Edvard Grieg Field: Combining Deterministic Scenario Modeling with the Power of Assisted History Matching (incl 4D Matching)

Purpose: Improve predictability (e.g. to optimize timing for infill wells)

Presenters:
Solveig Sæl (geologist)
Arnstein Kvilhaug (geophysicist)

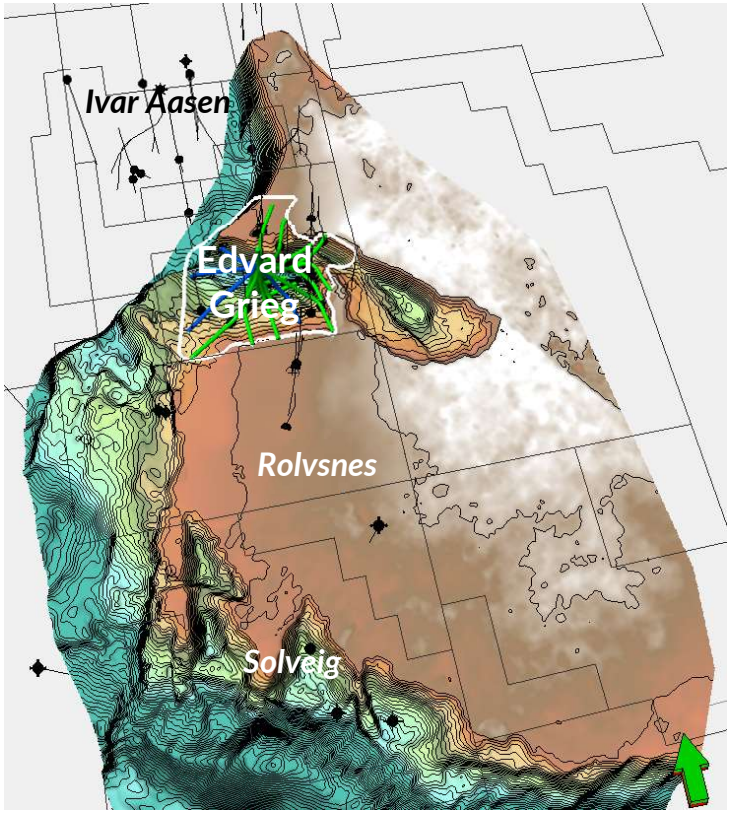
FORCE seminar: Assisted History Matching
7.12.2022

Outline

- Introduction
  - Geology
  - Reserves prediction challenges
  - Status 2018: Need better predictability ➔ Implement assisted History Matching (?)
- Two parallell, but integrated, workflows:
  - Deterministic ➔ 'Testlab'
  - Assisted History Matching (ResX)
- 4D matching in ResX
- Summary

Edvard Grieg | Intro

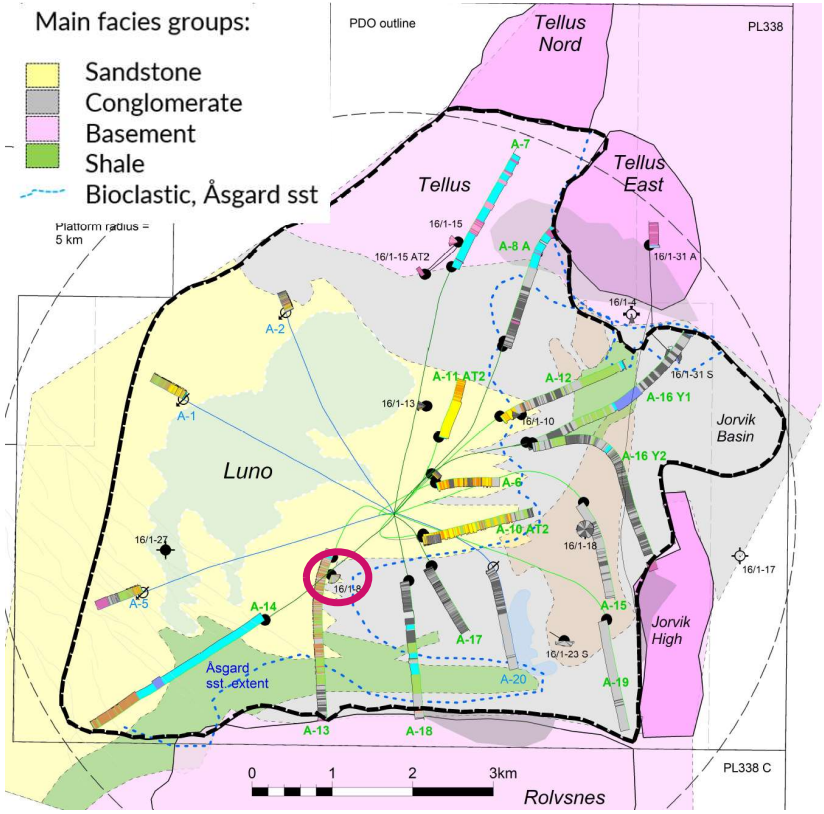
Utsira High, Basement map



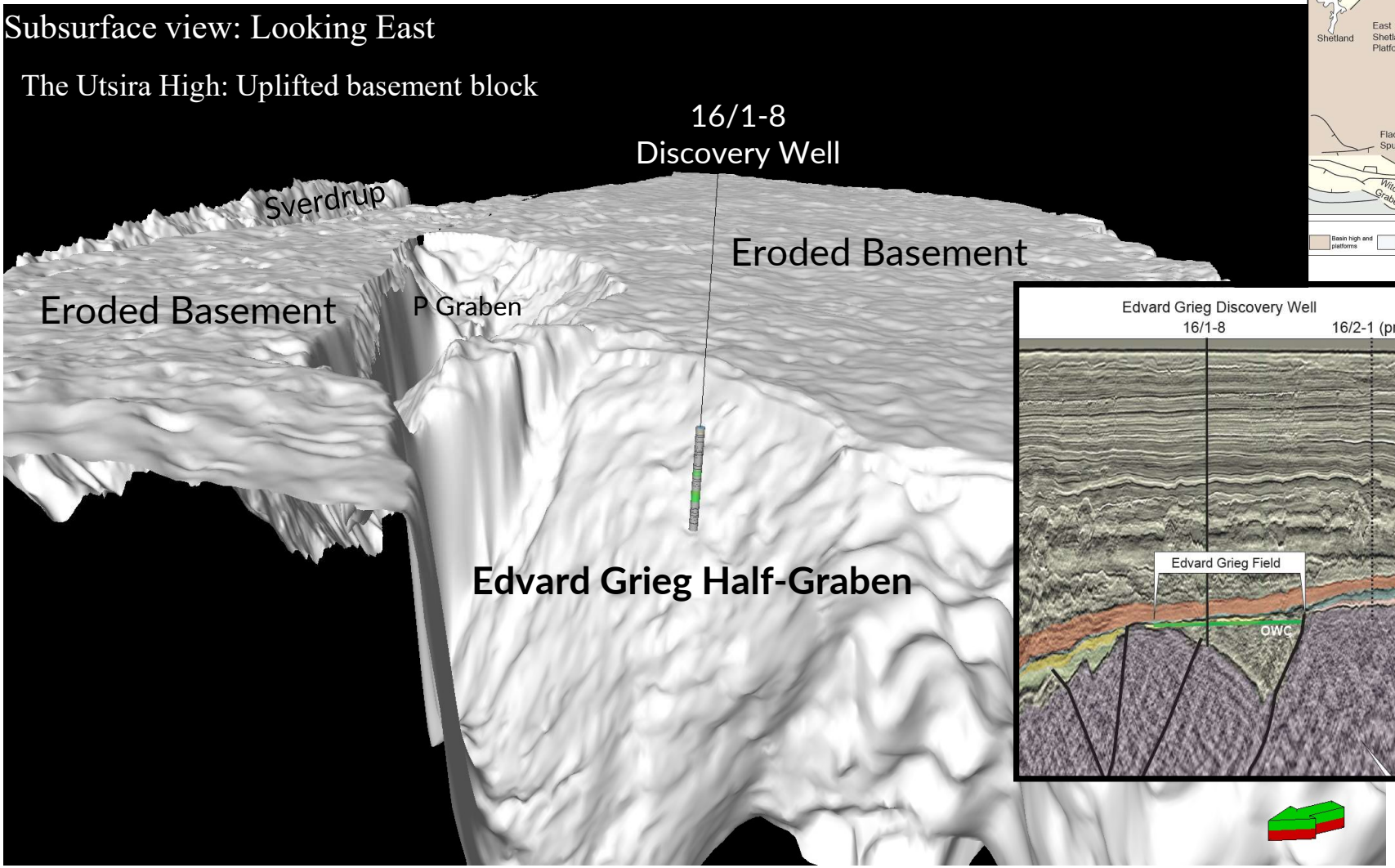
PARTNERSHIP
Aker BP (OP), 65 %
OMV (Norge) AS, 20%
Wintershall Dea Norge AS, 15 %

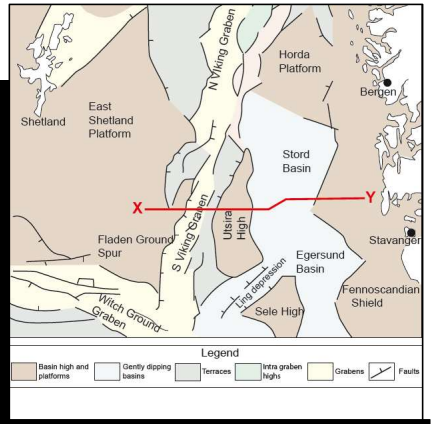
- Oil field, 16/1-8 (2007)
- Production start 2015
- 13 OP (1 MLT), 4 WI
- Platform with full processing facilities, tie-in of Ivar Aasen, Solveig, Rolvsnes

Main Facies Elements

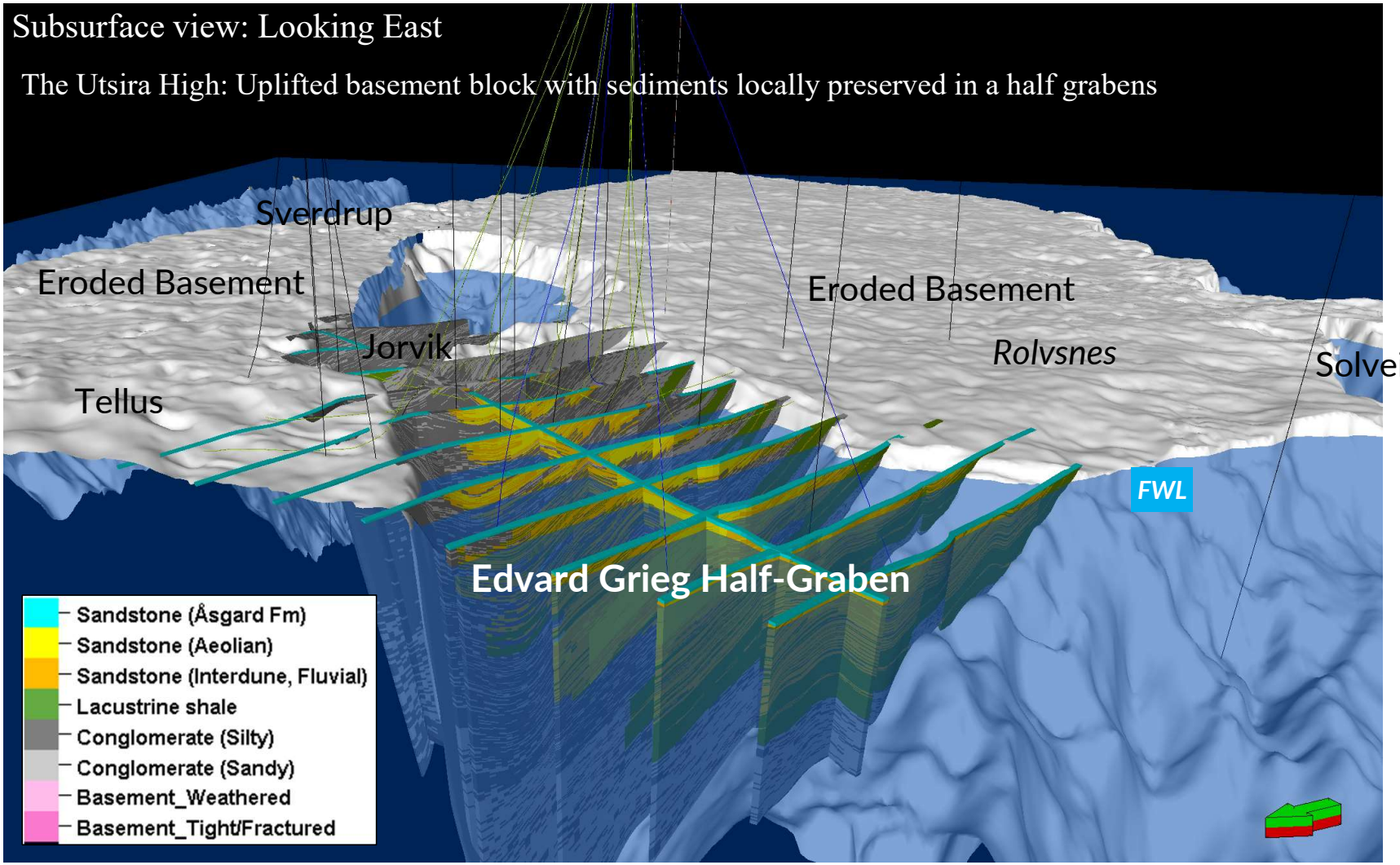


Edvard Grieg Half-graben | Basement map





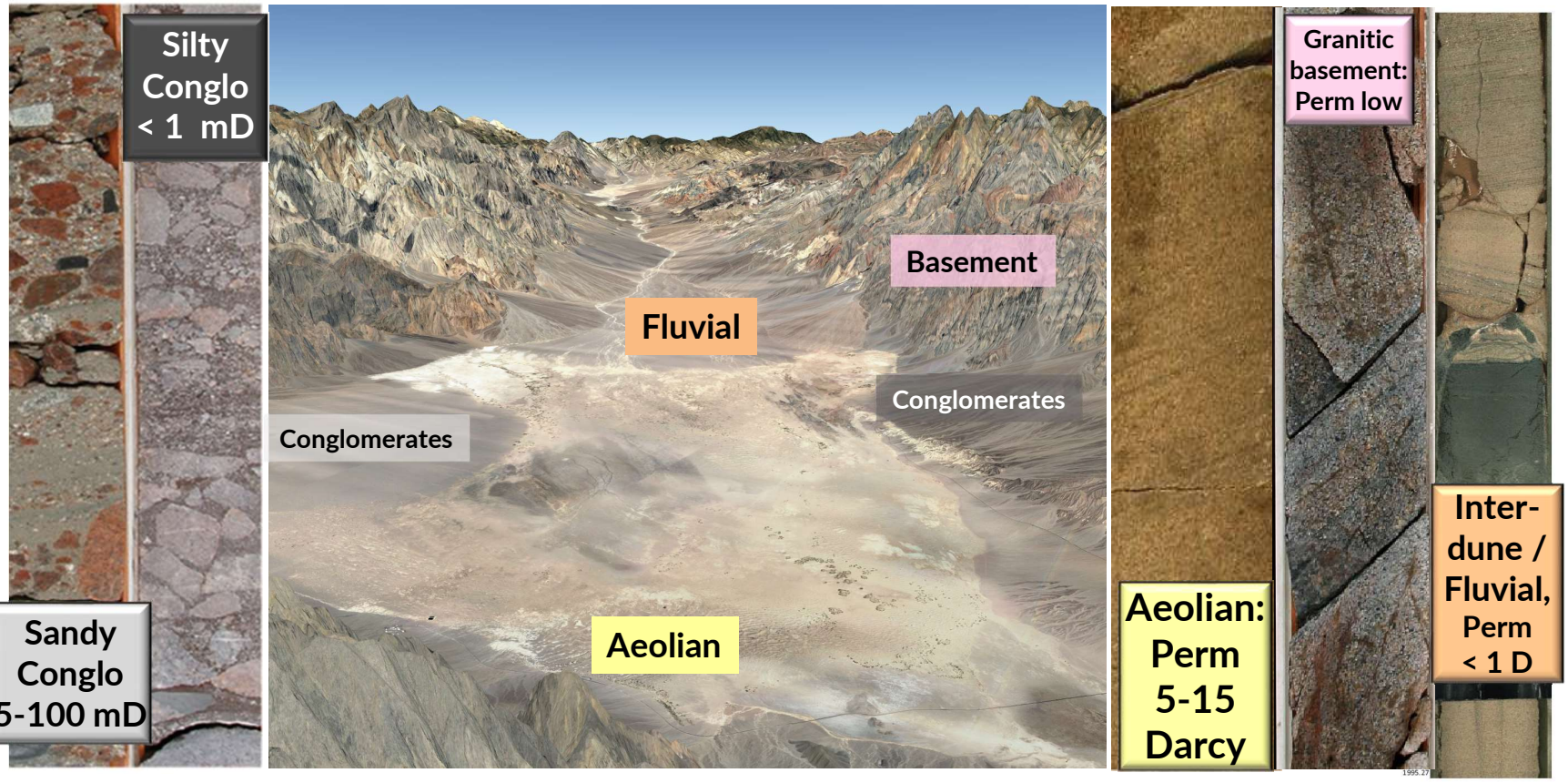
Edvard Grieg | Half-graben filled with sediments



