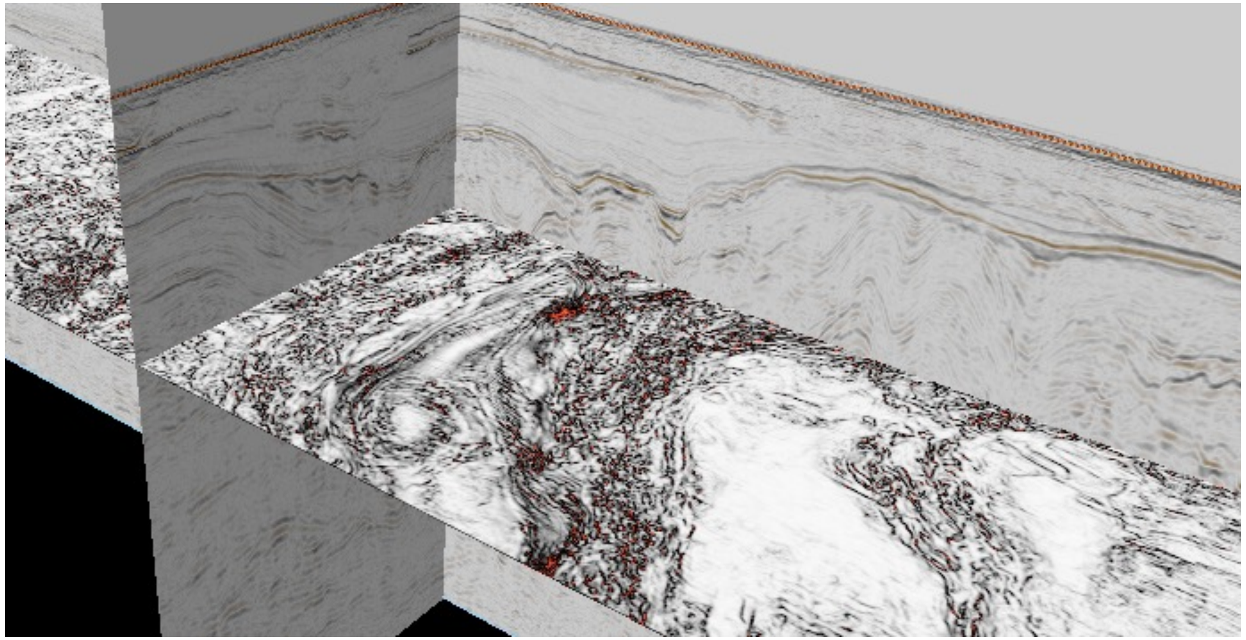
Seismic imaging
Lecture 4



Dr Rebecca (Becky) Bell

1st floor, office 1.38

rebecca.bell@imperial.ac.uk

Imperial College London

Module schedule – week 2

	Monday	Tuesday	Wednesday	Thursday-GEMS	Thursday-EDSML	Friday - GEMS	Friday-EDSML
09:00 - 12:00	Introduction to seismic imaging	Visualising and interpreting seismic data	Machine learning and seismic imaging Practical: Machine learning group practical	Introduction to wireline log data Practical: QC of wireline log data	Group project	Stratigraphy and structure Sedimentary basins	Group project
	Lunch	*Lunch*	*Lunch*	*Lunch*	*Lunch*	*Lunch*	Submit 12 noon
14:00 - 17:00	Practical: Introduction to seismic imaging	Practical: Visualising and interpreting seismic data		Identifying rock types in wireline logs Practical: wireline log interpretation	Group project	Practical: Sedimentary basins	Independent study

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 4:

Understand how to view seismic data and the SEGY file format

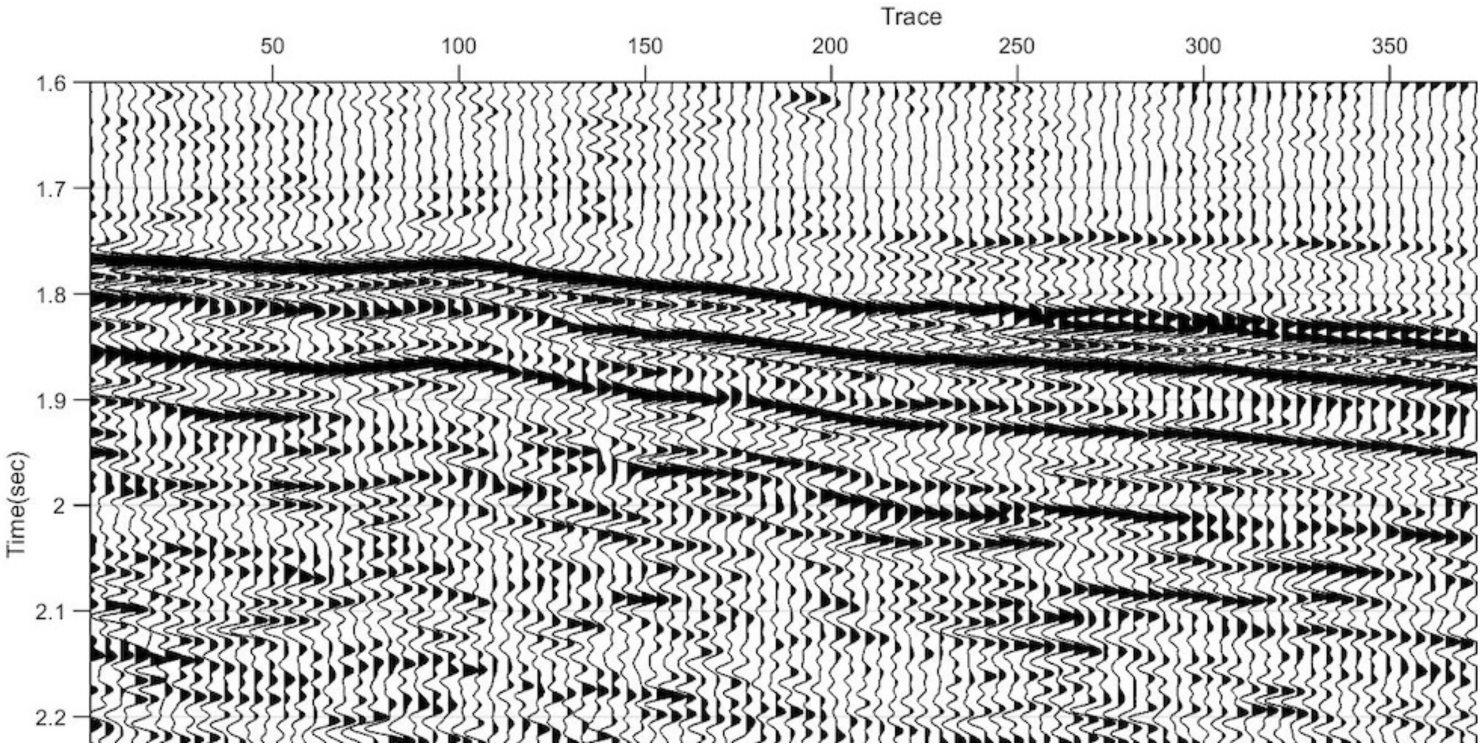
1) How seismic data is recorded and visualised
2) The SEGY file format
3) Open source SEGY data

This lecture directly links to Exercise 3:
Visualising 3D seismic data with Python

What is post-stack seismic data?

