ASSURING INTEGRITY OF CO2 STORAGE SITES THROUGH GROUND SURFACE MONITORING
WP2.1&WP2.2: FAULT CASE PART

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IFP Energies nouvelles

MAIN GOALS

- To characterize the impact of faults on surface deformations

- considering various fault properties

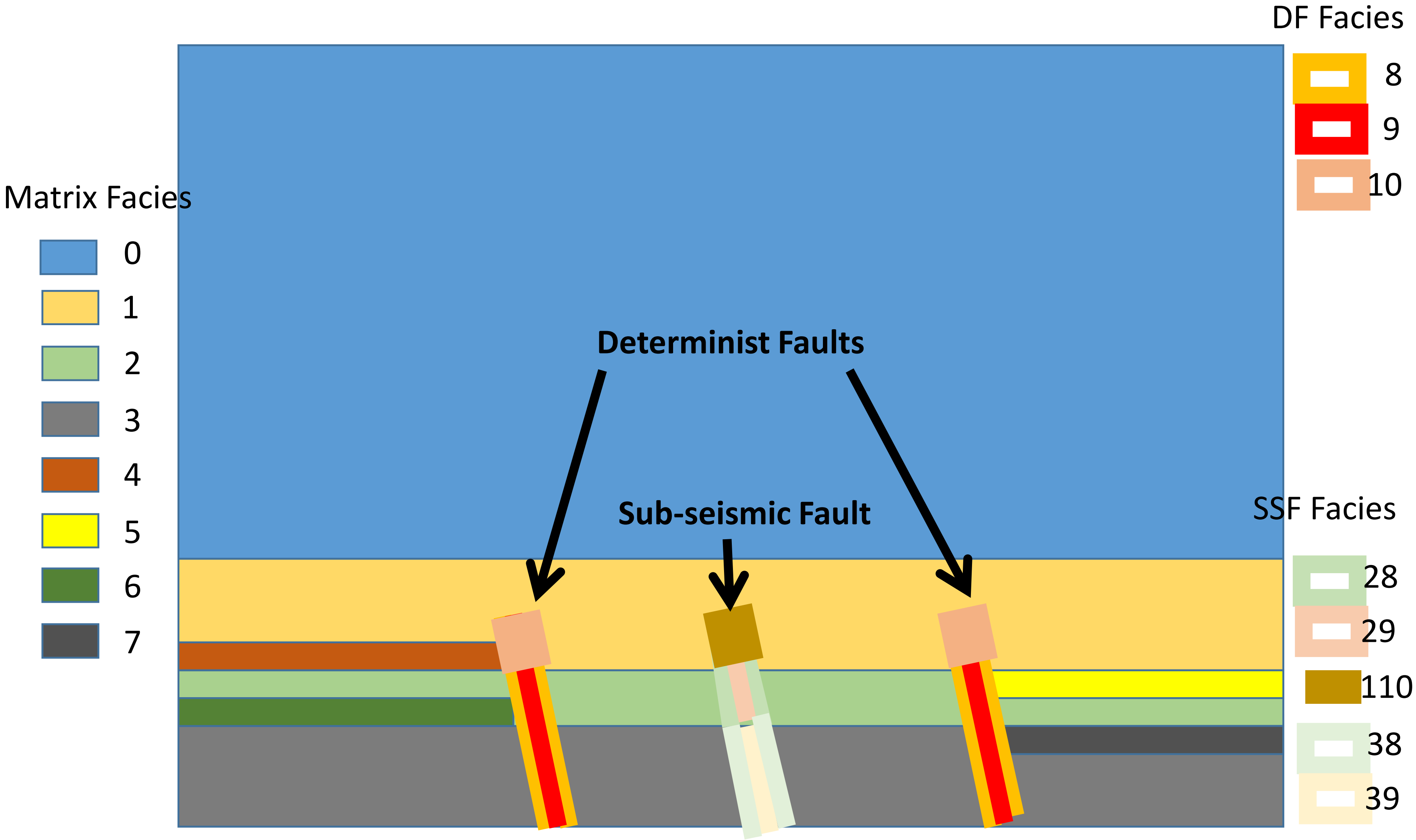
→sealing faults:
the fluids may flow on the fault plane and not through the fault

→open faults:
the fluids may flow on the fault plane and through the fault

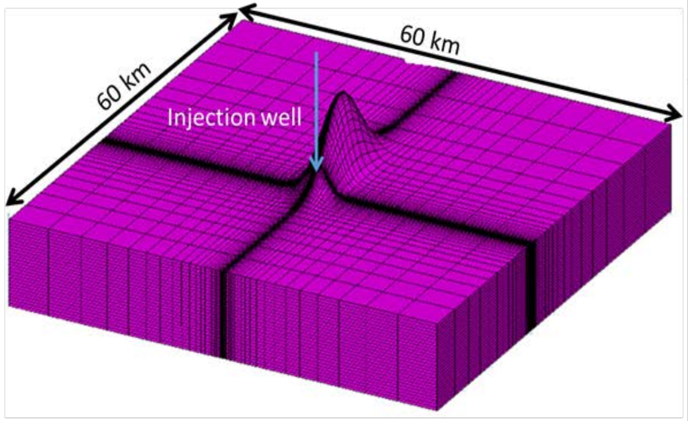
- To characterize an heterogeneity impact

Hypothesis of elastic deformation

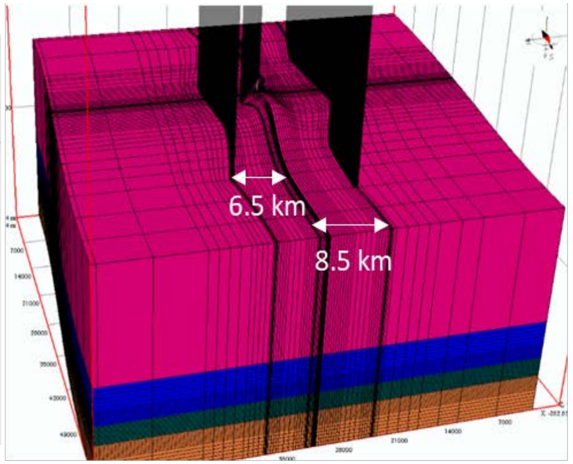
CONCEPTUAL MODEL



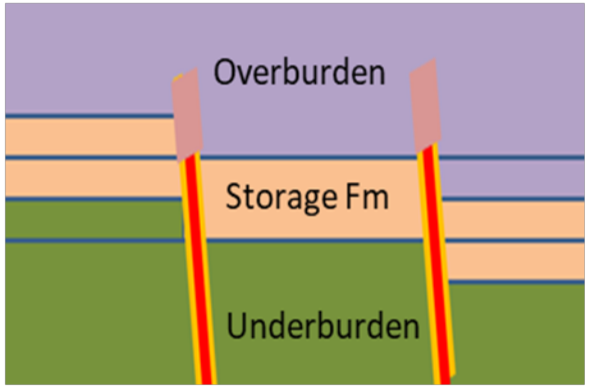
SYNTHETIC FAULT CASES



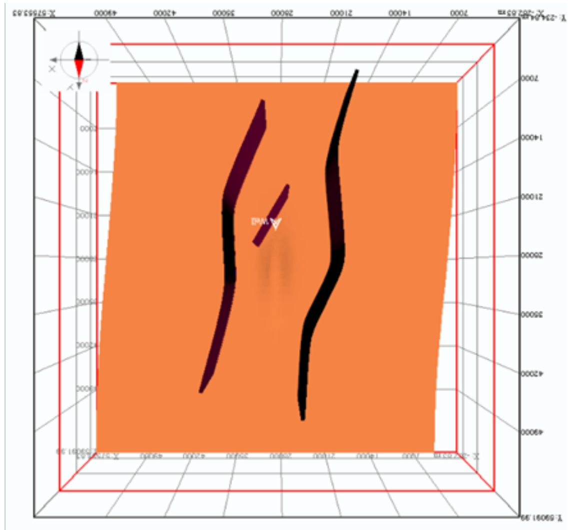
Anticline trap



Anticline trap with sealing or draining faults



Faults (core and damage zones) with throw



- The anticlinal structure is reused
- 2 seismic faults are explicitly modelled
- An additional sub seismic fault is located near the well
- Seismic faults have a throw of 50m

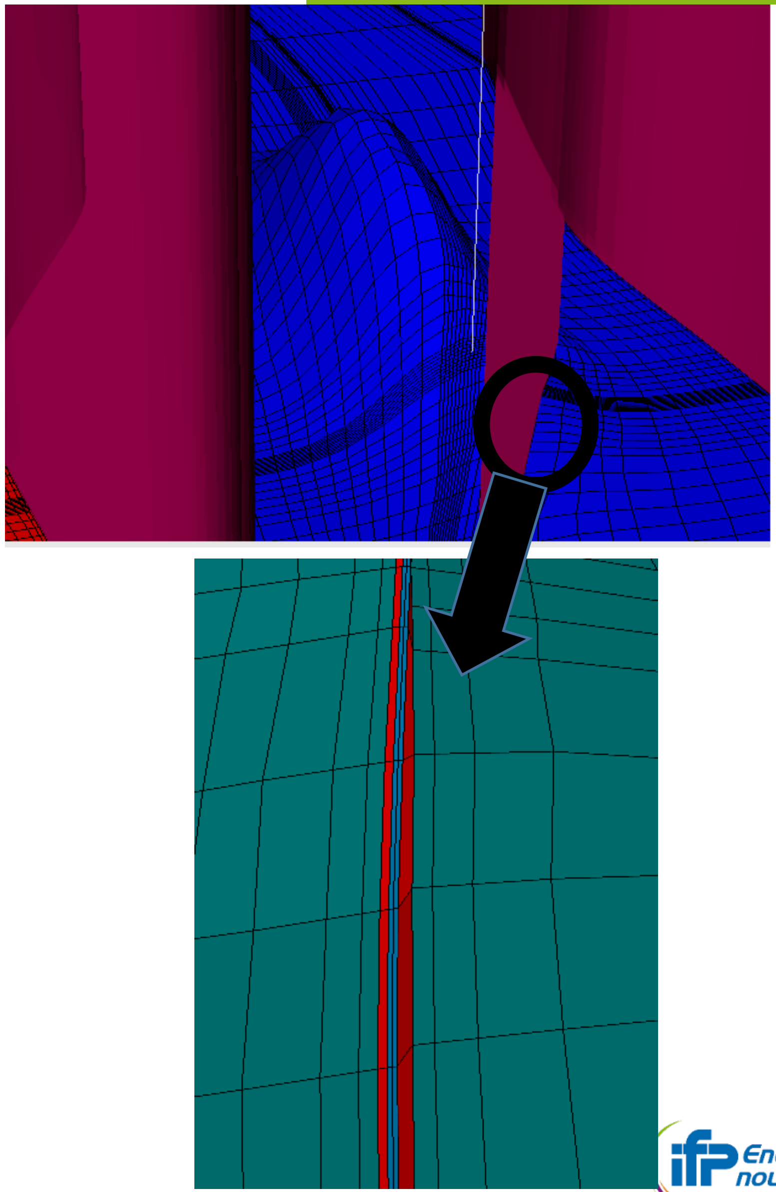
MESH OF THE FAULTS

- The faults are modelled using 2 facies

→fault core (using two cell thickness)

