INTRODUCTION to AMPLITUDES

Since 2008 SoleGeo is focused on exploration in NORWAY providing geo-science consultancy services in the APA2008, APA2009 and the 20th round.
The objective is adding value in generating new leads and prospects using "Analogues" and ... **"Amplitudes and other seismic Attributes"**

APA=Awards in Predefined Areas
The APA system ensures that very large areas close to existing and planned infrastructure are available for industry. The APA2009 attracted applications from 44 companies for its mature parts of the Norwegian continental shelf (NCS). Awards will be announced early 2010.
(www.npd.no and www.regjeringen.no)

- « Exploration Revived » , NPF 2-day conference, March 2009, Bergen

- AAPG European Region Annual 2-day conference, November 2009 Paris-Malmaison, European Resources : Current status and perspectives

EBN : Harold de Haan, Fokko van Hulten, Berend Scheffers
« Inventory of Unconventional Hydrocarbons in the Netherlands »,
Shallow, Tight, Coal-Bed Methane, Shale and Basin Centered Gas.
Reference : TNO report 034-UT-2009-00774/B
http://www.ebn.nl/files/ebn_report_final_090909.pdf

AAPG European Region
Annual Conference,
November 2009
Rueil-Malmaison
European Resources : Current status and perspectives
....
Southern Permian Basin

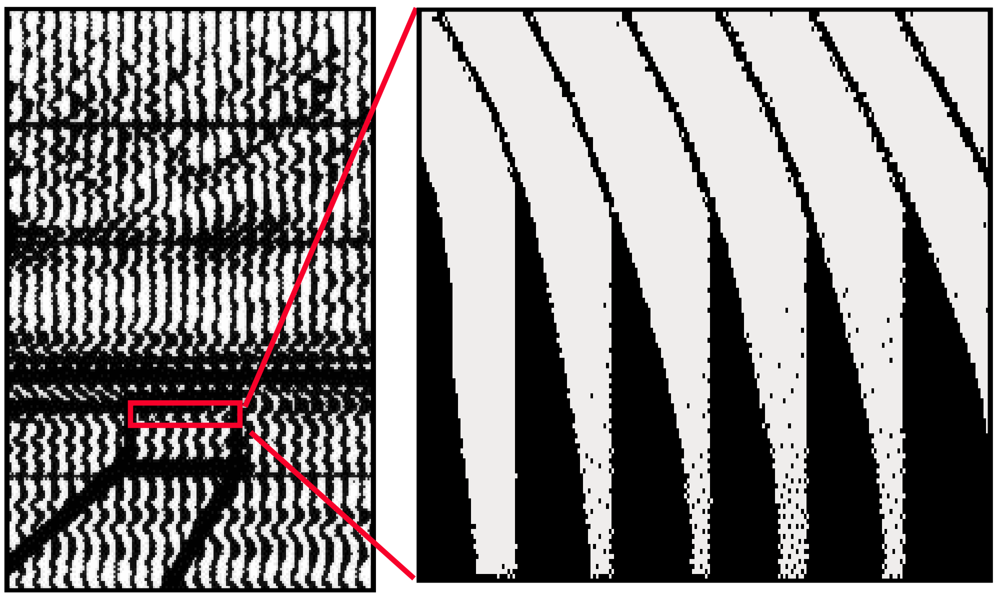
Geophysicist explaining Amplitudes ?

EBN and TNO preparing workshop Utrecht ?

Seismic Amplitudes

Measurements containing information about physical properties of the subsurface

2D - Surface Seismic Data



Challenge of today, More subtile traps, deeper as well, Thanks to better data and techniques that work

- Amplitude attributes , DHI, fluid detection, fluid (contact) mapping
- Stacking in seismic processing→stacking in interpretation: Spatial Stacking, CTD-Stacking, CCB Common Contour Binning
- Filtering (in F-K) domain → filtering in interpretation: Spectral Decomposition

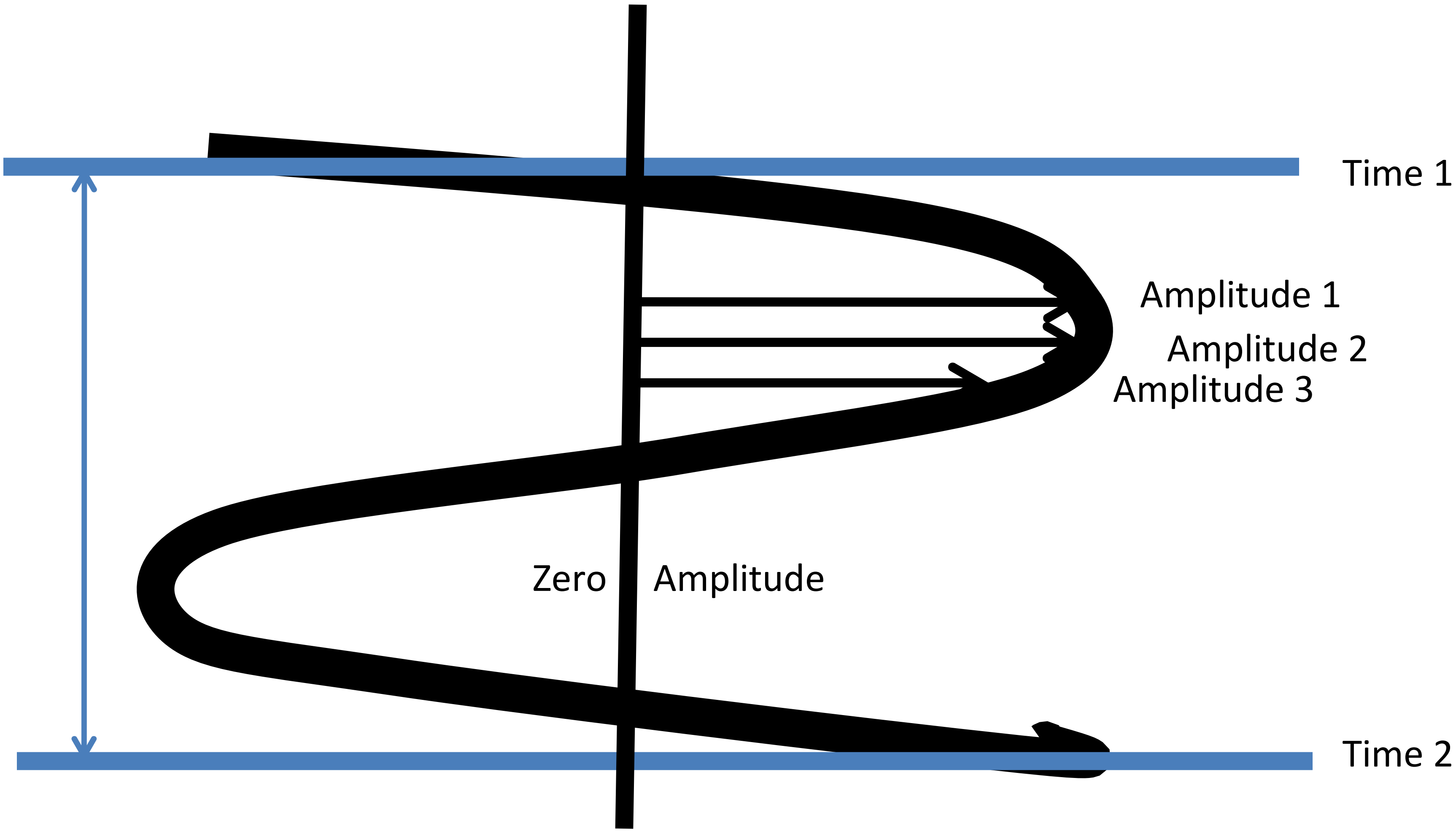
2D and 3D Seismic
Interpretation,
IFP school,
Ipoh, Malaysia 2007

