

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

Understanding the Groningen field using Geoscience Stress Modeling

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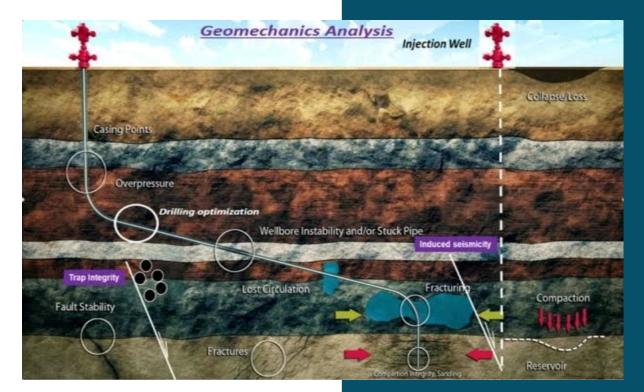
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Ephesia Consult

AREAS OF APPLICATION AND IMPLEMENTATION

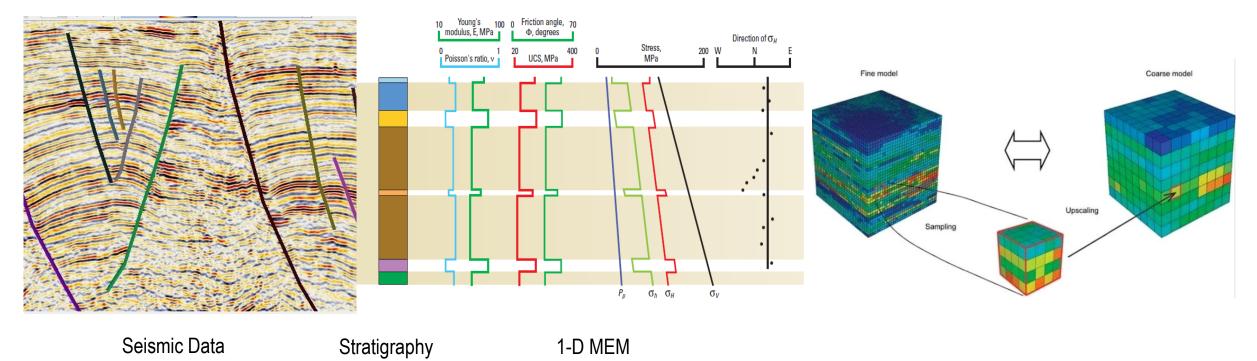
- Exploration/Appraisal assessment
- Drilling assessment/trajectory design
- Field Development Planning (FDP)
- Production improvement/risk reduction
- CCS asset performance
- Storage asset integrity
- Geothermal asset integrity





HIGH-RESOLUTION METHOD FOR GSM

3-D High Resolution



1-D Sonic Resolution

Grid Resolution



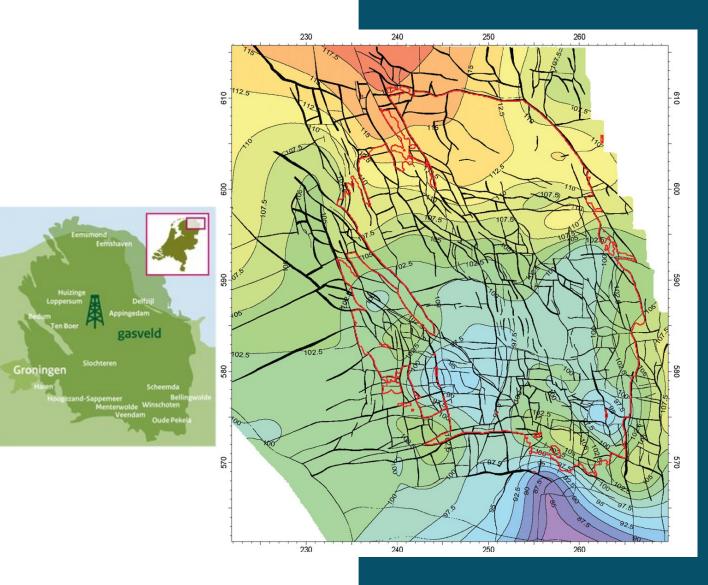
GRONINGEN FIELD OVERVIEW

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 m³ 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



