Subsurface knowledge creation based on facts, concepts and actions:

Better practice and new coherence by dialogues

Hans Rønnevik
Lundin

Loppa High

Drill, core and test

6-8 years later:
Harvest, drill and learn until the reservoirs are produced

Edvard Grieg

National policy ; Parliamentary Act 25 1973-4:

- *Activity: licensing with firm wells*
- *High and low probability prospects*
- *Norway select companies and companies select countries*
- *Knowledge and data are national resources*

Scientific philosophy;

- *Unfold subsurface reality by interactions (Bohm)*
- *Reality and perceptions are created by bifurcations (I Prigogine)*
- *Reality is a given chaos, models of it are self referencing (Gödel)*
- *Indirect data must be calibrated by facts*
- *Continuous better practice by awareness of incompleteness*
- *Basic geological principles; Hutton, Walter, Wheeler, Vail*

Knowledging through dialogues (David Bohm by W vd Heuvel) :

- *Dialogues should unfold itself, not be enforced, controlled or limited. Listen and respond without resistance then the coherence will come.*
- *It is like exploring in unknown territory: We don't know what we're going to find, we'll find it when we go there*

Knowledging experience from NCS

- *All fields are unique and most fields "impossible" before proven otherwise by the drill bit*

Surprises; disccovery specific

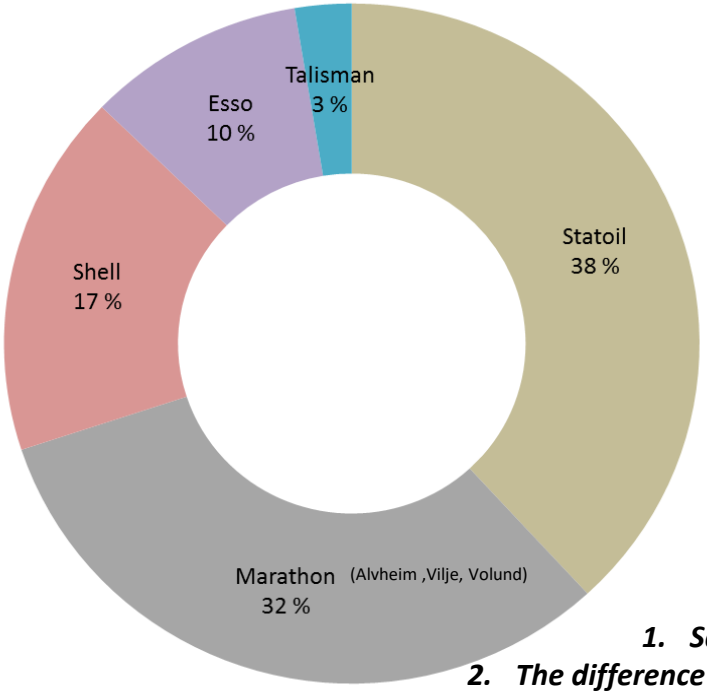
- ***Ekofisk**; Chalk as commercial reservoir*
- ***Sleipner East**; CO2 lean gas in Paleocene pinch out trap*
- ***Snorre;** Upper Triassic commercial reservoir and under saturated oil from the Møre Basin*
- ***Oseberg Oil** : 380 m oil unfolded beneath 300 m gas found from the 4th well*
- ***Vigdis**: oil discovery in the migration shadow*
- ***Borg;** oil in stratigraphic down flank pinch out play; the analogue for EG and JS concept*
- ***Troll Oil** commercial with oil leg varying from 5 -28 m beneath commercial gas*
- ***Lavrans and Kristin** good porosity below 4500 m*
- ***Goliath** deep oil proved Triassic source rock for oil*
- ***Alvheim** the gas satellites that became a major oil field*
- ***Haugaland and Loppa High fields** ongoing oil migration and new reservoirs to NCS*
- *etc.*

Consciousness is created by experiencing the unknown becoming explicit
Fact based learning from prospect to production
Technology step changes follow discoveries

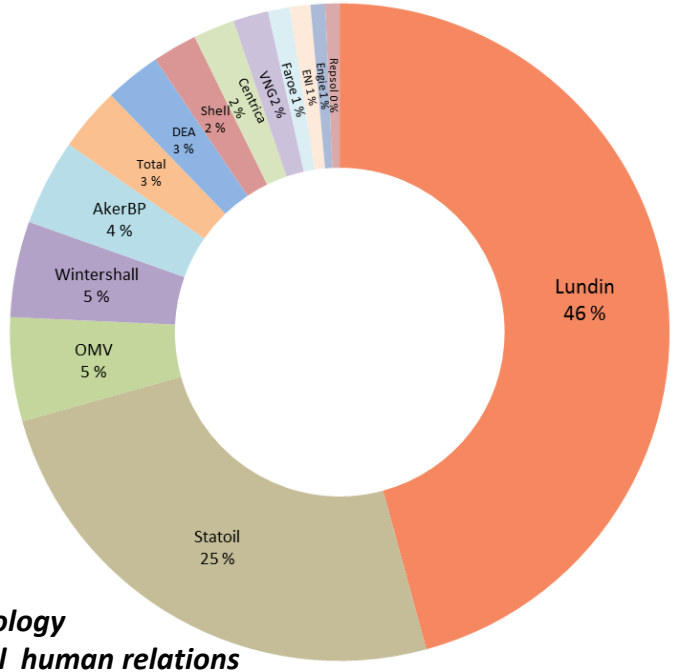
Increasing diversity of companies paid off

Cultural diversity not more of the same

Resources discovered 2001-2006 (by Operator) Total: 140 MSM3 o.e.



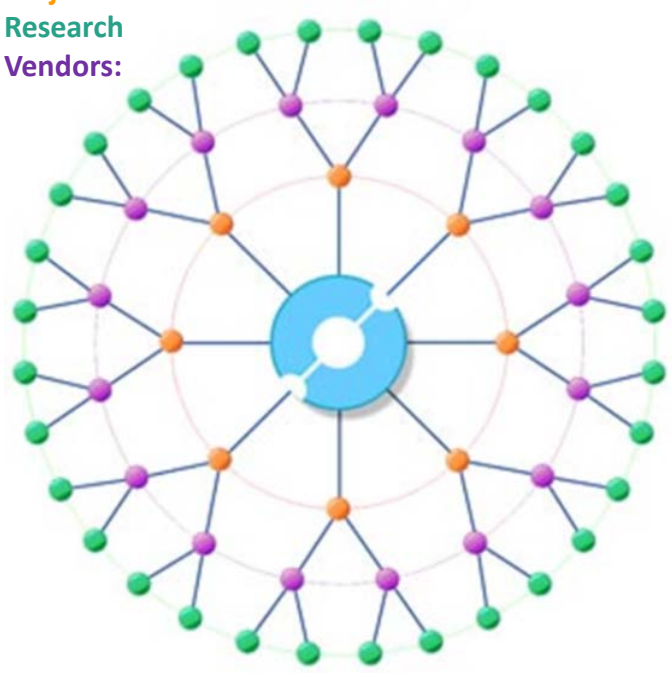
Resources discovered (over 5 MSM3 o.e.) 2007-2017 (by Operator) Total: 1105 MSM3 o.e.



1. ***Same data, theories and technology***
2. ***The difference is in the internal and external human relations***
3. ***Teleological diversity need free flow of ideas, data and tools in open networks to prosper***
4. ***Learn and operate with logic (IQ) and associative (EG) intelligence and create new relations with unity (SQ) intelligence***

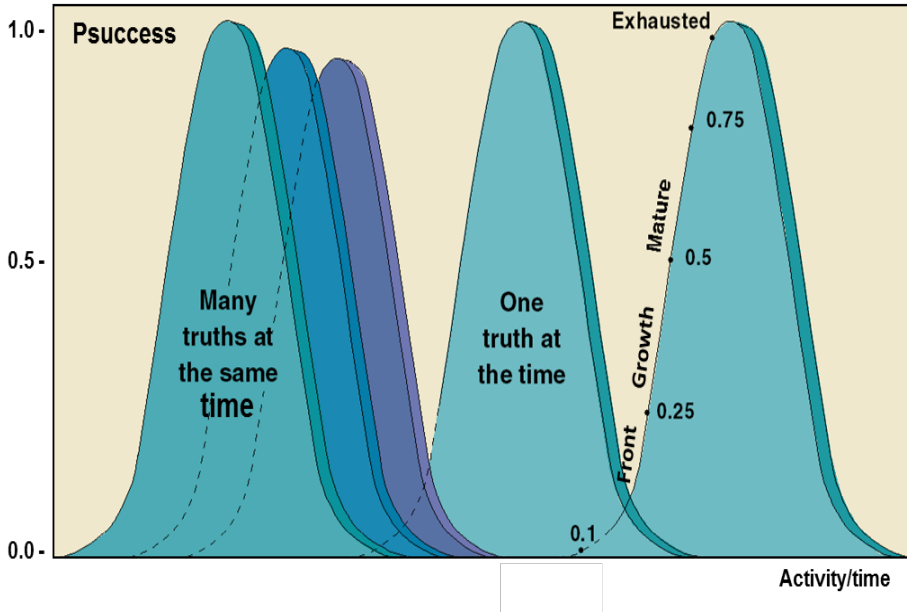
Stability through knowledging

Projects
Research
Vendors:



- always
- usually
- general
- by and large
- more often than not
- half the time
- often
- sometimes
- occasionally
- been known to happen
- never
- cannot be true

Unfolding the tacit **Explicit focus**



1 Teleological self organizing processes; conscious or unconscious
2 Surfacing the tacit through unblocked dialogue between diversity of skilled humans
3 Open honest networking with operational and theoretical peers

Knowledge economy needs networking and co-creation

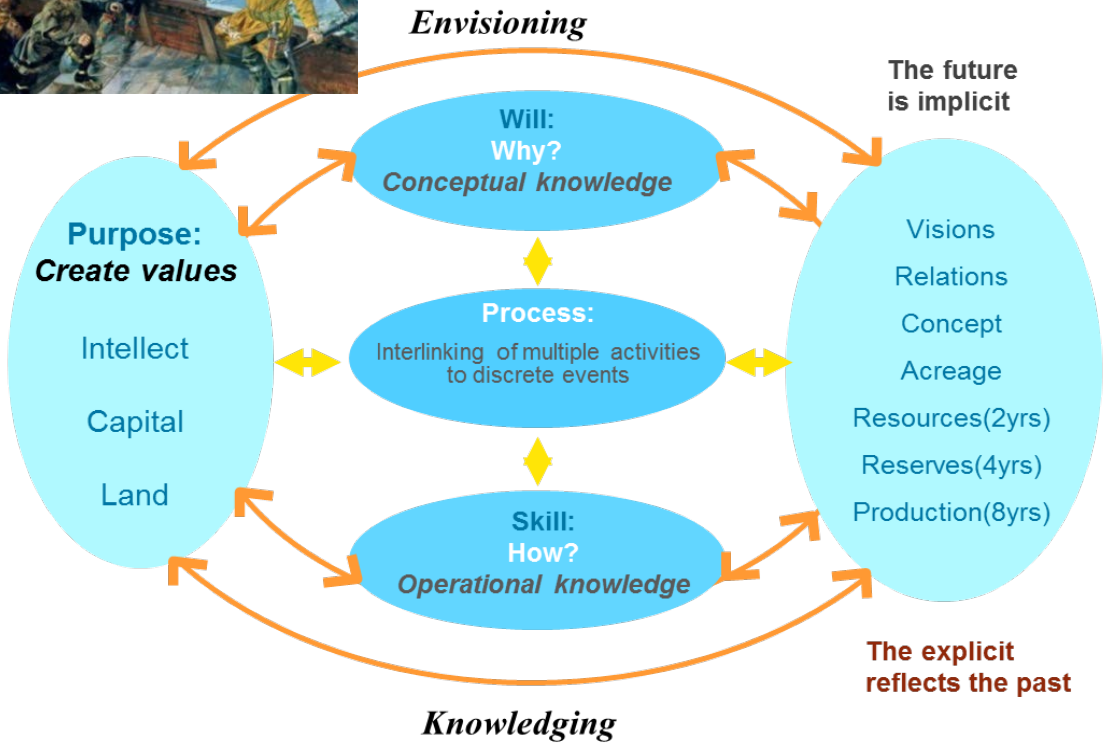
	Competition 1600	Cooperation 1970	Co-creation 2000
Goals	Profit	Create value	Steward
Values	Growth	Trust learning	Responsibility for the whole
Shareholders	Stockholders	All people	Ecosystem
Domain	5 - 10 yrs	Global decades	Centuries
Structure	Hierarchy, matrix BU	Team	Community
Performance measures	Financial accounting	FA + social accounting	Social and resource accounting
Assets	Plant inventory	PI + intellectual capital	Ideas, info creativity visions
Management	Decision maker	Coach advocate	-
Atmosphere	Fear	Truth openness, learning	Freedom, lifelong learning
Technology	Vacuum	In harmony with changes	Appropriate tech.

From 2nd to 5th generation

1. Scientific Integration by people prior to computing
2. Continuous restructuration process dependent on relational quality between people
3. Purpose oriented teams with unlimited access to explicit data
4. Culture based on faith, respect, trust and honesty

Organic growth strategy: action and change

"We don't know what to find, we'll find it when we go there"



"Computers": Insufficient instructions and explicit data

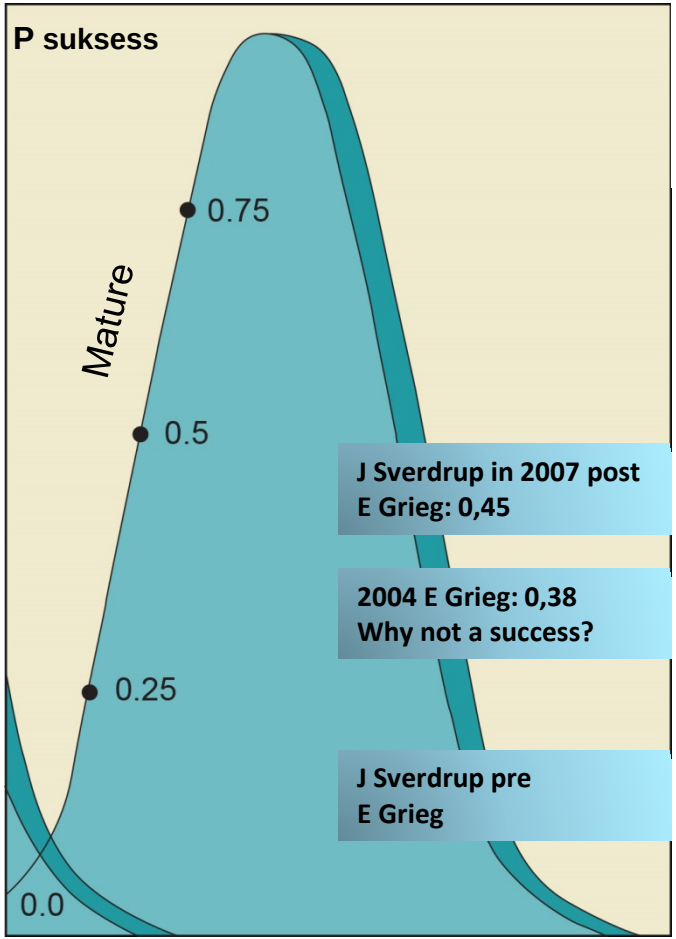
"Big data" ; Lack the tacit domain facts

Operational implementation:

- *Online adapting to reality by the people that did the prognosis*
- *Acquire factual data when possible*
- *WL program determined by well results*
- *Stakeholder dialogues during operations ;*
  - *Test and /or side-track ?*
- *Decisions based on benefit cost analysis*
- *Transfer of operational knowledge between areas*

Perceptions of reality need will and skill to unfold the tacit

- always
- usually
- general
- by and large
- more than not
- half the time
- often
- sometimes
- occasionally
- has happened
- never
- impossible



The Juniper project in 1990's
(A Hurst and Lucy Foley)

Success — Non

0 — 1

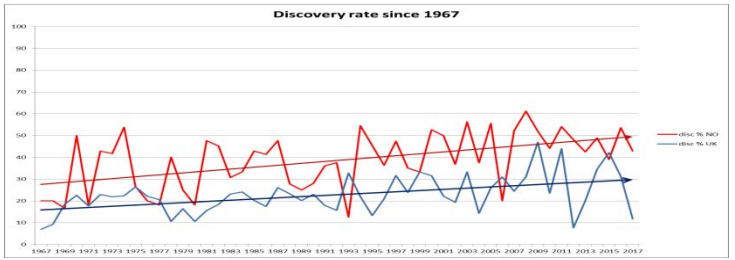
The usefulness in the emptiness
To know what thou knowest not is omniscience

Linking of diversity of factors at highest possible entropy level based on Hutton, Walter, Wheeler and Vail principles prior to computing

Reliable perceptions emerge from dialogues between skilled explorers versus $(P= (Pn)^n) \rightarrow 0$ *n* ➡ ∞

Calculation do not compensate for input ambiguity

Success includes serendipities (30-40%)



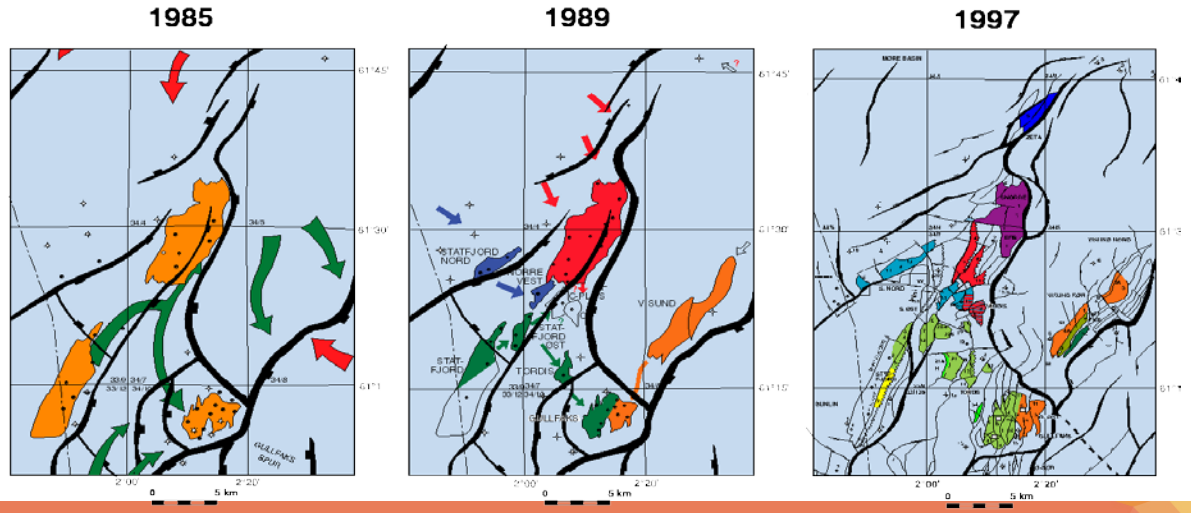
2 out of 30 companies shared a positive view