- Once we have stacked CMP gathers (lecture 3) the stacked traces are positioned at their CMP location to produce the stacked seismic section (this is called 'post-stack' data. The CMP gathers are 'pre-stack' data)

- For 2D data the traces will be spaced at the CMP interval



Stacked seismic sections provide an approximate image of the subsurface

https://www.mathworks.com/matlabcentral/fileexchange/51122-cqi_plotmatrix-data-varargin

Sampling (Digitization)

- The seismic traces are not recorded continuously. The continuous (analogue) signal is recorded discretely (sampled) at a constant time interval

- The time interval (Δt) must be chosen to allow the analogue signal to be reconstructed from the sampled values

- The maximum frequency (f_{max}) to be preserved must satisfy the Nyquist criterion:

$$f_{Max} \leq \frac{1}{2\Delta t}$$

delta-t (s)

This is the minimum sampling (maximum time interval) to preserve information in a signal

Temporal aliasing (time domain)

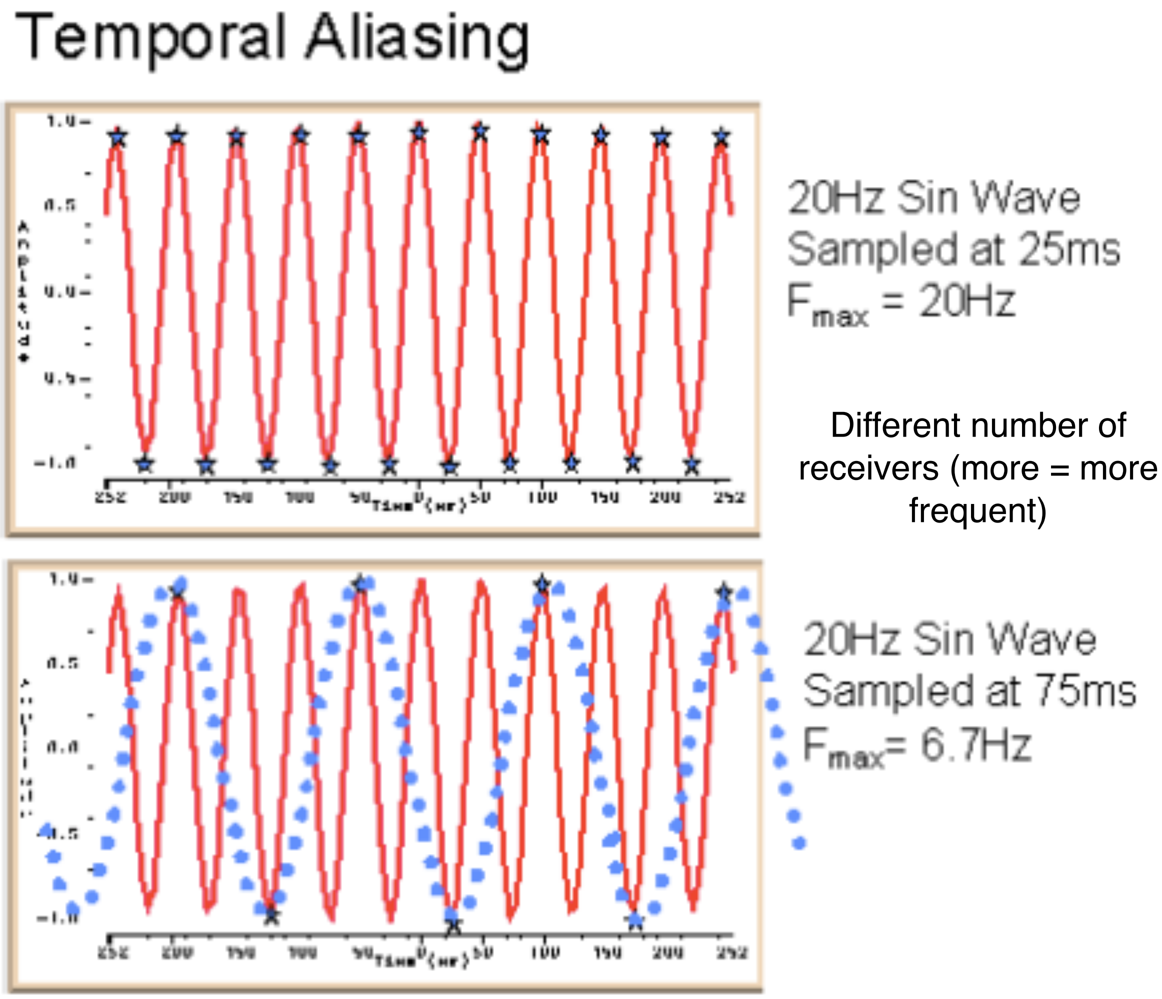
The top slide shows that a good representation of the 20Hz signal can be made by samples taken every 25ms (marked by the blue stars).

F_{max} = 1/2d =1/ 2*0.025 = 20 Hz

In the bottom slide samples are taken every 75ms. An insufficient number of samples are taken and the higher frequency information is "lost" or *aliased*. The original 20Hz red curve appears as a 6.7Hz blue dotted curve.

F_{max} = 1/2d =1/ 2*0.075 = 6.7 Hz

Before the data are sampled the higher frequencies which would be aliased by the chosen sampling interval must be removed by an analogue filter in the recording system.



Different number of receivers (more = more frequent)

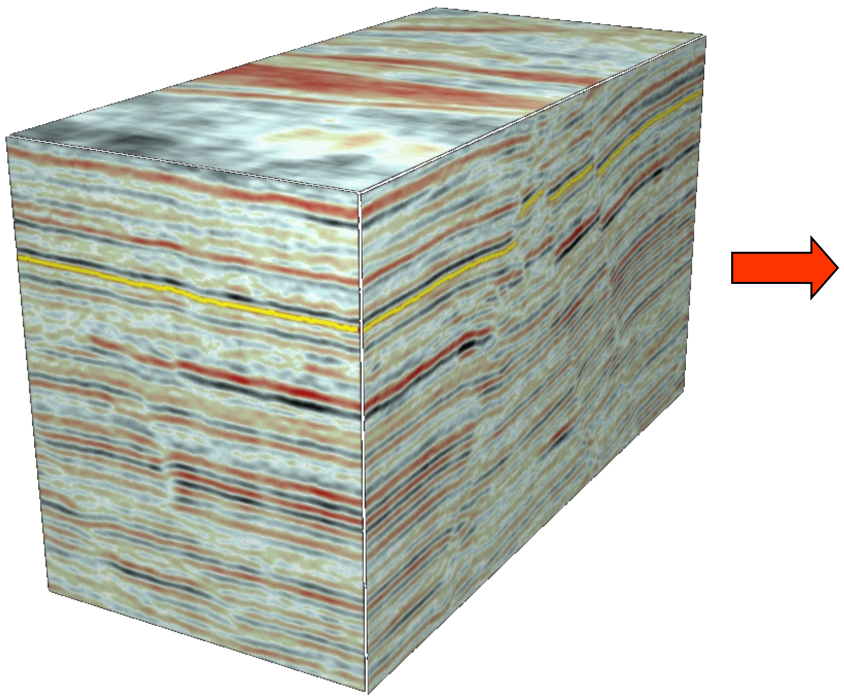
http://www.xsgeo.com/course/acq.htm

Quiz question

- You would like to collect high-frequency seismic data up to 100Hz to identify glacial channels ahead of wind farm development. What is your maximum sample rate?