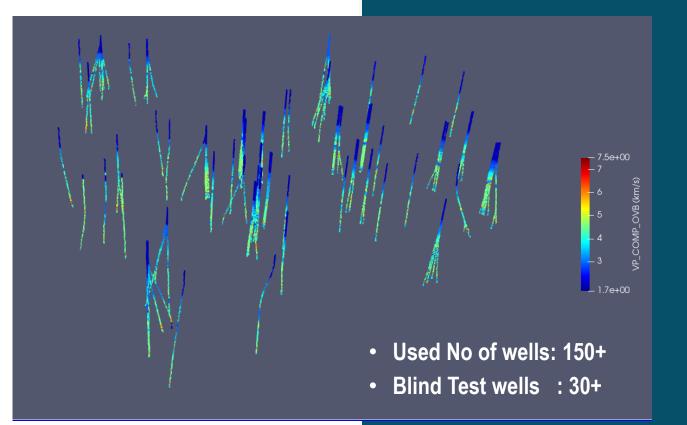


1st STEP: GEOSTATISTICAL MODELLING

- ✓ 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





GEOSTATISTICAL SOLUTION – SONIC DATA COMPARISONS

WHM-1 TVD TVD 0.0 7 1.13471 VP 200 km = 7.1 Scot km = 7.1 P-velocity	CONTENDED CONTENDED	SAU-1 ITVD TVD 00 7.0 1:15384 VP 0.0 7.0 0:00 km/s 7.00 0.00 km/s 7.00 0.00 km/s 7.00 0.00 km/s 7.00	MDN-1 [TVD] TVD VP_L00810 0.0 7.0 1:13502 VP 2.00 km/s 1.00 P-veocity	TVD VP_LOGE1 1:13451 VP 0.0 7: 1:13451 VP 0.00 7: 1:10401 VP 0.00 7: 1:10401 VP 0.00 7: 1:10401 VP 0.00 7: 1:10401 VP	Contraction Contracti	1:12983 VP	SMR-1 [TVD] TVD VP_L00810 1:12890 VP 0.00 7.00 VP 0.00 km/s 7.00 VP 0.00 km/s 7.00 P-Velocity	OLD-1 ITVD TVD VP_LO381C 1:12945 VP 0:0 7:0 0:0 7:0 0:0 7:0 0:0 7:0 0:0 7:0 0:0 7:0 0:0 7:0 0:0 7:0 0:0 7:0 0:0 7:0 0:0 7:0 0:0 0:0 0:0 0:0	HGL-1 [TVD TVD 1:13427 VP 0.0 7.0 VP_L00811 0.0 7.0 VP 0.0 km is 7.00 P-veocity	BRH-1 [TVD] D BRH-1 [TVD] VP_L06810 1113463 VP 000 km/s 1.00 P-velocity	ODP-1 [TVD] TVD VP_L038 TVD 0.0 7 1:14723 VP 0.0 km/s 7.6 Particular 2.6 Partic	1:13376 VP	0.0 7.0 1:12454 VP	SW0-1 [TVD] TVD 0.0 7.0 1:13458 VP 0.0 7.0 2:00 km/s 7.00 9.00 9.00	UHZ-1 TVD TVD 0.0 7.0 1:13598 VP 0.0 0.0 0:00 km/s 7.00 0.00 km/s 7.00 9:00 km/s 7.00 0.00 km/s 7.00		UHM-1A [TVD] TVD 0.0 7.0 1:14419 VP 0.0 7.0 0:00 km/s 7.00 0.0 7.00 1:14419 VP 0.00 km/s 7.00 0:00 km/s 7.00 0.00 km/s 7.00	HND-1 [TVD] TVD VP_LOGS10 1:14219 VP 0.00 mm 1.00 P-velocity