Infusing 4D seismic data into the third wave of automation

(fourth industrial revolution?)

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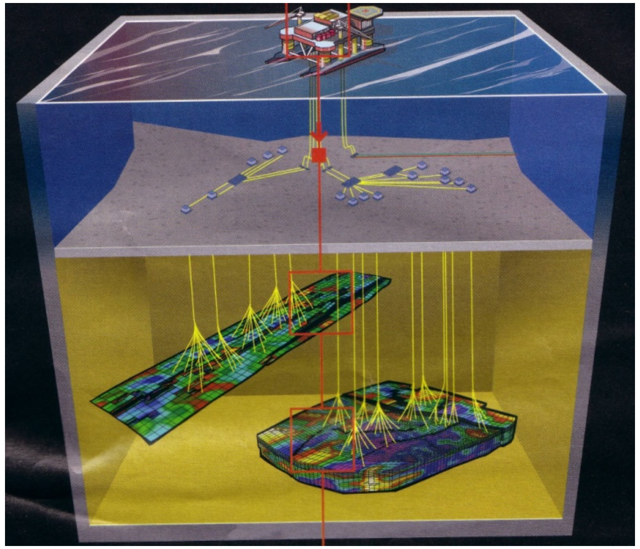
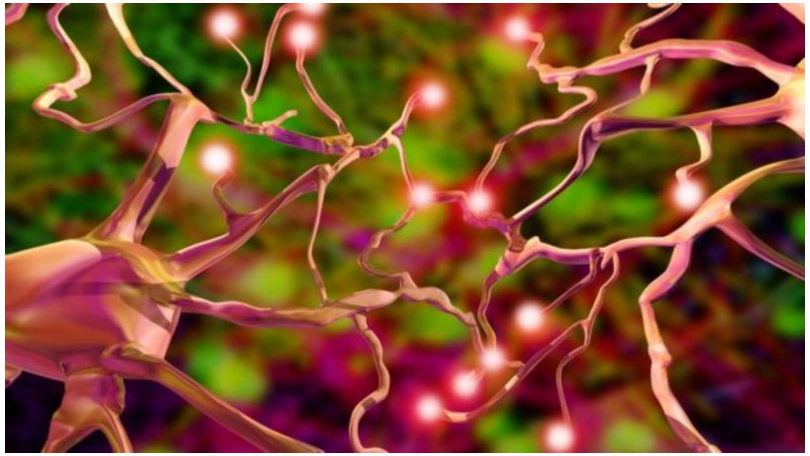




Introduction

Shepherd (2016)

THE BIG SIX – A SCORE CARD

FIELD	PRODUCTION 2016 Billion barrels oil	Recovery Factor as of 2016
FORTIES	2.74	~ 61%
BRENT	2.02	~ 53%
NINIAN	1.22	~ 47%
PIPER	1.09	~ 80%
MAGNUS	0.86	~ 56%
BERYL	0.84	~ 40%
TOTAL	8.77	

Introduction

SOME OF THE NEW TECHNOLOGY SINCE THE UK NORTH SEA STARTED UP IN 1975

1970s Routine use of 3D seismic (first survey shot by Exxon in 1967)

1980s Start of routine horizontal well drilling

1980s Increasing use of geostatistics in reservoir geology

1980s Locate The Remaining Oil techniques developed

1990s Common use of 3D computer models in reservoir geology

1990s Vastly improved resolution of 3D seismic

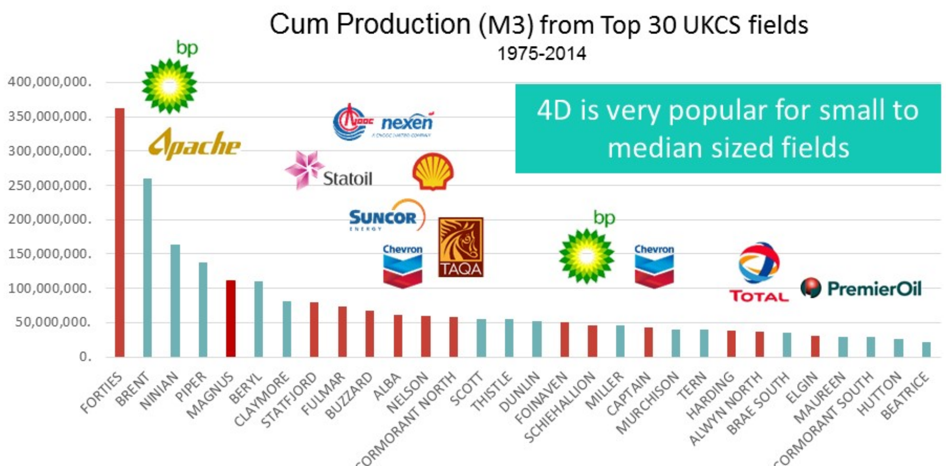
1990s Common use of 4D seismic

1990s Implementation of Enhanced Oil Recovery techniques

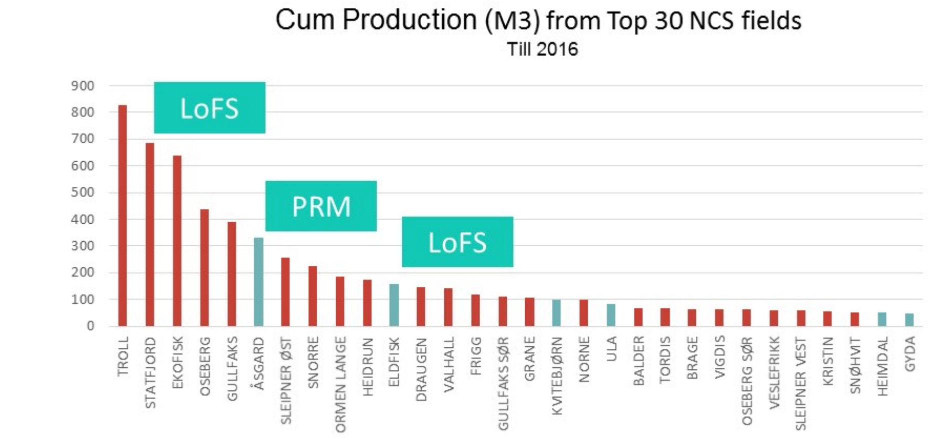
1990s Growing understanding of structural geology as applied to reservoirs

2000 Integrated reservoir management teams

Shepherd (2016)



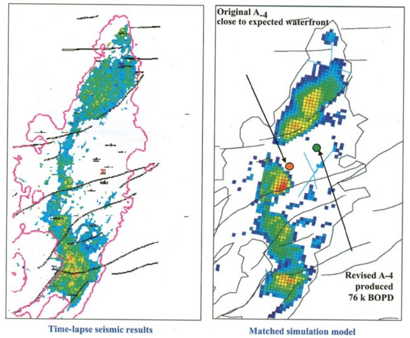
Data from OGA 2016

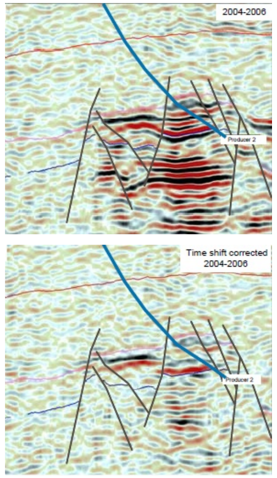


Data from http://www.norskpetroleum.no

A selection of acknowledged benefits from using 4D seismic as a reservoir monitoring tool

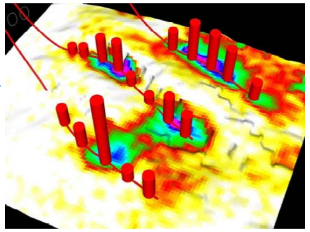
- Re-pressurisation/displacement by water
- Re-pressurisation by gas
- Displacement efficiency
- Water over-run
- Flood movement
- WAG optimisation
- Gas exsolution and dissolution
- Baffles
- Compartments
- Faults and fault transmissibilty
- Intra-reservoir connectivity
- Seismic PLT
- Geomechanical assessment
- Coning
- Perforation performance