Seismic Reservoir
Analysis,
Next-Schlumberger
training,
Bandung , Indonesia
2007

Rueil-Malmaison, 13 January 2010

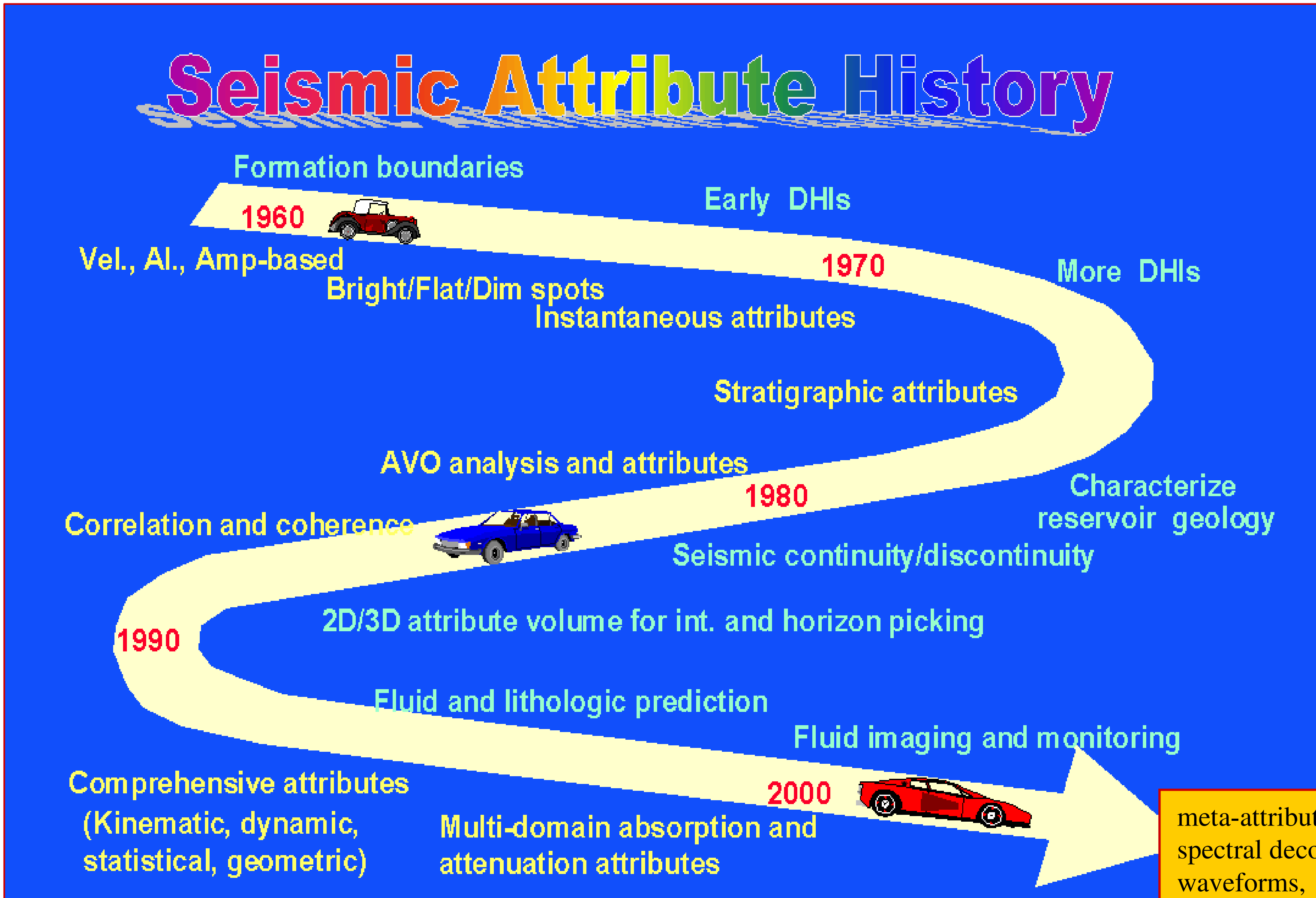
Seismic Amplitudes

1D – Seismic trace



Amplitude is just a basic and common seismic attribute as a function of time
After depth conversion also as a function of depth

Seismic Attributes



meta-attributes,
spectral decomposition,
waveforms,
3C, 4D, pre-stack attributes,
CCB (common contour binning=STACKING)….

Hydrocarbon Indicators

Amplitude Changes on Stack Sections
- Amplitude brightening (bright spot)
- Dimming (dim out)
- Change in multiple pattern
- Amplitude shadow underneath hydrocarbon zones

Velocity Changes
- Lowering of velocity in hydrocarbon zones
- Time sag underneath accumulations
- Stacking velocity variations at edge of reservoirs
- Other velocity variations

Wavelet Changes
- Polarity reversal (phase change) at reservoir edges
- Phasing because reservoir reflection is only one component of a composite reflection

Seismic Amplitude Interpretation
EAGE, SEG, Short Course DISC training 2001,
Fred J. Hilterman

Hydrocarbon Indicators, Continued

Frequency Changes
- Lowering of frequency immediately beneath reservoir because of deconvolution operator
- Lowering of frequency beneath reservoir because of attenuation

Flat Spot
- Horizontal reflection where other reflections dip, produced by fluid-interface reflection

Gas Chimney Effects
- Deterioration of data quality
- Time sag
- Distortion of reflections

And, finally

Changes in Amplitude with Offset
- Gas and high GOR reservoirs may exhibit larger reflection amplitudes as the distance between source and receiver increases ... Class 2 AVO anomalies

Modified from Sheriff, 1989

Geological Constraints for Hydrocarbon Indicators

Structural Conformity
- HCI limits must honor trapping mechanisms such as rollover, up-dip pinch outs, trapping faults, etc.

