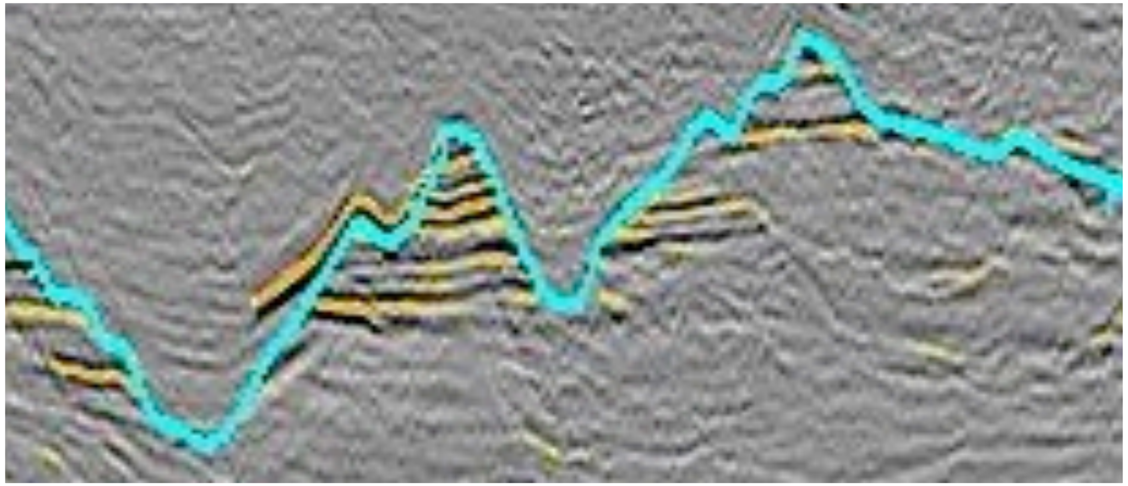
Seismic imaging
Lecture 5



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Module outline

Day 2 morning- Visualising and interpreting seismic data

Lecture 4: The SEGY data convention and where to find data

Lecture 5: How to interpret seismic data

Lecture 6: Seismic attribute analysis and machine learning (future outlook)

Day 2 afternoon- Exercises

Exercise 3: Reading SEGY data and visualizing 3D data

Exercise 4: Calculating seismic attributes

Lecture outline

Objective of lecture 5:

Conventional seismic interpretation and geological features imaged in seismic data

1) Limitations of conventional seismic interpretation

2) Common geological features that may be observed in near-surface seismic data used for environmental/geoenergy applications

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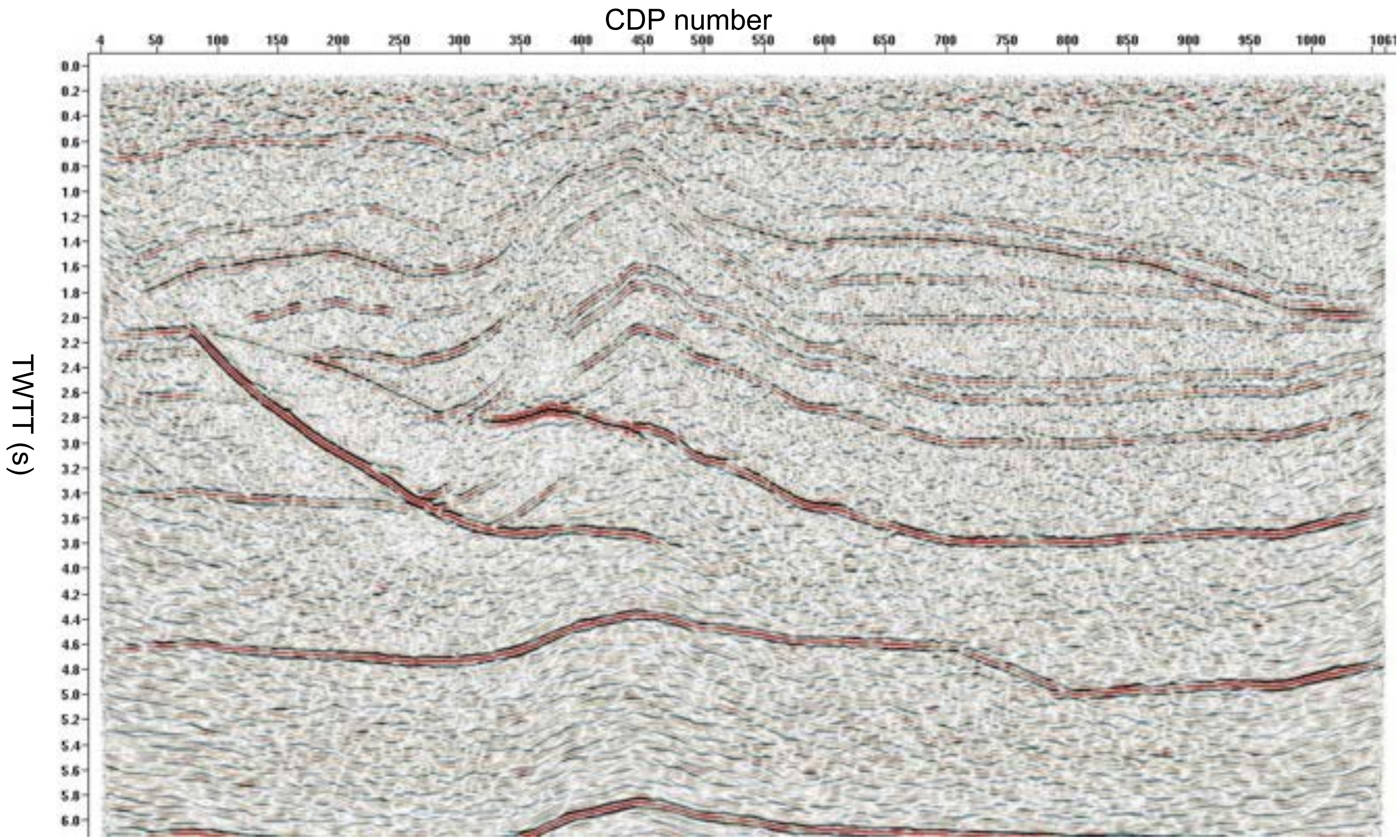
3) Conventional seismic interpretation 'deliverables'

Seismic interpretation: Where to start?



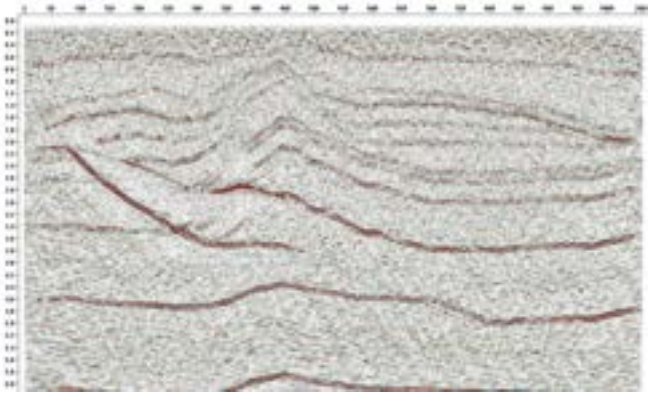
Time-migrated seismic section

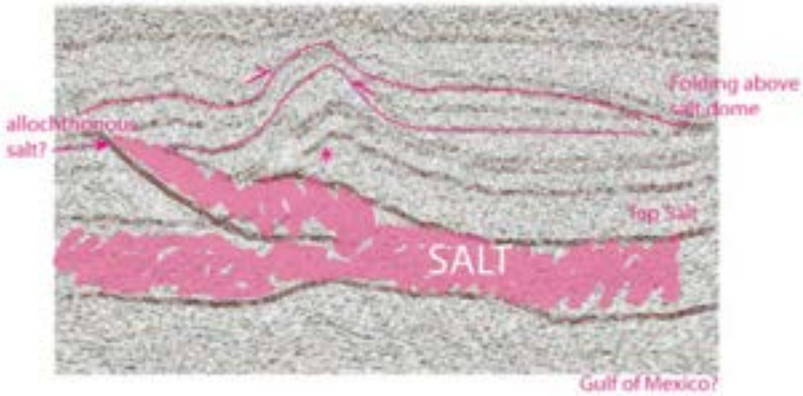
Bond et al. 2007

Uncertainty in seismic interpretation

• Seismic interpretation is subjective- different people will interpret the same section differently

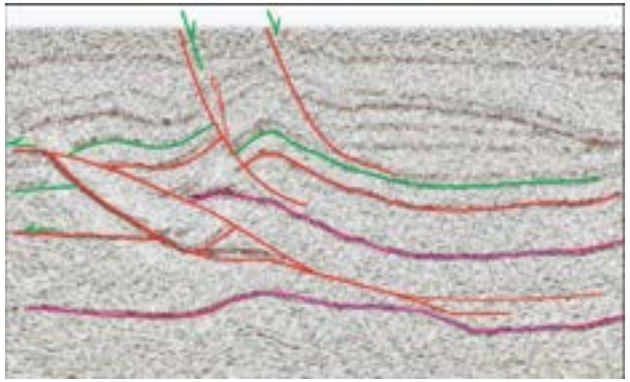
• The seismic section on the previous slide was given to 412 people to interpret- ranging from students to experienced academics and industry geologists



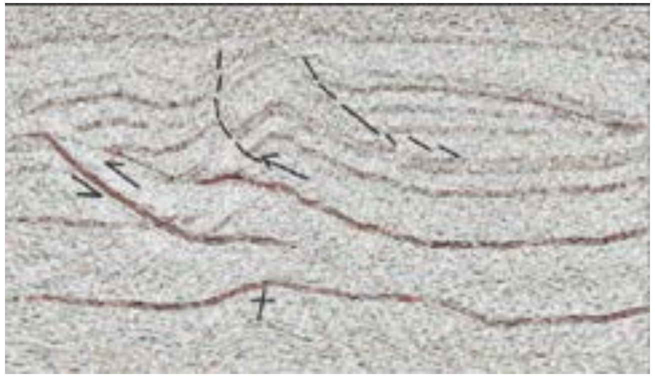


Salt?

Very different interpretations resulted…



Normal faults?

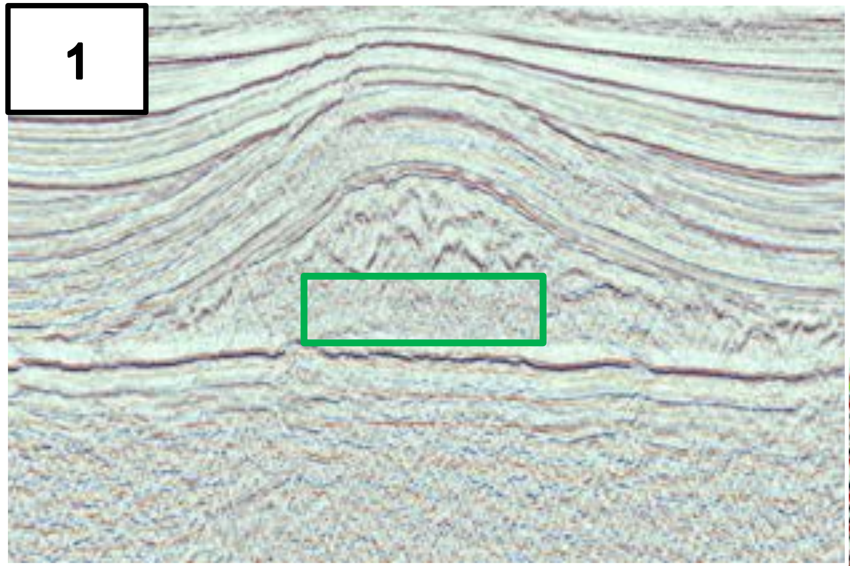


Thrust faults?

