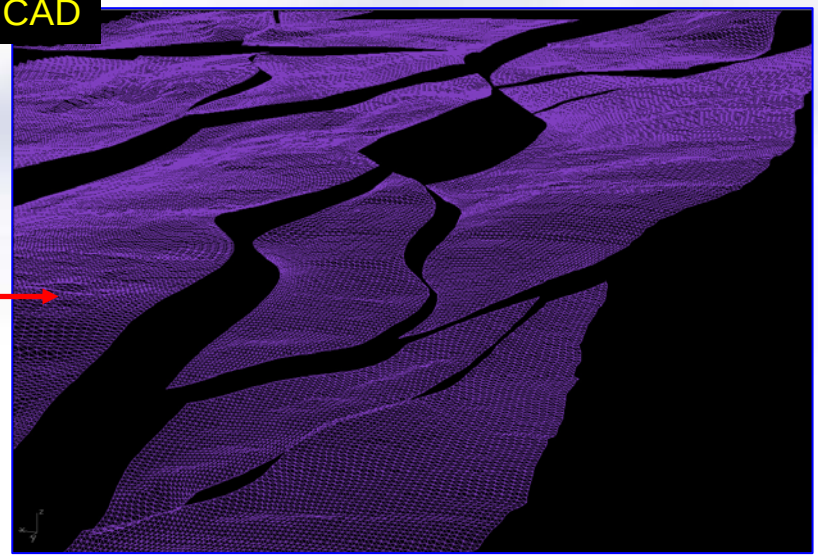
# Structure model and CAD wireframes

3D seismic modelling



Data conversion

CAD

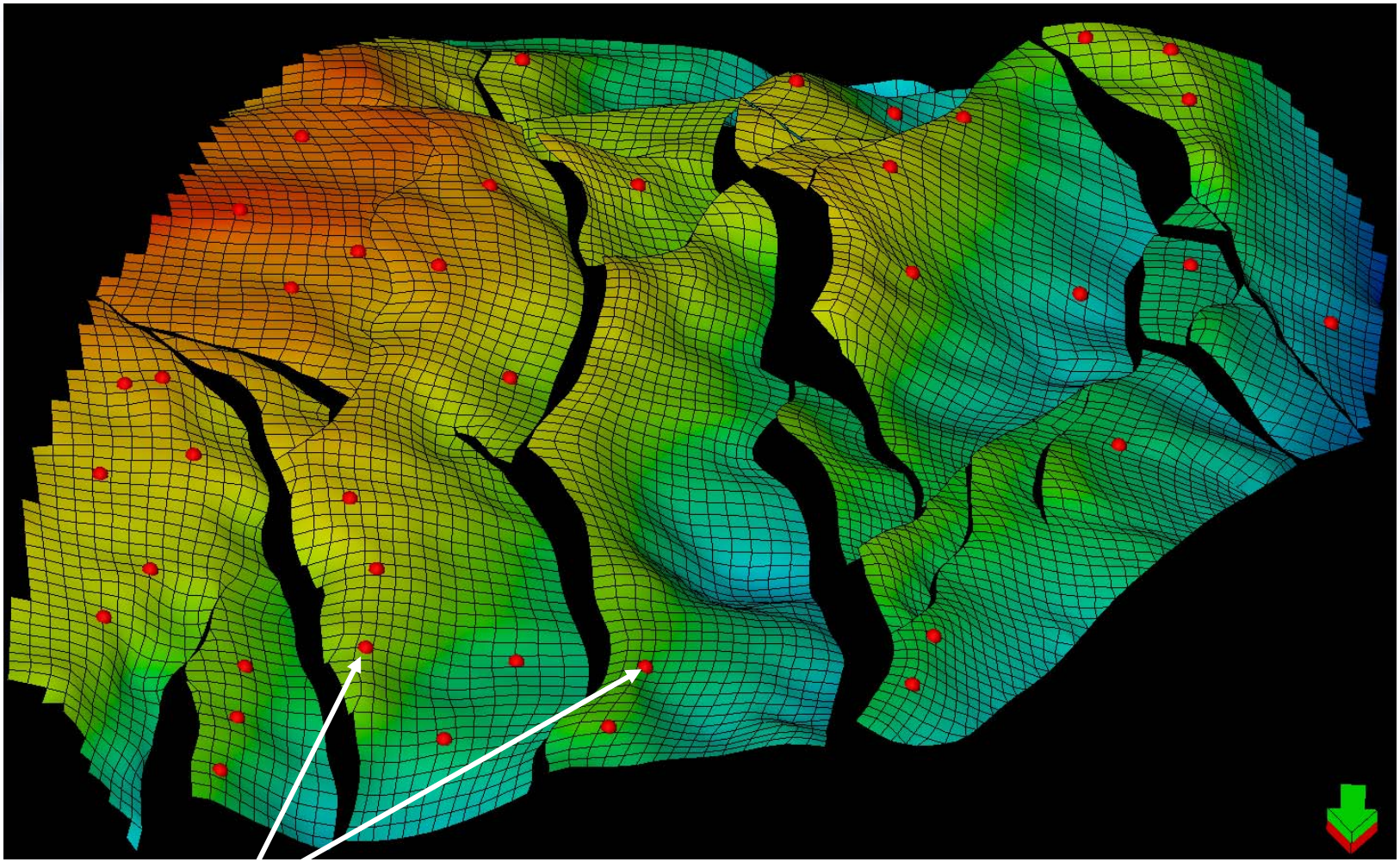


# Time to Depth

Need to know