Snorre Field; New reality unfolded by the drill bit ; Upper Triassic was a commercial reservoir

Snorre reserves 2025 million boe. PDO; 798 million boe:

- *34/4-1 in 1979; 100 m oil column in Mid Triassic Lomvi Formation*
- *34/4-4 in 1982; 161 m oil column in Upper Triassic reservoir*
- *34/7-1 in 1984; oil in Upper Triassic with* OWC at 2586
- *34/7-3 in 1984; oil in Statfjord and Upper Triassic with a common OWC at 2610 m*
-

Spill from Statfjord impossible after oil populations showed diversity of migration routes beyond prediction
The under saturated oil migrates from the Møre Basin
Basin modelling predicted gas due to lack of fact

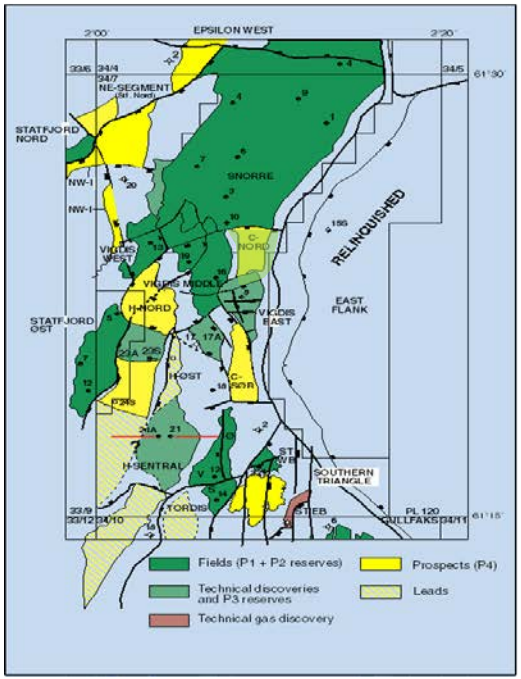


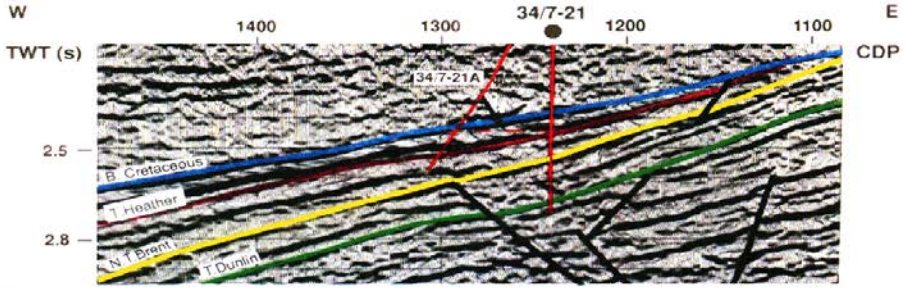
Borg Field; result of conceptual exploration beyond seismic resolution

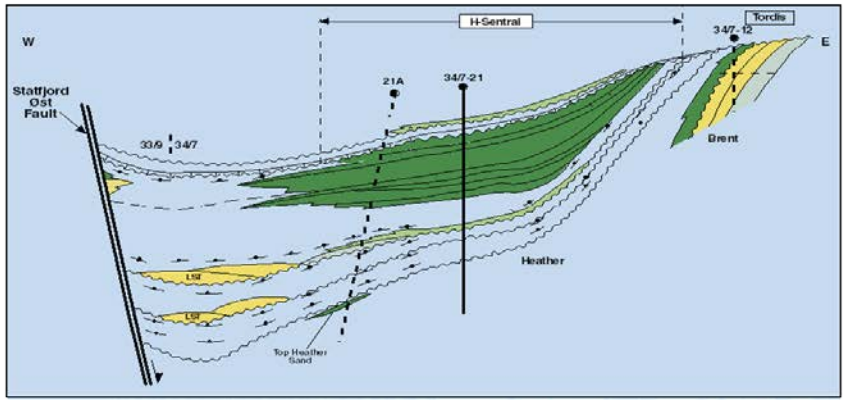
34/7 -21 proved oil in Volgian sand down flank from Statfjord Øst, Tordis and Vigdis

- *The common predrill view; Draupne shale or if sand in the oil migration shadow*
- *Known large scale erosion had occurred in Volgian on northern Tampen Spur*
- *80 models were developed to demonstrate the tautology of modelling*
- *Exploration in 34/7 was guided by obligatory work program*

In the flank of the Volgian inverted Tampen Spur. Concept for Luno(EG) and Avaldsnes(JS)



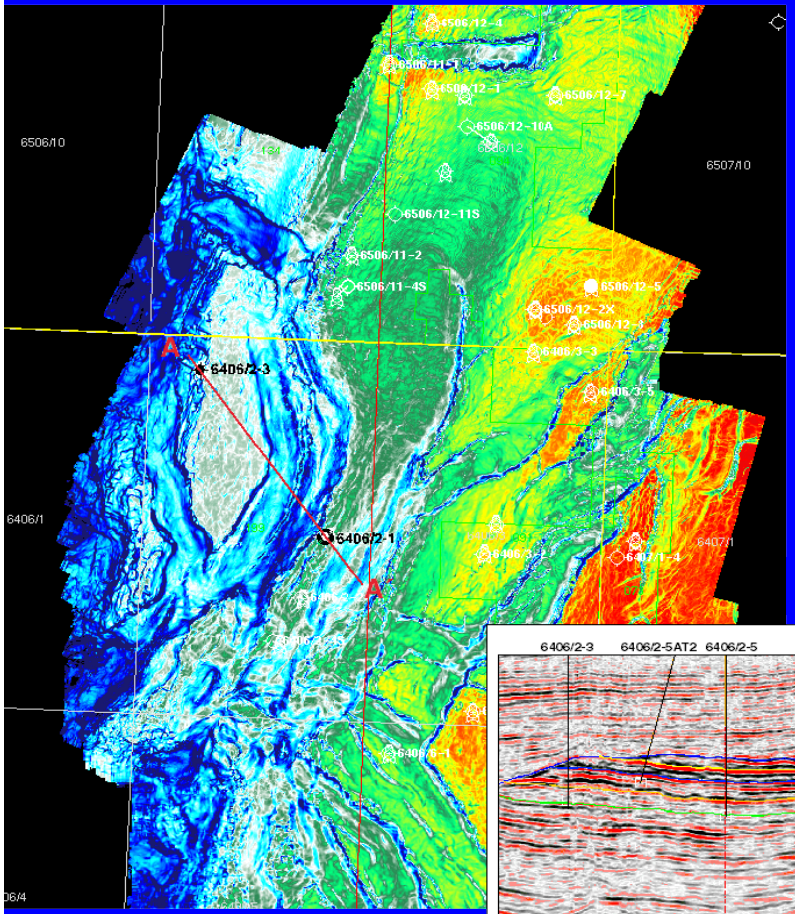




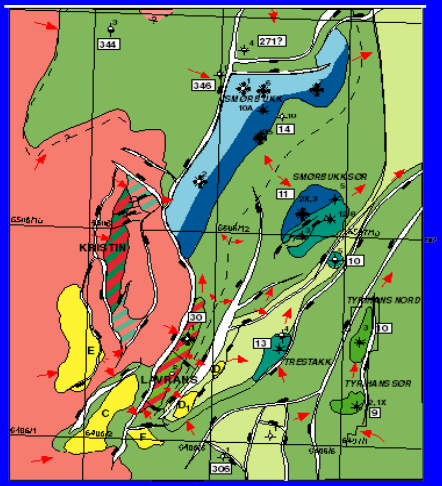
Linking of multi scaled diverse parameters (no linking or upscaling algorithm)

Lavrans and Kristin reservoir porosity "impossible" before proven otherwise by the drill bit

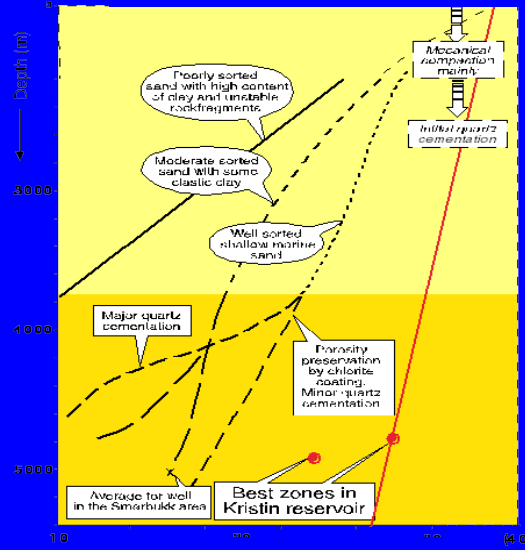
Automatic mapping



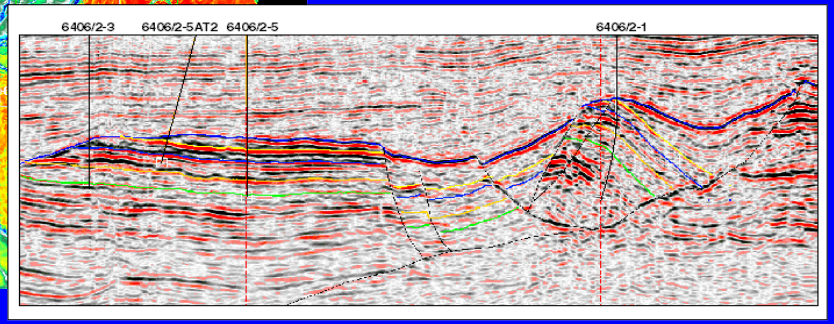
Petroleum systems



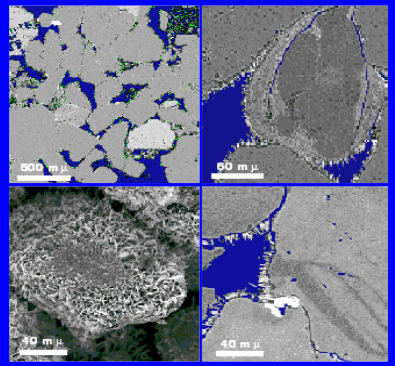
Porosity vrsus depths



Seismic profile



Petrographic relations



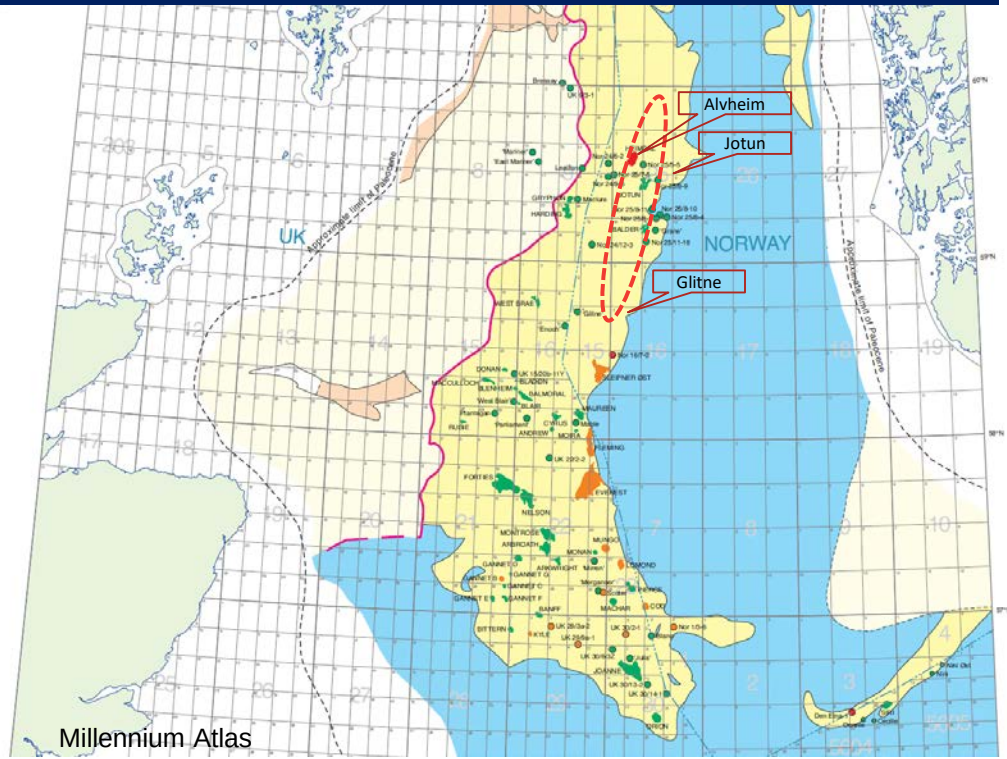
Conceptual and technical synergy

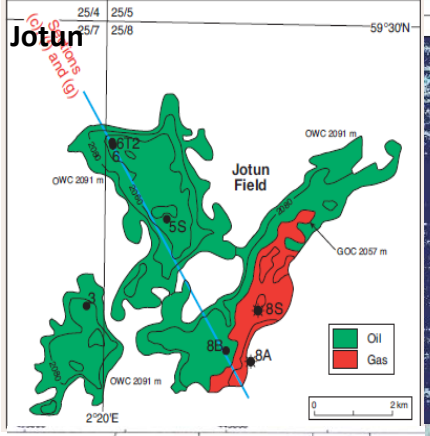
Synergy between 4 persons covering:

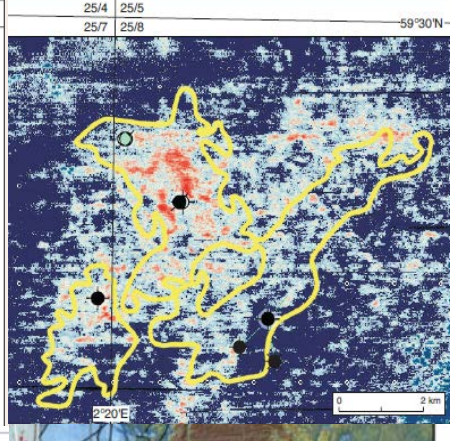
- *Production (Jotun)*
- *Development (Glitne)*
- *Exploration (Alvheim +, Scolty Torphins)*

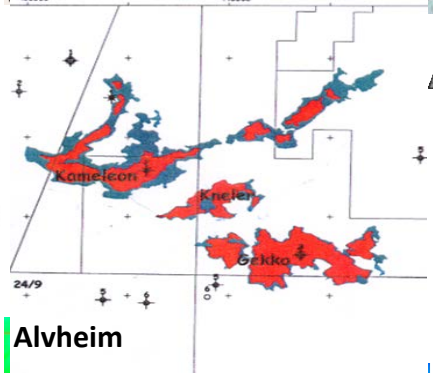
Learning:

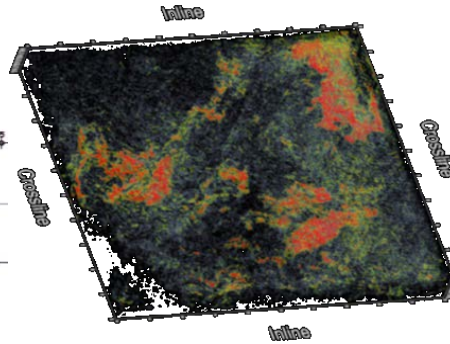
1. *Significant areas with petroleum without seismic anomalies*
2. *No absolute difference between oil and gas*