Bond et al. 2007

Non-unique seismic facies

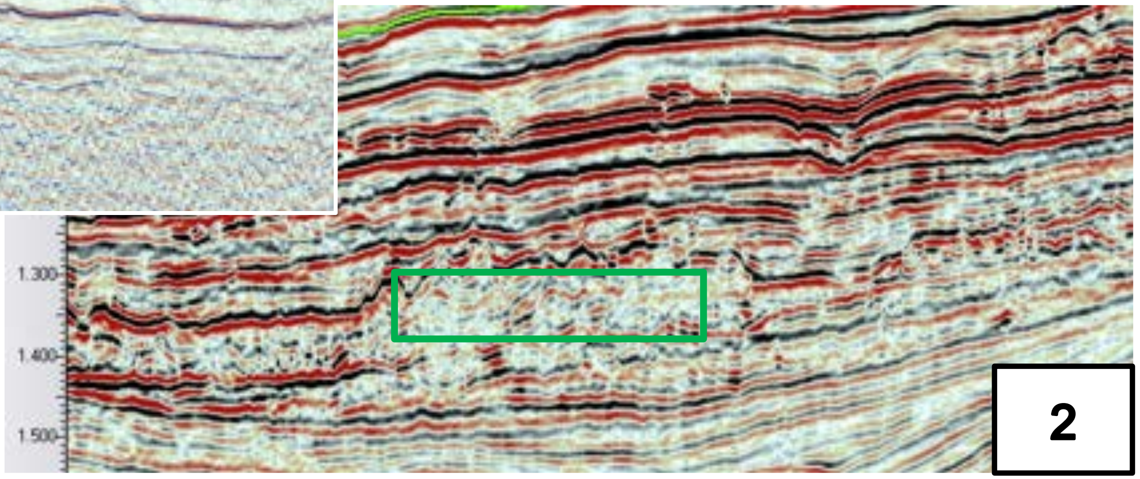
- One of the difficulties of working with seismic data is that different geological features can look similar. The way geological features look in seismic data (their ‘**seismic facies**’) is non-unique
- This is also a challenge for any deep learning attempts to automate seismic interpretation (we will come back to this in lecture 7)



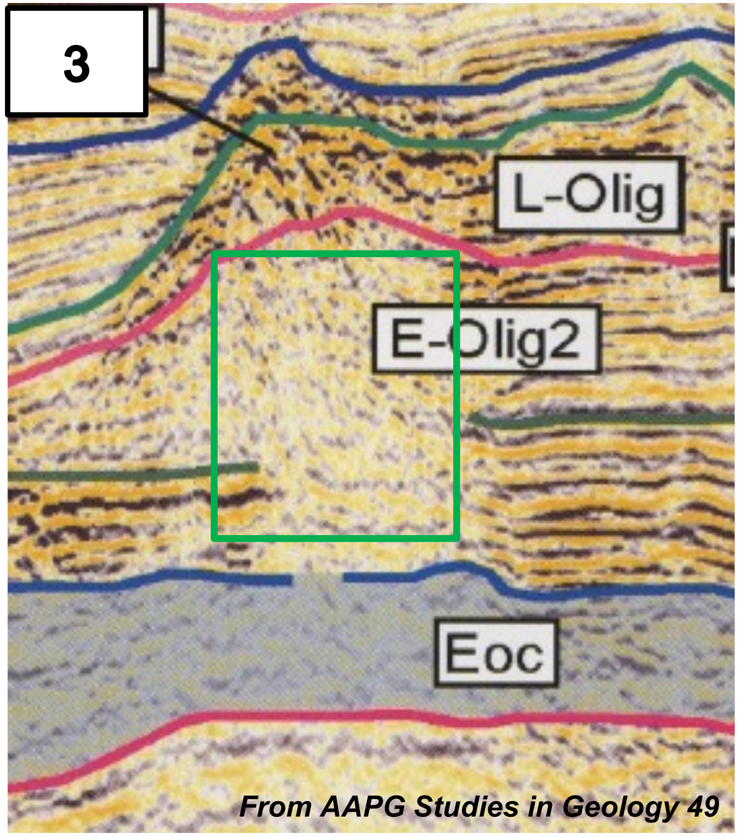
The seismic facies in each green box would be described as ”low amplitude, chaotic reflections”

Acoustically transparent

But the three images show 1) salt, 2) debris flows and 3) coral reef



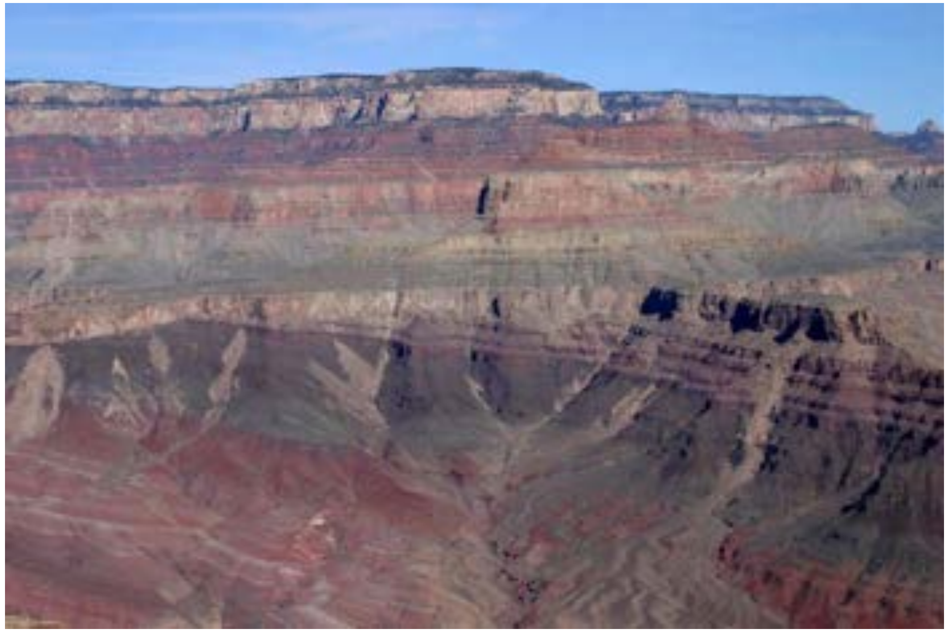
Same seismic facies = acoustically transparent for each green box but fundamentally each box has 3 different material (diff labels)



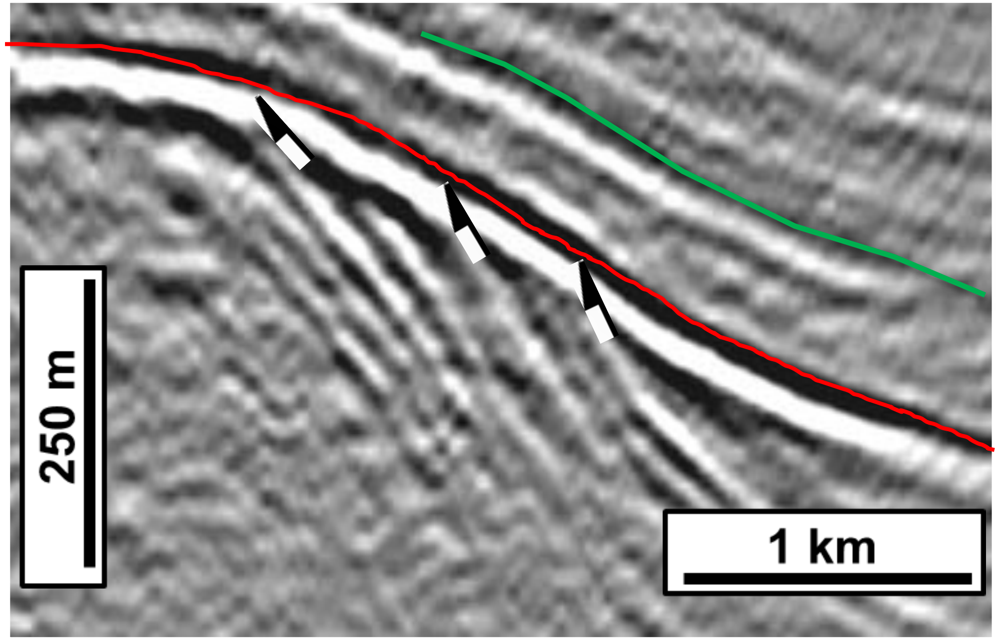
From AAPG Studies in Geology 49

Geological features in seismic data

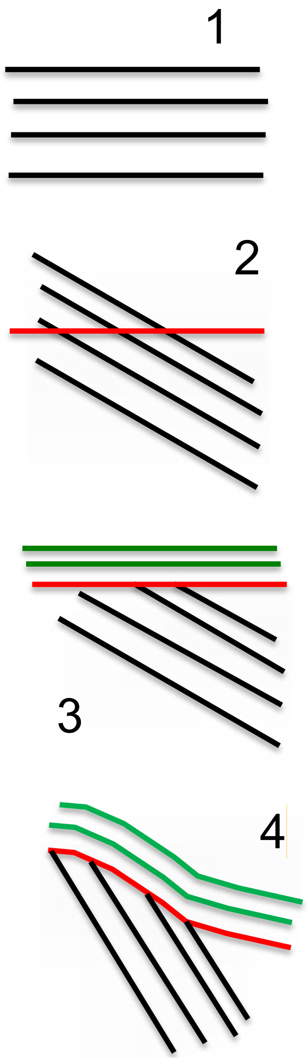
Angular unconformity - surface of erosion or non-deposition that separates younger less-tilted rocks from older more steeply dipping rocks



In the field (Grand Canyon)



In seismic data
(Cooper-Eromanga Basin, Australia)



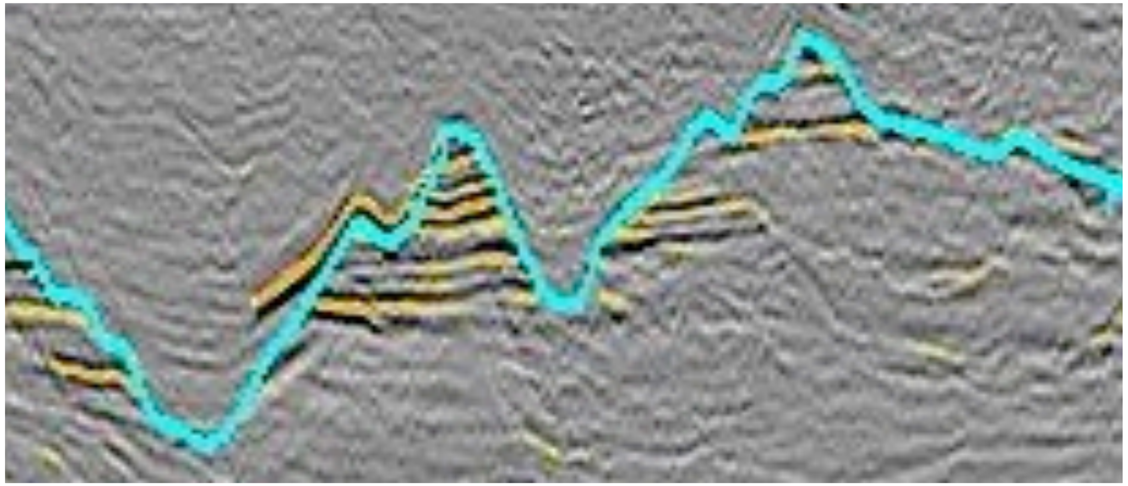
** Watch lectures to see lines being drawn **

Caused by: changes in sea-level and commonly tectonics

Geological features in seismic data

Down-cutting unconformity (channels/canyons)- surface of erosion or non-deposition that separates younger rocks from older rocks