Edvard Grieg | Facies

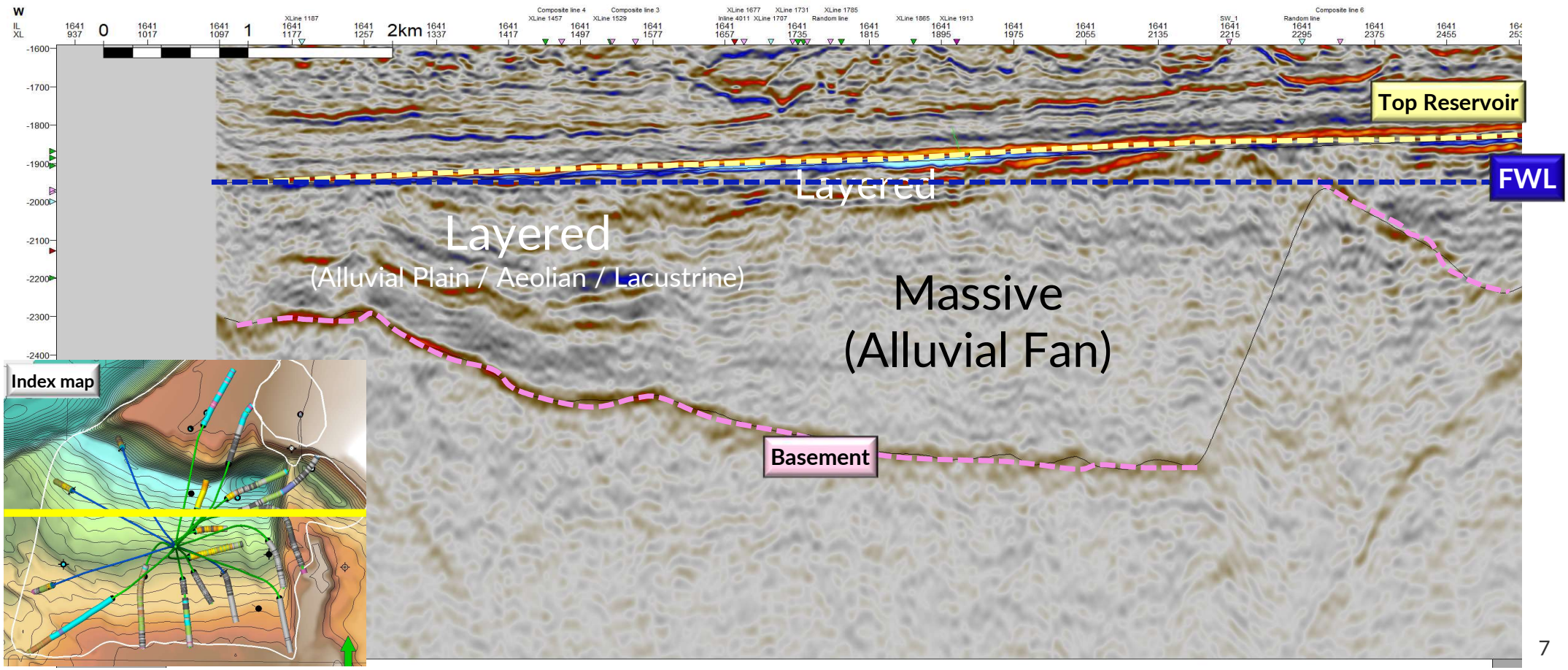
Death Valley Analog

- **Variations in Geology → large variations in well potential**
  - Sand PI: 200 – 1000 $Sm^3/d/bar$
  - Conglomerate PI: 5 – 100 $Sm^3/d/bar$
  - Basement PI: 30 - 50 $Sm^3/d/bar$



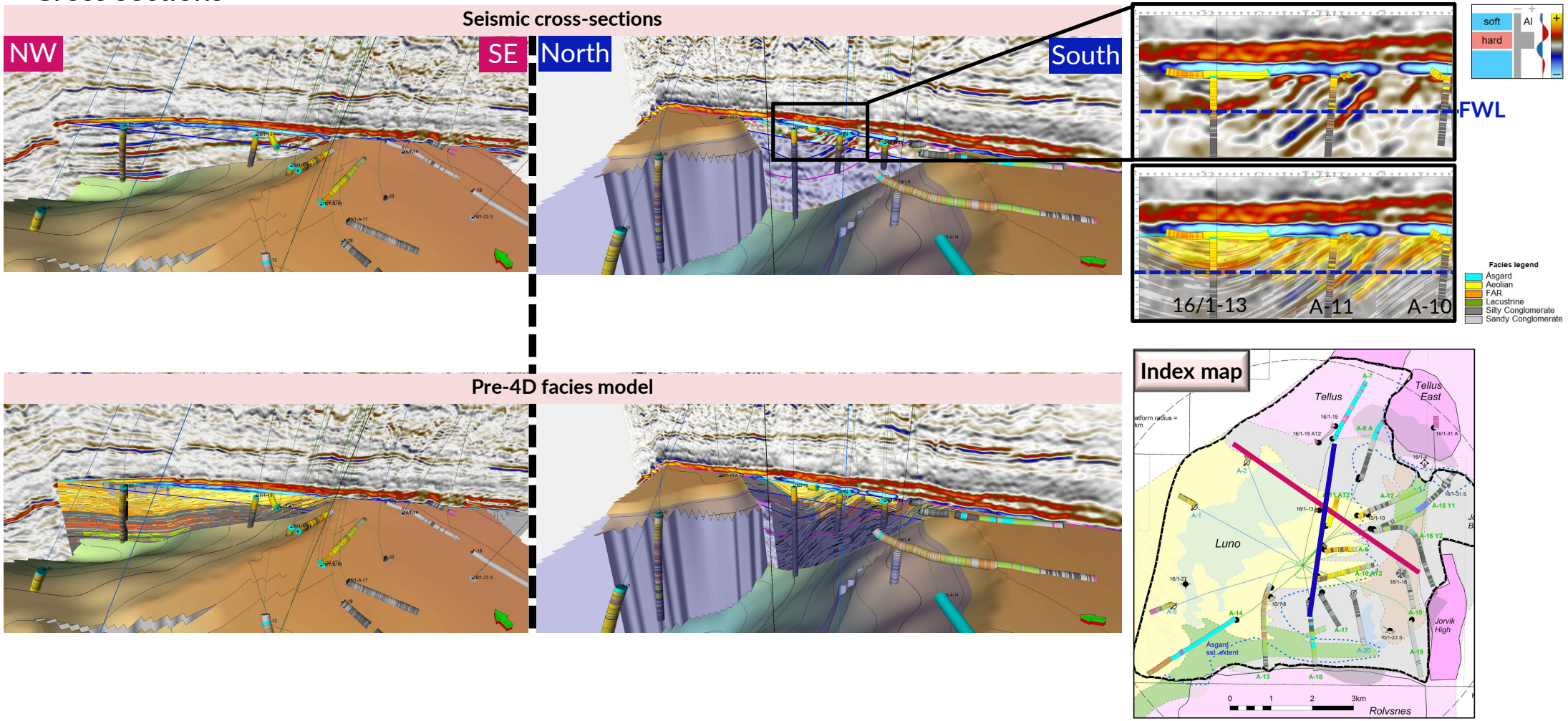
Edvard Grieg Half Graben

Facies Architecture vs Seismic Response



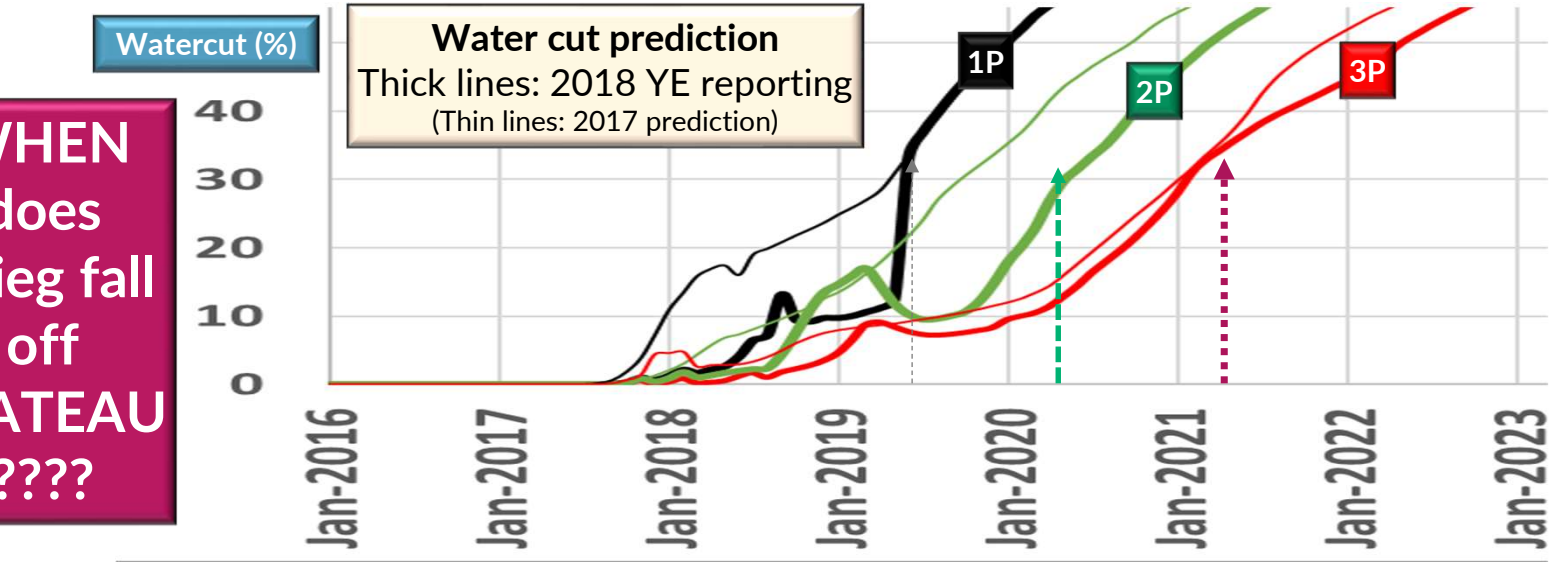
Facies Configuration | Sand vs Conglo Controlling Flow

Cross sections

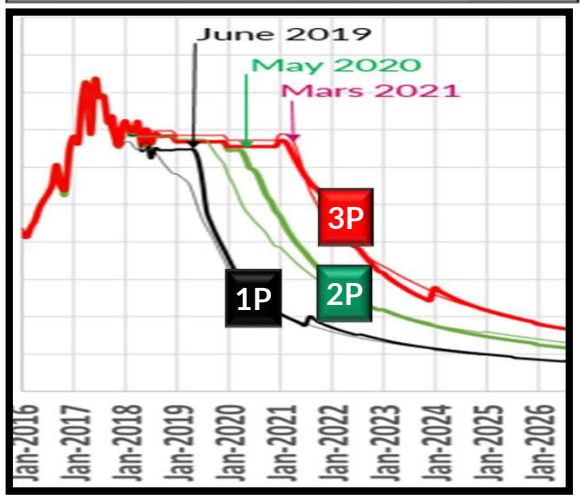


Model predictability 2018 model

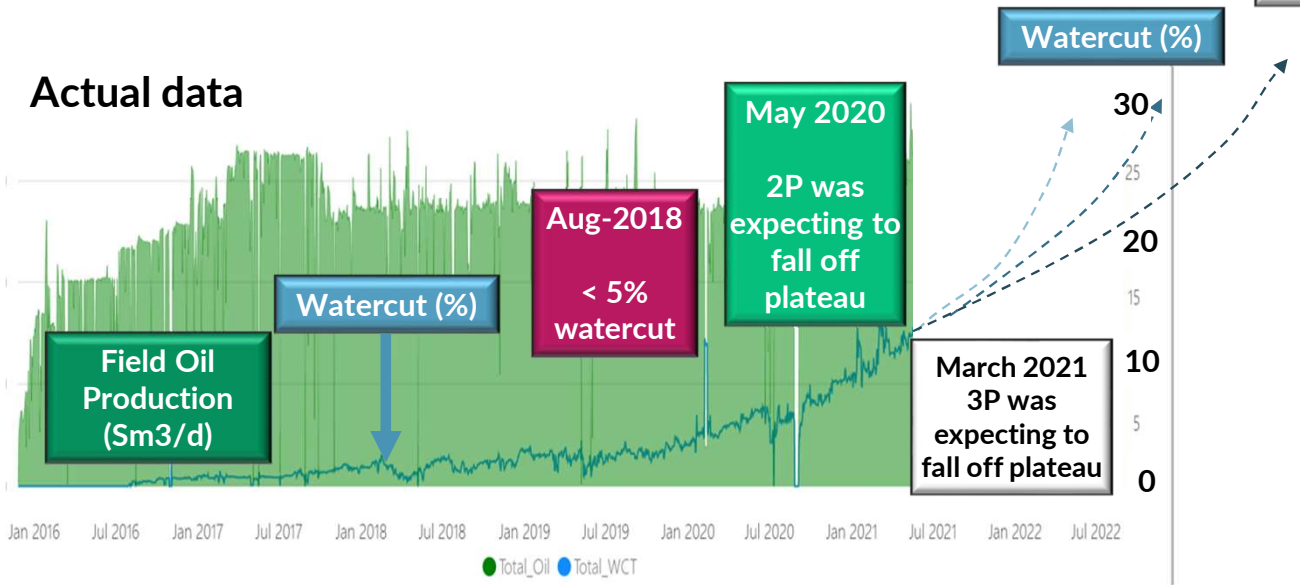
WHEN does Grieg fall off PLATEAU ????



When water cut exceeds ~35 % the field falls off plateau



Oil production rate (YE2018 prediction)

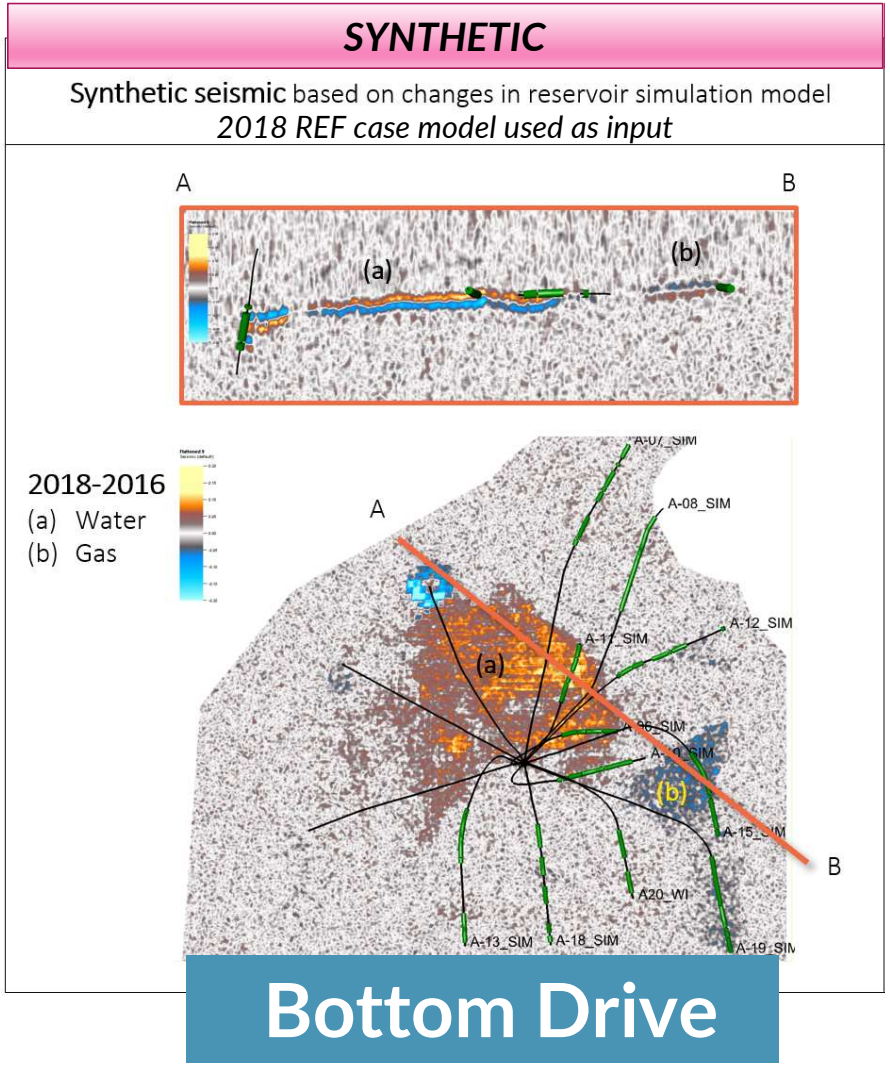


2018: Observation of sea water tracer in main producer ➔ where is the water front?

