Quantifying Fluid Flow in Sedimentary Basins: A Petroleum Perspective

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The Petroleum Industry’s Interest in Fluid Flow Includes

- Production from oilfields
- Predicting pore pressure
- Seal capacity and petroleum leakage
- CO_2 storage

Outline

- Looking into sedimentary basins
- Modelling fluid flow
- Learning about leakage
- Some things we don't know

Looking into Sedimentary Basins: Seismic Images and Downhole Logs

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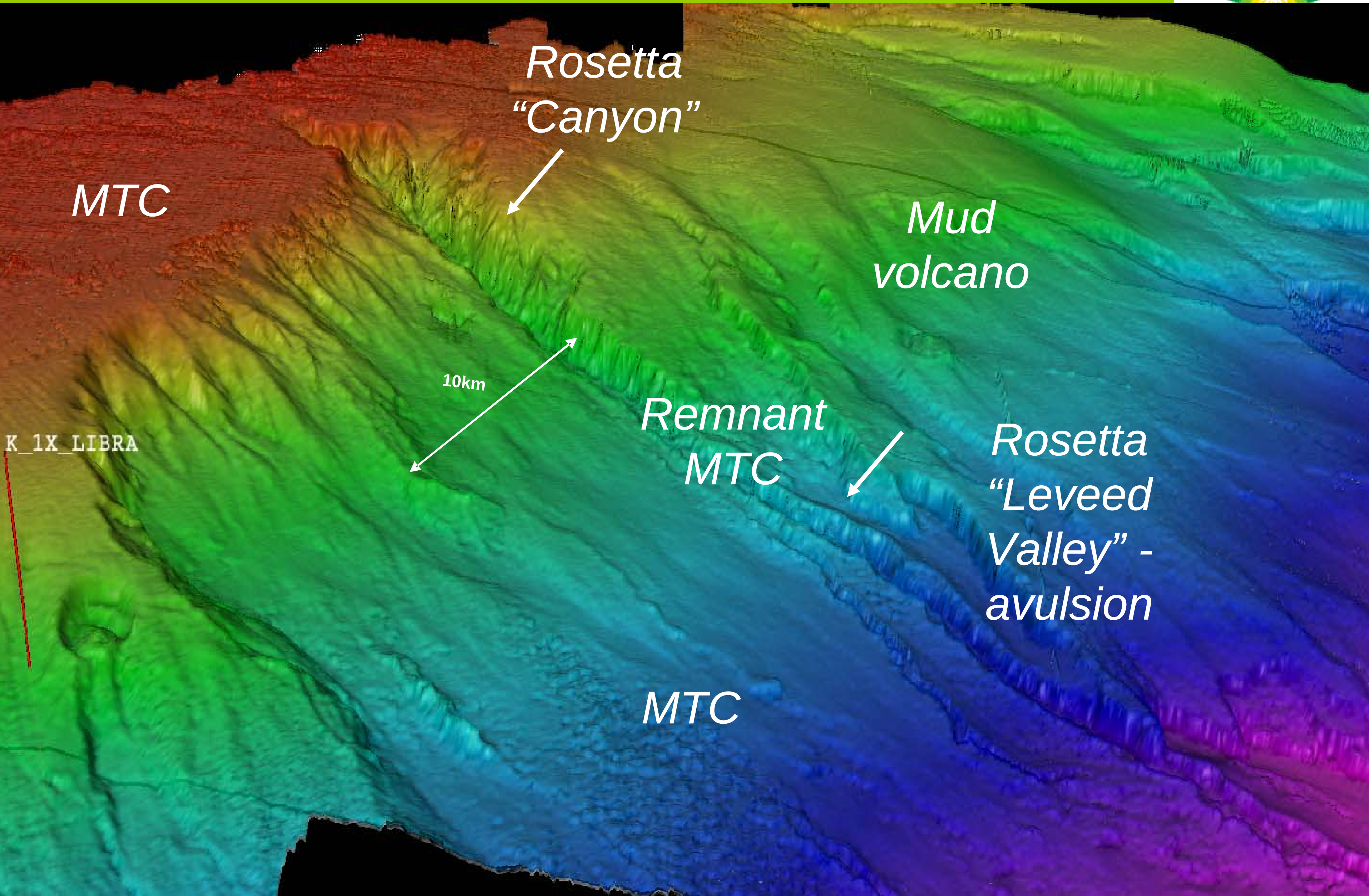
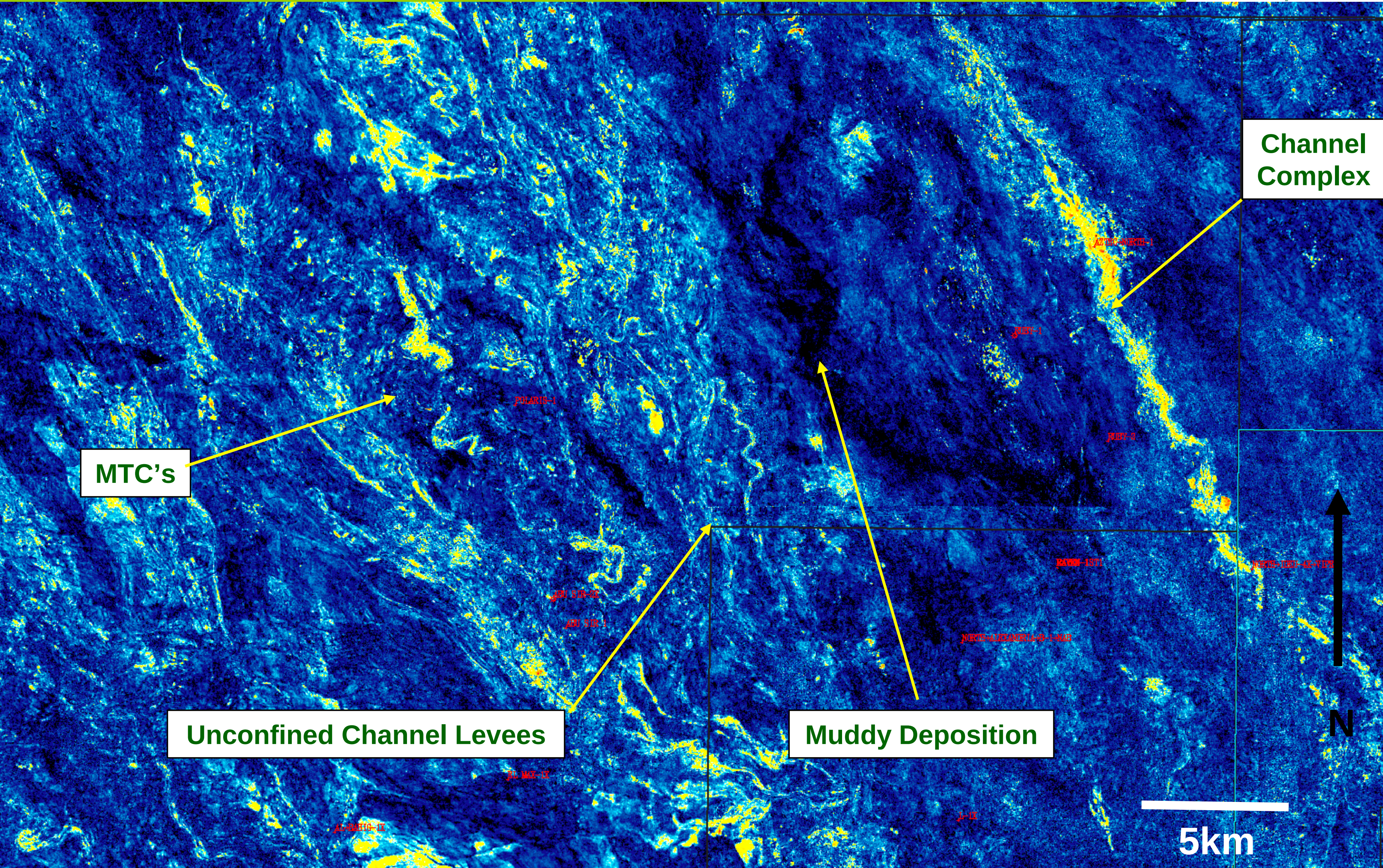
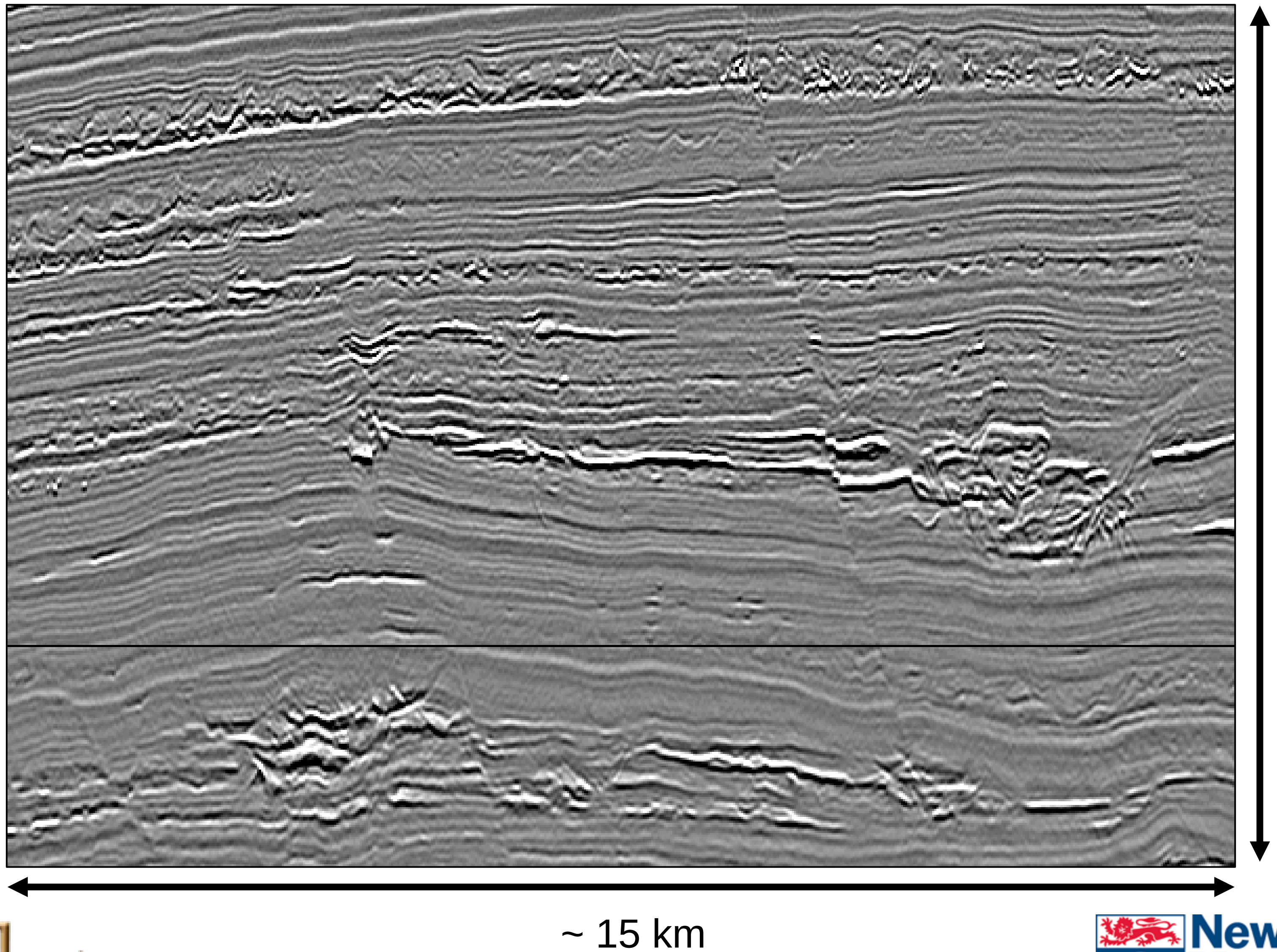
Perspective view of West Nile Delta seabed



