Outils Numériques pour les Géosciences ONG-2025
11 avril 2025 - Montpellier, CEMD

Understanding the Groningen field using Geoscience Stress Modeling

Dr Nick Koutsabeloulis
nick@geomexgroup.com

Dimitri D'Or
dimitri.dor@ephesia-consult.com

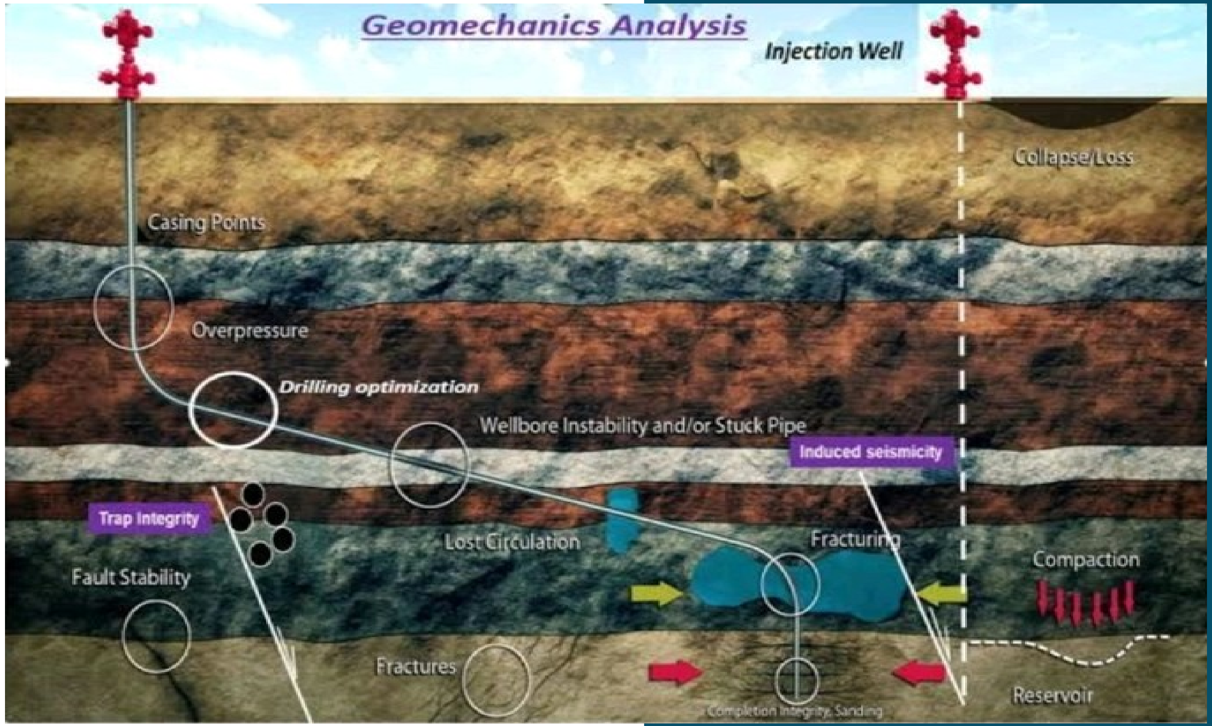
Philippe Pluyaud
philippe.pluyaud@ephesia-consult.com

Geomex Software Solutions

Ephesia Consult

AREAS OF APPLICATION AND IMPLEMENTATION

- Exploration/Appraisal assessment
- Drilling assessment/trajectory design
- Field Development Planning (FDP)
- Production improvement/risk reduction
- **CCS asset performance**
- **Storage asset integrity**
- **Geothermal asset integrity**