4D seismic: Synthetic (2018) vs. Real data

SYNTHETIC

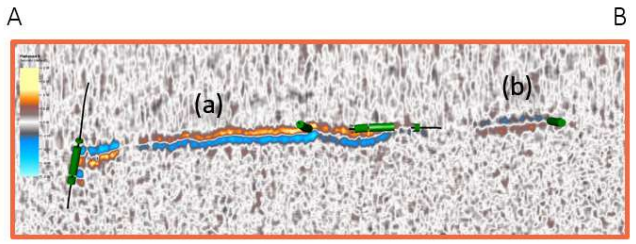
Synthetic seismic based on changes in reservoir simulation model
2018 REF case model used as input



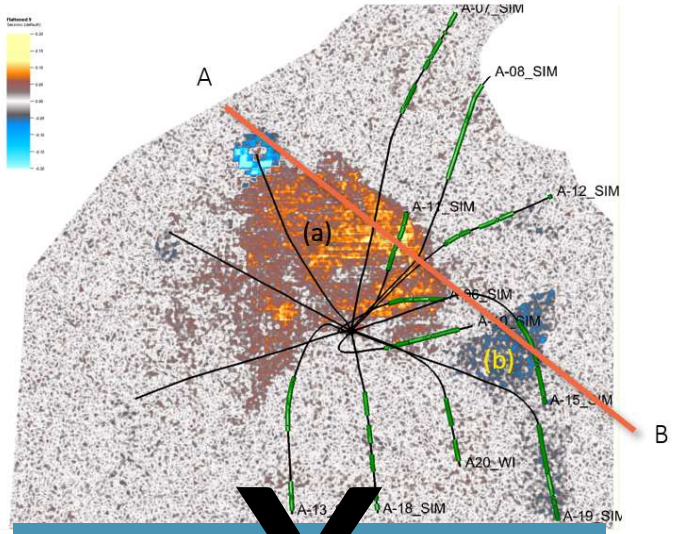
Bottom Drive

4D seismic: Synthetic (2018) vs. Real data

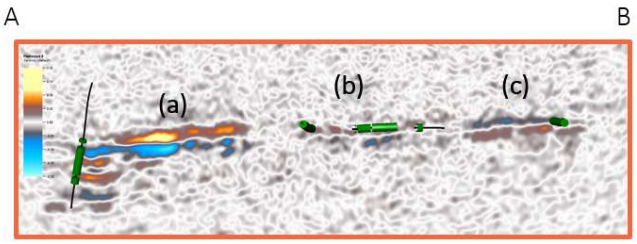
SYNTHETIC	***REAL DATA (2018 – 2016)***
Synthetic seismic based on changes in reservoir simulation model *2018 REF case model used as input*	**Real seismic** based on actual changes in reservoir

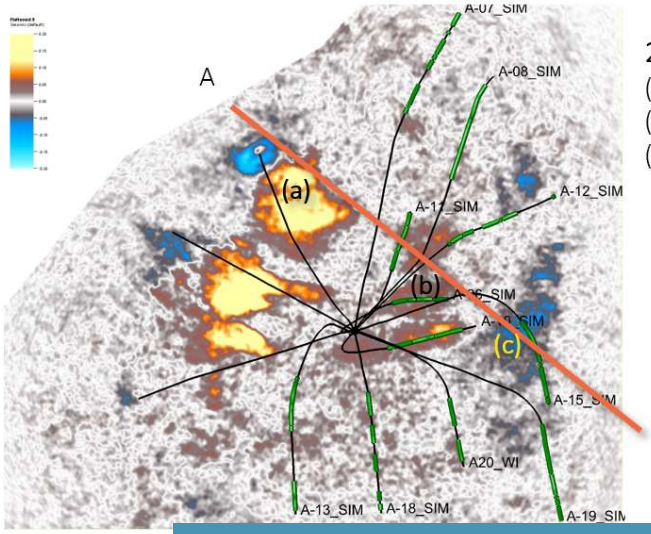


2018-2016
(a) Water
(b) Gas



Bottom Drive ✗





2018-2016
(a) Water
(b) Reduced Gas
(c) Gas

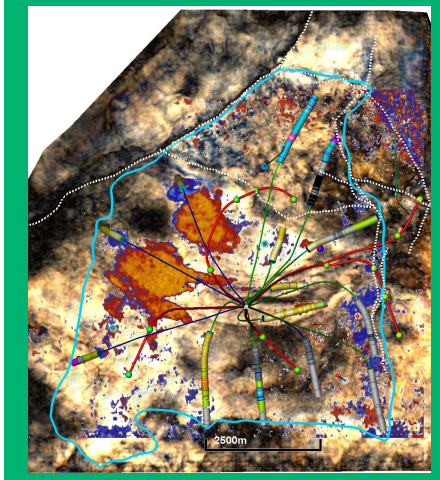
Sideways Drive

2019 model update ➔ Improved, but not good!

Improved match, but lacking important concepts

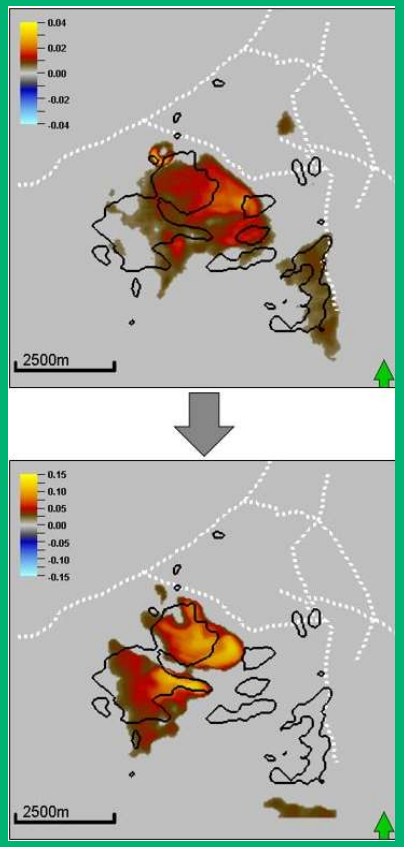
4D matching

2018-2016 Real 4D



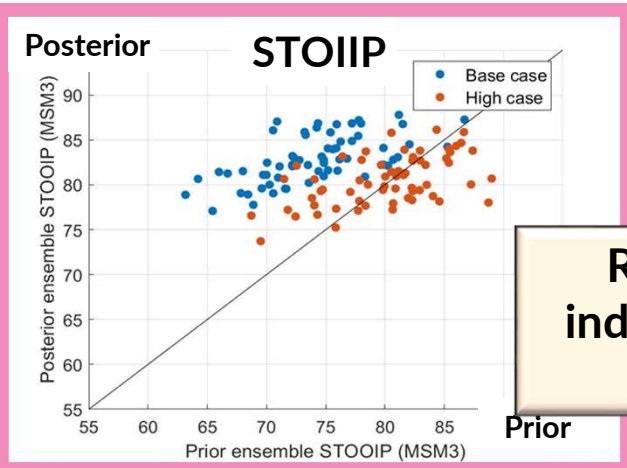
Improved 4D match, but too much water

2018 model

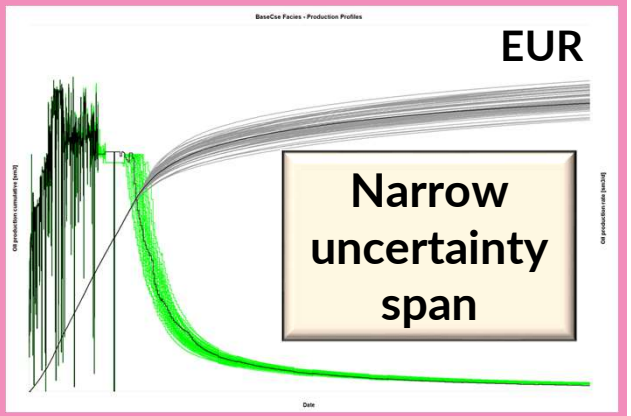


2019 model

ResX



ResX study indicates more STOIIP



Narrow uncertainty span

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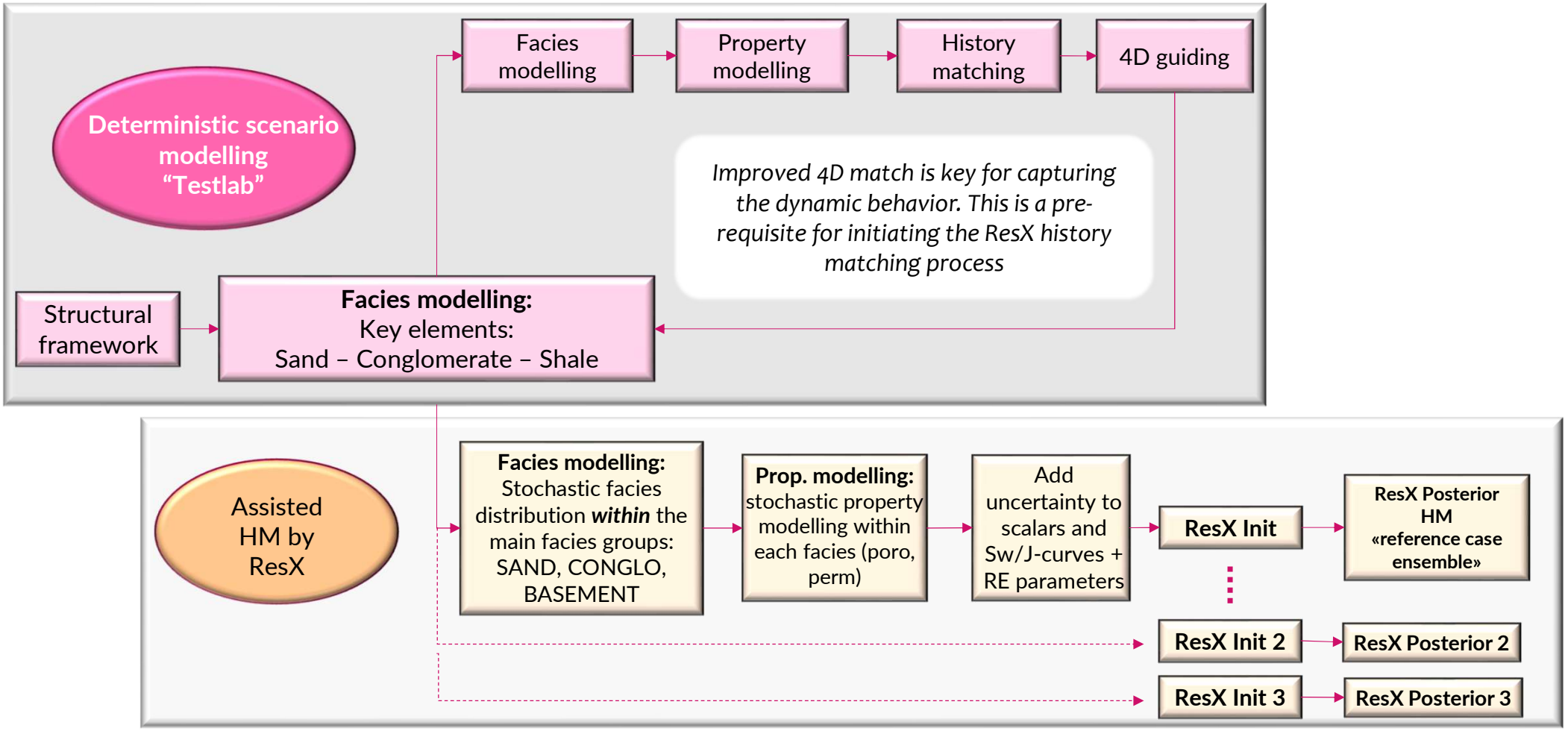
Static/Dynamic Modelling Workflow

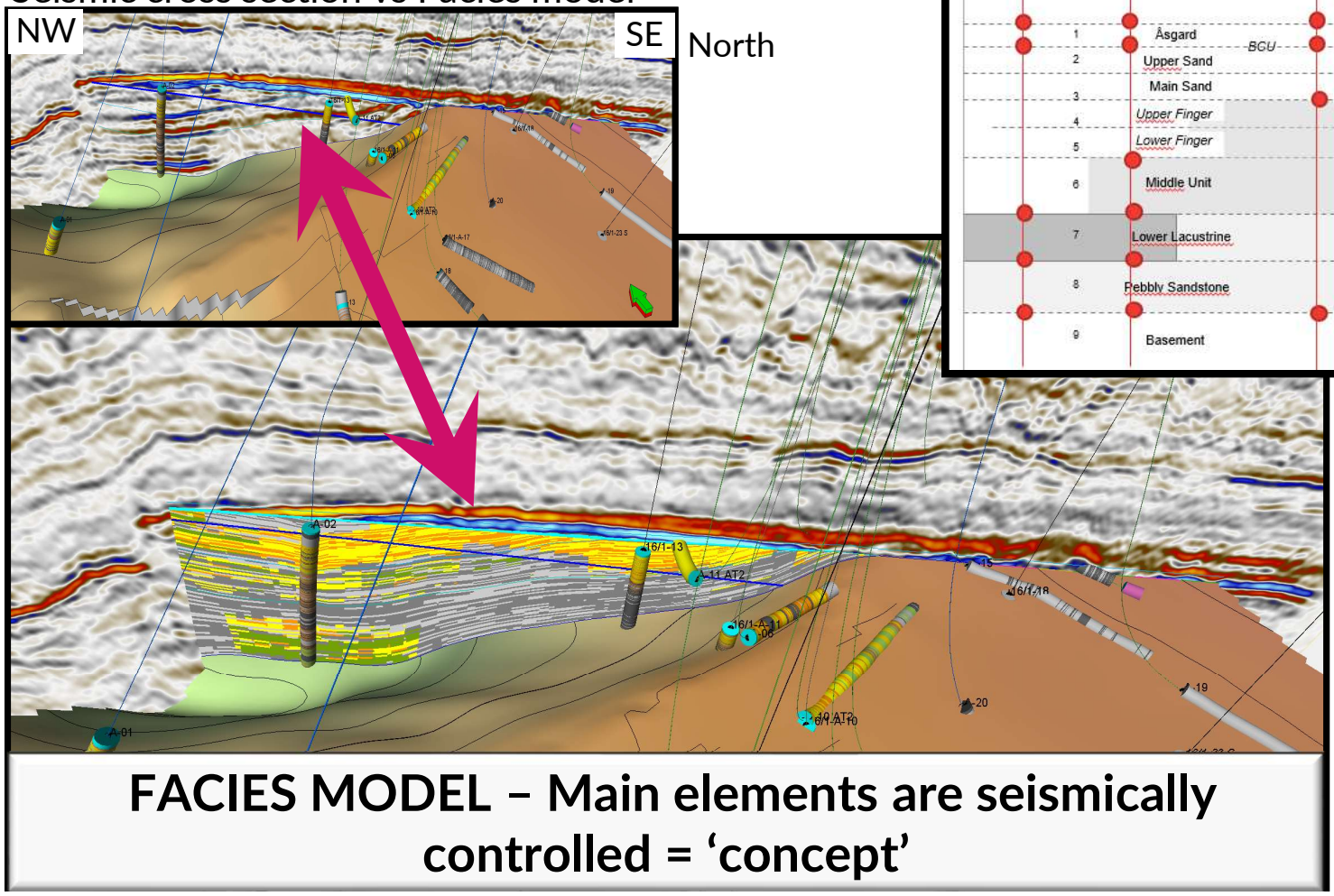
Concept Driven

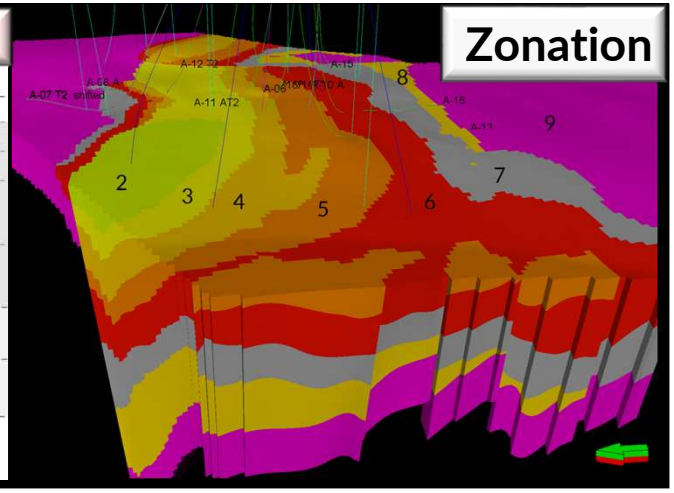


Updated geological concept

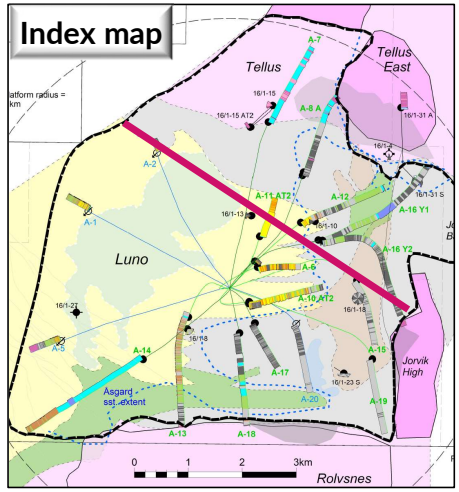
Improved understanding of Structure and Facies Configuration

Seismic cross section vs Facies model



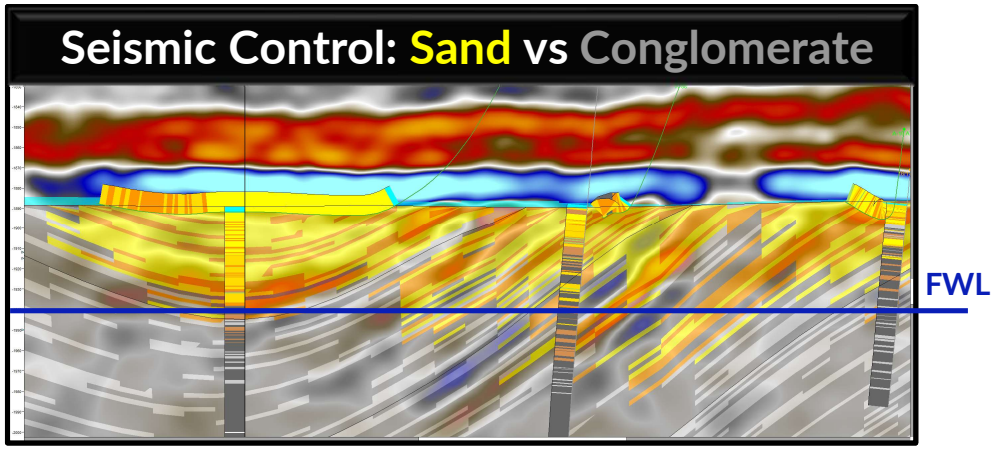


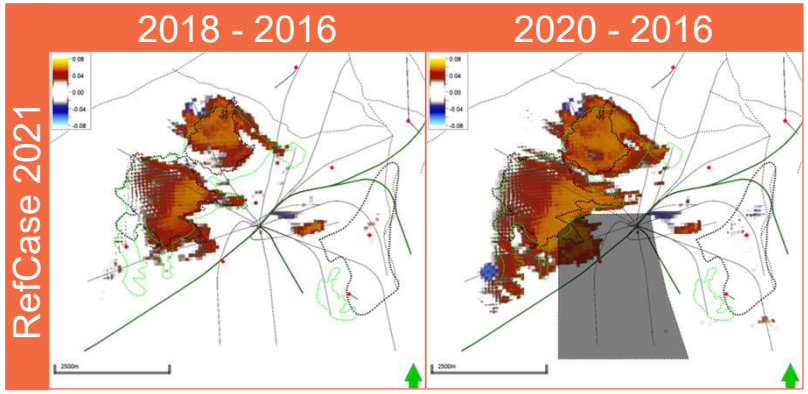
FACIES MODEL – Main elements are seismically controlled = 'concept'



Concepts| What do we mean?