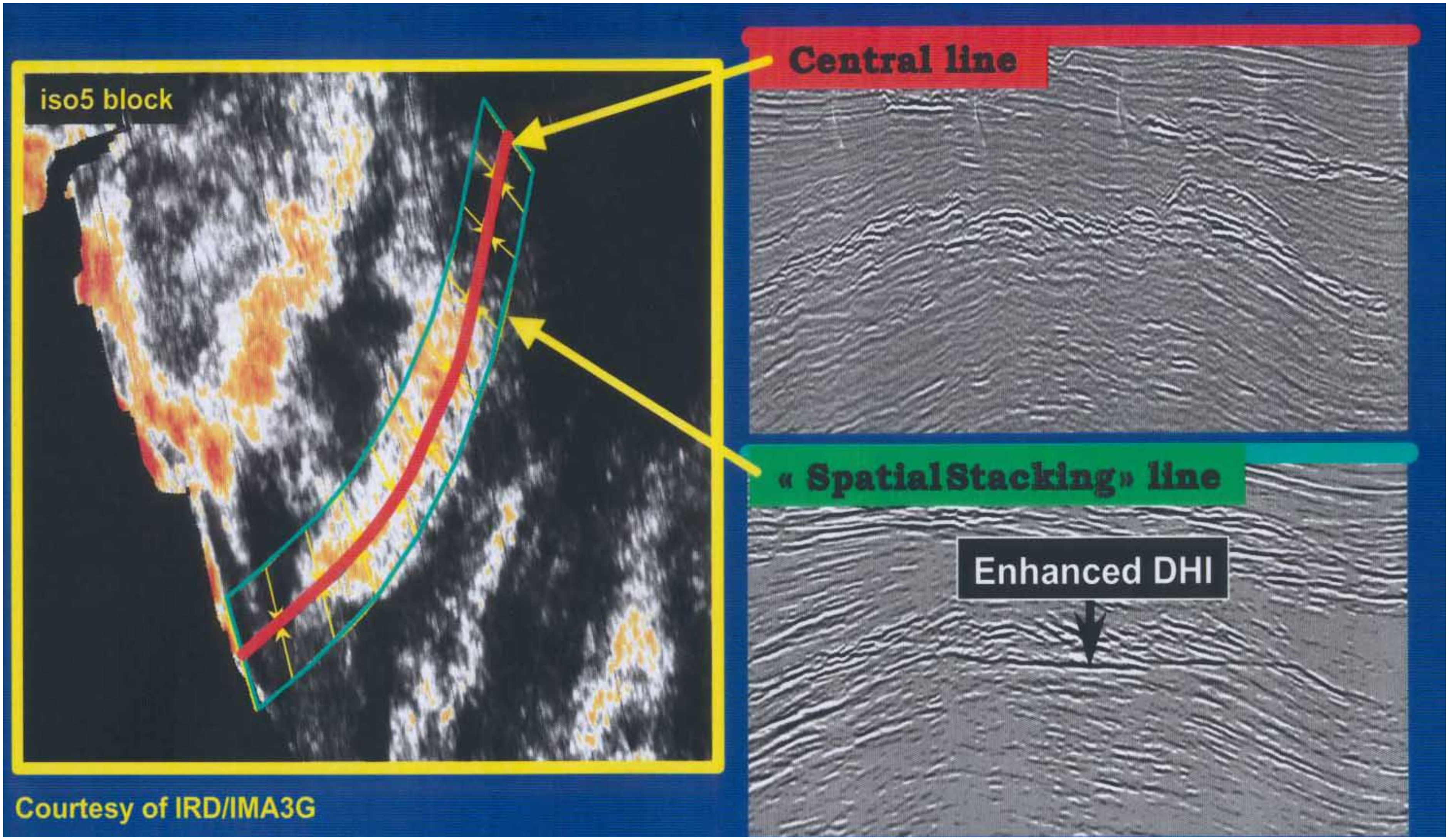
Down-dip Limits
- The down-dip limits of HCIs are expected to exhibit a flat event if a pore-fluid interface is anticipated.
- The HCI limits must confirm to the structural down-dip contours.

Others: ______

Amplitude interpretation must make sense geologically. Apply less *Principle of Least-Squares* and more *Principle of Least Astonishment.*

Modified from Sheriff, 1989

Stacking in interpretation : FLAT SPOT ON MAP AND SECTION



W. Beydoun *et al.,* 2000 - Courtesy TOTAL

In a 3D seismic cube at each (x,y,t) we can compute all kind of attributes representing e.g. at best some rock physics property or enhancing some geological feature (geometrical enhancement)

Seismic Attributes for prospect identification and Reservoir Characterization,
The book: SEG Geoph. Development series , No 11, 2007 based on:
EAGE, SEG, Short Course DISC training 2006, Satinder Chopra and Kurt J. Marfurt
« Seismic Attribute mapping of Structure and Stratigraphy

- **Basic concepts of attributes**
- **Multi-attribute display**

Spectral decomposition

Geometric attributes

- **Dip and azimuth**
- **Coherence**
- **Curvature and reflector shape**
- **Lateral changes in amplitude and pattern recognition**

Attributes and the seismic interpreter

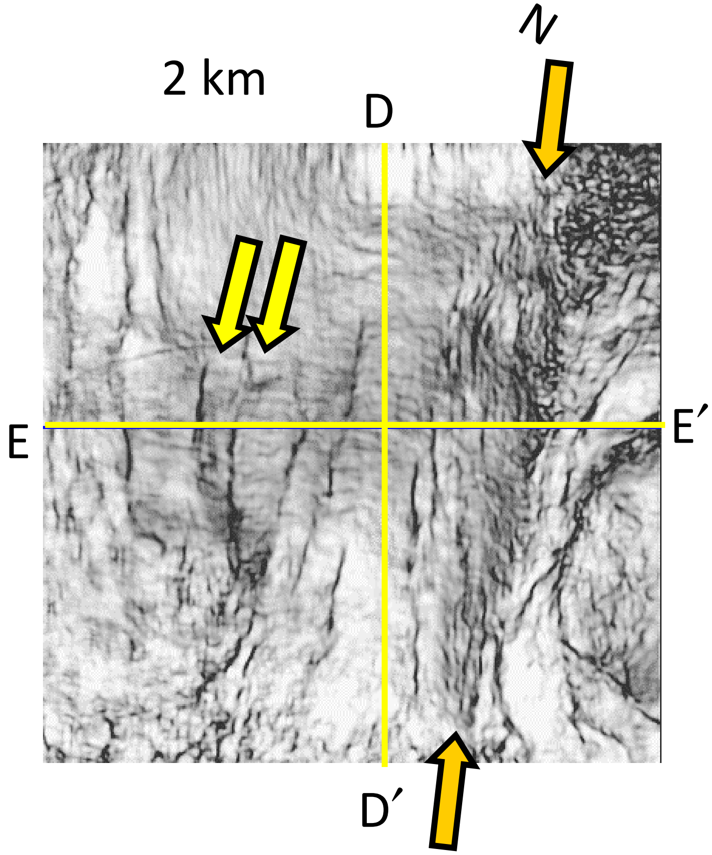
- **Structural deformation**
- **Clastic environments**
- **Carbonate environments**
- **Shallow stratigraphy and drilling hazards**
- **Reservoir heterogeneity**