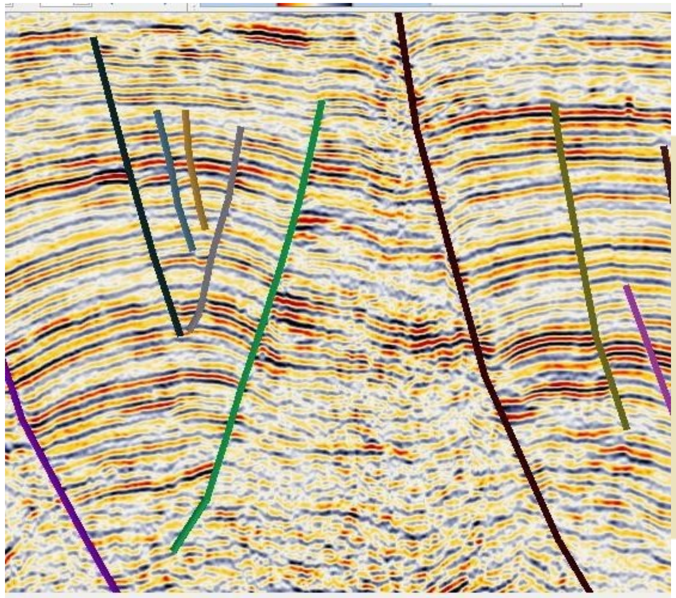


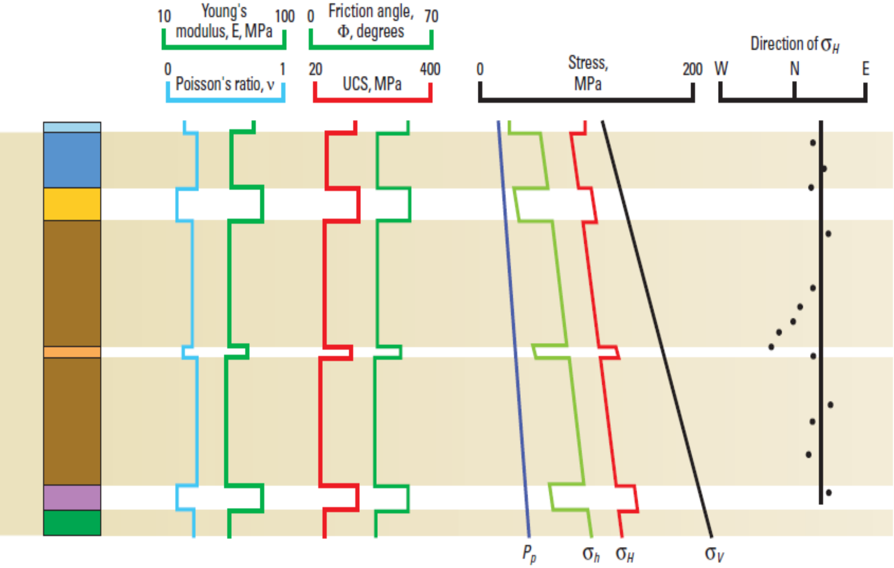
HIGH-RESOLUTION METHOD FOR GSM

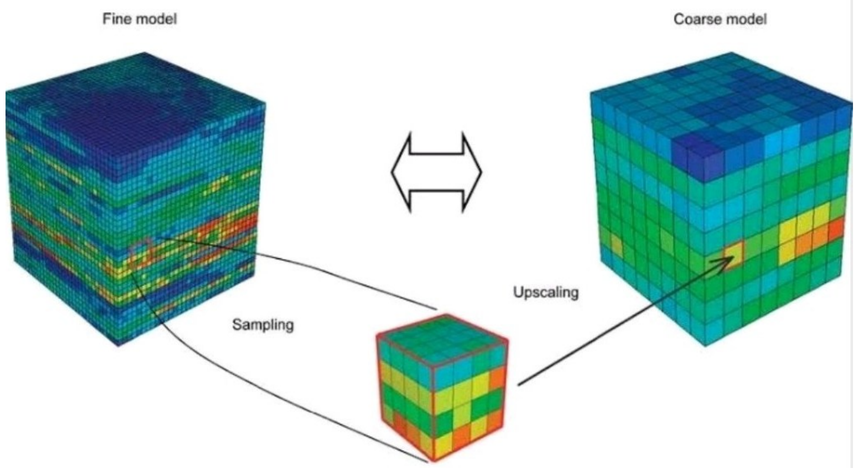
3-D High Resolution

1-D Sonic Resolution

Grid Resolution







Seismic Data

Stratigraphy

1-D MEM

GRONINGEN FIELD OVERVIEW

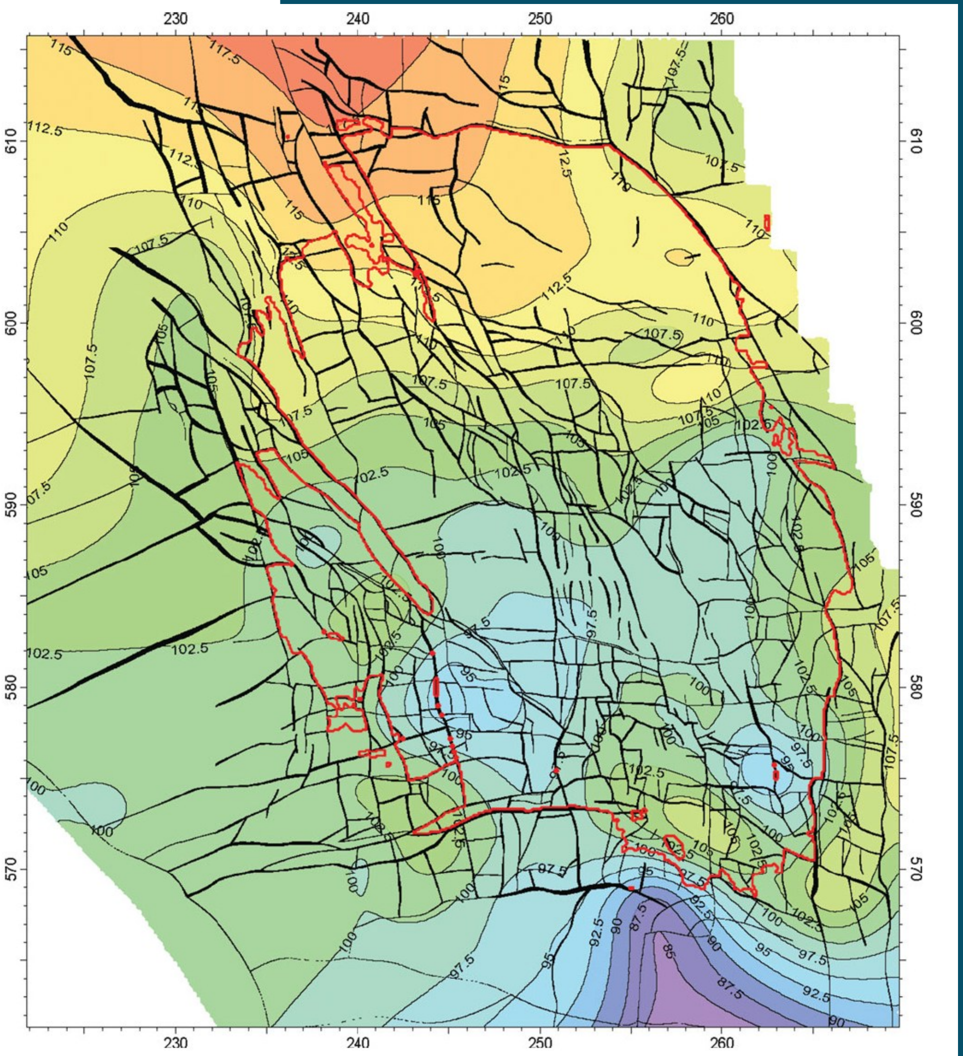
The Groningen gas field was a natural gas field in the Groningen province at the north-eastern part of The Netherlands.

With an estimated 2,740 billion m^3 of recoverable natural gas, it was the largest natural gas field in Europe and one of the largest in the world.

The gas field was discovered in 1959.

Gas extraction resulted in subsidence above the field. From 1991, this was also accompanied by earthquakes, which led to damage to houses and unrest among residents. It was decided to phase out gas extraction from 2014 onwards.

https://public.yoda.uu.nl/UU01/1QH0MW.html

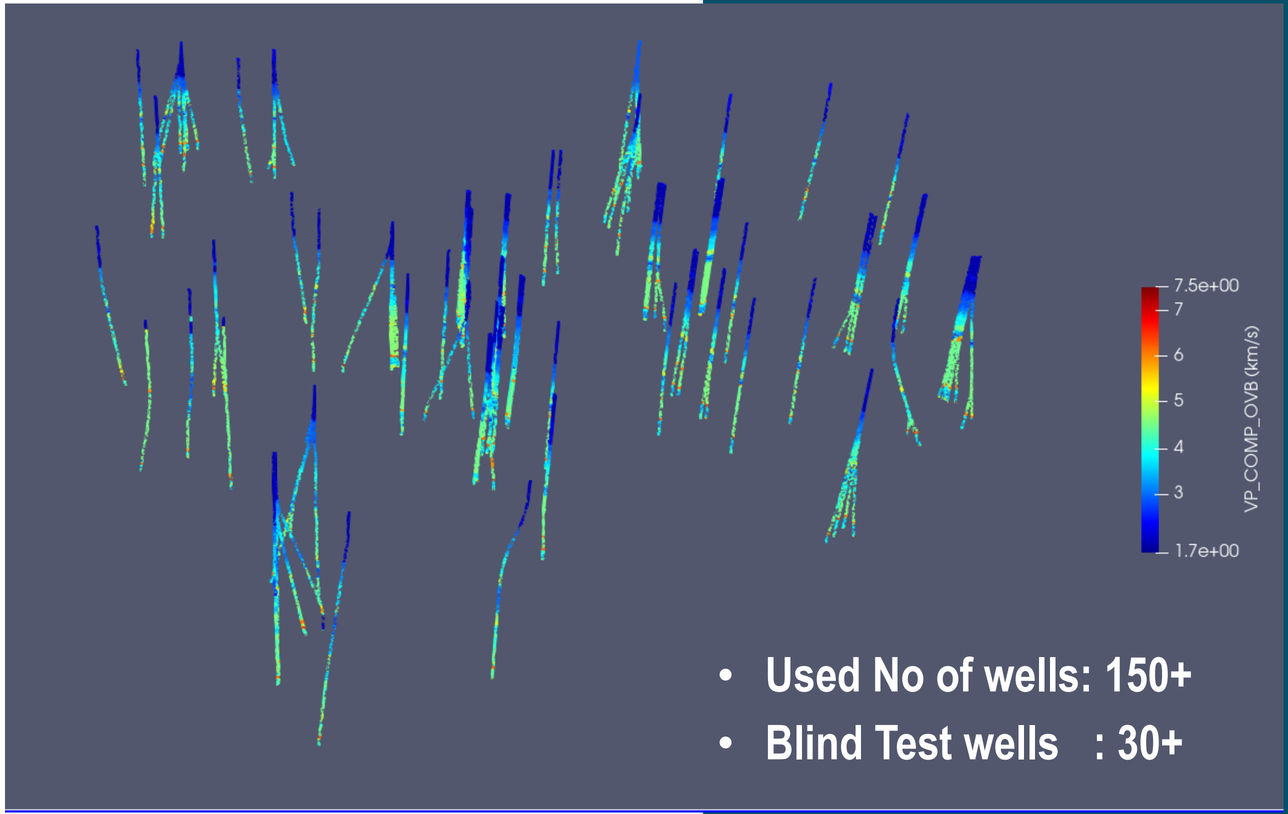


1st STEP: GEOSTATISTICAL MODELLING

- ✓ Use Sonic Data – Sparse Modelling
- ✓ Use Seismic Data – Dense Modelling
- ✓ Create Sparse and Dense Variograms
- ✓ Create CrossVariogram
- ✓ Perform Kriging/Cokriging
- ✓ Generate Seismic Cube