40ms RMS Amplitude Extraction



Seismic Section



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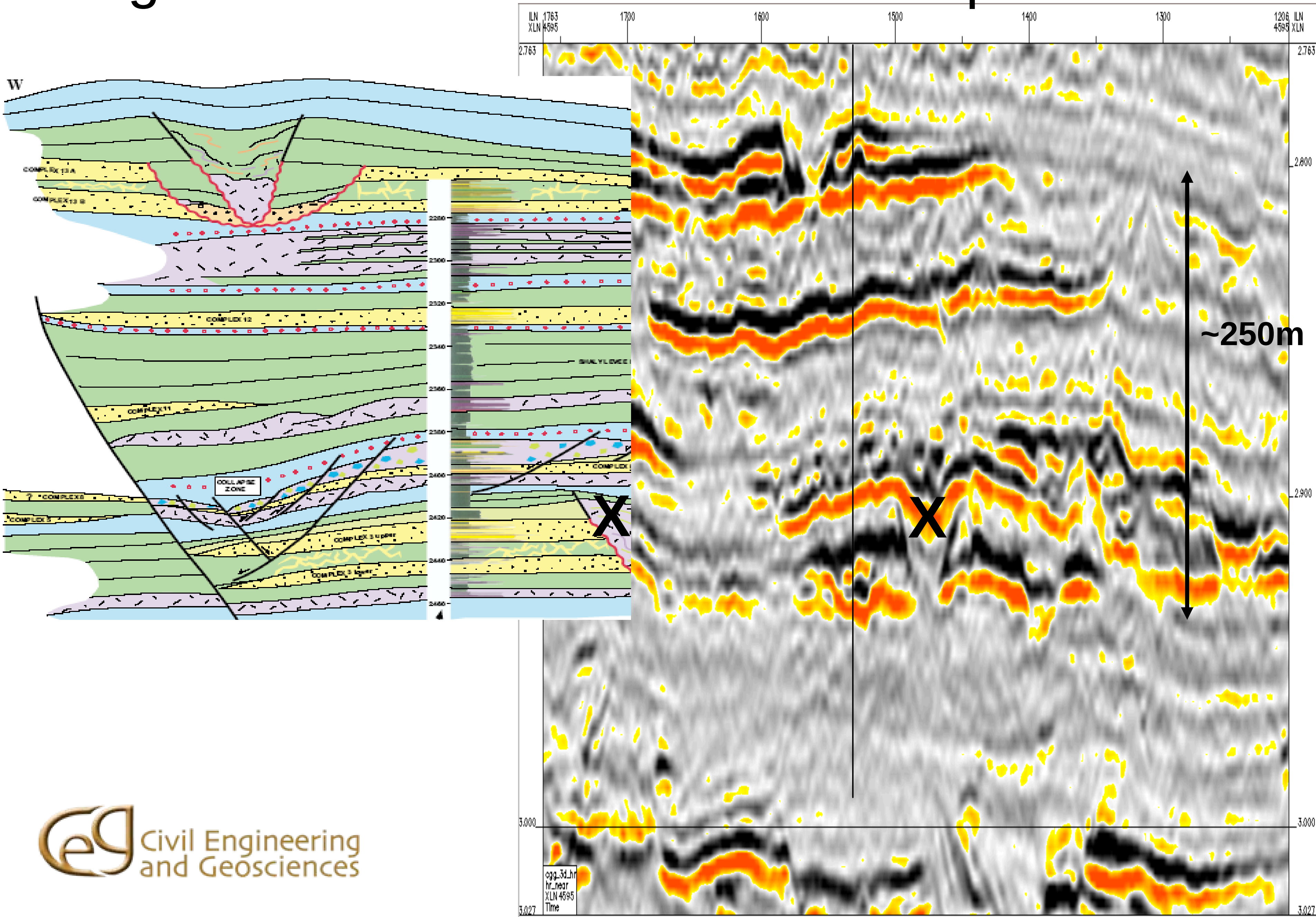
High Resolution Seismic with Interpretation



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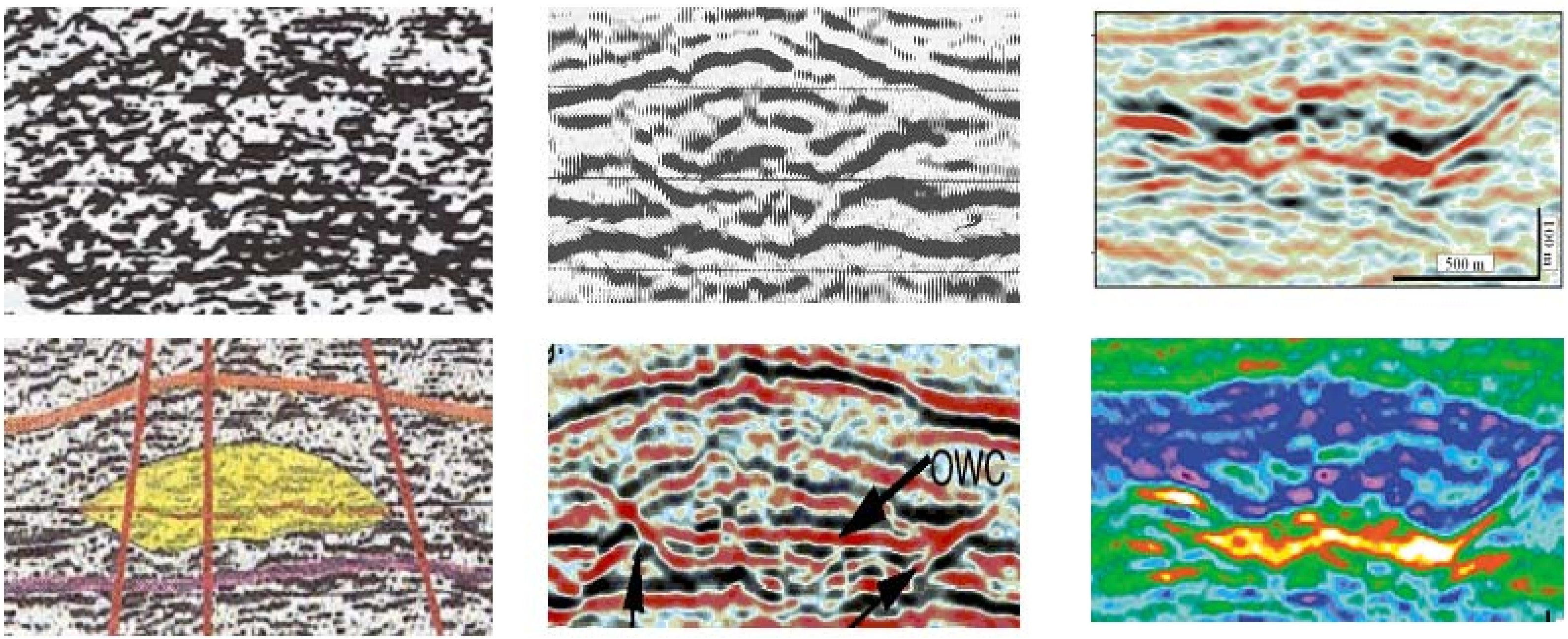
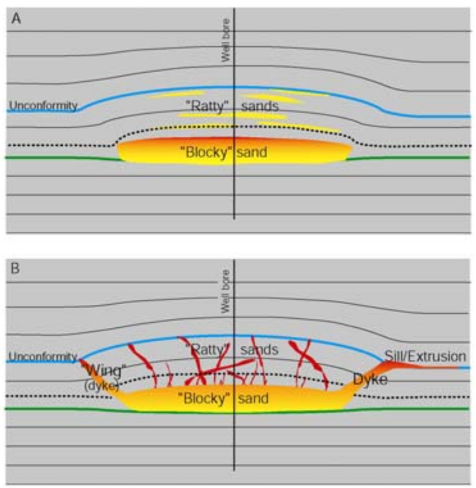
True Structure of Alba Reservoir Revealed by Enhanced Seismic Data Quality

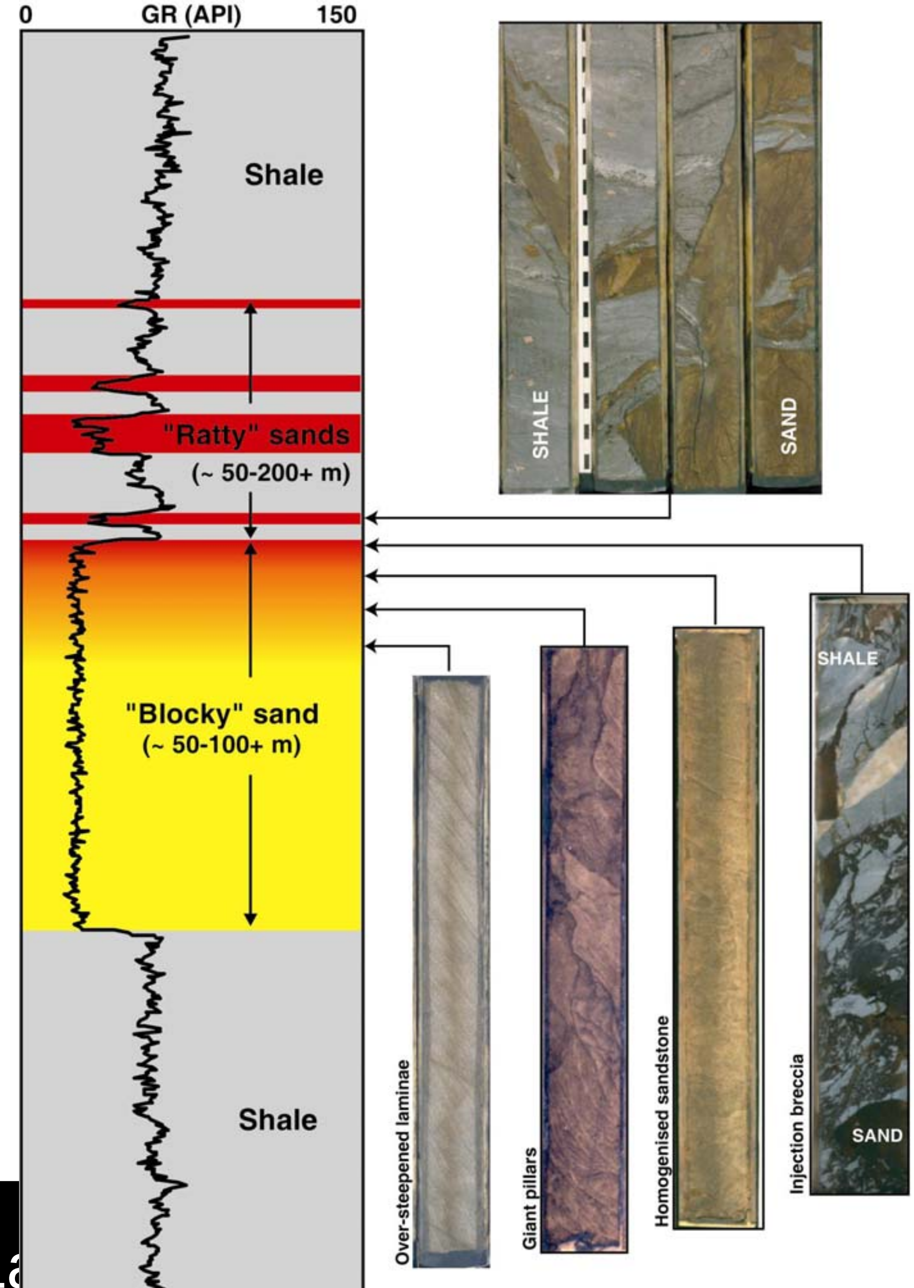


1985 2D | 1989 3D | 1999 3D

Bain (1993), Newton & Flanagan (1993), Lonergan & Cartwright (1999), MacLeod et al. (1999)