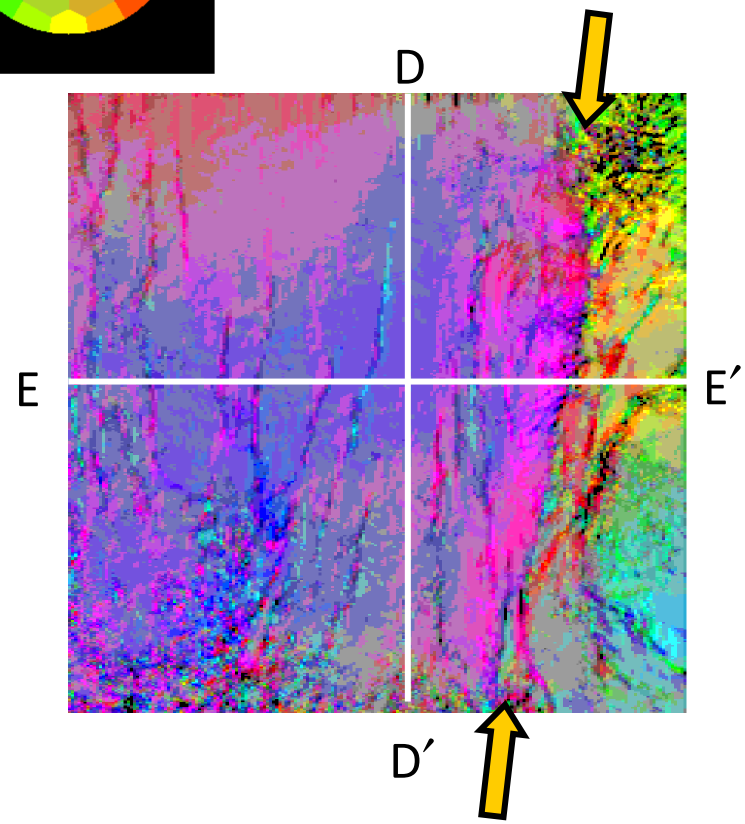
Attributes and the seismic processor

- **Influence of acquisition and processing**
- **Structure-oriented filtering and image enhancement**
- **Prestack geometric attributes**

Coherence Time Slice (1.1 s)

Dip / Azimuth Time Slice (1.1 s)





Enhancement of geometrical features: structural deformation

(Gersztenkorn et al., 1999)

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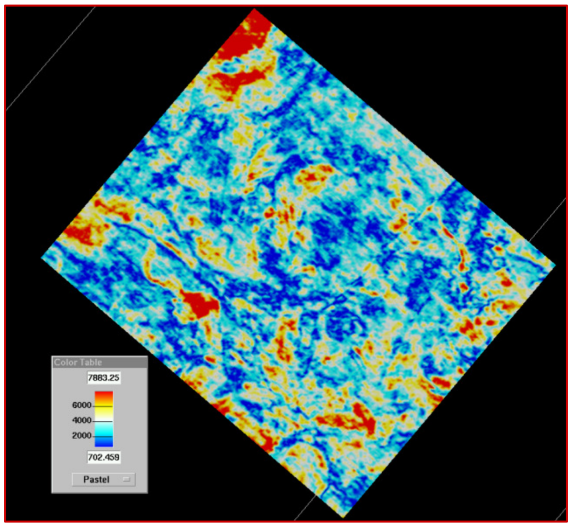
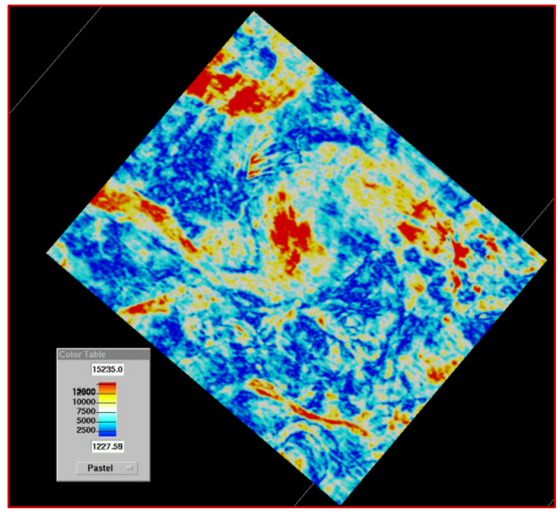
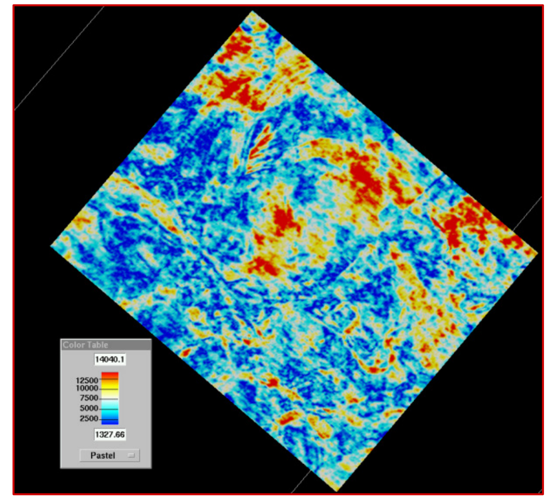
Spectral Decomposition (CWT)