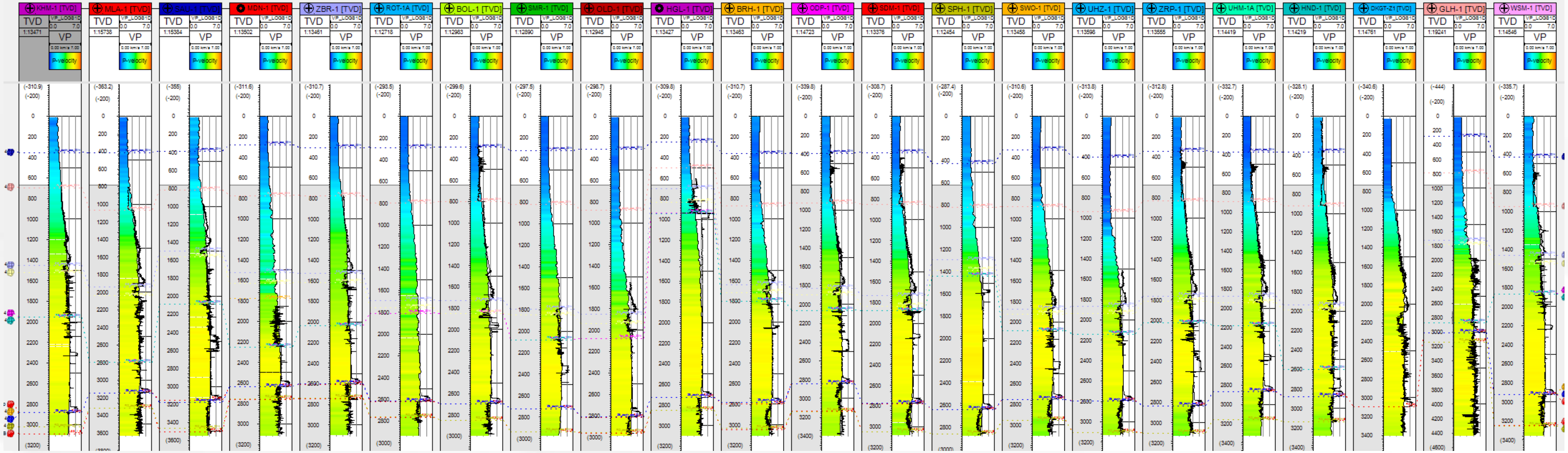
Generated Model

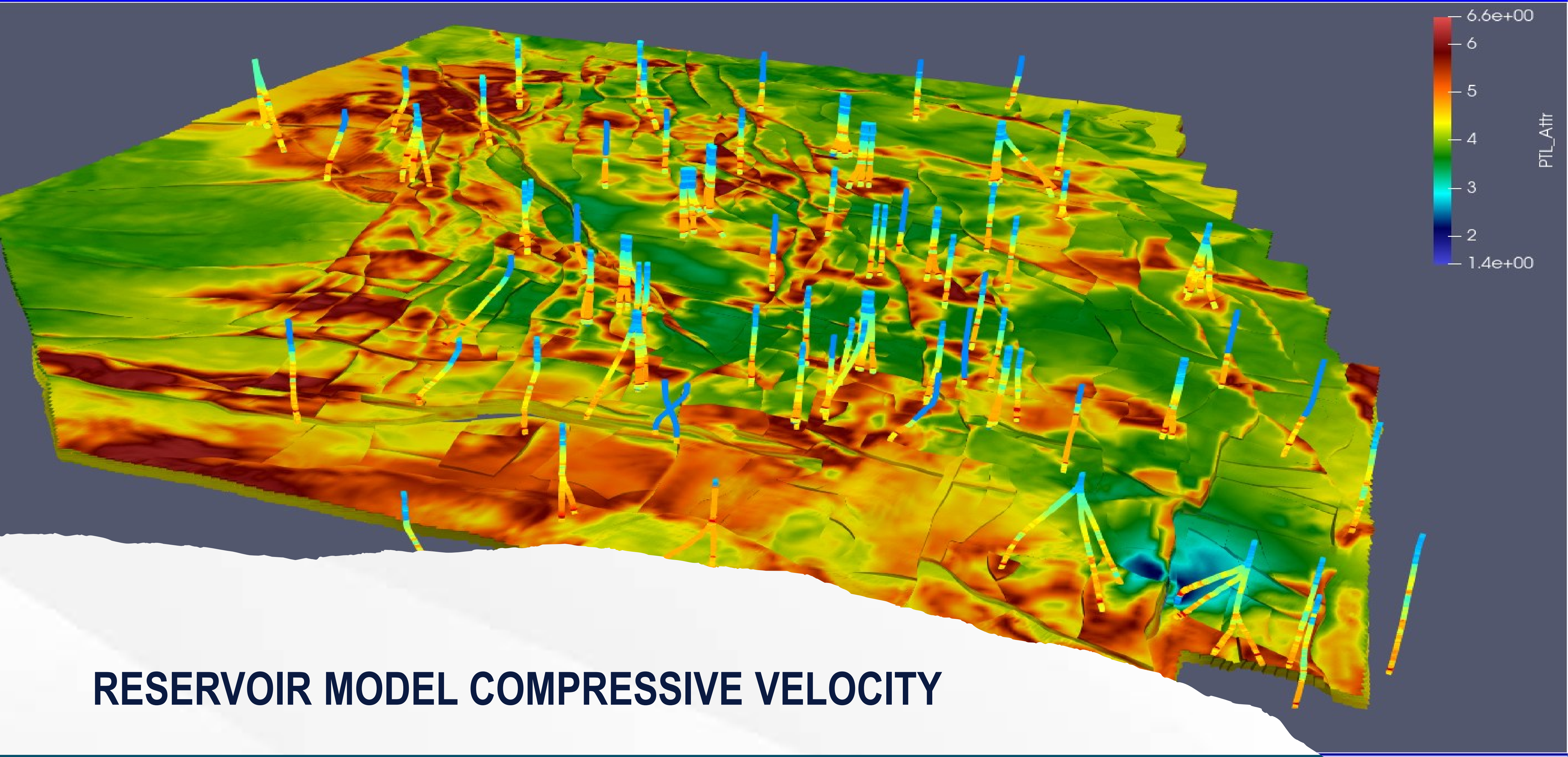
- Resolution: 60x60x10m
- Size: 550+M cells