Borehole evidence for remobilized/injected origin of massive sandbodies overlain by ratty sands

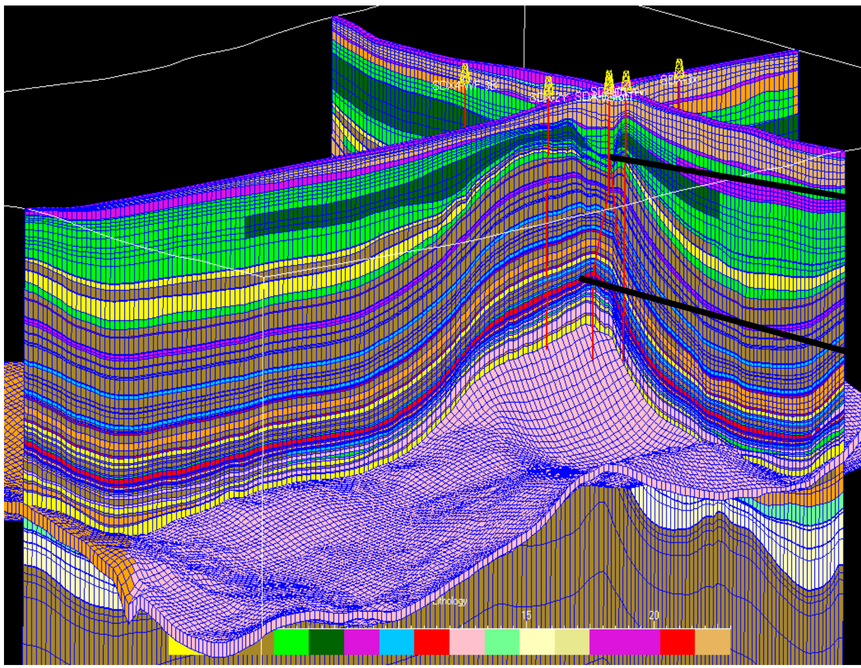


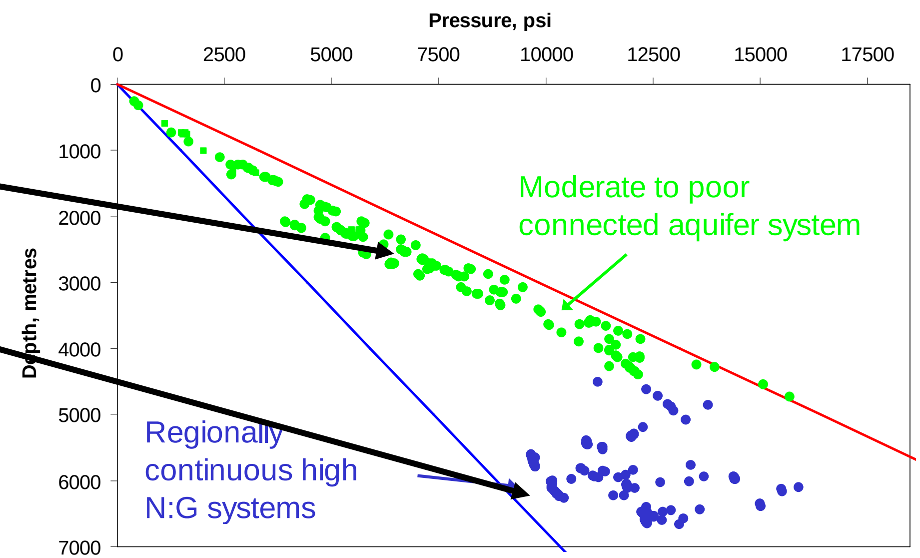


Fluid Flow, Pore Pressure Prediction and Safe Drilling: A Caspian Example

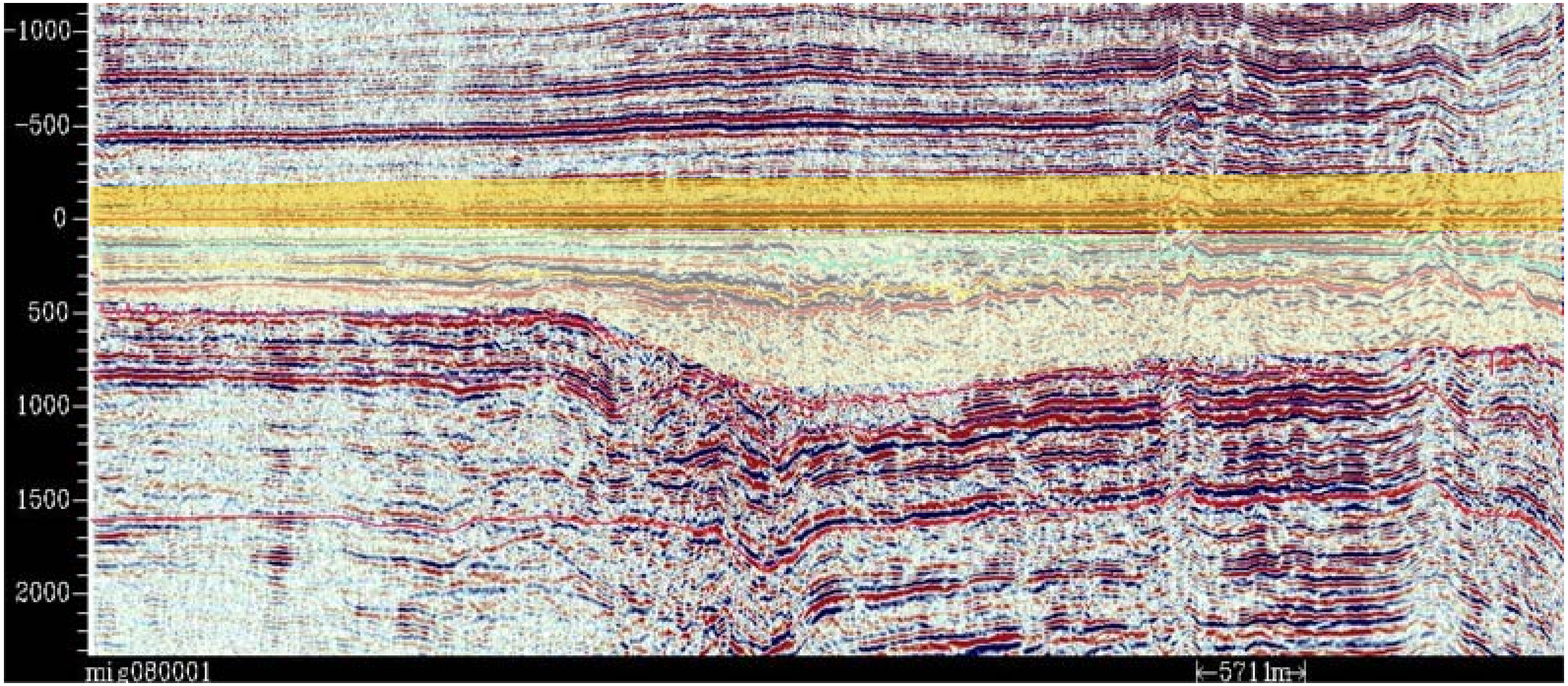
Stephan J. Duppenbecker et al.

The Challenge: Safe Drilling into High and Complex Pressure Regime





Step 1: Basin Scale Seismic Gives the Basic Sequence of Rock Types



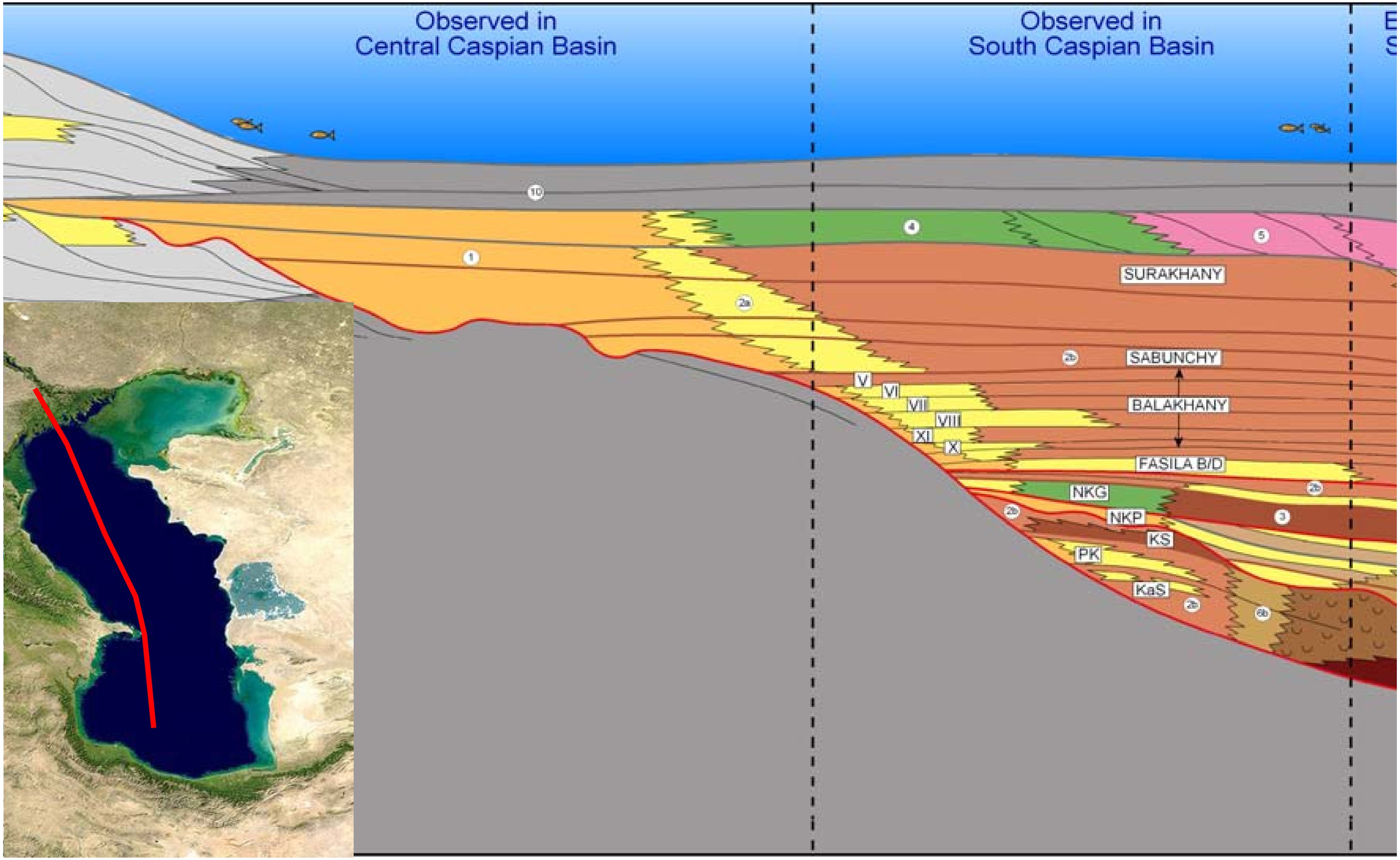
Section about 100 km 5km

Step 1=: Fieldwork to help calibrate seismic stratigraphy

- Interbedded fluvial and fluvio-deltaic sands with shallow water lacustrine mudstones.

