Cake & Discuss The Property Model

Organization Committee

Sonja Kuhlmann

Marine Seignole

Olso facilitator

Jamie Good Quin

HSE & Other Practicalities

Welcome to "Cake & Discuss"

- *13 April 23: The Structural Framework*
- *22 August 23: The Grid*
- 7 November 23 : The Property Model
- **23 April 24 : The Property Model**

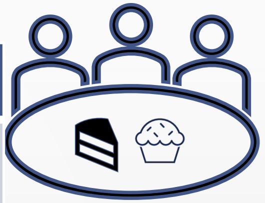
Session 5: 27 august
The Uncertainty Study

Welcome to "Cake & Discuss"

- Fundamental spirit of FORCE
  - Cooperative forum
  - Facilitate cooperation within the industry
- Group discussions
  - Discussion based on impulse talk
  - Small group: Mix of experience and expertise
  - Summary session
- This is not a place where we can solve all the issues but discuss and share experiences
  - If you want to bring up a topic suggest an impulse talk

How this works

- Welcome and introduction
- Divide audience into groups
- Each group chooses a discussion keeper
- “Impulse” talks round today's topic
- Discussion time after talk
    - Have you seen this?/What’s your best practice? ….
- Round the room: each group present findings
- In total 3 impulse talks and follow-up discussion in groups and presentation to other groups
- Closeout and feedback
- Mingle, talk & enjoy food and drinks throughout the afternoon



Time	Duration	Activity
12:30-12:50	20 min	Intro to concept Presentations "who is here today" Sort groups
12:50-13:00	10 min	1. "Impulse" talk
13:00-13:15	15 min	Group discussion
13:15-13:20	5 min	Break (deliver talking points)
13:20-13:40	20 min	Presentations and overall discussion
13:40-13:55	15 min	2. "Impulse" talk
13:55-14:40	45 min (20+5+20)	Group discussion Break (deliver talking points) Presentations and overall discussion
14:40-14:55	15 min	3. "Impulse" talk
15:55-15:40	45 min (20+5+20)	Group discussion Break (deliver talking points) Presentations and overall discussion
15:40-15:55	15 min	Closeout / feedback

The groups

Group 1	Group 2	Group 3	Group 4

Choose a discussion keeper

- Role:
  - Make sure everybody in the group gets talking time
  - Time keeping
  - Make sure the key ideas are on the flip chart
  - Find a presenter to other groups- 1 presenter per impulse talk
  - When problems are raised
    - -> probe for solutions
    - -> keep the discussion going
  - TAKE A PICTURE OF YOUR FLIP CHART / SHARE YOUR PPT
    - Send it to marine.seignole@akerbp.com

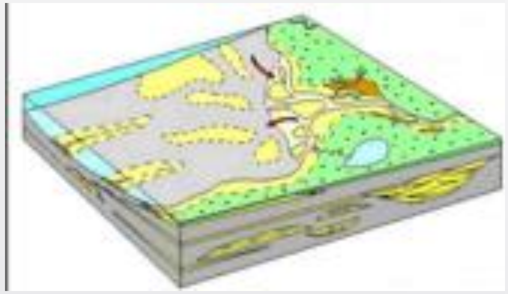
Impulse talk topics

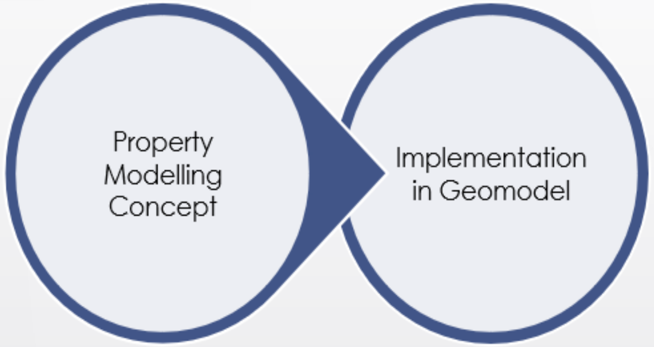
- Knowledge share on best practices for property modelling / Considerations for selection of algorithms & modelling approaches
- Ways to include diagenetic overprints in reservoir modelling of clastic reservoirs
- A hierarchical approach to sedimentological reservoir characterization: a systematic, contextual method to distribute reservoir properties across the geomodel

Impulse talk 1

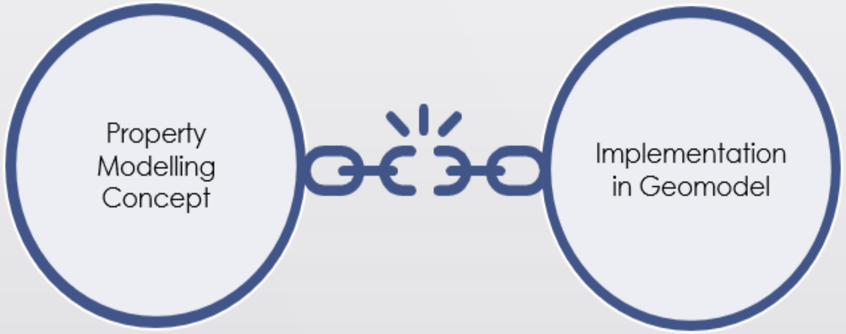
Flow of the model

Concept





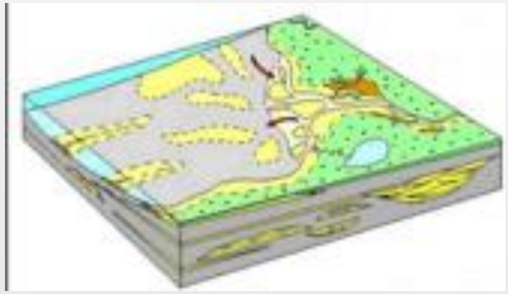
Implement a property modelling concept sounds easy …



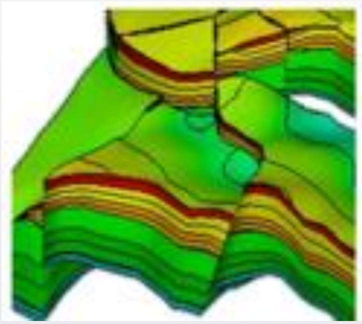
… but it poses some technical challenges

Flow of the model

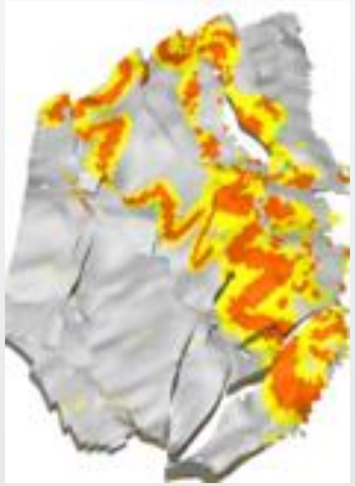
Concept



structure model

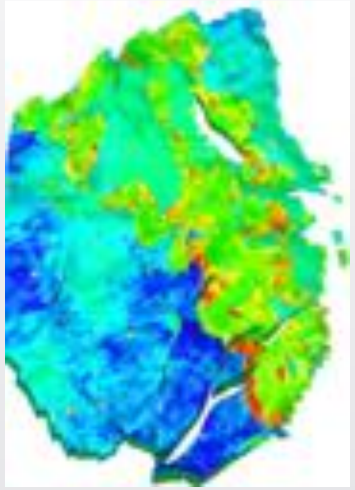


Facies model



1.Object Modelling (OBM).
2.Sequential Indicator Simulation (SIS).
3.Truncated Gaussian Simulation with/without trends.
4.Multipoint Statistics (MPS).
5.…

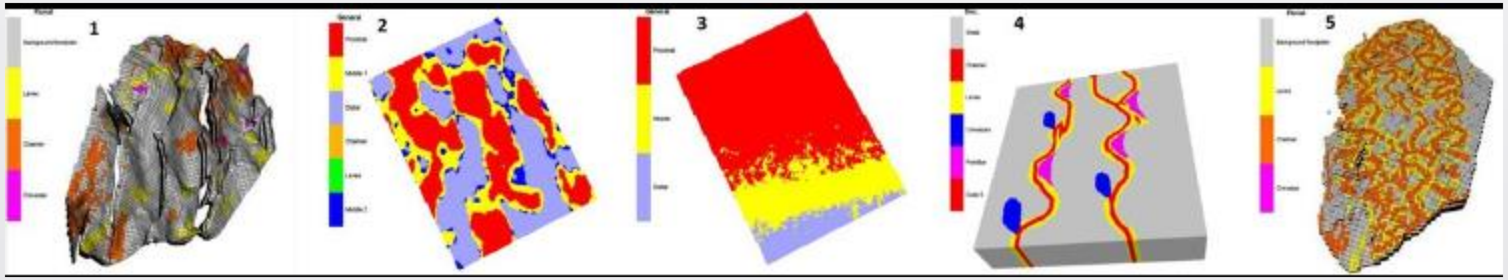
petrophysical model



1. Kriging.
2. Kriging with trend.
3.Sequential Gaussian Simulation (SGS) .
4.Gaussian Random Function Simulation (GRFS).
5.…

Facies model

- Number of facies
- How to select best algorithm



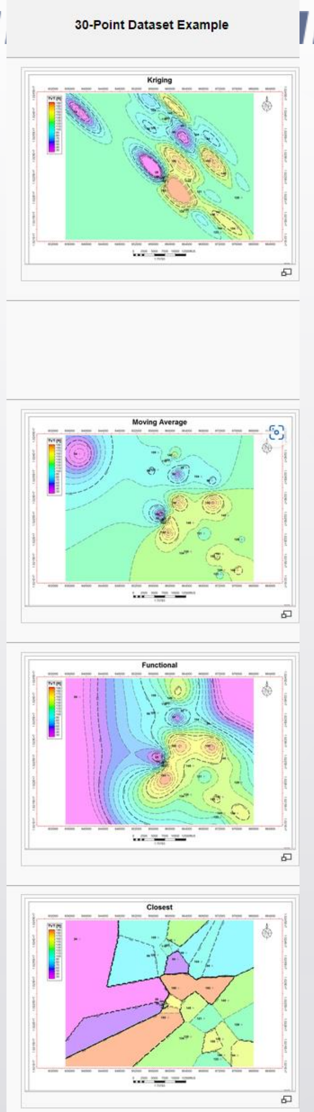
SIS TGS TGS with trend MPS objects

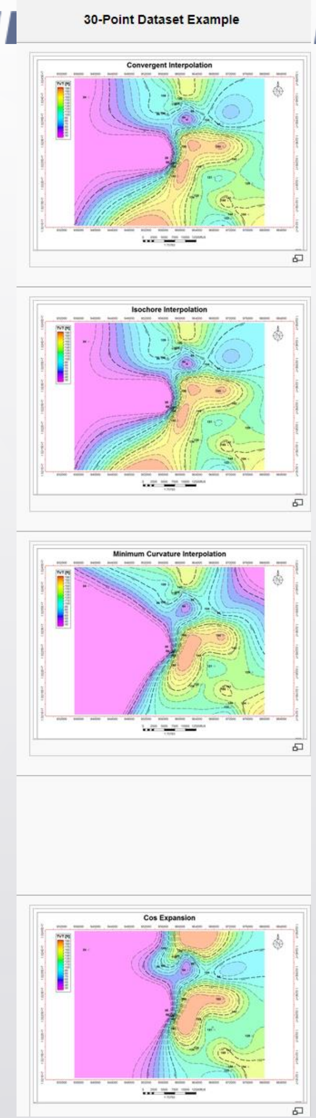
- Use of trends
- How to QC

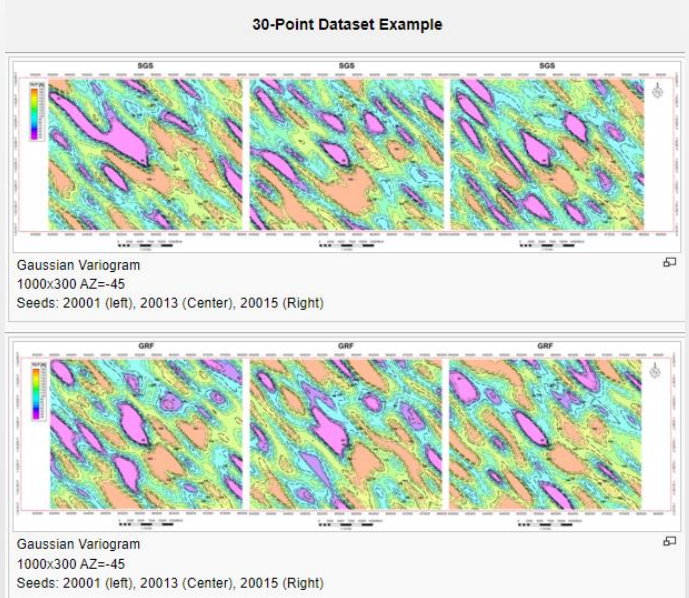
Property modeling

- Algorithm selection:

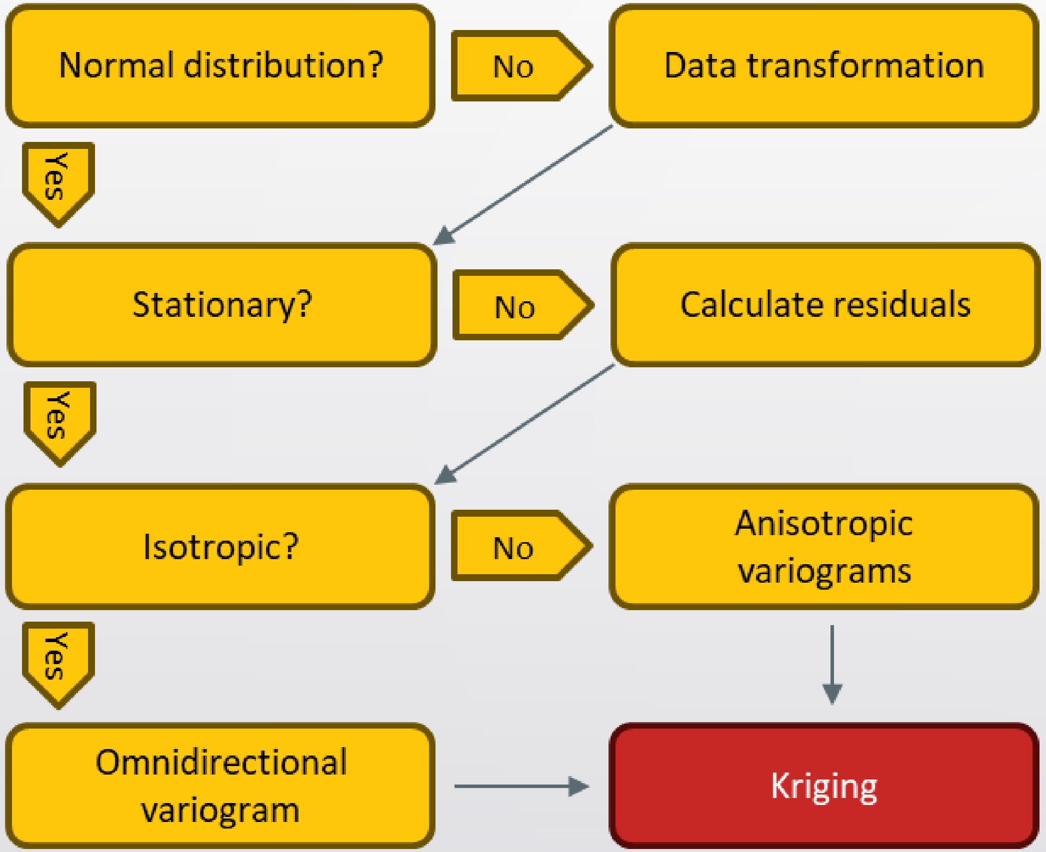
  Same 13 data points data set example



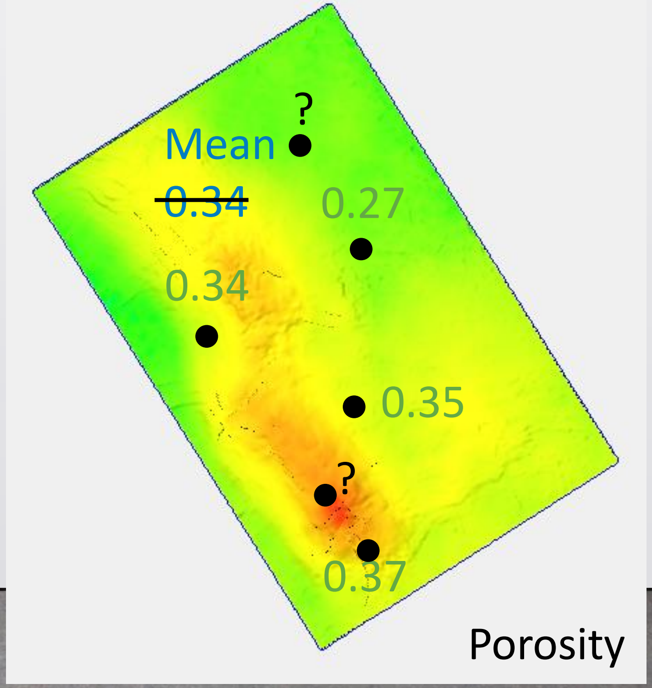




Geostatistics basics - kriging



- Kriging assumes the data come from a stationary stochastic process
  - Globally fluctuation is zero (go back to mean of data)
  - Fluctuation depends only on distance and not on any other property (such as position) of a location



