Relationship of Petroleum Geology to Science

Velledits Felicitász

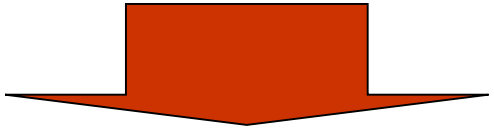
Petroleum geology

use geological disciplines, advanced geophysical techniques and basin modelling to explore and produce oil and gas

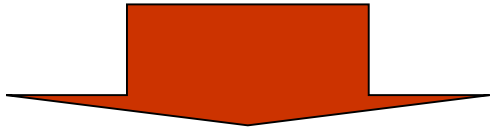
1. Sedimentary geology

almost all petroleum occurs in sedimentary rocks (sandstones and carbonates).

Sedimentary environments (sedimentary facies) determine the **shape, extension**, and **distribution of reservoir rocks, seal and source** and their **primary composition**.



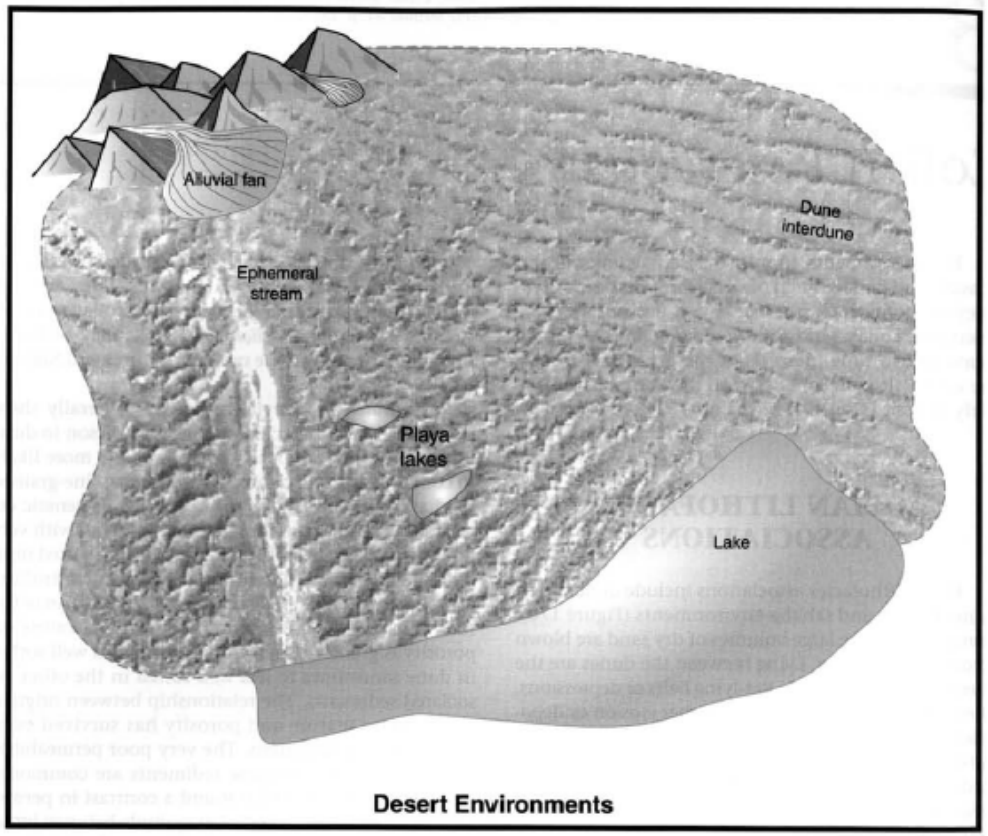
- Determine the petrophysical quality (porosity, permeability) of the reservoir rocks



Sedimentological models are used **to predict** the location of different **facies** in the sedimentary basins, and the likely **presence of source rocks** with a high content of organic matter, **reservoir rocks** and **cap rocks**.

Paleogeography

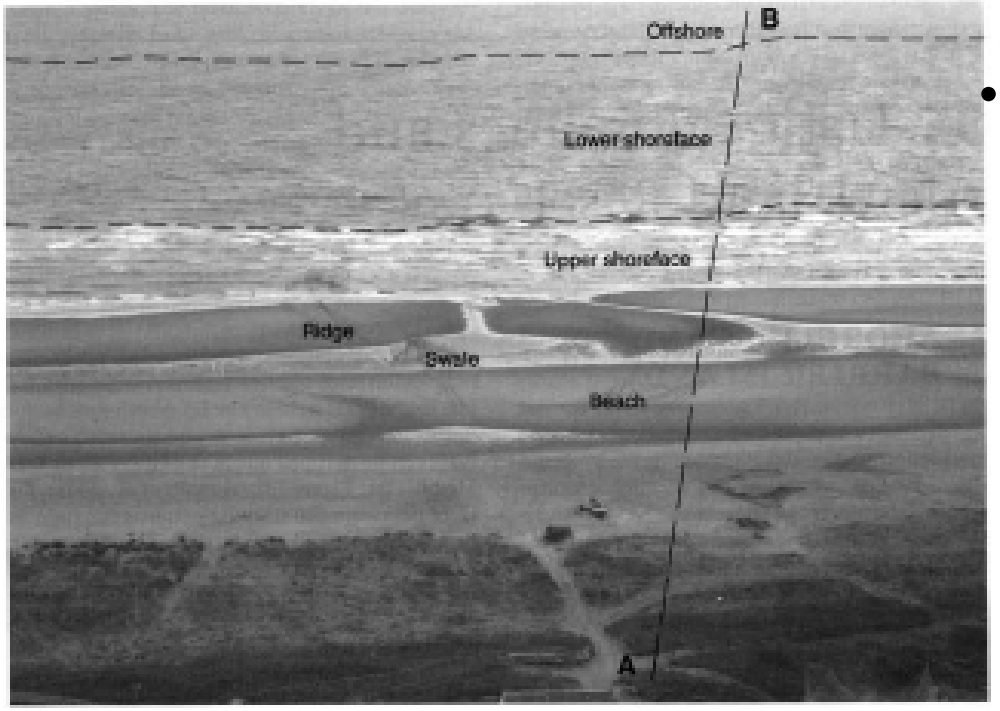
(facies distribution, different rock types distribution)



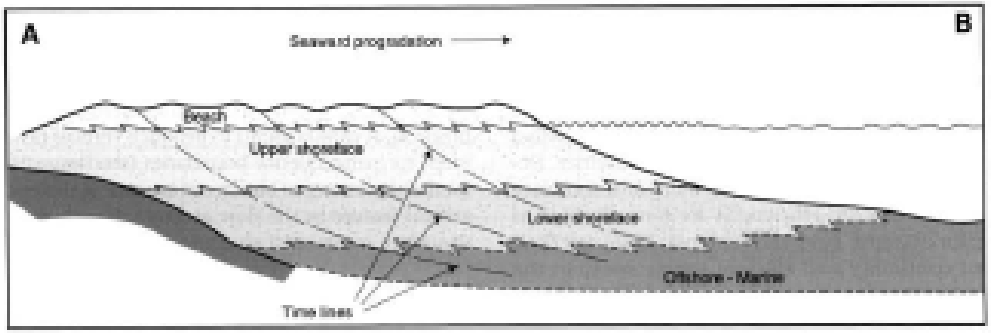
Eolian lithofacies associations include dune, interdune, fluvial, and sabkha environments.

Shephard 2009

Reservoir rocks deposited in different environments have different size and geometry

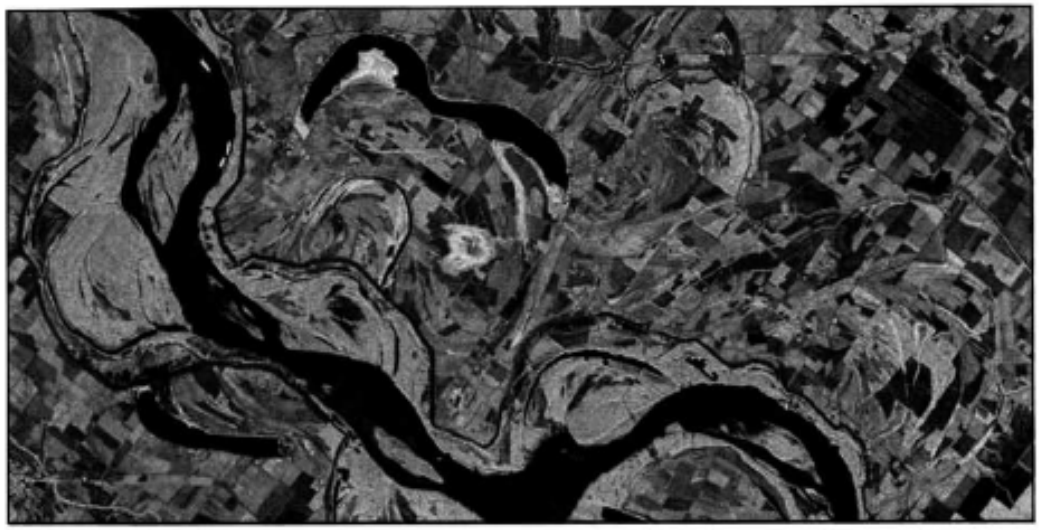


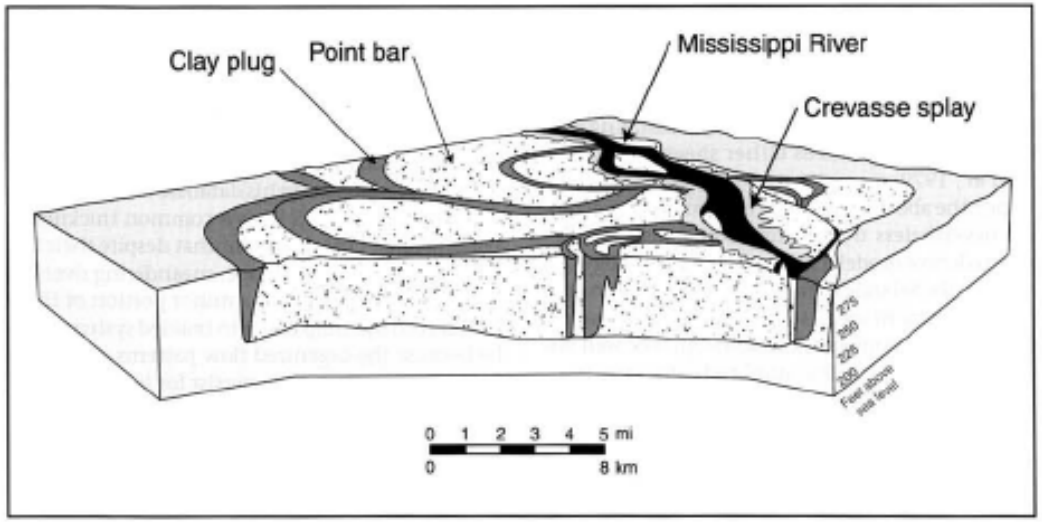
- Sand bodies deposited on the shore have elongated shape, show layer-cake geometry.



Shepherd 2009

Reservoirs in meander river deposits have labyrinthine form





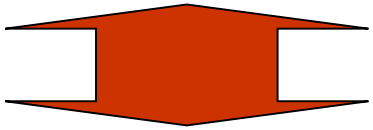
Shepherd 2009

Micropaleontology

(a widely used means of relative dating and correlating sedimentary rocks and sequences)

The **biostratigraphic correlation** of strata encountered in wells is based on microfossils, spora and pollens.

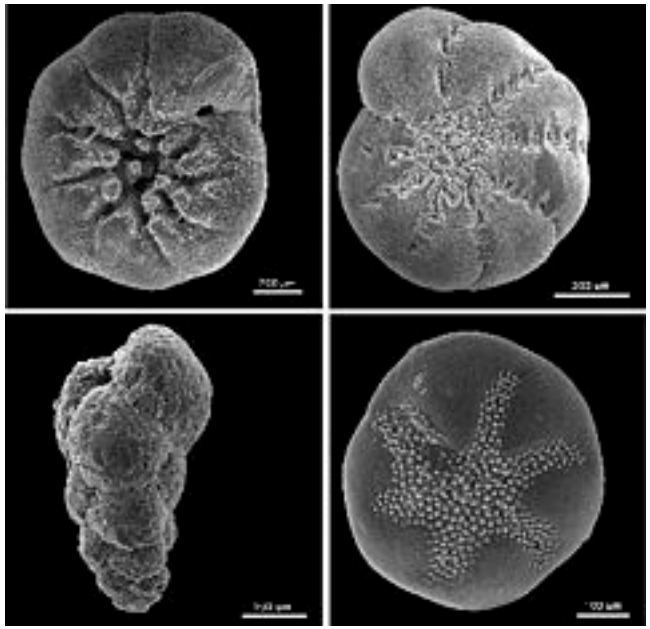
In cuttings or even in core samples the chance of finding macrofossils is poor.



By contrast a few grams of rock from the drill cuttings may contain several hundred microfossils, palynomorphs.