P-velocity	OKGT-21 [TVD] TVD VP_LO3810 1:14761 VP 0.00 7.0 0.00 7.0 1:14761 VP 0.00 km = 1.00 0.00 km = 1.00 P-verocity P-verocity	CLH-1 [TVD] TVD VP_LO3810 1:19241 VP 0.0 7.0 1:19241 VP 0.0 800 km 1.00 Pueboty	WSM-1 [TVD] TVD VP_L00815 0.0 7.0 1:14546 VP 0:00 km/s 1:00 PL/VEOCTY
(-310.9) (-200)	(-363.2) (-200) 0	(-355) (-200) 0	(-311.6) (-200) 0	(-310.7) (-200) 0	(-293.5) (-200) 0	(-299.6) (-200) 0	(-297.5) (-200) 0	(-298.7) (-200) 0	(-309.8) (-200) 0	(-310.7) (-200) 0	(-339.8) (-200) 0	(-308.7) (-200) 0	(-287.4) (-200) 0	(-310.6) (-200) 0	(-313.8) (-200) 0	(-312.8) (-200) 0	(-332.7) (-200) 0	(-328.1) (-200) 0	(-340.6) (-200) 0	(-444) (-200) 0	(-335.7) (-200)
200 4 49	200 ** 400	200 · · · 400 · · · · · · · · · · · · · ·	400	400 600	400	200 400	200 400	400	400	200 400 600	200 1400	200	200 **	400	200	400	200 	200 400 600	400	400 600 800	1. 200 400
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	2200 2400 2500	2000 2000 2200 2400	1800	1800	- 1800		1800 · 1800 · 2000	2000	1800 2000 2200	- 1800 2000	2000 2200	2000		1800		1800	2000	2000	2000	2600 2800 - 3000	
2400	- 2800 · · · · · · · · · · · · · · · · · ·	2000	2400 .2500	2400 • • 2600• • • • • • • • • • • • • • • • • • •	2400	2400	2200	2400	2400	2400	2800 - .2800 - 9000 -	2400	2200	2400	2400 2500	2400	2500	-2000	2800	3400 11	2800
(3200)	3400	3400 (3600)	3000	3000	(3000)	(3000)	2800	(3000)	3000	(3200)	3200 (3400)	3000	2800	3000	(3200)	3000	(3400)	3000	3200 3400	4200 4400 (4500)	(3400)