In the field

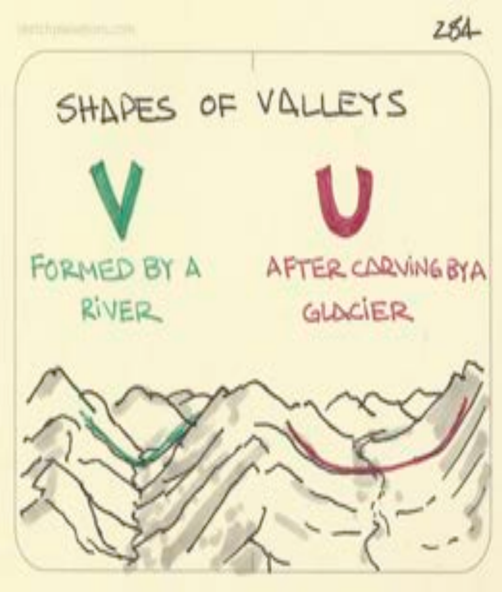


In seismic data

Images are of different places

Caused by: changes in sea-level (which may be caused by tectonics)

Geological features in seismic data

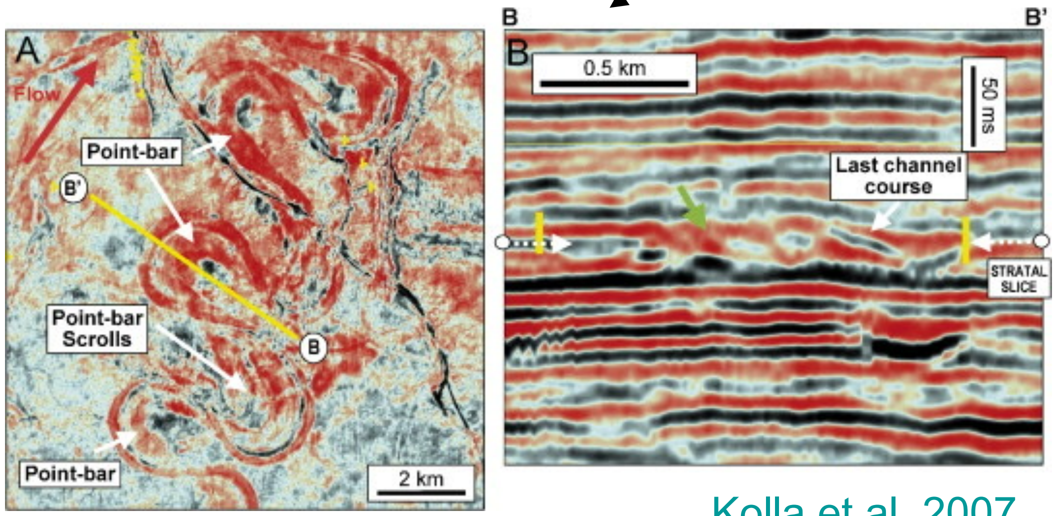


www.sketchplanations.com

Rivers

Glacial Channels

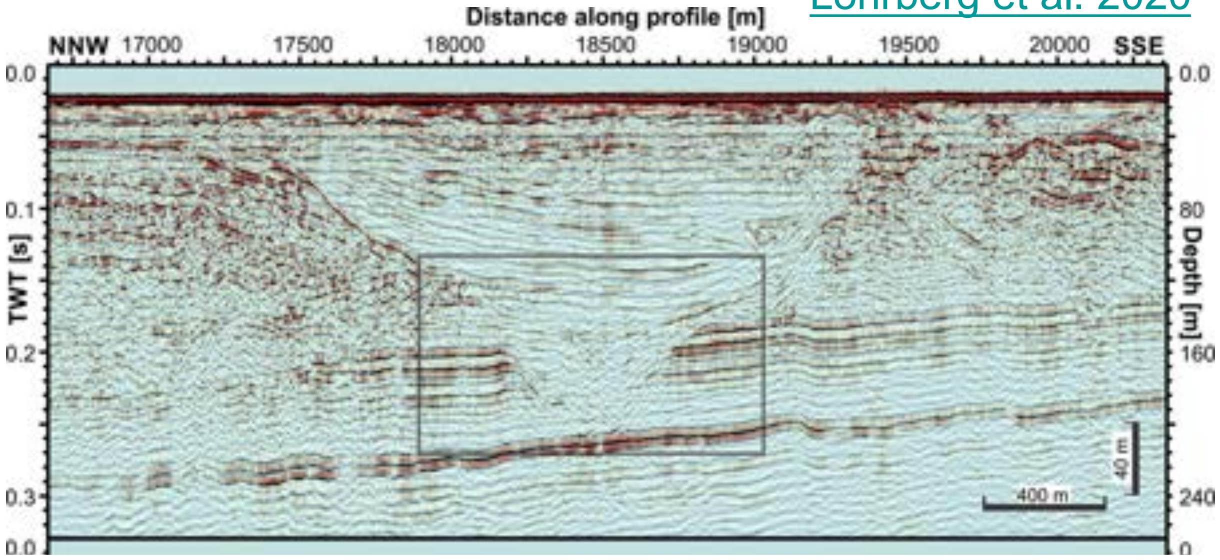
www.geocaching.com



Timeslice

Kolla et al. 2007

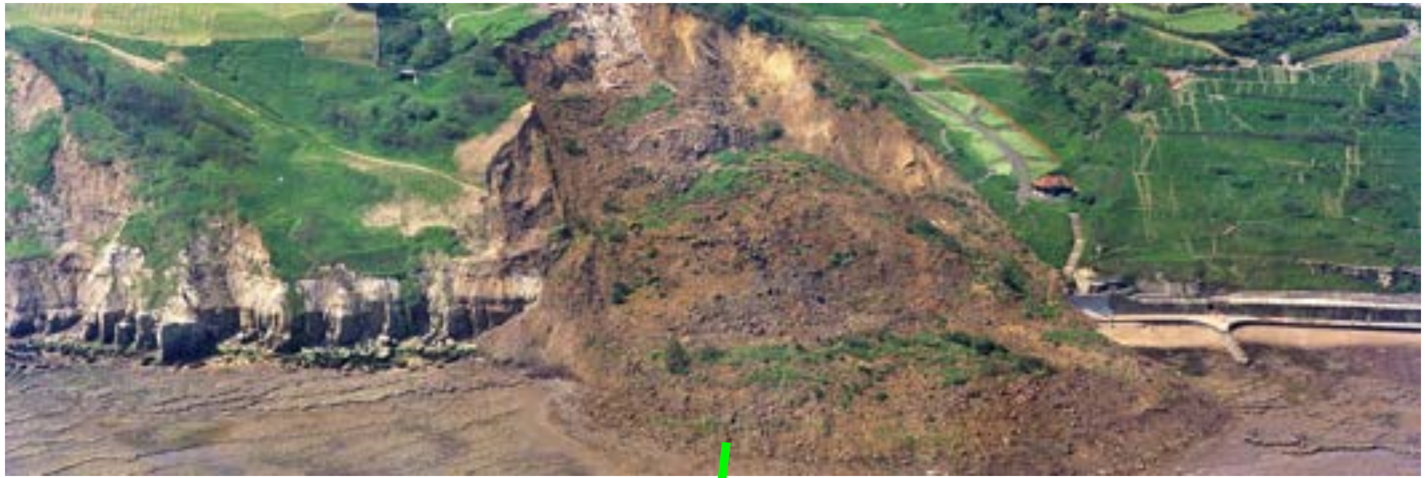
Lohrberg et al. 2020



Geological features in seismic data

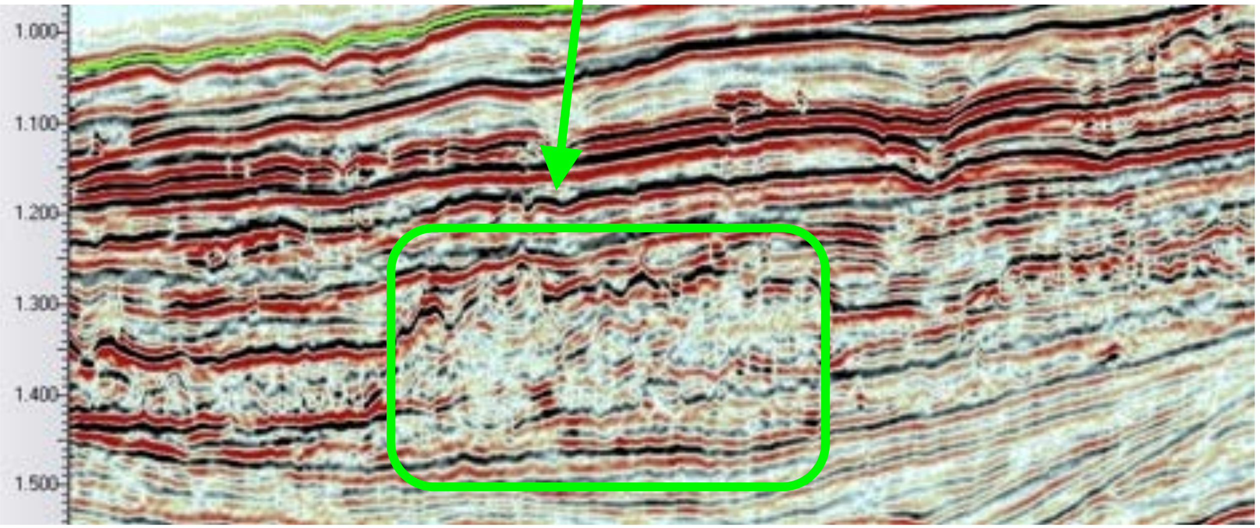
Mass transport deposits- sediment packages that move and deform under the influence of gravity- Includes landslides, mudslides, submarine slides.

In the field



Mass transport deposit i.e. landslide has muddled up all the layers and then when they are deposited on, it retains the mesh of different material type