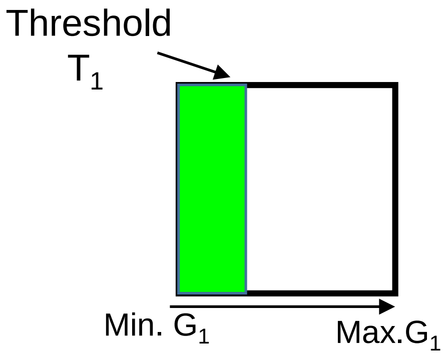
→fault corridor (using one cell thickness for each side)

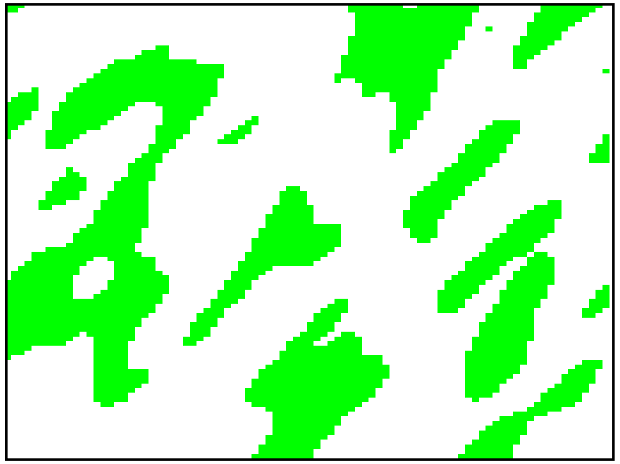
- Each fault facies have their own mechanical/flow properties



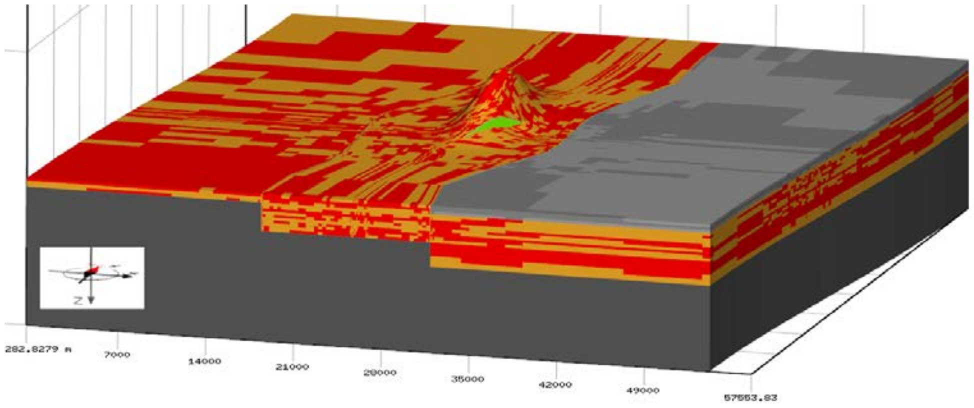
HETEROGENEOUS CASES: TRUNCATED GAUSSIEN

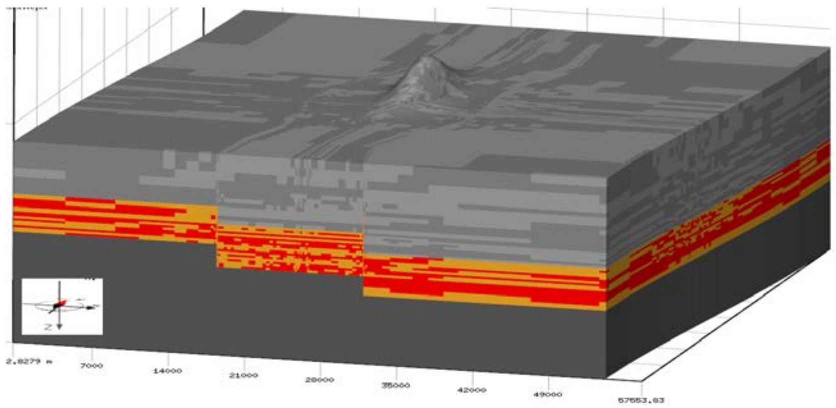
Truncated - Gaussian





Resulting lithofacies simulation

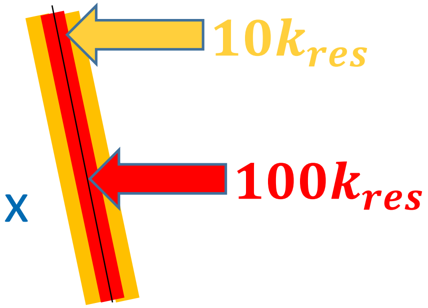


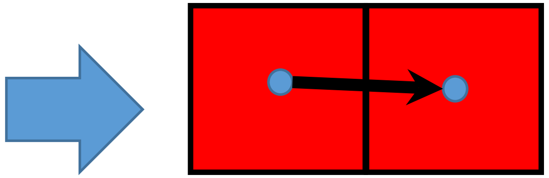


5 MODELS BY STUDIED CASES

- Homegeneous : no fault, no throw

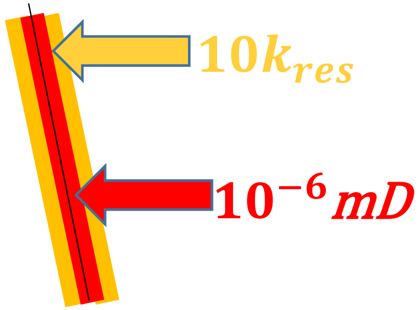
Fault core transmissivity

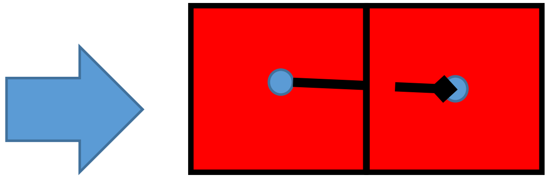




$T_{core}^{Fault} \neq 0$

- Open faults
- Open faults with heterogeneous matrix

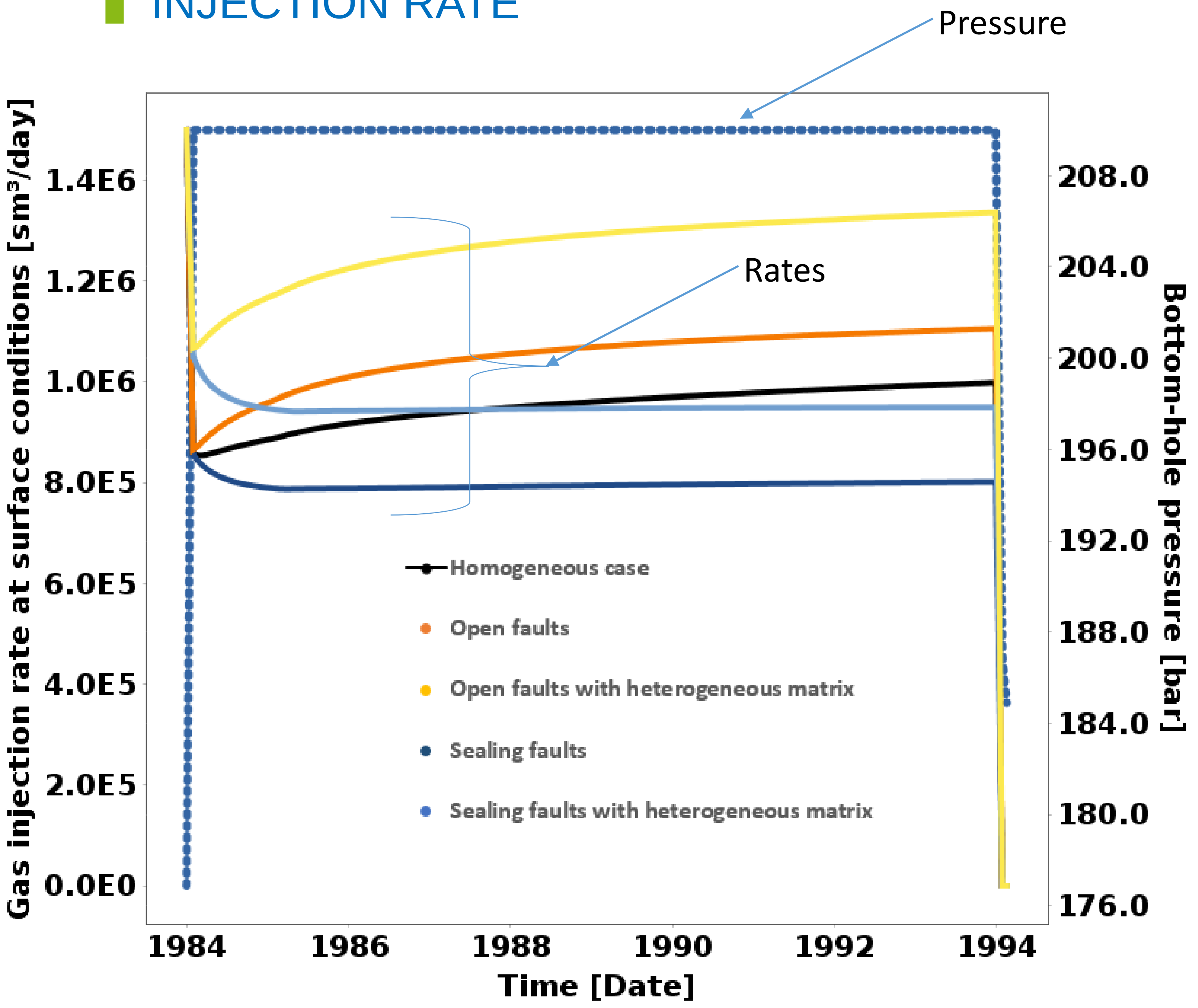




$T_{core}^{Fault} = 0$

- Sealing faults
- Sealing faults with heterogeneous matrix

INJECTION RATE



- Injection are done with
  - a pressure control for carbonate and sandstone I cases