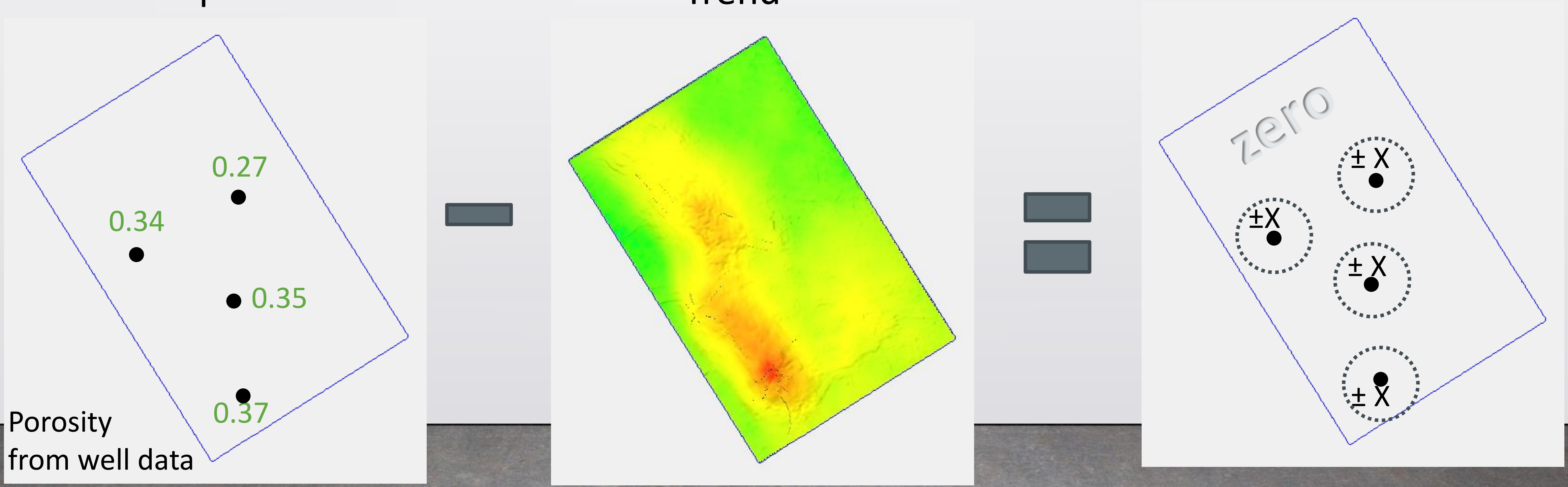
Geostatistics basics - trends

- Prior removal of trends, kriging of stationary residuals (explicit treatment)
  - Trend is known
    - Physics are understood
  - Simple function
    - Low frequency

Input

Trend

Residuals
→ Kriging with Residuals



Questions to Discuss

FACIES MODELLING

- Use of geostatistics
- Algorithm selection
- Number of facies
- Use of trends
- How to QC

PROPERTY MODELLING

- Use of geostatistics
- Algorithm selection
- Use of trends & secondary properties
- Modeling vs calculation ?
- How to QC

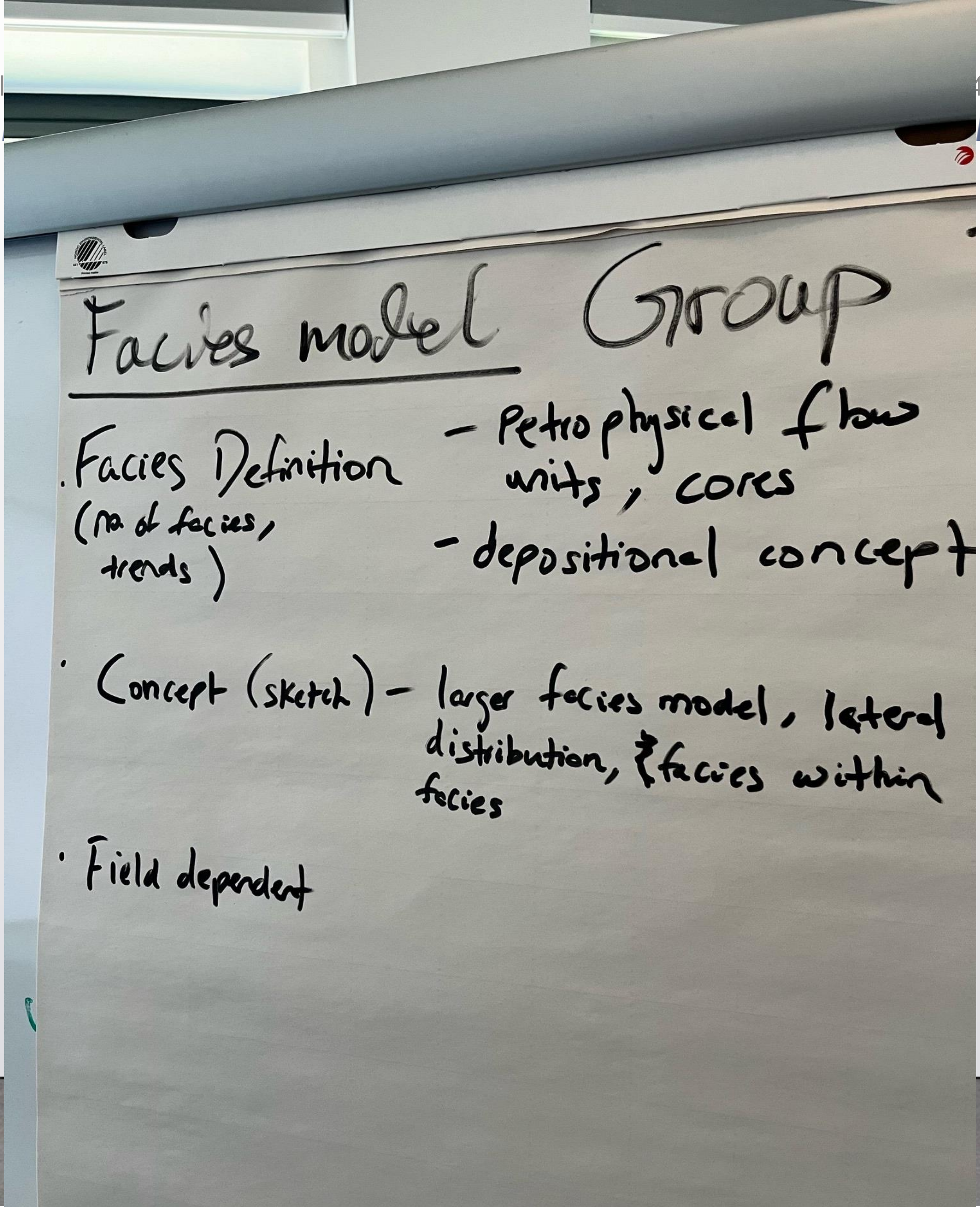
Group - Notes

- TAKE A PICTURE OF YOUR FLIP CHART
  - Send it to marine.seignole@akerbp.com

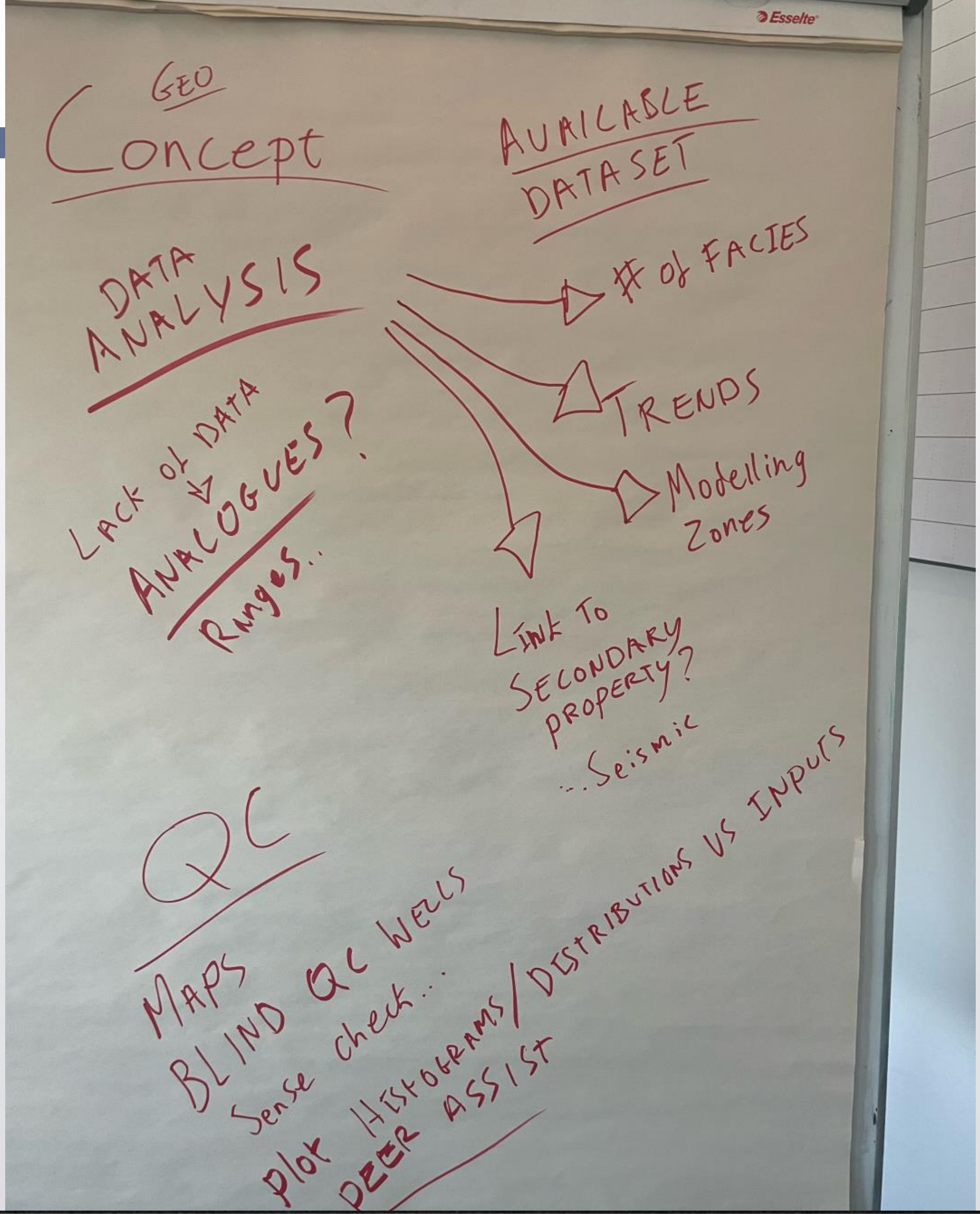
Group oslo

- Facies Modelling
- As few facies as possible
- Facies should always be petrographically unique
- Purpose of the model – necessity for facies, gas or oil.
- Zonation and facies.
- Facies that are not present data,
- What is critical for dynamic behave
- Are there alternatives?
- Are facies always necessary.
- Trends, are they related to structure,
- Trap of matching global statistics trends are always present
- Facies used to capture geometry despite
- Early test of dynamic input – understand impact of different facies approaches.
- Flow properties
- Remember there is no perfect model
- Ensemble models – scenarios - use time to capture multiple

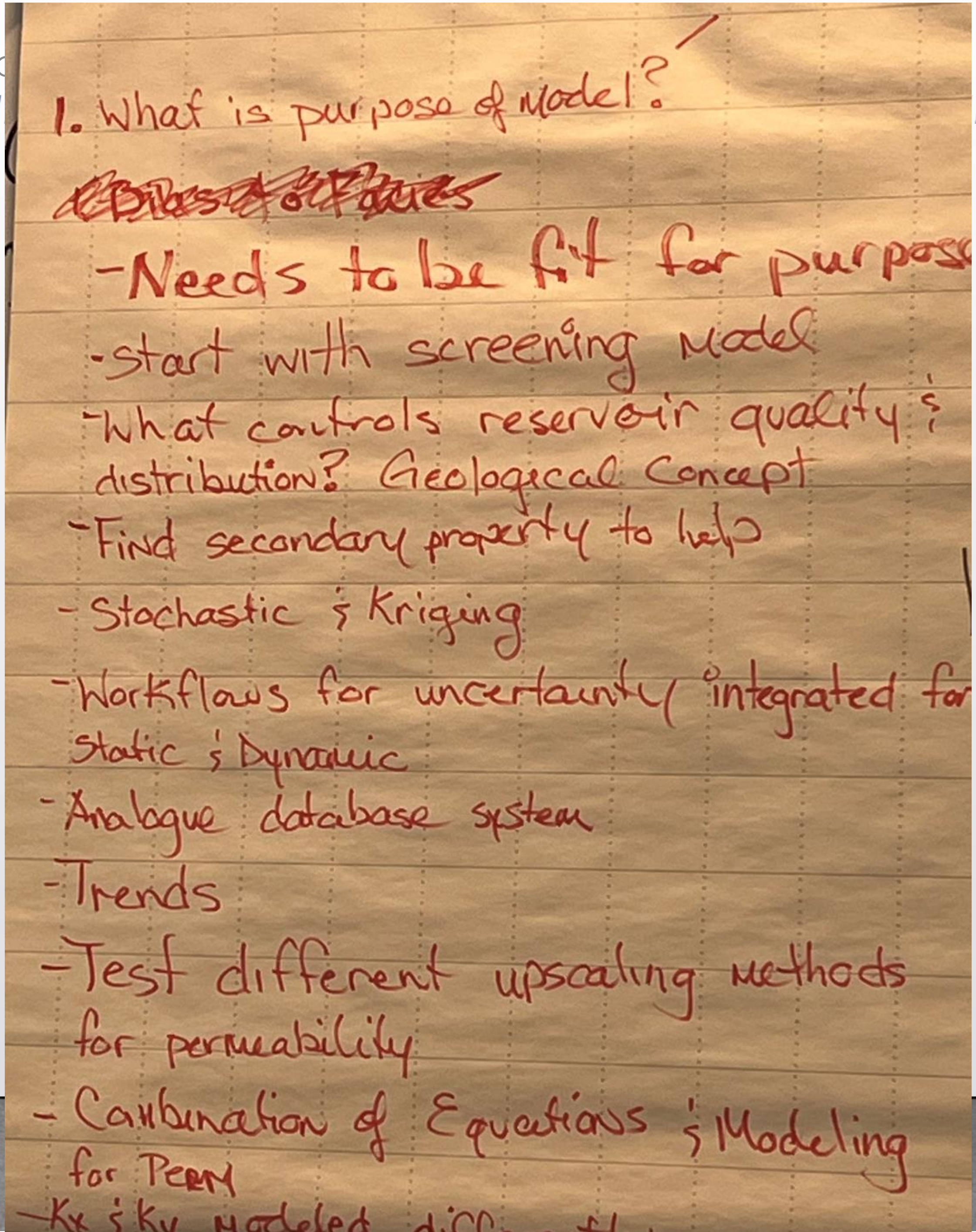
Group 1


Facies model Group
Facies Definition (no. of facies, trends)
- Petrophysical flow units, cores
- depositional concept
Concept (sketch) - larger facies model, lateral distribution, facies within facies
Field dependent

