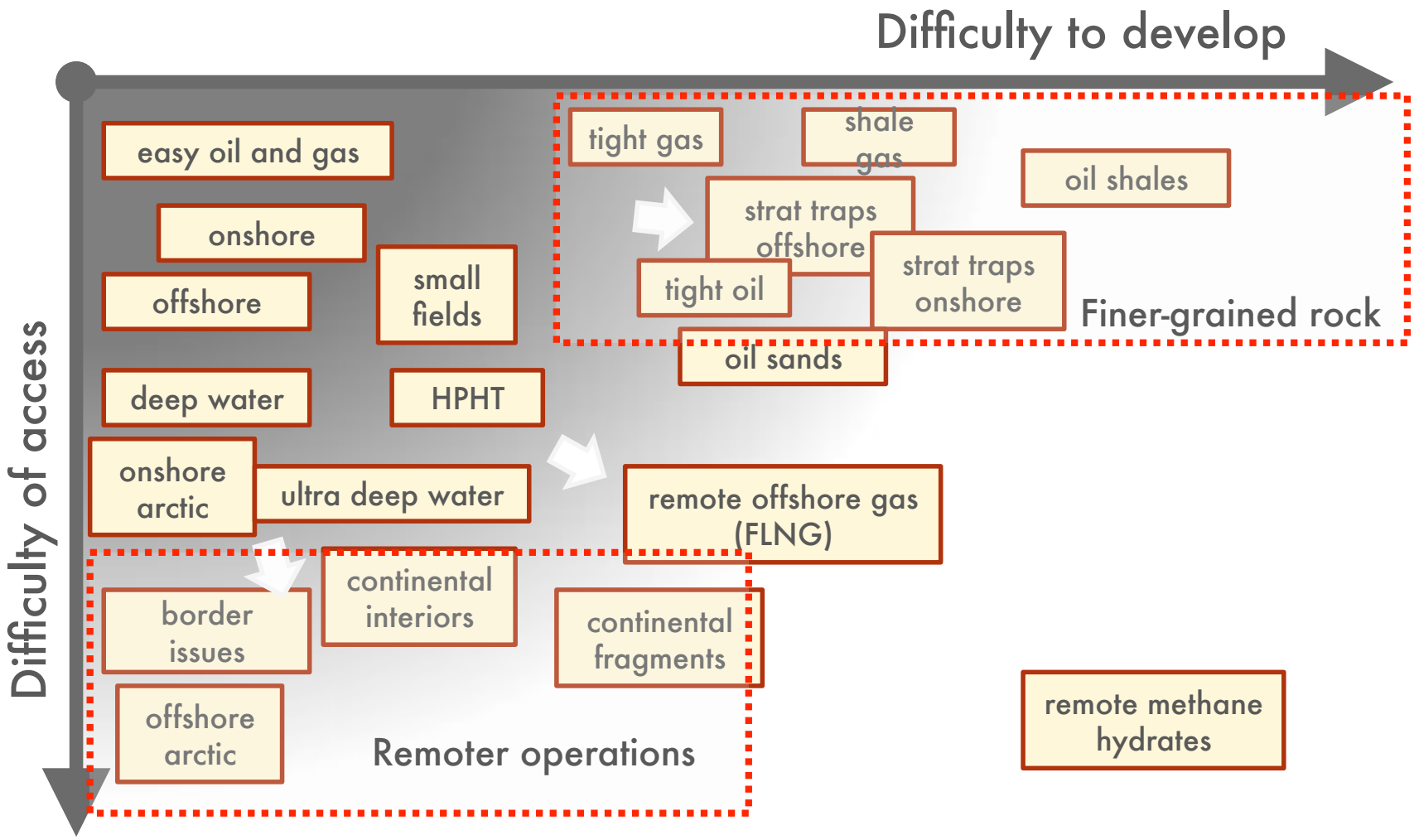
# Future Geoscience Technologies for Unlocking Hard Resources