In seismic data
Offshore West Africa

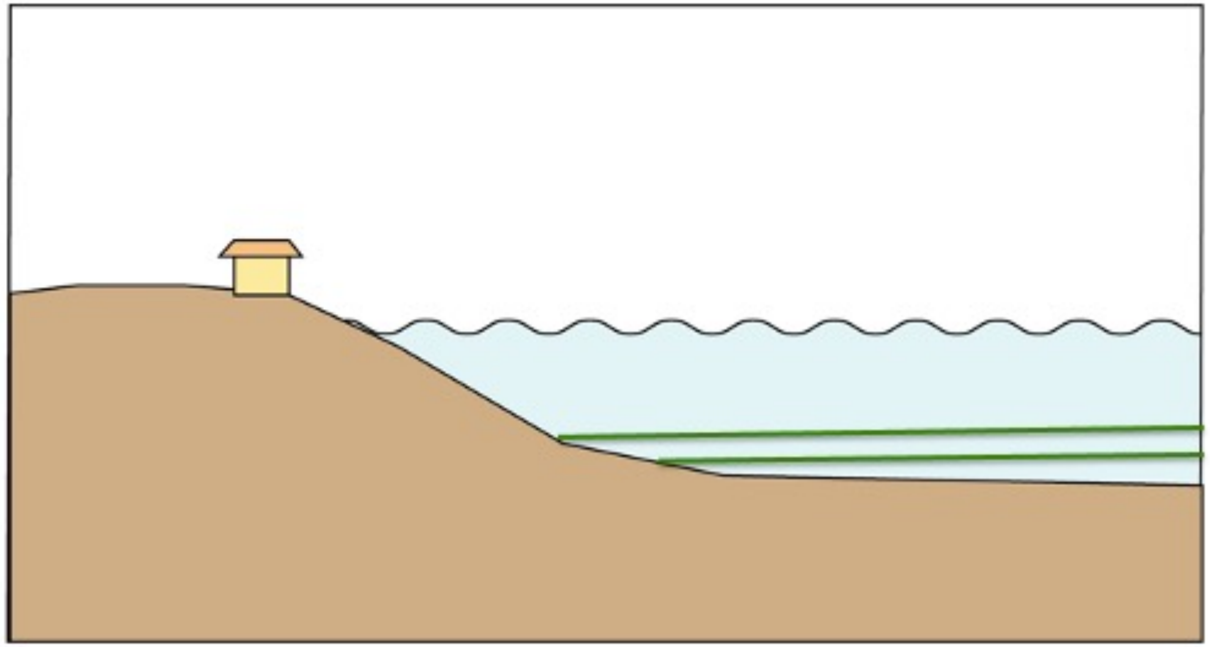


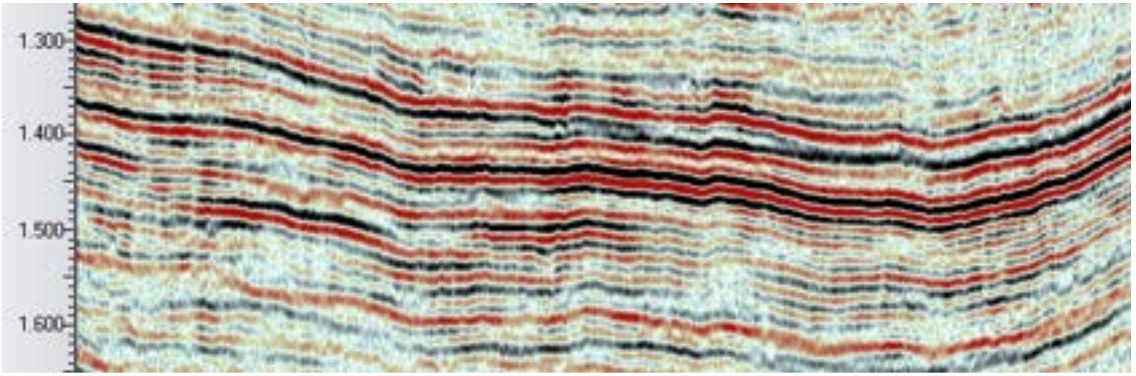
Caused by: slope instability (e.g. high rainfall, high pore fluid pressure along slide surface)

Geological features in seismic data

Vertical aggradation

- Sedimentation in areas of high relative sea-level (ie there is lots of space for sediments to fill)





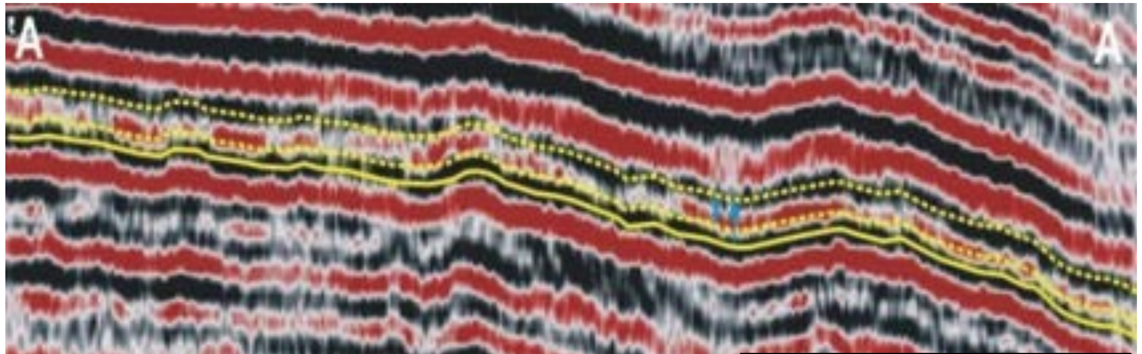


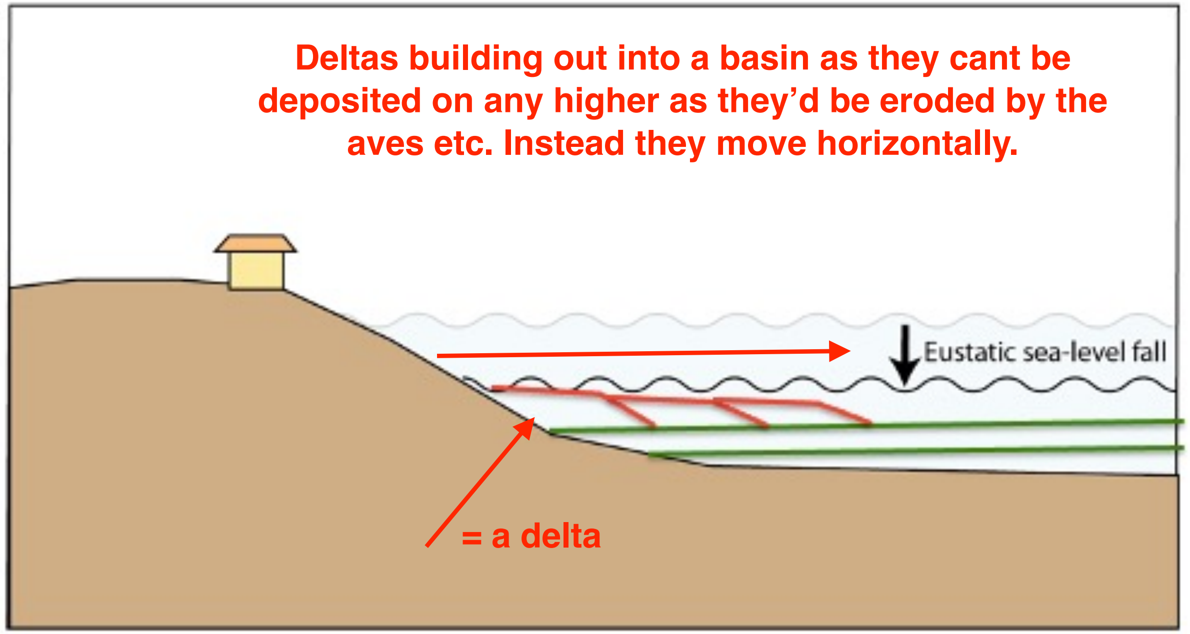
Image courtesy of Statoil

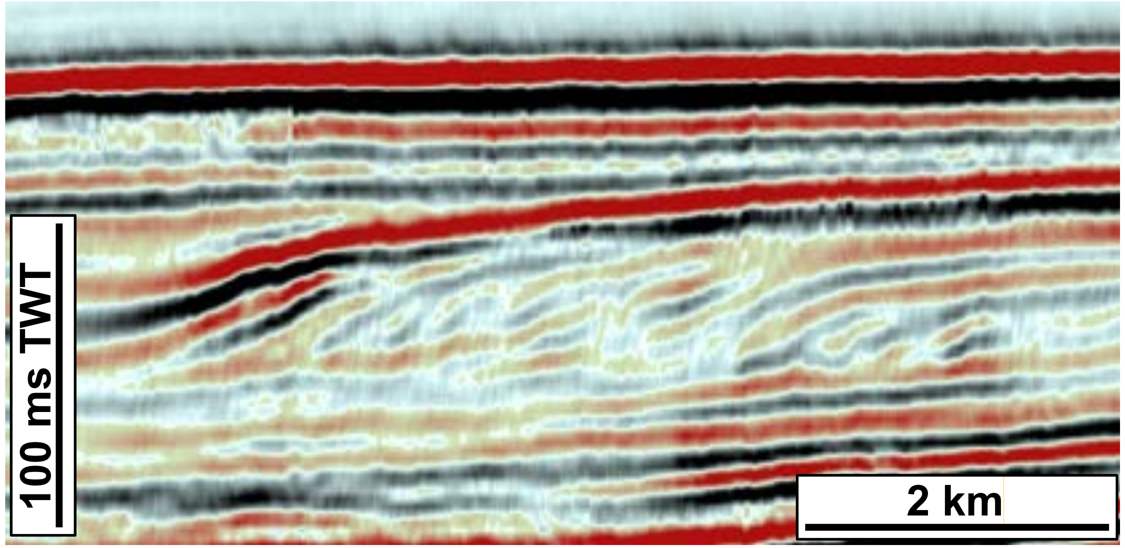
- **Parallel, continuous, variable amplitude** reflections
- **Above** – an interbedded mudstone-sandstone succession, Pliocene, offshore West Africa
- **Below** – an interbedded carbonate-mudstone succession, Cretaceous, offshore Oman
- How unique are the seismic facies interpretations?

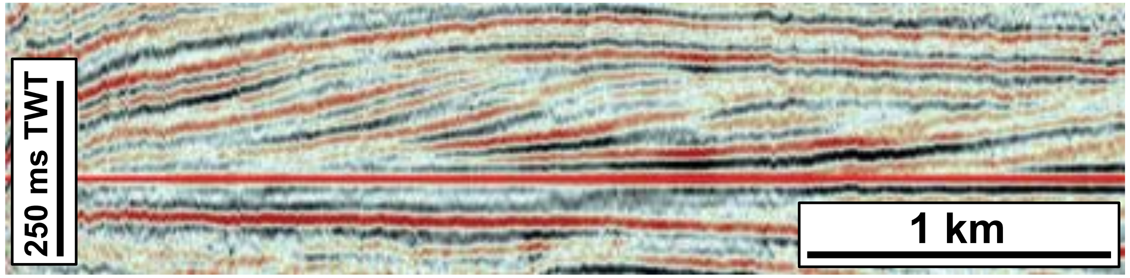
Geological features in seismic data

Horizontal progradation

- Sedimentation in areas of low relative sea-level (ie limited space so sediments build outwards rather than upwards)



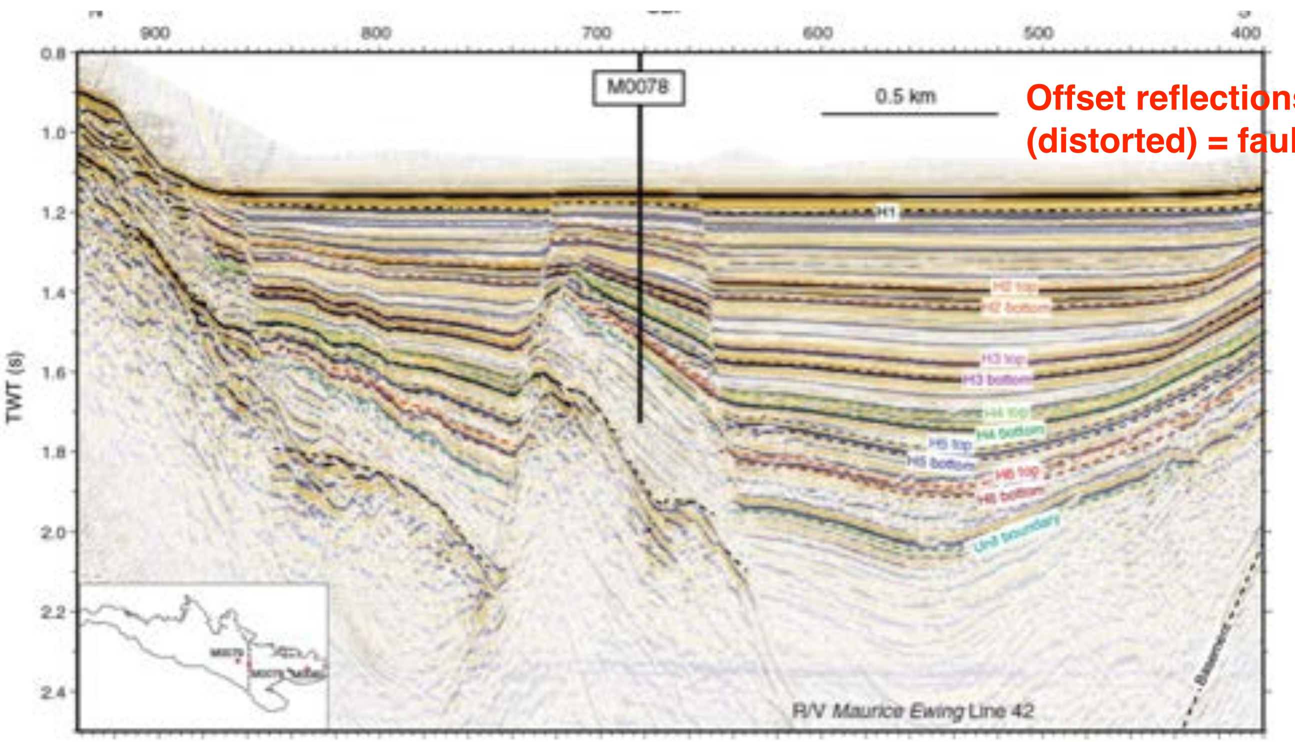




- Deltaic clinoforms
- **Above** - Pliocene-Pleistocene succession, offshore Namibia
- **Below** – Triassic, Barents Sea, offshore northern Norway