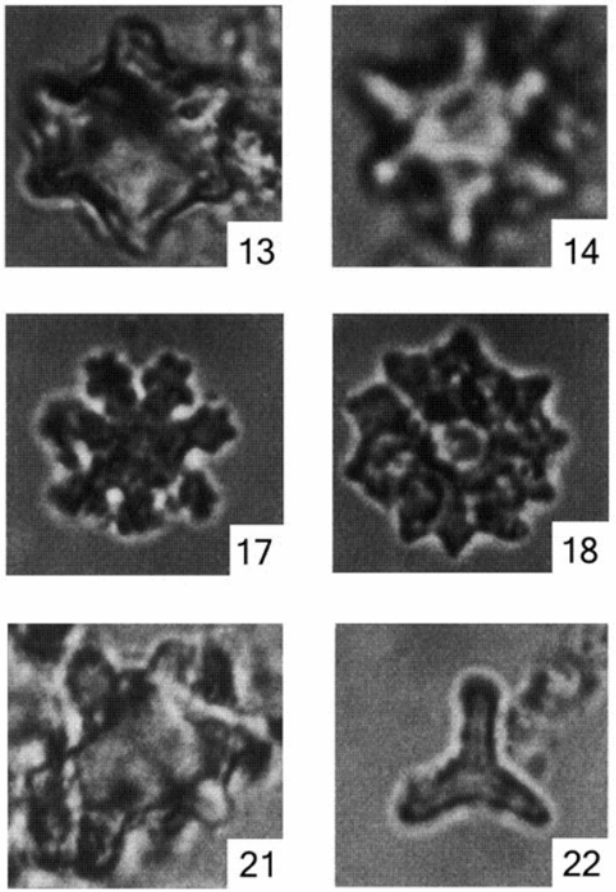
These provide better stratigraphic resolution than macrofossils.

foraminifera

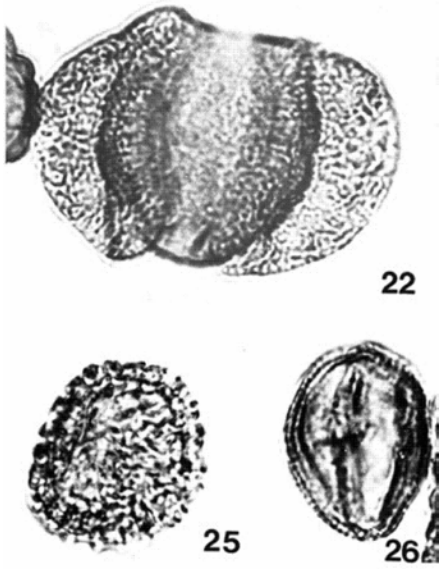




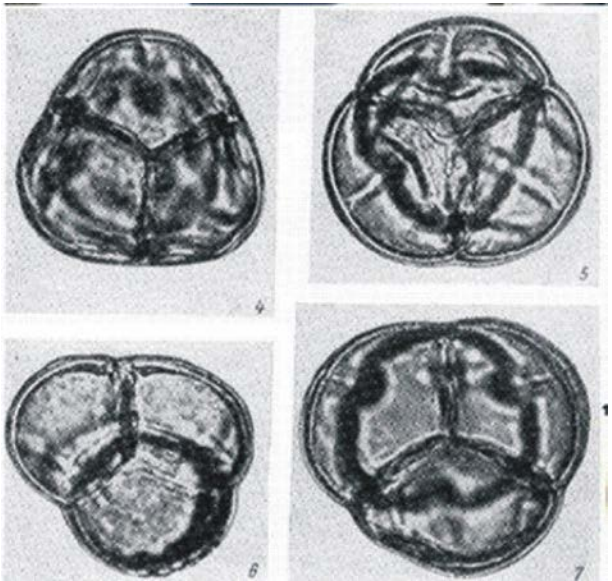
nannoplacton



spora



pollen



Organic geochemistry

- includes the study of organic matter in sediments and its **transformation** into hydrocarbons.

- Correlation of source rock with hydrocarbon.

Tectonics and structural geology

provide an **understanding** of the
- processes of deformation of the subsurface,
- subsidence, **folding** and **uplift** of our basin.
Tectonic events are responsible for the creation and dynamic history of a basin.
The timing of the folding and faulting that forms structural traps is very important in relation to the migration of hydrocarbons
.

Seismic methods

have become the **main tool** for **mapping sedimentary facies, stratigraphy, sequence stratigraphy** and **tectonic development**.

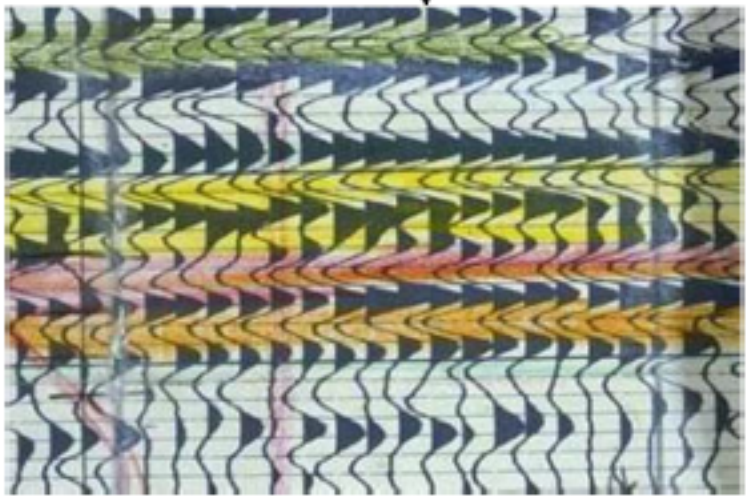
Geological interpretation of seismic data has become a new and expanding field.

Seismic and other geophysical data are often the only information we have, particularly for offshore exploration where drilling is very costly.

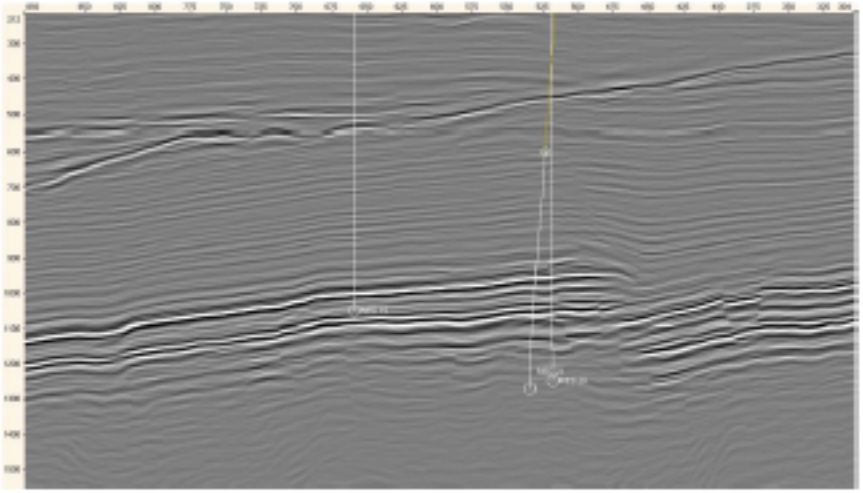
Seismic is a method which can show us the structure of the underground:

- We generate acoustic wave on the Earth surface (e.g.) dynamite is exploded in a shallow well, or by vibration.
- This wave spread through the layers below us
- In the boundary of two layers some part of the wave are reflected
- In the surface we measure the reflected wave with a geophone.
-From our measurement we could assume the stratification of the underground
-With the manipulation of the recorded waves we can detect gas reservoirs, facies distribution etc.

Seismic Trace



Variable Density Display



Closeup of seismic reflections or 'amplitudes' generated at the interface of stratal boundaries.

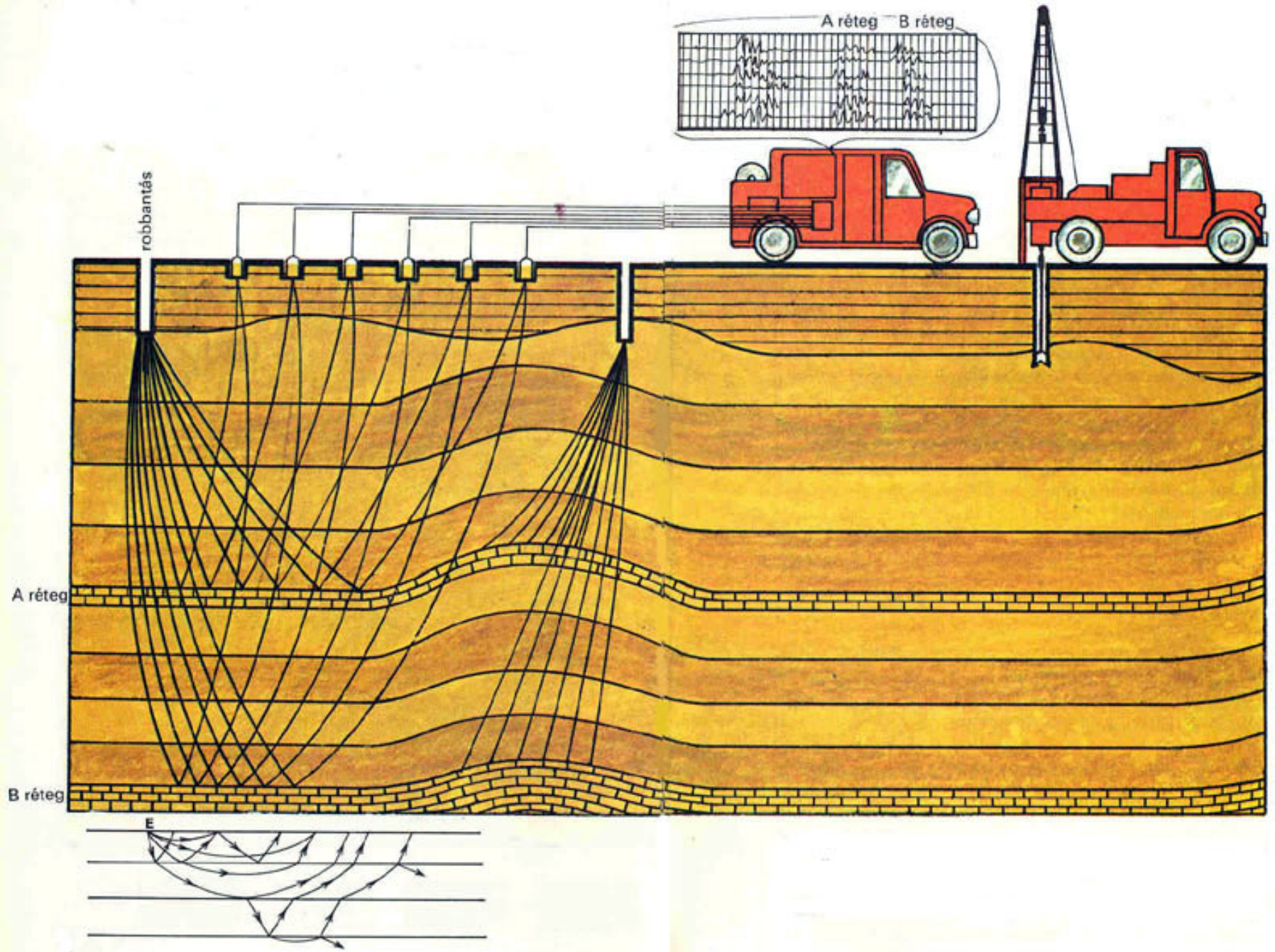
Each vertical line is called a seismic trace. In this case, the further the amplitude peak occurs away from the vertical base line, the stronger the reflection energy (the higher the amplitude) was of that stratal boundary.

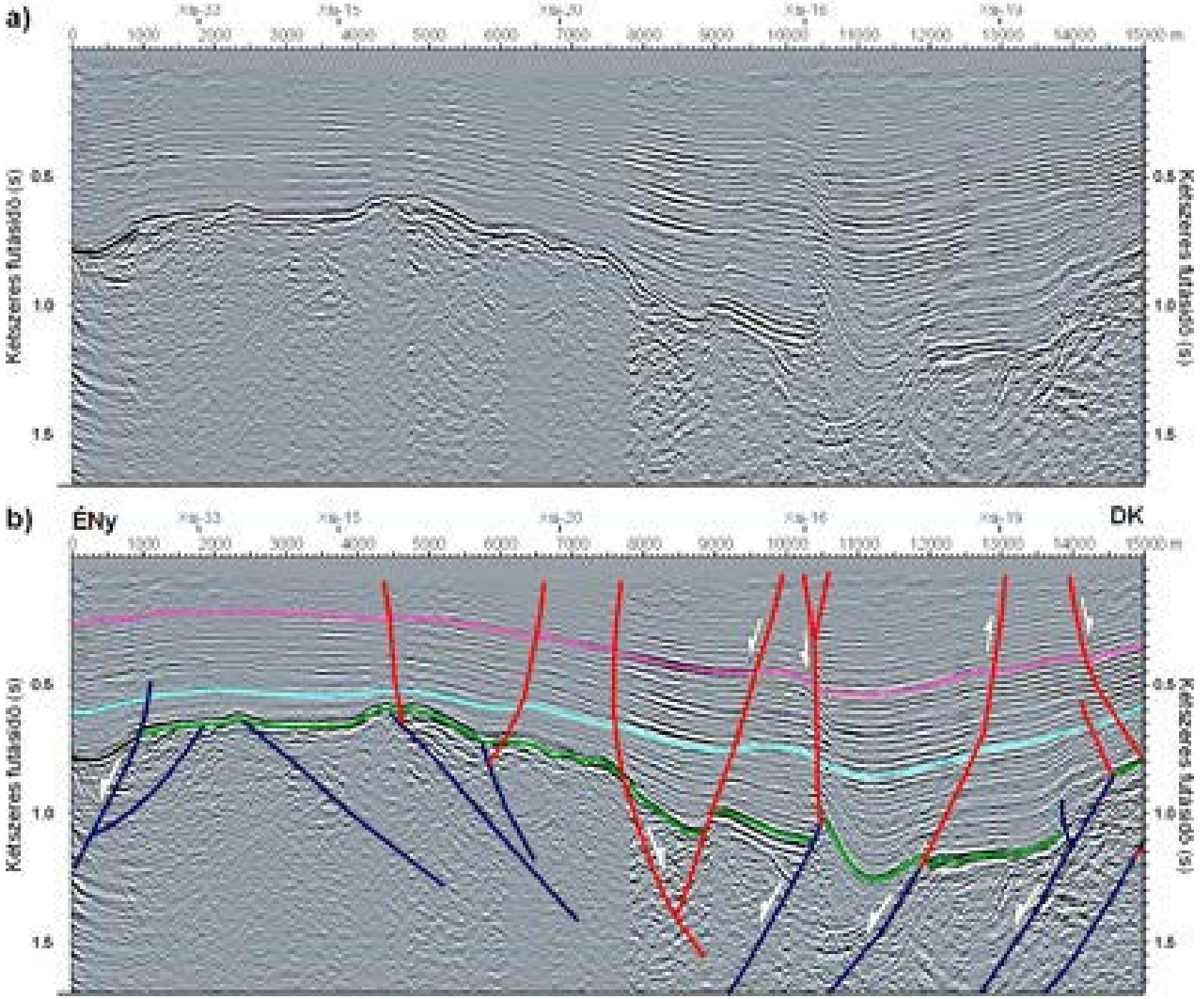
Depth scale in TWT (two-way travel time) → information on interval velocities is used to convert TWT into depth.