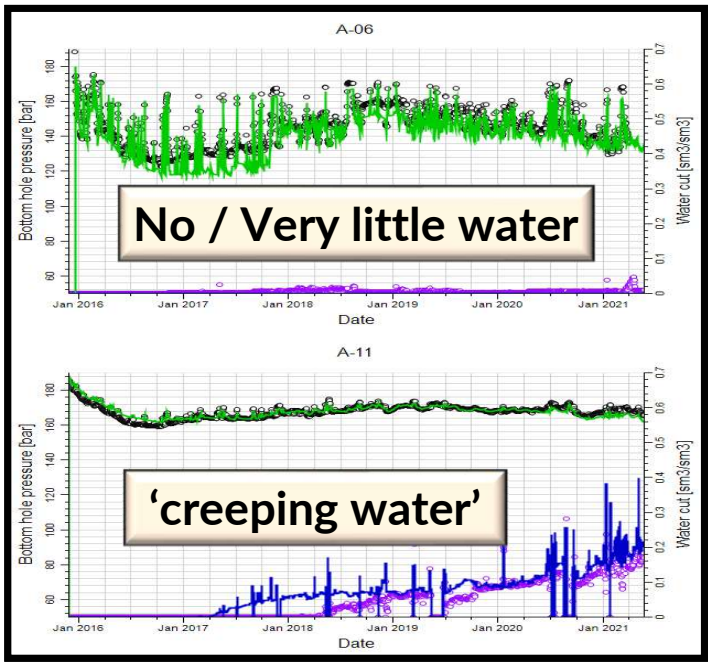
- Deterministic inputs controlling flow
- Examples:
  - Seismic controls: Structure, Bedding dip, Facies
  - 4D matching
  - Water Cut and Tracer Match (perm streaks)
  - Aquifer study (size, connection, energy)





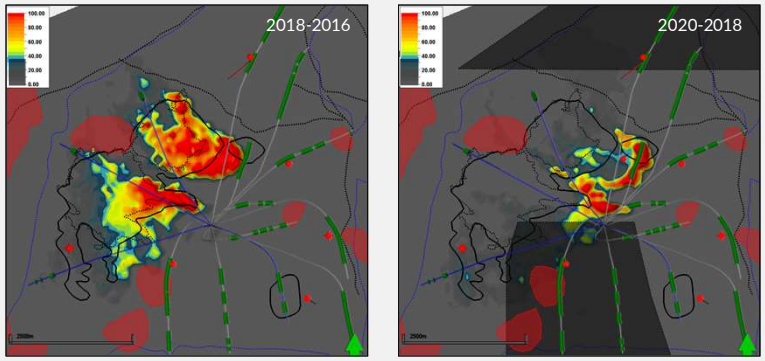
Improved match

- **Pressure**
- **4D**
- **Water Cut**



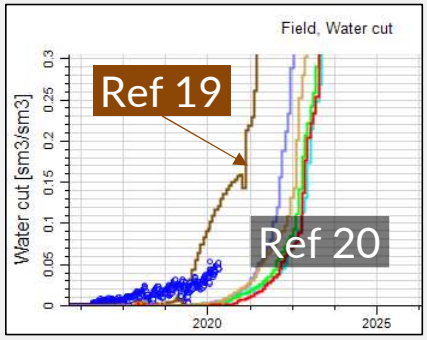
Improved Reservoir understanding => Improved History Match

2019: (still) Poor 4D match

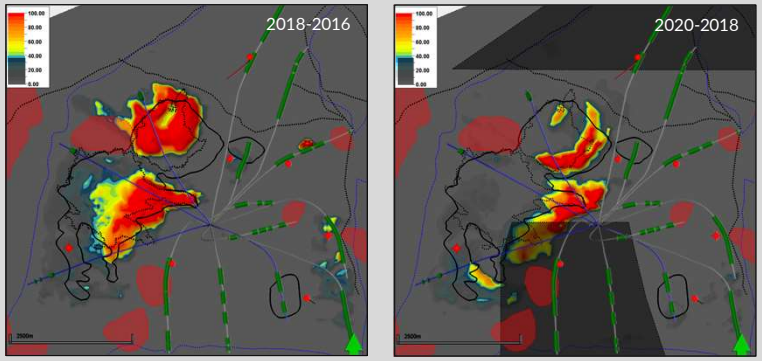


Lack of key concepts!

➔ **Bottom drive dominates**

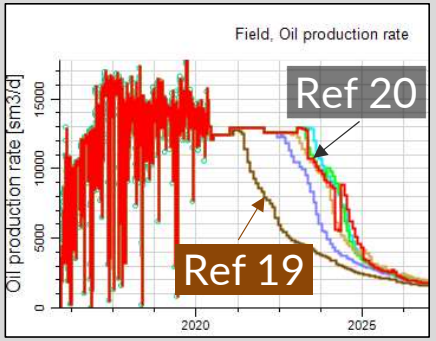


2020: Improved 4D match

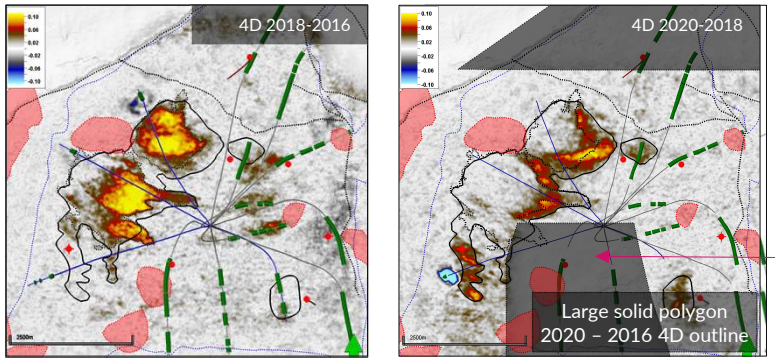


Improved Reservoir understanding (concept)

- ➔**Sideways sweep**
- ➔**Delayed water breakthrough**
- ➔**'creeping water' vs. 'massive water breakthrough'**



4D Seismic



'Testlab' PURPOSE

- Dynamic behaviour
- 4D match

Deterministic model **challenges:**

- STOIIP

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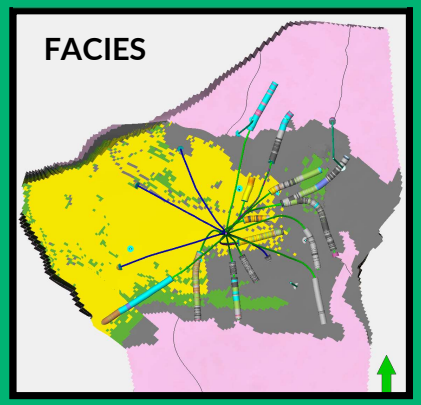
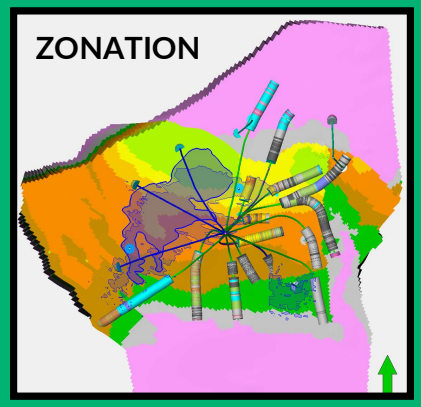
Assisted history matching by ResX

AkerBP

ResX Init

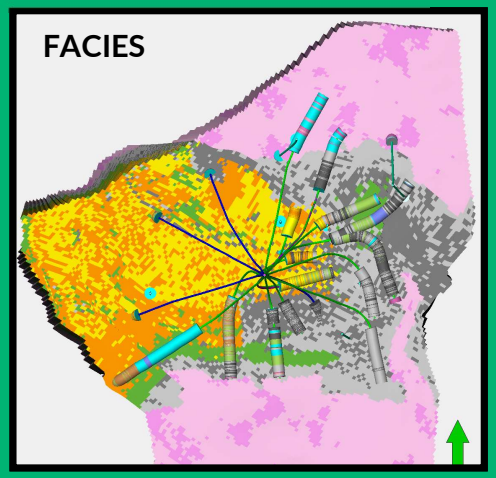
Deterministic Input

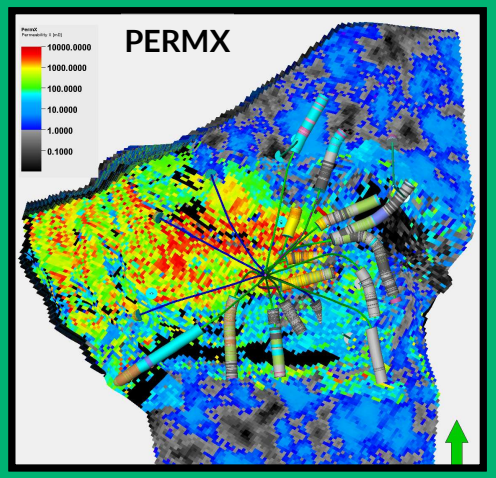




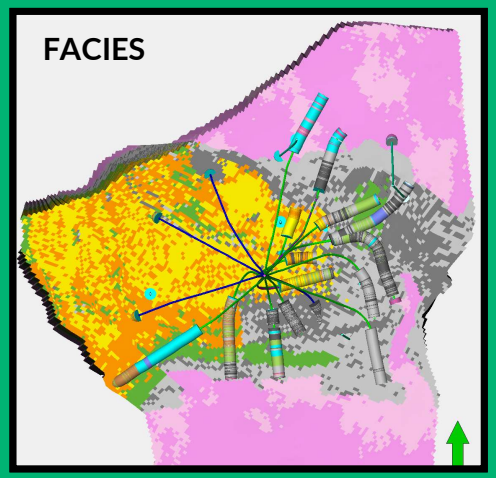
Stochastic Realizations

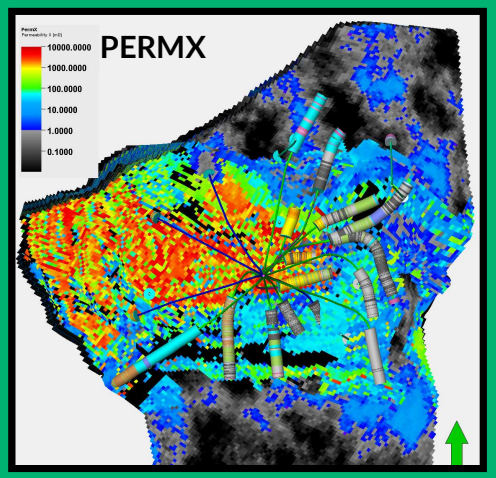
ResX Init, r1





ResX Init, r2

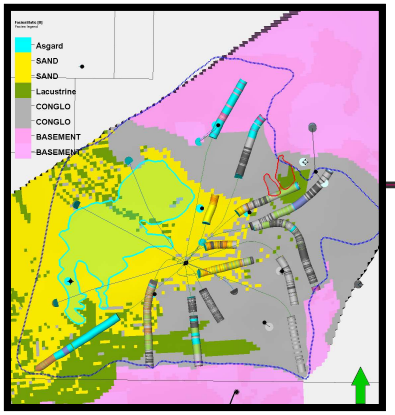




+
TopRes unc.
N/G,
poro,
FWL,
J-curves,
RelPerm,
+ + +

ResX Init – Concept 1

Concept 1



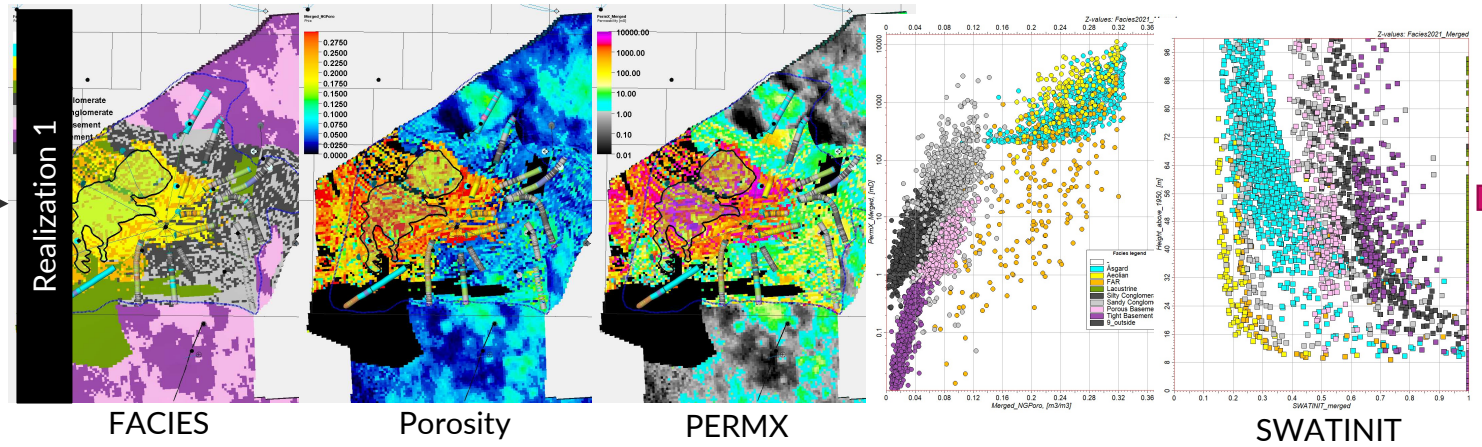
Facies fractions and distribution within the main facies groups