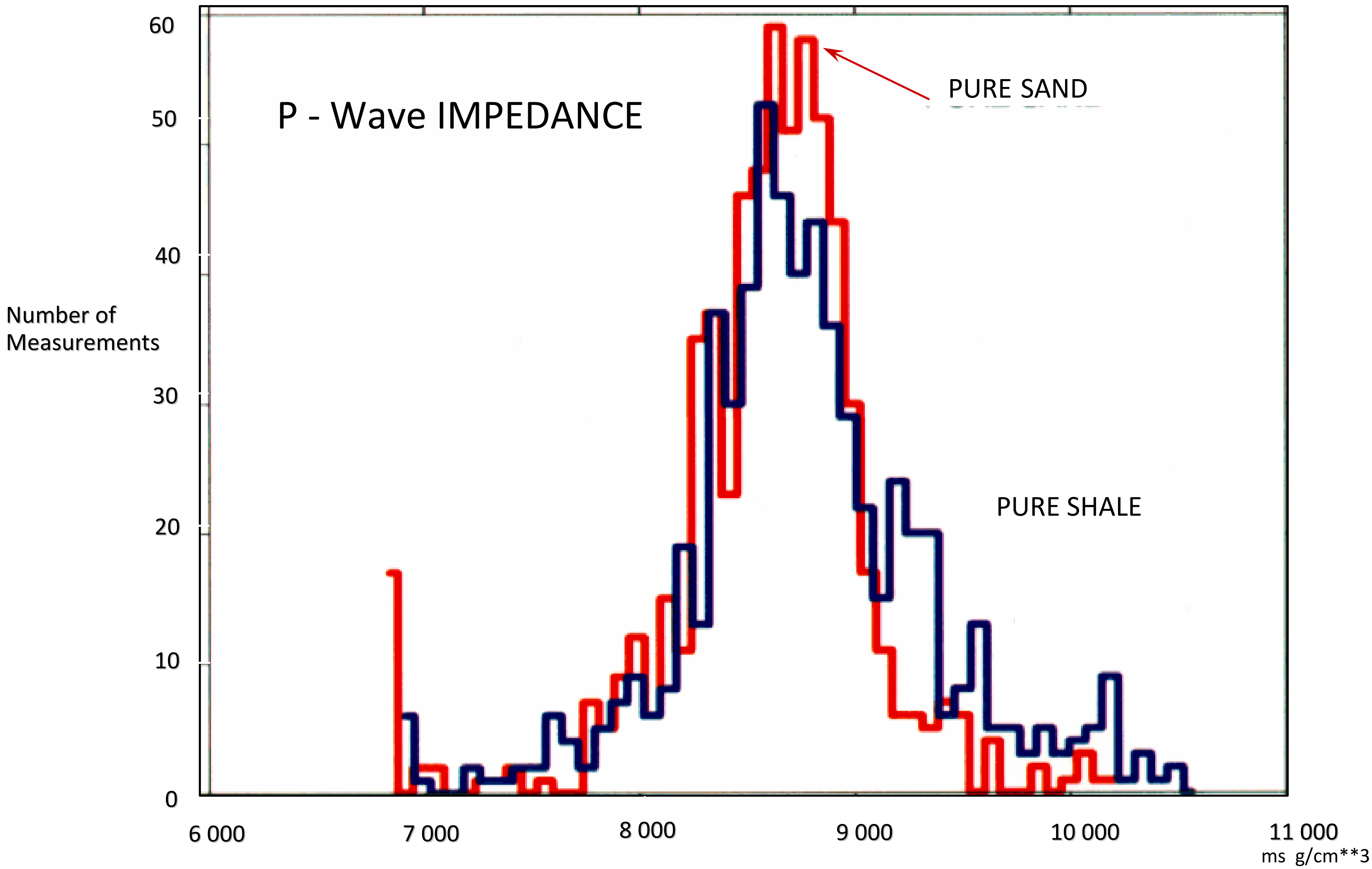
15Hz

45Hz

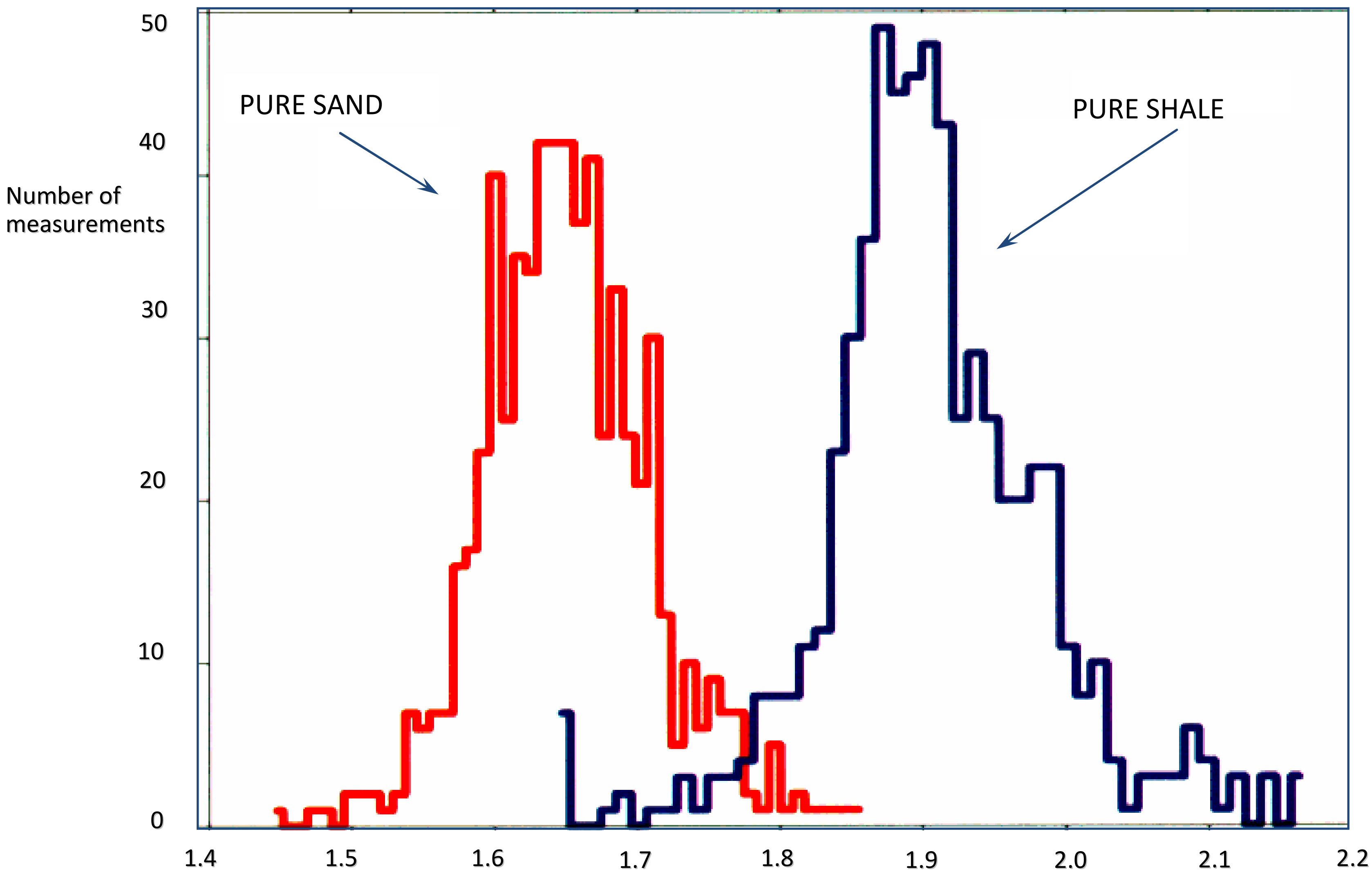
75 Hz

Different areas brighten up at different frequencies to highlight the main meandering, indicating variations of thickness within the channel (good connectivity), or channels composed of sedimentary sub bodies, some of which may be deposited during catastrophic event like flooding (poor connectivity).