In former days seismic information was mainly used to define (trap) geometry. Today (3D) seismic data sets yield information on

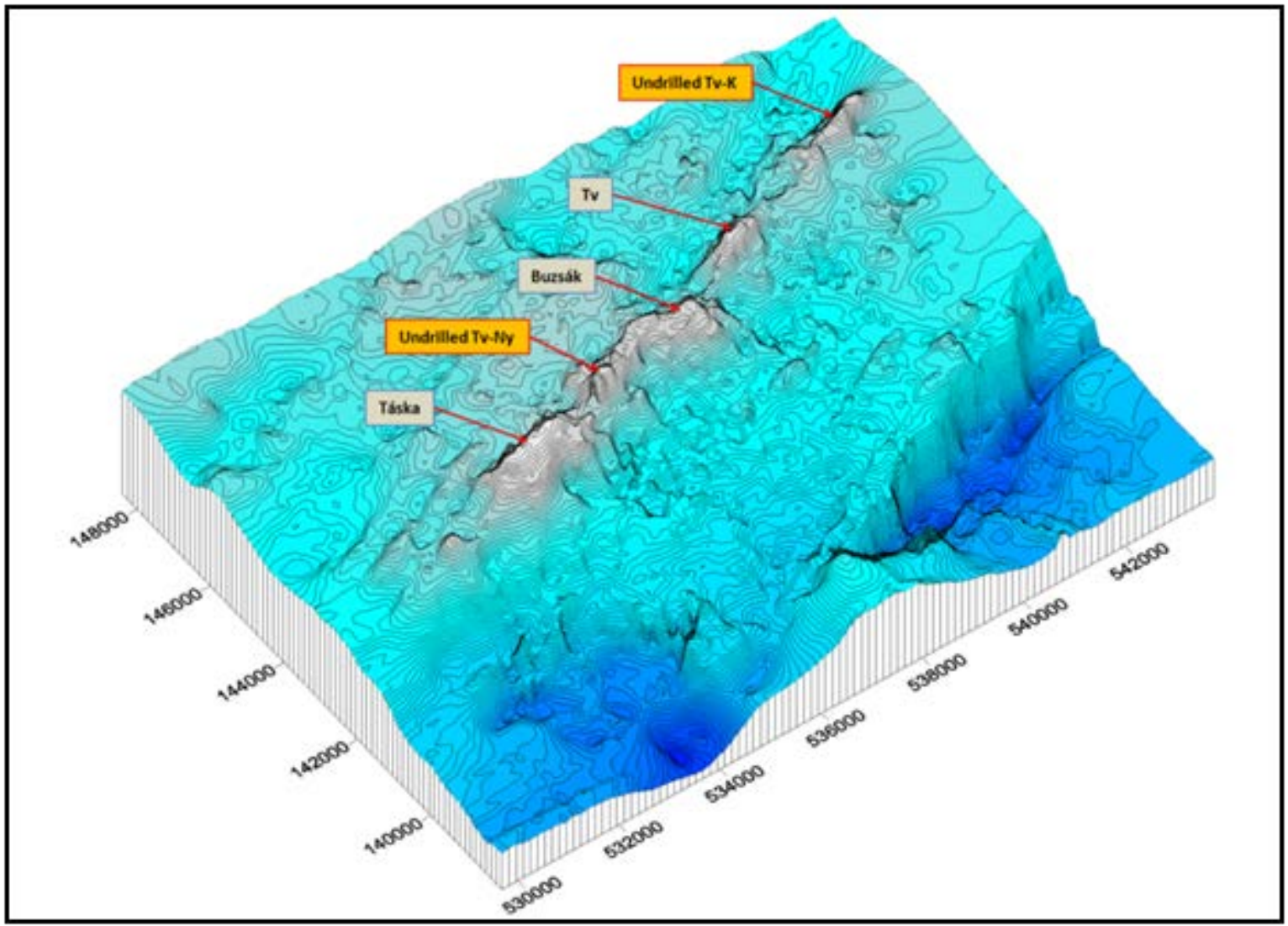
- lithology,
- fluid type,
- porosity.