NG and poro mean values and variograms for each facies

Perm for each facies and zone

Correlation factor between poro and perm

J-curve (shape and Swirr) + FWL uncertainty



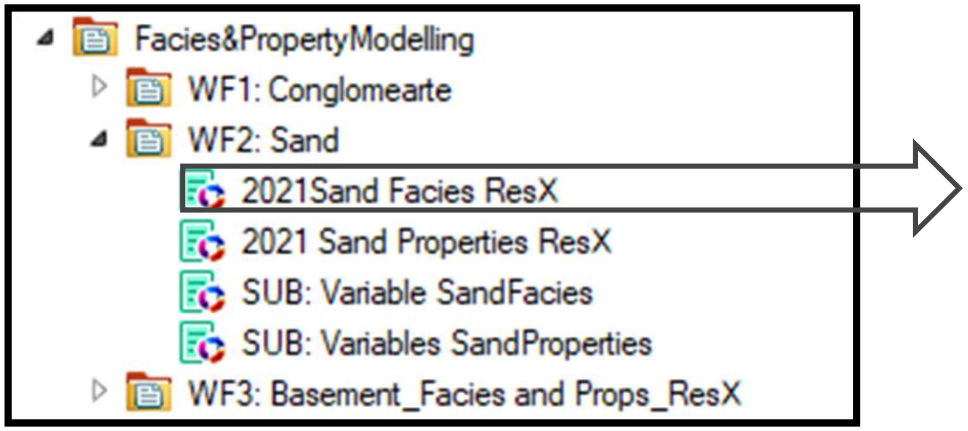
FACIES Porosity PERMX SWATINIT

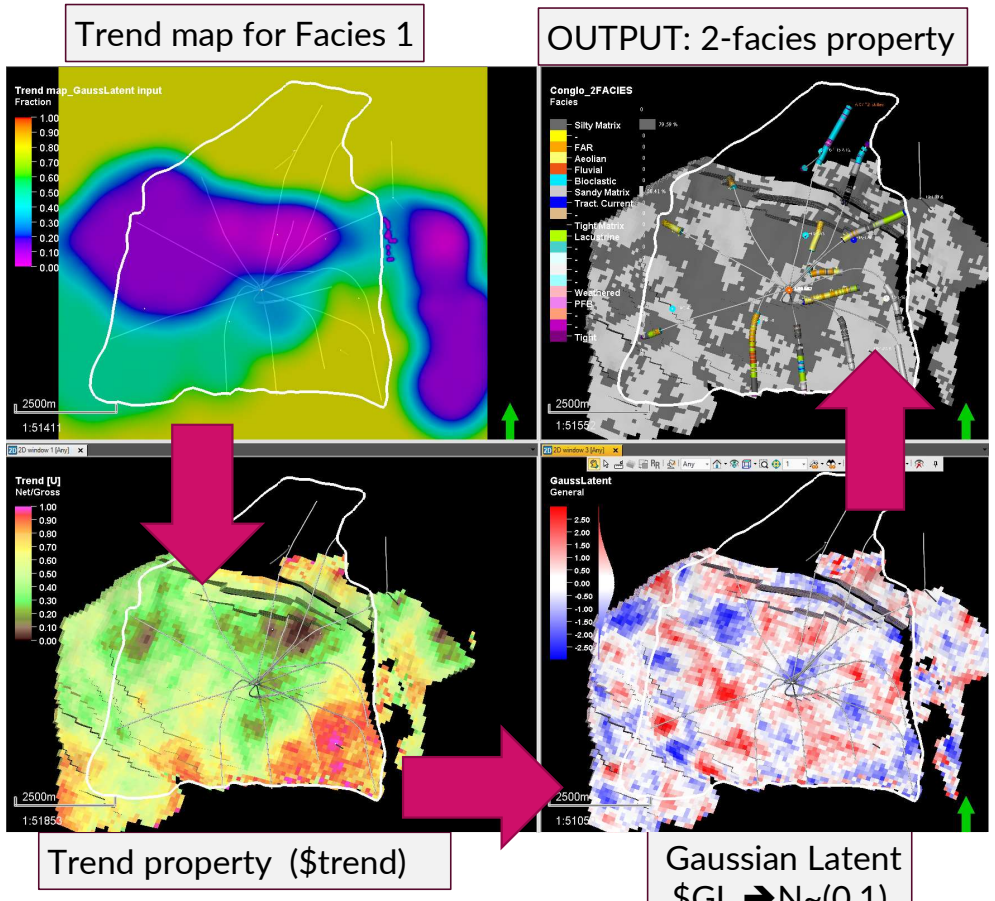
Realization n

Add on uncertainties to scalars and RE parameters, simulate to create ResX Init

ResX Init | 2-facies Modeling Workflow

- **Simple / Pragmatic**
- **Flexible**
- **Logic can be re-used**

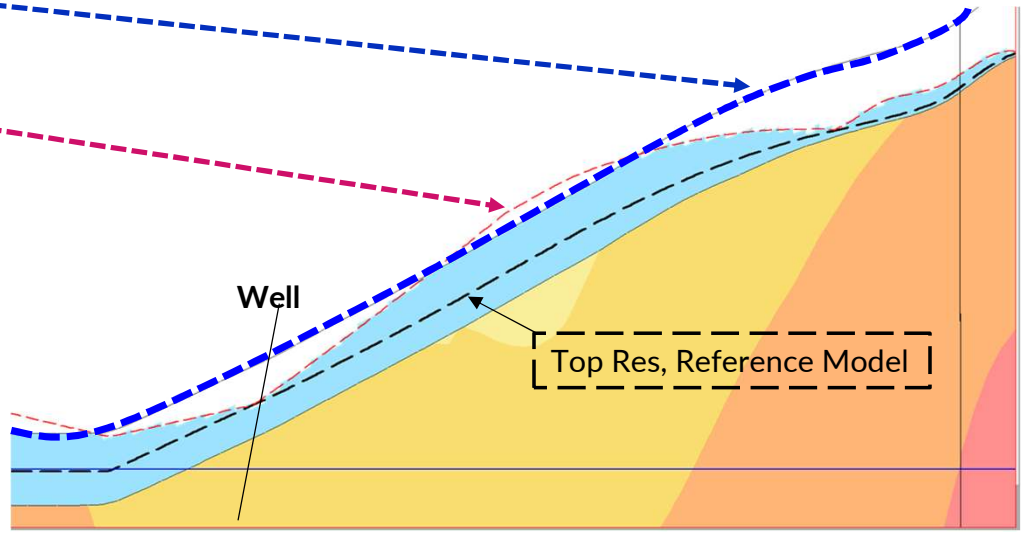


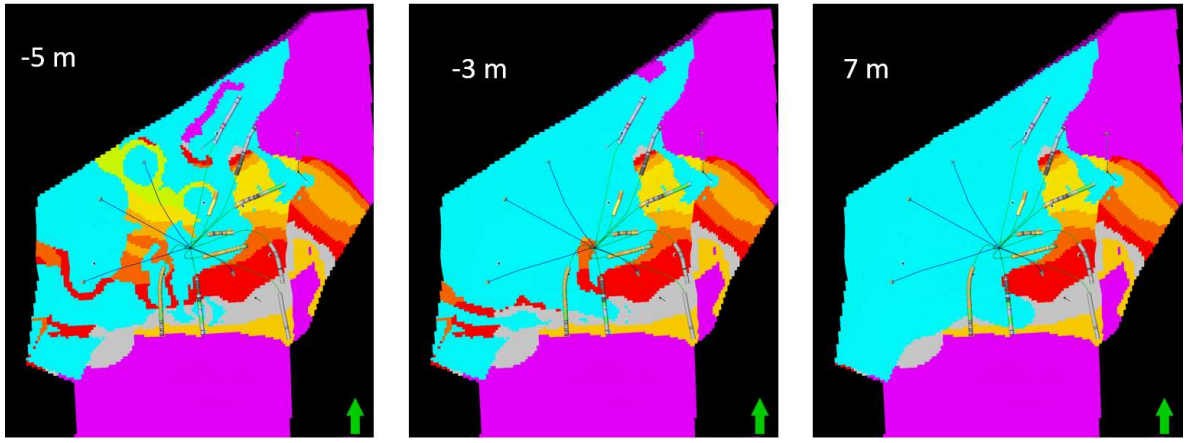


Syntax (Petrel property calculator):
IF($GL > InvCumNormal(0 , 1 , $trend) , *Facies1* , *Facies2*)

ResX Init | Top Reservoir Uncertainty

- (1) Framework envelope:
- (2) Vary top reservoir surface for each run
- (3) Define ACTNUM=0 above topres





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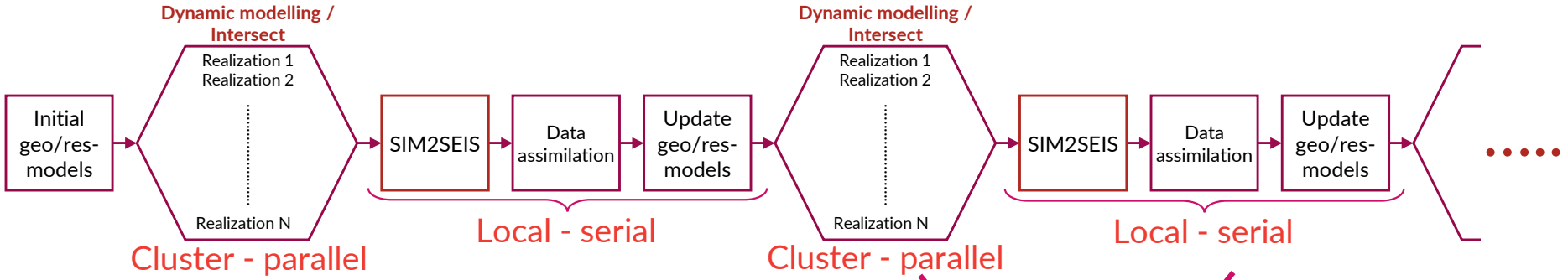
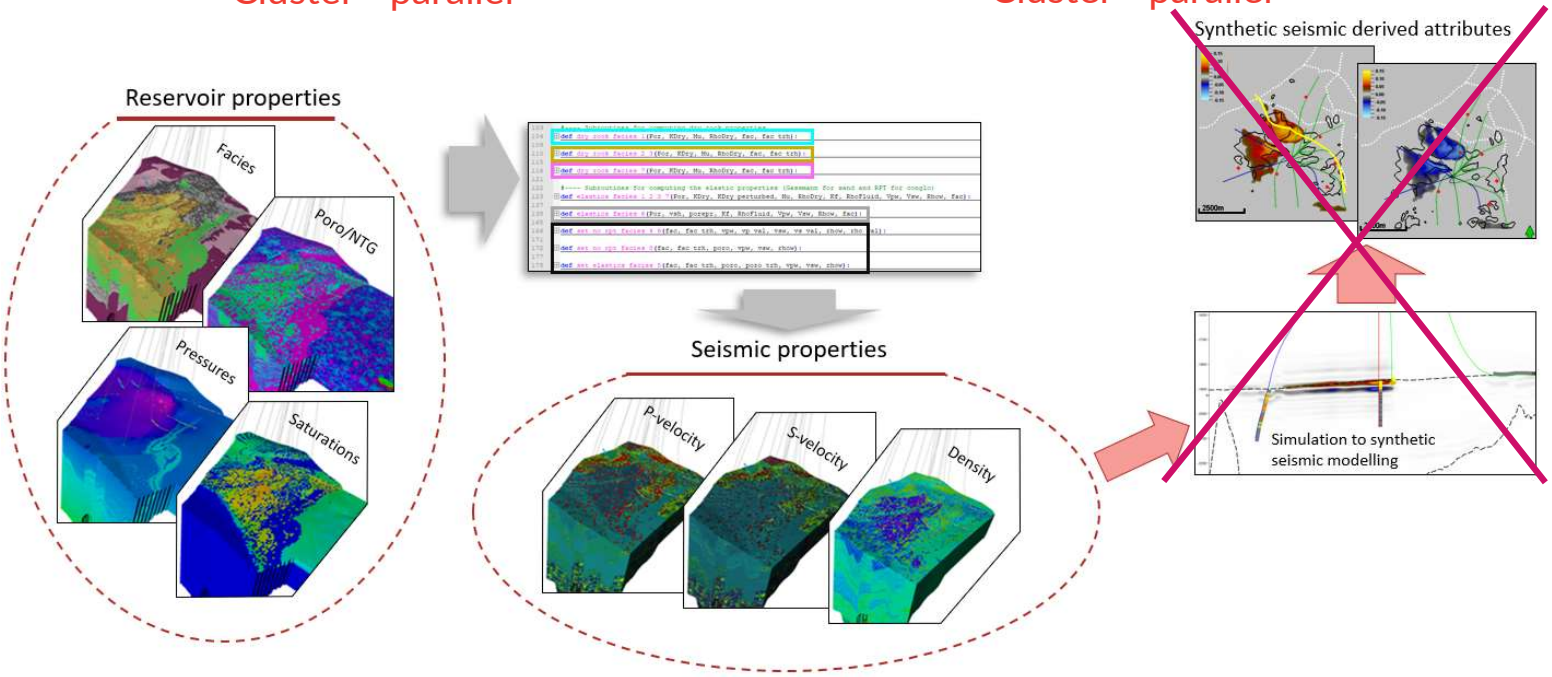
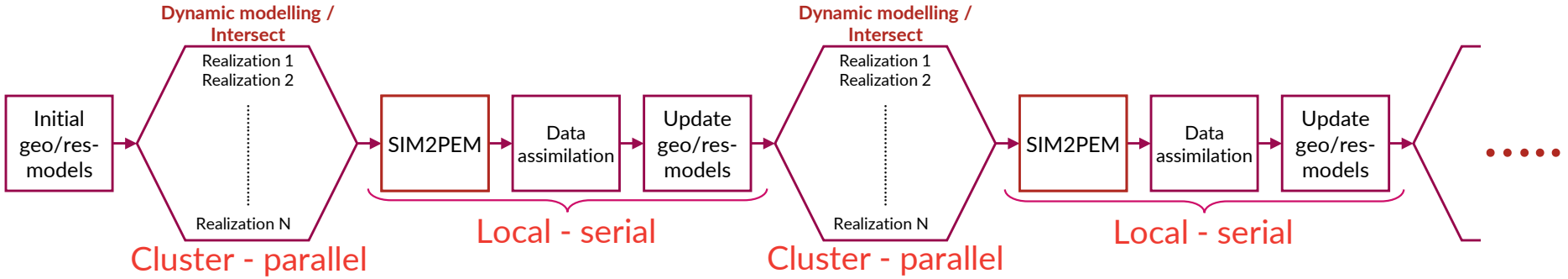
ResX 4D Match | ResX Modelling Workflow

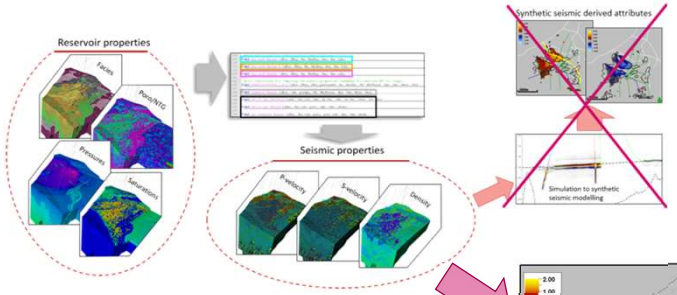




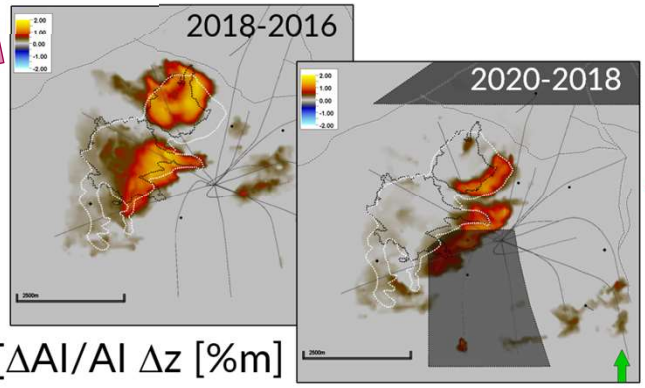
- SIM2SEIS <30 min
  - ResX: 100 x 30 min = 50 hours

ResX 4D Match | ResX Modelling Workflow





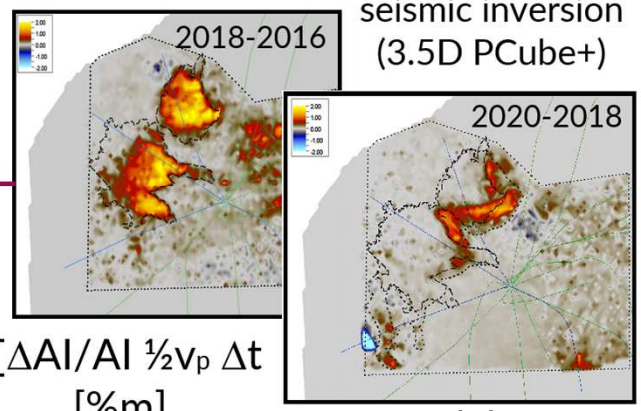
- SIM2SEIS <30 min
  - ResX: 100 x 30 min = 50 hours
- SIM2PEM ~ 3 min per realization



∑ΔAI/AI Δz [%m]

Data assimilation

Computed from seismic inversion (3.5D PCube+)



∑ΔAI/AI ½v_p Δt [%m]

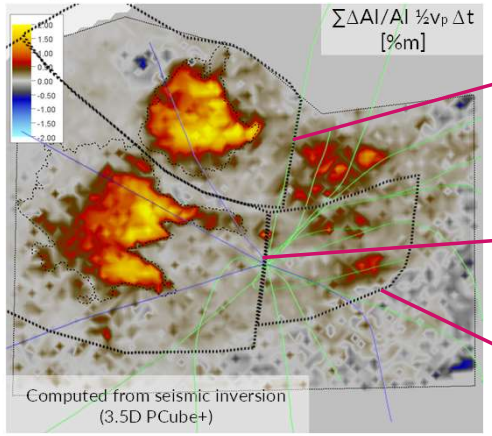
«Real data»