the velocity of the rocks to convert from time to depth

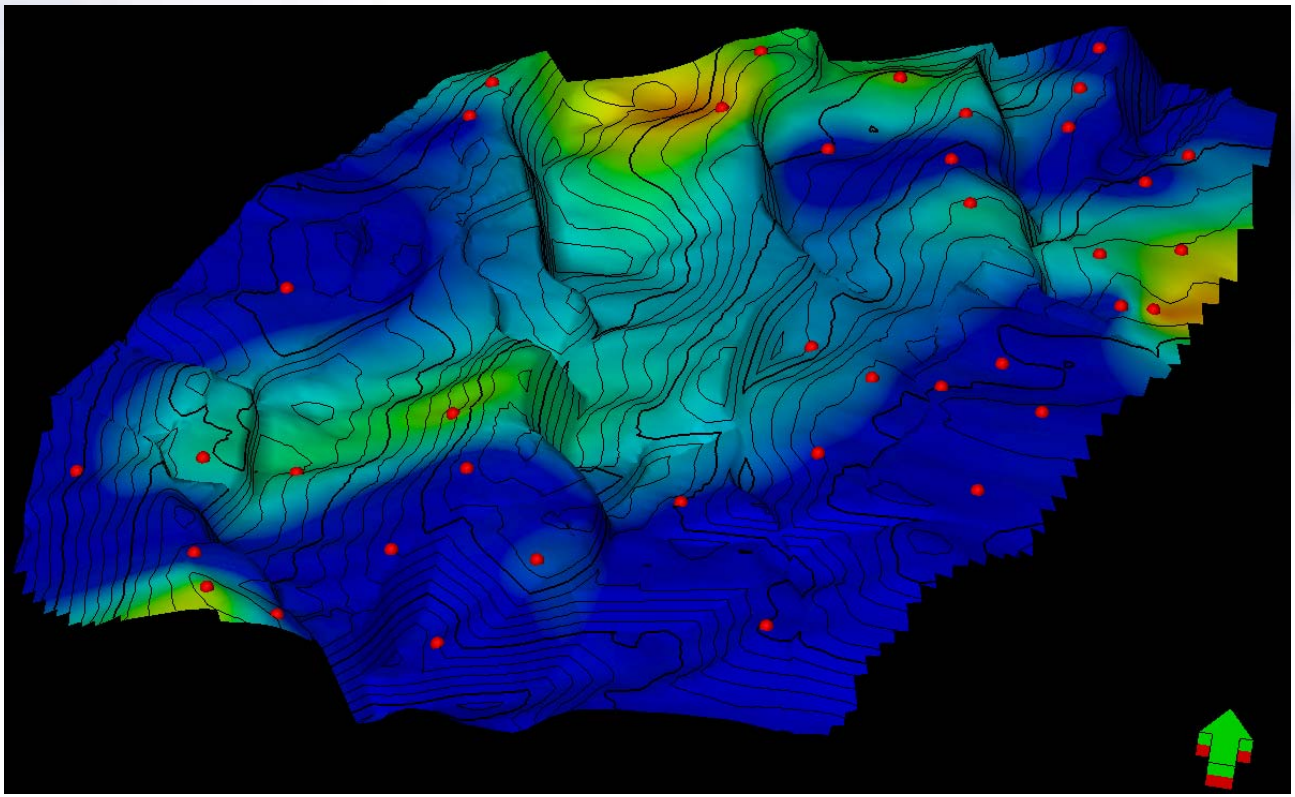
Can get velocity from the seismic reflection travel time (inaccurate) or borehole data (more accurate)