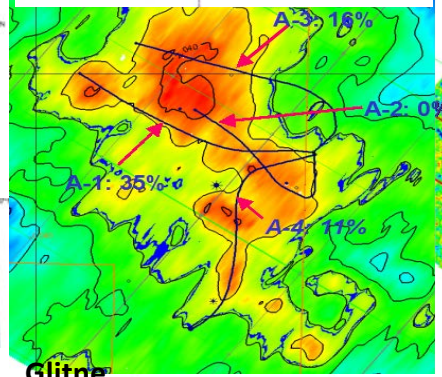


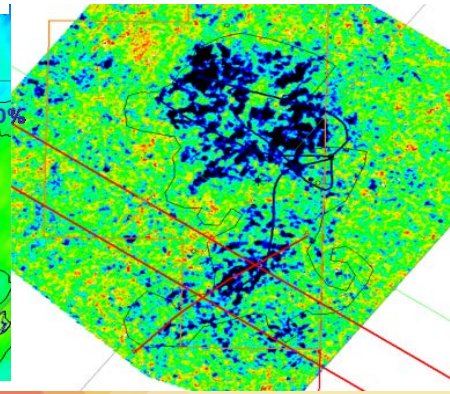






Alvheim



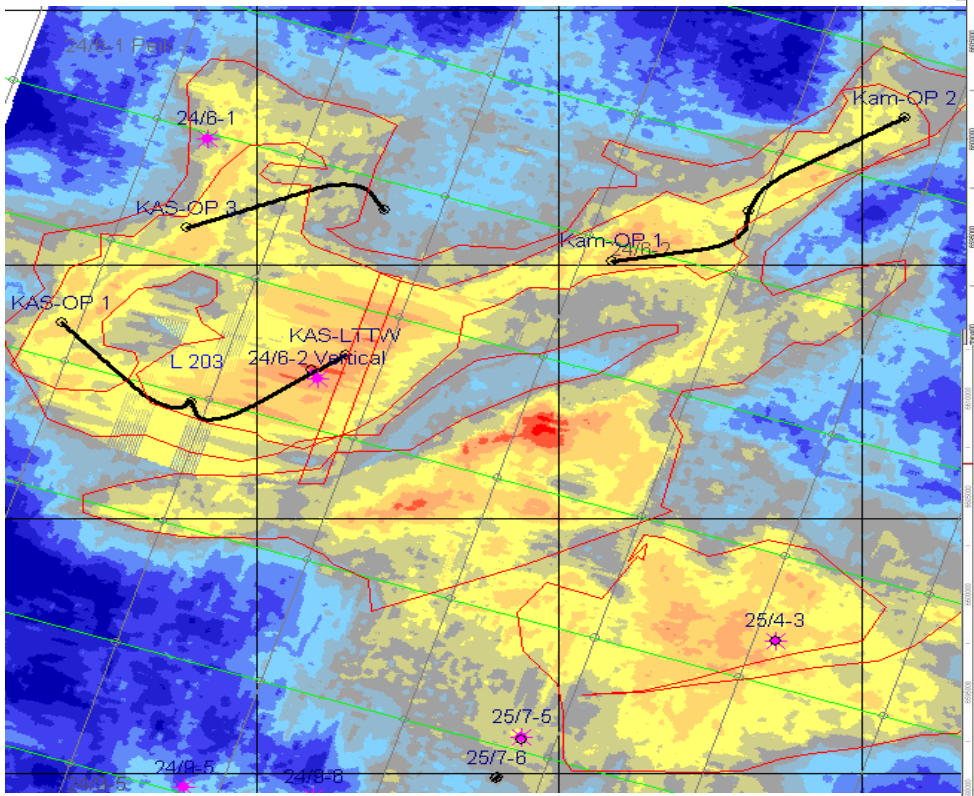


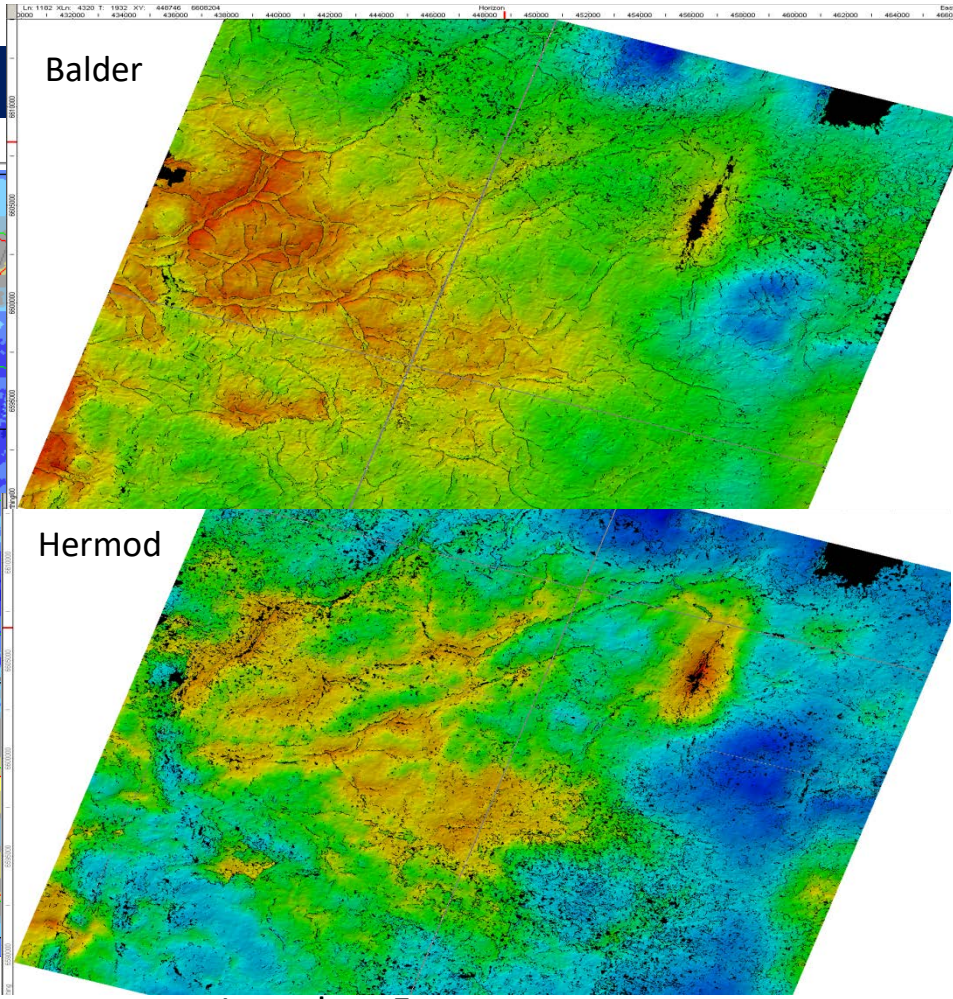
Glitne

Alvheim; The gas satellites that became a major oil field

Kingdom, Gigaviz, AcecaFMB, Petrel and multi cube data

Kameleon,Boa and Kneler vision; 300 mill bbls (area * h)

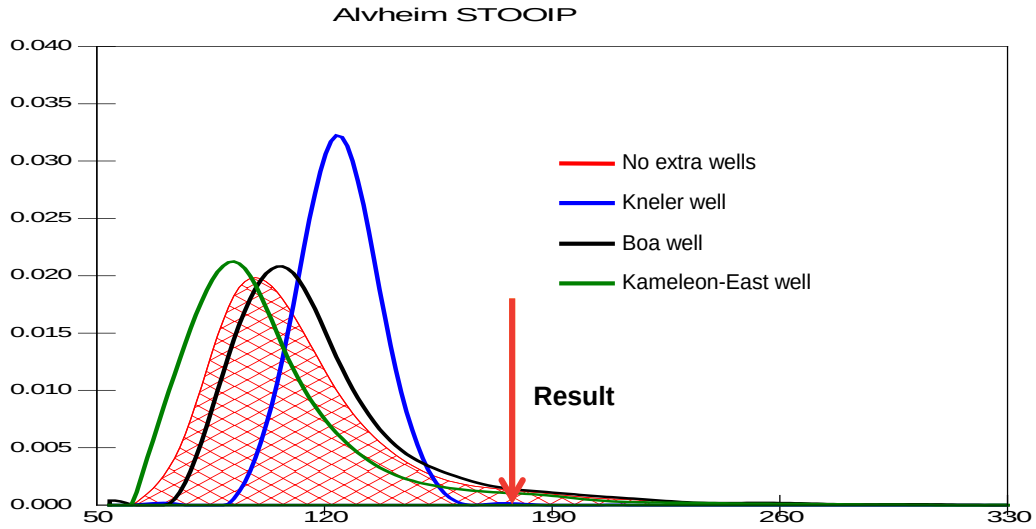


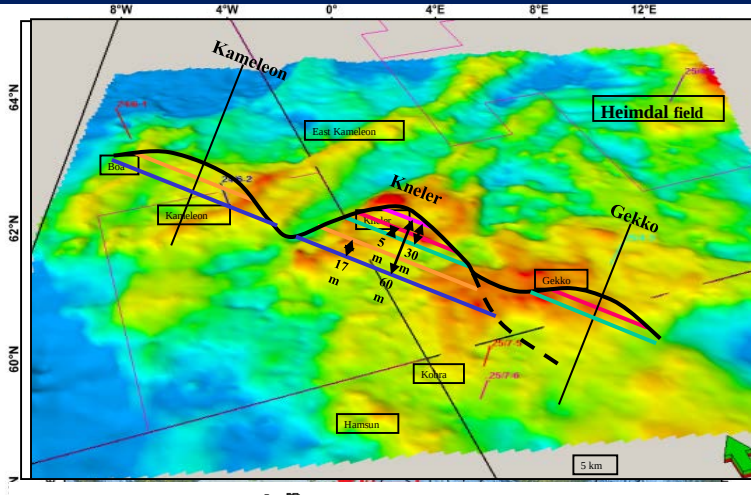


Less than 5 sec pr map

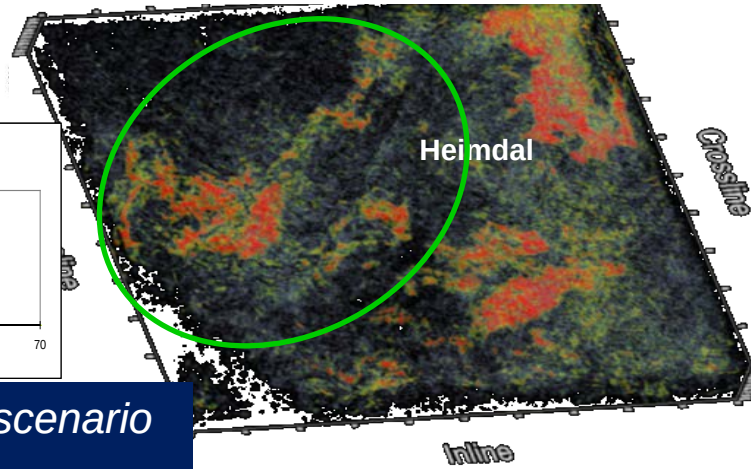
Tools more advanced than available data

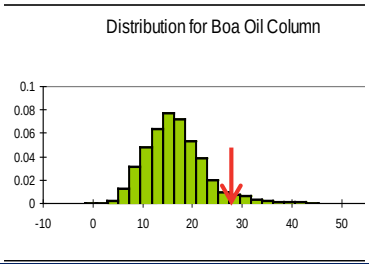
Scenario based approach (NCC); drill on largest uncertainty to obtain highest change impact; Kneler

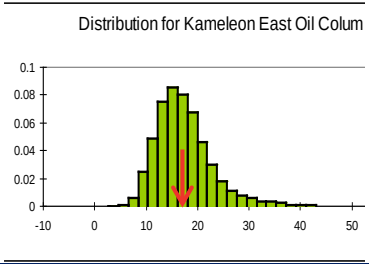


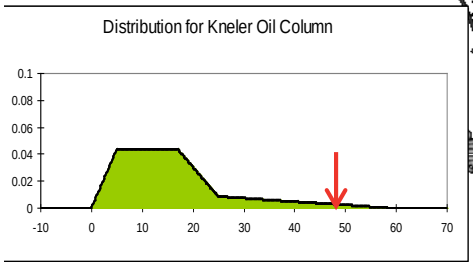


AVO "gas" anomaly also over understurated oil



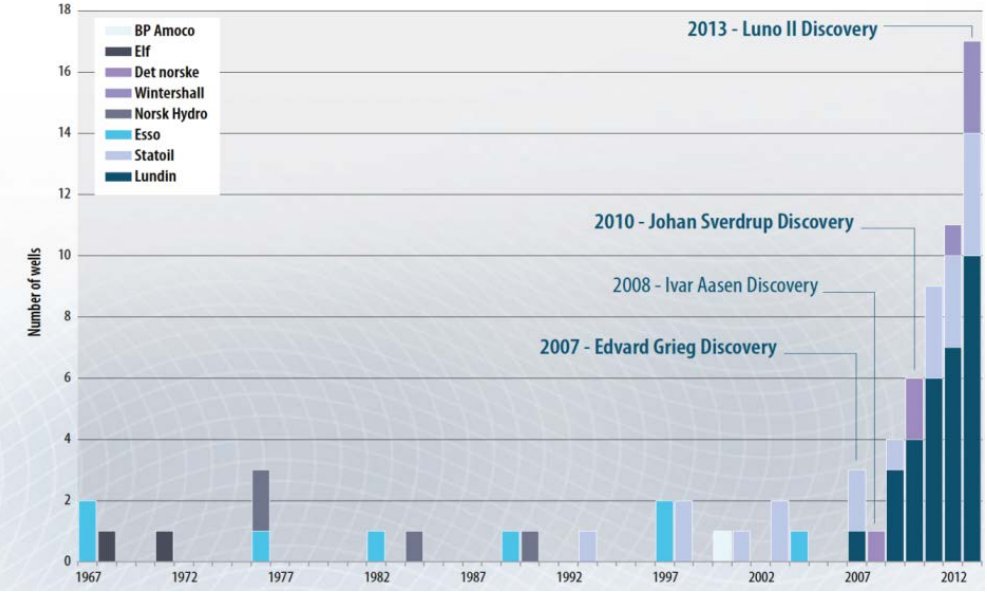


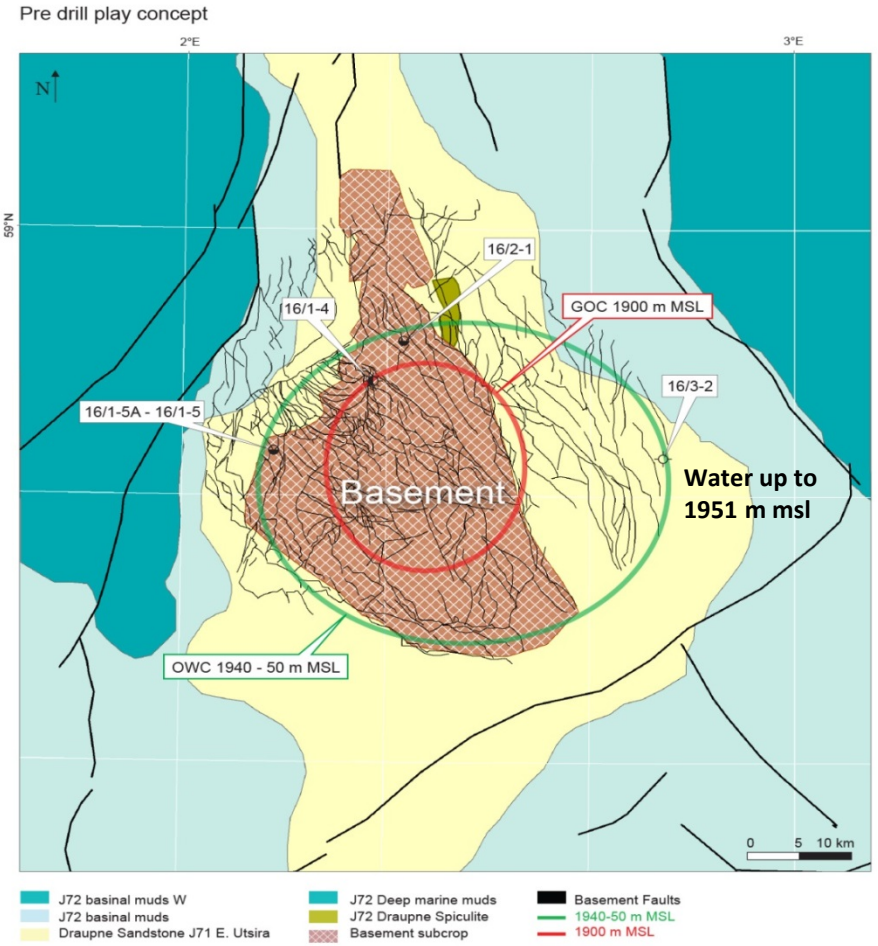




- *Reality beyond 3 standard deviation to the highest defined scenario*
- *Expected value decisions recreate the past.*

Play concept; 40-50 m oil leg in Volgian shallow marine sand



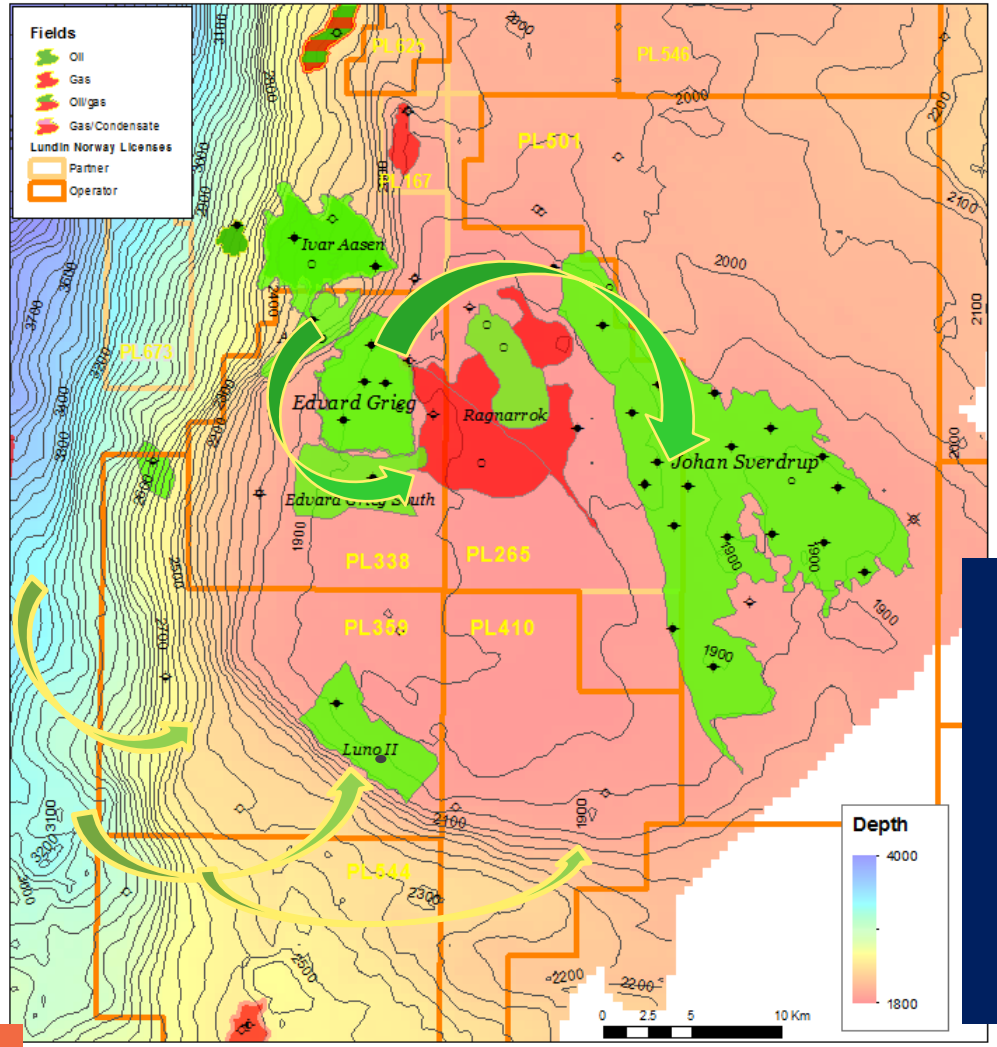


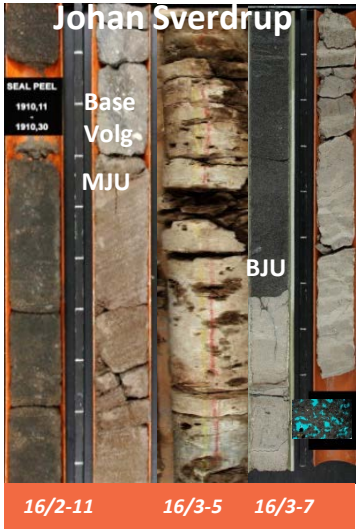
Pre drill reservoir concept 40-50 m oil leg beneath a gas cap was defined by 4 pre chalk wells