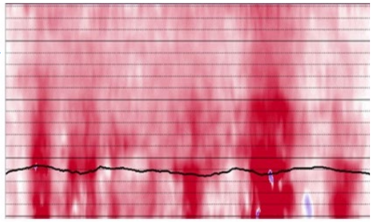




Alsos et al. 2009

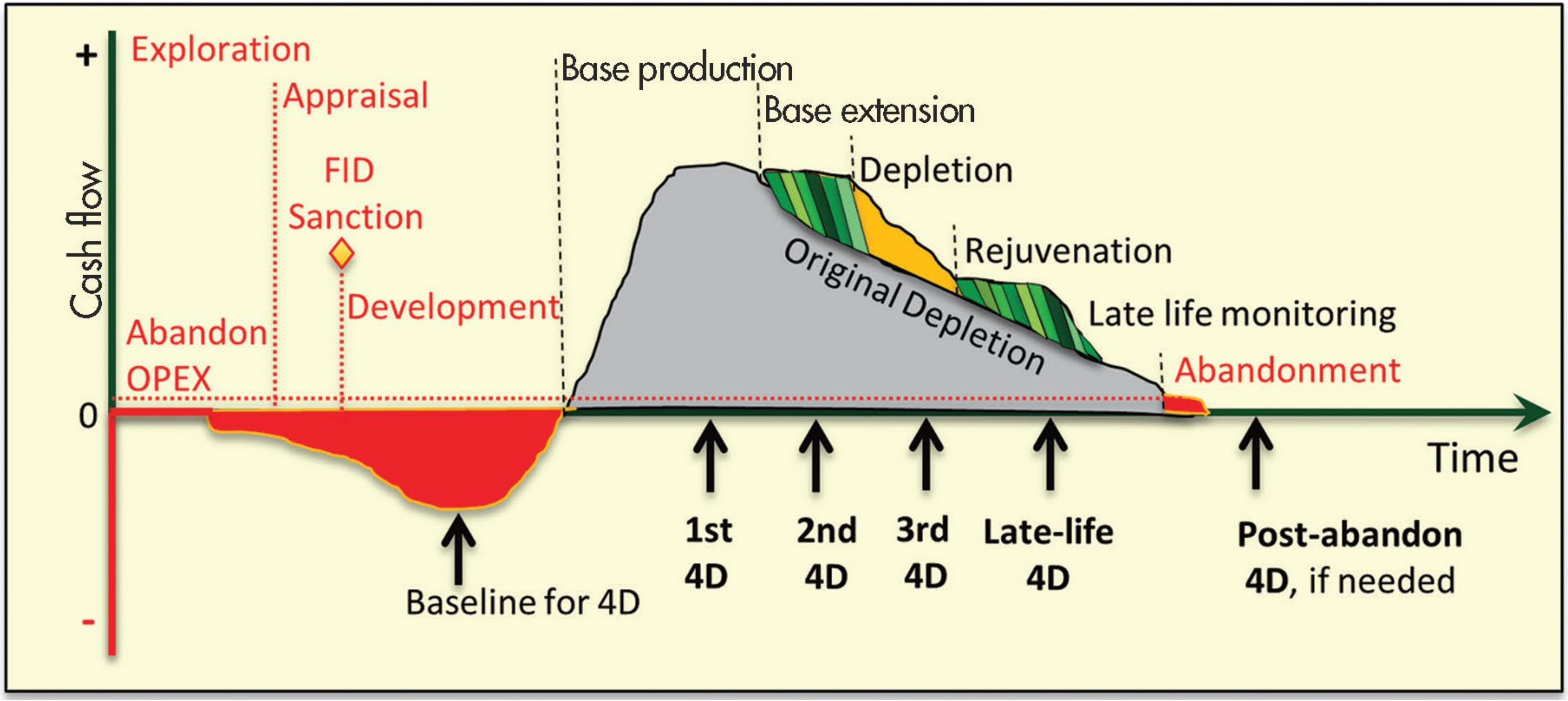
- Seismic PLT predicts fractional flow profile (Barkved 2005, Gouveia 2004)





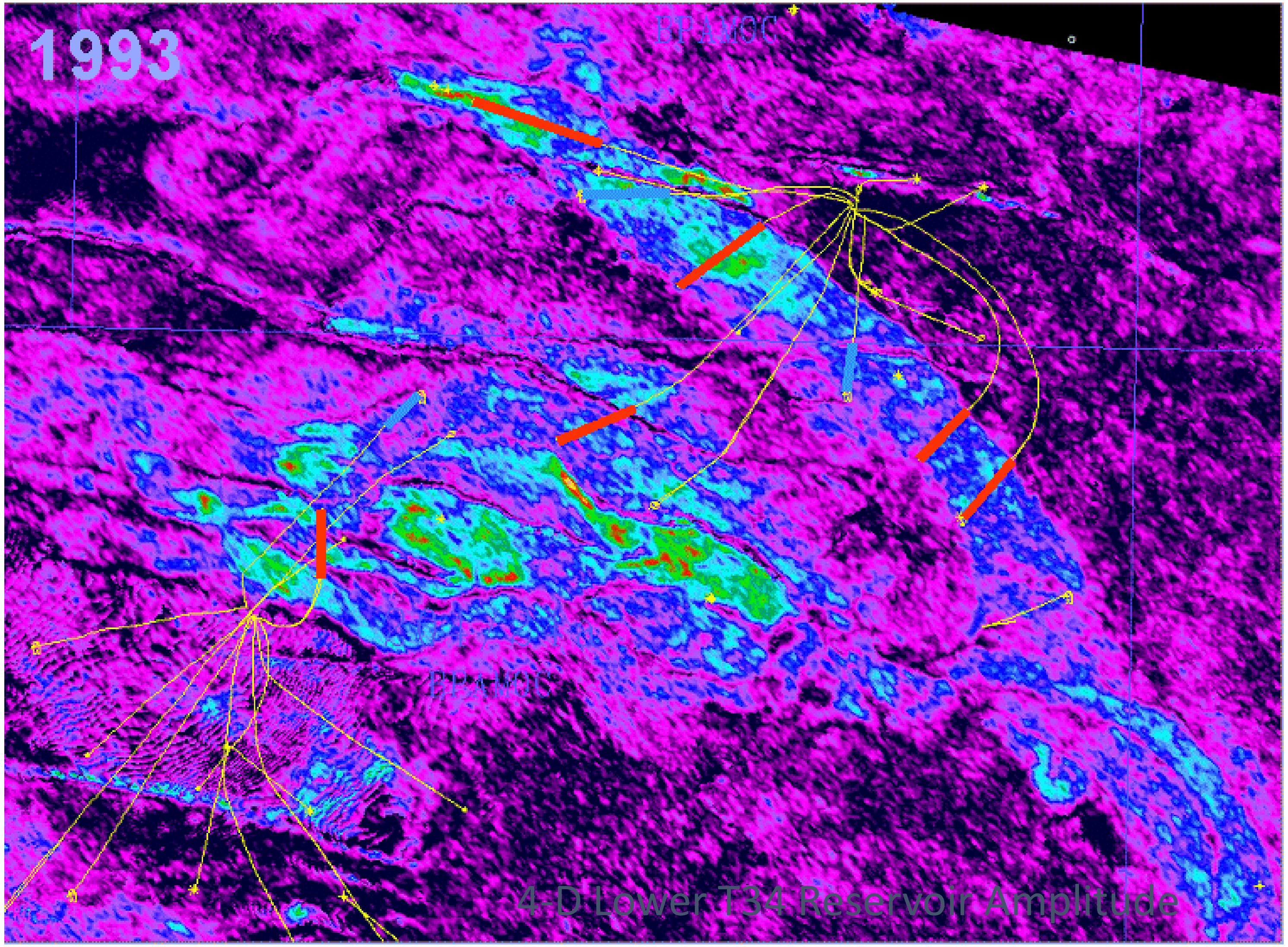
- In clastics, chalks, hard-rock carbonate, deep HPHT condensate, heavy oil, …