RESERVOIR MODEL COMPRESSIVE VELOCITY





- 6.6e+00

PTL_Attr

- 6

- 5

3

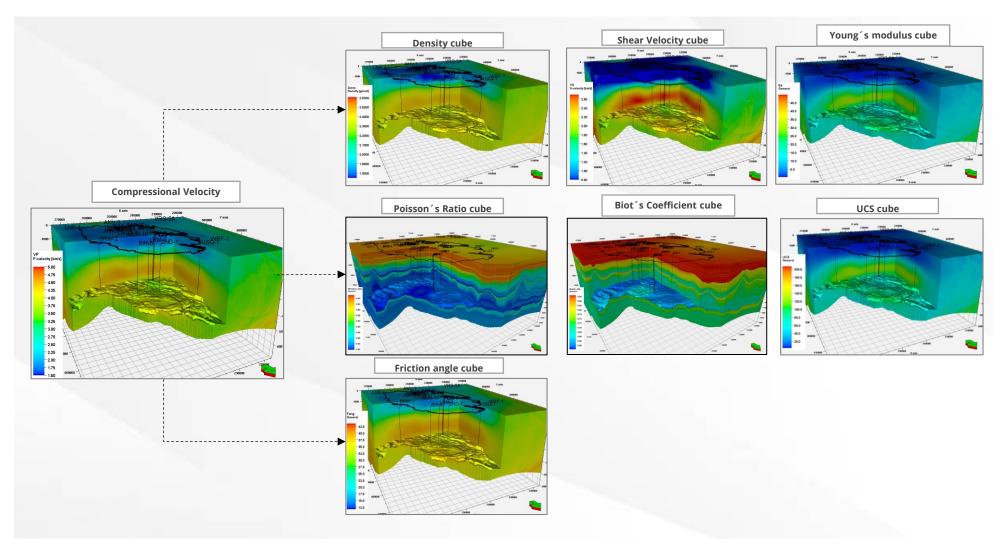
1.4e+00

ANALYTICAL SOLUTION





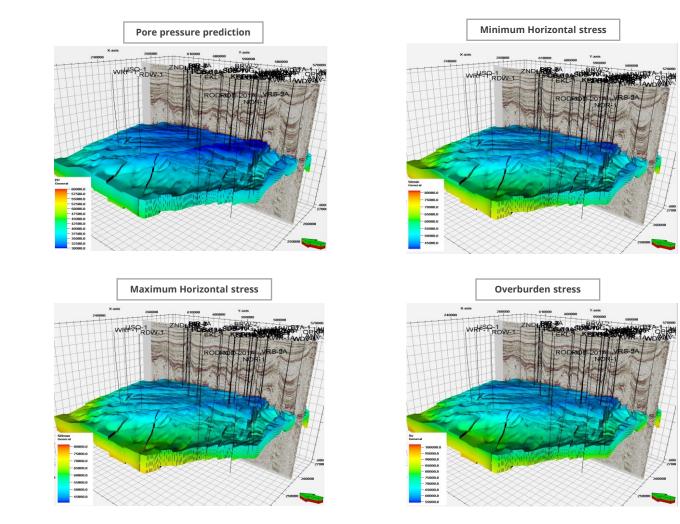
ANALYTICAL SOLUTION – MECHANICAL & STRENGTH PROPERTIES

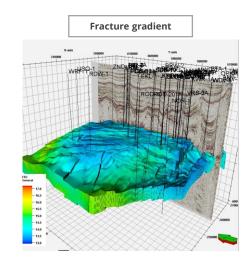






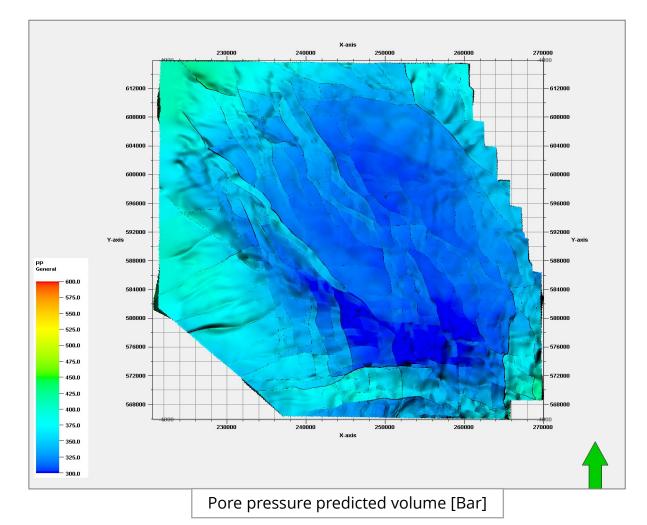