Geological features in seismic data

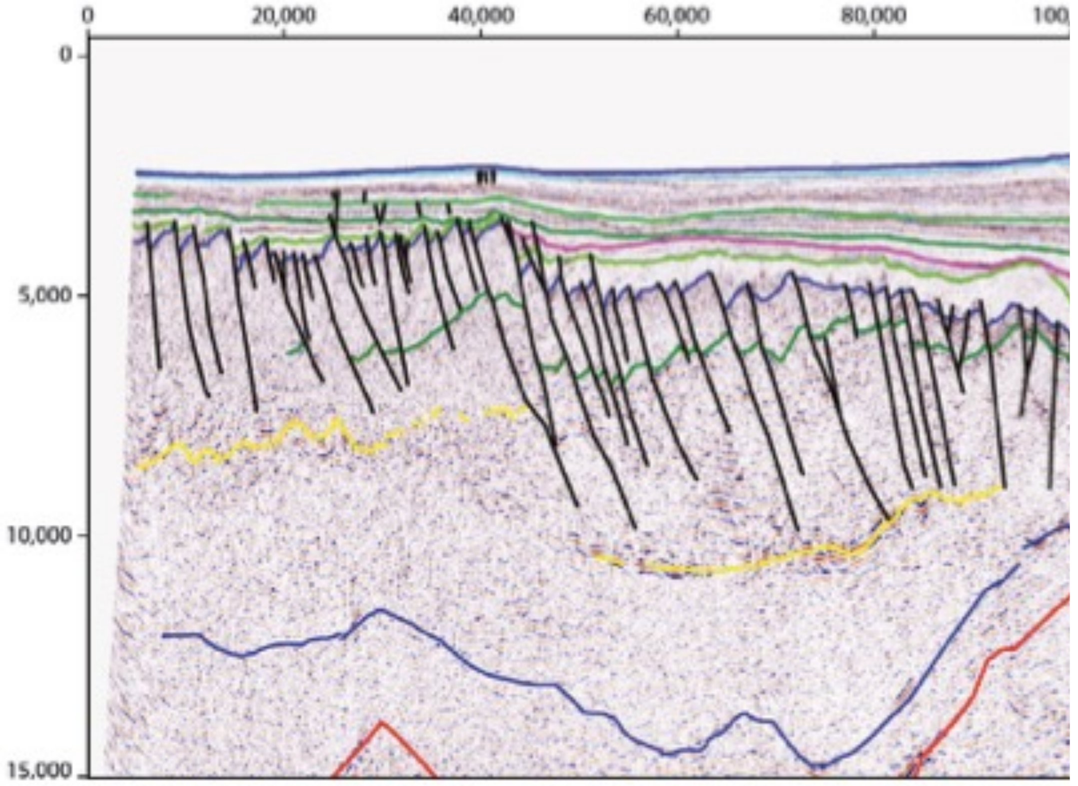
Active faults from the Gulf of Corinth, Central Greece



Offset reflections (distorted) = fault

Faults extend to the surface and offset young sediments

Inactive faults from NW Shelf Australia



Faults are buried and haven't deformed recent sediments

McNeill et al. 2019

Earthquake hazard

Ion

Not a significant Earthquake hazard

Geological features in seismic data

In Ex 5 you will try to identify areas of salt using Machine learning!

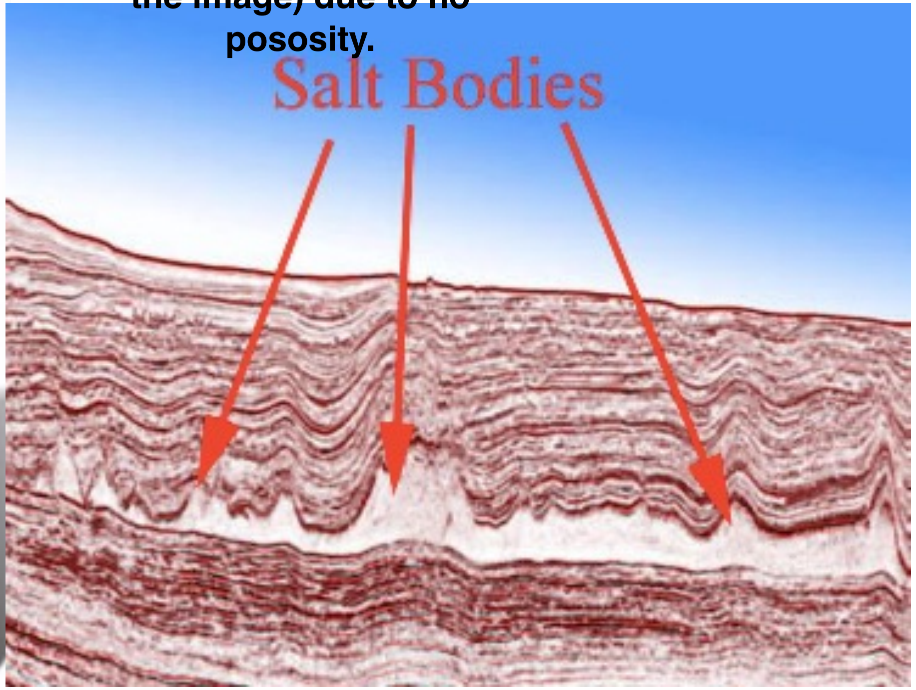
Modern salt flats in Bolivia

Salt is crystalline (has no porosity) and has low density. No matter how deep salt is buried, its density stays low (there is no porosity to squeeze out)

Geological model of salt diapir

When dense sediments deposit on top of salt, because it is less dense it wants to rise

Salt has 0 amplitude (white in the image) due to no pososity.



Salt diapirs in seismic data

Because salt is crystalline there is no layering in it and it looks 'transparent'

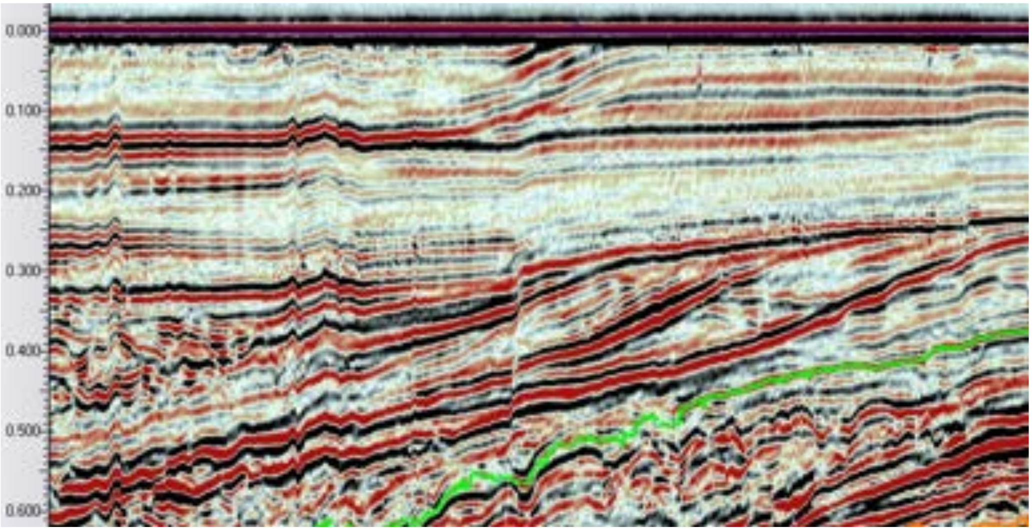
https://blogs.agu.org/georneys/2011/07/20/geology-word-of-the-week-h-is-for-halokinesis/

Quiz question

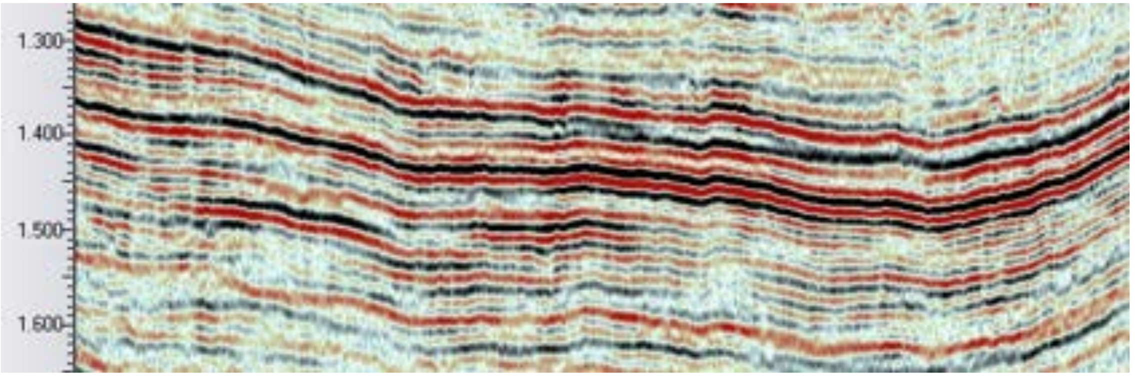
Which of these images shows evidence of sea level fall?

A

Curved features indicate low sea level



B



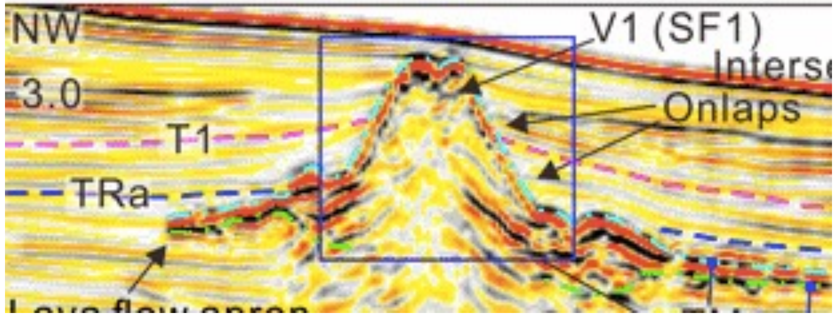
C - Both

D - Neither

Quiz question

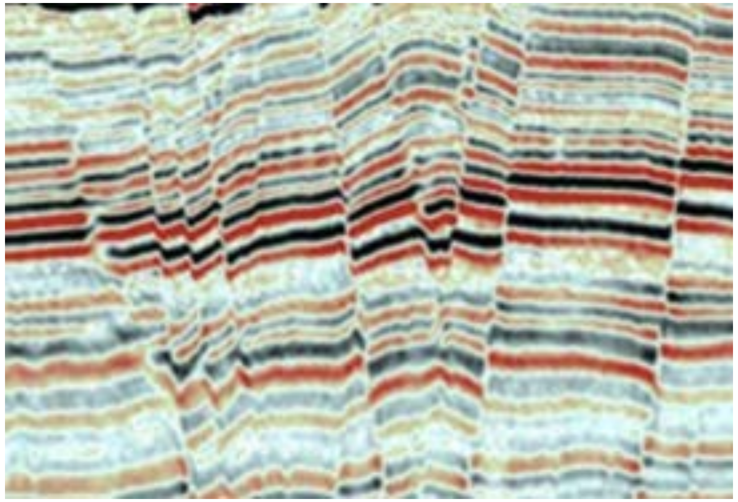
Which of these images shows a buried volcano?