# Depth conversion



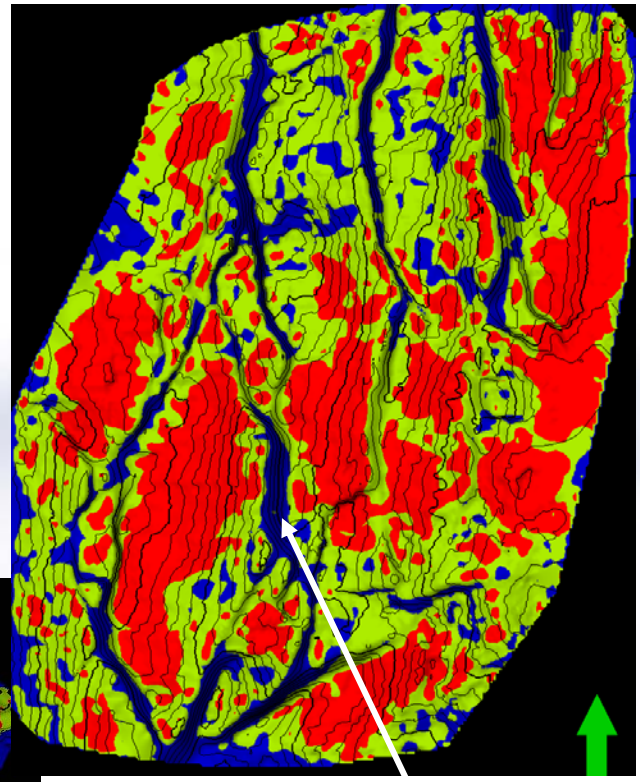
All of the 3D geological volume is tied to all of the borehole control