ANALYTICAL SOLUTION – PORE PRESSURE, STRESS & DRILLING GRADIENTS

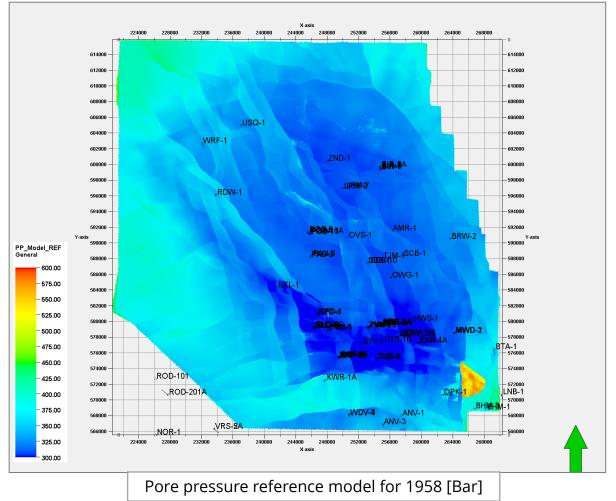






RESERVOIR PORE PRESSURE PREDICTION



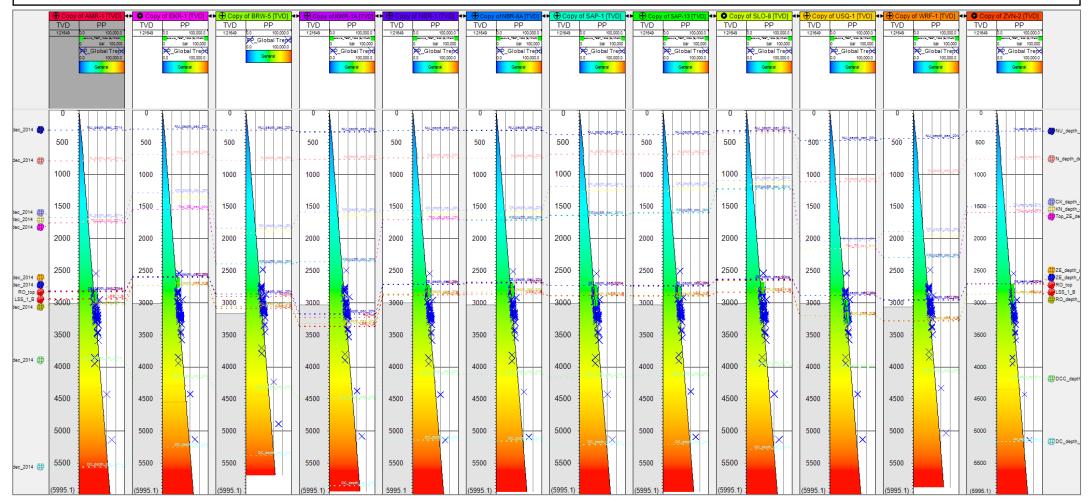




PORE PRESSURE PREDICTION REVIEW

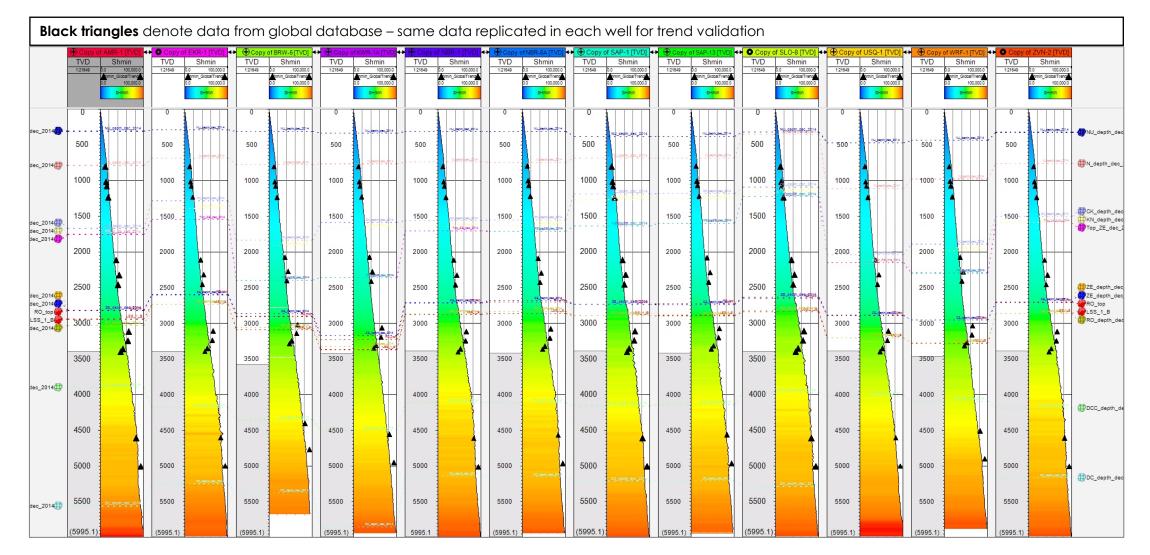
Blue crosses denote data from global database - same data replicated in each well for trend validation