Bruce Levell

23 September 2013
Imperial College: 100 years and Beyond

# Hard resources

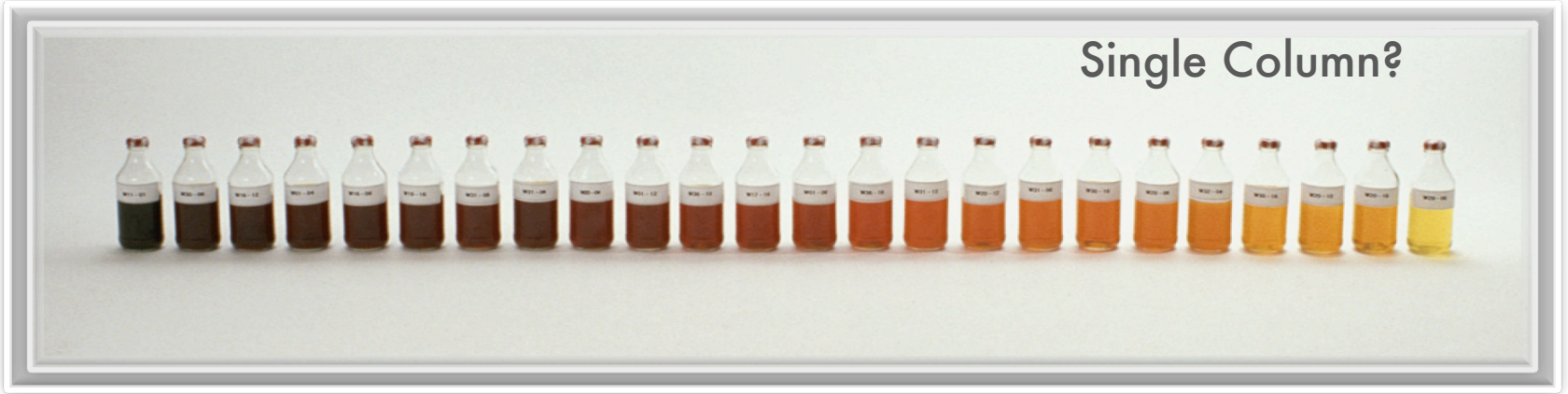


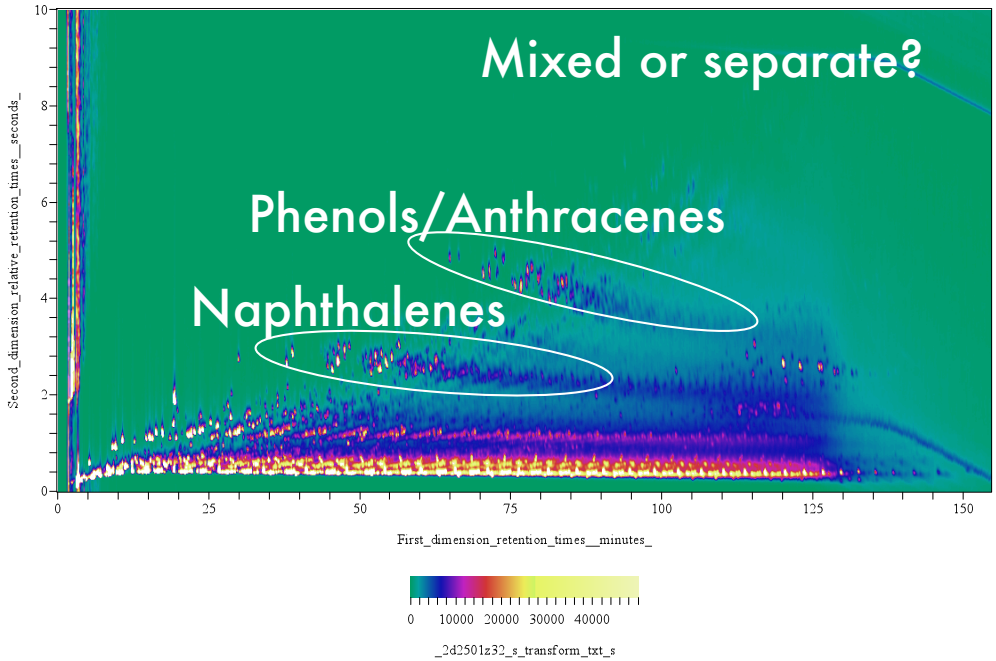

With - Continuing time pressure..... increasing cost pressure

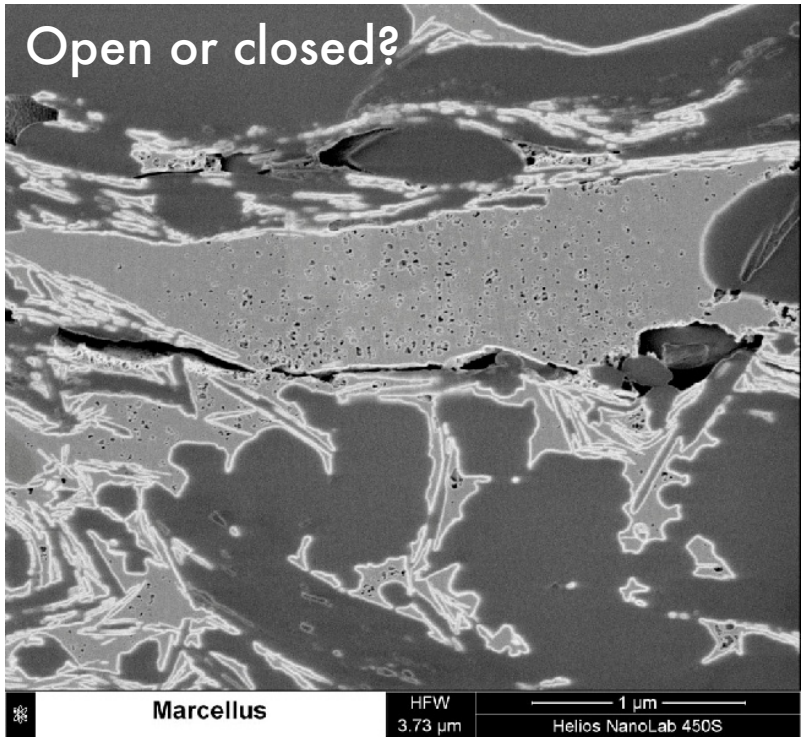
# Geoscience Technology Themes

1. **Petroleum systems** - analytical geochemistry, sampling, analytical petrophysics fine grained rocks, rock / fluid interactions EOR / IOR for both oil and gas
2. **Fluid flow and geomechanics** – water and hydrocarbons, burial, uplift and stress histories, seismic diagnostics,
3. **Comprehensive and self-consistent seismic interpretation**- horizons, seismic geomorphology, facies, rock properties, depositional and structural "dynamics"
4. **Shared earth models** - linked or coupled modelling, self-consistency as a constraint
5. **Data and knowledge management** - regional…local, analogues, parameters, geological rules
6. **New geological insights** - vertical movements, events, earth systems, quantification

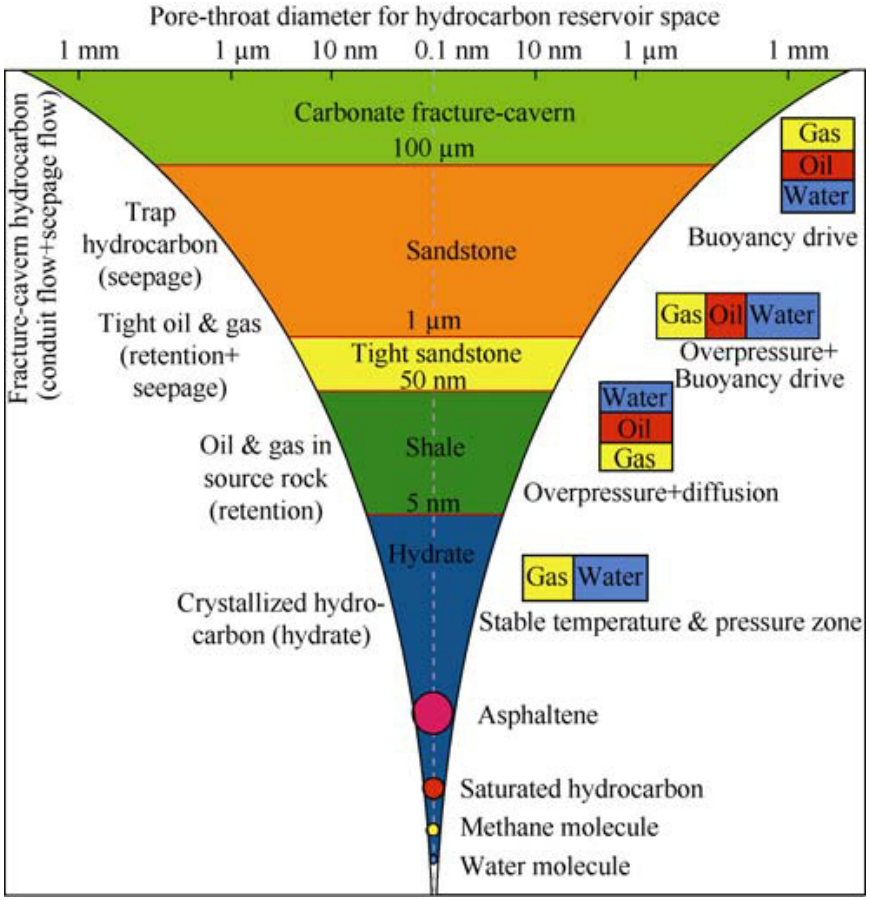
# Analytical techniques – fluids and rocks



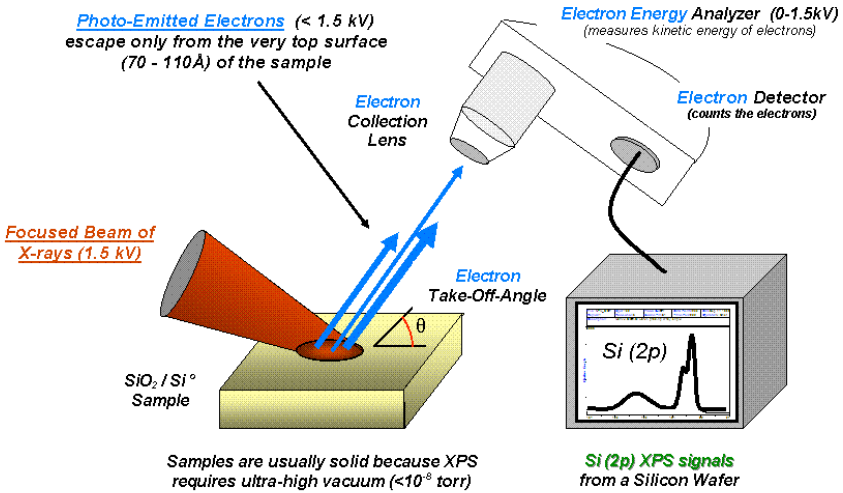



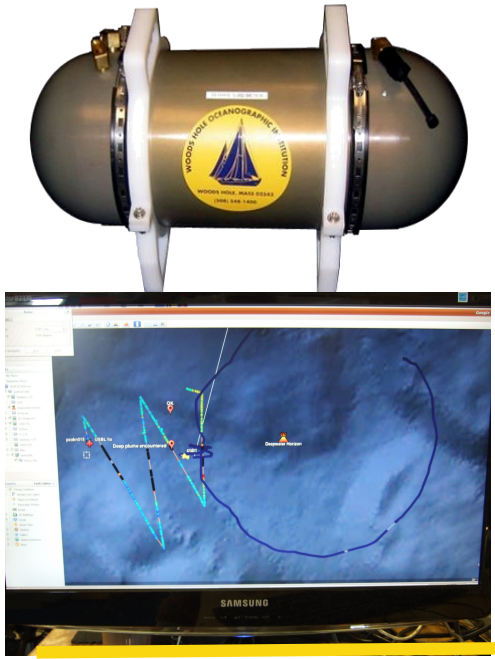
# Petroleum systems - Fine grained Rocks