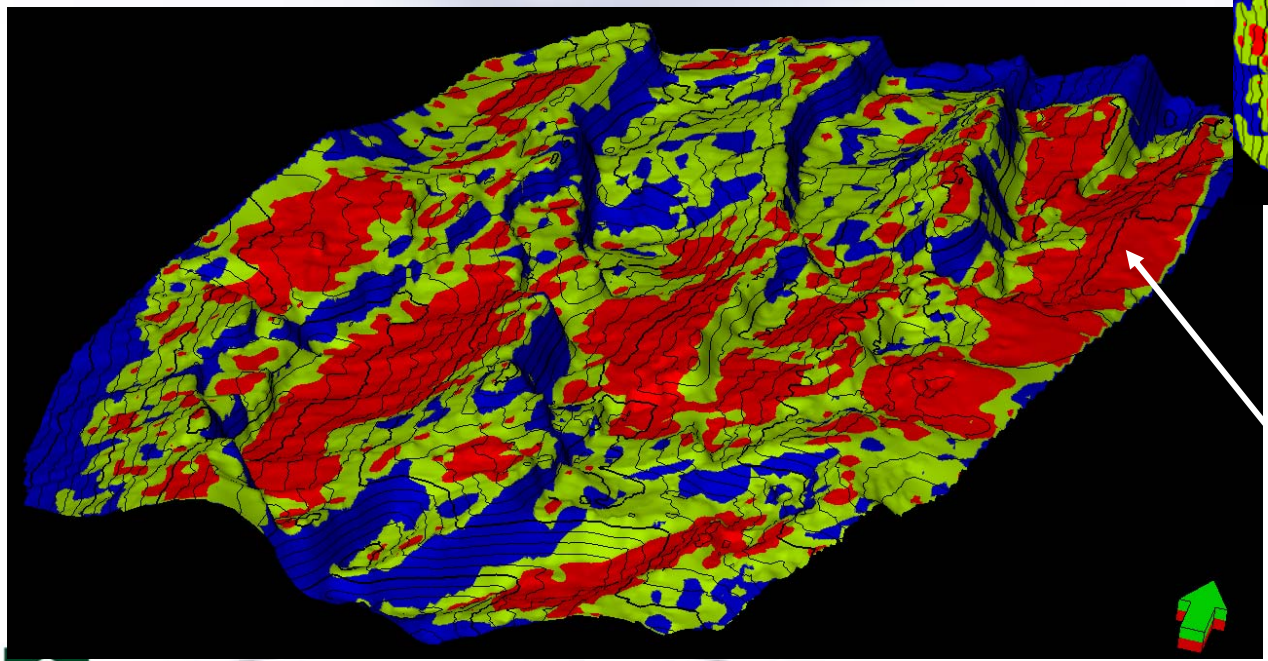
# Depth error estimate



To estimate the likely depth error away from borehole control we sequentially remove one borehole at a time re-compute the full depth conversion then test the accuracy of the prediction against the removed borehole. In this way the likely error away from the boreholes can be estimated.

# Confidence classification



Lower confidences adjacent to faults that impact the seismic

Higher confidences in strong seismic imaging and stable reflector areas

# Fault position accuracy

**Data acquired several years ago, mining now progressed into the edge of the seismic volume – accuracy of interpretation can be tested**

**Mined faults within the seismic volume indicate fault location**

**better than ~20m (this case ~5m)**

# Targeting shafts and boreholes

- **Shaft sites chosen to avoid structurally complex areas**
- **Drilling strategy has been enhanced to test mine block geological variations.**
- **Each block defined and drilled to enhance geological model of the orebody, numerous holes still ongoing.**

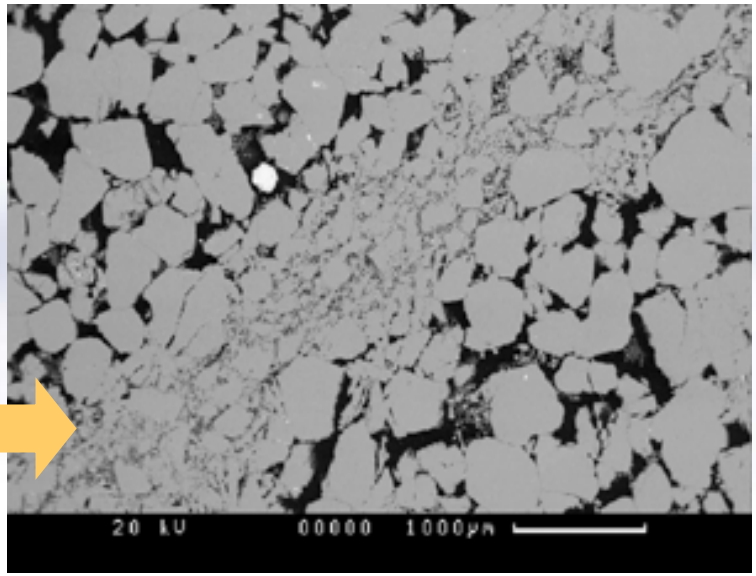
# Generic advantages of 3D seismic reflection for mining