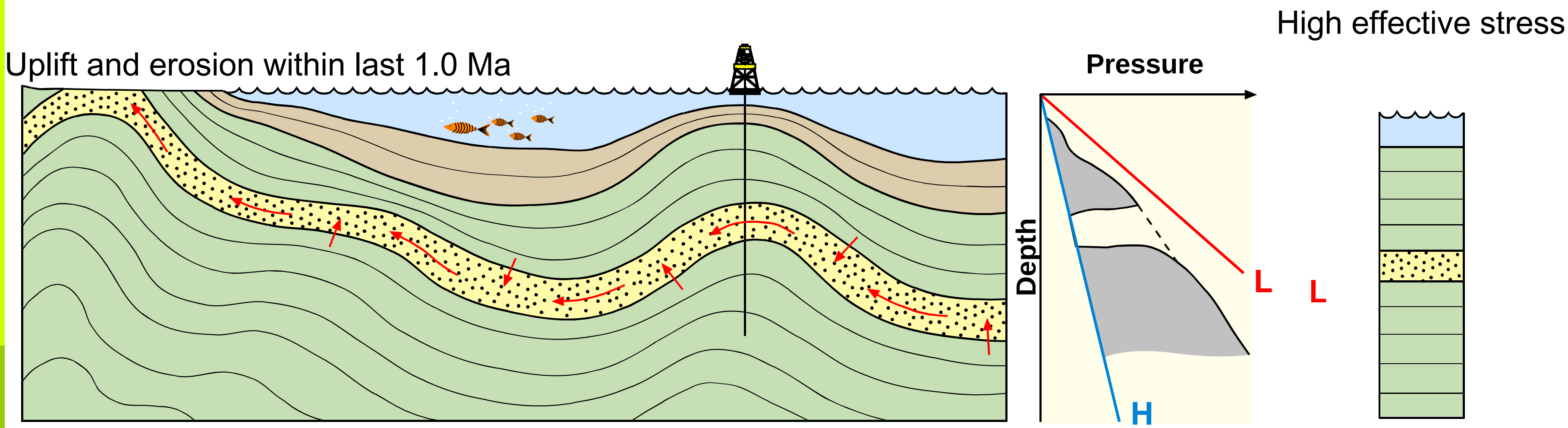
- Mudstones with exposure indicators.

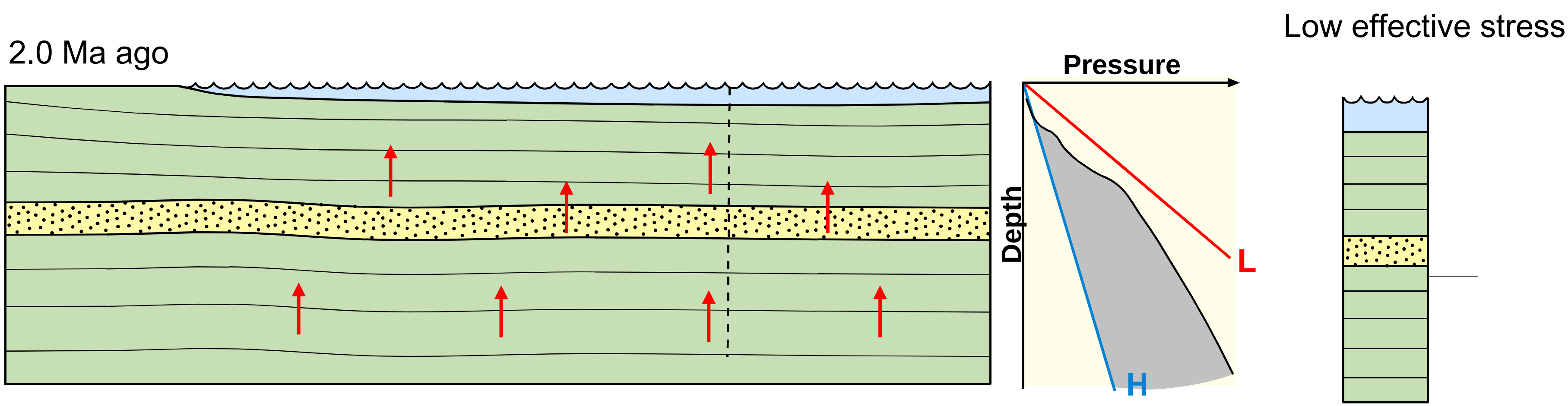
Step 2: Build Regional Geologic Cross - Section



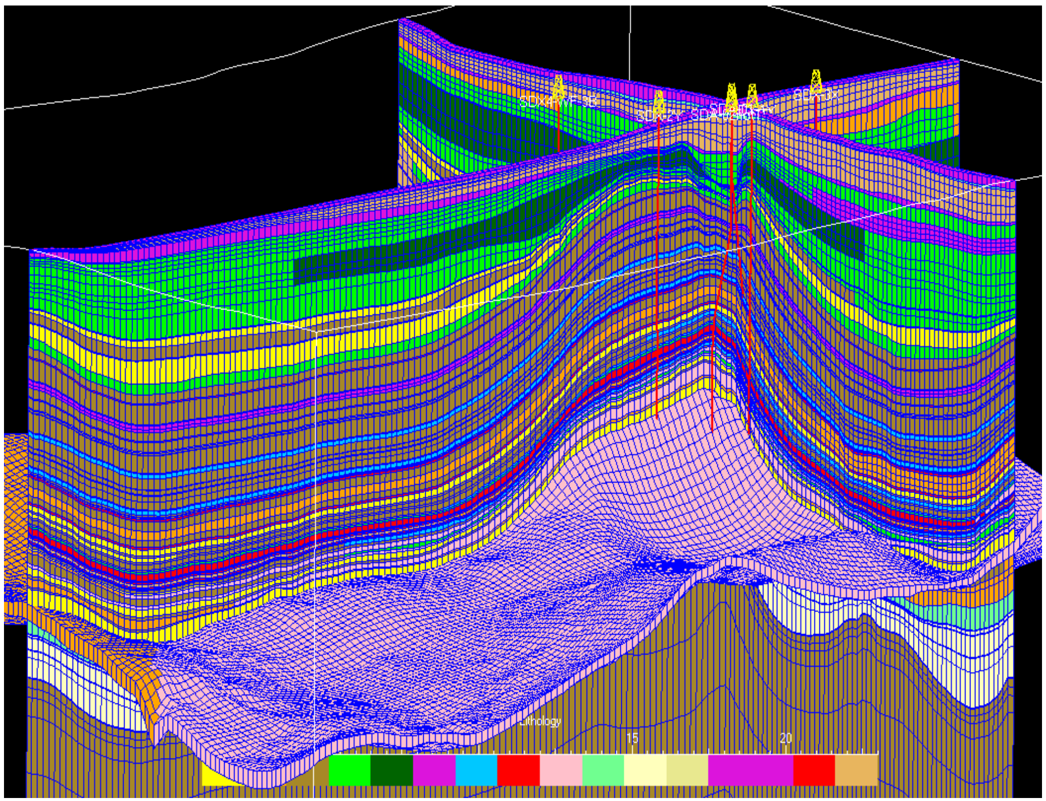
Step 3: Evaluate Geological History of Chosen Geological Structure

UPLIFT EVENT WITHIN LAST 1MY



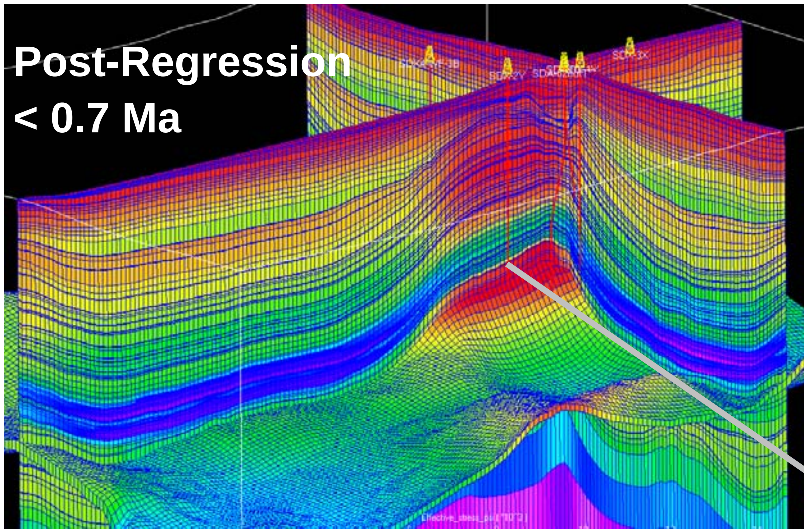


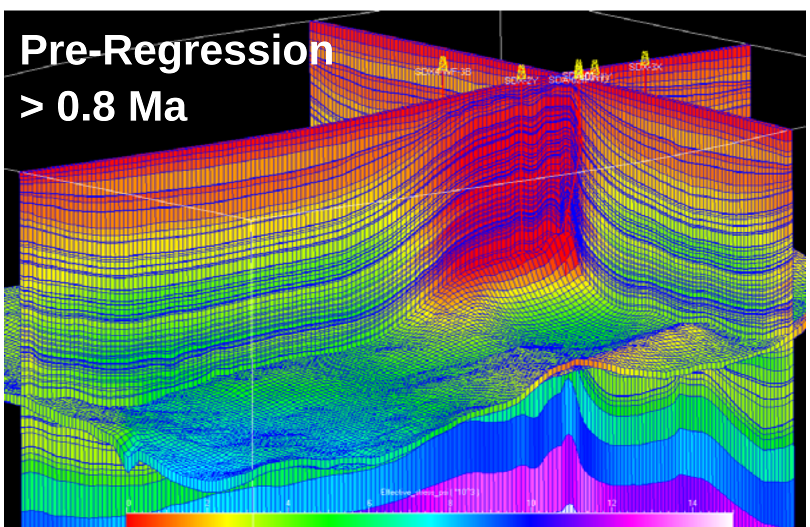
Step 4: Build 3D Geological Model and Parameterize in Terms of Fluid Flow