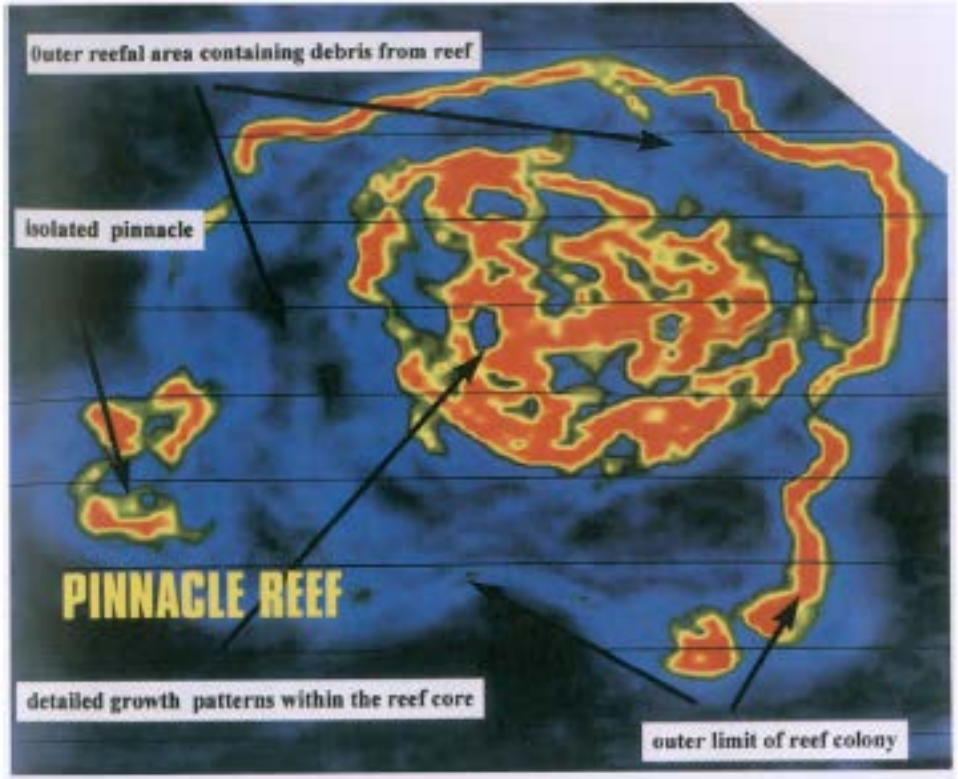
Sachsenhofer 2017

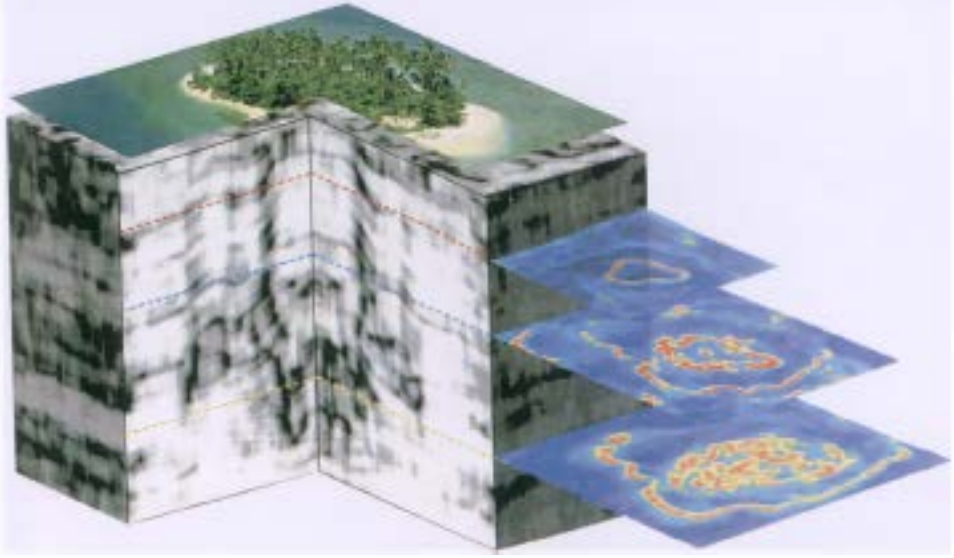

A réteg
B réteg
robbantás
A réteg
B réteg
E


a)
b)
ÉNy
DK
Kétszeres futásidő (s)
0.5
1.0
1.5
0
5000
10000
15000 m

Basement morphology of a given time



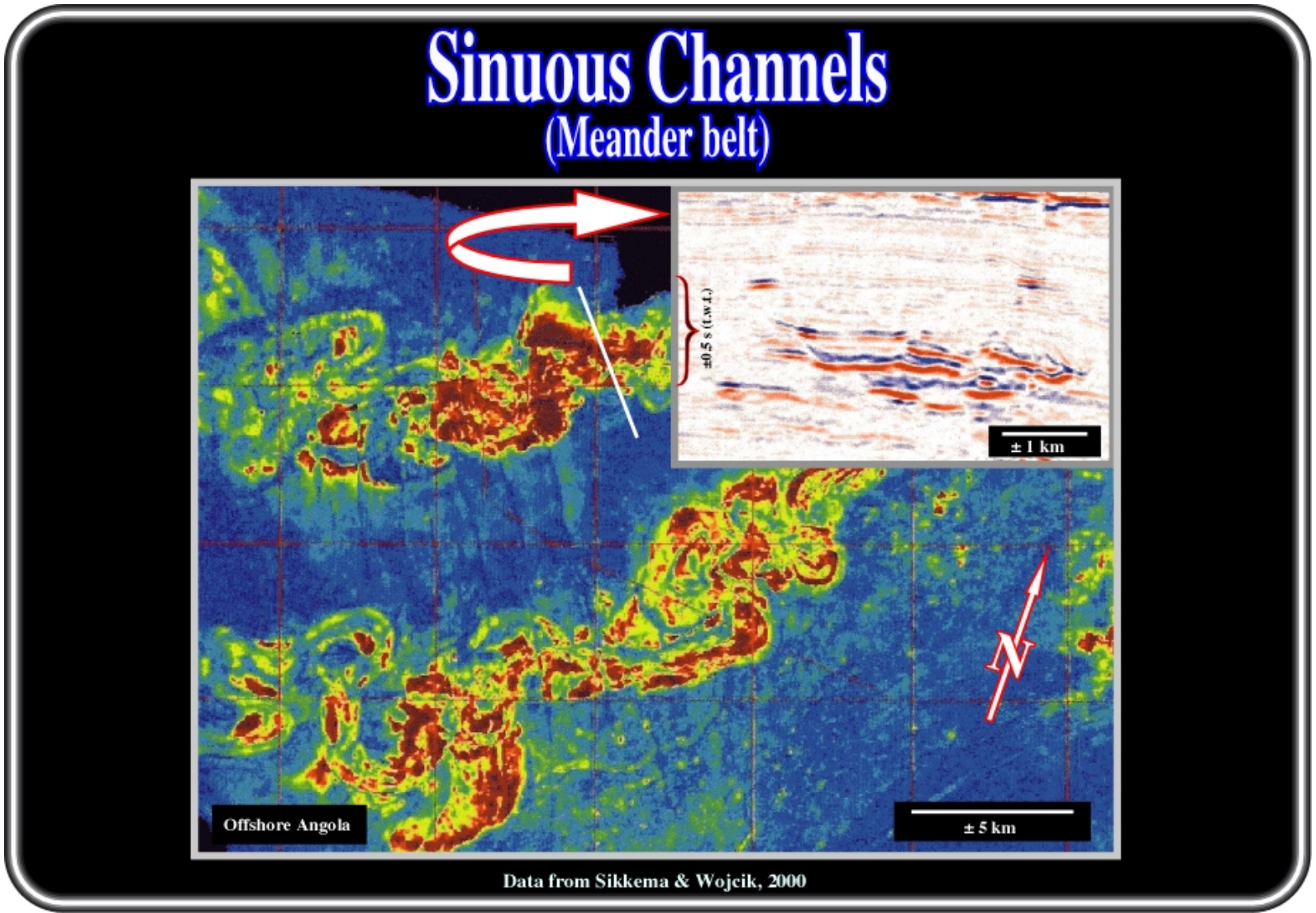


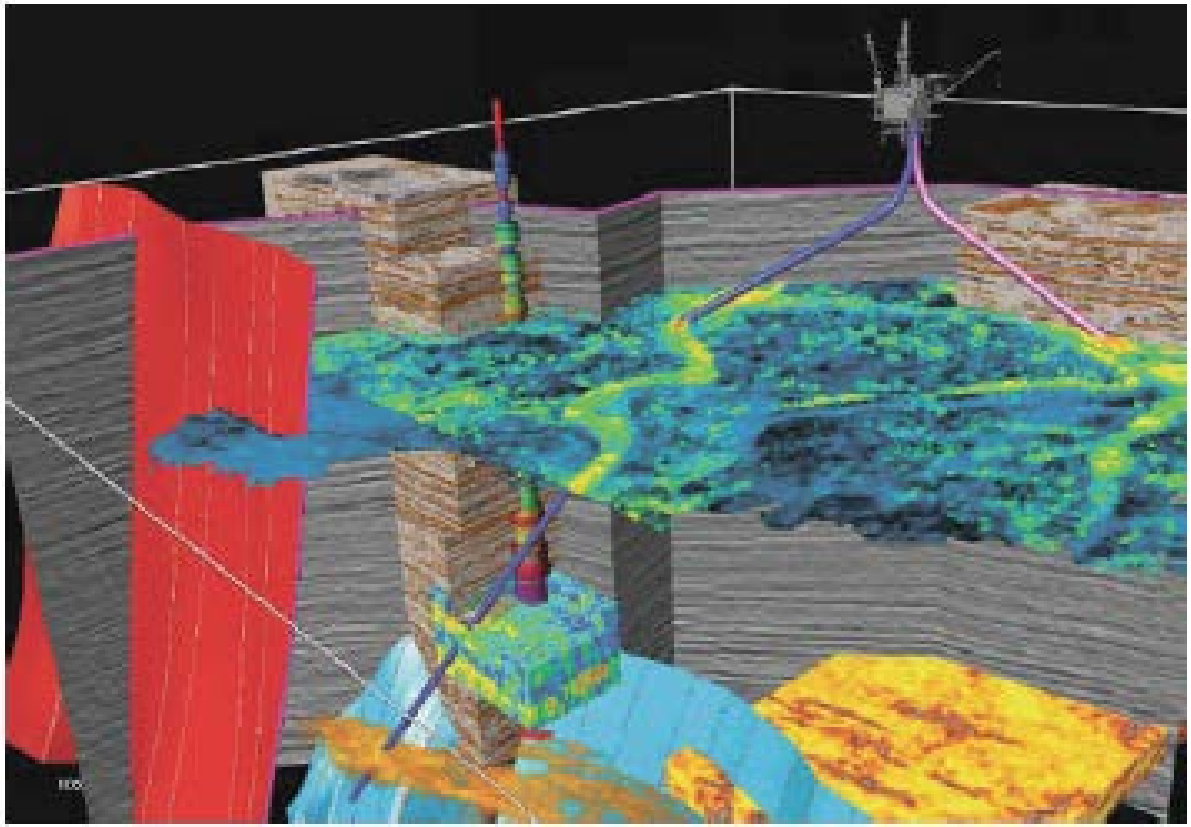


- Time slice
- Displays the reflections from a given depth level.
- Shows a „map” of the geology at a constant depth

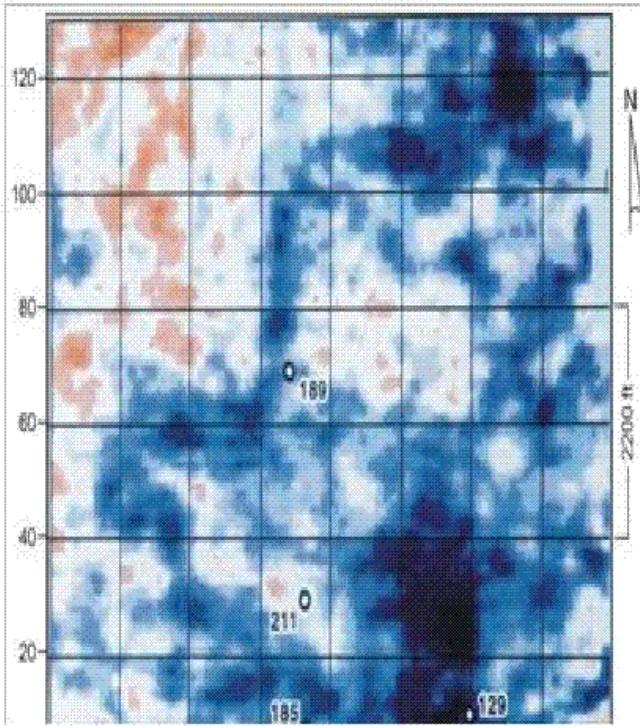
Limestone reef imaged by 3 D seismic, and geophantasmogram.
These images were produced by Coherence cube technology.
Selley & Sonnenberg 2015

Time slice


Sinuous Channels
(Meander belt)
±0.5 s (t.w.t.)
± 1 km
N
Offshore Angola
± 5 km
Data from Sikkema & Wojcik, 2000



Time slice



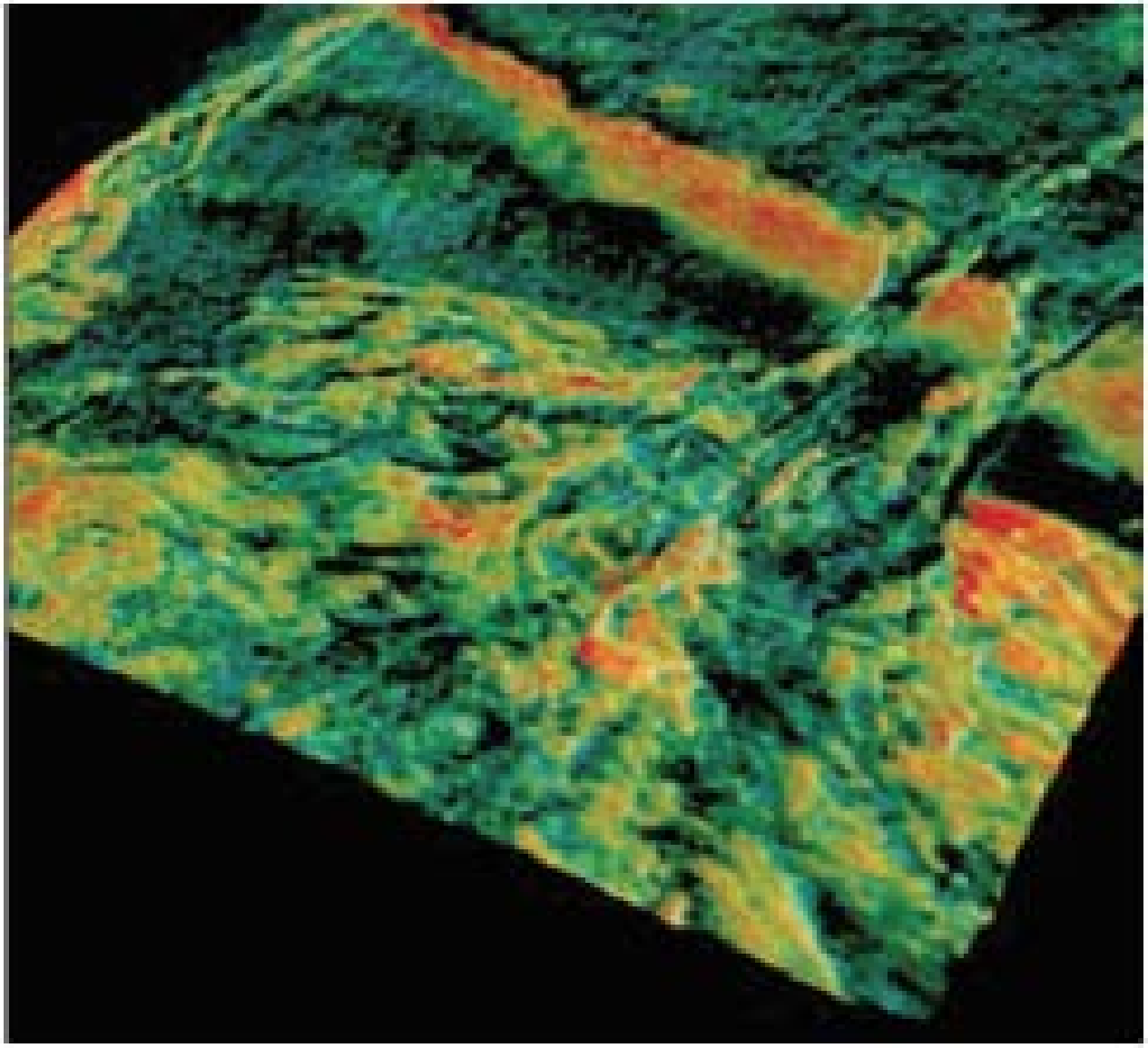
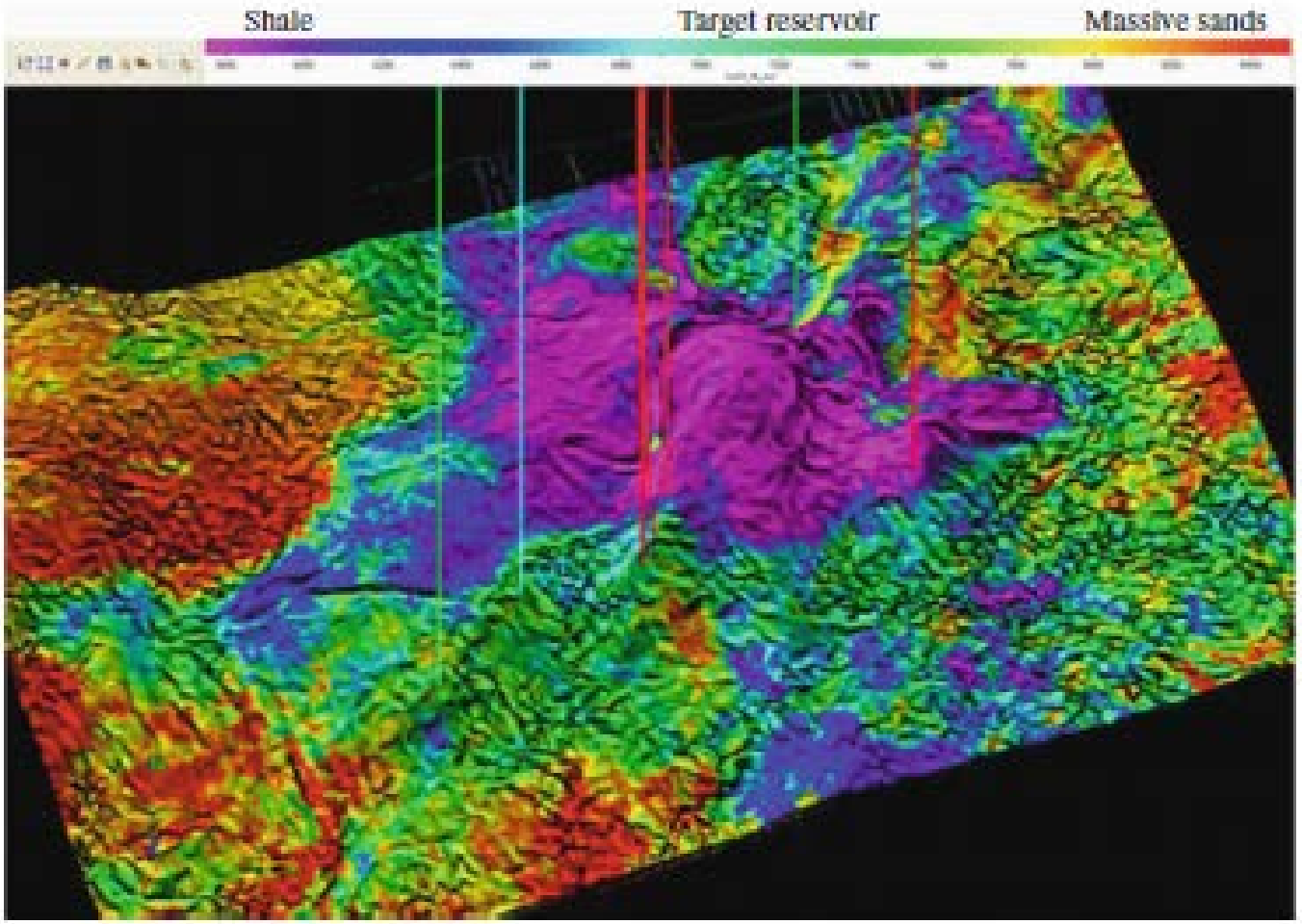


Fig. 17.32 Interpreted 3D seismic volume showing a channel fan complex with a shelf edge (Source: James 2009)



Lithology

Main reservoirs:

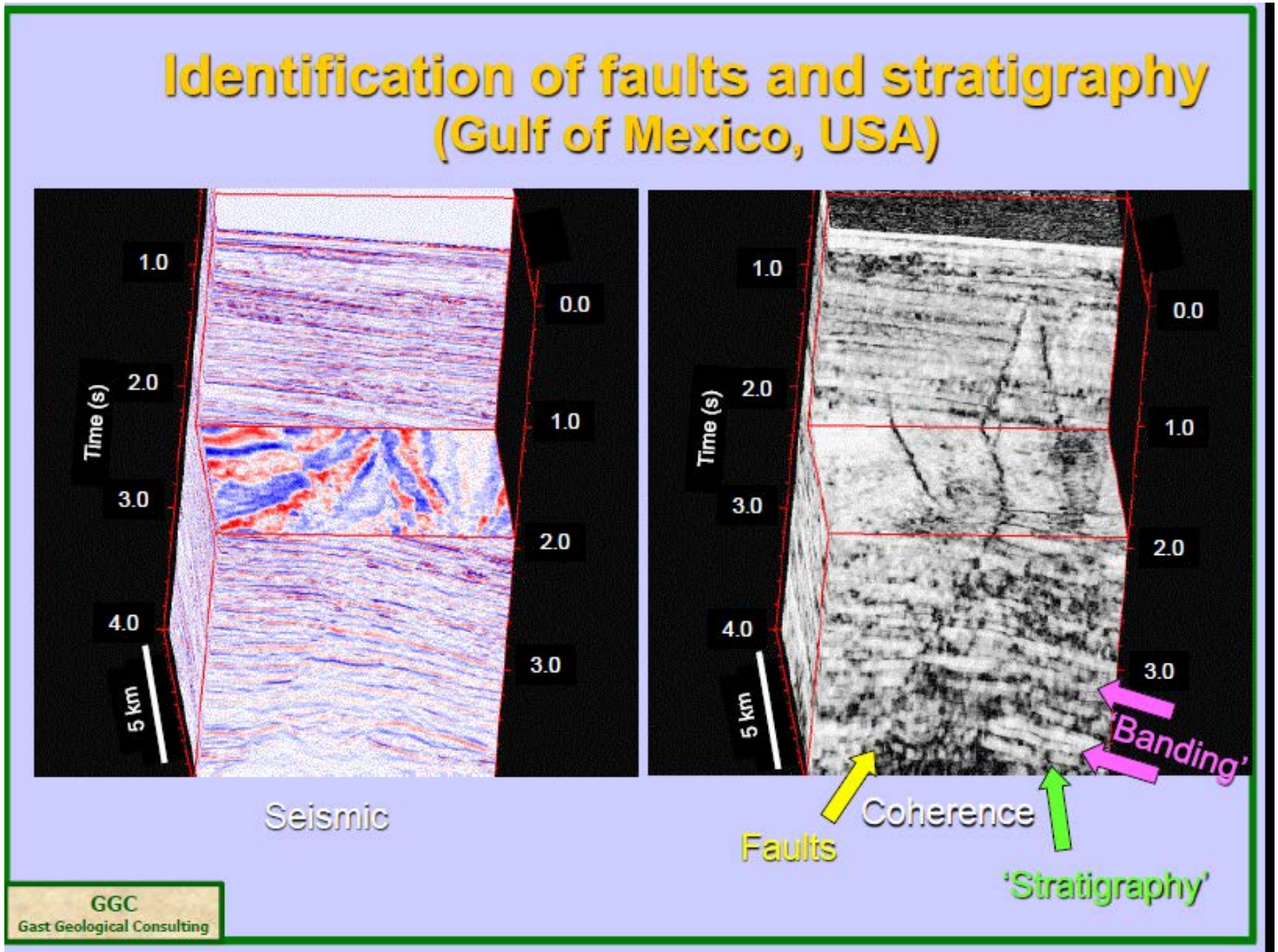
- green: sandstone, crosscutted with faults

Source rock:

- violet coloured: organic rich shale

Coherence

comparing the reflexions from two adjacent points



Seismic Processing Methods

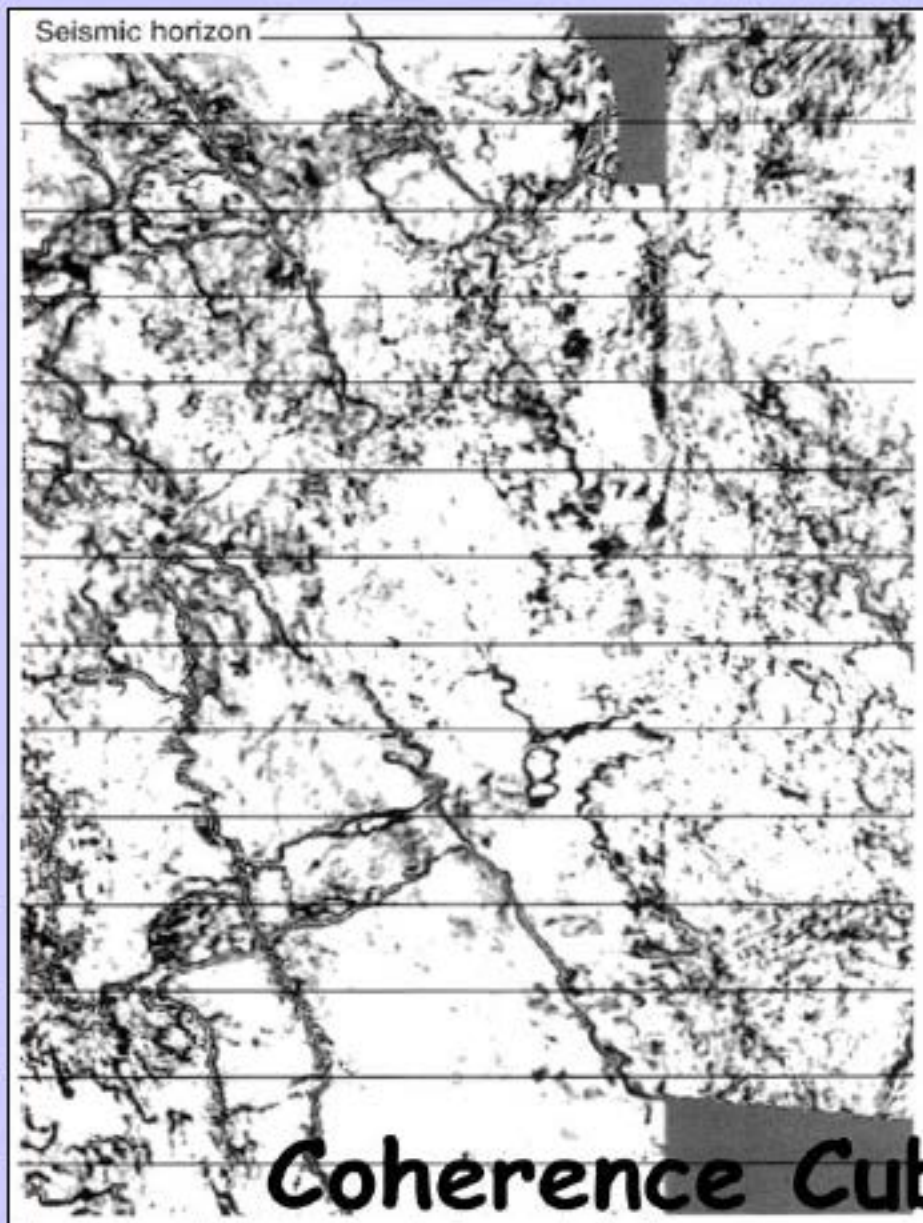


Fig. 3. Interpreted horizon map, showing complex faulting.

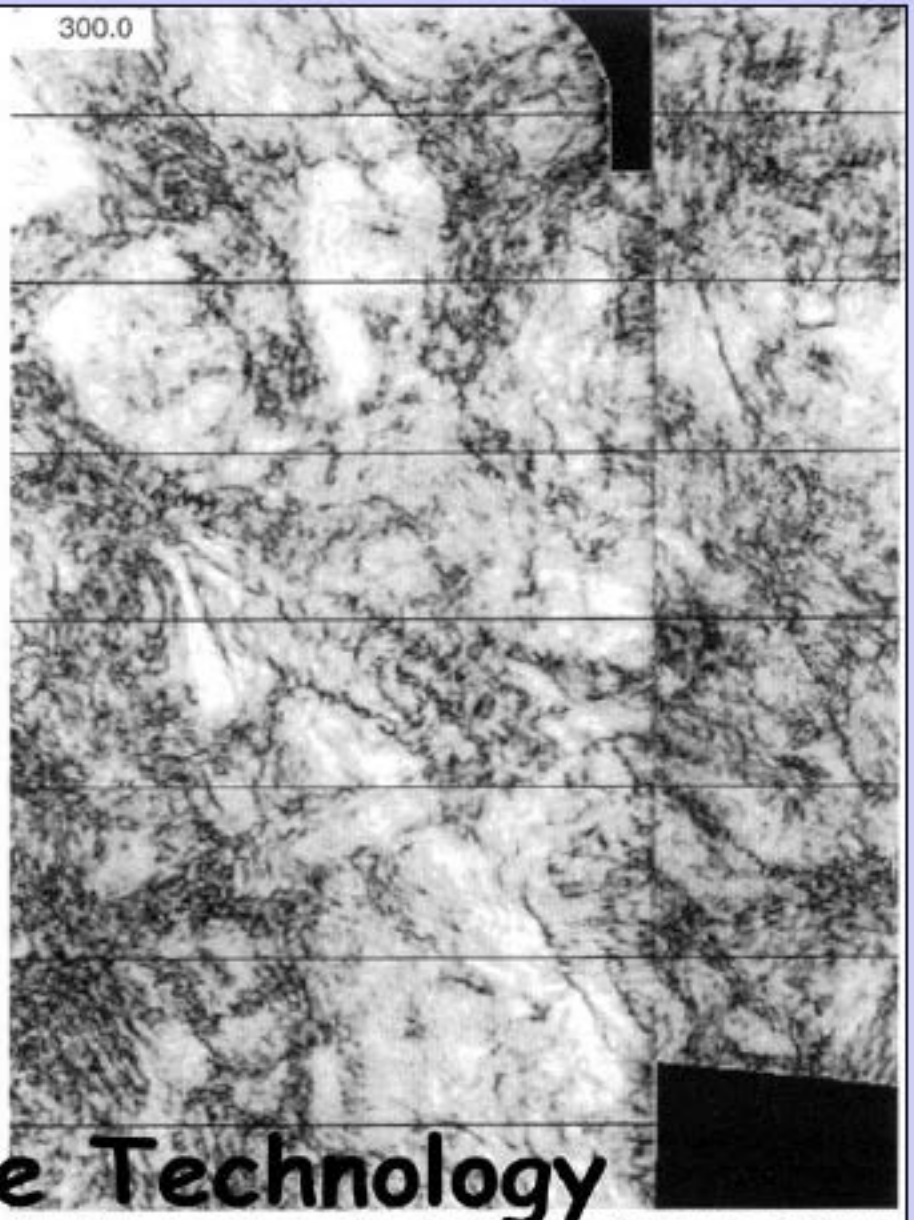
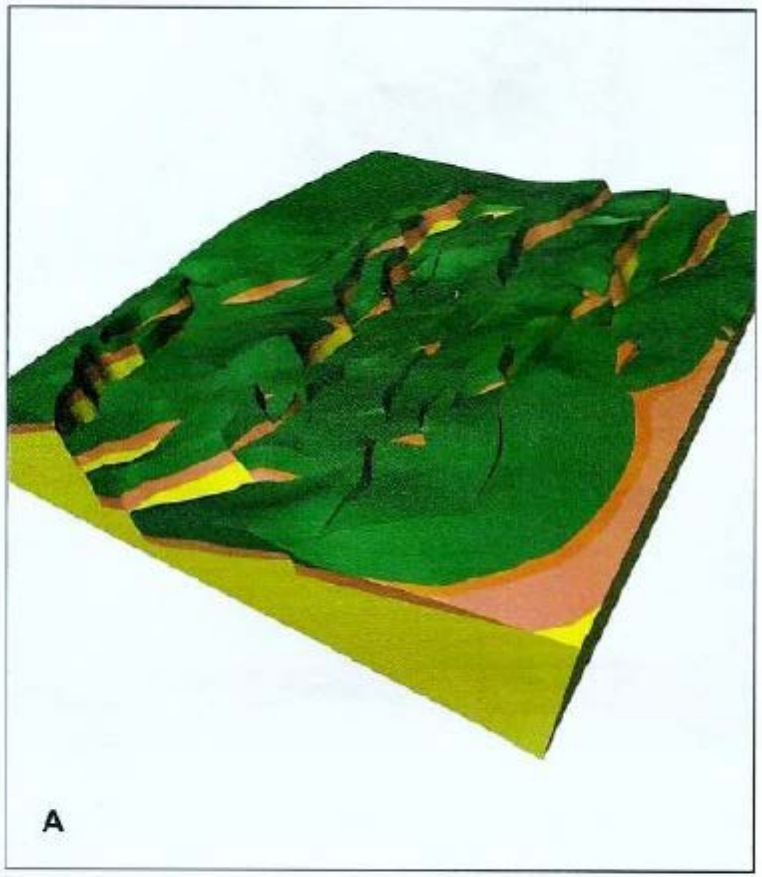


Fig. 4. Coherence cube timeslice, showing complex fault trends, significantly upgrading conventional interpretation.

Coherence Cube Technology

Faults



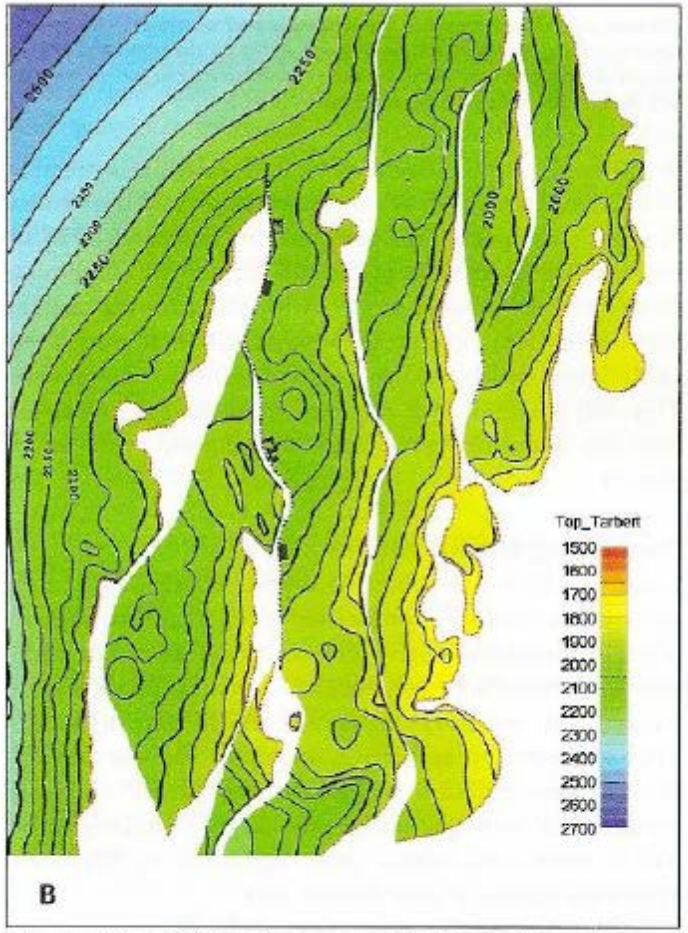


Figure 5 Block model (5a) and contour map (5b) of the Gullfaks area, Norway, showing complex faulting with both fault geometries and horizon-fault intersections precisely modelled. Image courtesy of Roxar.