Group 2


GEO
Concept
AVAILABLE
DATASET
DATA
ANALYSIS
# of FACIES
TRENDS
Modelling
Zones
Lack of DATA
ANALOGUES?
Ranges...
LINK TO
SECONDARY
PROPERTY?
..Seismic
QC
MAPS
BLIND QC WELLS
Sense check...
plot HISTOGRAMS/DISTRIBUTIONS VS INPUTS
PEER ASSIST

Group 3


1. What is purpose of Model?
-Needs to be fit for purpose
-start with screening Model
-What controls reservoir quality & distribution? Geological Concept
-Find secondary property to help
- Stochastic & Kriging
-Workflows for uncertainty integrated for Static & Dynamic
-Analogue database system
-Trends
-Test different upscaling methods for permeability
- Combination of Equations & Modeling for Perm

Impulse talk 2

wintershall dea

FORCE WORKSHOP

Ways to include diagenetic overprints in reservoir modelling of clastic reservoirs

KAY REHBERG

Stavanger, April 23, 2024

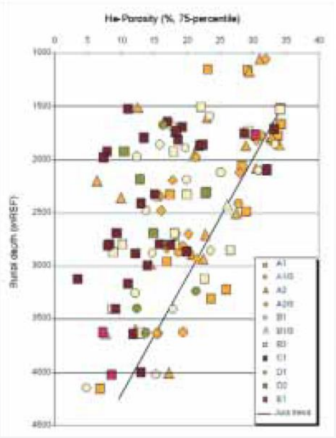
Diagensis in reservoir models

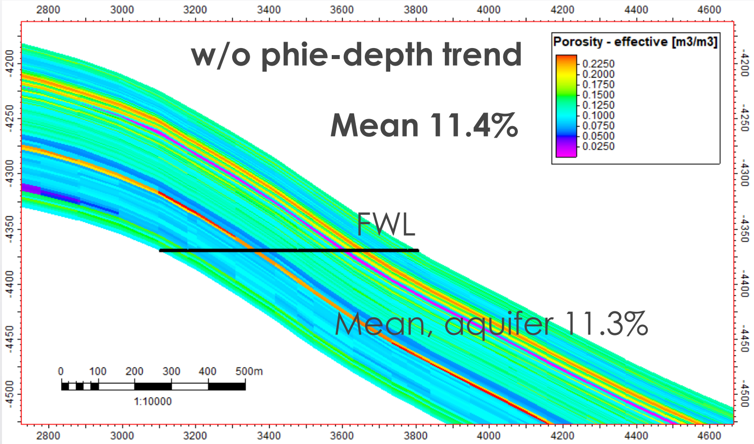
- **Diagenesis, does it matter ?**

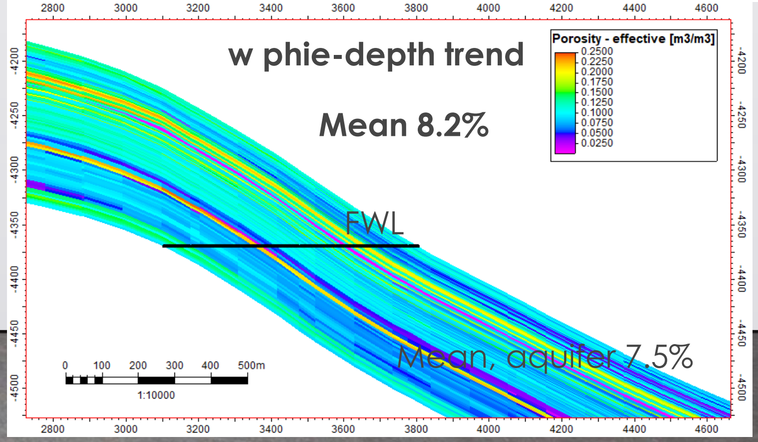
- Static Modelling Objective: Predict reservoir quality in reservoir models
- Simple approach: I'm not a petrographer, I chose to ignore it

- **What can go wrong?**
- Production forecast, if diagenesis controls reservoir quality and it is not or wrongly captured in the model
- Development concept based on wrong assumptions (e.g. underestimated risk of water production)

- **Example:**
- Porosity-Depth trend in deeply buried sandstones with high fraction of secondary porosity due to grain dissolution
- Vertical trend reduces Phie and kh downflank and below contact
- Impact: Water breakthrough (time, rate)



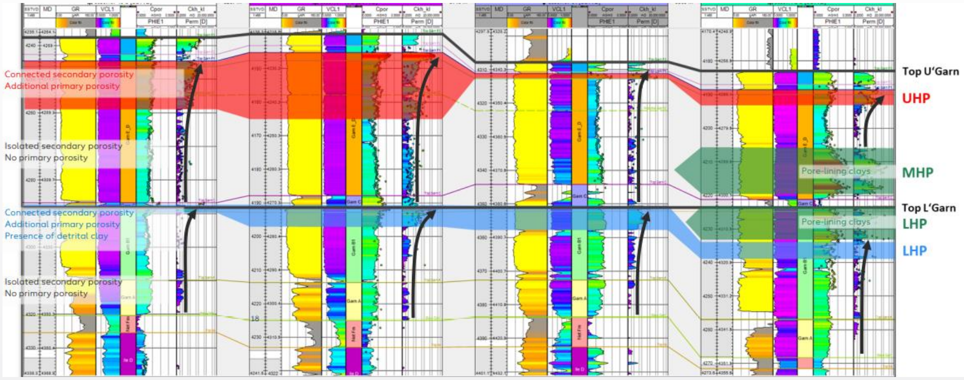


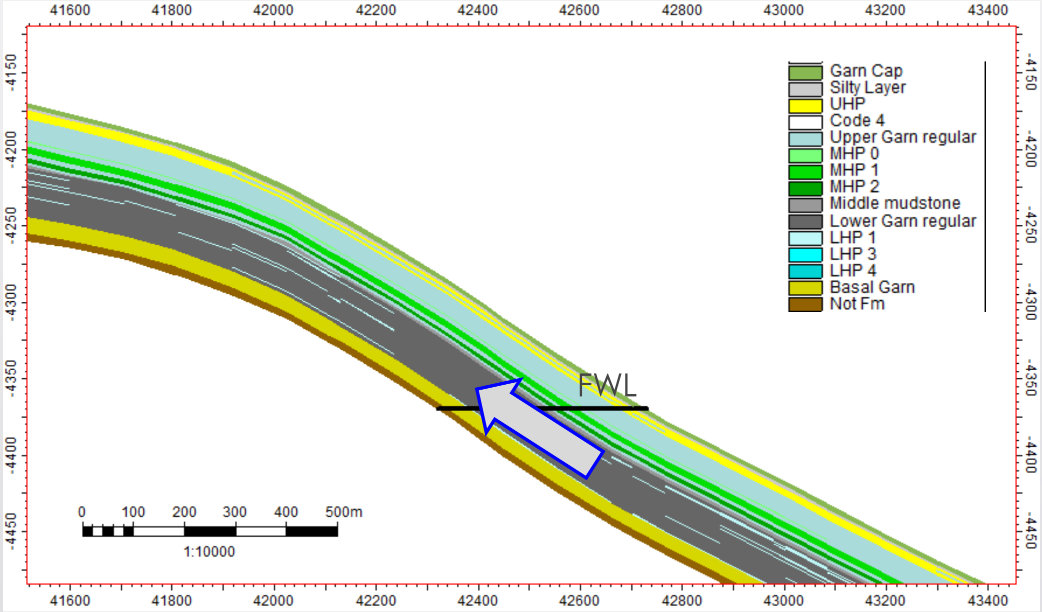


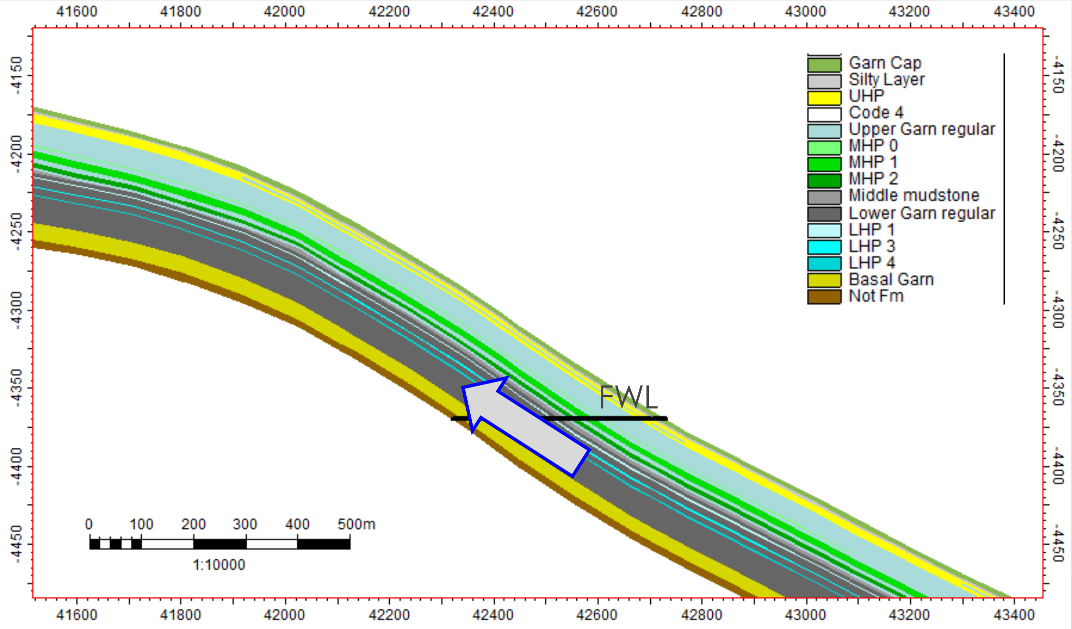
Diagensis in reservoir models

- **Example:**
- **Grain dissolution and pore-lining clays enhancing phie and kh**

- **Scenarios**
- Uncertainty in geometry, lateral extend, proportion
- Patchy (left) vs. sheet-like (right)







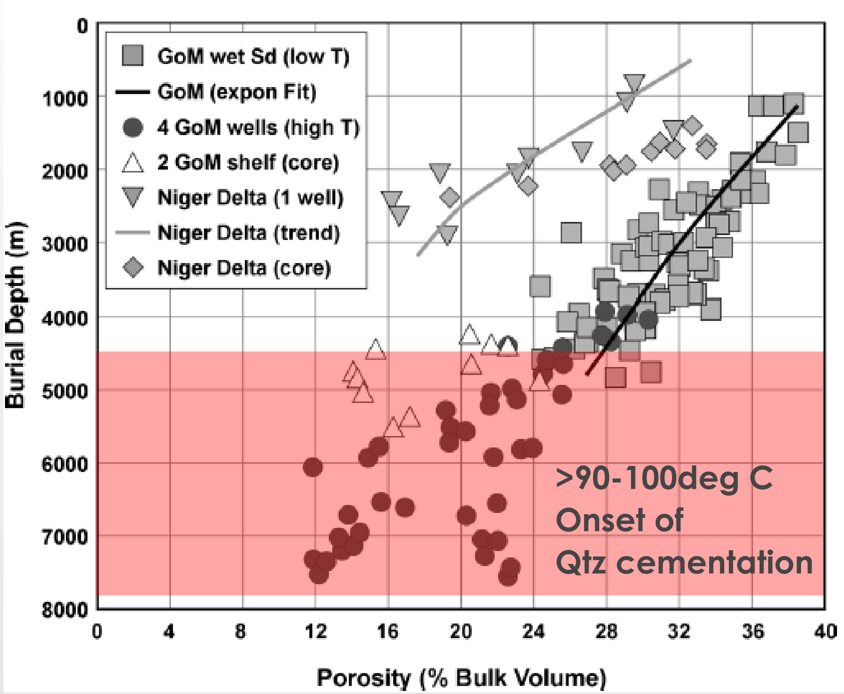
compaction

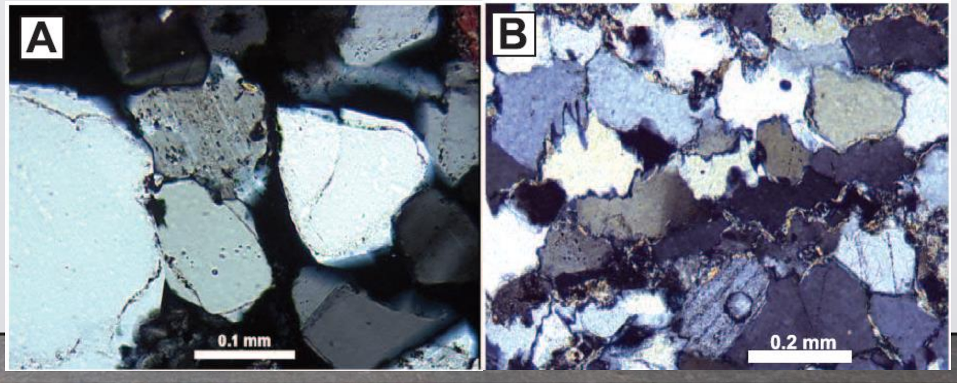
- **Background**

- Sandstone porosity decreases with increasing depth (regional porosity-depth)
  - useful in unlithified sands with limited textural and mineralogic variability where mechanical compaction is the dominant porosity-reducing mechanism (e.g., GOM deep-water Tertiary turbidites, Taylor et al. 2010)
  - extrapolation of compaction trends to greater depths is difficult (increase cementation rates); basin specific
- Sandstones can deviate from normal porosity-depth trends if affected by
  - processes or conditions have limited compaction and/or cementation, or
  - porosity enhancement by dissolution of grains or preexisting cements

- **Factors**
- sand composition
- grain coats, carbonate cements, authigenic clays
- Texture (grain size, sorting)
- fluid chemistry
- temperature
- effective stress
- Time
- Complex interplay results in a range of different rock properties

Golf of Mexico (Taylor et al. 2010)





(A)quartz overgrowths, (B) sutured intergranular and stylolitic contacts (Morad et al. 2010)