Seismic surveillance throughout field life

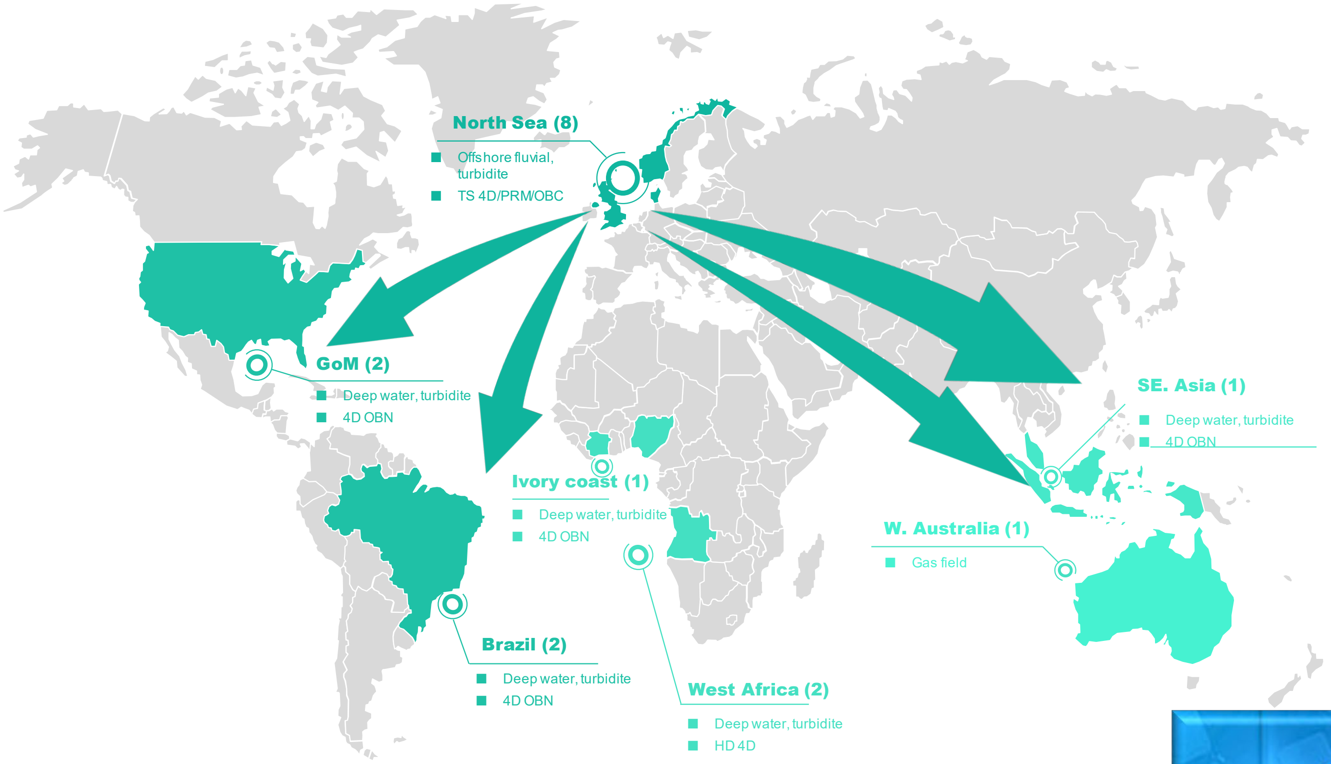


Blangy et al. 2017

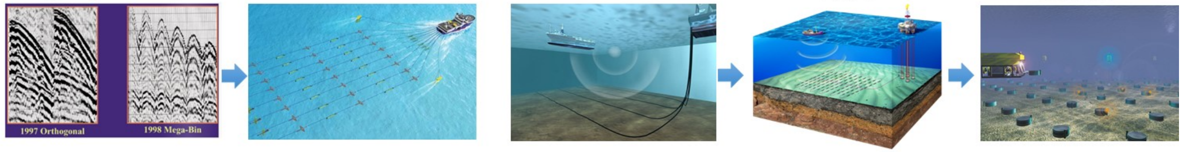
4D seismic as a tool for monitoring production and recovery

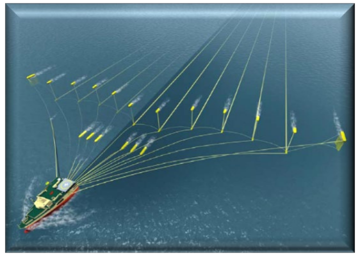


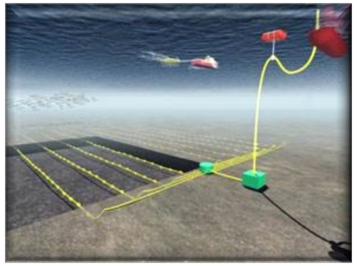
Global trends in application

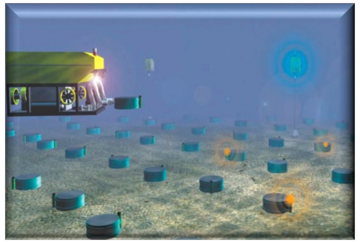


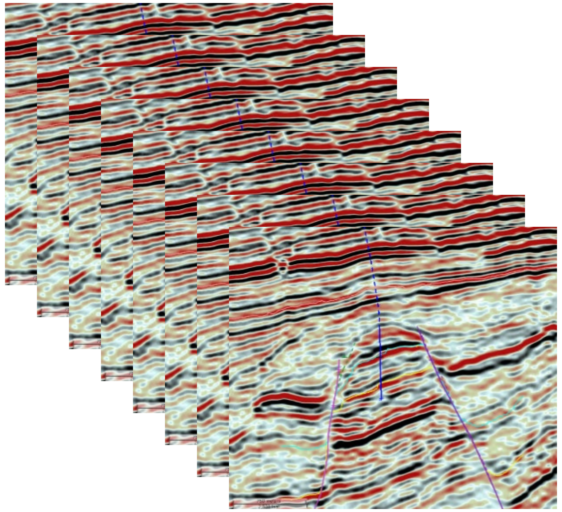
Global trends - acquisition volume



Towed streamer  5Gb post-stack or 250Gb pre-stack

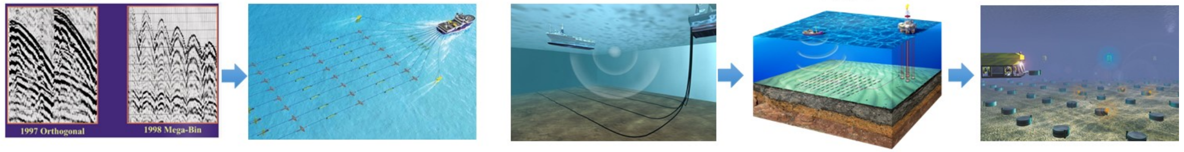
PRMs  2Gb post-stack or 1Tb+ pre-stack

Nodes  5Gb post-stack or 3Tb+ pre-stack



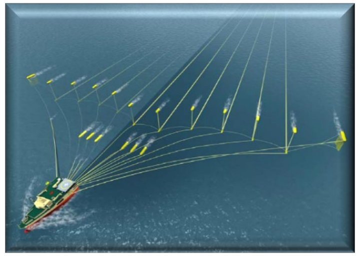
Processing and interpretation generates many more duplicates, updates, so cubes x 50 at least