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





Shmin PREDICTION REVIEW



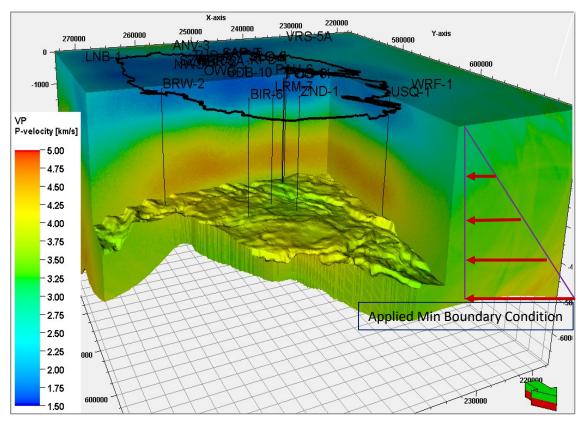


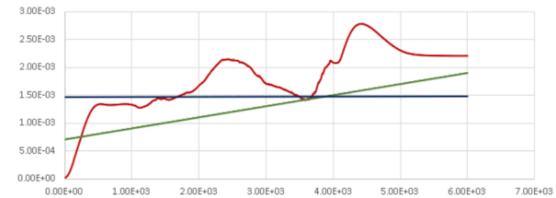
NUMERICAL SOLUTION





NUMERICAL MODEL BOUNDARY CONDITIONS - APOLLO



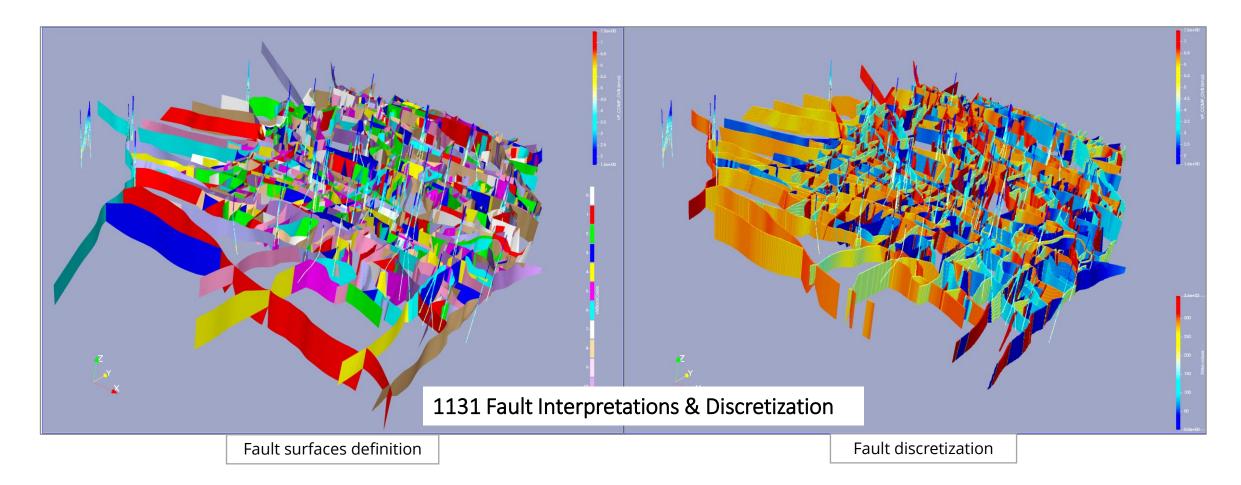


- Resolution: 60x60x10m
- Size: 550+M cells