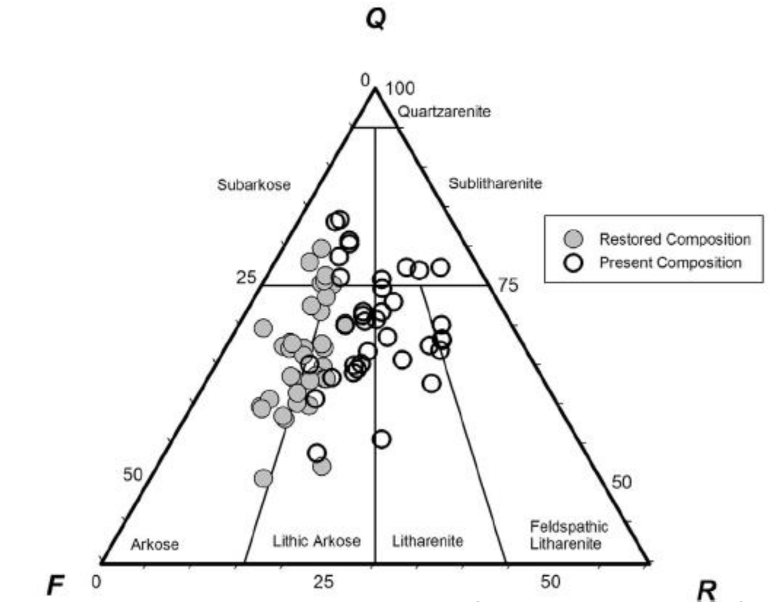
Grain dissolution

- **Background**

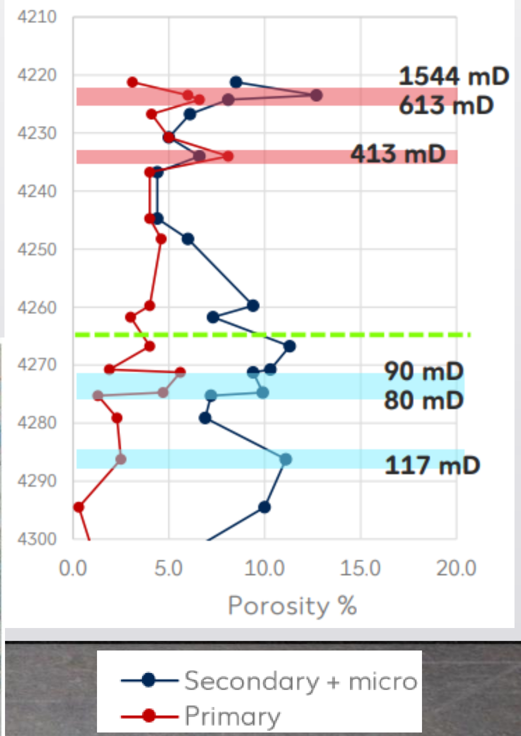
- formation of secondary porosity due to dissolution of unstable framework grains
- intragranular and moldic pores (pore network)
  - dissolved components precipitated in the pore network as an authigenic phase (e.g., kaolinite, illite) with decrease in perm or transported out (increase in phi / perm)

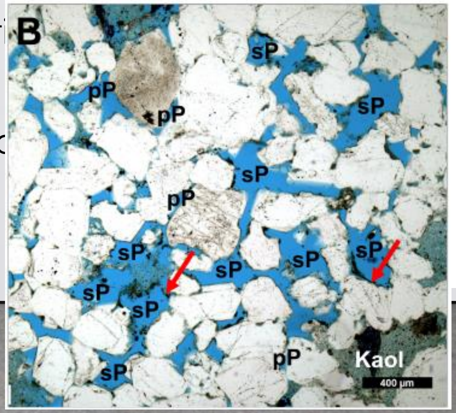
- **Factors**

- Presence of unstable grains (feldspars, volcanic fragments, carbonate minerals); meteroic waters
- Strong or weak link to depositional facies
- Pore fluid composition, temperature, pressure (acidic condition help dissolut meteoric waters)
- might be very localized depending on the distribution of the unstable minera flow paths of the diagenetic fluids



North Sea (Taylor et al. 2015)





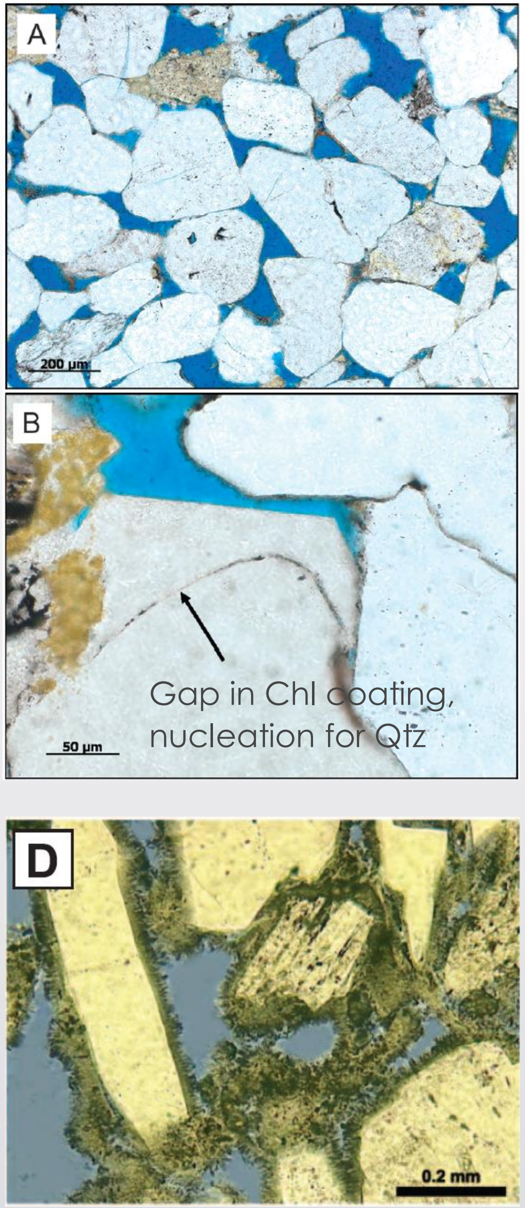
(B) Grain dissolution of Fsp, high secondary porosity

Grain coating, pore lining

- **Background**

- formation of grain coats on the surface of detrital quartz grains prior to the onset of quartz precipitation inhibit cementation by forming a barrier that prevents nucleation of quartz
- Porosity is preserved, Permeability may be preserved or destroyed
- grain-coating of Fe-rich clays are transformed into chlorite rims during mesodiagenesis
- authigenic coatings of (infiltrated) smectitic clays, transformed into illite during mesodiagemesis
- microcrystalline quartz coatings on detrital quartz grains

- **Factors**
- Petrographic evidence of grain coatings
- Link to depositional facies
- Chlorite coatings known from deltaic and near-shore marine sandstone facies
- Spatial distribution, lateral and vertical trends
- Quantify effect on porosity and permeability



(A, B) Chlorite grain coating, (D) Chlorite pore lining. Taylor et al. 2010)

Diagenetic Alterations in a fluvial-dominated Delta

Delta-front deposits and distributary mouth bars

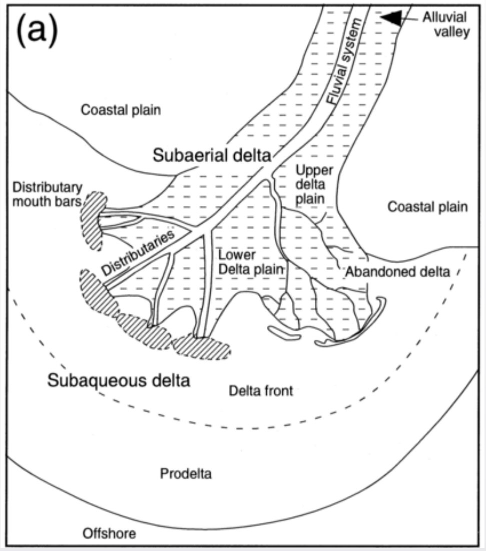
- thin authigenic coatings of (infiltrated) smectitic clays, transformed into illite
- abundant grain coating and ooidal Fe-rich clays
- grain-coating Fe-rich clays are transformed into Fe-chlorite rims during mesodiagenesis
- patchy or laterally extensive carbonate cementation associated with layers rich in carbonate bioclasts or mud intraclasts (e.g., lags) along **flooding surfaces**
- dissolution and kaolinization of detrital feldspars and micas occur in the landward extension of the deltaic deposits (meteoric waters)

Delta plain

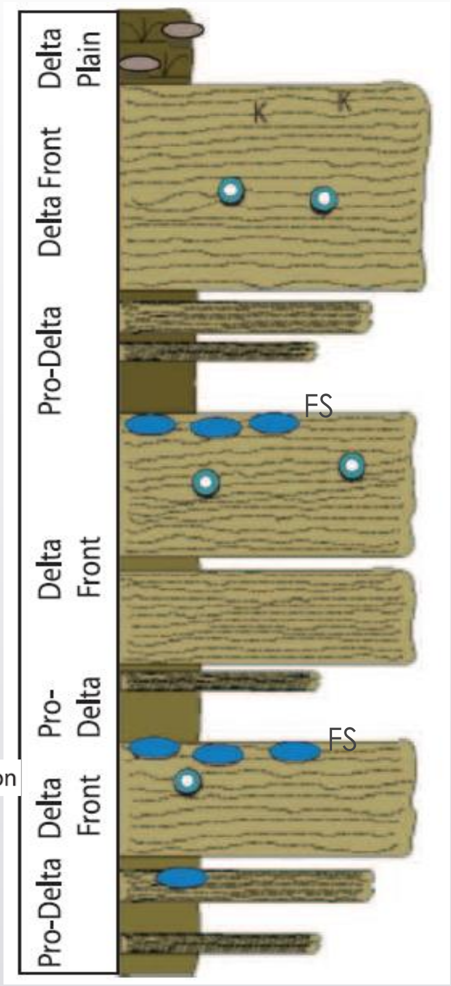
- Siderite (bacterial fermentation of organic matter)

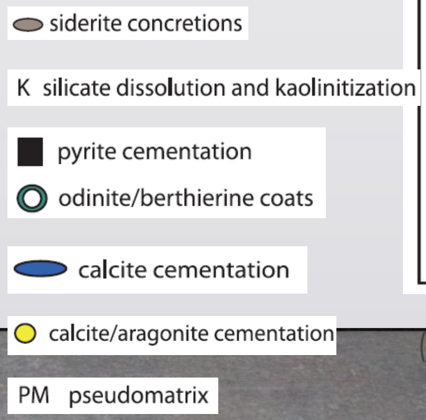
Reservoir Quality and Heterogeneity

- chlorite coatings preserve porosity (and to some extend permeability) during burial through inhibition of quartz cementation



after Suter (1994





(Morad et al. 2010)

diagenesis in reservoir models

Depositional Facies
- Reservoir architecture
- Depositional Facies distribution

Property model
- Porosity
- Permeability
- Biased to depositional Facies

Diagenetic alteration model
- Link to Facies or Rock Types
- Enhancement
- Preservation
- Reduction
- Spatial distribution
- Geometries
- Porosity
- (Permeability)
- Heterogenity or Barrier

Property adjustment
- Properties adjusted by diagenetic overprint
- Enhancement or Reduction
- Biased or unbiased to Facies or RT

Revised Property model
- Carry forward in static workflow
- ....

Static Models
- Scenario 1
- Scenario 2
- …

Dynamic models
- Initialization
- History matching under uncertainty

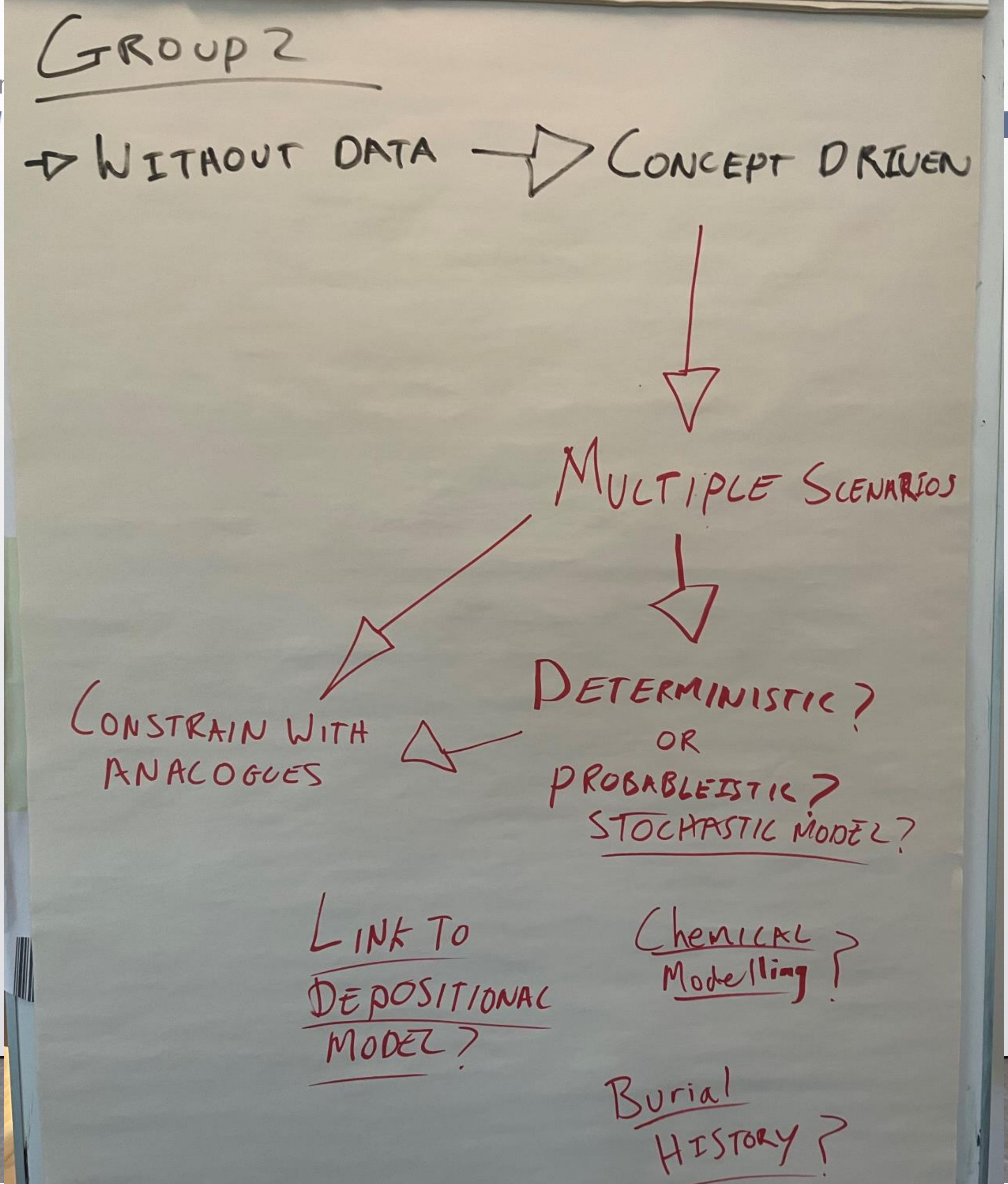
› Experience with including diagenetic overprint in facies or property modelling