Hydrocarbon indicator: bright spot, flat spot, AVO

Bright spot results from the increase in acoustic impedance contrast when a hydrocarbon (with a lower acoustic impedance) replaces the brine-saturated zone (with a higher acoustic impedance) that underlies a shale (with a higher acoustic impedance still), increasing the reflection coefficient.

Hydrocarbon Indicator: Bright spot, Flat spot, AVO

- Bright Spot: Amplitude anomaly caused by a large gas reservoir.
- Up to depth of 3 km, the addition of gas in sandstone results in a decrease in velocity and density.
- Works best in young, shallow reservoirs.
- **Not all bright spots are caused by the presence of hydrocarbons! Evaporite and coal can appear on seismic as bright spot as well.**

Seismic Processing Methods

Let's look at two examples:

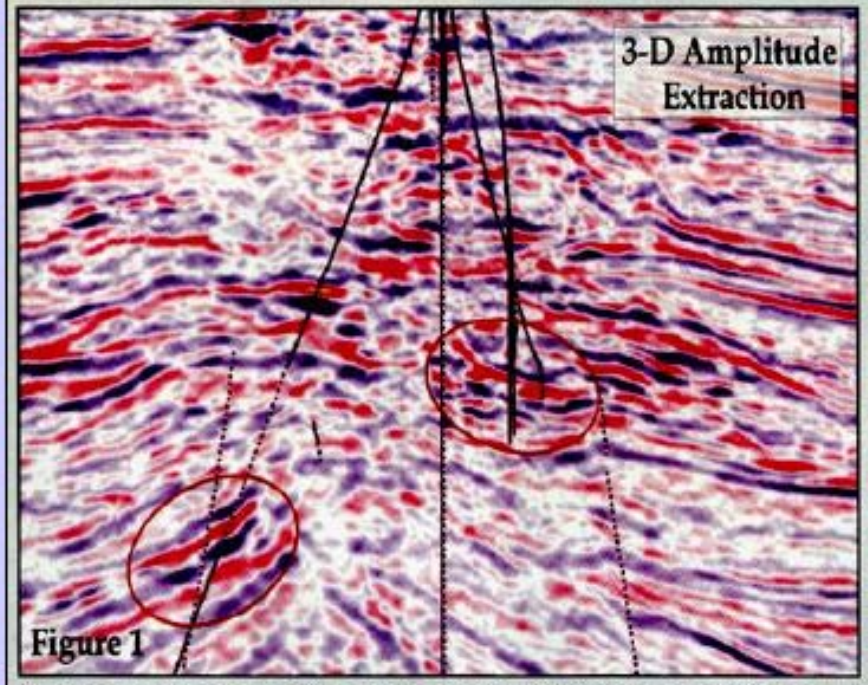
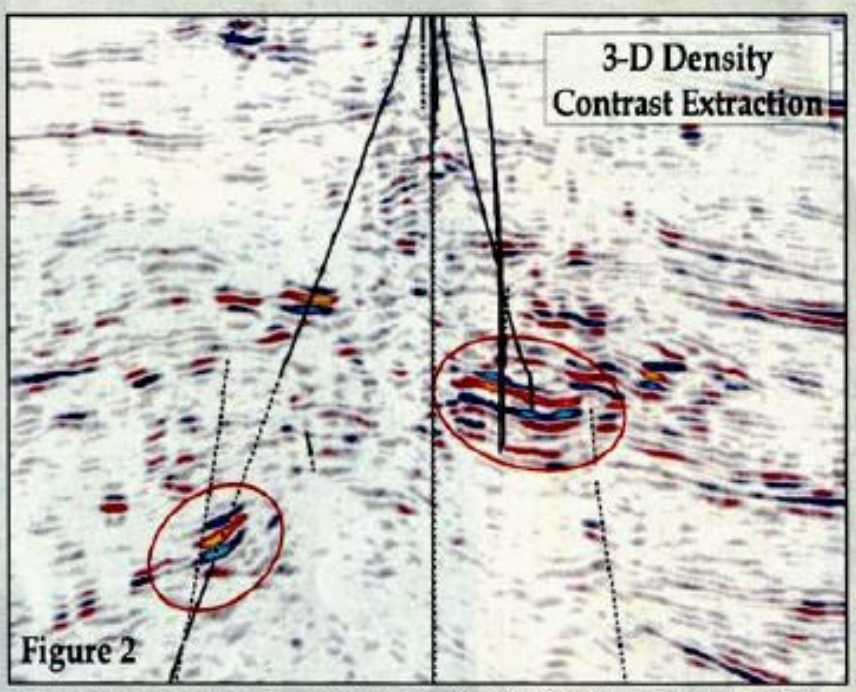
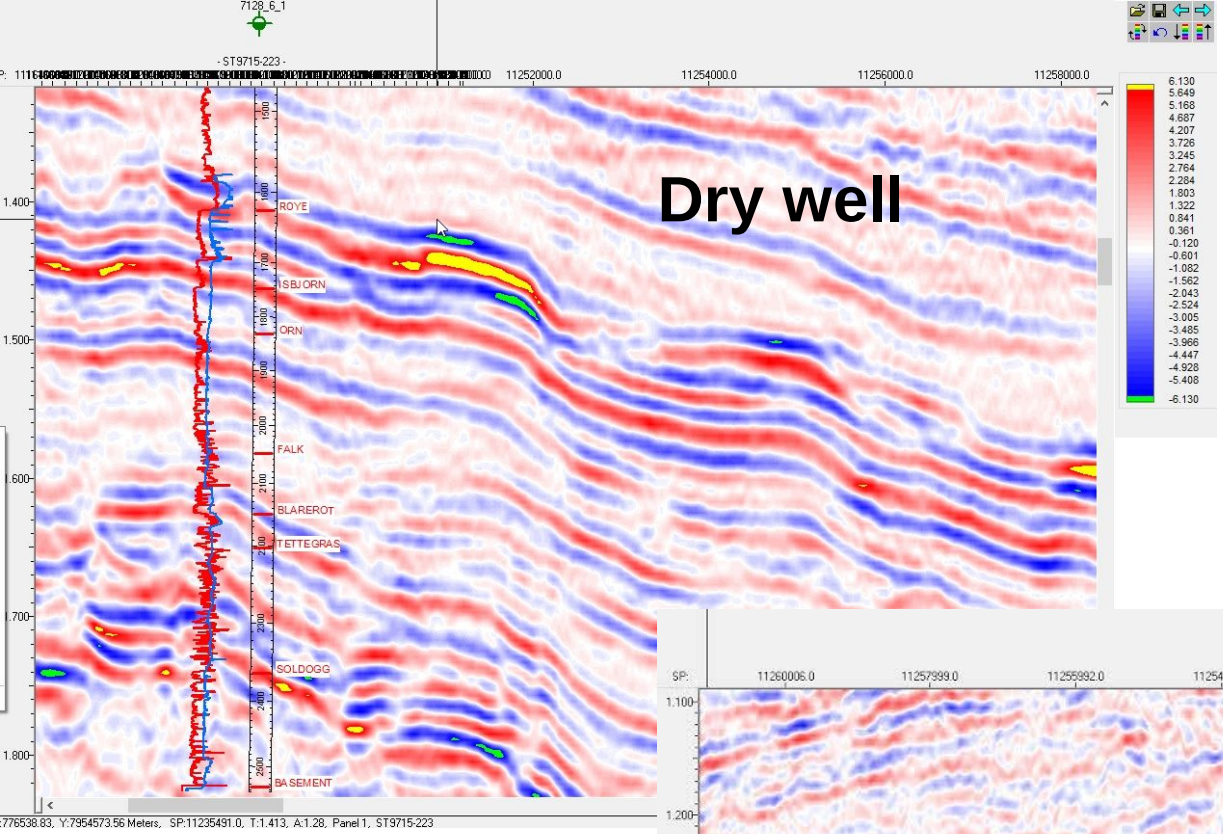
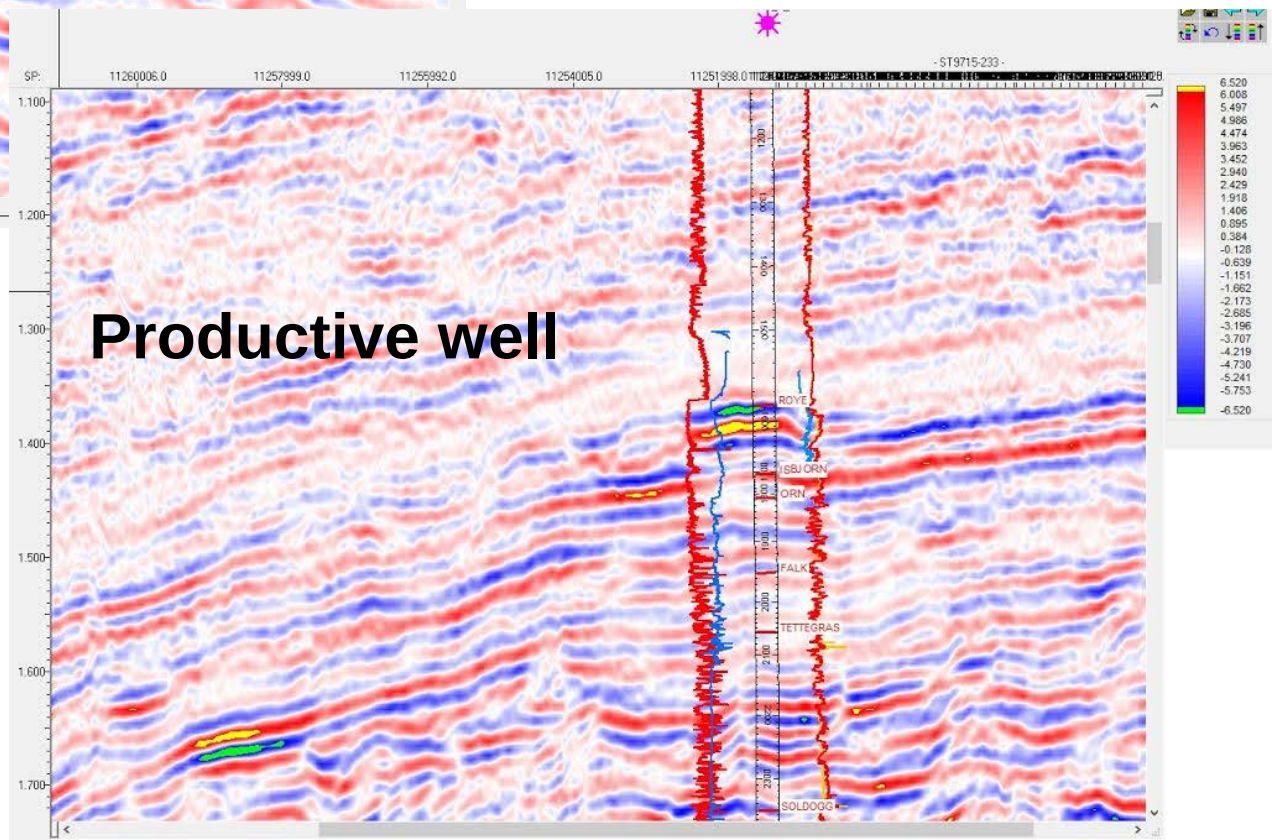


Figure 1 shows a conventional 3-D seismic profile in which we've circled events that are associated with non-bright pay. Notice there are no distinct brightness variations around these pay zones relative to the surrounding area.



Compare this same profile to the 3-D Density Contrast Extraction in Figure 2. As you can see, these pay zones have an associated density anomaly on the Density Contrast extraction, not evident in Figure 1.