- No. of Differential equations: 1.6+B
- No. of Integration Points: 4.4+B





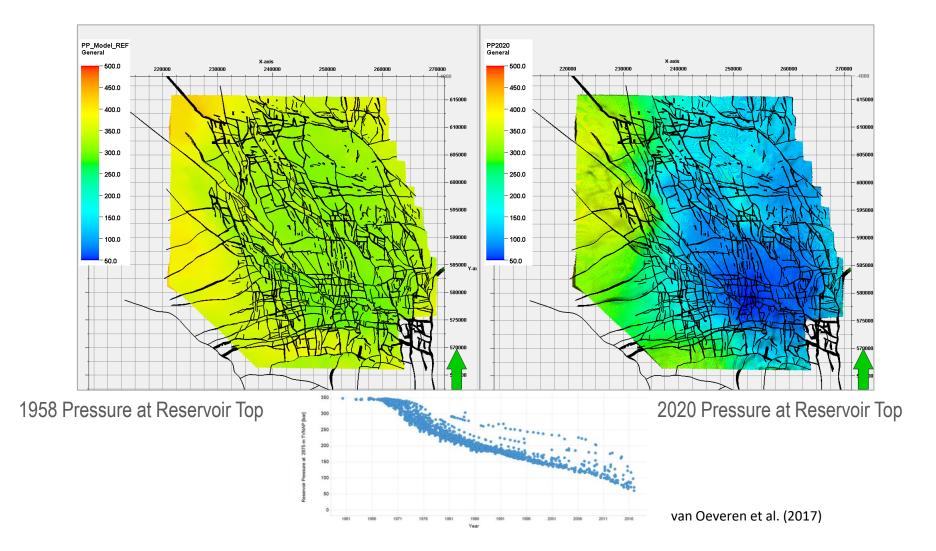
NUMERICAL MODELLING OF FAULTS USING EDFM





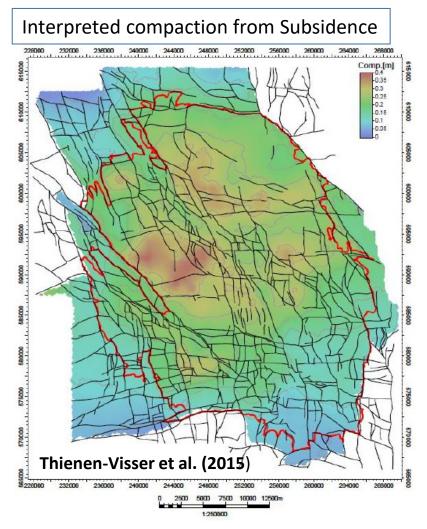


NUMERICAL SOLUTION – 4-D PRODUCTION PRESSURES

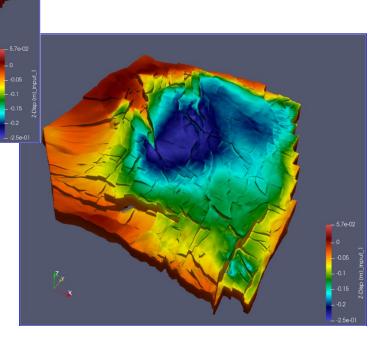




NUMERICAL SOLUTION – COMPACTION & SUBSIDENCE (m)