› … there are different ways

Group - Notes

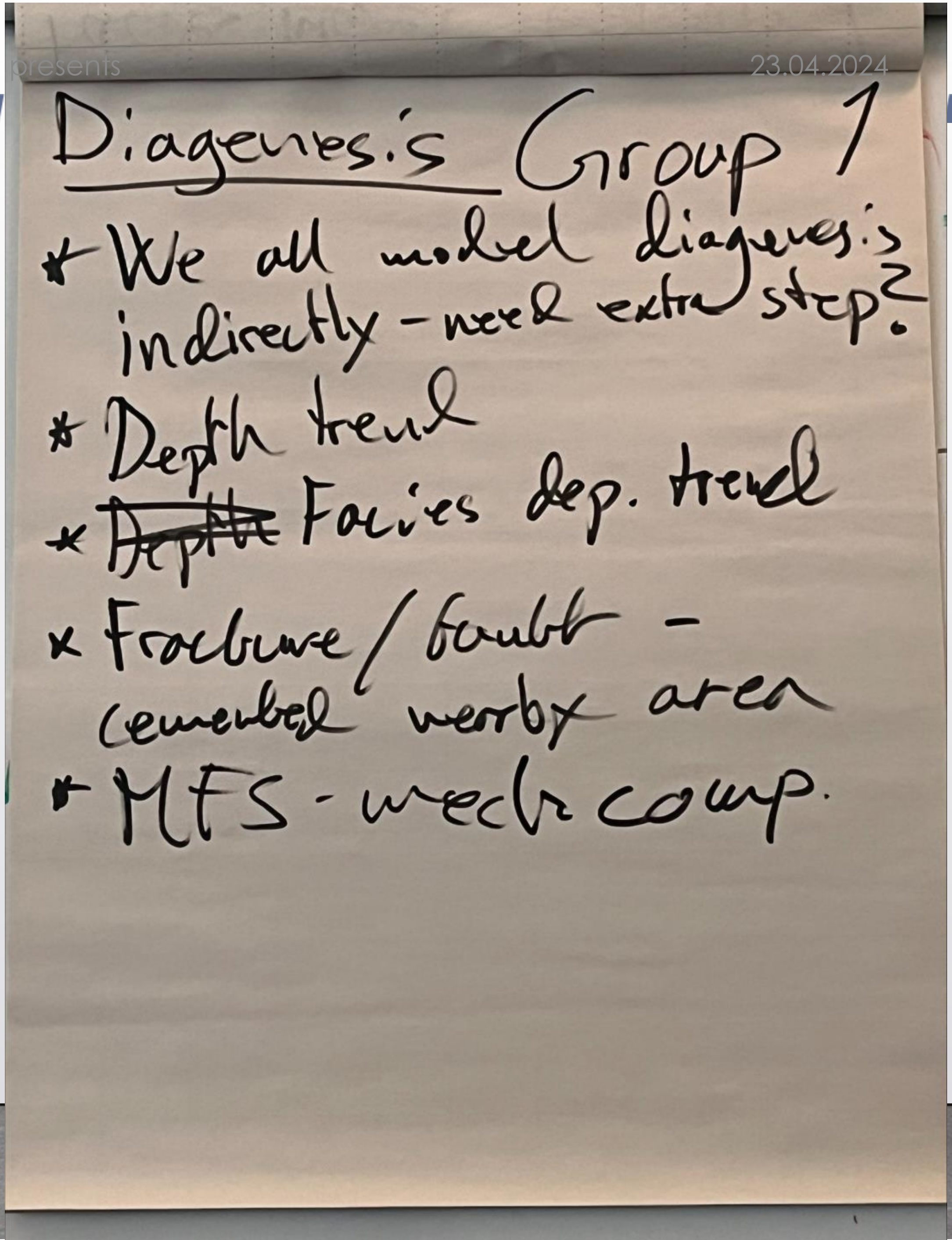
- TAKE A PICTURE OF YOUR FLIP CHART
  - Send it to marine.seignole@akerbp.com

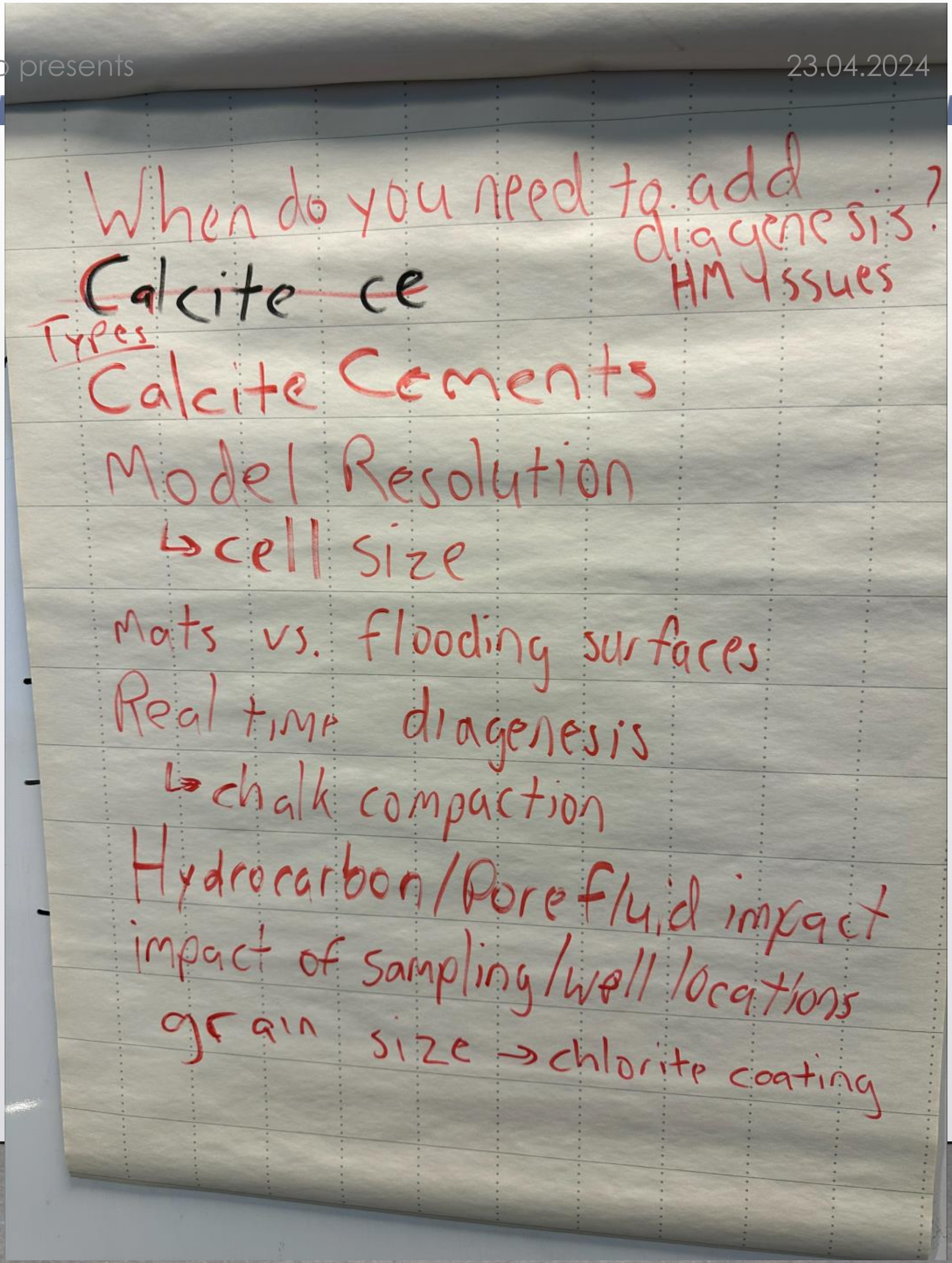
group2


GROUP 2
WITHOUT DATA
CONCEPT DRIVEN
MULTIPLE SCENARIOS
CONSTRAIN WITH ANALOGUES
DETERMINISTIC ?
OR
PROBABLEISTIC ?
STOCHASTIC MODEL ?
LINK TO DEPOSITIONAL MODEL ?
Chemical Modelling ?
Burial HISTORY ?

oslo

- Depth Trends
- Is it relevant – thin columns, thin reservoirs – not important
- Carbonates – discount from discussion
- Grain coats only important after 90 degrees.
- The easiest way to capture perm depth trends is using a regression
- Corruption of depth trends from facies trends.
- Different trends in oil and water filled part of the reservoir. Filling history
- Analogue data can be very important
- Fine grained sands can be much more impacted by perm reduction than coarse facies. Easier to fill pore throats, more non quartz minerals more fines.
- Apply depth trend to logs =>petrophysical model => convert back.
- Remember diagenesis is not the only issue remember faceis etc.
- Calcite stringers, hard grounds, bitumen cements baffles,
- Sedimentologists working hand in hand with petrographers


Diagenesis Group 1
* We all model diagenesis indirectly - need extra step?
* Depth trend
* ~~Depth~~ Facies dep. trend
* Fracture / fault - cemented nearby area
* MFS - mech comp.


When do you need to add diagenesis?
Calcite ce
HM issues
Types
Calcite Cements
Model Resolution
↳ cell size
Mats vs. flooding surfaces
Real time diagenesis
↳ chalk compaction
Hydrocarbon/Pore fluid impact
impact of sampling/well locations
grain size → chlorite coating

Impulse talk 3

Hierarchical approach to address reservoir architecture and its implementation in property modelling

Gijs A. Henstra & Carsten Elfenbein, Aker BP

FORCE Cake & discuss – The Property Model 23rd April 2024

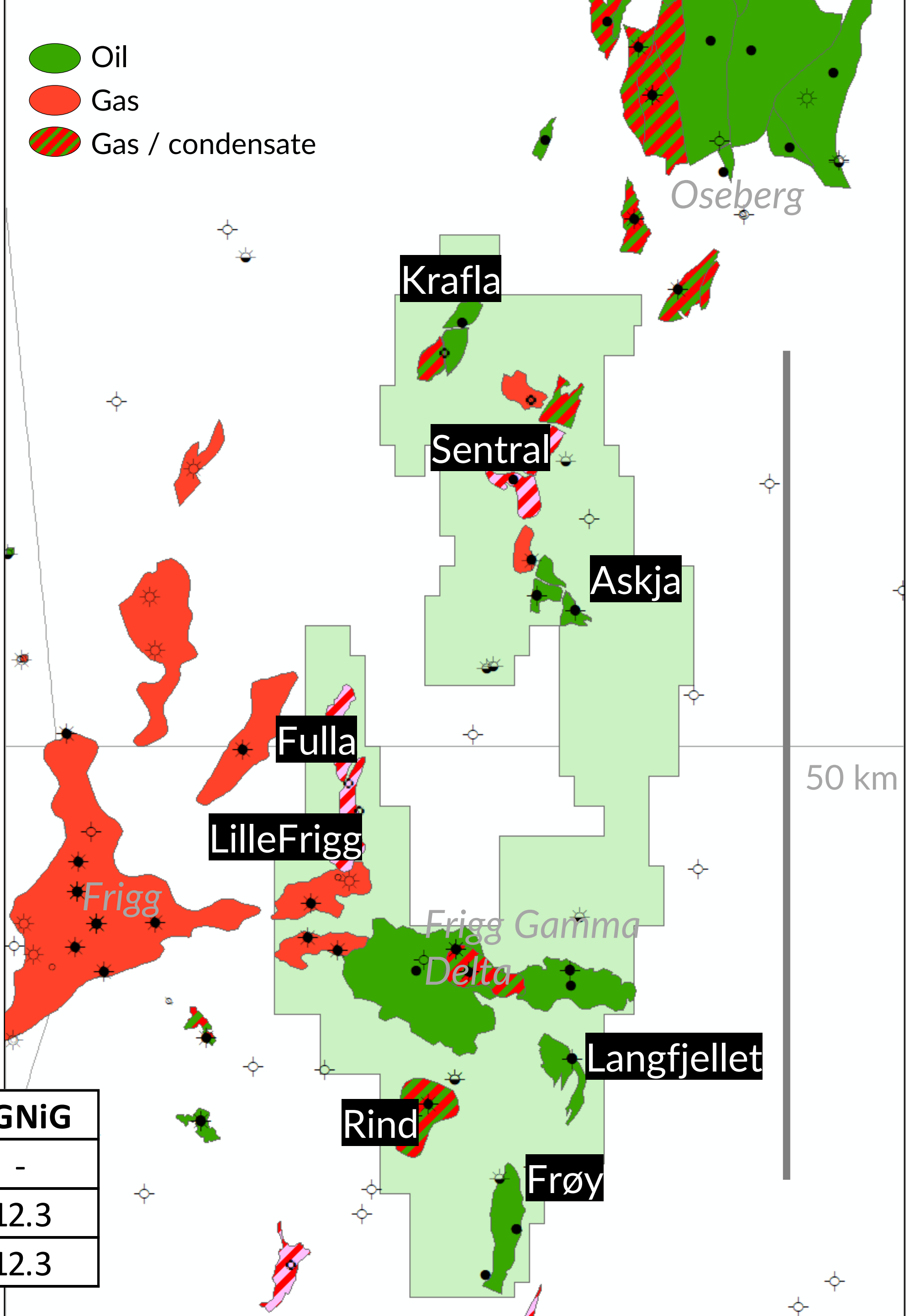
Yggdrasil

Location overview

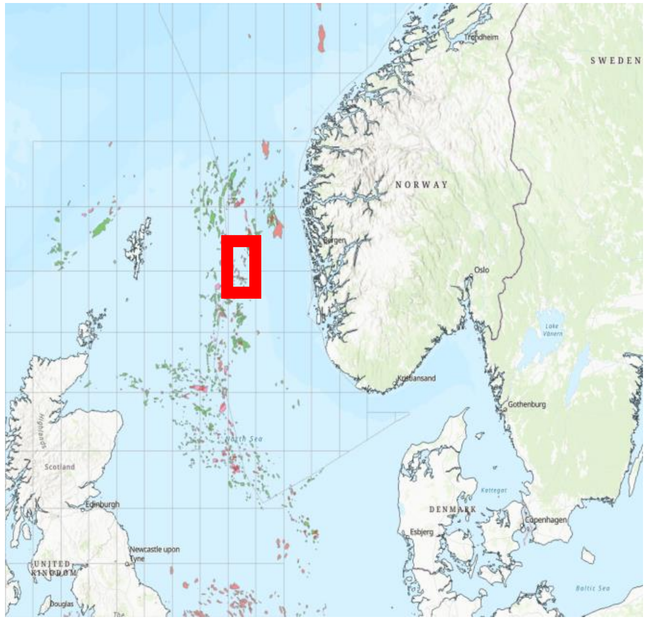
The Yggdrasil area is composed of

- PL 026
- PL 035
- PL 272
- PL 364
- PL 442
- PL 873

	Aker BP (op.)	Equinor	PGNiG
PL 035 & 272	50	50	-
PL 873	47.7	40	12.3
PL 026, 364 & 442	87.7	-	12.3



AkerBP



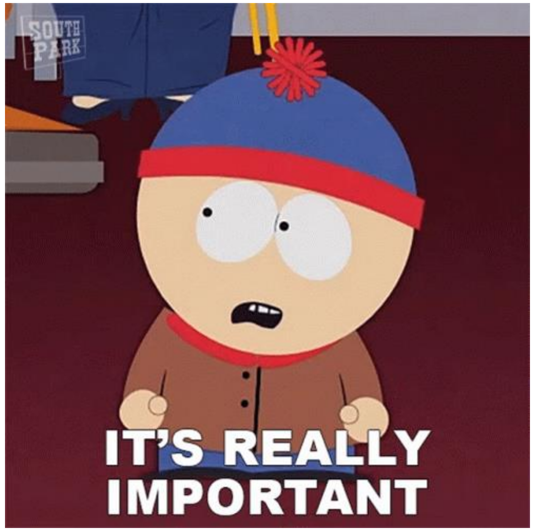
Yggdrasil PDO area

Jurassic reservoirs

Eight fields, One task:

- Develop a regional depositional model (for the Mid-Jurassic reservoirs, Tarbert Fm) to link all the Yggdrasil fields together conceptually; enable comparisons between fields (property-wise) and communication across assets/disciplines

- Implement the same regional concepts in all local reservoir models, so that the depositional model is recognizable in the property distributions