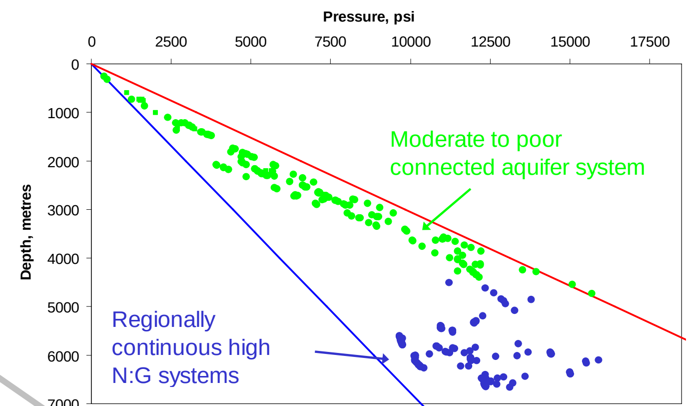


Code	Name	Color	Pattern
1	Limestone		
2	Shale_45CF		
3	LW_N:G		
4	Shale_35CF		
6	Shale_45CF_DW		
7	Shale_45CF_carb		
8	Shale_45CF_MTC		
13	HG_N:G		
21	Tight_Shale_55CF		
22	Evaporite_Mudstones		
23	Evaporites		
5	LW_N:G_Sandy		
88	SR_Rich		
99	SR_Lean		

Steps 5 and 6: Run Model, Compare Results to Existing Data, Recalibrate Model, Iterate



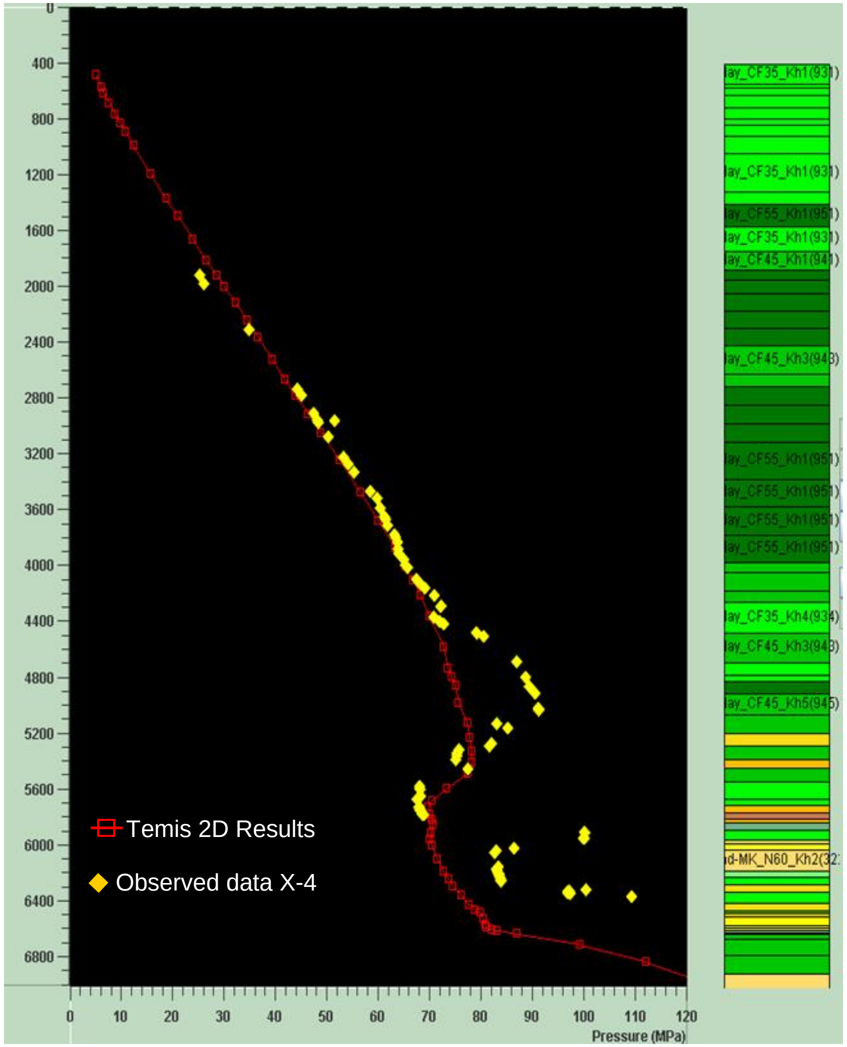




Model calibrated to well data

1D Result from Early Fluid Flow Simulation

Depth



Fluid Pressure

Leakage: Geological to Human Timescales

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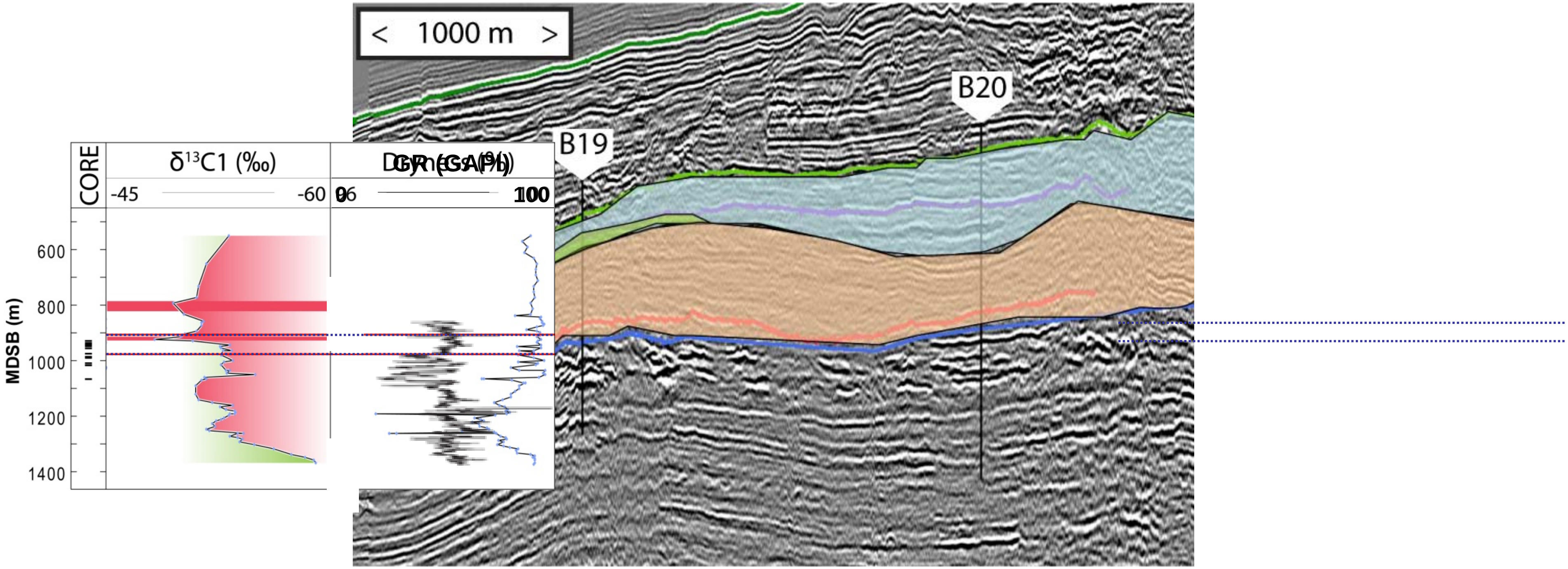
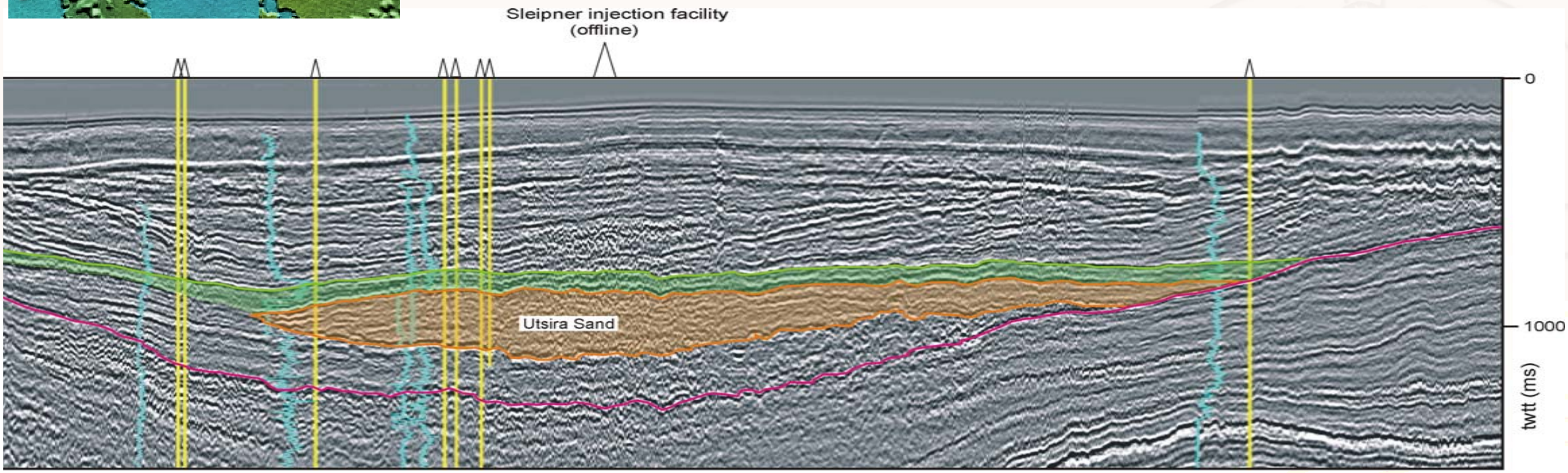
Gas Leakage on Geological Timescales