- **Used No of wells: 150+**
- **Blind Test wells : 30+**

GEOSTATISTICAL SOLUTION – SONIC DATA COMPARISONS

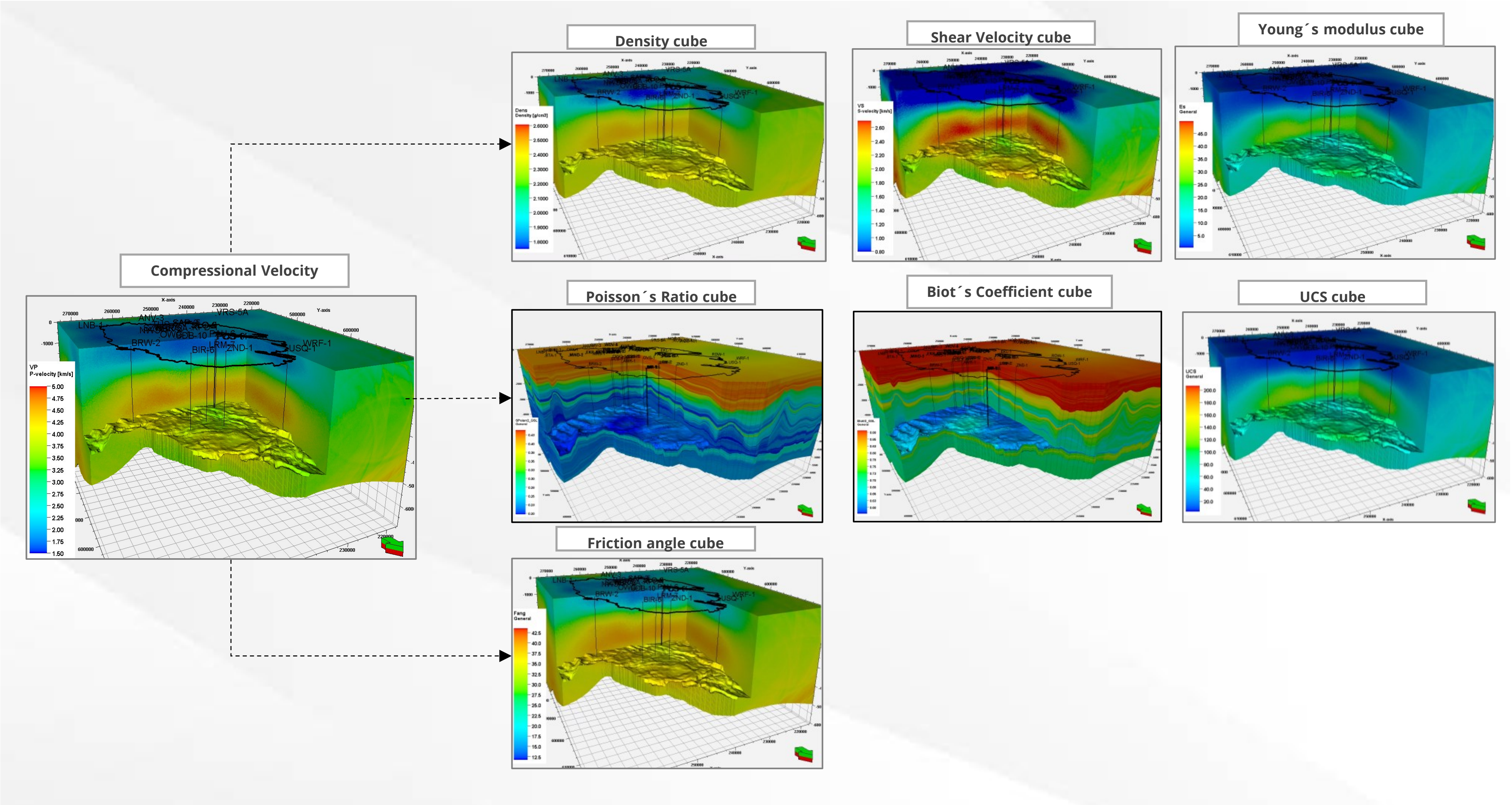




RESERVOIR MODEL COMPRESSIVE VELOCITY

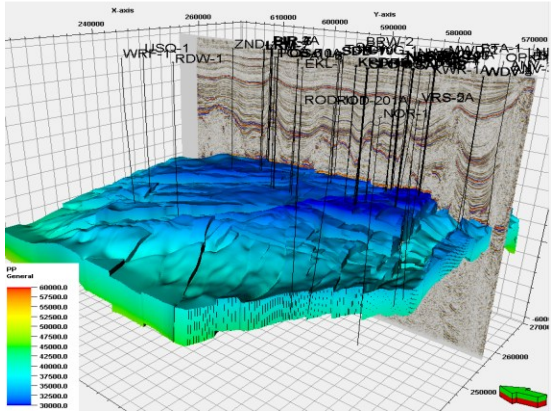
ANALYTICAL SOLUTION

ANALYTICAL SOLUTION – MECHANICAL & STRENGTH PROPERTIES

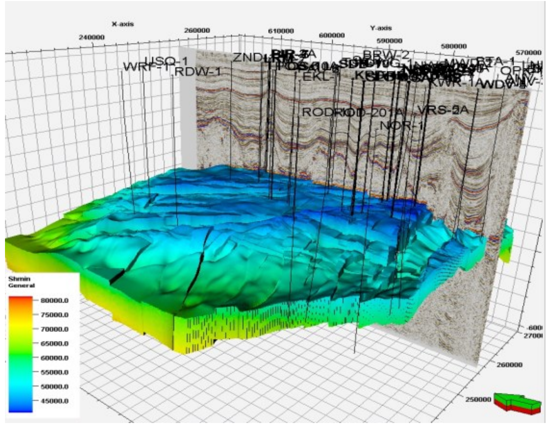


ANALYTICAL SOLUTION – PORE PRESSURE, STRESS & DRILLING GRADIENTS

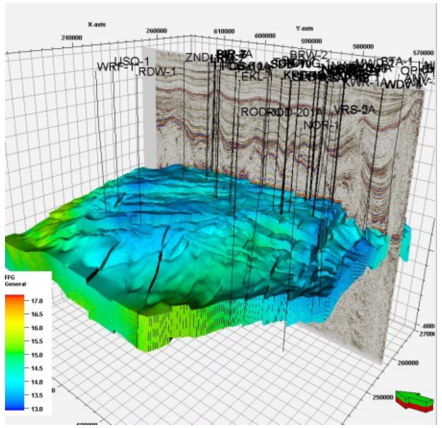
Pore pressure prediction



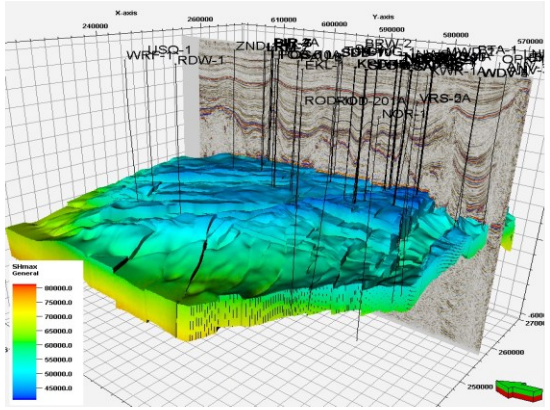
Minimum Horizontal stress



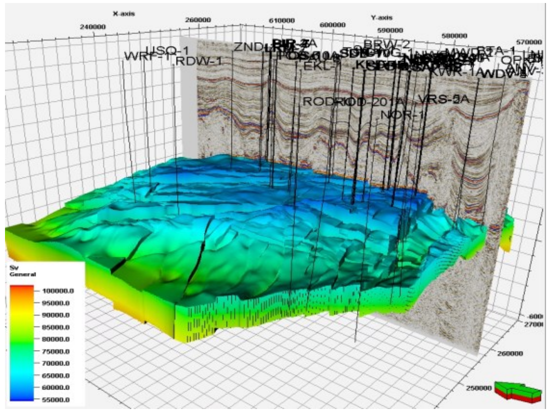
Fracture gradient



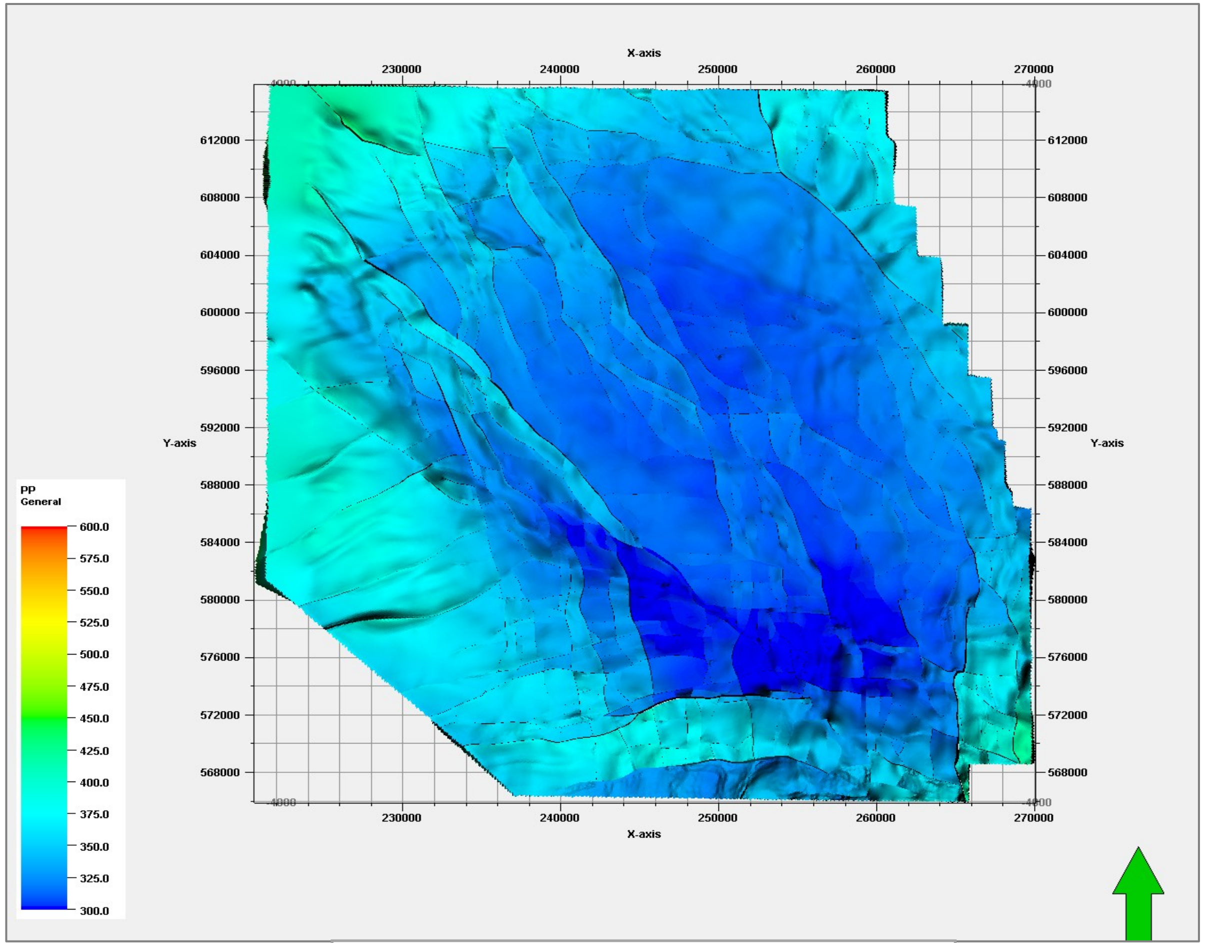
Maximum Horizontal stress



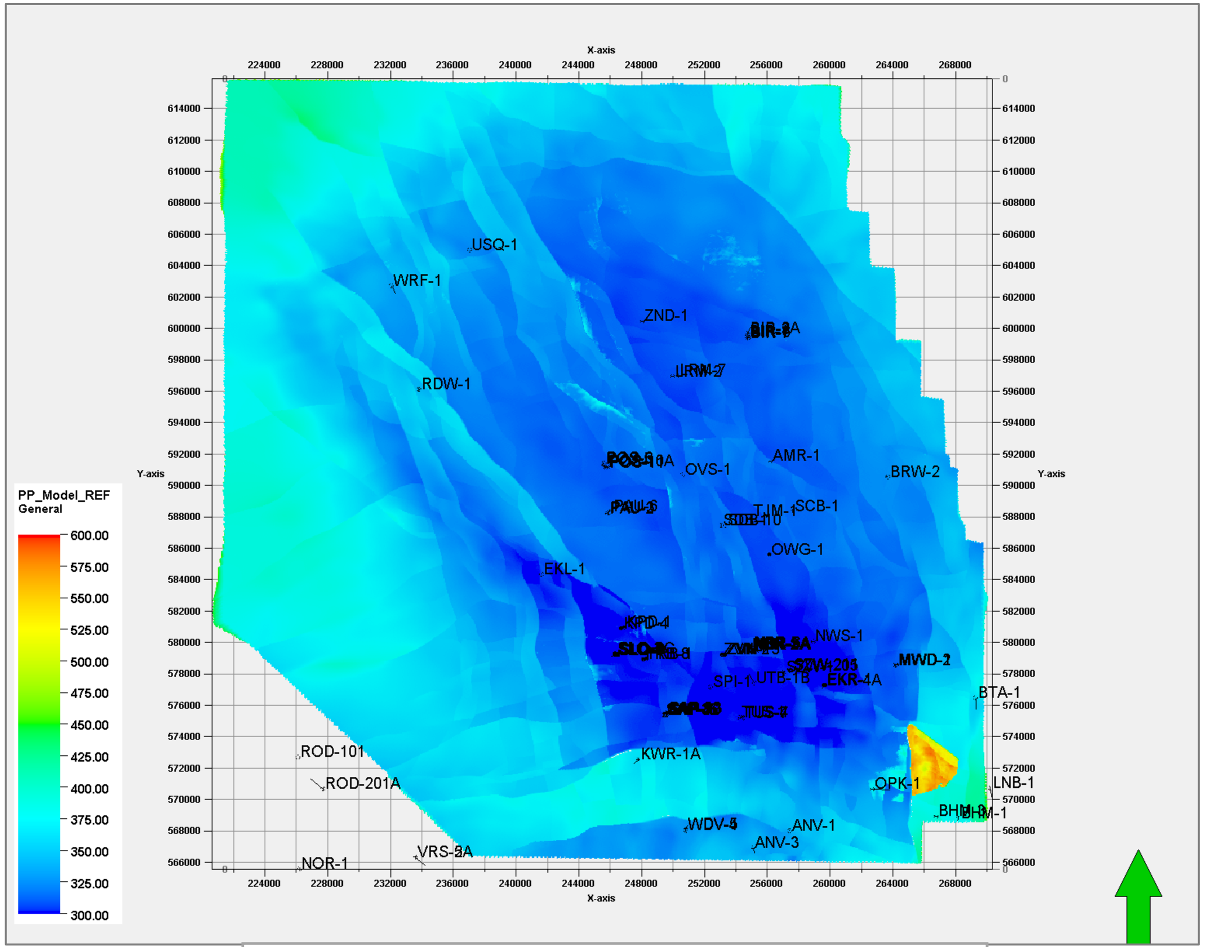
Overburden stress



RESERVOIR PORE PRESSURE PREDICTION



Pore pressure predicted volume [Bar]