## X-Ray photo electron spectroscopy - surface analysis



# Remote sensing and remote operations

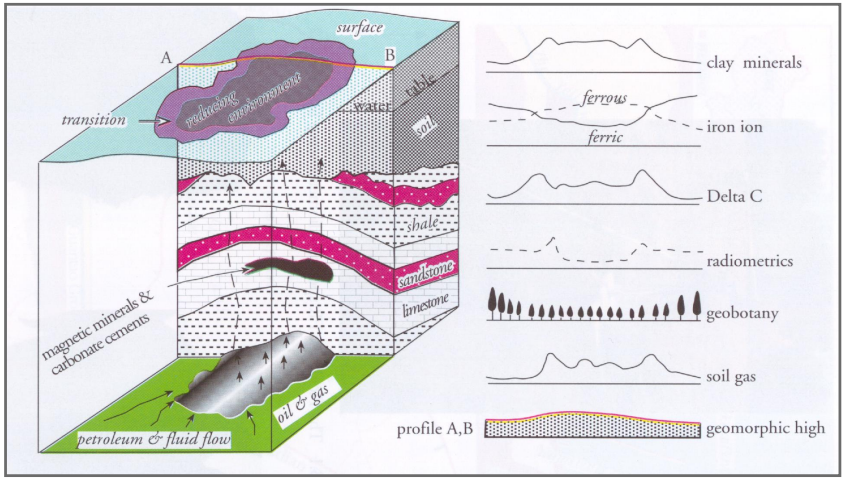



**TETHYS:** mass spectrometer- low molecular weight gases and volatile organics.

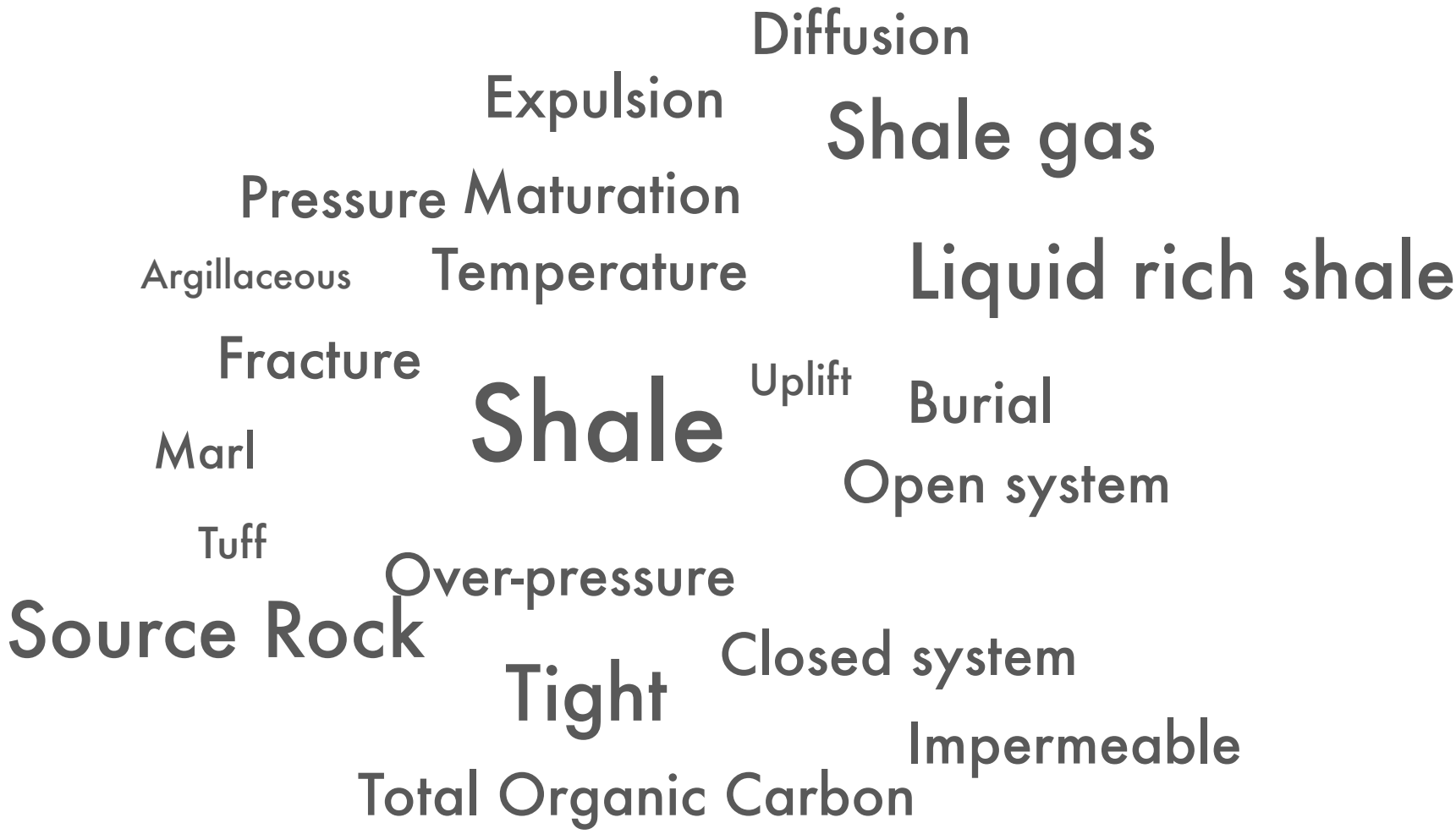
- Depth 5000 m
- Power 25 watts
- Mass Range 2-200 AMU
- Detection Limit ~1 ppb
- Sampling < 1 meter

(Camilli 2009) Wood's Hole

Insitu inc. "Scan Eagle"