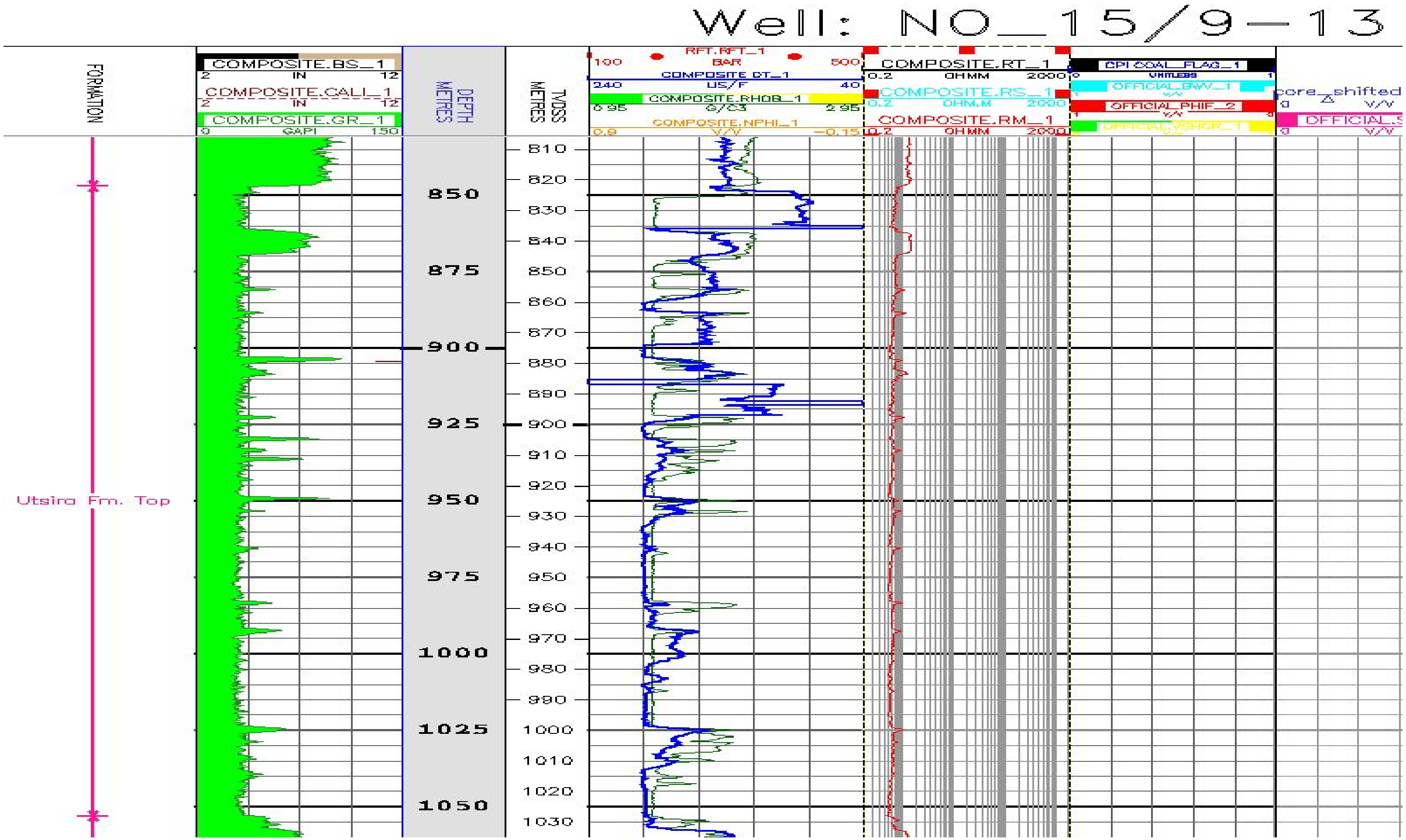


Storage at Sleipner

CO_2 separated from natural gas
~ 1 Mt per year since 1996
>10 Mt now in situ



Utsira formation well logs



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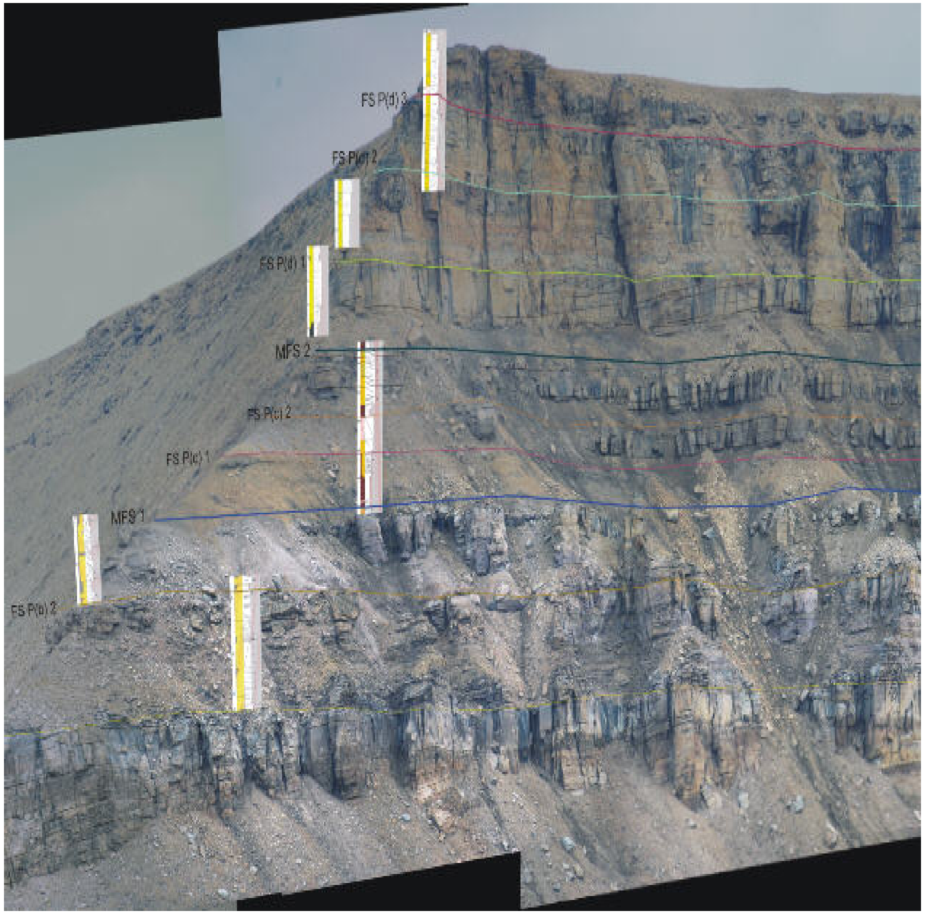
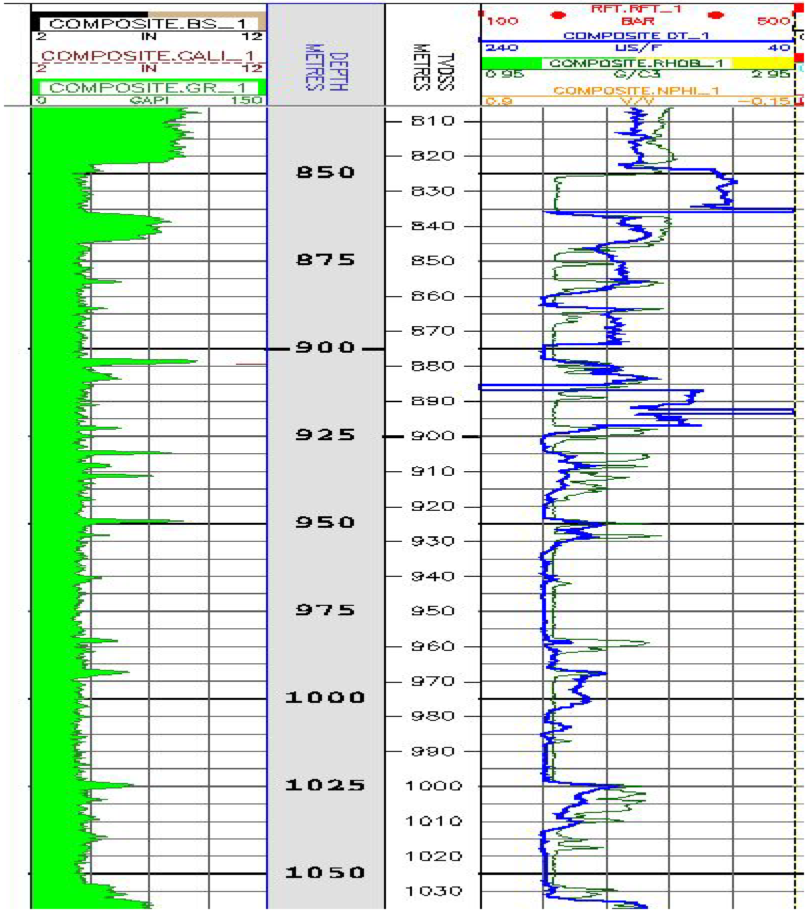
Field analogue of the Utsira formation?





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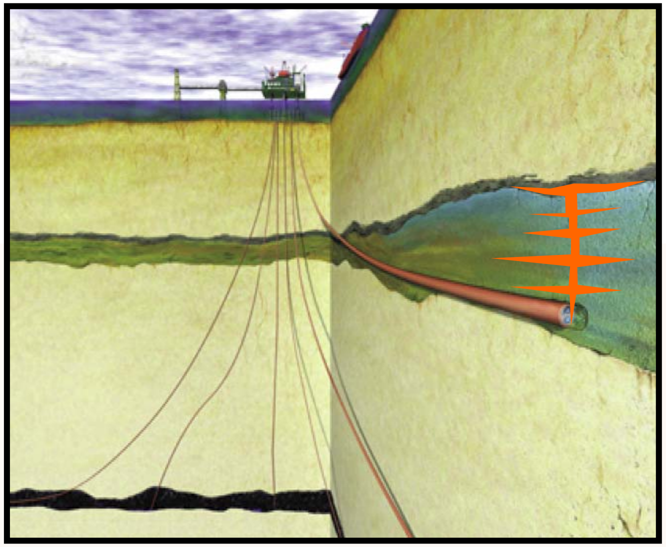
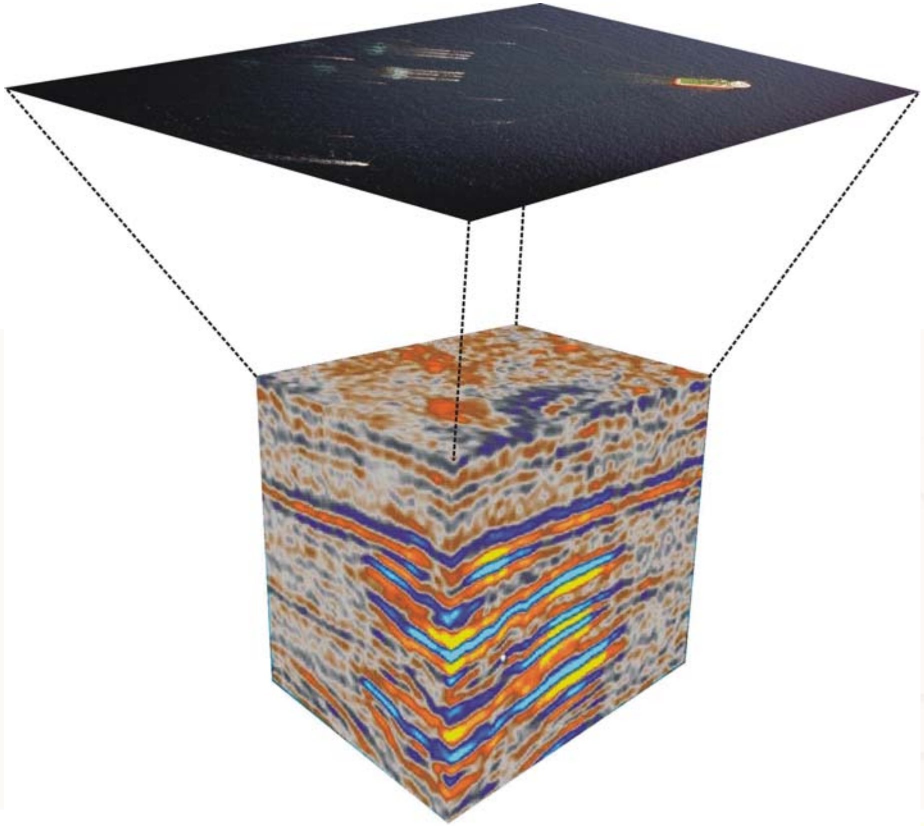
Deep monitoring at Sleipner