  → injection rate will change according to synthetic case permeability

  - a rate control for sandstone II

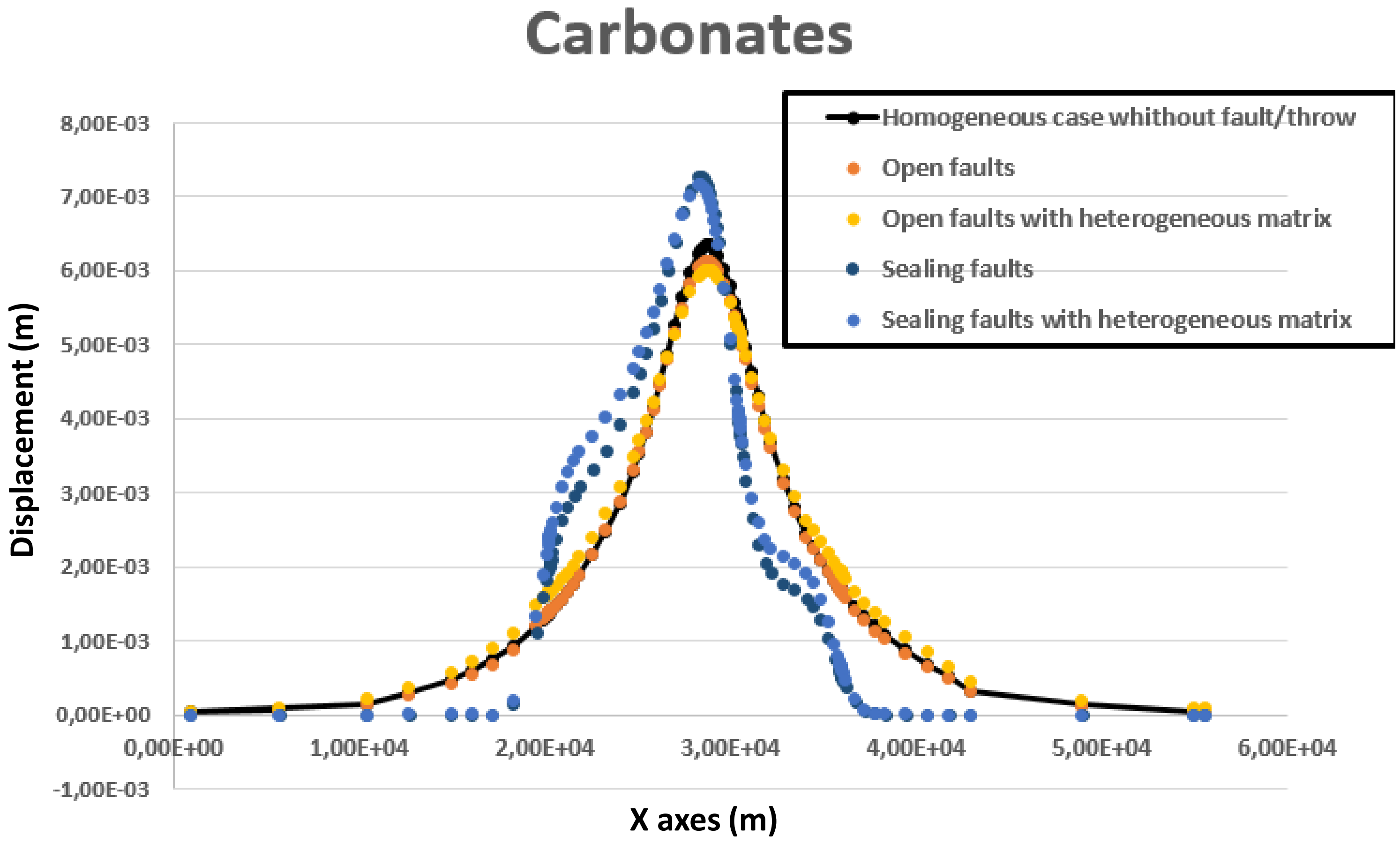
Few results illustrated on Carbonate and Sandstone I scenarios

Carbonate Case	Brindisi & Michigan Basin	Baroni et al., 2015 Michael et al., 2010
Sandstone I case	In Salah	Baroni et al., 2011; Deflandre et al., 2013; Tremosa et al., 2014; Michael et al., 2010; Flett et al., 2008; Schembre-McCabe et al. 2008
Sandstone II case	from Snohvit, Decatur & Otway	Estublier et al. 2009; Niemi et al. 2017; Mt Simon, Zhou et al. 2010; Ruqvist et al. 2019; Cook 2014

More may be founded in :

- **D2.2_Deliverables_Task2-2 : Assuring integrity of CO2 storage sites through ground surface monitoring (SENSE) - WP2.2: Understanding the mechanism of surface movement (Deliverable D2.2).**
  BOUQUET Sarah, ESTUBLIER Audrey, FOURNO André, FREY Jérémy, MALINOUSKAYA Iryna
- **D2.1_Deliverables_Task2-1 :Assuring integrity of CO2 storage sites through ground surface monitoring (SENSE) – WP2.1: Presentation of conceptual models (Delivrable D2.1)**
  BOUQUET Sarah, ESTUBLIER Audrey, FOURNO André, FREY Jérémy, MALINOUSKAYA Iryna