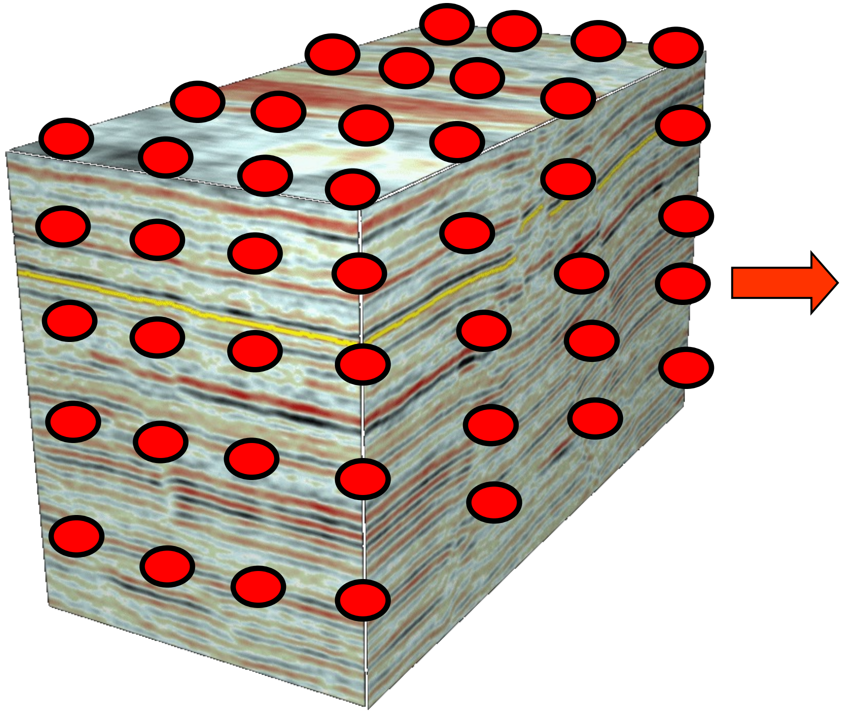
= 1/2(100) (s)

3D seismic: How do we view it?



The 3D seismic volume can be sliced in any direction, viewed in 3D or made semi-transparent. This gives interpretation of 3D seismic data on workstations some significant advances over 2D seismic data or paper-based interpretation.

3D seismic: How do we view it?



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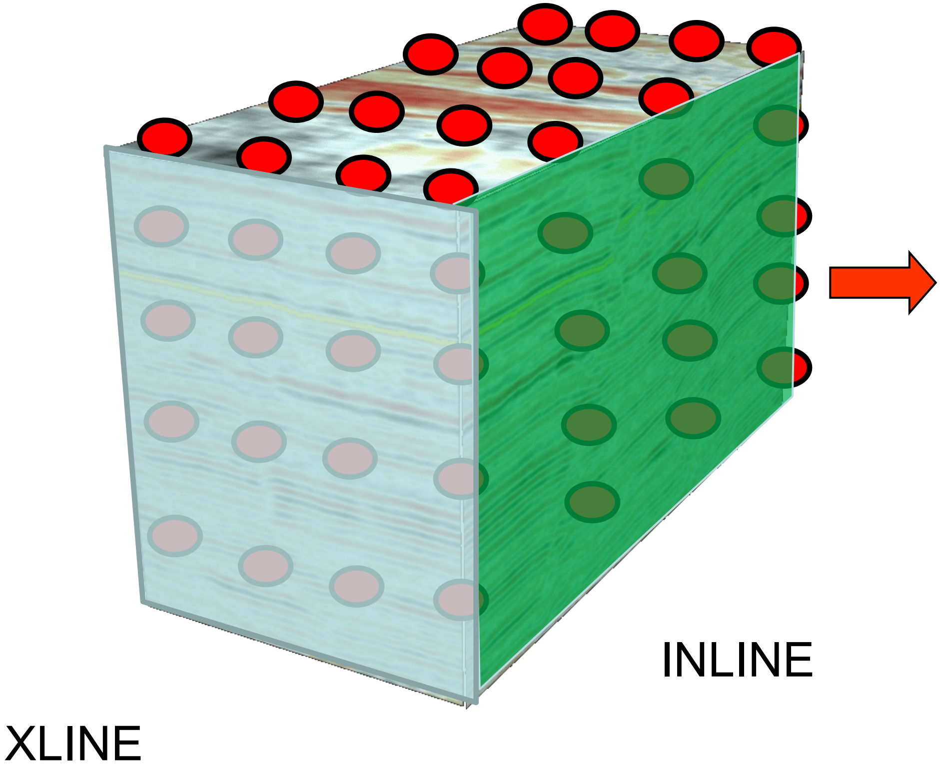

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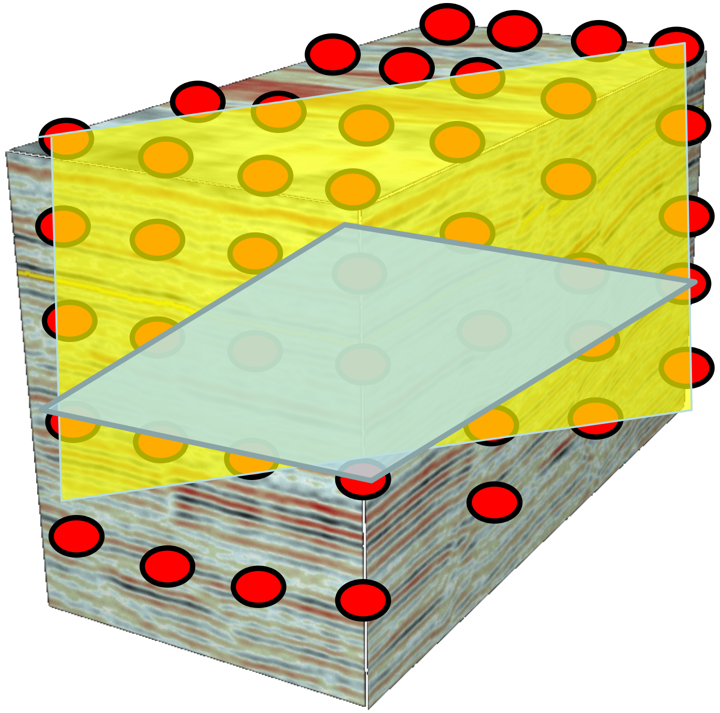