A



seismic data can be intuitive. A buried volcano looks like a volcano…

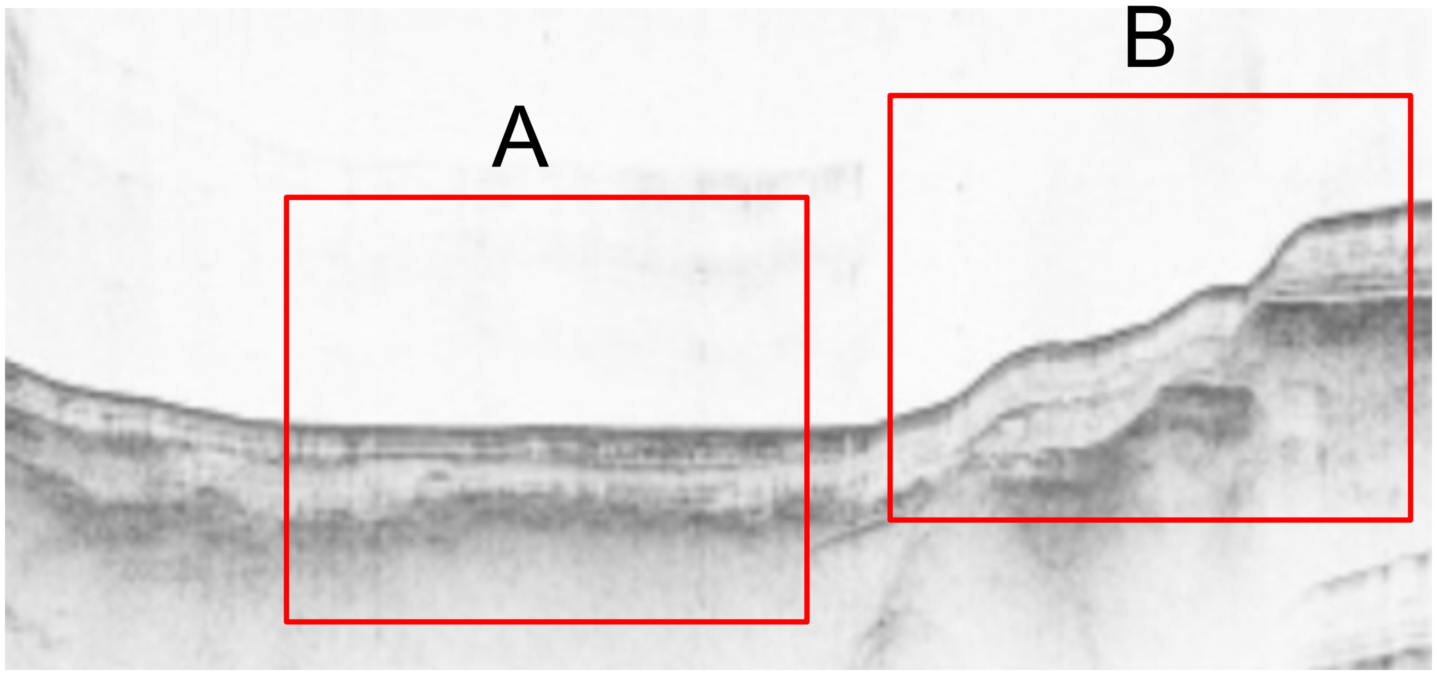
B



Quiz question

You work for a company who lay communications cables offshore. In which area would you choose to lay your cables?

B has faults which means its susceptible to earthquakes. An earthquake could damage cables.



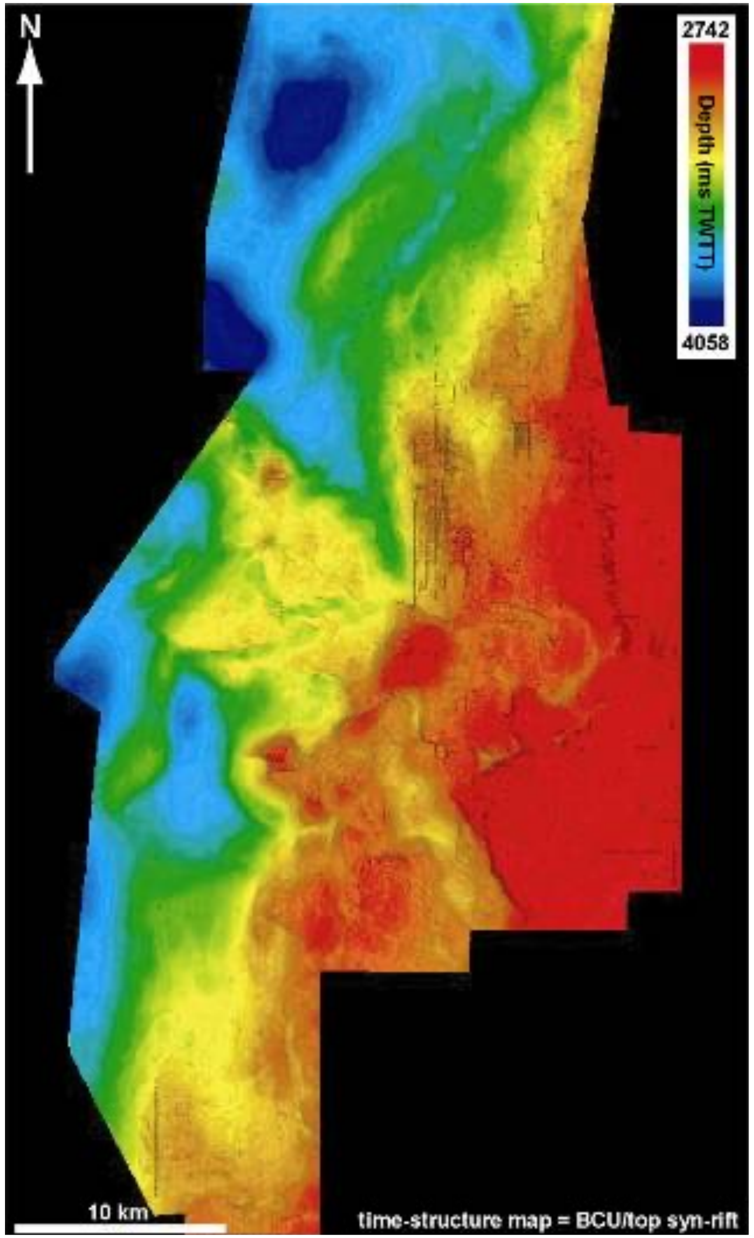
Seismic interpretation deliverables

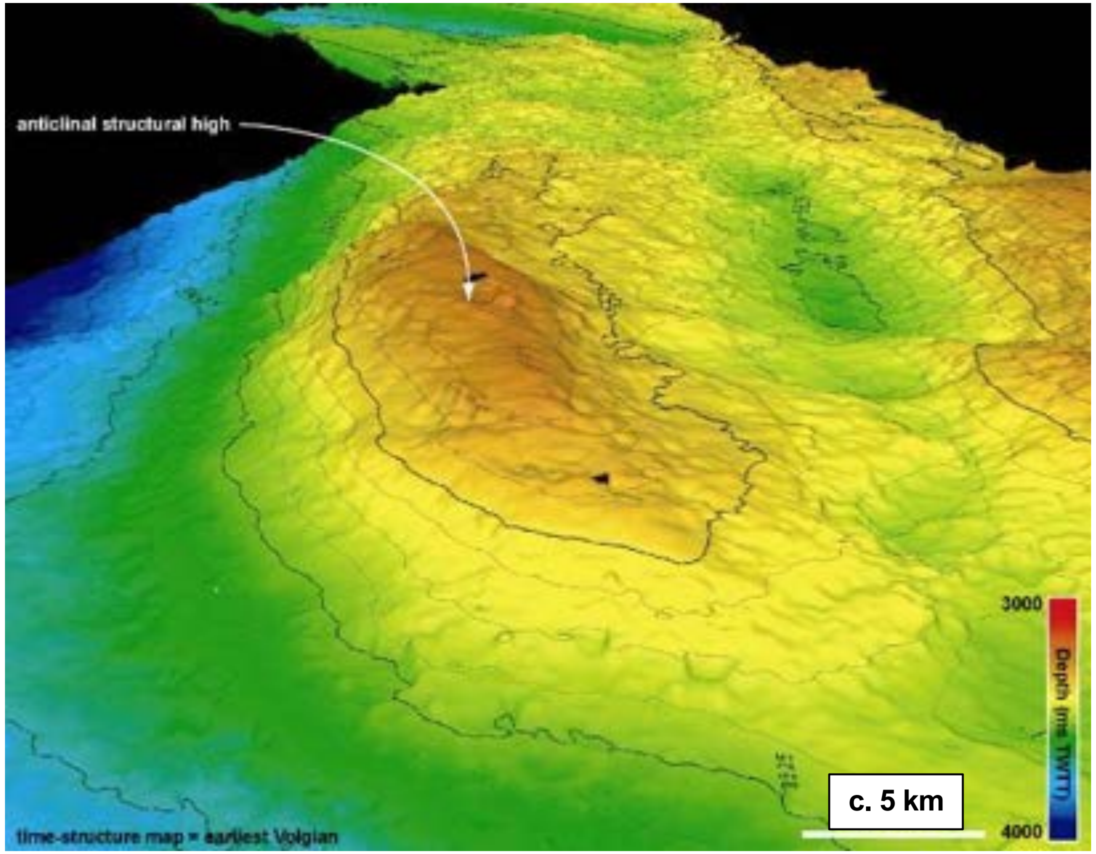
- Time/depth-structure maps
- Fault interpretations
- Maps of ‘seismic facies’