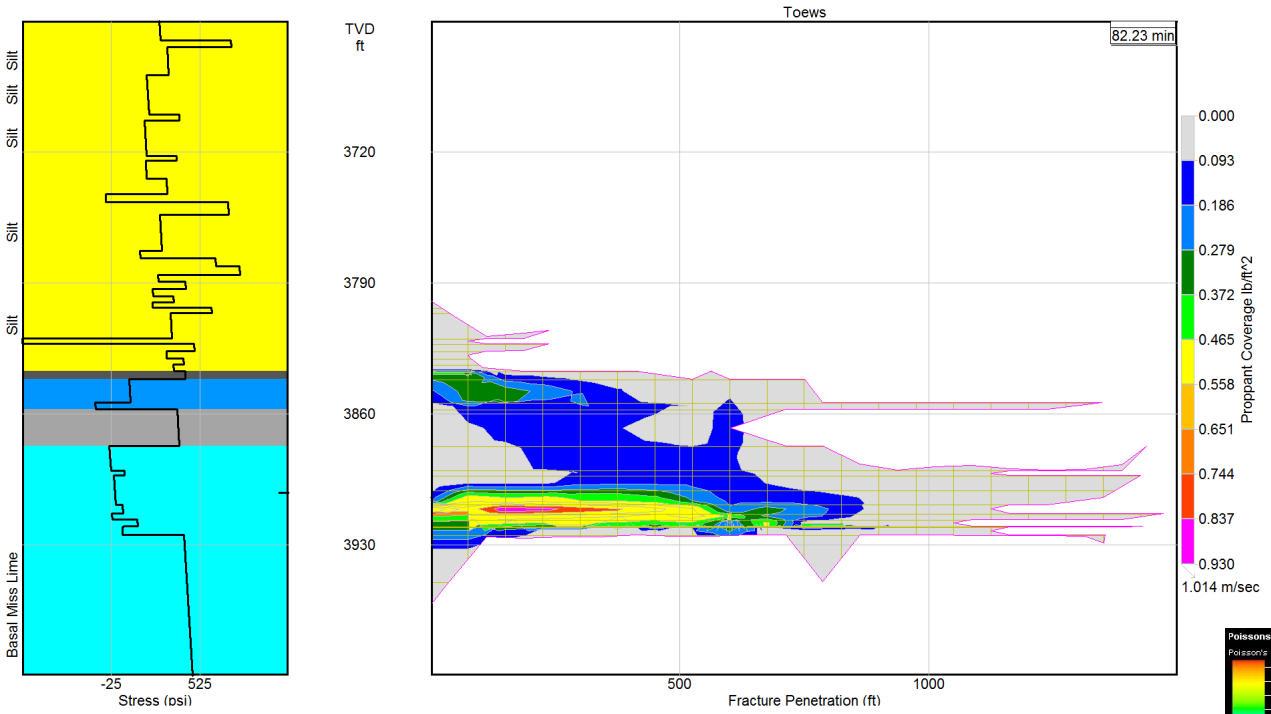


# Petroleum systems - new insights from fine grained rocks



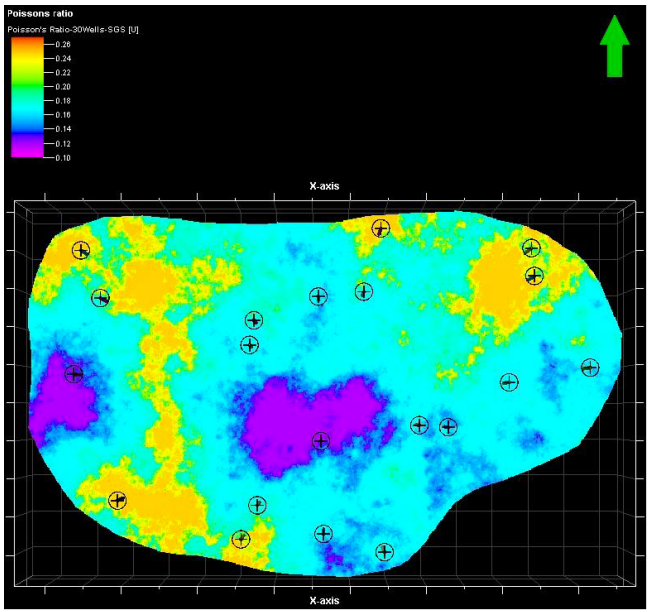
# Petroleum systems - Geomechanics

## Fracture model from in situ stresses

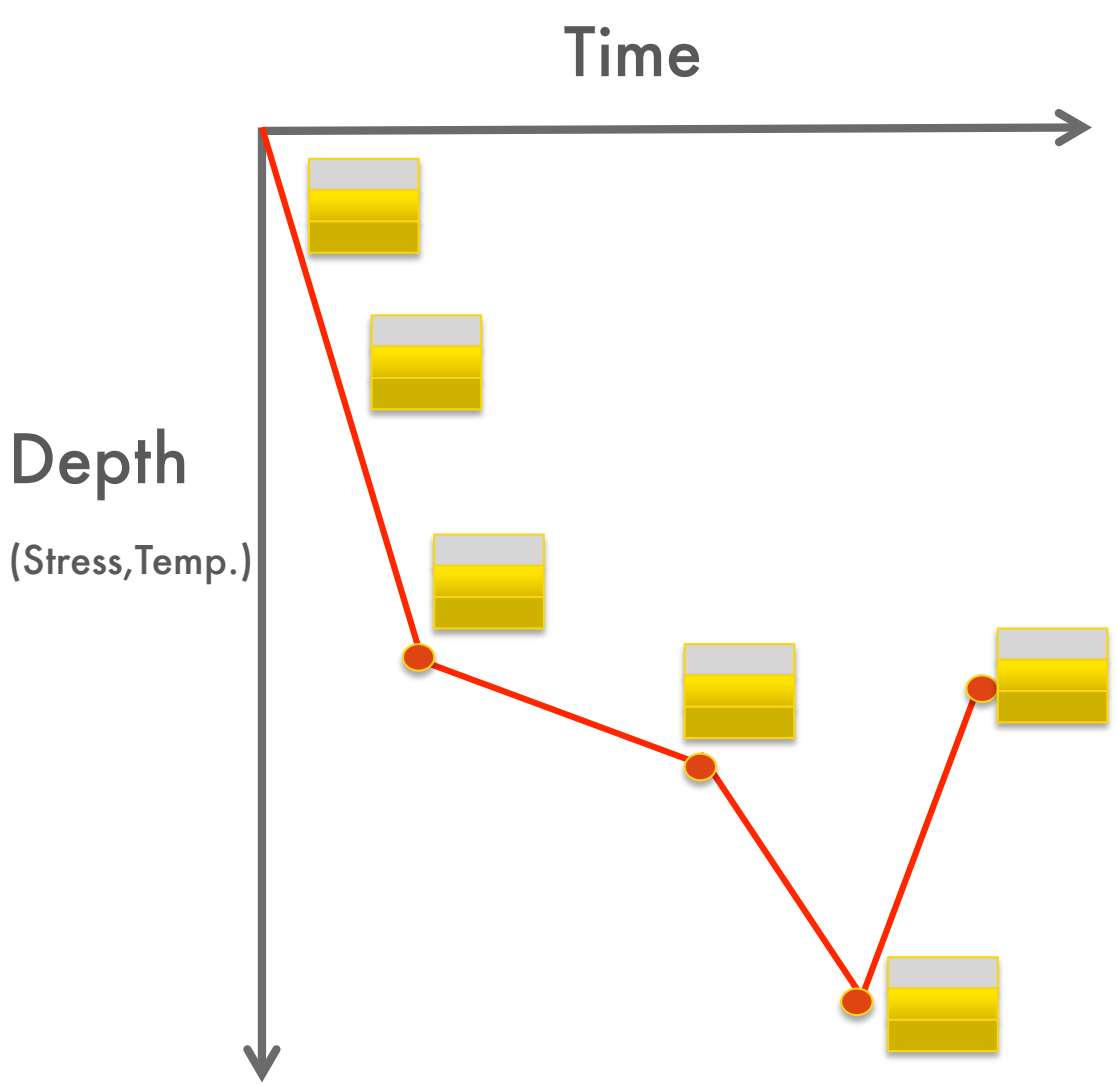


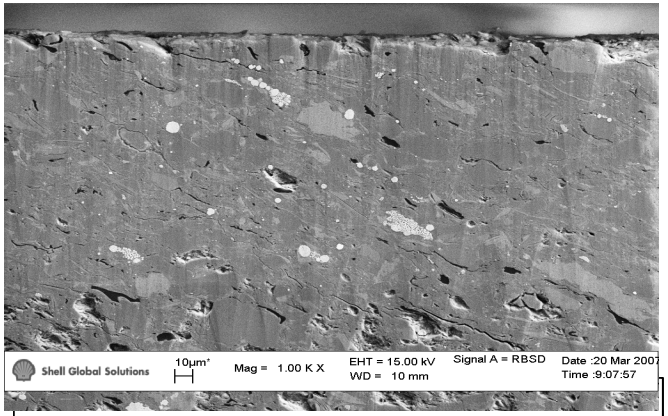

Poisson's ratio from well logs Marcellus Shale – (no scale)