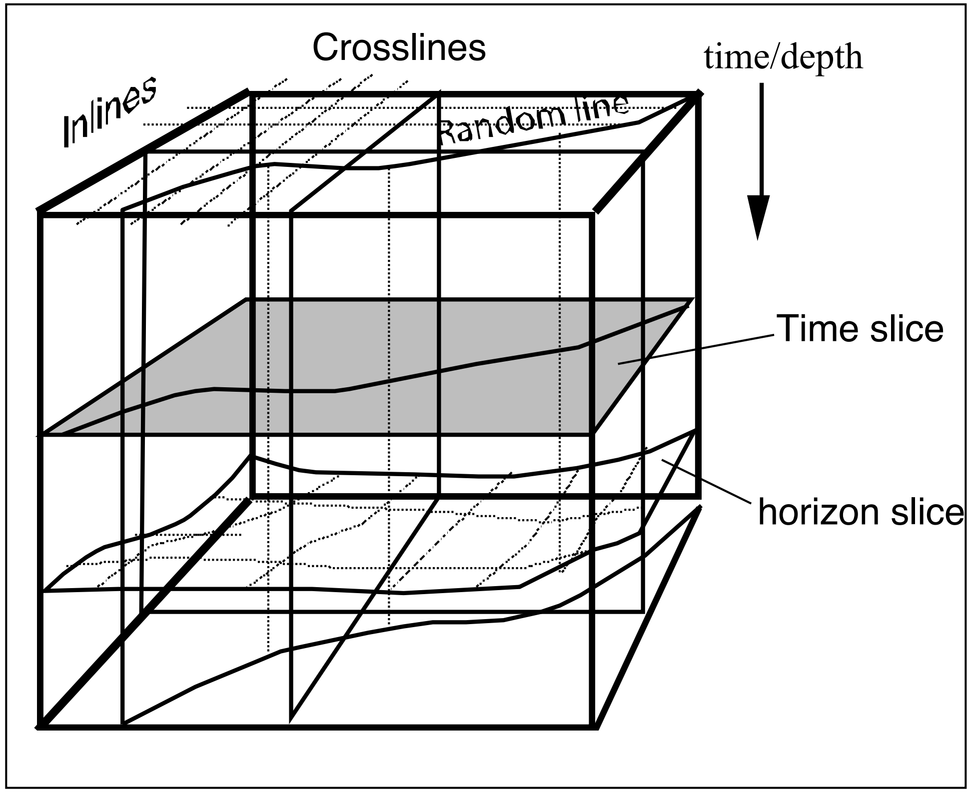

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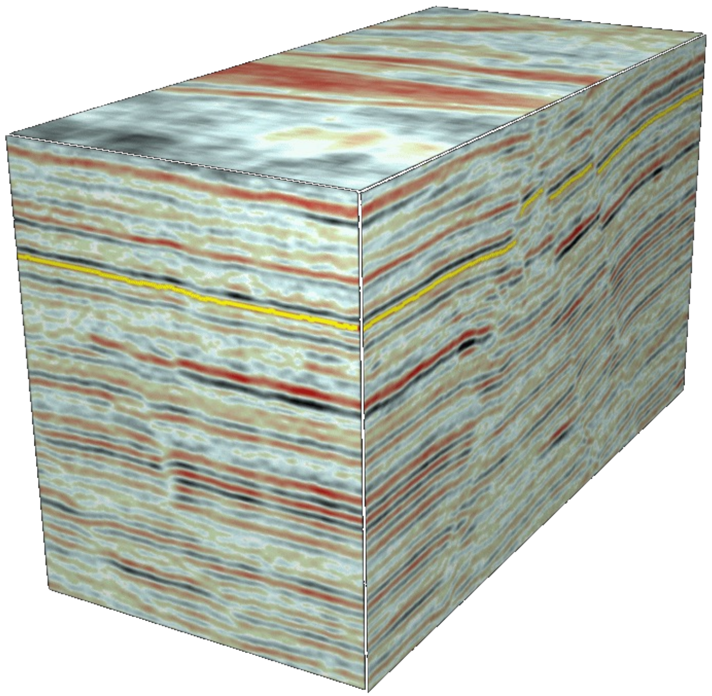
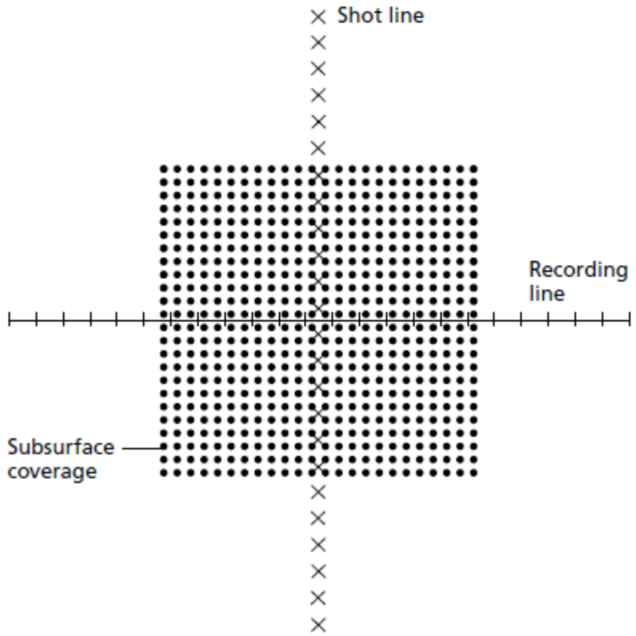
3D seismic: How big is it? – an example



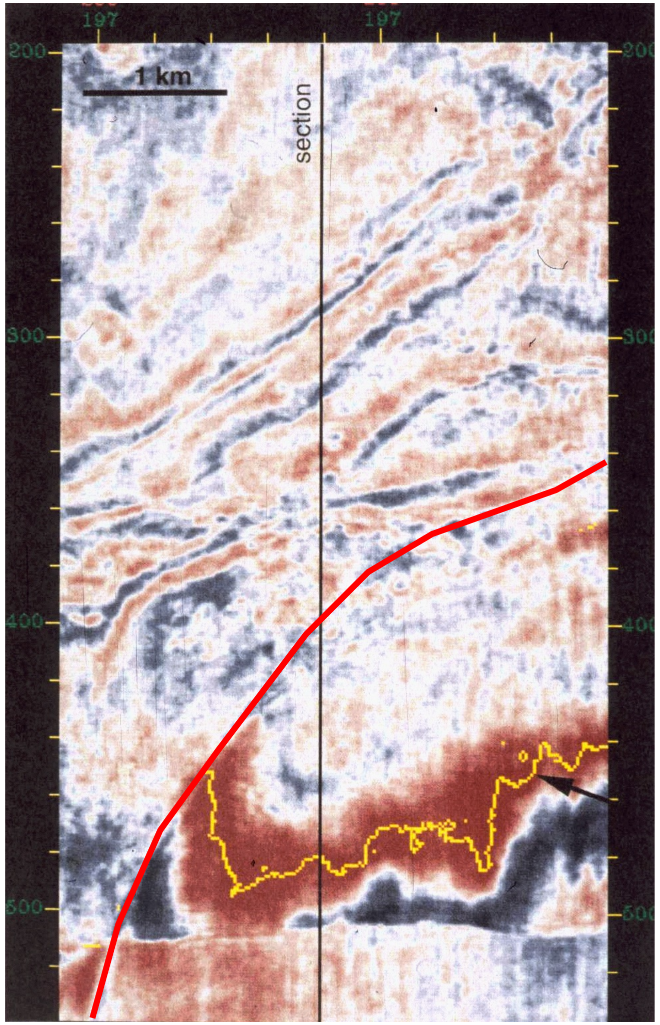
A 10 km x 10 km (100 km^2) 3D survey at 12.5 CDP interval contains 800 x 800 traces which equals 640,000 traces per 100 km2 dataset!

Time samples are recorded at every 4 ms, so a single trace covering 4 secs in time = 1000 time traces resulting in 6.4 x 10^8 samples for our 100 km^2 3D seismic survey.