Global trends - acquisition frequency

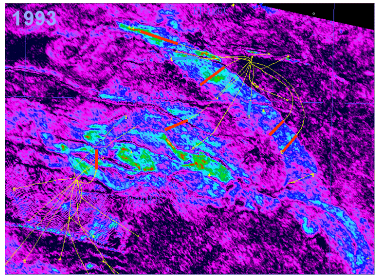


1990-2000 2000-2010

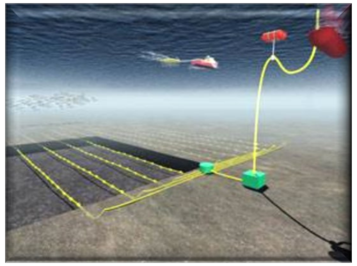
Towed streamer



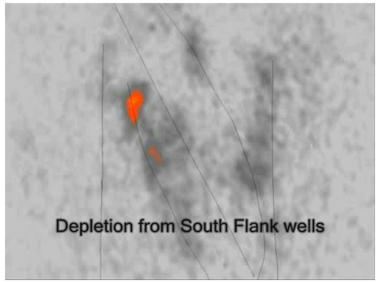
One every few years



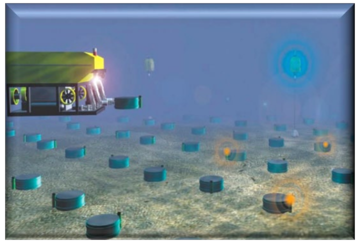
PRMs



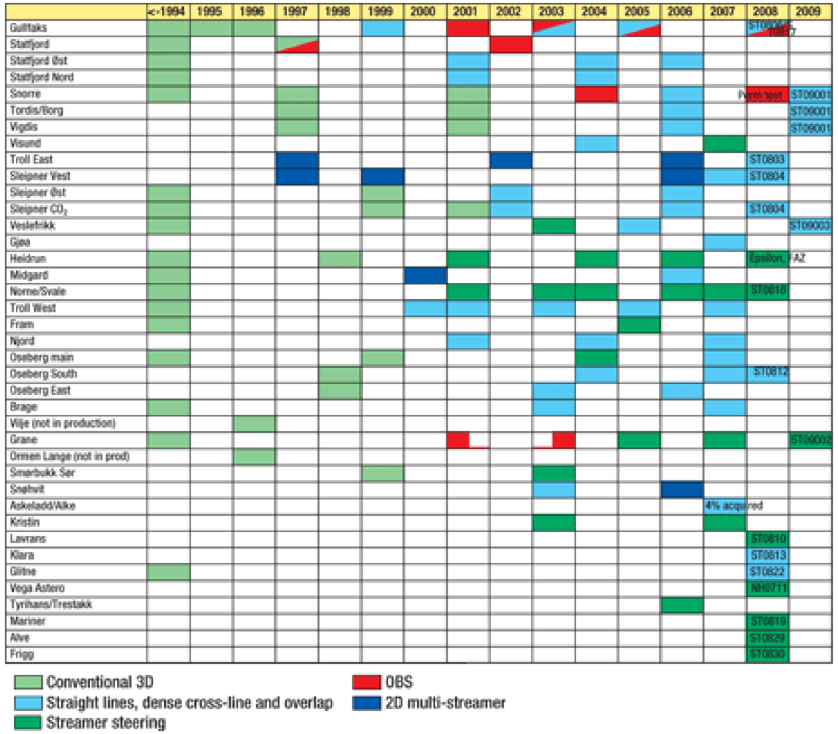
Two per year



Nodes

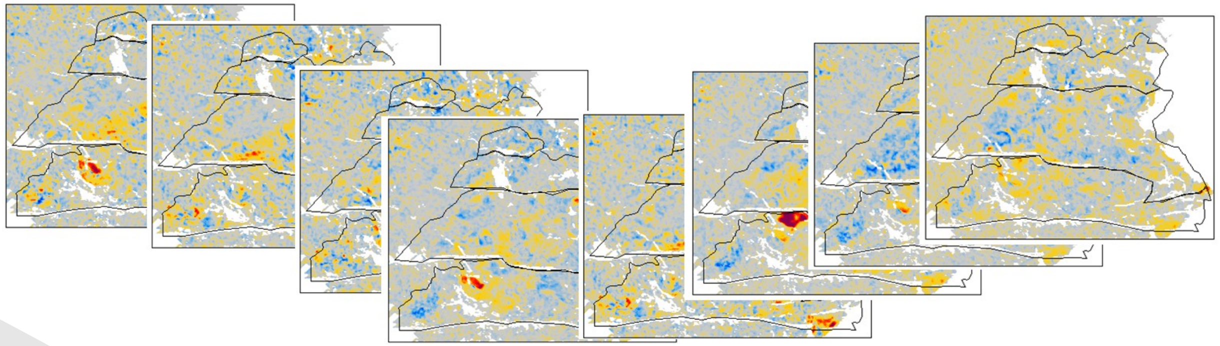


One every 6months to year or on demand



Sandø et al. 2009

Global trends – multiple data streams



Compaction

Simulation analysis

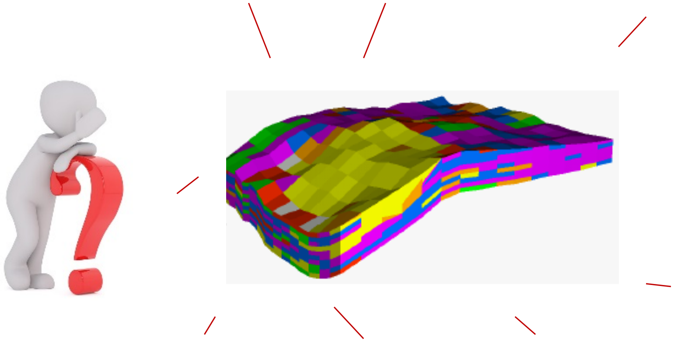
Saturation logs

Production/injection data

Tracer injection

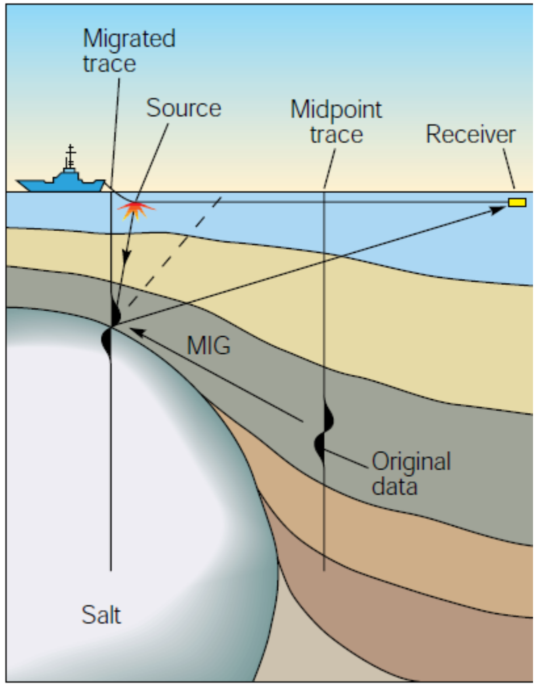
Injectivity analysis

Pressure transient analysis



The drivers for tomorrows technology

- Field targets will be more challenging
    - Mature/later life fields
    - Smaller signals
    - Thinner targets
    - More complex reservoirs (pre-salt versus Albian, Carbonates, stacked)
    - More complex mixed fluid environments
    - More sophisticated IOR and EOR chemistry
    - Deeper targets
    - Deeper water
    - More geo-hazards



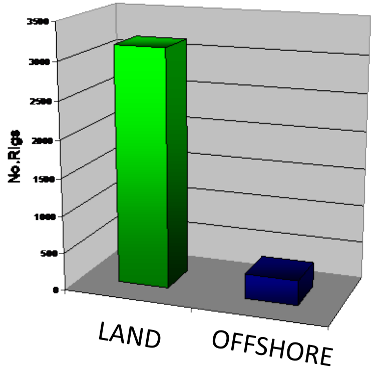
- Our technology must address the socio-economics of the future, we will demand much **more for less** regardless of the oil price

- Higher **quality** data, more volume

- Reduced environmental impact

- Land versus marine

- **The technical backdrop – the influence of significant improvements in worldwide technology**



Jack 2006

Selected, relevant, fast-paced technologies outside the oil and gas (energy) sector

- Electronic engineering Moore's law continues to be applicable, predicting a favourable increase in computer power by 1 million by 2040, but with a pessimistic (realistic) limit of only 10!

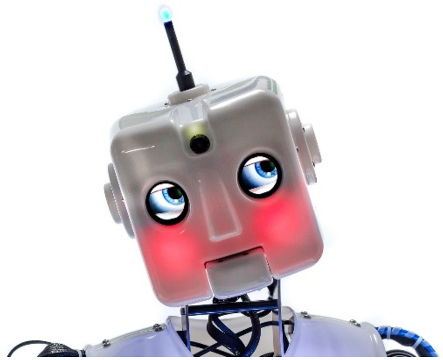
- Quantum/optical computing – too early for these to be useful

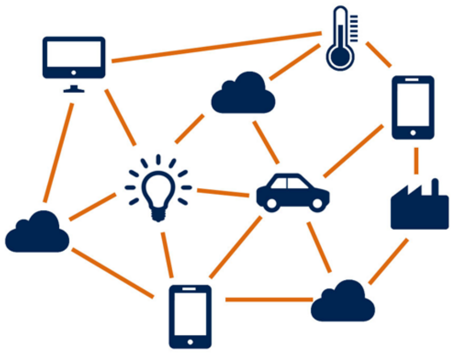
- Massive increase in data storage – in proportion to Moore's law

- Internet of things – mass connectivity of devices at all scales in society commensurate with increase in processor power. Smart technologies are expected to be the norm.

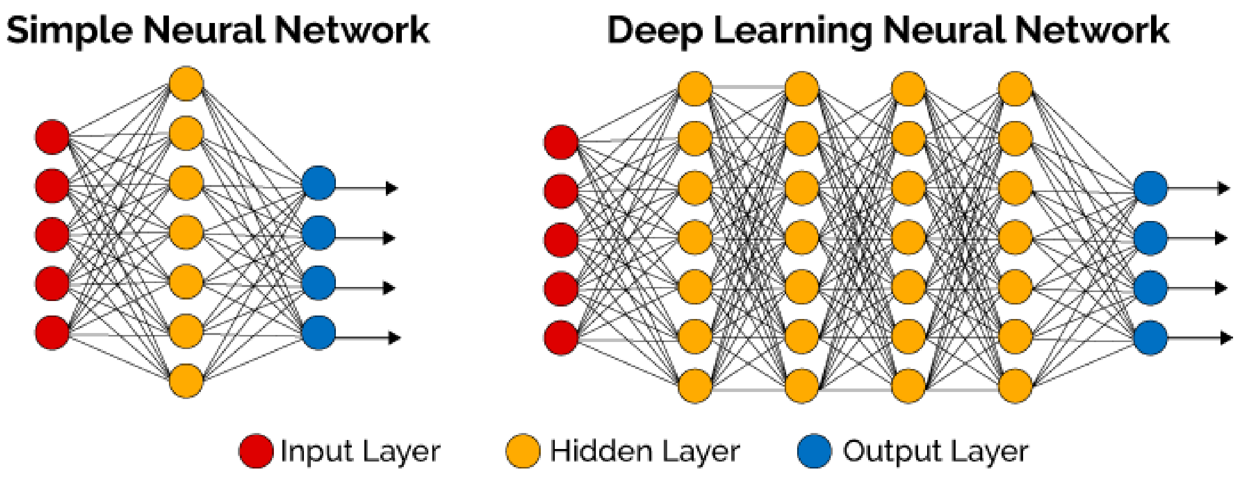
- Global internet coverage, mass corporate communication