- Optimising shaft locations for minimal haulage and planning
- Delineate regions of homogeneous blocks before entering the ground
- Reducing risk on future capital expenditure programs

# Application of geological (fracture) models to enhance sub-surface understanding

- Have a geological depth model of the sub-surface from the 3D seismic reflection survey interpretation
- Can we use our observations in a borehole or at outcrop to enhance our understanding of flow in the sub-surface from our geological model?
- e.g. Platinum mine = layered crystalline rock with faults
- e.g. Coal mine = layered sedimentary rock with permeability and faults

# Faults Properties: Barriers to Flow


*Reduced permeability in crushed fault rock*
*($10^5$ reduction possible)*

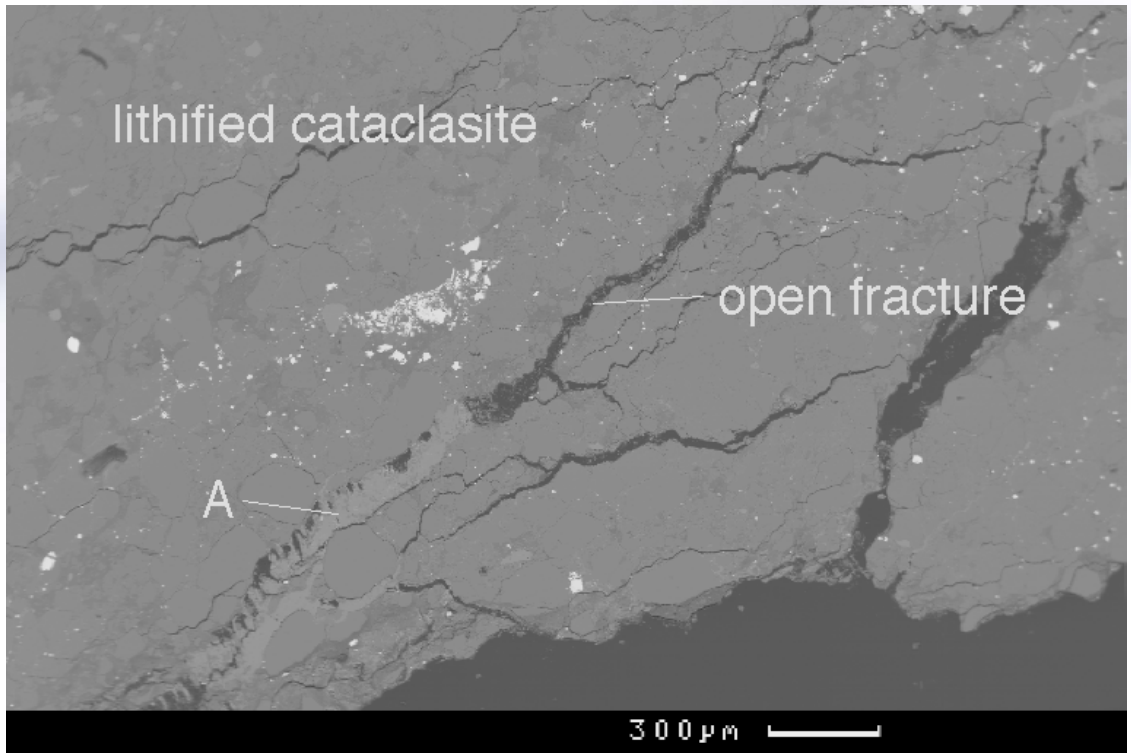
# Faults/Fractures: Conduits to flow

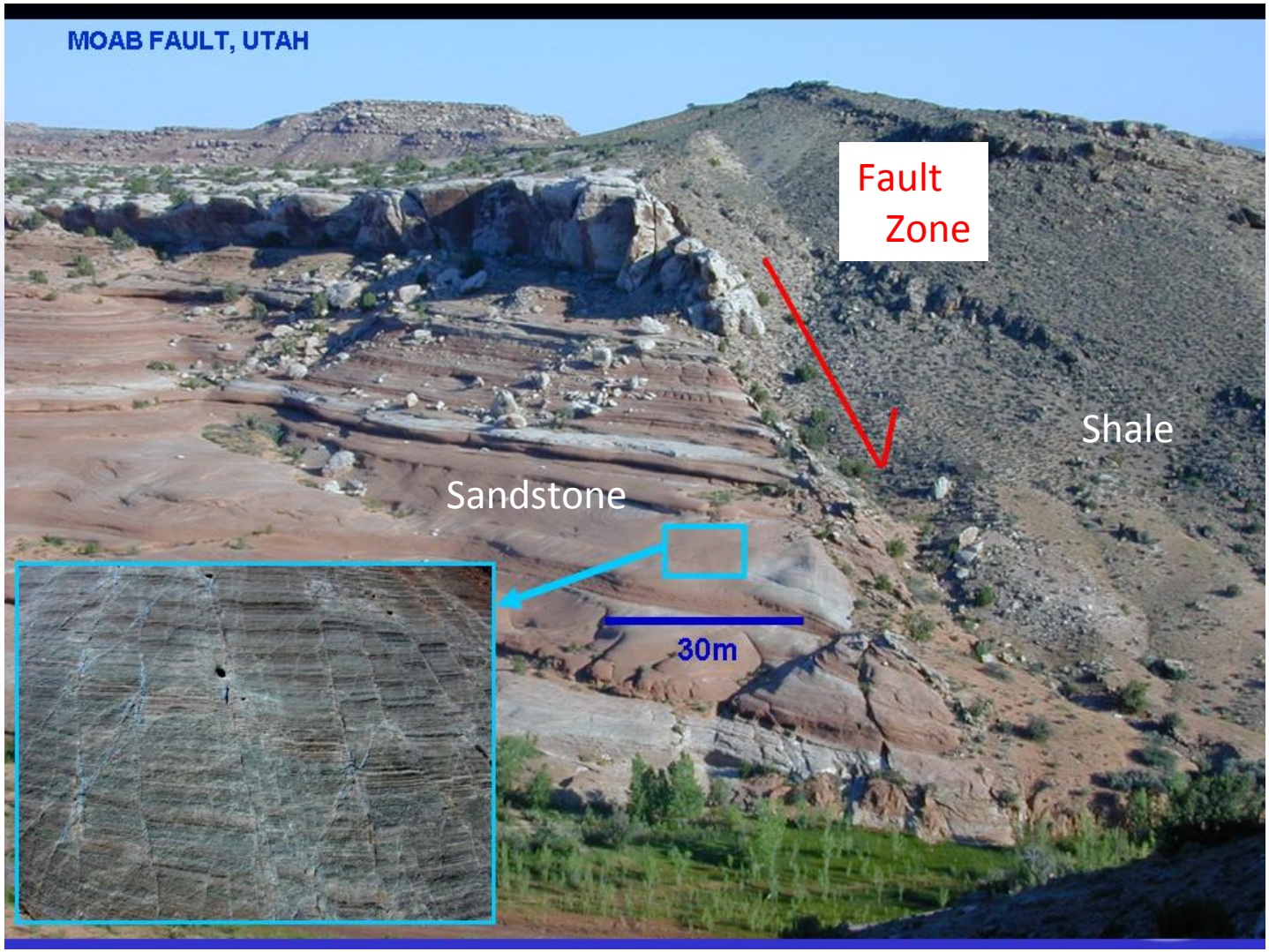
- Impacts on long term viability of site.