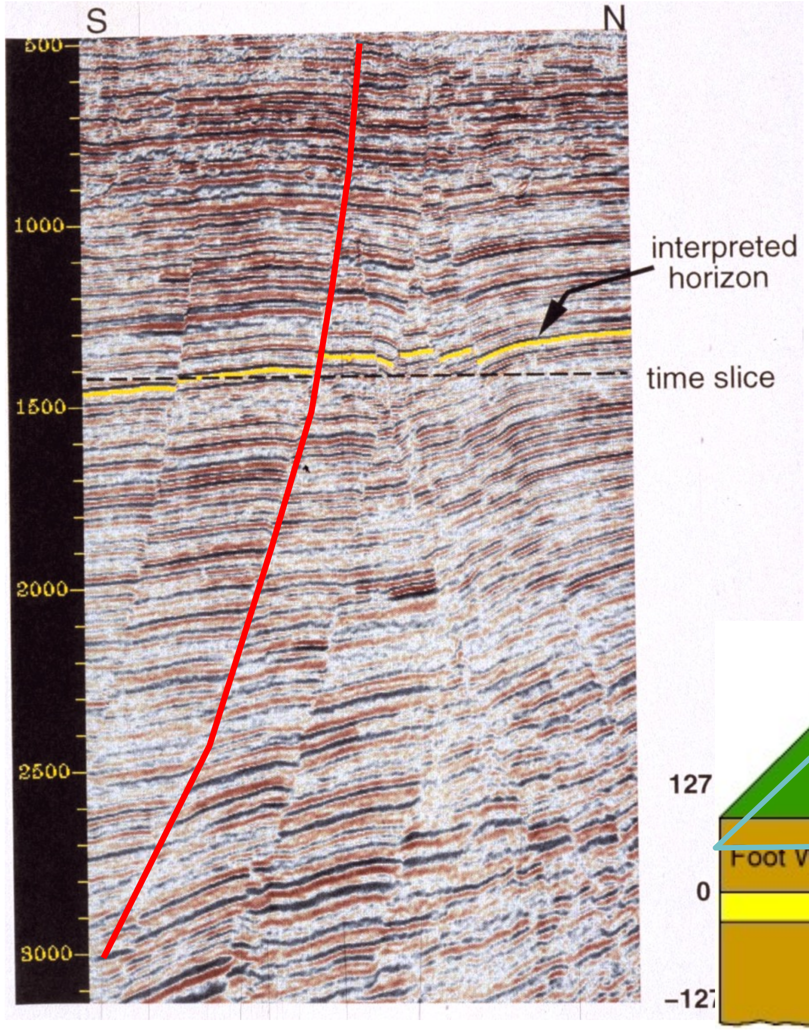


3D seismic volumes can range from a few 100 Mb to 10's or even 100's Gb

3D seismic: How do we view it?

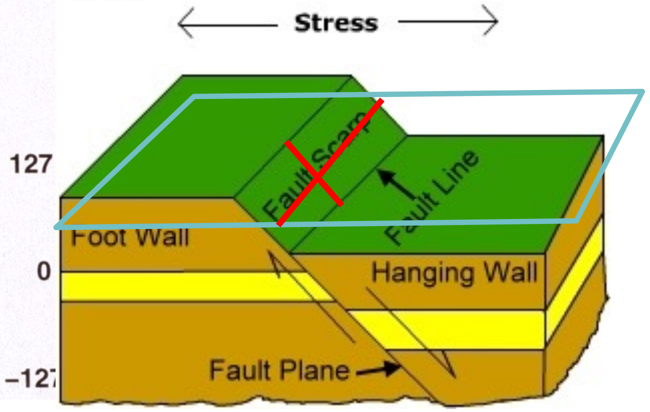


Time slice at 1420 ms



Vertical seismic section

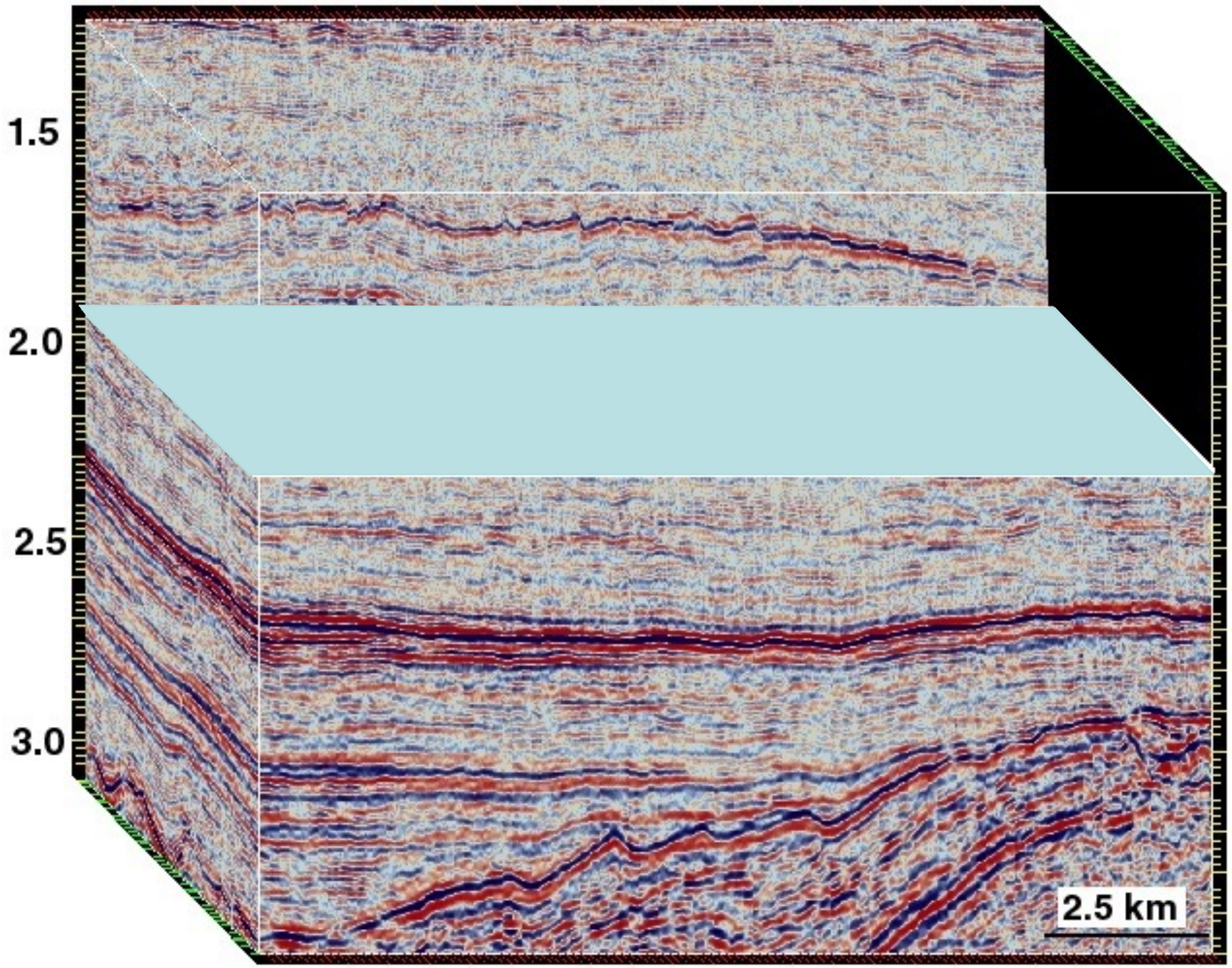
This timeslice (left) and vertical seismic section (right) come from the same dataset in the Gulf of Mexico. Note the development of normal faults and mapped seismic horizon (yellow)



3D seismic: How do we view it?

Understanding of the relationship between features observed in vertical and map-view (timeslice) seismic sections can be aided by using 3D visualisation packages. **We are going to use a package called *Mayavi in Ex 3 and 4.***

In the example to the right from the Northern North Sea it is difficult to identify channels in the vertical section, but they are clear in the horizontal time slice.