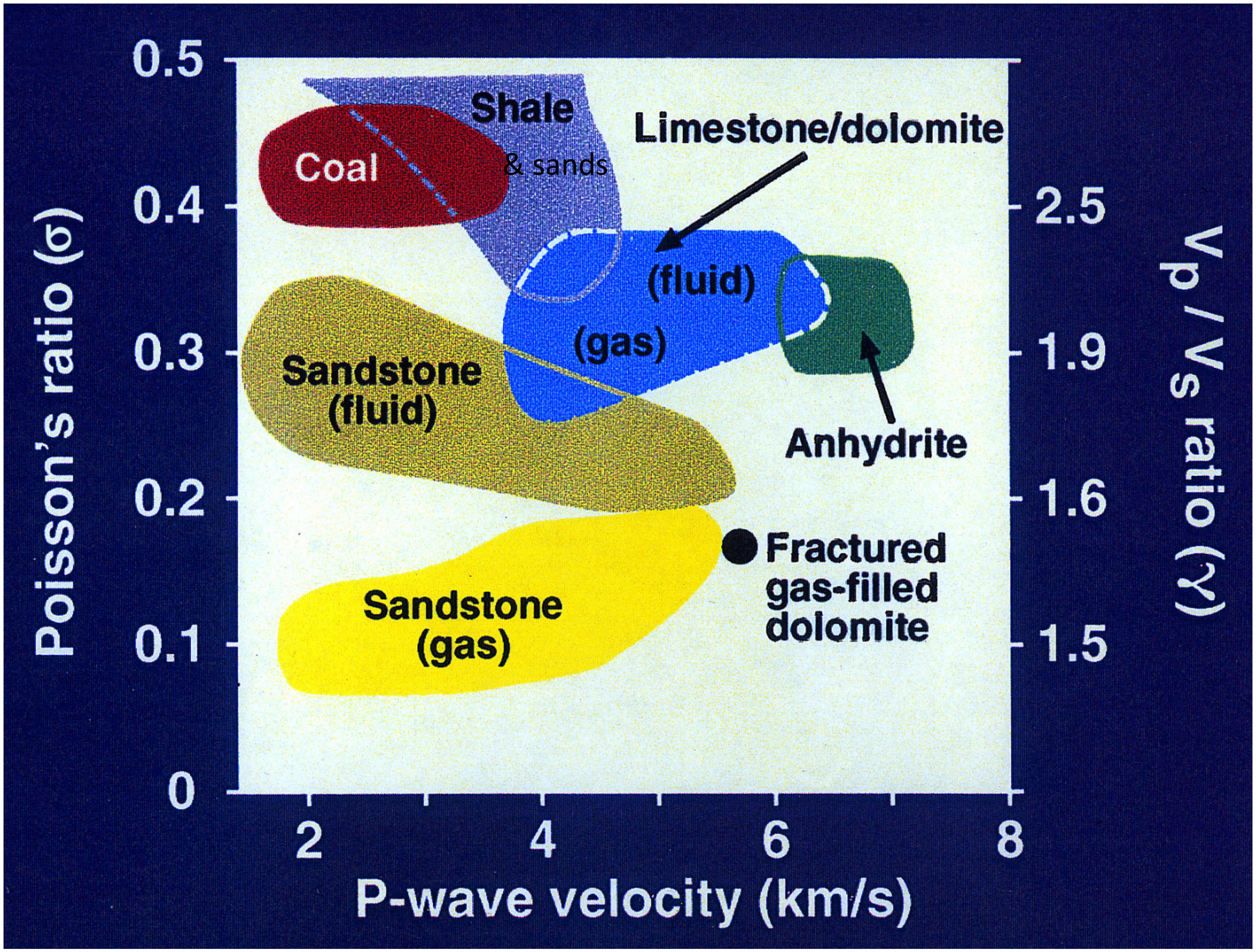
P WAVES IMPEDANCE IS NOT DISCRIMANT



V_P / V_S RATIO or POISSON'S RATION σ IS DISCRIMANT



POISSON'S RATIO σ versus P VELOCITY



AVO – AVA & POISSON'S RATIO σ

- **Variation of the Reflection Coefficient versus Incidence Angle is directly linked to the Poisson Ratio of the media :**

$$\sigma = \frac{1-2\left(V_s / V_p\right)^2}{2\left(1-\left(V_s / V_p\right)^2\right)}$$

- **AVO Analysis allows to approach the Poisson Ratio and so to approach :**

  - ✓ **Reservoir Lithology Prediction**
  - ✓ **Petrophysical Reservoir Characteristics**
  - ✓ **Fluids Variations Prediction.**

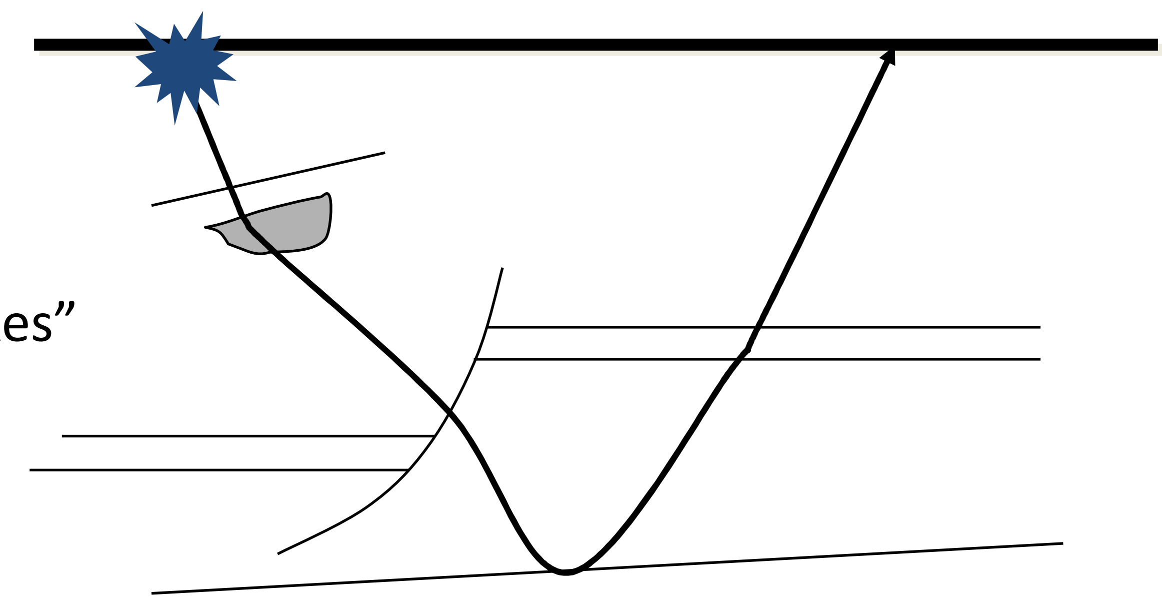
Stacking (adding to improve S/N ratio)
for interpretation,
but why not subtraction too ? -> time lapse seismic