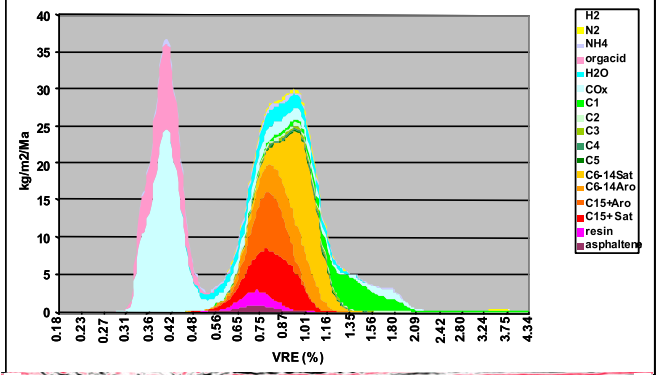
Eshkalak et al SPE 163690-MS 2013

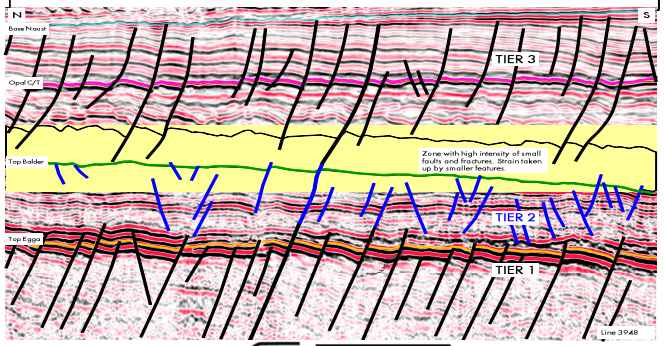


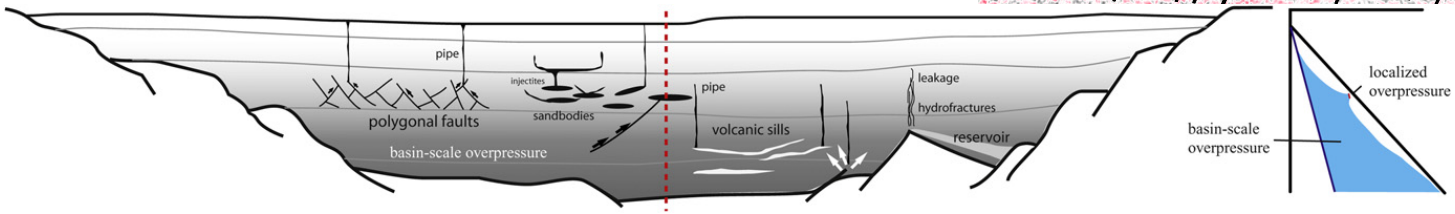
# Fluid flow and geomechanics



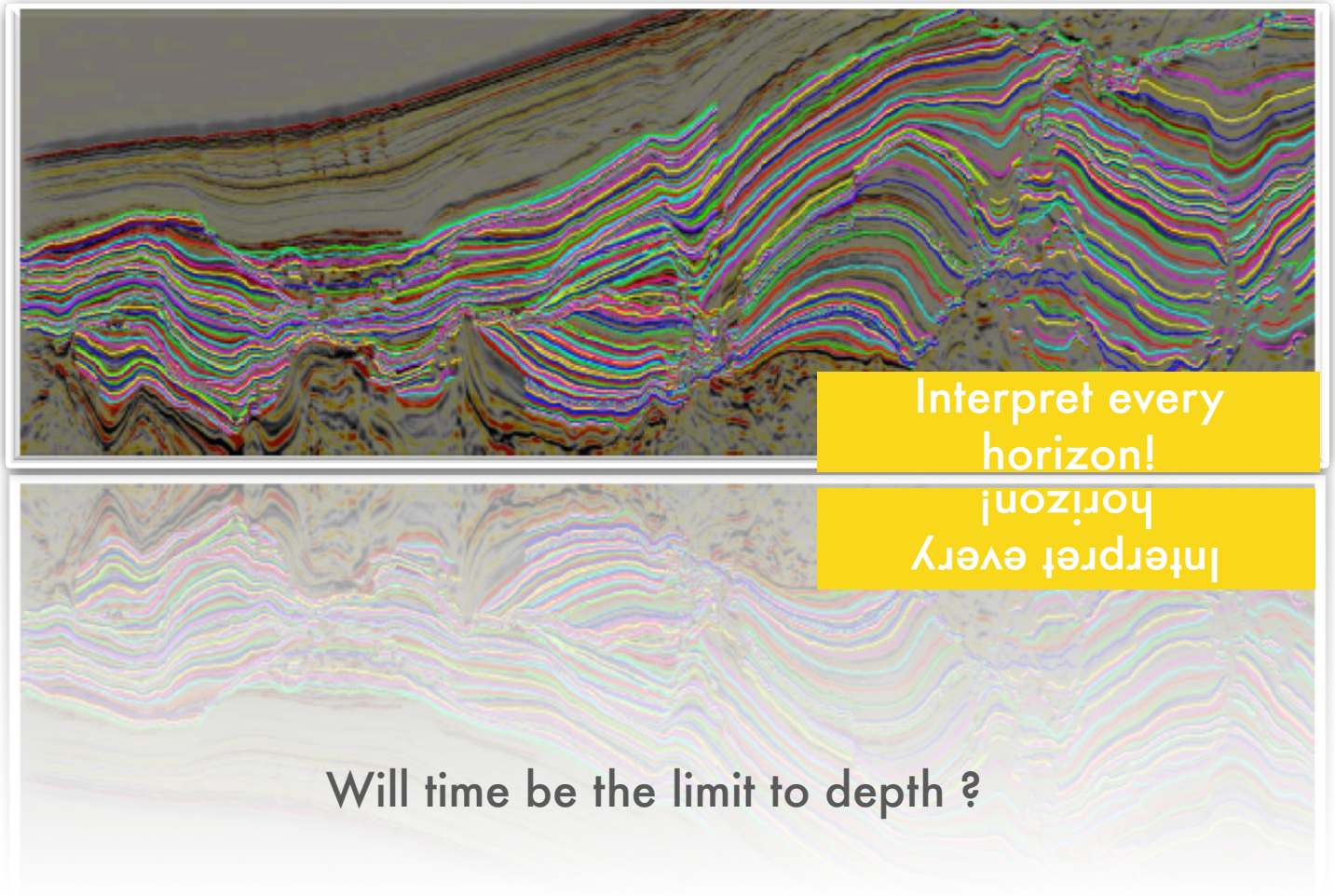



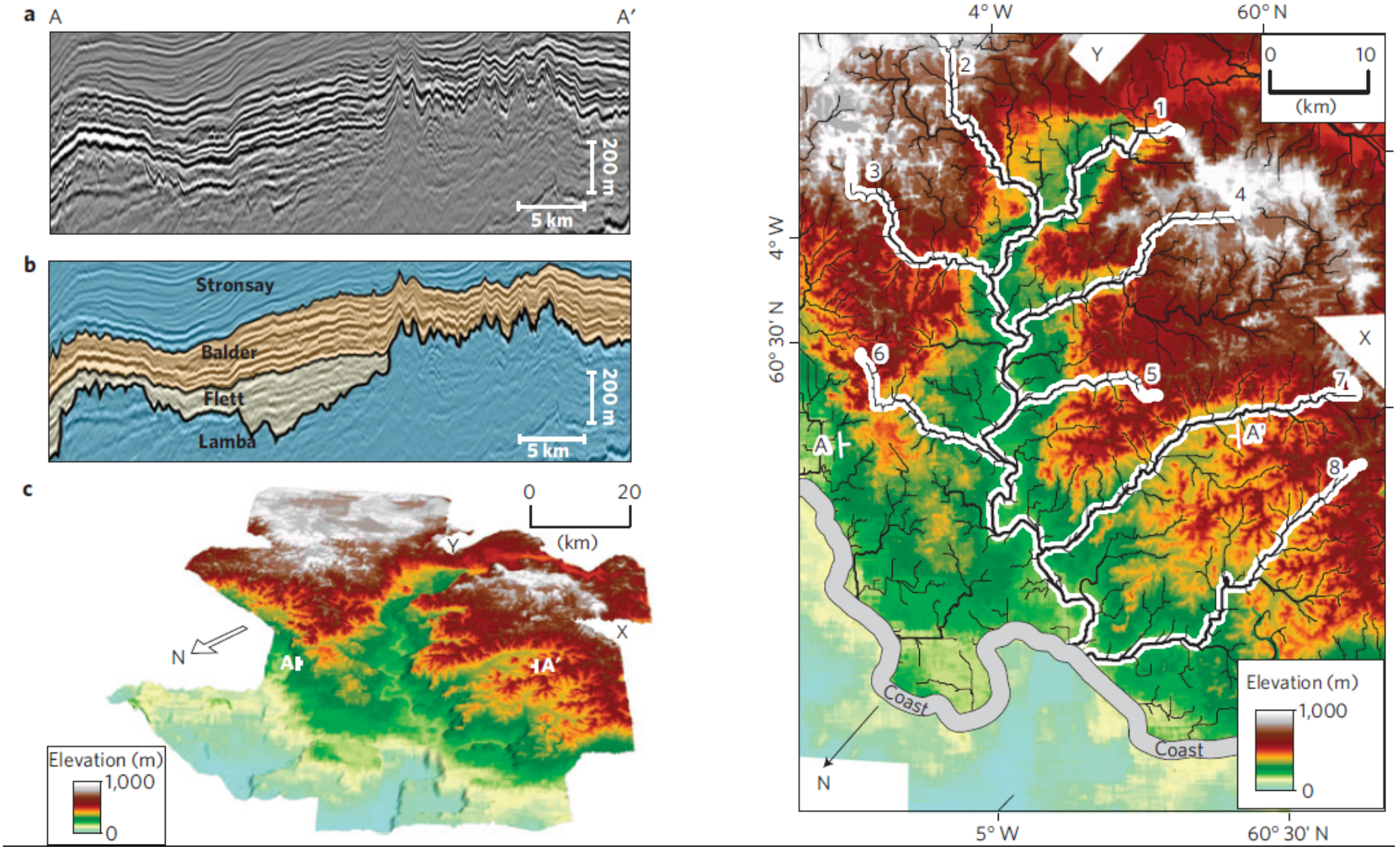



# Comprehensive interpretation - reflections

- From: Horizons > structure > depositional sequences > petroleum systems > detailed structure > petrophysics > hydrocarbons
- To: All (many more) - horizons, depositional surfaces, seismic facies, faults and fractures, rock and fluid properties, kinematics ..... and all self-consistent.



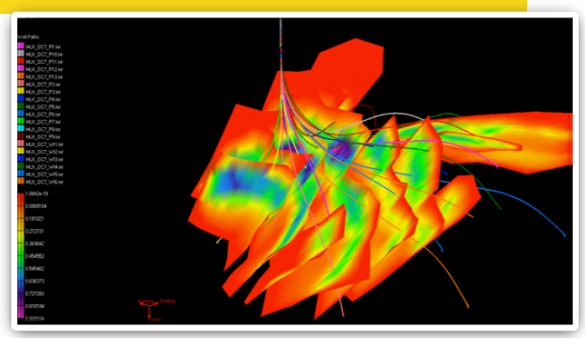
# Comprehensive seismic interpretation - example