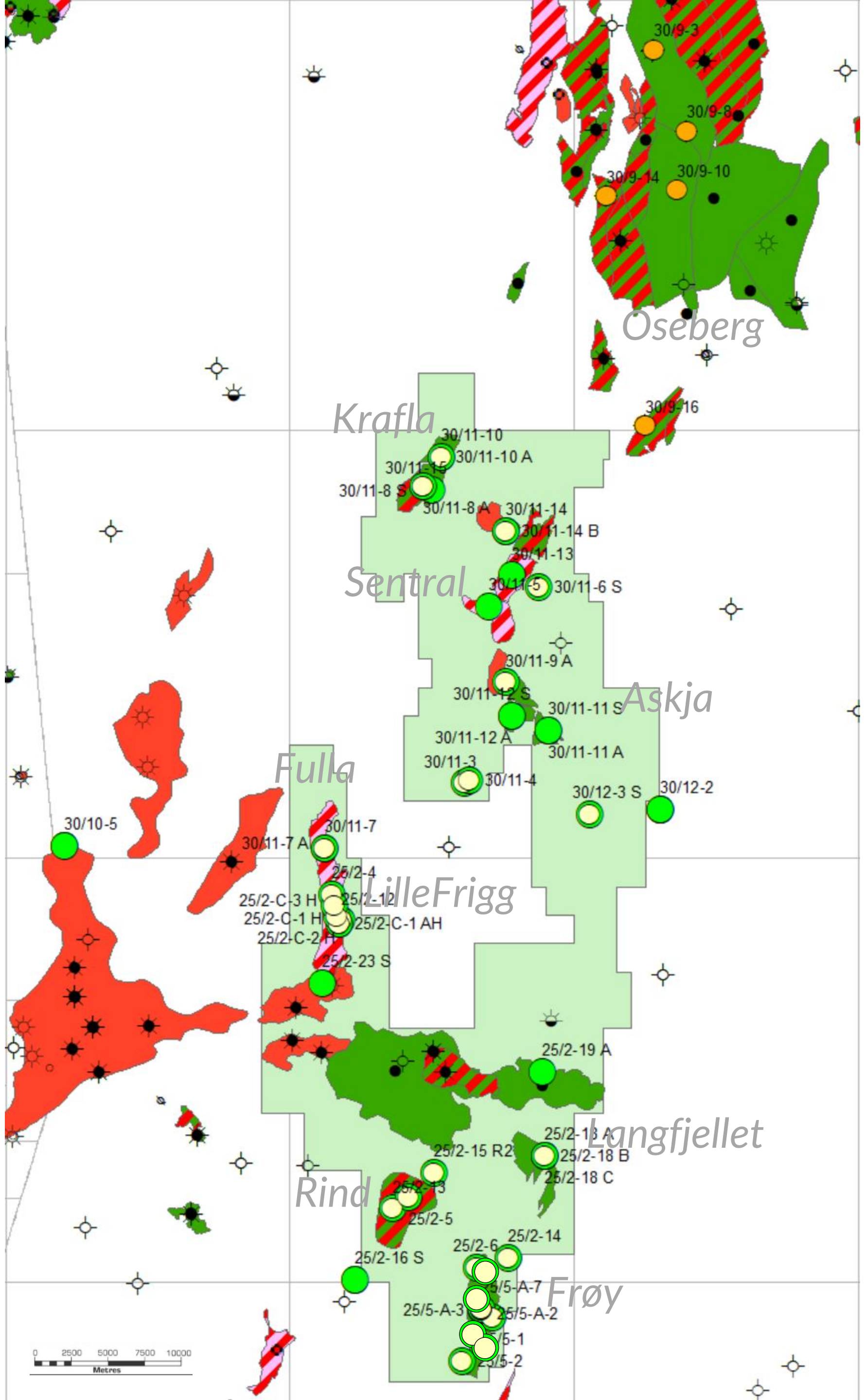


Yggdrasil

Jurassic study well database

- Well log correlation
- Cores studied
- Literature

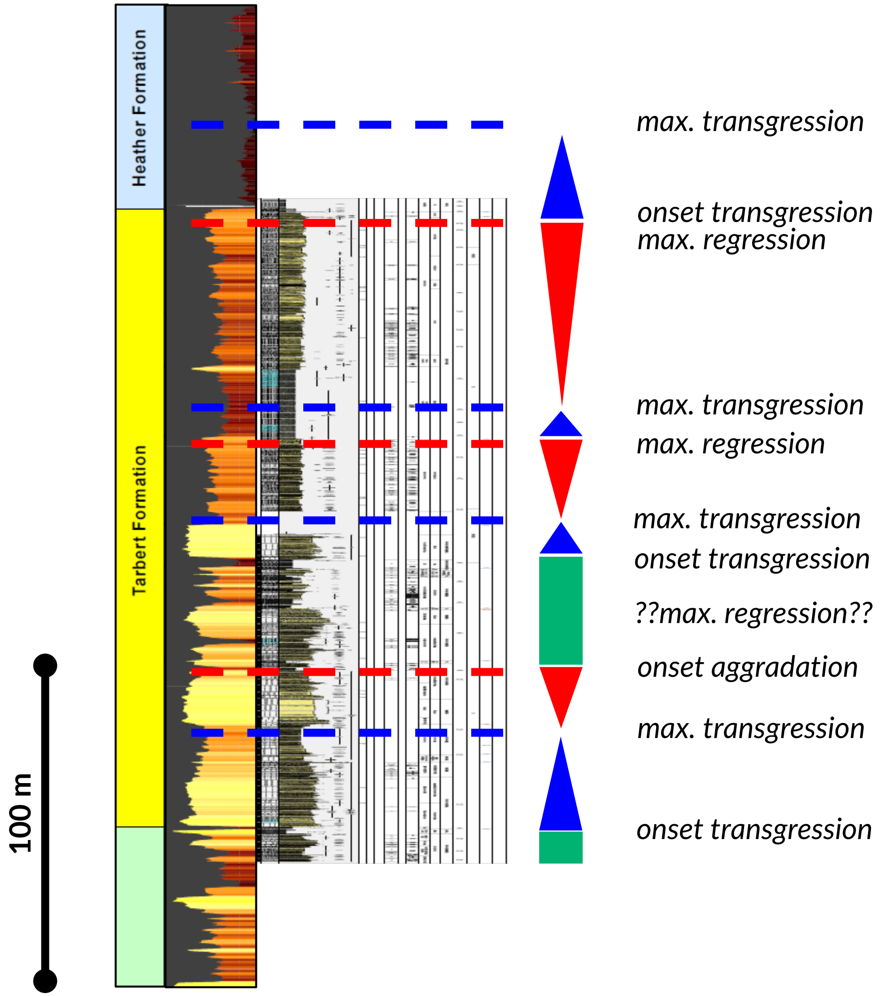
...35+ wells, >2500m core

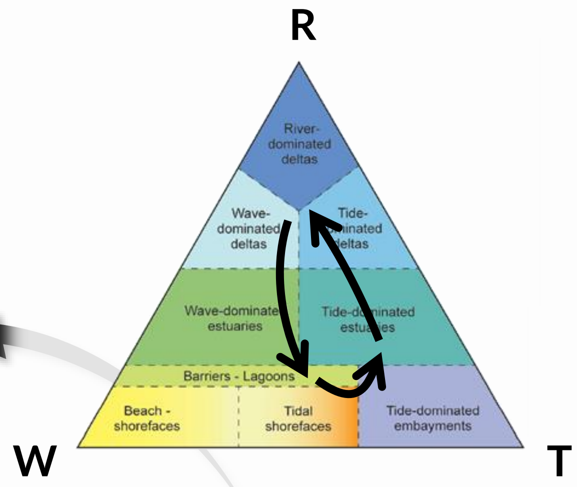


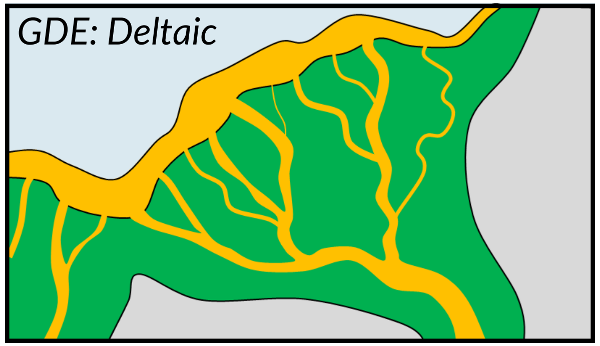
50 km

Yggdrasil PDO area

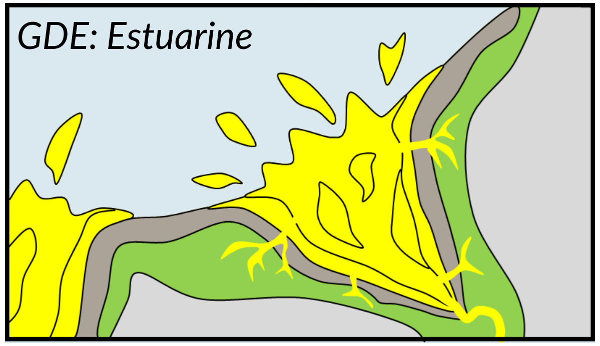
A very effective method: R-A-T cycles



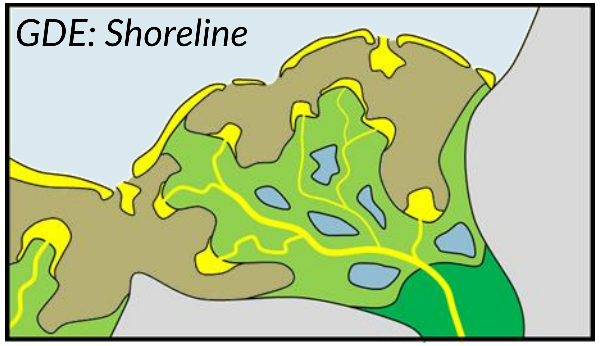




Sedimentation rate > rate of accommodation, decreasing SL rise, stillstand or fall:
regressive



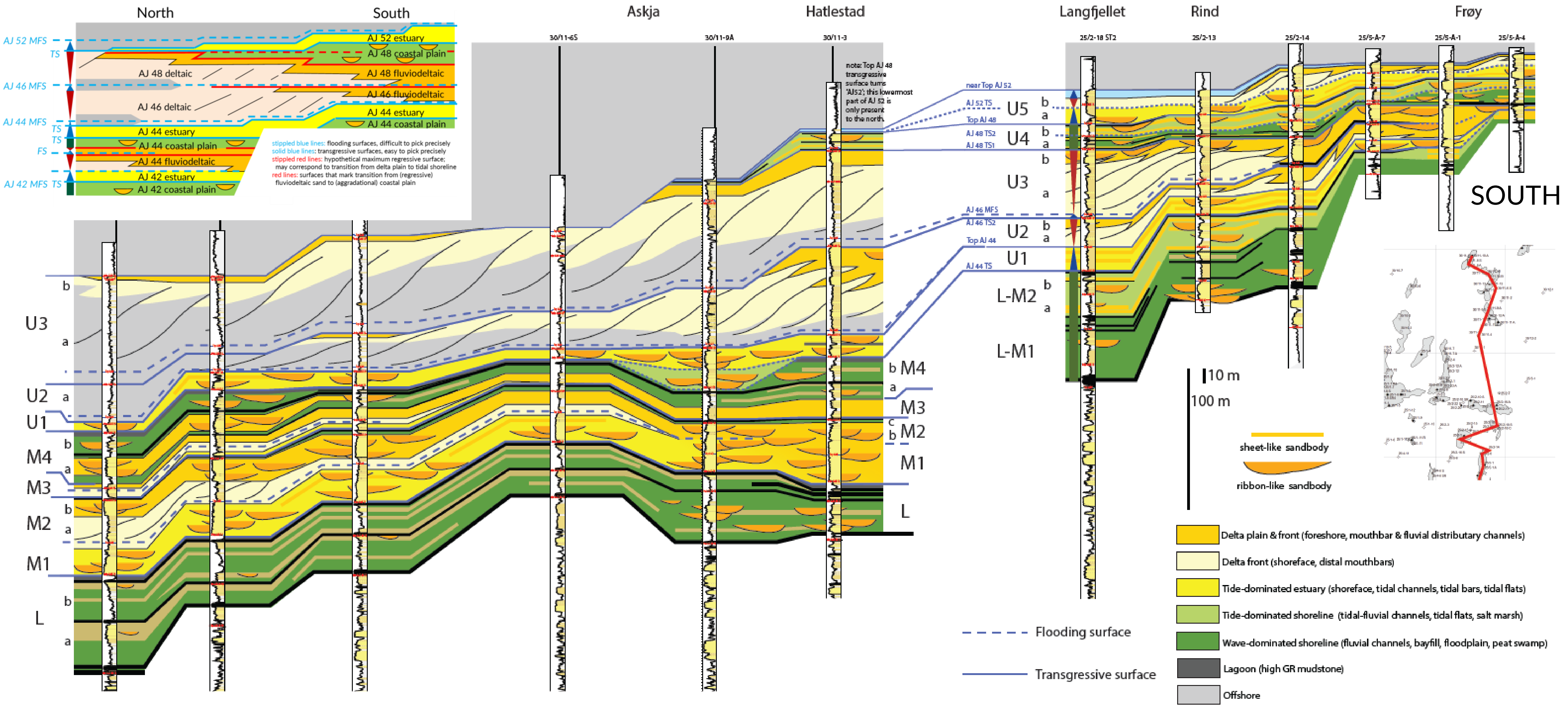
Sedimentation rate < rate of accommodation, highest rate of SL rise:
transgressive



Sedimentation rate ≈ rate of accommodation, early SL rise:
aggradational

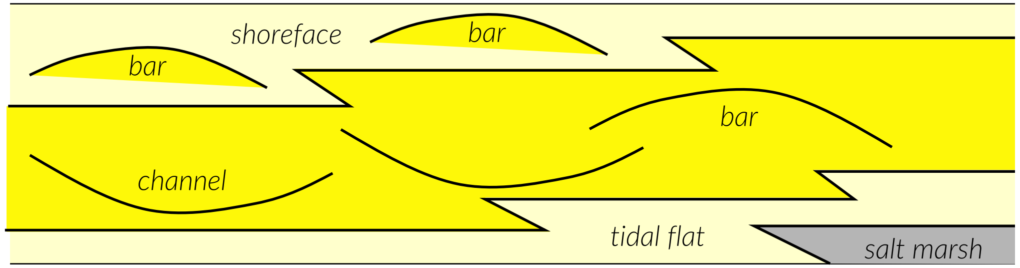
Correlation based on R-T cycles, lithostratigraphy, biostratigraphy and sedimentology.

AkerBP



Some examples of reservoir architecture, and how it impacts on fluid flow – different zones, different modelling strategy!

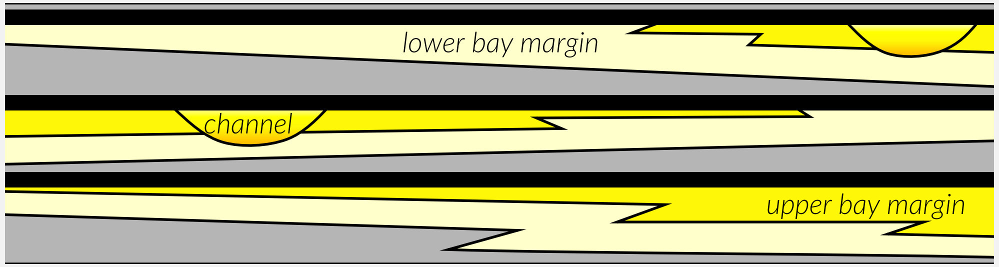
Transgressive



In many cases where we recognize delta front as DE, the reservoir typically consists of thick accumulations of fine-grained shoreface sandstone with relatively moderate reservoir properties, interspersed with relatively coarse-grained channels/bars. The entire interval can be considered net, but the properties of channels/bars may be orders of magnitude better.

Examples are RU2 & RU3 at Frøy; the lower part of UT 3.3 at Munin; H5 at Rind & Langfjellet.