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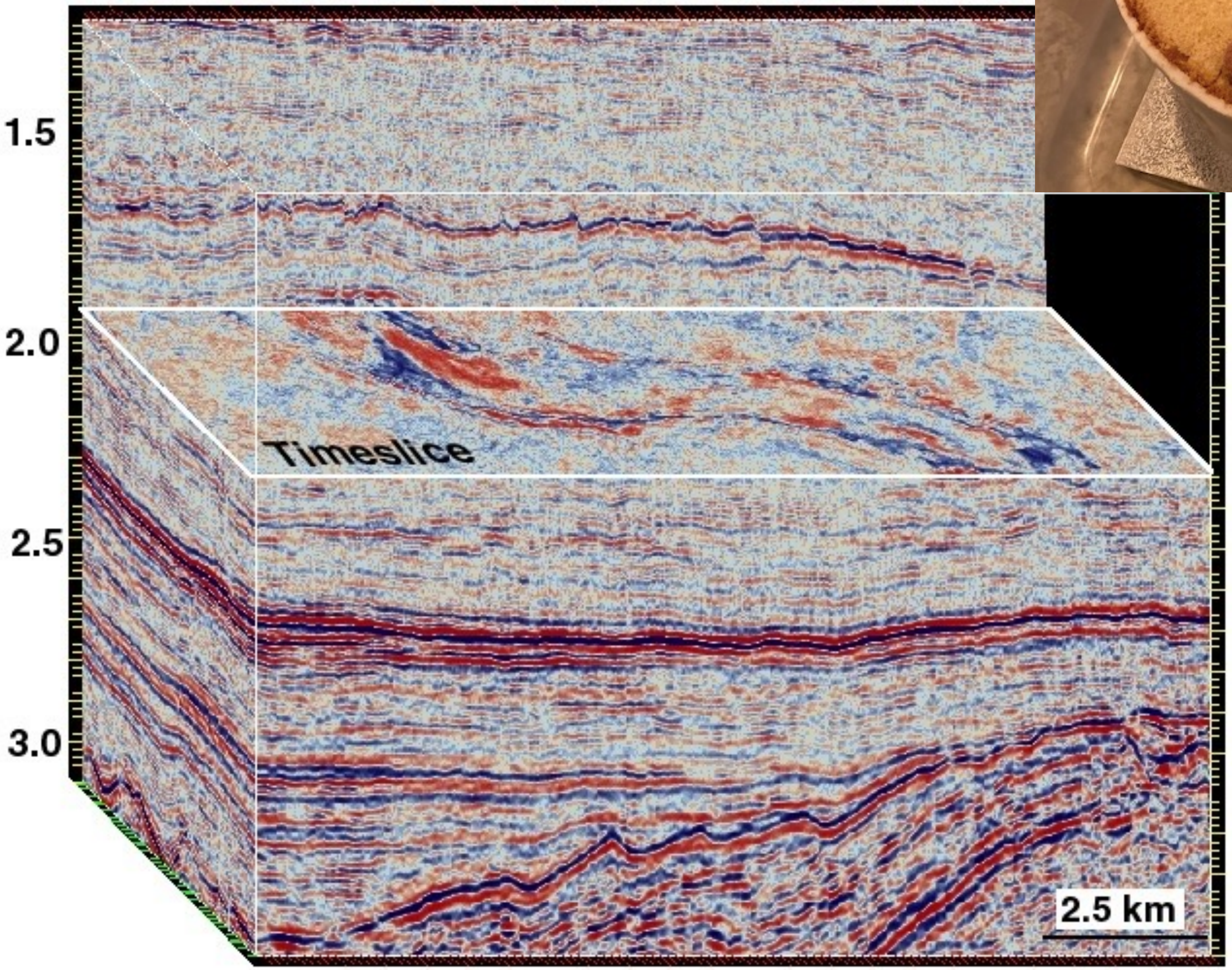
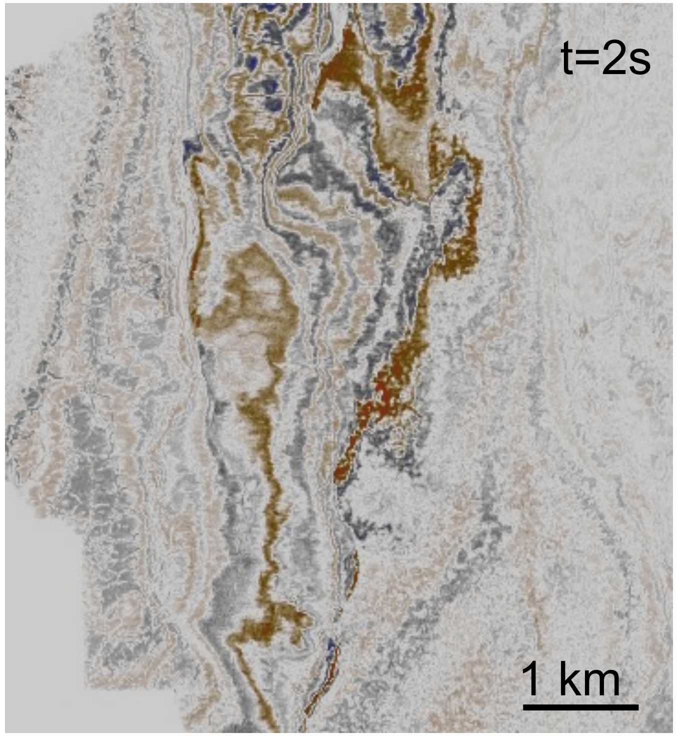


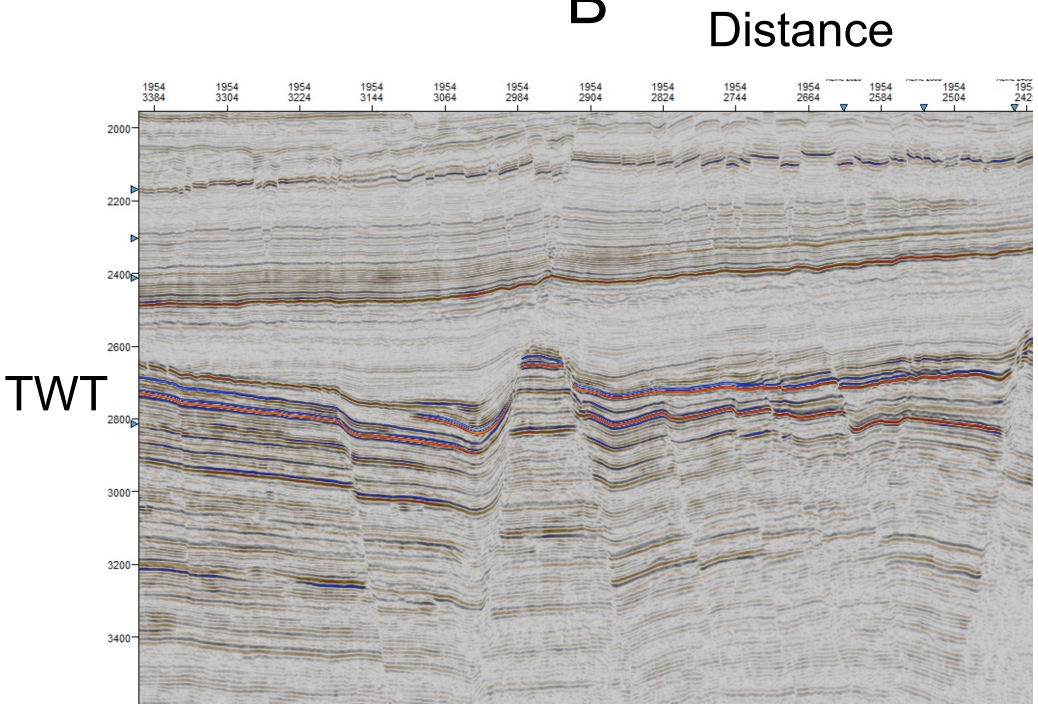
Quiz question

Which of these images shows an inline?