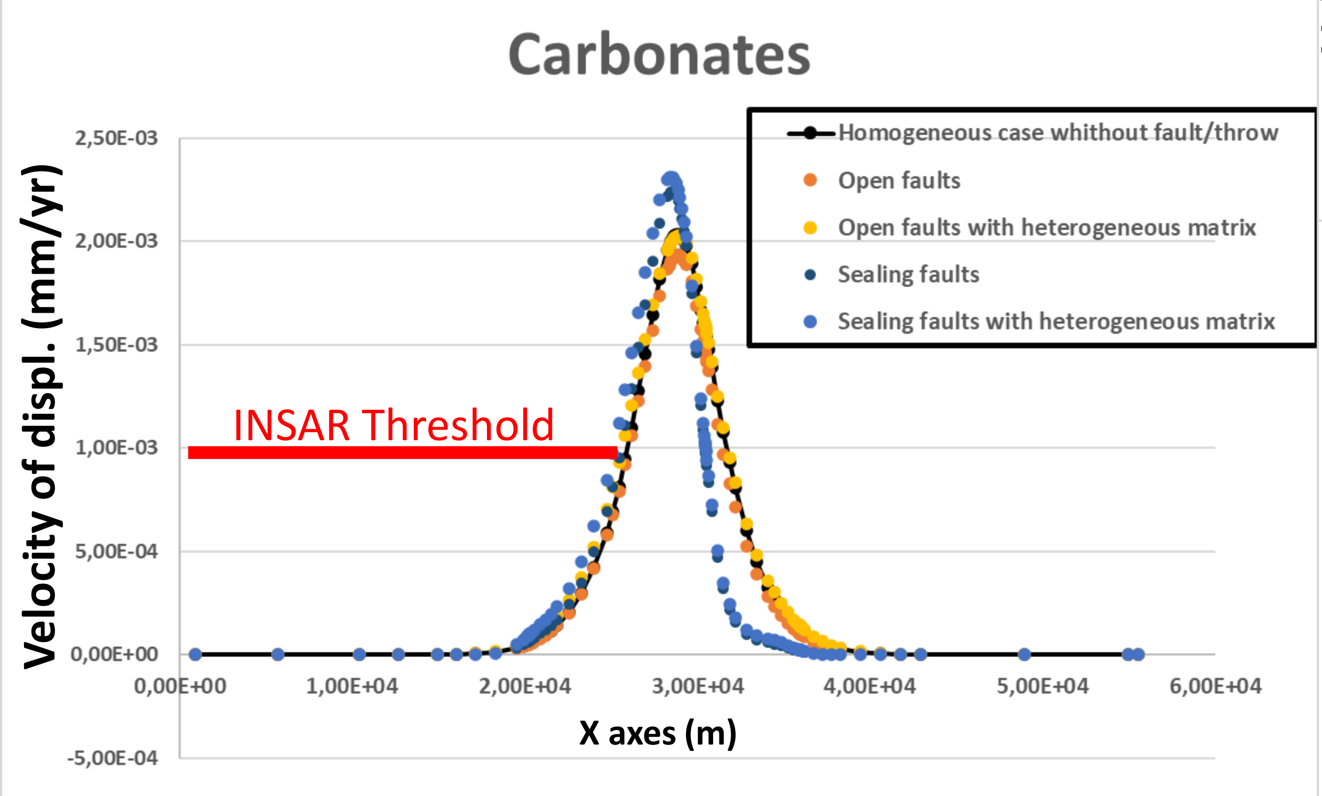
TOP DISPLACEMENT AFTER 13 YEARS

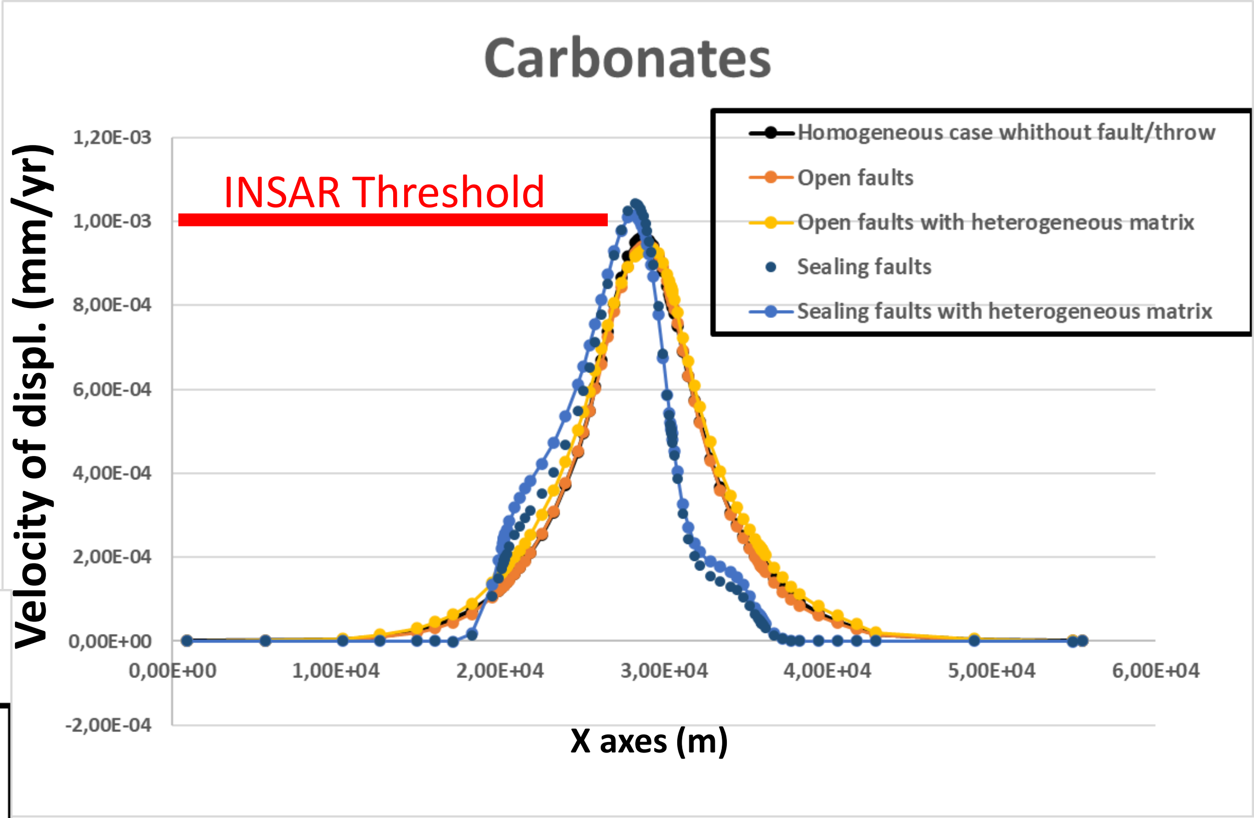


- The sealing faults have a major impact on CO_2 injection.
- Non-Gaussian shape of the displacements

VELOCITY 1YEARS / 5YEARS

1 year

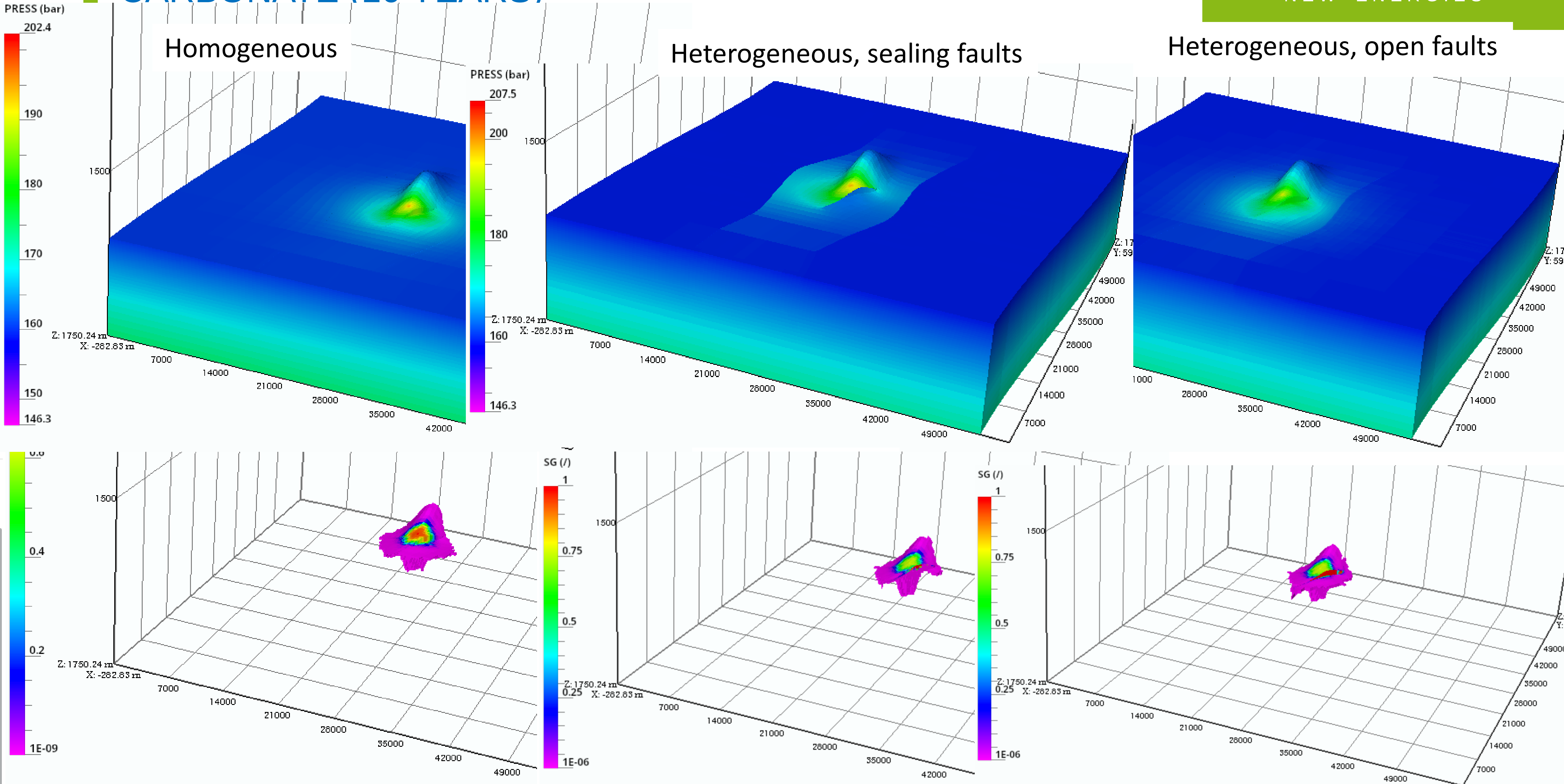




5 years

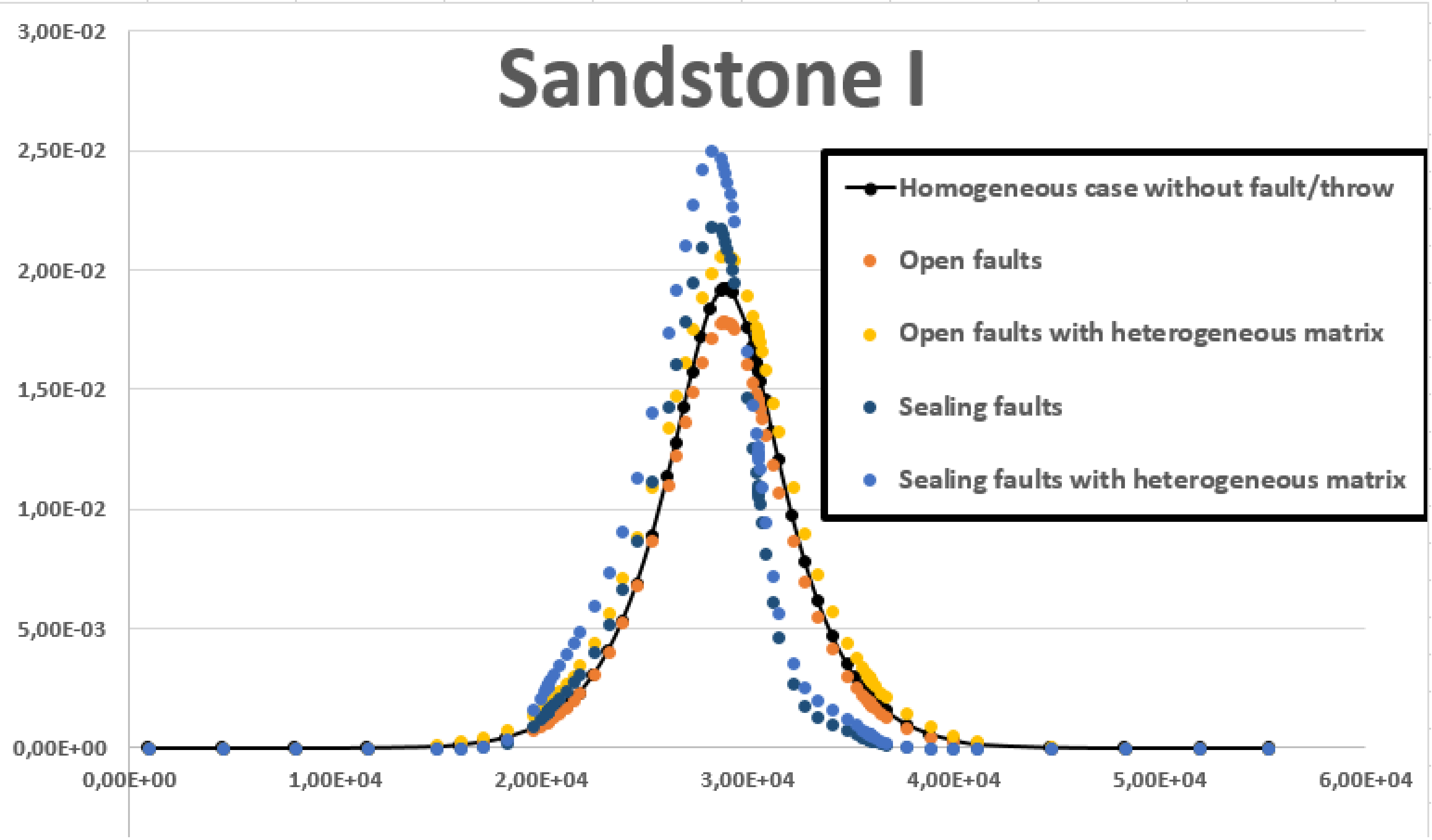
The sealing faults have a major impact on CO2 injection.
→Increase of the velocity of the displacements