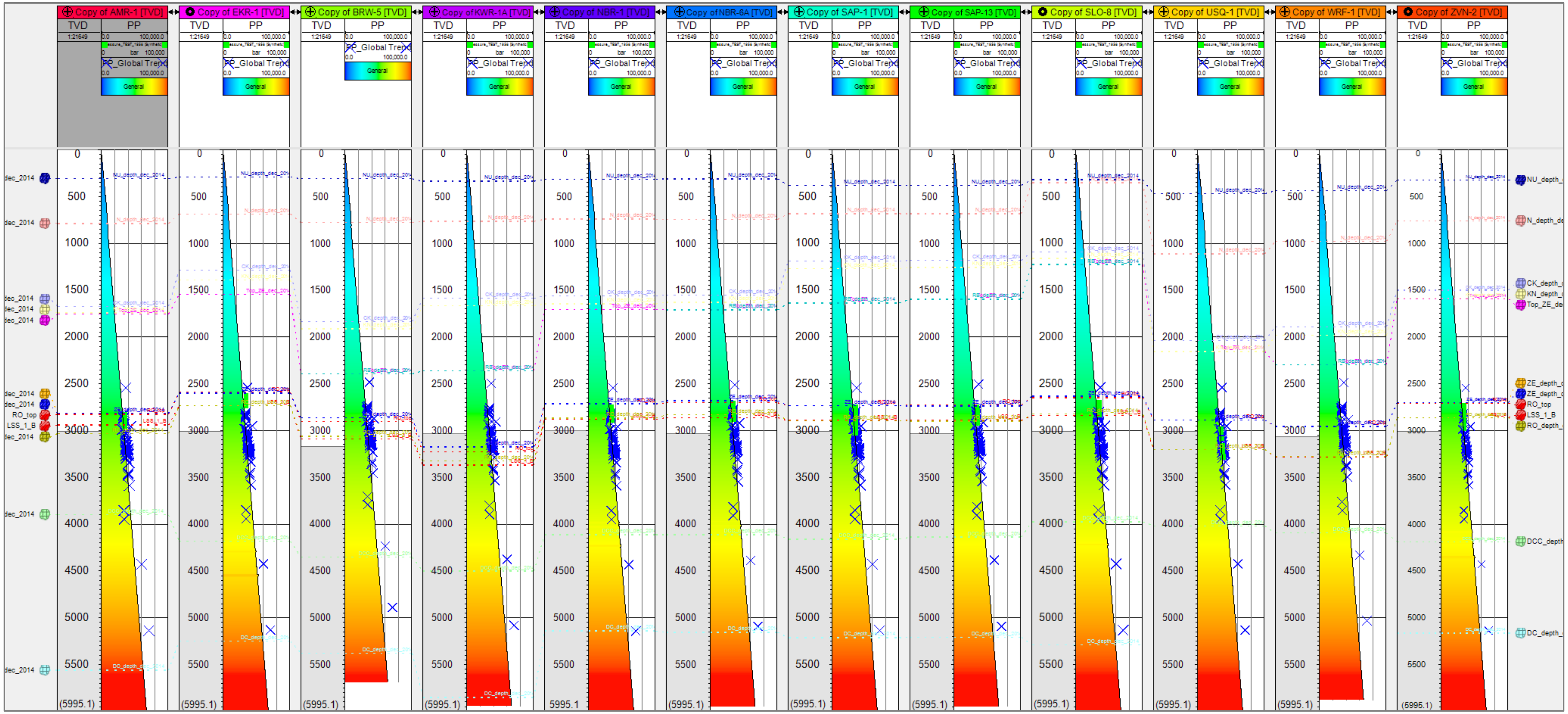


Pore pressure reference model for 1958 [Bar]

PORE PRESSURE PREDICTION REVIEW

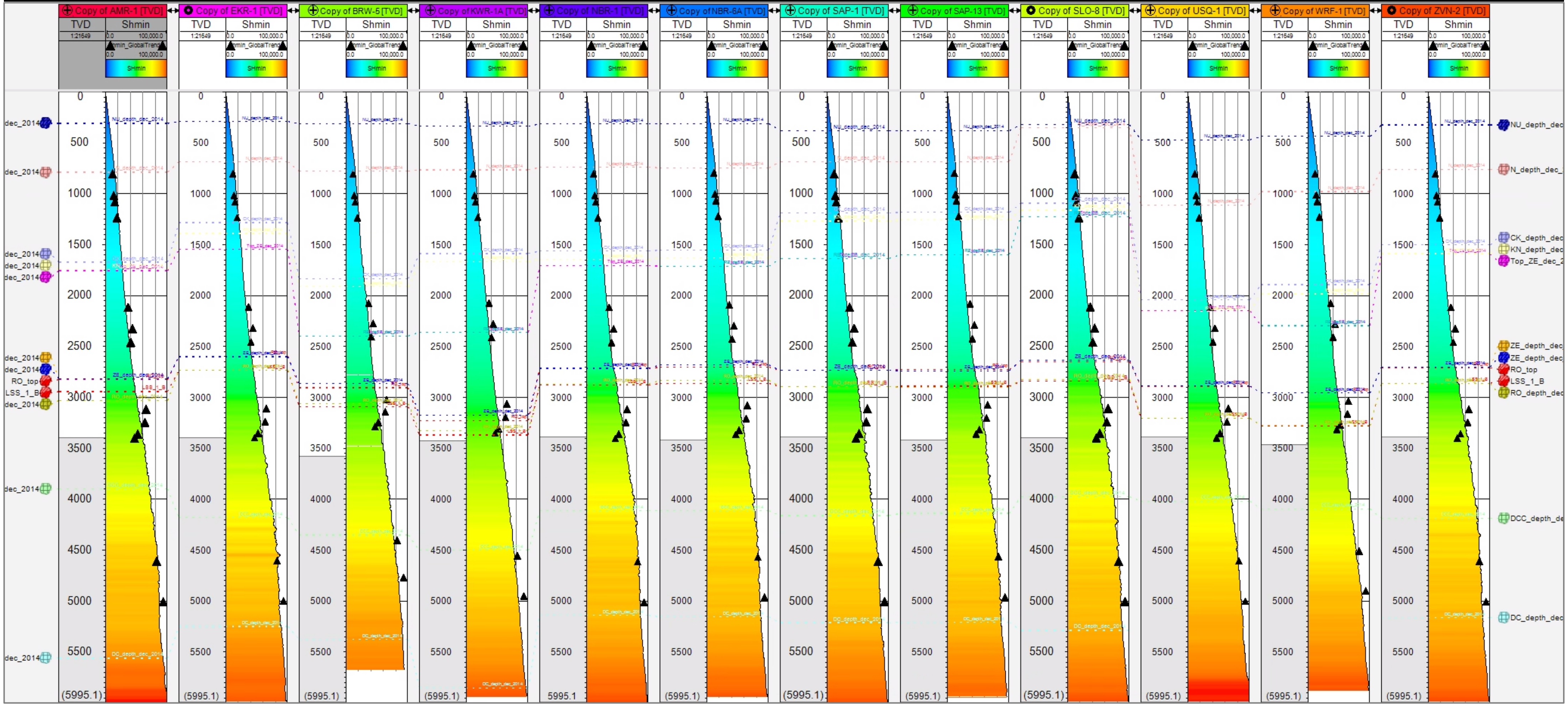
Blue crosses denote data from global database – same data replicated in each well for trend validation

Green squares correspond to modelled pressure data for the field. Difference between modelled and measured is ± 10%.