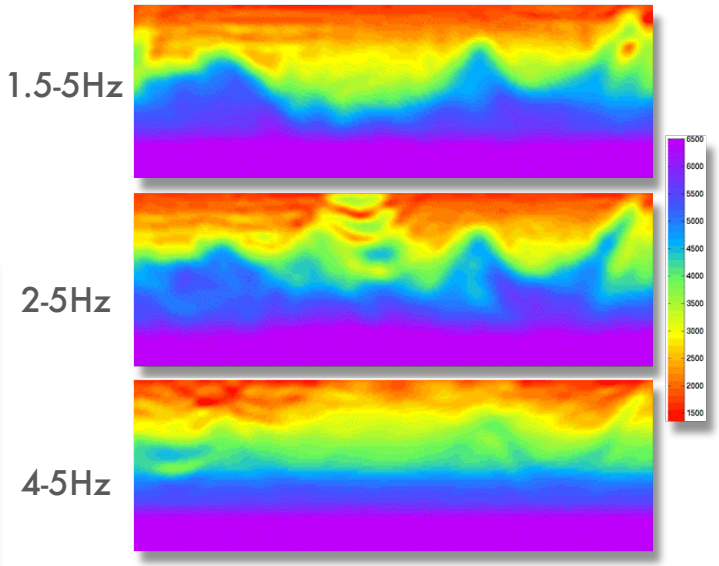


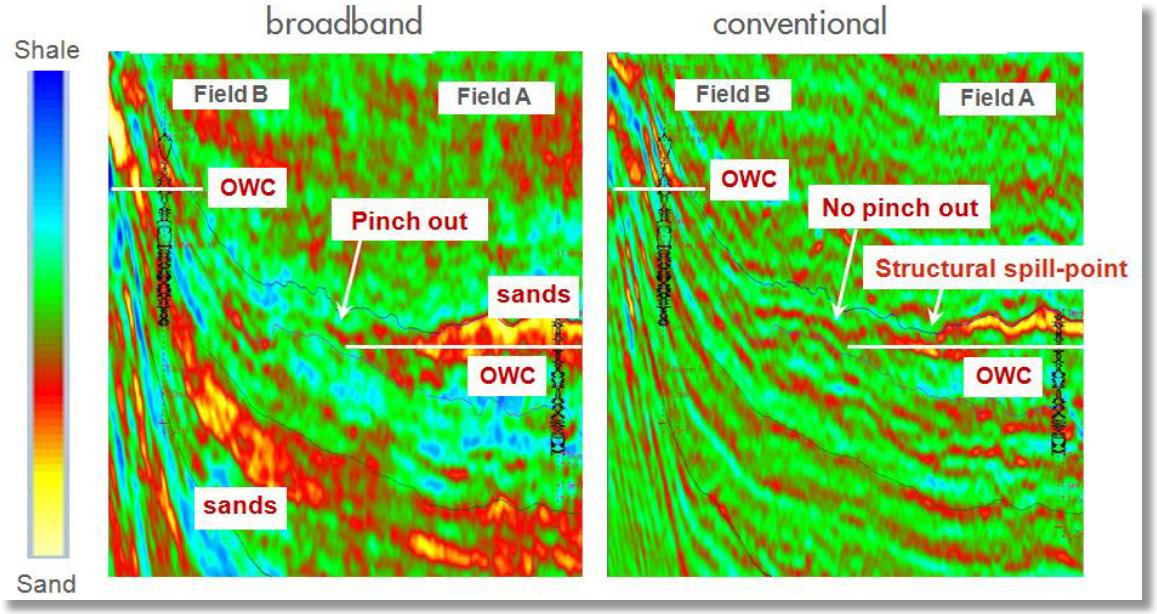

**Transient convective uplift of an ancient buried landscape –Nature Geoscience July 2011 pp562 - 565**
Ross A. Hartley, Gareth G. Roberts, Nicky White & Chris Richardson
doi:10.1038/ngeo1191

# Shared earth models – motivations (……this time around !)

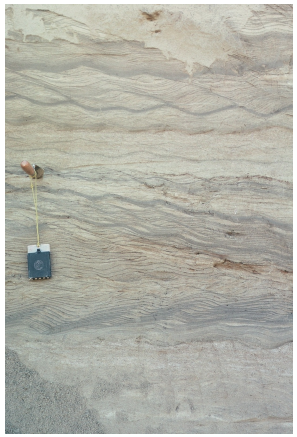
- High cost, complex Well Engineering
- The "Deliberate search for the Subtle Trap"
- Smarter Appraisal
- Planning  and executing Enhanced Oil Recovery
- Sub surface storage
- Broadband Seismic inversion