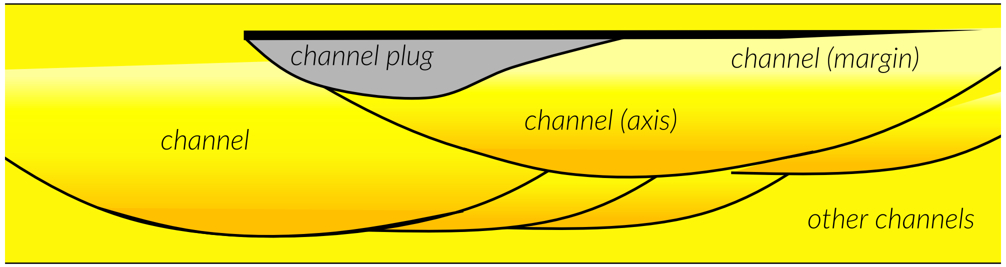
Aggradational



Where we recognise coastal plain as DE, the reservoir tends to be rather heterogeneous, consisting of numerous sub-environments and associated architectural elements. These reservoirs contain a lot of thin non-net intervals that can be rather extensive (=fieldwide). Good reservoir properties are present in ribbon-shaped distributary channels, lobate crevasse deltas/mouthbars and tabular bay margin deposits. Here, we need a sophisticated approach to capture reservoir heterogeneity. Also, we should expect that in some fields, these channels exist but have not been drilled yet.

Examples are RU4 at Frøy; MT 1, and parts of MT 2.1 and MT 2.2 at Munin; H3-H4 at Rind & Langfjellet.

Regressive



The best reservoirs did form in inner estuary and lower delta plain environments. A high energy / low accomodation environment produced amalgamated, sheet-like reservoirs. Isolated, small pockets of non-net exist in the form of cemented channel lags and mudprone channel plugs (mudstone and coal).

Examples are RU5 at Frøy; UT1 at Munin; H2 at Rind & Langfjellet.

Next objective: break down R-T cycles into smaller building blocks, ultimately down to lithofacies level

- For each of the cored wells we have lithofacies logs with a resolution down to cm-dm-scale…

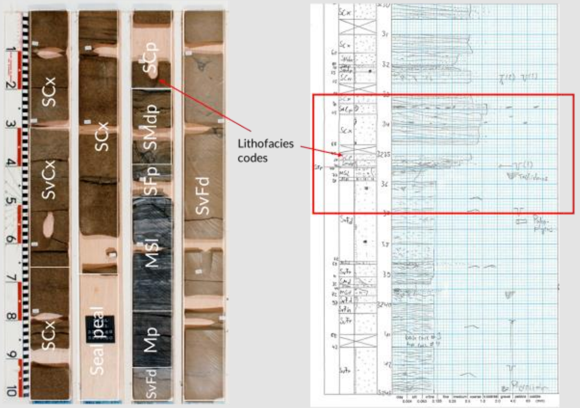
  … and R-T cycles that measure 10's of meters.

- **Work with the goal in mind: input to geomodel!**

- For a meaningful distribution of reservoir properties we need to enable the petrophysicist to test various ways of grouping facies:

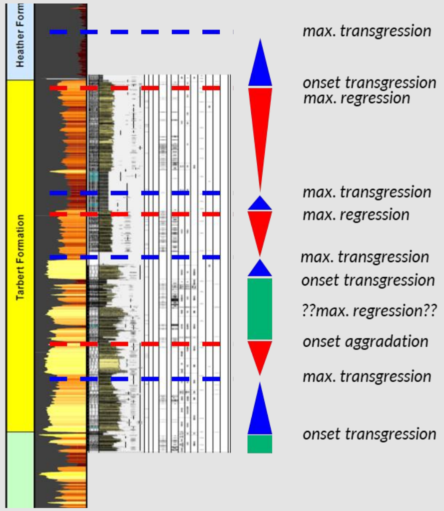
  We have tried a hierarchical approach, with more levels than usual.

Variability over cm's to dm's



Variability over 10's to 100's of meters

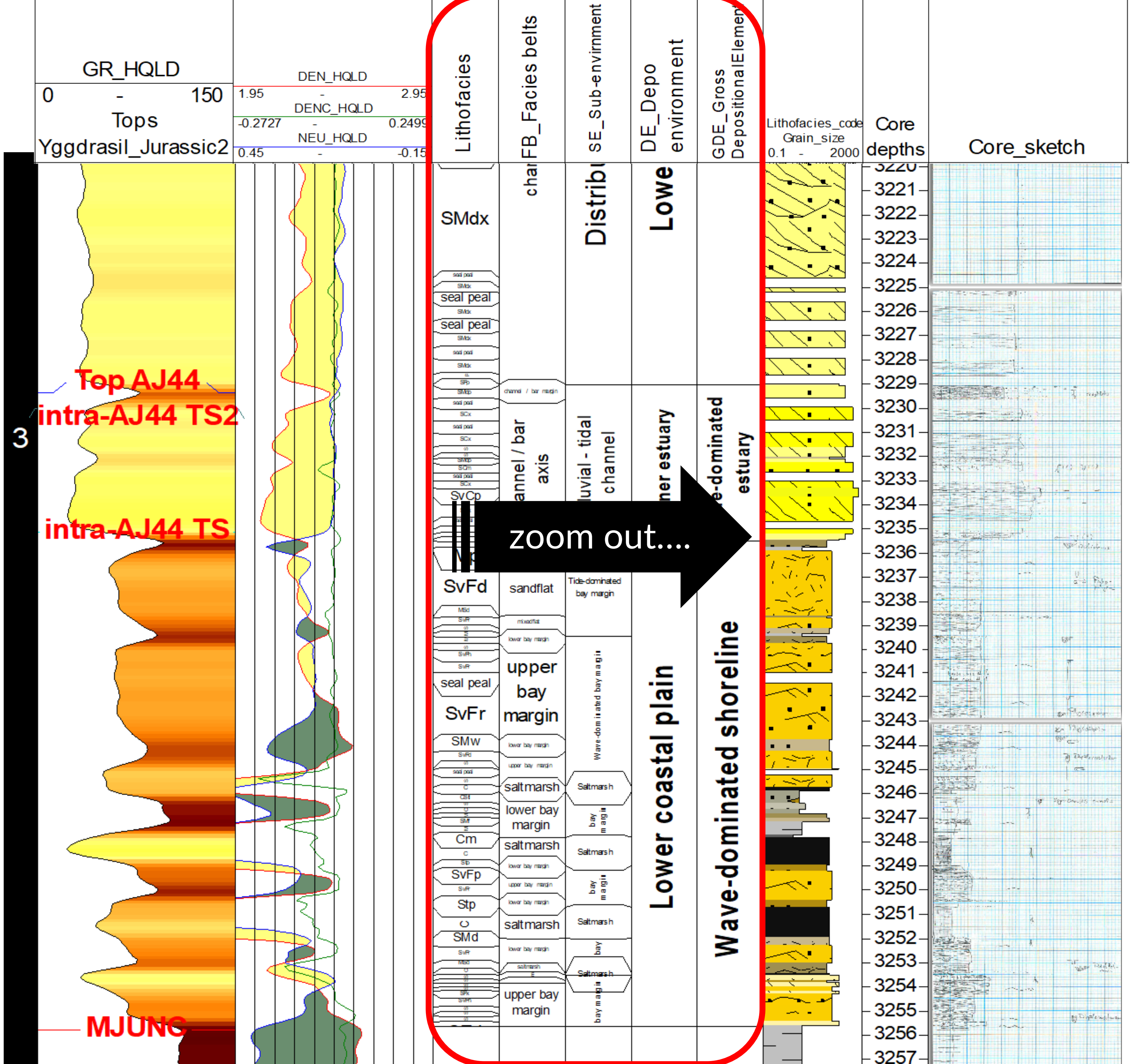
Variability over 10's of meters



Variability over km's to 10's of km's

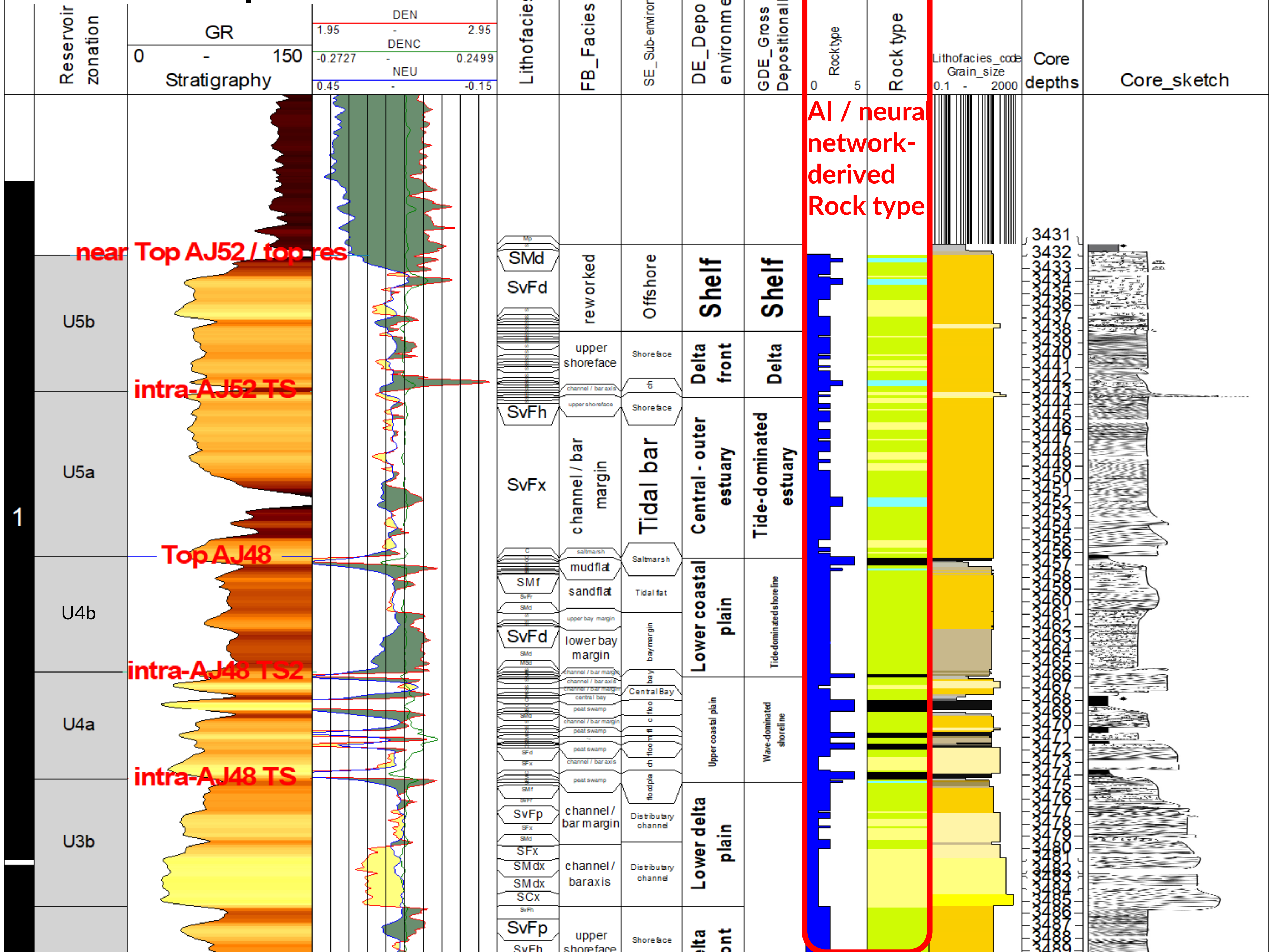
AkerBP

So what do we men by “Hierarchical” description / interpretation:



Facies belt (FB)
Sub-environment (SE)
Depositional environment (DE)
Gross depositional environment (GDE)

All lined up...

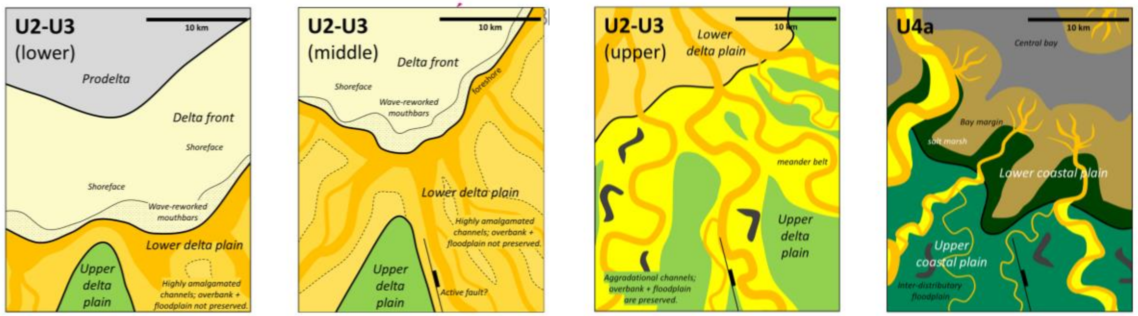


Spatial distribution of rock types will be through **conceptual link** with FB, SE and DE.

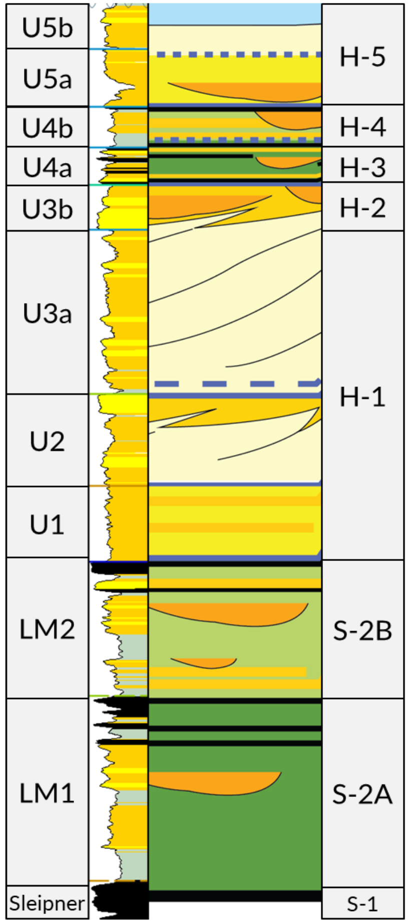
→ Same rock type can occur in a variety of settings

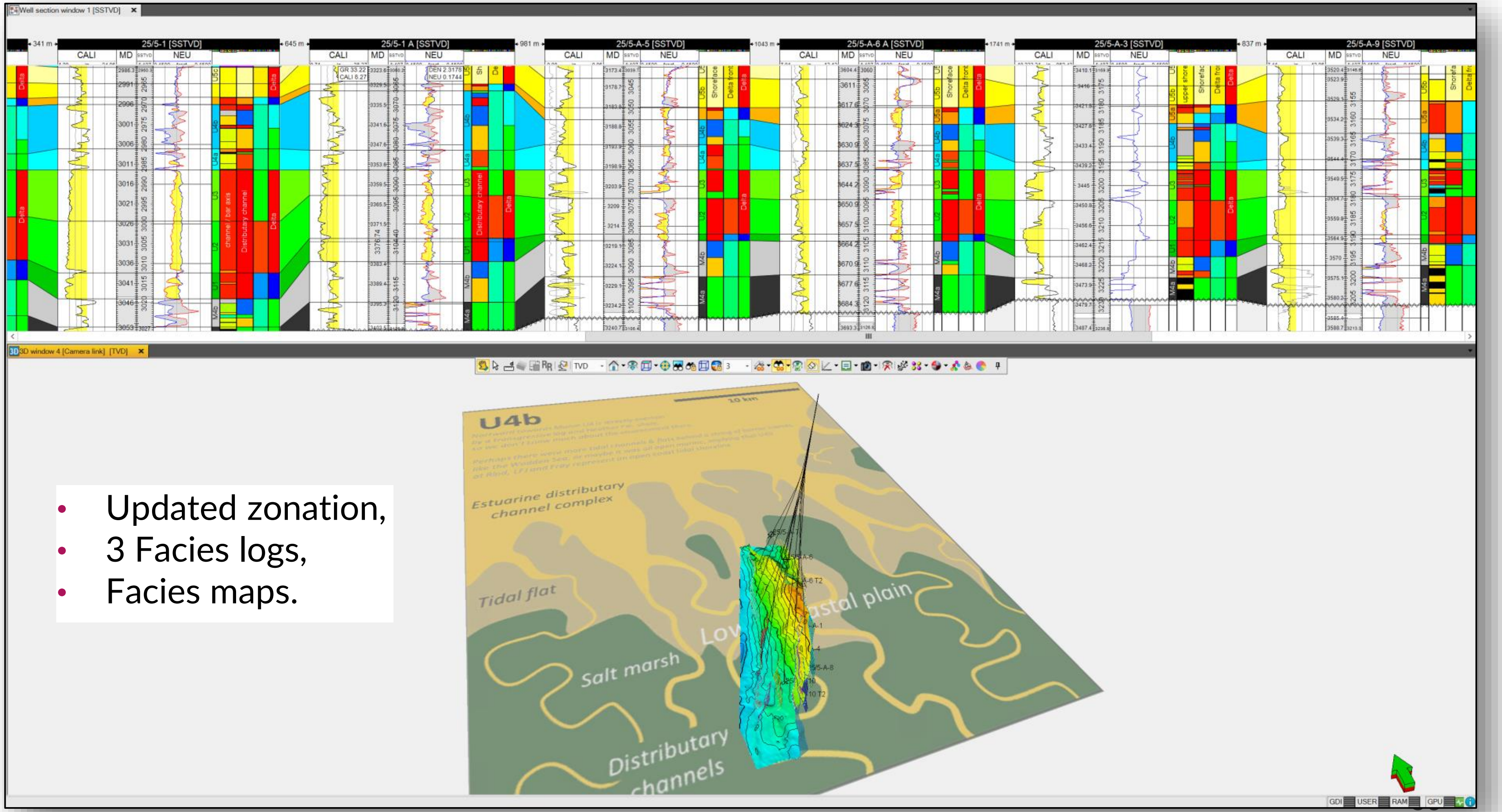
- RT 1, good
- RT 2, intermediate to poor
- RT 3, cement
- RT 4, coal

How is the concept communicated to modellers?