Model derived attributes –Relative AI change thickness map

ResX 4D Match | Input data

AkerBP

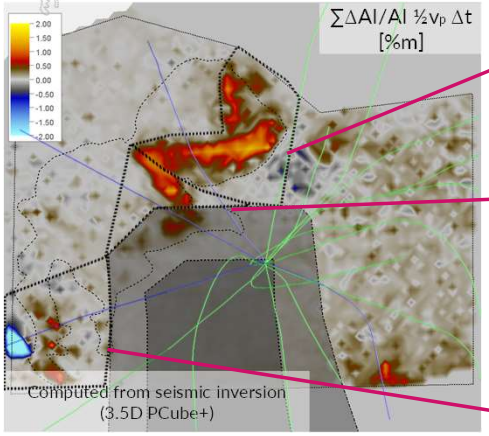
4D water in 2018



2018-2016

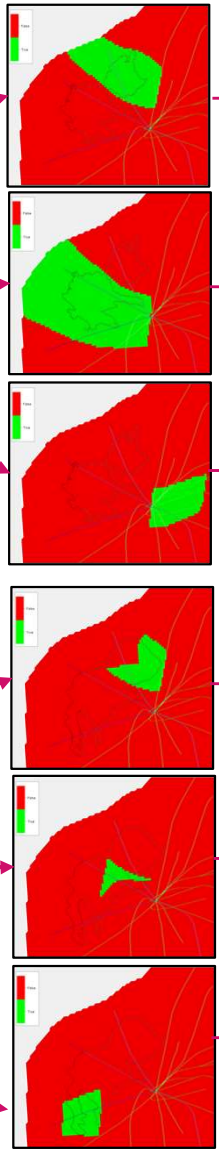
1: Observed data

4D water in 2020

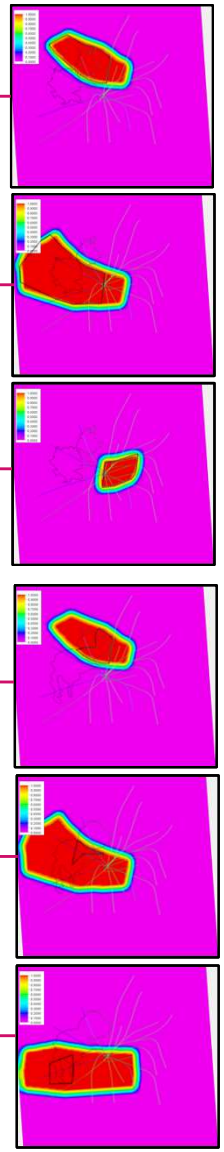


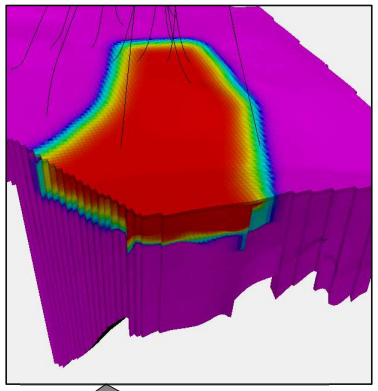
2020-2018

2: Data filter

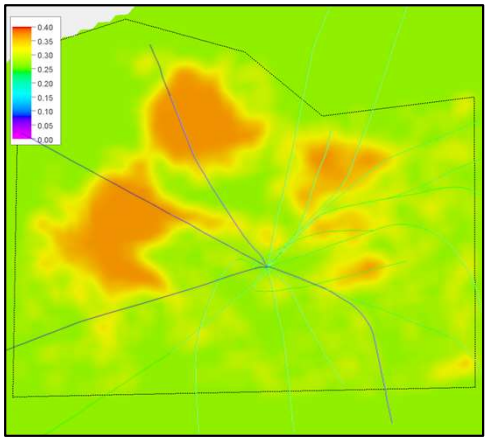


3: Localization

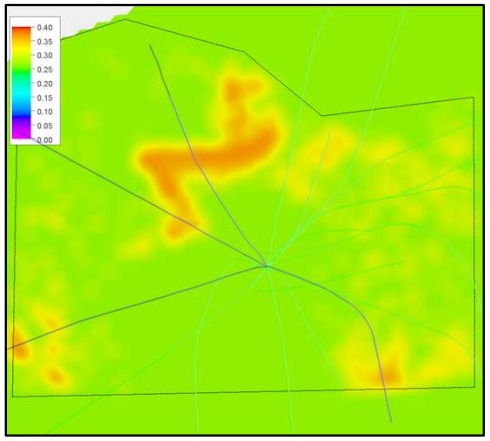




Restricted to
2045m TVDSS



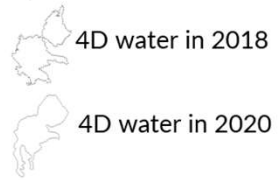
4: Tolerance map



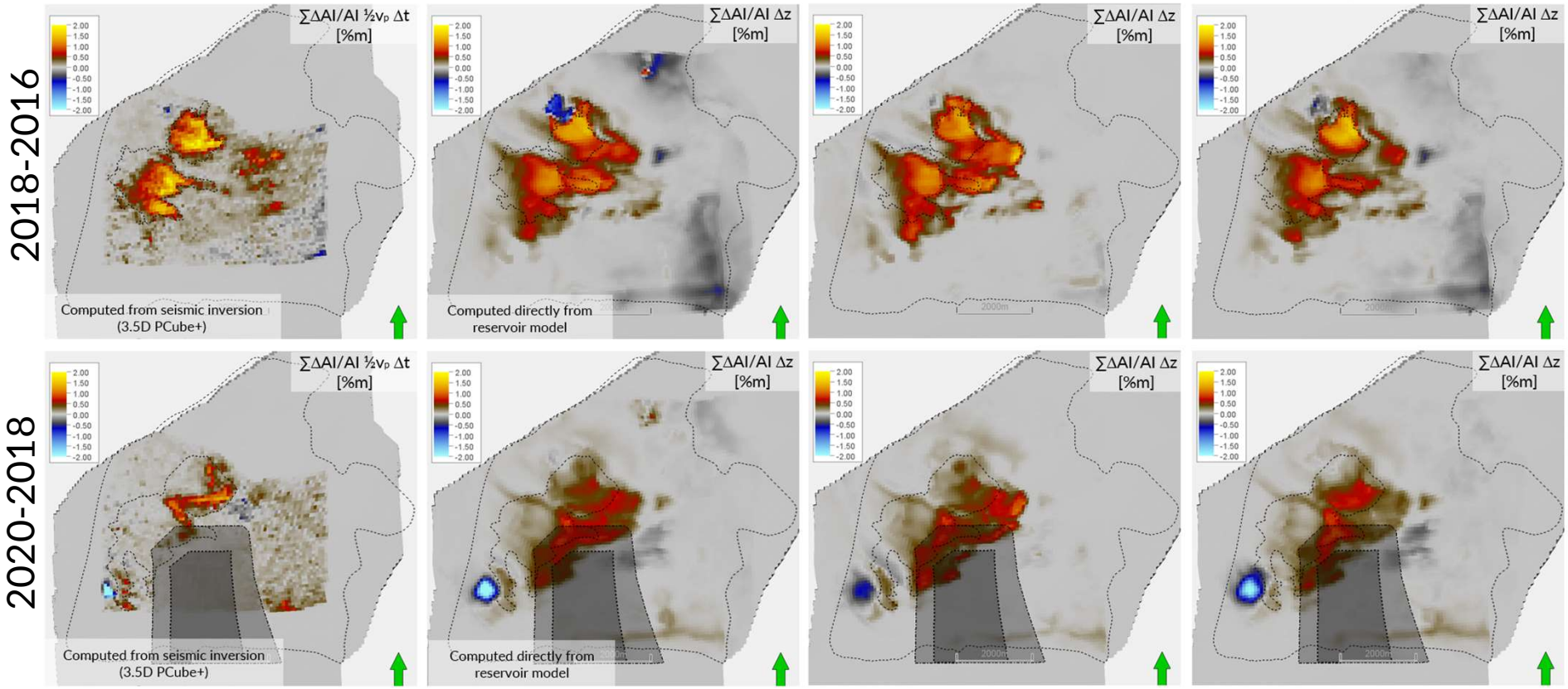
ResX 4D Match | Combining production and 4D data

Initial observations after conditioning to 2018-2016 and 2020-2018 seismic differences

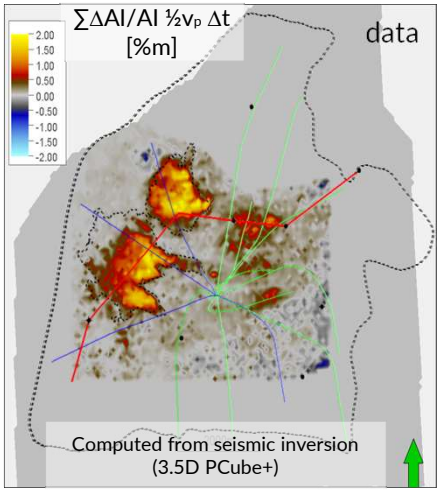
AkerBP

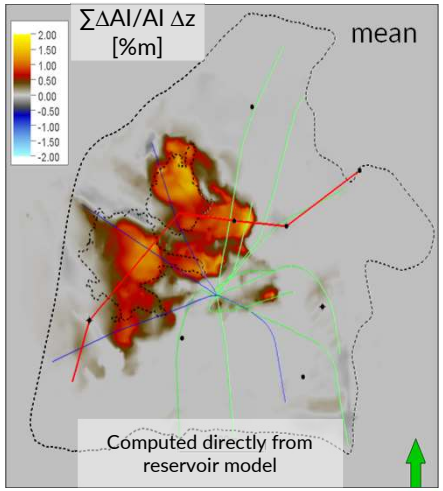


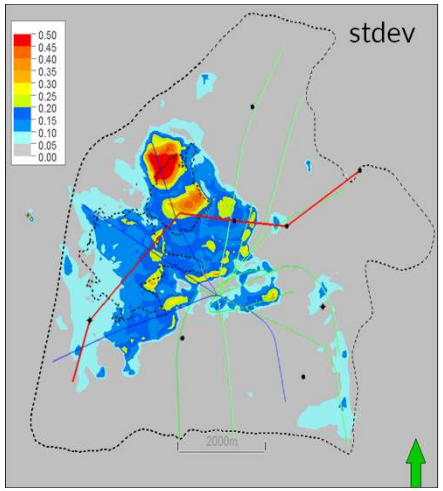
- Quantitative comparisons between observed 4D data and simulated mean show
  - Little to no improvements 4D-wise when constraining to production data only
  - Increased 4D match when also constraining to 4D data

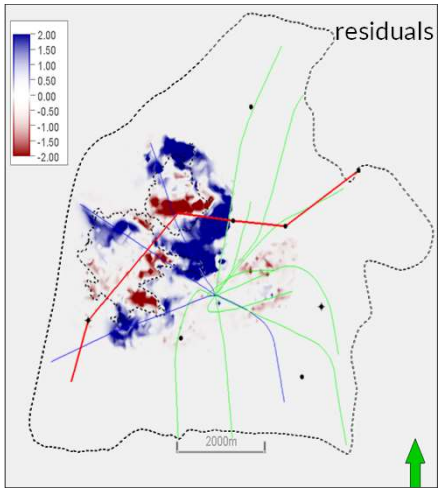


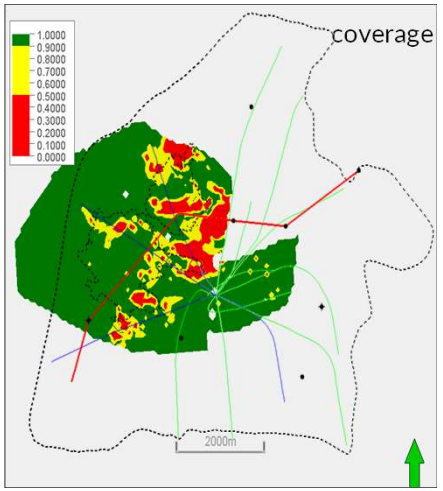
ResX 4D Match | Conditioned to production data only (2018-2016)

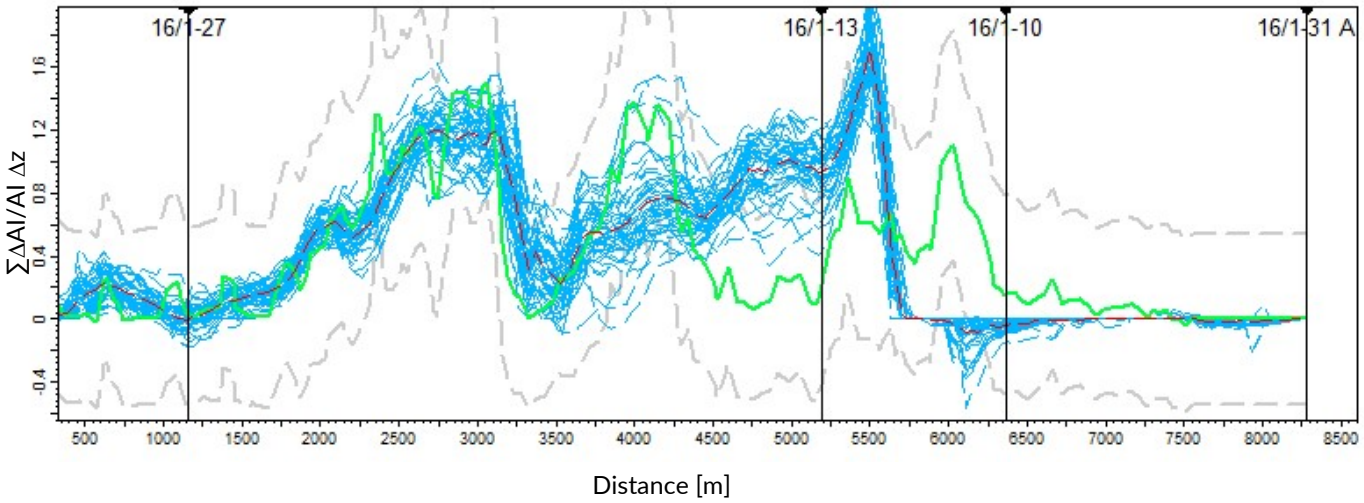










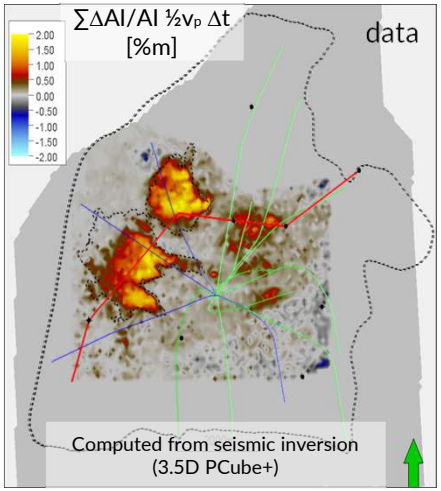


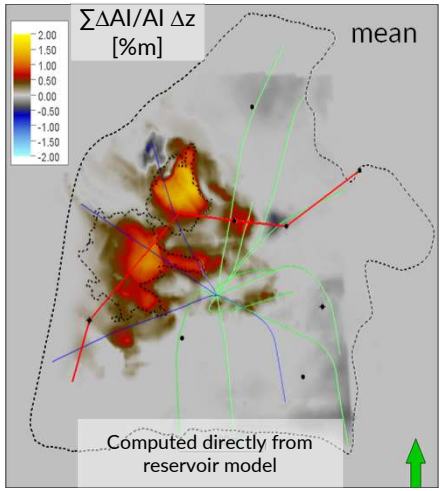
$$residuals = \frac{\sum_1^N (data_{sim} - dat_{obs})/\sigma_{tolerance}}{N}$$

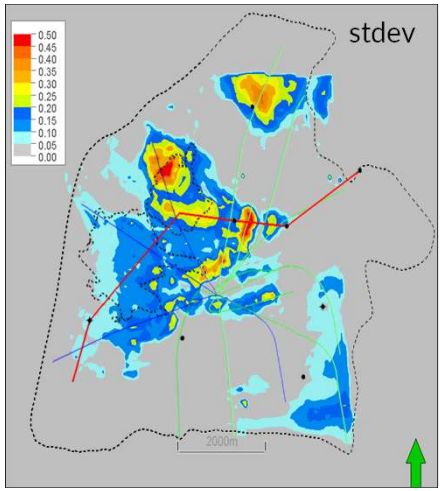
$$coverage = fraction\ of\ ensemble\ members\ within\ 2x\ \sigma_{tolerance}\ of\ the\ data$$

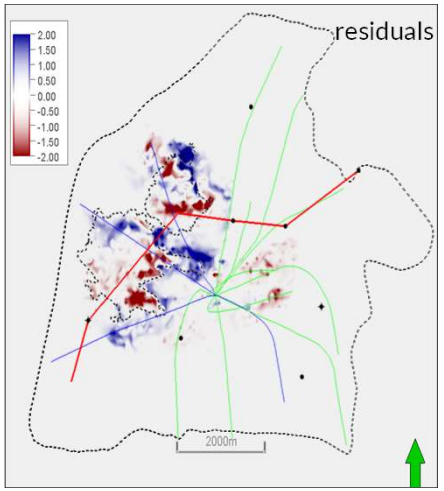
- Data
- Mean posterior
- Posterior ensemble
- Data ± 2 ∗ $\sigma_{tolerance}$

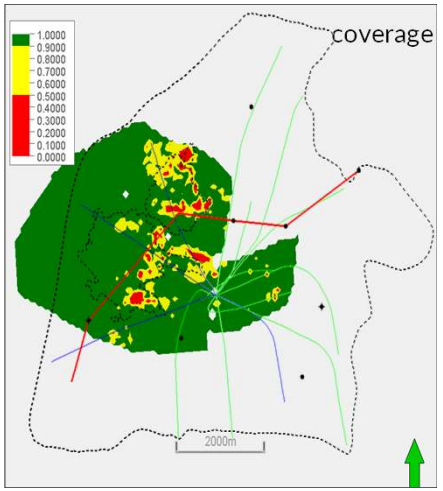
ResX 4D Match | Conditioned to production + 4D data (2018-2016)