- Provides porosity for fluid flow.

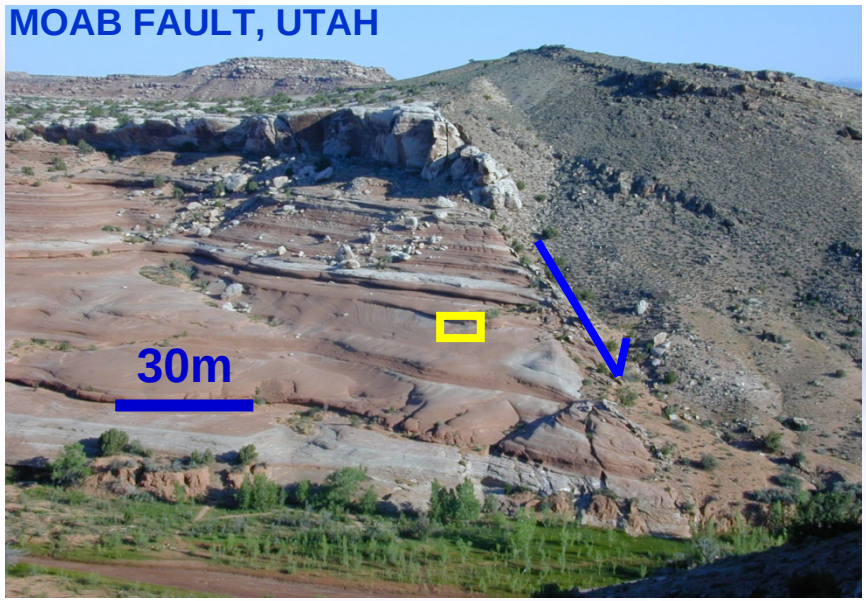
- Large surface area for fluid rock interaction / chemical exchange.