Attempts are being made to automate all these processes

Structure Maps

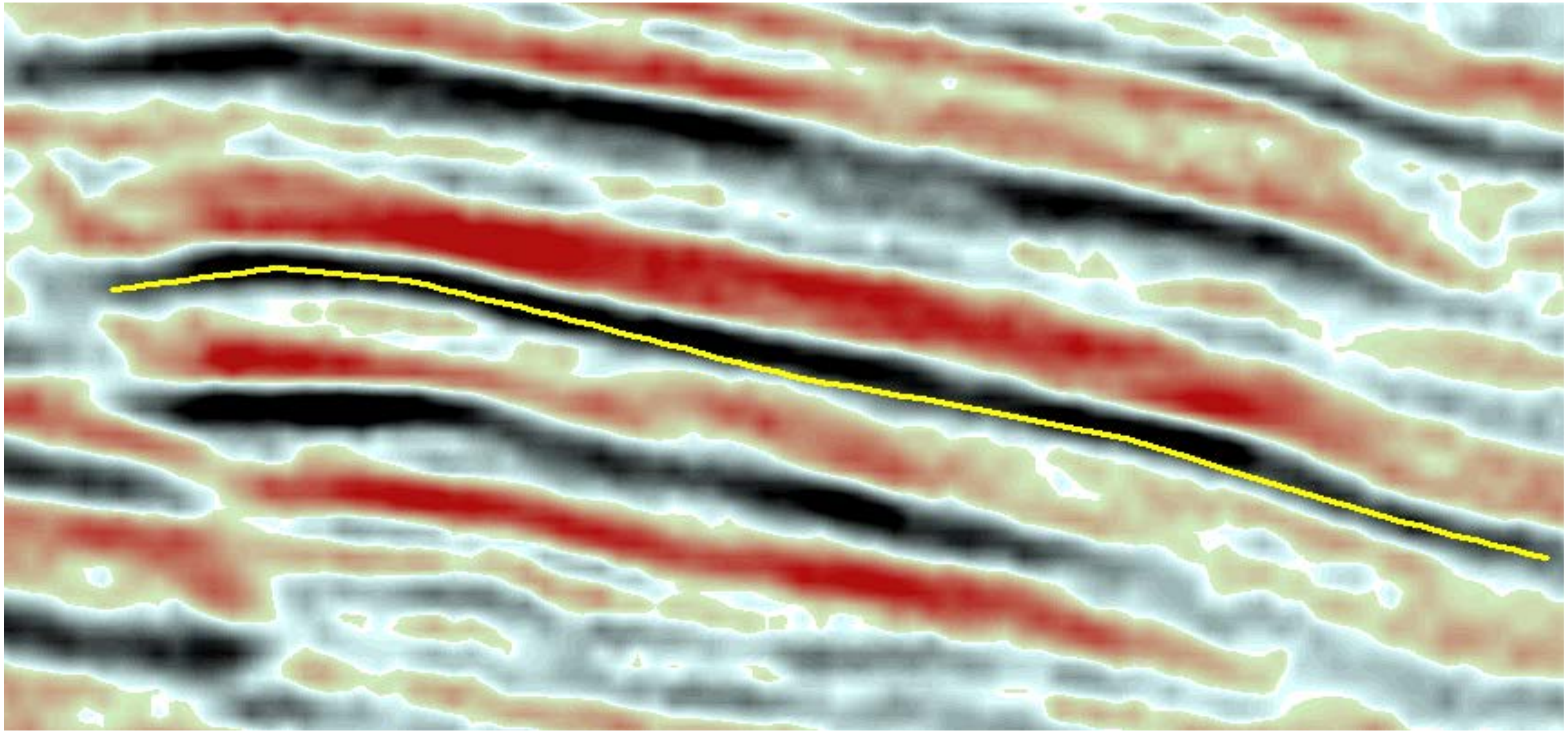
Analagous to DEM maps (but underground)





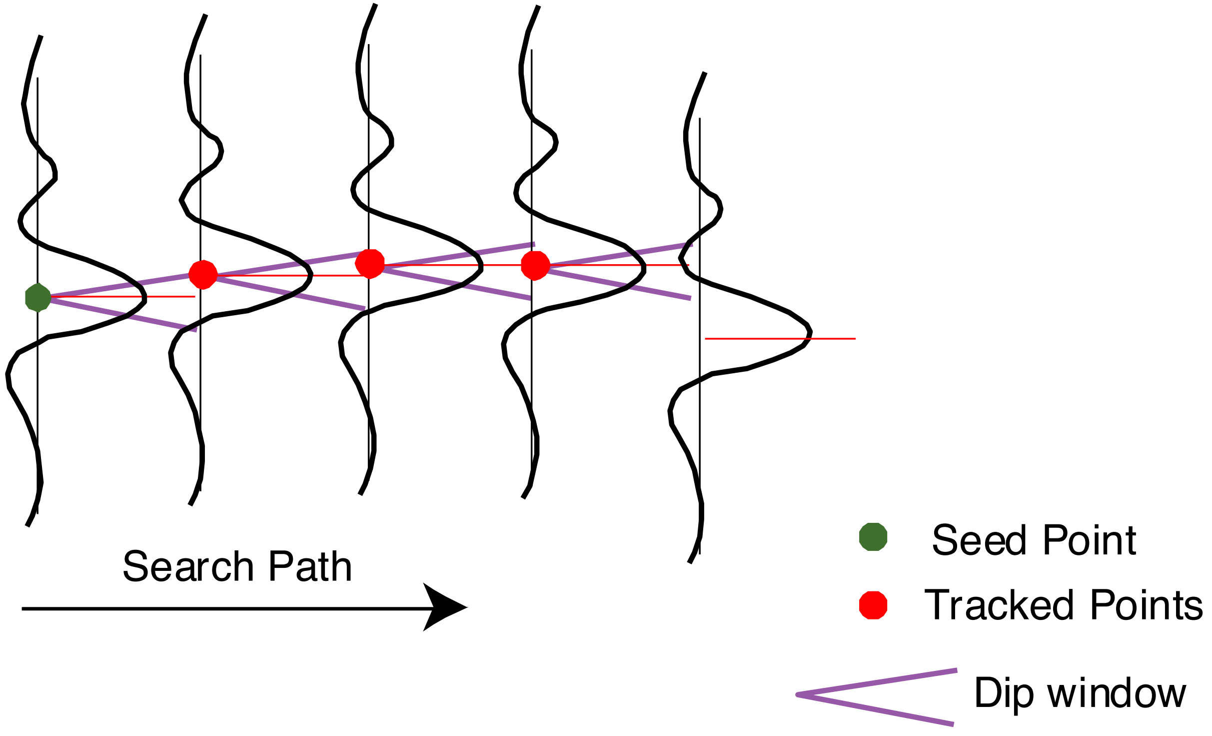
- The **key** seismic deliverable
- Can be either in time (time-structure map generated from time-migrated data) or in depth (depth map generated from depth-converted seismic data)
- A bit like a satellite-derived Digital Elevation Model, but underground!

Picking Techniques



Manual or point-picking is a common method available on any interpretation platform. This is simply a point-and-click method and gives the interpreter full control over the location of the interpreted seismic horizons and is very useful in noisy datasets. However, in this example to the left the interpretation does not sit directly on the reflection event of interest; this may result in some important geometric details being lost…

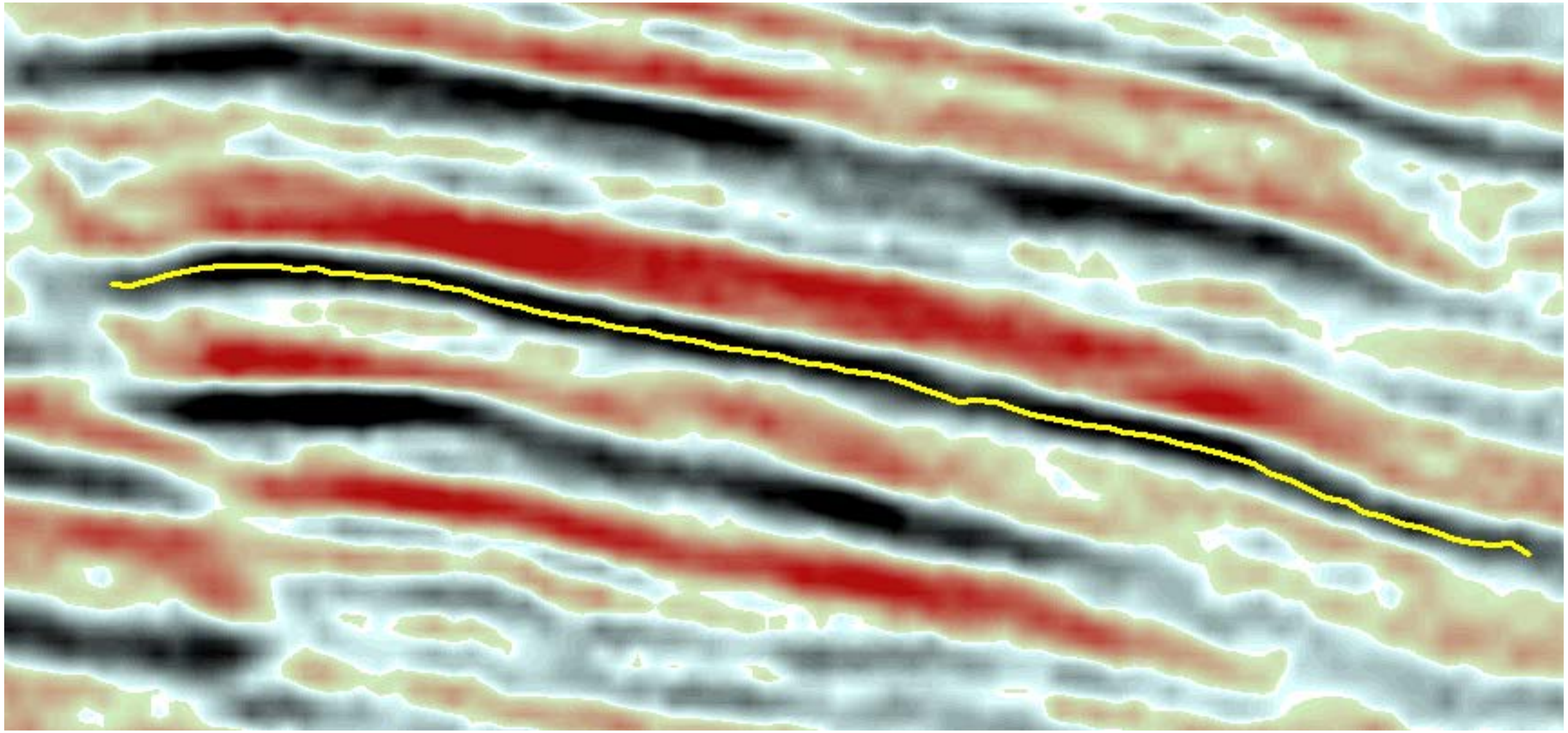
Picking techniques



(from Dorn 1998)

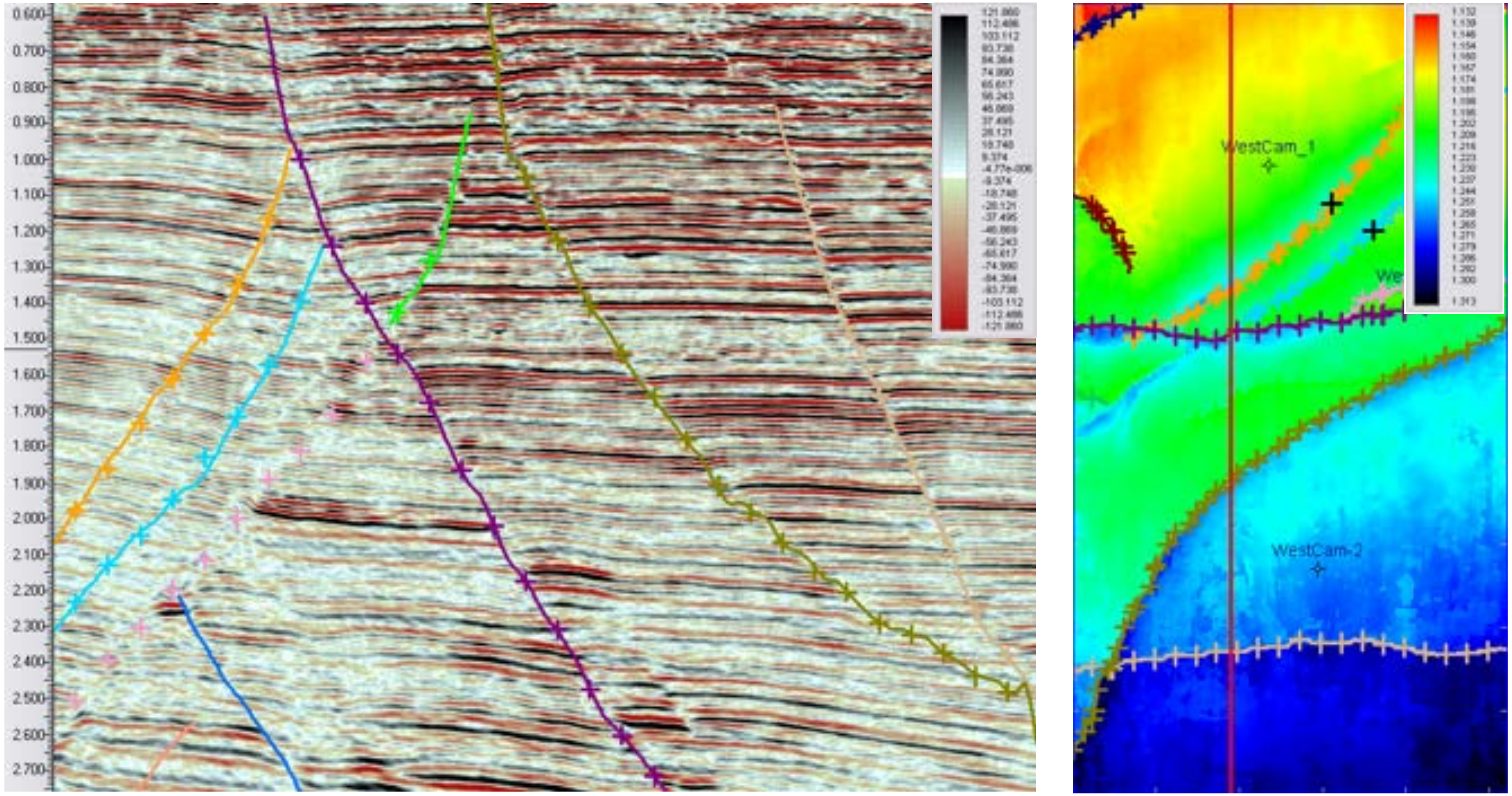
In this example it would be preferable to utilise an automatic waveform tracking approach. In this method the software searches in a “window” centred around the previously picked point and chooses (if found) the seismic event which corresponds most closely to the first point.