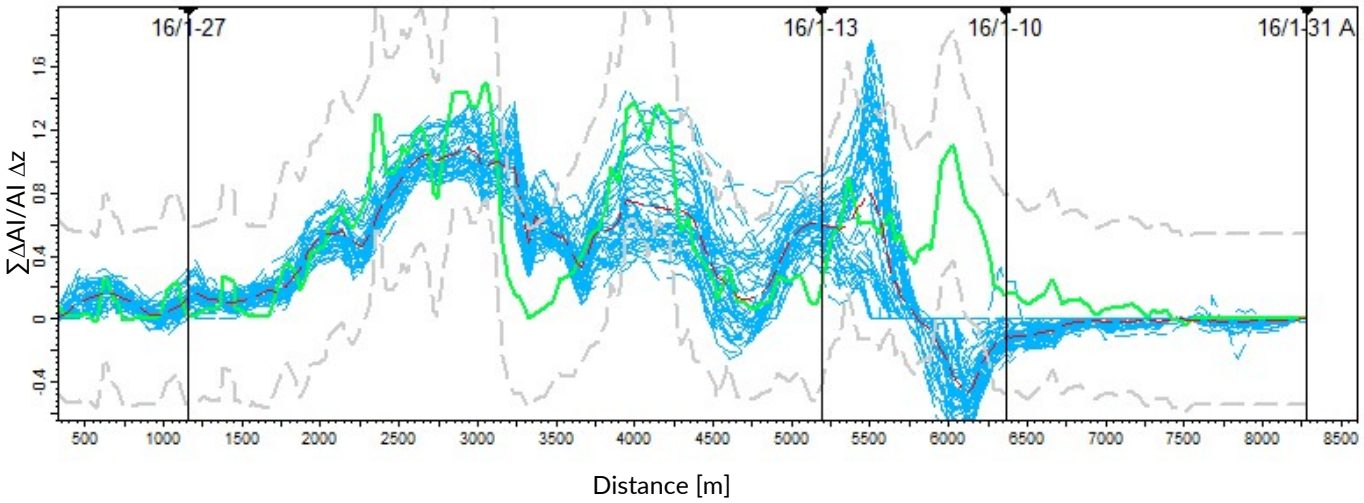












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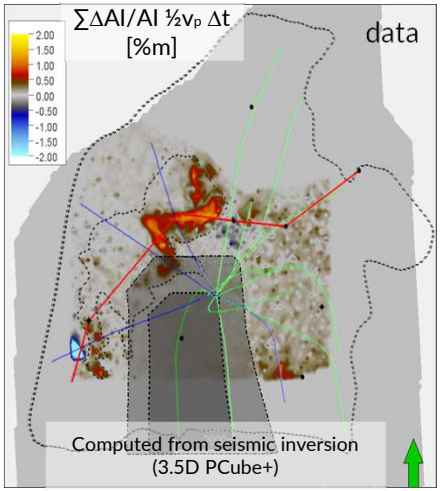
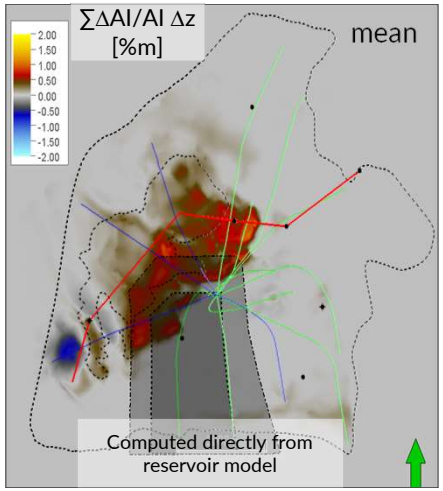
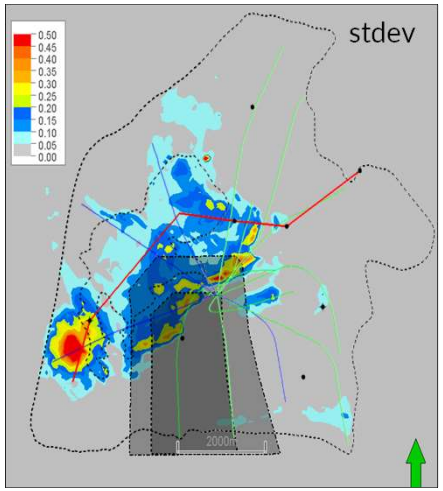
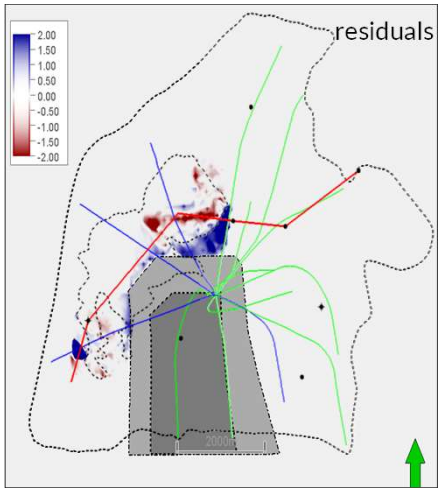
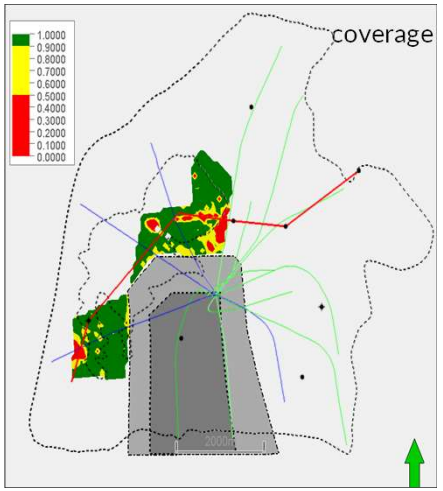
ResX 4D Match | Conditioned to production data only (2020-2018)

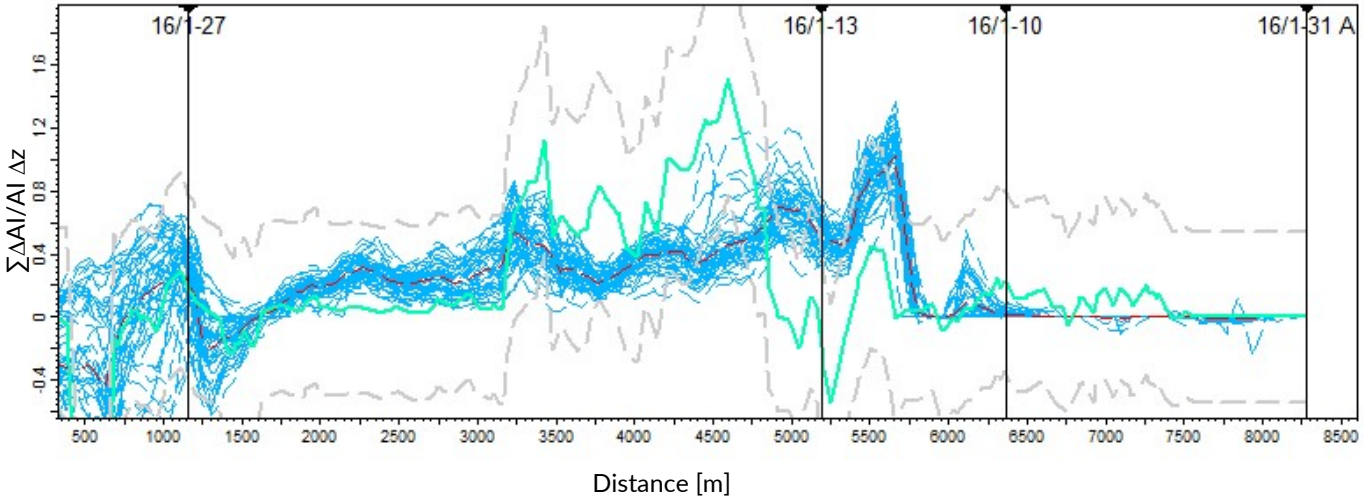












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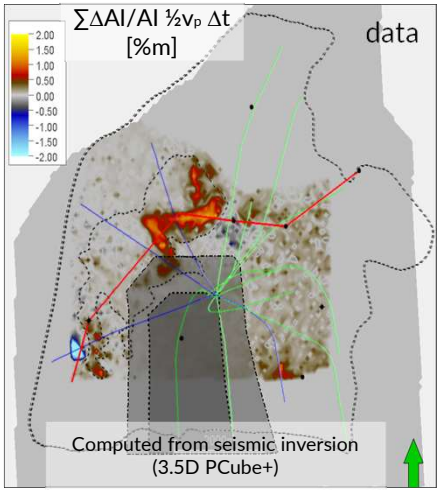
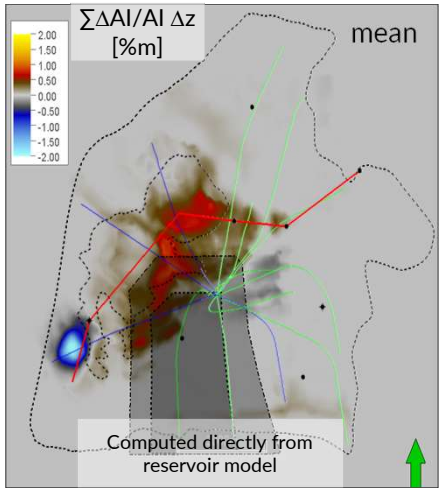
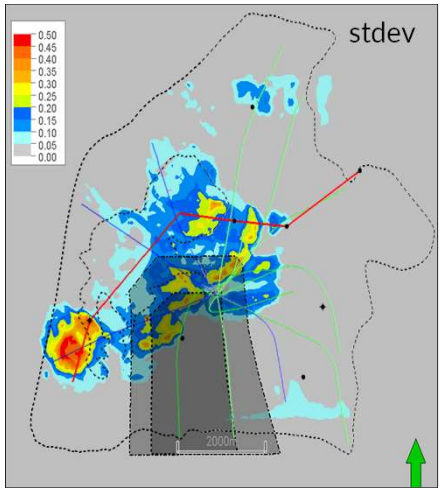
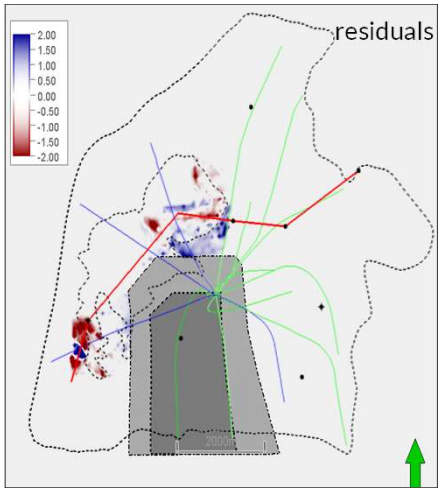
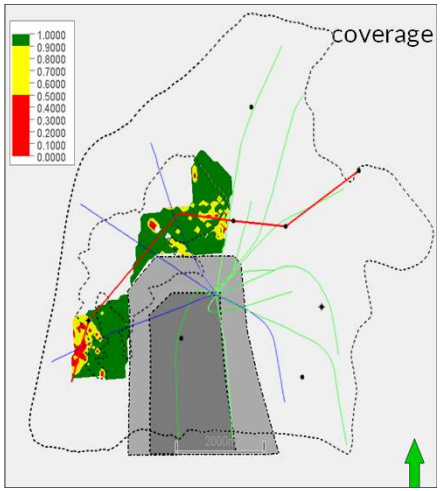
ResX 4D Match | Conditioned to production + 4D data (2020-2018)

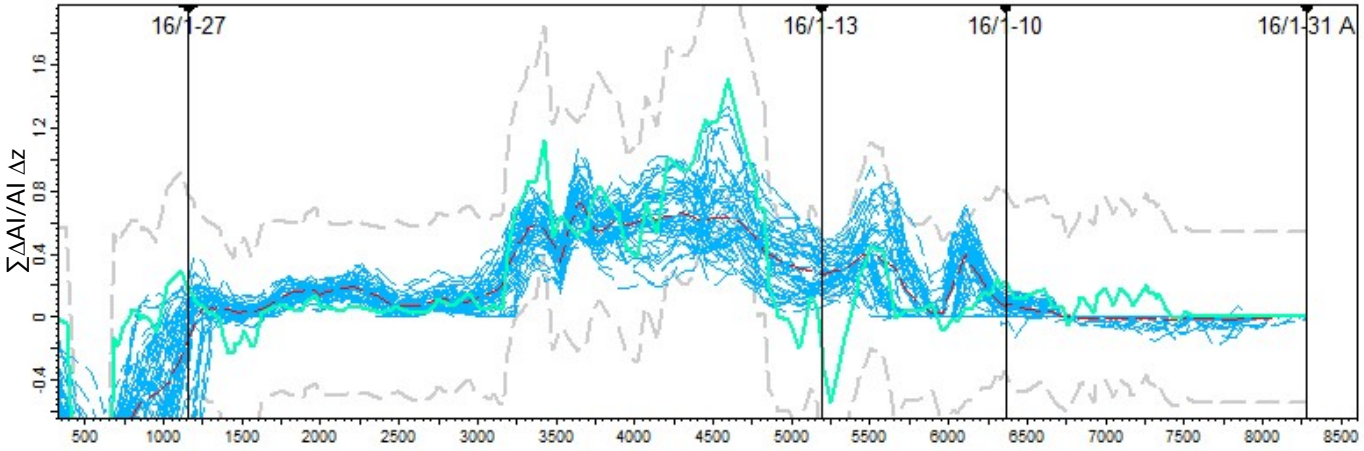












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Outline

- Introduction
  - Geology
  - Reserves prediction challenges
  - Status 2018: Need better predictability ➔ Implement assisted History Matching (?)
- Two parallell, but integrated, workflows:
  - Deterministic ➔ 'Testlab'
  - Assisted History Matching (ResX)
- 4D matching in ResX (Arnstein)
- Summary

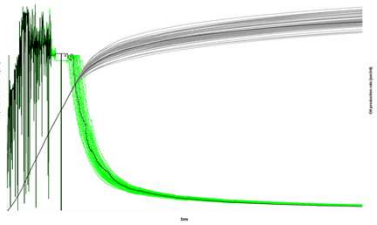
Ensemble of Ensembles

CONCEPT 1

ResX Init, concept 1

AHM

ResX Posterior, Concept 1

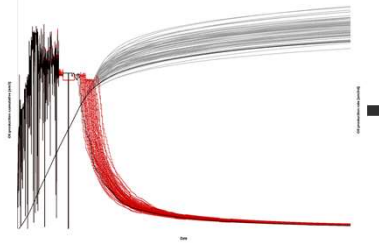


CONCEPT 2

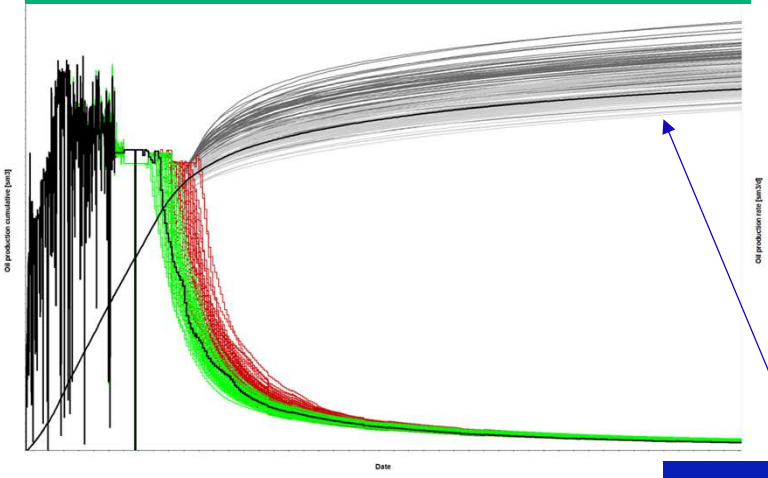
ResX Init, concept 2

AHM

ResX Posterior, Concept 2



Ensemble of Ensembles



Increased Uncertainty span

Edvard Grieg UA 2021 | **Overview**

Production data conditioning:

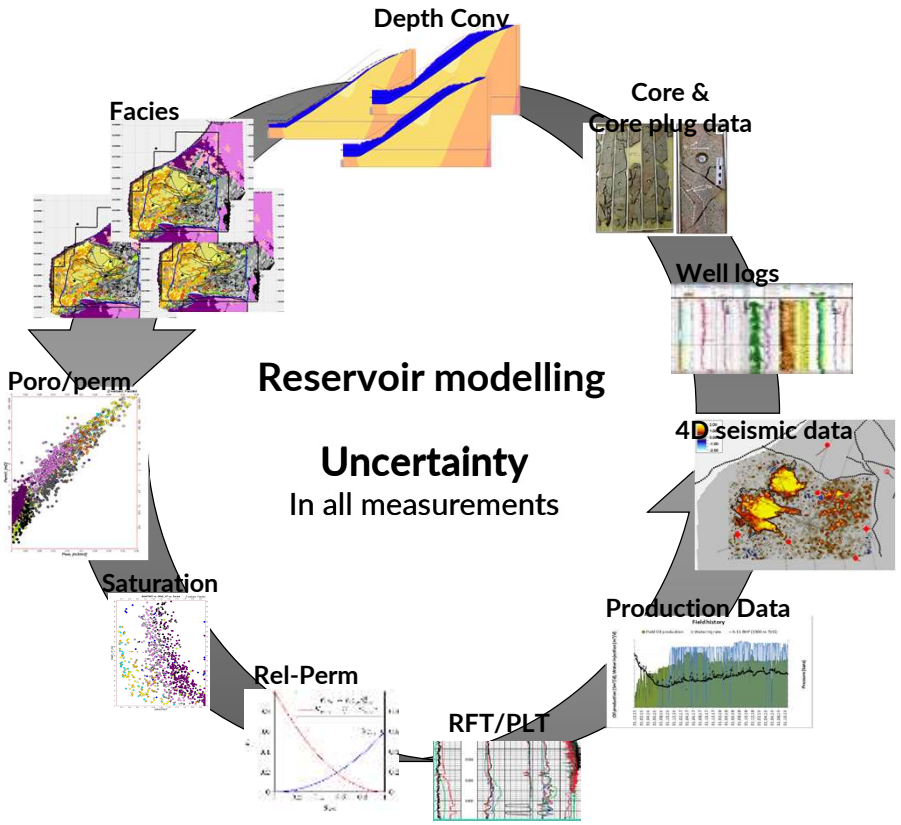
100 ‘BaseCase’, 100 ‘LC’, 100 ‘HC’