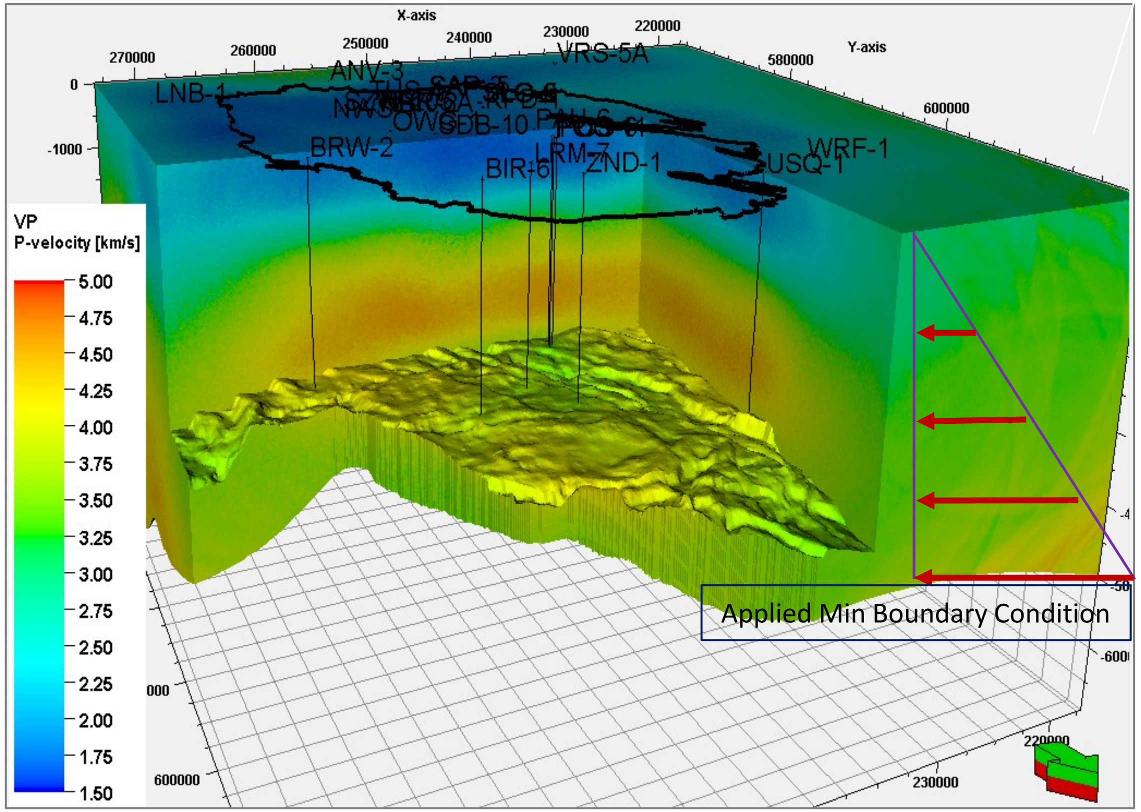
Shmin PREDICTION REVIEW

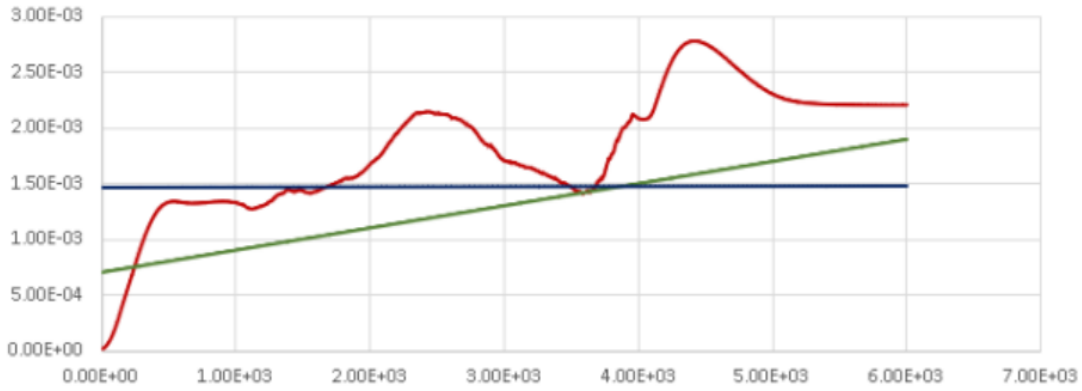
Black triangles denote data from global database – same data replicated in each well for trend validation



NUMERICAL SOLUTION

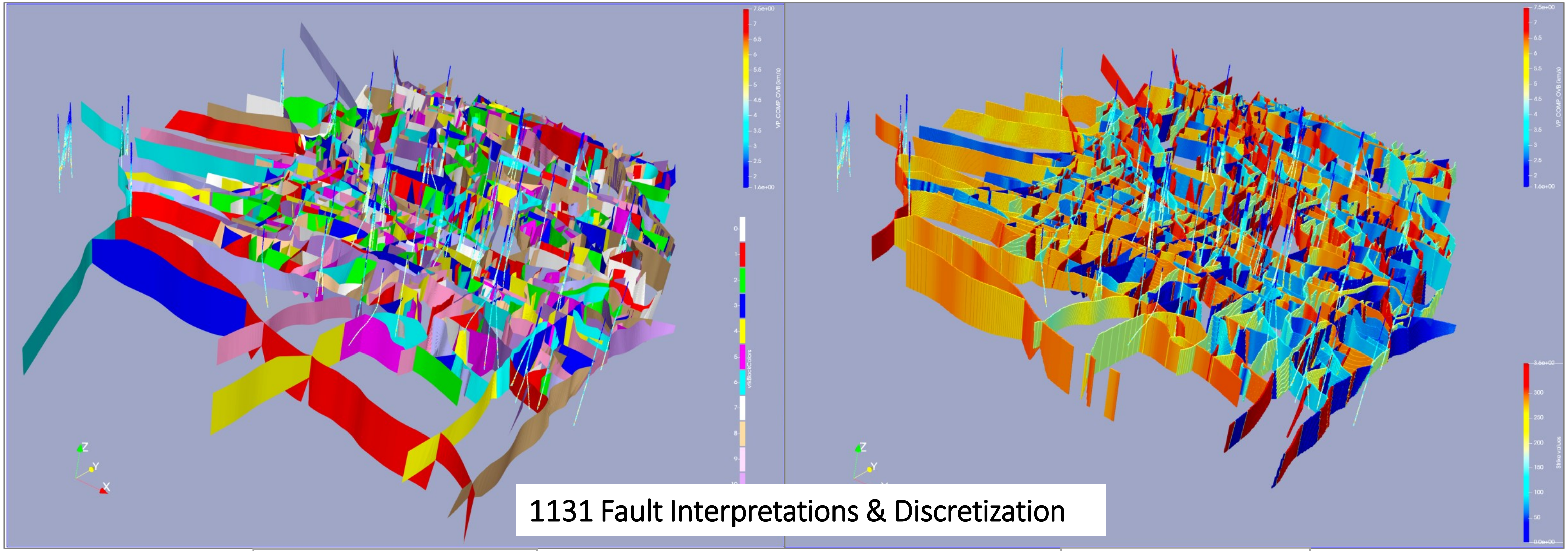
NUMERICAL MODEL BOUNDARY CONDITIONS - APOLLO





- Resolution: 60x60x10m
- Size: 550+M cells
- No. of Differential equations: 1.6+B
- No. of Integration Points: 4.4+B

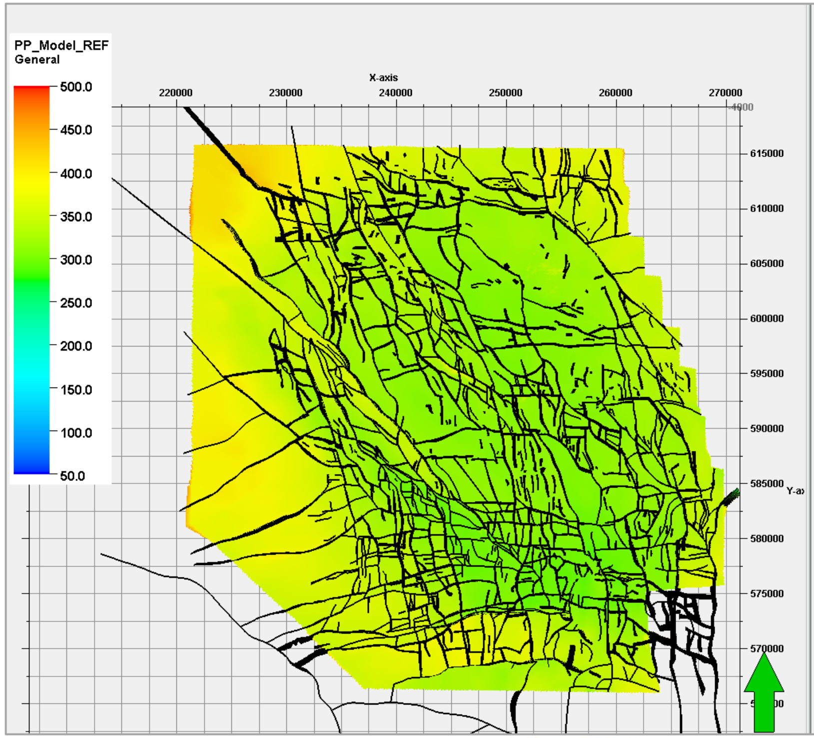
NUMERICAL MODELLING OF FAULTS USING EDFM



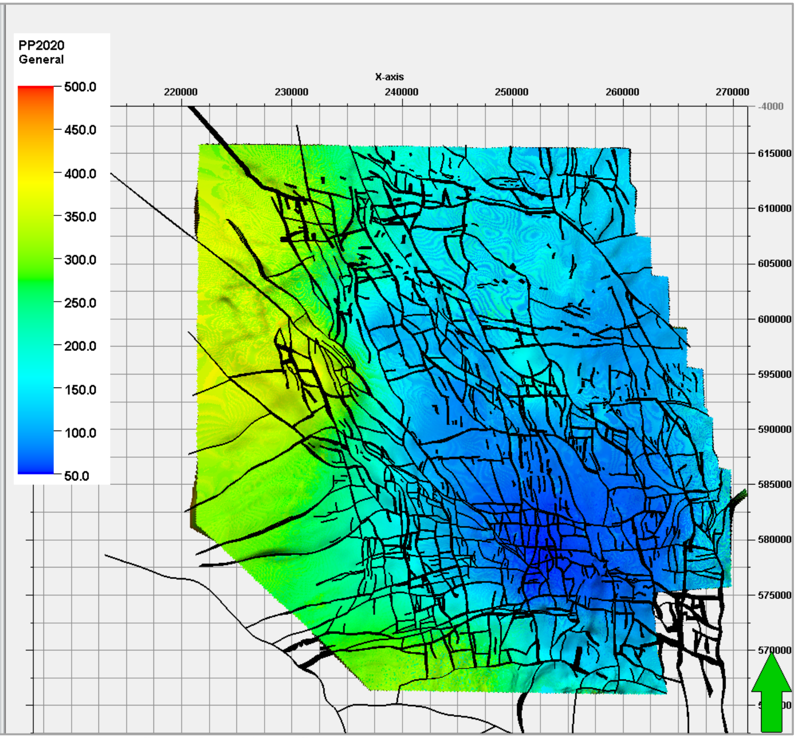
Fault surfaces definition

Fault discretization

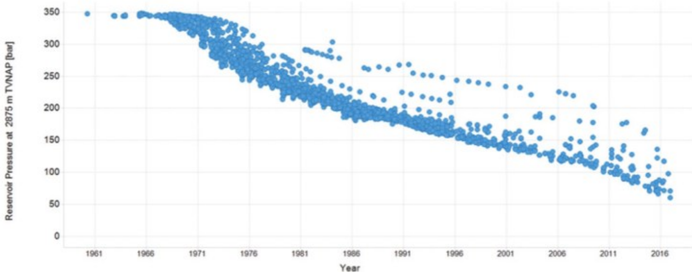
NUMERICAL SOLUTION – 4-D PRODUCTION PRESSURES