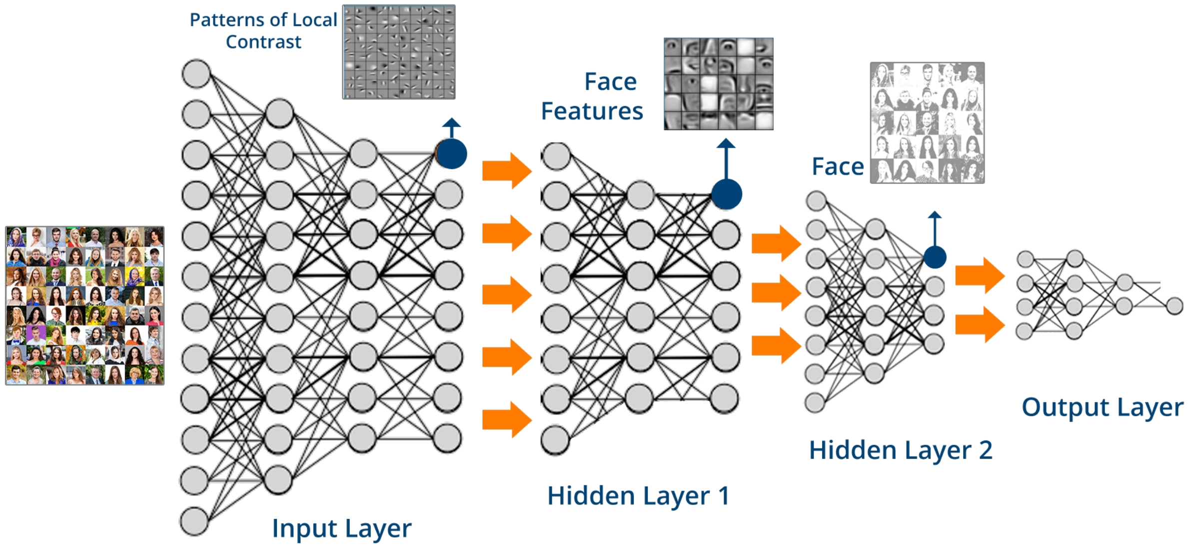
- Machine learning/'Big Data'/AI/robotics - data analytics
- Block chain
- Virtual and augmented realities
- Cloud computing and storage

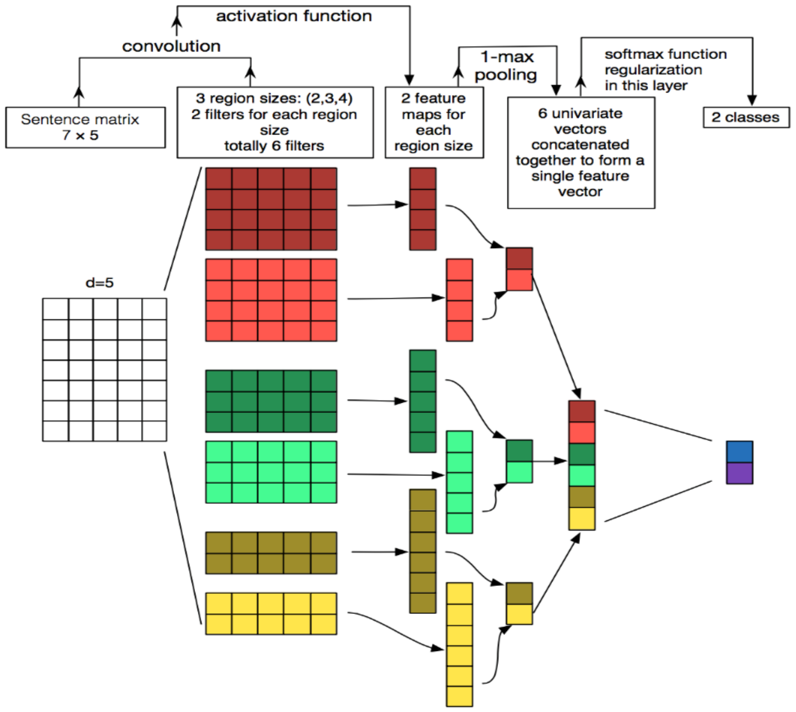




The new wave is in full swing!

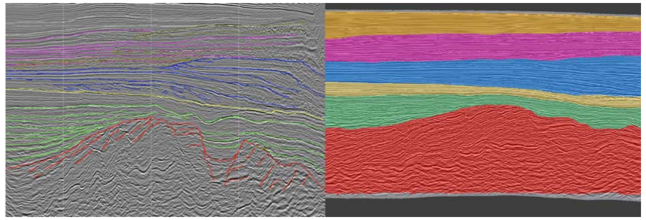


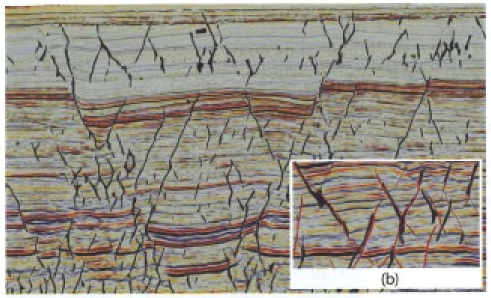




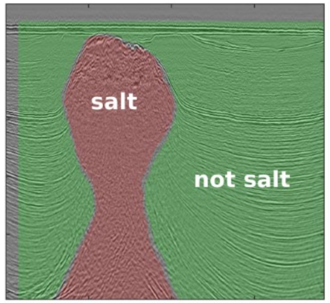
ML – conventional applications in seismic

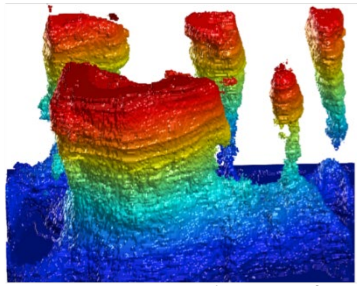
Structural or stratigraphic interpretation