CARBONATE (10 YEARS)



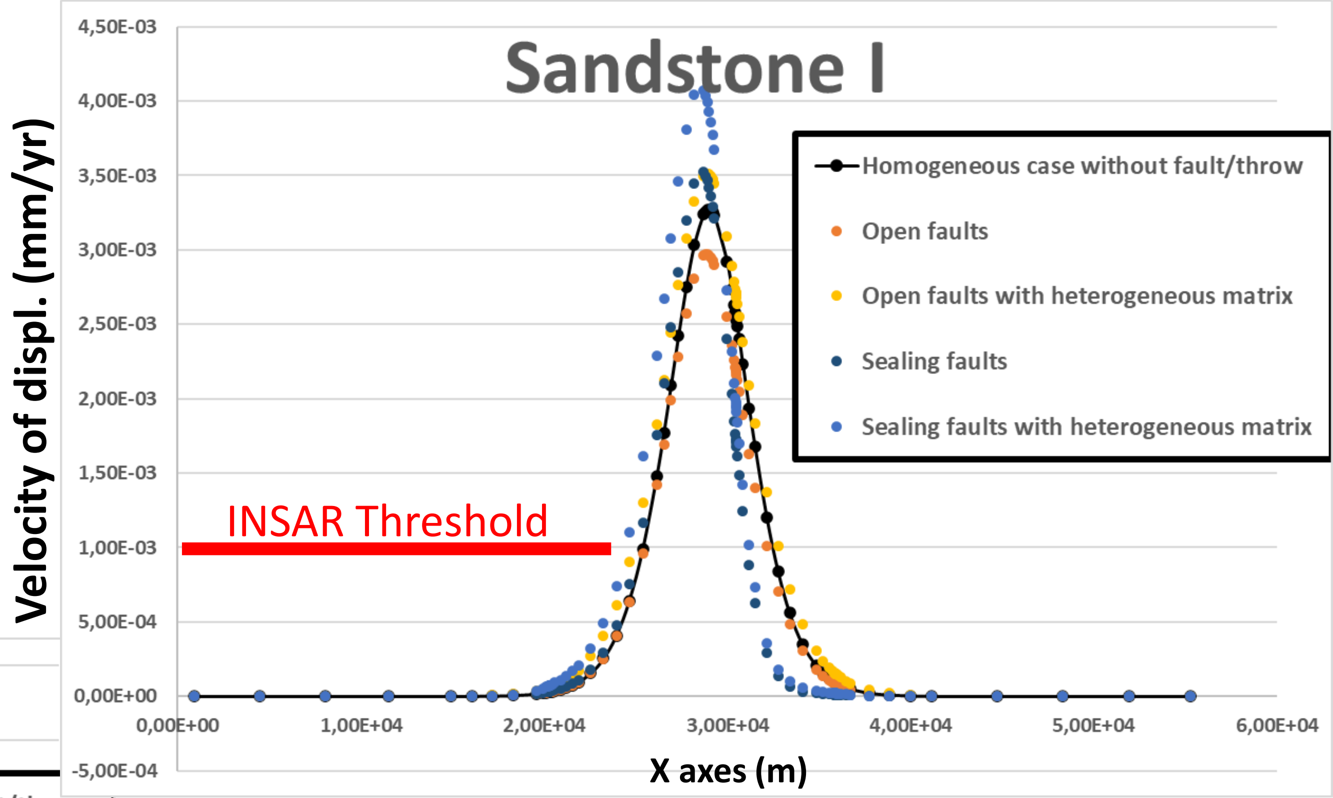
TOP DISPLACEMENT AFTER 13 YEARS

NEW ENERGIES



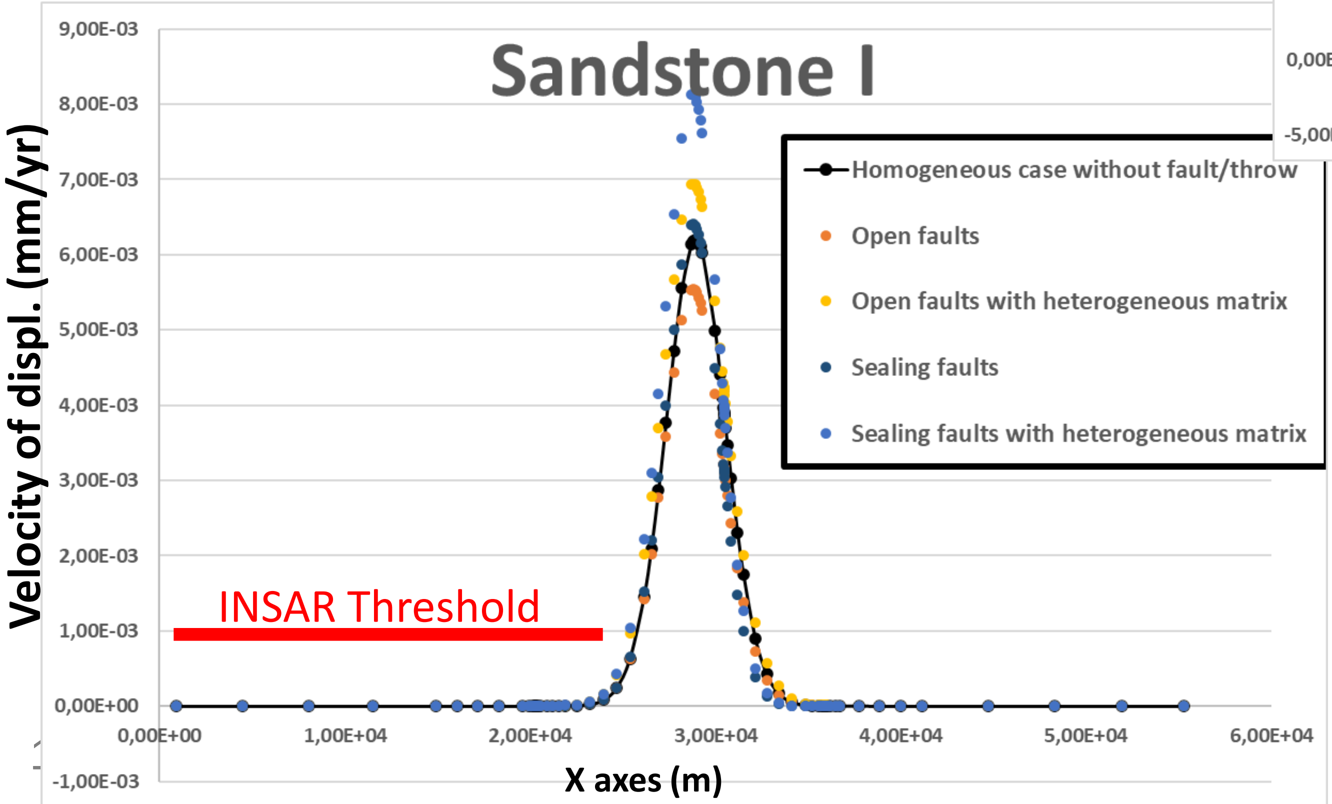
- The sealing faults have a major impact on CO_2 injection.
- Non-Gaussian shape of the displacements