Migration the last 1.5 mill years defined by 3D seismic and all 17 wells drilled from 67—98

AMI; Saga pre chalk, Statoil post chalk and Mobil (other area): ***PL 265***

Under saturated fresh oil in new reservoirs on the NCS





Secured follow up acreage:

Apa 2004: PL 338 : 100% 1 firm well

Apa 2005: PL 359 : 70/100%

Apa 2006 : PL 410 : 100%

Apa 2008: Pl 501 : 40/100% 1 firm well

Farm in to PL 265 : in 2009: 10%

Data strategy:

Cored through hiatuses

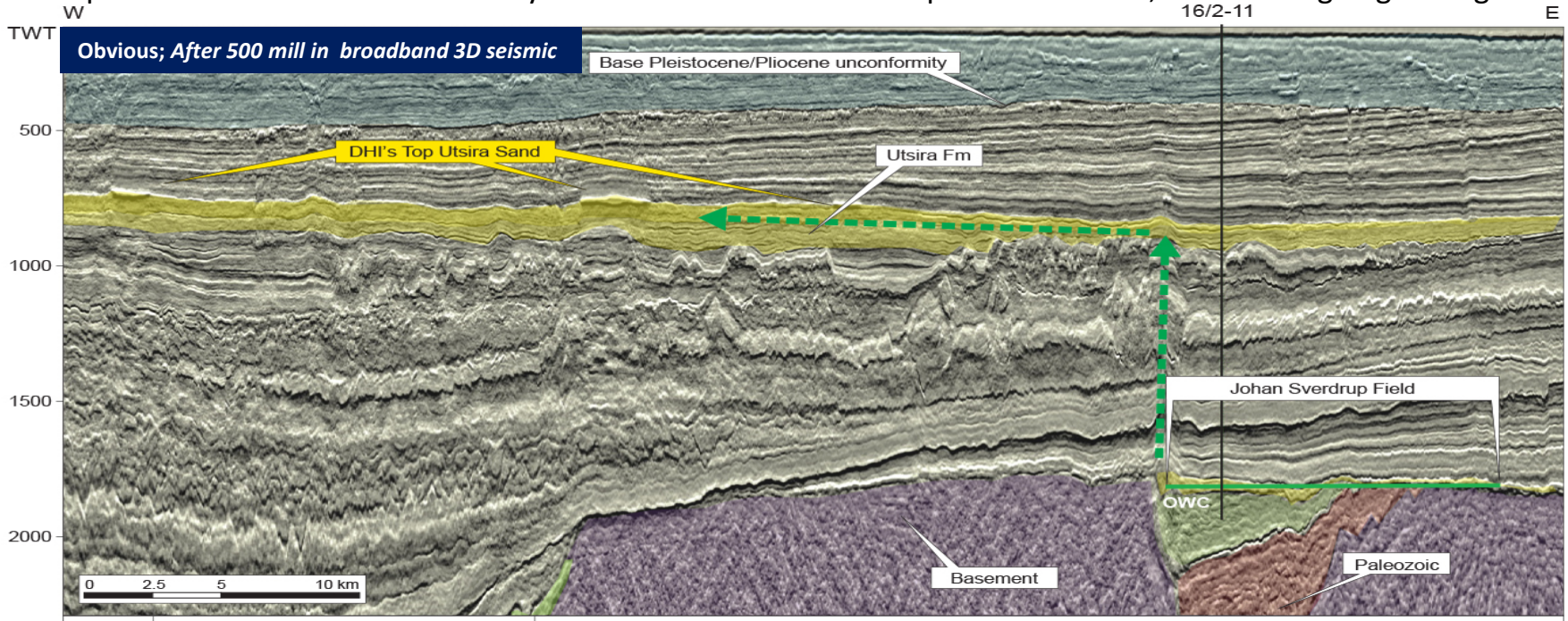
Tested for continuity

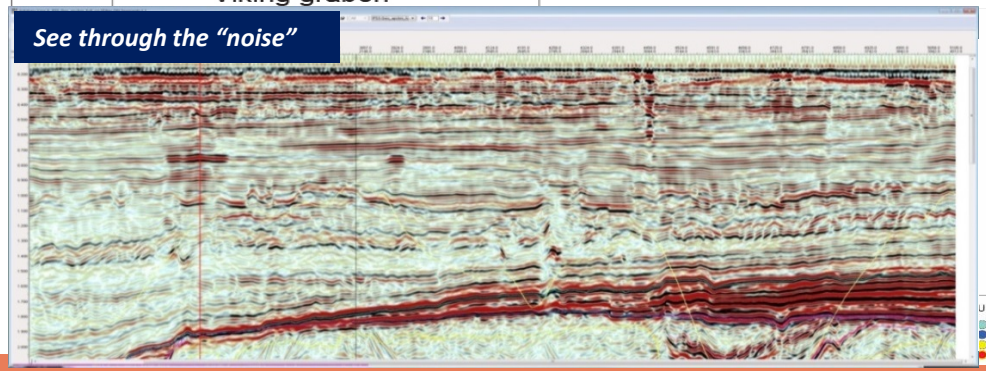
Generic learning:

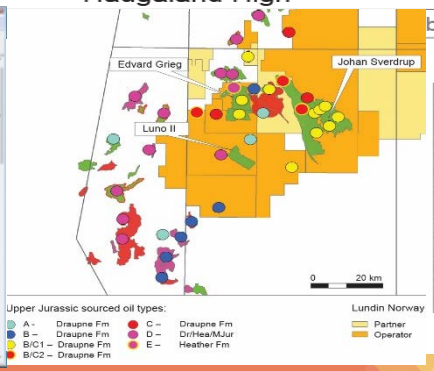
Ongoing oil migration

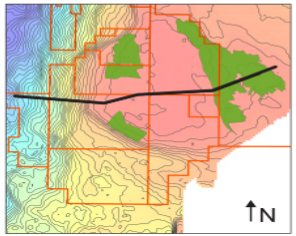
Broadband 3D unfold a holistic perspective of the subsurface

The Sverdrup structure existed from 1.5 mill years after Plio-Pleistocene uplift and erosion; late and ongoing oil migration

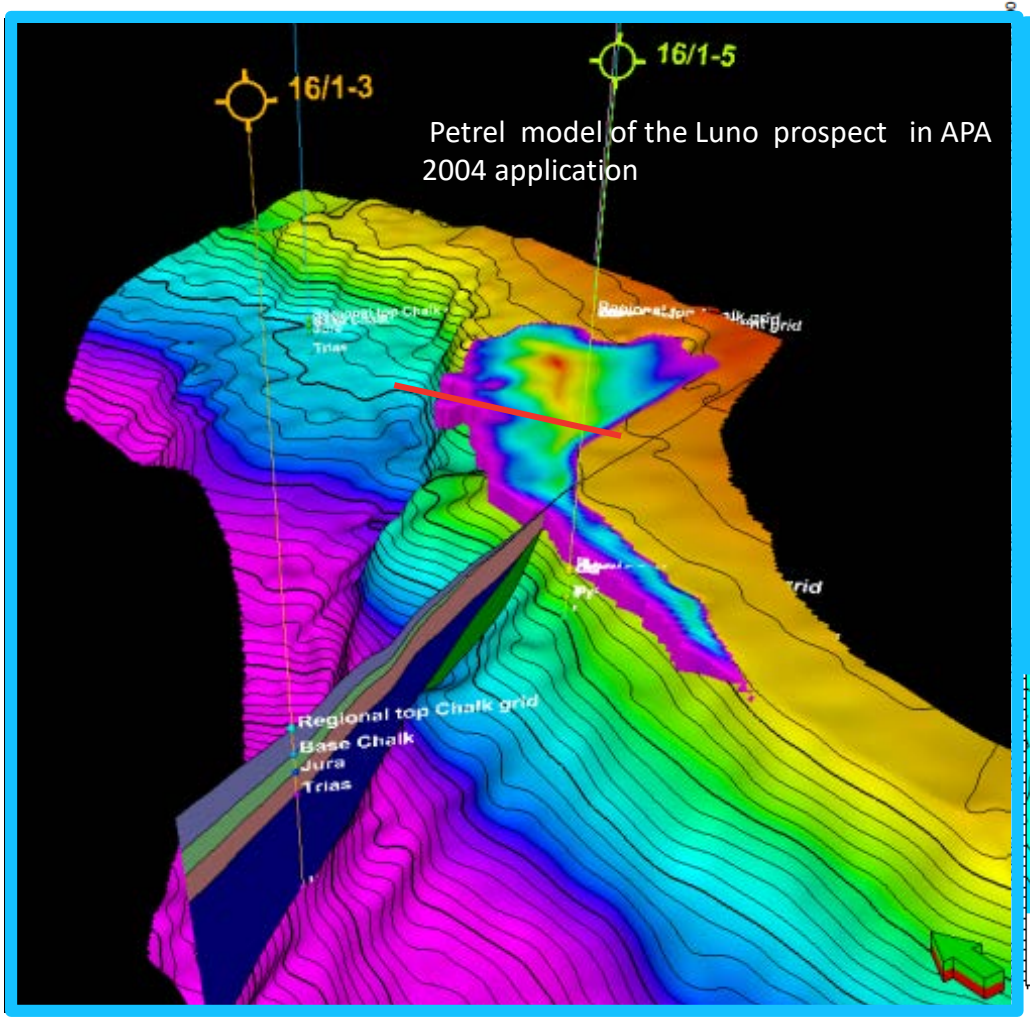


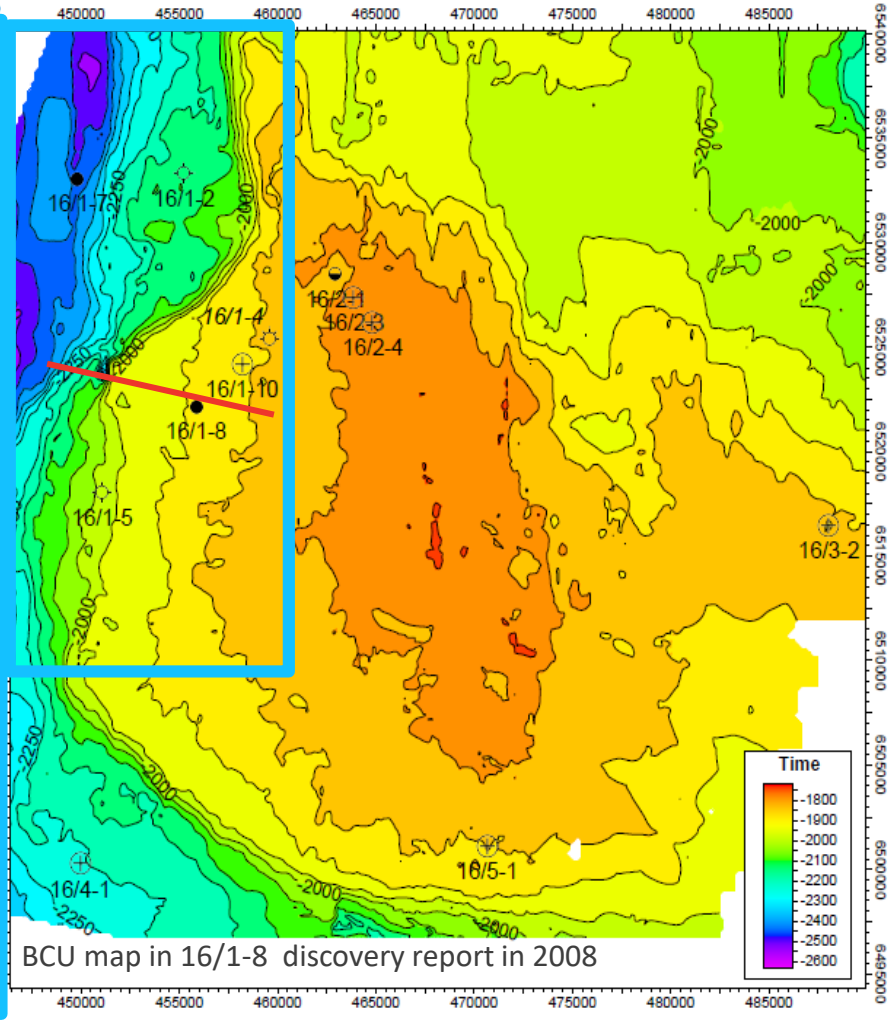






The Luno prospect; in a regional context oil shallower than 1951 m msl

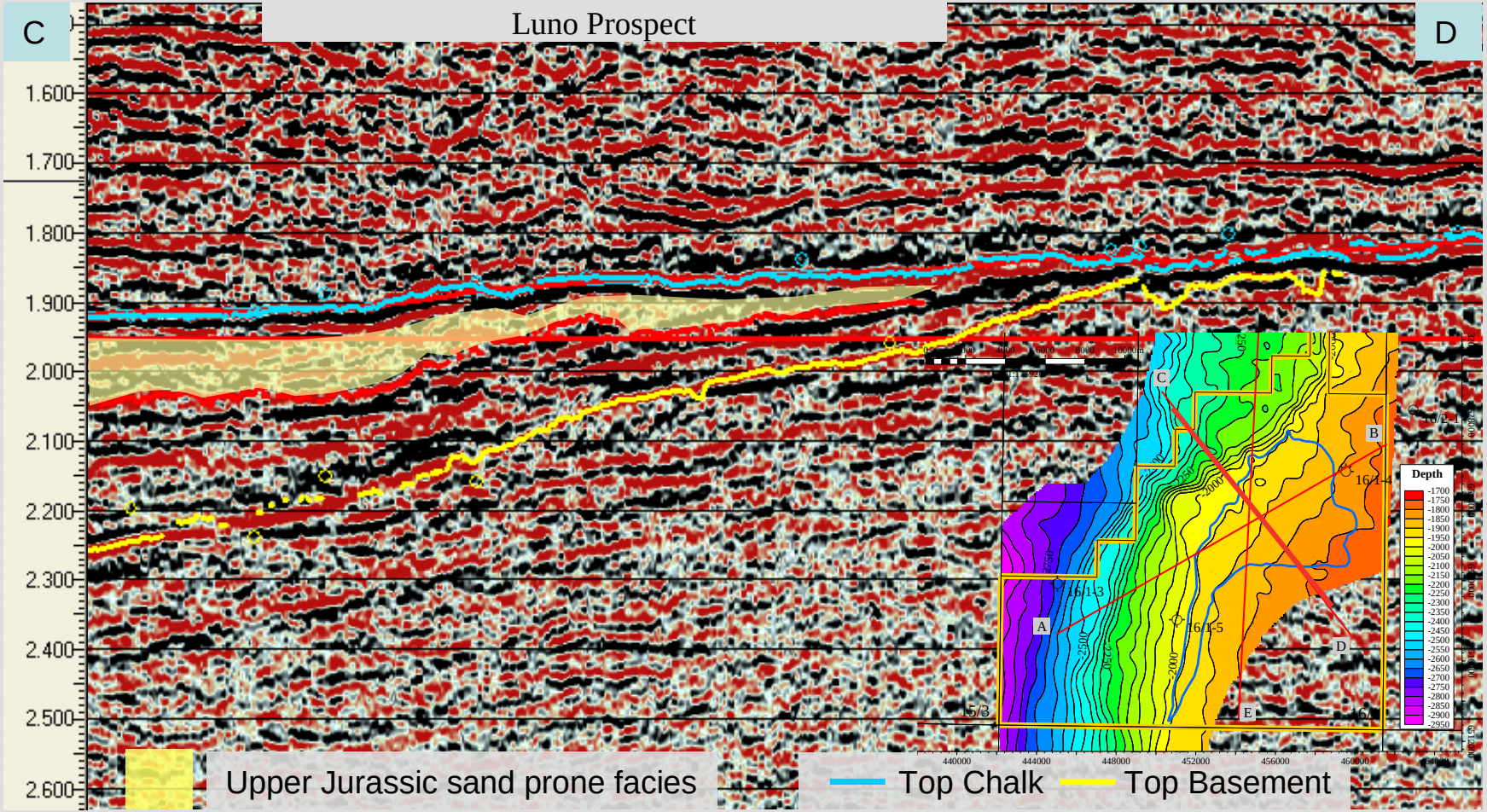




BCU map in 16/1-8 discovery report in 2008

Luno play concept APA 2004;