CO_2 injection commenced 1996

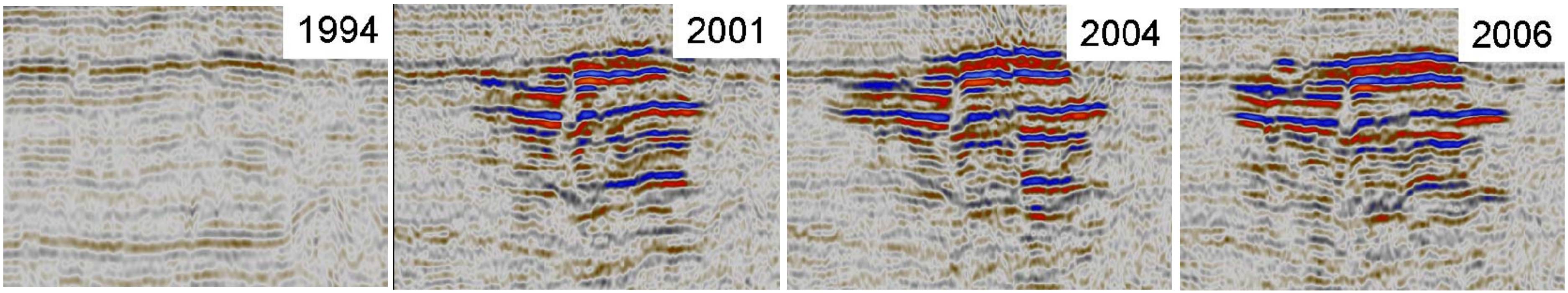
~ 1 Mt CO_2 injected per annum

> 10 Mt currently *in situ*

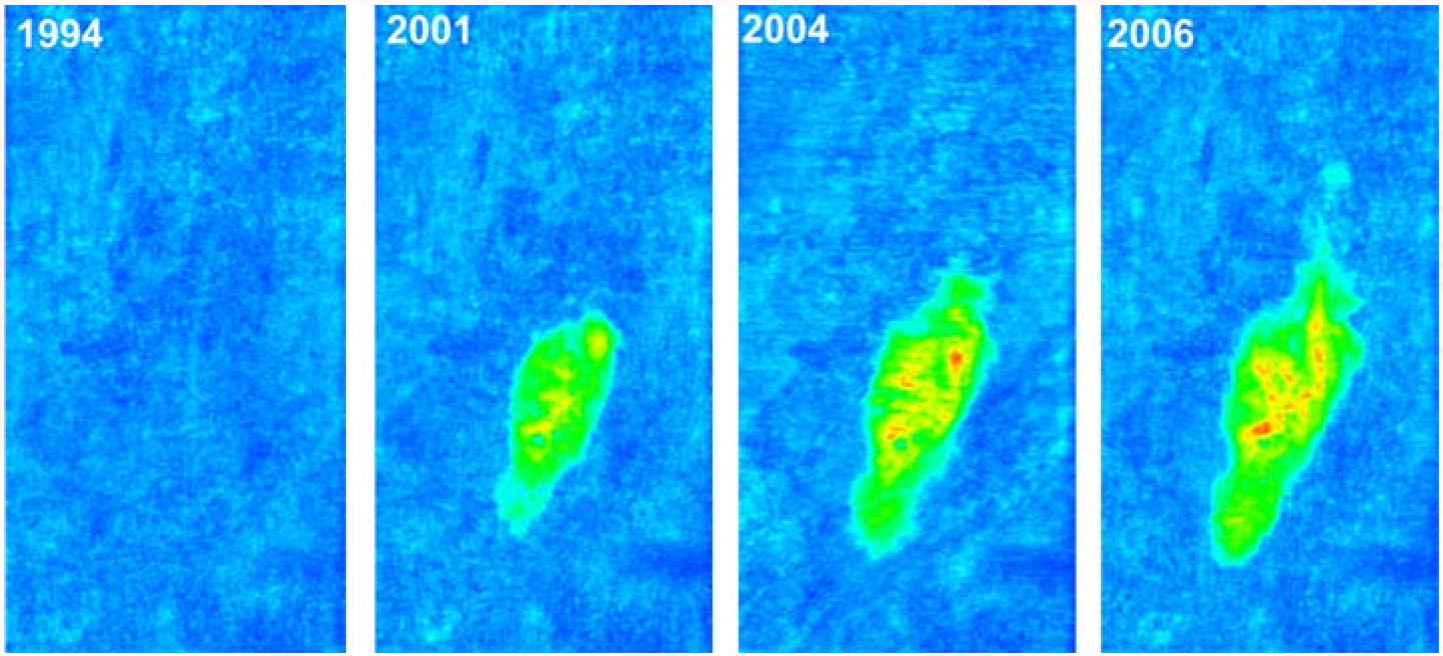


Surface seismic – 3D coverage

Sleipner plume displayed in 2D

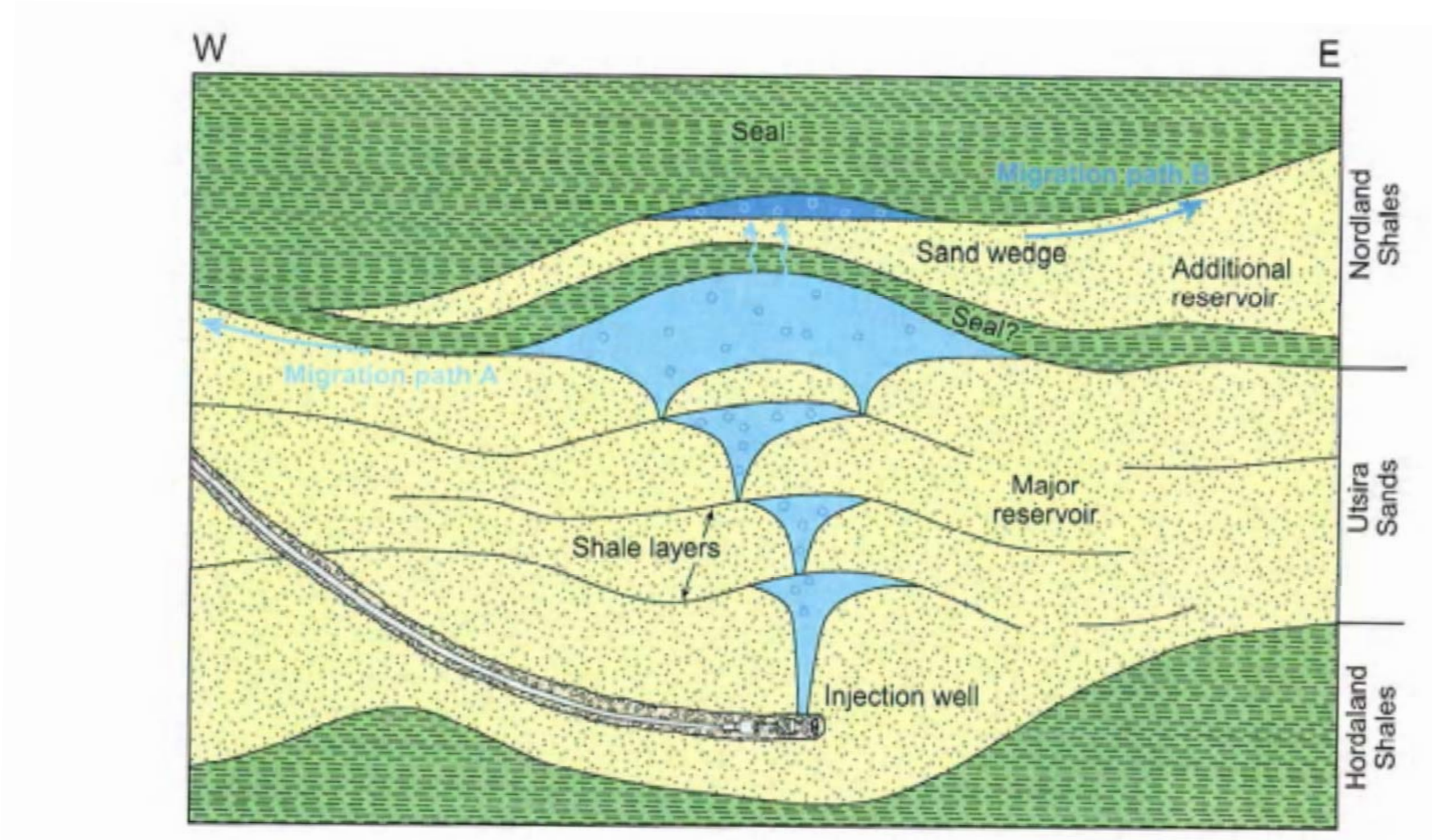


vertical sections



horizontal slices

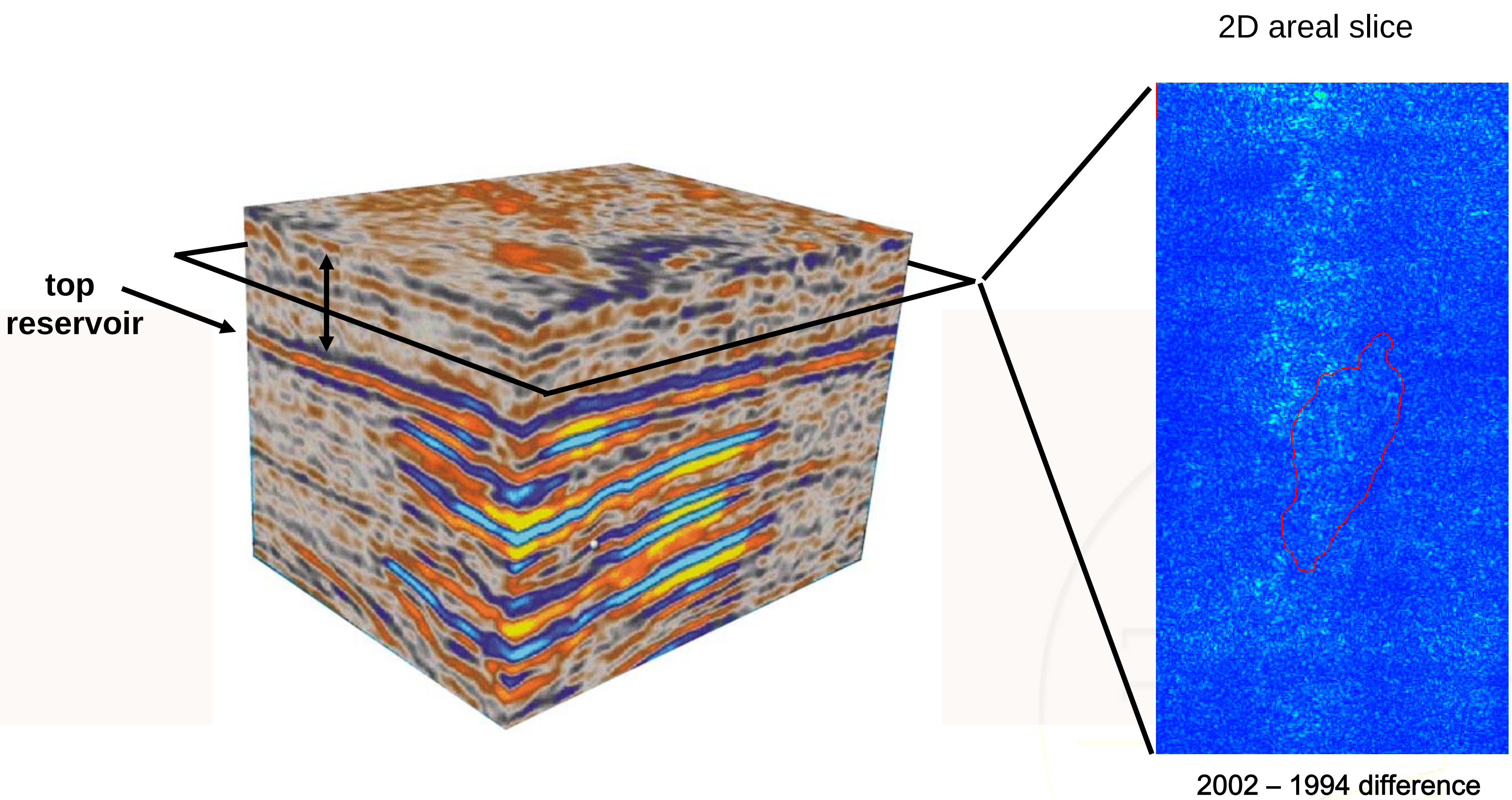
Early CO_2 flow models



Zweigel et al, 2002

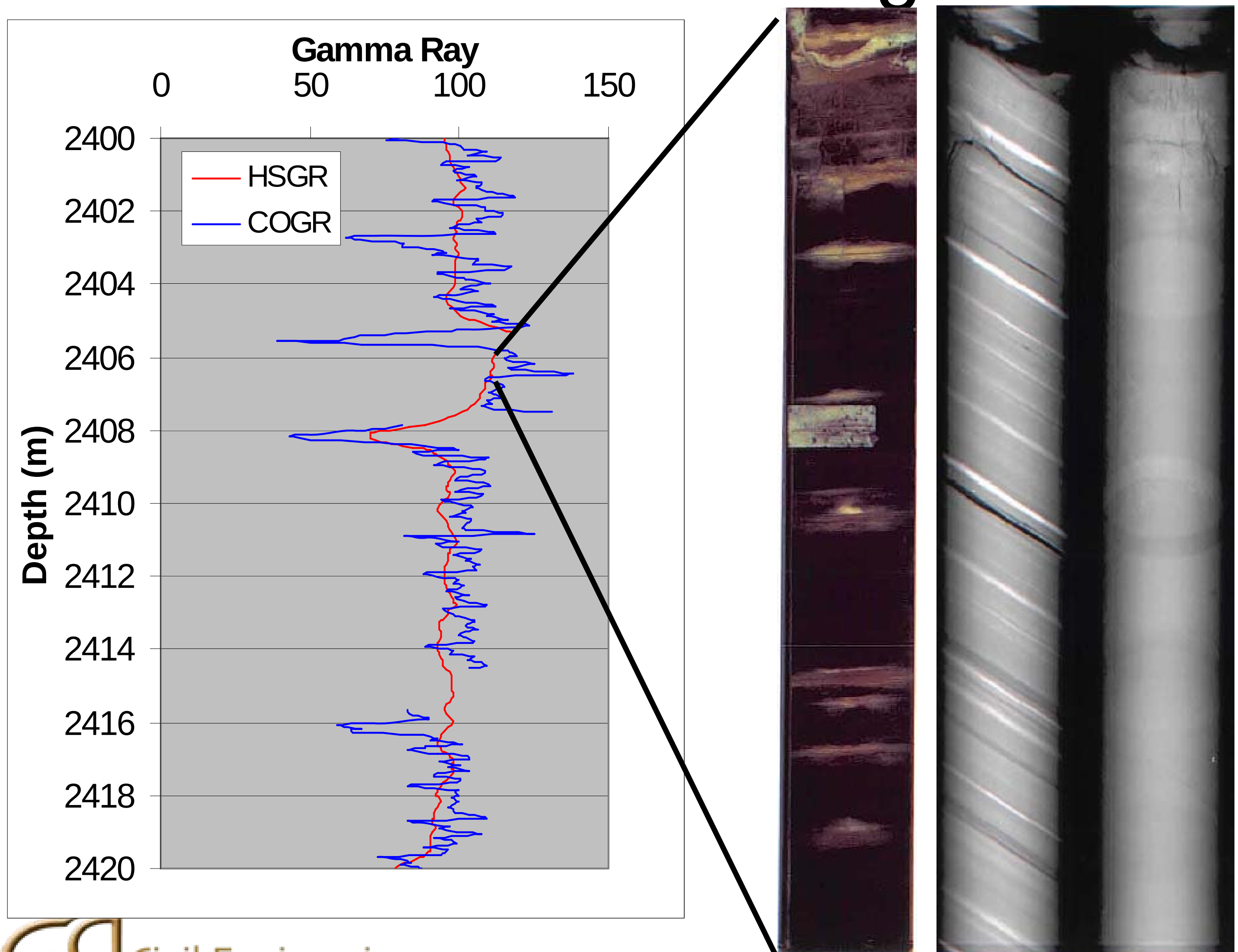
Detecting migration in 3D volume above reservoir

Early warning of subsequent leakage



Sleipner 2002 – no detected migration of CO_2 from the reservoir

Uncertainties 1:
Sub-seismic and sub-log discontinuities