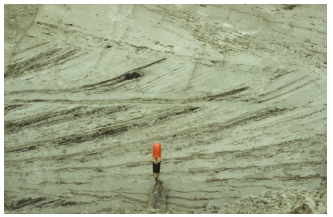


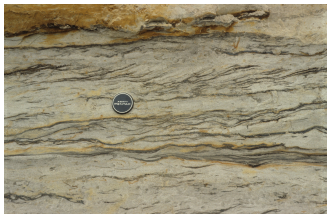


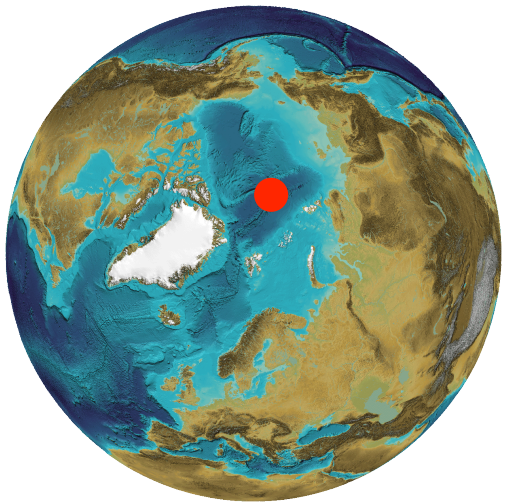



# New Geological Insights – "events.. dear boy.. events"

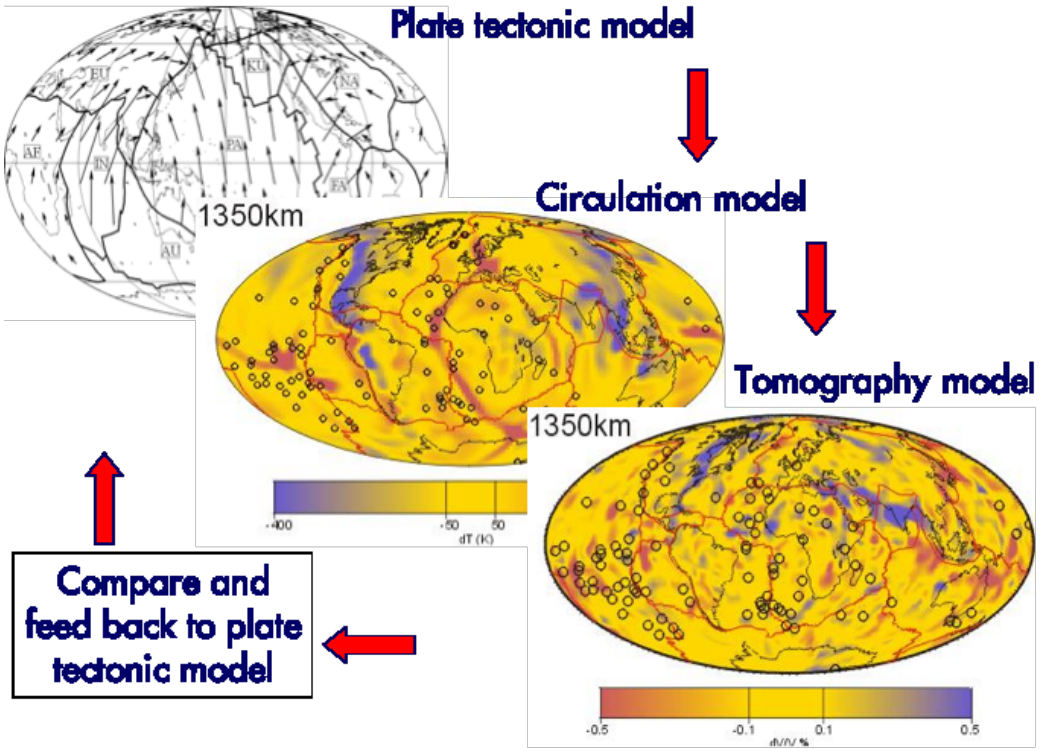


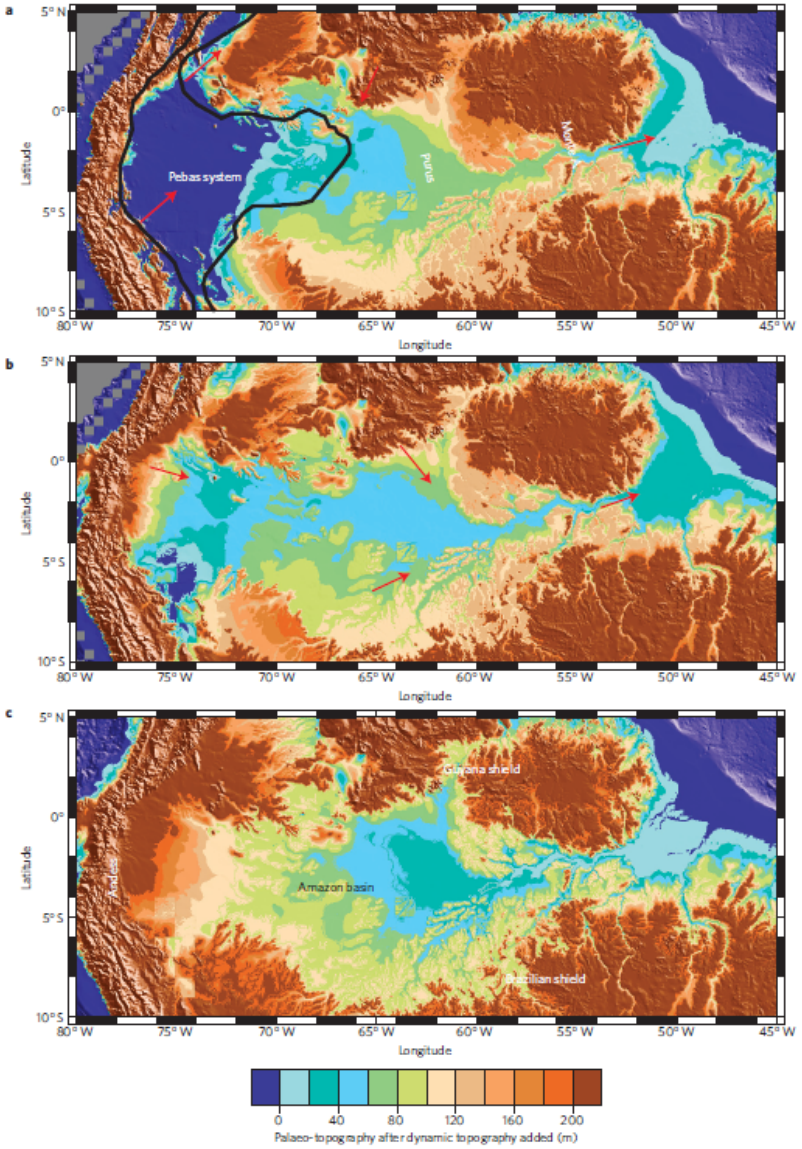






# New geological Insights : Vertical movements / earth systems




Nature Geoscience 3: 870–875 (2010)
DOI: doi:10.1038/ngeo1017

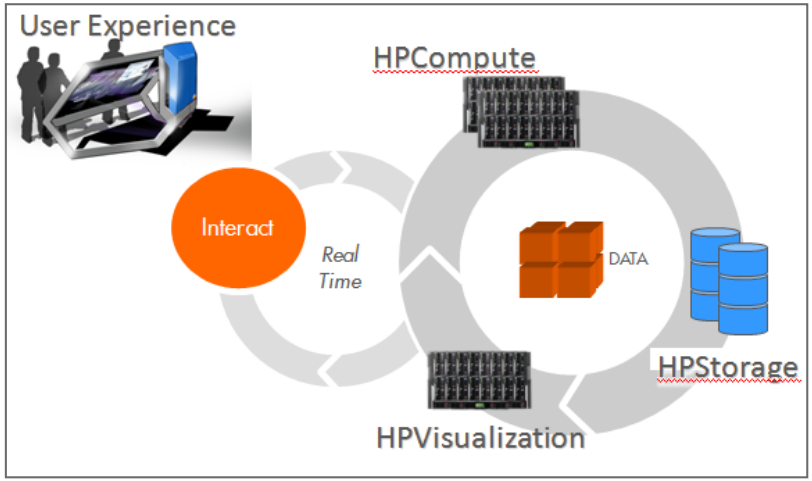
# New Geoscience technologies - Drivers

## Measurement:

Geochemical analysis
Rock characterisation
Seismic–multi azimuth,wider bandwidths
Non–seismic
Petrophysics
Geo-mechanics

## Understanding:

Earth systems
Fine-grained rocks
Global geological data
Vertical movements
Events




## Integration:

Petroleum systems
Co-visualisation
Semi-automated interpretation
"Closing the loop"
Quantification

UNIVERSITY OF OXFORD

# Summary- Geoscience Technology Themes

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2. **Fluid flow and geomechanics** – water and hydrocarbons, burial, uplift and stress histories, seismic diagnostics,
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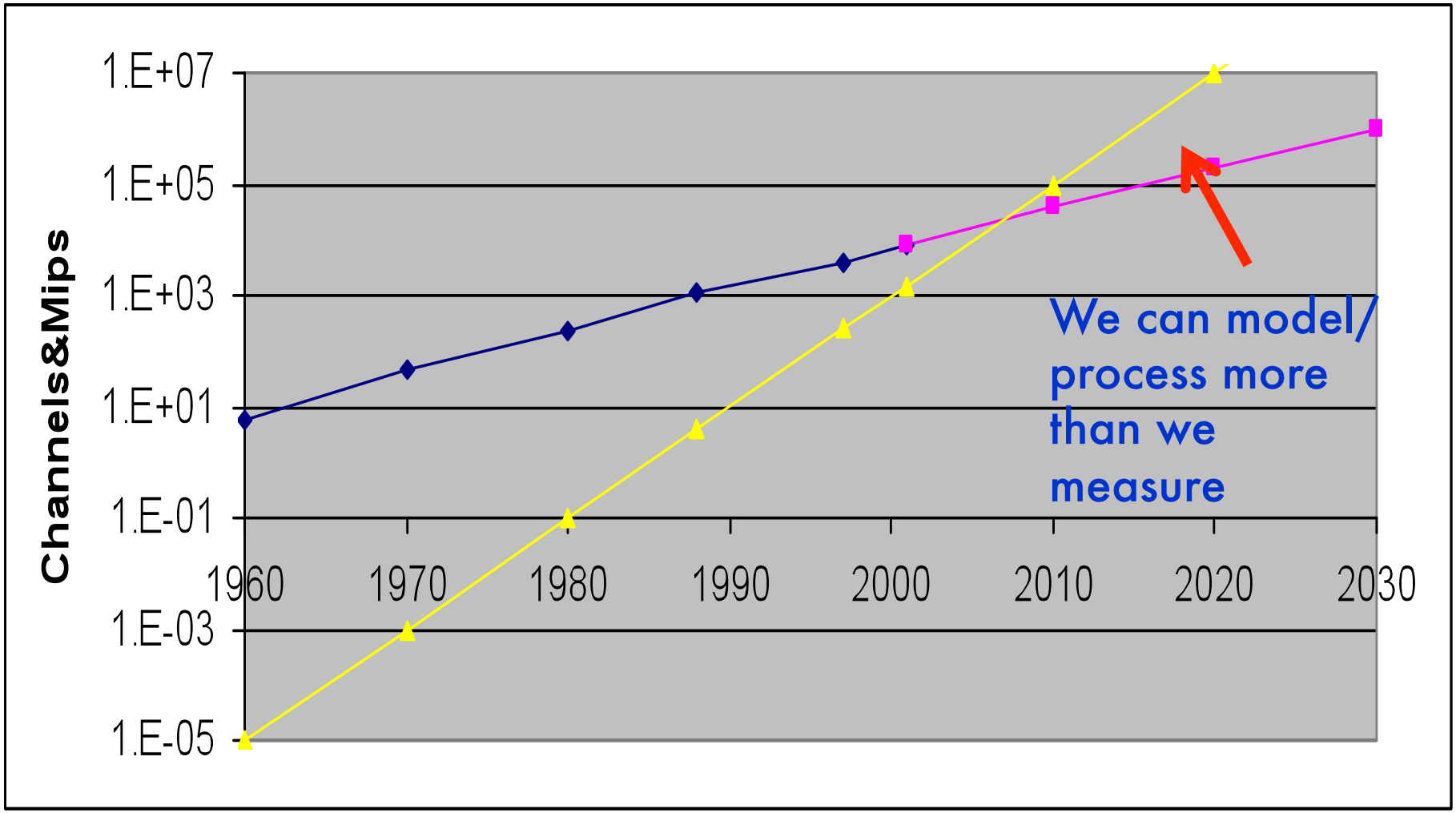
5. **Data and knowledge management** - regional…local, analogues, parameters, geological rules
6. **New geological insights** - vertical movements, events, earth systems, quantification

7. ….. And a continuing Geophysics Revolution……

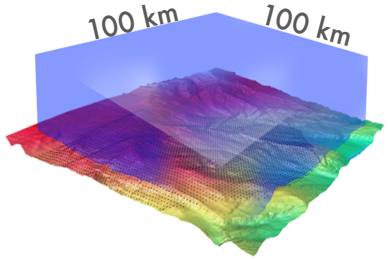
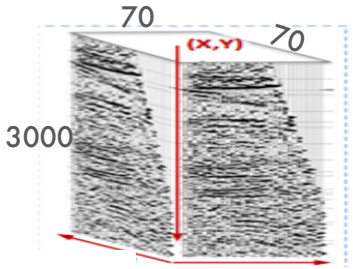
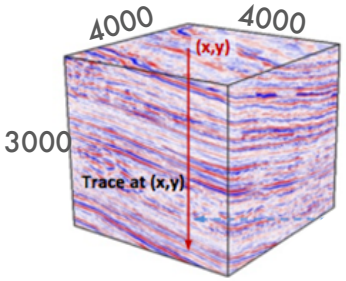
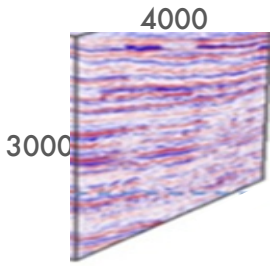
# Geophysics technologies – Computation versus channel count