Dry well
7128_6_1
- ST9715-223 -
11252000.0
11254000.0
11256000.0
11258000.0
ROYE
ISBJORN
ORN
FALK
BLAREROT
TETTEGRAS
SOLDOGG
BASEMENT
6.130
5.649
5.168
4.687
4.207
3.726
3.245
2.764
2.284
1.803
1.322
0.841
0.361
-0.120
-0.601
-1.082
-1.562
-2.043
-2.524
-3.005
-3.485
-3.966
-4.447
-4.928
-5.408
-6.130
776538.83, Y:7954573.56 Meters, SP:11235491.0, T:1.413, A:1.28, Panel 1, ST9715-223

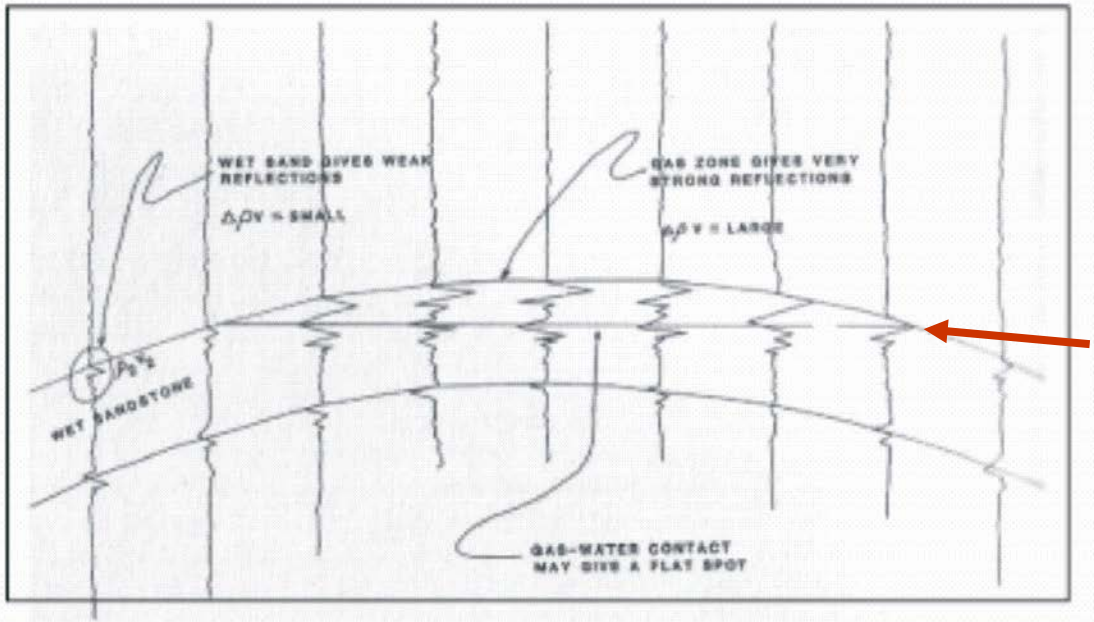

Productive well
SP:
11260006.0
11257999.0
11255992.0
11254005.0
11251998.0
- ST9715-233 -
ROYE
ISBJORN
ORN
FALK
TETTEGRAS
SOLDOGG
6.520
6.008
5.497
4.986
4.474
3.963
3.452
2.940
2.429
1.918
1.406
0.895
0.384
-0.128
-0.639
-1.151
-1.662
-2.173
-2.685
-3.196
-3.707
-4.219
-4.730
-5.241
-5.753
-6.520

Bright Spot: Amplitude anomaly caused by a large gas reservoir.

Up to a depth of ~3 km, the addition of gas in a sandstone results in a decrease in velocity and density

→ increase in velocity and density contrast
→ high amplitude

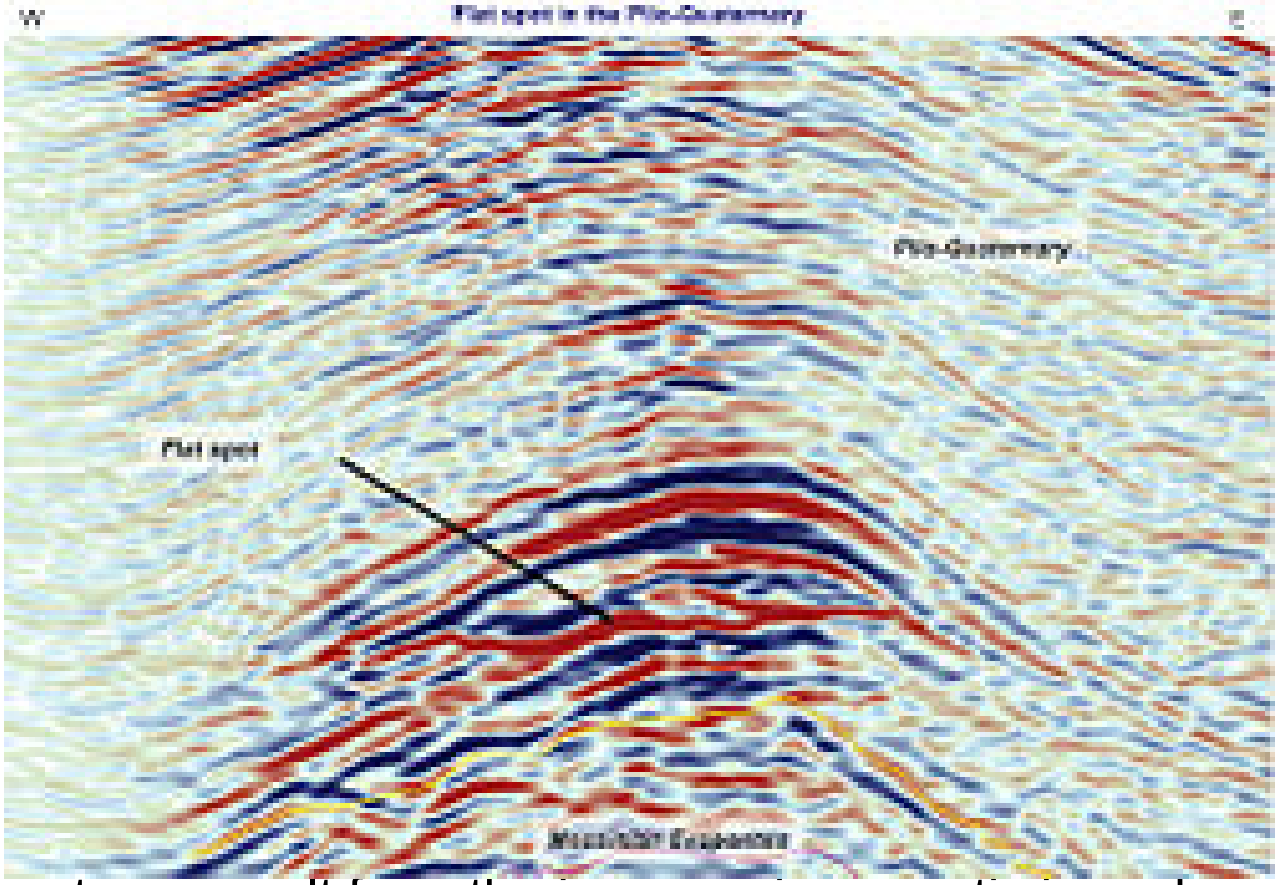
Gas-water contact may cause Flat Spot.



Schematic to show amplitude increase (bright spot) through gas-bearing part of the sandstone and flat spot caused by the gas-water contact (Laudon, 1996).

Flat spot: caused by huge impedance contrast.
The boundary between gas/water is always horizontal.

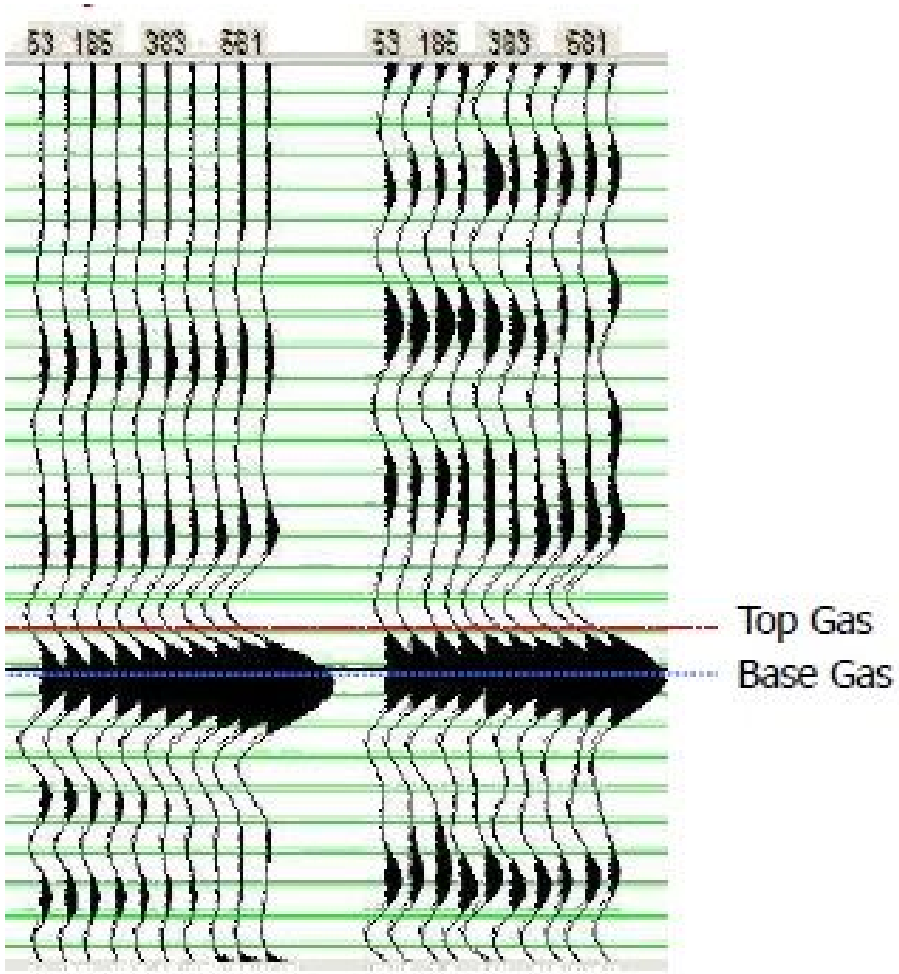
Hydrocarbon indicator: bright spot, flat spot, AVO



- A flat spot can result from the increase in acoustic impedance when a gas-filled porous rock (with a lower acoustic impedance) overlies a liquid-filled porous rock (with a higher acoustic impedance). It may stand out on a seismic image because it is flat and will contrast with surrounding dipping reflections

Hydrocarbon indicator: bright spot, flat spot, AVO

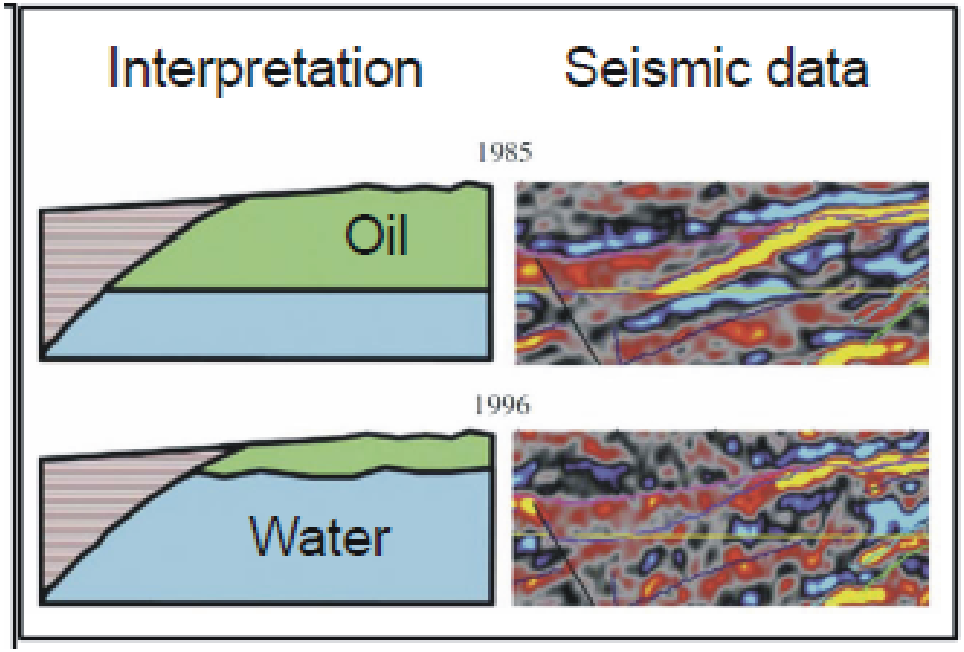
(Variation in seismic amplitude with change in distance between shotpoint and reciever)



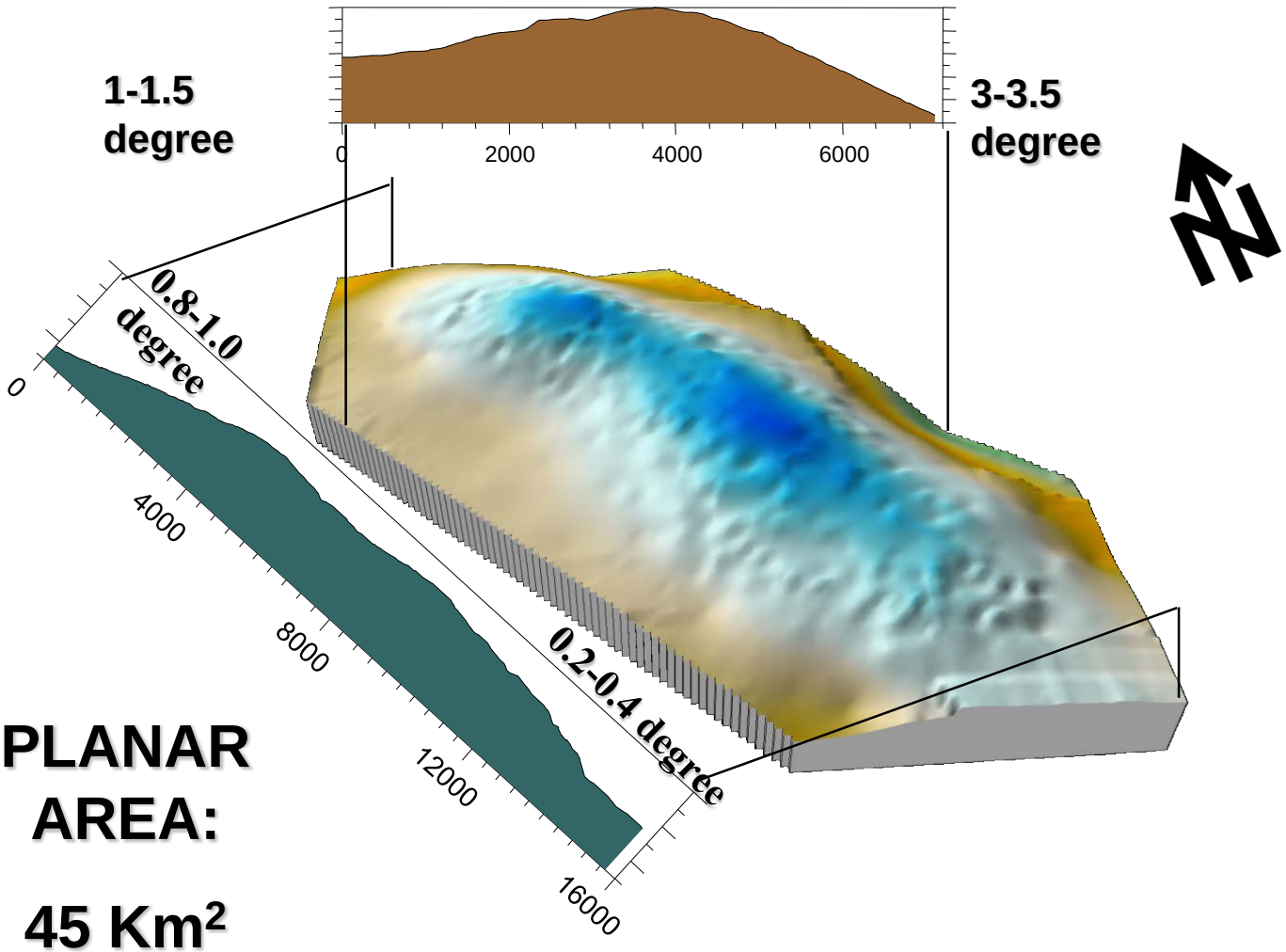
4D seismics

(repeated 3D seismic surveys; time-lapse seismic)

- allow fluid and rock changes to be monitored during field production.