A



B



3D seismic: How do we view it?

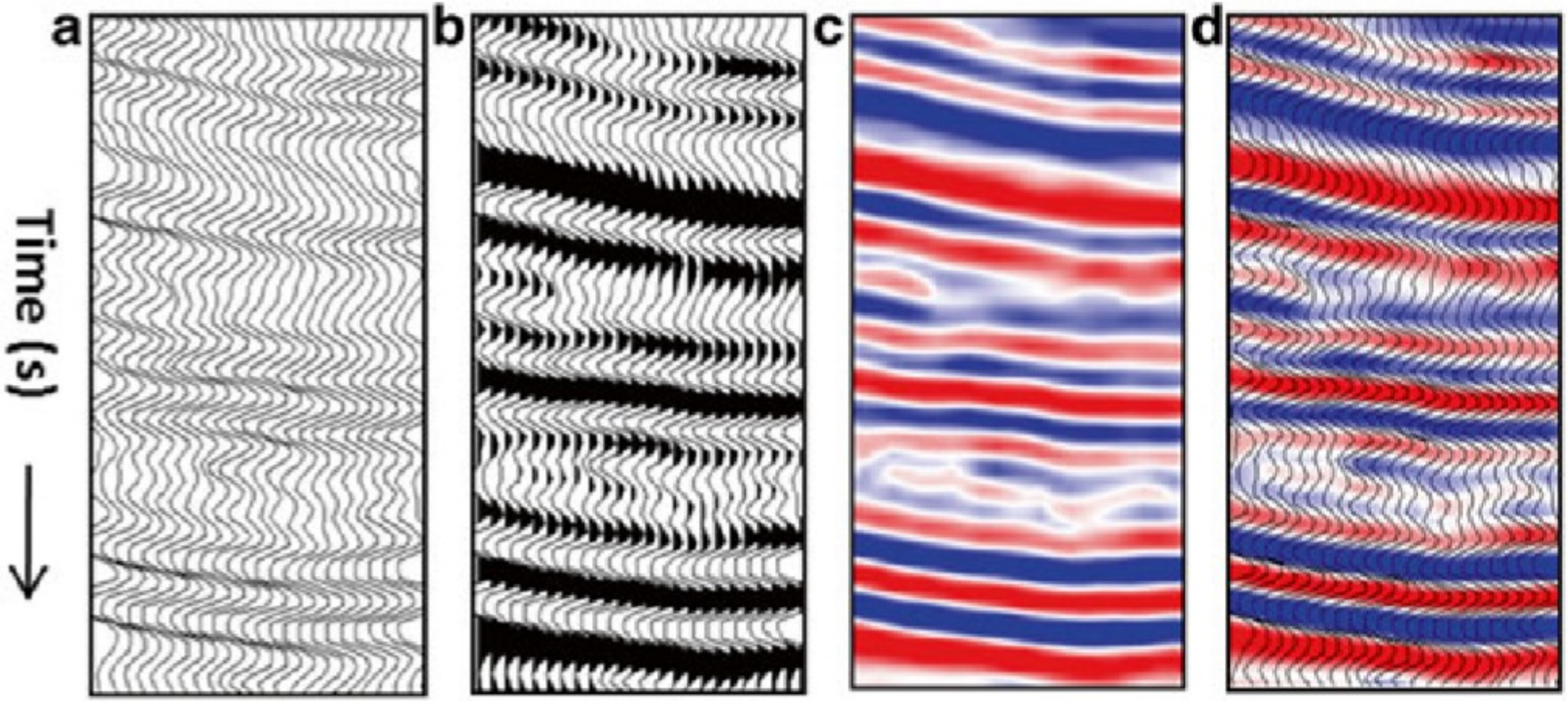
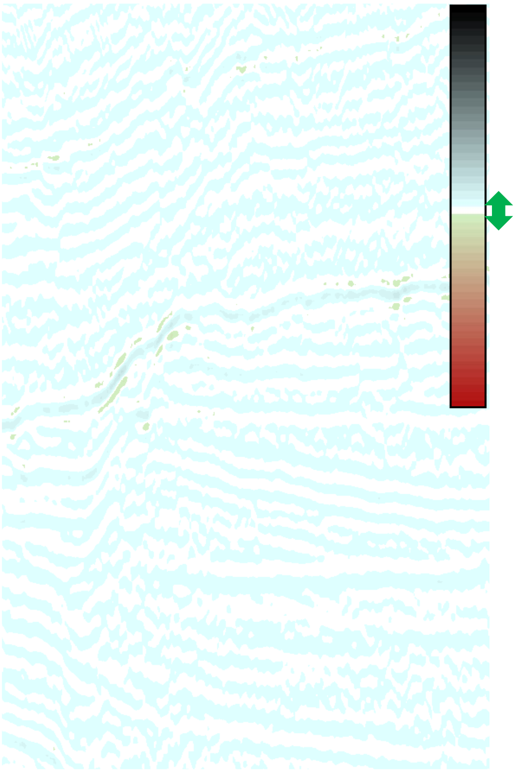


Figure 6: Types of seismic data display modes: (a) Wiggle. (b) Wiggle and variable area. (c) Variable density. (d) Combination of (a) and (c).

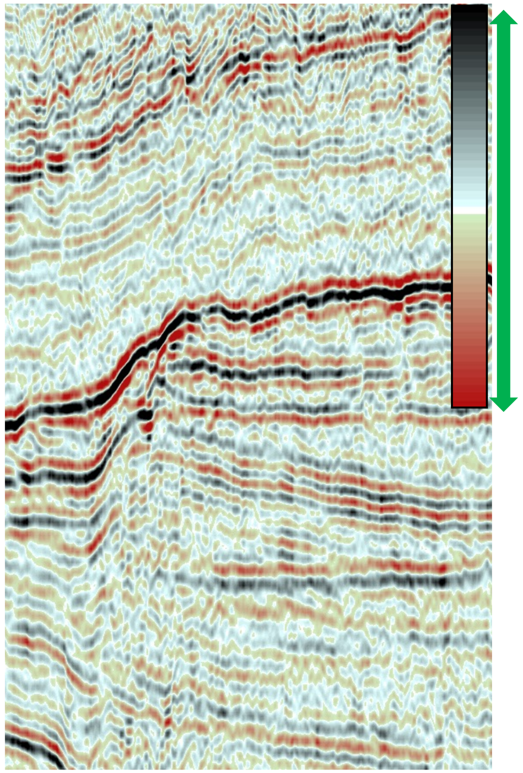
Niranjan 2016

Dynamic range

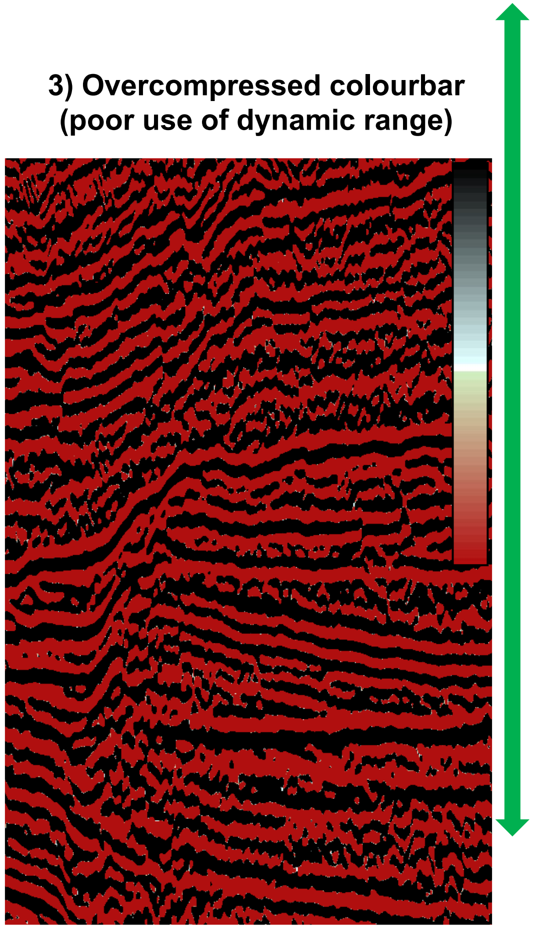
1) Undercompressed colourbar
(poor use of dynamic range)