Repeatability

- same acquisition geometry
- same shooting direction, same offsets
- accurate positioning of recording instruments
- if possible, same source/receiver
- if impossible, adjust source/receiver for repeat frequency, directivity

- reprocessing of base seismic - 'dual processing'

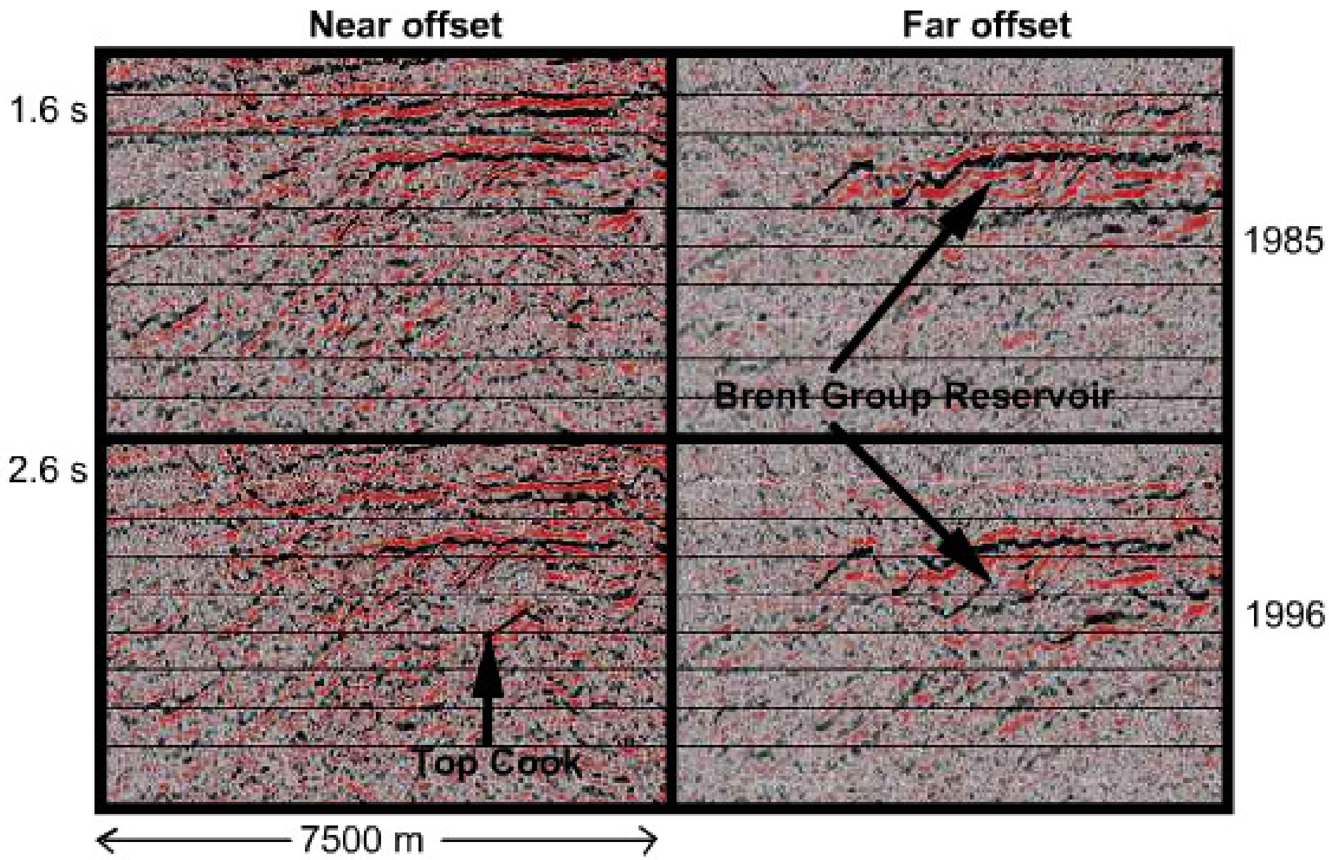
Rule of thumb:
"repeat your mistakes"



AVO and Time Lapse: Pressure and Saturation changes measured from 4 offset stack cubes

Input data

Near and far offset stacks from 1985 and 1996

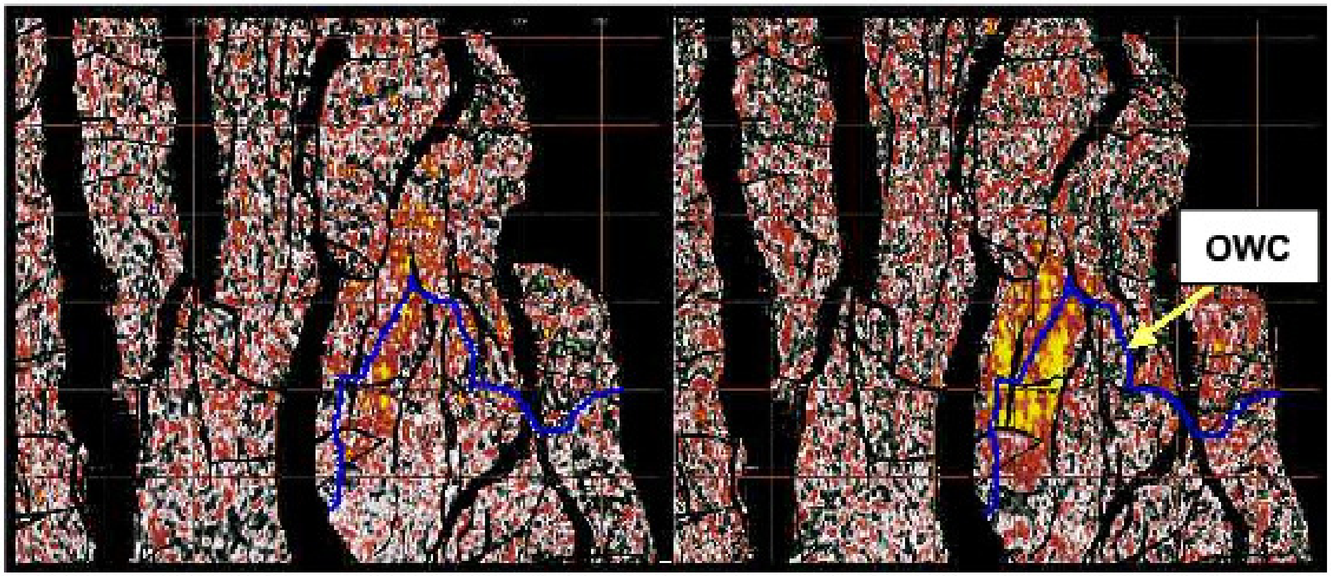


This slide shows four seismic profiles taken from the four offset cubes that went into the calculation of the pressure and fluid related attribute cubes. We observe the nice AVO-increase at top Brent reservoir interface, and also the time lapse increase from 1985 to 1996 both on near and far offset stacks.