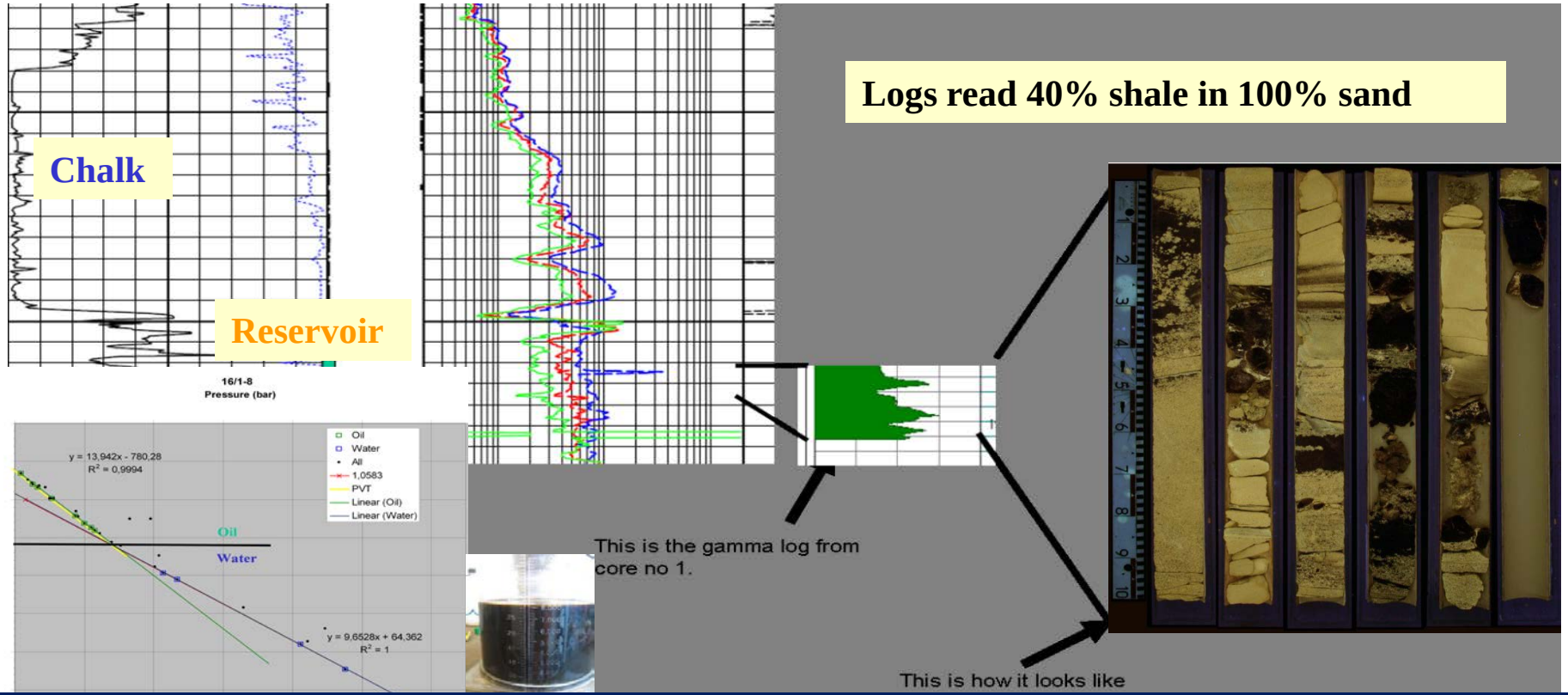
Saturated oil in an Upper Jurassic and Triassic inlier basin flanking an inverted high (16/1-5)



Coring and sampling was necessary for discovery in16/1-8

Wire line read K^+ and do not separate arkosittic rocks from shale

Well suspended for later testing

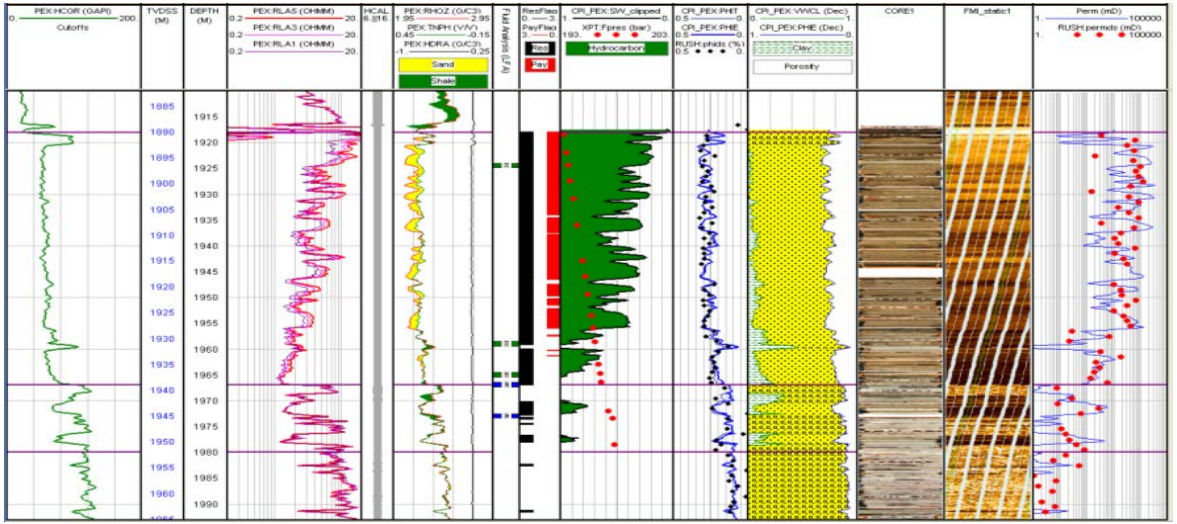


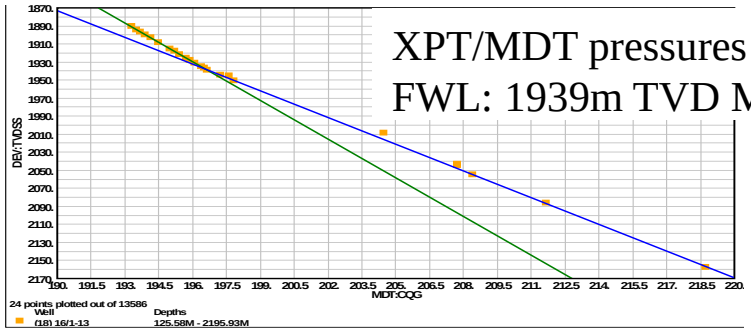
Well results:

Under saturated oil in alluvial/eolian to marine Valanginian/ Lower Jurassic/Upper Triassic reservoirs

Testing of 16/1-10 and coring of 16/1-13 essential for PDO

4-5 delineation wells with coring and testing was considered as minimum prior to PDO





XPT/MDT pressures
FWL: 1939m TVD MSL

Porosity 30%
Perm: 12Darcy

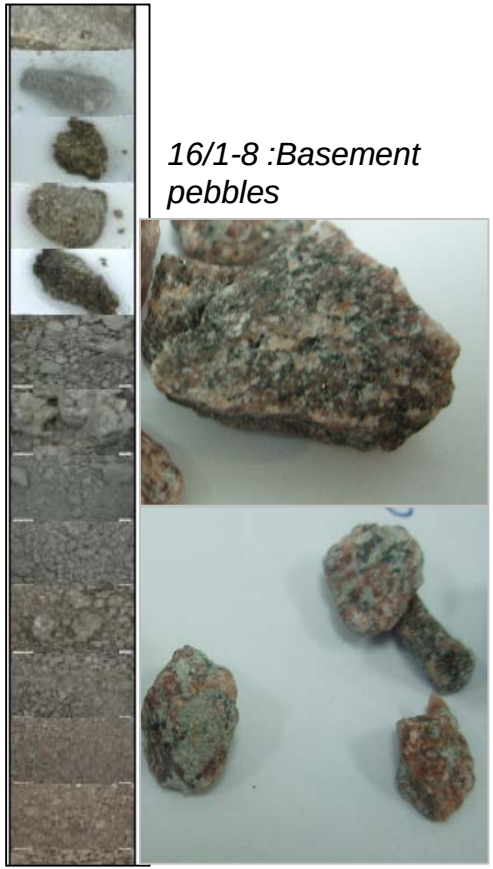
Porosity 28%
Perm: 8Darcy

Proximal reservoir facies needed cores and tests for connectivity

Petrophysics need calibration: Mineralogy, pebble size and resolutions

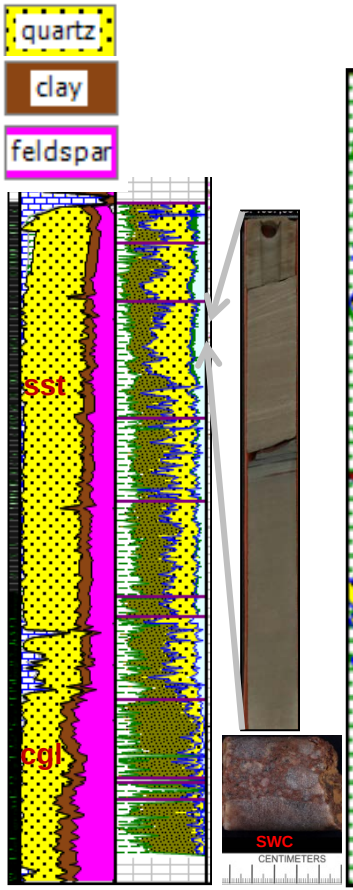
Online acquisition of mineralogical and visual data are needed step changes

Photo communication

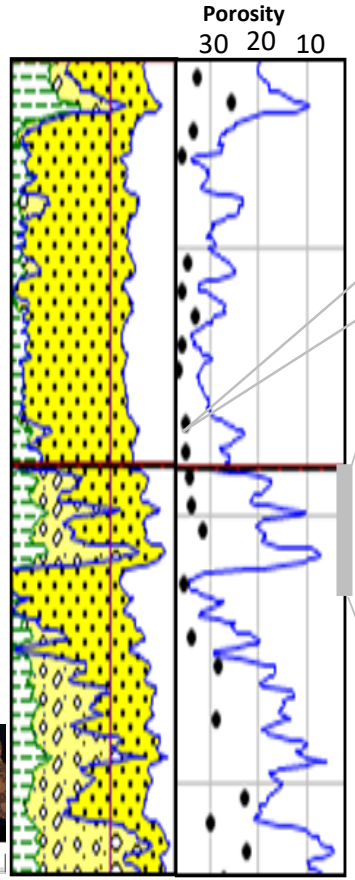


16/1-8 :Basement pebbles

"Online cuttings chemistry by XRD/F" 16/4-8

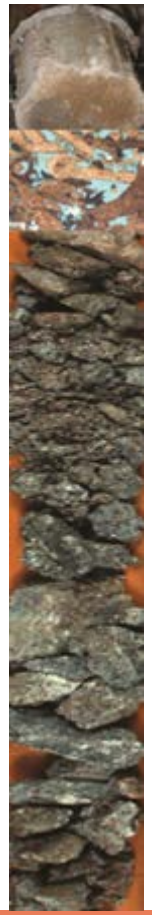


WL sampling density limit the display of reality EG pilot

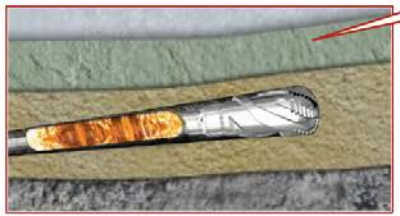


Testing proved continuity of bio clastic sand in 16/1-15

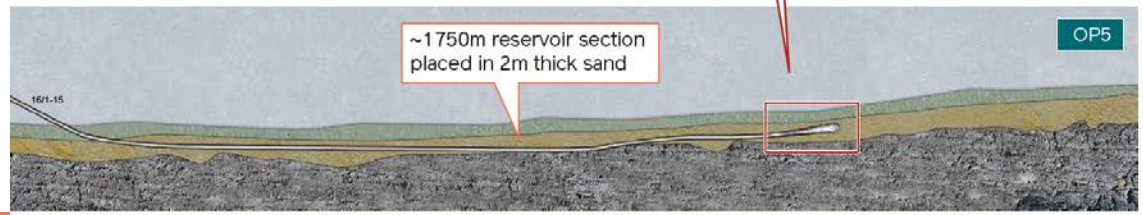
Test of 3 m bioclastic sand; 3000 bbls/day (470 sm3/d)and in basement rubbel 105 sm3/d (660 bbls/day)
Active oil migration between EG and JS in the Lower Cretaceous bioclastic sand?

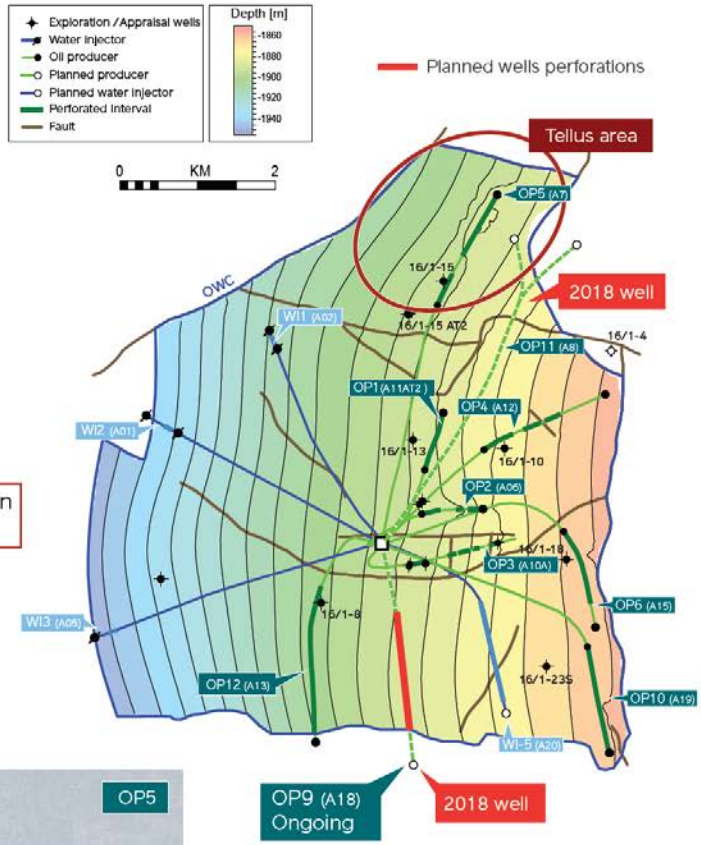


Edvard Grieg
2017/2018 Development Wells



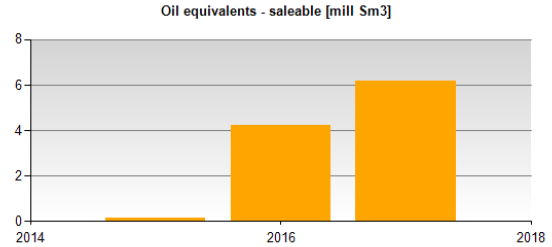
Wired pipe – real time high resolution images for geosteering