2) Suitably compressed colourbar
(perfect dynamic range)



3) Overcompressed colourbar
(poor use of dynamic range)



It is important to use the dynamic range of the data in the colour bar to display seismic data well

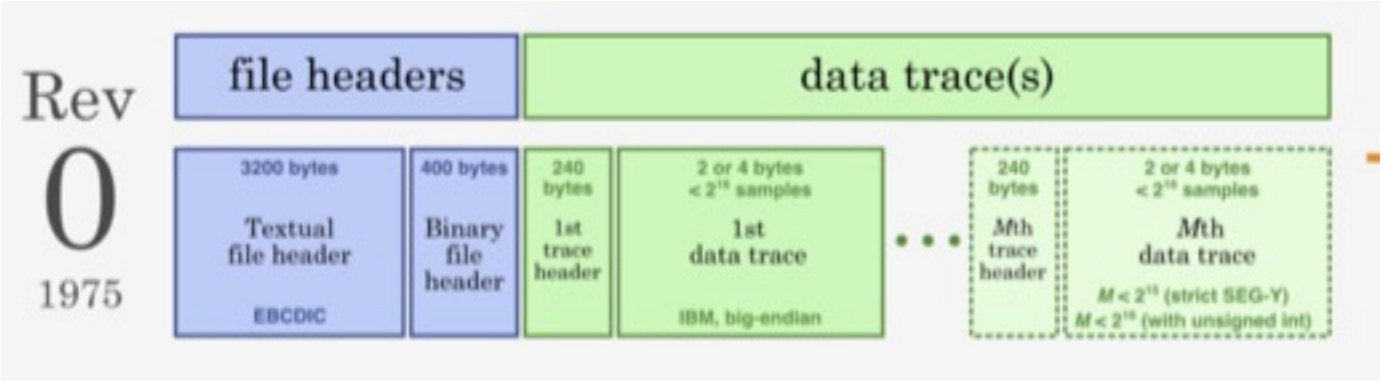
You will explore this issue in Ex 3

How are seismic data stored?

- 3D Post-stack seismic data are effectively a grid of samples. As a data scientist you may think this is quite a simple data type to store
- However, seismic data storage has a long history dating back to 1975 when the SEGY file format was established for saving single-line seismic data to magnetic tapes (needed to make sure all the metadata stored with the trace data)
- We still use the same file-format today, although it has been updated periodically
- Not the most efficient file format for modern data science
- In Exercise 3 the first thing you will do is convert SEGY data into a more efficient format (e.g. a numpy array)

The SEGY file format

- Developed by the Society of Exploration Geophysicists (SEG) released in 1975 for storing seismic data in a consistent way throughout industry
- Built for reading and writing data to tapes, not for efficiently viewing inlines, xlines and time slices
- The SEG-Y file mostly involves the trace data, but it also includes a number of headers: A text header, a binary header, a header for each trace



https://www.troika-int.com/about-us/resources/segy-seismic-data-exchange-format

The SEGY file format

Text header: known as the EBCDIC. Human-readable header describing the data (bit like a ReadMe file). Contains information on acquisition, processing and geometry.

Typically, crs = UTM for SEGY files.

```python
base_segy = segyio.open('data/TNW_small2', ignore_geometry= False)
print (segyio.tools.wrap(base_segy.text[0]))
```

```
C 1 SEGY OUTPUT FROM Petrel 2017.1 Thursday, November 18 2021 12:55:27
C 2 Name: TNW_3DUHRSsubset_ImperialCollege20211104 Crop 1 Type: 3D seismic    C
3                                                                             C
4 First inline: 2000    Last inline: 2571                                     C
5 First xline:  1316    Last xline:  1839                                     C
6 CRS: Undefined                                                              C
7 X min: 676054.47 max: 676326.12 delta: 271.65                               C
8 Y min: 5987532.19 max: 5987827.05 delta: 294.86                             C
9 Time min: -92.05 max: -47.05 delta: 45.00
C10 Lat min: - max: - delta: -
C11 Long min: - max: - delta: -
C12 Trace min: -92.00 max: -47.10 delta: 44.90
C13 Seismic (template) min: ~-39.39 max: ~66.61 delta: ~106.01
C14 Amplitude (data) min: ~-39.39 max: ~66.61 delta: ~106.01
C15 Trace sample format: IEEE floating point
C16 Coordinate scale factor: 100.00000
C17
C18 Binary header locations:
C19 Sample interval                : bytes 17-18
C20 Number of samples per trace    : bytes 21-22
C21 Trace date format              : bytes 25-26
C22
C23 Trace header locations:
C24 Inline number                  : bytes 5-8
C25 Xline number                   : bytes 21-24
C26 Coordinate scale factor        : bytes 71-72
C27 X coordinate                   : bytes 73-76
C28 Y coordinate                   : bytes 77-80
C29 Trace start time/depth         : bytes 109-110
C30 Number of samples per trace    : bytes 115-116
C31 Sample interval                : bytes 117-118
C32
```

Challenges for data scientists

- There are a number of tools available to convert SEGY data into a format which is more efficient for viewing inlines, xlines, time slices and for doing calculations with it. We are going to use ***segyio*** in Exercise 3

- The size of SEGY data makes it difficult to work with on an individual workstation. In Exercise 3 we will work on a 500 Mb subset of an 8Gb data volume (TNW_small2.segy)

- People are working on web API's to host data in the cloud and allow people to access parts of the data quickly and easily (e.g. oneseismic)

Pad non-cubes using NaN or 0's to allow data loading (bonus ex)

- Data loading problems will occur if the data is not a perfect cube and inline/xline spacing not regular. You can explore this in the bonus exercise and this may be an issue if you download data from an open-source repository

- Not all SEGY files will contain all the information you expect (the metadata quality will vary between files…)

How can we access seismic data?

- Seismic data is often proprietary when first collected
- After a moratorium period academics and industry are often required to make the data open access (some countries are great at insisting on this- e.g. Geoscience Australia)
- There is no single centralized location to access these datasets
- The SEG wiki have a good summary of many repositories for open SEGY data- https://wiki.seg.org/wiki/Open_data
- The Marine Geoscience Data System is a good option for academic datasets

Exercise 3

- Explore the SEGY file format
- You will load and visualize 3D SEGY data in terms of inlines and xlines
- You will visualise the data in 3D using Mayavi
- Fix data loading issues (in the Bonus exercise…)

Key points

- Appreciate how 3D seismic data are commonly visualized (inlines, xlines, horizontal slices, arbitrary lines)
- Understand that seismic data in stored in the SEGY file format involving various header information as well as the trace sample data
- Know some open-access repositories for downloading free SEGY data
- Appreciate the key challenges of working with SEGY data (primarily, huge file sizes)