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Uncertainties 2: Sometimes large-scale geological discontinuities compromise the seal….but not where oil & gas is retained

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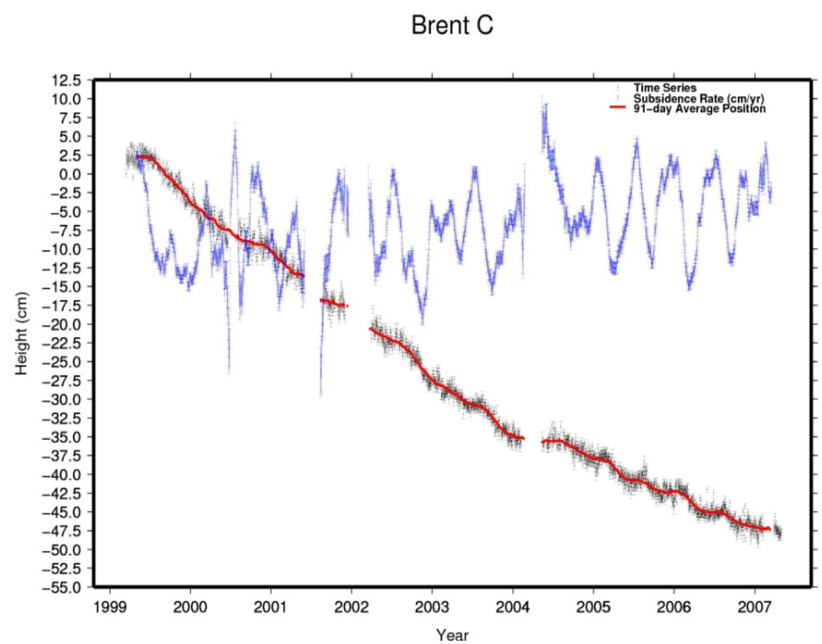
Uncertainties 3:
Rapid Changes in Stress Regime may cause fracturing of the overburden



Probably not relevant to Rad Waste?

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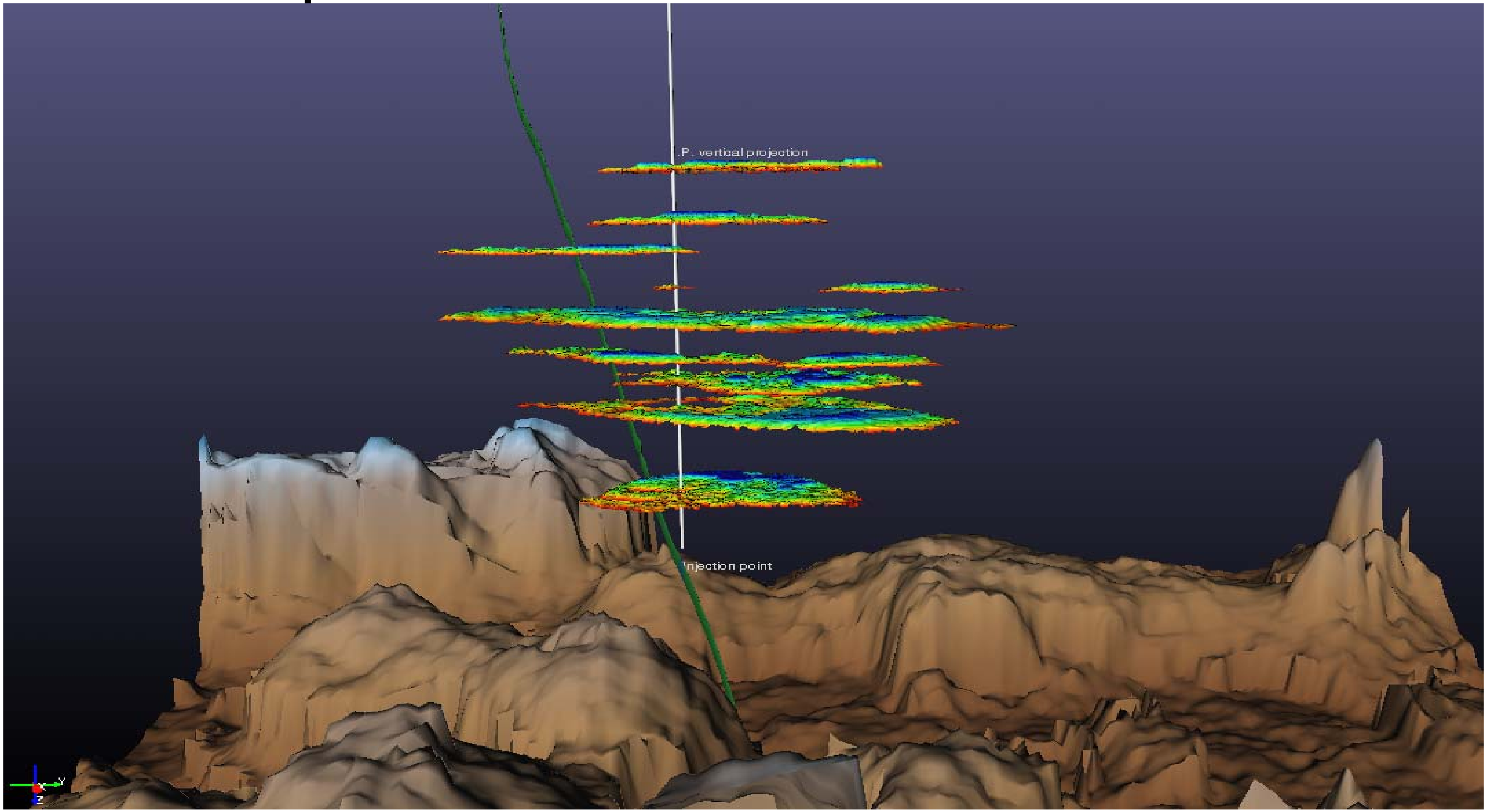
Uncertainties 4:
where there is leakage, what are the rates and flowpaths?



Finally

- Our ability to image the subsurface and to model fluid flow on human and geological timescales is better than ever
- But: there is always uncertainty

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