Based on these four offset stack cubes, changes in intercept and gradient were estimated and plugged into the derived saturation-pressure equations.

Pressure and Saturation changes
Attributes calculated from time lapse seismic

Based on the derived equations, the following maps were generated:



Saturation changes Pressure changes

- 27% of remaining reserves in this segment have been produced in 1996
- Notice that pressure anomaly crosses the OWC and terminates close to faults
- Observed pore pressure increase (measured in wells) in the segment is 50-60 bar

This slide shows estimated saturation and pressure changes taken along the top Cook interface. The blue solid line shows the original oil-water contact within this segment.
For the pressure changes we observe that the anomaly terminates very nicely with major faults, both to the west and to the east. We also see that the anomaly extends beyond the original fluid contact, a strong indication that this really is a pressure effect. Pressure measurements in two wells within the segment confirm a strong pressure increase, of the order of 50-60 bar.
The anomaly on the saturation attribute to the left is somewhat weaker than the pressure anomaly. In the southern parts of the segment we observe that the anomaly follows the original oil-water contact line as expected. However, in the northern part we see that the anomaly is crossing the oil-water contact line, and this is unrealistic. This is probably caused by leakage between the two cubes, and means that the pressure-fluid discrimination has not been optimal. On the other hand one might say that these two attribute maps adds information compared to studying differences on stacked data only.

The Future of 4D - downhole

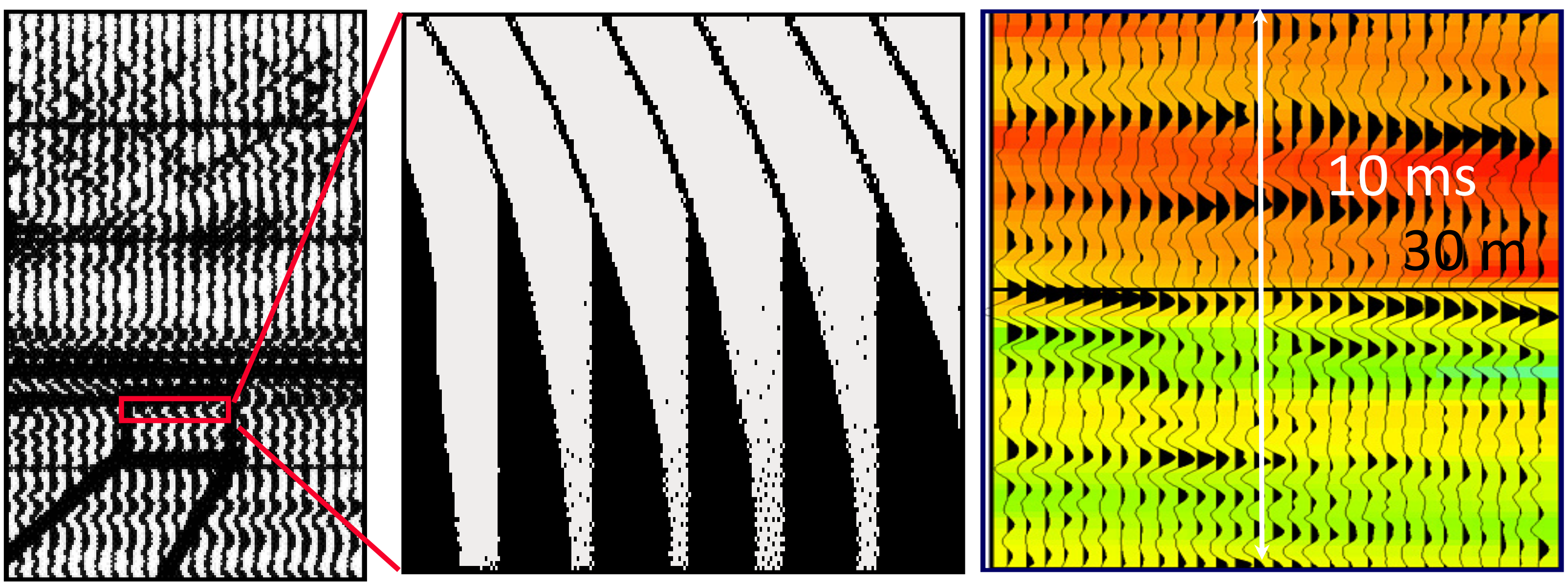
The Vision: By leaving the surface, seismology has a new dimension of opportunity.

To image reservoir structure and fluids at 1m resolution

The Enabler: Sub-surface seismic by moving both receivers and sources downhole.

- Input from other down hole sensors (P, T, flow, resistivity, etc.) provides in-situ rock and fluid property change calibration and better quantitative calibration of field models

Surface Seismic | Down Hole Seismic



The discovery patterns of the resources of the rift and gas provinces of the North Sea compared with some analogous provinces worldwide

Exploration Histories and Future Potential in ***6th Petroleum Geology Conference*** *series 2005 6:25-33; doi:10.1144/0060025*: A. SPENCER, K. CHEW and G. LECKIE

The discovered resources of the North Sea petroleum systems total around 100 billion barrels oil equivalent recoverable. Of these 70% occur in the Jurassic-sourced petroleum system of the Central and Northern North Sea (CNNS). The second major petroleum system occurs in the Southern North Sea (the Anglo-Dutch Basin, ADB), contains around 30% of the resources, is Carboniferous-sourced and gas-bearing. The discovery patterns of the resources in the two basins are here analysed by comparison with some analogous basins. The CNNS can be compared geologically with other oil-prone basins: Sirte, Bohai Wan, Gulf of Suez, Cambay/Bombay, Marib–Al Jawf and the southern part of the West Siberian basin. The ADB can be compared with gas-prone basins: Poland, Dnepr-Donets, Gippsland, Gulf of Thailand, NW Australia and northern West Siberia. The discovery patterns of the basins are compared with each other using:

- resource growth with respect to exploration wells;
- field size distributions;
- discovered volumes with respect to exploration wells;
- exploration efficiency.

A simple 'ranking' based on these criteria suggests that the CNNS is of middle rank while the ADB is, surprisingly, almost 'worst in class'.

Conclusions and … the road ahead

The stimulus for innovation is as strong as ever, what will be made clear today
Even if the immediate economic context is uncertain, the industry is responding.

Are explorers or production technologists mostly technology driven or … opportunity driven ?

Multidisciplinary, intensive collaboration.
Seismic (amplitude) data for Constraining or Assimilation
in static model building and simulation

In Seeking innovations in geophysical technology,
one should not forget also to look into the past and also to look at the ....

Geology … The road ahead

Amplitudes

Sola, Rogaland, Norway (Onshore :-)