1958 Pressure at Reservoir Top



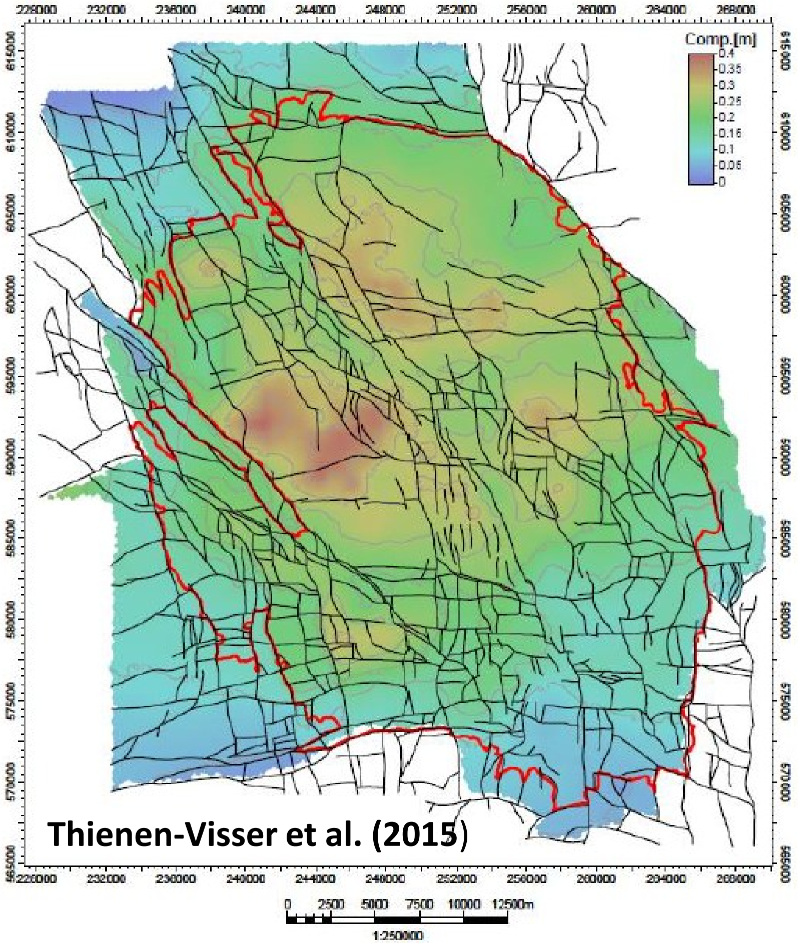
2020 Pressure at Reservoir Top



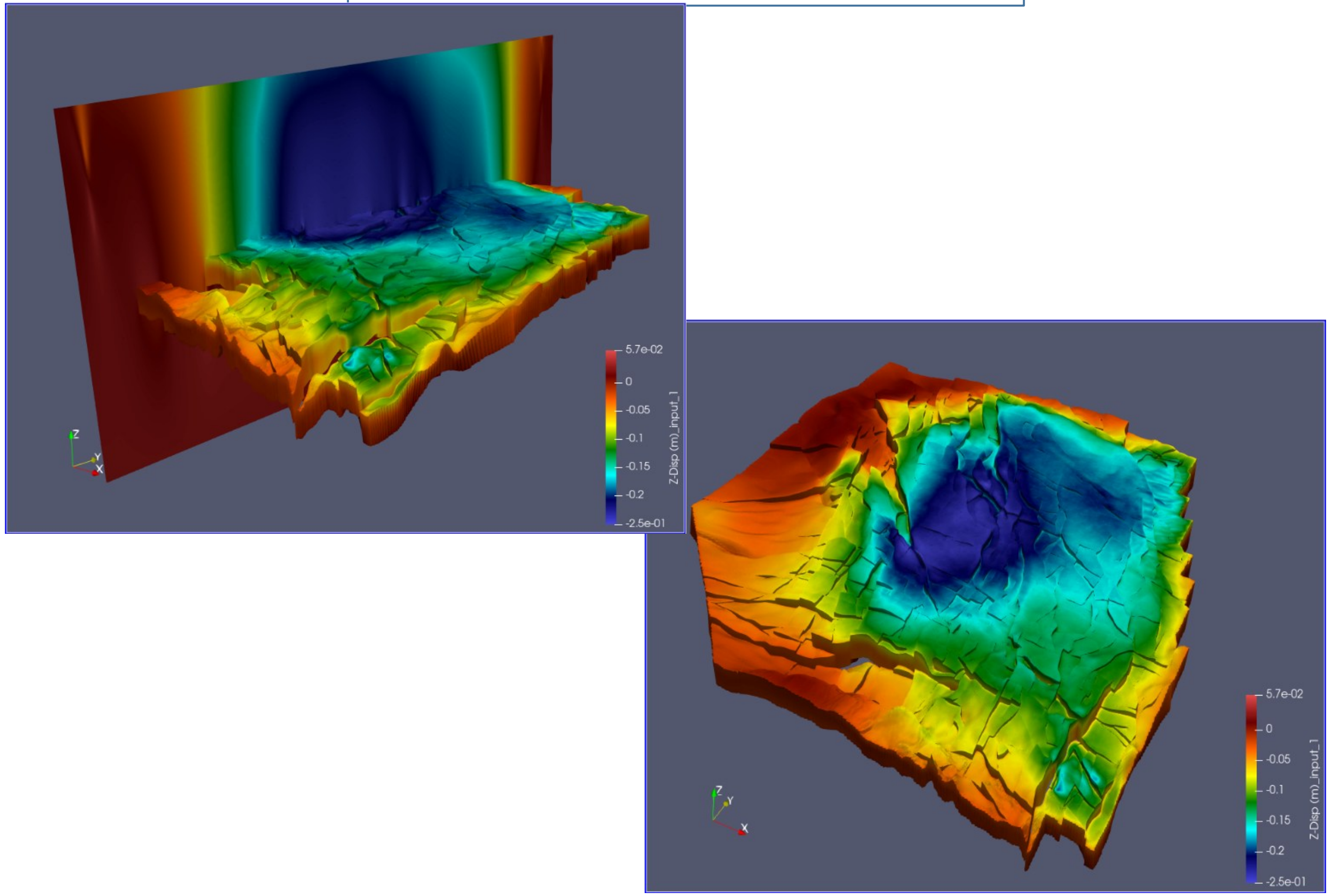
van Oeveren et al. (2017)

NUMERICAL SOLUTION – COMPACTION & SUBSIDENCE (m)