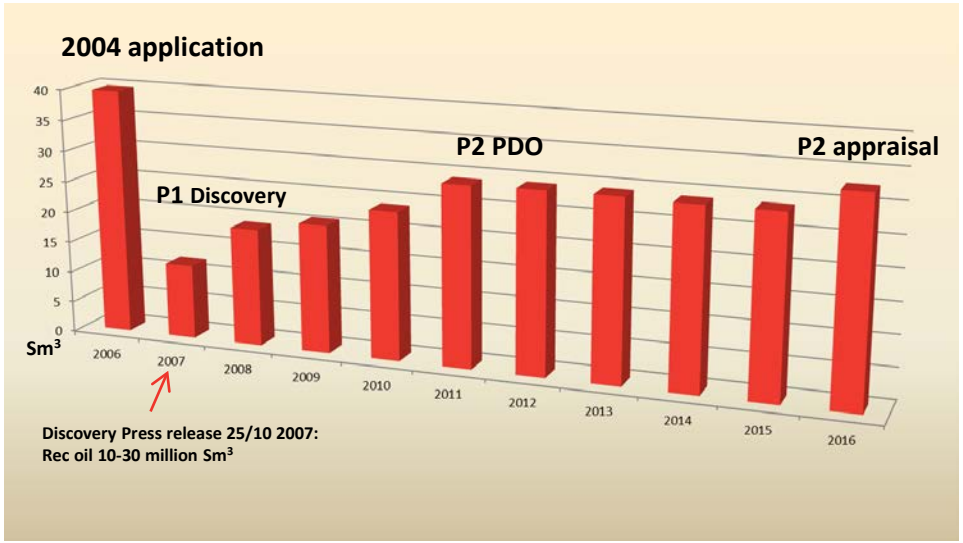


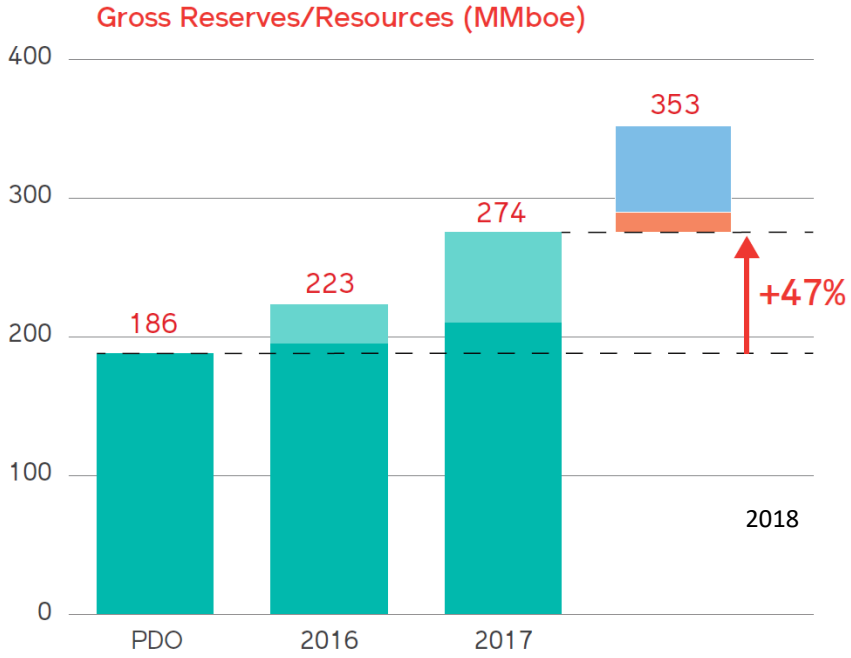


From Luno resources in 2004 to EG reserves in 2018

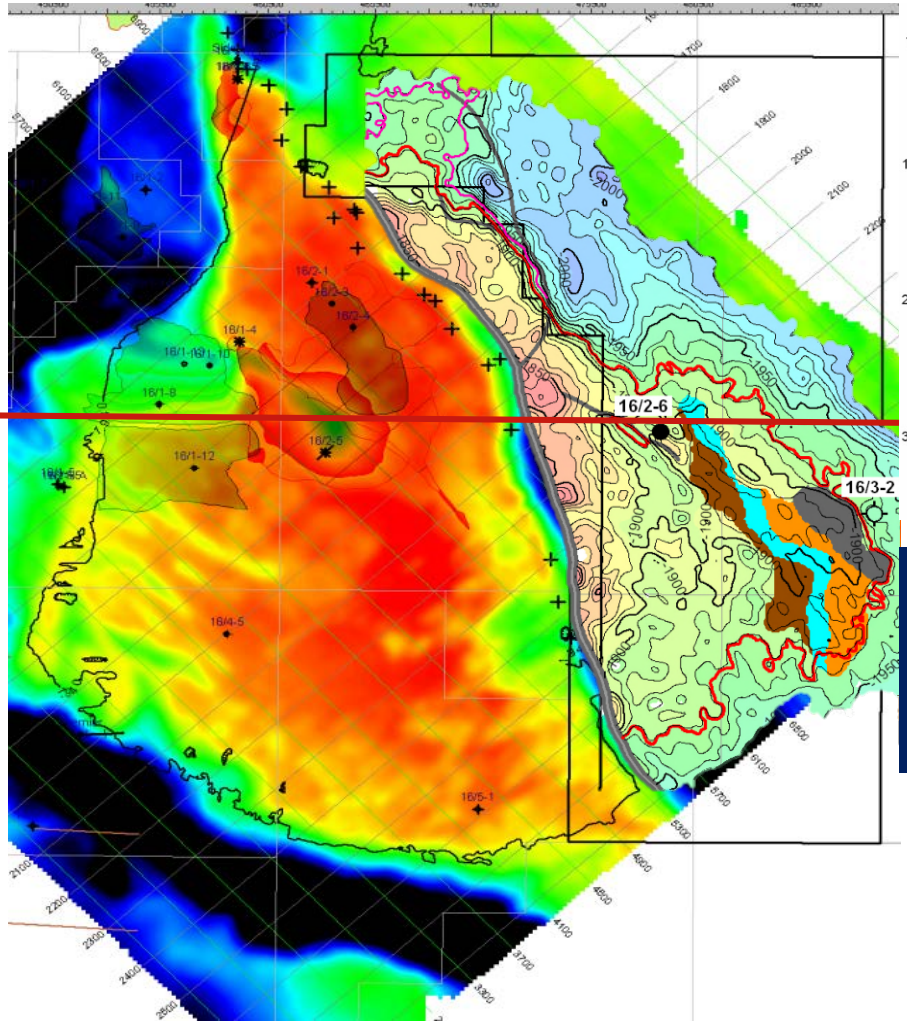
Subsurface learning from exploration, delineation, development and production phases
Reservoir volumes change by improved knowledge and audit high cut filtering
PDO reserves are audited "proven" economic volumes without upside.

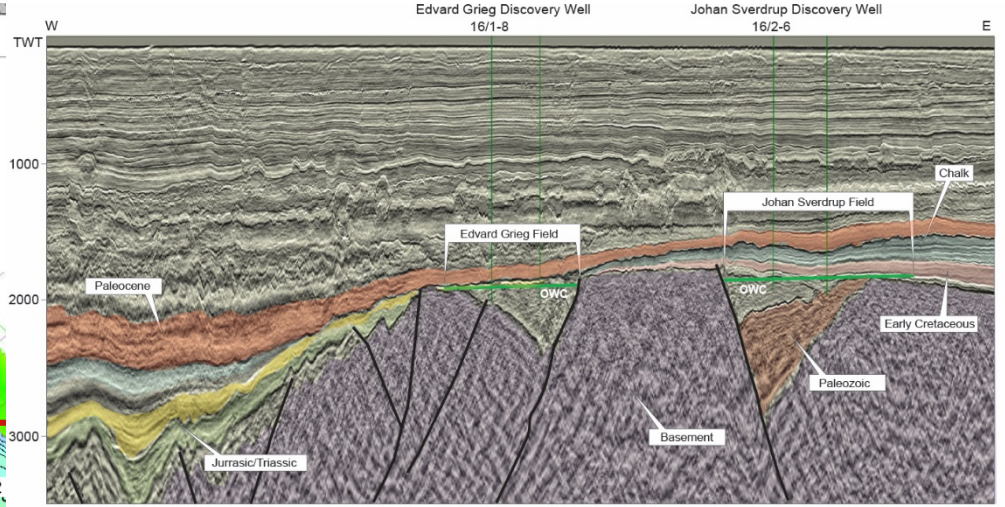






The 16/1-8 discovery; triggered the16/2-6 Avaldsnes discovery(2010)





- 16/2-6 was drilled in PL 501 awarded in APA 2008
- Prospect and initial delineation on vintage 3D
- First Broad band seismic on NCS 1700 km^2 in 2009
- 2650km^2 Broadseis survey in 2010/11

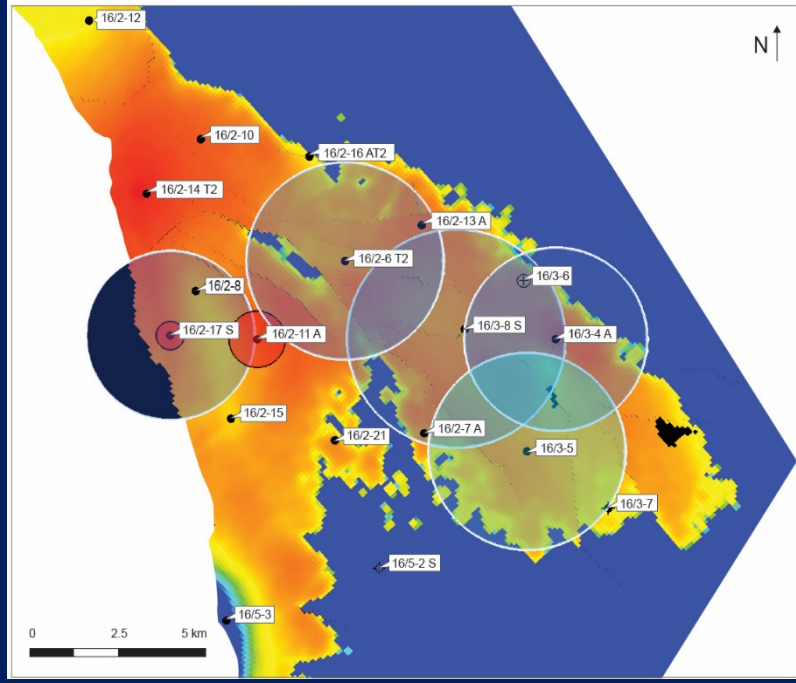
Attacking maximum uncertainty to learn fast

Delineation: 22+7 wells and 6 tests

- *Sequence variations between major hiatuses*
- *Reservoir quality and continuities*
- *Top reservoir related deterministic to Draupne shale thickness and velocity variations in overburden*
- *80m difference at same time depth*
- *Porosity and saturation uncertainties due to drilling mud invasion*
- *OWC and GOR variations*
- *Thickness variation of movable oil beneath FWL*

Status;

600 mill bbls shifted by the last 2 wells prior to PDO
Post PDO pilot wells covered remaining needs
Factual generative learning by actions create value

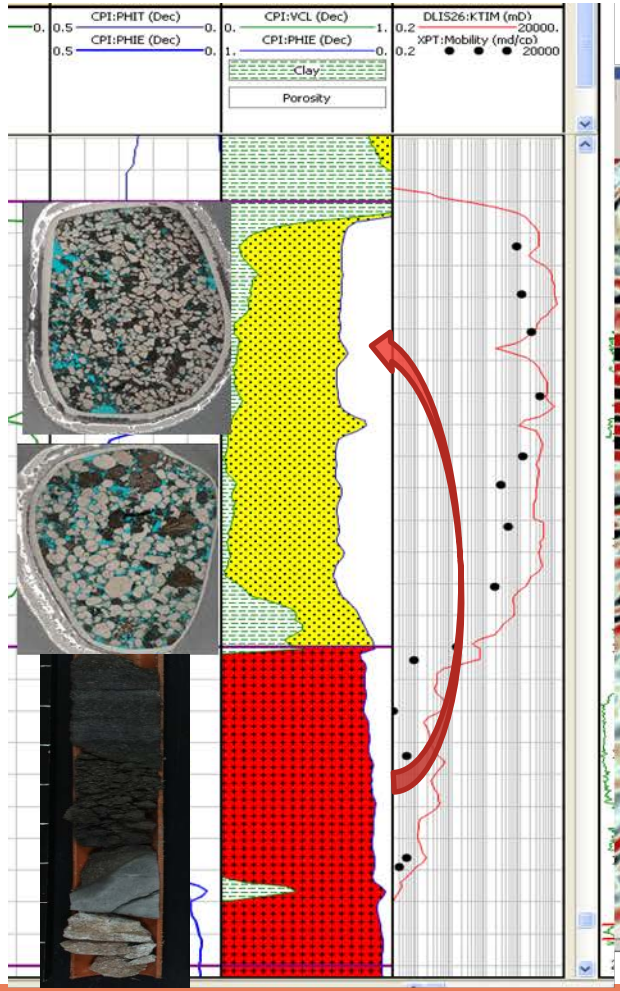


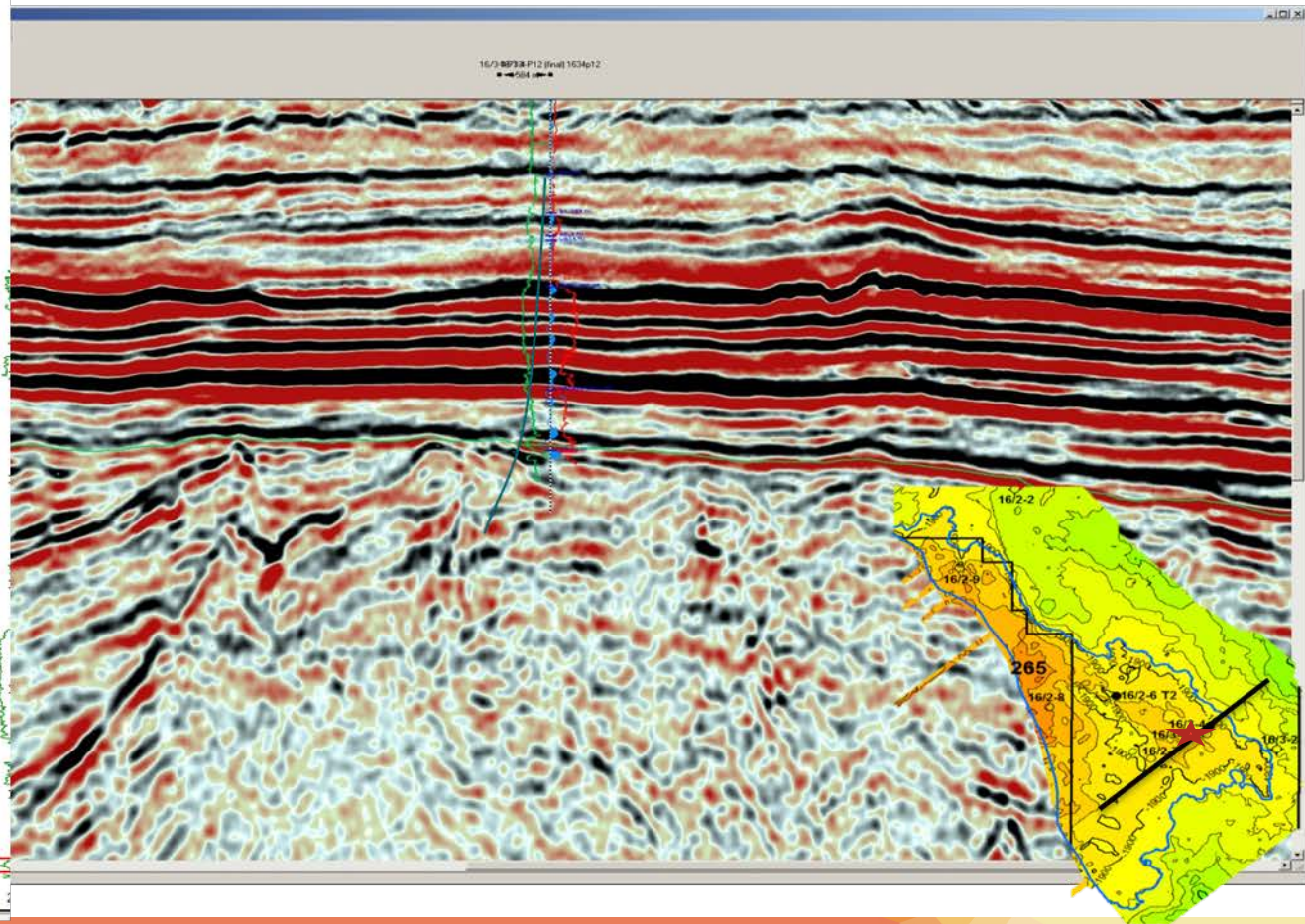
Discovery well 16/2-6 (2010);

- Unfolded all major Jurassic reservoirs within 22 m
- Condensed by wrench fault induced hiatuses
- Cores necessary for sequence resolution
- Discovery Press release 17/09 2010:
  - Rec oil 15-60 million Sm^3
- Press release 30/11-2011 (1 year delineation) :
  - 800-1800 bbls in PL501 and 1200-2600 bbls in 265/501
- Current ; 2.1 and 3.1 billion barrels

Sand below seismic resolution over the crest in 2-3. delineation wells

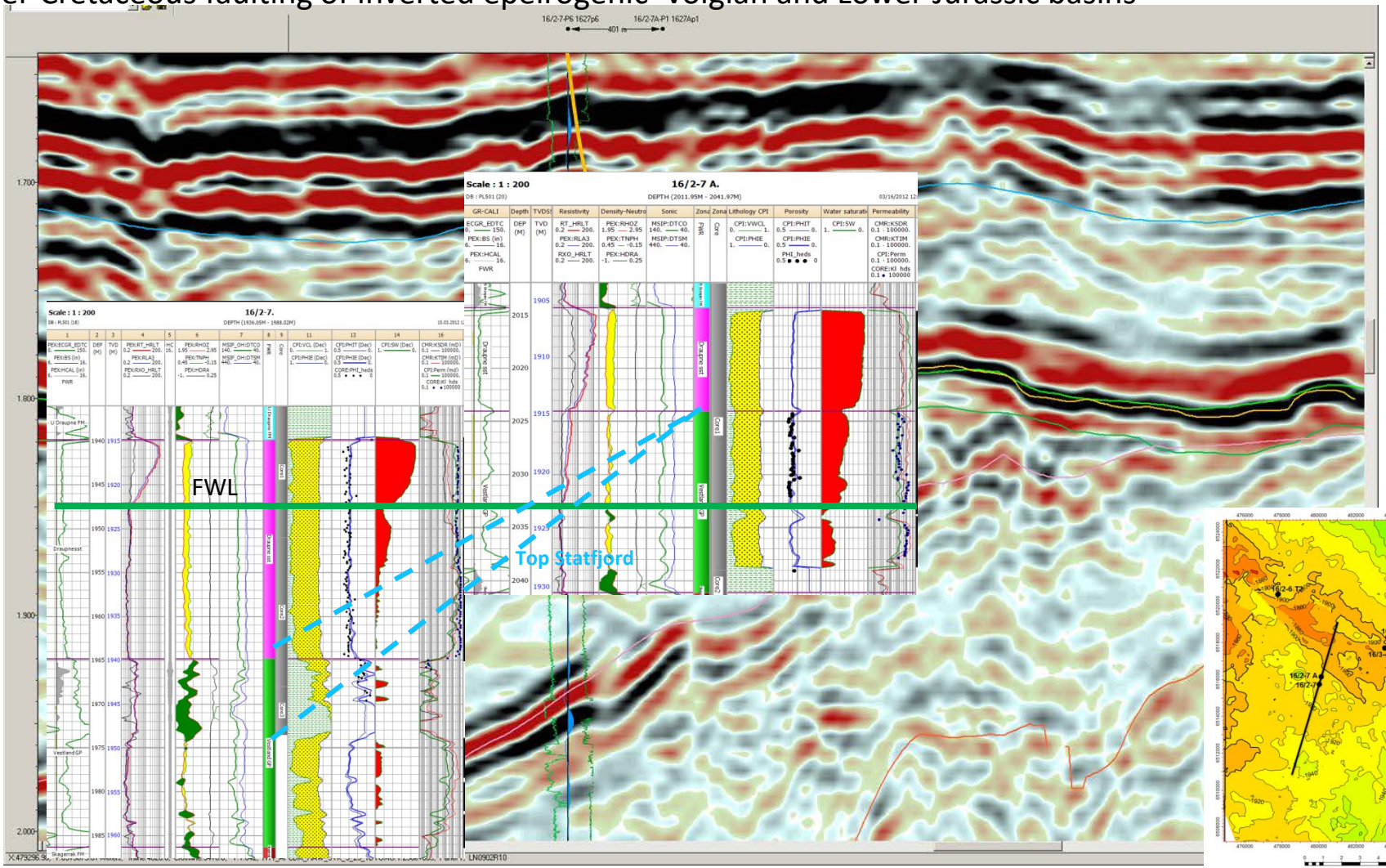
Shallow marine local derived sand over weathered basement