Computed Compaction & Subsidence

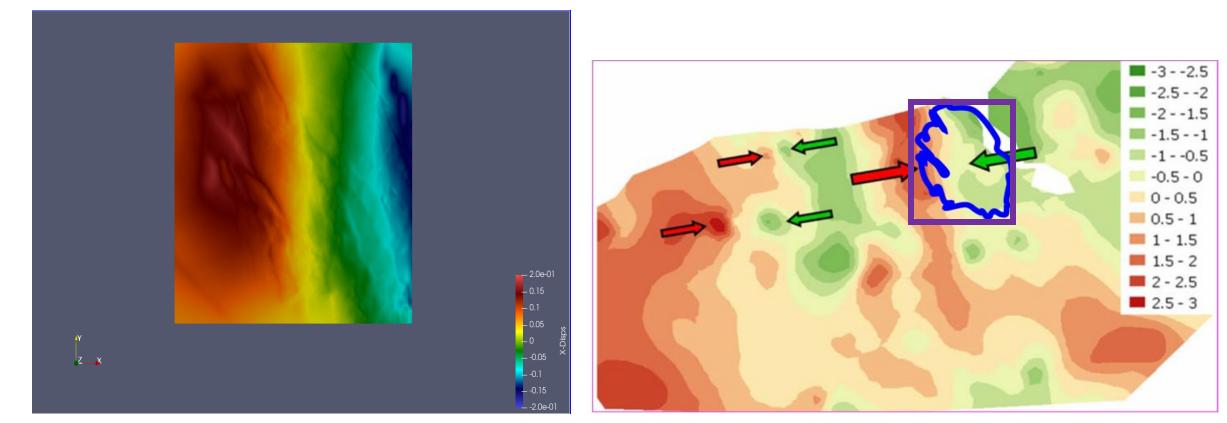




NUMERICAL SOLUTION – RESERVOIR E-W HORIZONTAL DEFORMATION

Predicted Horizontal Deformation (Av 2.9 mm/y)

InSAR Observed Horizontal Deformation (mm/y)

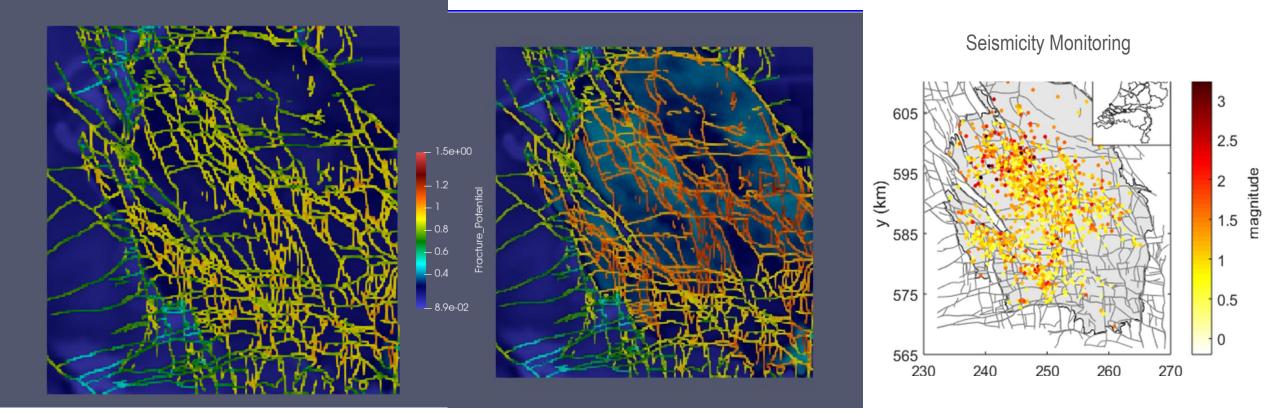






NUMERICAL SOLUTION – 4-D PRODUCTION SOLUTION/CALIBRATION

3-D Fracture Potential Attribute



4-D Fracture Potential Attribute



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