VELOCITY 1YEARS / 5YEARS



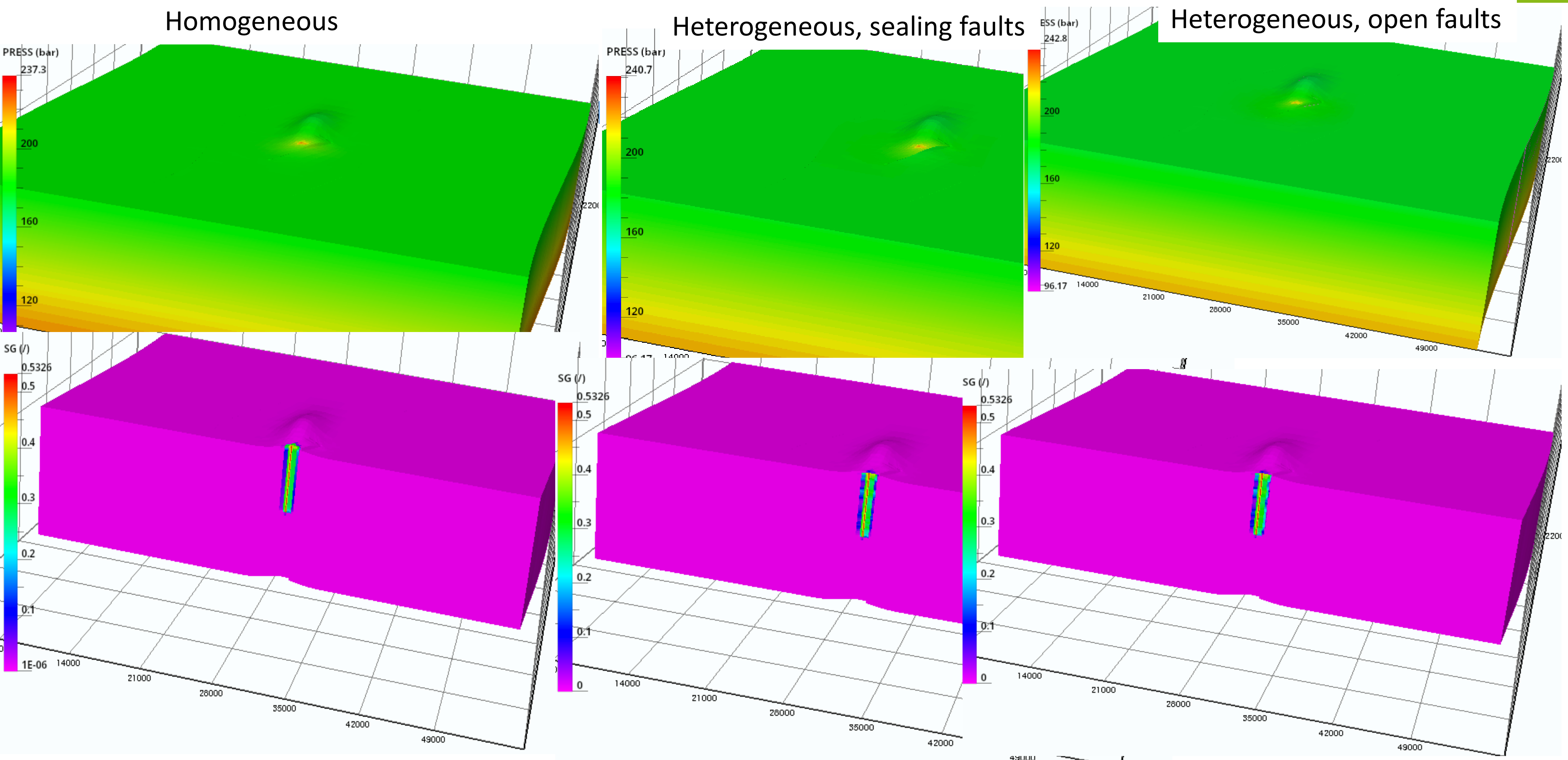
5 years

1 year

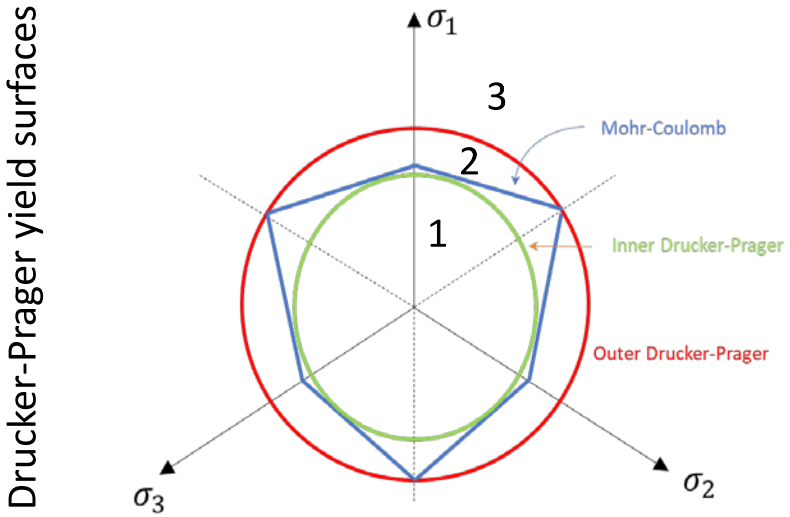


The sealing faults have a major impact on CO2 injection.
→Increase of the velocity of the displacements

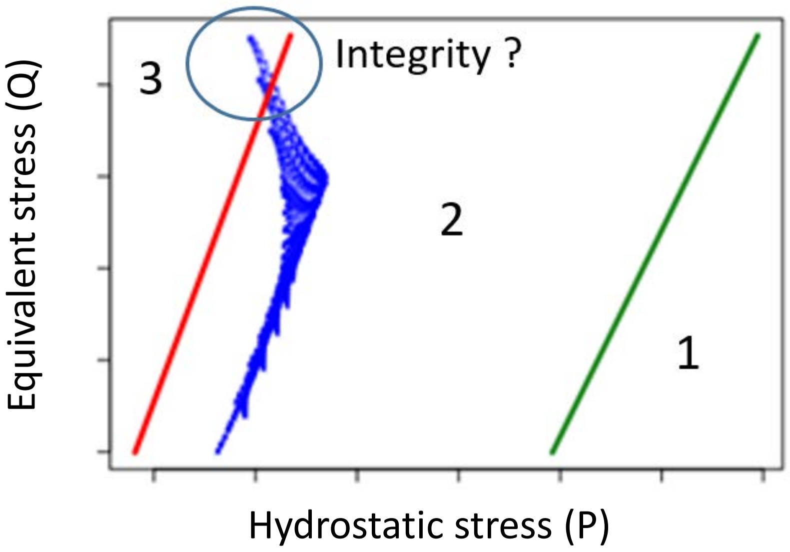
SANDSTONE I (10 YEARS)



INTEGRITY ANALYSIS



Stress /element representation



- 3 scenarios
  - Carbonate
  - Sandstone 1
  - Sandstone 2
- 2 facies distributions
  - Homogeneous
  - Heterogeneous
- 2 fault hydraulic behaviors
  - Sealing faults
  - Open faults
- 4 Initial stress regimes
  - Extensive - Sx/Sz = 0.8 - Sy/Sz = 0.8
  - Compressive - Sx/Sz = 1.1 - Sy/Sz = 1.6
  - Strike Slip 1 - Sx/Sz = 0.6 - Sy/Sz = 1.1
  - Strike Slip 2 - Sx/Sz = 0.8 - Sy/Sz = 1.3

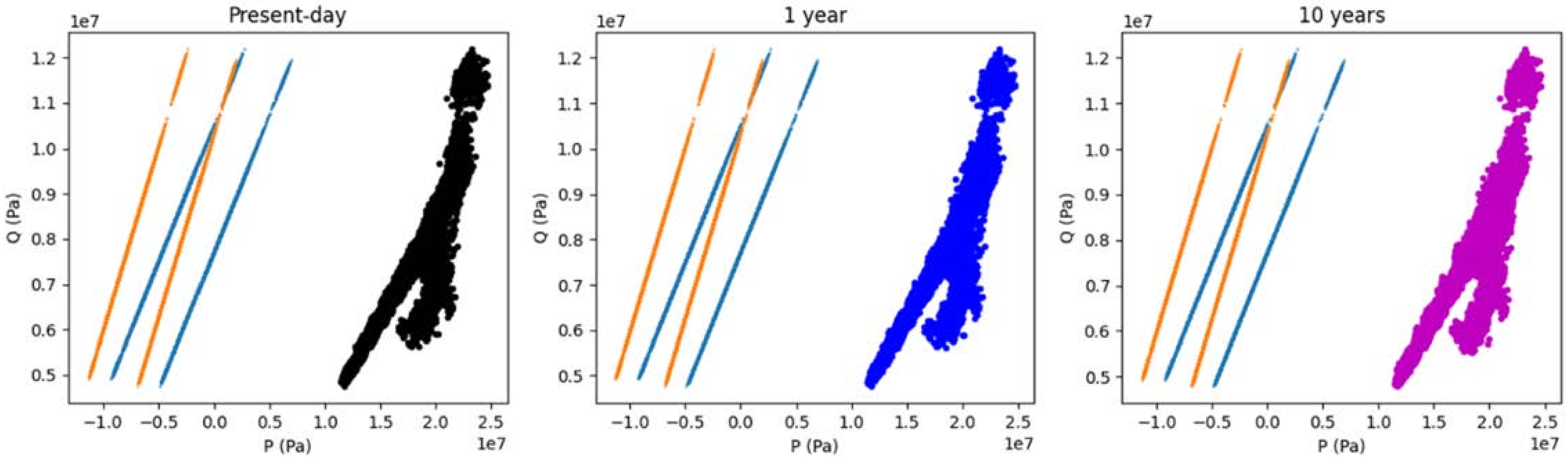
CAPROCK INTEGRITY

- Sandstone 1
- Sealing faults
- Heterogeneous

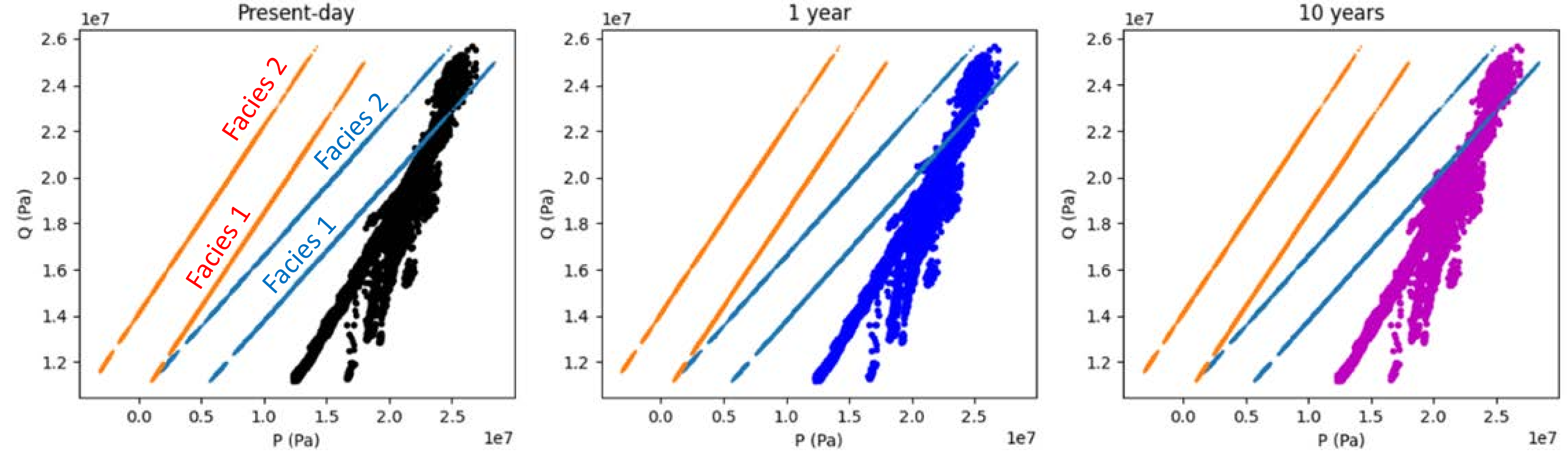
- Facies 1 :
  - Cohesion = 4.89 MPa
  - Friction = 20.78°
- Facies 2 :
  - Cohesion = 6.67 MPa
  - Friction = 21°