Picking Techniques



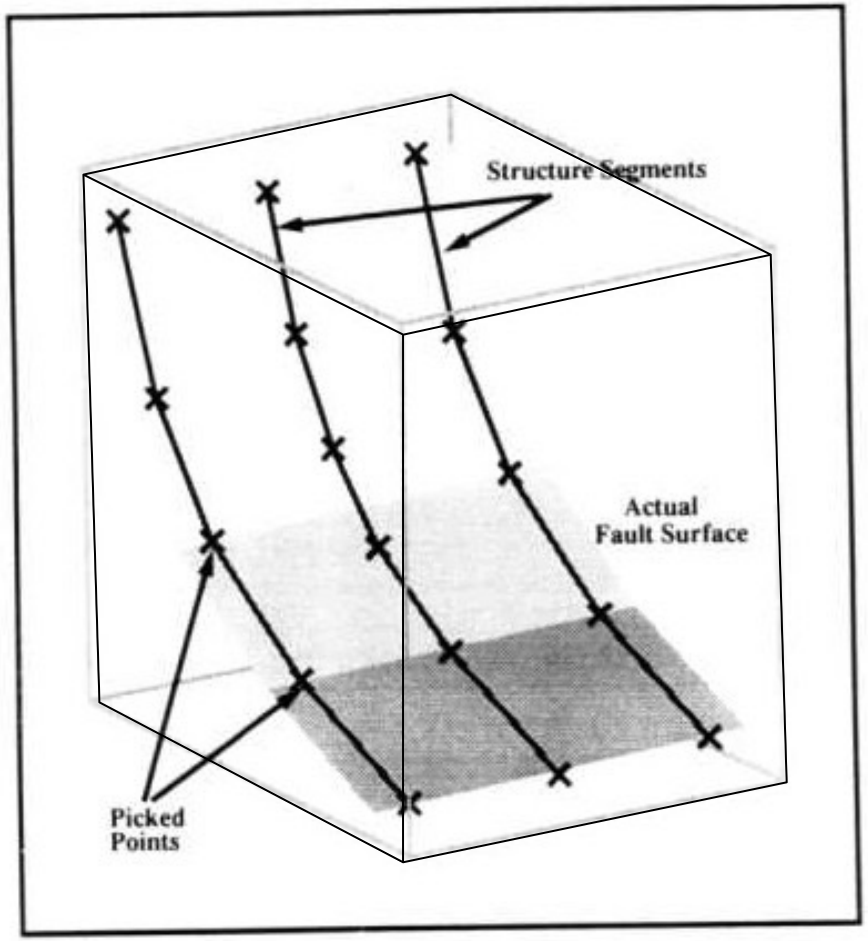
In this example it would be preferable to utilise an automatic waveform tracking approach. In this method the software searches in a “window” centred around the previously picked point and chooses (if found) the seismic event which corresponds most closely to the first point. Note how the mapped horizon in this image more closely follows the reflection event than the previous image.

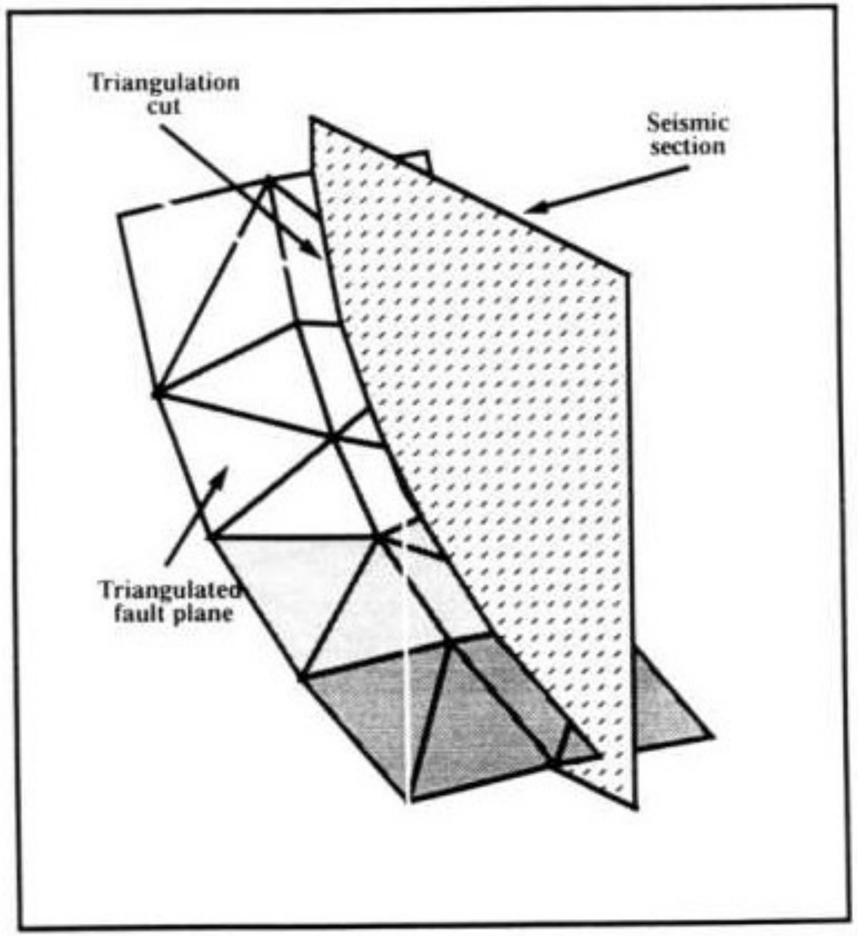
Fault Interpretation



Interpretation of faults in a Gulf of Mexico 3D seismic dataset. This is an example whereby the main focus of the interpretation is to define the regional-scale structure of the basin.

Fault Interpretation



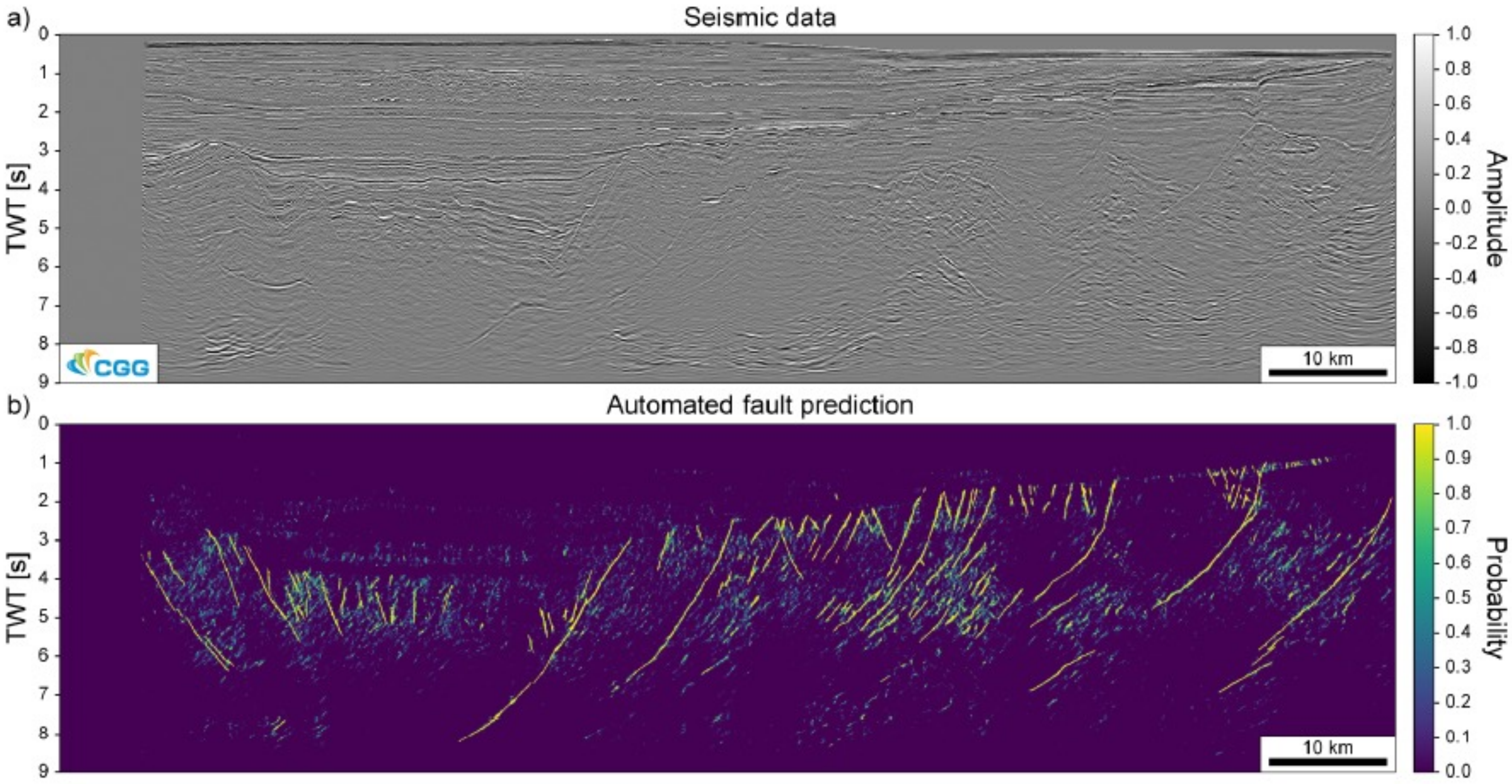


Creation of a fault surface by triangulation and gridding of a series of fault sticks. These sticks are typically picked on seismic sections perpendicular to the fault but may also be picked on timeslices.

Machine learning- the future of interpretation?

In this example 10 seismic profiles through a 3D cube have been interpreted as "training data"

A python scripts treats the cube in small blocks and searches for things that look like the training data. These features are coloured in terms of the probability that they are faults



Example from Dr. Thilo Wrona (GFZ Potsdam), using data from CGG

Key points

- Understand that conventional seismic interpretation is very subjective and seismic facies are non-unique
- Know how to recognise some key geological features in seismic reflection data
- Appreciate the key conventional deliverables in seismic data interpretation and consider how data science may be able to contribute to (or revolutionise?) this field