Langfjellet reservoir zonation
NEW vs OLD



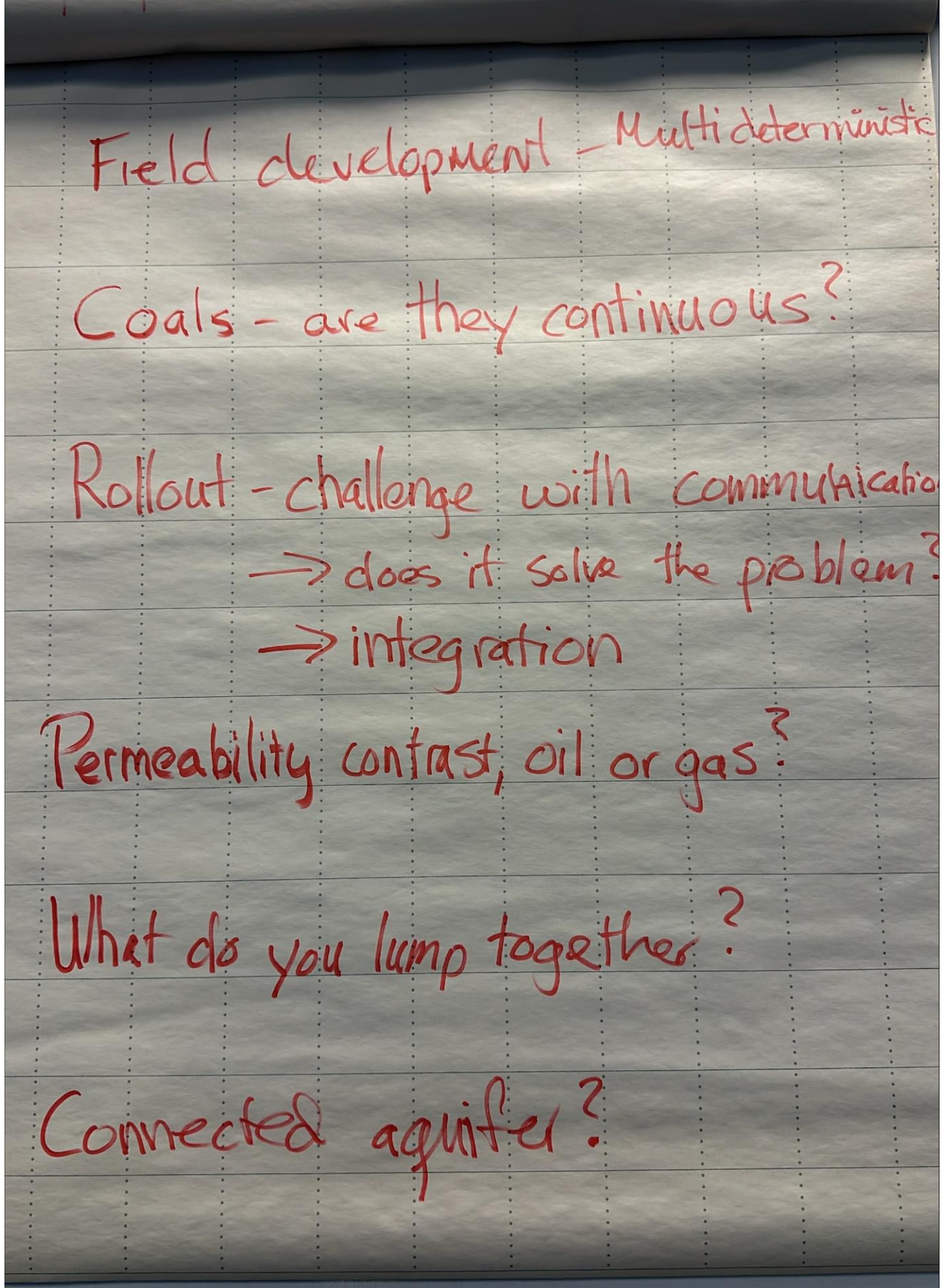


- Updated zonation,
- 3 Facies logs,
- Facies maps.

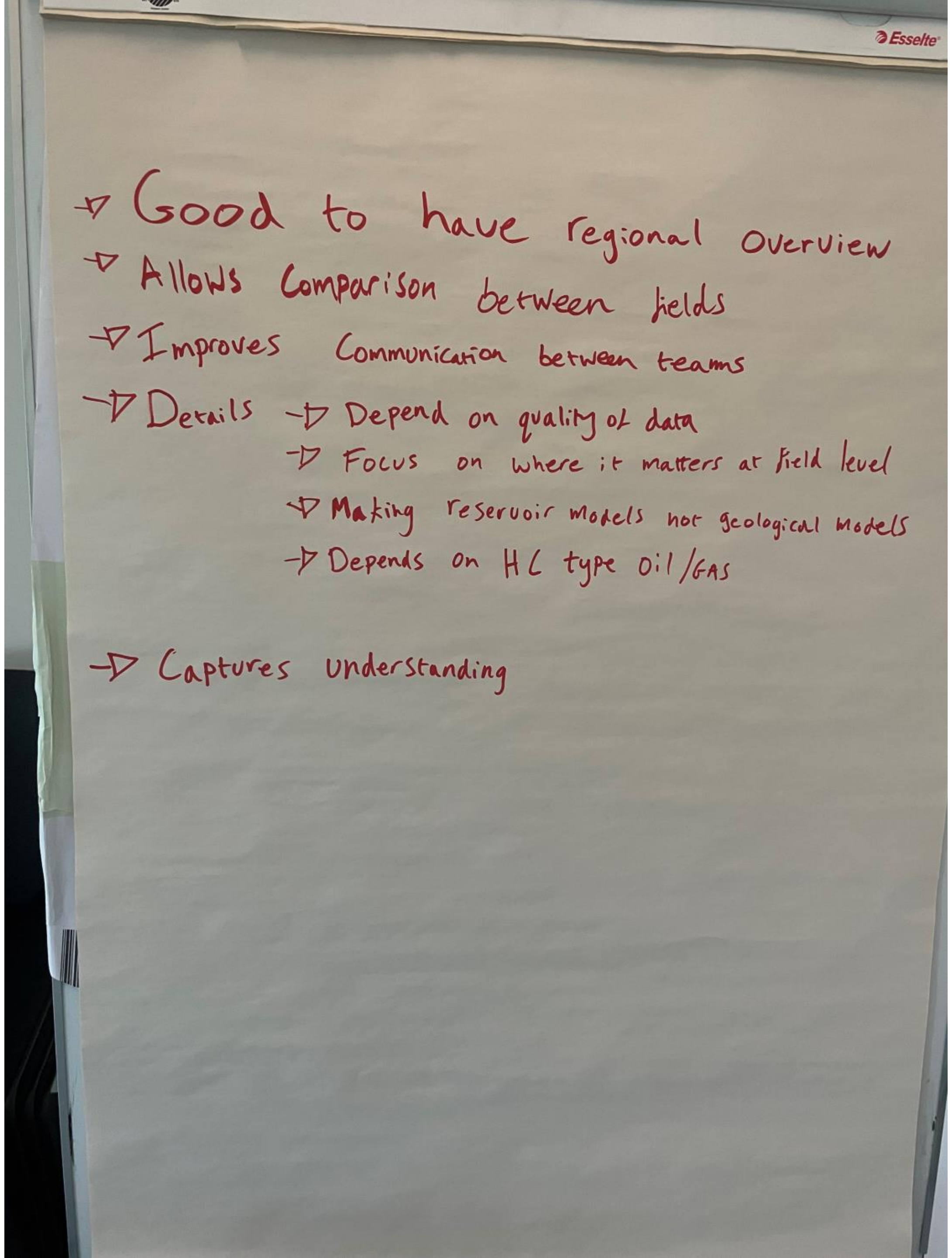
Possible discussion points:

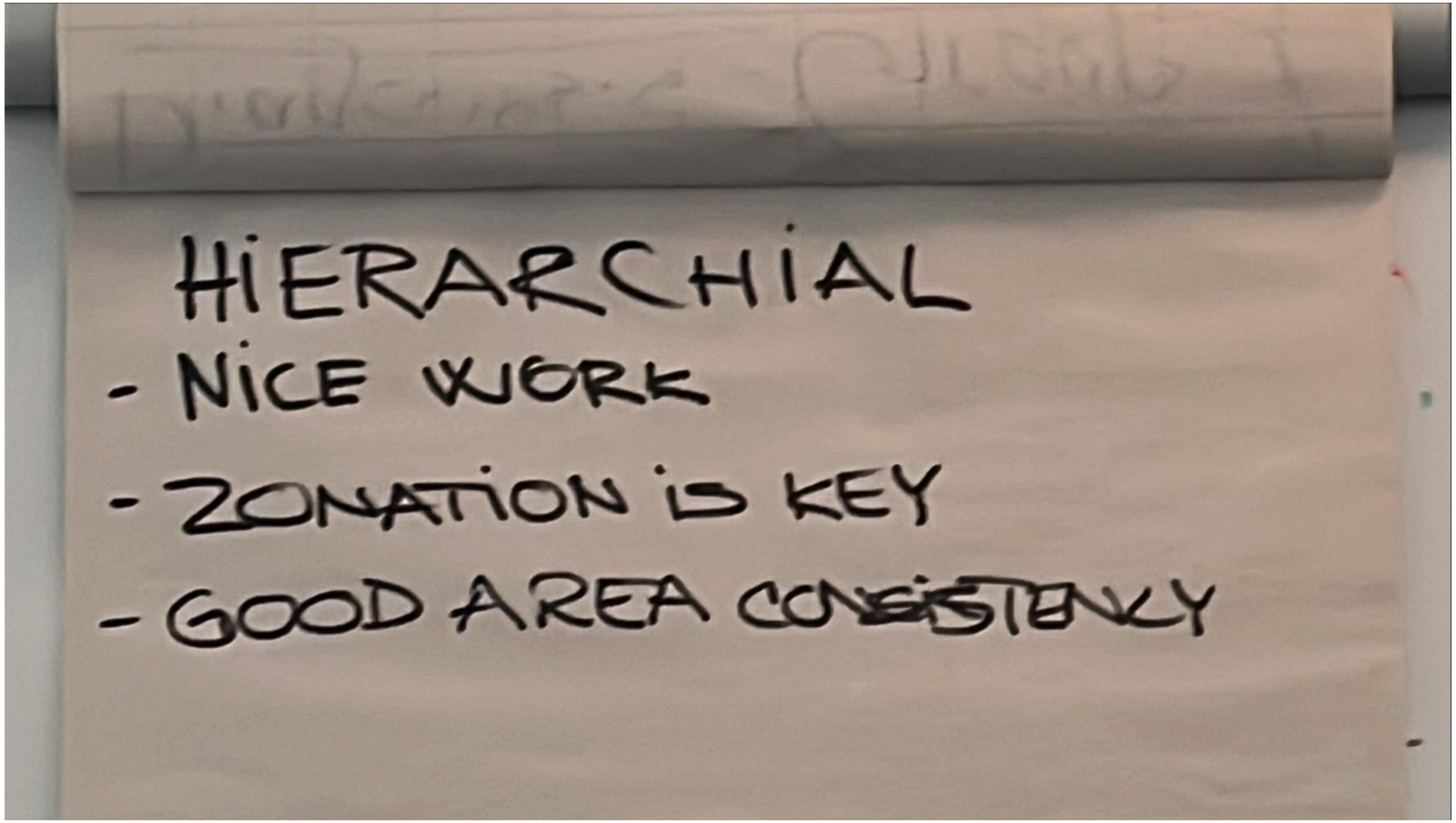
- Right balance between deterministic (=conceptual) and probabilistic approaches
- Are we over-engineering?
- Are we missing essential points for fluid flow (too pixelated vs too layered; homogenous front vs thief zones)?
- Diagenetic overprint of sedimentary facies is difficult to handle (impacts on link between facies description and rock types)

www.akerbp.com


Field development - Multi deterministic
Coals - are they continuous?
Rollout - challenge with communicatio
→ does it solve the problem?
→ integration
Permeability contrast, oil or gas?
What do you lump together?
Connected aquifer?

AkerBP


Esselte
Good to have regional overview
Allows comparison between fields
Improves communication between teams
Details
Depend on quality of data
Focus on where it matters at field level
Making reservoir models not geological models
Depends on HC type Oil/GAS
Captures understanding


HIERARCHIAL
- NICE WORK
- ZONATION IS KEY
- GOOD AREA CONSISTENCY

- Sedimentology
- Zonation becomes very important – petrophysical properties can be qc of model. Also maintain scenarios. The correlation scheme is very good but are there different alternatives
- Shape of rock types
- Communication between geomodellers, feedback from modellers, maps. Vertical proportion curves.
- Influence of structure

Feedback

- Format
- Session length
- Venue /Connection to other location
- Session topics
- Other feedback

Next dates

- Cake&Discuss
  - 27 August 2024: The Uncertainty Study

- FORCE IRM group
  - 29 April 2024: CO_2 Storage Project Design – Insights from projects

Feedback: 14 returned questionnaires

- Participants:
  - 15 people in Stavanger (+2): various company (ConocoPhillips-DNO-AkerBP- Omv Norge –Wintershall Dea-Norske Shell- university of Stavanger- Directorate)
  - 5 registered in Oslo but more joined for some of the talks- all AkerBP

  ->More companies representation, good mix of recuring participants and newcomers

- Format and length:
  - exchange of experience seems to be appreciated by all as well as the social and relax setting .
  - Some would have like more time to the discussions (2).
  - The connection with Oslo has worked fine

- Topics:
  - the mix of topics were well received and considered relevant-
  - one commented that practical topics are easier to relate than the general first session.

- Topics suggestions:
  - from static to dynamics. History matching iterations
  - well planning
  - operational knowledge sharing.