- Strong impact of the initial stress regime on caprock integrity

Extensive stress regime - Sx/Sz=Sy/Sz=0.8



Strike Slip 1 stress regime - Sx/Sz = 0.6 - Sy/Sz = 1.1



Present-day 1year 10years

CAPROCK INTEGRITY

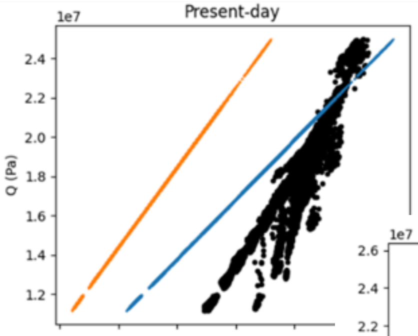
- Sandstone 1
- Sealing faults
- Heterogeneous/Homogeneous

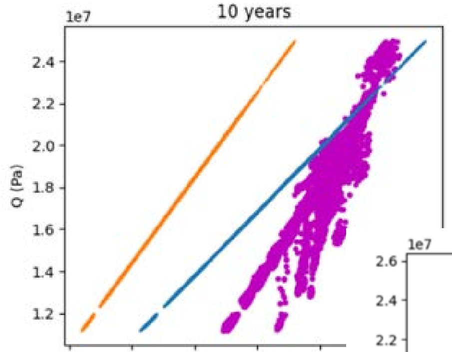
- Facies 1 :
  - Cohesion = 4.89 MPa
  - Friction = 20.78°
- Facies 2 :
  - Cohesion = 6.67 MPa
  - Friction = 21°

- Weak impact of caprock heterogeneities

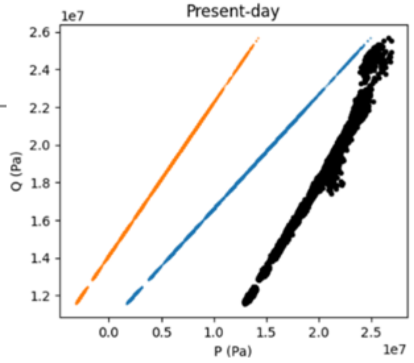
Strike Slip 1 stress regime - Sx/Sz = 0.6 - Sy/Sz = 1.1

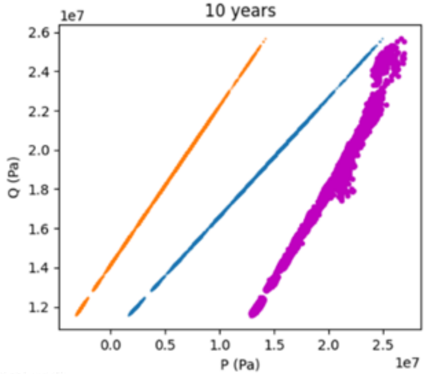
Heterogeneous





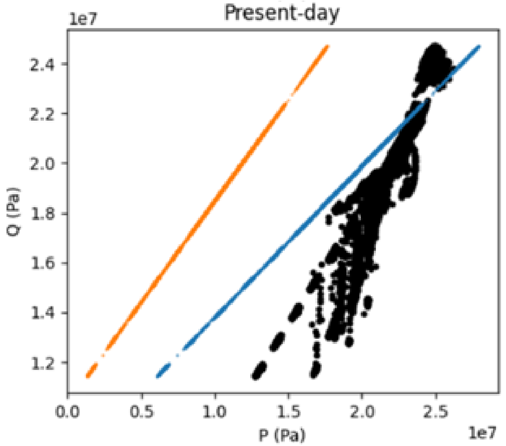
- *Facies 1*

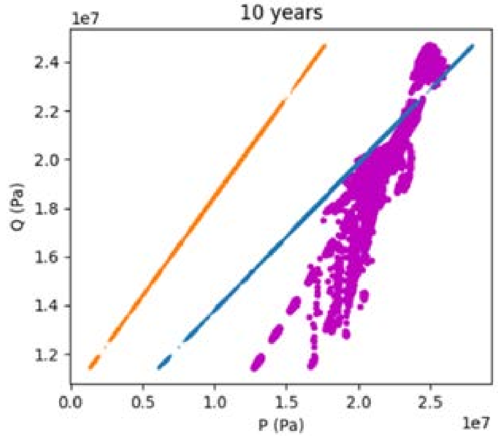




- *Facies 2*

Homogeneous





- *Facies 1*

Present-day → **10years**

FAULT STABILITY

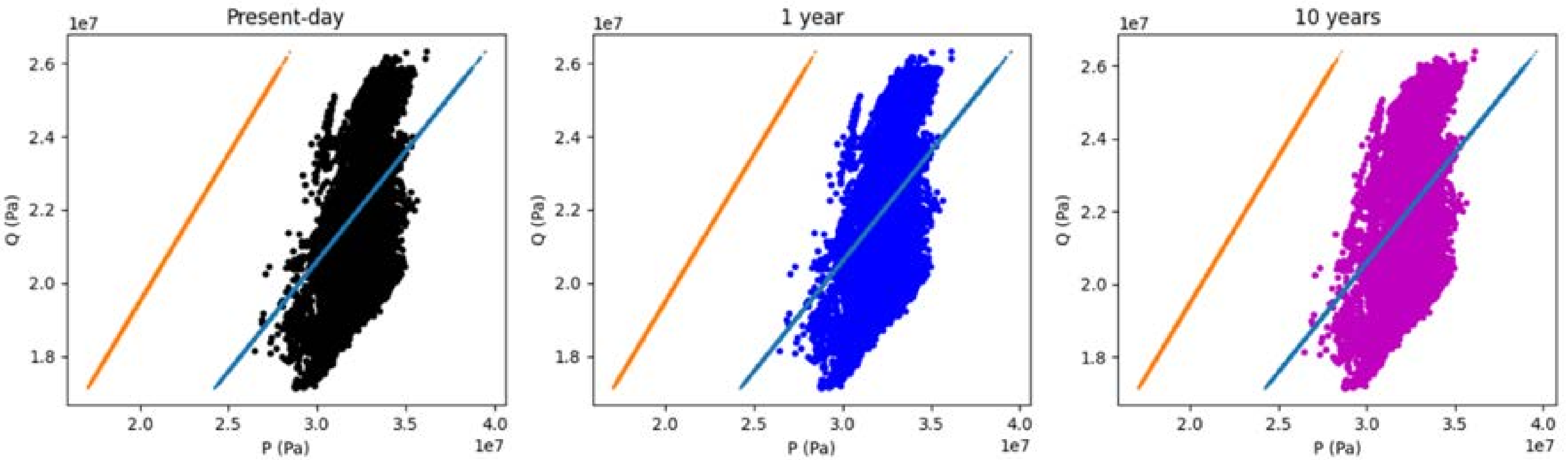
NEW ENERGIES

- Sandstone 1
- Sealing faults
- Heterogeneous

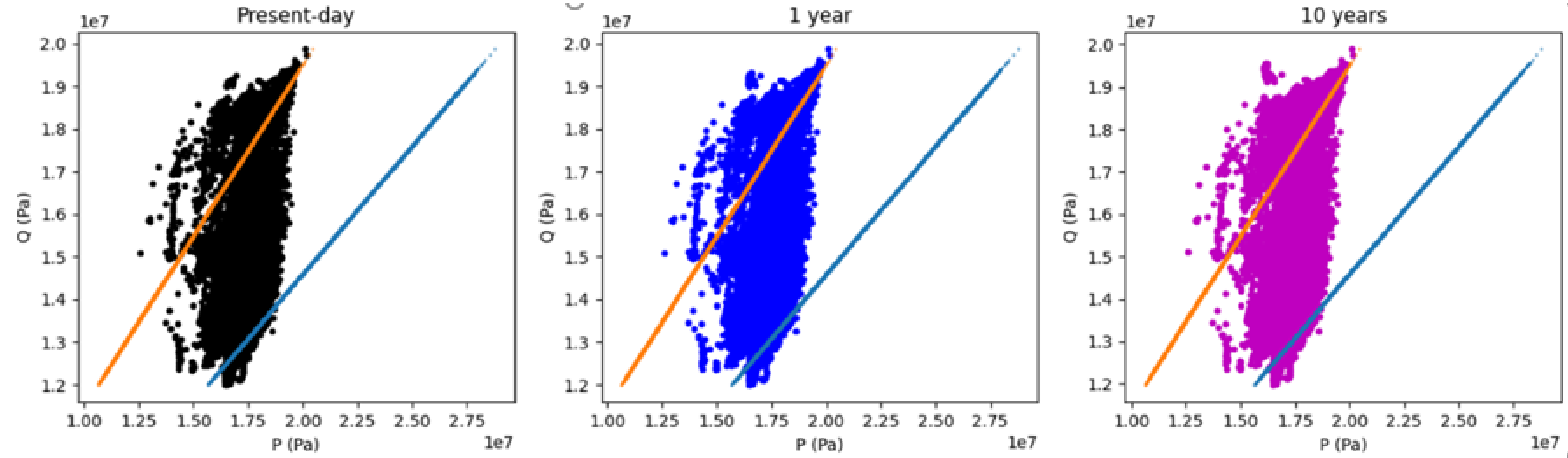
- Faults :
  - Cohesion = 1.62 MPa
  - Friction = 20.78°