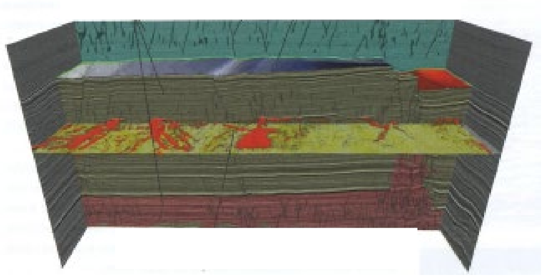


Faults/geobodies/chimneys/salt
Hence model building

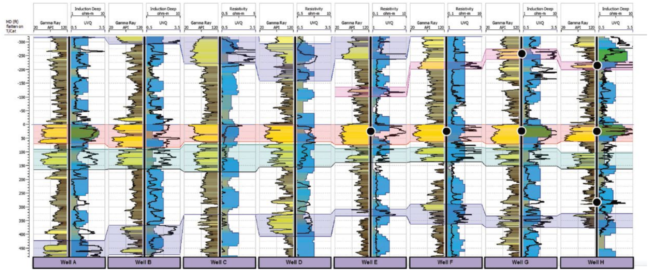




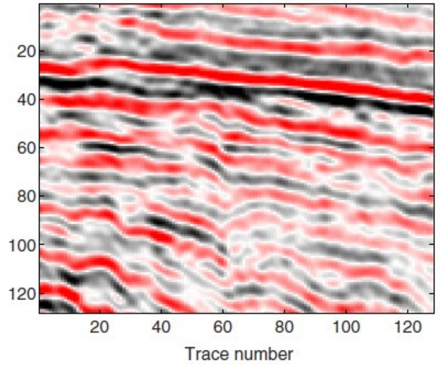
Agilescientific



Lithofacies & saturation identification

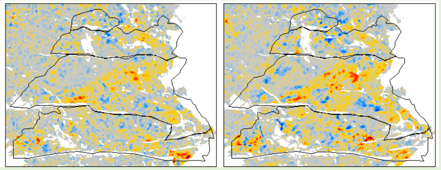


Processing QC, interpolation/reconstruction



Easy gains for the 4D tooolbox

Anomaly interpretation



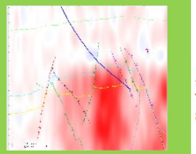
4D well tie

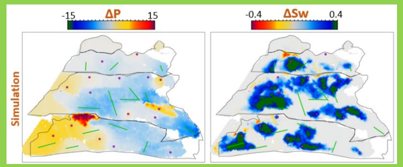
4D imaging

Sim2seis modelling

Stress and geomechanics

Property inversion



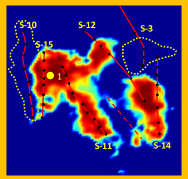


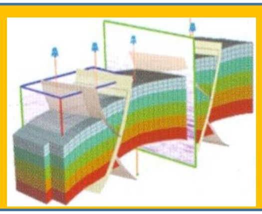
Pressure and saturation estimation

4D inversion to impedance

Dynamic model updating

Model updating

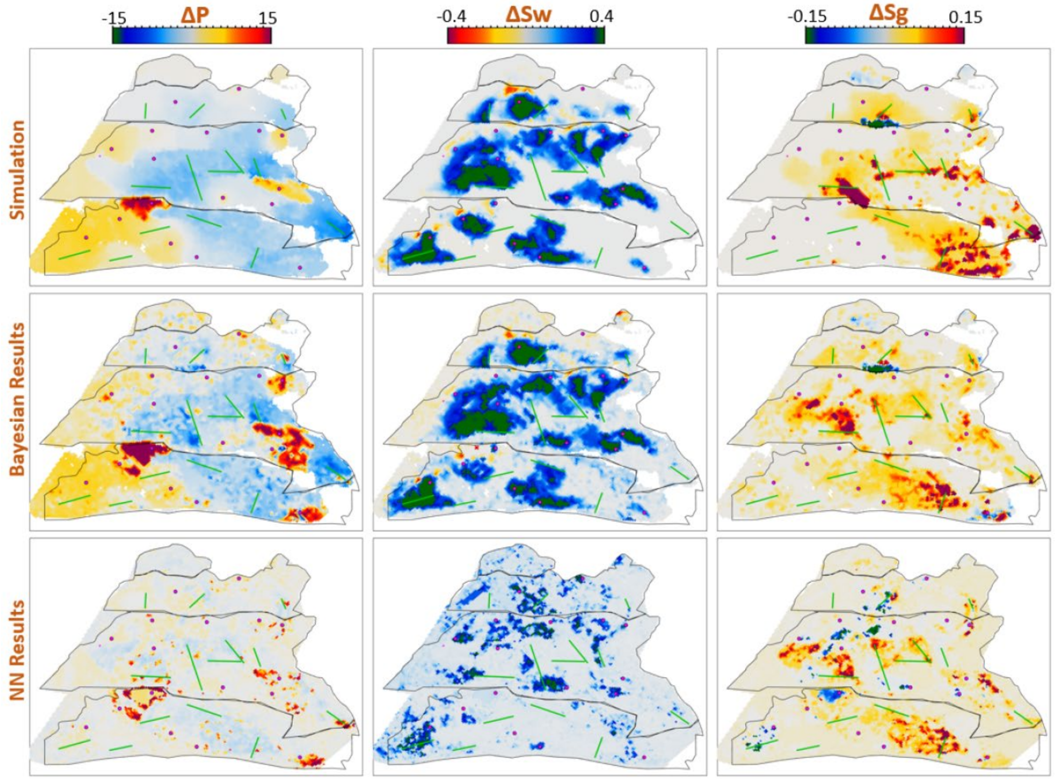




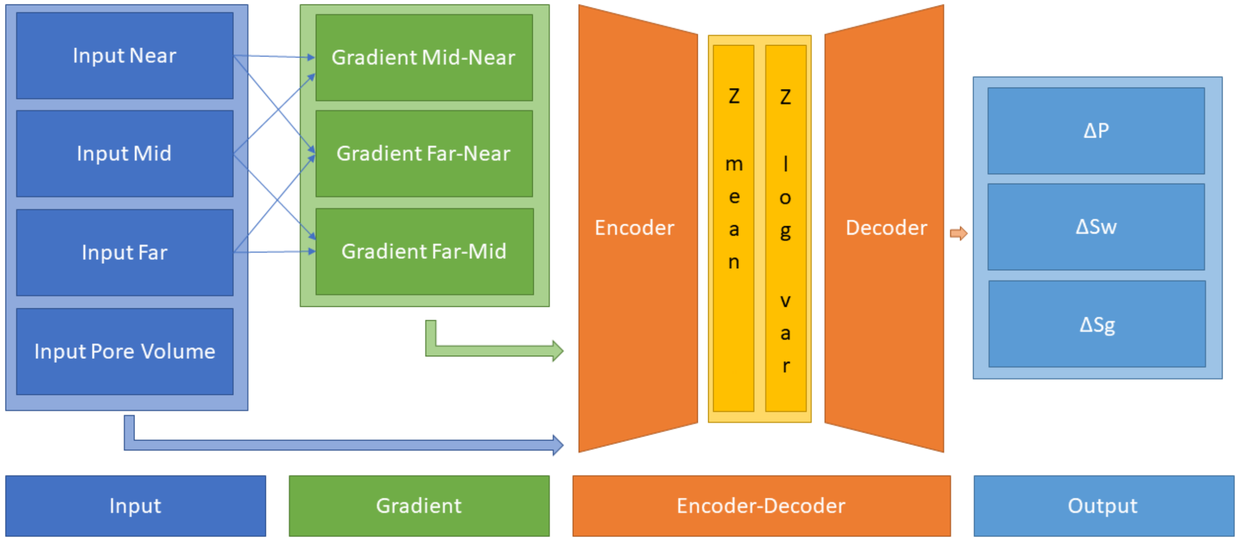
Seismic history match

Well2seis connectivity analysis

Easy gains: example 1 – pressure and saturation inversion

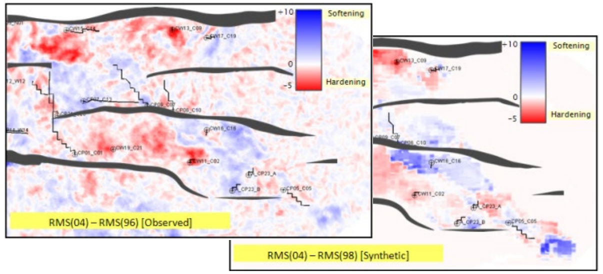


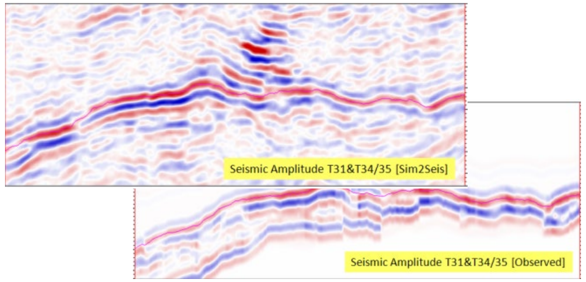
2004 time-step – Bayesian inversion versus neural inversion