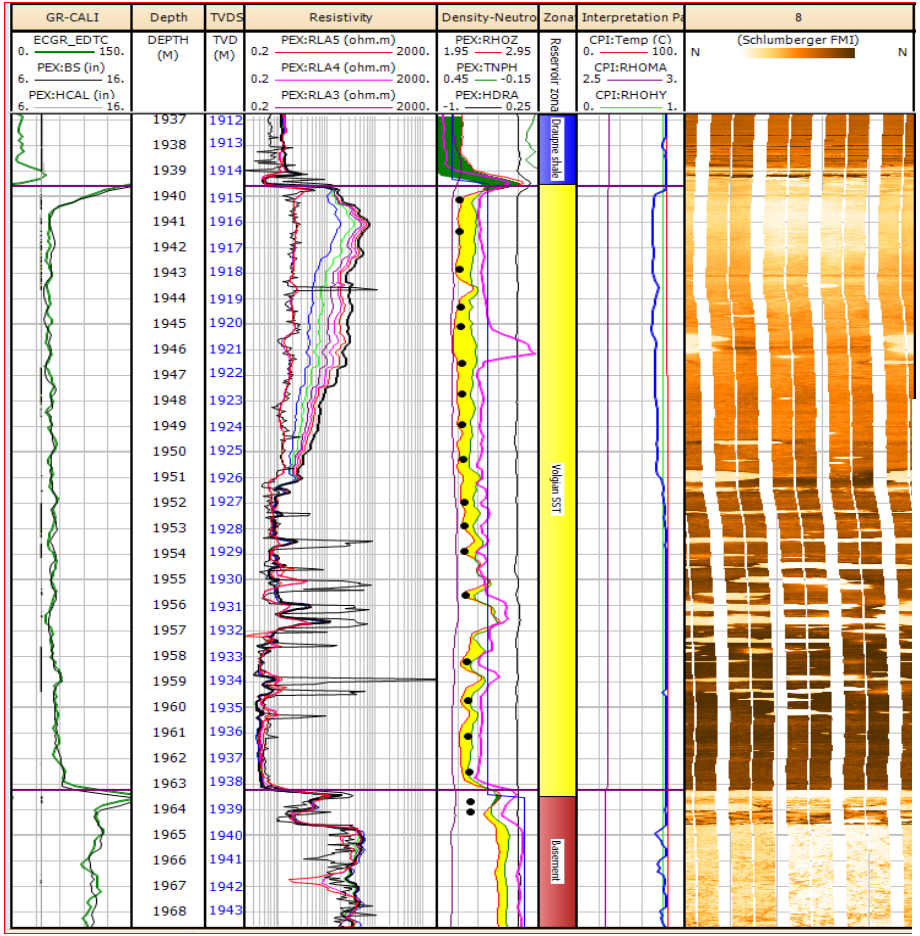


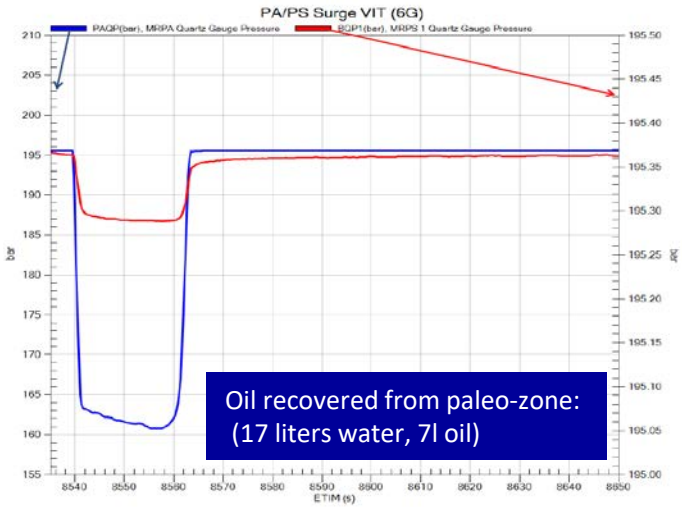
Adapted -17 m to reality during operation by a 400 m sidetrack (August 2011)

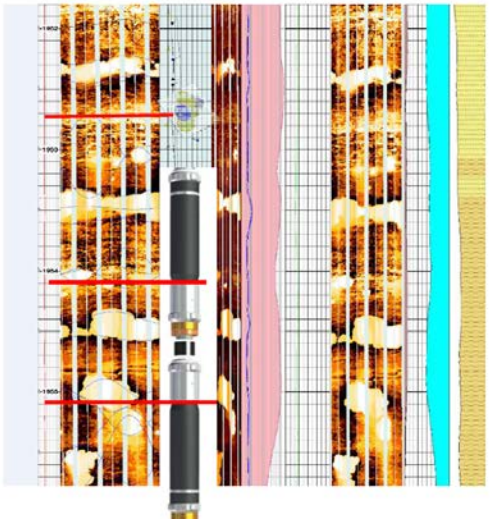
Lower Cretaceous faulting of inverted epeirogenic Volgian and Lower Jurassic basins



Proving vertical permeability and activation of residual oil by surge test







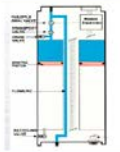
Surge Testing Interval

PS depth: 1952.6

PA depth : 1955.1 -1954.1

Large Volume Sample Chamber

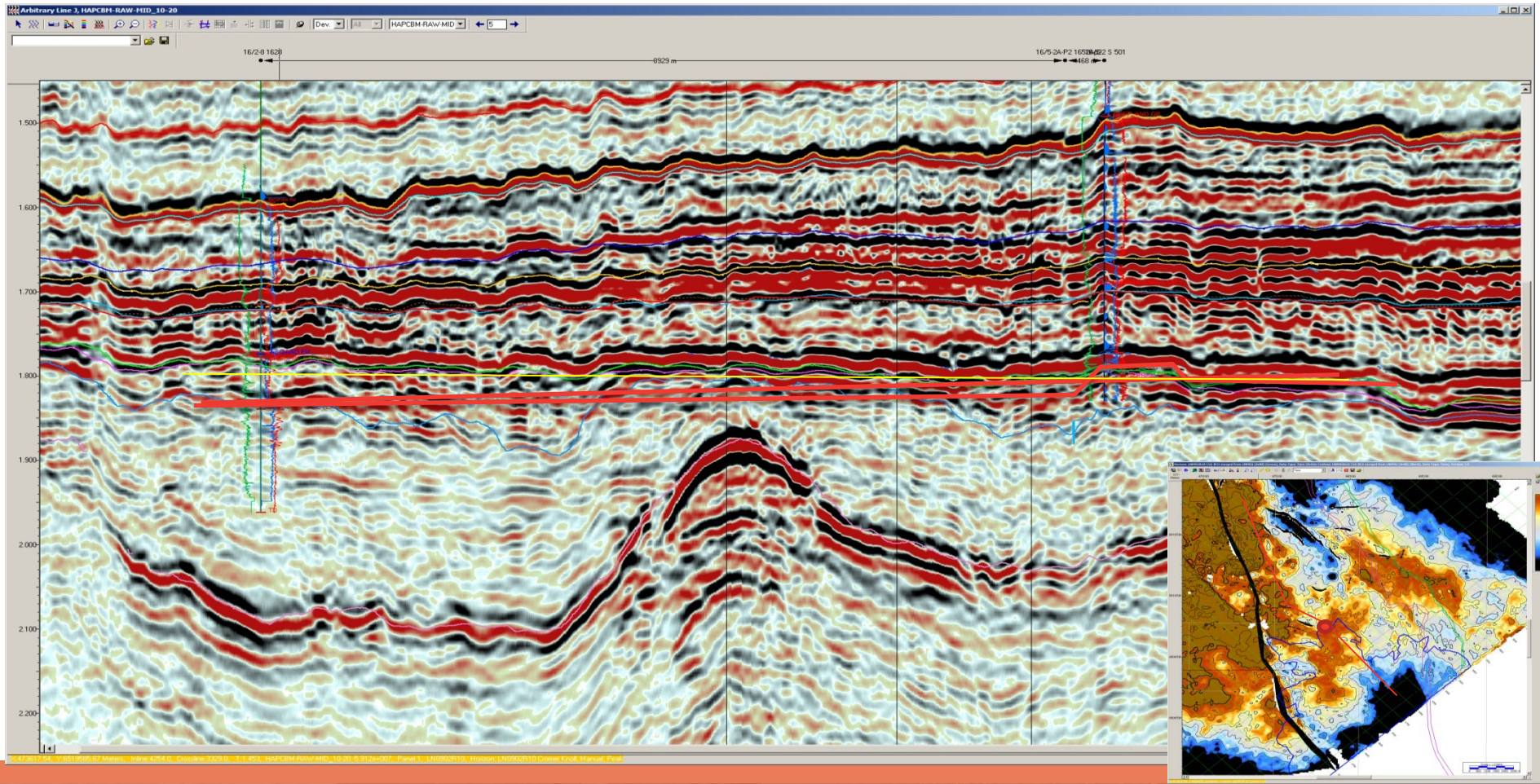
- 6 gal



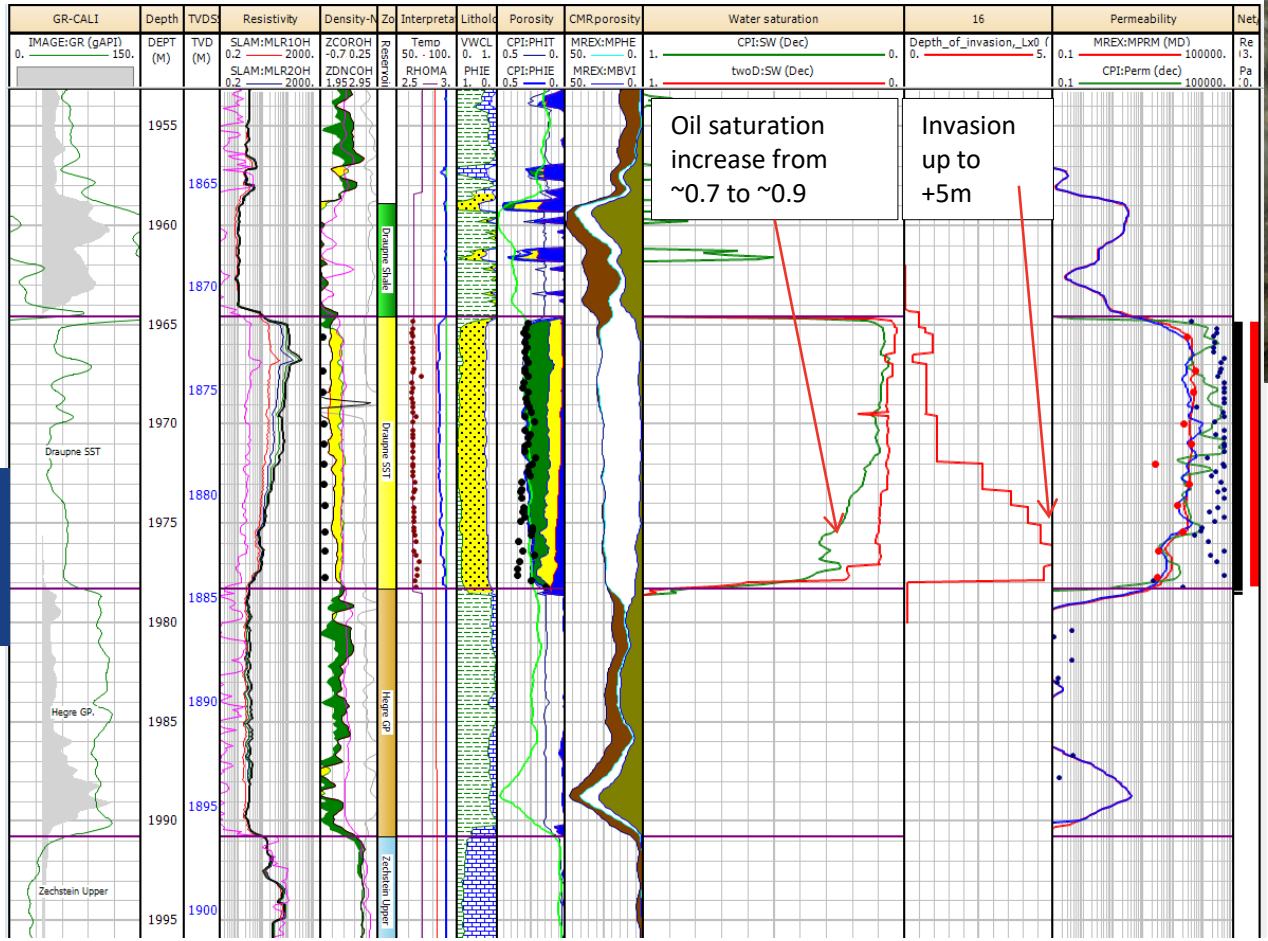
Velocity variations are significant and deterministic

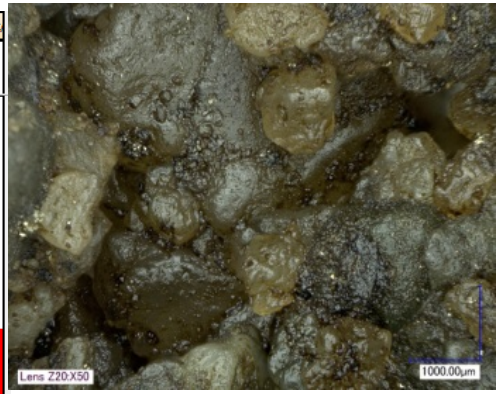
16/2-8 and 16/5-2;

Same time depth varied with 80 m in depth. Detailed deterministic approach needed. Reality is not stochastic



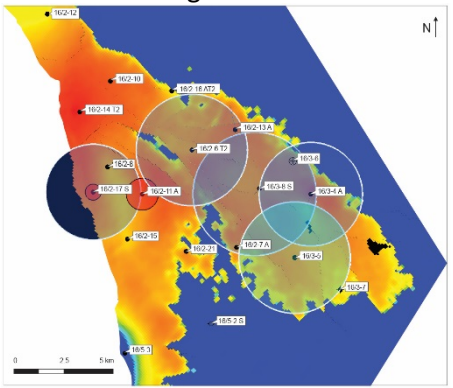
Deep mud invasion in good reservoirs deteriorate log interpretation





Sh under estimation of 10%

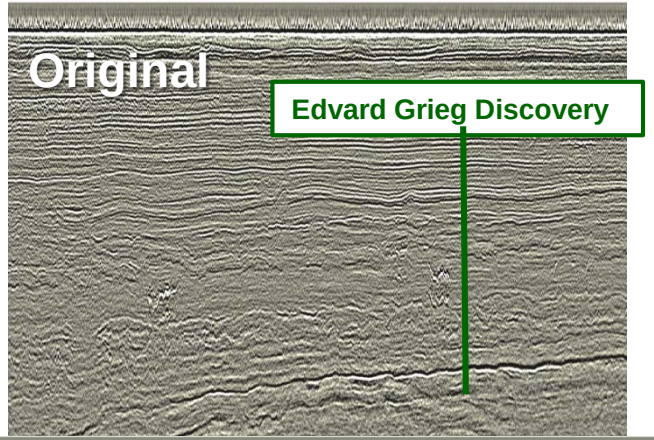
- No mud cake
- Deep mud invasion
- New procedures necessary in constructing CPI

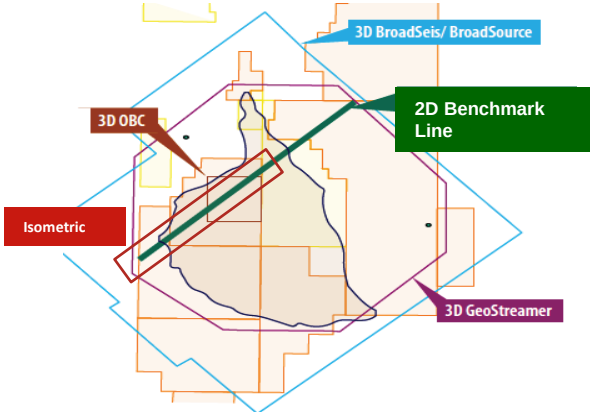


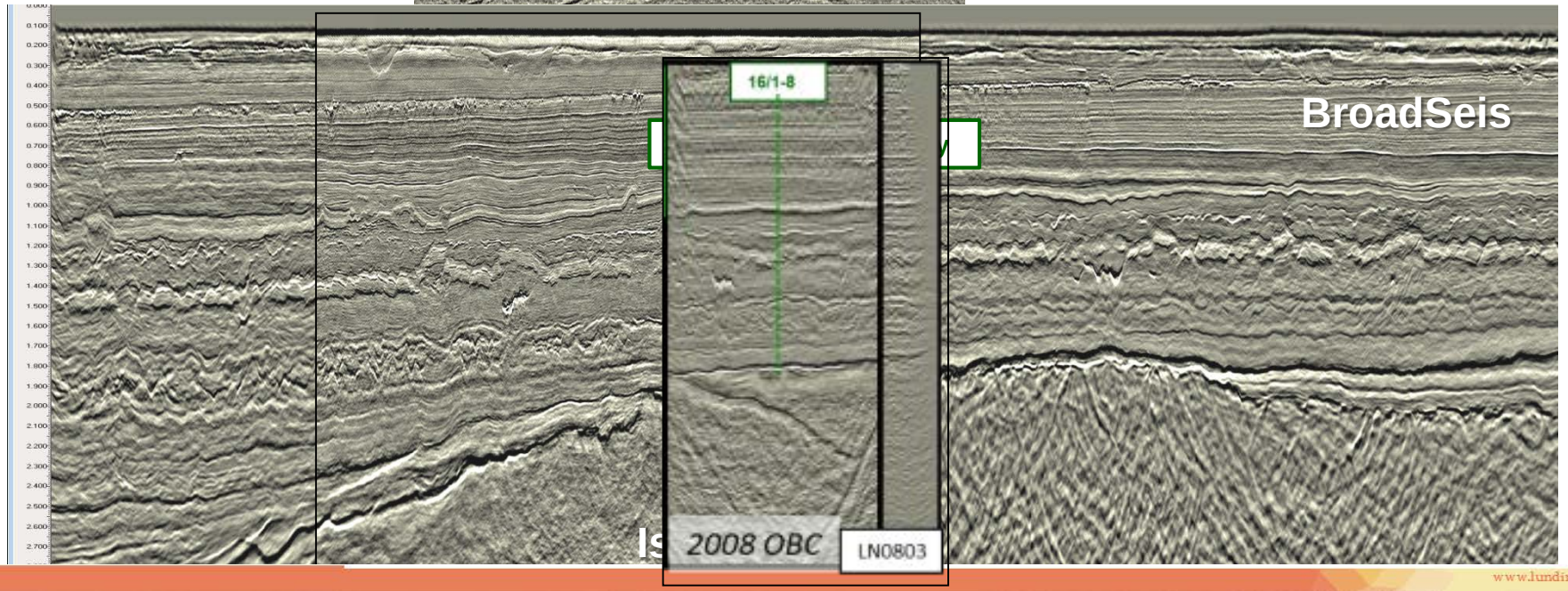
60 + Darcy sand do not have 40 m transition zones