- Strong impact of the initial stress regime on fault stability

Compressive stress regime - Sx/Sz = 1.1 - Sy/Sz = 1.6



Strike Slip 1 stress regime - Sx/Sz = 0.6 - Sy/Sz = 1.1



Present-day **1year** **10years**

FAULT STABILITY

NEW ENERGIES

Compressive stress regime - Sx/Sz = 1.1 - Sy/Sz = 1.6

- Sandstone 1
- Sealing faults
- Heterogeneous

- Faults :
  - Cohesion = 1.62 MPa
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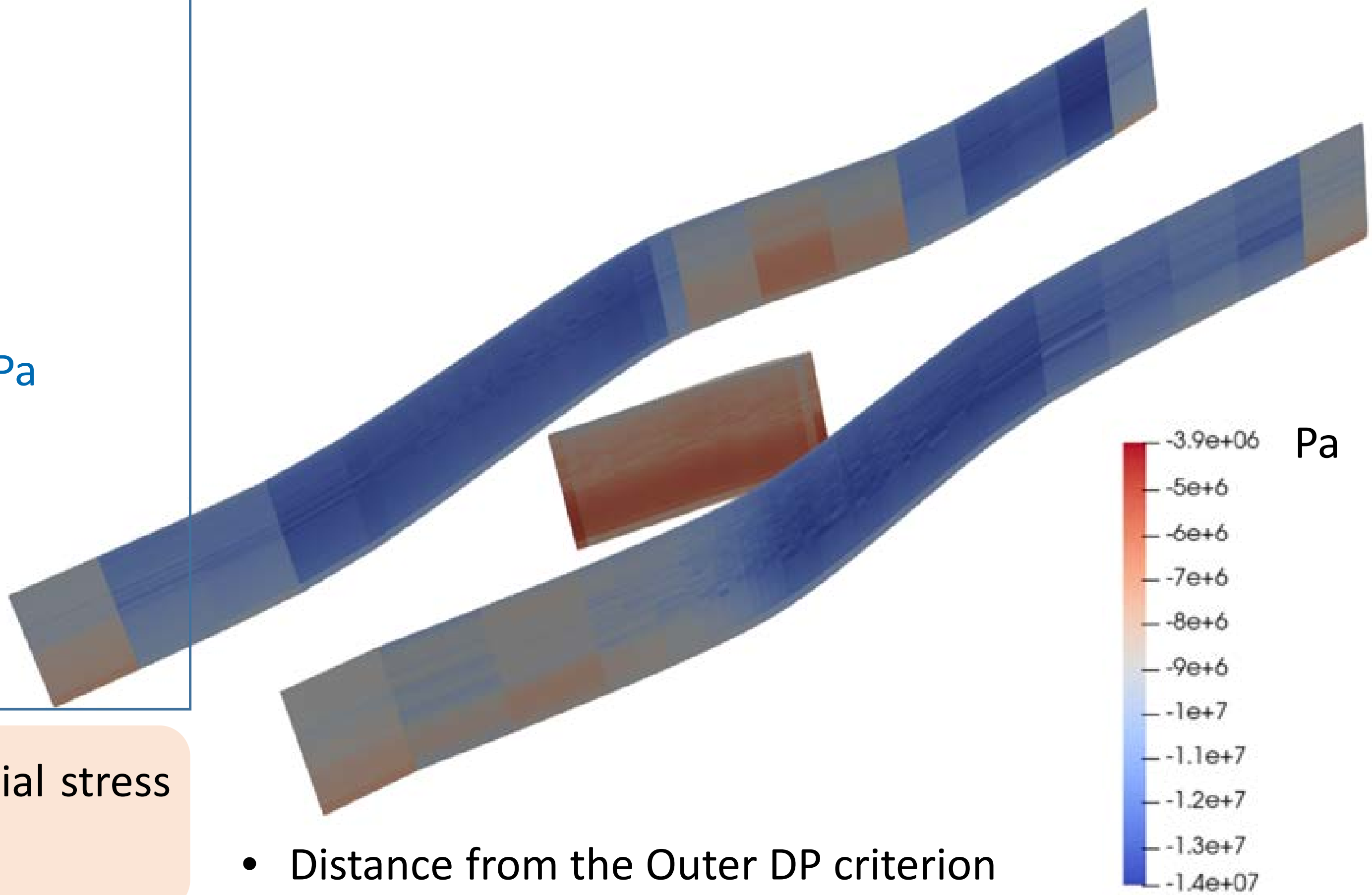
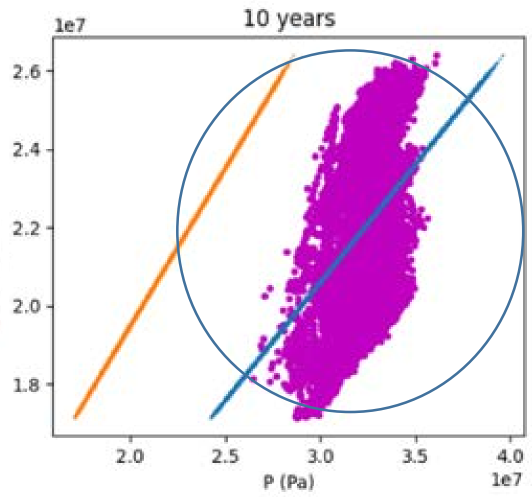




- Strong impact of the initial stress regime on fault stability

- Distance from the Outer DP criterion

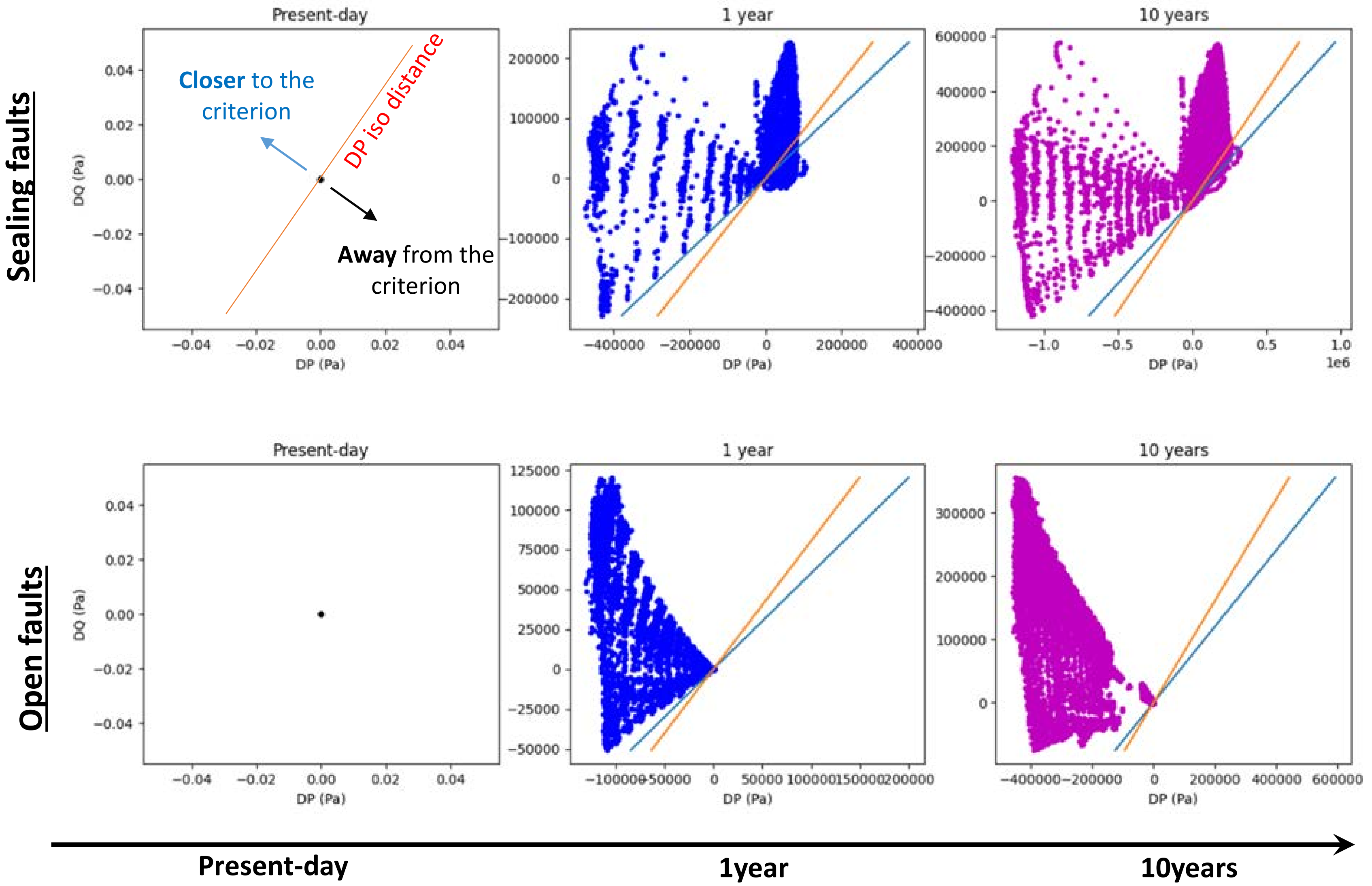
FAULT STABILITY : INDUCED STRESS VARIATION

- Sandstone 1
- Sealing/Open faults
- Heterogeneous

- Faults :
  - Cohesion = 1.62 MPa
  - Friction = 20.78°

- Impact of the initial stress regime on induced stress variations

Compressive stress regime - Sx/Sz = 1.1 - Sy/Sz = 1.6



CONCLUSIONS

- Hydraulic behavior of faults as an impact on :
  - … induced stress variation during injection
  - … the velocity of the displacements
  - … the shape of the surface displacements at ground level
  - … the center location of the maximum displacement area
  - ➢ BUT Difficulty to observe these impacts considering the INSAR detectability threshold

- Initial stress regime is critical since it define the initial distance to the considered criterion for both caprock integrity and fault stability analysis

- Chosen heterogeneities has a small impact on surface displacement, initial stress distribution and induced stress variation.

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