Production & 4D data conditioning:

50 ‘BaseCase’, 50 ‘LowCase’

RESULTS:

- **Concept driven:** Large correlation between chosen concept & Recovery
- **Very good history match for all wells**
- **Water cut:** field & well
  - conditioning to 4D seismic improves match
- STOIIP > RefCase STOIIP

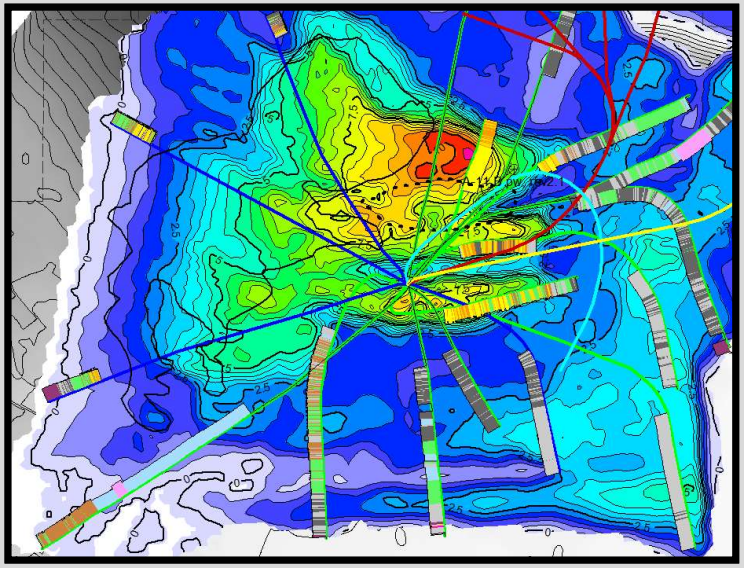


ResX Analysis | example

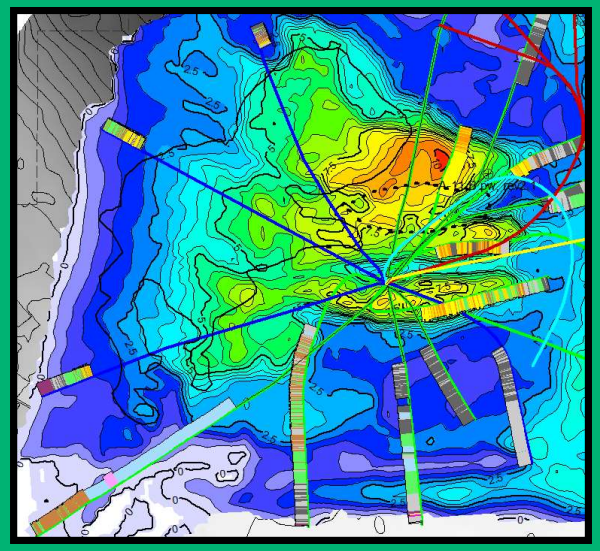
HCPV adjustments => 1 reason for match

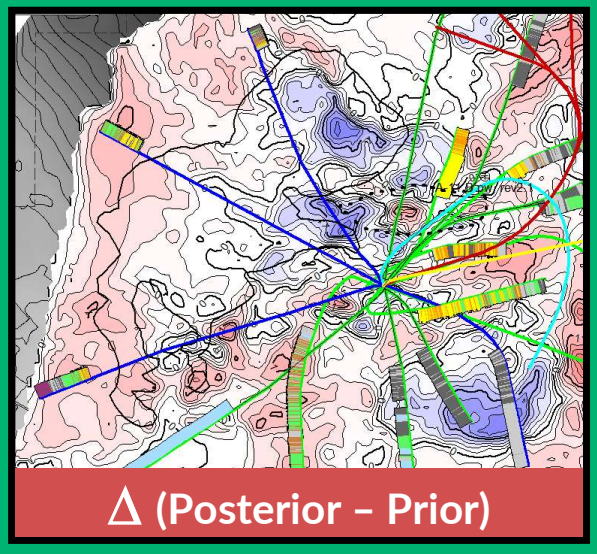
- PRIOR -

HCPV map



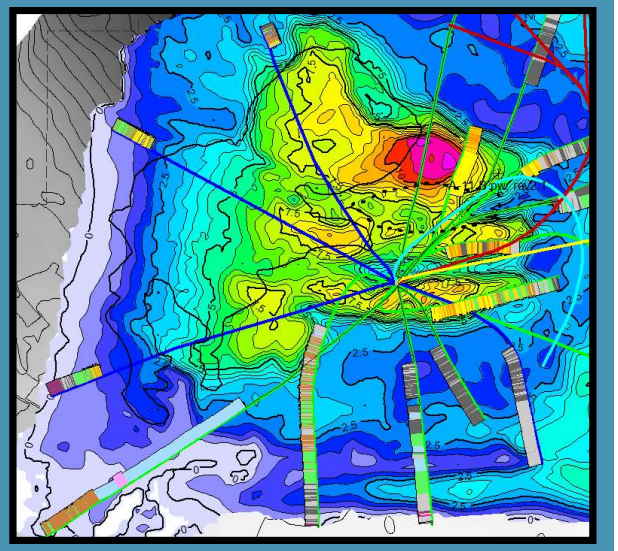
POSTERIOR | NO 4D

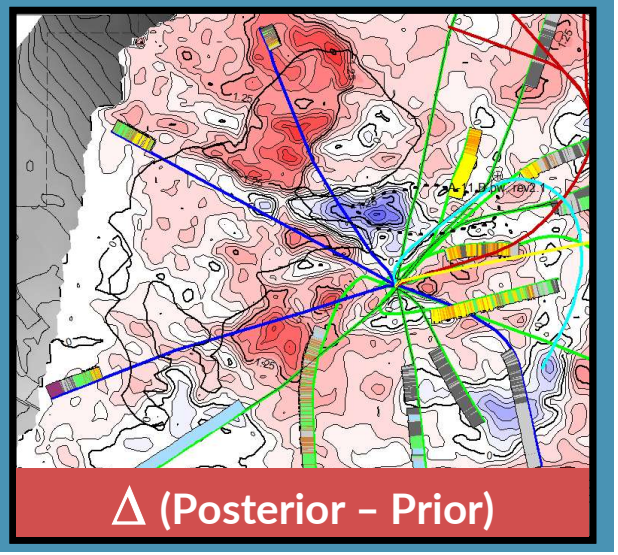




Δ (Posterior – Prior)

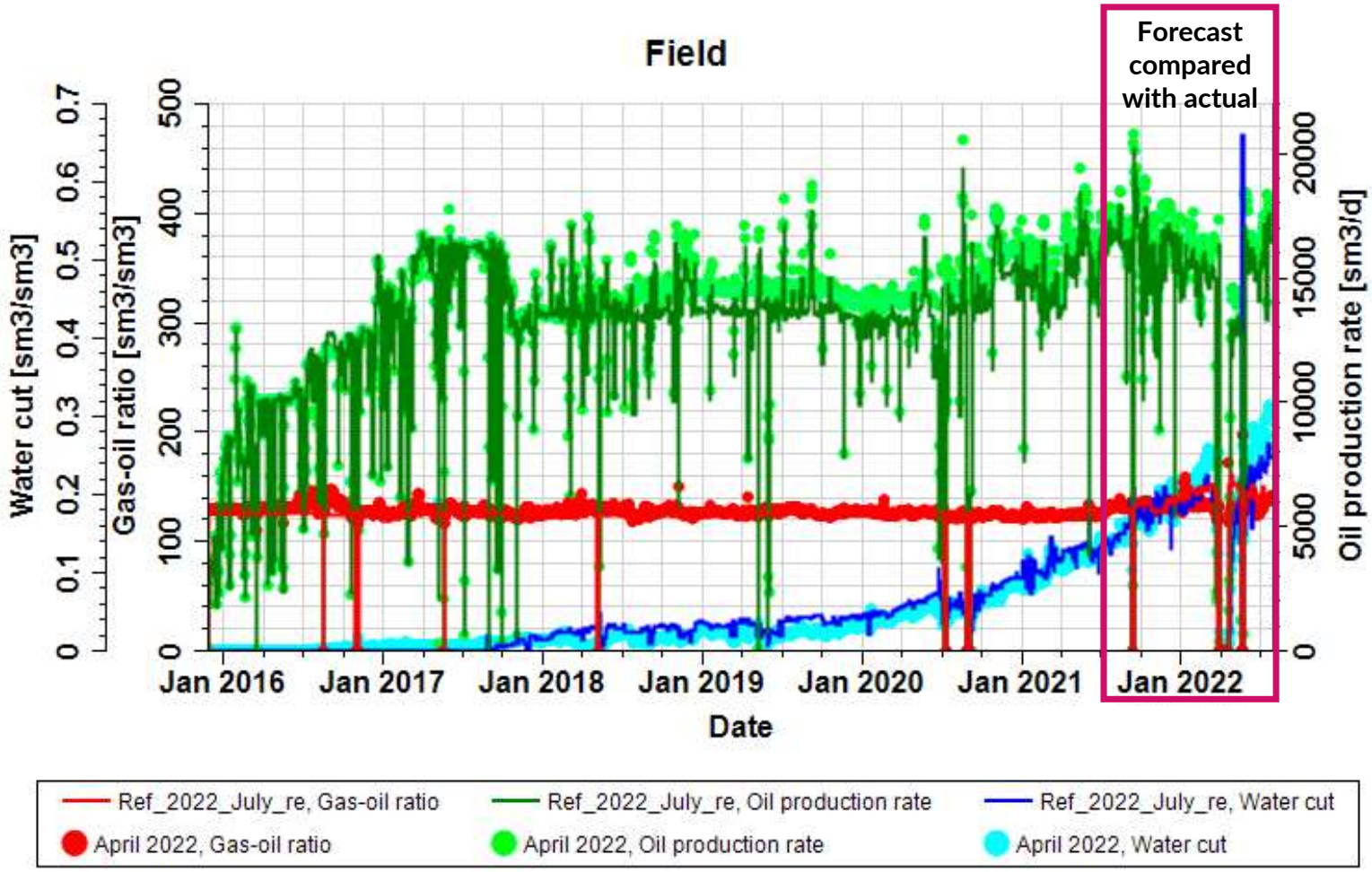
POSTERIOR | 4D





Δ (Posterior – Prior)

Has the predictability improved?

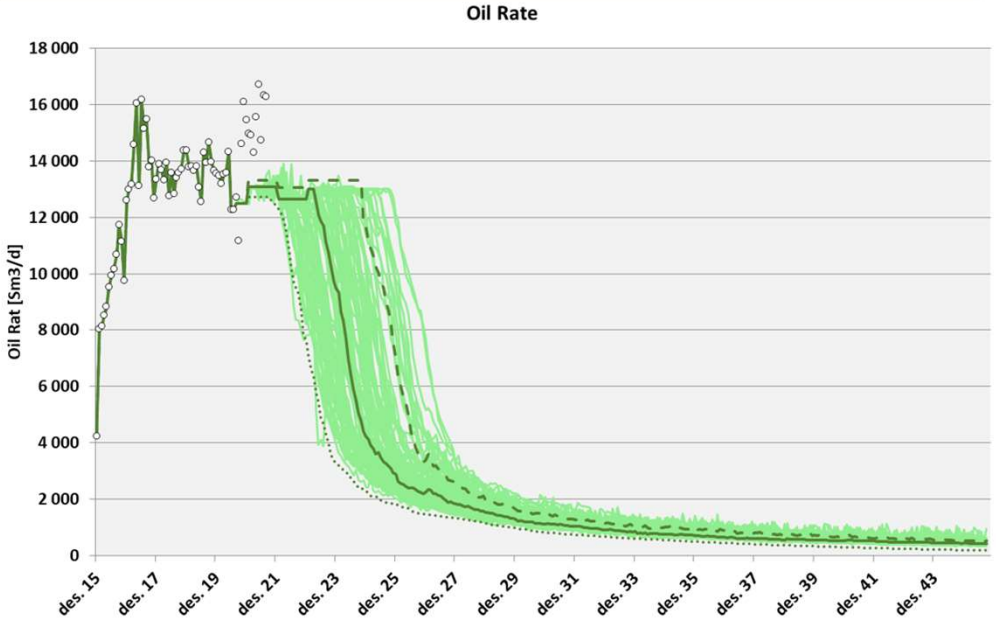


History Matched Ensemble | usage

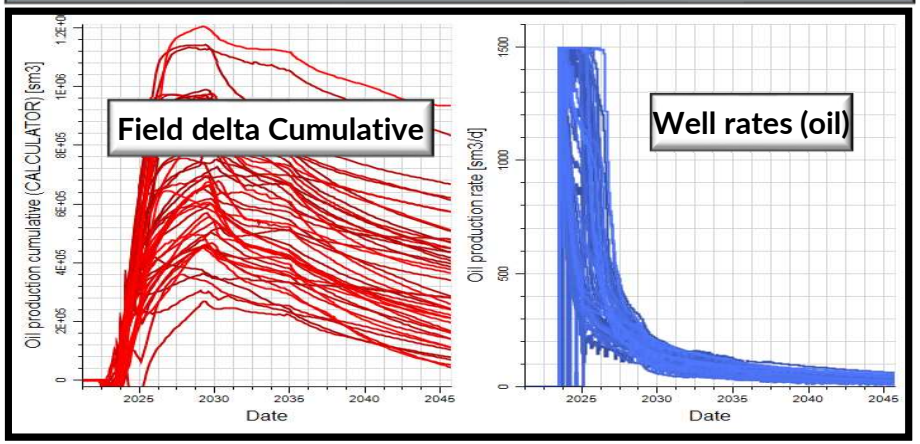
Predictability ;

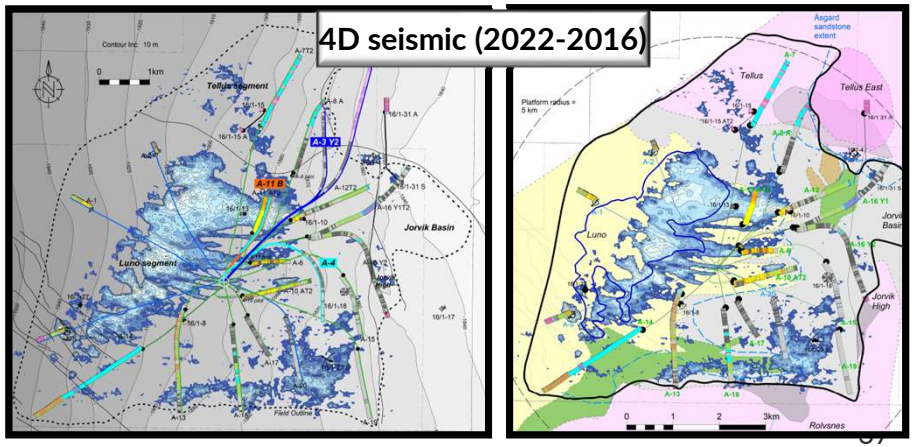
➔ Plateau length?

➔ Best timing for infill wells and tie-ins?



Infill wells planning





Summary

Assisted History Match on top of deterministic concepts has lead to higher confidence in the reamining reserves estimate (EUR, plateau length)

	Deterministic RefCase - BTE model	**Assisted HM** - Based on one concept	**'Ensemble of Ensemble'**
Pros	• (Dynamic) reservoir understanding • Communication	• Improved HM all wells • Ensemble of history matched models (not only 1 model)	• **Maintain consistency to established reservoir understanding (concepts)** • Increased uncertainty span • Improved predictability • Pragmatic! • Re-use 'Petrel Infrastructure' between concepts (e.g. updated structure)
Cons	• Uncertainty assessment • HM challenging	• Narrow uncertainty span	• Weighting between ensembles? • Cost (simulation time)

Thank you for your attention!

- and thanks to the Edvard Grieg subsurface team for great teamwork;

Kristian Eide-Engdahl
Geir Magnus Sæternes
Henrik Lundin
Magne Døsland
Jamie Good Quin
Knut Richard Straith
Camilla Akcora
Svein Erik Foyn
Abel Onana Ndingwan
Odd Kolbjørnsen
Jon Andre Haugen
Sanaz Javid
Gäel Chaupin
Tore Flikka
Odd Aasheim
Arnstein Kvilhaug
Solveig Sæl

And thanks to:
Partners, OMV and WintershallDea
And to Resoptima for a lot of support

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