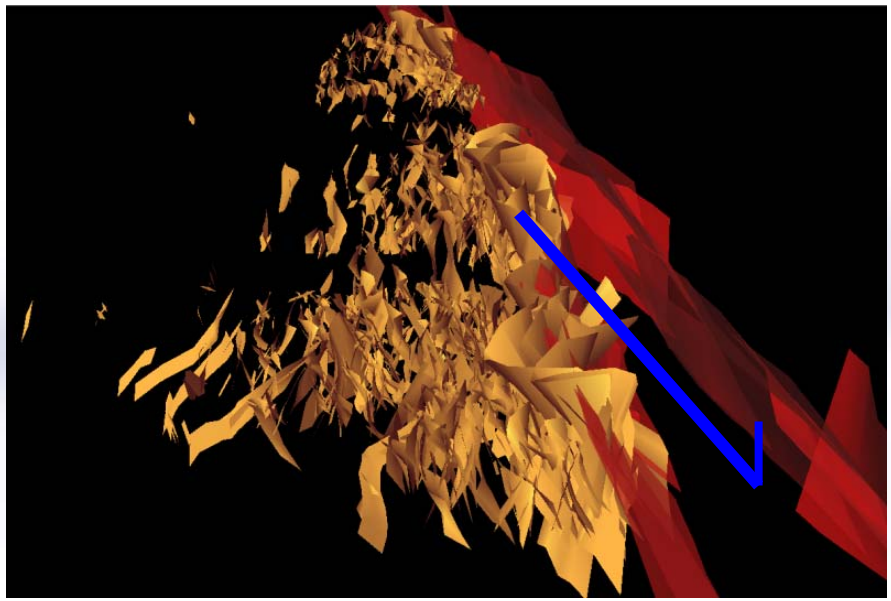
- Strength of rocks




MOAB FAULT, UTAH
Fault Zone
Shale
Sandstone
30m

# Small-scale fractures around faults



**Core or Outcrop: Provides databases on fault zone architecture and specimens.**

**$10^7$ small faults around one large structure.**

## Statistical model of fractures around the fault

Power law length distribution

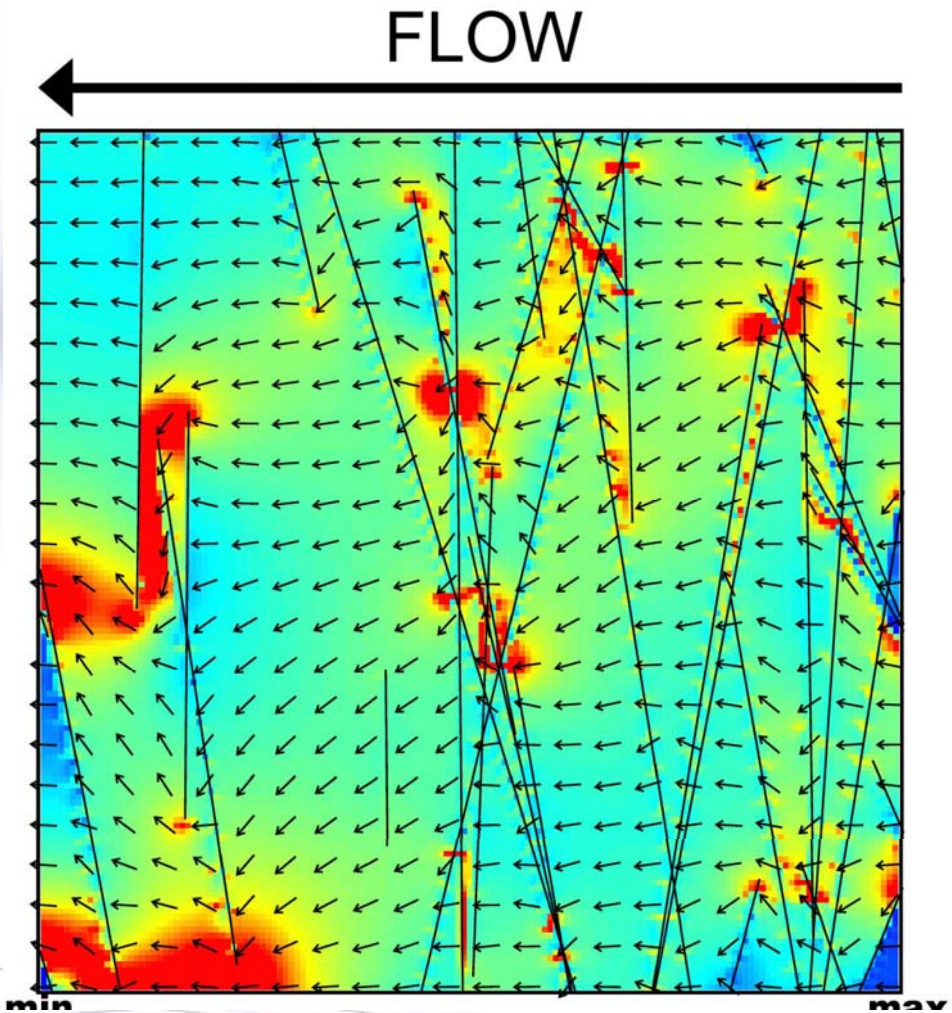
Orientation distribution (trend, dip)

Fault length–throw relationship

Spatial distribution – hierarchical clustering

Statistical spatial distribution resembles natural systems

# Fluid flow through faults with differing permeability



# Conclusions

3D seismic reflection imaging can be used for:

- Optimising shaft locations for minimal haulage and planning
- Delineate regions of homogeneous blocks before entering the ground
- Reducing risk on future capital expenditure programs