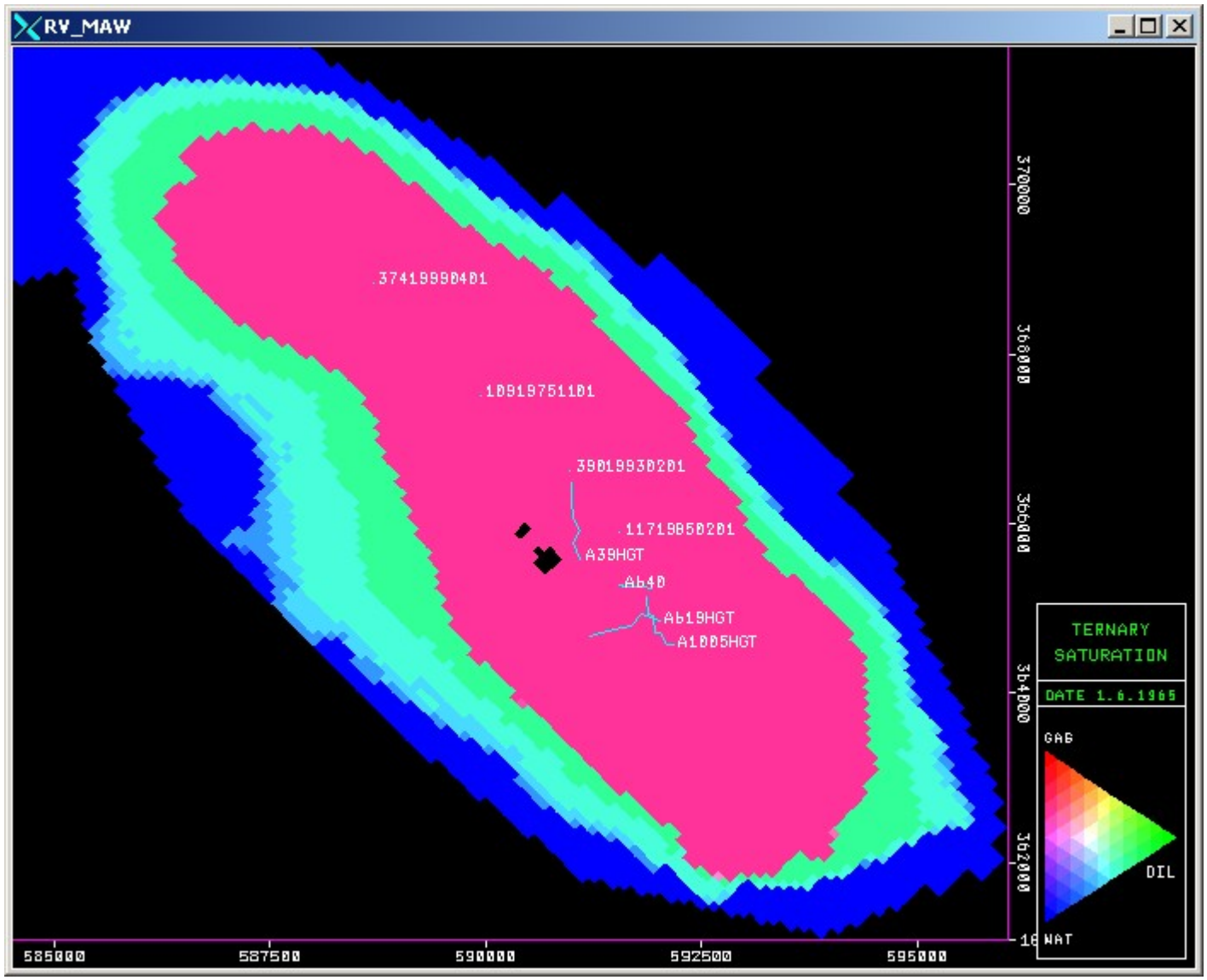
Static model



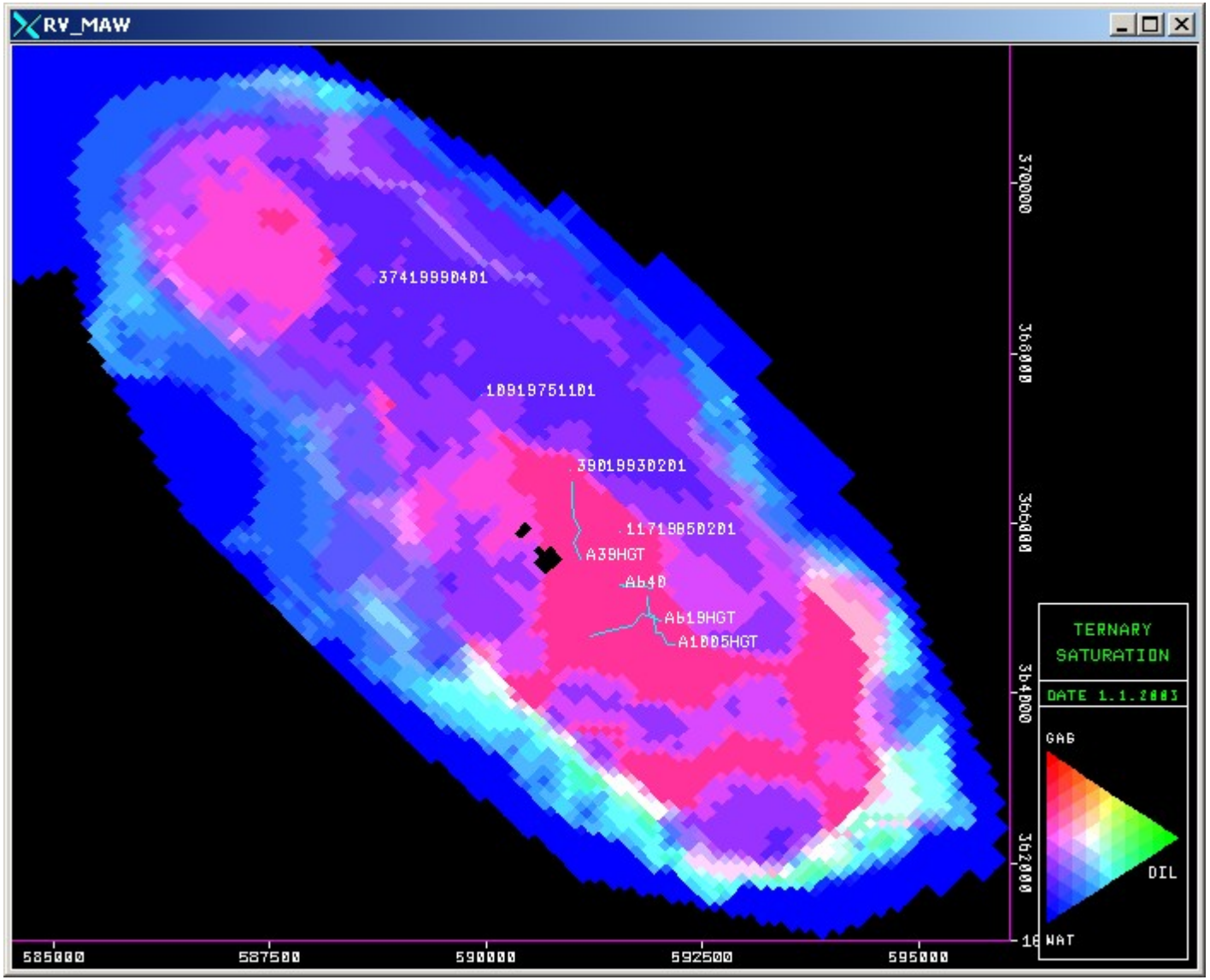
PLANAR AREA:

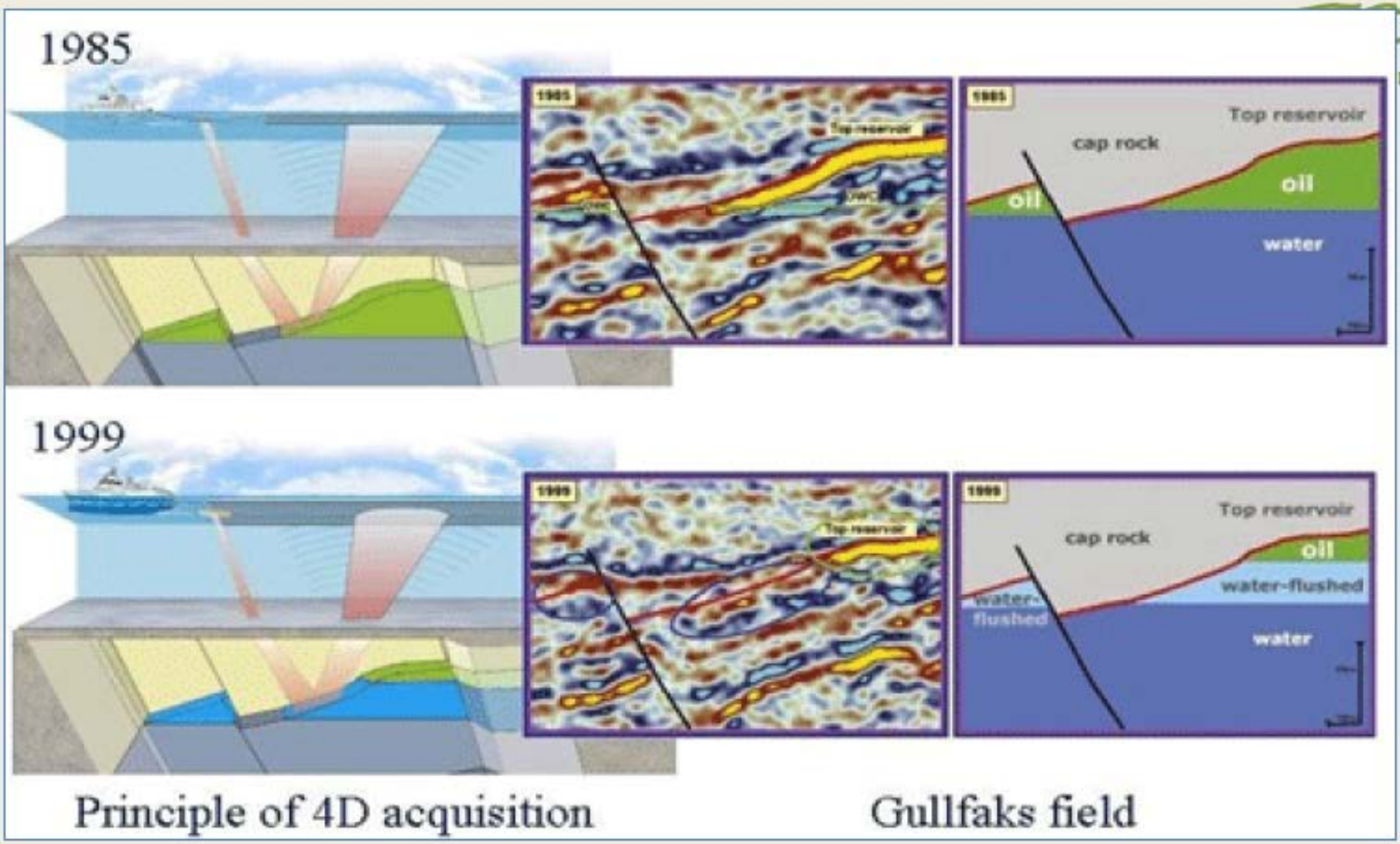
45 Km²

Dynamic model: initial saturation



Dynamic model: 35 years later





Prinsipp for og eksempel på 4D-seismikk. 4D seismic technology can thus be used to monitor variations caused by production and/or the injection of fluids and gas to improve recovery.