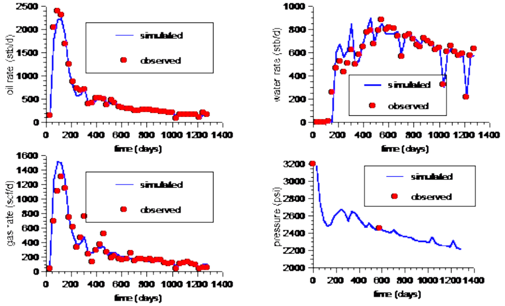


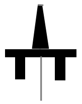
Dramsch et al. 2019

Easy gains: example 2 – the seismic history match

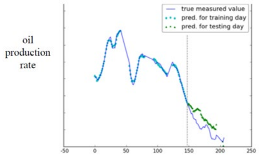








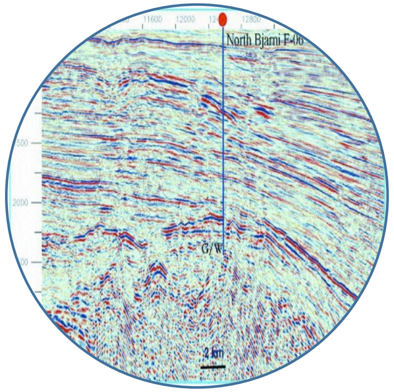
NN solution



Production forecast

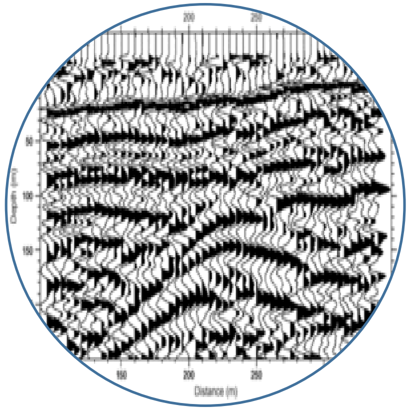
The bigger picture

Exploration



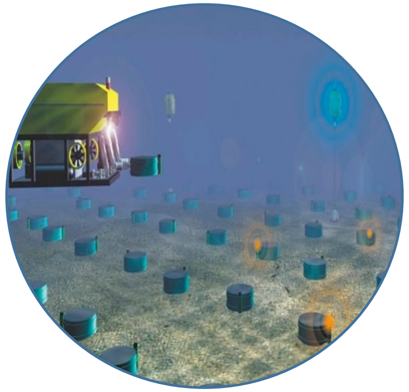
Years

Processing



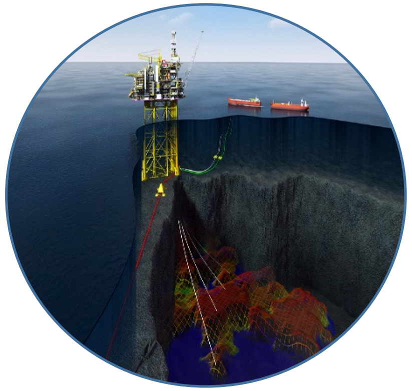
6 to 12 months

4D seismic acquisition

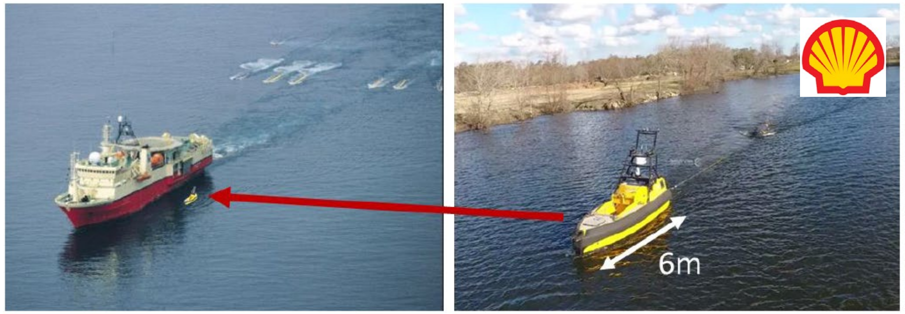


3 months

Interpretation, model building and decision making



1 – 2 years

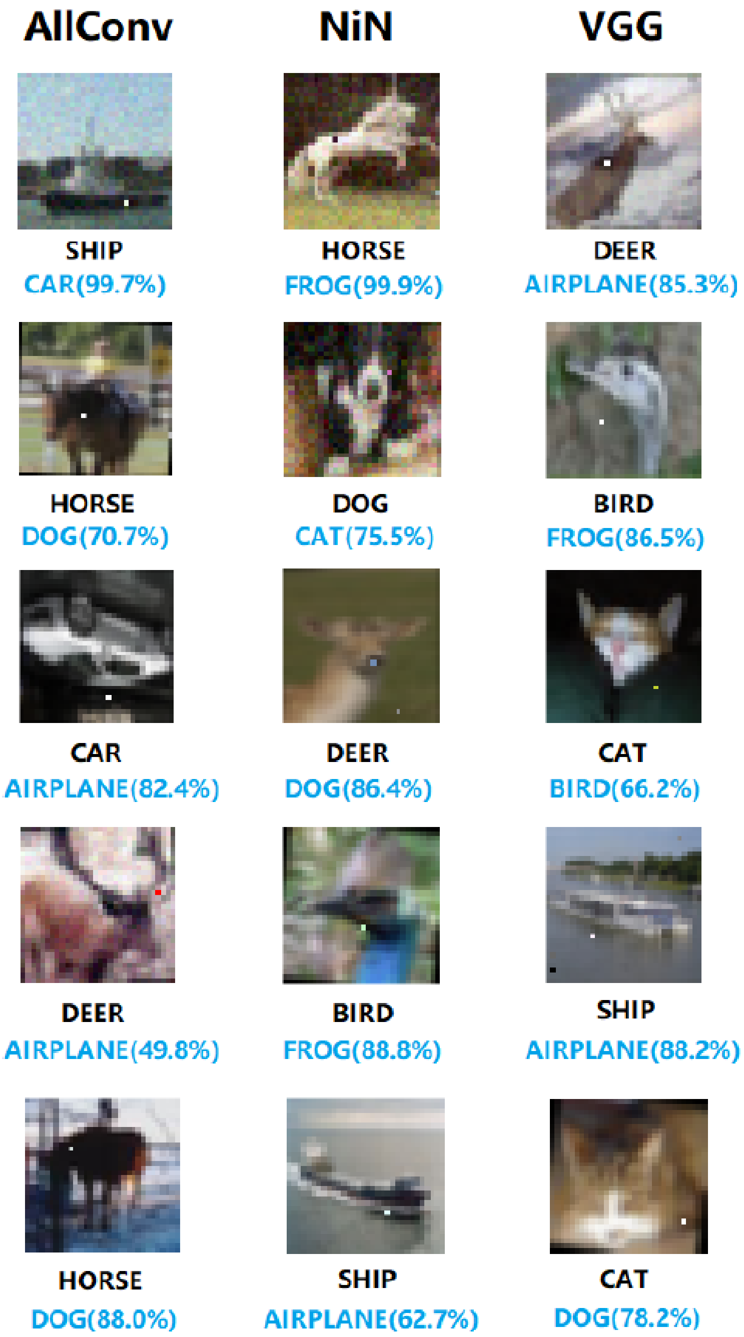


Chalenski et al. (2017)

The irrational DNN

One Pixel Attack for Fooling Deep Neural Networks

Jiawei Su*, Danilo Vasconcellos Vargas* and Kouichi Sakurai



Education and technology in an ever-changing ML landscape

- Rapid societal change: technology + workforce demographics – baby boomers retiring, millennials and Gen-Z

- TU Delft: '*A thunderstorm for which there is little time to prepare*'
- Morgan Stanley: '*The sector that could see the most profound benefits ….O&G'*

- *Role and nature* of education/training - industry & university
- *Mismatch* between employee skills and employer, need for alignment between providers

- *Classic learning model* will fail as massive change occurs
- Re-shape *cultures and practices* – e.g. new learning designs by Deloitte

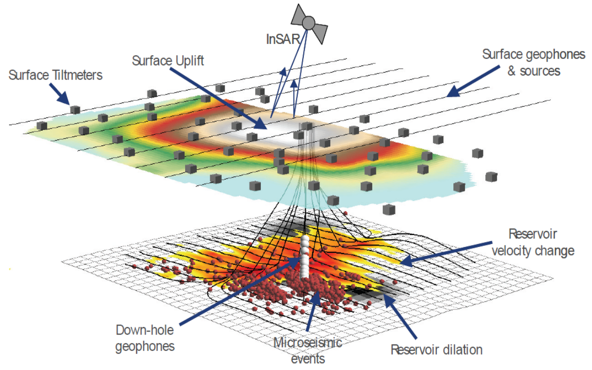
- Data scientist or geoscientist?

EAGE EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

London 2019
Dedicated session on 'Education in the future'

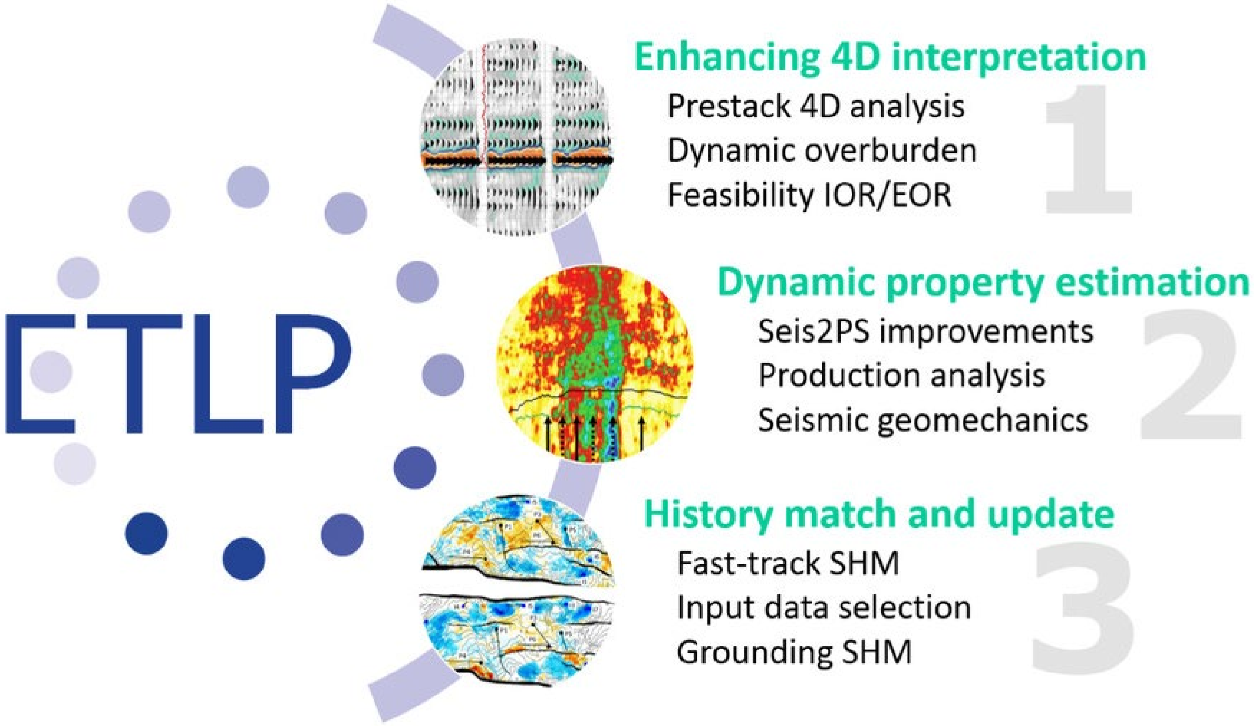
Closing remarks

- An industry transformation is upon us
- Machine learning/Deep learning is maturing to the point where data can be put back at the core again
- However the playing field of the near-future will not be the same - we will be playing 7 a side football and not with the full 11, played with a small rugby ball and hockey sticks, and smaller goals. Player of tomorrow must be fast, fit, skilful and broadly educated to handle the new generation game.
- Education/training/learning will need to be flexible, mobile and immersive
- Will ML/DL deliver 'more for less'?