Greed shadows for the truth (Unitization)

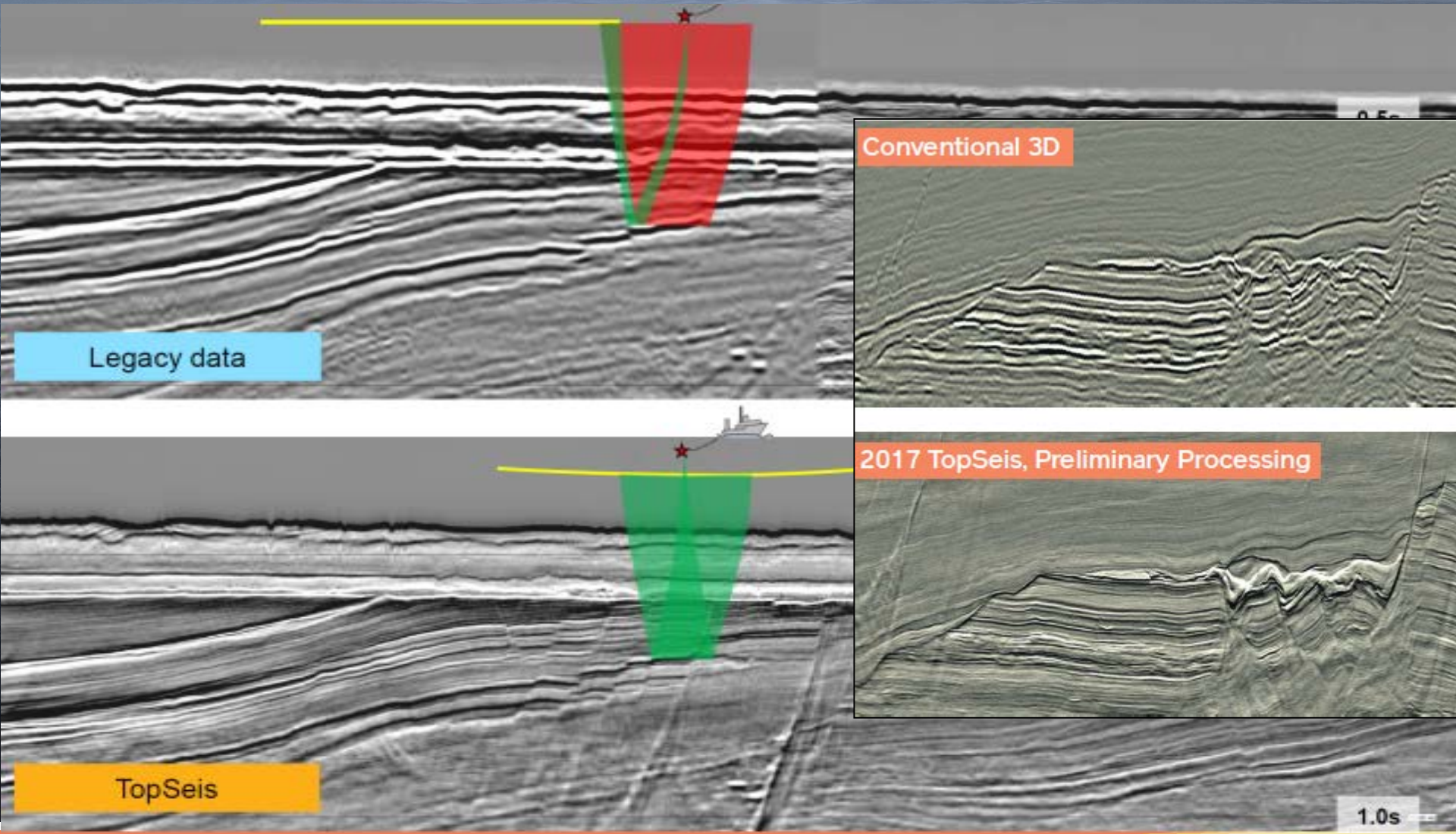
Broadband seismic as a new standard that unfold a holistic perception







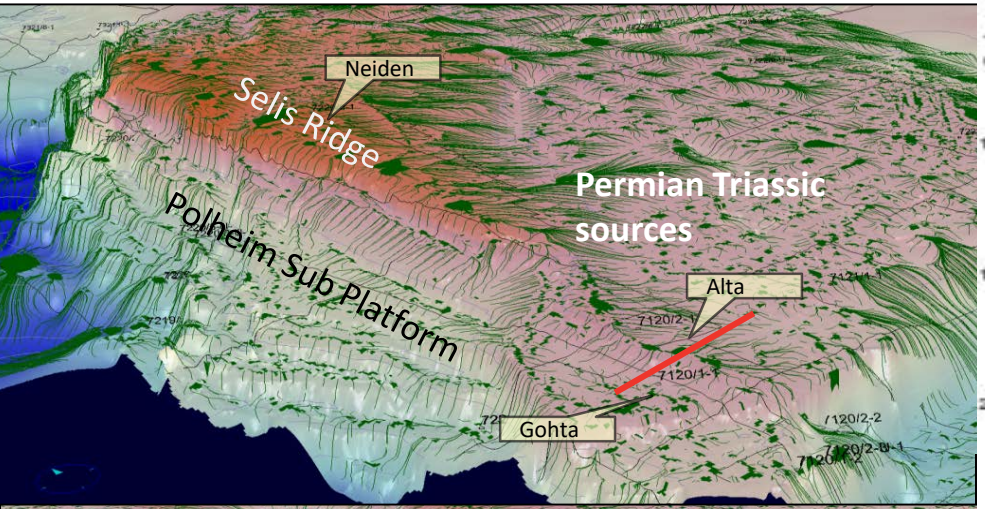
First TopSeis Survey, Barents Sea (2017)

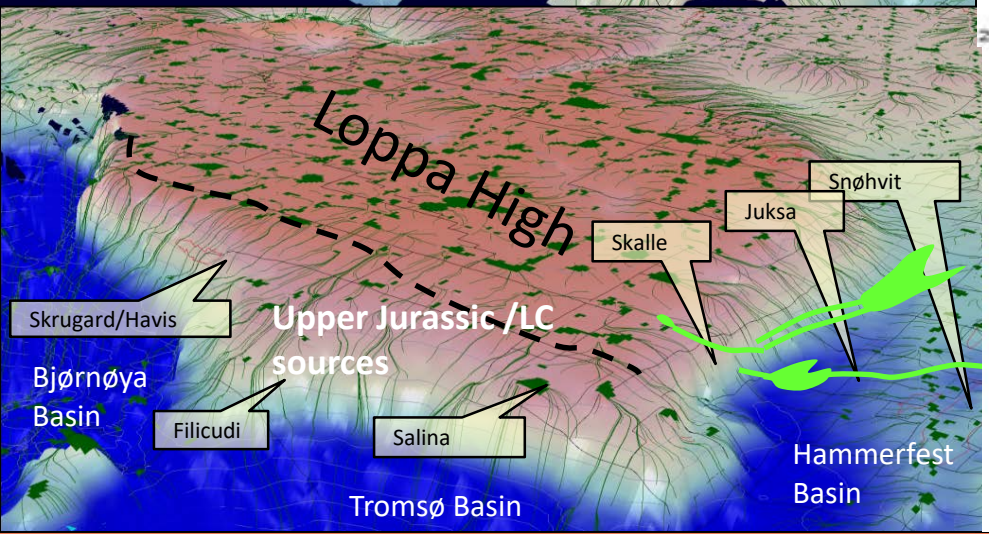


Revitalization of old concepts by new 3D seismic in 1998;

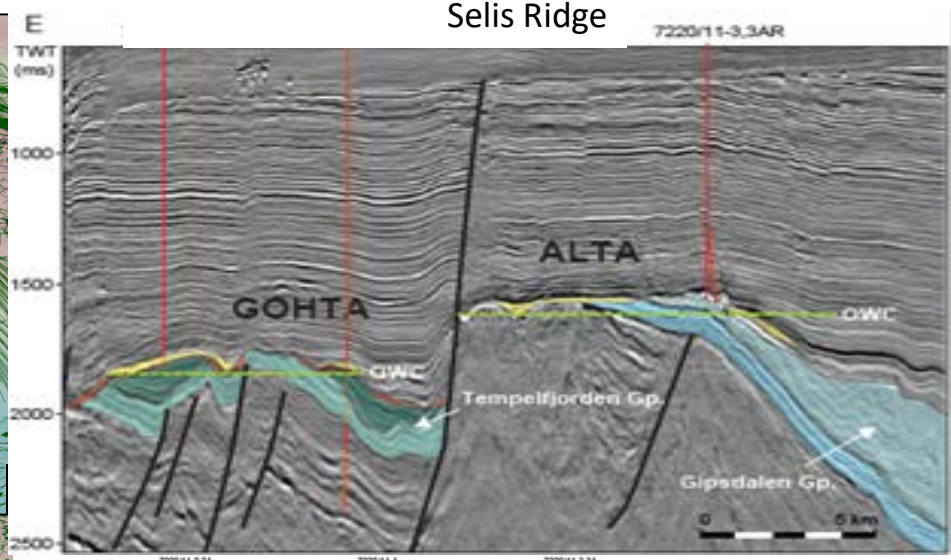
Maps are filtered information of sequence boundaries

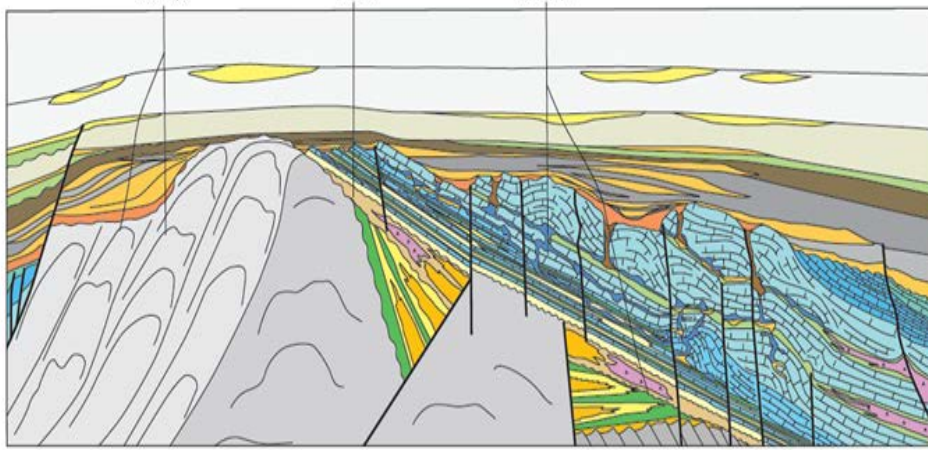
Migration in the channel systems not boundaries



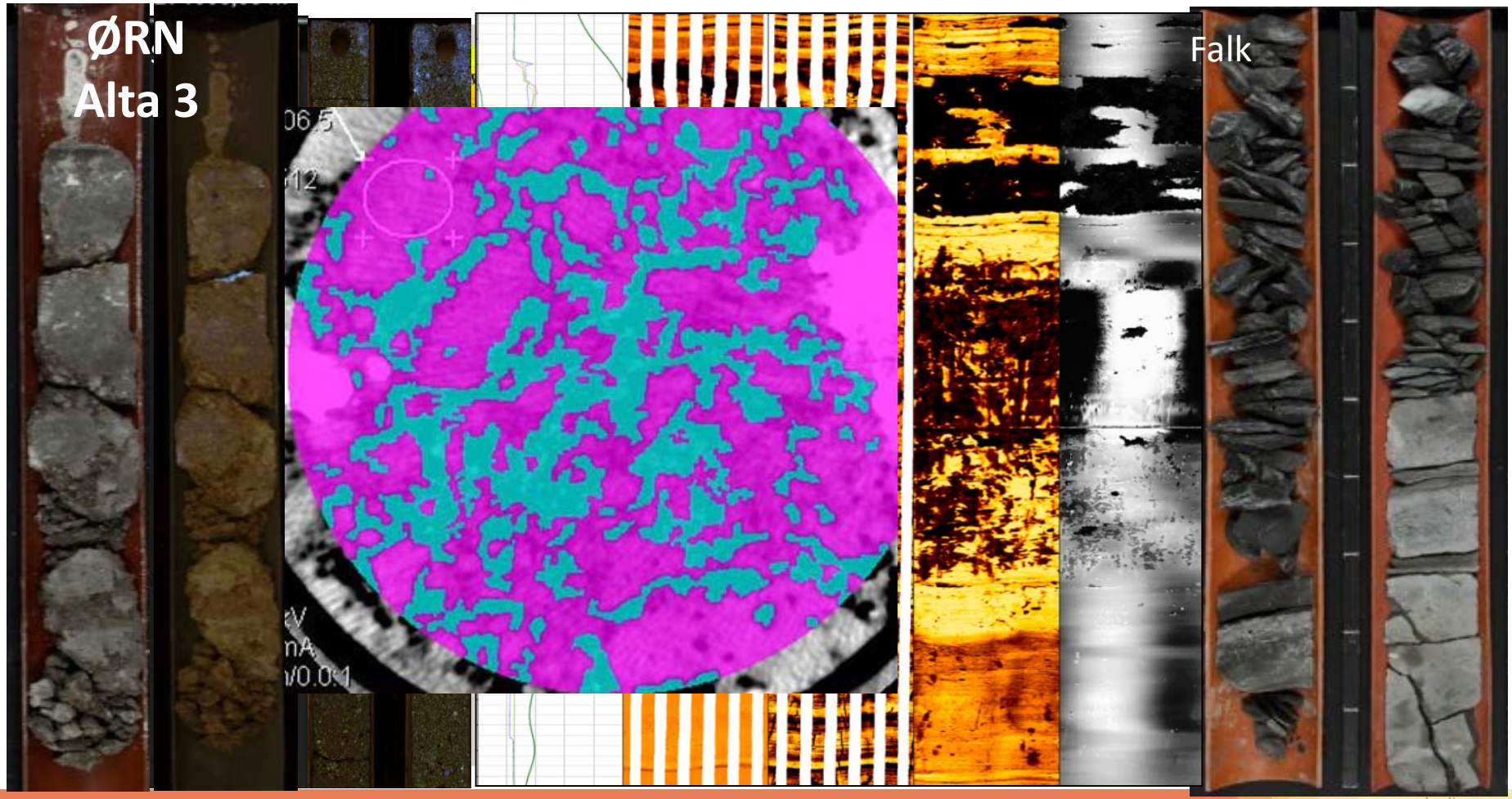


Selis Ridge

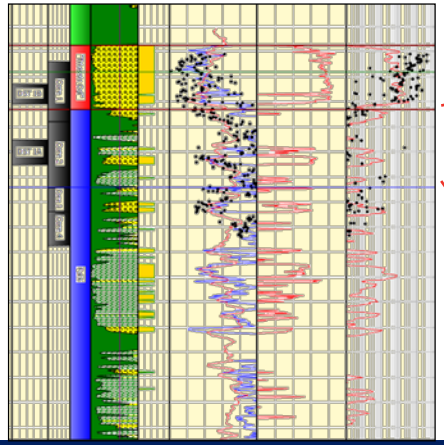




Carbonates reservoirs are about pore size

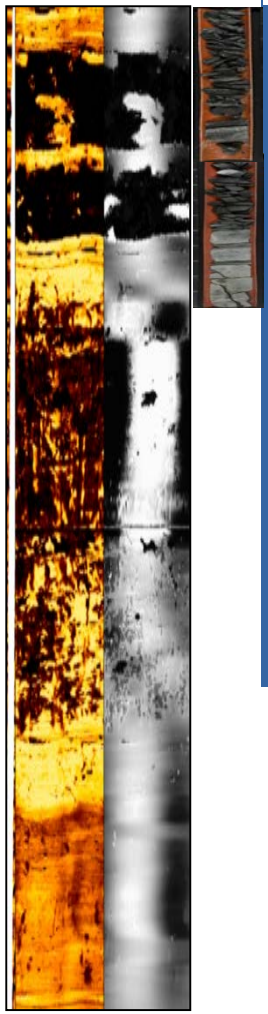


Wireline tools insufficient for macro porosity

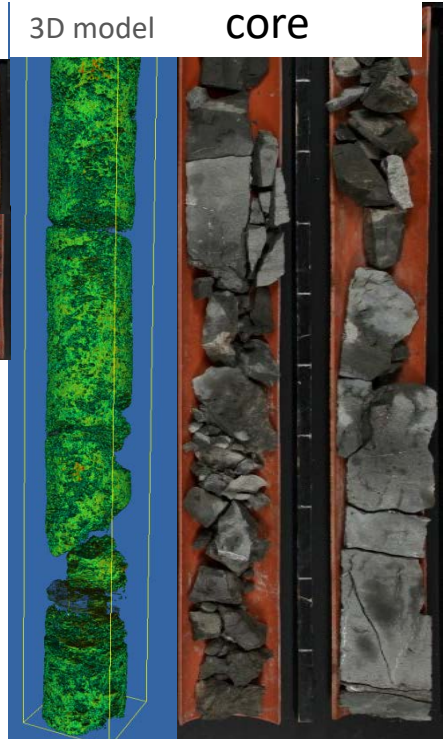


FMI

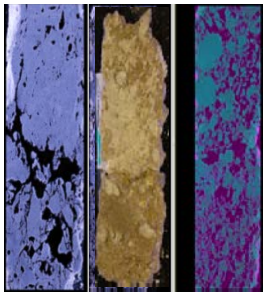
7m



3D model core



Porosity concealed by mud



Macro pore size systems:

- *Pores are larger than Wl methods*
- *Vertical pores*
- *Large scale mud invasion*
- *Coring in karstified reservoir is a must*
- *Need prediction of macro porosity ahead of bit*

True words are not beautiful, beautiful words are not true :

Avoid the empty raincoat syndrome (C Handy)
If you do something your are already doing the wrong thing (D Bohm):
Better not best practice

In the time of change the learners will inherit the earth while the learned will find them self managing a non existing world (Eric Hoffer)