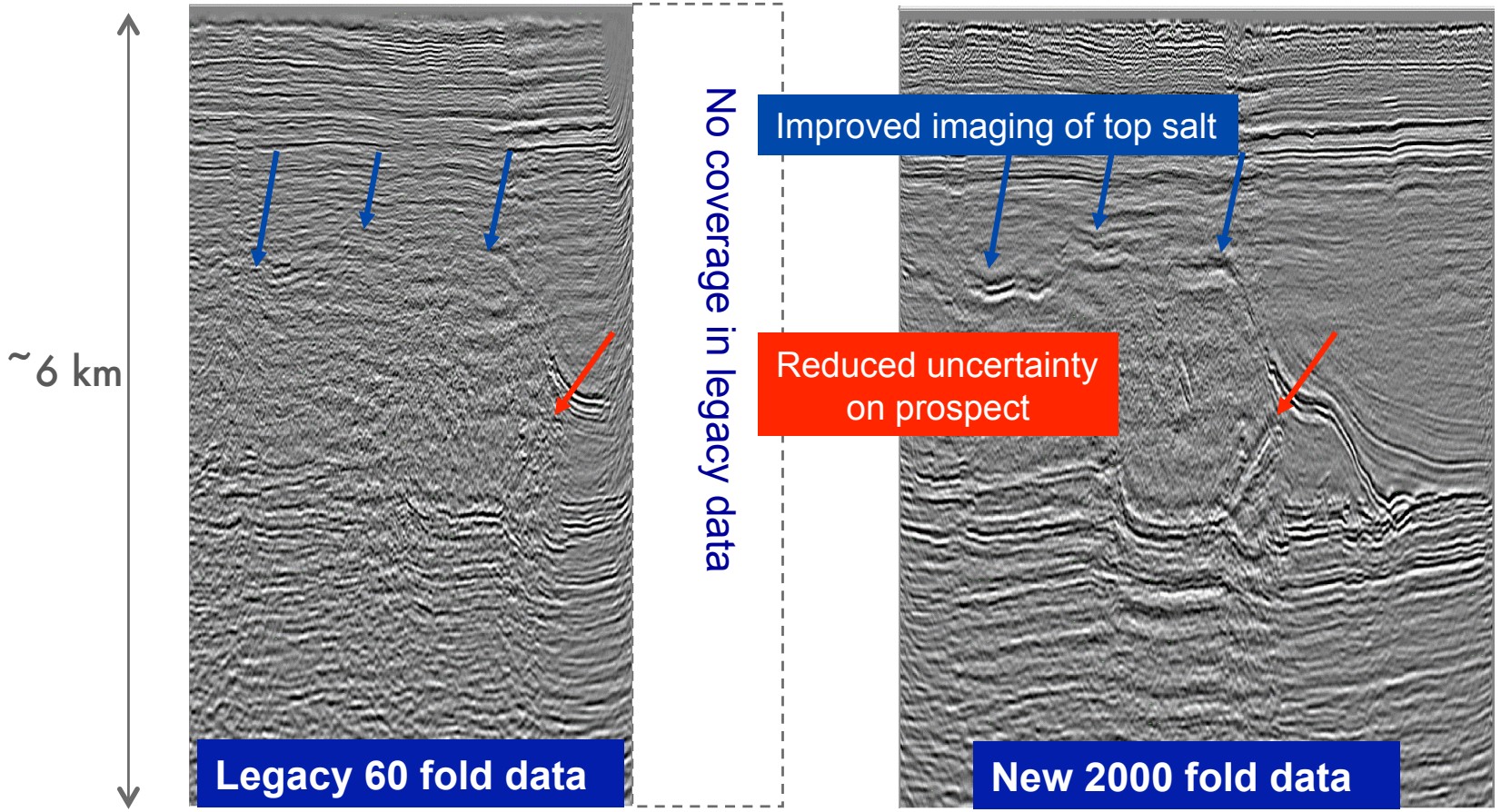
# Geophysics technologies – Data challenge OBS example

## Volumes

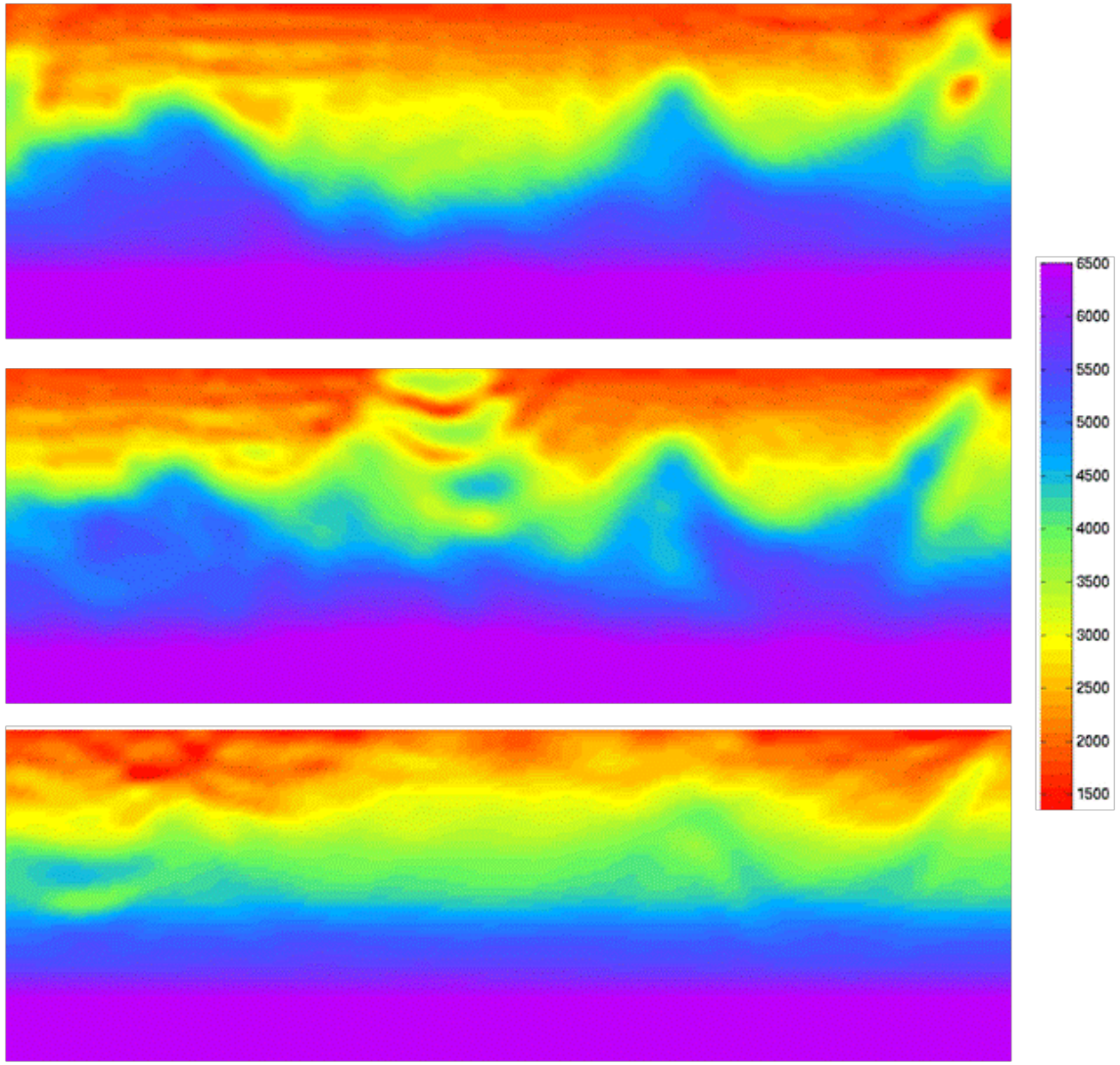
| 2015 Projection | |
|---|---|
| x, y, z | 100km, 100km, 15km |
| δx, δy, δz | 25m, 25m, 5m |
| nx, ny, nz | 4000, 4000, 3000 |
| | |
| OBS spacing | 400m x 400m |
| OBS range | 28km x 28km |
| num OBS / xy | 70 x 70 |
| num OBS | 250 x 250 |

| 470 TB | 29 MB | 96 GB | 24 MB |
|---|---|---|---|
| OBS Survey | Gather Data @ subsurface point | Stacked Volume | Stacked Traverse |
|  |  |  |  |
| 250x250 OBS | 4000X4000 gather volumes<br>14.7 million samples each<br>235 trillion samples | 48 billion samples | 12 million samples |

# Geophysics technologies – higher fold onshore data



# Geophysics technologies – Broad band for velocities




Fons ten Kroode, Steffen Bergler, Cees Corsten, Jan Willem de Maag, Floris Strijbos, and Henk Tijhof 2013

# Geophysics technologies – The User Experience, (or the Expereicne to know what to Use ?)