Interpreted compaction from Subsidence

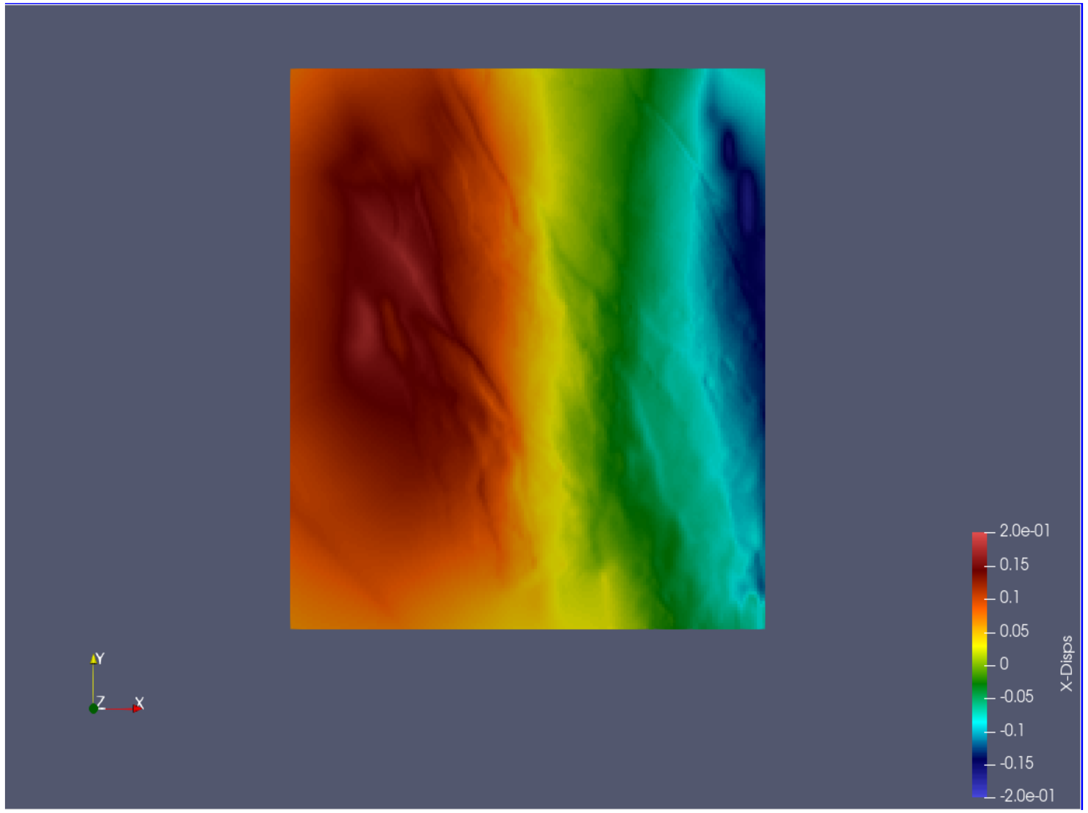


Computed Compaction & Subsidence

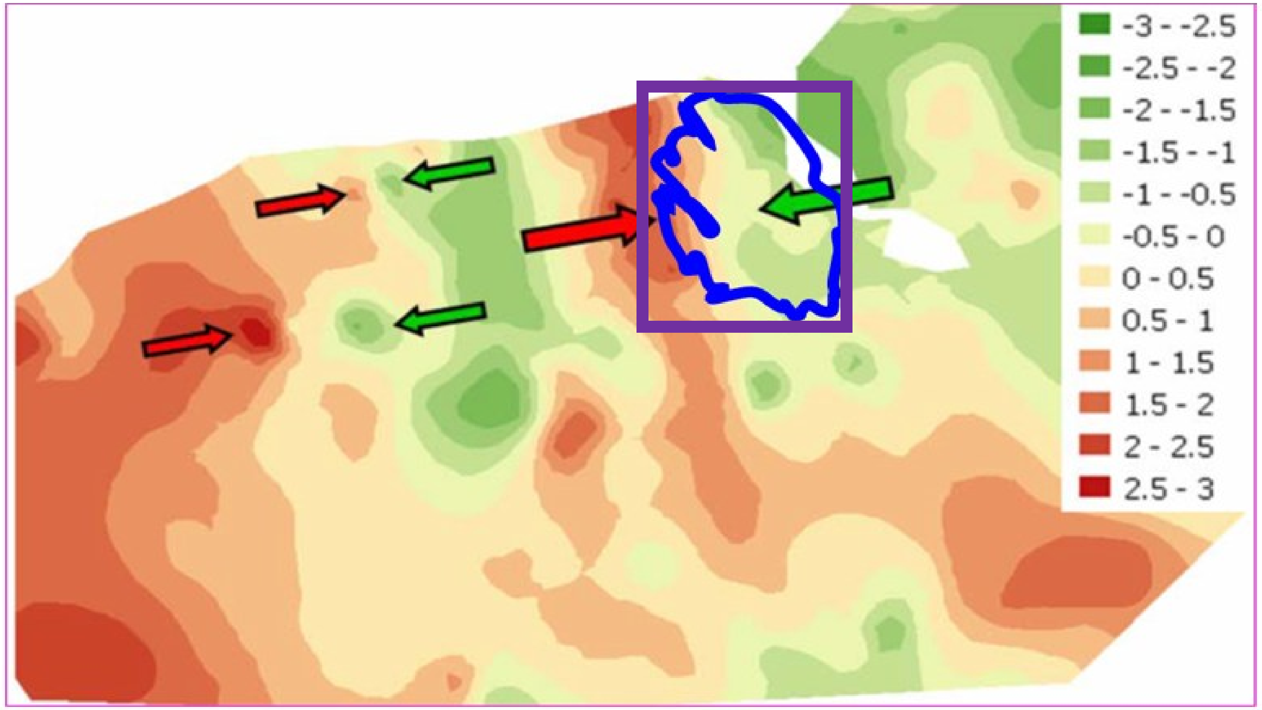


NUMERICAL SOLUTION – RESERVOIR E-W HORIZONTAL DEFORMATION

Predicted Horizontal Deformation (Av 2.9 mm/y)

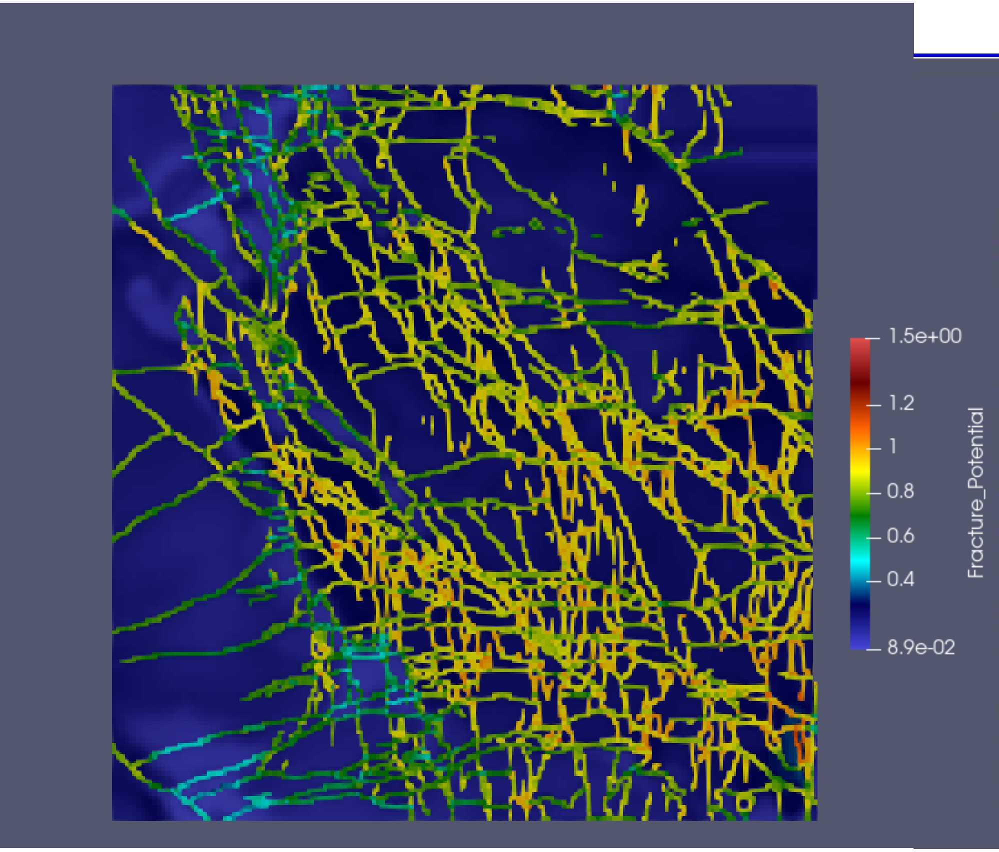


InSAR Observed Horizontal Deformation (mm/y)

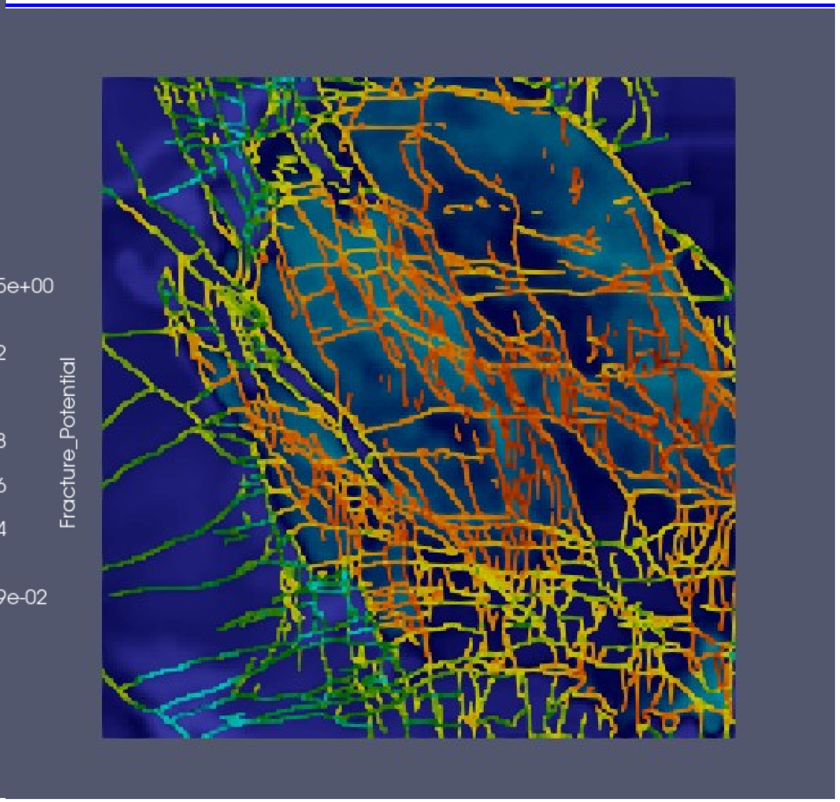


NUMERICAL SOLUTION – 4-D PRODUCTION SOLUTION/CALIBRATION

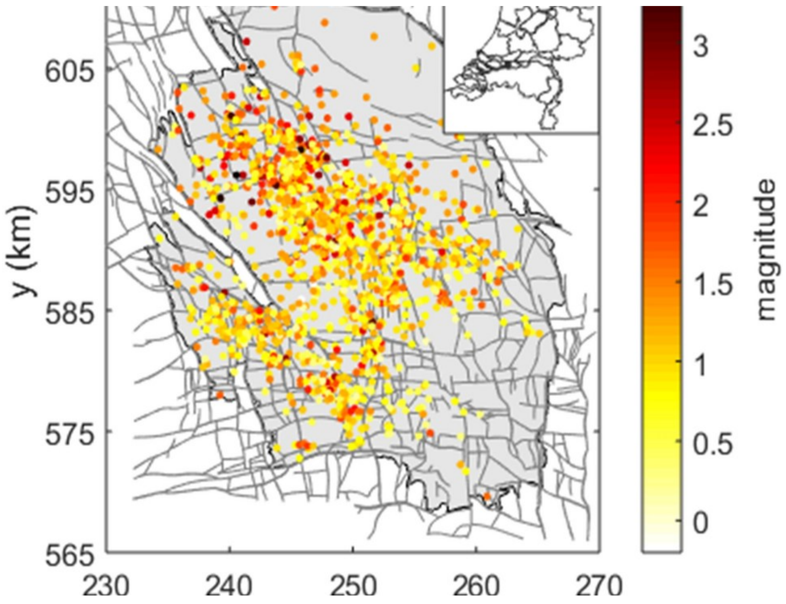
3-D Fracture Potential Attribute



4-D Fracture Potential Attribute



Seismicity Monitoring



RECOMMENDATIONS

Perform a study with:

- ✓ Seismic data
- ✓ Sonic data
- ✓ Core data and measurements
- ✓ Drilling information from existing wells
- ✓ Geological interpretations (Faults and/or DFNs)
- ✓ Reservoir Model with Pressures and/or Temperatures with time