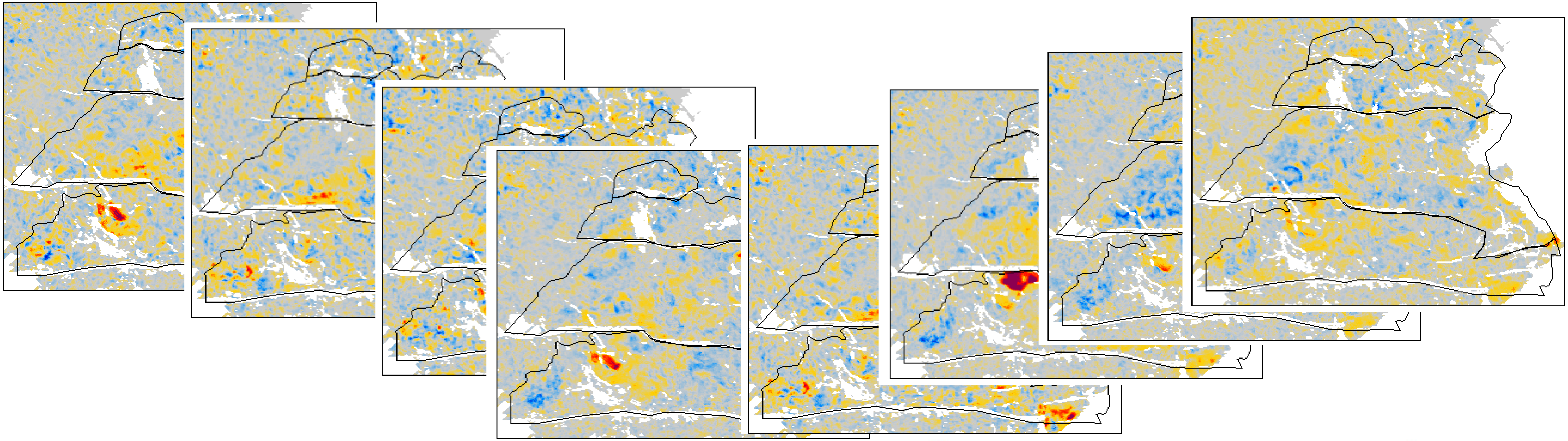


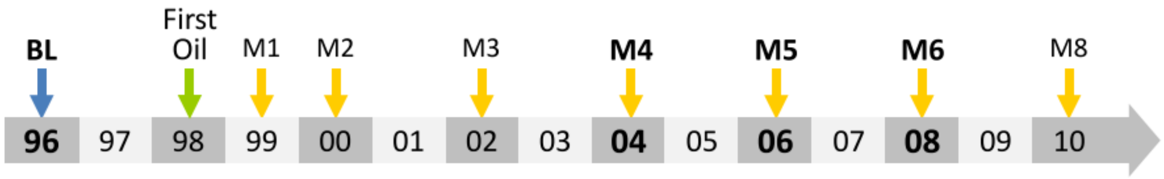
Acknowledgements

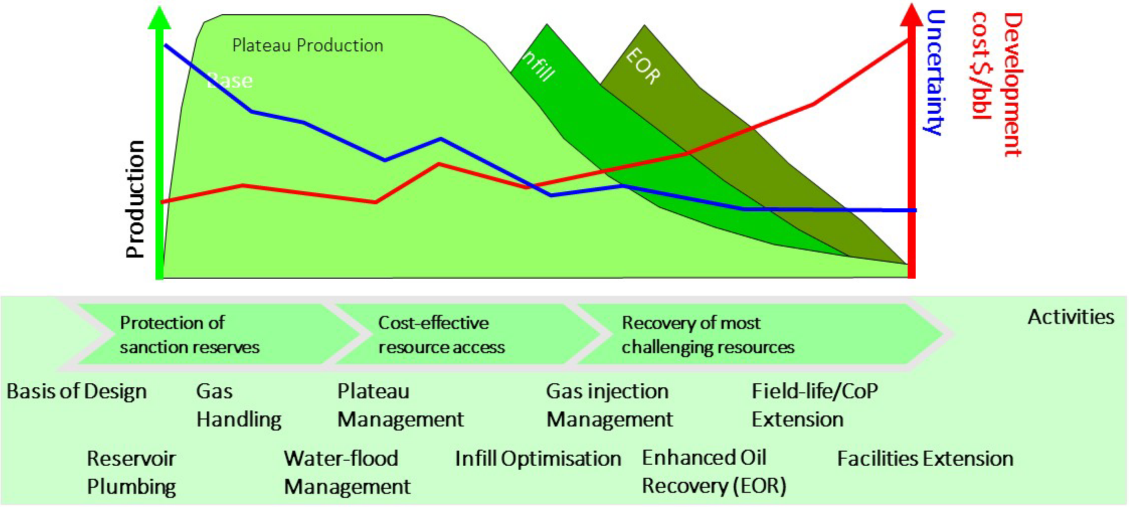
We thank the sponsors of the Edinburgh Time-Lapse Project, Phase VII for their continued support and discussion.



Emerging bottlenecks in 4D seismic interpretation

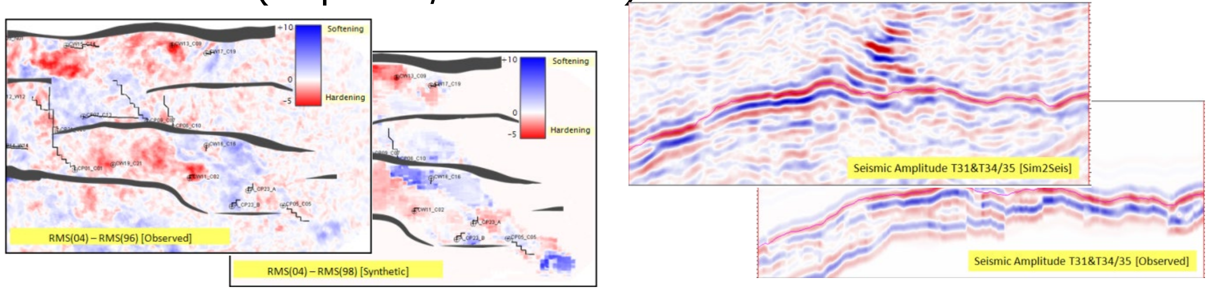






Easy gains: example 2 – the seismic history match

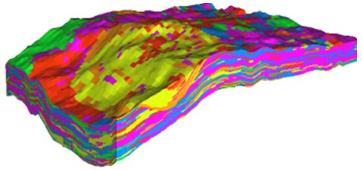
Direct comparison of predictions for seismic data (maps and/or sections)



Simulate, adjust model and re-simulate

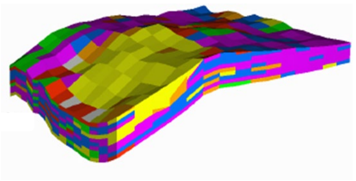
Direct comparison of predictions to well data

Geological model

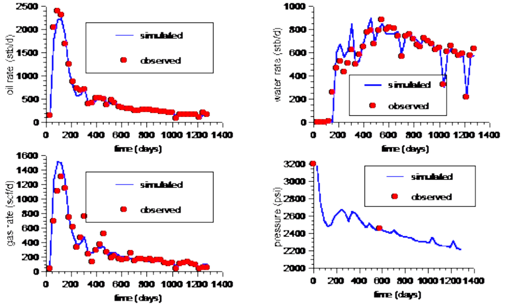


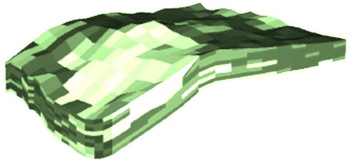
Upscale

Simulation model



Simulate, adjust model and re-simulate





Improved simulation model or many realisations